150 YEARS OF CELEBRATING THE MAHATMA

सत्यमेव जयते

स्वच्छ भारत
एक कदम स्वच्छता की ओर

Renewable Energy and Efficiency Measures in Built Habitat





CENTRAL PUBLIC WORKS DEPARTMENT
Ministry of Housing and Urban Affairs

CPWD

Proceedings of Seminar on

RENEWABLE ENERGY AND EFFICIENCY MEASURES IN BUILT HABITAT

March 8, 2019

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(The views expressed are purely of the authors and not of the editor or their organizations)

हरदीप एस पुरी
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सत्यमेव जयते

आवासन और शहरी कार्य
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भारत सरकार
MINISTER OF STATE (I/C)
HOUSING AND URBAN AFFAIRS
GOVERNMENT OF INDIA



Message

It is a matter of satisfaction that CPWD is organizing a one-day seminar on "Renewable Energy and Efficiency Measures in Built Habitat" on March 8, 2019 in New Delhi for focusing the attention of policy makers, academicians and other professionals in the construction sector towards clean and green energy and reduction of the carbon footprint by the installation of solar rooftops and promoting energy efficiency in the buildings.

The National Mission on Sustainable Habitat is one of the core missions under the National Action Plan for Climate Change and is the key policy initiative of the Ministry of Housing & Urban Affairs.

I am sure that the efforts made by CPWD towards Energy Efficiency will be highlighted through this seminar. I hope this Seminar will provide ample opportunities for the participants to deliberate on changes brought by the measures of generation of solar energy and efficiency in energy use in the micro climate surrounding the buildings. The learnings attained through adoption of these measures and takeaways will help in furthering the objectives of Sustainable Habitat.

I wish the seminar all success.

(Hardeep S Puri)

New Delhi
28 February, 2019

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MESSAGE

Climate change is a big threat to the mankind in the present times. It is, therefore, everybody's responsibility to take action for bringing positive changes in the field of Climate. Installation of Solar rooftops and Adoption of Energy Efficiency Measures like switching over to LED based lighting system etc. are two key measures to reduce carbon emissions in the building sector.

I appreciate many initiatives taken by CPWD in these two areas. It is now organizing one-day Seminar on "Renewable Energy and Efficiency Measures in Built Habitat" on March 8, 2019 in New Delhi to take these initiatives further.

I am sure that the knowledge disseminated through day long deliberations will benefit all those associated with the construction sector and many more innovative ideas will emerge which will drive the objectives further.

I congratulate CPWD for this initiative and wish the Seminar a grand success.

(Durga Shanker Mishra)

New Delhi
28 February, 2019

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PRABHAKAR SINGH

सत्यमेव जयते

DIRECTOR GENERAL
Central Public Works Department
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MESSAGE

Building sector alone in the country consumes about one third of the total energy consumed by the country which is enormous and requires dedicated efforts to bring it down which can only be possible through reduction in energy use by adopting energy efficient technologies and switching over on the abundantly available solar energy. CPWD as a matter of its green construction policy is using LED lighting and solar rooftops in all its construction projects.

Being a Principal Engineering Organization of Government of India, CPWD has always encouraged Energy Efficient Sustainable Technologies in its works which are Environment Friendly. CPWD therefore has a greater responsibility towards Nation Building and has also emerged as a front runner in the field of renewable energy and efficiency measures in energy use in built habitat. We also discharge the duty of Principal Technical Advisor to Govt. of India.

CPWD started its journey of sustainable construction reducing energy intensity by adopting various measures like passive solar architecture, solar streetlighting, use of low energy embodied materials, latest lighting technology and appropriate land scaping only.

Now Energy Performance rating of CPWD Buildings is planned to be evaluated by Bureau of Energy Efficiency formed under Energy Conservation Act 2001, a statutory body under Ministry of Power, Government of India.

I am confident that CPWD will not only establish new benchmarking in the construction of energy efficient buildings but in the construction of Net zero and Net positive buildings too by its constant endeavors in this field.

Organising this seminar is another milestone in the journey of CPWD towards building a sustainable habitat. I appreciate the efforts of Dr. K.M.Soni ADG (TD) and Sh. C.K.Varma CE CSQ (E) and his team in making this onerous task possible in a short time. This will bring new initiatives and more innovations in this arena.

My best wishes for the success of this seminar.

Place: New Delhi
Date: March 8 2019

(Prabhakar Singh)

DR. K. M. SONI

सत्यमेव जयते

ADDITIONAL DIRECTOR GENERAL (TD)
Central Public Works Department
Nirman Bhawan, New Delhi



FOREWORD

It has been CPWD's continuous endeavor to focus not only on new technologies but on sustainable ones also. Building construction has undergone many changes with times and had become energy intensive due to many facets and dimensions added to the habitat for the comfort and facilitation of inhabitants. Too much dependence on energy has created problem for the climate as increasing use of energy brings increased CO2 emissions.

The theme of the seminar is therefore relevant in the context of growing concern about climate change as the main thrust of this seminar will be to draw attention on sustainable growth. The renewable energy and energy efficiency measures in the built habitat are the two prime movers to enable positive climate changes to happen by way of reduction of carbon emission sizably.

The articles on various aspects of renewable energy and efficiency measures will give the readers a deeper insight into various initiatives being undertaken in this regard especially in the Government sector. Some articles dealing with futuristic concepts will provide insight of research being taken up as the same is likely to be converted into reality very soon with rapid technological advancements.

I hope this seminar will not only bring desired changes in the thought process of policy planners, professional, academicians but will also pave the foundation of new India having reduced carbon emissions.

My sincere thanks to all officers and organizers of the seminar for their untiring efforts in making this event a reality. I would also record my deep appreciation for the efforts put in by Sh. C.K.Varma CE CSQ(E), Sh. D.K.Tulani SE TAS(E), Sh. Rajiv Gupta EE(E) and Sh. V.K.Khetan EE(E) of CSQ unit for publishing the proceedings of the seminar in a short time.

Place: New Delhi
Date: March 8 2019

(DR. K. M. Soni)

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INDIRA PARYAVARAN BHAWAN– A HIGHLY ENERGY EFFICIENT NET ZERO ENERGY BUILDING

P. Bhagat Singh, Chief Engineer, CPWD, Thiruvananthapuram

Abstract

Energy efficiency in any building constitutes both optimisation/minimisation of energy consumption as well as maximisation of renewable energy generation. Indira Paryavaran Bhawan. New Delhi is an example of adoption of both these aspects to the maximum possible extent. By adopting several green building measures, the anticipated energy consumption has been minimised to 14 lakh KWHr per annum from the conventional estimate of around 22 lakh KWHr per annum. Renewable energy generation through solar power has been maximised to above 14 lakh KWHr.

Minimisation of energy consumption has been achieved through efficient architectural and building envelope planning and efficient Electrical & Mechanical Systems (E&MS) including HVAC and lighting.

Indira Paryavaran Bhawan is the GRIHA 5 star rated and LEED India Platinum rated Green building, designed for energy savings of more than 40%. This is also the first zero net energy building constructed in India with 100% onsite generated solar power. Due to inadequacy of rooftop area, additional area was provided through cantilever structural arrangement. The net zero energy building is the outcome of very high energy efficiency and renewable energy generation planning and execution.

Architectural and Building Envelope Planning

Indira Paryavaran Bhawan, the headquarters of the Ministry of Environment, Forests and Climate Change, in Jorbagh, New Delhi, was constructed by the Central Public Works Department (CPWD) as project management agency, in 2013. The G+7 storeyed structure with 3 basements has a plinth area of 32,000 sqm and is centrally air-conditioned with 400 TR capacity (HVAC). It has 7 lifts, and all essential services like DG sets, UPS, IBMS, fire detection and fire-fighting systems, CCTVs, access control, automated parking, and other electrical, landscaping and horticulture services.

The building has the advantage of natural ventilation throughout, with a central courtyard between the North and South blocks connected through corridors with stone jail and balustrades above the 4th floor level. An entrance atrium of four storeys height has been made in the middle of the North block and in the entrance to the South block. The building

has large span trusses at terrace and space frames in the central courtyard to support solar panels.



Figure 1: View of central courtyard

The AC plant room, electric substation, DG sets, fire-fighting pumps, robotic parking for 330 cars and sewage treatment plantsare located in the basements. Pedestrian entry has been provided in the front with vehicular access on the sides.

The building envelope has been designed to be ECBC compliant with envelope insulation to reduce heat intake. Outer envelope is with double walls of AAC blocks separated by rock wool insulation.Trees have been preserved to the extent possible and local materials used, besides reflective roofing, low heat transmission glass, energy efficient materials and practices.



Figure2 : Another view of Indira Paryavaran Bhawan

The following are the salient features of architectural planning;

Building orientation in present case is longer sides facing North and South WWR = 17%, Effective SHGC of fenestration = 0.25, Daylight area = 75.1%, and Wall and Roof assembly

including window glazing ECBC (ECBC 2007) compliant and Lux levels maintained according to NBC to avoid over lighting. Table 1 below provides ECBC/GRIHA Compliant and actual provisions of Building Envelope Parameters.

Table1: ECBC Compliant and actual Provisions of Building Envelope Parameter

S.No	Building Envelope Parameter	ECBC/ GRIHA Compliant Building	Actually provided	Detail of the provisions
1	2	3	4	5
(i)	U value (W/m^2K) of Wall Assembly	0.44	0.36	AAC Blocks (K = 0.16 W/mk) instead of clay Bricks (K=0.6 W/mK) Insulation of walls with Rockwool slabs (K = 0.04 W/mK)
ii)	U value of Roof Assembly (shaded)	0.41	0.34	Roof Insulation with PUF. Reflective Tiles (SR>70%)
(iii)	Fenestrations			
	a) U value	3.30	1.43	UPVC Windows (K = 0.19W/mK). Doubled Glazed Hermetically sealed (6-12-6 mm)Glass with U Value 1.5
	b) SHGC value	0.25	0.25	Glass with SHGC 0.32 (VLT 0.59) and Shading Devices.

Electrical & Mechanical Systems (E&MS)

The electrical load of the building was estimated to be 830 kW. The substation was constructed with two dry type transformers each of 1000 kVA, 11 kV/415 V located in the first basement. One step up dry type transformer of capacity 1250 KVA was provided for supplying power from solar panels to the New Delhi Municipal Corporation grid to make it a zero net energy building. Emergency power was provided by two 500 kVA, 415 volts, 50 Hz, radiator cooled DG sets. The DG sets were provided through synchronization panel with built in protections for the electrical system. The electrical changeover system was capable of

restoring power supply within 15 seconds of disruption (black-out or brown-out) of power.

UPS power was supplied on centralized basis to support critical services such as emergency lighting, administration workstations, security system, building automation system, and network server room.

In outdoor lighting system, 50 to 87 Lumens/Watt LED lighting fixtures with automatic controls powered by renewable source were provided for outdoor, security, street, landscape, and facade lightings against bench mark of 50 Lumens/Watt. In addition, all outdoor lighting fixtures were powered by stand alone solar energy panels.

All mandatory requirements of ECBC were complied including provisions of occupancy and daylight sensors, dry type transformer of 1000KVA installed having losses of 10W only at full load, cooling towers provided with variable frequency drive fans, building management system installed for controlling HVAC system, and geothermal cooling system installed. EPI actually achieved was 24.13KWh/m2/yr against benchmark of 74.01KWh/m2/yr demonstrating 67.39% reduction in energy consumption. ECBC/GRIHA compliant and actual provisions are given in Table 2.

Table 2: ECBC Compliant and Actual Provisions of Energy Consumption Parameters

S.No	Energy Consumption Parameter	ECBC/GRIHA Compliant Provisions	Actual Provisions	Details of Actual Provisions
(i)	Light Power Density (LPD)	10.8 W/m²	5.0 W/m²	a) 75% Building area is Day-Lit b) Efficient T5 & LED fixtures c) Occupancy Sensors
(ii)	HVAC	1TR/15m² (General Practice)	1TR/45m²	a) Chilled Beam system b) Chillers and AHUs VF Drives c) Geothermal Heat Exchange system
(iii)	Other Electrical Devices/Equipment	100 W/m² (General Practice)	40 W/m²	a) Regenerative lifts b) Energy efficient Devices/Equipment c) Thin client system for specified

Prominent systems that contributed to energy minimisation include chilled beam system of HVAC, geo - thermal heat exchange system and regenerative lifts, brief of the same is given in the following.

Chilled Beam System of HVAC

The building was designed for both air conditioning and heating. The air conditioning load was estimated to be 400 TR for which two 240 TR cooled screw chillers having one standby for conventional system and one 200 TR water screw chiller was provided for chilled beam system. Total load of the system would have been around 800TR, if conventional system would have been provided in the entire building.

Energy efficient chilled beam system of air conditioning with energy consumption less than 50% compared to conventional system has been provided. Active type chilled beam system was provided in the building comprising a casing with integral primary air duct fitted with sets of induction nozzles. The coils were used for cooling and heating operations (2-pipe system). The assembly had two separate chilled water coils with single supply and return connections. In the mixing section of the unit, conditioned secondary air was mixed with the primary air and discharged horizontally (Coanda effect) into the room via slots. The unit comprised external casing, edge profiles and suspension lugs. A short section of insulated flexible duct was used to connect the primary air ducting to chilled beam ensuring that flexible duct connection to the beam was sealed air tight. A balancing damper was installed in primary air duct to facilitate the air supply balancing of each beam to the scheduled static pressure at unit level. AHU's serving office are as envisaged with chilled beam system were provided with centrifugal fan, cooling coil and filter section. These air handling units were capable to deliver constant volume of air to plenum of chilled beams. Chilled beams were installed in all conditioned office spaces and corridors, receiving chilled water input at 16-17deg Celsius to avoid any condensation on surface. In addition, dry fresh air was injected into the AHU room which ultimately got mixed with the return air coming out from the conditioned spaces for formation of primary air. Then, the same primary air was injected into the plenum of active chilled beams which passed through the small nozzles creating negative pressure for induction. Finally, the induced air passed through these condary chilled water coil inside the beam. Therefore, sensible cooling effect could be created without any condensation. Primary air conditions were designed in such a way that air can take care of latent load present inside the spaces.

Dedicated outdoor Air handling units (DOAs) of variable volume type, double skin construction for noise control, comprising centrifugal fans, cooling coil section, stainless steel double sloping drain pan for zero water retention, heat recovery wheel, cooling coil, and

filter section were provided at terrace level over the space available adjacent to connecting corridors. The fresh air was pre-cooled by recovering energy from centralized exhaust stream thereby reducing the air conditioning load.

Server rooms catering to net working in the building were also air-conditioned through microprocessor based dual coil floor discharge precision units installed consisting of centrifugal fan, chilled water and DX cooling coil, filter section, humidification/ dehumidification system, and outdoor condensing unit to handle high sensible heat generated in server room.

All the un-conditioned spaces like toilets, stores, AC plant room, pantries and kitchen were provided with mechanical ventilation system. All the basements accommodating automated car parking were provided with a ventilation system with 12 air changes in normal mode and 30 air changes in fire mode. Additionally smoke extraction system was provided in all office spaces with 12 air changes.

The building was also provided with heating system. Hot water generators of total installed capacity 240KW are provided in the AC Plant room.

Geothermal Heat Exchange System

Vertical closed loop system of geo thermal heat exchange system to reduce the load on the HVAC system was adopted for the first time in a government building in India on such a large scale. The system utilises advantage of difference between ambient temperature and the temperature below ground level. The system has vertical closed loop system done with 32mm diameter HDPEU–loops, 180 in number and 80 m deep each. It resulted into reduction of 160TR load on cooling tower and consequent reduction in consumption of water to be achieved.

Regenerative Lifts

Energy efficient elevators were provided with a regenerative drive option, working as a generator when a heavy car returns to ground floor or empty car going up. Instead of turning the braking energy to heat, the electricity has been fed back to the network. It could save upto 25% of the energy consumed by a typical 13 passenger elevator. The power regenerated from the elevator was to be used for power requirement of the elevators. However, suitable tapping point for regenerated power of each elevator was provided for other uses.

Maximisation of Renewable Energy Generation :This has been achieved through installation of 930 KWp Roof Top solar Power Plant. Total area of the RCC slab terrace is 2500 sq.m, whereas the area required to accommodate solar panels is 6000 sq.m. To create this area of

6000 sqm, the entire central courtyard was covered with a stainless steel space frame. Additionally, MS supporting structure over the terrace was extended by providing cantilever, including at the fourth floor level on the southern side. In view of the high maintenance required for the solar panels, an adequate number of catwalks were provided in the entire supporting structure, with perforated bottom for easy draining of rain water. Out of the total area of 6000 m^2, the area covered by panels is 4600 m^2 and by catwalks it is 1400 m^2.

Hot water demand of 1000 litres/day was met from the installed solar water heating system of required capacity.

Zero Net Energy Concept

A zero-energy or a net zero building is a building with zero net energy consumption from outside source, which means that the total amount of energy used by the building on an annual basis is almost equal to the amount of renewal energy produced at site. Such a building is self-sufficient in energy requirements and thus highly energy efficient. It contributes very little greenhouse gases, saves energy produced either from non-renewable or renewable sources somewhere else, andmost of such buildings get half or more of their energy from the grid and return the same amount during non-peak hours of their use.

This building is the first ever zero net energy multi-storeyedbuilding with 100% onsite renewable solar power generation. With a solar power system of installed capacity 930 KWp, the building is also the largest rooftop solar system in multi-storeyed buildings in India. Brief details of solar power are given in the following;

Capacity of power generation	: 930KWp
Annual power demand	: 14 lakh units (KWh)
Annual power generation	: 14 lakh units (KWh)
Total area of solar panels	: 4600sqm
Total area of the system including catwalks	: 6000m^2
Photovoltaic panels	: mono crystalline, 20% efficiency

Energy generation started from19.11.2013. Energy thus generated was being fed to NDMC grid from where supply is taken thereby offsetting the total energy demand. Thus the annual electricity bill in this building becomes zero or negative i.e. net revenue on account of excess solar power generation.

Conclusions

With minimisation of energy consumption coupled with maximisation of renewable energy generation, net zero energy buildings can be constructed thereby reducing the burden on environment and also obviating the need to pay huge power bills.

Net zero energy buildings also help in reduction of transmission losses and help in reduction of carbon emission.

Reference

Bhagat Singh P & Soni, K M (2018). Indira Paryavaran Bhawan, First on site zero net energy building of India, NBMCW July issue, 24(1), 168-179.

SOLAR TREES INSTALLED IN NATIONAL SALT SATYAGRAH MEMORIAL AT DANDI, GUJARAT

Ajay Kumar Agrawal, Chief Engineer, CPWD, Gandhinagar

Abstract

Harvesting of natural resources, without disturbing balance of nature, for power and self suficiency, has been the main pillars of Gandhian philosophy. Tree shape mounting structure for PV Module, for solar power generation, is a concept developed and designed by Indian Institute of Technology, Bombay, in association with outsourced private consultant and constructed by Central Public Works Department. Importance of solar power in growth and survival of trees for photosynthesis, could be the inspiration behind adoption of tree shape structure for supporting PV modules. Availability of ample open space with no high rise building planned within the Memorial complex, which could obstruct througn shadow, is also one of the factors of consideration for such structres, which is unique in itself. Availability of bright sun almost throughout the year at such location is a tempting factor for harvesting solar power.

This paper is with the prime objective of giving glimpse of the solar tree system installed in the National Salt Satyagrah Memorial at Dandi.

Introduction

History and heritage are the part of national pride and consciousness.The National Salt Satyagraha Memorial at Dandi is one of such pride. This memorial is to recreate the spirit and the energy of the 1930 Dandi March to honour the spirit and the energy of the 1930 Dandi March led by Mahatma Gandhi and 80 of his fellow Satyagrahis. National Salt Satyagraha Memorial at Dandi Gujarat is a tribute to 80 Marchers of young age from different segments of society, accompanied Mahatma Gandhi on his Dandi Salt Satyagraha Yatra in 1930, who travelled 241 miles from Sabarmati Ashram, Ahmedabad to the beach of Dandi in Navsari district to challenge the mighty British empire. These are unsung heroes of our freedom struggle. Salt Satyagraha was part of civil disobedience against the draconian British rule.

National Salt Satyagraha Memorial

The National Salt Satyagraha Memorial was planned near the location where salt law was broken, which is in front of Saifee Villa, near Arabian Sea beach at Dandi, where Mahatma Gandhi halted. The memorial is constructed over 15 acre land and conceptualised and

designed as fusion of modern and contemporary architecture and technology, has the following main features;

Artificial lake: Artificial lake with plan area of about 14000 sqm to symbolise the sea shore aspect of the Salt Satyagrah.

Murals: 24 Narrative murals supported on granite monolith in natural shape and finish, depicting various important events and stories from the historic 1930 Dandi March from Ahmedabad to Dandi. Murals represent the spirit and determination of the 80 Marchers who accompanied Mahatma Gandhi.

Statues of marchers: Life size sculptures of Mahatama Gandhi and the group of 80 fellow Marchers.

A Frame In Duplex Steel & Glass Crystal: 40 mtr high A shape frame with two hands raised up in the sky, holding at the top a salt crystal, forming the canopy under which 5 metre high, the main statue of Mahatma Gandhi is placed. This 40 metre high Crystal tower with crystal made in glass is symbol of importance of salt, a gift of nature from the creator for human survival. A pyramid of light through laser will rise up in the sky illuminating the salt crystal at the apex with sun light levels going down towards evening.

Buildings: Single storey buildings in RCC frame with sloping roof and roof covering with Manglore tilesrepresentating contemporary architecture and design of the period of dandi March.

Horticulture works and landscaping: About 7.5 acre land has been developned as green area with variety of big and small trees, plants, shrubs and grass. Hard area comprises of pathways for movement of visitors with top finsh with 75 mm thick red sand stone.

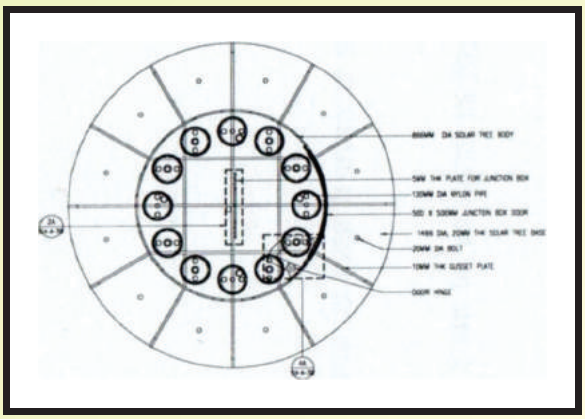
E&M Infrastructure: All required E&M services broadly comprising of DG Sets, LT panels, street lights, illumination of Marchers, pathways, lase lights for illumination of glass crysal etc.

Solar Tree: 41 Solar trees have been installed within the Salt Memorial complex for solar power generation for not only self-sufficiency in respect of electrical power requirements of the memorial but also equal quantum of surplus for feed into the grid. The peak power generation of the system is 182KW (peak). Out of this 142 KW is online system with net metering and other infrastructure such as inverter etc. 40 KW offline system in two parts of 20KW each with battery backup.

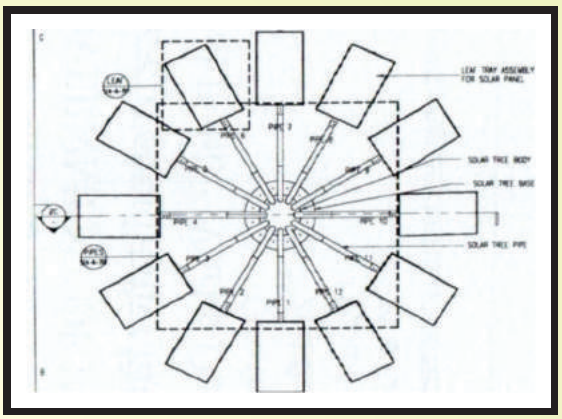
Design of solar trees

41 Solar Trees with 12 leaves in each and generating 182 KW(peak) have been installed. The main components of solar tree are;

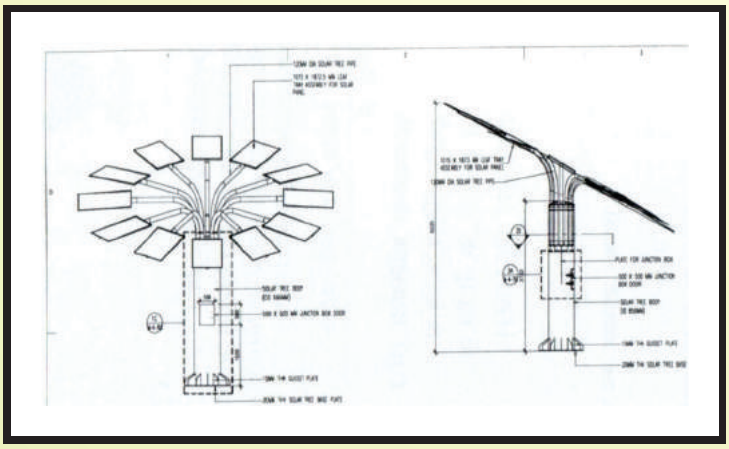
1. Foundation
2. Trunk
3. Branches
4. Leaves



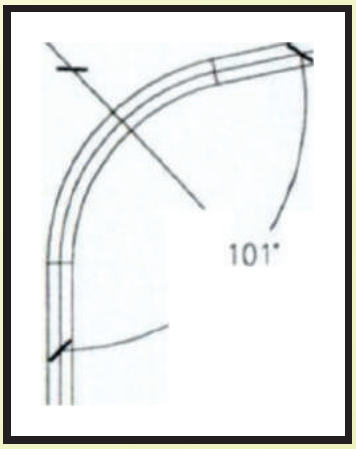
Typical Plan



Typical Plan with Leaves



Typical Front Elevation **Typical Side Elevation**



Typical Bending of Branch Pipes

Construction details

Foundation: Existing sub-soil starata just below the ground level is predominantly marine clay. This memorial complex has been developed by raising ground level by 1.7 mtr with compacted earh filling. Founding level is kept almost at the existing ground level with bottom

most layer of 225 mm thick Granuar Sub-base, followed by 100 mm thick levelling course in PCC and foundation with 200mm thick 3000MM X 3000MM RCC raft and 1500MMx1500MM RCC pedestal. Holding down bolts are placed in the pedestal for jointing base plate of trunk of solar tree.

Trunk: It is made with 8mm thick MS plate bent to shape and jointed with arch welding to form circular member of 866 mm outer dia. Close vicinity to coast provide potential corrossive atmosphere. Therefore multi-layer protective coatings have been provided with 1st coating of dip galvanisation of the entire trunk assembly, 2nd layer of two caots of Etch primer, 3rd layer of epoxy paint and final top layer of two coats of PU paint as per manufucturer's specifications for enhanced serviceable life.

Branches: 12 branches made in 316 grade SS pipes of 114 MM (OD) and 6MM wall thickness, bend to twevlve different angles to provide support to leaves and facilitate formation of one inclined plane surface for all leaves of the tree.

Leaves: Each leaf comprises of (i) Supporting frame in 316 grade Stainless Steel sections, (ii) Bottom cover with 2mm thick SS plate moulded to shape and with protrusions similar to veins of natural leaves (iii) Connecting member with branch in 316 grade SS, (iv) PV module on top fixed on supporting frame and (v) Required wiring.

Technical Specifications of Solar Module

Monocrystalline Solar PV Module, Make-Waaree		
S.No.	**Parameter**	**Technical Specification**
1	Cell type	Monocrystalline
2	Wattage	370WP
3	Efficiency	19.07 percent
4	No. of cells	72
5	Open circuit voltage	47 volt
6	Short circuit current	10.15 amps
7	Maximum power voltage	38.15 Volt
8	Maximum power current	9.70 Amps
9	Maximum system voltage	1000 Volt DC
10	Certifications/Standards	IEC-61215,IEC-61730-1,IEC-61730-2,IEC-61701,UL listed

Technical Specifications for on grid solar inverter

On Grid Solar Inverter, Make-Delta		
S.No.	**Parameter**	**Technical Specification**
1	Maximum DC power	37.5 kw peak dc
2	Rated output power	30 KVA
3	Efficiency	98.6 percent peak
4	IP Rating	IP-65
5	Input voltage Range	200-1000 Vdc
6	Nominal Output Ac voltage	415 Volt
7	Total Input current	60 amps
8	maximum output current	50 amps
9	Harmonics	Less than 3 percent at rated power
10	output frequency range	45-55 HZ
11	Certifications/Standards	IEC-61000,IEC-62116,IEC-61727,IEC-62109-2:2011,IEC-61683:1999

Technical Specifications of "off grid" solar inverter

Off Grid Solar Inverter, Make-consul Neowatt		
S.No.	**Parameter**	**Technical Specification**
1	System Rating	20 kw
2	Efficiency	more than 88 percent
3	IP Rating	IP-20
4	MPPT voltage Range	165-265 Vdc
5	Nominal Grid input voltage	415 Volt
6	Battery Voltage	240 Volt
7	Maximum Input current	70 amps
8	Harmonics	Less than 5 percent at rated power
9	output frequency range	47.5-52.5HZ
10	Certifications/Standards	IEC-60068,IEC-62116,IEC-62040,IEC-61683:1999



Concept of Solar Tree



Completed solar Trees- A View



Erection of trunk over foundation



Finishing coats on trunks



Cladding on leaf bottom

Assembling of leaf components

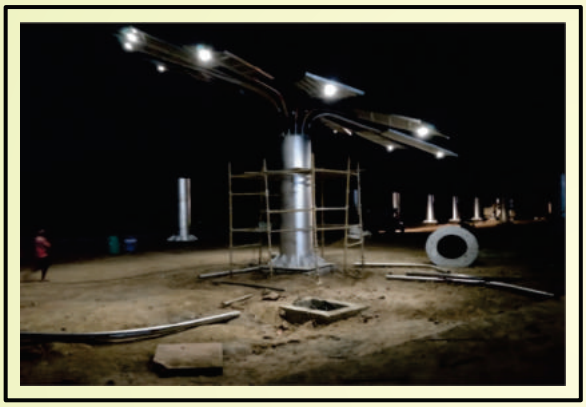
Wiring in leaf



Assembling of leaf components



Installation of pre-assembled leaf & branch



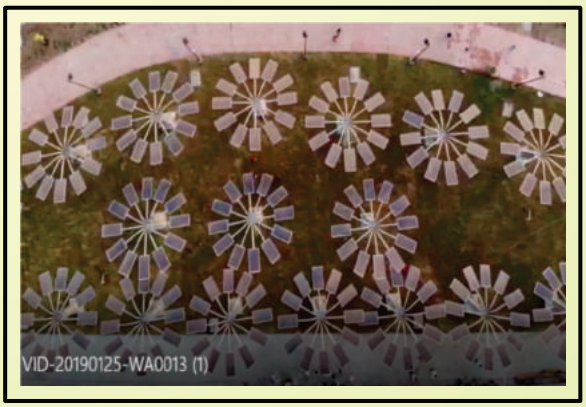
Partly assembled Tree at night



Installation of leaf and branch assembly



Partly assembled Tree at night



Installation of leaf and branch assembly

Conclusion

Solar power harnessing through PV module, as leaves of tree shaped structures, is an aesthetic expression. This draws attention to the abundance of non-conventional energy, being constantly provided free, by nature itself. This concept of solar trees installed at National Salt Satyagraha Memorial, is metaphor of nature's system of using solar energy, with analogy to trees. This model of solar power generation system may not be as efficient as compared to other models. However, two fold benefits have been drawn. Firstly, adoption of shape in harmony with nature has provided uniqueness to the entire system, merging with unique features of the Memorial. Secondly, the Memorial has become self-sufficient in respect of electric power requirements, besides revenue generation through surplus power generation. In solar power harnessing systems, the mounting structures of PV modules is invariably, given least importance. In this case, equal importance has been given to the structure also, which has resulted in a spectacular panorama, created by the cluster of 41 solar trees. The solar trees have become one of the main attractions of the visitors to the Memorial. The cluster of solar trees could not escape the attention of the Hon'ble Prime Minister of India, on the occasion of Inauguration of the Memorial on 30th January 2019.

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SUSTAINABILITY IN BUILDINGS AND BUILT ENVIRONMENT - A COMPREHENSIVE APPROACH IN THE NBC-2016

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Abstract

The indiscriminate use of natural resources since the development of civilization particularly their exploitation in the last one century or so in the process of industrialization and in the pursuit of comfort-at-all-cost, has resulted in a situation of almost no return. Under the circumstances, 'Sustainability' is the mantra and saviour of civilization. The most important aspect in achieving sustainability is to address the cardinal principles of sustainability of reduce, reuse and recycle with due consideration to sustainability objectives in respect to space and time.

Every building has to be a part of overall sustainability scenario in a larger context simultaneously keeping time duration in mind over which the sustainability is to be achieved because of cost implications and likelihood of paradigm shift in materials, technologies and developmental requirements during different times.

The comprehensive approach would require to deal with all aspects relating to siting, form and design; external development and landscape; envelope optimization; selection of appropriate materials; water and waste management; building services optimization; constructional practices including selection of appropriate technologies; and commissioning, operation, maintenance and building performance tracking. This paper discusses approach to sustainability incorporated in the National Building Code of India, with a view to making appropriate decisions during conceptualization, planning, design, construction, and operation and maintenance stages of the built facility.

Introduction

Modern buildings in India consume about 25 to 30 percent of total energy, and up to 30 percent of fresh potable water, and generate approximately 40 percent of total waste. India is now entering the phase of rapid urbanization. Various studies indicate that by 2050, the built up area of all the buildings in India may become four times the current mass, which may pose a major challenge in preserving our fragile environment. Although the present energy consumption per capita in India is a fraction of that of most developed nations, but with its projected growth, unless enough measures are taken, it may lead to acceleration of environment degradation, contributing to increased carbon footprint leading to global

warming and climate change.

Sustainable built environment being environment friendly results in much better health and productivity of occupants at minimal additional initial cost over the cost of conventional buildings, also substantially reducing the life cycle cost. The sustainability concepts and features have to be advantageously applied during all the stages of a building project. This need has been fulfilled in 'Part 11 Approach to Sustainability' of the National Building Code of India 2016 (NBC 2016). Further NBC 2016 in its Part 3 'Development Control Rules and General Building Requirements' covers detailed administrative provisions for solar energy utilization. The Code promotes in its various provisions particularly those in Part 8/Section 2 'Building Services, Electrical and Allied Installations' to plan buildings electrical services in a manner to integrate with alternate sources of energy such as solar energy. This chapter of the Code covers provisions relating to electrical installations of Solar Photovoltaic Power Generation System. Lightning protection for buildings with roof-top solar PVs and water heating systems and large solar PV power plants/farms are also covered in this section of the Code.

Comprehensive Approach

The comprehensive approach relating to buildings and built environment requires to deal with all aspects relating to siting, form and design; external development and landscape; envelope optimization; selection of appropriate materials; water and waste management; building services optimization; constructional practices including selection of appropriate technologies; and commissioning, operation, maintenance and building performance tracking. The objective is to ensure that the building is built sustainably using optimum embodied energy and optimization of operational energy and least maintenance. The progressive thought requires that the building and built environment should not be designed only to reduce the adverse effect to the environment but should intend to cause positive effects to the environment, economy and the society at large. The approach would therefore generally require that projects are sited with a view to avoiding disturbance to ecology; external/township development and landscaping promotes efficiency, safety and orderliness; envelop optimization promotes substantial energy conservation; material selection is based on their life cycle analysis with respect to various criteria such as embodied energy, resource reuse and upgradation, recycled content, reusability or recyclability, abundance, local availability, rapid renewability, compliance in maintaining clean air and water, etc; water and waste management promotes efficient water usage, water and waste recycling and reuse, rain water harvesting, effective solid waste management; building service optimization ensures complete building management system

encompassing all building services facilitating overall functionality and required efficiency and environmental performance; constructional practices and management contributes towards all goals of sustainable built facility; and the operation and maintenance then takes care of required asset and facility management to ensure that the same remains sustainable.

The comprehensive approach includes the following;

i. Siting, form and design

ii. Sustainable external development and landscape

iii. Envelope optimization

iv. Environment friendly and energy efficient materials

v. Sustainable water and waste water management

vi. Building services optimization

Before initiating the formal design process, it is critical to evaluate all the passive design options to take advantage of local site and climatic conditions to reduce overall energy consumption and allow buildings and its operations to seamlessly integrate with its immediate environment while minimizing the overall negative impact on the environment.

To achieve sustainability objectives, this should ensure proper landscape design including microclimatic conditions, barrier free external landscape, noise reduction/mitigating practices, pervious paving design, avoiding heat-island effect, preserving to soil, ensuring ecological design to conserve bio-diversity through protection and use of existing vegetation, rain water harvesting, etc.

The building envelope should be utilized to conserve energy substantially to maximize daylight, natural ventilation (access to fresh air) (Fig. 1), view to the exterior, enable to modulate solar heat gain (Fig. 2) and control/reduce noise. The primary components of building envelope which affect the performance of a building, are walls, roof, fenestration (openings with or without glazing), floor, and surface finishes. The building envelope may also be designed to integrate systems for renewable and rainwater harvesting taking into account various climatic zones into account (Methods for calculation of solar radiation on buildings are covered in IS 11907:1986 'Recommendations for calculation of solar radiation on buildings').

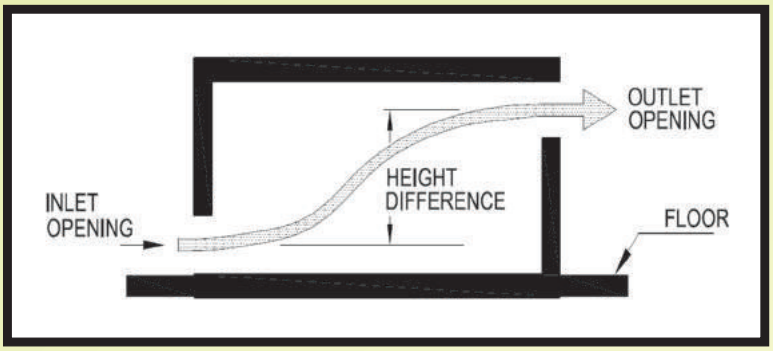


Fig 1: Enhanced ventilation through wall openings

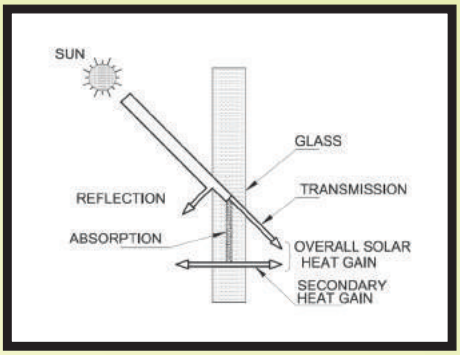


Fig 2: Mechanism of solar heat gain

Various methodologies to achieve the thermal performance with use of insulating materials along with design of openings with shading devices (Fig. 3) are available for proper design of building envelope. Also, available envelope optimization methods can be used such as inverted earthern pots for roof insulation, mud phuska and brick bat coba also. Similarly, use of screens (jalli) reduces heat ingress and yet allow the air movement.

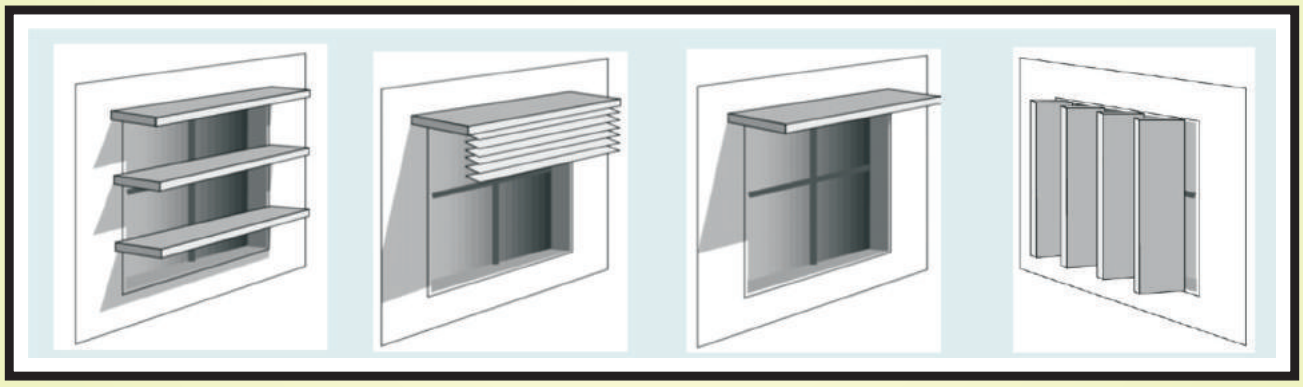


Figure 3: Commonly used shading devices

Also, renewal energy integration in envelope can be ensured through following measures:

a) Integration of Solar Thermal Technologies

b) Integration of Photovoltaic Technologies

Selection of environment friendly and energy efficient materials from the considerations of embodied energy, transportation, toxicity and safety is essential. Environmental concerns and human health and safety, minimization of green house gas emission and life cycle assessment are essential for selection of materials.

The use of rapidly renewable materials, recycled materials minimizes the adverse impact of natural resource consumption in the manufacture of new building materials. The use of local materials supports the local economy and reduces the negative impact of transportation.

A description of life cycle analysis with respect various relevant criteria may involve embodied energy (Table 1), resource reuse and upgradation, recycled content, reusability or recyclability, local availability, their source of manufacturing, rapidly renewability, and compliant to air and water pollution.

Table 1 - Classification of materials based on energy intensity

Sl No.	Category of material	Energy intensity (Range) (GJ/tonne)	Examples
1	High energy	>5	Aluminium, Stainless Steel, Plastics, Copper, Zinc, Cement, Plasterboard, Steel, Glass, Bitumen, Solvents, Hollow concrete blocks, Cardboard and Paper, Lead.
2	Medium energy	0.5-5	Lime, Gypsum board, Burnt clay brick, Burnt clay brick with improved vertical shaft, Soil cement blocks, Aerated block, Gypsum plaster, Concrete*in -situ*, Concrete blocks, Timber products, Medium density fibre board, Cellulose insulation
3	Low energy	<0.5	Sand, aggregate, Fly ash, Cement stabilized earth block, Straw bale, Stone

For achieving sustainable water and waste management, major considerations during planning and design include yield and quality of raw water sources; topography, geology, population density of service areas; intended uses of water; and treatment of waste water. Since these considerations may vary from project to project, all water and waste management system solutions are unique. During construction stage, the project teams have to monitor water consumption, control wastes and dispose off in an environmentally appropriate manner by selecting water efficient materials and technologies and value engineering of material and technology. Building projects are to be planned, designed and executed in accordance with the anticipated functional use. Appropriate metering and corrective improvements should be integrated in the system design detailing. It may be desirable to design water system taking functional homogeneity into account and facilitate function specific corrections.

Optimization of electro-mechanical services is one of the important aspects towards achieving a sustainable building. Reduction in heating, cooling and lighting loads through climate-responsive designs and conservation practices can enhance the energy efficiency of a building. In addition, an integrated project delivery (IPD) approach results in a well-designed, cost effective solution wherein all building systems and components can in coherence facilitate overall functionality as well as required environmental performance. The passive design features and proper initial planning helps in reduced energy demand and, therefore, the same should be carefully analyzed prior to actual sizing of equipment where provided.

In addition to achieving the optimum energy performance, the building should also provide the desirable thermal and visual comfort to its occupants. Incorporating solar passive techniques in a building optimizes building performance by minimizing the use of artificial energy and thereby minimizing load on conventional systems for heating, cooling, ventilation, lighting, etc.

Solar passive techniques that can be adopted in different climate zones of India are:

a) landscaping (to reduce heat island effect);

b) optimum building orientation;

c) arrangement and shape of buildings;

d) effective surface to volume ratio;

e) location and size of openings on building facade;

f) glazing type and performance;

g) shading devices on windows and judicious selection of building materials.

Prior to developing the design drawings, the design team should carry out a thorough review of the fundamental assumptions, owner's brief and available resources on site, in an integrated manner, addressing the key target issues like building orientation, building envelope, site energy harvesting, design assumptions and internal load assessment, and efficiency maximization. This would further require adopting appropriate natural and mechanical ventilation strategies, passive heating techniques, passive cooling techniques, pre-cooling of ventilation air, low energy mechanical cooling techniques, etc. For air-conditioned buildings, the HVAC System may be designed keeping in view, the aspects like appropriate equipment sizing, selection of unitary/ variable refrigerant flow systems/central

system for air-conditioning based on the actual needs, use of refrigerants having zero ozone depletion potential (ODP) and least global warming potential (GWP), use of efficient systems/methodologies in respect of chillers, chilled water pumping systems, thermal energy storage technique, vapour absorption system, air handling units, fans and blowers, controls, etc.

In respect of electrical system, efforts should be made to select electrical installations and systems which are energy efficient, while complying with the national Standards for the same which provide apart from efficiency, the various other important requirements including relating to performance and safety. The requirements for energy efficient design of electrical installations in buildings may be classified under the following four categories:

a) Minimizing losses in the power distribution system,

b) Reduction of losses and energy wastage in the utilization of electrical power,

c) Reduction of losses due to the associated power quality problems, and

d) Appropriate metering and energy monitoring facilities.

The active energy efficiency measures include making use of energy saving equipment, low energy lighting, efficient motors, low loss transformers, efficient appliances, suitable power carrying devices and optimized electrical distribution. These active measures along with high efficiency standby emergency generating plants using diesel, natural gas, alternate fuel, etc coupled with high efficiency uninterruptible power supply (UPS) systems contribute towards sustainable development. Passive features include good practices like simple switching off (to turn off a device when not in use), paying attention to vampire electric loads (associated with electronic appliances like computers), etc.

The optimal use of daylight should be made to reduce the load of the electric lighting system by dimming or switching off luminaires when natural light provides ample illuminance for the task performed in the space. Daylight harvesting has a significant energy saving potential if it is integrated with the building design after comprehensive understanding of site, building orientation, weather conditions, materials and system design. Lamps, luminaries, ballasts and the controlling systems should be monitored for achieving energy efficiency through artificial lighting. Factors that play crucial role in designing an energy efficient lighting system are reflectance, design of interior spaces, efficiency of lighting systems, task lighting, controlling systems, and monitoring and maintenance.

Similarly, efficiency needs to be achieved in other services like lifts, escalators and travelators with least environmental impact. Also, all efforts should be made to utilize in the

building, the renewable energy available in various forms for which the following considerations should be made:

a) Solar energy utilization – Solar energy may be utilized in building through Solar water heating systems, solar steam systems for cooking, laundry, etc., solar assisted refrigeration/air conditioning systems, solar photovoltaic systems, wind energy utilization, waste utilization, waste heat utilization, solid waste utilization, bio-fuels, hydropower and other renewable energy sources.

NBC 2016 in its Part 3 'Development Control Rules and General Building Requirements' covers detailed administrative provisions for solar energy utilization. The Code prescribes installation of Solar Photovoltaic Power Generation System for all plots having size 500 m2 and above. The Code also encourages such installations for plots smaller than 500 m2. Following other provisions in this respect have been specified in this chapter of the Code:

a) Installation of either solar panels on roof tops, or integrated photovoltaic panels on walls/windows, or solar photovoltaic (PV) banks on open areas.

b) Utilization of power so generated for either in-house or for transfer to the grid.

c) The Authority shall have required provisions in the building bye-laws and mechanism for required clearances and approvals.

d) The Authority shall specify minimum generation requirement.

e) The Code provides guidance for minimum generation requirements.

The Code also prescribes requirement of installation of Solar Water Heating System for the following building occupancies for supplying hot water:

a) Residential buildings (except hostels of educational buildings and plotted houses) having plot area 4 000 m2 and above;

b) Plotted houses having plot area of 250 m2 and above;

c) Hostels for schools, colleges and training centres for more than 100 students;

d) Institutional buildings; and

e) Assembly buildings.

Following other provisions in this respect have been specified:

i) The Authority shall have required provisions in the building bye-laws and mechanism for

required clearances and approvals.

ii) The Authority, considering the availability of solar energy for harnessing, shall decide the minimum capacity to be installed subject to a minimum of 25 litre per day hot water yield for each bathroom and kitchen.

For solar water heating system and their installation, reference to following Indian Standards should be made:

- IS 12933 Solar flat plate collector — Specification

  (Part 1): 2003 Requirements (second revision)

  (Part 2): 2003 Components (second revision)

  (Part 3): 2003 Measuring instruments (first revision)

  (Part 5): 2003 Test methods (second revision)

- IS 12976 : 1990 Solar water heating systems — Code of practice

NBC 2016 in its Part 9/Section 1 'Plumbing Services (including Solid Waste Management), Water Supply' covers provisions relating to installation (including piping) for solar assisted water heating systems.

The Code promotes in its various provisions particularly those in Part 8/Section 2 'Building Services, Electrical and Allied Installations' to plan buildings electrical services in a manner to integrate with alternate sources of energy such as solar energy. This also covers provisions relating to electrical installations of Solar Photovoltaic Power Generation System. Lightning protection for buildings with roof-top solar PVs and water heating systems and large solar PV power plants/farms is also covered in this chapter of the Code.

Further, NBC 2016 in its Part 8/Section 3 'Building Services, Air Conditioning, Heating and Mechanical Ventilation' covers provisions relating to utilization of solar heat energy for heating buildings. Also, various passive heating (like solar chimneys, trombe walls, etc) and passive cooling techniques (nocturnal cooling, courtyards, etc) have been discussed in Part 11 of the Code.

The Code also prescribes use of Solar Photovoltaic Systems for lighting purpose in remote non-grid areas. The use of common SPV lighting systems, a) Solar lantern, b) Fixed type solar home lighting system, and c) Street lighting system has been prescribed. Guiding provisions on their use have been provided.

Construction Practices

The framework for sustainable construction practices includes the following issues:

a) Pre-construction pre-requisites;

b) Planning for sustainable construction;

c) Preparation of sustainable construction management plan;

d) Planning, monitoring and control of environmental descriptors;

e) Sustainable work execution procedures;

f) Effective use of water;

g) Construction waste management ;

h) Post-construction closeout;

i) Construction methodology for heritage buildings; and

j) Alternative use, de-construction, dismantling, demolition.

Commissioning, Operation, Maintenance and Building Performance Tracking

Typically, the first step in the commissioning process should involve formation of a commissioning team that comprises the owner, users, occupants, operation and maintenance (O&M) staff, and design professionals and owners. The next step is the preparation of the project requirements, which should address building systems such as lighting, air-conditioning, water systems, etc as well as the design intent and the functional specifications for the key building systems. The project design document should include a commissioning plan. Prior to the handover stage, the commissioning team should verify the installation of the systems, conduct functional performance testing, training of the O&M personnel, etc. A post occupancy commissioning report should be provided to the owner and/or relevant authorities once the necessary tests have been conducted and the areas that need correction have been rectified. In all commissioning processes, the elements relating to sustainability should be ensured for their proper operation at subsequent stages.

During the handover stage, records of meter readings for the different building systems, and other data should be provided to the asset management team. A simple guide for occupants will help the team understand the working of the systems in the building.

O&M programmes that focus on improving energy efficiency of building systems can help

save energy without a significant capital investment. From small to large sites, these savings can represent significant savings each year, and can be achieved with minimal cash outlays.

Effective operation and maintenance is one of the most cost-effective methods for ensuring reliability, safety and efficiency of a building. Inadequate maintenance of energy-using systems is one of the major causes of energy waste. Energy losses from steam, air and water leaks, uninsulated lines, maladjusted or inoperable controls and from poor maintenance are often considerable. Also, inadequate maintenance of systems that consume water, including plumbing and HVAC systems (as applicable); can result in excessive usage of water. Good maintenance practices result in substantial savings in energy and water, and to be considered as a resource.

Subsequent to the commissioning and handover stage, regular monitoring of the performance should be carried out which will provide information on whether the set environmental performance and targets have been met or not. As part of the measurement and verification (M&V) process, an ongoing monitoring of the energy and water systems should be carried out. This will ensure ongoing accountability of energy and water consumption during the life of building.

Conclusion

Achieving sustainable building construction would require understanding of sustainability concerns during conceptualization, location/siting, planning, material selection, design, construction, operation, maintenance and deconstruction. Each stage is a sub-system of overall system of the building. Maximizing each sub-system may not necessarily result in maximizing the overall system. It is, therefore, important that each stage should be understood clearly from its overall contribution and its inter-linkages during the life cycle of the building project. There is need to provoke the thoughts leading to greater awareness and triggering conscious analysis while making sincere efforts to make sustainability all pervasive. However, over a period of time, it should be intended to build a culture of bringing 'sustainability' into mainstream to make it essential part of all construction projects at par with quality, safety and functionality. Towards this, the National Building Code of India wherein the concept, approach and features relating to sustainability have been duly incorporated is poised to play a significant and leading role.

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FREE COOLING AND OTHER MEASURES FOR IMPROVING IAQ AND ENERGY EFFICIENCY IN HVAC SYSTEMS

C S Mittal, Former CE(E), **Vishesh Swamiwal,** EE(E) & **Nikhil Gupta,** AEE (E), CPWD

Abstract

This paper deals with some of the simple measures taken to improve Indoor Air Quality and reduce energy consumption at low/air side of HVAC during design stage in one of the prestigious project of CPWD: Supreme Court Extension Project, New Delhi

Introduction

Air-conditioning: The objective of providing air-conditioning in any building is to provide conditions to people so that they can work in comfort, safely and efficiently. But whenever we think of providing air-conditioning, the first thought which strike to us is the power consumption. Air-conditioning is considered as power guzzler and in most of the cases constitute about 40% -70% of total Electricity bill of a large building.

Heating, ventilating, and air-conditioning (HVAC) in a Business/Institutional building consume more energy than any other activity in the building. According to U.S. Department of Energy Studies of commercial buildings, HVAC equipments typically account for over 40% of a building's energy usage.

In a typical Water Cooled Central AC system at Delhi, having water and air cycles, the equipment wise break up of power consumption is as follows.

System Average Energy Use

Chiller = 0.65 kW/Ton

Pump = 0.10 kW/Ton

Cooling Tower = 0.05 kW/Ton

AHU Fan = 0.2 kW/Ton

Total for System = 1 kW/Ton

High side/water side energy consumption: 70% (not 80% because AHU fans run for almost full time, while chiller keeps on switching ON/Off or runs on reduced load for quite some time)

Low side/air side energy consumption: 30% (not 20% as AHU fan runs for full time of AC operation unlike chiller and pumps)

Since high side of HVAC (particularly chillers) has largest share of energy consumption, lot of attention is drawn towards energy efficiency of chillers. We normally provide best in class high side equipments (chillers having IKW of 0.62 to 0.68, high efficient pumps with VFD, CTI certified cooling towers etc.). Another second most important area of energy consumption is by AHU's /air side.

Indoor Air Quality, International Perspective: Environmental Protection Agency (EPA) defines indoor air pollution as chemical, physical or biological contaminants in the breathable air inside a habitable structure or conveyance, such as in homes, schools, offices, and vehicles. It is hard to come up with another problem that affects more people than indoor pollution. Yale School of Medicine states that “Americans spend approximately 90% of their time indoors. The EPA and its Science Advisory Board have consistently ranked indoor air pollution among the top five environmental risks to public health. The average person breathes 3,400 gallons of air each day, making ambient air pollution a major environmental problem. Poor indoor Air quality adversely affects employee productivity. A recent study by teams from Harvard and Syracuse Universities on indoor air quality suggests that employees in green environmental conditions performed 61% better on cognitive tasks than in standard office conditions. And if one doubles the ventilation, cognitive performance can be increased by more than 100%. As per estimates over 90% of the total operating cost of commercial office buildings is attributed to the cost of employee salaries. It means that small investments /efforts in improving IAQ should be appreciated by one and all.

Indoor Air Quality, Indian Perspective: There has been lot of talk on IAQ in media. In past few years the quality of air in major cities has deteriorated a lot and people living in such cities are aspiring to have good indoor air quality at work place and living place. It is the duty of owners and designers of buildings to do their bit to improve IAQ, so that users of such buildings can breathe comfortably indoor.

What affects Indoor Air Quality?

- Moisture and mould
- Pollutant sources
- Amount of ventilation

What can be done by AC design Engineer?

- Increase ventilation rate
- Better maintenance of ducts, filters, AHU coil
- Adopt methods to reduce mould, fungi etc.

Night Purging

Ours is a daytime building and in such buildings AC systems are kept switched off during night and weekends. This means excessive heat is not removed from spaces during that period and when AC systems are switched on next day in the morning, the heat thus built up needs to be removed. Due to this reason, we need to switch on large AC plants about 1 to 2 hours before the actual start of business/office hours. This compels complete AC system to work at higher load and lot of energy is consumed every day morning even before activities/ functioning start in the building.

It is a fact that in the early morning hours ambient air quality is much better as compared to indoor air quality (in terms of Oxygen, CO2 content etc.) and outside air temperature (even in extreme hot season) is much less than indoor air temperature. This phenomenon has been made use of to reduce energy consumption as detailed below:

Fresh air Grills and dampers in AHU rooms have been designed and to be controlled through IBMS, so that outside cool air is used every day early morning (for an hour from 5 to 6 pm), to completely replace the indoor air having excessive heat and poor air quality with fresh outside air. While doing so, chiller is kept off.

It was observed that once this is done, indoor air temperature reduces by about 5 deg Celsius in the month of September and indoor air becomes very comfortable. It means we need not run chiller much before in the morning hours to cool indoor air before office is made functional.

Since we are replacing complete indoor air with fresh air every day, Indoor CO_2 and CO levels come at par with outdoor levels, thus improving IAQ.

As this is a centrally AC building having closed windows, this measure alone shall result in saving of about 7% electrical energy for HVAC system. We shall be required to switch on AC plant only about half an earlier before office timings instead of one and half hour otherwise, thereby saving of running of High side for 1 hour out of 10 hours, resulting in 70% of 1of 10 hours for 180 days of AC operation i.e. 7% of HVAC bill.

Free Cooling

When the enthalpy of the outside air is less than the enthalpy of re-circulated inside air, conditioning from outside air is more energy efficient than conditioning the re-circulated air. When outside air is sufficiently cooled, no additional conditioning is needed.

All of us observe that in Delhi climate, in the month of March/April and in the month of October/November, on many days we feel better outside than in AC rooms.

Hence this common observation has been used to save energy and improve IAQ at our project. For making use of this common observation to our advantage, we plan to monitor outdoor air quality and whenever outdoor air quality is better (in terms of enthalpy) we plan to (i) switch off Chiller (ii) control the dampers in AHU rooms in such a fashion, so as not to re circulate air, but to take fresh air in and exhaust stale air. As we have already planned for night purging (explained above) no additional controls or dampers are required. This scheme shall be monitored and implemented through IBMS only. We expect that we shall be able to use this arrangement at least on 20 working days in a year out of 180 working days of AC chiller operation, thereby saving of about 70% (high side saving) on 20 of 180 days i.e. 7.8 % annual (only low side operation) on HVAC bill.

Controlled intake of Fresh Air

In any AHU room, we normally take 5 to 15% fresh air (5 cfm to 15 cfm per person) to contain indoor CO2 levels within permissible limits. We normally lock the fresh air damper at a set point i.e. fresh air at certain rate is being taken inside irrespective of its actual requirements and indoor air quality remains non-controlled. In the heat load calculations, one of the major heat source is fresh air. If we provide more than required fresh air (to maintain IAQ), we are unnecessarily loading our chiller.

At our project we are monitoring return air in each AHU room, using CO_2 sensor and based upon set point we are modulating fresh air damper, so that only required quantity of fresh air is taken in AHU room.

By making this arrangement we shall assure indoor air quality and also avoid unnecessary burden on HVAC system. Although no data is available at present, but we estimate to save at least 3% of HVAC bill due to this measure.

Dampers

ASHRAE Standard 90.1-2004 limits the leakage rates of dampers as shown in Table 3. These limitations are mandatory provisions of Standard 90.1. Air handling units with dampers that

do not meet these leakage rates prevent the building in which they are installed from meeting ASHRAE 90.1. In the LEED NC rating system, non-compliance with a mandatory provision of ASHRAE 90.1 disqualifies the building from LEED certification.

TABLE 3 - ALLOWABLE DAMPER LEAKAGE RATES

Climate Zones	Maximum Damper Leakage at 1.0 in w.g. cfm per ft^2 of damper area	
	Motorized	Non-motorized
1, 2, 6, 7, 8	4	Not allowed
All others	10	20(a)
Dampers smaller than 24" in either dimension may have leakge of 40 cfm/ft^2		

Source: ASHRAE Standard 90.1-2004

Consider a 16,000 cfm AHU with a 8' x 4' wide (500 fpm) outdoor air damper. At a leakage rate of 10 cfm/sft, such a damper leaks 320 cfm when closed – that's equivalent to 2% of design airflow. The same 96" x 48" damper with a leakage rate of 4 cfm/sft only leaks 128 cfm, or 0.8% of design.

At this project we have provided damper with a leakage rate of 5 cfm/sft. That means less leakage (say half of leakage of 10 cfm/sft) by saving 1% leakage from closed dampers, we are saving about 1% heat load, thereby 1% annual energy bill by this simple measure.

VFD Speed control of AHU blower fan: We always design AHU blower for peak cfm requirement after adding about 15% safety margin. Requirement of cfm changes with weather condition and human load also. In our case we have not provided VAV box, as we have large halls in most of the area. We are sensing relative humidity of return air and modulate fan motor speed based upon temperature and humidity. As we know power consumed in AHU fan is proportional to cube of speed of fan.

Considering above facts, we have estimated saving about 40% of Low side due to this measure or 12% of Overall HVAC energy bill.

Use of IE3 class fan motor, suitable for VFD drive: As we have used IE3 rating motors in all AHUs (against IE1 rated motors otherwise), estimated energy saving due to high efficiency of these motors shall be about 6% of low side or 1.8% of overall HVAC energy bill.

Use of FEG 70 fans: Normally fan efficiency is not prescribed in tender document. We have provided minimum FEG 70 fans. As these fans are at least 10% more efficient than normal fans, estimated energy saving due to this measure shall be about 10% of low side or 3% of overall HVAC energy bill.

Maintenance issues: To address the maintenance issue, contractor who has installed the system is required to maintain and operate the system on comprehensive basis not only during guarantee/warrantee period of one year but for another 5 years also, so as to make sure that system is properly maintained and responsibility can be fixed.

Conclusion

In these days of ever-escalating energy costs, the value of high-performance air handling units with modern controls cannot be ignored. By using the above simple and cost effective methods at low side alone, it was possible to reduce energy consumption of comfort HVAC system by 35.6 % of overall HVAC bill. This shall result in annual saving of about Rs 63,30,078/- (2100 Tr*0.8 df*1 Kw/Tr*180 days*7 hr effective operation of plant *Rs 8.4 /unit*0.356) to Government. Moreover good indoor air quality is provided to occupants of building without providing any costly measures.

ENERGY EFFICIENCY MEASURES IN I P BHAWAN, NEW DELHI IN ESCO MODEL

C.K. Varma, CE CSQ(E) & **V.K. Khetan,** EE(E) TAS

Abstract

I.P. Bhawan is a Central Government Office Building located at IP Estate, New Delhi. In this Bhawan various offices are located in two blocks namely Y-shape building and Drum-shape building, which function from 9 AM to 7 PM on 6 days a week from Monday to Saturday. This building expends on an average of Rs. 20 lakhs per month on electricity bill. This is a huge payment and there is always a problem of non-availability of budget under the Head 2059-Lease Charges because of which there is a constant pressure to reduce the electricity bill.

In order to address this problem, Energy Efficiency Measures were required to be implemented in this building so that electricity consumption can be brought down and consequently electricity bill can be reduced effectively. However, there was no fund available for capital expenditure on these measures. Accordingly, ESCO (Energy Service Company) model was selected to implement Energy Efficiency Measures. In this model there is no upfront expenditure on account of Capital Investment on Energy Efficient Lighting, Fans & Air conditioners. This model also guarantees savings for a set period of time in exchange for payment from the energy cost savings. A Performance Contract is signed in this model between the user and the ESCO company which was M/s EESL (Energy Efficiency Services Limited) in this case. EESL is the joint venture company of 4 Navratna PSUs of Govt. of India namely NTPC, PFC, REC and PGCIL under the administrative control of Ministry of Power. The Performance Contract was signed on 24/04/2015 and work was started thereafter and completed in December 2016.

This paper analyses the methodology adopted and deliverables achieved on account of Energy Efficiency Measures undertaken in this building in ESCO model.

Introduction

Huge Electrical Energy is consumed in every modern office building due to activity pattern of the occupants which is very intense and use of numerous electrical and electronic gadgets. The consumption pattern of Electricity reflects the rise in demand every year. It is therefore very much desirable to control this consumption of electricity. However by bringing the awareness campaign alone, it was not possible to achieve it. The only possible way to achieve this objective was to bring in efficient technology which included LED lighting & 5Star

labeled Air Conditioners.

However this technology being cost intensive, it was not possible to employ it without making a huge expenditure. Therefore, implementation was done using a business model known as ESCO model. The model is explained in Figure 1.

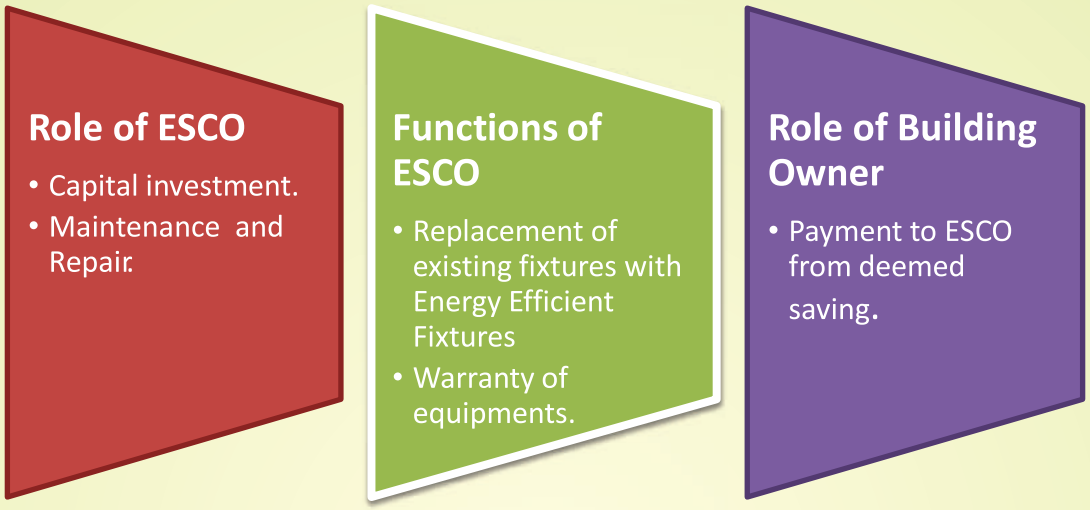


Figure 1: ESCO Model explained

Energy Auditing

Before implementation of the energy efficiency measures, it is necessary to identify the equipments which are energy inefficient. This is done by carrying out the energy audit of the building. Therefore energy audit was first conducted and it was found that most of the indoor lightings were 40 W tube lights with Electro mechanical chokes. Only in a very small portion of the building, LED fittings were installed where the renovation work was carried out in the recent past. Similarly the outdoor light fittings were equipped with 250 W Metal Halide lamps and control gear consuming huge amount of electricity. Most of the Window/ Split Air-conditioners were also non-star rated and therefore energy inefficient.

The following parameters were considered while carrying out the energy audit-

1. Power Factor of 0.9 was considered for calculating KVAH.

2. Since the compressor of ACs turns off for a certain period of time after desired inside temperature is achieved, ACs will be partly loaded for some time. Hence load factor of 0.75 was considered for window/split AC to take care of this aspect.

The details of energy audit carried out are given in Table 1:

Table 1 Energy Audit Report

Sr. No.	Item Name	Watt, W	Number	Annual Use Days	Daily Use in hrs	Annual Baseline KWH	Annual Baseline KVA H
1	1 x 40 W T/L	46	134	275	9	15256	16951
2	2 x 40 W T/L	92	1073	275	9	244322	271469
3	1 x 28 W T/L	32	363	275	9	28750	31944
4	2 x 28 W T/L	64	666	275	9	105494	117216
5	1 x 36 W T/L	36	31	275	9	2762	3069
6	2 x 36 W T/L	72	57	275	9	10157	11286
7	1 x 18 W D/L	20	25	275	9	1238	1376
8	1 x 9 W D/L	11	65	275	9	1770	1967
9	3 x 36 W (2 x 2panel)	120	182	275	9	54054	60060
10	2 x 11 W (1 x 1 panel)	26	196	275	9	12613	14014
11	2 x 36 W (2 x 2 panel)	80	53	275	9	10494	11660
12	1 x 14 W (2 x 1/2 panel)	16	15	275	9	594	660
13	4 x 14 W (2 x 2 panel)	67	66	275	9	10944	12160
14	Metal Halide(250 W)	280	17	365	11	19111	21234
15	Gate Light (36 W CFL)	40	4	365	11	642	713
16	Post Top Lantern (36 W CFL)	40	20	365	11	3212	3569
17	Pole Twin Fittings Metal Halide (2 x 250 W)	560	7	365	11	15739	17488
18	Pole Single fitting Metal Halide (250 W)	280	2	365	11	2248	2498
19	1.5 TR Window AC	2170	215	175	9	551112	612347
20	1.5 TR Split AC	2230	36	175	9	94831	105368
		Total				**11,85,343**	**13,17,049**

Conceptualizing Energy Efficiency Plan

After carrying out the energy audit, the Energy Efficiency Measures were implemented through replacing light fittings, post - top lights and Air-conditioners which were less energy efficient with more efficient LED fittings and Air-conditioners with 5 star labeled energy efficient Air-conditioners. The proposal is shown in the Table 2.

Since it was not possible to measure the energy consumed in the building office wise because of a single HT connection, the deemed energy saving of 5,00,558 KVAH per year was worked out based on wattage of the fixture replaced and annual day use. In financial terms, with present tariff rate of Rs. 9.50 per unit and maintenance cost @ Rs. 0.5 per unit, the saving worked out to Rs. 50,05,580/- per year.

