Solar Lighting & LED Technology

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Abstract :

In former times, the predictability of sunlight and it's modification by weather formed the basis of seasonal and daily work, play and rest schedules. The everyday structures were designed to relate very specifically to those movements and the resulting local climates.

In the recent past, concern with natural lighting experienced a brief renaissance and sunlight in building construction has generally been ignored or treated merely for direct day lighting through openings. A number of factors like inconsistent and varied intensity levels & direction have resulted in poor utilization of sunlight in buildings. In the indoor working area artificial light, consuming large energy is now a days generally employed as they provide flexible & optimal light requirements.

Use of optics/optoelectronics/solar energy technology for indirect lighting of buildings will not only reduce the energy consumption but will provide a clear energy source. The main focus of this paper is to try alternative design solutions by making maximum use of latest optics/optoelectronics/solar energy technology in building lighting so that the disadvantages in direct sunlighting can be overcome and optimize design solutions for creating comfortable visual and thermal environments with minimal use of other energy sources can be achieved.

➢ **KEY WORDS: Solar Panels, LED's,CFL, energy, cost.**

➢ PRESENT BUILDING DESIGN PRACTICES:

To increase the "demand" for more power plants, the power and lighting industries were very effective in promoting ever-increasing illumination levels and incorporating them into codes. In some cases "required" light levels were so high that artificial lights had to be used all the time, regardless of the external climate and availability of natural light. Such lights often heated buildings to the extent that air conditioning was needed year-round.

Increased lighting requirements were also fostered by an unconscious conspiracy of building professionals. Electrical and mechanical engineers, being paid percentage fees, were happy to have their portions of building budgets increase dramatically. No more effort was required to specify more fixtures or larger lamps and air-conditioning units. It was much easier to design for quantitative goals than to address qualitative needs.

Electrical engineers, untrained in the principles of perception or space design but given the design responsibility, were happy to have the crutch of simplistic numerical standards as the principal design criteria.

➢ DESIGN OF BUILDINGS CONSUMING HIGH ENERGY.

Too many architects abdicated much of the responsibility for the design of a building's interior environment to engineers in exchange for the freedom of designing any glass box that met their fancy, regardless of its functional implications. Separating skin from structure, they maintained the myth that nothing had been compromised.

Extolling the exterior forms of Miss-like curtain-wall buildings, without reference to their well-known environmental discomforts (glare, overheating on the sunny side, underheating on the shady side), encouraged more and more such buildings to be built.

Many architects liked to design such curtain-wall office buildings because the process was easy and profitable. Little more was required than deciding on a building shape ad selecting materials- a curtain-wall system and color, an acoustic ceiling system and a recessed light fixture. Beyond that, the only design effort expended often appeared to be in the main lobby.

- **DESIGN OF GREEN LIGHTING:**

Now that the idea of limitless cheap energy has been recognized as a myth, users are beginning to question the qualities of the totally artificial environment produced by the architecture of technology. It is time to reexamine the traditions of the world's indigenous architectures, which evolved around climate and human needs. Former sunlighting present practices in less wasteful countries need merely be further developed for today's more stringent context of programmatic needs, user expectations, and advanced building materials and processes.

The green lighting design comprises: current situation survey of the electric illumination industry and market investigation; study of potentiality for electricity conservation in illumination and cost/benefit analysis; technical measures; economic measures; policies and laws for implementing lighting efficiency programs; and measures of implementation of green lighting engineering.

The technical measures it should contain are:

- application and dissemination of high-efficiency lamps such as thin-tube or circular fluorescent lamps, compact fluorescent lamps, high-pressure sodium vapor lamps and metal halogenate lamps, LED's etc.
- Application and dissemination of high-efficiency fittings such as high-efficiency inductance ballasts and electronic ballasts, and control apparatus including light regulation devices, sonic control devices, light control devices, time control devices and induced control devices and energy-saving transformers for neon lamps;
- In new projects, designing illumination in styles that promote energy conservation, including object/background illumination design methods and rational lighting design.
- It should also reduce environmental pollution

- **SUN LIGHTING:**

- When natural light was the only alternative, building occupants accepted the glare and heat of sunlight or adjusted the situation. Today, adequate glare-free artificial lighting is available. Sunlighting/solar energy for indirect lighting must therefore achieve control of quality as well as quantity or it will be shut out and not utilized.
- The best use of sunlighting/solar energy for indirect lighting is not only to save energy and guard against rising energy prices but, more important, to create more pleasant, delightful luminous environments for the occupants. To achieve these objectives, sunlighting must be given the highest priority and be used

economically with elegance in the design of both interior spaces and exterior architectural images

- The challenge and promise of sunlighting/use of solar energy for indirect lighting today is to use the sun as it was used in the past to provide economical illumination, comfort, and delight, in the context of rigid expectations of visual and thermal comfort, by making use optics/optoelectronics/solar energy technology for indirect lighting of buildings, as Sunlighting/use of solar energy offers the dual potential of buildings that are both comfortable to use and economical to operate.

