8. LIGHTING SYSTEM

Syllabus
Lighting System: Light source, Choice of lighting, Luminance requirements, and Energy conservation avenues

8.1 Introduction

Lighting is an essential service in all the industries. The power consumption by the industrial lighting varies between 2 to 10% of the total power depending on the type of industry. Innovation and continuous improvement in the field of lighting, has given rise to tremendous energy saving opportunities in this area.

Lighting is an area, which provides a major scope to achieve energy efficiency at the design stage, by incorporation of modern energy efficient lamps, luminaires and gears, apart from good operational practices.

8.2 Basic Terms in Lighting System and Features

Lamps

Lamp is equipment, which produces light. The most commonly used lamps are described briefly as follows:

- **Incandescent lamps:**

Incandescent lamps produce light by means of a filament heated to incandescence by the flow of electric current through it. The principal parts of an incandescent lamp, also known as GLS (General Lighting Service) lamp include the filament, the bulb, the fill gas and the cap.

- **Reflector lamps:**

Reflector lamps are basically incandescent, provided with a high quality internal mirror, which follows exactly the parabolic shape of the lamp. The reflector is resistant to corrosion, thus making the lamp maintenance free and output efficient.

- **Gas discharge lamps:**

The light from a gas discharge lamp is produced by the excitation of gas contained in either a tubular or elliptical outer bulb.

The most commonly used discharge lamps are as follows:

- Fluorescent tube lamps (FTL)
- Compact Fluorescent Lamps (CFL)
- Mercury Vapour Lamps
- Sodium Vapour Lamps
- Metal Halide Lamps

Luminaire

Luminaire is a device that distributes, filters or transforms the light emitted from one or more lamps. The luminaire includes, all the parts necessary for fixing and protecting the lamps, except the lamps themselves. In some cases, luminaires also include the necessary circuit auxiliaries, together with the means for connecting them to the electric supply. The basic physical principles used in optical luminaire are reflection, absorption, transmission and refraction.

Control Gear

The gears used in the lighting equipment are as follows:

- **Ballast:**

A current limiting device, to counter negative resistance characteristics of any discharge lamps. In case of fluorescent lamps, it aids the initial voltage build-up, required for starting.

- **Ignitors:**

These are used for starting high intensity Metal Halide and Sodium vapour lamps.

Illuminance

This is the quotient of the illuminous flux incident on an element of the surface at a point of surface containing the point, by the area of that element.

The lighting level produced by a lighting installation is usually qualified by the illuminance produced on a specified plane. In most cases, this plane is the major plane of the tasks in the interior and is commonly called the working plane. The illuminance provided by an installation affects both the performance of the tasks and the appearance of the space.

Lux (lx)

This is the illuminance produced by a luminous flux of one lumen, uniformly distributed over a surface area of one square metre. One lux is equal to one lumen per square meter.

Luminous Efficacy (lm/W)

This is the ratio of luminous flux emitted by a lamp to the power consumed by the lamp. It is a reflection of efficiency of energy conversion from electricity to light form.

Colour Rendering Index (RI)

Is a measure of the degree to which the colours of surfaces illuminated by a given light source confirm to those of the same surfaces under a reference illuminent; suitable allowance having been made for the state of Chromatic adaptation.

8.3 Lamp Types and their Features

The Table 8.1 shows the various types of lamp available along with their features.

TABLE 8.1 LUMINOUS PERFORMANCE CHARACTERISTICS OF COMMONLY USED LUMINARIES

Type of Lamp	Lumens / Watt		Color Rendering Index	Typical Application	Typical Life (hours)
	Range	Avg.			
Incandescent	8–18	14	Excellent	Homes, restaurants, general lighting, emergency lighting	1000
Fluorescent Lamps	46–60	50	Good w.r.t. coating	Offices, shops, hospitals, homes	5000
Compact fluorescent lamps (CFL)	40–70	60	Very good	Hotels, shops, homes, offices	8000–10000
High pressure mercury (HPMV)	44–57	50	Fair	General lighting in factories, garages, car parking, flood lighting	5000
Halogen lamps	18–24	20	Excellent	Display, flood lighting, stadium exhibition grounds, construction areas	2000–4000
High pressure sodium (HPSV) SON	67–121	90	Fair	General lighting in factories, ware houses, street lighting	6000–12000
Low pressure sodium (LPSV) SOX	101–175	150	Poor	Roadways, tunnels, canals, street lighting	6000–12000

8.4 Recommended Illuminance Levels for Various Tasks / Activities / Locations

Recommendations on Illuminance

Scale of Illuminance: The minimum illuminance for all non-working interiors, has been mentioned as 20 Lux (as per IS 3646). A factor of approximately 1.5 represents the smallest significant difference in subjective effect of illuminance. Therefore, the following scale of illuminances is recommended.