Table 2 Energy Efficiency Plan for IP Bhavan, New Delhi

Sr. No.	Item Name	Watt, W	Number	Annual Use Days	Daily Use in hrs	Annual Baseline KWAH	Annual Baseline KVAH	New Item	Watt, W	New Annual Energy, KWAH	New Annual Energy, KVAH	Annual Savings, KVAH	Apportioned Monthly Cost savings, Rs.	Monthly payment to ESCO Company (92% share)
1	1 x 40 W T/L	46	134	275	9	15256	16951	1 x 18W LED Tube	20	6633	7370	9581	7984	7345
2	2 x 40 W T/L	92	1073	275	9	244322	271469	2 x 18W LED Tube	40	106227	118030	153439	127866	117637
3	1 x 28 W T/L	32	363	275	9	28750	31944	1 x 18W LED Tube	20	17969	19966	11978	9982	9183
4	2 x 28 W T/L	64	666	275	9	105494	117216	2 x 18W LED Tube	40	65934	73260	43956	36630	33700
5	1 x 36 W T/L	36	31	275	9	2762	3069	1 x 18W LED Tube	20	1535	1706	1363	1136	1045
6	2 x 36 W T/L	72	57	275	9	10157	11286	2 x 18W LED Tube	40	5643	6270	5016	4180	3846
7	1 x 18 W D/L	20	25	275	9	1238	1376	1 x 10 W LED D/L	12	743	826	550	458	421
8	1 x 9 W D/L	11	65	275	9	1770	1967	7 W LED D/L	8	1287	1430	537	448	412
9	3 x 36 W (2 x 2 panel)	120	182	275	9	54054	60060	45 W LED PANEL (2 x 2)	49	22072	24524	35536	29613	27244
10	2 x 11 W (1 x 1 panel)	26	196	275	9	12613	14014	10 W LED PANEL (1 x 1)	11	5336	5929	8085	6738	6199
11	2 x 36 W (2 x 2 panel)	80	53	275	9	10494	11660	30 W LED PANEL (2 x 2)	33	4329	4810	6850	5708	5251
12	1 x 14 W (2 x 1/2 panel)	16	15	275	9	594	660	10 W LED PANEL (2 x 1/2 panel)	11	408	453	207	173	159
13	4 x 14 W (2 x 2 panel)	67	66	275	9	10944	12160	25 W LED PANEL (2 x 2)	28	4574	5082	7078	5898	5426
14	Metal Halide (250 W)	280	17	365	11	19111	21234	120 W LED Outdoor light	132	9010	10011	11223	9353	8605
15	Gate Light (36 W CFL)	40	4	365	11	642	713	20 W LED outdoor Light	25	402	447	266	222	204
16	Post Top Lantern (36 W CFL)	40	20	365	11	3212	3569	20 W LED outdoor Light	25	2008	2231	1338	1115	1026
17	Pole Twin Fittings Metal Halide (2 x 250 W)	560	7	365	11	15739	17488	2 x 120 W LED Outdoor light	264	7420	8244	9244	7703	7087
18	Pole Single fitting Metal Halide (250 W)	280	2	365	11	2248	2498	120 W LED Outdoor light	132	1060	1178	1320	1100	1012
19	1.5 TR Window AC	2170	215	175	9	551112	612347	1.5 TR 5 star Rated Window AC	1610	408890	454322	158025	131688	121153
20	1.5 TR Split AC	2230	36	175	9	94831	105368	1.5 TR 5 star Rated Split AC	1490	63362	70402	34966	29138	26807
						1185343	**1317049**				**816491**	**500558**	**417133**	**383762**

The performance agreement to be entered between EESL and CPWD was analyzed and deliberated in detail and after required modifications; the agreement was signed for execution of energy efficiency measures. The salient features of the agreement are as below:

1. The total capital investment for replacing the above electrical gadgets will be made by EESL.
2. The cost of deemed energy saving will be shared in the ratio of 92:8 between EESL & CPWD.
3. The period of the contract will be five years.
4. All the electrical gadgets will be maintained by EESL for the contract period from their own funds.

Implementation

After the Energy Efficiency Plan was conceptualized and savings were reflected, the implementation part was taken up. It was the most challenging part of the entire scheme because users were affected by these changes. First they were not accustomed to the changes and secondly they also were not used to LED lighting because they have to get used to increased illumination on account of pointed lighting. The work began after convincing the users of the positive aspect of the changes. The agencies involved were also sluggish in carrying out the work.

The work which was proposed to be completed within a period of three months as per the agreement was considerably delayed & completed with much of the persuasion and efforts because of number of issues like quality of materials, workmanship, slow response of the implementing agencies involved in the execution of work etc.

The implementation was done on deemed energy saving with the assumption that the electrical load will not increase during the period of agreement, so that actual saving in electricity units may be correctly ascertained. However, the electrical load was substantially increased during/ after implementation. Since a rooftop Solar PV Plant of capacity 200 KWP was installed during this period which almost fully compensated for increased load.

Verification of Savings

The comparison of annual electric consumption before, during and post implementation of the project is tabulated below:

Financial Year	Annual Electric Consumption (In Lakh Units)	Remarks
2014-15	22.34	Before Implementation
2015-16	21.88	During Implementation
2016-17	17.98	During Implementation
2017-18	17.44	After Implementation

The verification was duly carried out with the help of electricity bills of respective periods.

Conclusion

Annual electric consumption during F.Y. 2014-15 before implementation was 22.34 Lakh units which was brought down to 17.44 Lakh Units in 2017-18 after implementation. Thus the measures implemented through ESCO Model brought down the electricity bill substantially and there was a saving of 4,90,000 unit of electricity during 2017-18. Further this also brought down the CO2 emission to the extent of 4,90,000 units x 0.80 Kg per unit of electricity which works out to 392 Tonnes during 2017-2018 by avoiding 4,90,000 units of generation of electricity.

The system though worked well but the gap in the Performance Contract is that it is based on deemed energy saving. No actual measurement of energy consumption can be done because it is not possible to measure changed electricity consumption on account of variation in utilization pattern and increase of load due to addition of electrical equipments etc. This gap needs be filled. Automation including Sensor technology should also be incorporated to conserve the electricity further. Day light harvesting should also be employed to conserve more electricity.

References

Energy Performance Agreement dated 24th April 2015 between Central Public Work Department andEnergy Efficiency Services Ltd. (EESL) for implementation of energy efficiency measures at I.P. Bhawan on deemed energy savings based ESCO model with 100% financing by EESL.

ENERGY PRODUCTIVITY IMPROVEMENT IN BUILDINGS

Raju Gulati, Carrier Air Conditioning and Refrigeration Ltd.

Abstract

HVAC system is a key contributor towards energy consumption in a building with high usage variability as compared to other loads in the present day buildings. The challenges are due to building rarely operating at full load, building loads varying continuously, changing weather conditions and compatibility within equipment in plant room.

The paper aims to address above challenges by optimization of HVAC chiller plant system and control through Plant System Manager (PSM) with various in-built algorithms and strategies.

Introduction

Energy optimization is key focus area in the modern day building. Designer should look at the full HVAC system for further improvement in energy efficiency in the operations of the buildings by addressing the challenges faced during real time usage.

ASHRAE (American society of heating, Refrigeration & Air Conditioning Engineers) labels plant room efficiencies as indicated in Fig. 1 which indicate upto 0.85KW/TR efficiency is considered good to operating level in real situation. However plant room efficiency level of more than 1.0KW/TR certainly needs improvement through various interventions like installation of PSM System apart from other system level approaches.

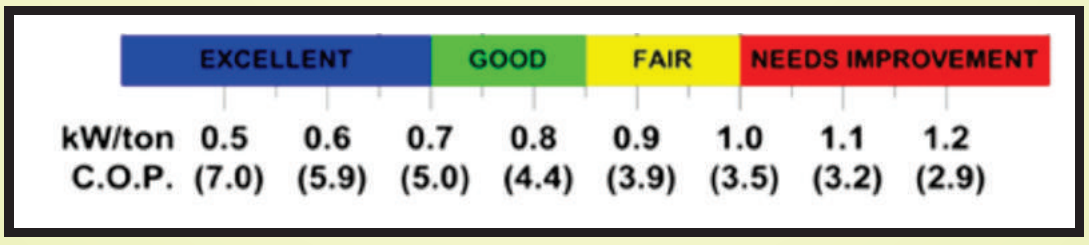


Fig. 1 ASHRE Scale of Plant Room Efficiency

While plant room may be designed at efficiency upto 0.85KW/TR level but in real time operation there is always upward variance with respect to design level. It calls for effective solution to control and monitor the plant room efficiency level continuously to keep the actual level as near to target efficiency level in real life situations as shown in Fig. 2.

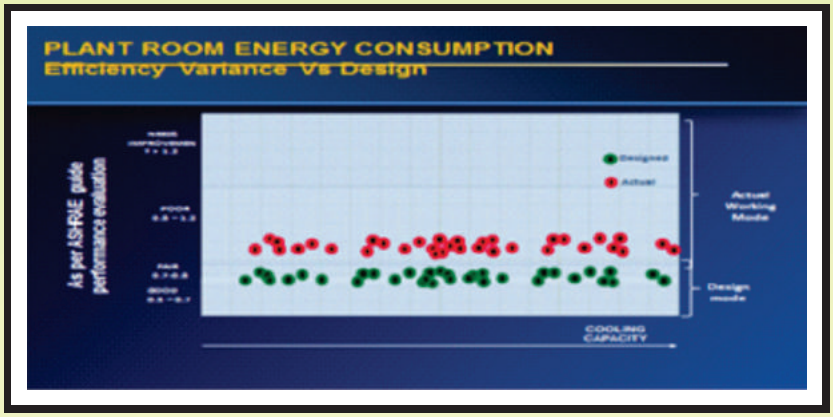


Fig. 2: Plant Room Efficiency Variation V/S Design

Suggested Solutions to Address the Challenges

The system is an optimization solution i.e PSM (Plant System Manager), it allows the existing chilled water system to operate more efficiently under varying conditions. Plant System Manager is a software and hardware system solution designed to provide an optimized control system using the equipment commonly found in a chiller plant: chillers, pumps, cooling towers and valves. It minimizes energy use over the entire chilled water system without affecting the building environmental comfort and automatically adapts to changing conditions in “REAL TIME” as the system's conditions change over time. A basic PSM System is indicated in Fig. 3.

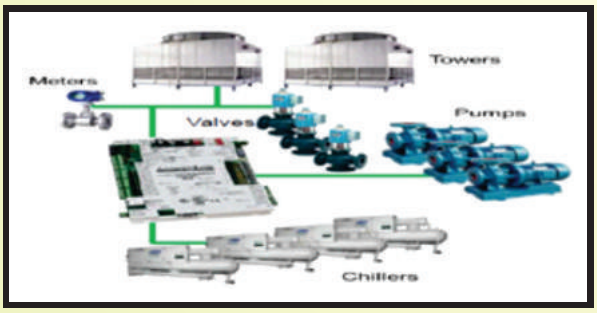


Fig. 3: Basic PSM System representation

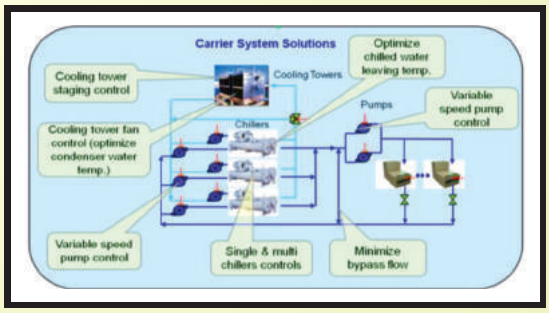


Fig. 4: Various optimization strategies

Working Principle

Web-based building automation system provides all needed to develop and maintain successful energy-saving strategies and is depicted below in Fig. 4. A fully integrated system with powerful reporting, trending and scheduling capabilities Supports BACnet®/ Modbus®/ LonWorks integration.

Optimization control Strategies

Chiller sequencing based on actual weather and building load data compare with chiller

optimization control algorithm to run always optimize point of chiller loading ratio. Control algorithm, design to operate based on actual weather condition and different chiller load to achieve optimum condenser water supply temperature by activating optimum cooling tower staging and cooling tower fan speed. This combined effect improves the chiller plant performance.

System Flexibility

In order to achieve flexibility following points needs emphasis.

i) User friendly interface with access to logic/graphic and text version of the programming

ii) Can be accessed from anywhere in the world regardless the browser choice

iii) One license with unlimited simultaneous users

iv) Almost all standard protocols are supported

v) FDA-21CFR compliance

No. of Schedulers, Reports & Trends supported are unlimited as long as bandwidth supports the network. PSM provides following unique features as given in the following;

i) Web based user interface

ii) Complete system control via web browser

iii) High speed communication

iv) Subsystem Integration

v) Large list of third party protocols that can be integrated

vi) Built In energy management functions

vii) Graphical programming and online DDC diagnostics

viii)Trending of all points in system

ix) Powerful alarming

The unique features of a PSM system are shown in Fig. 5.



Fig. 5: Unique features of a PSM System

It not only saves energy, it saves on expenses. Unlike other systems that require costly custom programming and are more difficult to use, our energy-saving features are fully integrated at installation. Features like Setpoint Optimization calculates optimum setpoint values based on actual operating requirements, Optimum Start assures comfortable settings at time of occupancy based on building conditions and system capacity and Demand Reduction reduces energy use on a short-term basis in response to utility pricing, billing criteria, regional consumption, etc.

Dynamic energy dashboards consist of preconfigured screens for both air-cooled and water-cooled plants, allowing the customer to see both current and historic plant energy performance at a glance. Energy use data, including kW/Ton, iKw/kW, and coefficient of performance can be displayed both graphically and numerically.

Generation of User Friendly Energy Reports

i) Energy consumption or demand reports available in 3D bar, line, pie chart, or tabular data

ii) Easy and convenient access using multiple Internet browsers

iii) Advanced and intuitive user interface with system tree display designed for simplicity of use

iv) Integrates the Environmental Index feature into energy reports, enabling you to intelligently compare efficiency with comfort

v) Adobe Acrobat and Microsoft Excel reports generated on both client and server archive

vi) JAVA application design to easily integrate with the WebCT system's energy data

vii) Integrated Report Manager for scheduling reports on a monthly, quarterly or yearly basis

viii) Supports energy and water sub-metering

ix) Existing utility data can easily be imported via MS Excel spreadsheet

A sample energy report of a PSM System is indicated in Fig. 6.



Fig. 6: Sample Energy Reports

Energy-saving functions are combined with a wealth of other standard operating features, some of which include:

I) Thermo graphic Color Floor Plans - convey a quick understanding of facility-wide comfort and operating conditions

ii) Hierarchical and Group Scheduling - supports customized, graphically displayed schedules for building, floors, zones or equipment groups to flexibly manage energy use

iii) Trending - enables operators to track and troubleshoot building conditions

iv) Logging/Reporting – extracts and formats operating data from a browser to Acrobat®, Excel®and other applications with a single click

v) Logical Alarming – generates alarms and notifies users following specified sequence of events

Dynamic colour (example red color indicates problem area/ zone at simple glance) floor plans provide an immediate understanding of conditions in your building. Graphics can be customized for specific information needs. A sample floor layout depicting the dynamic colours is shown in Fig. 7. Monitoring and storing the energy usage data helps to manage utility consumption. A typical energy usage display is represented in Fig. 8.



Fig. 7: Sample floor layout

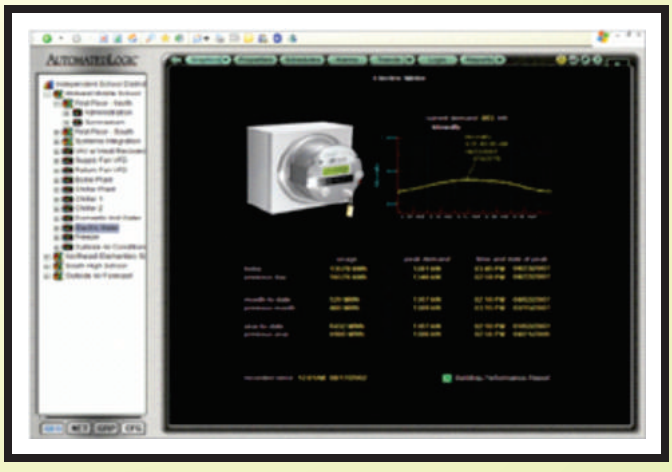


Fig. 8: Energy Usage Display

For visibility into what is working and what not, alarm conditions are graphically represented and sorted by source, type, criticality and Prognostic Alerts for effective intervention to reduce the costly down time, as indicated in Fig. 9. A scatter plot graph can show changes between two time periods, compare differences between equipment, determine an equation for use in the actual control sequence and show the sweet spot for best operation (Fig. 10).

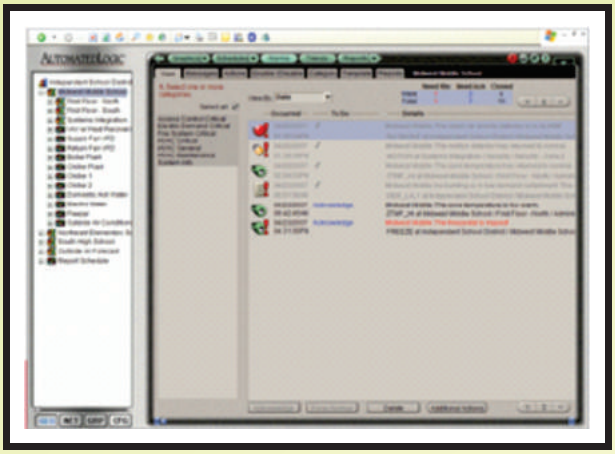


Fig. 9: Alarm Condition Display

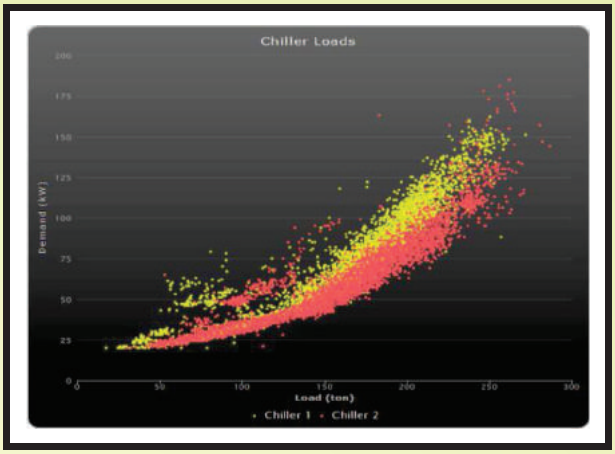


Fig. 10: Scatter Plot Graph

Case Study

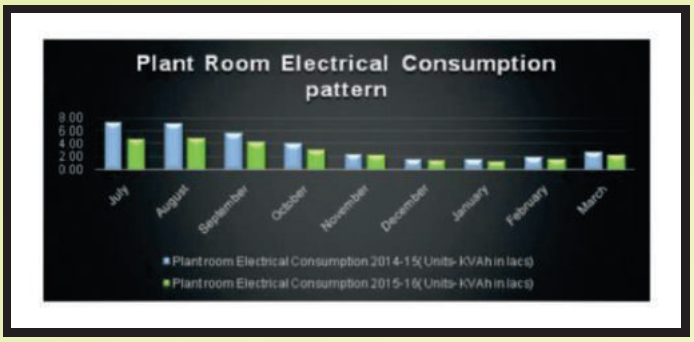
Brief details of a case study of a running hotel in Delhi which has been benefitted by installation of optimization control as well as equipment retrofit. For more details you can refer to BEE website:-

Taj Hotel, Delhi Case Study – Recognized by BEE

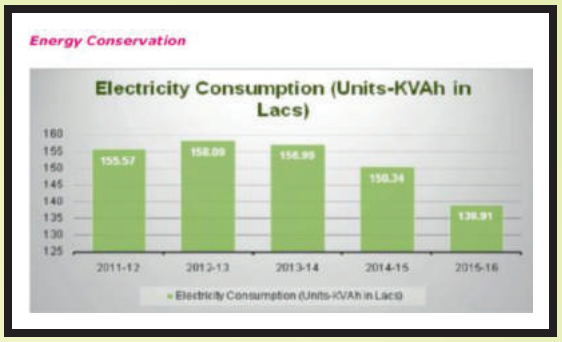
Energy Conservation Initiatives:

1. Building HVAC system optimization & Revamp

Till 2014, 52-58% of total electrical consumption was from HVAC and in HVAC also 40-45% was contributed by Chillers/Heat machines and its connected accessories like pumps and cooling tower. The Carrier's AdvanTE3C team carried out a detailed Energy Assessment of the entire HVAC system which included studying the building load and energy pattern. On the basis of assessment, new Carrier Heat machine 23XRV 520TR, Plant System Manager with advance controls and other plant room equipment's were introduced into system. AdvanTE3C team did the entire project execution and handed over the project on July 1st, 2015.It resulted in improving the plant room efficiency by 26%, providing a saving in excess of **1000,000KWH** in a span of 9 months. By the end of financial year 2015-16 , hotel was able to provide **90 lacs** of monetary saving through electrical unit's consumption reduction. In spite of unavailability of major saving months i.e. April, May, June where HVAC runs on 100% load, 90% of proposed savings were achieved. The system is operated in fully automated mode using the Carrier advance Plant Room System optimization using multiple strategies such as Cooling tower staging , Cooling tower fan speed control , Condenser water pump speed control , secondary water pumps speed control , Chiller staging , chilled water reset etc. The controls system also does the Energy diagnostic of the plant room to identify areas of potential energy waste and provide relevant information on waste avoidance and correction. There was major reduction of electricity generation through Diesel Generator, where 23000 ltrs of HSD consumption was less than year 2014-15.



(Real Time Data) 1



(Real Time Data) 2

Key Takeaways on Unlocking Real Efficiency from Plant room

1) Potential energy savings can range from 3 -15% based on field and lab tests.

   Actual energy savings will depend on many variables; type of facility, location, plant size, existing equipment selection, duration of use, how well the system is currently controlled, and other considerations. The more system equipment that is metered, the more effective the optimization algorithm can be.

2) It provides clear, concise, graphically rendered, and most importantly actionable data regarding the system performance.

3) Automatically adapts to changing conditions as the system's conditions change over time

4) Little to no risk in terms of negative impact on existing plant operation

5) Performance monitoring and Validation earns credit under GRIHA & LEED

6) Improving energy productivity is to reduce GHG emission and become REAL GREEN

Reference

Carrier PSM System Description.

ECO-NIWAS SAMHITA 2018: ENERGY CONSERVATION BUILDING CODE FOR RESIDENTIAL BUILDINGS

Prashant Bhanware, Indo-Swiss Building Energy Efficiency Project, New Delhi

Abstract

ECO Niwas Samhita 2018 (Part I: Building Envelope) is the new Energy Conservation Building Code for Residential Buildings; launched by Ministry of Power (MoP) on 14 December 2018. It is applicable to all residential buildings and residential parts of 'mixed land-use projects', both built on a plot area of 500 m2.It focuses on building envelope and aims to improve the thermal comfort and reduce the energy required for cooling and lighting in new dwellings. It has been prepared to set minimum building envelope performance standards to limit heat gains (for cooling dominated climates) and to limit heat loss (for heating dominated climates), as well as for ensuring adequate natural ventilation and day lighting potential. The present paper gives key aspects of the code and explains it's provisions for better understanding of this code.

Introduction

Building sector in India consumes over 30% of the total electricity consumed in the country annually and is second only to the industrial sector as the largest emitter of greenhouse gases (GHGs). Out of the total electricity consumed in the building sector, about 75% is used in residential buildings.

The gross electricity consumption in residential buildings has been rising sharply and is expected to continue the trend. Projections show the electricity consumption of 260 TWh in 2016-17 will rise to anywhere between630 and940 TWh by 2032.

Among various reasons, increased use of decentralized room based air-conditioning units in homes for thermal comfort is an important reason contributing to this rapid increase in the electricity use in residential buildings. The demand for air-conditioning will continue its exponential growth with improvement in household incomes and will become the dominant contributor of electricity consumption and GHG emissions. One of the best ways to limit this growth is to design new buildings in such a way that the thermal and visual comfort in these buildings, without the use of artificial systems, is significantly improved as compared to the usual design practice. Design of building envelope has the highest potential to do so.

The code aims to improve thermal and visual comfort in new dwellings by improving the

building envelope, so that: a) the installation of air-conditioner is either avoided or delayed substantially, b) the capacity of the cooling system required is reduced, c) the operating hours of cooling system is reduced and d) there is no or very limited requirement of artificial lighting during the daytime. This will help in reducing the energy required for cooling and lighting in residential buildings.

Code applicability

The code applies to (a) 'Residential buildings' built on a plot area 500 m^2 and(b) Residential part of 'Mixed land-use building projects', built on a plot area of 500 m^2.'Residential building' includes any building in which sleeping accommodation is provided for normal residential purposes with or without cooking or dining or both facilities. This includes, a) One or two family private dwellings and b) Apartment houses including group housing and excludes a) Lodging and rooming houses b) Dormitories and c) Hotels.

Provisions of the code

The building envelope consists of walls, roof, and fenestration (openings including windows, doors, vents, etc.). Code provisions define minimum building envelope performance standards to limit heat gains (for cooling dominated climates) and to limit heat loss (for heating dominated climates), as well as for ensuring adequate natural ventilation and daylighting potential. Details of these provisions are explained below:

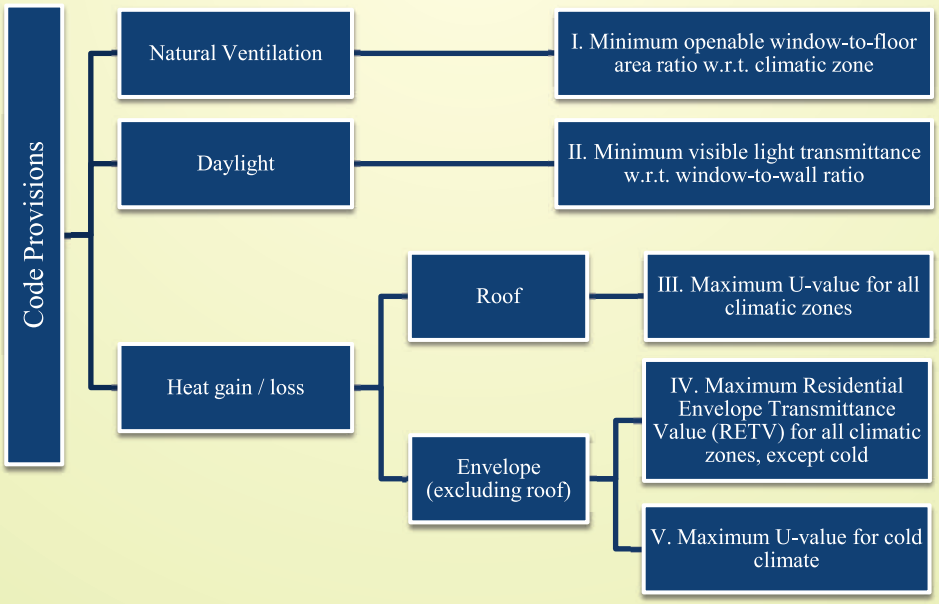


Fig. 1: Provisions of Eco-Niwas Samhita 2018

I. Openable Window-to-Floor Area Ratio (WFR_{op})

The code defines minimum openable window-to-floor area ratio (WFR_{op}) as given in Table 1

It is the ratio of openable area ($A_{openable}$) to the carpet area (A_{carpet}) of dwelling units.

$$WFR_{op} = \frac{A_{openable}}{A_{carpet}} \#(1)$$

Table 1: Minimum requirement of window-to-floor area ratio (WFR_{op})

Climatic zone	Minimum WFR_{op} (%)
Composite	12.50
Hot-Dry	10.00
Warm - Humid	16.66
Temperate	12.50
Cold	8.33

WFR_{op} indicates the potential of using external air for ventilation. Ensuring minimum WFR_{op} helps in ventilation, improvement in thermal comfort, and reduction in cooling energy.

II. Visible Light Transmittance (VLT)

The code defines the minimum VLT of the glass used in non-opaque building envelope components (transparent/translucent panels in windows, doors, etc.) with respect to the window-to-wall ratio (WWR) as given in table 2 . WWR is the ratio of the area of non-opaque building envelope components of dwelling units to the envelope area (excluding roof) of dwelling units.

$$WWR = \frac{A_{non-opaque}}{A_{envelope}} \#(2)$$

Table 2: Minimum visible light transmittance (VLT) requirement

Window-to-wall ratio (WWR)	Minimum VLT
0–0.30	0.27
0.31–0.40	0.20
0.41–0.50	0.16
0.51–0.60	0.13
0.61–0.70	0.11

VLT of non-opaque building envelope components indicates the potential of using daylight. Ensuring minimum VLT helps in improving daylighting thereby reducing the energy required

for artificial lighting.

III. Thermal Transmittance of Roof (U_{roof})

The code defines the maximum value of thermal transmittance of roof (U_{roof}) as 1.2 W/m^2.K.Uroof characterizes the thermal performance of the roof of a building. Limiting the Uroof helps in reducing heat gains or losses from the roof, thereby improving the thermal comfort and reducing the energy required for cooling or heating.

IV. Residential envelope transmittance value (RETV)

For building envelope (except roof) for four climate zones, namely, Composite Climate, Hot-Dry Climate, Warm-Humid Climate, and Temperate Climate

The code defines a maximum value of Residential envelope transmittance value (RETV) for building envelope (except roof) for four climate zones, namely, Composite Climate, Hot-Dry Climate, Warm-Humid Climate, and Temperate Climate, as 15 W/m^2.

RETV is the net heat gain rate (over the cooling period) through the building envelope (excluding roof) of the dwelling units divided by the area of the building envelope (excluding roof) of the dwelling units. Its unit is W/m2.RETV formula (equation 3, coefficient as per Table 3) considers heat conduction through opaque and non-opaque building envelope components and solar radiation through non-opaque building envelope components.

$$RETV = \frac{1}{A_{envelope}} \times \left[\left\{a \times \sum_{i=1}^{n}\left(A_{opaque_i} \times U_{opaque_i} \times \omega_i\right)\right\} + \left\{b \times \sum_{i=1}^{n}\left(A_{non-opaque_i} \times U_{non-opaque_i} \times \omega_i\right)\right\} + \left\{c \times \sum_{i=1}^{n}\left(A_{non-opaque_i} \times SHGC_{eq_i} \times \omega_i\right)\right\}\right] \quad (3)$$

Table 3: Coefficients (a, b, and c) for RETV formula

Climate zone	a	b	c
Composite	6.06	1.85	68.99
Hot-Dry	6.06	1.85	68.99
Warm-Humid	5.15	1.31	65.21
Temperate	3.38	0.37	63.69

RETV characterizes the thermal performance of the building envelope (except roof). Limiting the RETV value helps in reducing heat gains from the building envelope, thereby improving the thermal comfort and reducing the electricity required for cooling.

V. Thermal transmittance of building envelope (except roof) for cold climate ($U_{envelope,cold}$)

The code defines the maximum value of thermal transmittance of building envelope (except roof) for cold climate ($U_{envelope,cold}$) as 1.8 W/m2.K.$U_{envelope,cold}$ formula (equation 4) considers heat conduction through the opaque and non-opaque building envelope components.

$$U_{envelope,cold} = \frac{1}{A_{envelope}}\left[\left(U_{opaque} \times A_{opaque}\right) + \left(U_{non-opaque} \times A_{non-opaque}\right)\right] \#(4)$$

$U_{envelope,cold}$ characterizes the thermal performance of the building envelope (except roof). Limiting the Uenvelope,cold helps in reducing heat losses from the building envelope, thereby improving the thermal comfort and reducing the energy required for heating.

Compliance check

For compliance checking, the only information required is:

- Dimension of all building components, which can be taken from architectural drawings (plans, sections and elevations)
- Thermal properties of materials and its thickness used in building envelope: Material and its thickness can be taken from the section of external wall, roof and fenestration. Thermal properties of commonly used construction material are given in the code document.

With the above information, the compliance check can be done either through manual calculation or using a compliance check tool.

- Manual calculation: It can be done using the formulas given in the code provision section. An example of manual calculation is also given in the code document.
- Compliance check tool: The tool is a JAVA based application which can be downloaded from BEE website (https://beeindia.gov.in/latest-news/eco-niwas-samhita-2018-part-i-building-envelope-book-film-tool) or BEEP website (https://www.beepindia.org/wp-content/uploads/2013/12/EcoNiwasSamhita_ComplianceCheckTool.zip). The information on the building envelope can be systematically entered in the tool and it calculates the values for all code provisions. A report with all the results as well as all the input information can be generated through this tool.

Thus, the compliance check can be done by most of the building sector professional and it doesn't require any energy simulation expert.

Conclusions

Eco-Niwas Samhita 2018 is a 'simple' code, targeted at building envelop which has highest impact on energy use in residential building. To keep the code simple, the provisions are kept either prescriptive or trade-off type, requiring easy calculation and avoiding any specialist (e.g. energy simulation expert). Still, design flexibility has been given to innovate and vary important envelope components such as wall type, window size, type of glazing, and external shading to windows to meet the compliance. The compliance check tool has been developed to ease the process (calculations and documentation) of compliance check. With this simplified code and the tool, efforts have been made to make this code 'easy to implement'.

Acknowledgement

The author would like to thank Bureau of Energy Efficiency (BEE) and Swiss Agency for Development and Cooperation (SDC) for supporting Indo-Swiss Building Energy Efficiency Project (BEEP), under which the technical work was done for the development of Eco-Niwas Samhita 2018. The author would also like thank the team members of project management and technical unit of BEEP and Ashok B Lall Architects team for their contribution in the development of the code.

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[2] NITI Aayog. India Energy Security Scenario, 2047. New Delhi: NITI Aayog,Government of India. Available at http://indiaenergy.gov.in/iess/default.php (accessed on 1 May 2018).

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(EnergyConservation Building Code for Residential Buildings) Part I: Building Envelope

Annexure: Definition of parameters

$A_{openable}$: openable area (m2); it includes the openable area of all windows and ventilators, opening directly to the external air, an open balcony, 'verandah', corridor or shaft; and the openable area of the doors opening directly into an open balcony. Exclusions: All doors opening in the corridors. External doors on ground floor, for

example, ground-floor entrance doors or back-yard doors.

A_{carpet} :carpet area of dwelling units (m2); it is the net usable floor area of a dwelling unit, excluding the area covered by the external walls, areas under services shafts, exclusive balcony or verandah area and exclusive open terrace area, but includes the area covered by the internal partition walls of the dwelling unit

$A_{non-opaque}$: area of the non-opaque building envelope components (m2). It includes transparent/translucent panels in windows, doors, ventilators, etc.

$A_{envelope}$: envelope area (excluding roof) of dwelling units (m2). It is the gross external wall area (includes the area of the walls and the openings such as windows and l doors).

A_{opaque_i} : areas of different opaque building envelope components (m^2)

U_{opaque_i} :thermal transmittance values of different opaque building envelope components ($W/m^2.K$)

$A_{non-opaque_i}$:areas of different non-opaque building envelope components (m^2)

$U_{non-opaque_i}$:thermal transmittance values of different non-opaque building envelope components ($W/m^2.K$)

$SHGC_{eq_i}$:equivalent solar heat gain coefficient values of different non-opaque building envelope components

ω_i :orientation factor of respective opaque and non-opaque building envelope components; it is a measure of the amount of direct and diffused solar radiation that is received on the vertical surface in a specific orientation (values are defined in the code document)

BIOLOGICALLY EFFECTIVE HUMAN CENTRIC LIGHTING

Biju John, EsyLux

Abstract

Daylight makes people happy, helps them perform well and has controlled human biorhythms since time immemorial. Human Centric Lighting is the magical formula for an age where people spend more and more time working indoors. But brighter light also means higher energy consumption. Sitting for long periods with poor posture is bad for the back, and people are also generally exposed to less fresh air than in the past – now that we have largely moved into buildings to work, often at desks, we have a number of problems to contend with. We now also know how much the human body misses natural light. Even large windows and the best-designed architecture don't have the same effect as being under open skies.

Introduction

It is about 16 years since the role of the intrinsically photosensitive retinal ganglion cells (ipRGCs) in the human retina was discovered. And yet it has taken quite a while for lighting manufacturers to pay sufficient attention to the biological effect of light. That might seem a little surprising at first. However, mass implementation of this type of lighting only became possible after the introduction of the LED and subsequent improvements in its quality.

Lighting Boosts Vitality, Concentration And Health

This is one reason why many people still do not know what biologically effective light or human centric lighting is all about. A glance out of the window is enough to answer that. There are two fundamental states: dimmer, warm white light in the early morning and evening, in contrast to bright, cold white light with a high proportion of blue during the day. The transitions between them are of course fluid and dynamic, determined by the interplay of the earth's rotation, the sun's path and blue skies.

Each light condition affects the human body in a different way. When the bright, cold white light of the forenoon sun hits those ganglion cells in the retina, it triggers several biological processes. The ganglion cells do not contribute to conscious recognition or vision. Instead their role is to transmit non-visual information. They therefore react to changes in light colour and brightness. One of the main consequences of bright, cold white light hitting the cells is the suppression of the body's production of melatonin – a neurotransmitter which makes us tired. Through this and a number of other processes, a bright, cold white light during the day

increases vitality, well-being and concentration, and helps us make fewer mistakes.

Light is therefore the most important timer for the human day/night rhythm. Bright, cold white light during the day stabilises this rhythm, which results in more restful sleep and therefore contributes to good health. However, it is also important for the light to become dimmer and warmer in colour as evening approaches, so that we can start preparing for rest in good time. In short: Bright, cold white light activates and stimulates while dimmer, warm white light aids relaxation.

Human Centric Lighting And Energy Efficiency – A Conflict Which Can Be Overcome

The advantages of indoor lighting that simulates daylight's changing light colour and brightness are very clear. Especially in the workplace, this is a classic win-win situation. Employees have a greater sense of well-being, are more motivated and therefore perform better. The employer also benefits from this, through the increase in employee satisfaction as well as through their higher productivity. Ultimately, this type of lighting is advantageous to the whole company.

However, every benefit comes with a challenge. After all, something else has a significant effect on the way office buildings are run these days: increased energy efficiency requirements. The brightness of biologically effective light is continually above the 500 lux prescribed by standards, and at times significantly so. Peak values can range from 700 or 800 lux to over 1000 lux, which indicates higher consumption despite the use of LEDs.

Sensors And Intelligent Light Management Provide A Solution

The solution for this comes from the demand-driven building automation and is based on the use of intelligent presence detectors as well as a technology which not only provides biologically effective lighting but also implements it in an energy-efficient way.

The sensors in the presence detector alone reduce costs dramatically, since they automatically ensure that the light only shines when people are present. Each presence detector also has a light sensor. This compares the workplace brightness level to a prescribed value. Of course, the existing daylight entering through the window is taken into consideration here. If this is sufficient for work, the presence detector switches the artificial light off. Even more energy can be saved if the detector also has constant light control. This continually adjusts the artificial light so that, combined with the available daylight, the targeted amount of light is achieved. This allows the best possible use of daylight.

Adaptive Human Centric Lighting Control

The technology now combines all of these benefits, which make a difference even when controlling a normal light, with a biologically effective lighting. This initially sounds simpler than it actually is. Conventional constant light control cannot be used with biologically effective lighting. A conventional constant lighting control system maintains a single light value throughout the day, e.g. the aforementioned 500 lux. Although a biologically effective lighting also has to maintain a standard minimum value at the workplace, biologically effective lighting is in fact much brighter and, above all, its brightness level constantly changes. The solution lies in the adaptive constant light control. This adjusts itself based on a value which also continually changes according to the desired brightness pattern. In one sense, this is a real innovation since, for the first time, it enables optimum use of daylight even within biodynamic brightness patterns. This technology also applies trusted building automation principles to the most modern form of indoor lighting.

The technology reflects the concept of symbiosis. This term is frequently used very broadly and to refer to all sorts of things, but it fits this context precisely. On the one hand, humans are benefiting from nature. Nature has taught them which light suits them best, meaning they are now able to simulate that light in indoor spaces. On the other hand, nature also benefits. Presence-based, daylight-dependent control combined with adaptive constant light control ensures the most energy-efficient implementation possible – thereby minimising the use of natural resources.

Pictures

An optimal indoor lighting system is based on the dynamic progression of natural daylight, on the interaction between the sun and the sky. Brightness and light colour change over the course of the day, and the illuminance always considerably exceeds the standard required minimum as shown in Fig.1. More blue in the forenoons, more red in the evenings: Biologically effective light stabilises employees' day/night rhythms as shown in Fig. 2.



Figure 1: Natural daylight Picture



Figure 2: Working place Picture

Comparison of different type of lighting control is shown in Fig. 3.

Manual switching

Office space without automation — the light and other devices frequently stay on all day and use energy unnecessarily.

Presence- and daylight dependent switching

Presence- and daylight-dependent switching using a presence detector automatically reduces energy consumption.

Daylight-dependent constant light control

The best use of daylight: constant light control with a presence detector.

Energy-saving potential with biologically effective lighting

Technology with biodynamic lighting as well as presence- and daylight-dependent adaptive HCL light control.

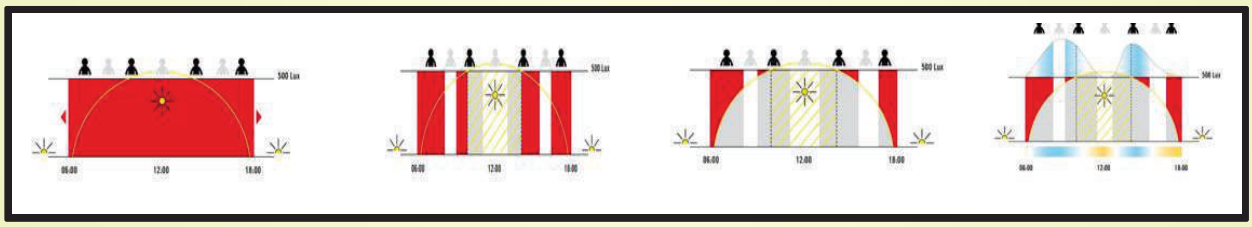
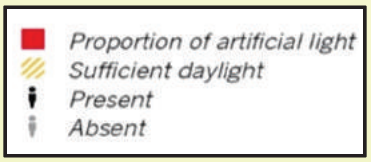


Figure 3:Comparison of different type of lighting control

Legend



Conclusion

Human centric lighting approach has energy-saving potential with biologically effective lighting. It increases productivity, employee loyalty and motivation. It also reduces errors, absence of employees from work place and accidents at work.

ROLE OF ENERGY EFFICIENCY & SOLAR POWER IN SUSTAINABLE DEVELOPMENT

Usha Batra, Special DG (WR), CPWD, Mumbai

Abstract

With growing population and rapid shift towards energy intensive lifestyle, the demand for energy will keep on increasing. At all India level, total installed power capacity in March 2016 was 302 GW where coal-based power accounted for 61.25 percent at 185 GW and solar was merely 2.2 percent with 6.7 GW. The share of thermal power including coal, gas and diesel was 69.53 percent with about 210.67 GW showing great dependence on thermal sources.

Since, India has ratified Paris climate deal on 2.10.2016 as 62nd country and recently cabinet has given approval for ratification of Kyoto protocol on 23.01.2017, energy from renewable resources needs to be given priority. Although as per Kyoto Protocol only developed countries are mandatorily required to undertake mitigation targets, India hastaken this step to encourage other developing countries to undertake this exercise.

Ministry of new and renewable energy has a target of solar power generation of 100GW by 2022 which can make India one of the largest green energy producers in the world.

Energy conservation is an effective counter measure of saving natural resources and global warming. The paper explains the importance and means of energy conservation and energy efficiency and renewable energy including innovations in these fields. It also covers the potential of renewable energy resources in addition to the installed and targeted capacity by Government of India (GOI)up to 2022, especially the solar power.

Introduction

In India although renewable energy has increased its share considerably, reliance on conventional energy and its imports is steadily rising due to increase in demand due to change in lifestyle in an unsustainable manner, which can be addressed by greater emphasis on energy conservation and energy efficiency being the least disruptive path. India, home to 18% of the world's population, uses only 6% of the world's primary energy. India's energy consumption has almost doubled since 2000 and the potential for further rapid growth is enormous. This demand needs to be reduced through energy conservation, energy efficiency and lastly through renewable energy which serves the dual purpose of fulfilling the demand simultaneously reducing the global warming.

Alarming air quality levels in many Indian cities and around the world have highlighted the deteriorating environment as well as health of the citizens thereby arising a desperate quest for clean energy. From May 7 to 11, 2016, Portugal made history by working only on renewable energy viz solar, wind and hydro for 107 hours. For the first time, on April 9, 2016, solar energy surpassed energy from burning coal in meeting power requirements in the UK, when solar energy generated was 29 GWh as compared to 21 GWh from coal power stations.

Also, in Germany, on May 8, 2016, renewable sources of energy produced 87percent of the energy consumed. As the world is slowly embracing green initiatives and moving towards renewable energy, India has also revised its target of renewable power capacity from 20GW to 100GW by 2022.

Energy Conservation

Energy conservation is of great importance because we rely on energy for everything we do. December 14th is celebrated as World Energy Conservation day globally to highlight the importance of energy consumption and its use in our day-to-day life, its scarcity and impact on sustainability of global eco systems. Energy conservation is the most economical solution to energy shortages, reduce strain on the environment and bring down electricity expenses. Energy conservation is useful due to the followings:

- Energy resources are limited – India has approximately 1% of world's energy resources but it has 18% of world population.
- We use energy faster than it can be produced, whereas most of the energy sources we use cannot be reused and renewed – Non-renewable energy sources constitute 70% of the fuel use which may last only for another 40 years or so.
- Energy saved is energy generated –one unit of energy saved is equal to 2 units of energy produced as it not only saves money but also reduces the demand for fossil fuels (coal, oil, and natural gas) leading to lower emissions of carbon dioxide (Co2), the primary contributor to global warming, and other pollutants.
- Conservation mitigates numerous adverse environmental and social impacts associated with energy production and consumption e.g. air pollution, acid rain and global warming, oil spills and water pollution, loss of wilderness areas, construction of new power plants.
- Extends the lifetime of equipment and reduces the maintenance cost by operating fewer hours and at less than maximum capacity.

“Energy conservation” and “Energy efficiency” are often used interchangeably, but energy

conservation means using less energy and is usually a behavioural change, like turning off lights or setting thermostat at appropriate temperature and energy efficiency means using energy more efficiently, and is often a technological change.

Energy Efficiency, Consumption and Possible Savings

It is estimated that 40 - 60% consumption can be reduced by adopting energy efficiency measures. Distribution of sector wise consumption in India during 2016 is given below in Fig. 1.

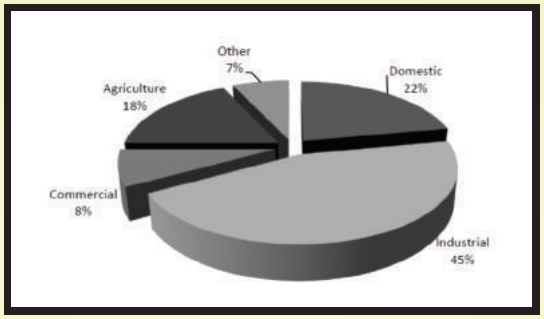


Figure1: Distribution of sector wise consumption

Maximum consumption is in industrial sector, which is 45%, followed by building sector which includes residential/ domestic and commercial -30%, agriculture -18% and others - 7%. Due to maximum consumption, maximum possible saving is in industrial sector. PAT (Perform, achieve and trade) scheme under the Ministry of Power, Govt. of India is a mechanism to enhance energy efficiency in energy intensive large industries. BEE has identified savings of 66.86 lac TOE from industrial sector through PAT, maximum (50%) is from thermal power plants followed by other industries.

The next highest consumption and possible saving sector is the building sector which includes residential and commercial buildings. By incorporating energy efficiency measures laid down by ECBC in new buildings, there can be a potential saving up to 40-60%.

Renewable Energy

Renewable energy sources have the potential to provide 3,078 times the current global energy needs, of which solar energy 2,850 times, wind energy 200 times, biomass 20 times, geothermal 5 times, wave-tidal energy 2 times, and hydropower 1 time.In order to promote renewable energy and energy security, it is decidedthat 8% of total consumption of electricity, excluding hydro power, shall be from solar energy by March 2022.

Energy Efficiency in Buildings

It is well known fact that building sector accounts for nearly 40 percent of global energy consumption and hence can play a key role in energy efficiency. Building envelope being the main cover protecting the building plays the most important role in energy efficiency. It is possible to achieve energy efficiency to the extent of 40-50 %. Good envelope design alone can contribute to 50% of this, meaning thereby that energy saving potential of good envelope design alone is to the extent of 20-25%. It is also the permanent source of saving energy thereby reducing the demand for air conditioning and does not require any performance check. Good envelope design envisages;

- Appropriate orientation & shape of the building with respect to sun and wind direction.
- Appropriate WWR for light & ventilation i.e. design that increases daylight to reduce the need for daytime lighting.
- Shading devices to allow the desirable sun and cut-off the non- desirable sun, besides shading of walls and roof.

Besides this, Architectural development / design features that further help in increasing energy efficiency are;

- Use of landscape elements in altering the micro-climate, providing buffer for heat, sunand airflow.
- Use of energy efficient lighting and equipment in buildings.
- Maintaining the temperature of Air conditioning as 24-26 instead of 18-20.

Orientation

In hot zone (Hot & Dry, Hot & Humid) the building should be oriented North- South (Fig. 2).

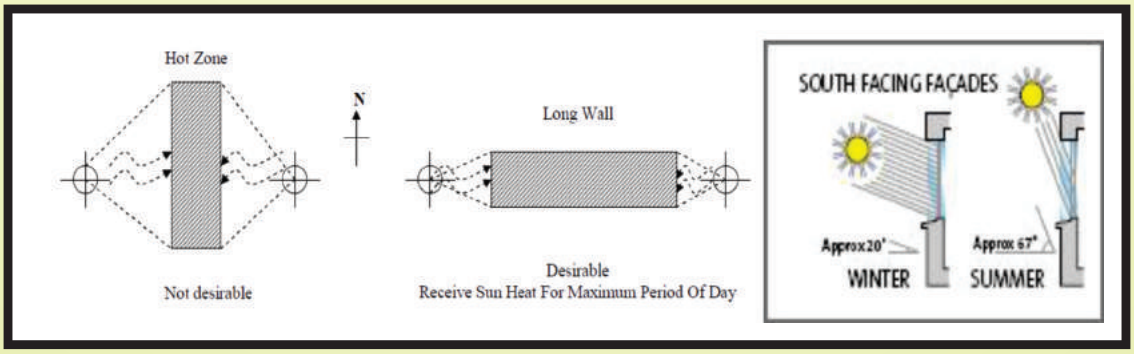


Figure: 2

In cold zone If the long axis of the building should make an angle of 30 with E-W direction(Fig. 3) as it receives sun heat for maximum duration.

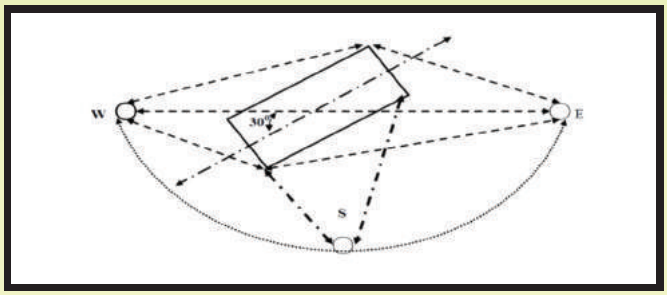


Figure: 3

WWR(Window to wall ratio)

The lesser the perimeter, the lesser is the heat gain from solar as well as conduction. The depth of a building also determines the requirement for artificial lighting. The greater the depth, higher is the need for artificial lighting. The circular geometry has the lowest perimeter as well as S/V ratio thus is most energy efficient in composite climate.

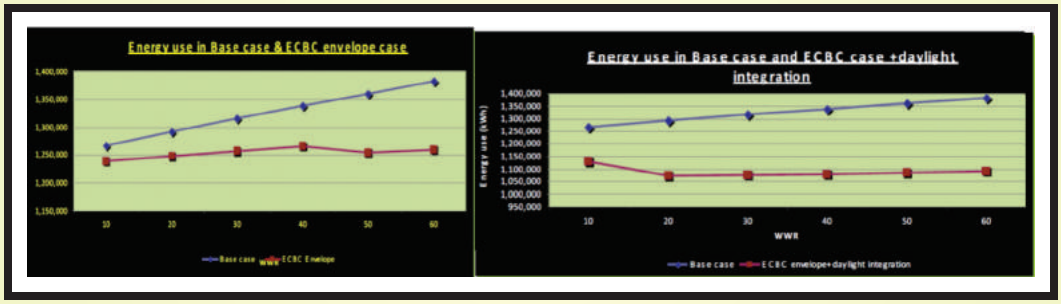


Figure: 4

Although lowest energy consumption is in the case of WWR 10%, but electricity consumption increases due to increase in artificial lighting. Minimum electricity consumption with sufficient daylight is in the case where WWR is 20-30%. Therefore, buildings must be designed keeping this fact in mind and glass facades must be avoided.

Shading Devices

External shading devices need to be designed according to the orientation of the building. Unfortunately, many buildings are now being designed without shading devices copying western design leading to larger energy consumption. Shading must be provided as under;

- North - no shading is required.
- South – permanent horizontal shading required with desired size as sun faces most part of the day.

- East and West - preferable to design movable shading devices as sun is very low during this period.
- Walls and roof can be shaded in many ways e.g. plants, solar panels, louvers, pergolas etc. for energy-efficiency.

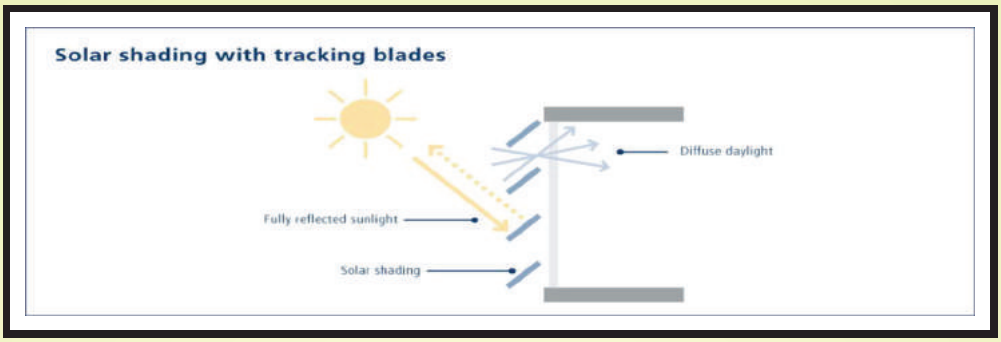


Figure: 5

Passive Features for Energy Efficiency

Buildings in different climatic zones require different passive features to make structures energy-efficient. In hot and dry zone e.g. Jaisalmer, Jodhpur, it is imperative to control solar radiation and movement of hot winds by providing shading, reducing exposed area, controlling and scheduling ventilation, and increasing thermal capacity. The presence of "water bodies" is desirable as they can help increase the humidity, thereby leading to lower air temperatures. In warm and humid zone such as Mumbai, Chennai and Kolkata, main design criteria are to reduce heat gain by providing shading, and promote heat loss by maximizing cross ventilation. Dissipation of humidity is most essential to reduce discomfort. In moderate zone e.g. Pune and Bangalore, it is desirable to reduce heat gain by providing shading, and to promote heat loss by ventilation. In cold climate zone, generally, the northern part main design criteria are to resist heat loss by insulation and controlling infiltration. Simultaneously, heat gain needs to be promoted by admitting and trapping solar radiation within the living space. In composite zone, such as Delhi, Kanpur and Allahabad. The design criteria are more or less the same as for hot and dry climate except that maximizing cross ventilation is desirable only in the monsoon period.

Improvement in Energy Efficiency beyond Building Envelope

Further improvement in energy efficiency can be achieved by improving thermal performance of the envelope using thermal insulation as per ECBC norms for various climates.As per research paper Published in International Journal of Environmental Science and Technology -volume 14, NOV 2017,optimum level of insulation has been found to be

30% above U-values prescribed by Energy Conservation Building Code 2007.

Now we have ECBC 2017 which prescribes 3 levels of energy efficiency:

(a) Energy Conservation Building Code Compliant Building (ECBC Building)

(b) Energy Conservation Building Code Plus Building (ECBC+ Building)

(c) Super Energy Conservation Building Code Building (Super ECBC Building)

Renewable Energy

After energy efficiency, dependence on conventional energy can be reduced by use of renewable energy through construction of net zero buildings such as Indira Paryavaran Bhawan constructed by CPWD, construction of energy plus buildings and utilizing renewable energy potential by other means.

India has an estimated renewable energy potential of about 900 GW from commercially exploitable sources viz. wind – 102 GW at 80 metre mast height, small hydro – 20GW; bio-energy – 25 GW; and 750 GW solar power, assuming 3% wasteland is made available. National Institute of Wind Energy has used advanced modelling techniques and revised the estimated wind power potential at 100 metre to 302 GW.Installed Grid Interactive and off grid Renewable Power Capacity in India as of September 30, 2016 with targets up to 2022 is given in Table 1 and 2.

Table 1: Installed Grid Interactive Renewable Power Capacity in India

	Total Installed Capacity (MW)till Sept 2016	**2022 target (MW)**
Wind Power	28082.95	60,000
Solar Power	8513.23	100,000
Biomass Power (Biomass & Gasification and bagasse)	4882.33	*10,000
Wasteto-Power	115.08	
Small Hydro Power	4323.35	5,000
Total	**44,783.33**	**175,000**

Table 2:Off-grid power as of July 31, 2016

Source	Total Installed Capacity (MW)
Waste to Energy	161.39
Biomass(non-bagasse)Cogeneration	651.91
Biomass Gasifiers	-
- Rural	18.15
-Industrial	164.24
Aero-Generators/Hybrid systems	2.79
SPV Systems	330.00
Water mills/ micro hydel	18.81
Total	**1,347.29**

Solar Power

Solar potential, estimated by India's National Institute of solar energy is around 750GW based on the assumption that 3% of wasteland in each state can be used for solar power projects, plus an assessment of the potential for rooftop solar power.The solar resource is strongest in the north and northwest of the country e.g. Rajasthan, Jammu and Kashmir, butis also considerable in a number of other states, including Maharashtra, Madhya Pradesh, and Andhra Pradesh.

Solar power is taking momentum to meet the target of 2022.Jawaharlal Nehru National Solar Mission, launched in 2010. Initial target of 20 GW by 2022 was upgraded in 2014 to 100 GW by.It consists of 40 GW of rooftop solar photovoltaic (PV) and 60 GW of large and medium scale grid-connected solar power projects (Table 1) as part of a broader 175 GW target of installed renewable power capacity by 2022, excluding large hydropower. With this ambitious target, India will become one of the largest green energy producers in the world, surpassing several developed countries. The total investment in setting up 100 GW will be around Rs.6,00,000 crore.

As regards solar rooftop, all major sectors i.e. railways, airports, hospitals, educational institutions, government buildings of central/state/PSUs are being targeted besides the private sector.Solar PV modulesprovided on rooftop are of two types, silicon-based solar cells provide higher efficiency (15% - 20%) but are relatively costly to manufacture, whereas thin film cells are cheaper but less efficient (5% - 10%). Increased efficiency of cells will require less space for same capacity and is therefore more useful. Good quality PV modules

generally have a useful life of 25 to 30 years, although the performance steadily degrades by about 20% over life time.

Mounting structures can be either fixed or tracking. Tracking systems on an average cost approximately 2 % more and produce about 20% more power compared to fixed tilt mounting system, therefore are beneficial to use.

A grid connected rooftop solar requires 10 sqm of area per KWp and on an average costs Rs. 8 crores per MWp thus 1KWp system costing around Rs. 80,000 generally has a payback period of 6-8 years. 40 GW target of solar rooftop capacity by 2022 will require 4,000 lakh sq. m. of area and will cost Rs.3,20,000 crore.

CPWD has installed rooftop solar panelson existing buildings having roof area of 1500 sqm or more and has already completed instalment and started electricity generation in many buildings. Total installed capacity as on December 2016 is 6.98 MW from solar plants installed on 47 buildings with 6.1 MW installed on 41 General pool office buildings (GPOA) and 0.88 MW on 6 non GPOA (General pool office buildings).

A rooftop solar power plant set up by the Radha Soami Satsang Beas, Educational and Environmental Society, Punjab inaugurated on 17th May 2016 is the largest rooftop solar plant on a single roof spread across 42 acres (17 ha), havinga capacity of 11.5 MW. The campus holds a capacity of 19.5 MW across multiple roofs totalling 82 acres (33 ha), the largest in India. The project would help in abatement of 4 lac ton of carbon dioxide emissions in the next 25 years which is equivalent to planting of 2 lac trees. Besides meeting its own power requirements, it will feed surplus power into the grid.

In Haryana, solar rooftop power plant installation of 3-5% of connected load has been made mandatory for all residential buildings with plot size of 500 square yards (0.04 ha) and more, for all government and private educational institutions and offices with connected load of 30KW and above and for private hospitals and nursing homes, malls, industrial and commercial establishments, hotels, banquet halls and tourist complexes of 50 KW and above. This is on lines of San Francisco which has also passed legislation for mandatory rooftop solar installations for all commercial and residential buildings up to ten storeys as an initiative of achieving solar power goal.The other major rooftop solar power plants are in USA of capacities as 10.0, 6.4, 5.38 and 5.0 MW and in India in Noida, UP of 4.1 MW capacity.

Solar Park

Solar park is a large chunk of land developed for setting up of a number of solar power projects wherein the solar power developers will be made available land which is free from

statutory clearances with common infrastructure facility such as water, transmission lines, roads, drainage, communication network etc. in place. Ultra-Mega Solar Power project is a single power project with capacity of over 500 MW which may be set up in some of these Solar Parks.

These parks will be able to accommodate over 20,000 MW of solar power projects. As on date, 33 parks with capacity of about 19,900 MW in 21 states have been sanctioned. As minimum land requirement is approximately about 2ha per MW, this would require 39,800 ha land. This requirement can be reduced to a great extent by solar sharing method which was first adopted in Japan.

Shade of solar panels have no negative impact on crop growth if arranged in a particular configuration that allows sufficient sunlight and wind to pass through to the plants especially for fruits and vegetables, it reduces irrigation requirements due to shading and farmers can meet their electricity needs in addition to selling the surplus power to the grid. If implemented at a large scale, farmers can earn about 30-40 percent profit sharing in power generation revenue.

Gujarat Energy Research and Management Institute (GERMI) is also awaiting large scale implementation of another proposal that would involve putting a layer of solar panels over one another which would generate 70 percent more energy than a single layer panel.

Cochin international airport is the country's first airport in the world that completely operates on solar power. It has 12 MWp solar power plant with 46,150 solar panels, producing 50,000 to 60,000 units of electricity per day against consumption of around 48,000 units. Over the next 25 years, this green power project will avoid carbon dioxide emissions by more than 3 lakh metric tons, which is equivalent to planting 3 million trees.

The largest solar park in the world of 648-megawatt is spread across 2,500 acres in the town of Kamuthi in the Ramanathapuram district of India which will supply clean, and green energy for 3,00,000 homes.

Other solar parks more than 150 MW capacity are 21 in USA, 5 in China, 3 in India, 2 in Chile, 1 each in Pakistan, Germany, France and South Africa.

Studies have revealed that solar and wind are almost complementary to each other and hybrid of two technologies would help in minimizing the variability apart from optimally utilizing the infrastructure including land and transmission system. The existing wind farms have scope of adding solar PV capacity and similarly there may be wind potential in the vicinity of existing solar PV plant.

Other Experimental Initiatives

As part of reducing environmental pollution and consumption of non-renewable resources, country has already started use of solar panels on car, train, bus, truck and aircraft on experimental basis which may be implemented later on large scale. Solar trees, roof tiles and solar panels on vertical surface are also being experimented.

Route 66 in Missouri, USA is underway construction of solar panelled roads that would also produce energy. The roads would be covered with tempered glass such that cars can drive on them. The hexagonal panels(Fig. 6) also have LED lights that would perform the task of signage eliminating the need of paint markers. Also, they would have heating features to prevent the accumulation of snow on the road which is a common problem in USA. Other than USA, France is also planning to make 600 miles of solar panelled roads.

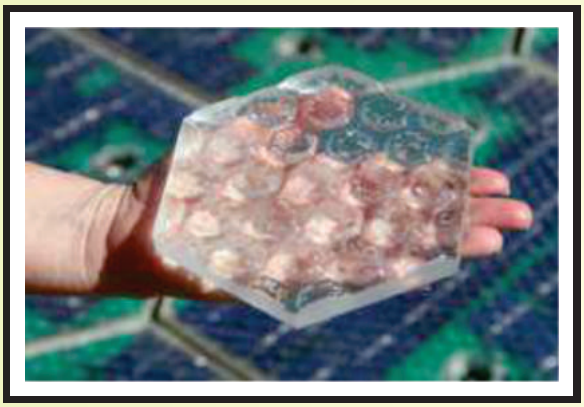


Figure 7: Solar panelled road



Figure 8: Floating solar plant

To save on land, another innovation is floating solar plants as shown in Fig. 7. The first floating solarplant of 10KW was set up in Rajarhat, Kolkata in 2015 and occupies a mere 0.01 ha of land.SECI has initiated a hybrid solar-wind project with 300 MW capacity in Andhra Pradesh,10 MW each in Andhra and Kerala and 5MW in Lakshadweep. This innovation can help to electrify the very remote rural areas and villages that still await power supply through the existing water bodies in rural areas.

As per TOI Feb 13,2017, Solar panels are installed on Indian warships for the first time. Looking at the suitability to marine environment, panels with innovative properties like anti-rust, withstanding high wind speed, perform on flat installations and having low weight were used.

Innovations in maintenance of solar systems are also being attempted. With greater installations, there would be a rising need for cleaning of solar panels to maintain their efficiency which calls for time, labour and scarce resource like water. As a first time ever,

Kibbutz solar park in Israel has been using robots to clean panels. Additionally, they do not use water and instead use microfibers to clean and for each minute a robot cleans about 100 sq feet panel area. According to a media report, Israel based company Ecoppia is setting up a robotic solar cleaner manufacturing unit in Chennai in foresight of the cleaning requirements that would arise with rapid solar installations.

Conclusions

Energy conservation, energy efficiency and renewable energy are effective countermeasure against the future exhaustion of natural resources and global warming. Good building envelope design can contribute immensely in energy efficiency. Renewable energy sources especially solar have huge potential to provide many times the current global energy needs.

Fulfilling the MNRE's solar target of 100GW by 2022 can make India one of the largest green energy producers in the world. Tracking system and high efficiency PV module can save roof space and increase capacity. Solar sharing, especially with double layer can tremendously reduce the requirement of land as well as irrigation along with extra income for farmersand must be used to avail the benefits. Innovative solutions like solar panelled roads, floating panels, robotic cleaning and use of microfiber instead of water for cleaning of panels address many of theissues like maintenance, water shortage, land availability and will prove to be very useful. Disposal or partial reuse of solar panel needs research looking at 25 years life of solar panel.

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ENERGY EFFICIENCY IN PUBLIC BUILDINGS

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Abstract

This paper provides an overview of the significance of energy use in public buildings, typical barriers to achieving energy efficiency potential, and pro-active policy and program tools to address and overcome these barriers. Energy efficiency features are easiest and economic to be provided during construction and easy to achieve in a public building having a demonstration effect for private sector to follow. Once followed, this will have pioneer effect in implementation of energy efficiency policies.

Definition of Energy Efficiency

Energy efficiency is defined as eliminating waste and getting more or better energy services from the same amount of energy resource. Energy efficiency opportunities exist at different stages of energy production but our focus is on end-use energy efficiency in public buildings.Energy efficiency is helpful in;

- Freeing up budgets for other uses by reducingpublic building operating costs.
- Diminishing the impact of energy price volatility (increases).
- Reducing air and water pollution from lower energy supply and use.
- Improving the reliability of the energy supply system while reducing capital requirements for new energy supply due to slow (or reverse) energy demand growth.
- Strengthening local economic development by shifting spendingfrom capital-intensive energy supply to employment-intensive energyefficiency measures.
- Mitigate climate change impacts.

Importance of Energy Efficiency in Public Buildings

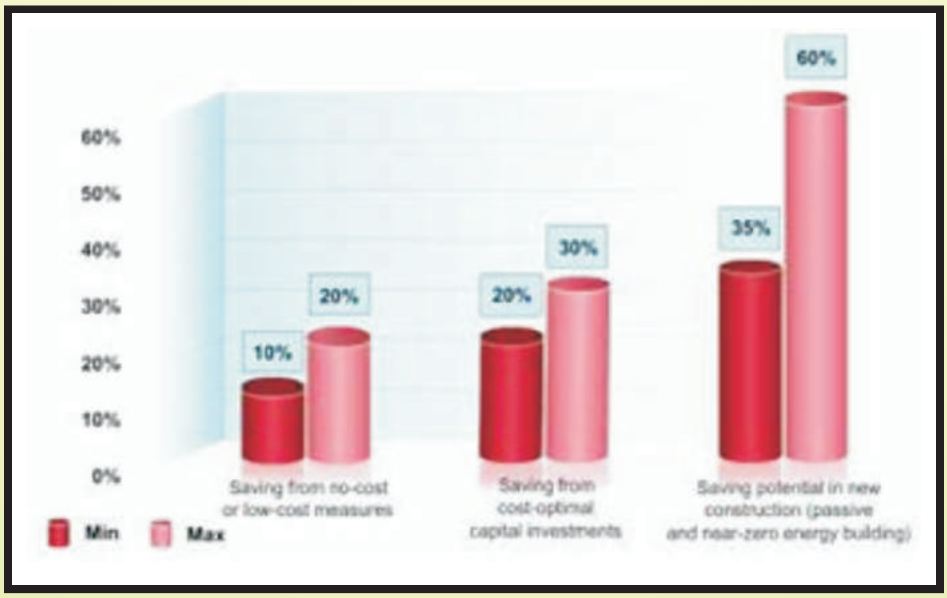
Public buildings include government offices, institutional buildings such as schools, universities public libraries, museums, and conference halls, hospitals and health care facilities, public recreation facilities and swimming pools, security and protection facilities such as police and fire stations, jails and prisons.These public buildings represent between 10% and 20% of the total floor space, and correspondingly a similar percentage of totalbuilding energy use. With growingdependence on energy imports and rise in energy

cost, public sector needs to cut energy costs across the board, including inthe building sector, which can be accomplished most cost effectively without compromising comfort and service quality through energy efficiency measures.

Highly visible examples of energy efficiency in public buildings can have significant effects throughout the whole economy, in several ways like public buildings can “lead by example” and influence other building owners to take similar action, efficiency projects in public buildings can provide a proof-of-concept, along with reliable measured data on energy and cost savings and return on investment, can serve as a test bed and training ground to help familiarize contractors, installers, and facility operators with innovative technologies and practices, and public agencies can pioneer implementation of new energy efficiency policies such as energy- efficient procurement.

Energy Efficiency Opportunities for Existing Public Buildings through Retrofitting

The largest energy end uses in public buildings are in space heating/cooling , lighting (indoor and building exterior, including parking lots), water heating, computer and office equipment, refrigeration, and other loads such as hospital or laundry equipment. Opportunities for energy efficiency in existing public buildings for such loads include at least 10%savings from low-cost operational measures and tune-ups, and 20-30% or more fromcapital investments that are life-cycle cost-effective. Measures that can reduce up to 35-60% of building energy use are more cost-intensive, and are generally only realized in newly constructed buildings or during comprehensive thermal modernization.