➢ THE SOLAR ENERGY RESOURCE:

- The amount of energy from the sun that falls on the earth is enormous.
- All the energy stored in the earth's reserves of coal, oil, and natural gas is matched by the energy from 20 days of sunshine.
- Outside the earth's atmosphere, the sun's energy contains about 1,300 watts per square meter.
- About one-third of this light is reflected back into space, and some is absorbed by the atmosphere (in part causing winds to blow).
- By the time it reaches the earth's surface, the energy in sunlight has fallen to about 1,000 watts per square meter, at noon on a cloudless day.
- Averaged over the entire surface of the earth, 24 hours per day for a year, each square meter collects about the energy equivalent of a barrel of oil.
- So each day, on average, a square meter collects 4.2 kilowatt-hours of energy. This figure varies by location and by weather patterns.
- Deserts, with very dry air and little cloud cover, receive the most sun, more than 6.0 kilowatt-hours per day per square meter.

2.1 PHOTOVOLTAICS :

In the 1970s, a serious effort began to produce photovoltaic panels that could provide cheaper solar power. The three basic types of solar cells are single crystal, polycrystalline, and amorphous. The cost of PV panels is also coming down drastically due to advances in these semiconductor technology, manufacturing process and the annual production rate.

➢ EVOLUTION OF ARTIFICIAL LIGHTING:

Artificial lighting sources are fluorescent tubes, 60-plus Watt incandescent light bulbs, high intensity discharge lamps etc. which all share three key characteristics differentiating them on the evolutionary tree as a species apart from the indicator lamp.

- First, they are rarely viewed directly. Light from a lighting source is viewed in reflection off of the illuminated object.

- Second, the unit of measure (flux) is the kilolumen (kim) or higher, not the mlm, lm or worse yet the Cd often used for indicator LED lamps.
- Finally lighting sources are predominantly white with CIE color coordinates very near the Planckian, producing good to excellent colour rendering.
- Today there really is no such thing as a commercial 'solid state lamp' for use in illumination. However, a branch in the evolutionary tree is forming and differences are beginning to appear in the technologies used for low power LED indicators and the high power LED light sources that will evolve into lighting sources.

➢ SOLAR LIGHTING AND LED TECHNOLOGY:

Use of solar energy for illumination of building has been exercised now a days very rapidly. However the **cost of solar panel is still prohibitive**. **It is therefore necessary to make use of latest lighting technologies so as to make the use of solar energy commercially viable**.

It is a proven fact that the latest LED technology is getting more popularity as per as energy requirement criteria is concern.

The first LED is developed in 1962 and was made of compound semiconductor alloy gallium arsenide phosphate, which emitted red light.

In 1968 the first commercial LED were introduced at 0.001 lm / LED until mid 1990. These commercial LED's were used exclusively as indicators. In terms of number of LED's sold, indicators and other small signal applications in 2002 still consume the largest volume of LED's with annual global consumption exceeding several LED's per person on the planet.

➢ LIFE & EFFICIENCY OF LAMPS:

Table 1. Comparison of efficiency and life of different kinds of lamps

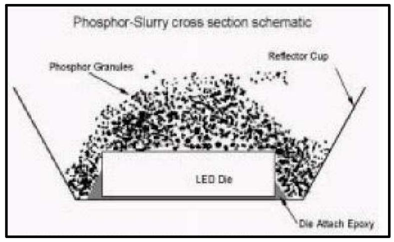
Lamp	Efficiency (lm/W)	Life (h)
Incandescent bulb	7-17	1000-2000
Halogen lamp	17-25	2000-4000
Mercury vapor lamp	25-50	6000-12000
Spherical fluorescent lamp	50-60	6000-8000
Compact fluorescent lamp (CFL)	50-90	3500-9000
Straight-tube fluorescent lamp	65-100	8500-12000
Loop fluorescent lamp	50-90	6000
Metal halide lamps	45-100	6000-9000
High pressure vapor lamps	45-110	6000-12000

The Life of super bright LED's is 1,00,000 hours and the efficiency (lumen/ watt) is more than that of any other light source.