20–30–50–75–100–150–200–300–500–750–1000–1500–2000, … Lux

Illuminance ranges: Because circumstances may be significantly different for different interiors used for the same application or for different conditions for the same kind of activity, a range of illuminances is recommended for each type of interior or activity intended of a single value of illuminance. Each range consists of three successive steps of the recommended scale of illuminances. For working interiors the middle value (R) of each range represents the recommended service illuminance that would be used unless one or more of the factors mentioned below apply.

The higher value (H) of the range should be used at exceptional cases where low reflectances or contrasts are present in the task, errors are costly to rectify, visual work is critical, accuracy or higher productivity is of great importance and the visual capacity of the worker makes it necessary.

Similarly, lower value (L) of the range may be used when reflectances or contrasts are unusually high, speed & accuracy is not important and the task is executed only occasionally.

Recommended Illumination

The following Table gives the recommended illuminance range for different tasks and activities for chemical sector. The values are related to the visual requirements of the task, to user's satisfaction, to practical experience and to the need for cost effective use of energy.(Source IS 3646 (Part I) : 1992).

For recommended illumination in other sectors, reader may refer *Illuminating Engineers Society Recommendations Handbook/*

Chemicals

Petroleum, Chemical and Petrochemical works	
Exterior walkways, platforms, stairs and ladders	30–50–100
Exterior pump and valve areas	50–100–150
Pump and compressor houses	100–150–200
Process plant with remote control	30–50–100
Process plant requiring occasional manual intervention	50–100–150
Permanently occupied work stations in process plant	150–200–300
Control rooms for process plant	200–300–500
Pharmaceuticals Manufacturer and Fine chemicals manufacturer	
Pharmaceutical manufacturer	
Grinding, granulating, mixing, drying, tableting, s terilising, washing, preparation of solutions, filling, capping, wrapping, hardening	300–500–750
Fine chemical manufacturers	
Exterior walkways, platforms, stairs and ladders	30–50–100
Process plant	50–100–150
Fine chemical finishing	300–500–750
Inspection	300–500–750
Soap manufacture	
General area	200–300–500
Automatic processes	100–200–300
Control panels	200–300–500
Machines	200–300–500

Paint works	
General	200–300–500
Automatic processes	150–200–300
Control panels	200–300–500
Special batch mixing	500–750–1000
Colour matching	750–100–1500

8.5 Methodology of Lighting System Energy Efficiency Study

A step-by-step approach for assessing energy efficiency of lighting system is given below:

Step–1: Inventorise the Lighting System elements, & transformers in the facility as per following typical format (Table – 8.2 and 8.3).

TABLE 8.2 DEVICE RATING, POPULATION AND USE PROFILE

S. No.	Plant Location	Lighting Device & Ballast Type	Rating in Watts Lamp & Ballast	Population Numbers	No. of hours / Day

TABLE 8.3 LIGHTING TRANSFORMER / RATING AND POPULATION PROFILE:

S. No.	Plant Location	Lighting Transformer Rating (kVA)	Numbers Installed	Meter Provisions Available Volts / Amps / kW / Energy

In case of distribution boards (instead of transformers) being available, fuse ratings may be inventorised along the above pattern in place of transformer kVA.

Step–2: With the aid of a lux meter, measure and document the lux levels at various plant locations at working level, as daytime lux and night time lux values alongside the number of lamps "ON" during measurement.

Step–3: With the aid of portable load analyzer, measure and document the voltage, current, power factor and power consumption at various input points, namely the distribution boards or the lighting voltage transformers at the same as that of the lighting level audit.

Step–4: Compare the measured lux values with standard values as reference and identify locations as under lit and over lit areas.

Step–5: Collect and Analyse the failure rates of lamps, ballasts and the actual life expectancy levels from the past data.

Step–6: Based on careful assessment and evaluation, bring out improvement options, which could include :

i) Maximise sunlight use through use of transparent roof sheets, north light roof, etc.

ii) Examine scope for replacements of lamps by more energy efficient lamps, with due consideration to luminiare, color rendering index, lux level as well as expected life comparison.

iii) Replace conventional magnetic ballasts by more energy efficient ballasts, with due consideration to life and power factor apart from watt loss.

iv) Select interior colours for light reflection.

v) Modify layout for optimum lighting.

vi) Providing individual / group controls for lighting for energy efficiency such as:
   a. On / off type voltage regulation type (for illuminance control)
   b. Group control switches / units
   c. Occupancy sensors
   d. Photocell controls
   e. Timer operated controls
   f. Pager operated controls
   g. Computerized lighting control programs

vii) Install input voltage regulators / controllers for energy efficiency as well as longer life expectancy for lamps where higher voltages, fluctuations are expected.

viii) Replace energy efficient displays like LED's in place of lamp type displays in control panels / instrumentation areas, etc.