Examples of low-cost operational measures and tune-ups efficiency opportunities include poorly insulated building envelope, thermally inefficient windows and door infiltration of

outside air due to a leaky building envelope, inefficient or poorly maintained heating, cooling, and water heating equipments, heating/cooling/ventilation/hot-water distribution systems and controls thatare poorly designed, poorly controlled, or in need of adjustment.

Other opportunities include inefficient lighting equipment, lighting design, and controls; and limited useof day lighting, inefficient office and miscellaneous equipment, high energy consumption of installed mechanical equipment when theequipment is in standby and unused/off modes.

Policy Background

Various governments have considered theopportunities and benefits of building energy efficiency, including the facts that buildings represent approximately 40% of overall national energy use, andpublic buildings are responsible for up to 20% of this overall building energyuse. Governments have noted thatenergy efficiency can promote sustainable solutionswith energy use reductions of at least 20% that are technically feasible and cost-effective. Energy efficiency can reduce the region's dependence on imported energy and,CO2 emissions to mitigate climate change.For all of these reasons, various Governments world over have issued a number of directives thatrequire increased energy efficiency in both new and existing public buildings. It has promoted the exemplary role of the public sector, proposing to accelerate the refurbishment rate of building through a binding target and to introduce energy efficiency criteria in public buildings.The plan focuses on instruments to trigger the renovation process in public and private buildings and to improve energy performance of the components and appliances used in them.

Despite the clear opportunities and benefits of energy efficiency in public buildings, several factors like physical, resource related, and institutional, contribute to wasteful or inefficient use of energy in public buildings. These include;

- Lack of attention and leadership on energy efficiency from top management and elected officials due to higher priorities in other sectors of social importance.
- Divided responsibilities for energy management and capital investment among several agencies or departments of the same government such as, an estate agency, tenant organizations, budget office, design and construction authority.
- Little direct incentive for the agency occupying the building to save energy or reduce operating costs for instance, the agency may not pay utility bills or even rent; and savings go back to the general fund and are not available to the agency for other purposes.

Main Barriers to Improving Energy Efficiency in Public Buildings

Understanding barriers of improving energy efficiency in public buildings enable policymakers to identify the most effective policy and programmatic tools for overcoming them. Common barriers are economic, structural and regulatory, and those related to information and resources as given in the following;

Economic barriers

- The purchase price of efficient equipment is generally higher than for inefficient equipment and life cycle costing is often not well understood or incorporated into public sector purchasing criteria.
- State and municipal funds for energy efficiency financing are limited. Available mechanisms, such as loans, bonds and credit guarantees are generally inadequate, and regulations in many countries place restrictions on municipal borrowing.
- Low (below-market) energy prices resulting from national energy subsidiesare a major disincentive for energy efficiency investment. Such subsidies lengthen the payback periods for energy-efficient equipment.

Structural or regulatory

The separation between the energy consumer and the bill payer creates a “split incentive.” When government agencies or specific departments are not responsible for paying from their own budgets for the electricity or gas they consume, they have little incentive to improve their efficiency.

Information related

There is limited information and awareness about public building energy use and the low-cost opportunities for saving energy through efficiency improvements.

Resource related

Available resources to address the complicated technical aspects of building energy efficiency are limited. This includes human resources such as dedicated personnel and technical expertise as well as readily available energy efficiency products and services.

Effective Approach for Overcoming Barriers

An effective approach for addressing barriers to energy efficiency improvements is to adopt an energy efficiency plan that outlines the energy saving objectives at the national level and includes a number of supporting element which can be strategic planning documents;

policies, along with laws andregulations to implement them; and a set of complementary programs aimed at accomplishing the policy goals.

In addition, there are a number of other important elements that must be in place toensure that a strategy is effective. Some of them are;

Sustained high-level support

The strong support of senior government officials is very important, as is the provision for continuity of leadership in the event of turnover in elected officials and/or government staff.

Assignment of responsibility and accountability

It is critical to designate particular institutions on national, regional, and municipal levels that will have the authority and responsibility for the implementation of energy efficiency regulations and programs including coordinating the activities of other agencies, providing technical assistance, collecting and reporting information, and allocating funding.

Adequate financial and staffing provisions

Ultimately, the success of any policy or program depends on the availability of financial and human resources to sustain its administration and implementation. Financial resources may include government revenues, government borrowing, third party(such as ESCO) funding, and other financial tools, such as carbon finance.

Measurable goals and metrics, with a specified timetable

Examples of goals include quantitative energy savings targets such as achieving 25% energy savings in all new public buildings, and objectives for specific actions to be completed such as carrying out energy audits in 50% of existing public buildings, as well as procedures to be followed such as designing all new public buildings to be 40% more efficient than the existing stock, or using life cycle cost criteria when purchasing new equipment.

Regular reporting on progress made

Agencies should be required to report back to senior officials or the legislative body on actions taken and results achieved. Ideally, they should also be required to make their results and lessons learned available to the energy efficiency community and the broader public.

Addressing Specific Barriers and Improving Public Sector Energy Efficiency

Effective policy and program tools: The key to having an effective energy efficiency program in place is to provide an initial set of“foundational” policies, as well as additional policies and

programs that address the specific barriers. Governments should aim to put in place policies that not only directly reduce energy use in public buildings, but also help overcome market barriers to efficiency for the building stock as a whole, both.

Additional public sector policies and programs that can be extremely effective atimproving energy efficiency include:

Improved energy management practices in public buildings: This includes operator training, energy audits and retro commissioning, and building energy performance measurement, bench marking, and disclosure ("energy labeling"). Pilot testing such activities in public building first can pave the way for broader programs that include all types of buildings.

Energy efficient purchasing: Providing authority and incentives for public sector purchasers to prioritize efficiency when making purchasing decisions can create significant buyer demand for energy-efficient appliances and equipment that affects the entire market.

Conformity to the Codes of Energy Efficiency Codes and Specifications

New or renovated public buildings are required to be early adopters of energy codes, energy performance specification and/or requiring these buildings to exceed or by some percentage the energy efficiency requirements that apply to all buildings.

To address economic barriers, policy makers can initiate pricing reforms to move toward cost based pricing and eliminate or reduce energy subsidies, thus encouraging consumers to make economically rational energy use and energy saving investment decisions, provide legal authority for the national government, provincial governments, or municipalities to borrow adequate funds for energy efficiency, provide legal authority for public agencies to contract with energy services companies(ESCOs) to implement projects using energy performance contracting or equipment leasing agreements and leverage private sector funding, for instance, through public private partnerships to attract private capital through the outsourcing of service and management contracts. Such contracts allow private sector firms to both operate and invest in upgrading the operational efficiency of municipal buildings, district heating systems, street lights, and other public infrastructure.

To address information related barriers, policymakers should

- Invest in energy metering, monitoring, and reporting systems to compile data on building energy consumption, establish baselines, and monitor progress, as well as compare performance and improvements among similar buildings in the public stock.
- Mandate consumption-based billing at the building level, and encourage interval meters

for electricity along with real-time displays online or in public areas of each building.

- Carry out public awareness campaigns to ensure stakeholder involvement and support for efficiency policies and programs. By providing information on end use energy efficiency measures and their benefits, such programs can promote significant savings among decision-makers, as well as public sector staff and other consumers.

Conclusion

Energy efficiency in public sector can "lead by example" to help promote behavioral changes among citizens and businesses. Public sector energy efficiency initiatives can provide visible demonstrations of energy-saving projects, provide test beds for new energy-efficient technologies, and help catalyze the market entrance for energy efficiency products and services. A bigger market uptake of energy efficiency products and services can create competition and bring down the prices of new technologies. Efficiency features are easiest and least costly when designed and implemented from the start in new public buildings or as part of major renovations, where efficiency can capture the otherwise "lost opportunities" of saving energy and money for many decades to come. Public agencies can pioneer implementation of new energy efficiency policies such asenergy efficient procurement.

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GRID CONNECTED SOLAR PV ROOFTOP PROGRAM IN INDIA

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Abstract

India, with its large population and rapidly growing economy, needs access to clean, cheap and reliable sources of energy. India lies in the high solar insolation region, endowed with huge solar energy potential with most of the country having about 300 days of sunshine per year with annual mean daily global solar radiation in the range of 4 – 7 kWh/m2/day. Solar power can help meet energy requirements for commercial and residential buildings through installation of solar rooftop plants on vacant rooftop areas. With falling costs of solar panels and other equipment, the economies have become even more compelling.

Rooftop solar is considered as an environmentally stable power source and is increasingly cost-effective for home owners, business owners, and their communities. It has a significant share in development of the solar PV sector in key global solar markets such as Germany, Italy, China, US, Japan, etc. Approx. 58% of global solar PV installed in last four years cumulatively has been contributed by rooftop segment, taking rooftop's share in total solar PV installations to 40%.

The Govt. of India has set an ambitious target of 175GW of Renewable Energy by 2022, of which would be 100 GW of Solar Energy. Further, 40 GW of the 100 GW has been envisioned from Solar Rooftop plants. According to MNRE, the cumulative market potential for solar rooftop in India is ~125GW.

Currently in its nascent stages of development, the solar rooftop sector faces various barriers which are preventing rapid scale up. Thus far most implementation of Solar Rooftop has been undertaken in the CAPEX mode. RESCO mode is gaining popularity among Industrial and Commercial consumers as DISCOM tariffs continue to rise.

Types of Rooftop Systems

1. Off Grid: These systems are installed on a stand-alone basis and operate independently of the grid. They are generally installed in conjunction with a battery storage system in order to store excess solar energy at a later stage. This system functions irrespective of grid availability.

2. Grid Connected: These systems are connected to the grid through a power conditioning and supply excess power generated to the grid. Currently in India, there are two types of

metering through which payments and settlements are made by the utility, net metering and gross metering. These have been described in detail in the following sections. Typically, grid connected systems are installed without battery storage.

Business Models

Business models for rooftop solar prevalent in India can be categorized based on Ownership and Revenue structures. These have been described in brief in the figure below:

Owners and Revenue Structures

Capex mode

a. Capital expenditure on solar PV system costs is incurred by the end user

b. The CAPEX can be financed through a combination of equity and debt

Resco/Opex model

c. Operational expenditure is incurred by the end user in form of tariff or lease payments

d. Solar PV system is owned by the RESCO

Metering Structure

Net Metering

a. In net-metering, excess solar generation is fed back into the grid

b. Solar units fed into the grid are settled against units consumed from the gird

Gross Metering

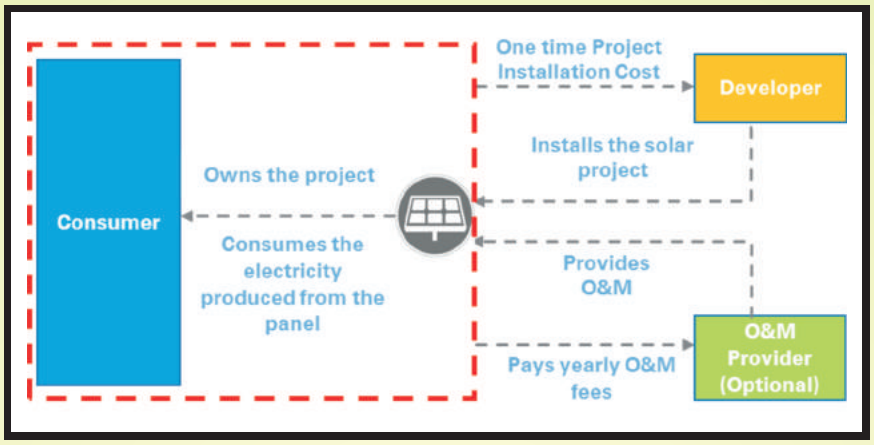
a. In gross metering, all of units generated through solar are fed into the grid

b. The units fed into the grid are settled at a pre-determined Feed-in-Tariff. Most of the states have come up with policies supporting solar rooftops. As of 6th Jan 2017, 20 states have come out with Solar Policy supporting grid connected solar PV rooftop systems. State Electricity Regulatory Commissions of 34 states have notified regulations for net-metering/ gross-metering with most of the states preferring net-metering policy.

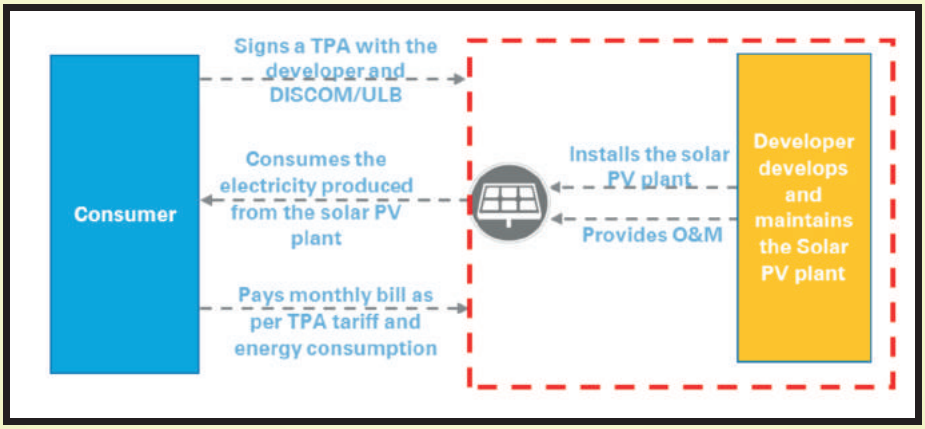
The DISCOM/ULB - EESL Business Model

EESL would work as an implementation partner of the DISCOM/ULB for installation of grid connected solar rooftop plants under two different models as briefed below:

Under the CAPEX model, EESL will be installing the solar rooftop plant in the designated area. EESL's responsibilities would include design, engineering, supply, installation and commissioning of the system. EESL would provide Repair & Maintenance during the warranty period.



Under the RESCO model, there will be zero upfront cost (barring cost of approvals and meter) of installation of the solar rooftop plant for the consumer. Power generated from the solar PV roof top would be charged on a monthly basis to the roof top owner.



Roles and Responsibilities

EESL - EESL or their appointed agency will be responsible for the following, not limited to:

- Conducting a site survey and feasibility analysis for the project
- Design and Engineering
- Procurement and Installation of the Solar PV plant
- Successful commission and interconnection at the specified metering points
- Facilitating regulatory approvals from the authorities

• In case of RESCO model, replacement of any defective parts as and when required will responsibility of EESL or its appointed agency. In case of CAPEX model standard warranty of system functioning for 5 years will be provided to building owner.

Rooftop Owner - Following will be the responsibility of the rooftop owner, not limited to:

CAPEX Model

- Obtaining regulatory approvals for setting up of the project
- Free of cost access to rooftop to EESL for carrying out installation
- Regular operation and maintenance of plant, post commissioning
- Safety and Security of the equipment
- Electricity & Water supply during construction and O&M phase

RESCO Model

- Long term Power Purchase Agreement with EESL
- Free of cost access to rooftops of buildings for the entire duration of the project
- Payment security mechanism such as an irrevocable revolving letter of credit, security deposit, bank guarantee. This would be as agreed at the time of signing of contract.
- All approvals for setting up the project under Net metering
- Safety and Security of the equipment
- Electricity & Water supply during construction and O&M phase

Advantages of RESCO over CAPEX model

Installing solar rooftop plants under the RESCO model offers various advantages to the building owner. These have been enlisted in the table below:

Parameter	CAPEX Model	RESCO Model
Upfront Investment	Entire amount to be invested by the building owner	Zero upfront investment to be made by the building owner
Operation and Maintenance	To be carried out by the building owner with assistance from developer	To be carried out by the developer, **free of cost**, for contract duration (10-25 years)
Replacement of Inverter	To be carried out by the owner at his own cost	To be carried out by the developer **free of cost,** for contract duration (10-25 years)
Replacement of faulty components	To be carried out by the owner at his own cost	To be carried out by the developer **free of cost** for contract duration (10-25 years)

Conclusion

The benefits of installation of solar rooftop plants are tremendous including reduction in carbon di oxide emission, reduced T&D losses, zero cost of operation and upfront cost and energy cost savings. Utility participation can act as a key catalyst driving solar rooftop as their participation can, 1) help in faster customer aggregation owing to their customer knowledge and customer access, 2) result in reduction in default risk, and 3) facilitate improved and faster operations and maintenance. It is estimated that rapid scale up of the segment and overall cost reduction could result in a decrease in the overall cost of solar power by 60-80 paise/kWh.

LIGHTNING & SURGE PROTECTION FOR SOLAR ROOF TOP SYSTEMS

Brijesh Malik, Vice President DEHN India (P) Limited

Abstract

Lightning is a natural phenomenon which takes place due to formation of heavy electric field between earth and clouds. The discharge of energy when opposite ions come enough closer to each other takes place in the form of lightning strike which carries huge amount of current to the tune of 200KA. In electrical terms Lightning is defined as a wave shape having some rise time of 10 micro sec and time to half as 350 micro seconds (known as 10/350 micro sec wave).

Introduction

Tall structures, trees, metal parts and sometimes even human beings can be hit by lightning strikes. With the lightning strike high electromagnetic interference is created and it can damage the electronic equipment physically or by corrupting the software loaded in these electronic devices.

The damages of lightning can be as hazardous as damage of complete building, fire or sometimes non-availability of the very essential services. Lightning strike, if happen on a building with solar rooftop system installed, in the vicinity or on the power line entering the facility can cause various damages like fire at site, damage to solar panels, fire panels, BMS, automation system, essential services of hospital, bank, communication system like telephone, computer system, printers, CCTV etc. and failure of electrical & electronics equipments / components at site like PV inverter, PV combiner boxes, UPS etc.

These damages can occur due to high energy surges travelling in power and PV cables lines. The possibilities of damages are also due to moderately low energy surges (8/20 micro sec) travelling/created in the power and pv-dc lines.

Any damage of electrical & electronic components may cause discontinuity in services; hence lightning and surge protection at such sites are vital and important. External lightning protection is installed to prevent the damages to structures and Surge Protection Devices (SPD) is used for protection of electrical/electronic equipment against direct/indirect Lightning, Extremely High Energy (10/350 micro sec) Lightning Impulse and Moderately Low (8/20 micro sec) Energy Surges.

Photovoltaics (PV) are on the rise and a key pillar of the globally growing electricity supply

from renewable energies. The International Energy Agency (IEA) predicts that the share of renewable energies in power generation worldwide will be between 12% and 23% in 2035. In particular power generation in PV power plants will experience very rapid growth. The number of photovoltaic systems – both roof-mounted systems and ground-mounted systems such as solar parks – will continue to grow in the long term. This development involves large-scale changes of electrical equipment. Every PV system installed must be maintained to ensure continuous yield. To prevent failure and increase the service life of the inverter, reliable lightning and surge protection is required. A typical solar rooftop with lightning protection system is shown in Fig. 1.

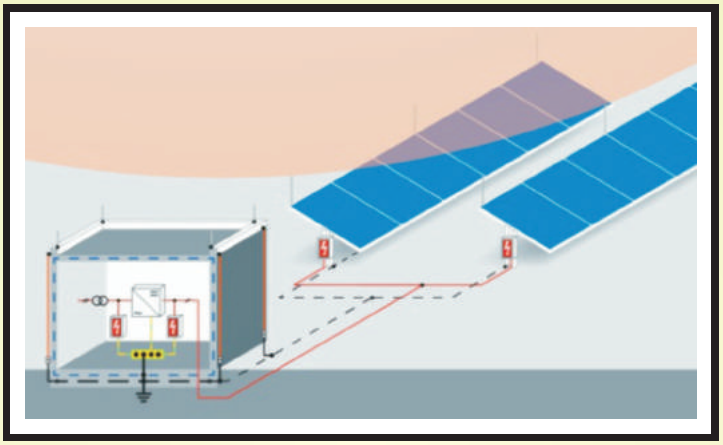


Figure 1: Solar Rooftop with Protection System

The selection and arrangement of lightning and surge protection measures are based on the lightning protection zones concept according to IS/IEC 62305. This standard defines protection zones in which different coordinated protective devices are installed. External lightning protection systems are installed as result of a risk analysis according to IS/IEC 62305-2 or the state building code. A lightning protection system provides optimal protection due to the interaction of external lightning protection including air-termination system, down conductor, earth-termination system and internal lightning protection including lightning equipotential bonding, surge protection and separation distance.

External lightning protection for PV system

Widely used roof-mounted systems are particularly prone to direct and indirect lightning strikes. Since the PV system is directly connected to the electrical installation of the building, lightning effects may have serious consequences for the building and persons inside. The external lightning protection is designed as per rolling sphere method and directly mounted on structure using suitable clamps.

The angled air-termination rod is fixed on panel structure using two saddles which provides

firm connection between air terminal and structure. The air-termination rod is adjustable to the inclination angle of the PV system. The standard design is angled to 55° which corresponds to a PV system inclination of 35°. Further structure is connected to earthing system hence no additional earthing is required for air terminal network.

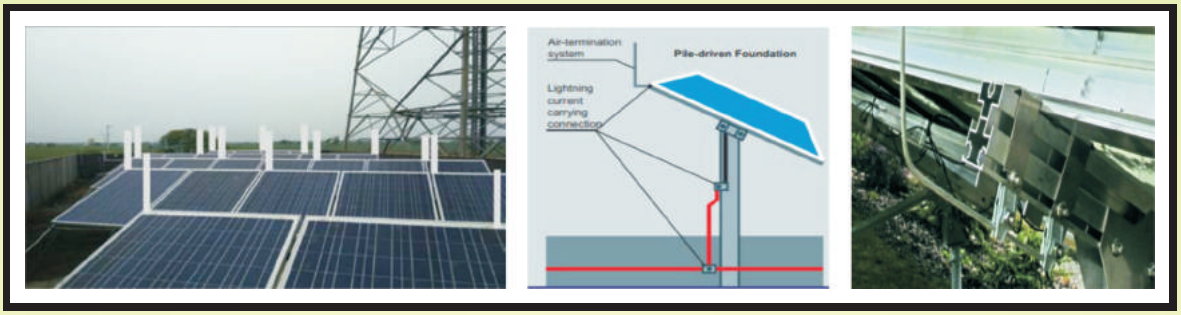


Fig. 2: Angled air termination rods on solar panels Figure 3: Surge protection in a PV panel

For DC and AC voltages, surges need to be protected using suitable SPDs. For specific combinations, SPD details are given in the following;

Type 1+2 SPD at combiner box or at input of Inverter / DC side

Combined lighting current and Surge arrester type 1 + type 2 for PV generator circuits up to 1000/1500 V DC with safe disconnection of DC arc using integrated bypass DC fuse in parallel, arrester according to EN 50539-11.

For use according to IEC 60364-7-712 combined disconnection and short-circuiting device having fault indication.

Maximum PV voltage: <= 1000 / 1500 V d.c.

Total discharge current (DC '+' / DC '–') to PE Iimp (10/350 µs) : 12.5 kA

Total discharge current (DC '+' / DC '–') to PE In (8/20 µs) : 30 kA

Voltage protection level (DC '+' / DC '–') to PE: <= 2.5 / 3.75 kV

Short-circuit current rating Iscpv: 1000 A

Type 1+2 SPD at Output of Inverter / AC side

The device shall be non-exhausting metal encapsulated, spark gap-based technology for fire safe operation at site.

- The device shall be tested from KEMA or VDE as per the latest & valid IEC 61643-11:2011 standards.

- Maximum continuous operating voltage (Uc) shall be 255 V AC for L-N and N-E SPD along with the additional abnormal voltage test up to 485 V AC / 50 Hz for 24 hours for L-N SPD (due to neutral disconnect / neutral floating at transformer level).
- The device shall be capable to discharge Lightning impulse current (Iimp) up to 25 KA (10/ 350 µs) for L-N and 100 kA (10/ 350 µs) for N-E SPD.
- The device shall have voltage protection level (Up) of 1.5 KV for L-N and N-E SPD.
- The device shall have Follow current extinguishing capability [L-N]/[N-PE]: 25 KArms / 100 Arms.
- The device shall have follow current limitation/Selectivity without tripping of a 35 A gL/gG fuse up to 25 KArms.
- The device shall have mechanical flag based local indication and remote indication for all L-N and N-E SPD.

External lightning protection system for Buildings

The external LPS is intended to intercept direct lightning flashes to the structure, including flashes to the side of the structure, and conduct the lightning current from the point of strike to ground. The external LPS is also intended to disperse this current into the earth without causing thermal or mechanical damage, or dangerous sparking which may trigger fire or explosions.

The functions of the external LPS are:

- To intercept a lightning flash to the structure (with an air-termination system),
- To conduct the lightning current safely to earth (with a down-conductor system),
- To disperse it into the earth (with an earth-termination system).

External Lightning protection system consist of following components.

a) Air Termination system

b) Down conductor system

c) Earth termination system

a) Air Termination system – Three methods can be used to determine the arrangement and the sitting of the air-termination systems.

- Rolling sphere method
- Mesh method
- Protective angle method

These methods are depicted in Figure 4 below.

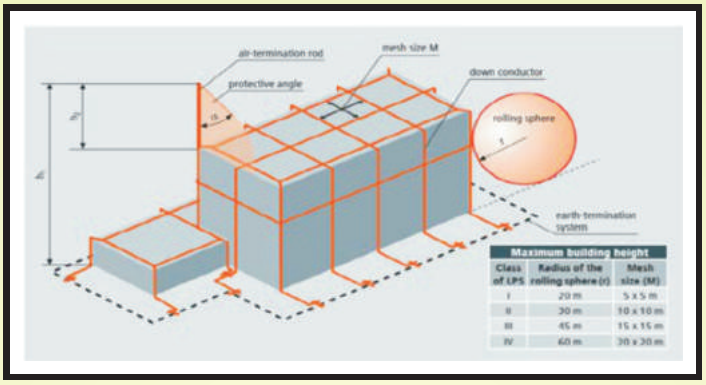


Figure 4: Types of Air Termination System

When determining the sitting of the air-termination systems of the lightning protection system, special attention is paid to the protection of corners and edges of the structure to be protected. This applies particularly to air-termination systems on the surfaces of roofs and the upper parts of facades. Most importantly, air-termination systems must be mounted at corners and edges. The rolling sphere method is the universal method of design particularly recommended for geometrically complicated applications.

b) Down Conductor system – The down-conductor system is the electrically conductive connection between the air-termination system and the earth-termination system. The function of down-conductor systems is to conduct the intercepted lightning current to the earth-termination system without intolerable temperature rises, for example, to damage the structure.

To reduce the probability of damage due to lightning current flowing in the LPS, the down-conductors shall be arranged in such a way that from the point of strike to earth:

a) several parallel current paths exist

b) the length of the current paths is kept to a minimum

c) equipotential bonding to conducting parts of the structure is performed

An equal spacing of the down-conductors is preferred around the perimeter. Typical preferred values of the distance between down-conductors are given 10m, 15m, and 20m

distance for class I&II, III and IV respectively as per Table 4 of IEC 62305-3: 2010 & Table 7 NBC-2016.

Example for site constraints: As per LPL-III, the distance between two down conductors is 15 meters. However, in case of any site constraint where down conductors at any side or part of side is not possible then the same shall be compensated at the other side keeping into consideration that the distances between down-conductors on that side should not be less than one-third of the distances as per given LPL, i.e. 1/3rd of 15 meter = 5meter.

A variation in spacing of the down-conductors of +20 % is acceptable as long as the mean spacing conforms to Table 4. (Refer to IS/IEC 62305-3 Clause E.5.3.1& NBC-2016 Clause-11.5.2.1)

c) Earth Termination system – The earth termination system is a localized entirety of interconnected conductive earth electrodes or metal components for proper earthing/ grounding. The down conductor is to be terminated at earth for safely discharge the intercepted lightning current by air termination system.

When dealing with the dispersion of the lightning current (high frequency behavior) into the ground, whilst minimizing any potentially dangerous overvoltage, the shape and dimensions of the earth-termination system are the important criteria. In general, a low earthing resistance (if possible lower than 10 Ohm when measured at low frequency) is recommended.

Summary of the three methods to design Lightning protection as per IS / IEC 62305 & NBC 2016

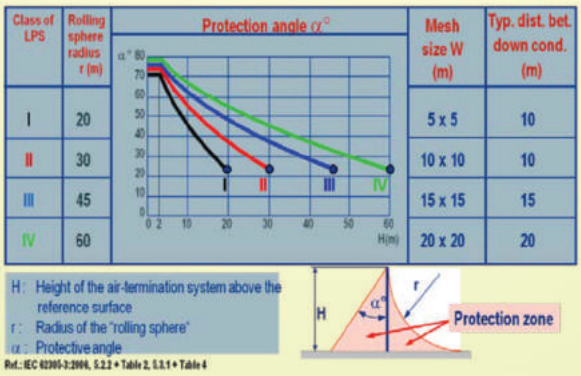


Figure 5: Summary of the three methods to design Lightning protection

Electrical isolation of external LPS – separation distance (Ref: IS/IEC 62305-3 Clause E.6.3 & NBC-2016 Clause 11.5.2.6)

There is a risk of uncontrolled flashovers between components of the external lightning protection system, metal and electrical installations within the structure, if there is insufficient

distance between the air-termination or down-conductor system on one hand to metal and electrical installations within the structure to be protected, on the other.

Metal installations such as water and air conditioning pipes, fan units, antennas and electric power lines, produce induction loops in the structure which are induced by impulse voltages due to the rapidly changing magnetic lightning field. These impulse voltages must be prevented from causing uncontrolled flashover which can also possibly cause a fire. An arrangement indicating the distance between the down conductor and metal installation is shown below in Fig. 6.

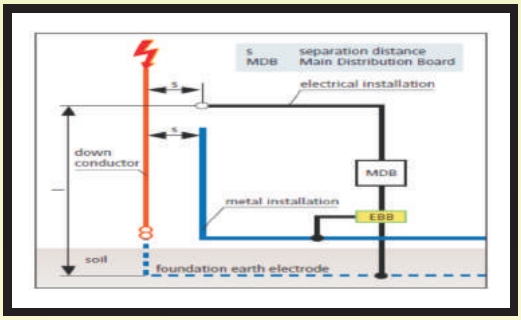


Figure 6: Arrangement of the down conductor and metal installation

The formula for calculating the separation distance is given in IS/IEC 62305-3 as & NBC-2016 Clause 11.5.2.6) is $s = k_i*(k_c/k_m)*l$ where ki depends on the selected class of LPS, k_m on the electrical insulation material, k_c on the (partial) lightning current flowing on the air-termination and the down-conductor, and l is the length, in metres, along the air-termination and the down-conductor from the point, where the separation distance is to be considered, to the nearest equi-potential bonding point or the earth termination.

Lightning Protection Zones Concept

Definition of Lightning Protection Zones (LPZ) (excerpt from IS/IEC 62305-4)

LEMP protection of structures with electrical and electronic systems in accordance with IS/IEC 62305-4

Zone	Description
LPZ 0_A	Zone where the threat is due to the direct lightning flash and the full lightning electromagnetic field. The internal systems may be subjected to full lightning surge current.
LPZ 0_B	Zone protected against direct lightning flashes but where the threat is the full lightning electromagnetic field. The internal systems may be subjected to partial lightning surge currents.
LPZ 1	Zone where the surge current is limited by current sharing and by SPDs at the boundary. Spatial shielding may attenuate the lightning electromagnetic field.
LPZ 2	Zone where the surge current may be further limited by current sharing and by additional SPDs at the boundary. Additional spatial shielding may be used to further attenuate the lightning electromagnetic field.

*LEMP – Lightning Electro-Magnetic Pulse

In correspondence with the requirements and loads on surge protection devices regarding their installation at site, these are classified as followings

1. Lightning Current Arresters

2. Transient Surge Arresters

3. Combined Lightning Current and Surge Arresters

The highest requirements on discharge capacity are made on lightning current and combined lightning current and surge arresters, which realize the transition from Lightning Protection Zone 0A to 1 or 0A to 2. These SPDs must be able to conduct partial lightning currents, wave of 10/350 µs several times without destruction in order to prevent the entering of destructive partial lightning currents into the electrical installation of a building.

At the boundary from LPZ 0B to 1 or downstream, lightning current arrester are used at the boundary. From LPZ 1 to 2 and higher, surge arresters are used for protection against surges. Their function is to further reduce both the residual load of the upstream protection stages and limit the inducted or own surges as shown in Fig.7.

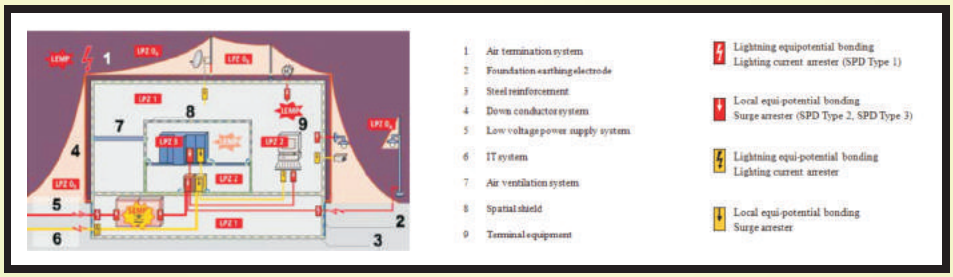


Figure 7: Arrangement of Lightning Protection System in different type of LPZs

Equipotential Bonding concept

Basic SPM

The basic Surge protection measures against LEMP (Lightning Electromagnetic Pulse) are as follows:

Earthing and Bonding: The earthing system conducts and disperses the lightning current into the earth. The bonding network minimizes potential differences and may reduce the magnetic field. The main function of the equipotential bonding network is to prevent hazardous potential differences between all devices/installations in the inner LPZs and to reduce the magnetic field of the lightning strike.

Earth-termination system:

The earth-termination system of the structure shall comply with IEC 62305-3. In structures where only electrical systems are provided, a type A earthing arrangement may be used, but a type B earthing arrangement is preferable. In structures with electronic systems, a type B earthing arrangement is recommended.

For Earthing, UL listed 17.2 mm dia, 3 meter long copper bonded rods with 250 micron bonding are installed as best industry practice.

Equipotential bonding:

Equipotential Bonding Bars (EBB) are a central component of the equipotential bonding system and must clamp all connecting cables and cross-sections which occur in practice so that they have high contact stability; they must be able to carry currents safely and have sufficient corrosion resistance. They are used to bond the following:

- All Conductive services entering an LPZ (directly or by using suitable SPDs)
- The protective earth conductor PE
- Metal components of the internal systems (e.g. cabinets, enclosures, racks)
- The magnetic shields of the LPZ at the periphery and inside the structure

For efficient bonding, bonding bars should be connected to the earthing system by the shortest possible route and SPDs should be installed in such a way as to use the shortest possible connections to the bonding bar as well as to live conductors.

Magnetic Shielding And Line Routing - Spatial shielding attenuates the magnetic field inside the LPZ, arising from lightning flashes direct to or nearby the structure, and reduces internal surges. Routing of internal lines can minimize induction loops and reduce internal surges.

Extended metal components such as metal roofs and facades, steel reinforcements in concrete, expanded metals in walls, grids, metal supporting structures and pipe systems existing in the building are particularly important when shielding against magnetic fields and thus for the installation of lightning protection zones. A meshed interconnection creates an effective electromagnetic shield. The usual practice is to install a meshed system of conductors into the reinforcement, said system typically having a size of a10 m. Suitable routing of internal lines minimizes induction loops and reduces the creation of surge voltages internally in the structure. The loop area can be minimized by routing the cables close to

natural components of the structure which have been earthed and/or by routing electrical and signal lines together.

Coordinated Spd System For 230/400 V Ac Power Supply System - A coordinated SPD system limits the effects of externally originated and internally created surges.

The protection of internal systems against surges requires a systematic approach consisting of coordinated SPDs for both power and signal lines. The rules for the selection and installation of a coordinated SPD system are similar in both cases.

SPDs for power supply systems:

SPDs used as part of the fixed building installation are classified into type 1, 2 and 3 surge protective devices according to the requirements and stress on the places of installation and are tested to IEC 61643-11:2011 by 3rd party international test labs like KEMA or VDE as shown in Fig. 8.

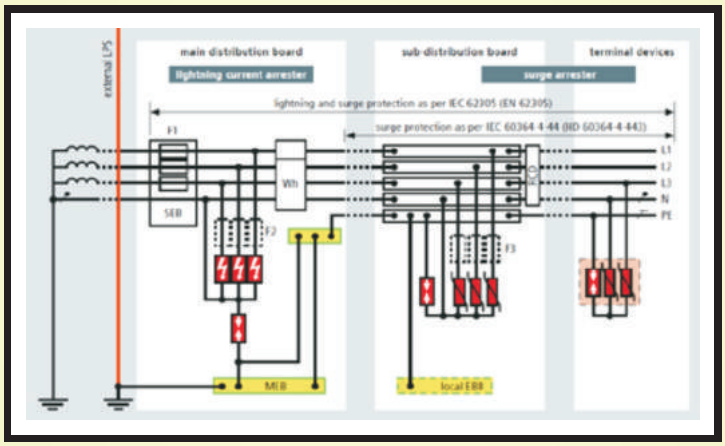


Fig. 8 Various types of SPDs for power supply systems

Type 1 SPD - These are used as part of the lightning and surge protection system at the boundary from **LPZ** 0A to **LPZ 2** and higher. These SPDs are installed at Main's entry level / LT Panel / incomer level of 230/400 V AC power supply. These surge protective devices (SPDS) are based on metal encapsulated spark gap-based technology for fire safe operations at site. SPDs able to discharge lightning impulse current (Iimp) up to 100 KA (10/350 µsec) for N-E connected SPD and 25 KA (10/350 µsec) for L-N connected SPD. Voltage protection level (Up) of L-N & N-E SPD shall be 1.5 KV to protect the terminal equipment. The SPD shall have mains-side overcurrent protection due to inbuilt fuse for all L-N SPD and operation of SPD shall be independent of load current due to inbuilt fuse. The device shall have mechanical flag based local indication and remote indication for all L-N and N-E SPD. The device shall have follow current extinguishing capability (Ifi) upto 50 kArms along with the limitation / extinction of mains follow currents up to 100 KArms (220 KApeak) for L-N SPD.

Maximum cont. operating voltage (Uc) of SPDs is 255 V AC for L-N & N-E. SPDs shall be tested according to IEC 61643-11:2011 by 3rd party international test labs like KEMA or VDE for ensuring the performance & safety of installation.

Type 2 SPD - To protect against surges of 8/20 µsec, type 2 SPDs with a discharge capacity of about some 10 kA (8/20 µs) are used at the transition from **LPZ 0B** to **LPZ 1**. These SPDs are installed at Sub-distribution level / DB level / close to equipment to be protected of 230/400 V AC power supply. These surge protective devices (SPDS) are based on heavy duty zinc-oxide varistor for L-N SPDs and spark gap /GD tube based technology for N-E SPD. SPDs able to discharge nominal discharge current (In) up to 10 KA (8/20 µsec) for L-N connected SPD and 20 KA (8/20 µsec) for N-E connected SPD. Voltage protection level (Up) of L-N & N-E SPD shall be 1.5 KV to protect the terminal equipment. The SPD shall have mains-side overcurrent protection due to inbuilt fuse for all L-N SPD and operation of SPD shall be independent of load current due to inbuilt fuse. The device shall have mechanical flag based local indication and remote indication for all L-N and N-E SPD. Short-circuit withstand capability (ISCCR) up to 25 KA. High reliability is due to "Thermo Dynamic Control" in SPD monitoring device. SPDs shall be tested according to IEC 61643-11:2011 by 3rd party international test labs like KEMA or VDE for ensuring the performance & safety of installation.

Type 3 SPD - The last link in the lightning and surge protection system for power supply systems is the protection of terminal devices (transition from **LPZ 1** to **LPZ 2** and higher). The main function of a type 3 surge protective device installed at this point is to protect against over voltages arising between the conductors of an electrical system, in particular switching over voltages. These SPDs are installed at equipment level to be protected. These surge protective devices (SPDS) are based on combination of heavy duty zinc-oxide varistor and spark gap /GD tube based technology. SPDs are able to discharge nominal discharge current (In) up to 3 KA (8/20 µsec). SPDs shall be tested according to IEC 61643-11:2011 by 3rd party international test labs like KEMA or VDE for ensuring the performance & safety of installation.

Isolating interfaces - Isolating interfaces limit the effects of conducted surges on lines entering the LPZ. Earthing and bonding should always be ensured, in particular bonding of every conductive service directly or via an equipotential bonding SPD, at the point of entry to the structure.

ENERGY EFFICIENCY MEASURES AT PRESIDENT'S ESTATE, NEW DELHI: A CASE STUDY

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Abstract

Considerable Electricity saving achieved in the President's Estate owing to launch of 'ROSHNI', a green innovative concept by the then President of India in 2008. The Programme envisaged environment management to create eco-friendly sustainable urban habitats. It was decided to make the President's Estate a green, energy efficient and zero waste model township.

Introduction

The President's Estate comprises of main Building (Rashtrapati Bhavan), Sch-A, Sch-B and Dalikhana. It is a living heritage located on the Raisina Hills in the heart of city over an area of 340 acres comprising offices of President's Secretariat & Cabinet Secretariat, around 1000 Residential dwellings housing over 5000 people and green areas of rich biodiversity. One of the objectives of the Roshni initiative was to change individual attitudes, behavior and lifestyle relating to energy consumption by increasing awareness.

Objectives

- To conserve water and encourage its reuse and recycling.
- To conserve energy and promote use of new and renewable sources of energy.
- To improve waste management system and promote 3 R's viz; reduce, reuse and recycle.
- To control air & noise pollution.
- To enhance Green cover and conserve biodiversity.
- To make residents of urban habitats more responsive to eco-friendly lifestyles.

Major Interventions

i. Solid waste management

ii. Liquid waste management

iii. Water conservation

iv. Bio-diversity conservation

v. Energy Audit & Energy conservation

vi. Use of new and Renewable Energy Source

vii. Stakeholder participation

Target was to reduce the energy consumption @2% per annum through energy efficiency measures & promoting renewable energy.

Methodology

i. Metering at major Load Centers

ii. Monitoring of Electricity Consumption

iii. Conducting Energy Audit

iv. Identification of Energy saving potential

v. Metering all users of President's Estate

vi. Deployment of Energy Efficiency Measures (EEM)

vii. Evaluation of outcome of EEM and further action.

Energy & Water Audit

Apart from internal Energy audit, water audit was also conducted as pumping of drinking water across the President Estate, from & across four major Under Ground Tanks, involved significant Electricity Consumption. Water meters were installed at main bulk receiving points and water leakage of around one lakh liters/ day out of total supply of twenty-two liters/day was identified & rectified.

Third party confirmatory Energy Audit was conducted by National Productivity Council.

Energy Conservation

The trend of Electricity consumption from 2006-07 to 2011-12 is shown in the Fig. 1.

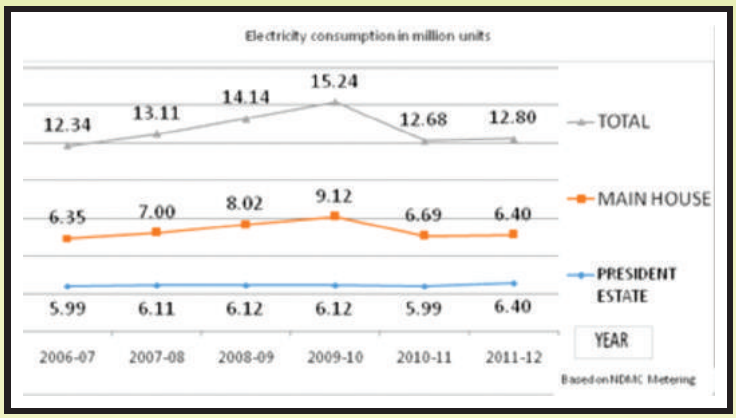


Fig. 1: Electricity Consumption in Million Units

Comparative Electricity Consumption from 2009-2012

There is overall reduction in Electricity consumption from 15.2 MU in year 2009-10 to 12.7 MU in year 2010-11 (Fig. 2 & 3) and no appreciable increase in Electricity consumption in next year i.e. 2011-12 compared to previous year despite regular increase in electrical load.

Electricity Consumption 2009-10 vs 2010-11

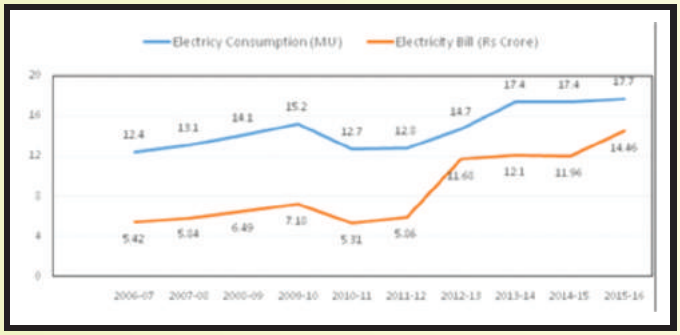


Fig. 2

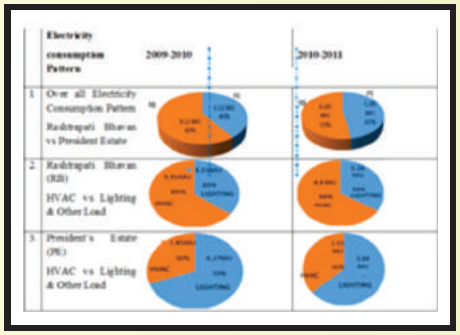


Fig. 3

Energy Efficiency Measures (EEM) taken at Rashtrapati Bhavan

1) Installation of APFC panel to have PF >0.97.
2) Replacement of old WTAC/STAC system with VRV / Star rated units in a phased manner.
3) Awareness & sensitization programmes for turning off lights, Air Conditioners and other devices when not in use.
4) Incandescent lamps used in pathway Lights and stone poles replaced with CFL.
5) ON/OFF schedule circulated and enforced for Street, Pathway & Security Lights (Fig. 4).

MAIN BUILDING TIMINGS

No.	MONTH		SUNRISE	LIGHT "SWITCH OFF" TIME	SUNSET	LIGHT "SWITCH ON" TIME
1	January	1st-15th	07.14 AM	07.00 AM	05.33 PM	05.45 PM
		16th-31st	07.13 AM	07.00 AM	05.48 PM	06.00 PM
2	February	1st-15th	07.09 AM	07.00 AM	06.00 PM	06.15 PM
		16th-28th	07.00 AM	06.45 AM	06.11 PM	06.30 PM
3	March	1st-15th	06.46 AM	06.30 AM	06.21 PM	06.45 PM
		16th-31st	06.31 AM	06.15 AM	06.29 PM	06.45 PM
4	April	1st-15th	06.11 AM	06.00 AM	06.39 PM	06.45 PM
		16th-30th	05.56 AM	05.45 AM	06.47 PM	07.00 PM
5	May	1st-15th	05.40 AM	05.30 AM	06.56 PM	07.15 PM
		16th-31st	05.30 AM	05.15 AM	07.05 PM	07.30 PM
6	June	1st-15th	05.23 AM	05.00 AM	07.14 PM	07.30 PM
		16th-30th	05.23 AM	05.00 AM	07.20 PM	07.30 PM
7	July	1st-15th	05.27 AM	05.15 AM	07.23 PM	07.30 PM
		16th-31st	05.33 AM	05.15 AM	07.21 PM	07.30 PM
8	August	1st-15th	05.42 AM	05.30 AM	07.12 PM	07.30 PM
		16th-31st	05.50 AM	05.30 AM	07.01 PM	07.15 PM
9	September	1st-15th	05.59 AM	05.45 AM	06.43 PM	07.00 PM
		16th-30th	06.06 AM	05.45 AM	06.28 PM	06.45 PM
10	October	1st-15th	06.14 AM	06.00 AM	06.07 PM	06.30 PM
		16th-31st	06.22 AM	06.15 AM	05.52 PM	06.15 PM
11	November	1st-15th	06.33 AM	06.15 AM	05.56 PM	06.00 PM
		16th-30th	06.44 AM	06.30 AM	05.27 PM	05.45 PM
12	December	1st-15th	06.56 AM	06.45 AM	05.24 PM	05.45 PM
		16th-31st	07.06 AM	06.45 AM	05.26 PM	05.45 PM

Fig. 4 : ON/OFF timings for security/street lights

6) Following changes made in operation of Heating Ventilation and Air conditioning(HVAC) System:

S.N.	Existing Practice	Modified Practice
i.	Museums: Air Conditioning (AC) System operated from 9 AM to 5 PM	Air Conditioning System operation aligned with visiting Hours from 10 AM to 4 PM.
ii.	Banquet Hall, Loggia & Ashoka Hall: Central AC system made functional in the evening for a function scheduled next day for doing flower decoration& preserving their freshness etc.	Full Central AC System operated just 2 Hrs before scheduled function.
iii.	Indoor Temperature: 22-23°C	25-26°C, Pedestal Fans (silent type) used at suitable locations to improve air circulation. Split / Window type Air Conditioners used along with ceiling fan.
iv.	Kitchen: Air Conditioning operated 8 AM to 7 PM on working days.	Fresh ambient Air supplied in morning hours and Air Conditioning system operated after 10 AM as per requirement.
v.	Chilled water Tank: Chiller used to run from 8 AM to 5 AM.	Chiller operated from 5 AM to 1 PM as per requirement.
vi.	Heaters to Police Post: Usually issued in end October/beginning November.	Issued by end of Nov when ambient Temperature dropped below 15°C.Initially single coil heater provided and later additional coil fixed in December& January.
vii.	Entry Gates of Ashoka Hall, Upper Loggia & Banquet Hall were often kept open till start of function.	Except VVIP entry, general entry facilitated from side doors and whenever main doors required be opening, only partly opening and promptly closing to avoid loss of cooling.
viii.	Hot Water Generator: Electricity Heated	PNG Heated
ix.	**Swimming Pool** Water was preheated to 18-19°C by Solar Water Heating and further heated to 24-25°C by electricity operated Hot Water Generator during month of December & January as shown in the Fig. 5 & 6.	Swimming pool water covered with insulating mat during period when not in use in winter and water temperature maintained to 20-21°C.
		
	Fig. 5 : Solar Water Heating System	Fig. 6: Swimming Pool

7) Standard Operating Procedure (SOP) prepared for major activities.

Energy Efficiency Measures (EEM) taken at President's Estate

1) Installation of APFC panel to have PF >0.97.

2) Monitoring of Billing Section.

3) Metering in all dwelling units motivated users to conserve electricity.

4) Metered connections to contractors for construction work discouraged wastage of electricity.

5) ON/OFF schedule enforced for Street & Security Light (Fig. 7).

6) Replacement of Security & streetlights to Induction lights/LED lights in phased manner.

Switching ON/OFF timings of street and security lights of President Estate (outside main building), Retreat Building, Shimla & Rashtrapati Nilayam, Hyderabad

No.	MONTH		LIGHT "SWITCH OFF" TIME	SUNSET	LIGHT "SWITCH ON" TIME
1	January	1st-15th	07:14 AM	06:45 AM	05:35 PM	06:00 PM
		16th-31st	07:15 AM	06:45 AM	05:46 PM	06:15 PM
2	February	1st-15th	07:09 AM	06:45 AM	06:00 PM	06:30 PM
		16th-28th	07:00 AM	06:30 AM	06:11 PM	06:45 PM
3	March	1st-15th	06:46 AM	06:15 AM	06:21 PM	06:45 PM
		16th-31st	06:31 AM	06:00 AM	06:29 PM	06:45 PM
4	April	1st-15th	06:11 AM	05:45 AM	06:39 PM	07:00 PM
		16th-30th	05:56 AM	05:30 AM	06:47 PM	07:00 PM
5	May	1st-15th	05:40 AM	05:15AM	06:56 PM	07:15 PM
		16th-31st	05:30 AM	05:00 AM	07:05 PM	07:30 PM
6	June	1st-15th	05:23 AM	04:45 AM	07:14 PM	07:45 PM
		16th-30th	05:23 AM	04:45 AM	07:20 PM	07:45 PM
7	July	1st-15th	05:27AM	05:00 AM	07:23 PM	07:45 PM
		16th-31st	05: 33 AM	05:00 AM	07:21 PM	07:45 PM
8	August	1st-15th	05:42 AM	05:15AM	07:12 PM	07:45 PM
		16th-31st	05:50 AM	05: 15 AM	07:01 PM	07:45 PM
9	September	1st-15th	05:59 AM	05:30 AM	06:43 PM	07:30 PM
		16th-30th	06:06 AM	05:30 AM	06:26 PM	07:15 PM
10	October	1st-15th	06:14 AM	05:45 AM	06:07 PM	06:45 PM
		16th-31st	06:22 AM	06:00 AM	05:52 PM	06:30 PM
11	November	1st-15th	06:33 AM	06:00 AM	05:36 PM	06:15 PM
		16th-30th	06:44 AM	06:15 AM	05:27 PM	06:00 PM
12	December	1st-15th	06:56 AM	06:30 AM	05:24 PM	06:00 PM
		16th-31st	07:06 AM	06:30 AM	05:26 PM	06:00 PM

Fig. 7, ON/OFF timings for security/street lights

8) Following new & renewable energy pilot projects were undertaken.

I. Solar Photo Voltaic plant (Fig. 8)

- 320 Solar Panels installed on Rooftop of Auditorium.
- Off-Grid
- Capacity: 50 Kwp.
- Generation: 120 KWH/Day



Fig. 8: Rooftop SPV System at Auditorium

ii. Solar standalone street lights (Fig. 9)

- 2 nos. x 14W T-5 fluorescent tube.
- 2 nos. x 12V 75AH batteries.
- 2 nos. SPV module (75 Wp) having Mono-Crystalline Silicon Solar Cells.
- 2700 Lumens light output.



Fig. 9: Solar Lights

iii. Solar water heating system(Fig. 10)

- 75 Nos 300LPD
- 154 Nos 500LPD
- 2 Nos 100 LPD



Fig. 10: Solar Water Heating System for Residence

iv. Solar Pump(Fig. 11)

- 2HP capacity solar powered pump.
- 24 nos 75 Wp SPV module having Mono-Crystalline Silicon Solar Cells.
- Operating Voltage 24 Volt dc.
- Head (water lifting): 60 mtr (30,000 LPD).
- System Efficiency is 12.75%.



Fig. 11: Solar Pump

V. Wind Solar Hybrid System(Fig. 12)

- Capacity: 10 KWp (2KWp x 3 Nos.- Wind
- 1.8 KWpx3 Nos.- Solar)
- Type: Grid interactive (Without battery backup)
- Solar PV Modules: 100 Wp x 12
- Type of Wind Turbine: Axial (2 Blades)



Fig. 12: Wind Solar Hybrid System

vi. Solar Powered Traffic Blinkers(Fig. 13)

- LED based solar blinkers



Fig. 13: Solar Powered Traffic Blinker

Challenges

It was difficult to amend & enforce habits pertaining to Energy Conservation and persistent efforts made through awareness programme.

Lessons Learnt

Significant Energy conservation can be achieved by commitment of the top management, sustained efforts for promoting disciplined Energy use, respect for resources and inculcation of Energy conservation behaviors.

Achievement & Recognition

New & Renewable energy contributed around 10% of total energy saving of 3.5 MU during 2010-11.

The president's Estate became the first Urban Habitat to be awarded the “ISO 14001:2004 Certification”, for its Environment Management System (Fig. 14).

The Roshni initiative was awarded the prestigious “Golden Peacock Award for Environment Management” for the Year 2012 by the institute of Directors (IOD) under the Category-Government (Fig. 15).



Fig. 14: President's Estate awarded ISO 14001:2004



Fig. 15: 'Roshni' initiative awarded

Conclusion

President's Secretariat commitment and target driven approach helped to achieve significant Electricity saving. Small efforts towards Energy Efficiency Measures through participative approach yielded good and sustained results.

Nowadays HVAC system of commercial buildings accounts for 70-75% of its total electricity consumption. It is prudent to follow adaptive thermal control rather than fixed thermal control for energy conservation as well as for good health. National Building Code (NBC) has also migrated from fixed thermal comfort in NBC-2005 to adaptive thermal comfort model in NBC-2016 and recommended temperature of 26°C & 18°C in peak summer & winter respectively. Adaptive thermal control adopted at President's Estate and thermostat of Air Conditioning system set at 25°C. This along with optimization of operating time resulted in significant Energy conservation. Indoor temperature during winter was maintained in the range of 19°C to 20°C.

Estimate shows that 70% of the building stock in India, which will be required by 2030, is yet

to be constructed. With improving life style and prosperity, it is likely that energy consumption on account of Air conditioning will increase many fold. Energy consumption in buildings on account of lighting has reduced to half with introduction of LED based lighting systems. So now almost 70% energy consumption in buildings is on account of Heating, Ventilation & Air conditioning (HVAC). India has committed to reduce emission intensity of GDP by 35%, from 2005 level, by 2030. Building sector consumes 30% energy, second only to Industrial sector. There is pressing need to follow 'Cool Biz' model introduced in Japan which is based on adaptive thermal control model. The Cool Biz campaign was initiated by the Japanese Ministry of the Environment from summer 2005 as a means to help reduce Japanese electricity consumption by optimizing use of air conditioning. This was enabled by changing the standard office air conditioner temperature to 28 °C (about 82 °F). Liberal summer dress code was introduced in the bureaucracy of the Japanese government so that staff could work in a little warmer temperature. The campaign then spread to the private sector as well. The campaign is a rare example of strong government commitment and top down approach that has successfully led to behavioural change.

Energy Conservation Building Code (ECBC) 2017 provisions are mandatory for all buildings with connected load of 100 KW / 120 KVA Contract Demand. ECBC stipulates buildings in Energy Efficiency benchmark of ECBC, ECBC Plus and Super ECBC. While technological intervention is necessary to reduce Electricity consumption and make buildings ECBC compliant, it alone will not yield desired result unless supplemented by proper operational control and behavioral modification.

Reference

1. NDMC meter reading and Electricity bills.
2. National Building Code 2016.
3. Energy Conservation Building Code 2017.
4. Glimpses of Presidency 2007-2012.
5. Roshni: A PRESIDENT'S ESTATE INITIATIVE.
6. Cool Biz Campaign: Initiative of Japanese Government.

FIVE SIGNIFICANT ENERGY SAVING FEATURES IN VERTICAL TRANSPORTATION

Vinit Nagpal, Kone Elevators India Ltd

Abstract

Vertical transportation system is an important feature of high rise buildings. Due to continuous use, this system consumes considerable amount of electricity. This consumption can be reduced significantly by adopting some measures. This paper gives an insight into those measures which make a vertical transportation system energy efficient.

Introduction

Lifts/ elevators are the necessity of any high rise building without which it is not possible to occupy/ inhabit these buildings. Operation of these lifts require considerable amount of electricity. This requires energy efficiency into the operation of lifts for conservation of energy. There are five solutions by which substantial saving of energy can be achieved as illustrated in the figure 1.

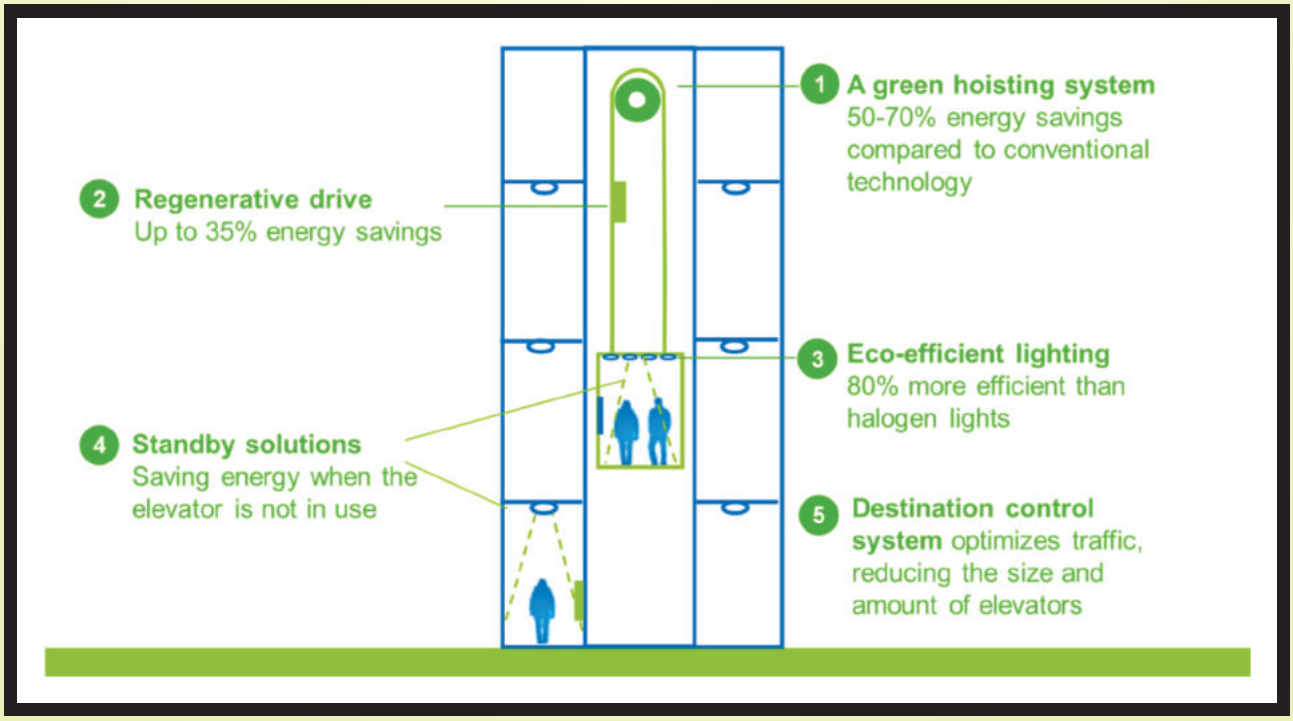
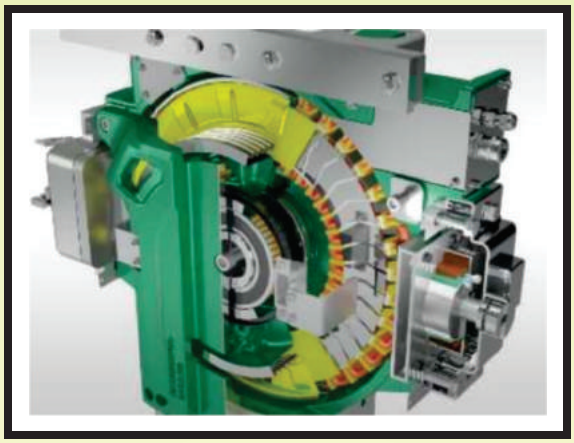


Figure 1: Energy efficient features in a vertical transportation system

All these features are now described in little more details.

1) Energy Efficient Gearless Traction machine & Hoisting System



- 50-70% energy savings compared to Geared technology
- The new innovative copper winding system reduces the amount of energy lost
- Energy efficient Machine with silent brakes
- Balanced hoisting of elevator car improves the efficiency of the hoisting.

2) Regenerative drive

- Up to 35% energy savings compared to Non Regenerative Drive
- Whenever elevator travels in lighter direction, the Machine act as generator and Feedback the energy to the other electrical equipment in the same building
- This will reduce the net energy Consumed.

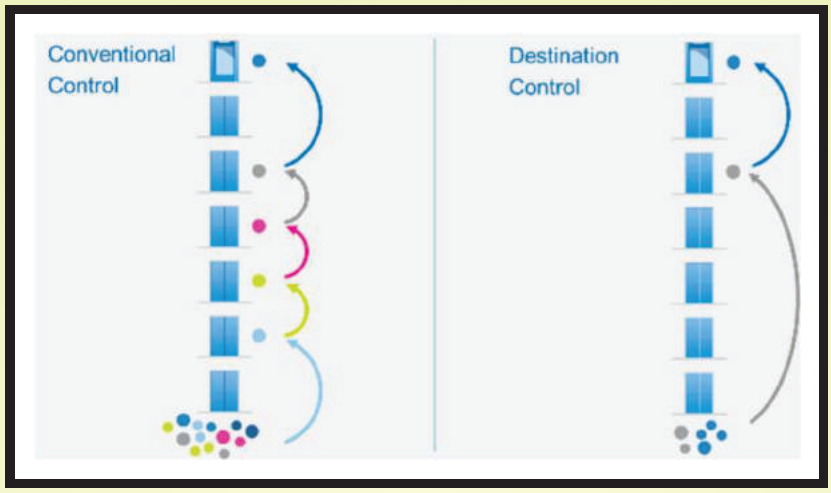
3) Eco-efficient lighting

- 80% more efficient than halogen lights
- Long lasting, energy efficient and eco friendly LED lighting



4) Standby solutions

- Saving energy when the elevator is not in use. Automatic Switch OFF Car Light/Fan, Drive/Controller Power Optimization when the elevator in idle condition.



5) Destination control system

- Analysis of the transportation demand to determine the optimum number and size of elevators.
- Optimizes traffic, reducing the size and amount of elevators
- DCS Groups the People to the destination and reduces the number stops and operates the elevator effectively.
- AI based Control system optimizes the elevator traffic pattern by effective call allocation, Waiting time reduction thereby increased the Elevator Handling capacity

Conclusion

Vertical transportation system has many possibilities for energy conservation as described above. However there are endless possibilities for further conservation by technological intervention.

CONTRIBUTION OF SECI IN RAMPING UP ROOFTOP SOLAR INSTALLATIONS

R.K. Jain & Mohammad Yameen, Solar Energy Corporation of India Ltd.

Abstract

The country rooftop solar market has come a long way from negligible capacity in 2012 to over 1.5 GW of installed projects as of end-2018. The segment is a significant participant in the country's plan to have 100 GW of installed solar energy capacity by 2022. In this regard, the Solar Energy Corporation of India Ltd. (SECI), established in 2011, is playing a proactive role in driving rooftop solar. Here we discuss the key trends in the Indian Solar rooftop market and SECI's role in driving growth in this space.

Introduction

The government has set a target of achieving 175 GW of renewable energy capacity by 2022. This includes 100 GW of solar energy, 60 GW of wind power, 10 GW of biomass and 5 GW of small-hydro power. In the solar segment, 40 GW of capacity is targeted through rooftop projects. The fulfillment of these targets will help India achieve its intended nationally determined goal of lowering the emissions intensity of GDP by 33-35 per cent by 2030, as compared to the 2005 levels as well as increase the share of renewable energy generation capacity to 40 percent of the installed energy capacity by 2030.

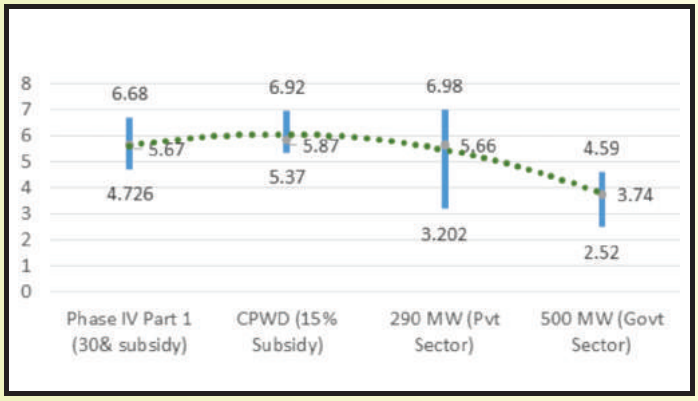
The total installed solar photovoltaic (PV) capacity in India has increased exponentially from around 3 MW in 2009-2010 to more than 20 GW as of now. This growth can be attributed to positive policy interventions from Government, reducing cost of solar modules, learning curve and economies of scale. The tariff of electricity generated from solar power plants has reduced drastically, from around Rs. 12/kWh in 2010 to Rs. 2.44/kWh in 2017. This has completed the grid parity for solar energy and has made it cost competitive and economically beneficial.

Rooftop solar is beneficial in a number of ways. It reduces requirement of land for generation of electricity, reduces dependency on grid power, reduces diesel generator requirement and serves as a long-term reliable source of power. It Reduces transmission and distribution losses and reduces peak load demand for DisComs. With reducing cost, rooftop solar has become financially viable, particularly for larger consumers, resulting in financial savings because of reduced electricity bills. General payback time is 5-7 years.

The Government has been promoting grid-connected rooftop solar plants by providing

subsidy and other incentives like accelerated depreciation, net metering policies etc. Most of the grid connected rooftop solar plants are being implemented under net-metering arrangement. In this, arrangement, the excess solar energy generated at any time of day is fed into the grid and energy is drawn from the grid when the solar generation is not adequate to meet the demand, at the end of settlement period, the consumer has to pay for the net electricity drawn from the grid. As solar electricity has become cheaper, grid-connected rooftop solar plants have become financially rewarding.

In the solar rooftop segment, SECI is the implementing agency for the Ministry of New and Renewable Energy's (MNRE's) rooftop subsidy programme. SECI has been a pioneer in implementing grid-connected rooftop solar schemes on pan India basis. The first such scheme was launched in January 2013 for a cumulative capacity of 26.6 MW. Subsequently a 50 MW Scheme was launched in two parts, first in the year 2014 and second in the year 2015. Another Scheme with a total capacity of 50 MW was launched in 2015 for CPWD and Government buildings. In 2016, a 500 MW scheme for Residential, Social and Institutional sectors was launched and in December 2016, another 500 MW scheme for Government buildings was launched.



Trend of Solar Rooftop PV Levellized Tariff In General Category States (Rs./kWh)

Under SECI's Schemes, the projects are being implemented under two business models - CAPEX and RESCO. CAPEX stands for Capital Expenditure and RESCO stands for Renewable Energy Services Company. In CAPEX mode, the rooftop owner makes the investment and purchases the solar plant whereas in RESCO mode, the RESCO player installs the plants with own investment and the rooftop owner has to purchase the power generated from the solar plants, at a pre-determined tariff as per the Power Purchase Agreement. Projects with capacity more than 40 KW are generally accepted by RESCO players. RESCO mode has become a value proposition for consumers having sanctioned load in the range of 40 kVA or higher.