➢ LED's:

LED's are special diodes that emit light when connected in a circuit. They were frequently used as "pilot" lights in electronic appliances to indicate whether the circuit is closed or not. A a clear (or often colored) epoxy case enclosed the heart The two wires extending below the LED epoxy enclosure, or the "bulb" indicate how the LED should be connected into a circuit.

➢ CONSTRUCTION DETAILS OF LED'S:



First generation white pc-LEDs are made by depositing in measured quantities of a slurry mixture of phosphor and epoxy within a containment cup surrounding the pump die during the encapsulation step .Several factors inhibit process uniformity, including the difficulty of measuring precise small quantities of a viscous fluid, slurry settling both before and after dispensing, distribution of the mixture within the cup, and phosphor powder grain size variations.

➢ ADVANTAGES OF LED:

•Reduced Maintenance Costs

Since LED based light sources last at least 10 times longer than a normal light source, there is no need to replace the light source, reducing or even eliminating ongoing maintenance costs and periodic relamping expenses. The long life of a LED also allows for trouble free designs.

•More Energy Efficient—Be the Environmental Solution

LED light source are more efficient than incandescent and most halogen light sources. When viewing LED lighting as an alternative, it is important to consider the total system level benefits. For example, due to the decrease in energy used for the lighting of a building, air handling costs drop, generating both additional initial and ongoing investment savings. Additional benefits such as the directionality of light for general lighting and vivid true colors without the need for filters in signaling applications add to the energy efficiency on a system level.

•Design Flexibility and Unobtrusive Hidden Light

LEDs are typically much smaller than conventional light sources, allowing for dramatically different lighting designs capitalizing on the unobtrusiveness of the source. Light emitting diodes provide the lighting designer with additional options and choices compared to conventional technologies.

•Vivid Saturated Colors—Without Filters

Light Emitting Diodes require no filters to create colored light, resulting in deeper saturated colors without wasted light. Deep reds, greens, blues and other colors can be produced in monochromatic form directly form the solid state element. There is no need for expensive filters, and there is no wasted energy.

- **Directed Light for Increased System Efficiency**

The light emitted from an LED is directional. Typical conventional sources such as incandescent, halogen, or fluorescent lights are omnidirectional, emitting light in all directions. A side benefit from the directionality of light emitted from the LED solution is the reduction of light pollution.

- **Instant On, Full Color, 100% Light**

Light emitting diodes have turn on times measured in microseconds. The instant on feature of LEDs provides additional reaction time in safety critical applications. There is no flickering or warm up period as the source reaches ignition temperature in an LED lighting system and the emitted wave length is reached instantaneously.

- **No Mercury in the Light Source**

Unlike most fluorescent sources, LEDs contains no Mercury. LED is Solid State technology made in Silicon Valley using similar technologies that are used in the latest microprocessors. As it is a solidstate device, it has no moving parts, no fragile glass environments, no mercury, no toxic gasses, and no filament. Eliminating Mercury from your lighting system will enable you to meet new and future increasingly stringent environmental regulations.

- **No Heat or UV in the Light Beam**

Conventional light sources (as well as some LEDs) contain invisible radiation as well as the visible component of light in the beam. This radiation can be very short wavelength blue, known as ultraviolet light, or long wavelength red, known as infrared, which causes heat. Ultraviolet light can, and will, damage materials, cause color changes and eventually breakdown many materials. Museums and other applications where ultraviolet light is a liability use expensive low flexibility light pipes to filter out this harmful component of the generated light. Frequently the light sources used for these light pipes is a very bright, hot, incandescent or halogen sources, generating most of their light as heat. Infrared light can damage displayed objects, increases air conditioning costs, decreases environmental comfort, and when reflected off reading surfaces increases eyestrain.

- **Cold Start Capable**

Many light sources in use today are not well suited to cold environments. The cold start ability allows for instant on/off control without specially designed circuitry, simplifying your system design while lowering the cost of the electronic driver.