8.6 Case Examples

Energy Efficient Replacement Options

The lamp efficacy is the ratio of light output in lumens to power input to lamps in watts. Over the years development in lamp technology has led to improvements in efficacy of lamps. However, the low efficacy lamps, such as incandescent bulbs, still constitute a major share of the lighting load. High efficacy gas discharge lamps suitable for different types of applications offer appreciable scope for energy conservation. Typical energy efficient replacement options, along with the per cent energy saving, are given in Table-8.4.

TABLE 8.4 SAVINGS BY USE OF HIGH EFFICACY LAMPS							
Sector	Lamp type				Power saving	
	Existing		Proposed		Watts	%
Domestic/Commercial	GLS	100 W	*CFL	25 W	75	75
Industry	GLS GLS TL	13 W 200 W 40 W	*CFL Blended TLD	9 W 160 W 36 W	4 40 4	31 20 10
Industry/Commercial	HPMV HPMV	250 W 400 W	HPSV HPSV	150 W 250 W	100 150	37 35

* Wattages of CFL includes energy consumption in ballasts.

Energy Saving Potential in Street Lighting

The energy saving potential, in typical cases of replacement of inefficient lamps with efficient lamps in street lighting is given in the Table 8.5

TABLE 8.5 SAVING POTENTIAL BY USE OF HIGH EFFICACY LAMPS FOR STREET LIGHTING

Existing lamp			Replaced units			Saving	
Type	W	Life	Type	W	Life	W	%
GLS	200	1000	ML	160	5000	40	7
GLS	300	1000	ML	250	5000	50	17
TL	2 X 40	5000	TL	2 X 36	5000	8	6
HPMV	125	5000	HPSV	70	12000	25	44
HPMV	250	5000	HPSV	150	12000	100	40
HPMV	400	5000	HPSV	250	12000	150	38

8.7 Some Good Practices in Lighting

Installation of energy efficient fluorescent lamps in place of "Conventional" fluorescent lamps.

Energy efficient lamps are based on the highly sophisticated tri-phosphor fluorescent powder technology. They offer excellent colour rendering properties in addition to the very high luminous efficacy.

Installation of Compact Fluorescent Lamps (CFL's) in place of incandescent lamps.

Compact fluorescent lamps are generally considered best for replacement of lower wattage incandescent lamps. These lamps have efficacy ranging from 55 to 65 lumens/Watt. The average rated lamp life is 10,000 hours, which is 10 times longer than that of a normal incandescent lamps. CFL's are highly suitable for places such as Living rooms, Hotel lounges, Bars, Restaurants, Pathways, Building entrances, Corridors, etc.

Installation of metal halide lamps in place of mercury / sodium vapour lamps.

Metal halide lamps provide high color rendering index when compared with mercury & sodium vapour lamps. These lamps offer efficient white light. Hence, metal halide is the choice for colour critical applications where, higher illumination levels are required. These lamps are highly suitable for applications such as assembly line, inspection areas, painting shops, etc. It is recommended to install metal halide lamps where colour rendering is more critical.

Installation of High Pressure Sodium Vapour (HPSV) lamps for applications where colour rendering is not critical.

High pressure sodium vapour (HPSV) lamps offer more efficacy. But the colour rendering property of HPSV is very low. Hence, it is recommended to install HPSV lamps for applications such street lighting, yard lighting, etc.

Installation of LED panel indicator lamps in place of filament lamps.

Panel indicator lamps are used widely in industries for monitoring, fault indication, signaling, etc. Conventionally filament lamps are used for the purpose, which has got the following disadvantages:

- High energy consumption (15 W/lamp)
- Failure of lamps is high (Operating life less than 1,000 hours)
- Very sensitive to the voltage fluctuations Recently, the conventional filament lamps are being replaced with Light Emitting Diodes (LEDs).

The LEDs have the following merits over the filament lamps.

- Lesser power consumption (Less than 1 W/lamp)
- Withstand high voltage fluctuation in the power supply.
- Longer operating life (more than 1,00,000 hours)

It is recommended to install LEDs for panel indicator lamps at the design stage.

Light distribution

Energy efficiency cannot be obtained by mere selection of more efficient lamps alone. Efficient luminaires along with the lamp of high efficacy achieve the optimum efficiency. Mirror-optic luminaires with a high output ratio and bat-wing light distribution can save energy.

For achieving better efficiency, luminaires that are having light distribution characteristics appropriate for the task interior should be selected. The luminaires fitted with a lamp should ensure that discomfort glare and veiling reflections are minimised. Installation of suitable luminaires, depends upon the height - Low, Medium & High Bay. Luminaires for high intensity discharge lamp are classified as follows:

- Low bay, for heights less than 5 metres.
- Medium bay, for heights between 5 – 7 metres.
- High bay, for heights greater than 7 metres.