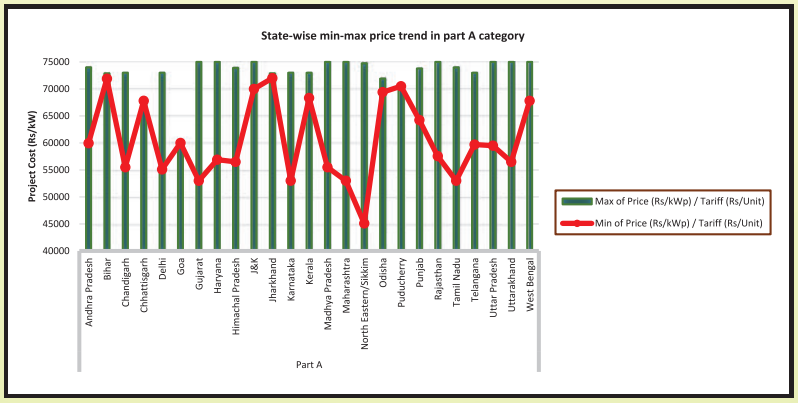
When SECI first started our rooftop programme, we mainly awarded projects under the

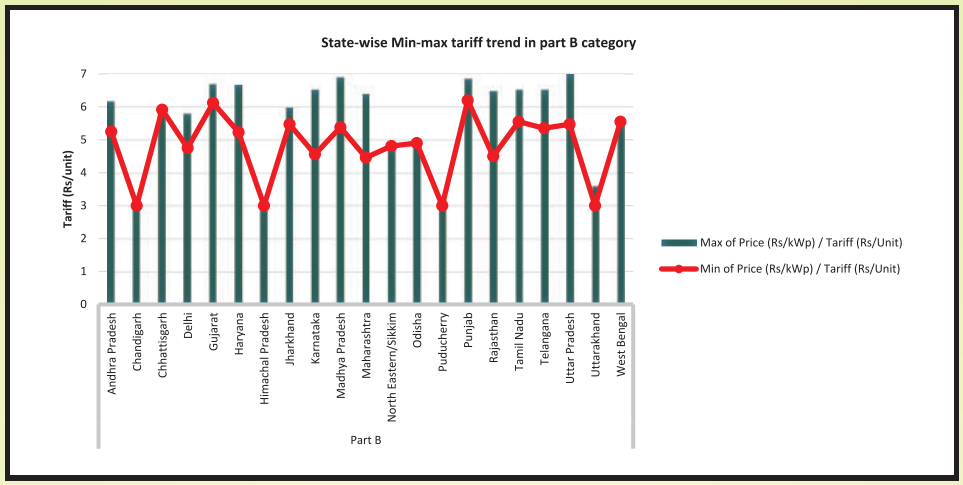
CAPEX Mode. Subsequently, some projects were offered in RESCO mode and the market response was very positive. Encouraged by the success of RESCO business model, the Central Public Works Department (CPWD) approached SECI for installing solar rooftop projects at the Government building either owned or maintained by them. Hence, we came out with an exclusive 50 MW scheme in RESCO mode for CPWD and other Government buildings in 2015.

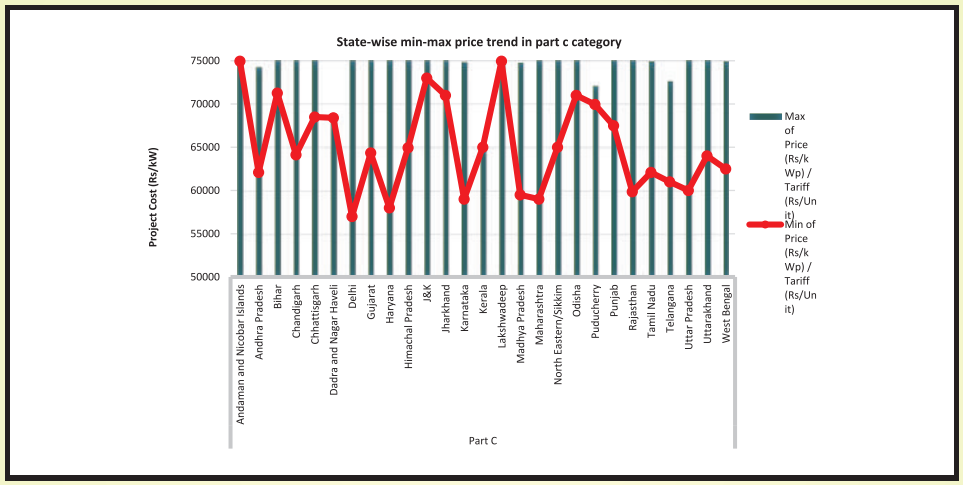
In the 500 MW rooftop solar tender floated in 2016 for residential and institutional sector, 300 MW was offered under the CAPEX mode and 200 MW under the RESCO mode (Part C). In the CAPEX mode, 200 MW was for larger capacity project (Part A) (26 KW to 500 KW), while 100 MW was exclusively for residential and smaller capacity projects (Part B), (less than 25 KW). The tender allowed capacity transfer from one state to another.

Around 132 bidders submitted their bids for the tender and 122 won projects under it. In Part A of the tender, the lowest project cost was Rs. 53 per watt in Tamil Nadu, Maharashtra, Karnataka and Gujarat, while the highest was Rs. 75 per watt in Rajasthan, Uttar Pradesh, West Bengal and Jammu & Kashmir. In Part B of the tender, the lowest tariff (with 70 per cent subsidy) was Rs. 3 per KWh in Himachal Pradesh and Uttarakhand, while the highest tariff with 70 per cent subsidy was Rs. 4081 per kWh in the Northeast. With 30 per cent kWh in Maharashtra, while the highest was Rs. 6.98 per kWh in Uttar Pradesh. In Part C of the tender, the lowest project cost was Rs. 57 per watt and the highest was Rs. 74.95 per watt in Delhi. The 200 MW tender under the RESCO mode was not subscribed as much as SECI had expected. Out of the 200 MW, we received bids only for 100 MW. This can be attributed to the apprehensions about security of payments in residential, social and institutional sector. Companies are more comfortable with the RESCO mode in government projects. A total of around 136 MW has been commissioned under the tender.

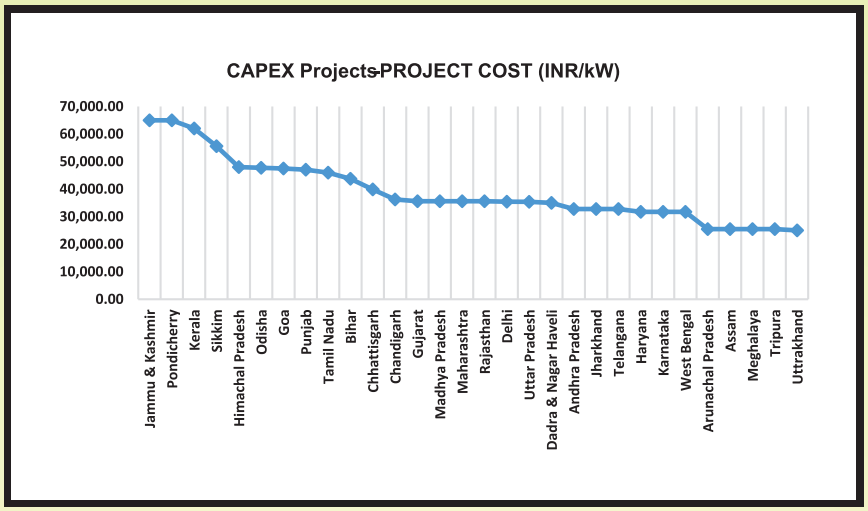
Cost Trend under 500 MW tender for Residential, social and institutional sectors is shown in the following graphs:

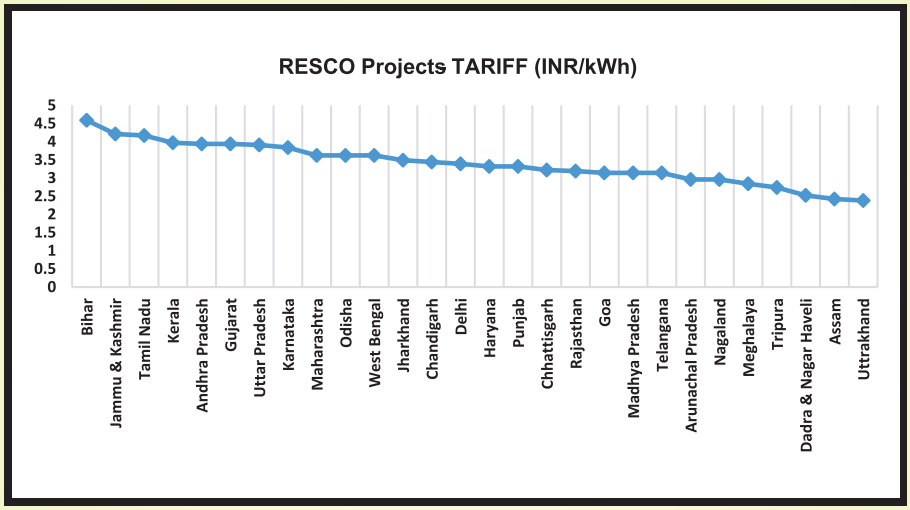






Released by SECI in December 2016, the rooftop solar tender of 500 MW was for rooftop projects on Government buildings only. Award was given to the successful bidders for a cumulative capacity of around 226 MW. The tender had the provision for performance-based incentive, where up to 25 percent of the project cost will be given to the bidder as incentive upon 80-100 per cent of the target. The power generated from the systems will be used for meeting the captive requirement of the buildings and the surplus power, if any, will be fed into the grid under the net metering arrangement of the respective state. Around 140 MW projects are expected to be commissioned under the tender. The price trend of this tender is shown in the following graphs:





In addition to implementing MNRE's rooftop solar schemes, SECI has also been providing PMC services to Government Organisations. 5 MW rooftop solar plant has successfully been completed at GAIL Pata, TP. Another project of 8 MW is under implementation at Banaras Hindu University. As of now, more than 370 MW rooftop solar projects have been successfully commissioned under SECI's Schemes. SECI has also announced launch of 97.5 MW rooftop solar tender for Government buildings. Any government department in the country can take benefit under this new scheme being implemented by SECI.

Conclusion

SECI has played a significant role in transforming the rooftop solar in the country and making rooftop solar systems more accessible and affordable. This will provide energy security and more sustainable development in the country.

HIGH EFFICIENCY STRUCTURALLY INTEGRATED ROOF TOP SOLAR POWER SYSTEM

B B Makkar, CPM, SCPZ, **C S Mittal,** Former CE(E) & **Vishesh Swamiwal,** EE(E), SCP

Abstract

Solar photovoltaic panels convert electricity directly from the sun and this electricity can be used to cater to the power requirement of the building. The roof of any building receives abundant solar radiations and when these are converted to electricity, can produce green power which is free from carbon emissions. This paper deals with providing the rooftop solar plant of maximum capacity in the project "Additional Office complex for Supreme Court of India" and it is advantages.

Introduction

Importance of solar power system is evident to everyone, as it provides green energy in an eco-friendly manner. Installing solar power systems at roof top is not a new subject either and lot many installations exist in India. This paper deals with the experiences of providing mega capacity roof top solar power plant at one of the prestigious government buildings "Additional Office complex for Supreme Court of India" at heart of Delhi.

CPWD was assigned the C/o Additional Office complex for Supreme Court at the old site of popularly known as Appu Ghar, Pragati Maidan, Delhi. This complex has 3 Levels common basements and 6 blocks namely

A. Library Block (G+5),

B. Judicial Block (G+8),

C. Conference Block (G+5),

D. Lawyers Chambers (G+8),

E. Facilities Block G+8)

F. Services Block (G+3)

Capacity Planning:

While the detailed planning of the building complex was being done, thrust was being given by our Government for solar power energy. Inspired by the government thrust, it was decided

to provide the maximum possible size of roof top solar power plant at this complex. As per load calculations, there was a mandatory requirement of providing 60Kwp (1% of estimated load) solar power system to get our building rated as 3-star GRIHA building. Planning team thought why don't we try to achieve, as close to self-sufficient in power as possible. Lot of permutation and combinations were thought.

Since it was a multistory complex, having central air conditioning system, the demand for power (after considering all diversity factors) was 6000 KW. The total roof top area was 7400 Sqmtr (without considering Service Building). Further examination, detailed engineering of other services and building models indicated that we shall be able to get not even 25% roof top area for installation of Solar PV cells, due to

(i) Use of the roof for providing:

- Pressurization fans for HVAC
- Fresh Air fans for HVAC
- Expansion tanks for HVAC
- Cable trays
- Electrical Panels

(ii) Shade on roof due to:

- Lift Machine rooms
- Staircase Mumty
- Water tanks
- Service Installations at (I) above

Considering that only 1850 Sqm roof top area was eligible for providing Solar PV cells and our target was to provide a solar plant of at least 20% of estimated maximum demand capacity i.e. 1200 Kwp. Brainstorming sessions were held with all stake holders, National and International literature /articles on solar power studied, Site visit to few best known installations made. First idea which was worked out was to provide Solar PV films on façade facing South west. Here we had two limitations namely:

- Very little area of façade was available facing south west and clear from shadow.
- Cost of such installation.

- Non-availability of commercial success reports of such works.

Second idea was to provide solar tree like structures in the campus, but this idea was also dropped as it would require open space, which was also not available.

Finally, we thought of making roof top MS structure at Mumty/Lift Machine room roof level at all blocks, so that all services as listed at (i) PV cells can be installed on complete 7400 Sqm area on this MS structure without any shade from service installations (the only shade still available was due to higher height buildings on lower height buildings). As our appetite for power was still not getting fulfilled, we provided the stainless steel space frame structure to cover open spaces in Block B to get about 2000 sqm more area. The idea of extending this roof structure at all sides was also explored but not agreed as it was making the building look like an industrial building while we wanted to make it a monumental building (extension of existing monumental building of Supreme Court).

We have also considered now area over of mumty of all staircase and approximate area for the same comes to around 600 sq.mtr. By doing so now we had 7400 + 2000 + 600 = 10000 Sqm area for our installation.

Technology/Efficiency and capacity selection for Solar PV

As the objective was to generate maximum overall electricity per day (not only installed capacity), we were looking for the PV modules which can give maximum guaranteed generation per year per KW, be long lasting in their performance and yet be commercially viable. Hence high efficiency Solar PV module (20.4%), with degradation rate of 0.4% per year from 6th year onward, providing 1745.33 units generation /KWp of installed capacity at 15 deg tilt have been provided.

Placement of PV modules had been planned to provide maximum installed capacity and maximum generation. We have provided 1400KWp in 10000 Sqm total area which means 7.10 Sqm/Kwp thus making maximum utilization (against industry standard of 10-12 Sqm/KWp).

Abstract of product Catalogue of PV module used is reproduced for reference only.

More guaranteed power: 95% for first 5 years, -0.4%/yr. to year 25.[8]

ELECTRICAL DATA		
	E20-327	**E19-320**
Nominal Power[12] (Pnom)	327 W	320 W
Power Tolerance	+5/–0%	+5/–0%
Avg. Panel Efficiency[13]	20.4%	19.8%
Rated Voltage (Vmpp)	54.7 V	54.7 V
Rated Current (Impp)	5.98 A	5.86 A
Open-Circuit Voltage (Voc)	64.9 V	64.8 V
Short-Circuit Current (Isc)	6.46 A	6.24 A
Max. System Voltage	1000 V IEC & 600 V UL	
Maximum Series Fuse	20 A	
Power Temp Coef.	–0.38% / °C	
Voltage Temp Coef.	–176.6 mV / °C	
Current Temp Coef.	3.5 mA / °C	

OPERATING CONDITION AND MECHANICAL DATA	
Temperature	– 40°C to +85°C
Max load	Wind: 2400 Pa, 245 kg/m² front & back Snow: 5400 Pa, 550 kg/m² front
Impact resistance	25mm diameter hail at 23 m/s
Appearance	Class A
Solar Cells	96 Monocrystalline Maxeon Gen II
Tempered Glass	High transmission tempered Anti-Reflective
Junction Box	IP-65 Rated
Connectors	MC4
Frame	Class 1 black anodized (highest AAMA rating)
Weight	18,6 kg

As per product catalog, useful life of PV panels is 40 years.

Abstract of product Catalogue of Invertors used is reproduced below for reference only.

Technical Specifications

Model		M30A_121	M50A_12s
DC Input	Max. input voltage	1100V	
	Operating voltage range	200~1000V	
	MPP voltage range (full power)	520~800V	
	Start voltage	>250V	
	Rated voltage	600V	
	Max. input current	Each MPPT: 30A Total: 60A	Each MPPT: 50A Total: 100A
	MPP tracker	2	
	Connection type	6 pairs MC4	12 pairs MC4
	Protection	–	15A fuse per string + & -, Type2 SPD
AC Output	Rated output power	30kW / 30kVA	50kW / 50kVA
	Max. output power	33kW / 33kVA*	55kW / 55kVA*
	Max. output current	50A	80A
	Rated voltage	3Ph 230/400V Y or Δ	
	Operating voltage range	±20%	
	Operating frequency range	50/60Hz ±5Hz	
	Power factor (adjustable)	0.8 ind ~ 0.8 cap	
	Protection	–	Type 2 SPD
	THD	<3%	
	Night time consumption**	<3W	<2W
Efficiency	Peak efficiency	98.5%	98.6%
	Euro efficiency	98.2%	98.4%
Information	DC Switch	DC Relays	
	Communication port	RS-485	
	Display	20 x 4 LCD	
Certification		VDE-AR-N 4105 BDEW GB/T 19964: LVRT EN 61000-6-2	VDE 0126-1-1 NB/T 32004: 2013 IEC 62109-1/-2 EN 61000-6-3
General Data	Operating temp. range	-25~60°C (Derating above 40°C)	
	Protection level	IP65	
	Operating elevation	<2000m	
	Cooling	Cooling fans	
	Dimension (W x H x D, mm)	612 x 625 x 278	612 x 740 x 278
	Weight	48kg	74kg
	Container loading	20ft 84pcs 40ft 168pcs	20ft 72pcs 40ft 144pcs

Execution Phase and further increase in capacity:

At the time of calling tenders we had planned for 1150 KWp capacity. As earlier stated we had high appetite for capacity so more areas were being explored. Open area in 'B' block was covered with space frame to create about 2000 sqm. of area for Solar Panels. Even after that we installed Solar Panels on frame for exhaust pipes meant for exhaust from DG Set. With this way we succeeded to install about 1400 KWp of Solar Power.

Likely Benefits:

The accrued benefits shall be as under

a) Generation of Green Electricity and Reduction in Electricity Bill

Considering Invertor efficiency, DC collection losses and any other factor, we expect to generate 1745*0.88 units/year/Kwp. Hence we shall be generating 2149840 units/year (1745 units/year/Kwp*1400KWp*0.88 units per day*365 days/year) thereby saving energy charges of Rs. 1.80 Cr. per year (Rs 8.4 /unit for HT consumer due to TOD metering peak demand surcharge).

b) Reduction in heat load for AC plant

Since PV module shall be converting 20.4 % of solar radiation and an estimated 5% radiation shall get reflected to atmosphere because of solar structure Grid, heat load of roof 267 TR (original A Block 103+ B block 84 TR +C Block 15 TR + D Block 40 TR + E block 25 TR) shall reduce to 200 TR, thereby estimated energy savings of Rs 607824 (67 TR*1 KW/Tr* equated 6 hr* 180 days annual operation of AC plant *Rs 8.4 /KWhr).

c) Energy Savings for 40 years

The life of PV panels is 40 years as per product catalog. Hence we are likely to get green energy for 40 years, considering degradation, assuming 80% average power produced for 40 years from this system, we shall be producing 40 year x 2203586 units/year x 0.8 = 704 lacs energy units.



Aesthetical views

The installation scheme of solar power plant has been designed to have pleasing elevation of the building photographs below prove the same.





Conclusion:

Solar power is the need of the day to reduce carbon foot print and achieve self-sustainability of the buildings. Capex model adopted at this complex not only provided an opportunity to CPWD engineers to use their technical and imaginary skills to provide a world class installation of Mega Solar Power system, but also save whopping Rs. 5913 Lacs from electricity bill (at present cost and tariff) in next 40 years of useful life to Government of India.

ENERGY SAVING STRATEGIES IN STPI, MOHALI & PGIMER, CHANDIGARH

Rajeev Kumar Sao, Project Manager, PGIMER Project Circle, CPWD, Chandigarh

Abstract

250 Bedded Hospital (Extension of Nehru Hospital) at PGIMER, Chandigarh (Fig.1) & Incubation and Data Centre Building STPI, Mohali (Fig.2) are 24X7 operation buildings and some of the energy efficiency strategies which have been employed in both the projects are as follows:

- Use of double layered AAC blocks with insulation in-between for building envelope.
- Use of DGU with high performance glass having solar factor of 0.2 and U value of 1.6 W/SqmK.
- Highly efficient centrifugal with VFD and screw chillers with VFD to cater to part-load on cooling system.
- Chilled Water and heating Water pumps with VFD controls.
- LED lighting with LPD value of 0.5 W/ft2 with occupancy sensors with centralized control and monitoring system.
- Day-light sensors in the office areas and motion sensors in the corridors and toilet areas.
- BMS for monitoring real-time building performance.
- Use of heat recovery wheels.
- High Delta-T on evaporator and condenser with reducing the approach to the wet bulb for cooling tower design.
- High C.O.P. chiller at duty conditions.
- Variable speed drives for partial load equipments e.g. secondary chilled water pumps, air handlers, etc.
- Chiller plant manager for energy optimization.
- Air source hot water generator for better plant COP.
- Low pressure drop filtration on air side.

- Use of automatic tube cleaning system for chillers.
- All the equipments used comply with either ECBC super or ECBC plus category of ECBC 2017.

Introduction

CPWD North Zone-I carried out construction of above buildings with all the modern and innovative E&M technologies. CPWD received following awards and recognitions for these projects



The main features of the buildings are as follows:



Figure 1: 250 bedded Hospital PGI **Figure 2: Incubation and Data centre STPI**

More than 80% of the spaces in both the buildings have access to the daylight as shown in Fig.3. Dimmable fixtures with daylight sensors has been used in these spaces to reduce energy consumption on artificial lighting during daytime.



Figure 3: Access to the daylight

STPI building houses Tier III data centre (as per uptime standards) with 160 racks on the first floor (Fig. 4). in row cooling comprising of energy efficient close-coupled, air capture from hot aisle variable speed fans, controls architecture with aisle containment has been provided to prevent hot spots and for energy saving. IP based power distribution rack with the facility to monitor and control 34 different parameters have been provided.



Figure 4: Tier III data centre

Highly efficient dimmable LED fixtures along with occupancy & Light sensors (for daylight harvesting) have been judiciously used as shown in Fig.5. Lighting of the building is 60% more efficient than what ECBC prescribes. All the lights of the building can be dimmed, controlled, monitored, scheduled through IPAD/Smart phones. Tunable/ Dimmable LED Fixtures have been used for human circadian centric lighting.



Figure 5: Dimmable LED fixtures along with occupancy & light sensors

IP based lighting control system (Fig.6) comprising of occupancy sensors, daylight sensors, dimmers, touch panels have been used. Instead of switches touch panels with proximity sensors has been used.



Figure 6: IP based lighting control

Circadian Lighting which follows the biorhythm cycle of human beings has been provided for energy saving and speedy recovery of patients (Fig.7).

- High CCT and High Lumens during morning to mid- afternoon.
- Lower CCT and Lower lumens during evening.
- Sleep better, so recover faster.



Figure 7: Circadian Lighting

Building Management System

- Control, Monitoring, Scheduling of Complete Air Conditioning System
- Control, Monitoring, Scheduling of Ventilation Equipment
- Control and Monitoring of Electrical System
- Monitoring and control of all Pumping Systems
- Monitoring and control of DG Sets
- Monitoring and control of Electrical Panels
- Monitoring of all Lifts
- Monitoring and control of STP

Smart Features

There are more than 30 different E&M services in each of the two buildings. All the systems are IP based and are scheduled, monitored and controlled through highly advanced BMS system. Each ACB & MCCB of the building can be controlled as well as monitored for energy management and power quality. For indoor air quality CO_2 & CO sensors have been installed, water meters, smart meters have been installed at every place to monitor energy consumption.

Faculty cabins and private wards (Fig.8) have been provided with FCUs and VAV boxes for personalized control and energy saving.



Figure 8: Faculty cabins and private wards

60 KW and 100 KW Solar PV Generation with grid interactive panel (Fig.9) and 10 KLD solar water heating has been provided on the specially built steel structure above the various services on the terrace of STPI & PGI building respectively to get the maximum benefit of the solar power and to reduce heat load from the roof.



Figure 9: Grid interactive Solar PV Panels

4 X 200 KVA ultra high efficiency UPS with flat efficiency curve has been provided in both the projects. (Fig.10)

UPS efficiency has large effect on data center and hospital efficiency because total IT load and entire hospital critical load goes through it.

- Improvement over typical from 80% to 96% efficiency at 30% load corresponds to loss reduction of 80%.

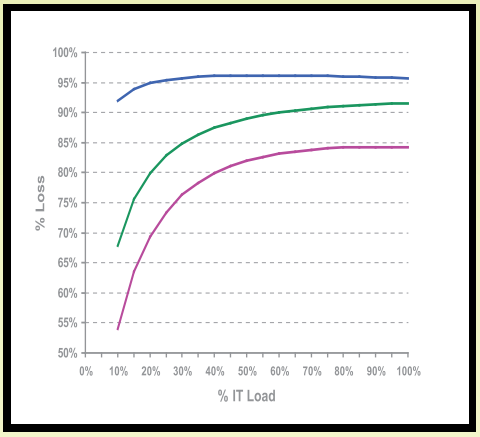


Figure 10: Ultra high efficiency UPS with flat efficiency curve

Exit signages and emergency lights with supercapacitor backup (Fig.11) have been provided which not only eliminates the requirement of frequent replacement of batteries but also reduces the power lost in charging.



Figure 11: Exit signages and emergency lights with supercapacitor backup

10 nos Modular OTs has been provided with medical grade touch panels (Fig.12) connected with BMS for precise control of temperature, RH, Fumigation and air changes. Optimal control along with Energy recovery wheel is expected to save lot of energy.



Figure 12: Modular OTs with medical grade touch panels

Lifts have been provided with regenerative braking for energy recovery (Fig.13).



Figure 13: Lifts with regenerative braking

Highly efficient fast charging stations (Fig.14) for electrical vehicles have been provided which can be monitored and controlled through mobile app.



Figure 14: Highly efficient fast charging stations

Daily approximately 1500 runs are required for carrying blood, urine drugs and other samples of patient for a hospital of this magnitude. Automated Material Transport system (Fig.15) has been provided which reduces the use of Lifts and thus saves energy.



Figure 15: Automated Material Transport system

Due to use of low flow fixtures and sensors water consumption in the two buildings has been reduced by 30 KLD and 60 KLD respectively which in turn will reduce the energy requirements due to reduced pumping.

Conclusion

The above strategies have helped to reduce the building energy consumption by 152.17 Kwh/m_2/annum and 146 Kwh/m_2/annum for STPI data centre and 250 bedded hospital PGI respectively vis-a-vis benchmarked weighted EPI of the two projects. This translates into annual energy savings of 1.5 crores and 4 crores respectively for the two buildings.

NEXT GEN SOLAR ROOFTOP: INTEGRATION WITH ARTIFICIAL INTELLIGENCE

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Abstract

Artificial intelligence is slated to play a lead role in the field of solar power generation also. There are endless possibilities the way AI can help in the solar power generation. In fact, AI is venturing into those terrains where humans find very difficult, and that makes it an even better alternative to human intervention. Thus finest creation of human intelligence, AI can finally replace humans from the field of clean and green energy. A combination of machine learning, deep learning and neural networks, AI is becoming smarter than the smartest human brain and is even able to perform where humans have the biological limitations.

AI can thus be a great asset in performance and control of solar power installations. Installation of solar PV panels on the rooftop and connecting them with power distribution system of the building through net metering will at best give power feed to the electrical system at a depreciated rate and as such in this case a static system without the consideration of many dynamics has been kept in place. It is only the hardware in place while intelligent software for manipulation of hardware is missing and AI will be useful in such conditions. In addition safety and breakdown aspects can also be taken care of by AI. This is discussed in this paper.

Introduction

Normally a solar rooftop PV plant is designed for a specific capacity which is based on the shadow analysis of the space where it is to be placed. The place of installation and type of installation of the plant is also normally fixed. The solar plant is connected to the power distribution system through power inverter which converts DC power generated by the solar panels in to AC power with protections provided at both the ends of inverter. This AC power then goes to meet the power demand of the building. Normally it is grid interactive i.e. connected with the power supply incoming to the building from the Discom so that power supply to the building is continuous as per demand, because solar plant generates power during solar radiations. Generally solar plants generate electricity for 4-5 hours in a sunny day with peak capacity reaching when solar radiations hit the solar panel maximum which is also called the peak capacity of the plant.

The below diagram depicts a simple rooftop PV plant, designed based on shadow analysis of the available rooftop.

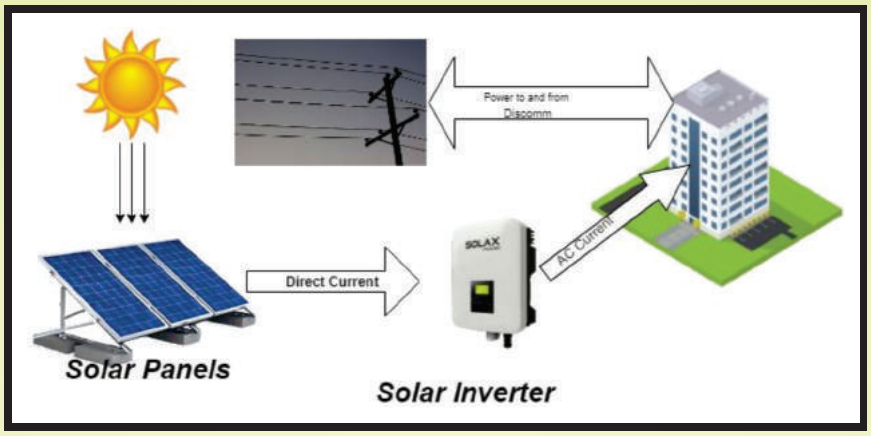


Figure 1: Schematic diagram of conventional solar PV Plant system

Obviously this system of designing a solar PV system is though simple and straight forward but with wastage of precious building rooftop space. In this case only centre of rooftop is considered with a very limited area for solar energy generation. Most of the roof space is considered unworthy of solar power generation and location of solar PV Panels is also without consideration of other services like water tanks and distribution lines, fire fighting tanks and connected lines, outdoor units of air conditioning units, dish antenna and other communication devices mounted on rooftop etc. The best of the best is thus chosen and most of it is left unutilized thereby not utilizing the maximum area as gained from the experience of rooftop projects in many government buildings. The area provided to the solar companies was not fully utilized in the name of non-availability of shadow free area.

AI Aided Design of Solar Installation

In case of AI (Artificial Intelligence) based solar rooftop plant, the algorithm with self learning ability will first consider total rooftop area available and then analyzing all possibilities, the solar PV System will be optimally designed in terms of generation capacity taking into account all locations and existing services like water storage tanks, fire fighting tanks etc and future requirements as well. This is possible because AI can analyze big data, available and obtained through extrapolation; while humans have the limitation of leaving them. The integration of solar PV System with AI is shown in Figure 2.

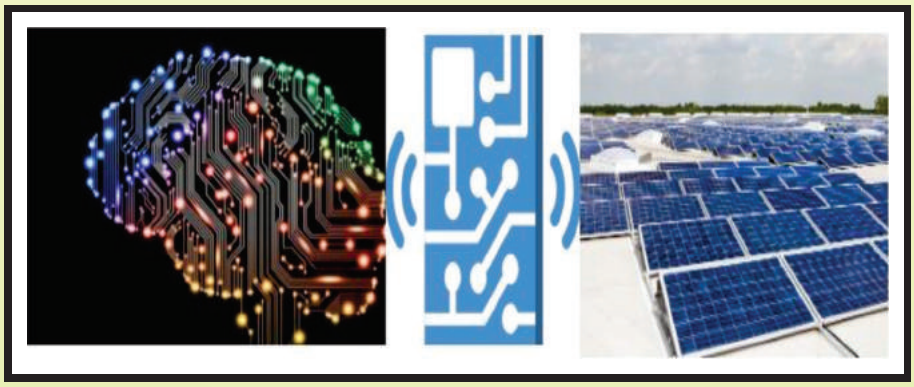


Figure 2: Integration of Solar PV System with AI

Additionally the time involved in the entire process will be very small compared to the system available and used at present for designing the solar rooftop plants. A pictorial representation of AI based solar rooftop plant is depicted in Figure 3.

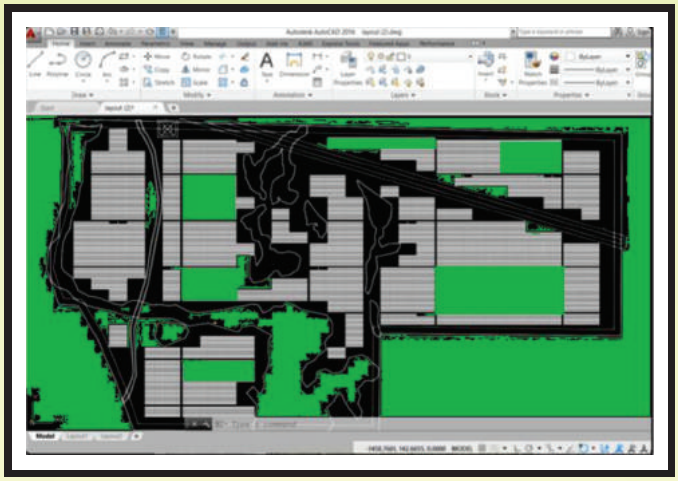


Figure 3: Pictorial representation of AI based rooftop solar design

An optimally designed solar rooftop may still have uncertainty in terms of power generation due to various weather conditions like wind, fog, smog, rains and seasonal changes like summer, winter affecting amount of solar radiations. The AI can take care of entire weather dynamics, change of solar angles due to seasonal variations etc in its predictive analysis and take corrective action if solar panels are tiltable, movable and turnable. Thus, AI can take care of orientation of solar plant depending upon environmental conditions and adapt them for energy maximization. AI techniques can thus provide a breakthrough in the performance and control of solar power through modeling, analysis and prediction of all conditions affecting the generation of power from PV Panels.

Safety & Maintenance of Solar Installation

Safety and maintenance aspects of solar panels can also be controlled through AI. As solar PV panels are the potential fire and shock hazard to the people living under the roof, earthing of the system is to be provided to prevent any shock as well as fire incidence. In addition lightening protection system is also required to prevent any damage to the installation due to lightening. Still, possibilities of fire and shock remain as periodic disruptions happen in the system on account of system disturbances like generation of surge voltage in the system, malfunctioning of one or more power modules due to ageing and maintenance etc. AI can be very useful in such situations to analyze and provide solutions as well.

Dust and dirt accumulation on solar panels can also reduce the performance of solar system and therefore needs periodic as well as need based cleaning and maintenance. Robotics equipped with AI can carry out such tasks very efficiently and based on their past learning can do it further effectively which humans avoid being of repetitive nature of work. Robots will

also not have the attitude of getting bored of their duties because the intelligence injected into them will not allow it resulting into significant improvement and efficiency.

Predictive Maintenance of Solar Installation

Predictive maintenance supplemented with preventive maintenance is another advantage of artificial intelligence. AI can be very useful in predictive maintenance by way of analysis of data regarding spot inconsistencies which help in prediction when the panel or inverter is going to fail. This will provide the system engineer to organize inventories in advance and avoid breakdown and thereby reducing the downtime in case of breakdown. Crawling Robots and Autonomous Drones with real time AI supported analysis can carry out this task dutifully and with due diligence without any human back up. The benefits of predictive maintenance are shown in Figure 4.

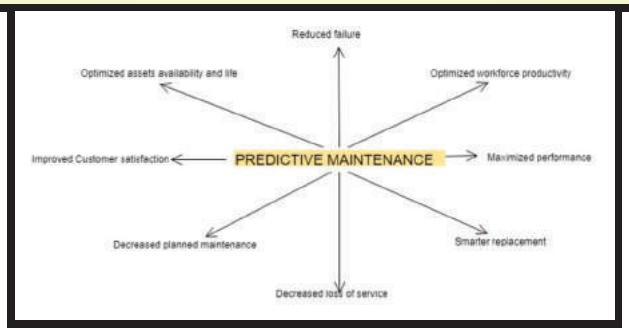


Figure 4: Advantages of Predictive Maintenance

Conclusion

AI has therefore many advantages in the field of solar power generation in analyzing, maximizing and monitoring of solar power generation with safety and efficiency. Though the cost may be prohibitive in the beginning, but with economies of scale and competition in the field of AI, the technology will be available economically with intelligent solutions to the prediction of energy, its performance, safety of the installation and inhabitants, cleaning and maintenance & above all predictive maintenance of the PV Plants. This will obviate the human presence to a great extent but whether that will put humans totally in the hands of machines is a big question, only time to answer.

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SOLAR NET METERING: PERSPECTIVE AND CHALLENGES

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Abstract

The depletion of fossil-fuel resources has necessitated an urgent search for substitute energy sources. For rapid change of weather conditions, seasonally and periodically, standalone Solar Photovoltaic (SPV) system and wind energy system are not sufficient to ensure continuous supply of energy. In such a context, grid connected energy systems are now being implemented, that combines Renewable energy (RE) including solar and utility grid.

The energy meter which can move in both the direction is known as smart bi-directional meter or import-export meter or the net meter. It can record quantum of energy as taken from the utility grid (import) and quantum of energy as pushed to the utility grid (export). This energy (export) comes from the Rooftop PV Power Plant. Here, in the system of net metering, major focus is on optimum utilisation of the electricity as generated by the rooftop Solar PV Power Plant. The quantum of energy, which is surplus after self-consumption of the user, is sent to the utility grid for its utilisation. Through this process, the electricity bill of the consumers is reduced both in tariff slab and in quantum of energy used by the consumer from the utility/DISCOM grid.

India has fixed a target to add 100 GW of Solar Energy by 2022. Out of this, 40 GW is Rooftop Solar PV, which is the area of potential coverage of net metering. Though India has already installed 24.6 GW of Solar Power till date: penetration of Rooftop with Net Metering is not upto the mark. This paper is aimed to develop a knowledge base on Net Metering System on Solar PV Projects. This article covers the Net Metering concept, a critical review of schemes available in India, role of Distribution Companies (DISCOMs), impact on electricity bills and revenue of DISCOMs, gross meter and a proposed intervention in the policy level. With the increasing penetration of Solar PV in India, a pragmatic and doable net metering policy is needful.

Key words: SPV Systems · Net Metering· DISCOM· Proposed New Electricity Policies

Introduction

Grid Connected Rooftop Solar project offers various benefits. These include savings in Transmission & Distribution losses, environmental benefits like Green House Gas emission

reduction, reduction in water consumption level associated with thermal power generation. Rooftop PV is installation takes place with effectively no extra land requirement.The avoided capacity of the DISCOM during peak solar generation is again a great benefit.

State regulatory framework allows DISCOMs to be eligible for deemed Solar RPO benefit. This is because the solar power is primarily consumed by the consumer when the solar power as generated from the rooftop system is either less than or equal to the energy need of the consumer. The extent of impact of grid connected rooftop solar system on DISCOMsmay invite an uncertain future for its revenue and business model.

Globally Rooftop solar installations have been driven by incentives as offered through various schemes. These incentives are in the form of upfront capital subsidy, tax credits; net metering, solar specific Renewable Purchase Obligations etc. In India, governments, both at centre and state have launched different schemes to harness the available solar energy potential.

The Government of India has recognized Renewable Energy (RE) as a technology to help the Indian Power System and reduce pollution. Till date, considerable efforts have been put in place to develop the rooftop Solar PV sector in India by the government, regulatory commissions and agencies concerned. Rooftop Solar PV assists DISCOMs also by reducing the peak demand during daytime and decreases T & D losses as the power is consumed at the point of generation. Success of Rooftop can be detrimental to the business of DISCOMs in the sense that they lose out mainly on prime and subsidized consumersthat they were paying their charges with higher tariffs. In such a position, to make solar a success story in India and also to address DISCOM concerns, regulatory frame work needs to evolve continuously based on experiences, studies and challenges faced by all the stake holders.

Concept of Net Metering

Net metering is such a billing system where customers are allowed to sell excess electricity generated by Solar PV Plant to local or preferred electric utility(DISCOM).Here net energy between export of Solar PV generated energy and import of DISCOM energy for a billing month is recorded. It can record both the import and export energy values in compliance with parameters as notified by the Central Electricity Authority (CEA) metering regulations and DISCOM procedures in existence. DISCOM procedure is guided by the regulations of the State Electricity Regulatory Commission.

Net metering policies vary state to state. Rooftop solar users normally are entitled for adjustment of their electricity bill at the same rate at which they purchase the electricity from the grid of the DISCOM.This rate covers the variable cost of the power, fixed costs of the

installations, required infrastructure which make the electric grid safe andstable.This includes the cost of infrastructure as needed by the DISCOM to accommodate solar systems into their grid. Through the credit or received payment, net-metered customers can effectively avoid cost payment for the grid.

Process of Approaching for NET Metering in West Bengal

- The consumer/user will fix up / select the vendor. There is no such restriction in regard to select a vendor like the vendor should have experience of this and that etc.
- The vendor will provide detailed technical specifications to the consumer/user.
- The consumer will approach to the nearby Divisional Manager or Regional Office of the WBSEDCL or the CESC and will place an application as per format of the WBSEDCL/CESC regarding the installation of the plant. Online application can also be placed.
- Then WBSEDCL will visit at the site and in case of their satisfaction, they will provide an agreement format, where in case of WBSEDCL, a No Objection (NOC) Letter is required from the State Nodal agency for Renewable Energy, which is WBREDA.
- A copy of application, as submitted to WBSEDCL, may also be placed to WBREDA with other technical documents. WBREDA will take fees from the consumer/user/applicant for physical inspection and evaluation towards issuance of the NOC. Then WBREDA will do an inspection. In case of the satisfaction of WBREDA, they (WBREDA), they will issue NOC.
- Then the agreement in between the consumer and WBSEDCL can be executed. After completion of this process, WBSEDCL will provide Net Meter to the consumer premises.

Necessary Documents for Obtaining NOC from the SNA

- Copy of the contract agreement, order to the implementing agency/vendor towards supply, installation, commissioning of the Solar Photovoltaic [SPV] Power Plant.
- Single Line Schematic Diagram of the Grid Interactive Solar PV System in triplicate.
- Certificates/Test reports complying IEEE Standard. IEC test certificate of 61000 of Grid-tied inverters is also required as per the 'CEATechnical Standards for Connectivity of the Distributed Generation Resources Regulations 2013'with complete manufacturer's specification of the Inverter.

- IEC test certificates of PV Modules: IEC 61215, IEC 61730.
- Protection scheme at DC side and AC side including Test result of the earthing system.
- Copy of current electricity bill of the Distribution Company like WBSEDCL, CESC.

Eligibility Criteria for Net Metering in West Bengal

- Areas where grid quality power supply is stable at least 1st half of the day.
- Consumer must have Three Phase Power Supply.
- Consumers, other than individual households are eligible for net metering system.

Advantages

- It will reduce electricity bill in two ways.
- Quantity of power consumption will reduce.
- Slab of electricity tariff will reduce.

Disadvantage

- If three phase power supply is not at the consumer premises, the consumer will not be eligible for net metering.
- In case of load shading for the FIRST HALF of the day, no solar power can be feed to grid.
- In the evening and at night, the Solar Power Plant fails to supply in the event of grid failure – implying the plant fails when it is needed most by the consumer. The Central Electricity Authority [CEA] (Installation, and Operation of Meters) The Amendment of CEA Regulations in 2014 has a provision to have battery with the Rooftop PV Power Plantfor use by the consumer in case of load shedding or grid failure. In many occasions, this note is overlooked by concerned stake holders.
- The inverter of Solar Plant is stated not capable to support the reactive power requirement So, the Solar Plant in Net Metering mode is not capable of supplying dynamically varying reactive power support, required for the consumer appliances.
- In West Bengal minimum capacity of PV Net metering system is 5KWp. So, consumers cannot have a Net Metering arrangement with lower capacity PV
- A small consumer (10 KW or less size) is likely to spend about Rs. 40 to 50 thousand per kWp to get about 1200 to 1300 kWh of Solar Electricity per year per kWp. With average

cost of capital @ 12 % p.a, annual depreciation @ 4 %, annual O & M @ 3-4 %, average annual expenses are of the order of Rs. 9000/- per kWp. The average per unit cost is Rs 6.50 per kWh or unit. This cost is competitive only for those consumers whose energycharges are more than Rs.6.50 per unit or so.

Revenue of DISCOM

It is said that the loss of revenue to DISCOM is limited. It is limited to the loss in 'cross-subsidy'. If these consumers who were paying more than the cost of supply, will install rooftop Solar PV system in net metering mode, it will be a loss to the DISCOM. DISCOMs will be benefitted, if subsidized category of consumers (those having tariffs below the cost of supply) adopt the rooftop solar systems. The extent of impact of grid connected rooftop solar system on DISCOMs may invite an uncertain future for its revenue and business model.

Generally the retail tariff of electricity is designed in such a way that the fixed cost for the grid upkeep is not recovered by the fixed charges payable by the consumers. The fixed cost in the electricity business is more than 50% of the total cost, whereas the fixed charge payable by the consumer is just about 15% or less. A large portion of the fixed cost is recovered through the Energy Charges. Thus a Solar consumer may put some burden on non-solar consumer by not paying his/her fair share for grid upkeep.

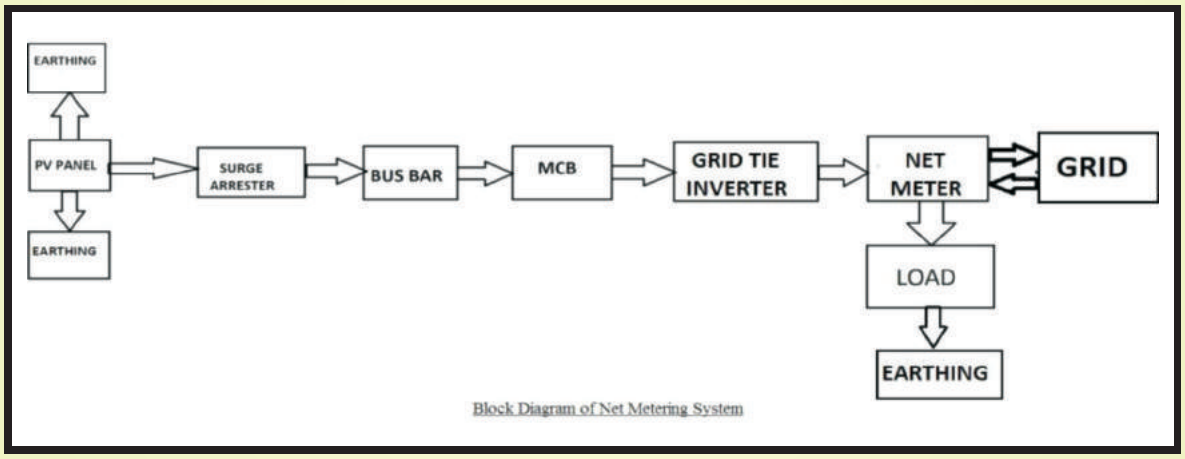
Concerns of DISCOM

- There should be a cap for the capacity of SPV sources by which may otherwise lead to issues relating to the uncomfortable power flow and upper recovery of revenue by the DISCOM. For example, in CESC area in Kolkata, the Netaji Subhash Chandra Bose International Airport authority has installed 15 MWp of PV plant there. This is because, in the regulation of the West Bengal Electricity Regulatory Commission (WBERC), there is no upper cap of PV installation in net metering mode. It may be kept in mind that on today's principle, Net Metering is intended primarily for partial offsetting the consumer's own requirement.

- SPV sources beyond a capacity (say 500kWp) can be subjected to ABT [Availability Based Tariff] or DSM [Demand Side Management] so that DISCOMs are not burdened on account of fluctuations of generation from the large PV sources.

- The cumulative capacity of a SPV Sources against a Distribution Transformer [DT] varies widely from 20 to 80 % in India, which requires an upper cap. Primarily, the concern for limiting the cumulative capacity of SPV sources against one DT in case of DISCOM arise out of the Power Quality issues like Voltage Regulation and Harmonics.

- Net Metering is more beneficial for consumers who are paying at a higher rate as it is offsetting their high energy charges. Slab tariff exists almost everywhere. Consumer with high consumption under slab tariff is paying at a high rate for consumption beyond highest slab. Inverter is tested once by the DISCOM during testing visit at the time of Net Meterinstallation.
- Inverter is tested only once by DISCOM during initial testing at the time of installation of the Net Meter. Though the consumer is advised to submit yearly testing certificate, it is practically very difficult to monitor such activity over the time. There is a rare possibility of failure of inverter to disconnect the system in case of power failure.
- Smart Meter has different categories like Prepaid, Post Paid, Export-Import [Net Meter].Higher Self Power Consumption is there for smart meters, 5 watts vs 0.7watts for the ordinary meters.
- In the USA, in general, the consumer pays for the difference. In Germany, the consumer has to pay for the injected power.



Block Diagram of Net Metering System

Net Metering Impact on Customer Bills

Bills of electricity consumers are linked with the electric utility's [DISCOM] cost for providing electric services. This covers the cost of fuels as used to generate electricity. This includes the cost of transmission & distribution of the electricity for its supply at the consumer premise and the maintenance cost of the utility grid. There exists consumer assistance government programmes at different states forlow-income group like people under below poverty level. Energy efficiency measures, environmental improvements etc are also covered within the cost of electricity.

All electricity customers have electric meter. This meter records the quantum of electric power as delivered by the DISCOM. As electricity is used, the meter moves forward. Here the meter records energy use in kilowatt-hours (kWh). Customers are only billed for their “net” energy use.

So when rooftop solar users generate electricity, they avoid paying for the utility's power. This is justified as they do not use this electricity from DISCOM. But, they also avoid the payment for all of the fixed costs of the grid required to deliver power when they need it .

Proposed updatation of Net metering Policies

After the net-metering concept was introduced, costs of producing solar power have declined substantially. Financial benefits of net metering have not been adjusted to reflect this reduction of solar power installation cost. It was plan fully limited to a certain quantity of utility to incentivize the market. With that accomplished, many states are now meeting or exceeding their caps on net metering customers, even with some states are granting extensions to the upper caps of Solar Installation under net metering mode.

State legislatures and state regulatory commissions across the country are taking initiatives to modify and re arrange the prevailing backdated net metering policies. It is to enforce their limiting caps and to eliminate the shift in costs from customers with rooftop solar systems to customers without the systems. Until this is applied, non-Solar net Metered customers will bear ever-increasing costs continuously.

Presently Net Metering is necessarily associated with solar generation. So, other forms of Power Generation like electricity from Biogas, Biomass, aero-generator etc are not considered here.The future perspective of Net Metering is to be seen in this perspective.

Conclusion

The Government of India has decided that Solar rooftop is going to play a leading role in meeting India's fast growing energy demand. Indiahas set its ambition target to be a global leader in solar power. The present study indicates that India provides multiple benefits to DISCOMs in terms of meeting the day time peak demand, curbing technical losses, reducing power purchase cost from generation companies etc. In some cases, it also affects utility business through reduction in sales volume, reducing demand etc. In the country, solar roof-top provides limited installed capacity using huge potential. Now this segment requires effective support from major stakeholders of the countrylike policy makers in the NitiAyog,State Planning Boards, ElectricityRegulators, DISCOMs etc.

There is a need to formulate a dedicated and modified mechanism to improve the capacity of

DISCOMs. The Ministry of New and Renewable Energy (MNRE) has taken initiative to introduce a programme to build capacity of DISCOMs creating solar cell, developing interconnection framework, web portal for online processing etc.

There is a need to change popular perception on Net Metering in a significant manner.

Acknowledgement

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8. Ms Shreya Karmakar, IIT, Dhanbad

ENERGY EFFICIENCY IN BUILDINGS

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Abstract

Energy efficiency in buildings is of prime importance as a building consumes large amount of energy in materials used in its construction and maintenance and equipment installed in it for its operation. Design of building, its orientation, selection of building materials, electrical fixtures, and electrical and mechanical equipments installed in it, including landscaping have large effect in making a building energy efficient. In selection of energy efficient building materials, their embodied energy needs to be considered while evaluating their qualifying for being energy efficient including energy required in their transportation, utilizing during construction, operation and maintenance. Since, during life cycle of building energy required exceeds multi fold to its embodied energy, energy efficiency and energy conservation during its life cycle also become important.

Therefore for evaluating energy efficiency of the building, embodied energy of the building has to be considered.

Introduction

The building sector is the biggest single contributor to energy consumption and so also for the green house gases emission. As per the International Energy Outlook 2017 of the US Energy Information Administration, projects among all regions of the world, the fastest growth in building energy consumption by 2040 will occur in India. Energy consumption for residential and commercial buildings in India is expected to increase by an average of 2.7% per year between 2015 and 2040, more than twice the global average increase. Therefore, energy efficiency measures in buildings are going to play a crucial role in energy conservation and curtailing green house gases emissions.

Pradhan Mantri Awas Yojana (PMAY) alone has a target of 20 million houses which include requirement of slum rehabilitation. 20 million houses of even 30 sqm carpet area, supposedly having plinth area of about 35 sqm will 4.257*35*20M = 2980 millionGJ. If 25 GW solar capacity is considered of the country, it will consume about 20 years to generate such energy.

The term 'energy efficiency' is frequently used nowadays in many forums including by the manufacturers of electrical and mechanical equipments. Energy efficient equipment means something lasts longer or performs better than conventional and same time uses less

amount of energy. Energy efficient equipment compared to old model performs better and consumes less energy.

The term energy efficiency needs to be used in a wider sense in the buildings compared to equipments. Instead of focusing on the energy efficiency of a single item, appliance or equipment, or materials used in the building, by the building to keep it under comfortable conditions or by the users occupying the building, energy efficiency of whole building is to be considered including embodied energy of the building. If one of the two buildings of same type uses and has less embodied energy, requires less energy during construction, maintenance and operation, with same comforts base, that will be treated as more energy efficient building compared to the other. Therefore, buildings have to be energy efficient in terms of embodied energy, and energy used in their maintenance and operation during their life cycles.

Energy conservation means using less consuming energy materials, appliances, equipment and following lifestyle taking advantages of appropriate design, climate and nature. In short, energy efficiency through conservation means using less energy and avoiding wastage. And thus, energy conservation is another way of contribution to energy generation as it saves the amount of conserved energy hence helps in reduction of equivalent amount of energy required to be generated. Therefore, energy efficiency has to be dealt through energy generation, energy consumption and energy conservation.

Energy Efficiency

Energy efficiency in a building has to be started from conceptual stage to execution of the building and also during its life cycle operation. Each one involved in the building construction, maintenance, operation, and use has to contribute in energy efficiency. These include;

i. Planners and architects

ii. Civil, electrical & mechanical (E&M) engineers

iii. Contractors, builders, suppliers and manufacturers

iv. Building owners and policy makers

v. Landscape architects and horticulturists

vi. Users of the buildings

Thus for optimising energy consumption and conservation, architects, engineers and

horticulturists have to make contribution along with contractors, owners and equipment manufacturers by way of energy efficient designing of building, supplying and installations of equipment and fixtures including selection and use of energy efficient building materials. Users have to contribute in energy consumption by adopting lifestyle suitable for energy conservation.

Building Design and Specifications

Architect has to design a building to make optimum use of sun, heat and air simultaneously protecting the building from moisture. Building facade plays a major role in energy efficiency being the permanent feature of the building and as such energy inefficient building remains permanently inefficient till it is retrofitted from energy efficient criterion. Good architectural design using freely available solar light can reduce energy requirements considerably during its life cycle. In case solar heat gain is not required, measures like shading devices, solar reflective glass or solar power generation panels on such surface make the building energy efficient.

Window to wall ratio (WWR), window glazing and glazing properties have large impact on building's energy efficiency. WWR has to be adopted based on climatic conditions of the area in which buildings are located. National Building Code (NBC) and ECBC guidelines provide details of making buildings energy efficient and as such those provisions should be adopted to make buildings energy efficient. Thus, passive architecture saving considerable energy needs to be adopted based on climatic conditions, measures like orientation, shading devices, skylights, suitable courtyards and corridors, trees, pergolas, canopies, louvers, landscaping etc. simultaneously making use of geothermal technologies, solar power and wind to harness energy as much as possible to make building energy efficient. Height of the building, external wall thickness, type and design of doors/windows, and type of roof also have considerable effect on energy efficiency. Bungalows, temples and forts were designed according to warm weather conditions of India. Large thickness of wall was helpful in insulation, security and prevention of moisture ingress inside the building. Size of doors and windows, glass surface and its type, wall thickness, building envelope and materials used in it, storey height, landscape and horticulture around the building play very important role in energy requirement of the buildings.

Providing energy efficient fittings, fixtures, appliances and equipments during its construction is a better approach than during retrofitting or maintenance period as it is energy efficient as well as economic also in long run. LED lightings and star rated equipments are being provided nowadays in all the government buildings. Such energy efficient lighting and equipment prove to be cost effective within a short span of their use as additional cost

involved in energy efficient measures is paid back in very less period compared to the life of the building ranging.

Energy efficiency is also an essential part of green building concept all over the world. \30-35% points have been earmarked for energy efficiency and indoor air quality by IGBC and GRIHA council in their rating criteria for new buildings. Now energy is used as per the requirements of the users and occupancy at a particular time rather utilising in full building at all the times by use of Smart lighting and fixtures, sensors and Intelligent Building Management System (IBMS) by which operation of lights, fans, heating areas, and air-conditioning zones can be controlled as per the requirements in offices, institutions as well in residential buildings. Smart meters have also indirectly infused the concept of energy savings in the consumers.

Embodied energy

Embodied energy is the energy consumed by all of the processes associated with the production of a building, from the extraction of building materials, their processing, manufacturing, transport and delivery though it does not include the operation and disposal of the building material during its life cycle. Embodied energy is said to be the 'upstream' or 'front-end' component of the life cycle impact of a home.

Building materials consume numerous amount of energy in their production. Hence, energy consumed by a material is the total of embodied energy, energy required in its transportation, installation and use. Most of the times, embodied energy is ignored during use of building materials and only the energy required in their use and operation is considered. As per Table 1, it may be observed that cement is high embodied energy material so also the steel, more than 4 times of even cement while there is a move to go for RCC monolithic construction using steel and cement for rapid construction nowadays. Recycled materials and materials produced from waste materials are considered low embodied energy materials hence they are green as well as low embodied energy materials.

Scalar total of energy input required to produce the product including transporting them to the building site is reported as given in Fig. 1 in one of the case. It is observed that Aluminium and steel have the most embodied energy because to the high energy required to produce them.

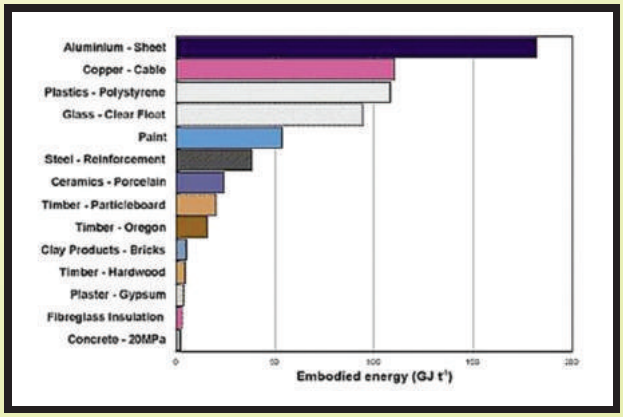


Figure 1: Embodied energy of various materials

Table 1: Basic EEV of Materials: (Reference: IE (I) Journal-AR-Page 47-50, vol 84, October-2003, Dr P S Chani, Dr Najamuddin, and Dr S K Kaushik): EEV of Different Basic Construction Materials (Supplementary reference: Bansal and Nandy, 2010)

Items	EEV (MJ)	Units	Sizes in mm
Soil	0	0	0
Cement	6.70	MJ/Kg	0
Sand	0	0	0
Fly ash	0	0	0
Steel	32.00	MJ/Kg	0
Standard Burnt Bricks	4.50	MJ/Bricks	229*114*76
Clay Fly ash Bricks	2.32	MJ/Bricks	200*100*100
Sand Lime Bricks	2.79	MJ/Bricks	200*100*100
Hollow Cement Concrete Blocks	11.00	MJ/Blocks	400*200*200
Aerated Blocks	11.50	MJ/Blocks	400*200*200
Fal G Blocks	7.90	MJ/Blocks	300*200*150
Solid Concrete Blocks	10.40	MJ/Blocks	300*200*150

The EEV has been taken as the same, without adding for handling/transportation etc inputs by the authors.It may be understood that the materials used for the same functional purpose like glass, PVC, timber, steel or aluminium, say for windows will have varied amount of embodied energy hence there is a always a choice available to select energy efficient material for same function though aesthetic may be varying. Also, density of materials and embodied energy has no direct relation. Apart from this life cycle analysis of the products is to be seen as replacement of products leads to multiplicity of energy requirements hence durability has to be considered.

Let us examine a building having brickwork with clay bricks, AAC blocks, and flyash bricks. As reported by Bansal and Nandy as reproduced in Table 2, it may be seen that Embodied Energy Value (EEV) of bricks is very high compared to other materials.

Table 2: Materials input per sqm of walling with 1:6 Cement Sand Mortar (Bansal and Nandy, 2010)

Building Material	Wall Thickness	Units of Blocks Required	Cement (kg)	Sand (cum)	Plaster	EEV of Blocks	EEV of Cement
Brick	(9" thick wall)	116	14.5	0.06	Required	521.7	97.2
Hollow Concrete Block	(8" thick wall)	13	7.5	0.03	Required	137.5	50.3
AAC	(8" thick wall)	13	7.25	0.029	Required	143.8	48.6
HF (fly ash block)	(9" thick wall)	40	1	0.029	Optional	208.9	6.7
HF(soil-cement block)	(9" thick wall)	40	1	0.029	Optional	240.6	6.7

Lifecycle of Equipment, Users and their Lifestyle

Even if energy efficient appliances are available, sometimes users do not consider life cycle concept and long term expenses required in running and their operation but adopt short term measures by using less energy efficient fixtures and appliances though they prove to be expensive ultimately. In fact, it is always beneficial to throw out old less energy efficient products and appliances and replace them with new energy efficient as by doing so, considerable energy is saved by which cost of substitution is recovered easily. Habits and lifestyle also play a major role in energy conservation. Using blankets, wearing suits in warm weather and operating air-conditioners at low temperature lead to wastage of energy. Similarly, leaving appliances on standby mode whenever not needed consumes energy. Hence, habit is to be made to purchase standard and quality products which are durable and more energy efficient. Switching off lights and AC when not required and setting AC at comfortable temperature whether in house or office should also be part of habits. Putting AC on low temperature and using warm clothes or on heating mode without using warm clothes is not an energy efficient option.

Selection of energy efficient fixtures, fittings, appliances and equipments involves the decision of architects, engineers, builders and owners. Energy efficient fittings may use 80% less energy than conventional and are also durable hence their selection in new construction and substitution during maintenance period is always beneficial. A building may require cooling or heating as the case may be but in case the insulation to the walls and roof and double glazing is provided, it saves considerable energy and as such role of architects,

engineers, builders and owners is extremely important in energy conservation.

Advantages of Energy Efficiency and Switching over to Renewable Energy

Energy generation through renewable energy resources, adopting energy efficiency in construction and operation, and energy conservation is not only for individual but for society, future generations and health being of people i.e. for better quality of life. Advantages in brief can be summarised as given in the following;

- To help society to a low carbon future by reduction in CO_2 emission.
- To reduce dependency on natural gas, petroleum fuel and electricity and thus contribution to environment protection, pollution control and in prevention of global warming.
- To prevent wastage of natural resources through switching over to energy efficient fittings, appliances, equipment and cars like electric cars.
- To reduce energy consumption and using saved financial resources for better quality of life.
- For social responsibility by adopting energy conservation and dependency on carbon/pollution based energy resources by switching over to renewal energy.
- To live decent and healthy life by adopting energy conservation concept through behavioural change.
- To contribute in reducing global warming

CPWD has already provided rooftop solar power plants in all General Pool Office Accommodation (GPOA) and is providing solar plants in new buildings. CPWD has also switched over completely for providing energy efficient LED lights and fans and thus making its headway towards energy efficiency.

CPWD has already planned to construct green buildings conforming to minimum 3 star GRIHA norms where energy efficiency is part of green building concept. CPWD has also constructed India's first onsite net zero energy building in Delhi in which all the required amount of energy is produced from solar power plants provided on its rooftop and extended cantilever projections.

Recently CPWD has installed solar trees in Dandi Memorial complex at Dandi, Gujarat (Fig. 2).



Figure 2: Solar trees installed by CPWD in Dandi memorial, Gujarat

CPWD has also entered into MoU with Bureau of Energy Efficiency (BEE) for energy labelling in government buildings maintained by it. Thus CPWD is committed to energy efficiency and energy conservation.

Conclusions

The building sector consumes considerable energy hence buildings need to be constructed and made energy efficient by retrofitting if required. Energy efficient fixture, fittings and equipment always prove to be economic and durable considering life cycle analysis. Embodied energy of the building materials should be considered while making selection of materials in a building long with energy required in their transportation and operation and maintenance.

Energy conservation also depends upon habits and lifestyle of individuals and as such lifestyle should be adopted based on the climatic and weather conditions of the area in which buildings are located and used.

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SMART LED LIGHTING

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Abstract

Ledfication is happening in a big scale all over the world and it is the right solution to address power shortage and environmental issues. LED chip lumen efficacy has crossed more than 200 lumens/watt and is reaching to the saturation level. Colour rendering Index of LED has crossed more than 95, nearing to the natural day light. Indian government is working on different schemes and smart city projects to convert the conventional light sources into LED and has implemented BIS and Star rating as compulsory for Luminaire/Lamp to maintain the quality and safety of system. Digital nature of the LED technology brings illumination and IT together, allowing lighting systems to participate in the internet of Things. More focus and work are happening now for Smart LED Lighting and controls which will provide right amount of quality lighting at right place at right time.

Li-Fi

Li-Fi is a wireless communication technology which is capable of transmitting data at high speeds and was first introduced by Harald Haas during the year 2011. The major difference between Wi-Fi & Li-Fi is that wherein Wi-Fi uses radio frequency & Li-Fi uses the visible Light, ultraviolet & infrared to transmit the data. Visible Light spectrum is 10000 times larger than radio frequency spectrum.

Li-Fi is designed to use LED Light bulbs similar to those currently used in many homes & offices. Li-Fi Bulbs are outfitted with a chip that modulates the Light imperceptibly for optical data transmission. Li-Fi data is transmitted by the LED bulbs and received by photoreceptors. Data is transmitted by switching the current to the LEDs OFF&ON at a very high rate to give different strings of 1s & 0s. The LED intensity is modulated so rapidly that human eyes cannot notice the changes, so light output appears constant. LED to be kept ON to transmit the data and could be dimmed to below human visibility.

Photo detector picks up the signal which is converted in to data stream and sent to client.

Benefits of LI-Fi

- Higher speeds than Wi-Fi.
- More secure because data cannot be intercepted without a clear line of sight.

- Eliminates neighbouring network interference.
- Does not create interference in sensitive electronics, making it better for use in environments like hospitals and aircraft.
- By using LiFi in all the lights in and around building, the technology could enlarge greater area of coverage than a single WiFi router.
- It has less maintaining cost and implementing cost.
- Light sources of Li-Fi are already installed so it doesn't need any well-equipped equipment and provides good capacity.
- The transmission of Information through it is very cheap and affordable due to the Low energy consumption and efficiency of LED Bulbs.
- Li-Fi doesn't provide any issue of availability because in the world there is no scarcity of bulbs and the only thing is that they need to be replaced by LED's for the sending of information or data.
- A high rate of transmission of information up to10 Gbps can be succeeded.
- The issue of insufficiency can be eradicated because Li-Fi uses Light which is still not used in abundance.

Limitations of Li-Fi

- Need for a clear Line of sight.
- Difficulty with mobility.
- Requirement that Lights shall stay ON for operation.
- Other source of Light may interfere with the signal.

Human Centric Lighting

Light not only allows us to see the object but also influences our moods and activity levels. Physiological response to light depends on its characteristics such as intensity, colour temperature and colour spectrum. Artificial light has significance influence on the health and wellbeing due to our spending most of the time indoor.

Scientists have discovered a photo pigments called melanopsin in special photo sensitive cells in the eye retina, in addition to roads and cones which are part of the visual system. These cells, known as ipRGCs form the main neural conduit tithe suprachiasmatic (SCN) in

the part of brain where our circadian clock is located. Both the light and dark set the timing of SCN and disruption of this clock has-been shown negatively affect the health issues.

Human Centric Lighting can benefit the biological, emotional, health or well being of people. This can be achieved by dimming & changing the colour temperature of Smart Light source mostly LED to mimic the levels of sunlight throughout the day. By increasing the light levels will produce the cortisol, a hormone which promotes the wakefulness and dimming of light will stimulate the secretion of melatonin that helps us to sleep. This will help the people for smooth circadian rhythms and connection to outside natural light when they spend most of the time interior areas.

While working on lighting design for an office building more focus is given for amount of light, visual comfort and usage of daylight to reduce the energy. Designers generally do not give much attention on the effects of light on the circadian functions which regulate the sleep, mood and alertness. If later point is considered while preparing the lighting design then it will enhance the health and wellbeing of occupants of buildings which will improve overall effectiveness and reduce many of health-related diseases. Soft or dim light will help for creativity whereas bright light will help for focus and keep the body in alert.

Smart Home Automation

Smart home lighting is getting more popular and user can remotely control and schedule the lights through the app-based phone. Light will get ON as the owner steps inside the house. Light can be paired with Alexa or Google assistant and with the voice command. It can be tuned ON/OFF or dim/bright or different scene can be created as per the requirement. Light can be synchronised with the sunrise or sunset. Colour changing bulb and battery backup LED bulb are now getting widely popular for home lighting applications.

Smart Pole

Smart pole is likely to digitally transform the definition of the street light. In future street poles will not only carry luminaire but also will provide multi utility facilities. Since internet connectivity will be important part of the city plan, street pole manufacturers are increasingly considering the integration of 4GLTE wireless technology. Further other important accessories like cameras, weather monitoring device, speakers, sensors and charging points will be installed on the poles. Provision for billboard can also be given on poles which will help for the revenue generation.

As per the market research the global smart pole market is expected to reach over US$ 10,000Mn by the end of year 2022 and segment will register highest CAGR in the forecast period. Smart poles are finding application in highways & roads, railways, harbours, public

places and many other applications.

Power over Ethernet (PoE) Technology

Power -over –Ethernet is a technology used in wired Ethernet local area networks that delivers power over single twisted pair cables that delivers Ethernet data and it will allow building occupants and operators to intelligently control the light from internet connected computers, smart phone or tablet devices. In traditional AC power, most LED drivers for lighting use an AC to DC convertor to convert the AC mains power to lower DC voltage which will reduce the system efficiency. Power is provided via the power sourcing equipment located in the switch/hub and connected device receiving the power, i.e. LED lamp is called powered device (PD). As per the PoE standard maximum power device connected is limited 25.5W over a 50VDC to 57 VDC voltage range and standard is under ratification. Each LED light fixture can be standard RJ-45 connector plug and play device with its own individually addressable IP address. By adding the sensor to LED fixture, it can collect the information on ambient lighting, temperature, humidity and anonymous room occupancy data. Any new sensor or communication modules such as distributed short-range access points can add at low margin cost and with relatively low labour cost. Cabling cost is lower since data and power share the same cable. Installation is much safer since PoE, DC voltage is lesser dangerous than standard AC supply voltage and It is easier to integrate with other system in the building. There is no need for separate network for emergency lighting option.