- **Low Voltage DC Operation**

Unlike conventional light sources, light emitting diodes are current driven low voltage devices. This enables never before solutions that meet regulatory requirements without expensive safety interactions. Due to the low voltages required, disposable and rechargeable battery operation or alternative energy sources (such as solar or wind) can be easily used to power the light source

- **MEASUREMENT OF ILLUMINANCE:**

Luminous Flux (Unit-Lumen, Symbol - Φ)

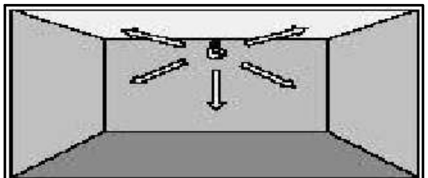


Figure 15: Luminous flux from a lamp

The lumen can be defined as a certain quantity of radiant energy emitted per second, weighted against the spectral sensitivity of the human eye. This can be well understood by comparing light source with shower. The quantity of water sprayed per second by shower is termed as stream of water. If in the place of shower an electric lamp is installed, the lamp would emit certain quantity of light per second. In technical word this quantity of light emitted per second by the light source is called the luminous flux. The luminous flux) is expressed in units called lumen. It is represented by symbol Φ and is a scalar quantity.

- **LUX METER:**

Illuminance (Unit – Lux, Symbol - E)

The luminous flux reaching the working plane per unit of area is called the illuminance. For the magnitude of illuminance it does not matter the direction form which the luminous flux reaches the plane. The illuminance is a scalar quantity. The illuminance on a plane due to one light source and due to another source on the same plane can therefore be added to arrive at a total value.

If the luminous flux is not uniformly distributed over the plane, one has to work out average illuminance (Eav) on that plane. The illuminance on the working plane is therefore the result of direct as well as reflected light.

The symbol of illuminance is E and unit is as follows:

In Metric System , Illuminance $E = \Phi/A$ lumen/m^2 or Lux

It is Measured with help of Lux meter

- **ENERGY EFFICIENT LIGHTING DESIGN CASE- STUDY:**

It is necessary to study the exact lighting requirement depending upon nature of task, duration of task, lighting levels during day time and other important factors, accordingly suitability of available energy saving lighting fixtures etc.

In present case a detailed study of illumination requirement is carried out for a residential unit with one bedroom, hall, kitchen, flat, with toilet and entrance foyer. The details of present electrical fittings provided are worked out. On and average a 40 watt tube fitting gives lux level during night hours up to 40 lux at table top placed 0.75mt. Above the floor level at the center of the room for room dimensions of 12 x 12 ft. At present the tube fitting is mounted at ceiling level which is 3.00 mt. high from the floor level.

For giving equivalent lux level at same point i.e. at tabletop placed 0.75mt. Above the floor level 2 nos. of CFL lamps of 8 watt capacity were placed to give out put of 38 lux. In same room two fittings, each consisting of 6 Nos. of super bright LED's were provided and they gave total illuminous output of 42 lux.

➢ RECOMMENDED VALUES OF ILLUMINATION:

Recommended values of illumination as per national building code of India are part VIII Building services – section 1 lighting and ventilation

	Homes:	**Lux**
a)	Kitchens	200
b)	Bathrooms	100++
c)	Stairs	100
d)	Workshops	200
e)	Garages	70
f)	Sewing and darning	700
g)	Reading (casual)	150
h)	Homework and sustained reading	300

Each of these fitting consumes only 1 watt of power. Which indicates use of LED's can give illuminous output equivalent output that produced by 2 Nos. of 8 watt CFL lamps (total 16 watt) in only 2 watt power consumption.

➢ ENERGY EFFICIENT LIGHTING DESIGN -CASE STUDY:

A recommended lux level for staircases is 100 lux in above table. Now a days in multi family complexes the lighting of the stair case is on throughout the night hours i.e. almost 12 hours.

In order to maintain this recommended lux level lot of energy will have to be put in which in my view is wastage of resources as the studies carried out for comfortable usage for stair cases and corridors reveal that up to 25 lux light out put is sufficient. As the usage is almost 12 hours day it is necessary to make use of LED fittings which are having almost 1 lack hours of life. That means ones if LED's are put in for usage considering their useful life they can be in service for almost

$$\frac{11{,}00{,}000 \text{ hours}}{12 \text{ hours /day} \times 365 \text{ days/year}} = 22.83 \text{ years}$$

And secondly in place of traditional lighting system if entire stair case lighting is done from construction stage itself on solar system then considering average life of solar panel about 25 years and LED fittings life of 25 years, usage of solar lighting systems for corridors, stair cases, bathrooms, night lamps, etc. mandatory and requested to the governments to make necessary laws.