System layout and fixing of the luminaires play a major role in achieving energy efficiency. This also varies from application to application. Hence, fixing the luminaires at optimum height and usage of mirror optic luminaries leads to energy efficiency.

Light Control

The simplest and the most widely used form of controlling a lighting installation is "On-Off" switch. The initial investment for this set up is extremely low, but the resulting operational costs may be high. This does not provide the flexibility to control the lighting, where it is not required.

Hence, a flexible lighting system has to be provided, which will offer switch-off or reduction in lighting level, when not needed. The following light control systems can be adopted at design stage:

- **Grouping of lighting system, to provide greater flexibility in lighting control**

Grouping of lighting system, which can be controlled manually or by timer control.

- **Installation of microprocessor based controllers**

Another modern method is usage of microprocessor / infrared controlled dimming or switching circuits. The lighting control can be obtained by using logic units located in the ceiling, which can take pre-programme commands and activate specified lighting circuits. Advanced lighting control system uses movement detectors or lighting sensors, to feed signals to the controllers.

- **Optimum usage of daylighting**

Whenever the orientation of a building permits, day lighting can be used in combination with electric lighting. This should not introduce glare or a severe imbalance of brightness in visual environment. Usage of day lighting (in offices/air conditioned halls) will have to be very limited, because the air conditioning load will increase on account of the increased solar heat dissipation into the area. In many cases, a switching method, to enable reduction of electric light in the window zones during certain hours, has to be designed.

- **Installation of "exclusive" transformer for lighting**

In most of the industries, lighting load varies between 2 to 10%. Most of the problems faced by the lighting equipment and the "gears" is due to the "voltage" fluctuations. Hence, the lighting equipment has to be isolated from the power feeders. This provides a better voltage regulation for the lighting. This will reduce the voltage related problems, which in turn increases the efficiency of the lighting system.

- **Installation of servo stabilizer for lighting feeder**

Wherever, installation of exclusive transformer for lighting is not economically attractive, servo stabilizer can be installed for the lighting feeders. This will provide stabilized voltage for the lighting equipment. The performance of "gears" such as chokes, ballasts, will also improved due to the stabilized voltage.

This set up also provides, the option to optimise the voltage level fed to the lighting feeder. In many plants, during the non-peaking hours, the voltage levels are on the higher side. During this period, voltage can be optimised, without any significant drop in the illumination level.

- **Installation of high frequency (HF) electronic ballasts in place of conventional ballasts**

New high frequency (28–32 kHz) electronic ballasts have the following advantages over the traditional magnetic ballasts:

Energy savings up to 35%

Less heat dissipation, which reduces the air conditioning load

- Lights instantly
- Improved power factor
- Operates in low voltage load
- Less in weight
- Increases the life of lamp

The advantage of HF electronic ballasts, out weigh the initial investment (higher costs when compared with conventional ballast). In the past the failure rate of electronic ballast in Indian Industries was high. Recently, many manufacturers have improved the design of the ballast leading to drastic improvement in their reliability. The life of the electronic ballast is high especially when, used in a lighting circuit fitted with a automatic voltage stabiliser.

The Table 8.6 gives the type of luminaire, gear and controls used in different areas of industry.

TABLE 8.6 TYPES OF LUMINAIRE WITH THEIR GEAR AND CONTROLS USED IN DIFFERENT INDUSTRIAL LOCATIONS

Location	Source	Luminaire	Gear	Controls
Plant	HID/FTL	Industrial rail reflector: High bay Medium bay Low bay	Conventional/low loss electronic ballast	Manual/electronic
Office	FTL/CFL	FTL/CFL	Electronic/low loss	Manual/auto
Yard	HID	Flood light	Suitable	Manual
Road peripheral	HID/PL	Street light luminaire	Suitable	Manual

QUESTIONS	
1.	What are the types of commonly used lamps?
2.	What do the following terms mean? – Illuminance – Luminous efficacy – Luminaire – Control gear – Colour rendering index
3.	What is the function of ballast in a lighting system?
4.	Rate the following with respect to their luminous efficacy – GLS lamp – FTL – CFL – HPSV – LPSV
5.	Rate the following with respect to colour rendering index – GLS lamp – HPSV lamp – Metal halide lamps – LPSV lamp
6.	Briefly describe the methodology of lighting energy audit in an industrial facility?
7.	List the energy savings opportunities in industrial lighting systems.
8.	Explain how electronic ballast saves energy?
9.	A CFL can replace a) FTL b) GLS c) HPMV d) HPSV
10.	Explain briefly about various lighting controls available?

REFERENCES

1. NPC Experiences