Some of the advantages of PoE are

1. Easier installation

2. Cost effective installation.

3. Uses smart power technologies

4. High reliability

5. High power transfer efficiency

6. Ability to perform power management.

Smart intelligent Street Lighting

Our country has got around 35 million street light and energy cost can reduce with up to 35 percent through intelligent on/off switching, targeted progressive dimming and efficient management of the consumption. Overall consumption can be reduced around 40 percent by detailed maintenance and preventive grid interventions. Intelligent street lighting dims the

lights when there is no activity and brightens when the movement detected. Street intelligent light can be remotely controlled and monitored, energy can be recorded and real-time lighting information can be collected.

Some of the benefits of the smart street lighting are

- Higher energy efficiency.
- Web access to control and monitor the street light.
- Reduced maintenance cost.
- Real time reports and controllability.
- Less environmental impact.
- Light intensity control.
- Life span is more.
- Varied lighting effects.
- Expendable infrastructure and scalability.
- Monitor traffic flow and parking and environmental monitoring, video cameras.

LED Lighting market is growing very fast and as per the market research, it is projected to register a growth of over 30 percent during 2015-20. LED is finding good acceptance by users for indoor and outdoor applications due to its lower initial and energy cost, higher efficiency and favourable government initiatives. LEDs are now not only used for Lighting but to transfer the data's(Life), horticulture lighting, to heal many deceases, indoor location tracking and many other applications. Due to raising awareness of customer for clean energy and quality lighting, Smart Led lighting solution will play important role in coming years and will have huge market potential in future.

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SOLAR POWER WITH ENERGY EFFICIENCY MEASURES IN A BUILDING

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Abstract

Today we are very much dependent on the power generated from non-renewable energy sources like oil, gas, coal, nuclear energy etc. Electricity generated through non-renewable is becoming expensive by every passing day. Also the use of these energy sources leads to increase in Green House Effect and contributes to Climatic Change, which is one of the biggest challenges facing the world today. Due to increase in Green House gases the average global temperature on Earth has increased by about 0.8° Celsius (1.4° Fahrenheit) since 1880.The basic problem is obvious, unprecedented growth of population, excessive urbanization and the resultant slumming of cities.The demand supply gap for electricity is increasing in the country, which makes it very important for people to start thinking of other ways of realizing their energy needs. The user of the building not only uses energy for lighting purpose but also for maintaining standard living temperature using AC, heater, DG sets, etc. It is easier task to power a single-story buildings-worth of electrical needs with a solar roof, but what about the power needs of skyscrapers? They have very limited roof space for direct solar power generation for 20 to 30 floors, at present Roof-Top Solar PV system and Ultra-Small Solar Cells are already in practice with for energy efficient measures of the building to some extent. This paper proposes primarily Solar Chimney Conceptual Model(SCCM), which will not only look into the electricity needs of the building but also energy efficient measures of the building to very good extent.

Introduction

The total installed capacity of the country in solar power generation has recently crossed 25 GW. This includes both large-scale and roof-top solar. In January 2018, Mercom had reported that India had achieved 20 GW in cumulative solar installations, meeting the original target set for 2022. Today, that target has been increased to 100 GW by 2022. However, achieving the remaining 75 GW of the target by 2022 will require a huge push and dedication with effective public- private participations. To mitigate the Climatic Change, one of the important measures identified involves in increasing the share of solar energy in total electricity consumption of the country. It is always good practice to find out the new methods and technology which is easily adaptable, economical, environmental friendly. Different methods of solar power generation generally practiced are listed below:

- Photovoltaic roof tiles
- Specially designed buildings(Passive solar design)
- Solar thermal collectors
- Solar panels
- Solar Chimney Power Plant with Collector
- Concentrating Solar Power (CSP) technologies

Energy Management and Its Importance

Energy management is the process of tracking and monitoring energy to conserve usage in a building. Energy management is the means to controlling and reducing a building's energy consumption, which enables:

- Reduce costs – energy represents about 25% of all operating costs in an office building.
- Reduce carbon emissions in order to meet internal sustainability goals and regulatory requirements.
- Reduce risk – the more energy you consume, the greater the risk that energy price increases or supply shortages could seriously affect your profitability. With energy management through a building monitoring system, you can reduce this risk by reducing your demand for energy and by controlling it so as to make it more predictable.

As energy management has developed, the role within an organization has changed over time.

Aspect	Old Way of Thinking	New Way of Thinking
Energy Audits	• Energy audit is an inspection survey and analysis of energy flows, for energy conservation in a building.	• Energy Audit is the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption

The Benefits of Improving Energy Efficiency	• The benefits are energy cost savings. The direct environmental benefits e.g. tonnes of CO2 avoided may be a social benefit for CSR reporting.	• There are multiple non-energy benefits – many of which are far more strategic and interesting to decision makers than mere energy cost reduction. • Energy savings may be the least attractive benefit of a project that improves energy efficiency and should be sold last – as a co-benefit to the non-energy benefits.
Energy Service Companies (ESCOs) & Energy Performance Contracts (EPCs)	• ESCOs and EPCs are the answer to all our problems.	• ESCOs and EPCs are applicable in some limited circumstances, mainly in the public sector. They are not the only answer and they definitely don't work at all in most sectors. ESCOs and EPCs are only one of many ways to bring finance to energy efficiency projects.
Measurement of Energy Saving	• It is hard to measure because it is a counter-factual and is invisible. It can't be metered.	• Units of energy saved can be metered and calculated just like units of energy delivered.
Energy Management	• A practice that is hard to systematise and is highly dependent on individuals.	• A practice that can be systematised and embedded into the operation of an enterprise through the application of International Standards.
The value of a kWh Saved	• Is the same at all times and in all locations.	• Is highly time and location specific.
Project Development	• Optimise the components.	• Optimise systems e.g. integrated design (which is still not very common at all).
Energy Prices	• Always go up.	• Go up and down.
The Availability of Investment	• There is no money for energy efficiency.	• There is a lot of money for energy efficiency – just a shortage of well developed, bankable projects.
Energy Efficiency	• Comes about through specific retro-fit projects with the aim of reducing energy costs.	• Comes about through retro-fit investments, investment into plant and building refurbishments carried out for other, non-energy, reasons, and through investment in new plant and buildings that improve the average efficiency of the sector.
Energy Storage	• "Electricity cannot be stored". • Only viable in massive hydro-electric schemes.	• Available in several forms. Rapidly becoming cheaper. • Economically viable in many situations behind the meter and in the grid.

i) Proposed Model- Solar Chimney Conceptual Model(SCCM)

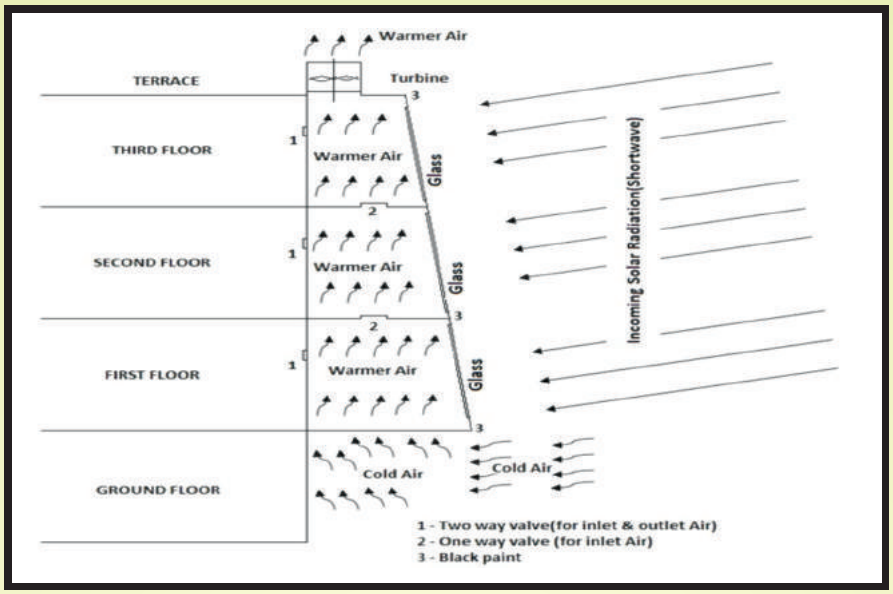


Fig. 1: Conceptual Model

Model Features

The proposed model consists of turbine and heat exchangearrangement features as shown in Figure-1for G+3 building having following features:

- The arrangement is made of MS structural framework with chambers for each floor as shown in Figure-1.
- Transparent glass (Clear Acrylic Perspex glass or toughened glass) is provided to create a Green House effect, so that incoming light radiation with shortwave enters the glasseasily and trapped and do not leave due to change in wave length from short to long.To cut the cost Perspex glass can be used in place of toughened glass.
- The inside chamber is provided with metallicsurface cladding (copper or aluminum) in top bottom and sides and painted with Black colour for maximum absorption of heat without reflection.To cut the cost aluminum cladding can be used in place of copper.
- Chambers of all the floors are connected with one way inlet valve from one floor to another as indicated in Figure-1 by “2”.
- The floor and chamber is connected with two way inlet outlet valve system so that air can enter in floor as well from floor to chamber depending on draft. It can be used in winter to make the floor warmer and in summer the excess heat can in exhausted out thus providing Energy Efficiency Measures. This is indicated as “1” in Figure-1.
- The terrace floor is provided with arrangement of Turbine so that the kinetic energy of

warmer air lifting out of the chimney is used to run Turbine and generate electricity.

- The chimney is made tapered as a result the rising air velocity is higher at the outlet of the chimney as shown in Figure-1.

Procedures

The incoming solar radiation is incidental on the metallic and glasssurface; as a result the air inside the chamber is heated up Green House Effect and direct conduction heating. The air inside the chambers becomes lighter which result in rising of the air in each chamber. Due to taper cross-section shown in figure the velocity of the air is maximum at the outlet and with this kinetic energy of warmer air turbine is made to run and generate electricity. Thetwo way inlet outlet valve system can be operated during winter to make the floor warmer and in summer expel out the excess heat thus making building marked with Energy Efficiency Measures.

Orientation

For best result the side of the building that is utilized for solar gain needs to be facing the south to take maximum advantage of the sun's potential energy.

Conclusion

While there are many methods to capture solar power depending on requirement and purpose. All the methods are having some merits and demerits and it is wise to choose or conceptual any model for best result. The proposed Solar Chimney Conceptual Model (SCCM) at this stage may be said to have advantagessuch as easily adaptable, stress more on energy efficient measures of the building, cost effective both in short-term and long- term as only initial cost is required, fewer moving parts, need less space compared to other solar generation methods,simple design and working and environment friendly.

Hence the proposed model can be adopted and further feasibility studies should be made before going for prototype construction. It is one again worth mentioning that solar power is not just optionin terms of fuel costs, but also in the fight against pollution. There are no fumes or pollutants being released into the air with using solar power.

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CONTINUOUS POWER QUALITY MONITORING – IMPORTANCE FOR RELIABILITY AND ENERGY SAVINGS

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Abstract

With the increasing use of sensitive electronic equipment and addition of non-linear loads including renewable energy grids, rooftop solar PV systems, continuous power quality monitoring is emerging as the only way to reliably and accurately spot Power Quality issues. The equipment that are used for improvement of one parameter or correction of power factor in latest type of automatic power factor correction panel can also interfere with total harmonic distortion in the system.

In state of art buildings like Net or Near Zero Energy Buildings and also buildings for software technology parks constructed by Central Public Works Department where IBMS is provided, the quality of power that is intended to be maintained has to be within limits so as not to cause disruption in operation of system.

Until recently there was no Indian standard for power quality and International standard-IEEE-519 was followed.

Recently a Gazette notification for IS 17036: 2018 'Distribution System Supply Voltage Quality' has been notified in the Gazette of India on 10 October, 2018. This will pave a way for further regulation and control of power quality.

In this paper effort has been made to include the causes and correction methodology of power quality.

Introduction

Uninterrupted power is a very important goal for every facility maintained by CPWD especially for hospitals and other special application building like Mausam Bhavan, Green rated buildings and for achieving the highest reliability for power systems requires a foresight. The required power quality is also of utmost importance for hospitals where very expensive and sophisticated medical equipment are installed which are used for specialised diagnostic and treatment of critically ill patients. But, in most cases, the challenges that risk the reliability of power systems are only understood in hindsight that is its effect become evident only it has already occurred. Good Power Quality (PQ) is critical to ensuring the highest reliability in any power network. Whether its voltage spikes, harmonics or

interruptions that last for only for a few milliseconds, the PQ issues can damage equipment, create nuisance disruptions in day-to-day operations and in worst cases pose a severe risk to safety and reliability of power systems as a whole. Considering the challenges of poor power quality there is also provision in Energy Conservation Building Code-2017 to provide a Total Harmonic Distortion Meter for any individual service that is beyond threshold of 1000 kVA.

The Trend Towards Continuous PQ Monitoring

Traditionally, PQ monitoring is performed on a case-to-case basis using field studies and portable devices to measure key parameters affecting PQ. The traditional approach to solve the problems and generally improve the PQ has been reactionary.

Typically, most modern BMS (Building Management Solutions) used in high-rise or commercial buildings come with a comprehensive range of centralised dashboards with distributed monitoring systems for power/ energy, security, fire and safety etc. However, monitoring and assessment of critical parameters concerning the power quality remains outside the technological and functional purview of monitoring frameworks of a typical BMS.

Permanently installed modern power quality monitors are built for continual monitoring with software to handle automated data collection, intelligent processing and actionable representation of results. The software is equipped to monitor and analyse a real-time performance as well as develop a long-term summary of performance based on the stored data. Such systems, integrated with a BMS have the potential to unravel insights that help to correlate problems observed on the surface with its underlying root causes in the electrical network.

In fact, continuous monitoring of PQ is probably the only way ahead to accurately monitor and analyse the issues arising due to poor PQ and this will improve un explained outages , equipment failure and enhancing reliability of operation of electrical system.

Key Benefits of Continuous PQ Monitoring

Continuous monitoring by its very nature enables users to spot the trends and easily extrapolate the risks to safety and reliability within specific points in the electrical network. With availability of intelligent alerts, the Managers are well-informed to take proactive measures.

Improved Energy Efficiency with Improved Power Quality

While recording electrical parameters with Power Analyser it is possible to record total power

factor also which is the product of Displacement Power Factor and Distortion Power Factor.

Distortion Power Factor cannot be improved with use of APFC Panel and special harmonic filters can only check distortion power factor. Distortion power factor is generated due to higher Total Harmonic Distortion and leads to avoidable energy loss. The energy load profiles can be tracked, analysed and co-related with PQ events to evaluate impact on consumption and crate an internal 'standard' to drive the energy efficiency programs.

How Power Quality Can Be Managed

Effective use of Continuous PQ Monitoring demands a new set of tools, communication interfaces and data processing systems as compared to the traditional methods of monitoring PQ.

Some key PQ measurement tools include:

- Advanced Power Quality Analyzers – the backbone of continuous PQ monitoring
- Digital fault recorders (DFRs) – trigger on fault events and record the voltage and current waveforms that characterize the event
- Smart relays
- Voltage Recorders
- In-plant power monitors
- Special-purpose PQ monitors
- Customized systems with specialized sensors/thermal imaging devices
- Energy meters

Linear V/S Non Linear Loads

Harmonic distortion issues are more prevalent in case of non linear loads. The performance of the system with only linear loads is shown in Figure 1.

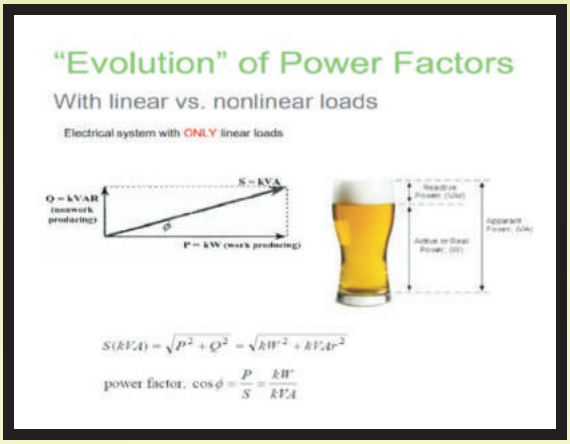


Fig 1: Electrical System wi th only Linear Loads (Source: Schneider Electric)

In case of non linear loads, performance of system is as shown in Figure 2. There are three components KW –Real Power, KVA –Apparent Power and KVAR -Reactive Power

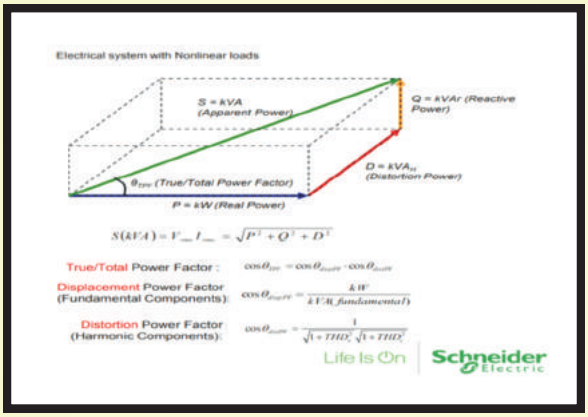


Fig 2: Electrical System with Nonlinear Loads (Source: Schneider Electric)

In case of Non-Linear loads, besides three components KW, KVA and KVAR there is one more component which is DVAR which comes into being because of Harmonics and is causing energy losses. IN addition to energy losses, there are other negative effects that are experienced and causing lot of losses in financial terms.

Voltage and Current Harmonics

Harmonics originate as currents but generate harmonic voltages as they flow through the impedances in the system and these harmonic voltages propagate through the installation. It is important to clearly differentiate between voltage and current distortion measurements; conventionally, current distortion measurements are suffixed with 'I' and voltage distortion figures with 'V'

When investigating problems that may be due to harmonics it is necessary to know the

harmonic spectrum because the effects depend on the harmonic order. Simple total harmonic distortion (THDI, THDV) measurements are of little use for diagnostic purposes.

Types of Equipment That Generate Harmonics

Harmonic load currents are generated by all non-linear loads. These include:

- Single phase loads, e.g. Switched mode power supplies (SMPS) – virtually all electronic devices
- Electronic fluorescent lighting ballasts
- Small uninterruptible power supplies (UPS) units Three phase loads, e.g.
- Variable speed drives
- Large UPS units

Fluorescent Lighting Ballasts

Electronic lighting ballasts have become popular in recent years claiming improved efficiency. Overall they are only a little more efficient than the best magnetic ballasts and in fact, most of the gain is attributable to the lamp being more efficient when driven at high frequency rather than to the electronic ballast itself. Their chief potential advantage is that the light level can be maintained over an extended lamp lifetime by feedback control of the running current – a practice that reduces the overall lifetime efficiency. Their great disadvantage is that they generate harmonics in the supply current.

LED Lamps

LED lamps if selected only for high Luminaries Efficacy without consideration for THD will cause serious power quality issues because management of THD involves use of circuitry that consume additional power thus affecting over all efficacy of luminaries always care is required to be exercised for drafting specification of LED luminaries.

Problems Caused by Harmonics

Harmonic currents cause problems both on the supply system and within the installation. The effects and the solutions are very different and need to be addressed separately; the measures that are appropriate to controlling the effects of harmonics within the installation may not necessarily reduce the distortion caused on the supply and vice versa.

Harmonic Problems within the Installation

There are several common problem areas caused by harmonics: -

Problems caused by harmonic currents:

- Overloading of neutrals
- Overheating of transformers
- Nuisance tripping of circuit breakers
- Over-stressing of power factor correction capacitors
- Skin effect

P**roblems caused by harmonic voltages**

- Voltage distortion
- Induction motors
- Zero-crossing noise

Effects on Transformers

Transformers are affected in two ways by harmonics.

Firstly, the eddy current losses, normally about 10 % of the loss at full load, increase with the square of the harmonic number. In practice, for a fully loaded transformer supplying a load comprising IT equipment the total transformer losses would be twice as high as for an equivalent linear load. This results in a much higher operating temperature and a shorter life. In fact, under these circumstances the lifetime would reduce from around 40 years to more like 40 days! Fortunately, few transformers are fully loaded with PC loads, but the effect must be taken into account when selecting plant.

The second effect concerns the triple-N harmonics. When reflected back to a delta winding they are all in phase, so the triple-N harmonic currents circulate in the winding. The triple-N harmonics are effectively absorbed in the winding and do not propagate onto the supply, so delta wound transformers are useful as isolating transformers. Note that all other, non-triple-N, harmonics pass through. The circulating current has to be taken into account when rating the transformer.

Other Effects Of harmonics

- Nuisance tripping of circuit breakers
- Over-stressing of power factor correction capacitors

Problems Caused By Harmonic Voltages

Because the supply has source impedance, harmonic load currents give rise to harmonic voltage distortion on the voltage waveform (this is the origin of 'flat topping').

Induction Motors

Core losses which are frequency and square of frequency dependent, spike with presence of higher order harmonics and cause overheating and reduction in life of motors.

Harmonic Mitigation Measures

Harmonic mitigation measures are required to:

- Meet local harmonic emission limits
- Reduce overloading of, e.g., cables and transformers
- Improve resilience of equipment by reducing voltage waveform distortion

Correct sizing of neutral conductors and transformers will eliminate the risk of overheating while careful circuit separation will help to minimize voltage distortion. These are wise and necessary steps to take to protect the installation but they do not help to meet the local emission limits for which further steps are necessary.

For large infrastructure items, for example, a large variable speed ventilation fan, it could be advantageous to select a unit with built in harmonic reduction in the form of a filter or an 'active front end'. Since this particular load is now electrically nearly linear, it causes no problems in the installation and has no effect on the supply.

This is also a practical approach if the installation is made up of large numbers of similar items, such as a data centre, where there is now a wide choice of equipment with low distortion power supplies and carefully controlled maintenance and purchasing policies are in place. However, generally, it is not practical to rely solely on equipment selection because purchasing and replacement cannot be sufficiently controlled so other mitigation measures are needed.

Mitigation methods fall broadly into three groups; passive filters, isolation and harmonic

reduction transformers and active solutions. Each approach has advantages and disadvantages, so there is no single best solution.

Passive Series Filters

Simple series band stop filters are sometimes proposed, either in the phase or in the neutral. A series filter is intended to block harmonic currents rather than provide a controlled path for them so there is a large harmonic voltage drop across it. This harmonic voltage appears across the supply on the load side. Since the supply voltage is heavily distorted it is no longer within the standards for which equipment was designed and warranted. Some items of equipment are relatively insensitive to this distortion, but others are very sensitive. Series filters can be useful in certain circumstances, but should be carefully applied; they cannot be recommended as a general purpose solution.

Isolation Transformers

As mentioned previously, triple-N currents circulate in the delta windings of transformers. Although this is a problem for transformer manufacturers and specifiers - the extra load has to be taken into account – it is beneficial to systems designers because it isolates triple-N harmonics from the supply.

Active Harmonic Conditioners

These can track harmonics on real time basis and regularly eliminates harmonics thus improving power quality. These filters/conditioners are very expensive and are used for critical applications.

Summary

Issues and disturbances in electrical networks arising due to Poor PQ are the root-cause of several business problems including productivity losses, downtime, loss of reputation and good-will, customer dissatisfaction and much more. The quality of electrical power is an important contributing factor to the development of any country and this can be achieved through continuous power quality monitoring which helps detect record and prevent power quality problems. The historical data collected through continuous PQ monitoring systems can be leveraged to build predictive maintenance models for vital assets using advanced data analytics technologies.

Continuous Power Quality monitoring provides a real-time “Health Check” of a facility's power system and must be viewed as a vital and integrated part of power system to maintain its reliability. However, given the traditional reactionary approach to measure, analyse and

improve PQ, it is still viewed as an additional cost by most stakeholders.

The relatively high level of investments in establishing a continuous PQ Monitoring infrastructure is one of the biggest concerns when it comes to widespread adoption. However, with falling computational costs and large-scale availability of economical options to monitor PQ, the trend in continuous monitoring will only continue to rise.

Conclusion

Virtually all modern electrical and electronic equipment involves some form of power control and so is a non-linear load. Linear loads are comparatively rare – undimmed filament bulbs and uncontrolled heaters being the only common examples.

A range of design strategies and mitigation techniques are available to mitigate the effects of harmonics in installations and to comply with any harmonic pollution regulations. Each successful strategy to prevent future problems will be a combination of good design practice, the right electrical equipment, and good maintenance.

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INDOOR AIR QUALITY & THERMAL COMFORT: CONCERN & MITIGATION

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Abstract

Everybody wants to breathe fresh and healthy air. A normal person breathes in nearly 13000 litres of air/day. We spend almost 90% of our time indoors in offices, home & often stay inside shopping malls even during holidays. There is much greater risk of adverse health effects from chronic low levels of exposure to indoor air pollutants over time. The sources of indoor air pollution are everywhere- Building materials, Combustion appliances (cooking), Chemical products and office Equipment etc. The common diseases that result from indoor pollution are dryness or irritation of eyes, nose, respiratory tract and throat, dizziness, fatigue, headache, irritability, lethargy and nausea, allergies, asthma, hypersensitivity pneumonitis and Legionnaires' disease, lung cancer and sick building syndrome. Volatile compounds can result in damage to the liver, kidney, blood system and the central nervous system [1].IAQ can be improved by removal of source of indoor contaminants, use of Air purifier, enhanced ventilation (40 CFM/person), having indoor plants that purify air and placement of portable water fountain. Adaptive thermal comfort models are progressively being adopted in Asian Countries and same also incorporated in our National Building Code (NBC) 2016.

Introduction

Indoor Air Pollution may be termed as chemical, biological and physical contamination of indoor air. Indoor air may be several times more polluted than the ambient air and cause a lot of negative impacts to our comfort, health & productivity. IAQ is the quality of the air inside buildings as represented by concentrations of air contaminants and thermal conditions that affects our health and comfort.IAQ is evaluated based on health and comfort. According to ASHRAE Standard 62.1, for an acceptable IAQ, there should be no known contaminants at harmful concentration, while a substantial majority - say 80% or more of the people exposed - do not express dissatisfaction.

Surface dust and carpets are reservoirs of fungi, VOC and dust mites which may be released when disturbed resulting in adverse effects on health. Prevalence of symptoms found in buildings with outdoor air supply less than 22 CFM/person [2].Occupant is exposed to 50 to 300 different individual VOCs, each present in µg/m3. This complex 'chemical soup' frequently results in odors that lead to complaints by the occupants in these non-industrial indoor environment. In new office buildings, total VOC concentration at the time of initial

occupancy is often 10 to 50 times higher than outdoor air.

Indoor air Contaminants

There are eight major indoor air contaminants.

a) Radon: It is commonly found in soil and building construction materials, especially those materials made of granite which have higher Radon exhalation rate than other terrestrial material. It is colorless, odorless radioactive gas. Radon gas is dangerous and may cause Lung Cancer.

b) Indoor aerosol: These are suspension of particles in air. A common category of indoor aerosol is particulate matters (PM) of various small sizes. These are smaller than the diameter of a hair and cause negative health effects such as development of chronic lung disease and increasing severity of asthma attacks in children.

c) Volatile organic compounds (VOCs): These are extremely diverse kind of gases. Many items at home contain VOCs, for example, cleaning products, furniture,paints, pesticides, adhesives etc. There are three common VOCs:

i. Formaldehyde: It is commonly found in furniture.

ii. Tetra-chloro-ethylene: It is commonly used in laundry.

iii. Benzene & derivatives: These comprise 60% VOCs found in Urban outdoor air.

d) Semi-VOCs: These have lower volatility. Phthalate is an example of semi-VOC which is used widely as plasticizers, cosmetics, plastic toys and food packaging.

e) Surface level Ozone: It is released from printers and photocopiers in Indoor air. Since Ozone is a strong oxidizing agent, it can react with the organic materials that make up our body and damage our lungs once inhaled. The matter becomes worse when NOx &VOCs in outdoor air (from vehicles) in presence of Sunlight (especially in summer) generate Ozone which sometimes crosses threshold limit (100µg/m3—8 Hr) in Delhi.

f) Combustion Products: The pollutants from combustion can be gas or particles. They usually come from incomplete combustion of fuels such as natural gas, liquefied petroleum, gas, fuel oil, kerosene, wood or coal. The common pollutants from combustion are: carbon monoxide, nitrogen dioxide, particles, sulfur dioxide, unburned hydrocarbons and aldehydes.

g) Bio-aerosols: These are airborne particles, large molecules or volatile compounds that

contain some biological materials. There are three types of Bioaerosols-bacteria, fungi and viruses. These contribute to sick building symptoms and building related disease. We should use Solar Radiation for cleaning indoor spaces.

h) Asbestos: It was widely used for building construction. When asbestos-containing materials are damaged, asbestos fibers are released. Tiny asbestos fibers remain in our body and cause negative health effect and even lung cancer.

Clean room applications and standards

It is a specially designed and constructed room in which the supply, distribution, and filtration of air, material of construction and operating procedures are regulated to control airborne particle concentration to meet appropriate level of cleanliness. Cleanrooms are used in hospitals to prevent disease transmission and infection in operating rooms. The cleanroom is also a valuable tool in both pharmaceutical industry and the semiconductor industry to ensure product quality. Particle concentration is used to evaluate a cleanroom. The smallest particle that a human can see is about 50 microns in diameter. The diameter of a bacteria is about 1 micron. In the cleanroom, the main source of contaminant is from people. Other sources of contaminants include the ambient, surrounding and the equipment. Different activities cause different level of particles as shown in Table-1.

Table-1

Sl. No.	Activity	Particles (≥0.3 µm)
1.	Sitting or standing with no movement	100,000
2.	Sitting or standing but with minimal head, forearm and hand movement	500,000
3.	Sitting or standing with average arm and body motion	1,000,000
4.	Changing positions, such as going from sitting to standing	2,500,000
5.	Slow-speed walking (e.g. 2 Km/hr)	5,000,000
6.	Average-speed walking (e.g. 3.5 Km/hr)	7,500,000
7.	Fast-speed walking (e.g. 5 Km/hr)	10,000,000

Quality and Standards of Clean room

Quality measures number of particles per unit volume. Particles per cubic meter are measured in ISO 14644-1 standard while US Federal standard '209D' measures particles in per cubic feet. Higher the ISO/Class number, the more the particles present and the cleanliness of the room is loweras shown in Table-2.

Table-2

Class	Maximum particles/m^3						US Federal Standard	Air change rate/Hr
	(≥0.1 µm)	(≥0.2 µm)	(≥0.3 µm	(≥0.5 µm)	(≥1 µm)	(≥5 µm)		
ISO 1	10	2.37	1.02	0.35	0.083	0.0029	-	-
ISO 2	100	23.7	10.2	3.5	0.83	0.029	-	-
ISO 3	1,000	237	102	35	8.3	0.29	Class 1	-
ISO 4	10,000	2370	1020	352	83	2.9	Class 10	300-540
ISO 5	100,000	23,700	10200	3,520	832	29	Class 100	240-480
ISO 6	$1.0x10^6$	237,000	102000	35,200	8,320	293	Class 1000	150-240
ISO 7	$1.0x10^7$	$2.37x10^6$	$1.02x10^6$	352,000	83,200	2,930	Class 10000	60-90
ISO 8	$1.0x10^8$	$2.37x10^7$	$1.02x10^7$	3,520,000	832,000	29,300	Class 100000	5-48
ISO 9	$1.0x10^9$	$2.37x10^8$	$1.02x10^8$	35,200,000	8,320,000	293,000	Room Air	--

Methods to maintain Cleanliness

There are four methods that are used in cleanroom to maintain cleanliness.

1) Positive air pressure: It is applied in the cleanroom to prevent contaminated air flowing in room from outdoors.

2) Filtration: All the air, entering the room, first passes through High Efficiency Particulate Air (HEPA) or Ultra Low Particulate Air(ULPA) filter to filter the particles and the other contaminants and subsequently circulated in the room.

3) Construction material: It should be carefully selected for the cleanrooms. For example, the floor, walls and other considered areas should be easy to clean in the cleanroom to avoid the accumulation of dust and other particles.

4) User Protocols: Items people use in the cleanroom like pencils, papers and the cleaning tools have to be carefully selected and gloves and masks are used.

Methods of Airflow in Cleanroom

There are mainly two types of cleanrooms. One is turbulent ventilated room, where the air flow is non-unidirectional. The air flows from the ceiling and then mix with the room air to remove airborne contamination through air extraction points at the bottom of the wall. The air changes are normally equal to or greater than 20 per hour, much greater than ordinary rooms such as offices.

The other type of cleanroom is unidirectional air flow cleanroom, where the air flow is laminar. Higher efficiency filters are installed across the entire ceiling of the cleanroom. The supply air sweeps across the room in unidirectional way at the speed of around 0.4 meter per second and exits through the floor with airborne contamination. This system uses more air and energy than turbulent air flow ventilated cleanroom. But because of directed air movement, it minimizes the spread of contamination within the room and sweeps it out through the floor.

Air Purifier

Indoor air can be 3-5 times more polluted than outdoor air. Indoor air quality can be improved by using air purifiers/cleaners. An Air purifier has two components, blower and filter. It can be portable or installed in the air duct to purify the air that flows into the room. Air purifier filters by mechanical means, electronic means, or in a hybrid manner as shown in Table-3.

Table-3

Air Purifier Type	Air Cleaning Technology	Particles Collection Mechanism	
		Small Particles d_p<0.1 µm	Large Particles d_p>1 µm
Mechanical	Filtration –Particles are *trapped directly* on filters	Brownian diffusion	Interception & Impaction
Electronic	Removal– Particles are *charged and deposited* on surfaces	Diffusion charging	Field Charging
Hybrid	Combined use of the *filtration and electrostatic techniques* ✓ To achieve *higher removal efficiency* ✓ To lower the cost of filters (electret filters)		

Clean air delivery rate (CADR) is used and measured in cubic feet per minute to evaluate the performance of air cleaners.

CADR represents the amount of clean air coming out of air cleaner on its highest fan speed.The efficiency of air cleaner depends on the particle size. Capacity requirement of air cleaner depends on room size. To calculate the CADR needed for a room, multiply the CADR of the air cleaner with 1.55. The result is room size in square feet, with ceiling height of about 8 ft. Therefore, an air cleaner with 100 cfm is suitable for a room of 155 square feet.

Building Related Health Issue

Sick building syndrome (SBS) and building related illness (BRI) are the two common building related health issues, caused by poor indoor air quality.

Ways to mitigate SBS and BRI

i. Remove or modify the air contaminant sources.

ii. Enhancing ventilation rates to extract the indoor air contaminants.

iii. Air cleaner/purifier can also remove indoor air contaminants.

iv. Certain common indoor plants like Snake plant, Money plant, Areca palm & Spider plant, as shown in Fig.1, provide a natural way of removing toxic agents such as benzene, formaldehyde and trichloroethylene etc from the air, helping neutralize the effects of sick building syndrome [7].

v. Indoor water fountain, as shown in Fig.2, also improves IAQ.



Snake Plant	Money Plant	Areca Palm	Spider Plant	Indoor Water Fountain
Fig.1				Fig. 2

Thermal Comfort

According to ISO 7730 standard, thermal comfort is defined as the condition of the mind which expresses satisfaction with the thermal environment. Parameters that influence thermal comfort are metabolism, clothing value, humidity value, air speed & air temperature.

Metabolism is a chemical reaction process in our body to produce energy and depends on muscular activity as shown in Table-4. It is measured in 'Met'. One 'Met' is equal to 58.15 W/M^2. A normal adult has body surface area of about 1.7 M^2. A person in thermal comfort with an activity level of 1 'Met' has a heat loss of about 100 Watts.

Table-4

Activity	Sleeping	Sitting in office	Teaching	Running
Metabolic Rate(Met)	0.8	1.2	1.6	9.5

Clothing reduces body heat loss due to insulation effect. Clothing is classified according to its insulation value. Unit of measurement of clothing insulation is 'clo'. 1 'clo' equals 0.155 M^2 °C/W. The entire clothing insulation is summation of all clothings on our body. 'Cool Biz' campaign started in Japan, recommends light clothing having low 'clo' as thermostat of Air Conditioners is mandated to be set at 28°C.

Comfort Temperature (Tco)

It is function of clothing insulation, metabolic rate and relative humidity.

Thermal Comfort Measurement

There are two indexes to quantify thermal comfort in a given environment.

1) Predicted Mean Vote Index (PMV): It predicts mean value of subjective ratings of comfortability by a group of a people. It is a 7 point thermal sensational scale as shown in Fig.3. When PMV Index is Zero, it means, thermal environment is comfortable but some individuals are still dissatisfied.

2) Predicted Percentage of Dissatisfied Index (PPD): It predicts dissatisfied people. When PMV Zero, PPD is 5%, meaning 5% people are dissatisfied as shown in Fig.4.

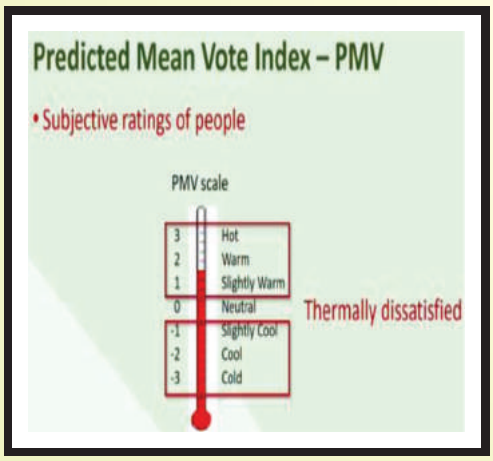


Fig. 3

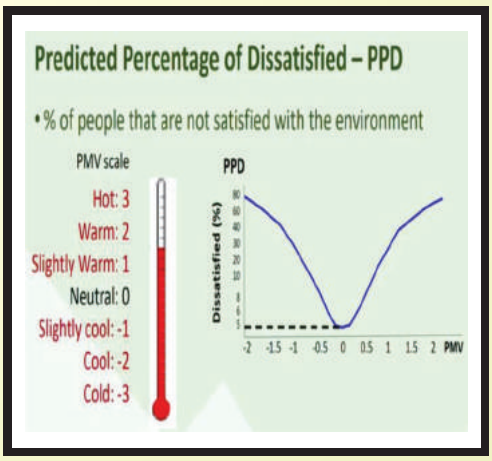


Fig. 4

Ventilation System

Fresh air for metabolism and contaminant dilution is supplied by ventilation system. There are three broad categories of ventilation-Natural, Mechanical & Mixed. Mixed ventilation system uses mechanical system (Fig. 5) for summer & winter and Natural ventilation (Fig. 6) during pleasant season.

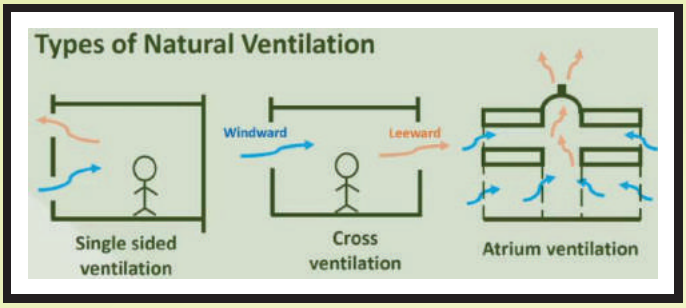


Fig. 5 Mixed Ventilation

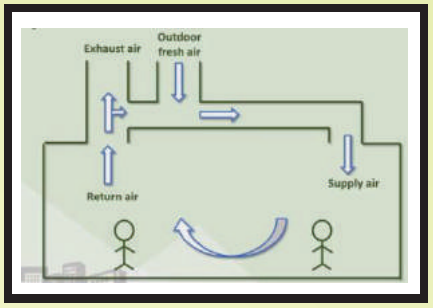


Fig. 6 Natural Ventilation

Ventilation Methods

There are mainly two kinds of ventilation methods used in green buildings, Displacement (Fig 7 & 8) and under-floor air distribution (Fig.9). Demand control ventilation (DCV) is used nowadays in smart buildings. DCV adjusts the outdoor fresh air supply rate automatically based CO_2 concentration which depends upon the number of occupants inside a hall / room.

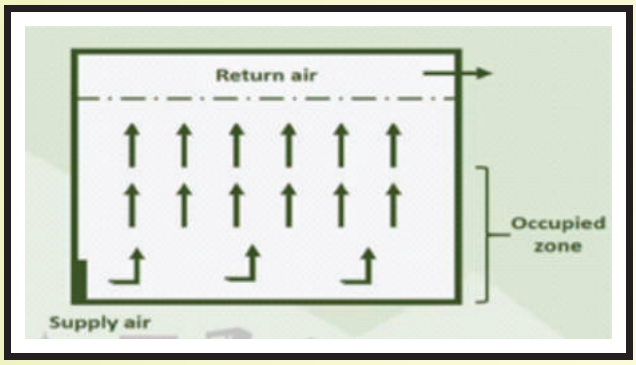


Fig. 7 Active Displacement Ventilation

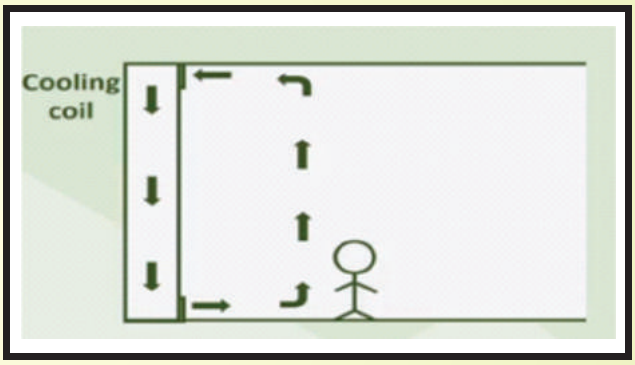


Fig. 8 Passive Displacement Ventilation

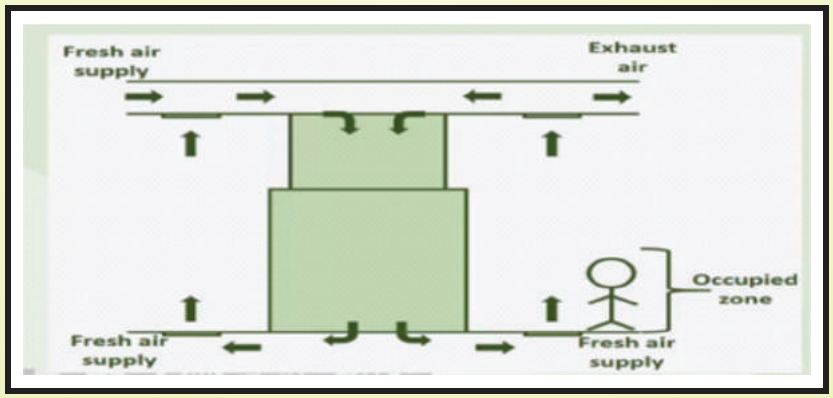


Fig. 9 Under-Floor Air Distribution System

COG Effect-Harvard Study [8]

Twenty-four participants spent six full work days in an environmentally-controlled office space. They were exposed to conditions representative of Conventional, Green & Green+ office buildings.

Conventional building

Typical (~500 µg/m3) volatile organic compound (VOC) levels and 20 cfm outdoor air per person.

Green building

VOC levels reduced to approximately 50 µg/ m^3 and 20 cfm outdoor air per person.

Green+ building, with enhanced ventilation

VOC levels reduced to approximately 50 µg/ m^3 and 40 cfm outdoor air per person.

Results

Cognitive function scores were better in green building with enhanced ventilation compared to others across nine functional domains, including crisis response, strategy and focused activity level.

Adaptive thermal comfort

Occupants' connection to the outdoors and control over the immediate environment allow them to adapt to (and even prefer) a wider range of thermal conditions than is generally considered comfortable.

In ASHRAE Standard 55, thermal comfort in commercial buildings is defined as a comfort level that meets the needs of 80% of its occupants. Conventionally, these needs are met by creating a highly predictable and controlled environment through mechanical equipments, such as HVAC.

Comparison of Comfort Temperature in summer with existing research[9]

Area	References	Tempeature for T_c (°C)	Comfort Tempeature T_c (°C)
Japan (Kanto)	This study (FR mode)	T_g	26.8
Japan (Gifu)	Rijal *et al.* [2]	T_i	26.1
Japan (Kansai)	Nakaya *et al.* [1]	T_{op}	27.6
China	Han *et al.* [3]	T_{op}	28.6
Singapore	de Dear *et al.* [4]	T_{op}	28.5
Malaysia	Djamila *et al.* [5]	T_i	30.1
Indonesia	Fedriadi and Wong [6]	T_{op}	29.2
Nepal	Rijal *et al.* [7]	T_g	21.1–30.0
India	Indraganti [8]	T_g	29.2
Pakistan	Nicol and Roaf [10]	T_g	26.7–29.9
Iran	Heidari & Sharples [11]	T_i	28.4
UK	Rijal and Stevenson [12]	T_i	22.9

Note: T_g: globe temperature. (°C), T_i: indoor air temperature. (°C), T_{op}: operative temperature. (°C).

Conclusion

Ventilation plays a very important role in diluting concentration of pollutants in indoor environment. Harvard's COG EFFECT Study reinforces the long held belief that apart from thermal comfort, enhanced ventilation (40cfm/person) is essential for proper Cognitive Functions. Often it is observed that though thermal conditions are maintained yet high concentration of pollutants like VOCs, CO, CO_2 and NOx in indoor air adversely affect our health and productivity.

By adopting appropriate clothing insulation and with adaptation in summer and winter, a person may feel comfortable in wide range of temperature say 15°C to 30°C without resorting to artificial cooling & heating when provided with adequate ventilation. National Building Code (NBC) has also migrated from fixed thermal comfort in NBC-2005 to adaptive thermal comfort model in NBC-2016 and recommended temperature of 26°C & 18°C in summer & winter respectively.

There is a need to have clothing standard in the country so that people wear clothes as per season i.e. high 'clo' in winter and low 'clo' in summer. If Japan can enforce 28°C setting of thermostat of Air conditioner in summer despite of relative high Humidity, why can't we do the same?

Buildings consume nearly 30% of total energy. HVAC in buildings accounts for nearly 70% of total energy consumption. Hence adaptive thermal comfort standards will help India meet emission reduction target which stipulates 35% reduction by 2030 of 2005 level.

There is increasing trend to install unitary (split & window) type air conditioners for big rooms and halls having several work stations. Thermal conditions of such spaces are maintained but often high concentrations of pollutants/contaminants are found in absence of mechanical ventilation/ treated fresh air. There is growing trend not to open window for sun light and ventilation. Architecture design of the buildings should promote natural ventilation. Natural ventilation should be resorted to improve IAQ during pleasant outdoor weather conditions. Demand Control ventilation systems should be used to improve indoor air quality.Both passive and active Night Ventilation are also capable of reducing the cooling energy demand and improving the indoor thermal comfort for occupants in the buildings with significant thermal mass [10].

The current methods of measurement of chemical and microbial levels are expensive and insufficiently precise for low level present in the office. Hence it would be prudent to have adequate ventilation to have acceptable quality of indoor air apart from thermal comfort to avoid Sick Building Syndrome and Building related illness.

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HARNESSING SOLAR ENERGY FOR METRO TRAIN OPERATION

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Abstract

Energy is a crucial input for economic growth. Currently, India is the third largest energy consumer in the world. India's energy policy focuses on developing alternative sources of energy like nuclear, solar and wind energy to meet the demand of its growing economy. Indian Government has announced an action plan to make India energy independent country by 2030.

For a Metro system, electricity is the main input cost to the operational expenses. The peak power requirement of Delhi metro is 200 MW. In 2017-18, the total energy consumption of DMRC was approx 825 MU and electricity bill was about 35% of total operating expenses.

In order to reduce carbon footprints and to mitigate the impact of electricity price rise of about 20% per annum in the period of 2009 to 2014, DMRC decided to explore the possibility of installing rooftop top solar plants on its premises.

In DMRC, installation of rooftop solar plants on curved/inclined roofs of metro Stations / Depots is an innovative initiative; no such plants existed on Metro/Railways either in India/abroad earlier. The structures for mounting solar modules and features for accessibility to these difficult roofs were designed through application engineering, and the associated challenges have been carefully navigated. Innovative designs for mounting structures have been adopted.

Introduction

Delhi Metro Rail Corporation Limited (DMRC) was registered on 3rd May 1995 under the Indian Companies Act, 1956 with equal equity participation of the Government of the National Capital Territory of Delhi (GNCTD) and the Central Government. Main objective of DMRC is to Plan, Design, Construct, Operate & Maintain a World Class Metro Network in National Capital Territory of Delhi & adjoining National Capital Region (NCR).

DMRC has operational network of 9 lines having 236 stations covering a distance of 327 kms in Delhi and National Capital Region.

DMRC's Commitment to Environment and Sustainability:-

DMRC recognizes the importance of protecting the natural resources of earth. We believe in

good environmental governance in all our activities. Accordingly, DMRC is engaged in developing and putting in place procedures and control measures to safeguard the environment.

DMRC takes all possible steps to preserve environment at all stages from “construction to Operation”.

Innovation drives DMRC's commitment to be a clean and green transport. Array of initiatives have been taken, one of the important one being tapping of the solar energy.

Brief Overview of Activities in Renewable Energy

In order to reduce carbon footprints and to mitigate impact of electricity price rise, in 2014 DMRC decided to go SOLAR and a dedicated Solar team was constituted.

DMRC has adopted Two – pronged strategy (Roof tops Solar Plants and Ground mounted / Off – site Solar Plant) for use of Solar Energy:-

Roof tops Solar Plants

It was felt that with significant solar footprint in National Capital Region, roof tops in DMRC premises (Stations and Depots) offered good potential to harness Green Solar energy due to the following:-

- Abundant shadow free solar irradiance readily available
- DMRC's own Grid network facilitating use as Captive plants,
- Load availability throughout the day, throughout the year

DMRC has successfully commissioned more than 25 MWp capacity roof-top solar plants till date. In an effort to mitigate impact on environment, DMRC has decided to use all its roof-tops (wherever feasible) for generating electricity through Solar. Efforts have been made to integrate solar PV power plants with the structures of upcoming depots and stations.

It all started in October 2012 when DMRC signed a Memorandum of Understanding with M/s GIZ, Germany to develop a “feasible business model using solar photovoltaic technology” for electricity generation. DMRC along with M/s GIZ carried out the detailed assessment study. An MoU was signed by DMRC with SECI (Solar Energy Corporation of India); a Govt. of India Company in September 2013. Subsequently, DMRC signed PPA with Sun Edison in Feb. 2014 and ultimately the first roof-top Solar Plant on a Metro station was commissioned in June 2014. It was dedicated to the nation by Hon'ble Urban Development Minister (UDM)

on 11th August 2014. It is worth mentioning that this was the biggest solar plant on roof-top of any Metro / Railway station in India under RESCO Model, at that point of time.

As per DMRC Solar policy, DMRC planned to commission 20 MWp rooftop solar plants by Aug 2017, which was achieved ahead of time schedule and Power Purchase Agreements (PPA) for total 35 MWp have already been signed till date.

In DMRC, installation of rooftop solar plants on curved/inclined roofs of metro Stations / Depots is an innovative initiative; no such plants existed on Metro/Railways either in India/abroad earlier. The structures for mounting solar modules and features for accessibility to these difficult roofs were designed through application engineering, and the associated challenges have been carefully navigated. Innovative designs for mounting structures have been adopted.

Solar installation in DMRC



The metro corridor from Badarpur to Faridabad 'dedicated to the Nation by the Hon'ble Prime Minister of India' in Sept. 2015, became the first metro rail corridor in the world to meet its daytime auxiliary Power requirement from Solar Power.

Financial aspect of Solar PV installations

All the Solar Power Plants pursued by DMRC are based on RESCO Model, wherein the capital cost is being invested by Solar Developer and DMRC has signed the Power Purchase Agreement for 25 years. DMRC only pays the Energy charges for the actual energy generated as per mutually agreed tariff. In this whole arrangement 'No Capital expenditure is borne by DMRC'.

In fact, DMRC is striving to make all future roof tops “Solar ready” i.e. fully equipped for installing solar panels / plants even at a later date, including facilities like Ladders, Life line, plumbing arrangement for maintenance etc.

A brief status pertaining to Roof-top Solar Implementations

- 25.0 MWp Commissioned So far
- The work for 8.0 MWp (approx.) of Solar Plant is in progress
- 26 MU Solar Energy was generated during FY 2017– 2018.
- Power Purchase Agreement already signed for 35 Mwp.

DMRC is also installing Solar Plants on the premises of Kochi Metro Rail Limited and NOIDA Metro Rail Corporation.

Maintenance Requirement of Solar Panels

Energy generation of solar panels depends on the geographical and physical conditions of the locations where the panels are installed. But, accumulation of dust on solar panels significantly reduces the energy generation of solar plants. At DMRC's metro stations, most of the solar plants are installed on rooftops which are along the road and this leads to accumulation of large amount of dust on the panels. Hence all such plants require cleaning at regular intervals to ensure optimum energy generation of solar plant. On the basis of the maintenance requirements, solar plants have been categorized as follows:

I. Panels installed in residential areas/depots require cleaning on monthly basis.

ii. Panels installed along the roadside on station rooftops require fortnightly cleaning.

Significant increase in energy generation of solar plants (i.e. approximately 20-25% average) was noticed by reducing the frequency of cleaning from monthly to fortnightly.

Maintenance being carried out at Rooftops

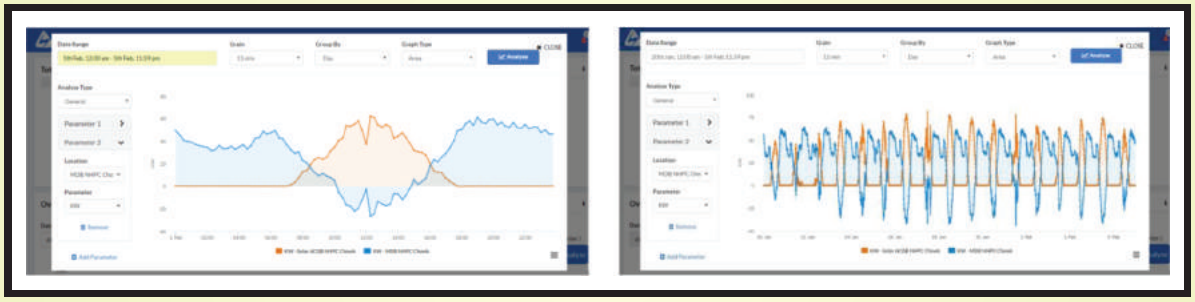


Online Remote Monitoring System for Solar PV Plants in DMRC

DMRC has commissioned Remote Monitoring System for all its Solar PV Plants. Solar Energy Generation from Solar plants is being monitored "on-line".

Generation / Consumption plot for a Typical Day

Generation / Consumption plot for a Fortnight period



The plot in Orange indicates "Solar Generation" and plot in Blue indicates "Grid Consumption". The screen shots show that we are energy surplus in day time and export energy to the DMRC Grid.

Remote Monitoring System is useful in monitoring of generation, efficiency, Capacity utilization factor, CO2 reduction and other useful electrical parameters. It can also monitor data from inverters and weather station which will help in comparing generation with various useful parameters like wind speed, irradiance, temperature etc.

Key features

- Data acquisition system is provided for each and every Solar PV Plant.
- Provision of online monitoring and downloading of the data
- Remote Monitoring system has various sensors, signal conditioning devices.
- The monitoring system has real time clock, internal reliable battery backup and data storage capacity to record data round the clock for a period of minimum 1 year.

- Historical data available for USB download and analysis.

Data is MS Excel compatible and can be represented in tabular & graphical form

Challenges faced and how the same were overcome

DMRC has its own 33 kV power supply distribution network and the solar energy generated from roof-top plants is fed in the 415 Volts system. Generally, the entire solar energy generated from roof-top plants is consumed with in the DMRC power network and No energy is exported to the grid / DISCOMS.

Roofs of metro stations/sheds have curved/inclined roofs instead of conventional RCC roofs and have 25 kV Overhead conductors below these roofs for powering the trains.

These required special innovations for design of Solar panels mounting structures and to create accessibility to these roofs. These issues were addressed by DMRC's team during Design stage.

Moreover, below the Station roofs – as 25 kV Overhead conductor for providing Traction power to the trains, is available, therefore the roof tops can be accessed only after getting power shutdown during Non – revenue hours (i.e. in Night from 02.00 hrs to 05.00 hrs).

For module mounting structures – special requirements included the following:-

- Suitable sealing arrangement with EPDM gaskets & Silicon Sealants were used.
- Module structure has been designed to withstand a wind load of 150 kmph (which is rare in Delhi) and pull-out tests have been conducted at site.
- Special arrangements using cage ladders and Lifelines were provided to ensure safety of the personnel involved in installation and maintenance activities.
- Water supply and power points near the roof were provided for extending temporary power for cleaning of Solar modules at Night. The cleaning/maintenance of modules has to be done during power block in non-revenue hours from 02.00 am to 05.00 am.

Efforts were made to integrate solar PV power plants with the station structures of metro Corridors which are under construction. In light of Faridabad corridor, DMRC has so far been successful in the endeavour and is striving to make all future roof tops “Solar ready” i.e. fully equipped for installing solar panels / plants even at a later date. The facilities like Ladders, Life line, plumbing arrangement for maintenance, etc. are being included in Design of new constructions.

Ground mounted / Off – site Solar Plant

In NCR region land is scarce and very costly, therefore in order to increase the share of solar energy in DMRC's power portfolio, On 17.04.2017, DMRC has signed Power Purchase Agreement (PPA) for 25 years with Rewa Ultra Mega Solar Limited (RUMS), Govt. of Madhya Pradesh to procure 345 Million Units / annum from Rewa Solar Plant at a Levelised Tariff of Rs. 3.30 per unit, to meet substantial amount of DMRC power requirement through clean Solar Energy.

DMRC is the first metro to procure Solar Power on RESCO basis through Inter State Open Access.

Power from this plant is likely to be available to DMRC from March - 2019.

Achievements

Paper on this initiative was presented in International Conference on Climate Action in Hannover, which was very widely acclaimed by diversified delegation from over 30 countries and reported in German Media also.

Solar PV Installations of Faridabad Corridor on the curved Station roofs was shortlisted in Top 20 innovations for the **Prime Minister's Awards for Excellence in Public Administration for the year 2017 under Innovations Category.**

On 25.03.2017, DMRC's solar initiative has been registered under Clean Development Mechanism (CDM) project on Solar, with United Nations Framework Convention on Climate Change (UNFCCC) for any metro or railway system in the world.

Outcomes: - Impact/ Benefits

Besides being a successful model of clean energy generation, this initiative of DMRC has impacted finances of organization in optimistic way. 54 MU Solar Energy was generated in DMRC till December 2018, resulted in cost saving of Energy bill due to the differential tariffs of DISCOM and Solar. By going solar, DMRC has also contributed in reducing 50 Kilo Tonnes of CO_2 emissions.

The Project will help in generating employment by installation and maintenance activities of solar plants, and “indirect employment” for manufacturers of solar panels, inverters etc. In view of success of this project, similar projects are now being taken up by Indian Railways, Kochi Metro, Chennai Metro, Lucknow Metro and NOIDA Metro.

ENERGY EFFICIENCY MEASURES AND GENERATION OF SOLAR POWER IN INSTITUTIONAL BUILDINGS.

Namita Nitesh, Architect, CPWD, Mumbai

Abstract

Buildings play an important role in the field of energy efficiency around the world because of their role as a major energy consumer. The pressure on our limited resources for energy generation has become great and thus, shifting to renewable alternatives has become the only option. A good design principle can help in making our buildings self-sustainable and would also help in eliminating our dependency on electricity.

Introduction

Energy Efficiency is the target for reducing the amount of energy required to provide services. Energy Efficiency is generally achieved by adopting a more efficient technology or by application of commonly accepted methods to reduce energy losses. The Modern buildings are integrated with number of smart appliances, thereby increasing the use of electricity and exploitation of non-renewable resources. This has in turn led to many environmental issues which can mitigated only by using renewable sources of energy.

One of the most important renewable source of energy is the solar energy which is plentiful and also the cleanest kind of energy known, as it is pollution free. The solar energy is generally utilised in the form of Solar Power which is derived with the help of photovoltaic effect which captures the sun's energy thereby converting it into electrical energy.

History of using Solar Energy

The Sun played a very prominent role in most of the ancient civilizations. Almost all ancient civilizations had their God of Sun which represented the power or energy. Many monuments were built considering the importance of the Sun. The famous Stonehenge of the Late Neolithic Age was oriented in such a way that the monument's Heel stone aligns perfectly with rising Sun. The Ancient Egyptians were the earliest known people to have used the Solar Energy in their houses, who designed their houses in such a way to heat them up in winters. The Ancient Greeks provided over hangs and South facing windows in their houses to get heat of the low lying Sun in winter and deflected the worst heat in summer. This was the use of Passive Solar Power for regulating the temperatures of their dwellings. The Greeks also developed the convex lenses known as burning glasses that could concentrate the Sun's

Rays to ignite fire. In 3rd Century B.C., the Greeks made history, for using Solar energy as a weapon to set fire the advancing ships. They used highly polished metal shields to amplify and focus the rays of the Sun to generate fire.



Fig 1: Greeks and the Burning Ships (Source: www.discovermagazine.com)

The Industrial Revolution of late eighteenth and early nineteenth centuries paved way for an expanded role of Solar Power. The French scientist developed Solar power steam engines but were not very useful due to the fact that the Solar powered machines were large, expensive and were less efficient.

The turning point came in the late nineteenth century, when scientists discovered, that a semiconductor could generate electricity if exposed to Sunlight. The photovoltaic effect was observed that when the sunlight strikes a semiconductor like Silicon, the electrons are released creating electricity. The term “Photovoltaic” comes from the Greek word “Phos” meaning light and “volt” means force. This photovoltaic effect became more workable source of energy in the form of Solar Panels. These solar panels were made of Silicon which had better efficiency in terms of capturing Solar Energy.

Measures for Capturing Solar Energy

Solar Energy is the radiant source of energy on which natural processes of life depends. The Sun's energy can be captured to generate electricity through a system of panels/mirrors or through passive solar methods. Basically, there are three Solar technologies – Passive Solar, Photovoltaic Solar and Solar thermal Power System.

Passive Solar Technology

The passive Solar technology is associated with radiation, conduction and natural convection. When the Sunlight strikes a building, the building materials reflect, transmit or absorb the Solar Radiation. This technology is simple, requires minimal maintenance and

has low energy cost. For Solar Passive technology certain aspects are to be considered:

1. The building form should be elongated on an east west axis. The building's south face should receive sunlight during day time. As far as possible, the building should follow the concept of the open floor plan.

2. The interior spaces of the building which require the most light and heating should be along the south face of the building. Less used spaces should be located in the north. The shading devises need be used to prevent summer sun.

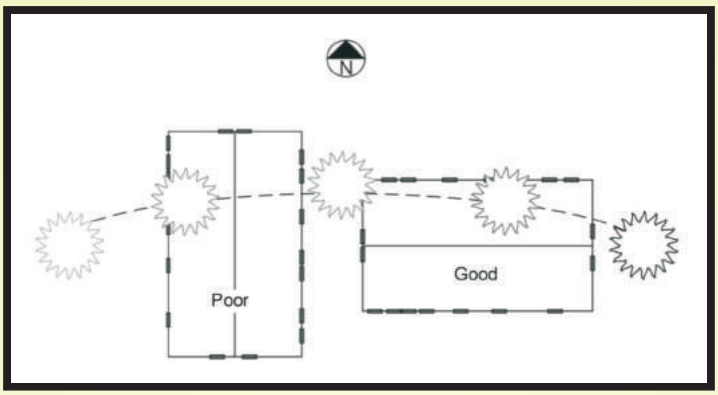


Fig 2: showing orientation of a building Passive Solar Gain. (Source:www.myfloridahomeenergy.com)

The architectural approach that takes into account the solar power is termed as Solar Architecture. The factors like orientation of a building to the sun, material selection for dispersing or absorption of heat, spaces with proper ventilation / circulation of air constitutes the Solar Architecture.

There are basically three approaches to gain Passive Solar Heating i.e. Direct Gain, Indirect Gain and Isolated Gain.

Direct Gain

In this type the actual working/living space acts as a heat absorber like the south facing Glass window which allows solar energy into the area where it strikes and heat up the building materials such as masonry floors, walls etc. The direct gain system normally utilises nearly 60-70% of the Sun's energy striking the window.

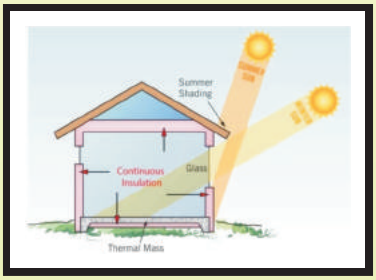


Fig 3: Direct Heat Gain. (Source: wwwcleantechnica.com)

Indirect Gain

In this system, the thermal mass is located between the direct sunlight and living area, wherein the thermal mass absorbs the sunlight striking on it and transfers it to the living space by convection, like Trombe Walls, Roof Ponds etc.

Isolated Gain

The Sunrooms or the Solar Green Houses are the best examples of it, when they are connected to the main area by means of a shared wall. The heat is transferred through radiation or through the vents by means of convection. The direct Sunlight entering the Sun-room is retained in the thermal mass and the air inside the room, which is passed on to the adjacent living room.

Similarly, the Passive Solar Cooling can be achieved through the provision of proper ventilation, keeping in mind the prevailing breeze directions. If a room can have windows only on one side then many widely spaced windows should be provided instead of single window. Wing walls can be provided which would accelerate the natural wind speed due to pressure difference made by the wing wall. The excessive heated area should have a thermal chimney which is a vent near the ceiling which acts as a exhaust outlet.

- **Photovoltaic Solar Technology:** This technology uses solar panels to capture the solar energy and converts or stores it, in the form of electrical energy. These solar panels/cells can be incorporated in the buildings during the design phase as a primary part of electricity supply. The Photovoltaic system (PV system) ranges from small rooftop-mounted Solar Panels on a building of few kilowatts to large utility-scale power stations of hundreds of megawatts. A rooftop system normally re-coups the resources invested in its manufacturing and installation within 2 years. It has a 30-year service lifetime.

- **Solar Thermal System:** Solar thermal power systems capture and concentrate sunlight to produce the high temperature heat needed to generate electricity. The solar thermal systems have solar energy collectors with two main components: Reflectors (mirrors/lenses) that capture and focus sunlight to a receiver. The heat transfer fluid gets heated and related in the receiver to produce steam. The steam is used to rotate the turbine, which produces electricity. The Solar thermal power systems have a tracking system that keeps the sunlight focused on the receiver throughout the day with the changing position of the Sun. This system is also called Solar Concentration system.

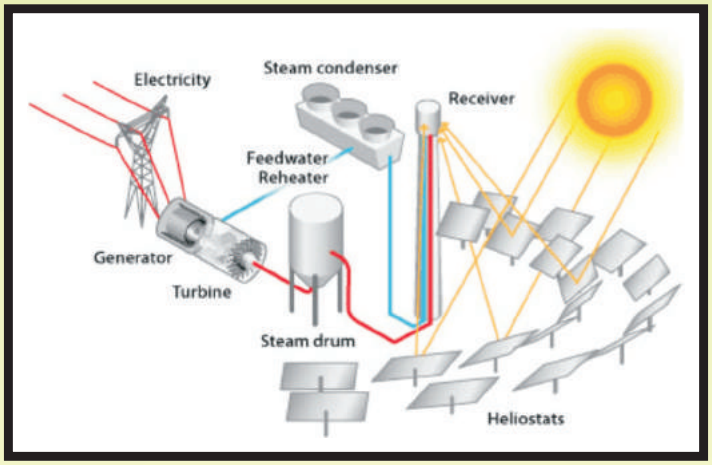


Fig 4: Showing Thermal Power Technology. (Source : www.solarthermalmagazine.com)

Environmentally Sustainable Energy: The Sun is the centre of our Solar System and is the greatest source of energy. According to a study published in "Scientific American" it is found that the Earth receives more energy from the Sun in an hour, than the entire world uses in a year. The Solar energy is considered to be more sustainable than any other source of energy as the sun's energy can be used indefinitely without compromising its future availability. The use of solar energy reduces the Carbon Footprints and can minimize the use of non-renewable resources. The Solar Power systems also operate silently without any noise and air pollution.

It is pertinent to mention that the Solar Energy Corporation of India, under the Renewable Energy Ministry is promoting many Solar Power Projects in the Jammu and Kashmir Region. These projects are expected to spur development in the remote areas of Jammu and Kashmir. The Ladakh region is set to house the largest single location Solar PV Plant in the world.

Merits and Demerits of Solar Power

The Solar energy being environmentally friendly is the affordable solution to our energy demand. There are many merits of using the Solar Power:

1. The Solar Energy is Free and Unlimited. The generation of Solar Power, is non-polluting, does not emit Green House Gases and Harmful waste, thereby cuts our Carbon Footprint.

2. Solar Power is very useful in remote areas where expansion of utility grid is expensive and difficult. It is an affordable and effective solution for isolated houses in rural areas.

3. The Solar Power is versatile, can be used for low-power utilizing equipments as well as for high powered equipments like geysers etc.

4. The system of Solar Power requires less maintenance and has a long service lifetime. The installation of panels in a tilted/inclined manner also helps in self cleansing.

It is also important for us to get familiarize with the demerits associated with the Solar Energy.

1. Solar Energy is not fully reliable Source of Energy. When there is no sun, there is no power generation, that is during night and when the sky is cloudy.

2. The Initial installation cost is high, and use of batteries for storing the Solar Power makes it much more costly, although in the long run, Solar Power is beneficial.

3. The Panels require a large area for installation, which is difficult at many places.

4. The Solar panels cannot be disposed off easily as they have a negative impact on the environment. But, it is pertinent to mention that these panels have a long life span.

Conclusion

The basic understanding of site's wind pattern, terrain, vegetation, sun exposure etc. can have significant effect on the energy efficiency of the building. The land resources have become scarce and buildings in urban areas are densely placed, and are the major consumers of energy. There is need for roof top Solar Power systems to be installed on all buildings. An example is being set by the Central Public Works Department, GoI, which has been installing Solar Panels on the Buildings having flat surface area of 1500Sqm. or more. The CPWD has also signed a Memorandum of Understanding with the Solar Energy Corporation of India (SECI) for generation of solar power by the using of rooftop Solar PV panels in all government buildings maintained by CPWD across the country.

Apart from the roofs the facades of the building can also help in generating electricity and increasing overall energy efficiency of the building. The Solar Facades can be provided in the form of curtain walls. It is further possible to use transparent Solar PV Façade which absorbs energy for Photovoltaic effect, but also ensures heat and light gain in buildings. Solar PV technology is also available in the form of Thin-Film technology Cells which is printed on glass in many thin layers.

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DECODING THE LED PUZZLE: USER'S PERSPECTIVE

Neeraj Singh, Fellow Member ISLE

Abstract

LED lighting has become a necessity due to energy efficiency and long term economy from the considerations of energy bills and thus is beneficial both to the consumer and the society.

The paper discusses the importance of LED lightings from the user's perspectives.