In case of residential unit under study general lux level observed with 40 watt tube was found to be 40 lux in bedroom & sufficient ambient light was found to be

comfortable by the illumination produced by one 8 watt CFL lamp was 25 lux. It can be easily seen that the recommended lux levels are on very high side almost four times greater than that of actually used comfortable light levels.
It is therefore necessary to reconsider the desired lux levels in the present era of energy insufficiency especially in Maharashtra and secondly referring to the mounting energy costs.

➢ CASE STUDY OF ONE BEDROOM FLAT:

Average present Daily Lighting Requirement

Room	Type	Power Required (watts)	Daily Use in Hrs.	Energy Consumed (W-H)	Lux Level Measured
Hall	1- Tube	40	5	200	40
Kitchen	1- Tube	40	5	200	42
	Incandescent bulb	15	3	45	25
Bedroom	1- Tube	40	3	120	38
	Incandescent bulb Table Lamp	15	8	120	100
Bathroom	Incandescent bulb	15	3	45	20
W.C.	Incandescent bulb	15	3	45	25
Passage	Incandescent bulb	15	12	180	18
Veranda	Incandescent bulb	15	12	180	22
			Total	**1135 WH**	

Proposed Daily lighting requirement Using energy saving Fittings for equivalent lighting level

Room	Type	Power Required (watts)	Daily Use in Hrs.	Energy Consumed (W-H)	Lux Level Measured
Hall	2-CFL's,12-led	16+3=19	5	95.00	38
Kitchen	2-CFL's	16+3=19	5	95.00	36
	6-LED	1.5	3	4.50	40
Bedroom	2-CFL's,12-led	16+3=19	3	57.00	38
	6-LED Table lamp	1.5	8	12.00	100
Bathroom	6-LED	1.5	3	4.50	25
W.C	6-LED	1.5	3	4.50	32
Passage	6-LED	1.5	12	18.00	25
Entrance/ Veranda	6-LED	1.5	12	18.00	10
			Total	**308.5**	

% Reduction in energy requirement:

Light use in(Hr.)	Initial WH Requirement	Proposed WH Requirement	% Reduction In Energy Requirement
3	255	70.50	72.35
5	400	190.00	52.5
8	120	12.00	96.66
12	360	36.00	96.66
Total	1135.00	308.5	

- It is evident from the above case study that the power requirement is curtailed to almost 20% if energy saving fittings are used ,like CFL & LED's.
- It is therefore suggested that while designing lighting systems of buildings, the present practice of lighting design need be reviewed.

➢ DISCUSSION & CONCLUSION:

- It is evident from the above case study that the power requirement is curtailed to almost 20% if energy saving fittings are used ,like CFL & LED's.
- In place of traditional lighting system if entire stair case lighting is done from construction stage itself on solar system then considering average life of solar panel about 25 years and LED fittings life of 25 years, usage of solar lighting systems for corridors, stair cases, bathrooms, night lamps, etc. mandatory and requested to the governments to make necessary laws.
- In case of residential unit under study general lux level observed with 40 watt tube was found to be 40 lux in bedroom & sufficient ambient light was found to be comfortable by the illumination produced by one 8 watt CFL lamp was 25 lux. It can be easily seen that the recommended lux levels are on very high side almost four times greater than that of actually used comfortable light levels.
- It is therefore necessary to reconsider the desired lux levels in the present era of energy insufficiency especially in Maharashtra and secondly referring to the mounting energy costs.
- It is therefore suggested that while designing lighting systems of buildings, the present practice of lighting design need be reviewed.
- The utilization Optics/Optoelectronics/Solar energy Technologies has to be promoted that can help the existing photovoltaic systems to be used in more efficient and profitable manner to meet basic energy needs for indirect lighting in rural, urban-domestic, commercial, and industrial applications.
- Solar energy and energy efficiency must both be an integral part of any future energy system that addresses the issues of sustainable development.
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- Though the per watt cost of solar panels is reducing annually, still it is prohibitive but use of LED technology can reduce the pay back period substantially and make the photovoltaic systems more popular without assistance from the Government.
- Making Use of solar energy, electronics & LED's contribute to substantial reduction in CO_2 formation assisting formation of green environment.

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