Assurance of Energy Efficiency Promises

There are two main factors promised in the LED lightings, one as life expectancy and other performance. These are to be ensured to the users. Let us examine how these can be ensured.

Life expectancy

Firstly, it should be noted that LEDs, unlike traditional sources, will not turn off suddenly when their working life ends, but will slowly fade their initial luminous flux until they turn off completely. In fact, LEDs do not break (except for manufacturing damages) but decay gradually andconstantly.

The decrease of LED flux, normally after 50,000 hrs, is defined by the working life and is represented by the L70 or L80 mark (ref. fig. 1), which means that the 80% of the initial flux is maintained after 50,000 hrs.

The “B” letter followed by a number ranging between 10 and 50 indicates the quality of the fixture and defines the LED percentage that doesn't retain the declared characteristics when it reaches 50,000 working hours.

Suppose LED life is declared L80/B10 = 50,000 hrs. This means that when the LED reaches 50,000 hours of operation, 90% (B10) of the LEDs will maintain 80% of the initial luminous flux (L80) as shown in Fig. 1.

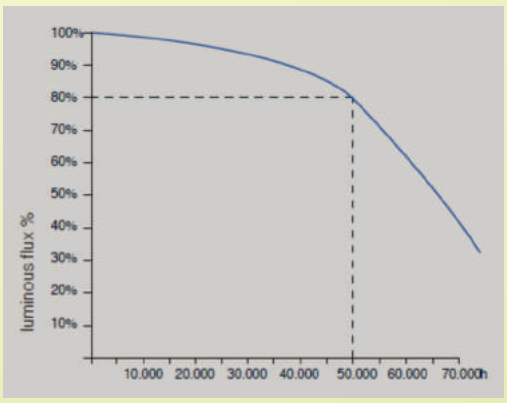


Figure 1: Relation between luminous flux and working hours of LED

Let us take another example. LED life declared L70/B50 = 50,000 hrs. This means that when the LED reaches 50,000 hours of operation, 50% (B50) of the LEDs will maintain70% of the initial luminous flux (L70).

Method to Ensure Working Life and Performance of LEDs as Promised

The following methods can be adopted for the same;

1) Check the LED Type chosen for the application: Unlike conventional light sources (lamps) of the past where fair amount of standardisation was present and there were limited variances in universal ratings, LEDs are continually evolving light sources with numerous types, many also not directly comparable in shape/size/ratings/type of use from manufacturer to manufacturer. However, a basic verification criteria has been illustrated as following;

   - Low / Mid Power Illumination class SMD LEDs (0.2W – 1W) usually individual LED drive current below 50mA – 200mA: These LEDs have High Junction Thermal Resistance (Rth>10^{0}C/W). These are Low cost LEDs meant for use in Indoor or controlled atmospheres, where ambient temperatures (Ta) are maintained around 25^{0}C. : Suited for Indoor Fixtures and advisable life declaration up to 25,000 hrs.

Available in Epoxy Die sizes: 2835 (2.8mm x 3.5mm) / 5630 (5.6mm x 3mm)/ 3030

(3mm x 3mm) etc.These LEDs can be mounted with close spacing of <5mm pitch

These LEDs can be mounted on Aluminium (MCPCB) / FR4 PCB and secured to Heat Sink surface via Thermal Tape/Thermal Paste with Thermal conductivity of 1W/mK or higher.

   - High Power Illumination class SMD LEDs (1W – 10W) usually individual LED drive current ranges between 250mA – 2000mA: These LEDs have LOW Junction Thermal Resistance (Rth< 6^{0}C/W) : The lower the Rth value, better is the heat dissipation from LED Junction to the heat sink. These are rugged professional LEDs meant for use in Outdoor and harsh Industrial atmospheres, where ambient temperatures (Ta) are expected to vary between -30^{0}C to +60^{0}C: Suited for Outdoor & Industrial Fixtures and permissible life declaration 50,000 hrs – 100,000 hrs.

Available in Ceramic Die sizes: 3030 (3mm x 3mm)/ 3535 (3.5mm x 3.5mm) / 7070 (7mm x 7mm)& Epoxy Die Sizes: 5050 (5mm x 5mm) etc.

These LEDs need to be mounted with spacing of minimum 8mm/W pitch in order to ensure adequate heat dissipation from each LED to the heat sink.

surface via Thermal Paste with Thermal conductivity >3W/mK or higher.

- Chip On Board (C.O.B.) LEDs (10W – 255W) Multi Chip Arrays mounted on single die: These LEDs require dedicated heat sink for each COB. Typicaluse of COB LEDs is for Industrial Bay Lights / Wellglass, Retail Spot Lights where dedicated long heat sinks are feasible in luminaire design.

- ENSURE that the LEDs are driven at below 70% of Maximum rated nominal value as specified in LM-80 test report of LED

2) Check the Power Adaptor (Driver) Specifications to Withstand Abnormal Supply Conditions like Prolonged Over Voltage (>270V) / Under Voltage (<130V) / Surge Voltage (>2KV/ 4KV / 10KV / 20KV) / Surge Current (>5KA/10KA) :

   - Abnormal Power Supply kills most LED Lights.

   - Most common occurrences and related failures are of prolonged High Voltage beyond 270V, which exceed the Driver or Power supply units' standard performance band. – In order to protect from such conditions, either the Driver need to be equipped with High voltage cut-off & auto restore feature inbuilt or luminaire be provided with additional Overvoltage / Under Voltage Protection relay.

   - Next common occurrence and related failures are of “Floating Neutral” or improper/ missing Neutral Grounding at Supply Distribution Transformer, which results in high Voltage between Phase and Neutral many times exceeding 360 – 440V. – In order to protect from such conditions too, either the Driver need to be equipped with High voltage cut-off & auto restore feature inbuilt or luminaire be provided with additional Overvoltage / Under Voltage Protection relay.

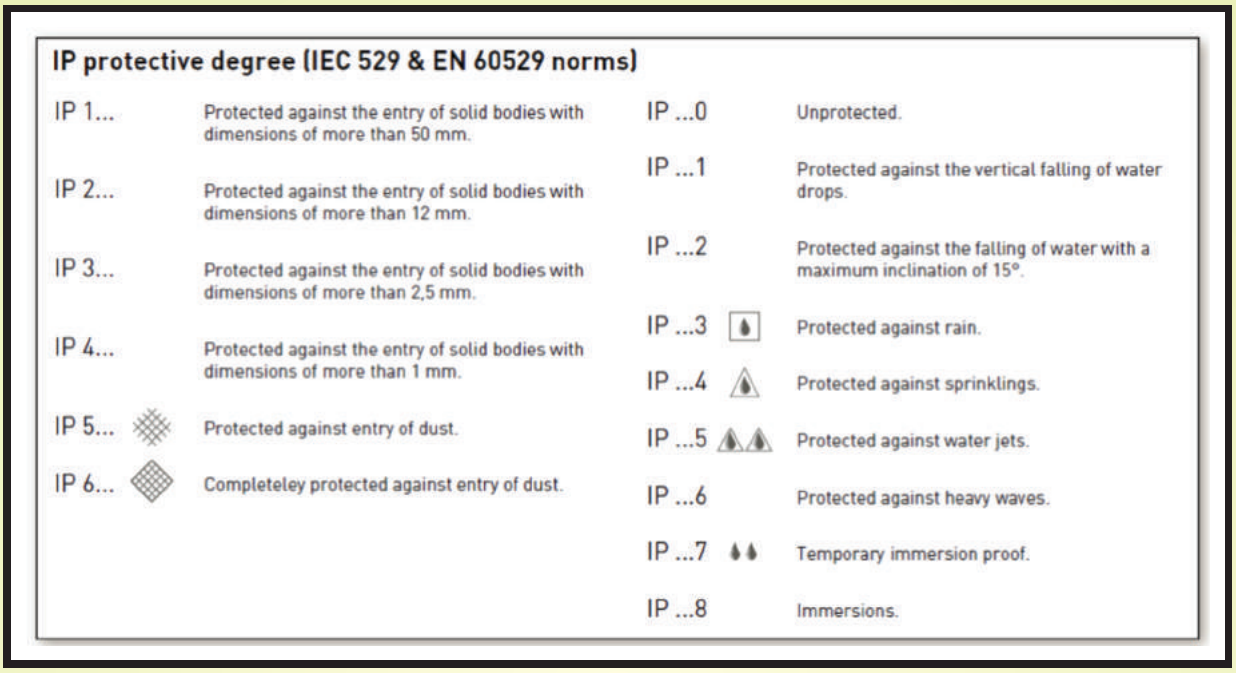
   - Surge Voltages / Surge Currents: These are Transient low time but extremely high magnitude Surges caused by Lightning or Grid Switching. Surges can be between 2KV to 20KV or beyond, and with 5KA to 10KA current occasionally. : Protection against Surges is achieved by – (A) – Internal Surge protector (MOV) provided in Driver / Power Supply Unit or (B) – External Surge Protector (MOV / TMOV based and with / without Overvoltage relay / GDT / Fuse)

3) Check the Mechanical Construction of the Luminaire:

   - Check Heat Sink adequacy – This is dependent largely on type of luminaire and it is up to the luminaire manufacturer to ensure the same. While some luminaires have direct exposed heat sink fins, others can depend on large surface area and increased volume

of air around the heat sink surface where LED PCBs are mounted.

- Ingress / Impact protection ratings of Luminaire - Ensure IP & IK ratings for correct application.



INTERNET OF THINGS - GAME CHANGER IN THE FIELD OF ENERGY EFFICIENCY

C.K.Varma, CE, CSQ (E), CPWD

Abstract

Internet of Things (IOT) is an emerging technology which is sweeping almost every aspect of our life. IOT is also going to play very important role in energy efficiency in future. The paper discusses the measures to be provided to further enhance the efficacy in the field of energy efficiency. It is analysed whether IOT would be helpful in making energy efficiency more efficient.

Introduction

IOT is an emerging technology encompassing almost every sphere of our life in this world whether consumer electronics like music system, comfort equipment like air conditioning or any other system helping in our day to day life like lighting system etc. IOT is linked to objects, human being and cloud defined in information technology as illustrated in Fig.1 like a triangle.

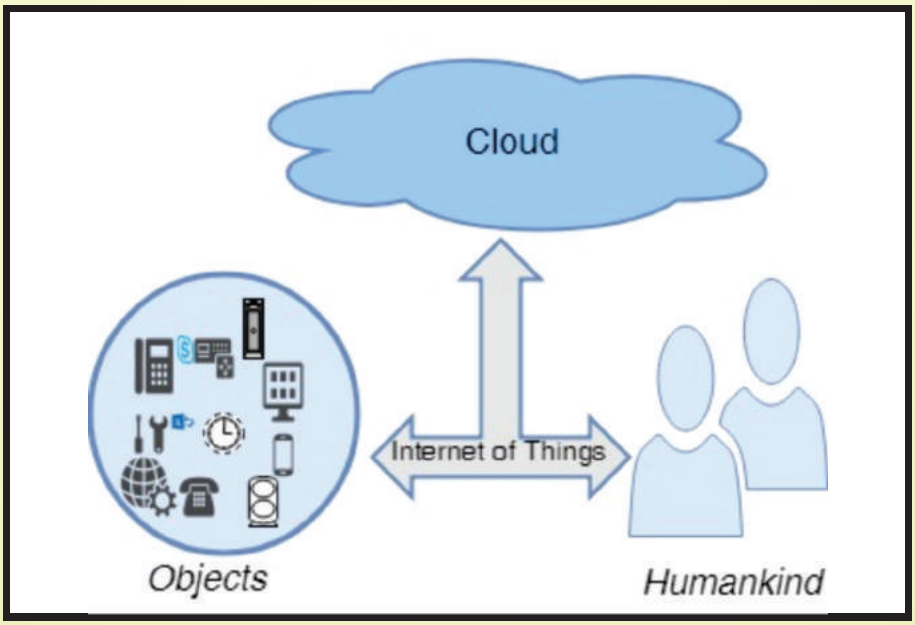


Figure 1: Illustration of IOT

In future, IOT is also going to have close relation in energy conservation and energy efficiency. Controls are going to play important role in IOT, both remote and local. Monitoring of energy equipment and fixtures would be feasible through remote sensing as such they can be used as per requirements.

New and Innovative Technologies

Innovative technology plays a dominant role in energy conservation/ energy efficiency. The emergence of LED in the field of lighting technology has made a significant change in the consumption of energy in our homes and offices. According to one estimate nearly 30% of the energy produced in the country is consumed in building sector alone. Out of this nearly 30% is spent on lighting in the built habitat. Use of LED has changed this consumption significantly to the tune of 50 % of what was consumed earlier. Similarly HVAC consumes about 60% of the energy in the built environment. Use of Energy efficient chillers has also reduced this percentage significantly. Rest 10 % of the energy consumed in the building sector goes in the other usages like air circulation through fan, water supply pumps, vertical transportation like lifts and other miscellaneous services/activities. Here also many technological advances have reduced the consumption of electricity significantly. Thus greater overall electricity conservation is achieved using new technologies aiming for energy efficiency only.

Energy efficiency using new and innovative technologies alone is not sufficient to bring down energy consumption but energy conservation is equally important preventing wastage of energy. The wastage of energy has also to be eliminated while using energy efficient equipments and technologies and the equipments are to be switched off when not in use. If switching on and off of electric equipments when they are not in use can be controlled without human intervention, energy can be conserved using new and innovative technologies.

Leaving this task to machines will therefore be efficient and also will be without human interventions which may or may not be logical always. Sensors and Building Management systems are the answers to this machine based controlling of elimination of wastage of electricity. It is estimated that another one third of electricity can be saved by employing effective and efficient control systems. This also is one of the reasons Energy Conservation Building Code 2017 has included control systems as one of the pre requisites for energy saving in the building sector.

IOT and Energy Efficiency

With the introduction of many new technologies, it is now possible to achieve even higher energy efficiency than with employing control systems only through IOT. With IOT, every equipment in the system communicates with each other within the same eco system and with user through mobile interface. The big data analytics and cloud technology enable intelligent and communicative control system to be available and make energy efficient

system further efficient focused on continuous basis.

A set up of things which includes electronics, software, sensors, actuators and web based connectivity, communication, exchange of data and controls is in a broad way Internet of Things. It is the ability to communicate and transmit information through internet making IOT as a popular technology which is going to sweep almost every aspect of our life in the coming future. Besides improving the quality of life and work, IOT is also transforming our lives enormously. Simple to be accessed and easy to manipulate IOT which is based on IP based system is a great aid in achieving environmental control and thereby controlling the micro climate of any human made system.

Examples of IOT are too many. There can be simple applications or complex ones depending upon the type and size of applications as IOT solutions are sensors and actuators based interacting in an autonomous way on real time basis. For example there can be temperature sensing in a space to control the running of an air conditioner or there can be multiple devices connected in a built space in an interactive mode to achieve energy efficiency of all the services put together. This may therefore involve energy monitoring, energy measuring, demand side management, energy modeling to energy forecasting without disturbing comfort parameters of the occupants all through one technology. This is going to be far more intelligent and complex based on big data analytics unlike the most recent but traditional technologies like Building Management Systems (BMS) and PLC based systems. One of the applications of IOT for controlling the Energy Efficiency in HVAC system has been shown in the Fig. 2 below:-

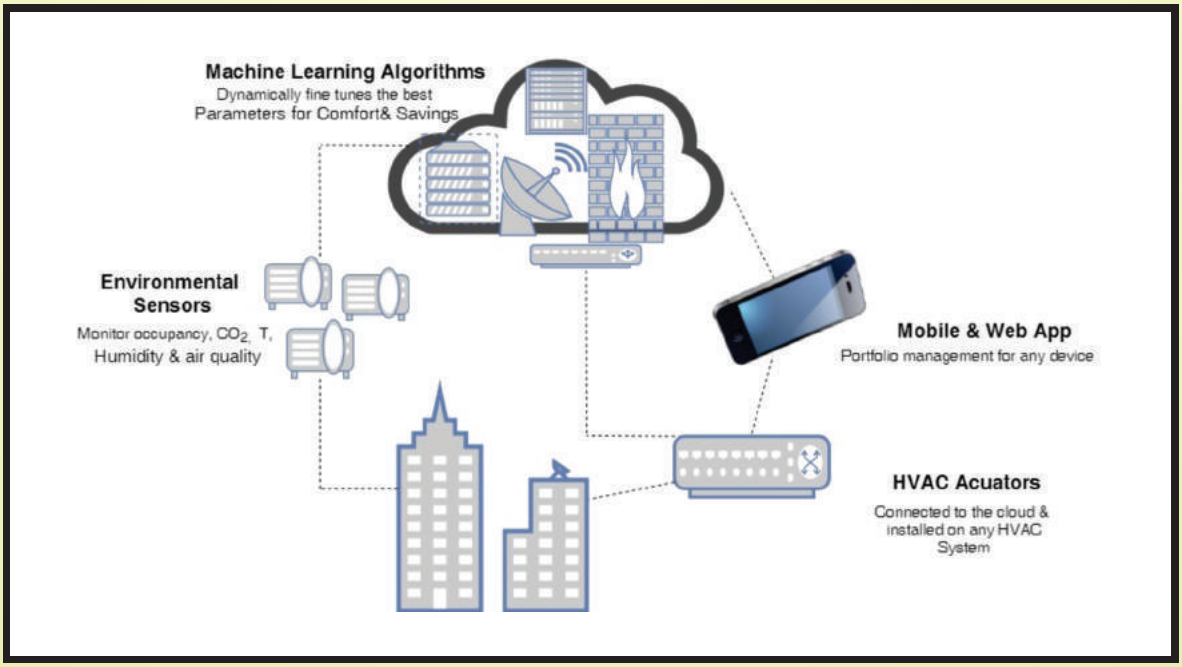


Figure 2: Control of HVAC system through IOT for energy efficiency

With the injection of IOT, already placed energy efficient equipments and systems will be made to communicate with each other and with the surrounding environment, and through analysis of big data so generated, the user through mobile interface will be able to monitor and control the energy consumption. The concept of IOT APP has been explained with the help of Fig. 3 shown below:-

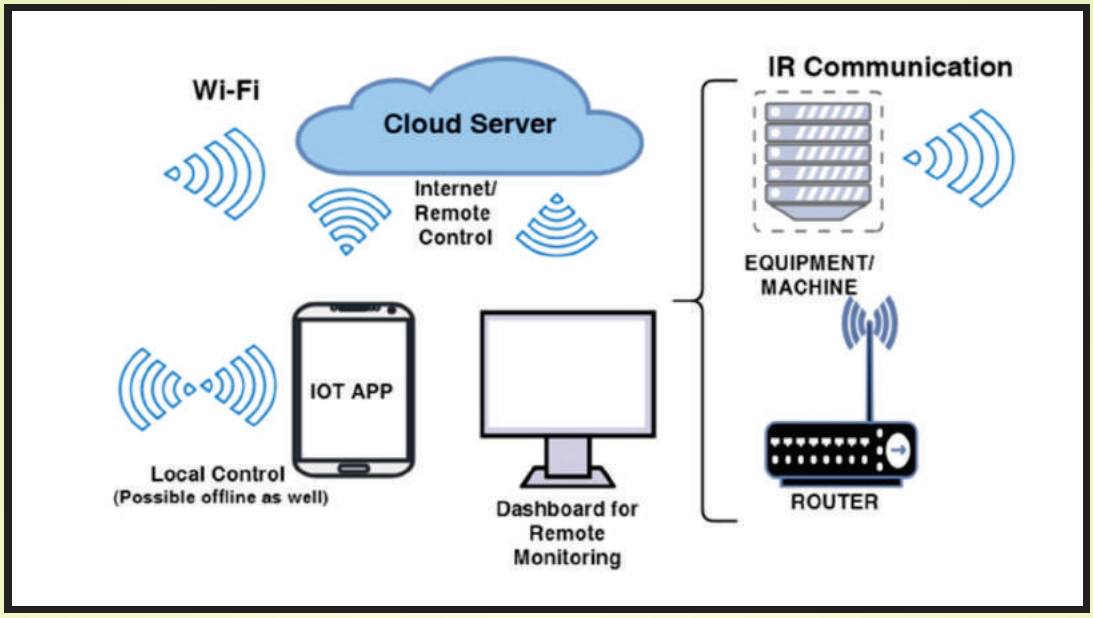


Figure 3: Concept of IOT for energy efficiency

Conclusion

With the advancement of information technology (IT), IOT will play a very important role of energy efficiency. The number of connected objects will be without any limit imposed on the size or nature of equipments which can communicate to each other for efficiency through IOT. Smart phones with IOT apps will be the user interface for control and big data analysis. The impact assessment of IOT in energy efficient buildings is yet to be made but it is certain that this will continue to be big achievement. Further, even IOT will not remain a preferred technology in the domain of energy efficiency in future as it will soon be replaced by BIOT (Block Chain IOT) and machine learning.

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BUILDING GREEN! INDIRA PARYAVARAN BHAWAN- A LUXURY OR NECESSITY OF THE DAY

Rajesh Kaushal, Chief Architect, CPWD, New Delhi

Abstract

As an architect of a Net zero energy/Energy Positive building and a responsible citizen, the following article as a compendium of useful facts for the concerned institution is presented.

After the alarming increase in global warming and threatening decrease in the non-renewable source of energy, it has become a necessity and a compulsion to increase the efficient use of the energy resources materials and developing sustainable concept. Basically the main aim of green building concept is to minimize the demand on non-renewable source of energy, maximize the energy efficiency of these resources, when in use and maximize the reuse, recycling and utilization of renewable resources.

Definition of Green Building

Green Building is the result of efficient use of resources –energy, water, land, materials while creating a positive impact on human health (mental and physical) and on the nature throughout the buildings life cycle.

Green building reduces the impact of built environment on human and nature by:

- Efficient use of resources.
- Increase in work productivity
- Reducing environment degradation.

Perception and Realities about Green Buildings

It is commonly believed that the cost of green building is higher than the normal building; the incremental cost is always relative and depends on the extent of eco friendly features already considered during design. The incremental cost will appear less if the baseline design already at a certain level of good eco-design; it would appear huge if the base design has not considered green principles. It is also a perception that green building has to be air conditioned and it takes more time though once the design is completed and the simulation is done according to the green building parameters there is no delay.

Indira Paryavaran Bhawan

This was achieved in Indira Paryavaran Bhawan (IPB) building through careful site planning, most appropriate building form, and usage of materials which incorporate low embodied energy operating efficiently, easy maintenance, very low effluent disposal and energy production on-site. This is a building with an amalgamation of both active and passive technology.

IPB is one of the simplest yet exquisite example of a green building. It is one of the trendsetter official buildings which was designed and executed by CPWD. It is intelligently designed in every aspect whether it is energy efficiency, reusability, renewability, functionality. The spaces are designed in innovative ways that interest and intrigue will generate in the end user.

Design of a building shall be the result of shall be a result of a design philosophy that focuses on increasing the efficiency of resource usage i.e. energy, water and material while minimizing the impact of the building on Human Habitat and the Environment in general both during the construction as well as during its lifecycles. This is intended to be done through careful site planning, most appropriate building form, usage of materials which incorporates low embodied energy operating efficiency, production on site, needless to state, while meeting the above parameters requirement of the 'Green Building'. The building will be the state of Art in modern amenities and comfort with Intelligent Building Management System which optimizes the energy consumption in the Government programme and to set as Flag Bearer. The Development of the Green Building is 58% higher than the conventional building but substantial savings at the operational level,15-20% annually more than offset the increases capital cost over its life cycle besides imposing reduced burden on the natural environment.

Salient features of IPB are as given in the following;

- Cost : Rs 195 Crores
- Structure : Ground + 7 Storeyed (Superstructure) with 3 Basements (water table 5 m below ground)
- Plinth Area : 32,000 Sqm

General provisions include central Air conditioning (HVAC) 400TR capacity,7 lifts, fire fighting and fire alarm, DG Sets, UPS, BMS and CCTV systems. Special provisions are roof top Solar PV system 930 KWp, fully automated robotic car parking, modular furniture and work

stations, audio visual systems in conference halls, sewage treatment plant 30KLD capacity. The project was started on 28.01.2011and completed on 31.08.2013.

Net Zero Energy and Solar Power Generation

- Capacity of Power generation : 930KWp
- Annual Power Demand : 14 Lakh Units(KWh)
- Annual Power Generation : 14 Lakh Units(KWh)
- Total area of the Solar panels : 4600 m2
- Total area of the system i/c catwalks : 6000 m2
- Photo Voltaic panels : Mono crystalline : 20% efficiency

Salient features of site planning

- Priority for pedestrians in the front with vehicular access on the sides.
- Appropriate building envelope design by orientation specific shading devices and envelope insulation to reduce heat intake.
- Preservation of maximum possible number of trees standing at site.
- Appropriate building envelope design by orientation specific shading devices and envelope insulation to reduce heat intake.
- Eco park within the courtyard shall contain a self sustaining low requirement floor fed with rain water harvesting.

Architectural concept

Prior to the green building concept the building is planned in a way to ensure a welcoming environment and a home to the users that surely does a productive increase in their efficiency. A large atrium (75mx20m) is created in the front of building which gives the building a feeling of grandeur and magnificent and it also helps in ensuring the cross air passage with a water body between the atrium which keeps the environment cool even in the hottest summer ,and decreases the heat island effect. The two blocks north and south are connected with a bridge at a height of 20 m which again create the passage for air to move around giving the building a very modular look.

The environment of the building is kept very interactive; each space is separate yet connected to each other. Every part of the building is visible from the grand atrium.

Energy saving features

Large savings in HVAC system by using high efficiency measures is achieved like pre cooling of air through geo-thermal heal exchange and use of renewable energy in parts. Lifts, toilets, service acres are placed on east and west sides and office areas mainly facing the south and norm to reduce A/C load. Zoning is adopted to create high conditioned areas, low conditioned areas and only ventilated areas and optimizing the air conditioning parameters by opting for ambient air temperature more appropriate to Indian conditions. Other measures adopted include reducing Fan power by using "Displacement Ventilation System" with air supply from the bottom, rooftop solar thermal air conditioning by using Vapour Absorption Method (VAM) Machines and hybridization with PNG fed absorption chillers, use of high efficiency screw chillers using refrigerants which have almost zero ozone depletion potential, use of Recycled waste water for air conditioning, use of permanent, durable and local materials such as sand stone on exterior, use of ECBC compliant designing practices, adoption of Universal design parameters to provide barrier free movement for physically differently abled, intelligent Building Management System to optimize energy usage through Occupancy sensors, Fire prevention and Fighting and Parking management, and highly sensitive Security System including access control using bio metric smartcard readers. Radio frequency Tags, CCTV surveillance etc.

Apart from the above, reduction of conventional lighting load by ensuring 75% day-light use, generation of energy by deploying thin film transparent PV modules on space frame over the terrace, central court-yard and also the floor on southern side, usage of high efficiency lighting fixtures, astronomical/ time switches and occupancy sensors are also the important features of energy efficiency.

The building is designed in such a way that there is free ventilation across the entire building. The two blocks namely North Block and South Block of the building are separated out to create a large central court yard and these Blocks are connected with two connecting corridors having 20 meter spans above 4th floor level. In the middle portion of the North block, huge entrance atrium is created with a clear height of 4 storey. The waffle grid slab at 4th floor level of this north block is 22 m in diameter with a central cutout of 4.6 m diameter. Similarly entrance in South Block has been provided with clear four storied height. The Building has large span Trusses at terrace and Space Frame in central courtyard to support Solar Panels. The Building has also been provided with adequate no. of shafts to enable smooth access to various MEP Services.

Building as an Engine

The wind direction is such that it is covering the overall envelope of thepassing air and causing the air to cool down because of the water body present in the atrium. The air is like sweeping across the whole atrium and bringing down the load requirement of the building for ventilation.

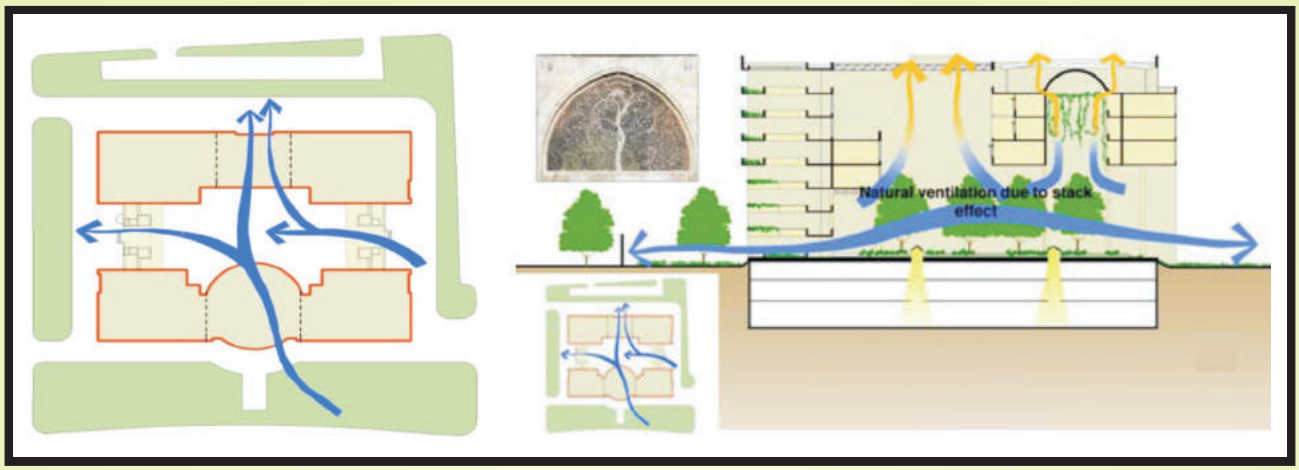


Fig 1: Wind direction across the building envelope

Fig. 2 is explaining the solar system working, geothermal energy use to minimise the energy load, hybrid ac system for ventilation and cooling, day lighting design with perimeter & inner courtyard fenestration, RCC reflective shelf with reflective surface.

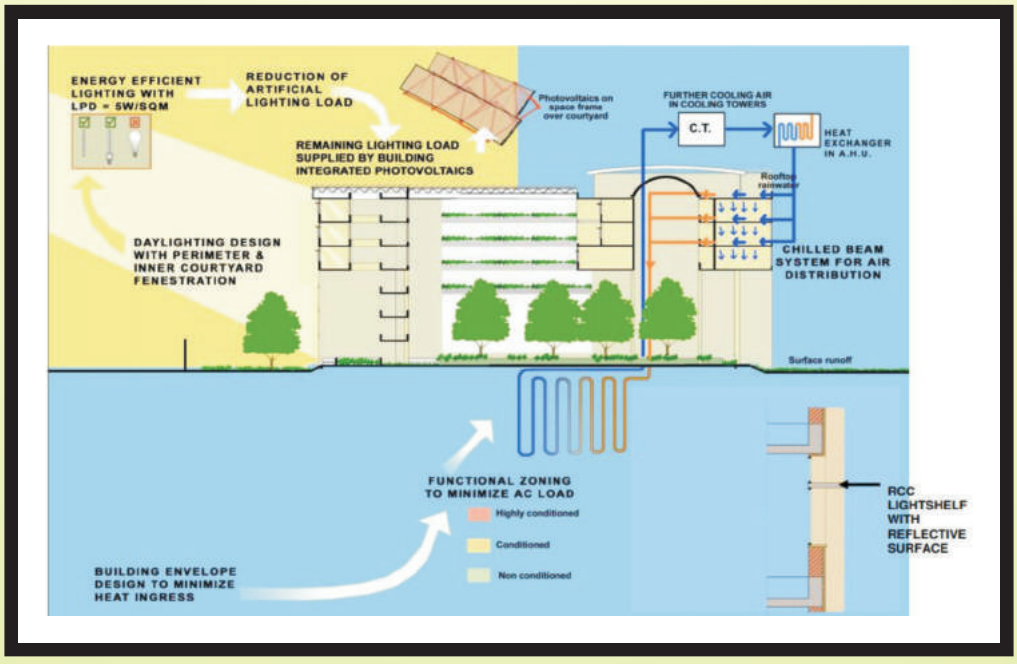


Fig 2: All the active system used in the Indira Paryavaran Bhawan.

Fig. 3 explains the solar system working, geothermal energy use to minimise the energy load, hybrid ac system for ventilation and cooling, day lighting design with perimeter & inner courtyard fenestration, RCC reflective shelf with reflective surface.

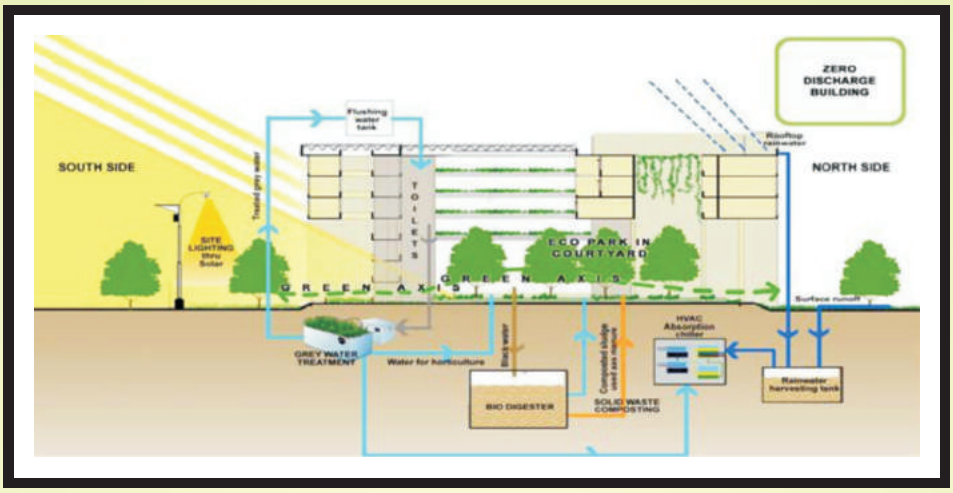


Fig 3:The system explaining the zero discharge building

Figure 4 shows the plan of the building Indira Paryavaran Bhawan showing the two blocks and the landscaping in the atrium and the water body. The toilet blocks are placed in such a way that it decreases the direct heat gain to the building envelope. Figure shows North block and south block of the Indira Paryavaran Bhawan and the huge atrium between the two blocks.



Fig. 4: Landscaping plan of IPB

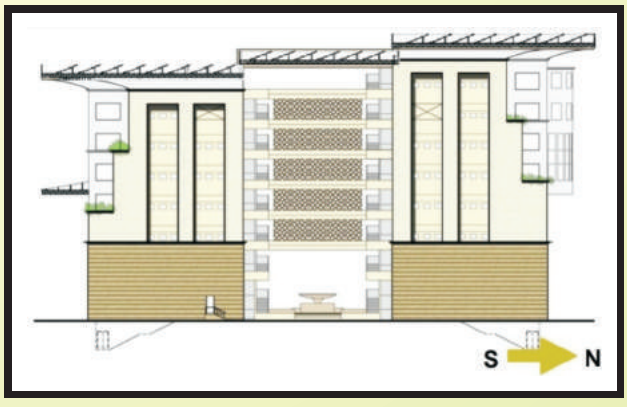


Fig. 5: North and South blocks with atrium

Stone Cladding

Two types of stone cladding upto 2-1/2 storey height with Dholpur stone (White sand stone) used in this project, one over flyash brick work following CPWD specifications and another

on AAC block masonry with key stones. ZERO BUILDIN

AAC block wall:

Outer walls are made with 300 mm thick Aerated autoclaved concrete blocks(AAC) have density almost 1/3rd that of bricks thereby withholding capacity of blocks was found to be inadequate for stone cladding. Key stones of width 300 mm were used to provide support to cladding stones at top and bottom of stone by providing groove in key stone. In this case AAC block masonry and stone cladding was done simultaneously which was a time consuming exercise.

Stone jali:

Stone jails with Dholpur stone (White sand stone) in connecting corridors of blocks and in staircase for natural ventilation has been provided. In connecting corridors, balusters of same stone fastened to RCC slab below in box section having opening top side and fixed to slab with dash fasteners. Jali panels inserted in between the balusters. Stone jali in staircases made in the form of tree supported on MS tube frame fixed to RCC beams of staircase with dash fasteners. At junction of two stone panels, adjustable stainless steel cramps has been used.

Structure

This is one of the rare projects in which design of RCC framed structure, design of steel structure and design of composite structure have all been used. The building has a height more than 35m and is situated in seismic zone IV.

The building has 3 basements with a total depth of 12m below GL and peak water table at 5 m below GL. Based on a raft foundation 1.35 m thick, the 3 floor retaining wall upto GL and all round the periphery of the building, is designed with number of service shafts. The basement structure is designed to accommodate robotic parking for 330 cars involving structural provisions for 6 car lifts, shuttle bays, turntables and effective movement of vehicles through out. It is also designed to accommodate all the bulk services including AC plant room, substation and DG sets, fire fighting pump house and sewage treatment plant .The basement slab at GL is designed to carry the load of 1.5 m high earth filling required for landscaping purposes.

The building has been designed as a RCC framed structure. At Ground level, the building has been grouped into six blocks and connecting corridors having spans of 20 m and a circular waffle slab of 22m dia were designed. Sizes of most of the columns are 750 mmx750 mm and the circular columns at entrance in North Block are of 1.20 m diameter and 4 storey height and are covered with stainless steel cladding.



This building has two blocks connected with connecting corridors from 2nd floor onwards. Each of these two blocks is divided in three parts by providing two seismic joints of 250mm width each. Normal grids are 6.00mX6.00m with column size 750mmX750mm. One part in one of the blocks has provision for conference room at ground floor and bigger size committee rooms at first floor. Seven storeyed composite columns were erected over RCC columns of the basement.

In order to create the total required area of 6000 m2 for supporting solar panels, the entire central courtyard had to be covered with space frame and Additionally, MS supporting structure over the terrace had to be extended further by huge cantilevers and terrace level and fourth floor level on Southern side. Keeping in view the requirement of high degree of maintenance of solar panels, adequate numbers of catwalks are provided in the entire supporting structure, with perforated bottom for easy draining of rain water. Out of total area of 6000 m2, area covered by panels is 4600 m2 and by catwalks is 1400 sqm. 100% on site power generation mandate given by the Ministry necessitated the covering of open to sky area in central courtyard with solar panels. To support these panels, some structure below was required. Initially it was to be covered with MS but in consultation with MoEF and for better aesthetics & less maintainability requirements at a height of 35.00 metre, space frame with nodes was provided. The structural design was submitted by the specialised agency (M/s Alcox Pvt Ltd) and checked by CDO, CPWD. Complete fabrication was carried out in the factory by using sections of make Jindal steel. Sizes of tubes used in the work are 48mm dia, 73mm dia, 114mm dia & 168mm dia with thickness varying from 3.68mm to 11.24mm.

Only covering of central open to sky courtyard with space frame could not provide required area for solar panels. Therefore area available at terrace which was only 2200 sqm was covered with MS box section with 6m cantilever all-round the building resulting in 12m cantilever at four corners. Additionally 6m cantilever was provided at 4th floor level on south face of the building. Box sections of size 250X450mm to 250X850mm depending on the span were used in the building for supporting solar panels.



Energy Efficiency Features

Energy Efficient Chilled Beam system of Air Conditioning

- Air conditioning by convection currents rather than air flow through diffusers.
- Chilled water circulated right up to the diffuser (chilled beam).
- Chilled beam has provision for draining out any condensation water.
- More than 50% savings in energy consumption on air conditioning.

Geo Thermal Heat Exchange system

- Utilises advantage of difference between ambient temperature and the temperature below GL.
- Vertical closed loop system done with 32mm dia. HDPE U – loops 180 in number and 80 m deep each.
- Reduction of 160TR load on cooling tower and consequent reduction in consumption of water to be achieved.

Regenerative passengers Lifts

- Energy efficiency through conversion of braking energy into electricity.
- 7 Nos Machine room less gear less lifts of OTIS Make

Other Energy Efficiency measures

- Chillers and AHUs with Variable Frequency Drives(VFDs)
- Heat recovery wheels
- Thermostat controls for HVAC
- LED lights and Occupancy & Lux level Sensors, etc

Materials

- Walls with Fly ash bricks and AAC blocks and not clay bricks.
- Entire Concreting , mortars and plasters with PPC.
- Locally available stone floorings, claddings, Terrazzo flooring and flooring with broken marble and Kota stone.
- High reflectance terrace tiles for low heat ingress.
- Rockwool Insulation of outer walls and concrete surfaces
- Rapidly renewable Bamboo Jute Composite for door frames & shutters.
- UPVC windows with hermetically sealed double glass (SHGC: 0.32, U value: 1.5 & VLT 59%).
- Calcium Silicate ceiling Tiles.
- Grass paver blocks in pavements and roads for ground water recharge.
- Low VOC Paints for better indoor air quality.

Water Conservation

- Low discharge water fixtures
- Recycling of waste water through STP(Sewage Treatment Plant)
- Low demand plants in landscaping
- Geothermal cooling
- Rain water harvesting
- Use of curing compounds

Conclusion

Considering the examples of green buildings, Indira Paryavaran Bhawan is one of the marvelous examples of the country and also well known in the world, and as per date has no problem so far in any of the active processes used as an sustainability parameter and are running smoothly be it solar energy generation, water conservation, BMS system, geothermal system, hybrid AC system, lighting system etc. The need of the hour is to build more such buildings, sustainable and energy efficient with minimum pressure to the non-renewable resources of the nature.

CPWD has taken a step towards this and now it is mandatory for every building build by CPWD to have 5 star energy rating and recently signed an MoU with Building Energy Efficiency (BEE) for energy labeling.

While designing the building passive parameters should be kept in mind as it plays major role in defining the active parameters and the living environment of the building such as orientation, day lighting, preservation of the natural features, Respect to the sites all these factors collectively help in reducing the pressure of the active parameters which will further add pressure on the electrical load of such building.

It is also necessary on the individual level to be sensitive toward the environment and be aware on the energy efficiency so that we can save some of the few energy left on the earth and pass it on to our future generation.

SUSTAINABILITY AND ENERGY CONSERVATION IN BUILT HABITAT THROUGH DAILY LIFE CHOICES: A FEW CASE STUDIES

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Abstract

Sustainability is defined as the ability of the current generation to meet its needs without jeopardizing the ability of the future generations in meeting theirs. In the current times of increasing population, depleting natural resources, rising pollution and growing climate change challenges, incorporating sustainability and energy conservation measures in our daily lives is not a choice anymore. This paper discusses four simple yet powerful case-studies showing how we can inculcate these inevitable virtues through some of our daily life choices: i) Energy conservation through building design and construction, ii) Energy conservation through energy-efficient appliances, iii) Distributed renewable energy generation, iv) Sustainable food choices.

Introduction

Global population has grown steadily over the last couple of centuries, along with remarkable industrial and economic growth. While it is indeed heartening to see a large, and increasing, section of the human population being able to not only meet their needs, but also afford increasing levels of physical comfort, there is another side to this picture as well. This massive industrialization and rapid urbanization over the last few decades, especially, has come with more than its expected share of impacts on the ecology and the environment. With the ruthless exploitation of fossil fuel reserves and the mindless depletion of forest cover, CO_2 levels have been rapidly rising over these last few decades, leading to severe rise in the anthropogenic global warming. This has led to a widespread phenomenon known as climate change, which comprises of a myriad of unpredictable and random changes in the climatic patterns and agricultural seasons, along with sporadic extreme weather events. Though this is a global phenomenon, tropical countries like India, having a disproportionately huge population, vis-avis the available resources, are much more vulnerable to the impacts of climate change phenomena. In such a scenario it's incumbent upon us, Indians, to take up this challenge of climate change proactively and adopt suitable mitigation and adaptation measures. This paper shows four simple case-studies for illustrating how simple daily life choices can help us practice energy conservation and sustainability.

Energy conservation and sustainability choices

I. Energy conservation through building design and construction

a) Glass-usage in building exteriors India

Is a tropical country, having immense amounts of sunlight availability. While this is a great blessing in form of a perennial renewable energy resource, it only calls for common sense to understand that our building designs and construction should respect, and make positive use of, this natural phenomenon. However, in the modern times, sometimes it becomes difficult to keep track of common sense in the din of intense market-forces and a blatant West-aping mentality. A simple example of this phenomenon is the growing use of glass in our building design and construction. This is a typical case of blind aping of the West, sacrificing even the commonplace common-sense. A glass structure is known to be an ideal example of a green-house, a structure meant to trap solar energy for increasing the indoor temperature for aiding plant growth, as illustrated in Fig.1. It doesn't take rocket science to understand that while glass-based construction is a wise decision for naturally bringing down the heating load in cold climates, it is a recipe for disaster for a tropical country like India, artificially and unnecessarily hiking the cooling load of our buildings. Table.1 shows the increase in the HVAC cooling load in office buildings due to the increased glass usage in exterior walls of a building.

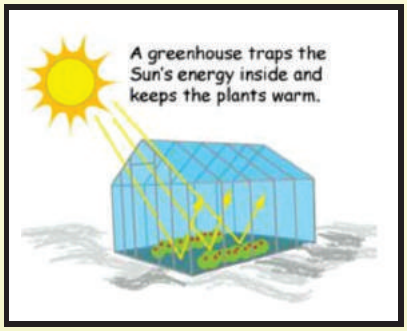


Fig.1

Table.1. Increase in HVAC cooling load of office buildings with glass usage in exterior walls (Source: Croome and Roberts, 1981)

Building area and glass usage	Required cooling capacity (TR) for 1000 ft^2 of floor area	% increase in cooling load (External without glass as base)
Internal zones (No glass)	2.8	--
External zones without glass	3	0
External zones with 25% glass	3.5	16.67
External zones with 50% glass	4.5	50
External zones with 75% glass	5	66.67

b) Building orientations:Vaastu and modern science

Another pertinent point in this regard is the relationship between building orientation and its corresponding impact on the building HVAC cooling load. Ansari et al. (2005) have done some interesting research in this regard. They have modelled and simulated the building HVAC cooling load variation with the changes in the building orientation; the results are shown in Table.2. It is interesting to see that the traditional Vaastu wisdom of having East-facing windows and doors is being validated by these results. Table.2 shows that having East-facing windows and doors minimizes the building HVAC cooling load.

Table.2. Building orientation and HVAC cooling load (Source: Ansari et al., 2005)

Orientation of windows etc. with respect to Sun	% increase in cooling load w.r.t. the minimum
East-facing	0
N-E facing	6.29
S-E facing	6.57
South-facing	6.57
S-W facing	15.8
N-W facing	18.53
West-facing	26.43

Thus, it is evident that if we take cues from our traditional construction materials and practices, which have been traditionally used in this country, capitalizing on the local wisdom, instead of blindaping of the West, then we can effectively cut down the energy requirements of our buildings in a significant way.

II. Energy conservation through energy-efficient appliances

The Energy Efficiency Standards and Labeling (EE S&L) program, or the star-rating program for electrical appliances, was launched by the Bureau of Energy Efficiency in the year 2006, for improving the energy efficiency of household and other appliances. Under this program, appliances are assigned stars numbering between one to five, in the increasing order of their energy efficiency and decreasing order of estimated annual energy consumption. This program has been a major success in the household and appliance energy efficiency domain in India. Through diverse media of advertisements, consumer awareness programs, and focused academic and research initiatives, the Government of India and the Bureau of Energy Efficiency have been successful in transforming the consumer's perception in this regard. Hence, what started as a voluntary program for energy-efficiency labeling, gradually transformed in a mandatory standard with which almost all the household and other appliances must necessarily comply. This led to a market transformation from non-energy

non-energy efficient products to energy efficient products, effectively resulting in an estimated avoided capacity addition of 7766 MW, during the 11th Five-year plan (2007 – 2012) [4].

Despite the remarkable success of the EE S&L program, there are still some low-hanging fruits in the energy-efficient appliances domain which can be emphasized to further enhance the energy savings in this domain. A very common example of this is using BLDC motor based ceiling fans, instead of the traditional single-phase induction motor based fans. Whereas a traditional fan consumes 70-90 Watts of electricity, the BLDC fans consume around 28-32 Watts only. This implies a reduction in demand of electricity by around 50 Watts, for each fan being used. Ceiling fans, being one of the most commonly used appliances, this could imply a reduction of around 15000 MW – 18000 MW [5] in the peak demand at the national level, during summer season. Several other such examples of energy-efficiency improvement are waiting to be harnessed.

III. Distributed renewable energy generation

Over the last few years the Government of India has laid special emphasis on the growth and exploitation of renewable energy resources, especially solar PV, in a big way. India has one of the most ambitious renewable energy expansion plans at present, with a total envisaged capacity of 175 GW of renewable based power to be added to the generation fleet by 2022. A sizable chunk of this, 40 GW, is targeted to be developed in terms of rooftop solar PV installations, while another 60 GW are envisaged to be installed as utility-scale large solar parks. However, the data recently released by the Ministry of New and Renewable Energy (MNRE) in December, 2018, shows that while almost 25% of the target for utility-scale solar PV parks has been accomplished, rooftop solar PV segment is languishing at around 5% of the target only, at present.

While the solar PV technology has greatly matured in the last few years, and the prices have dropped significantly, to panel prices as low as Rs. 28-32 per Watt-peak, people's mindset and perception of the technology still has to transform. Taking the balance of system for a grid-connected rooftop solar PV installation, consisting of the inverter, supporting structure etc., into account, the total installation cost for a 1 kW rooftop solar PV system comes out to be around Rs. 70,000 [6]; which goes up to around Rs. 575,000 for a 10 kW system [6], capitalizing on the economy of scale that sets in over this small range as well. While the 1 kW rooftop solar PV system is expected to generate around 1400 – 1500 units of electricity annually for most parts of the country, the 10 kW system would generate somewhere around 14000 – 15000 units of electricity. Considering a base slab price of Rs. 4 per unit for a small residential consumer, the simple payback period for the 1 kW rooftop PV system would be

around 11 – 12 years, which is not very encouraging. However, if the same 1 kW rooftop PV system is installed and used by a medium sized residential consumer, having significant energy consumption in the Rs. 6 per unit slab, the simple payback period would be in the range of 7 – 8 years. Most interesting, however, is the case of medium and large commercial consumers, who usually purchase grid electricity at around Rs. 8 – 12 per unit. If such a consumer installs a 10 kW rooftop PV system, the simple payback period for his case would be only around 3.5 – 4 years, which is very impressive, especially given the fact that the solar PV panels usually come with a 25 years warranty, while the complete system usually comes with a warranty of 5 years.

Thus this simple change in the outlook of medium and large commercial consumers can not only bring in significant electricity bill savings for them personally, but also help cut down on fossilfuel based capacity addition nationally, thus enabling a cleaner and greener future.

IV. Sustainable food choices

While all the above sections (**I – III**) have specific applicability, in terms of prospective target and beneficiary groups, big or small, this particular section has universal applicability, as food is the most basic requirement of every living entity. However, there is a unique difference between every other living entity and human beings. While all the other living entities are driven by the instincts which nature has provided them with, without any freedom to decide their course of action, human beings have been rewarded with this special prerogative of being able to choose and decide their course of action, and hence their destinies. Of all the choices which a human being has to make, the choice of type of food he or she takes is the most fundamental. There are several aspects to making this choice – religious, spiritual, moral, traditional, cultural, personal and ecological. Though each of these aspects are full-fledged subjects in themselves, and volumes can be written on each of these, here we will only focus on, and briefly discuss, the ecological perspective of making the food choice.

It is common knowledge that every living entity eats some or the other living entity for food, however the type of food one chooses to eat has not only a bearing on his or her body, thoughts, emotions and personality, but also on the environment and ecology around him or her. In the recent times there have been several dedicated studies on assessing the environmental impact of the food choices that we, as humans, make. Almost all such studies, unequivocally, point towards the heavy environmental degradation that a meat-based diet brings with it. Some of the key findings are summarized below.

a) Water crisis

One of the most disastrous effects of a meat-based diet is the heavy water consumption needed for producing it. As per [7], a typical pure vegetarian diet takes around 1137 litres of water per day for production, whereas a meat-based diet requires around 15,160 litres of water per day for production. As per [8], producing one pound of beef consumes around 2464 gallons of water, as compared to the requirement of 25 gallons of water for producing a pound of wheat. Given that a large share of humanity is already facing severe water shortages, and a projected 64% of the human population will be under water-stress by 2025 [9], isn't it high time that we switched to vegetarian food options? These results are summarized in Fig.2(a)-(b).

b) Food shortage

It's common sense understanding that because animal needs to be fed every day for its entire life before it is slaughtered for meat, the total amount of food consumed by the animal for meat production would be significantly high. Researchers estimate that on an average, an animal must be fed 10 kg of grains to produce 1 kg of meat [7].

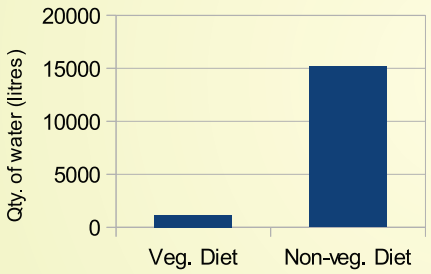


Fig.2(a). Water consumption for a day's food production [7]

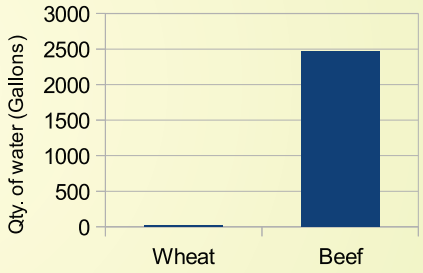


Fig.2(b). Water consumption for producing a pound of respective food [8]

c) Energy consumption

[8] reports that researchers from Cornell University have found that meat production is a highly energy consuming process as well. Their results show that it takes around 40 calories of fossil fuel to produce one calorie of protein in form of beef, whereas one calorie of protein in form of tofu needs only two calories of fossil fuel for production. The result is shown in Fig.3.

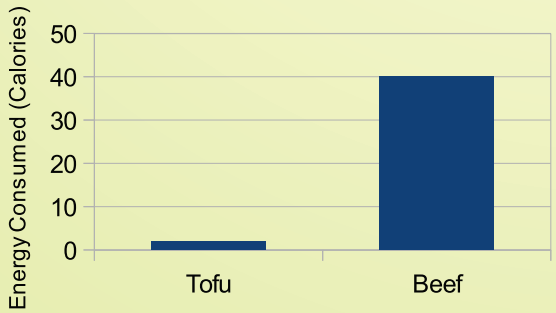


Fig.3. Energy consumption for respective food production [8]

d) Global warming/ Green-house gases' emissions

At an estimated annual emission of over 100 million tonnes of methane [8], the meat industry is one of the major producers of methane globally, which is a highly potent greenhouse gas, having a 23 times higher global warming potential as compared to CO2. [10] reports that researchers from Oxford Martin have found that widespread shifting of food choices from meat-based diet to vegetarian diet has the potential of cutting food-related green-house gas emissions by 63%.

e) Destruction of forests, ocean and biodiversity

It takes huge amounts of grains to rear cattle in farms for meat production, researchers report that at present world's cattle consume a quantity of food equal to the caloric needs of 8.7 billion people [7] – almost 120% of the current global human population. This leads to a huge destruction of the rainforests, and the associated biodiversity. As per the Rainforest Action Network, each fast-food hamburger consumed leads to a destruction of around 55 square feet of tropical rainforests, and along with it hundreds of plant and animal species. Similar is the fate of the oceans – estimates show that the fishery industry has led to the annihilation of almost 90 percent of large fish populations over the last 50 years. Some of these results are summarized in Fig.4.

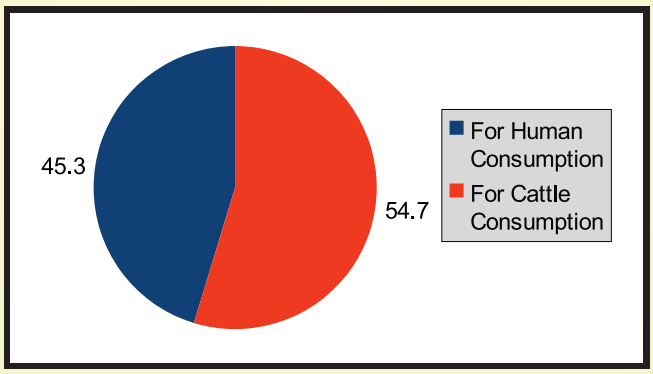


Fig.4. Relative percentage distribution of total grain produced globally [7]

Conclusion

This paper has attempted to show, through some simple case studies, the enormous potential for sustainability and energy conservation which we can easily tap by making some simple daily life choices. The cases discussed here are just indicative, the list is unending; and if we are sincerely committed to the goal of sustainability then many more innovative avenues for conserving energy and improving sustainability can be found. It would be apt to close this discussion by recalling the most fundamental sutra of sustainability, which, if each one of us can imbibe in the true sense, then this entire problem could be solved globally: “Remember, we don't inherit this planet from our ancestors, rather we borrow it from our children”.

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EFFICIENCY OF 0.5 KW/TR FOR CENTRAL PLANT - A REALITY NOW

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Abstract

Understanding the way to capitalize on opportunities of energy savings in total HVAC system. HVAC system consists of equipment's like chillers, pumps, cooling towers, AHUs, and many more. Performance of one equipment effects other equipment's performance also and hence overall HVAC system performance. Looking at what are the opportunities available for reducing overall energy consumption in plant rooms. We can even aim to maintain 0.5 kW/TR for complete plant room. In this technical paper, we are using case study of a Singapore project, where best equipment selection and their operating strategies together were applied in order to maintain 0.527 kW/ TR. Our objective of paper is to improve complete plant room energy consumption to 0.5 kW/TR or even lower.

Introduction

HVAC in buildings consumes more than 50-60% of total energy consumed, hence needless to mention that our decisions are no longer based of first cost but largely on life cycle cost. Life cycle cost is influenced more by operating cost, because plant runs for 20-25 years. In recent decades, significant gains in chiller efficiency at full & part load have been achieved through advances in Heat Exchangers, compressor, motor, driveline, and economizers. The biggest single efficiency gain has been at reduced 'lift' condition with the adoption of the variable speed drive. Mag Lev Chillers is biggest development that has happened in last decade in HVAC industry or so. Being completely lubrication free technology, and premium efficient motor and combined use with VFD, results in best real-world efficiency of plant rooms. Beyond automation, optimization is the next stage in improving efficiency. This would require the integration of intelligent logic that holistically operates the plant in the most efficient way. More on this is covered later in this article.

Body

For improving operating efficiency, decisions are based on not just buying efficient equipment, but also on keeping operating strategy in mind.

- **Chillers:** Mag Lev Chillers are completely lubrication free technology and with premium efficient motor. This technology and its combined use with VFD, results in best real-world efficiency of plant rooms. This also eliminates parasitic losses, which were associated with

with oil management system. Heat exchanger operating efficiency also improves because there is absolutely no oil in system and hence no deration while operation.

- **Chilled & Condenser water Pumps:** Distribution / Pumping also consumes significant energy in plant rooms, hence it is very vital to optimize pumping energy. This can be achieved by following ways.

A. Reduce chilled water flow

B. Apply VFD on Chilled water Pumps: Use of Variable Primary flow so that we can optimize pumping energy proportional to pumping demand, and hence save energy consumption.

- **Cooling Tower: Selecting Best efficiency cooling tower with low approach is right strategy**

Key components while making operating decision: Ways to reduce lift on chillers. We know that every 1-degree C of 'lift' reduction improves VSD chiller COP by 3 %

What are the Ways to reduce Lift in chillers?

- Reduce Entry condenser water temp
- Raise Chilled water temp
- Reduce fouling factor in condensers by applying ATCS
- Apply chillers in series-counter and reduce lift on both chillers
- Can we go higher than 9 deg C CHW? If yes then how?

Can entry condenser water temp be reduced?

- Conventional cooling tower approach = 4-5 deg C
- Optimized cooling tower approach =2.5 deg C
- Improve cooling tower approach to 2.5-3 deg C, this will result in lower ECWT by 1.5 - 2 deg C.

Can CHW temp be raised, and how much?

- Conventional coil design = 2.5 m/s Face velocity & approach 6-7 deg C
- Optimized coil design = < 2.0 m/s Face velocity & approach 3-4 deg C, with lower face

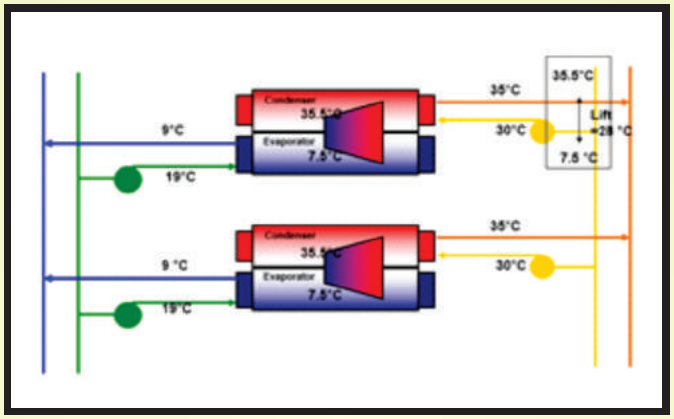
velocity in AHU coil, we can increase leaving chilled water temp from Chillers.

Can fouling factor in condenser be reduced?

By applying Automatic Tube Cleaning Systems, cleaning of condenser is performed automatically and hence clean tube and reduction in fouling factor is achieved.

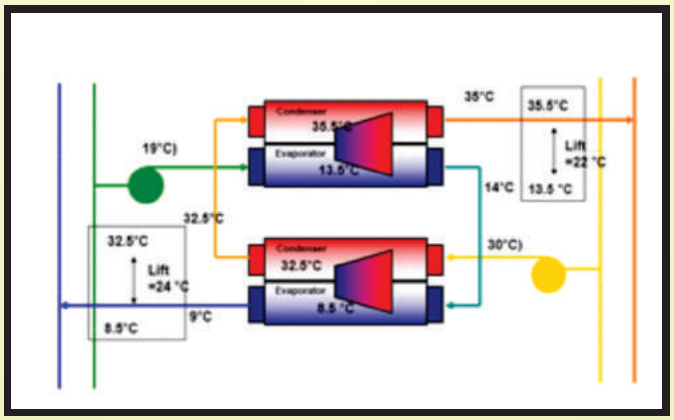
Can chillers in series counter arrangement, reduce lift further?

The answer is yes. The below schematic shows how series counter arrangement helps in reducing lift, and hence saving energy as well. Let's look at conventional arrangement of chillers,



For this duty, each chiller is seeing a lift of 28 deg C. We can plot same on PH chart as well.

Now let's look at alternate arrangement of chillers now, i.e. series counter arrangement.



For very same duty, chillers in series counter arrangement: High Side chiller is seeing a lift of 22 deg C, low Side chiller is seeing lift of 24 deg C. We can plot same on PH chart as well.

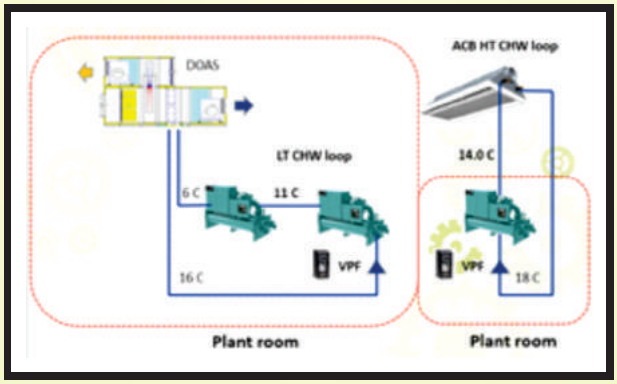
It is evident that for very same duty, with changing arrangement of chillers, lift on chiller can be reduced from 28 deg C to 22 deg C & 24 deg C respectively and hence energy savings

- 21% energy savings on chillers w.r.t. constant speed drive chillers
- 7% energy savings on chillers w.r.t. variable speed drive chillers
- Additional 7-8% energy savings with Maglev chillers

To summarise –

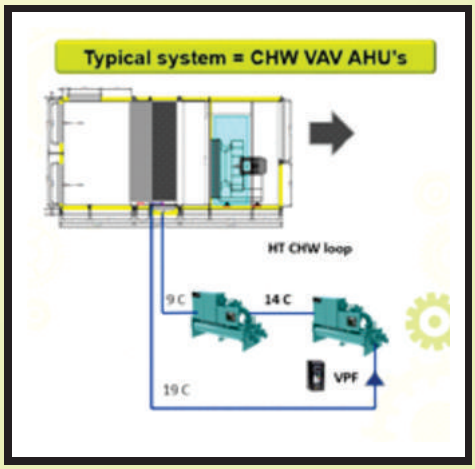
Savings associated with reduced flow in chilled water pipes and raised chilled water temp;

- Smaller CHW pipes
- Smaller CHW valves and fittings
- Reduced thermal insulation area
- Smaller CHW pumps, motor kW, and VSD's
- Smaller CHW pump electrical requirements

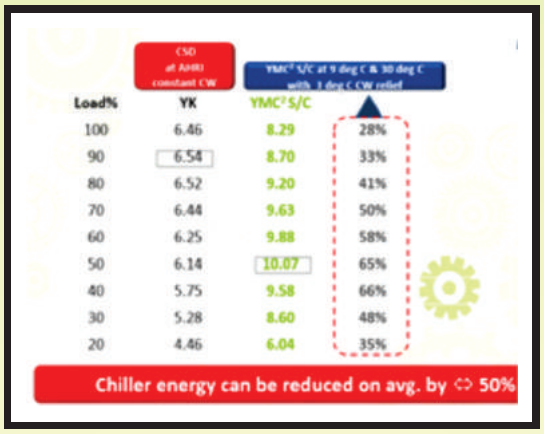


Costs associated with reduced flow in chilled water pipes and raised chilled water temp;

- Larger AHU coil HX areas and rows to achieve equivalent energy performance
- If the additional coil area cannot be accommodated in AHU height, the AHU footprint will increase



In the following table, comparison has been made between optimized series counter flow maglev efficiency performance with constant speed centrifugal chillers.

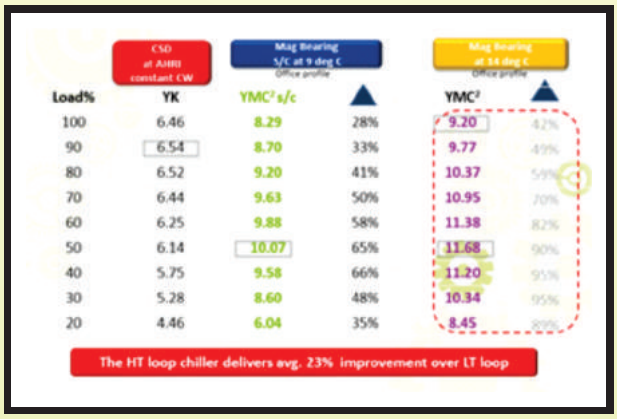


Are there more efficiency gains to be found? Can we go higher than 9 deg C CHW? if yes then how?

Decoupled system is answer to reduce lift further. There are 2 type of loads, Sensible & Latent Load. For sensible load, we can have higher chilled water temp like 14 or 15 deg C since no dehumidification needed. For Latent Load, we need dehumidification, hence higher temp will not work.

A typical application that de-couples loads is a chilled beam system. For Sensible Load, Chilled beams or Radiant cooling use chilled water supply temperatures of 14 deg C

How High Chilled water temp loop effects chiller performance??



Case Study 1 - Jem Project in Singapore has applied following;

- 2x2000TR Series Counter Flow

- 1x1000TR VSD + 1x500TR VSD WC Chillers
- Airside Equipment
- Environmental friendly refrigerant: R134a

1) Dual Chilled water loops – to take advantage of High temp loop for sensible load
2) Low Approach cooling tower
3) High Efficiency chillers in Series Counter
4) High Delta T to reduce Flows

With above configuration and arrangements, Jem Singapore Plant room Achieves 0.527 kW/TR (Annualized Average Plant room efficiency)

Case Study 2: Infosys Bangalore, Radiant cooling chilled water plant

- Chiller IkW/TR: 0.27
- Total Plant kW/TR: 0.4

Conclusion

Outcome achieved is given in the Table.

S. No	Strategies	Savings	Cost
A	Reduce Entry condenser water temp	Saves Chiller energy consumption	May Increase cooling tower cost
B	Raise Chilled water temp	Saves Chiller energy consumption	May / May not increase AHU cost
C	Reduce fouling factor in condensers by applying ATCS	Saves Chiller energy consumption	Will increase cost of additional ATCS equipment
D	Reduce chilled water flow	Saves pumping cost	Reduce Pump size, Pipe Sizes, Valve Sizes etc.
E	Apply chillers in series counter and reduce life on each upstream and downstream chiller	Saves Chiller energy consumption	No change
F	Are there more efficiency gains to be found? Can we go higher than 9 deg C CHW? if yes then how?	Saves system energy consumption	Increase cost of airside

Achieving 0.5 kW/TR is possible today with application of bringing best efficiency equipment and operating strategies together through best efficiency chillers – AHRI certified performance with maglev chillers technology, best efficiency cooling towers-CTI certified performance with lower approach and advanced chiller plant optimizer which brings many opportunities as listed below;

- Wide delta T CHW systems / reduce flow
- Apply variable primary flow
- Raise CHW supply temperatures
- Reduce entry condenser water temperature and fouling in condenser
- Apply chillers in Series counter-flow arrangement
- De-couple and condition outside air loads separately

Bringing equipment & strategies together will definitely help in achieving 0.5 kW/TR of complete plant room or even lesser. This goal is no more a dream and very much achievable.™

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ADDING IOT CONTROLS TO LED DRIVERS CREATES A FOUNDATION FOR SMARTER CITIES

Russ Sharer, Vice President of Global Marketing and Business Development, Fulham

Abstract

Outdoor lighting has been with us for centuries, but traditionally it has been inefficient since streetlights typically go on and off. With new LED technology municipalities are seeing new energy savings from streetlights, and they can use smart streetlights to create an ecosystem for smart city controls. However, smart lighting for cities is dependent on common standards, and the professionals mapping out tomorrow's intelligent lighting strategies can apply the lessons learned from past connected technology markets – without interoperability standards are worthless. Smart cities are demanding smarter systems integration, building a variety of community and citizen services on common standards, such as the Internet of Things (IoT). Thus article will explore the evolution of smart streetlights and how they can serve as a foundation for smarter cities based in IoT controls.

Introduction

The Internet of Things (IoT) has opened a new opportunities for device management. Smart cities in particular will benefit, but creating smarter cities means we need smarter integration strategies. Community and citizen services are going to need a stable, scalable IoT infrastructure that extends beyond historical control systems. Integrating wireless IoT controls in LED drivers for outdoor lighting will likely be the first step.

Adding wireless radio capabilities to streetlights seems a simple approach to adding IoT controls. There are fewer pieces of hardware, which simplifies installation and reduces overall maintenance and operational costs over time. It's also much simpler to connect power to one device, a wireless-enabled LED driver, rather than two devices. Using streetlights to create an IoT infrastructure is a simple but elegant approach.

However, there are some considerations we need to address before we can use wireless streetlights to create a wireless smart cities infrastructure. Let's look at the specific challenges of using streetlights to control smart cities.

Creating an IoT Wireframe

Lighting provides the perfect skeleton for an IoT infrastructure, especially streetlighting which can be extended to monitor and manage other devices. Unfortunately, real-world

economics often get in the way of innovation. For IoT to become a viable platform for managing city systems, it has to become financially practical to retrofit streetlights with smart LED drivers. The lighting industry is mature, and products installed today are built to last. The so-called “dumb” drivers in today's streetlights can be expected to have a useful life of 10 years, which delays retrofitting these lights with smart, wireless LED drivers for at least a decade.

Municipalities seeking to improve public safety usually start by adding new streetlights. If you consider the possibilities of installing new streetlights equipped with smart, wireless LED drivers, you realize that you promote public safety and save energy. For example, IoT can be used to power webcams from a centralized dashboard, which can be useful for law enforcement and for crowd control. Streetlights also are spaced at regular intervals throughout the city. As a result, they can be used to monitor traffic patterns, or to measure air quality or rainfall – any number of other applications other than simple lighting. Adding IoT capability to streetlight LED drivers also makes it easier to monitor and troubleshoot the lights themselves. It's more cost-effective to determine what, specifically has failed before you roll out a repair crew; the repair crew can arrive on the site with the parts and tools they need so there is only one trip.

However, if you plan to use street lighting to create a citywide control and management system, you need to have an open protocol that can support all the devices you want to manage. IoT is a logical choice to automate management of city systems since it is an open protocol, but not all devices are going to be interoperable with IoT. Lighting systems management predates IoT, so manufacturers have developed other standards for lighting communications and management; standard that don't talk Internet protocols.

For example, DALI, the Digital Addressable Lighting Interface, is one of the most widely used standards for digital lighting controls, but it is only useful for lighting. DALI was created by Philips in 1964 and evolved from an IEC standard. It has become a common interface for lighting controls and interoperability, especially dimming, but it is not designed to be interoperable with other control standards. There are wireless lighting control standards as well, such as Zigbee, which is competing with other wireless standards such as Bluetooth mesh and Wi-Fi that can handle IoT traffic.

A successful smart city management system is going to have to look beyond simple lighting controls. City managers are going to want a common protocol, like IoT, capable of managing different devices such as streetlights, traffic lights, etc., and that is capable of handling different types of data for analytics. Combining IoT with wireless communications is the ideal approach, especially if you use cloud computing for data management. With secure cloud

access, different city departments and service providers will be able to access the same information. It also will make it easier to aggregate data for big data analysis.

Four Reasons to Integrate Controls with LED Drivers

Even with such market obstacles, it still makes sense to integrate IoT controls in LED drivers for streetlights. When we considering the challenges to creating a centralized, smart cities infrastructure, we identified at least four reasons to integrating device controlsin LED drivers:

1. To Integrate the Right Controls System. When assessing the best approach for integrating controls, Fulham had many potential partners we could work with and many options. The first step was to select a medium. We decided to use a wireless system, since outdoors radios can work free of interference. Now we had to determine which wireless system was best for the task.

We also knew that we would have to minimize the cost of on-site hardware. In the past, these types of control systems required an expensive black box, a dedicated computer, or some other expensive piece of equipment linked directly to the lighting network. Not only does this add substantial start-up costs, it also required additional security for the equipment as well as specialized power protection equipment as backup in the event of a systems failure. There also had to be a means to update the system firmware.

By using a cloud-based system we only needed a small gateway as a bridge between the lighting control network and the remote monitoring center – a much more cost-effective approach than using dedicated equipment. We also recognized that using a cloud-based infrastructure would make it easier to create an IoT network, since cloud capacity could be added quickly and at a moderate cost.

2. To Ensure Protection from the Element. Once it was clear that we needed to create an outdoor lighting control network as the foundation for an IoT control infrastructure we knew we also needed an architecture that would protect the wireless controls from weather and vandalism. By integrating the control module with the LED driver, all the key components would be invisible since the light source, driver, and controls were all incorporated into the luminaire. Outdoor luminaires have to be designed to meet strict International Protection (IP) standards so integrating the controls into the driver would meet the standard and offer better protection.

3. To Improve Reliability with Driver Health Monitoring. LED lighting units are extremely reliable; much more reliable than incandescent, induction or fluorescent lights. When there is problem or failure in an LED luminaire you can usually track it back to the driver. Connecting

the LED drivers and integrating the control elements makes it possible to perform remote diagnostics as well as control. Operating hours, temperatures, and other performance characteristics can all be transmitted as data to a remote monitoring center.

With remote monitoring it's easier to detect problems, even before there is a failure. This can result in huge savings in repair costs since parts can be assembled in advance and repairs can be made in a single trip rather than two trips – one for diagnostics and one for repair.

4. To Improve Efficiency with Lowest Standby Power. Any time you install or upgrade a lighting system one of the primary objectives is to reduce overall power consumption. LED drivers are designed to use the lowest possible standby power. When activated in a streetlight driver, the wireless control module wakes up first, then the LED driver. We calculate that this configuration results in a 40 to 50 percent power savings compared to conventional 1-10V dimmer controls, even if the controller can power down from dim to off.

Conclusion

As IoT applications continue to take gain momentum for applications such as smart city controls, integrating LED drivers and wireless controls in streetlights is going to offer some clear advantages. Once a wireless infrastructure is in place it will be possible to scale the system, adding nodes and devices to be controlled as needed. Integrating drivers and wireless controls offers simplicity, reliability, and energy efficiency. The first step, of course, will be modifying streetlights with smart LED drivers that can create a wireless infrastructure for IoT communications.

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CASE STUDIES OF ENERGY EFFICIENT OFFICE BUILDINGS

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Abstract

Integrating energy efficiency measures during the early design phase of a building can result in energy-efficient design with no or very less incremental cost. The Indo-Swiss Building Energy Efficiency Project (BEEP) is promoting Integrated Design Process (IDP) charrette design methodology to design energy-efficient buildings. The IDP charrette design methodology, involves organising a design workshop (charrette) with the entire project team (client, architect, HVAC consultant, etc) with assistance from energy experts during the early design phase. The primary focus in charrette is on reducing heat gains or losses from the building envelope, improving natural ventilation, use of energy efficient space conditioning and application of renewable energy. Case studies of two office buildings have been presented in this paper which have been designed using IDP charrette approach. In the case of Aranya Bhawan (case study1), the building Energy Performance Index (EPI) based on monitored electricity consumption was found to be 43 kWh/m2.y which is 41% lower compared to the base case. In the case of India International Institute for Election Management (IIIDEM), a CPWD project, the building EPI based on simulation was found to be 82 kWh/m2.y which is 28% lower compared to the base case.

Introduction

Buildings are the second largest consumer of electricity in India after industries. Overall, buildings sector accounts for 33% (24% residential & 9% commercial) of the electricity consumption. Indo-Swiss Building Energy Efficiency Project (BEEP) is a joint project being implemented by the Bureau of Energy Efficiency (BEE) and the Swiss Agency for Development and Cooperation (SDC). BEEP has been providing technical support to CPWD and other public sector builders in design of energy-efficient buildings by conducting design workshops (charrettes) during the early phase of building design. This paper presents case-studies of two government office buildings that have been designed by conducting IDP charrettes.

Case Study 1: Aranya Bhawan, Jaipur

About the building & design process

The building is the head office of the Rajasthan Forest Department situated in Jaipur

(composite climate). The building was constructed by the Rajasthan State Road Development Corporation (RSRDC). Key details of this building are:

- Built-up area: ~10,000 m2 (excluding basement parking and service area)
- Number of floors: Five (G+4) + one basement level for parking and services
- Number of users: 344
- Types of spaces: Offices, museum, library, auditorium, guest rooms
- Building has three wings with the floor plans as shown in Figure 2.



Figure 1: Aranya Bhawan, Jaipur

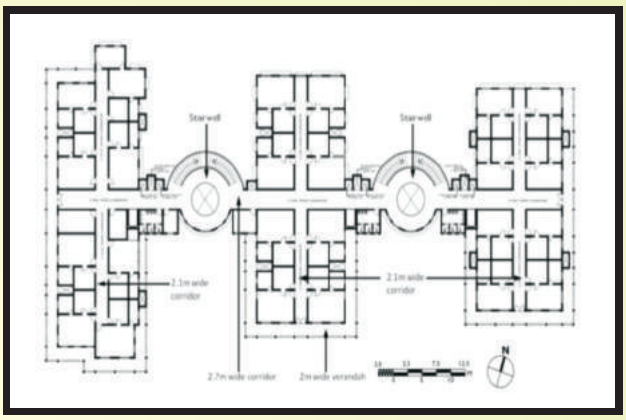


Figure 2: Ground floor plan of the building

A design workshop (charrette) for energy-efficient design with key project team members was organised at the design stage in December 2012. This workshop resulted in identification & selection of energy efficiency measures (EEMs) as well as building energy simulation carried out during the workshop resulted in quantifying energy savings. The construction of the building was carried out from 2013 to 2015. The building was inaugurated in March 2015 and fully occupied by April 2015. Energy monitoring of the building was done in 2015-2016.

Energy efficiency measures & renewable energy system implemented

During the design workshop, the main emphasis was on reducing heat gains, improving day lighting, energy efficient lighting and energy-efficient cooling systems and integration of renewable energy. Following EEMs were implemented:

I. Roof insulation (Figure 3): Roof of this building is insulated with 40 mm polyurethane foam (PUF) resulting a U-value of 0.6 W/m2.K. Also light coloured terrazzo tiles at top was incorporated to have high reflectivity.

ii. Wall insulation (Figure 4): External wall constructed as cavity wall filled with insulation. A 50 mm extruded polystyrene (XPS) insulation was used, resulting a U-value of 0.5 W/m2.K (without taking account thermal bridging).

iii. Efficient glazing (Figure 5): Double glazed unit (6-12-6 mm) with U-value: 1.8 W/m2.K, SHGC: 0.24 & VLT: 36% was used to reduce heat gains and get enough daylight. Relatively shallow floor plate (15 m deep) of the building helped in daylighting.

iv. Energy efficient lighting: LEDs and T5 were used to achieve a lighting power density (LPD) of ~6 W/m2.

v. Energy efficient cooling system: A centralised high efficiency water-cooled chiller (COP: 5.8) was implemented for air-conditioning the building. Given the water scarcity in Jaipur, a sewage treatment plant (capacity: 15 m3/d) was installed and treated waste water is used for the cooling towers.

vi. Solar photovoltaic (SPV) system: A 45kWp grid-connected roof-top SPV system (Figure 6) with net metering is installed to meet part of the building energy requirement.

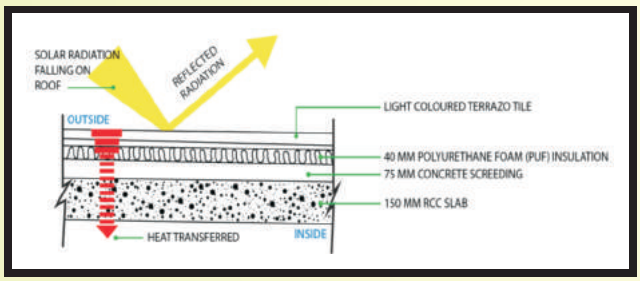


Figure 3: Roof insulation details

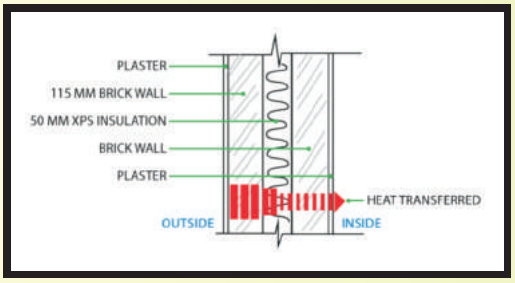


Figure 4: Wall insulation details

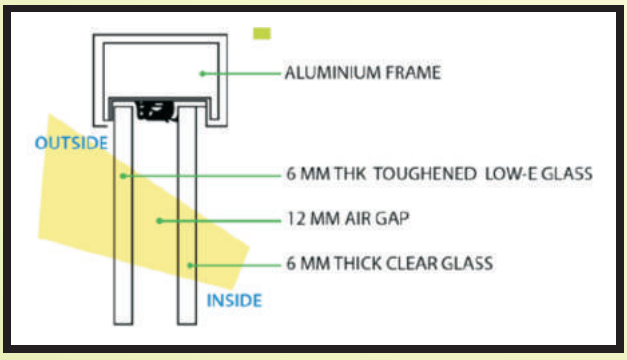


Figure 5: Glazing details



Figure 6: SPV system at the rooftop

Energy Savings

The energy simulation of the building was carried out using DesignBuilder software to quantify the benefits of the integration of EEMs. The energy simulation showed that the

cooling system size was reduced from 230 TR (before the design workshop) to 165 TR (after the integration of EEMs), which is a 28% reduction in the cooling system size. Reduction in energy consumption: The energy performance index (EPI) was reduced from 77 kWh/m2.y to 53 kWh/m2.y (31% reduction) after considering EEMs in energy simulation. This does not include the energy generated from SPV system.

Energy monitoring of the building was done to understand the actual energy performance of the building and to compare it with the estimated energy performance through energy simulation. The simulated EPI during the charrette (December 2012) was 53 kWh/m2.y as compared to the actual EPI (monitored data for May-15 to Apr-16) of 43 kWh/m2.y. 7 shows the comparison of monthly EPI for these two cases.

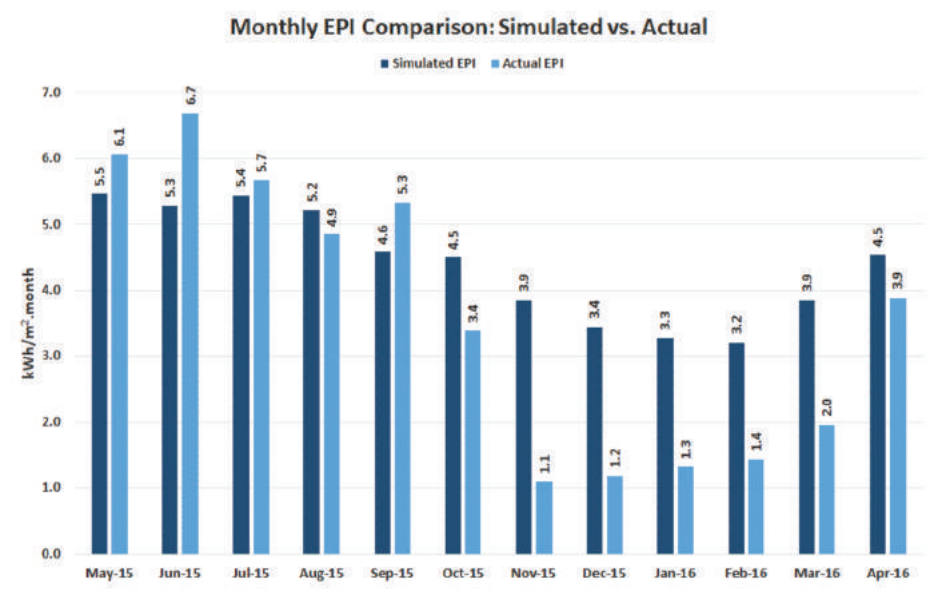


Figure7: Simulated and actual monthly EPI

Overall, there is a good agreement between the simulated and measured energy performance. Some variations are observed, which are explained below:

i. The simulation was done using the ISHRAE weather data file which gives the hourly data for a year with long term measured data. Weather conditions for the monitoring period may have differences as compared to the data considered in the energy simulation.

ii. During monitoring it was observed that the HVAC remained OFF during the period November - Mid March as the thermal comfort was good without any air-conditioning, while in simulation, the HVAC system was considered operational during this period.

iii. The artificial lighting energy consumed in winter (Nov-Feb) was also less than that estimated in the charrette due to better use of daylight.

iv. During the simulation, only weekends (Saturday & Sunday) were considered as holidays, whereas in the actual case there were 20 additional holidays.

The additional investment of around Rs 60 lakhs on the building (2% of the original budget), is expected to be paid back in less than 3 years due to annual savings of around 3,50,000 kWh/year.

Case Study 2: India International Institute of Democracy and Election Management (IIIDEM)

About the building & design process

The India International Institute of Democracy and Election Management (IIIDEM of the Election Commission of India (ECI) is located at Sector 13, Dwarka, New Delhi. The project is constructed by the CPWD. The key features of the project are:

- Built-up area: 26,240 m^2
- Number of floors: Institutional block - G+4, Hostel block - G+7
- Types of spaces: Training halls, offices, library, record rooms, computer labs, museum, auditorium, hostel rooms, dining facility

A design workshop for energy-efficient design with key project team members and the CPWD was organised at the design stage in July 2014. This workshop resulted in identification & selection of energy efficiency measures (EEMs) as well as building energy simulation to quantify energy savings. The construction of the building was carried out from 2015 – 2018. The building started functioning partly in January 2019. The performance of the building will be monitored in 2019-20 after it has been occupied fully.

Energy efficiency measures & renewable energy system implemented

The main EEMs taken in the institutional block of the project are as follows:

I. Dry stone cladding with air gap and insulated glazing to reduce heat gain inside the building.

ii. Non-occupied spaces (like staircase, machine rooms, toilets etc.) on the south-west face of the block.

iii. Free cooling, incorporating the use of ambient air for cooling whenever suitable.

iv. Heat recovery wheel (effectiveness 75%) to reduce the energy consumption for cooling

the fresh air.

v. Use of high-performance water-cooled chillers with better part load performance instead of air-cooled chillers. Automated control on the chiller to raise the chilled water temperature (gliding chilled water temperature) as per the cooling load.

vi. Solar hot water generation for kitchen.

vii. Renewable electricity generation through roof-top solar photovoltaics.

Energy Savings

The energy simulation of the building was carried out using DesignBuilder software to quantify the benefits of the integration of EEMs. The energy performance index (EPI) was reduced from 114 kWh/m2.y to 82 kWh/m2.y (28 % reduction) after considering EEMs in energy simulation. This does not include the energy generated from SPV system.

Conclusions

There is a large scope for reducing energy consumption in new office buildings. The following conclusions can be drawn from the two case studies:

I. In new buildings, the energy efficiency measures should be incorporated in the early design itself. An Integrated Design Charretre design methodology, which involves organising a design workshop or charrette with the entire project team (client, architect, HVAC consultant etc) and assisted by energy experts, has been employed. The IDP charrette primarily focuses on reducing heat gains or loss from the building envelope, improving natural ventilation, use of energy efficient space conditioning and application of renewable energy.

ii. In the case of Aranya Bhawan (case study1), the building Energy Performance Index (EPI) based on monitored electricity consumption, was found to be 43 kWh/m2.y, which is 41% lower compared to the base case. In the case of India International Institute for Election Management (IIIDEM), a CPWD project, the building EPI based on simulation was found to be 82 kWh/m2.y, which is 28% lower compared to the base case.

Acknowledgement

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GREEN ENERGY REVOLUTION IN INDIAN RAILWAYS- SOLAR ENERGY

Sanjay Nayyar, GGM/DFCCIL

Abstract

Indian Railways operates one of the world's biggest rail networks and is the single largest consumer of electricity in the country, accounting for almost 2% of India's total power consumption. In view of increasing demand of energy with de-carbonization of Indian Railways, the harnessing of Renewable energy sources especially Solar becomes imperative. Indian Railways is planning a massive surge of renewable energy deployment for its enormous network, aiming to meet 25% of its power demand with renewable, primarily solar, by 2025. India being the solar efficient nation, the harnessing of solar energy to the optimum level also assumes a very high priority, nationwide. The existing solar friendly policy of the Govt. also gives an extra impetus to the cause.

This very article on the subject matter makes an interesting reading and educates all our readers about the importance of Renewable Energy on Indian Railways and its all-round efforts to develop the solar resource to its optimum level while striking a proper balance with the conventional energy being utilized on IR. The article covers global and national scenario of Renewable energy (solar), importance & requirement for IR, technical nuances of its implementation in harnessing solar energy and its enhancing foot prints on National Scene.

Introduction

Indian Railways consume around 25 Billion units of electrical energy for its traction and non-traction application. The total energy bill paid for consuming this energy was about Rs.12, 636 Cr. (approx). Indian Railways has been consistently working towards controlling its energy bills. Moreover, the emission of Green House Gases affects the overall climate of India, which also calls for the need of reduction of emission of GHGs. In this area, Railway has already taken necessary initiatives towards the de-carbonization by synergizing the conventional energy with the available and up-coming corridors for wind & solar.



Solar Initiative of Indian Railways

As part of Indian Railways Solar Mission to reduce dependence on fossil fuels and keeping in line with Budget 2017-18 announcement of Hon'ble Finance Minister, to adopt a series of measures to promote clean energy, access to power and energy security, which will result in 20 gigawatts (GW) of solar capacity addition and feeding 7,000 railway stations with solar power, giving a major impetus to the shift to clean energy.

In the midst of this nationwide rise in renewable is Indian Railways, which aims to secure 25% of its energy requirements from renewable sources by 2025. Cutting down on fossil fuels for the sector will have a huge impact on the country's commitment to renewables, and subsequently the environment.

National Solar Scenario

India is Asia's second-biggest and the world's third-largest energy consumer, with its energy consumption set to grow at a CAGR of 4.2% till 2035. Besides having the world's fifth-largest capacity for power generation, it also has one of the most diversified power sectors in the world. As of March 2018, the total installed power capacity in India was of the order of 3,44,002 MW. Renewable contributed over 69,022 MW within this capacity. The renewable addition comprised of about 21,651 MW of Solar capacity and the remaining was from wind.

The last two years have witnessed considerable efforts being made to harness India's solar energy potential. There has been a more than 240% increase in solar power capacity addition during the last two years. At least 50 solar parks with an aggregate capacity of 40,000 MW have been sanctioned for 21 States.

Meanwhile, much of the solar delivery will be achieved through the installation of rooftop panels. In a union budget speech for fiscal year 2017-2018, Indian Finance Minister Arun Jaitley announced that 7,000 Indian railway stations would eventually be fitted with rooftop solar power systems. Jaitley claimed that 300 stations have been fitted with panels already, and that this number is expected to stretch to 2,000 soon.

With solar tariffs already falling to an unprecedented low of 2.44/kWh and wind tariff to 2.43 / kWh, the whole paradigm of incentives required for investments in renewable generation is very likely to undergo a tectonic shift. In fact, if this trend continues, the very need for Renewable Purchase Obligations may go away as a competitive price may cause the shift to renewable energy sources automatically. The CERC has also noted recently that there could be a need fairly soon for a re-look at the need for separate Solar and Non-Solar RPOs and also further to consider whether RPOs themselves may no longer be required as renewable energy appears to be already amongst the cheapest power options.

To provide a fillip to the sector, various incentives have been announced by the government. These include, among others, Inter-State transmission charges and losses on the CTU system being waived for 25 years for wind plants commissioned by 31 March 2019 and for solar plants commissioned by 31 December 2019, provided this power is being procured by distribution companies to meet their RPOs.

In view of the above scenario, IR may consider developing their own parks and connect them to the CTU through dedicated transmission lines. The RE projects in these parks may be got executed through third parties selected on the basis of tariff-based bidding. To begin with, the Railways may sell some portion of the capacity to third parties through PPAs that may be for 5 or 10 years. As the energy needs of the Railways grow, this power could then be used by the Railways themselves.

While module costs are dropping constantly, market tariffs are dropping even faster. It thus appears commercially better for the Railways to buy power through PPAs based on most recent benchmarks rather than establish its own capacities. The decision would, however, be based on situational priorities.

Solar Park

Renewable energy will therefore play a central role in bridging the supply and demand gaps in India's energy landscape. With the country having worked diligently towards achieving economies of scale in renewable energy production, a dramatic reduction in costs has already been seen in the prices of solar energy. With the wind energy space now receiving similar attention, price drops have occurred there too. On the solar power front, India is anchoring a global solar alliance. A scheme for developing 25 Solar Parks, Ultra Mega Solar Power Projects, canal top solar projects and one hundred thousand solar pumps for farmers are at different stages of implementation. The country is also creating Green Energy Corridors to ensure evacuation from renewable energy plants (e.g. large wind power capacities in Southern States and solar parks in Rajasthan), implementing the National Smart Grid Mission and driving new programmes for increasing energy capacities from wind and also from waste-to-energy conversion.

In furtherance of its renewable mission, the Govt. of India decided to set up large Solar Parks with a total capacity of 20,000 MW. Several solar parks are accordingly being set up by entities like Solar Energy Corporation of India (SECI), NTPC, REMCL generally in collaboration with State Governments & other Government bodies. A Solar Park is a concentrated zone of development of solar power generation projects. Infrastructure like transmission system, water, road connectivity and communication network etc. would be

developed, thus reducing the risk & gestation period of the projects.

On the one hand, while solar parks enable States to bring in investment from project developers, this would help large entities like the Railways in meeting their Solar RPO mandates. Some of the newer parks being developed by SECI also propose to have a small quantum of storage capacity available. While this may be meant to assist the grid manager in handling the impact of any sudden intermittency in output, thereby giving them more time to take other grid balancing measures, the benefit of better stability would be available the customers, as well.

In late February 2017, the Cabinet Committee on Economic Affairs, chaired by the Prime Minister, approved the enhancement of capacity from 20,000 MW to 40,000 MW of the Scheme for Development of Solar Parks and Ultra Mega Solar Power Projects.

The enhanced capacity would ensure setting up of at least 50 solar parks each with a capacity of 500 MW and above in various parts of the country. The total capacity when operational will generate 64 billion units of electricity per year which will lead to abatement of around 55 million tonnes of CO2 per year over its life cycle. It would also contribute to long term energy security of the country and promote ecologically sustainable growth by reduction in carbon emissions and carbon footprint. The State Government will first nominate the Solar Power Park Developer (SPPD) (who shall develop and maintain the Solar Park) and also identify the land for the proposed solar park. It will then send a proposal to MNRE for approval along with the name of the SPPD. The SPPD will then be sanctioned a VGF & Central Financial Assistance (CFA) or Achievement linked incentives upto 25 percent of the benchmark cost as per the milestones prescribed in the scheme. Solar Energy Corporation India (SECI) will administer the scheme under the direction of MNRE. The approved grant will be released by SECI. As stated earlier, MNRE is already implementing a scheme for development of at least 25 solar parks with an aggregate capacity of 20,000 MW, which was launched in December 2014. As on date, 34 solar parks of aggregate capacity 20,000 MW have been approved which are at various stages of development.

RESCO/Developer Model

- Zero upfront costs, procure power at rates cheaper than existing grid rates and enjoy savings for the term of PPA (usually 25 years) from day 1 of the system operation. BOOT option available for 10, 12 and 15 years.
- Entire system is owned by the developer.
- Responsibility of O&M for the system lifetime (25 years) is also with the developer.

- Purchaser consume the electricity generated, for which they must pay a pre-decided tariff monthly.
- It is a low-cost intensive option as compared to CAPEX/EPC model where the entire system is owned by the owners.
- The developers are selected through a tariff-based reverse bidding.
- The developer owns the asset (Plant). The consumer and the producer enter a PPA (power purchase agreement) for 15-25 years.

CAPEX Model

- Upfront Investment in the solar Asset having life of more than 25 years. Payback in year 6-7 after which Cost of Generation of Solar Power goes down to ~ Rs 1 / kWh.
- Entire system is owned by the Owner.
- Responsibility of O&M for the system lifetime (25 years) is also with the owner.
- Developer is responsible for installing the system and initial 2 years O&M
- The developers are selected through a system cost-based reverse bidding.
- Selected bidders are offered 30% subsidy on the system cost (exclusive of taxes).
- End consumer owns the asset (Plant) and can claim accelerated depreciation

Wheeling and Banking

Wheeling electricity—the process of transmitting electricity from a producer to a user(s) in the same balancing area or from one area to another has historically been used for conventional generation sources. However, as an increasing amount of variable renewable generation is being developed, policymakers and regulators are adopting new or revised wheeling (i.e., transmission) and renewable energy (RE) banking policies that could effectively support renewable development. Often, the highest-quality renewable resources are located far from major electricity load centers; wheeling polices can support transmission to deliver renewable generation to those load centers.

hen a generator is wheeling electricity, in some markets, it can virtually bank the electricity for consumption by an end customer at a later time. The bank is not a physical energy storage facility but rather, energy is virtually banked through accounting methods. For example, if a solar generator produces during the day but wants to sell to a consumer that needs electricity

at night, banking service allows the generator to put all of its generation on the grid during the day and then use banked grid supplied energy to serve the customer's needs at night.

Banking is a provision wherein an RE power-generating facility is allowed to bank the electricity it produces that is not used by its off-taker or to borrow the energy it needs to sell to the buyer in the event of its inability to produce for a given duration (from 15 minutes to one year). These deviations are accounted for and the net surplus or short-fall is financially settled on a monthly, quarterly, or annual basis. Banking provisions in India are typically provided at the point of consumption by the distribution licensees. The mechanism of net settlement of deviation from schedule for large wind and solar, introduced by CERC in 2015 provides a unique banking arrangement without any concessional treatment. As per this mechanism, the excess or under generation vis a vis schedule generation of such (regional level) wind and solar plants is settled at the PPA rate in the regional pool. Several SERCs have established banking regulations, which include, inter alia, the fee to be paid and the period or timing of withdrawal to be determined by the appropriate commission for intra-state transactions. Similar dispensation is not given to inter-state transfer; the existing banking mechanism is currently not adequate to enable inter-state transfer of wind and solar energy.

RPO compliances

Section 86 (1)(e) of the EA 2003 mandates the state electricity regulatory commissions (SERCs) to promote cogeneration and generation of electricity from renewable sources by providing suitable measures for grid connectivity and sale of electricity to any entity; it also specifies that, for purchase of electricity from such sources, a percentage of the total consumption of electricity in the area should be from a distribution licensee. Accordingly, all SERCs required that a certain percentage of the total electricity consumed by the Obligated Entities in their states have to procure renewable energy. This is known as the renewable purchase obligation (RPO).

As per the act, the obligated entities include distribution licensees, open access customers (those who purchase power from someone other than a distribution licensee), and captive customer (those who are self generating). In order to promote solar energy, the 2006 Tariff Policy was amended in January 2011 (Ministry of Power 2011), wherein SERCs were mandated to carve out minimum solar-specific purchase obligations (SPOs). Moreover, such SPOs should be at least 0.25% in 2012-13 and it should be increased to 3% by 2022. Accordingly, almost all states have specified an SPO. State targets range from 0.25% to 3%, however, many states do not have interim targets (MNRE 2015). The Tariff Policy was amended again in 2016, increasing the SPO to 8% of total consumption by March 2022 (Ministry of Power 2016).

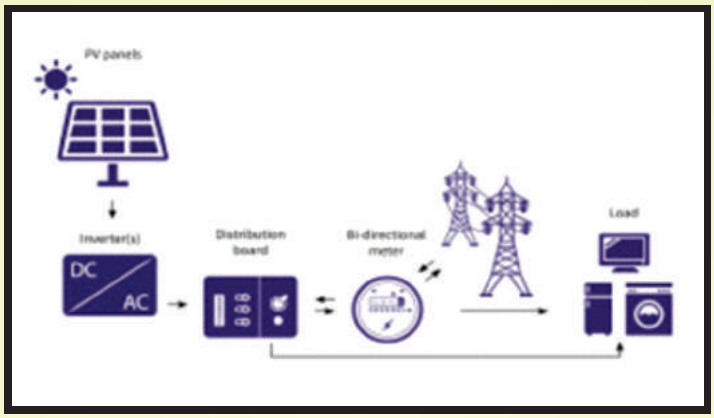
Net metering/ Gross metering

Gross metering:

The total energy generated by the solar rooftop plant is to be injected into the grid without allowing the generated solar energy to be consumed directly by the consumer.

Net Metering:

The energy generated by the solar rooftop plant is first allowed for self-consumption and the excess energy is injected to the grid.



The latest circular also limits the SRTPV(Solar Roof-top Photo-Voltaic) capacity to 100% of the sanctioned load of the building. Which means that if a buildings sanctioned load is 5 kW, the maximum solar that can be installed is 5 kWp.

Here is a comparison of net metering and gross metering on various parameters:

Connections

One of the major differences between the two type of metering is in the connections.

NM- In net-metering, the solar power generated is first intended to be used within the building and only excess is exported.

GM: In-gross metering, the solar power and the power needed for the building are two separate circuits.

No. of Meters

Both the metering type has two meters a bi-directional meter and a uni-directional meter. The meters are used in different ways.

NM- The bi-directional meter calculates both the import of power (energy imported from the grid). The uni-directional meter will measure the total solar generation.

GM: The bi-directional meter is used to measure the total solar generation and the uni-directional meter will measure the total import of power.

Billing And Payment

Net-Metering: There is only one bill generated which will give a measure of both total imported energy and total exported energy. The difference between both is taken and the payment is based on the net of import or export. In case of net export (export greater than import) the DISCOM will pay (account transfer) Rs. / kWh for the net exported energy. If the import is more than export, i.e. net import, the consumer will have to pay the DISCOM at the prevailing tariffs (slab based).

Gross-Metering: There will be two bills generated, one for the total export, where the DISCOM pay the consumer (account transfer) and the other for the total import (regular electricity bill), where the consumer pays the DISCOM.

Financial Benefit Comparison

For both the metering scheme, a PPA (Power Purchase Agreement) is signed between the consumer and the DISCOM which is for 25 years. As per the new guidelines, consumer can choose one of the metering and cannot change to the other later (irrevocable). This means that the financials play a crucial role in the choice of the metering.

GM: The returns from the solar is fixed for 25 years as all the energy generated is exported and the PPA is for 25 years. The trend of regular electricity bill has been that there is a hike in 5 to 7% in the rates year on year. This means that the cost of electricity that we intake from DISCOM would increase every year.

NM: The return from the solar is dependent on what is the savings on the electricity bill due to the installation of the solar system. As the electricity bill increases every year, the savings from solar also increases.

GM has a marginal advantage in terms of revenue generated. But within a few years, the benefit from self-consuming the energy will make NM more advantages. As solar is a long term asset, NM has better advantage in terms of financials.

As there is only one bill generated, there is less confusion in terms of the payment to be received from the DISCOM and the amount that has to be paid to DISCOM.

Overall, we feel both in terms of financials, long term benefits and ease of the system, net metering is the best and that's why we call Net-metering the NEAT METERING

Challenges / Opportunities & Threats

- Section 86 (1)(e) of EA 2003 requires SERCs to develop policies that will promote the sale its buyer (open access user), which could be an obligated entity or otherwise, regional/state transmission charges and losses are required to be paid depending upon connectivity of the generator and the buyer at the federal or state transmission networks. Further, if the generator and/or the buyer are connected at the distributed voltage level, appropriate wheeling charges and losses are also required to be paid. Importantly, the Capacity Utilization Factors of wind and solar projects as specified in the RE tariff regulations /orders issued by the CERC and various SERCs are in the range of 19-26.5%. This is much lower than that of the base load generation (generally at the level of 80-90%) (CERC 2014a). Based on the current mechanism for determining wheeling charges on INR (Indian rupee)/kW/day basis from various SERCs (e.g., Gujarat, Rajasthan, Andhra Pradesh), this makes the wheeling charges for RE generators almost four to five times the conventional open access transaction.

- PPAs are being signed for 25 years, often below the cost of “brown” power from the grid. Organizations that sign a PPA can reduce their electricity expenses and gain stability in financial planning as a result. A long-term renewable energy contract represents a real opportunity to hedge against increases in traditional energy costs but even with the promising competitive price trends, predictable prices alone won't guarantee that a renewable energy PPA will produce the valuable financial benefits organizations are seeking.

- Government policies are changing day by day, this may influence the implementation of Renewable as well as power procurement projects and we shall equip ourselves with the latest development in this regard. There is no single comprehensive policy statement for Renewable Energy in the country. The policy framework at the state level is no better. In fact, in many states policies have only created uncertainty for investments in Renewable Energy projects.

- Technology up gradation no doubt creates a positive impact on the development of renewable energy projects but simultaneously it also affects the price of generation.

- Banking of power is not applicable for Distribution Licensee.

- Accurate Scheduling and Forecasting Required.

- The lack of clarity on implementation of MW class or small project.
- Net metering and Banking are not available everywhere and Solar regulations varies from state to state, which limit the scope of developer.

Conclusion

Purchase Solar PV power from CTU-connected parks where tariffs are likely to be lower (due to economies of scale as well as pre-developed infrastructure) and inter-state transmission charges and losses are also waived for 25 years. This would further enable the Railways to re-schedule the power to another State based on operational needs more easily than from an RE resource electrically embedded in the State-level network. When RE resources connected to the STU or the Distribution network are used, there could be limitations on export as well as non-availability of any concessional wheeling charges at the State level that might otherwise be available for renewable energy.

Establish Railway owned RE parks with large capacities and connect the same to the CTU. While the park could be populated in increments of 250 MW, any portion of capacity that is not immediately required by the Railways could be sold to third parties through PPAs for 5 years or so. This would enable the Railways to get back the capacity as its own requirements increase with additional electrification. Execution of the RE capacity in these parks could be got done through the PPA mode by third parties selected on the basis of tariff-based bidding.

Establish RESCO / PPA model small capacities in strategic locations preferably for non-traction loads where loads are more predictable and therefore alternative supplies are easier to plan and obtain. These capacities could be directly connected to the loads. Such capacities could be ground-mounted or rooftop-mounted, depending upon availability of space with the Railways that could be leased out to the winning bidder for the PPA term.

SOLAR PHOTOVOLTAIC: HARNESSING ABUNDANT SOLAR ENERGY RESOURCE

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Abstract

Economic growth of any country is gauged by its energy consumption. For sustainable growth, energy should be both resource efficient and environmentally safe from the point of view of global warming. India will overtake China as the largest growth market for energy by late 2020s with the country's energy consumption growing by more than 4.2 per cent per annum, the fastest among all major economies of the world.

India has a great potential to generate electricity from solar energy and the country is on course to emerge as a solar energy hub. The techno-commercial potential of Solar Photovoltaic (SPV) in India is enormous. With GDP growing in excess of 7%, the energy 'gap' between supply and demand will only widen. Solar PV is a renewable energy resource capable of bridging this 'gap' as most parts of India have 300 – 330 sunny days/year.

Introduction

Average solar incidence in India stands at a robust 5 kwh/m^2/day. Apart from augmenting the energy supply, renewable resources will help India in mitigating climate change. At present, India is heavily dependent on fossil fuels for its energy needs. Most of the power generation is carried out by coal and mineral oil-based power plants, which contribute heavily to greenhouse gases emission. India, USA and China account for 7%, 15% & 30% respectively of the total CO_2 emissions of the world. Global warming is attributed to the growth of the emission of greenhouse gases. One of the key elements to consider is the stability of CO_2. Once emitted into the atmosphere, CO_2 can stay there for a very long time, even a century.

Solar Power, a clean renewable resource with zero emission, has tremendous potential of energy, which can be harnessed using variety of devices. Main driver of solar programme is Renewable Purchase Obligation (RPO), which is applicable to Power Distribution Companies and consumer with large captive power plant/contract demand. Solar Photovoltaic (SPV) is fastest growing 'green' energy generation technology due to increasing awareness of climate change hazards, energy security considerations, decline in solar energy generation cost and policy framework. It is estimated that 300 million Rooftop Solar installations will be completed by 2030 in India as Net-Metering Business Model is gaining acceptance and popularity.

Solar Energy Technologies

Solar Energy is utilized for both electricity generation (direct & indirect), heating & cooling applications like Concentrated Solar Thermal Energy Technology based on Parabolic Dish collectors, Solar Thermal Stirling Engine & High Efficiency Solar Thermal Air-conditioning Systems as shown in Fig.1.

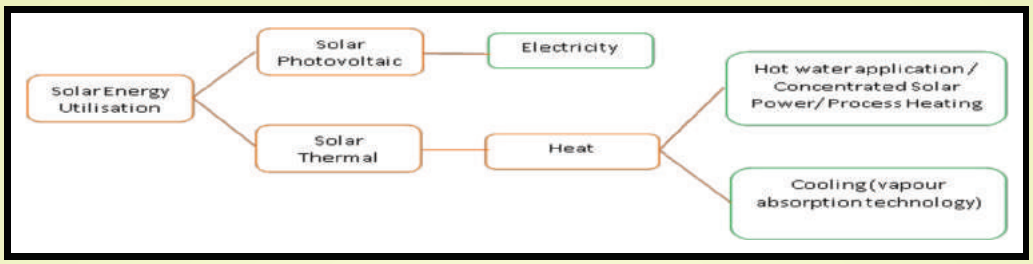


Figure 1: Solar Energy Technologies

Manufacturing of Solar Cell

Global manufacturing and Solar PV value chain is given in Fig. 2.

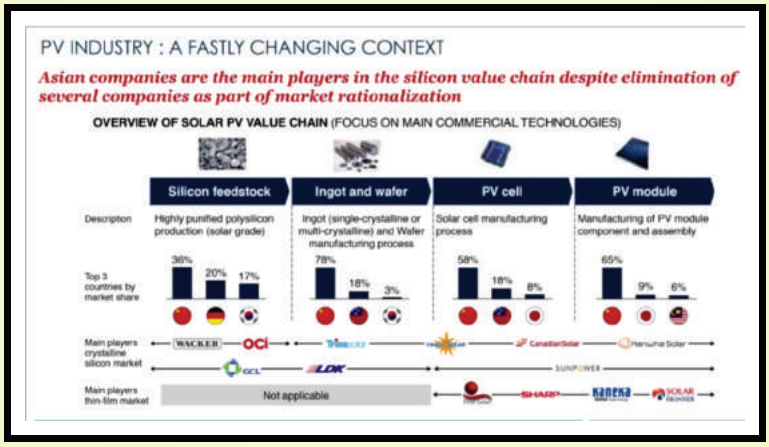


Figure 2: Solar PV Value Chain

India has 3.1 GW Solar Cell and 8.8 GW Solar Module Capacity. Existing capacity of solar cell production is mainly based on conventional Aluminum-Back Surface Field. Very few have ventured into PERC (Passivated Emitter Rear Cell) technology. Material usage for silicon cells has been reduced significantly during the last 12 years from around 16 g/Wp to less than 6 g/Wp due to increased efficiencies and thinner wafers.

Around 40 % of India's solar cell manufacturers have shut down their operation with industry utilization at only 21%. Indian Solar industry has suffered due to sudden and sharp price decline because of global over supply and lack of level playing field. We have imported around 80 % of solar modules in 2018, mainly from China.

Silicon based solar cell dominates the SPV market due to its abundance & suitability in

capturing solar photon (Fig.3). Poly/multi crystalline Si now dominates global SPV market (Fig.4).

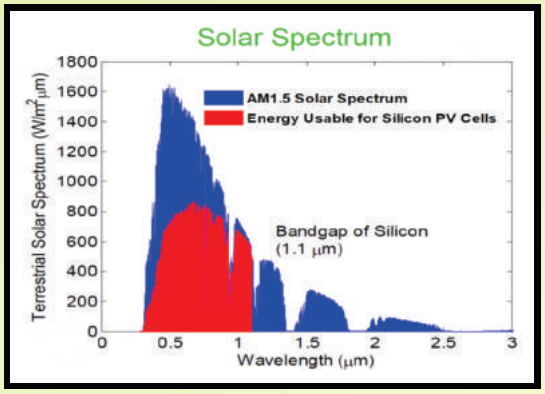


Figure 3

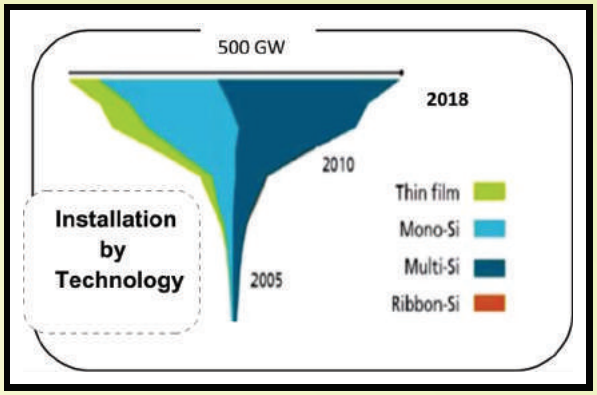


Figure 4

Solar Energy Installation

India ranks fifth after China, Japan, USA & Germany in terms of installed solar energy capacity. Installed Solar Power generation capacity in India is 25 GW against Global installed capacity of 500 GW (Fig.5 & 6). Solar & Wind energy sources contribute around 20% of the total installed power generation capacity in India.

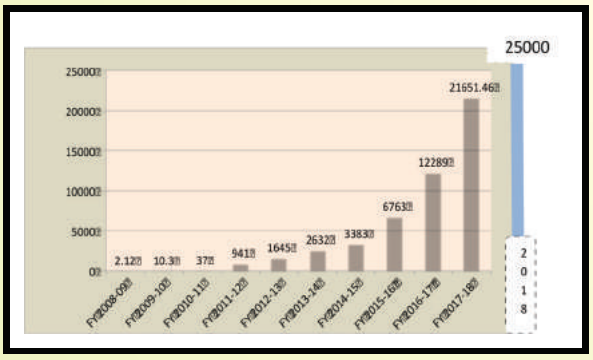


Figure 5:Installed Cumulative solar power Capacity in India (MW)

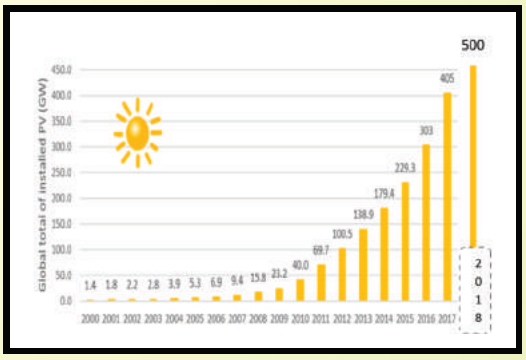


Figure 6: Installed Global solar power capacit (GW)

Cost of Renewable Energy

Grid prices of electricity are Rs 6 to 11 / unit in different states for commercial and industrial customer. Cost of generation of Renewable Energy is declining and now Grid Parity has been achieved as shown in the Fig. 7.

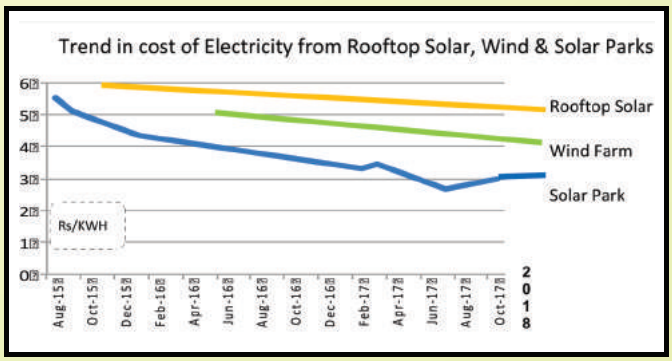


Figure7: Renewable energy generation cost trend

Grid parity (or socket parity) occurs when an alternative energy source generates power at a levelized cost of electricity (LCOE: cost of electricity generated over lifetime) that is less than or equal to the price of purchasing power from the electricity grid.

India's National Solar Mission & Contribution of CPWD

The country has a mission of solar power of 1,00,000 MW by 2022 which includes 20,000 MW through ultra-mega solar parks, 40,000 MW through rooftop and 40,000 MW from utility scale solar. The government has already taken up various measures to achieve this target. CPWD has installed 14 MW Rooftop Solar plants in this endeavour.

Sun-path

Sun path affects the length of daytime experienced and amount of daylight received along a certain latitude during a given season (Fig.8). The relative position of the Sun is a major factor in the heat gain of buildings and in the performance of solar energy systems.

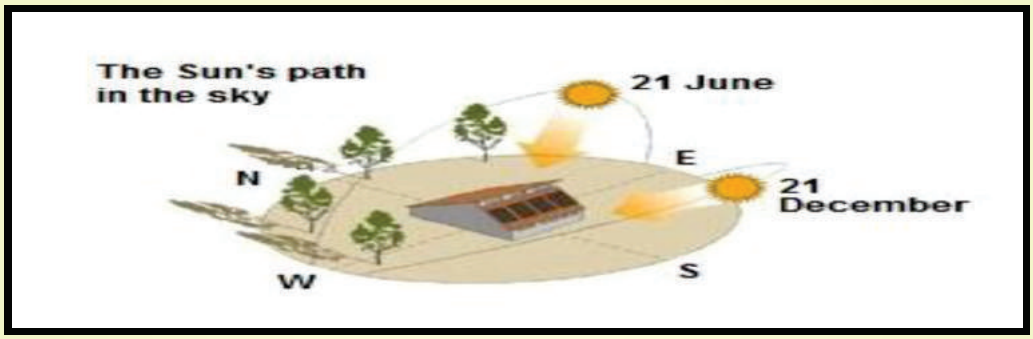


Figure 8:Geographic Orientation and Solar Angle

Solar Panel Orientation

The area of sky open to sunlight (9AM to 3 PM) for a site is called solar window. Solar panels are turned towards the terrestrial equator (Fig. 9), facing south in the northern hemisphere, so that during the day its orientation allows the panel to catch the greatest amount of solar radiation. It is essential to have an ideal panel orientation for static panels (without tracking system).

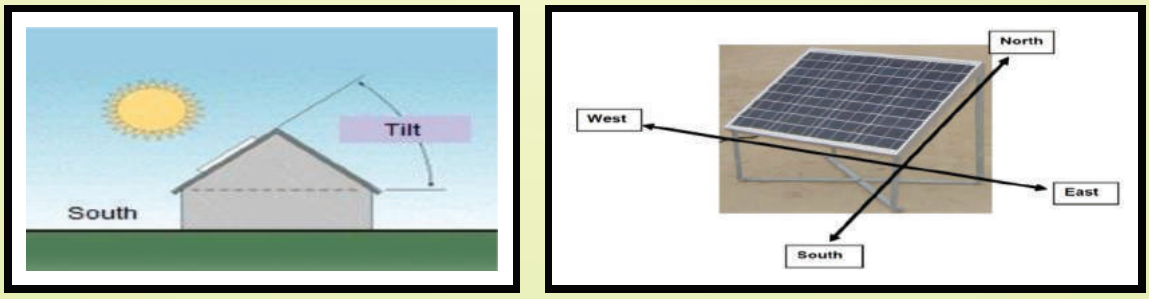


Figure 9: Orientation & Tilt of Solar Panel

INSOLATION

Insolation (incoming solar radiation) on Solar Panel with different tilt angles (location: New Delhi) is shown in the Fig. 10. We can get up to 10% more annual generation with seasonal change in optimal tilt of solar panel compared to fix tilt.

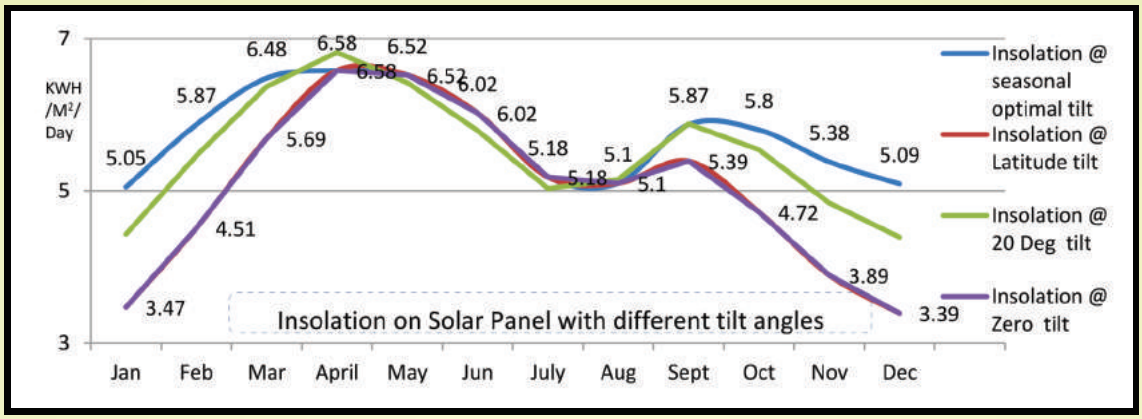


Figure 10: Comparison of Insolation at various 'fix tilt' of solar panel

Optimal Seasonal Tilt

In order to collect max solar energy, rays should fall perpendicular to solar panel. Optimum seasonal tilt angle, based on mathematical models and actual insolation data, for Delhi (28.7° N), is shown in the Fig. 11. High tilt angle (>30°) in Solar panel may cause shadow in adjacent row due to space constraint. Hence, Solar panel with 6°tilt for May, June & July and 27° tilt for remaining months of year will yield around 5% more annual generation. Solar water heating panels should be mounted with 52-53° tilt in order to capture max solar energy in winter.

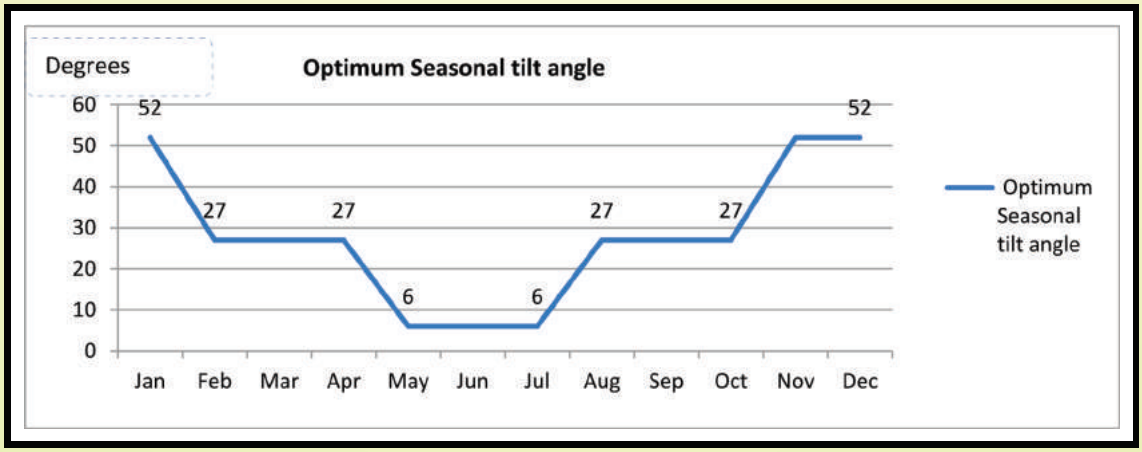


Figure11: Seasonal optimal tilt angle for max performance

Case Study: Comparative Rooftop Solar Power Generation

Performance of five Rooftop, Grid –Tied, Solar Plants for 2018 , installed at CGO Complex(150KWp), Indira Paryavaran Bhavan (IPV,930KWp), Pushpa Bhavan(PB,200KWp), Electronics Niketan (EN,200KWp), Rashtrapati Bhavan (RB, 100KWp), all with fix tilt angle, and one ideal installation with seasonal change in tilt (IPV@seasonal tilt) having per KWp annual electricity generation of 1018,1252,1270,1317,1349 & 1688 units respectively (Fig.12).

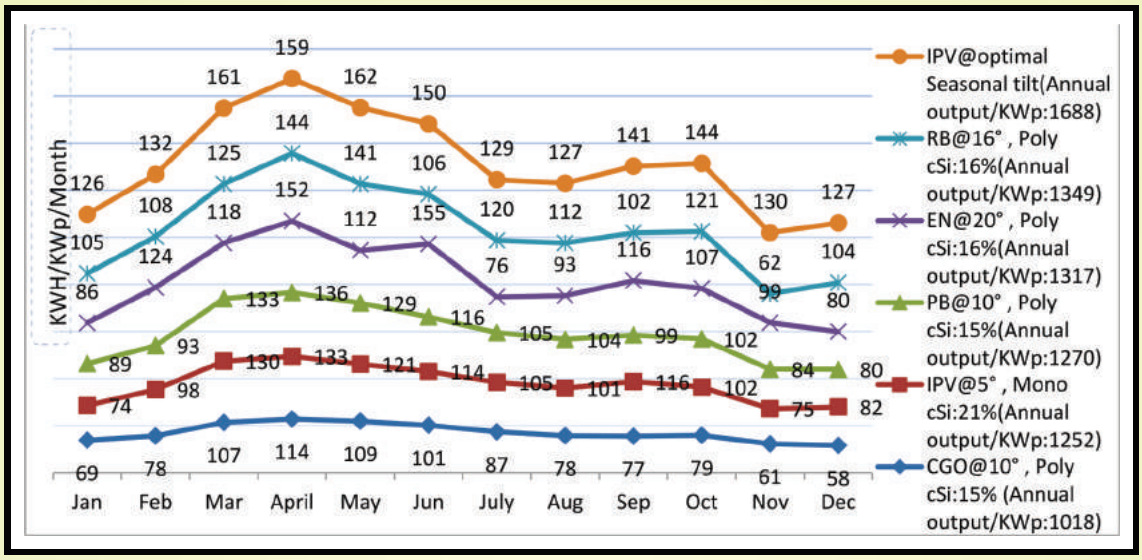


Figure12: Comparative output of rooftop solar plants at Delhi

Building Integrated Photo Voltaic (BIPV)

BIPV technology provides unique opportunities to convert glass windows, front facades, exteriors and other building integrated applications into solar panels, which will directly capture sunlight and convert them into power. BIPV solar panels may cost 25-30 per cent more than glass panels / cladding material, but over the years this cost can be recovered as these panels will also generate power for the building.

Building Integrated Photovoltaic is a new type of building material, which provides green energy as well as building preservation. Double Glass PV modules with glass on both front and backside are now available in different dimensions, thicknesses, shapes and colours with partial transparency and opaque options. Partial transparency of solar modules lets in natural light along with producing electricity making them ideal for roof, façade, canopy, parking lot, window, shelter, balcony and other applications. These also act as heat shield preventing excessive solar heat gain into building.

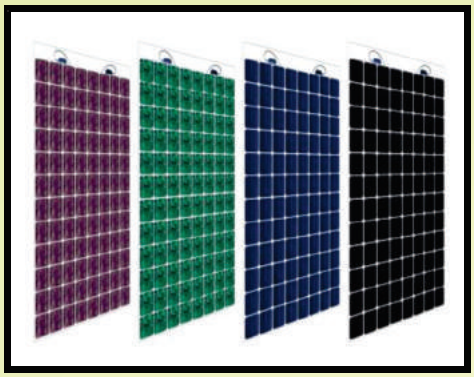


Fig.13- Double Glass PV modules



Fig.14- Applications in façade & balcony



Fig.15- Double Glass PV modules applications in Parking lot, façade & pergola

Main considerations in installation of SPV system

The most efficient way to install photovoltaic panels would be to engineer arrays that can be seasonally adjusted to an advantageous tilt. In order to avoid obstruction / shadow on solar panel, following space clearance should be ensured (shadow analysis):

a) East or West: The distance between solar panel and obstruction should be more than double the height of obstruction.

b) South: The distance should be equal to height of obstruction.

c) Adequate clearance between adjacent solar panels to avoid shadow. Spacing should not be less than 0.5 mtr for movement of maintenance staff.

d) Tilt angle adjustable mechanism with Cadmium plated /SS nut and bolt in GI/Al structure.

e) Ease of maintenance and safety aspect like railing in rooftop structure.

Solar ready houses

Site evaluation should take into account the relationship of the house to the path of the sun throughout the year. The location of any existing (or future) foliage that may shade the photovoltaic array should also be considered. It is recommended that the house's landscape design avoid tall trees and other objects that may eventually cast a shadow on the photovoltaic array. Areas to the east, south, and west of the house should be carefully landscaped to avoid shading the array during the corresponding portions of the day. Tilt of the rooftop should be due South and as max as possible. SPV mounting structure height (S to N) should be progressively raised to avoid shadow in the adjacent row especially with high tilt angles. Roof structure design should support additional weight of PV array. The provision for roof integrated mounting points for PV should be made at design stage.

Causes of Solar Panel Failure

There are several causes of failure of a solar panel, as given below, that lead to loss of optimal efficiency.

Panel Cracking

Physical impacts, oscillation from wind or manufacturing defects can lead to cracking (Fig.16). Cracks alter the optical properties of the panel and some incident light does not penetrate.

Panel Discoloration

It reduces the amount of sunlight that penetrates into a solar cell. For instance, purple discoloration (Fig.17) means that the panel does not absorb purple light and this causes loss of efficiency. Causes of discoloration are poor encapsulant quality, high temperatures, humidity.

Hot Spots

Hot spots occur when a panel is shaded, damaged, or electrically mismatched. Hot spots decrease power output as solar cells are attached in strings and just one hot spot can lead to multiple cells functioning poorly. To solve this problem, all shading should be negated, and electrical connections should be optimized. Hot spots can be easily seen with the use of an IR Gun (Fig.18) shows an example of multiple hotspots.

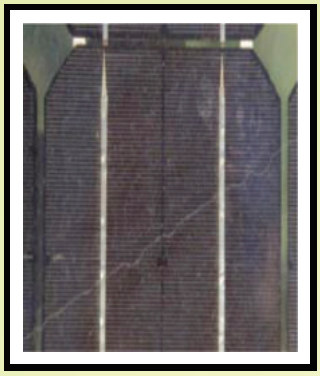


Fig.16-Panel Cracking

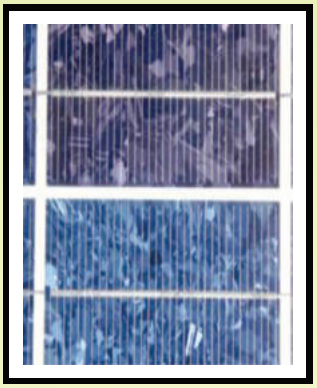


Fig.17-Panel Discolouration

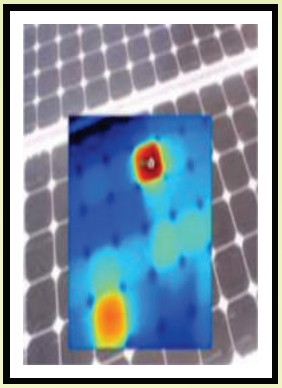


Fig.18-Panel Hot Spots



Fig.19-Panel Soiling

Soiling

It is one of the most prominent issues in dusty environments (Fig.19). Tilt angles less than 5 degrees were shown on average to have 5x more soiling than ones that were tilted more than 5 degrees.

Monitoring failure

Most inverters have in built monitoring system and expected to last for the lifespan of the system. Monitoring of SPV system could be at string level, inverter level and meter level.

Wind

All solar panels must be tested to withstand certain wind loads, which are significant for wind speed over 60 Km/Hr. Testing of panel is carried out in a wind tunnel and blasted with wind linearly from a single direction but field wind patterns are not linear and can cause damage to solar panels.

Maintenance

Panel Cleaning is important to maintain optimal energy output and to be carried out regularly. Cleaning early in the morning ,when the mirrors are wet from dew, is probably the best time to clean the panels because dust can easily be rinsed without damage to coating on panel. Detergent based solutions are normally able to restore the surface to 98% of its original reflectance. High-pressure sprays proved to be a very effective method for cleaning large-scale arrays.

Conclusion

Solar energy has helped utilities address critical issues such as high transmission and distribution losses and facilitated green and clean development. It has made consumer an

active investor to participate in energy sector where there is no need of land and dedicated transmission.

It is estimated that buildings stock in India will double in next 10 years. As living standards rise, demand for cooling and air conditioning will rise dramatically and can strain electric grids, worsen air pollution, increase fuel imports, and fuel climate change. SPV will not only augment electricity supply but also reduce the urban heat island effect by reducing the amount of heat gain in an urban area and provide opportunities to reduce smog & air pollution by introduction of electric vehicles.

Now with reduced cost of solar panel, payback period of grid-interactive SPV System is less than five years. The per-unit cost of solar rooftop system is around five rupees without considering subsidy and RECs (Renewable Energy Certificates), which is progressively decreasing and now Grid Parity has been achieved. Despite low Load Factor of SPV compared to Thermal, it has enormous potential of electricity generation due to distributed abundance of Solar Energy and zero emission. Need of the hour is to construct 'Solar Ready' buildings to integrate Solar PV and Solar Thermal systems. BIPV systems will become more prevalent with introduction of cost effective Double Glass PV modules and economy of scale. Provision of directional / angular adjustment should be provided to get maximum utilisation of incident sun light and increase electricity generation to maximum extent.

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ENERGY CONSERVATION AND REDUCTION OF ELECTRICITY BILLS

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Abstract

Energy conservation is very important not only from the money saving point of view but also from various aspects including environment impact, energy security, pollution control, global warming and their cumulative effects. Govt. of India is also pursuing hard on this subject and making mandatory the installation of solar power, use of LED lights, star rating of appliances, implementation of green buildings, creating awareness in the general public, and distribution of LED bulb etc. Study on various energy conservation measures and reduction of consuming electrical energy in use is presented in the paper.

Study of Electricity bills

Reduction of electricity bills is first and foremost part of energy conservation, hence understanding of the same is essential. Electricity Bills for several buildings maintained by different departments in the NDMC area have been studied for more than 3 years. Following are to be taken care in the bills;

Sanctioned load

It is mentioned at the top of bill in KW/KVA. KVA here is calculated by dividing sanctioned load in KW with monthly average power factor and fixed charges are calculated based on this KVA or actual maximum KVA whichever is higher. Actual KVA is calculated by multiplying MDI readings with multiplying factor and both of these data are given in every bill. Now a days per KVA fixed charges have been doubled and charged @Rs250/- per KVA per month giving rise very high amount in bill, therefore it's optimization is very important as by doing so Fix



charges can be reduced without spending any money. Normally it is noticed that actual demand is higher rather highest during peak summer season i.e. June and July based on that bills for last 2-3 years can be studied and accordingly the sanctioned load which is normally fixed theoretically at the time of connection can be got optimized/reduced. Study of MEA Headquarter building Jawahar Lal Nehru Bhawan, New Delhi has been made from this point of view and it was found that the sanctioned load is higher by more than 1500 KW but supply companies have some reservation to reduce the sanctioned load by bigger values so it has been reduced by 25% of the original sanctioned load leading to a saving of Rs.36 lakhs per annum. Similarly, the same method has been used at ITPO Pragati Maidan, New Delhi resulting into saving of Rs 96 Lakh per annum through reduction of sanctioned load from 7000KVA to 4200KVA.

Electricity Tariff

Tariff in the bills also needs to be verified/rechecked as it has been noticed that connections at the residence of even VVIPS were charged with wrong tariffs by a supply company in New Delhi area. The tariff was charged @ Rs.7.85 per KVAH against Rs.7.15 per KVAH as well as fixed charges were also charged at a higher rate of Rs.130 per KVA in place of Rs.125/- per KVA giving rise to a higher bill by more than 10%, therefore, tariff also need to be verified.

Average Power Factor

It is the ratio of total KWH consumption and total KVAH consumption during month, also mentioned in the bill. Normally it comes 0.8 to 1.0 but some time it may be shown below this due to faulty CT/PT as noticed at Vayu bhawan, New Delhi at 0.6 or so due to non-suitable PT and this went on for years giving rise of extra payments to electric supply company.

Now a days electricity bills are raised based on KVAH for sanctioned load 10 KW or more in non-domestic category in place of earlier system of KWH and penalty for users having power factor lower than 0.85. Due to billing in KVAH power factor plays very important role and bills are directly linked with its value means even if we maintain it at 0.99 our bill will be higher by 1%. People may think this 1 or 2% as immaterial but don't forget the generation by solar is also in this range (Shastri bhawan has 250KW solar which hardly gives generation 3% of the consumption in monetary terms it is hardly Rs 70000/- per month). It is also a fact that normally rating of power factor correction system (APFC) is provided @30% of transformer capacity which is insufficient to tackle full load of transformer. To deal full load of transformer APFC panel is needed @75% of transformer rating, moreover it's capacity deteriorated and within 4-5 years it exhaust its life but care is hardly taken for that giving rise a higher consumption of electricity on real time basis means loss of money on minute to minute basis

due to poor maintenance of power factor. In case, APFC panel is set at 0.99 giving rise to further poor power factor, also use bigger rating part which unable fine tuning. The power factor is also important from utilization of full capacity of transformer point of view as well and it is a system which works like a generator even at night time when solar power generation does not work. Power factor can easily be achieved better than 0.99 by taking care its capacity and setting APFC panel at unity level off course with properly designed panel. The improvement of power factor also reduces the fixed charges which are charged based on KVA. Power factor should be monitored on hourly basis. Sub-Station Operator should be directed to record KVAH, KWH, instantaneous power factor on hourly basis in their logbooks and calculation of daily average power factor which enable us effective monitoring. It is also noticed that power factor having connection with solar power and net meter has been charged based on power factor by default (0.93) giving rise to a higher fixed charges and hence taken away the benefit of solar power generation, may be due to the reason of not having proper measuring system with the supply companies for net meters.

Voltage Optimization

Single phase electrical equipments/appliances have been rated at 220-230 volts whereas our transformers at sub-station have been rated at 433 volts. So even at normal voltage from HT 250 voltage is received between phase to neutral giving rise higher consumption in fan load and reduced life of electrical appliances. By improvement of power factor, voltage drop by the transformer also reduces drastically giving rise to higher voltage at appliance end. Therefore, in new sub-stations one should go for on load tap changing system whereas old installation may be dealt with putting tapings at last possible point so as to get nearest rated voltage at the appliance end. As reduction of voltage by 10% gives rise to a reduction in consumption by 20%, therefore, it is an important method for reduction of consumption without spending any extra money. Sometimes there may be a confusion that assuming constant power appliances means appliances are rated at constant power but actually it is not, the consumption of appliance get reduces by reduction of voltage applied to it.

Effective and Efficient Functioning of Air-conditioning System

Air-conditioning is now a day's being used in almost all the buildings. Almost 80% consumption comes from air conditioning. There is a huge scope of saving (almost by 50%) by taking care the air-conditioning system. Followings are to be taken care in the air-conditioning;

Addressing leakage of air-conditioning energy

Air-conditioning should be done and maintained professionally, all the entries/gates must be

taken care for leakage of conditioned air and for that air curtains should be used invariably. In some of the air-conditioned areas metallic doors have been provided from safety point of view which gives rise huge leakage of air-conditioning energy and thus to be taken care effectively. Toilets in the buildings are also a potential source of exhaust/leakage for air conditioning energy and as such their ventilation should be designed accordingly.

Thermostat Setting

As per Bureau of Energy Efficiency room temperature should be maintained at 26 degree Celsius and it is very important from consumption point of view as per degree decrease in temperature gives rise to 6% extra energy consumption and 26 degree Celsius room temperature is suitable from human comfort point of view. Room temperature should be controlled precisely by using two way mixing valves in AHUs and VFD (Variable Frequency variable Voltage Drives) for controlling/reducing the speed of fans on achieving the desired temperature. There should be VFDs on secondary pumps as well. Normally they are installed without maintaining/implementing the scheme professionally giving rise to wastage of capital cost and loss of opportunity to save huge energy by effective implementation of the system. Huge energy can be saved by suitable/proper setting of thermostat but it will be meaningless if effective isolation of air-conditioning area to non air-conditioning area not done. VFDs with cooling tower fans should also be used to reduce consumption of cooling tower which depends on ambient conditions that changes drastically during the season and extra cooling of condenser water has no benefit rather wastage of energy in cooling tower.

Fresh Air control

Fresh air is very important for maintaining indoor air quality in the conditioned area. Now a days due to poor outdoor air quality indoor air also becomes of poor quality due to bio-aerosol, micro-biological contaminations etc. Extra fresh air intake gives rise huge load on air-conditioning system, therefore should be taken judiciously and suitable filters with innovative solutions(Such as indoor plants, filter-less technology based solutions etc.) should be preferred to be provided with AHUs to take care of these contaminated and reduce the fresh air load. Early morning fresh air may be used for flushing out the building as by doing so running of the plant may be delayed for one hour resulted in to huge saving but for which arrangement of running the AHUs on 100% fresh air should be made.

BTU Meters and direct display of condenser approach

To monitor the performance of chillers in air conditioning system, BTU meters should be installed invariably at the same time direct display for condenser approach should also be provided to monitor heat exchange performance of condenser. Per degree higher approach

of condenser gives rise 2% poor efficiency.

Use of Efficient motors

HVAC system should be preferred having IE-3 efficiency motors for pumps, cooling tower fans and AHUs.

Auto de-scaling system

De-scaling ones in a season may not be sufficient to maintain condenser approach. Auto de-scaling system using spung balls may be installed with all new installations as well as it may also be installed with existing systems to address the condenser approach.

Presence, movement sensors and Timers

Occupancy sensors should be installed in individually occupied rooms and movement sensors may be installed in toilets, corridors etc whereas timers should be installed with all outdoor lights.

Ceiling fans

Since air movement can add comfort and by doing so temperature settings in HVAC may be increased by 2 degree Celcious for same comfort level, giving rise a saving of 12%, ceiling fans should be provided even in air-conditioned areas as well. Nowadays BLDC (Brushless DC) fans are available in the market which consumes almost 60% power as compared to conventional BEE 5 star rated fans.

Conclusion

Energy can't be produced, it can only be converted from one form to other which has huge impact on environment and hence on all living things including our future generations. Energy conservation must be given even higher importance than energy generation. One unit saved at user end is equivalent to more than two units at generation from environmental considerations. Therefore in the interest of present and future generations, all the stakeholders should work honestly and seriously to save energy and stop its wastage.

CONTINUOUS COMMISSIONING OF BUILDINGS IN CENTRAL PUBLIC WORKS DEPARTMENT

Satvinder Singh, ECBC Master Trainer

Abstract

Central Public Works Department is maintaining large number of commercial buildings and residential complexes across all states in India. Most of buildings now constructed are hi tech buildings involving use of building automation system to optimize operation through real time control of set points. To effectively achieve optimization of energy use, continuous commissioning of building is very important aspect for maintaining comfort level of occupants with minimum energy consumption. Intent of continuous commissioning is to ensure that buildings operate throughout its life span as these are intended to operate as per initial design parameters. The equipment installed are required to be operated and maintained during their life cycle in a manner that targeted efficient designed performance is never compromised and optimum efficiency of equipment for management of desired comfort conditions with expanse of minimum energy use in building is attained.

Introduction

Continuous commissioning refers to a commissioning approach that is integrated into a facility's standard operation & maintenance program. As such, activities in support of the continuous commissioning effort are completed on a regular basis, compared to re commissioning approaches that tend to be distinct events. The continuous commissioning (CC) approach developed by the Energy Sciences Laboratory at Texas A&M University is a formalized continuous commissioning approach and is defined as “an ongoing process to resolve operating problems, improve comfort, and optimize energy use and to identify retrofits for existing commercial and institutional buildings and central plant facilities”

Continuous commissioning is the most costly existing building commissioning approach due to necessary allocations of staff and equipment as applicable to western countries where labour resources are exorbitantly high but in case of Indian scenario labour resources cost is very low in comparison to USA or other such countries; however, the additional costs can work to identify equipment inefficiencies as they occur, allowing for quick remediation, greater energy and cost savings, and better building services. By definition, continuous commissioning works to ensure more stable building operations over time than the re commissioning approaches.

In general, commissioning is the process of ensuring that a building performs according to its design intent and the needs of its owners and occupants (Anderson 1997). While additional research is needed to further pinpoint the costs and resulting benefits of commissioning new and existing buildings, numerous case studies have demonstrated resulting Operation & Maintenance -related energy efficiency improvements on the order of 5% to 30% covering a wide range of building uses. The resulting simple payback periods are typically less than 2 years and often less than 0.5 year.

The main reason for requirement of continuous commissioning in CPWD like set up is that work force engaged for maintenance is putting all out efforts for keeping the equipments up all the time so that occupants are not put to any un-comfortable experiences due to outage of any equipment.

Another reason for requirement of continuous commissioning is that there is a disconnect between CPWD engineers and client department as far as the payment of electricity bills is concerned. Presently electricity bills are paid by administrative set units of clients like administration office directly under Medical superintendent in case of hospitals. This makes tracking of energy use difficult and significant deviations in use of electricity remain un-noticed by concerned engineers responsible for maintenance. Due to gap due to non - access to electricity bills for maintenance engineers, significant deviations in energy use goes un-detected. The issue can be partly addressed through continuous commissioning if all equipment installed is operated at designed efficiency parameters on real time basis.

Commissioning of Buildings

Ideally, the building commissioning process begins during the planning stages of a new building design or new equipment installation. The fact is that the vast majority of buildings have never been commissioned. Even today, with mounting evidence of resulting expected benefits, very few new buildings undergo a complete commissioning process.

Instead, new buildings are typically turned over to the building operating staff with operating problems in place, incomplete documentation, and minimal operator training for building-specific equipment. These same problems occur with major equipment installations. Then, during building and equipment operations phases, the overall efficiency of mechanical systems degrades as sensors drift, short-term adjustments are made, occupants needs change, and so on. Even after adjustments are made, perhaps through a one-time re commissioning effort, performance degradation is continuous.

Commissioning of existing buildings (and more specifically the energy-consuming mechanical/ electrical systems within them and control systems that monitor them) is critical

to ensure energy-efficient operation. Additional benefits include extended equipment life, increased occupant satisfaction through improved space comfort, improved indoor air quality, and fewer operation & maintenance emergency calls.

Commissioning of existing buildings is quickly becoming one of the most important topics in the building management arena.

Table -1 (adapted from Federal Energy Management Program-Department of Energy-USA 2006) provides guidance on commissioning types and their suitability for different facility situations.

Table-1. Commissioning type consideration by facility condition

What Type of Commissioning Should I Choose?	
My Building is…	*Consider…*
…new or going to be undergoing major renovation.	Commissioning – ideal for new construction or major renovation, and best implemented through all phases of the construction project.
…old and expensive to operate and experiencing a lot of equipment failures.	Retro-commissioning – ideal for older facilities that have never been through a commissioning process.
…relatively new and was commissioned during construction, but energy use has been increasing.	Re-commissioning – ideal to "tune-up" buildings that have already been commissioned, bring them back to their original design intent and operational efficiency.
…large and complex, has a metering system and a preventive maintenance program, but still has high energy use and tenant complaints.	Continuous Commissioning – ideal for facilities with building automation system (BAS), advanced metering systems, and well-run O&M organizations.

Building commissioning, re commissioning, and retro commissioning are valuable services aimed at overcoming these and other challenges affecting the operation and optimization of HVAC systems. However, many building owners assume that once one of these services is performed, nothing more needs to be done. System degradation and whether their building continues to operate at peak efficiency are not on their radar, so to speak. They fail to realize that filter and belt replacement, oil changes, bearing inspections, and the like only scratch the surface of what should be done on a continuous basis to keep a building operating at optimum levels.

Continuous Commissioning—as defined by the Energy Systems Laboratory (ESL), a division of the Texas Engineering Experiment Station, which trademarked the term, and a member of the Texas A&M University System-is an ongoing process to resolve operating problems, improve comfort, and optimize energy use. Typically, it is implemented in two phases and consists of the following seven steps:

1) Visit the site to identify and quantify potential measures and savings.

2) Develop performance baselines for energy and comfort.

3) Examine the building in detail—to the air-handling-unit (AHU) and/or terminal-box level-to identify operating and comfort problems, component failures or degradation, and causes of system inefficiency.

4) Implement Continuous Commissioning measures.

5) Identify changes in operating procedures for the building staff, and document energy savings and comfort improvements in accordance with the International Performance Measurement and Verification Protocol (IPMVP).

6) Train the building staff.

7) Track/verify energy and comfort performance for at least one year in accordance with the IPMVP. (International Protocol for Measurement and Verification Practitioners)

Energy Use

Nearly every building today is designed with energy efficiency in mind. Variable-frequency drives (VFDs), chillers with low kilowatt-per-ton requirements, and highly sophisticated BAS are designed into most major commercial office buildings, hospitals, and schools. Simply designing, installing, and verifying (commissioning) these technologies, however, is not enough, if energy use is to be optimized over the long term.

In a study of 60 new buildings conducted by Lawrence Berkeley National Laboratory, 50 percent of the buildings suffered controls problems, 40 percent suffered HVAC problems, 15 percent had missing equipment, and 25 percent had energy-management systems, economizers, and VFDs that did not function properly. Remember, this was a study of new buildings. Existing buildings almost certainly would have fared far worse simply because of natural HVAC-system degradation and changing building conditions.

Primary Objectives

Integrate comprehensive commissioning approach into on-going facility O&M program.

Relative Cost

Highest cost option for existing buildings and systems.

Benefits

- Identifies and addresses problems as they occur

- Energy savings persist
- Should generate greatest energy savings.

Best Applications

Continuous commissioning™ is the preferred approach when resources (staffing and equipment) are available.

Applications

Continuous commissioning™ is the preferred approach when resources (staffing and equipment) are available.

The most frequently cited measures/ opportunities are

In order to run the installed equipment in buildings at designed efficiency parameters on real time basis, adjustment in operating parameters and set points is required to be made. Some of the possible opportunities in buildings are mentioned below:

- Adjust reset and set-back temperatures and temperature settings – Settings are often adjusted over time based on personal preferences, to compensate for inadequate system operation, or to achieve energy savings. In addition, sensors require periodic recalibration. Calibration of sensors and other measuring instruments is also required to be done as per recommended periodicity so that instruments continue to perform as per design so that there are no surprises in actual and read parameters.
- Staging/sequencing of chillers, and air handling units – Equipment should be operated in the most efficient combination of chillers and fans at varying load conditions.
- Adjust and repair dampers and economizers – Malfunctioning or poorly tuned dampers (including seals, actuators, and linkages) and economizers result in (1) increased supply air fan energy in the closed position or require additional air heating and cooling when open too much, (2) undesired building operating conditions due to lack of outside air, and (3) premature equipment degradation and replacement.
- Modify control strategies for standard hours of operation – Motors, pumps, fans, and air handlers often operate on a schedule even though not required by either the building tenants or the building operating plan due to change in building use requirement.
- Air and water distribution balancing and adjustments – Systems require rebalancing due to drift and changing building/workspace mission and/or tenant requirements.

- Verify controls and control sequencing including enabling and re-enabling automatic controls for set points, weekends, and holidays. Verify that overrides are released.

Summary

Cost-effective and easy to implement, process promises to reduce commercial-building energy consumption. When it comes to the operation and optimization of modern HVAC systems, building owners and operators face two main challenges:

Inadequate training. Many building operators find themselves responsible for technologies more advanced than their technical skills and expertise. Often, it is assumed that whatever does not work, was not installed properly, or was not tested fully will be identified and corrected by the appropriate subcontractor during the warranty period.

Controls complexity. In most cases, relatively simple pneumatic controls have given way to direct digital controls (DDC) and a host of new terms and technologies, such as PID, Barnet, LON, Ethernet and others. Additionally, rather than the three or four suppliers that dominated the pneumatic-controls industry 30 years ago, there are dozens of DDC manufacturers.

Conclusion

Over the last 10 years, Continuous Commissioning has been implemented in more than 300 buildings across the United States by the ESL and its authorized licensees. With the complexity of today's HVAC systems and controls, rising energy costs, increased focus on energy supply and source, and a "green" consciousness that has begun to permeate our decision making both at work and at home, Continuous Commissioning is a unique, easy-to-implement, and cost-effective way to reduce energy consumption in commercial buildings. There lies a great potential in CPWD maintained buildings for adopting continuous commissioning for overall improvement in comforts, Breakdown maintenance and optimum energy consumption.

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ENERGY EFFICIENCY IN VRF AIR CONDITIONING SYSTEMS

Senthil Thangam- Blue Star Limited

Abstract

The cost of the power is rising across the globe and the availability of the energy resources is also becoming scarce. There is a need to come with innovative systems which can work efficiently and conserve energy. Among the various modern Air conditioning systems available today VRF systems turns out to be one of the most energy efficient systems which integrates the electronics to enhance the efficiency of system to the next level. The paper describes VRF system in brief.

Introduction

A VRF System is a DX type air-conditioning system in which the outdoor unit (ODU) or condensing unit system is connected to multiple indoor units (IDUs). Refrigerant flows through refrigerant pipes laid between outdoor unit system to indoor units. Each IDU is provided with an electronic expansion valve which regulates flow of refrigerant depending on the set temperature and actual load inside each space. Each ODU is equipped with variable capacity compressor which modulates the overall capacity of the system based total demand. There is a continuous communication between IDUs and ODUs through a communication wire and PCBs. When some IDUs are switched off, there is no refrigerant flowing across.

Outdoor unit is equipped with Energy efficient variable capacity inverter scroll compressors. As all the indoor units will not be operational all the time, outdoor unit has to operate at part load conditions most of the time.

Though the compressor modulates the capacity, there are many other important components to be selected in a VRF system that are very important to enhance the overall efficiency of the system.

Advantages of a VRF System

The following are the advantages of VRF system;

- It is a dx type system, refrigerant directly cools the room. There is no secondary medium like water as in the case of chilled water system.
- Variable capacity compressor results in part load operation. Efficiency is maximum during part load conditions.

- Unlike the unitary system, there are many components that can be designed suitably to enhance the overall efficiency of the system. With this flexible design, we can get maximum efficiency with the given inverter compressor.
- The point of temperature measurement is at multiple points for maximum accuracy.

Indian Challenge

There are many challenges in India like very high ambient temperature and humidity conditions. Added to the same we also have the urban heat effect, unstable power conditions. There is a need to specifically design the VRF system to overcome all the above challenges to get the maximum efficiency.

Efficient Inverter Compressor

- VRF system is designed with high efficient 100% inverter scroll compressor with concentrated motor windings to reduce slip loss especially while operating at low speeds. This results in minimum 7% power saving.
- In this unique design of compressor, the suction gas directly enters into the scroll and there is no heat gain due to compressor motor assembly.
- Permanent rare earth magnets are used in the rotors of compressor Motor. This results in optimum design of stator and lower power consumption
- The optimum design logic in all inverter compressor results in operation of compressor with optimum speed with maximum efficiency at any load condition. Moreover starting current for any Inverter compressor is very low this helps to optimize electrical components and backup generator capacity.

Design for High ambient operation

- Globally VRF systems are designed to deliver actual capacity at 35°C ambient condition. However in a tropical Country like India, Ambient temperatures are always higher during most of the months in a year. Moreover urban heat effect in cities further increases ambient temperature conditions. This high ambient temperature results in deration in capacity and increased power consumption.
- The VRF systems are designed with compressors at the right frequency to deliver the capacity at higher ambient conditions.
- Outdoor unit condenser coils are specially designed with CFD Analysis to perform efficiently at very high ambient conditions. Condenser coil is oversized with 30% more

face area.

- The heat exchange in condenser is maximum which results in enhanced efficiency as high as 7%
- Condenser fans are fitted with high efficiency BLDC motor to regulate air flow depending on the actual demand.

Other Efficiency Enhancers

VRF System is also equipped with many features which result in enhanced efficiency.

We can set the capacity as per the actual requirement at 25%; 50% or 75% to ensure optimum use of AC system. This will result in optimization of power consumption.

AHUs can be integrated to any VRF system. By selecting appropriate AHU design, we can further enhance the efficiency of the system. For example, we can go for an AHU with larger evaporating coil which results in higher evaporating temperature and efficiency. High sensible load applications can be handled with higher CFM/TR AHUs.

Advanced Controllers

VRF system is equipped with many advanced controller systems which can be controlled with a central controller, PC or even smart phone.

To ensure optimum setting and usage of Air-conditioners in various areas, all units can be monitored and controlled by one user from one space.

BMS Compatibility

VRF system can be integrated with 3rd party BMS system. Depending on the usage requirement, the user can program operation of various indoor units as per the actual load condition.

Energy recovery system

Heat recovery indoor unit can be integrated on the VRF ODU system which can be used to pre-cool fresh air with exhaust air from condition space.

Conclusion

VRF system is the best energy efficient air-conditioning system which utilizes the latest energy efficient inverter compressor technology along with various electronic controls to deliver cooling with maximum efficiency.

INNOVATIVE AND SMART BUILDING MATERIALS FOR ENERGY EFFICIENT BUILDINGS

Snigdha Devi, IGEN -Energy Efficiency in Building programme

Abstract

Innovation is a wide concept that incorporates enhancements in processes, products or services. It includes incorporating new thoughts which produce changes that assistance tackle the necessities of an organization thus increment its competitiveness. The use of innovation to the construction industry isn't straightforward, in spite of the importance of this sector in the development and development of the wider economy. The construction industry utilizes a great deal of resources and makes a lot of pollution which is the reason there is a push for innovative building materials. Innovative building materials are putting forth energy efficient, green ways to develop buildings that will hold up longer than any time in recent memory. These materials will shape the construction industry and the world as they develop in the commercial market. In this paper, a few innovative materials that may shape the construction industry are described briefly.

Introduction

In the present world of modernisation and urbanisation we always look forward for advancements in new technologies so that it will add comforts and ease our daily life tasks. Food,Cloth and shelter are the most fundamental things in human life. By looking at the population of our country, it seems that there will be a huge demand for residential buildings for their shelters in near future. Accordingly, there will be a demand of more commercial buildings, institutions ,public buildings as well. The more buildings will built, the more energy it will consume .The rise of CO2 emission and other green house gas emissions will rise significantly with the rise in construction of buildings.Building materials also occupy a major share of this consumption. Therefore, there is a need to focus on the building material part as well to minimise the energy consumption of a building. With the advancement in technology and innovation, the buildings materials are becoming more versatile, more specific characteristics, performance and responsive to outer environments. Smart and innovative materials are designed with respect to the current needs of people and environment. This is one of the most growing sectors in various parts of the world. At present, this field is in the R& D phase and through the innovative and smart building materials, it is expected to make all kind of buildings more smarter, energy efficient, more sustainable and affordable in near future.

The Need of Smart and Innovative Building Materials

Quick urbanization is making immense open doors through a remarkable interest for the construction of buildings.The development area has been affected significantly by the worldwide downturn and is as of now moving to a more innovative and cross-sectoral model. Innovative building materials are a sub-sector of the development area. This sub-sector speaks to another age of development materials which show some specific and unique properties. Through Innovative building materials, new advances are incorporated into both residential and commercial buildings and frameworks to make them smarter, more sustainable, energy efficient and secure, in this way tending to ecological and social difficulties all around.

Materials are viewed as one of the most extravagant well springs of innovation. At the beginning of the 21st century materials progressed to wind up more versatile, material and insistent and the demand for articles with sculptural, aesthetic and multi useful, characteristics rocketed. No longer proposed for practical utilise alone, materials are assuming a vital job in taking aesthetic forward. These materials are intended to be responsive to outer improvements, for example, stress, temperature, moisture, Ph ,electric or magnetic fields. Their properties, for example, shape, colour, stiffness or viscosity can be changed fundamentally in an anticipated or controllable way in response to their environment.

The Difficulties Faced by Construction Sector

As indicated by the International Energy Agency, buildings represent 30 to 40% of energy use in Europe with an enhancement of 5 to 10% being utilised in processing and transport of construction products and components. This offers ascend to around 33% of the locale's CO2 emissions. Additionally, the on location construction industry and the assembling of construction materials likewise expend billions of huge amounts of natural resources, while creating a lot of non-recyclable waste.In India likewise Rapid urbanization is making tremendous open doors through an uncommon interest for the construction of buildings, which as of now represent in excess of 30 percent of India's total electricity consumption. In accordance with extending improvement, the nation's building sector is relied upon to expand five-fold from 2015 to 2050. India is at a one of a kind junction where 66% of the commercial and residential high structures that will exist in 2030 are yet to be built. Buildings consume energy at various periods in each phase of its life-cycle. Building materials share a major part of this consumption. In this way, the measure of energy consumed by materials consumed amid their life-cycle is an essential parameter in determining the energy efficiency of the building. Energy efficient building materials can support the constructions

both ecologically and economically as a result of their ecological positive highlights. Besides, with their different thermal properties (like heat storage, heat retention) they make commitment to the making of comfort in indoor environment. Thus, over the span of ongoing decades, this fragment has been under growing strain to improve its cost effectiveness, sustainability, and capacity, pushed by the undertaking and need to stand up to results of a worldwide global warming and climate change. Radical upgrades are required and these have of late likewise been empowered by governments. Increased awareness of climate change and other environmental concerns is changing priorities as individuals change the manner in which they live to confine the effects of their every day life on environment. In fact, customers are looking for innovative solutions that would enhance their quality of life while being environmentally friendly. The eagerness to utilize greener building materials for home construction has turned into a quickly developing pattern in the course of the most recent couple of years, predominantly spurred by developing environmental consciousness and cost saving open doors through better energy management.

The Solution for Future Improvements

The design, height, characteristics, and energy performance of buildings have been profoundly affected by the advancement of new innovations for new building materials showing specific properties. Traditional building materials, for example, concrete, steel and plastics have been enhanced and/or replaced by further developed materials considering unusual and sophisticated architecture and design while assuring energy efficiency, sustainability and security. The development of technologies and new materials to enhance building energy efficiency is an imperative instrument for reducing greenhouse gas emissions and for preserving the limited natural resources in the short to midterm.

Innovative & Smart Building Materials

Innovative and smart building materials extend from new forms of concrete (lower carbon, with strands that alter its resistance and durability or with air purifying capabilities), and innovative wooden structures, glass with improved qualities (photovoltaic embedded construction glass, electro chromic glass), to automated infrastructures. Green building materials, for example, cork, bamboo and woven flooring can likewise be viewed as a major aspect of cutting edge construction materials. Concrete creation from reused materials is likewise a dynamic development zone within the business, alongside wood from sustainable forests, energy-efficient lighting fixtures and water-efficient plumbing fixtures. Expanding urbanisation around the globe will keep on driving the construction of innovative buildings, where materials assume a key job. The affordability of our buildings additionally stands to enhance enormously from increased efficiency and new construction technologies and

materials. Energy, construction, and maintenance expenses can contribute generously to the budgetary weights of buildings , rendering them unreasonably expensive to numerous proprietors or occupants. Implementing energy efficient strategies results in lower energy consumption and lower service bills for proprietors and inhabitants. Enhanced construction strategies and practices create higher quality and progressively strong durable buildings that can diminish construction expenses and future maintenance and repair needs.

In the designing of energy efficient building, the utilization of energy efficient building materials is very important since the building materials can positively support the constructions in which they are utilized by reflecting their environmental positive features with their everything different highlights into the construction. Hence, for energy saving, it is very important to use the innovative and smart building materials for energy efficient construction. Creating innovative and smart building materials for sustainable construction has turned out to be a fundamental need, as well as a moral basic for the following ages. These new materials and construction advances incorporate cutting-edge and monetarily suitable sustainable arrangements in this manner expanding profitability, decreasing construction time and by and large favourably affecting the earth.

Some innovative building materials are given below

1. Aerogel
2. Titanium dioxide façade
3. Fiber composite adaptive system
4. Translucent concrete
5. Bio concrete

1. Aerogel

An aerogel is an open-celled, mesoporous, solid foam that is made out of an arrangement of interconnected nano-structures and that shows a porosity (non-solid volume) of no under half. Despite the way that aerogel is really a foam, it can take a wide scope of shapes and structures. The vast majority of aerogel is made out of silica, carbon based materials, press oxide, natural polymers, semiconductor nano-structures, gold and copper can in like manner outline aerogel. Regardless, inside the aerogel structure, no is solid material, with up to 99.8% of the structure involving just air. This remarkable composition gives aerogel a for all intents and purposes spooky appearance; along these lines it is as often as possible insinuated as 'frozen smoke'.Lowest bulk density of any alluded to material (as low as 0.0011

g cm-3),.By tailoring the production procedure, a lot of its properties can be adjusted.

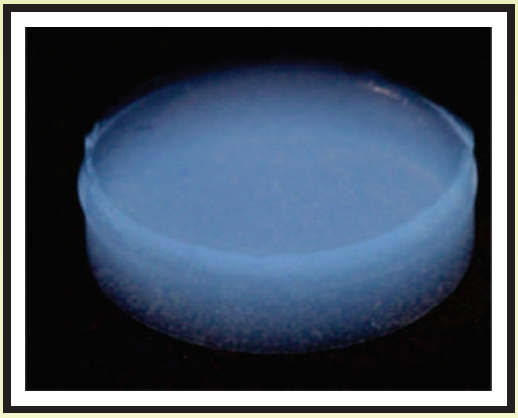


Fig 1: Aerogel (source: bookofjoe.com)

Chemical and Physical Properties of Aerogel

A standout amongst the most valuable physical properties of aerogel is its unimaginable lightness.It ordinarily has a density between 0.0011 to 0.5 g cm-3, with a normal of around 0.020 g cm-3. This implies aerogel is typically just multiple times heavier than air, and has been delivered at a density of just multiple times that of air. For a long time, aerogel was in the Guinness book of world records as the 'solid with the lowest density', before being removed as of late by the metallic micro-lattice and afterward aerographite.This a long way from renders aerogel excess be that as it may, as it has a further 14 world records to its name, including 'best insulator'. Further alluring properties of aerogel are recorded below mean free path of diffusion is low specific surface area (for a non-powder material) is high. Records held by some uniquely-formulated silica aerogels:

- It is the lowest density solid (0.0011 g cm-3)
- It has lowest optical index of refraction (1.002)
- It has Lowest thermal conductivity (0.016 W m-1 K-1)
- It has Lowest speed of sound through a material (70 m s-1)
- It has Lowest dielectric constant from 3-40 GHz (1.008)
- Record held by a specially-formulated carbon aerogel is -it has highest specific surface area for a monolithic material (3200 m g-1)

Applications

Aerogel is beginning to wind up an absolute necessity have material in the insulation industry

and has been utilised for quite a long while in cavity injected wall insulation and insulating boards. As of late, aerogel based mortar has been utilised to insulate historic buildings in Switzerland. The EMPA (Swiss Federal Laboratories for Materials Science and Technology) labs have worked with the manufacturing organisation Fixit AG to build up a render (insulating material) in view of aerogel, which they accept will give double the insulation of typical renders. The utilisation of aerogel along these lines is amazingly energy efficient and environmentally advantageous, as it will cut the utilisation of fossil fuel enormously in heating.

Upgrades in the fragility and brittleness of aerogels reported as of late implies that an entirely different universe of utilisation might be opened up later on, from cloths to heat proofing.It is utilised in window panes and solar collector covers because of its low thermal insulation and optical transparency.It can be utilised in buildings , for purification of indoor air for adsorption and catalysis, photo catalysis in environmental clean up, non combustibility (inorganic aerogels) in fire retardation boards in kitchens because of their low thermal conductivity and acoustic property for noise decrease.

2. Titanium Dioxide

It is the naturally happening oxide of titanium . When utilized as a pigment ,it is called titanium white or pigment white 6.Generally it comes in two distinct forms rutile and anatase. Titanium dioxide happens in nature as the outstanding minerals rutile, anatase and brookite, and furthermore as two high pressure forms, a monoclinic baddeleyite-like frame and an orthorhombic α-PbO2-like shape, both found as of late at the Ries pit in Bavaria. One of these is known as akaogiite is a very rare mineral.It is primarily sourced from ilmenite metal. This is the most across the board type of titanium dioxide-bearing metal the world over. Rutile is the following most inexhaustible and contains around 98% titanium dioxide in the metal. The metastable anatase and brookite phases convert irreversibly to the balance rutile stage after warming above temperatures in the range 600– 800 °C (1,112– 1,472 °F).Titanium dioxide has eight modifications – in addition to rutile, anatase, and brookite, three metastable phases can be delivered synthetically (monoclinic, tetragonal and orthorombic), and five high-pressure forms (α-PbO2-like, baddeleyite-like, cotunnite-like, orthorhombic OI, and cubic phases) additionally exist.Some of the titanium dioxide item attributes are the titanium dioxide façade takes a functioning position and attacks the issue of dirty air by aiming to help clean the air.The tower pulls dirt, oil and microscopic organisms out of the air ,creating just oxidation and water as a result. It has a wide scope of utilisation from paint to sunscreen to food colouring.

Properties and sources of titanium: It is a metal(ninth most plenteous element on earth) with

density of 4.5g/ML. Some of alternate properties are recorded below-

- Melting point is 1943K
- Boiling point is 3562 K
- It burns in air and it is the main metal which burns in nitrogen
- Incredible corrosion resistant
- Strong as steel and 45% lighter
- 60% heavier than aluminium and twice as strong.
- It has low module of elasticity and low module of expansion
- It is not magnetic.

Sources of titanium are on sun and meteorites ,on earth in igneous rocks, in ash, plants and animal bodies.

Applications of Titanium Dioxide

Titanium dioxide is immensely utilized in Building façade.It can be utilized in atmospheric cleaning(NOx removal from the atmosphere).It is utilized in Deodorisation(indoor odour and volatile organic compounds removal).It has self cleaning(dirt removal for exterior building façade) properties. It is utilized for water treatment(water sterilisation and odour removal) purposes. It has anti-bacterial(elimination of bacterial growth) properties.



Fig 2: The façade of the Torre de Especialidades sucks up pollution in Mexico City. (source: Smithsonian Magazine)

3. Fiber Composite Adaptive System

Fiber composite adaptive systems resembles self-organization forms in nature by building up a fiber composite that can sense, actuate and from this time forward efficiently conform to changing environmental conditions. Fiber composites which are anisotropic and

heterogeneous offer the probability for close-by assortments in their material properties. Embedded fiber optics would be used to sense different parameters and shape memory alloys integrated in a fiber composite material for incitation. The importance of the geometry, both locally and globally would enhance the adaptive capacities and hereafter the framework would indicate 'Integrated Functionality'.Its performative capacities and insight spring from the planned justifications of its material conduct, fiber association, topology definition and the overall morpho-mechanical system. The essential composite contains glass fibres and a polymer network. Detecting is finished by embedded fiber optics which can at the same time sense strain, temperature and humidity, teaching the topology to effectively conform to the changes. Geometrically, the material structure is described as a multi-layered decoration made out of a ceaseless surface with moving porosity, density, illumination, self-shading and so on. Actuation is finished by shape memory composite strips which change their shape by adjusting their scaled down scale atomic association from austenitic and martensitic states. A key increase of these strips through a wise geometry renders a couple of progress and mixes making different conditions of equalisation, thusly engaging predictable novel alteration of the structure.

Applications

FRP composites discovered application in civil engineering constructions , including both building systems and infrastructures , for retrofitting purposes in existing buildings, just as for architectural or structural purposes in novel gatherings. Latest uses of FRPs have been found in façades and building skins, with keen observations for case studies and novel design concepts.FRP composites are to a great extent utilised in the car, marine, modern or ballistic segments since quite a few years, yet found progressively applications in structural designing structures and frameworks just from the late 1990s.Major utilisation of FRP composites in structures ,since that period can be found particularly as coats, strips or wraps for the retrofitting of existing structures made out of conventional materials, for example, masonry, reinforced concrete ,timber or steel.The current patterns of architectural design are appearing a marked increment of FRP applications in building veneers and skins, both as across the board cladding boards, load-bearing pultruded individuals or adaptive solar protection panels and portable shading systems.



Fig 3: Arachnid Architecture as Human Shelter (source: Architect Magazine)

4. Translucent Concrete

Transparent concrete moreover called as translucent concrete or light transmitting concrete is practiced by overriding sums with transparent alternate materials. The bonding material in transparent concrete may undoubtedly transmit light by using clear resins the concrete blend. Use of optical strands and fine concrete in like manner used as transparent concrete.

Transparent concrete was at first made in 2001 by a Hungarian planner Aronlosonzi by using glass strands. Transparent concrete is made by blending 4% to 5% (by volume) optical strands in the concrete blend. This concrete has less weight contrasted with unique concrete.Transparent concrete is fabricated by utilising blend of fiber optics and fine concrete. These strands mix into the concrete like some other aggregates. These optical filaments can transmit light from characteristic and counterfeit sources into spaces encased by the translucent concrete boards. The fundamental explanation behind utilising optical fiber in concrete is that it can transmit light even an incident angel greater than 600.Transparent concrete is produced utilising fine materials as it were. It doesn't contain coarse aggregates. This concrete can have the compressive strength of that of high strength concrete around 70 MPa (10,000 psi).Materials utilized for creating translucent concrete are cement, sand, water and optical fiber.

Applications

The key preferred advantage of transparent concrete is that it can transmit light. Subsequently, it very well may be utilised to make green buildings. Since it can transmit light from normal just as artificial sources, the building can have less lights to fulfil its need for lighting. In this manner sparing a huge measure of energy cost.Transparent concrete uses sunlight as wellspring of light rather than electrical energy and diminishes power consumption. This concrete can likewise be utilised cold nations to transmit heat with sunlight.Translucent concrete is utilised in fine engineering as a façade material and for cladding of interior walls. Light-transmitting concrete has likewise been connected to different design products

5. Bio Concrete-Self Healing Concrete

Crack information is a phenomenon involved with durability. percolation of cracks may prompt leakage issues causing deterioration of the concrete matrix or corrosion of embedded steel reinforcement.In ongoing years a bacteria based self healing concrete is being created so as to broaden the administration life.Bio-concrete is a self-healing type of concrete intended to repair its very own cracks. It was produced by Dutch scientist and microbiologist Hendrik Jonkers utilising an additional fixing going about as a healing agent

and requires no human mediation to be repaired once set. To mend cracks in the concrete, Jonkers picked bacteria (Bacillus pseudofirmus and B. cohnii), that can create limestone on a biological premise. The positive symptom of this property: the bacteria expend oxygen, which thus keeps the inward corrosion of reinforced concrete. In any case, the bacteria do not cause any harmful effect on human health, since they can only survive under the alkaline conditions inside the concrete. In view of these discoveries, Jonkers and his group of analysts created three diverse bacterial concrete blends: self-healing concrete, repair mortar, and a liquid repair framework.

In self-healing concrete, bacterial substance is coordinated amid development, while the repair mortar and liquid framework possibly become an integral factor when intense harm has happened on concrete elements. Self-healing concrete is the most mind boggling of the three variations. Bacterial spores are encapsulated inside two-to four-millimeter wide clay pellets and added to the concrete blend with independent nitrogen, phosphorous and a nutrient agent. This inventive methodology guarantees that bacteria can stay lethargic in the concrete for as long as 200 years. Contact with nutrients happens just if water infiltrates into a crack - and not while blending bond. This variation is appropriate for structures that are presented to enduring, just as focuses that are hard to access for repair specialists. Subsequently, the requirement for costly and complex manual repairs is abolished.

Applications

As of late, bacterial concrete was liable to endurance tests under different external conditions on a committed testing building in Breda, Netherlands. Jonkers' creation can possibly lessen maintenance costs for bridges, tunnels and retaining walls.



Fig 4: Bio concrete (source:Smithsonian Magazine)

Challenges to Adopt the Advanced Building Materials

Consumer attitude and awareness towards greening and energy consumption has been changing in the course of the most recent decades. Awareness on environmental issues has expanded with higher acknowledgment of climate change, and the impact of human exercises on it. This better approach for speculation prompts a mutual consensus on taking activities on saving the environment and ecological balance. Consumers are increasingly persuaded that individual lifestyles must be changed. The increase in energy costs, over the economic crisis, urges people to look for solutions for energy sparing. In reality, crosswise over Europe, normal electricity cost for households and industries have expanded by 29% between 2005-2011, while it was just 5% and 1% in USA and Japan, separately over a similar timeframe. This better approach for speculation had extensive impact on client's enthusiasm towards the utilisation of advanced building materials. Helpful answers for low maintenance, automation, flexibility, health improving features, and optimal environmental integration in the short, medium and long terms are sought after. Customers speak to households as well as organisations and governments who are happy to execute answers for energy saving inside commercial buildings and public buildings.

One more test to receive any new building materials is that a nation's development part is liable to different national and international regulatory prerequisites and standards concerning energy consumption, environmental risks and impact, health and safety, quality of products, and so on. These surplus and confuse of controls and standards at national and international dimension are very difficult for the organisations to go along, as they are dependable of high administrative burdens and costs. Such complex regulatory structure can profoundly impact the aggressiveness of organisations in the development segment and its related markets, for example, advanced building materials. Undoubtedly, the huge measure of organization and documentation to demonstrate the congruity of the item to neighbourhood regulatory necessities and standards; and the distinctive dimension of transposition of international regulation and standards on the national markets make the circumstance very confusing and complex for the small companies or organizations.

Conclusion

Innovative building materials are very important for better management of the construction process and energy efficiency. Silica aerogels can be utilized for exterior thermal insulation applications. Past experiment results demonstrate that including the aerogel-based rendering the exterior surface of the un-insulated or the already internally insulated walls decreases altogether or removes the moisture risks. It also reduces the wall heat losses, and thus the house's energy consumption. The translucent concrete has good light guiding

property .This new sort of building material can coordinate the idea of green energy saving with the utilization self-sensing properties of practical materials. The primary favorable position of these materials is that when a solid wall is saturated with the capacity to transmit light, it implies that a home can utilize less lights in their home amid daylight hours. Energy saving should be possible by usage of translucent concrete in building. It is totally environment friendly on account of its light transmitting attributes, so energy consumption can be reduced.

These sort of innovative ,smart new building materials will help the industry to decrease its carbon footprint. A new age of concrete-based development materials based on new innovations could lessen embodied energy by 30%, lower costs by 15% and enhance insulation properties by 20%.The magnificence of these new segments is that they accomplish more than reduce the building industry's carbon footprint. They are in fact turned out to be less expensive and better performing than, and as solid as, traditional materials – and might be more fire-resistant, impermeable, provide better noise and heat insulation, and offer a cleaner indoor air environment because of the absence of volatile compounds.

Innovative and smart building materials are innovative products that may discover difficulty to get into markets because of customers' hesitance. Policy makers should empower the duplication of public demonstrators. The preliminary of the product into public infrastructure could demonstrate the qualities and the reliability of the idea in this manner urge clients to accept the new products. Companies in the advanced building materials sector require increasingly transversal competences. Technology is a necessary part of this new age of building materials. Designers, architects and engineers need to shift their traditional thinking and their approach to work to include cutting- edge technologies.

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HUMAN CENTRIC LIGHTING– A SUSTAINABLE CROSSROAD IN THE FIELD OF ILLUMINATION ENGINEERING

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Introduction

An eternal battle exists, regarding the definition of lighting design. Classical approach says, it is moreover engineering than “to play with” the lights. Debate still exists, and can be further inferred that both are essential components, but it is not the time to think about lighting design as a subject, rather Illumination Engineering, an interdisciplinary area with immense research 98 potentials. It was late 90's to early 2000, when the entire focus on the Illumination Engineering came with the urge of energy saving. A global energy crunch, which the entire world must confront with. Hence, the developments of energy saving components have been inducted in this field appropriately. Energy efficient light sources, energy efficient control gears and lastly the energy efficient lighting design including day light integration and lighting control came inherently. In Indian context, the lighting research and its application was very much concentrated on this area. But since, almost 1950's few global researches specially in US and Europe were started with aiming the human satisfaction and acceptance towards the lighting condition. Actually this human interference in lighting design officially reported since year 1924, when the eminent scientists Tyndell and Gibson developed Photopic Luminous Efficiency function, V(λ), which was published in Commission Internationale de l'E´clairage Proceedings. Cambridge: Cambridge University Press, 1924. Since, then Dr.Weston, Dr. Beutell, Dr.Peter Boyce, Dr.Marck Rea, Dr. Blackwell and many other scientists made continuous efforts to identify the human factors in lighting. The consistent efforts of the scientists towards integration of human acceptance as a key design parameter for lighting design, evolves todays human centric lighting approach. This human centric approach is a broader dimension of energy optimized lighting with highest degree of human performance.

Human factors in Lighting

To identify the relationship between lighting and human acceptance, it is first necessary to recognize the pathways by which lighting can affect human performance. There are three such specific pathways: through the human visual system, through the human circadian system, and through mood and motivation. Fundamentally, the visual performance is being considered as the human performance, but there are the two additional layers which govern the human performance. Figure 1 clearly depicts that if the visual performance is needed to

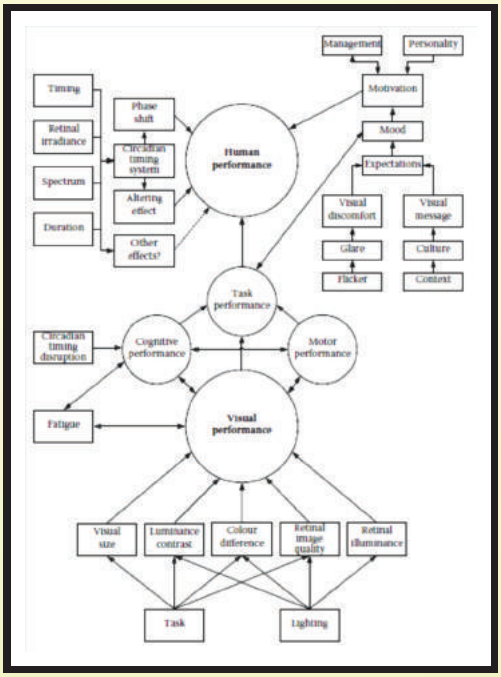
be shifted to human performance, the other routes where light can contribute, has definitely to be explored. There is a clear demarcation between visual performance, task performance and human performance. Cognitive performance takes a leader ship in task performance. Furthermore, the human circadian system is very much influencing along with the mood and motivation towards better human performance.

Several studies have been attempted towards investigations of human performance under lighting condition since last 50 years. Fundamentally the approaches can be assessed with two quality parameters e.g. face validity and generality. Table 1 depicts how the studies can be explained for the face validity and generality point of view.

Table 1

Type of approaches/studies	Face Validity	Generality
Real Task Studies	High	Very Low
Laboratory Simulation based studies	Moderate	Low
Analytical approach towards developments of a model	Low	Very High

Figure 1



The lumen realized in a light

In 1995, Robert Boynton gave the Frederic Ives Medal lecture – History and current status of a physiologically based system of photometry and colorimetry. In his talk, it was a brilliant overview of the history and technical foundations of photometry and colorimetry. In his lecture he assumed that the photometry, colorimetry and human vision should be homologous.

He developed a series of arguments for 'improving' both photometry and colorimetry based upon evidence from a suite of multidisciplinary experiments in the field neuroscience. Though this homology between photometry, colorimetry and human vision doesn't directly exist, but this lecture generates a view, that, human perception towards photometry and colorimetry should be a significant point to be considered.

Since 1924 and until recently, the photopic luminous efficiency function, V(λ),has been considered the sole spectral weighting function for quantifying light or, more formally, for quantifying luminous intensity, in candelas. V(λ), which has a peak efficiency at approximately 555 nm, does not, however, accurately represent what it was intended to do in 1924, namely to characterize the 'human eye's visual sensitivity' to electromagnetic radiation. Based upon a subsequent, large body of neuroscience research, we now know that V(λ) only approximates the spectral sensitivity of just two of the five photoreceptor types in the retina and, thus, does not fully characterize the spectral range of human visual (and non-visual) sensitivity to electromagnetic radiation. For this reason, a much broader universal luminous efficiency function as shown in Figure 2 [U(λ)] based upon the spectral sensitivity of all five photoreceptors in the human retina is proposed here to be used for the quantification of light. Like V(λ), U(λ) is bounded at the long-wavelength end by the spectral sensitivity of the long-wavelength sensitive (L) cone. Unlike V(λ) which is bounded at the short-wavelength end of the spectrum by the spectral sensitivity of the middle-wavelength sensitive (M) cone, U(λ) is bounded at the short-wavelength end of the spectrum by the spectral sensitivity of the short-wavelength sensitive (S) cone. By replacing V(λ) with U(λ), the full range of the human retinal sensitivity to electromagnetic radiation is more accurately represented. Moreover, because U(λ) brackets the spectral sensitivity of all known photoreceptors, it also includes the full range of non-visual responses to light generated by the human retina These proposed efficiency function is based upon basic research into the physiological and behavioral responses of the human visual and non-visual systems to electromagnetic radiation incident on the retina.

Figure 3 clearly depicts the spectral sensitivity of different cones, rods and Intrinsically photosensitive retinal ganglion cells (ipRGCs) with 380nm-780nm band.

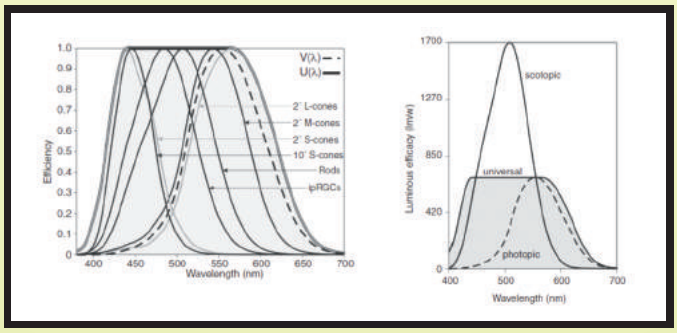


Figure 3 Figure 2

Human Centric Lighting

All the previous experimental studies have already proven that human factors should mandatorily be included in lighting. The previous trends of energy efficient lighting design has now been shifted towards human centric lighting with energy efficient approach. As mentioned previously, lighting can contribute to human performance, not only from visual acceptance point to view also from circadian route, motivation and mood. Hence, it is a proven fact that, spectrum color and intensity of light definitely influence human performance. The human centric lighting proposes the proper use of dimming and CCT shifting, which is termed as Kelvin Shifting, can improve circadian rhythms, mood, visual acuity and finally visual performance. Very recently Human Centric Lighting Society has been formed in US. The concept of human centric lighting evolved little lately, specially with the evolution of LED based lighting. As the LED based lighting systems are easy tunable, i.e. it can be dimmed or color can be changed instantly, hence, the image forming and non-image forming effect of light on human performances are thoroughly being investigated as well as implemented easily today. Figure 4 and Figure 5,6,7 show the setup of Illumination Engineering Laboratory at Technical University of Berlin, Germany for different human centric lighting related research.

Internet of Things (IOT) and Human Centric Lighting.

The application of Internet in every daily commodity is colloquially termed as Internet of Things. Lighting is one of the components which can be introduced in IoT family also. More precisely, lighting can also be 'controlled' using IPV6 protocol just like other existing communication protocols. Hence, using internet protocol the intensity and color of the light may be changed based upon the requirement. The concept of “smart lighting” can further be referred in this context, which says, using real time weather data though internet and also environmental conditions, light can be tuned. Hence, this IoT technology is being used in different SSL products used for different lighting design. Philips HUE is similar IoT based lighting product, which may be used tune any lighting condition instantly. In Figure 8 & 9, an experimental setup designed in Illumination Engineering Laboratory of Electrical Engineering Department, Jadavpur University has shown ,where it depicts clearly, a set how using this IOT RGB controlled lighting system , different lighting scene can be created instantly.



Figure 4



Figure 5



Figure 6



Figure 7

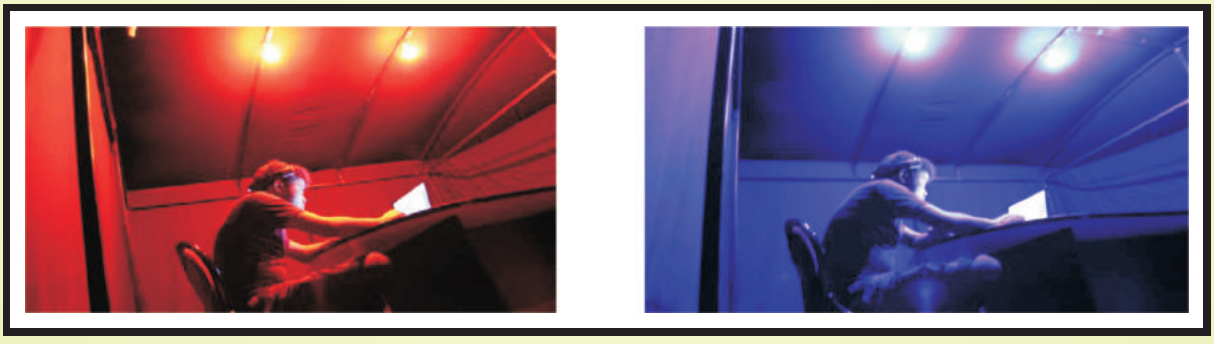


Figure 8



Figure 9

An approach for measurement of influence of lighting in human performance using EEG based technique: a noble approach developed by the author

Human cognition under lighting conditions present a complex yet scarcely investigated scenario. Added to this is the colour appearance of streetlights such as metal halide (MH) and high pressure sodium vapour (HPSV) lamps. As a result even simple object detection becomes highly complex. In the mentioned research work as done by the author EEG (Electroencephalogram) has been used to compare the object detection ability of human participants under MH and HPSV. The results suggest distinct brain activations for MH and HPSV. The outcome of this research opens up a new avenue, for assessment of human performance under different lighting conditions. Brain lighting to road lighting: perception matters is the research paper, published by the author says more clearly about the procedures.

Conclusion

This review paper clearly indicates that, the recent trend of research in the field of illumination engineering has been shifted in to a different dimension, i.e. human centric lighting. The development of the new generation solid state lighting products e.g. LED, has intensified this trend of research. The rapid advancement of Internet technology has also added another dimension on this human centric lighting. This internet data can be used to control the intensity and color of light based upon the requirement in real time. Furthermore, a new domain of research has been proposed by the author here which can be used to identify the influence of lighting on human performance .This technique can be used as future metric for measurement of human perception under different lighting conditions.

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ENERGY EFFICIENCY USING CONNECTED LIGHTING

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Abstract

The demand for energy gets increased day-by-day. With the current energy scenario and the further requirement of energy to fulfill various activities leaves energy savings in a realm of dreams. Increasing the energy efficiency along helps us to bring down the energy costs further and help us to tackle the future needs as well. With LED being revolutionized the world for the energy savings, the future improvement for increasing the energy efficiency lies in connected lighting. More than 70% of energy savings can be achieved using connected lighting than conventional lighting.

Introduction

Light is one form of energy. It has physical, emotional and psychological values. It enables our vision and helps us perform our visual tasks. Light controls our hormones (melatonin), sleep quality, biological clock and phase shifting, moods & depression, alertness, visual acuity and performance. Sun is the natural source of light. There are various sources available in this techno driven world to provide artificial lighting. Electroluminescence (Light Emitting Diode – LED) is the most energy efficient source in providing light. The lifetime of the LED light sources are com-pared to other sources. Around 50% of energy can be saved by using LED light sources. Additional 20 % energy can be saved using connected lighting.

Connected Lighting

Connected lighting is as simple as that every light point is connected to an intelligent system to deliver high quality, reliable illumination and serves as a pathway for information and services.

With normal lighting the luminaire remains dumb and provide light output and until manual input is given. The failure status of the luminaire remains unknown until a maintenance person identifies or an employee or public reports it. It is an established fact that with LED light sources energy is saved, but accounting exactly how much energy is saved is tedious. Connected lighting will be the most suitable solution to encounter all the real time difficulties.

Through connected lighting we can share information on lighting status like how much power is consumed on daily, weekly and monthly basis in dashboards, integrated sensors collect and share data about the space about occupancy and daylight. One of the key features in

connected lighting is that the lighting system can integrate with building's ecology and increase the efficiencies of other services. Delivers enhanced experience for building occupants by providing personalization and responds and adapts to the needs and preferences. Connected lighting provides reliable public lighting infrastructure. Through centralized street light control, failures in outdoor lighting installations can be easily detected by instant alarms. At the same time the option of dimming the lights during non-peak hours of the night would help us save the energy cost further.

Technology Benefits

- Efficacy: Light Emitting Diodes (LED's) are offering source level efficacy of >130 lumens/watts on AC powered drivers and reach up to >175 lumen/watt on DC powered drivers, for the artificial light sources LED's are the highest on efficacy scale.
- Efficiency - Fewer light points needed: LEDs being highest in efficacy, LED luminaires can deliver higher Lux/Sq. Ft. leading to lesser number of light points on ceiling.
- Compliance to Relevant Standards: Rightly designed LED Luminaires helps projects achieve compliance to relevant building standards – LEED (W/sq.mt), GRIHA, BREEAM, WELL etc.
- Capex & Opex: LED lighting provides considerable reductions in Capex Cost (reducing LED prices, comparably lower Installation costs, Lower 3rds costs (cables, switchgears), Higher PF results in to lower T&D losses, lesser loading on cables, Lesser load on HVAC etc.
- More controllable: Digital technology makes LEDs easy to dim and control (fine tune brightness, monitor from central location, alter light output to optimize energy efficiency)
- Durability – Fewer lamp replacement needed: LEDs are highly resistant to vibration and mechanical stress. This makes them suitable for road lighting (especially on bridges), elevated highways and where there is risk of vandalism.
- Directionality and less light pollution: Directionality contribute significantly to LED's energy saving potential. LEDs reduce light wastage by directing light to where it's needed most.
- Aesthetics: LED lighting provides a full spectrum of colors that can easily be controlled in a way to provide various experiences of unique landmarks and city center streets matching the occasion.

Economic benefits

- Lower lifetime cost: The Total Cost of Ownership (TCO) of LED lighting systems is at least 50% lower over the 50,000 hours lifetime.
- Income generation: Effective & Right LED lighting extends light hours in Application areas.
- For Outdoor Applications This promotes tourism, longer businesses hours for food vendors, shops, entertainment centers, and other evening activities, creating jobs and generating income. Increased sense of Safety and Security among Citizens, Improved image of Village/Town/City
- For Indoor Applications This improves alertness of space occupants, resulting in to better productivity per seat in offices, lesser accidents & quality rejections in industries, higher footfalls in Retails/Malls
- Energy savings: LED lighting is more efficient, requiring less energy from the grid and freeing up capacity during peak hours. This allows governments to meet growing energy needs from existing infrastructure, avoiding or postponing investments in power plants, transmission lines, and distribution networks. Better Demand Side Management for Power Producers.

Social Benefits

- **Road and citizen safety:** LED lighting provides better quality light, increasing visibility for drivers and pedestrians. Human Centric Lighting with LED's have a gamut of advantages and value beyond illumination.
- **Greener lighting:** As well as saving energy, LEDs reduce greenhouse gas emissions, saving about 0.6375 Kg per kWh. They emit no infrared radiation or harmful Ultra-Violet (UV) rays and contain no mercury - a toxic metal found in some lighting technologies.
- **Liveable cities:** LEDs enhance a city's aesthetic appeal, improving city branding and cultivating civic pride. Example – Varanasi Façade Lighting, North Block & South Block-New Delhi

Conclusion

Increase in demand for the energy leads to energy crisis. Connected Lighting which is the energy efficient solution in today's market scenario has a huge potential to contribute to energy savings. It has various features that adds values to the lighting system and provides easiness to the maintenance team during fault detections, spares allocation. It scores it benefits in all three dimensions technologically, economically and socially leaving no choice that it is the energy efficient solution.

INTEGRATION OF RENEWABLE ENERGY FOR SMART AND SUSTAINABLE BUILDINGS

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Abstract

Renewable energy and carbon less energy generation technologies have the potential to provide solutions to the forthcoming energy crisis and current rate of environmental degradation being faced by the developing world. The renewable energy sources such as solar energy, geothermal energy, biomass energy and fuel cell technology at its current and projected development stage can act as an integrated package for buildings in the coming decades to responsibly and judiciously, overcoming energy shortage in India. At the current rates of economic development and rapid urbanization, to suffice the energy requirement, India will require an assured supply of 3-4 times the current energy consumption by 2030. Today, renewables account for about 33% of India's total installed power capacity (including hydro). To extend low carbon pathway, it is necessary to enhance renewable contribution in total energy consumption. One most possible solution is to have or build captive/ decentralized capacities in buildings, institutional campuses, hospitals etc. to have renewable energy technologies integrated in them for self-generation. Along with adopting all energy conservation measures, this would reduce the burden on fossil fuel-based energy generation and lead India towards a low carbon energy generation trajectory.

The paper summarizes the availability, current status, major achievements and future potential for integration of renewable energy in buildings and built habitats. The paper also discusses about the advantages and specific barriers in promotion of renewable integrated buildings.

Introduction

India along with rest of the developing world is now at the cusp of a crisis for managing the balance between supply and the rapidly increasing energy demand, responsibly and judiciously. Confronted with this arduous challenge, generation and supply of energy that is clean, accessible and affordable to meet the demands is necessary for a positive and healthy economic growth. This sounds easier said than done as it is exacerbated by a growing global consciousness on conservation and sustainable development, considering climate change and its impacts on both the environment and socio-economic levels. India, while being cognizant of this fact, is striving to meet its energy requirements by advocating sustainable and clean energy alternatives to fossil fuels. India has adopted ambitious targets for reducing greenhouse emissions and promotion of clean and renewable energy through introduction of new policies and initiatives.

Presently, the buildings are invariably being designed for as comfortable and convenient

occupancy as possible all over the world, achieving which, the construction and buildings sector has become the third largest consumer of energy after industry and agriculture. Unfortunately, the larger part of this energy is produced by burning fossil fuels, mainly coal. Because of increased energy and climate concerns, interest in speeding the development and deployment of renewable energy resources in the developing world, and the effectiveness of building energy codes in delivering energy efficiency is being looked at.

The building sector is growing at a rapid pace, Real estate sector in India is expected to reach a market size of US$ 1 trillion by 2030 from US$ 120 billion in 2017 and contribute 13 per cent of the country's GDP by 2025 (India Brand Equity Foundation – Indian Real Estate Industry, 2018). Retail, hospitality and commercial real estate are also growing significantly, providing the much-needed infrastructure for India's growing needs. Hence, there exists a tremendous potential to conserve energy in buildings. This paper deliberates on the integration of renewable energy technologies in buildings towards achieving energy sustainability and efficiency. To achieve a significant reduction in energy consumption in the building apart from the standard energy-efficiency methods, proven renewable energy technologies can be implemented and integrated to make them self-sustainable and capable of generating power or energy that can be utilized by the occupants. The operational energy use in the building is of growing importance all over the world, renewable energy technologies can be deployed in buildings to suffice various daily requirements i.e. water heating, space cooling/heating and electricity production for self-sustenance.

Renewable Energy in India

Presently in India, the installed power capacity stands at 349.3GW (Central Electricity Authority, 2018), out of which 74.8GW (Ministry of New and Renewable Energy, 2019) is from renewable energy-based power plants. The growth of Solar PV in India got a boost in the year 2010 after the launch of JNNSM. In 2010 during the start of the mission, it was targeted to achieve a total of 20GW from grid-connected solar PV plants and 2GW from off-grid solar PV installations by 2021-2022. In the year 2015, the target was revised to 100GW out of which 60GW is to be achieved from grid-connected utility-scale projects and remaining 40GW from rooftop solar PV projects. The total renewable power target has also been revised and fixed at 175GW to be achieved by March 2022. It includes 60GW wind, 10GW Biomass, 5GW small hydro and 100GW solar.

Solar Energy

Solar energy based renewable energy systems are the fastest emerging options at small as well as large scale. Ranging from few Watts to Mega Watts capacity solar energy systems are installed to fulfil industrial as well as residential demand. Solar energy can be utilized through two conversion routes viz., thermal and photovoltaic (PV). Selection of conversion route

depends on the end use (heat, light etc.). Fig.1 shows the different end uses which we can meet through solar energy.

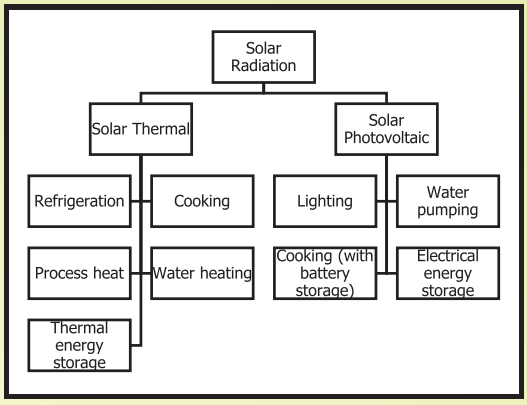


Figure 1: Solar energy and its applications

a) Solar Thermal

In a building, depending on the application, one may decide on the type of conversion technology to be adopted. If the demand is for process heat, cooking, water heating and refrigeration (vapor absorption technology), then solar thermal technology can deliver the best performance. Solar thermal technologies can be further classified based on the temperature range; low-temperature application, medium temperature application and high-temperature application. Solar water heating for domestic purpose falls under low-temperature application, and the institutions like mega kitchens and dairy industry which require steam at high temperatures and pressures, use the high-temperature solar thermal systems.

b) Solar Photovoltaic

Solar photovoltaic (SPV) is the most popular and preferred technology among the majority of the building owners because SPV can provide electricity that is required to power a variety of gadgets in a building. If the SPV system is grid connected, the building owner gets assured supply of electricity as long as the grid is alive, and gets reduced electricity bill from the Utility depending on the size of the SPV system installed. The SPV system can also be used without connecting it to the grid, but would require battery storage of suitable size for enabling continuous supply of electricity from the system. The photovoltaic technology is preferred due to reason like, ease of installation, low maintenance and it is modular, i.e., we shall add the capacity as large as possible.

c) Building Integrated Photovoltaic

“Building-integrated photovoltaics (BIPV) refers to the concept of integrating photovoltaic elements into the building envelope, establishing a symbiotic relationship between the architectural design, structure and multi-functional properties of the building materials and the generation of renewable energy” (Polysolar UK, 2018). The specifications of BIPV are based on the SPV technology and the types of utilization (Onyx Solar, 2018)

- BIPV panels can be completely customized based on the users' requirements
- Panels as large as 4m x 2m to as small as 1.2m x 0.3m are available
- U-values (U-value is the overall heat transfer co-efficient of any composite material) can be tailored based on the requirement, and it varies from 5.7$Wm^{-2}K^{-1}$ to 1 $Wm^{-2}K^{-1}$

- Solar Heat Gain Co-efficient (SHGC) varies from 41% in highly transparent panels to 5% in dark panels.
- Power density (Wm^{-2})depends on the transparency desired. Power density and transparency are inversely proportional.
- Power density varies from $57Wm^{-2}$ (dark panels) to $28Wm^{-2}$ in transparent panels

The location or zone where it is planned to install solar power plant must be free from shadow. If there are any obstacles which may cast a shadow on the location must be cleared before setting the power plant. The performance of the solar power plant is adversely affected by the obstacles in the path of solar radiation.

Bio-energy

The energy derived from either biomass or biofuels is known as bio-energy. 'Biomass' is a collective term used for all materials that are biogenic in origin, that is, derived from the products of photosynthesis (K. Lata and S. P. Mande, 2008).

Further, based on the source, the bioenergy resources are classified into plant-based and animal-based resources. In buildings, animal-based biomass resources can be utilised to generate energy. If we take the example of hostels, hotels and resorts which have a large kitchen can go for the kitchen waste biogas plant. Residential complexes can also make suitable provision of collecting the kitchen waste from each unit and utilize the same for production of biogas. In the industries like sugar-mills bagasse is used for meeting process heat demands but in biomass/bagasse deficit areas this system cannot run. Moreover, there are various factors such as climate, cost, land availability, public awareness etc. which affect the power generation from bioenergy sources.

Small Wind Turbines

Small wind turbines (SWT) are also gaining the same importance as that of a Solar PV. Also, the technology providers for small wind turbines are increasing in numbers. However, to obtain maximum output from small wind turbines thorough resource assessment is a must and the surrounding terrain plays a significant role.

The size/capacity of the wind turbine depends on the factors like energy demand, space availability and the availability of wind resource. Small Wind Turbines based on the technology can be differentiated into a vertical axis wind turbine (VAWT) and horizontal axis wind turbine (HAWT). Besides, wind turbines can also be categorized based on generator capacity. Wind turbines up to 100kW capacity are categorized as small wind turbines. Classification of wind turbines based on the capacity is given in Table 1.

In the context of buildings, small wind turbines can be integrated to meet energy demand. If

the campus has some space, the larger (comparatively) turbines can be installed on the campus (else, smaller (relatively) wind turbines can be installed on the rooftop. Small wind turbines of 5kW capacity can be installed in two square meters area. Small wind turbines can be combined with rooftop solar PV power plants. During monsoons generation from solar PV power plant reduces owing to reduced solar radiation but, wind speed increases during monsoons. Hence micro wind turbines can compensate for reduced solar PV generation in solar and wind hybrid systems.

Table 1: Classification of Wind Turbines

Wind Turbines	**Land based**	These range from 100kW to 3 MW
	Offshore	Larger than land based turbines, range up to 6MW
	Small	Decentralised, below 100Kw output

Energy Storage

Both solar and wind are indefinite sources of energy. Energy storage, therefore, is a necessity if power is required all the time from an independent off-grid solar or wind power system. In grid connected solar or wind power system, however, the backup is provided by the grid through its conventional energy supply. There are numerous ways in which energy can be stored viz.

- Thermal storage
  - # Sensible heat
  - # Latent heat
- Battery storage
- Compressed air
- Flywheel
- Hydro energy storage (pumped hydro) etc

Out of the options as mentioned above thermal and battery storage are the ones which can conveniently be integrated with the building.

Other Innovative Solutions

Energy Harvesting Floor Tiles

Energy harvesting tiles are designed to harvest the kinetic energy from the footsteps of the pedestrians. The tile moves some millimeters barely when one steps on it, and the pressure makes the wheel beneath the tile to rotate thus generating the power through electromagnetic induction. Presently these tiles are installed on the 'Bird Street' in London. The technology is developed by 'PaveGen Systems', London. PaveGen aims of installing

these tiles in stadium and sports complexes where it is expected to have higher footfall (Alphr) .

The Solar Thermal Air Conditioning System

The solar thermal air-conditioning system is a proprietary solution developed by 'Ecoline Solar Pte. Ltd., Singapore'. The technology is not entirely renewable energy based but; it helps in reducing the energy consumed by the compressor (Ecoline Solar). The novelty of this technology is that the solar energy absorbed by the solar collector (vacuum tube collector) is utilized superheat the refrigerant, thus reducing the workload of the compressor.

Barriers

The problem with green energy sources is that they are controlled by unreliable aspects. In other words, generation of power from RE sources is dependent on natural resources such as sunshine, wind, or ocean waves, therefore power generation from RE can be intermittent and inconstant. As a result, it is a challenge to rely on RE, 100 per cent. Some of the barriers are discussed below.

a. Availability of Power

One of the biggest concerns in RE integration is the power generation depends on natural resources that are uncontrollable by human. In PV energy, producing electricity is dependent on availability of sunshine; wind energy depends on the availability of consistent winds of certain speeds to move the turbines. The instability of producing energy in RE technologies is making the integration more complex, and it causes the cost to rise as support systems like energy storage systems such as batteries need to be incorporated allowing constant frequency and voltage.

b. Forecasting

Generally, forecasting in power systems is a major subject of power management system for grid system planning to ensure the stability and high reliability. Because most of RE technologies depend on weather and environmental factors, the prediction in power generation is hard in term of accuracy. Accuracy is usually obtained in case of load forecast in power system distribution, and it results in high quality of operation due to the constant producing of power and it is to ensure the future load demand. In RE technologies, forecasting studies are required in power generation, and if the main source of power is not constant and uncontrollable, RE integration become more difficult. In addition, each technology of RE has its own characteristics, so forecast studies and research will be different.

c. Cost Issue

Economic estimation is a prime part in RE integration for buildings since it is desirable to have rate of cost as low as possible. The two main aims of the RE incorporation are to save our

environment and reduce the cost of operation of the building. Also, location play a role in the total cost since transportation of materials is an aspect.

Other barriers:

1. Belief that the initial expenditure could be high
2. Delays in receiving the subsidy payments
3. Design issues with installation of RE technologies in building structure
4. Problems with respect to the space availability to install the RE systems required
5. Most RE systems require periodic maintenance, which creates extra responsibilities for building owners/managers
6. On existing buildings, the decision to install may disrupt some of the operations
7. Specialist training is required for the installation and management

The Benefits

Reduce or Eliminate Energy Bills

Installing solar panels can help you save a huge amount of money on your electricity bills. The more solar power generation from your panel takes place, the lesser power you need to buy from the electricity company, thus helping you cut down on the electricity costs.

Saving from day one

With renewable energy technologies, you can produce energy locally. The more renewable energy you're using for your power needs, the less you'll rely on imported energy, and the more you'll contribute to energy independence as a whole.

Renewable energy has numerous health and environmental benefits

Renewable energy generation sources emit little to no greenhouse gases or pollutants into the air. This means a smaller carbon footprint and an overall positive impact on the natural environment. During the combustion process, fossil fuels emit high amounts of greenhouse gases, which have been proven to exacerbate the rise of global temperatures and frequency of extreme weather events. The use of fossil fuels not only emits greenhouse gases but other harmful pollutants as well that lead to respiratory and cardiac health issues. With renewable energy, you're helping decrease the prevalence of these pollutants and contributing to an overall healthier atmosphere.

Employment opportunities

RE improves the situation of our socio-economic strata in different ways such creating new

jobs, skill development. In Brazil, 934,000 jobs were offered and 724,000 jobs in the U.S. in 2014(GE Energy, 2010)

Helping in the environment regeneration

RE technologies has zero fossil fuel emission, so the integration will help fossil fuel power generation plants to reduce emission of CO2 in way of less generating power, the country has already reduced its emission intensity by 21% between 2005-2014 (Weather.com, 2019). In India, the electricity sector, renewable energy (excluding large hydro) accounted for 20% of the total installed power capacity (71.325 GW) as of 30 June 2018. Thus, by incorporating this capacity of clean energy in to the grid, it would result in reduced dependence on fossil fuel-based energy generation. In addition, it will help in natural resource conservation by reduction in mining and extraction of fuels.

Conclusion

A renewable integrated building allows systems like heating, ventilation and air conditioning (HVAC), access control, life safety and lighting to share information and strategies with an eye on reducing energy consumption, improving energy security, providing value-added functionality and making the building easier to operate and self-reliable. A Renewable Energy Integrated building can not only increase energy and operational efficiency by 20 to 30 percent based on utility tariffs, it can also lead to environmental regeneration and reduction in building can not only increase energy and operational efficiency by 20 to 30 percent based on utility tariffs, it can also lead to environmental regeneration and reduction in the overall carbon footprint of a country's economic development. In India, from the last 5 years there has been a vigorous pursuit of activities relating to research, development, demonstration, production and application of a variety of renewable energy technologies for use in different sectors and enhancing deployment of renewables for the future.

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