Module I Electrical System Design

INDIAN STANDARDS
BUILDING SERVICE

Bureau of Indian Standards (BIS)

- National Standards Body which works on matters concerning to standardisation, certification and quality
- Objectives
  - Harmonious development of activities of standardisation, marking and quality certification
  - Providing new thrust to standardisation and quality control
  - Product specification, method of test, codes of practices, terminologies, basic standards
  - Standards formulation

Bureau of Indian Standards (BIS)

Bureau of Indian Standards (BIS)

- All standards are made keeping in view of
  - Safety
  - Ease of use and adaptability
  - Simple Technology
  - Value for money
  - Energy efficiency and environment

IS Codes

CODE	CONTENT
IS 3043	CODE OF PRACTICE FOR EARTHING
IS 732	CODE OF PRACTICE FOR ELECTRICAL WIRING INSTALLATIONS
IS 2309	PROTECTION OF BUILDINGS AND ALLIED STRUCTURES AGAINST LIGHTNINGCODE OF PRACTICE
IS 2675	SPECIFICATION FOR ENCLOSED DISTRIBUTION FUSEBOARDS AND CUTOUTS FOR VOLTAGES NOT EXCEEDING 1000 V AC AND 1200 V DC
IS 5216 Part 1	RECOMMENDATIONS ON SAFETY PROCEDURES AND PRACTICES IN ELECTRICAL WORK - General
IS 5216 Part 2	RECOMMENDATIONS ON SAFETY PROCEDURES AND PRACTICES IN ELECTRICAL WORK - LIFE SAVING TECHNIQUES

IS 3043

IS : 3043 - 1987
(Reaffirmed 2006)

Indian Standard
CODE OF PRACTICE FOR EARTHING
(First Revision)

Fourth Reprint JUNE 2007
(Including Amendment No. 1)

SCOPE – IS 3043

- Gives methods that may be adopted to earth an electrical system for the purpose of limiting the potential of current carrying conductors forming part of the system, that is, system earthing and noncurrent carrying metal work association with equipment, apparatus and appliance connected to the system (that is, equipment earthing).
- Applies only to land-based installations and it does not apply to ships, aircrafts or offshore installations

IS 3043 Sections

- Section 1 — General guidelines
- Section 2 — Connections to earth
- Section 3 — Earth-fault protection in consumer's premises
- Section 4 — Power stations, substations and overhead lines
- Section 5 — Industrial premises
- Section 6 — Standby and other private generating plant
- Section 7 — Medical establishments
- Section 8 — Static and lightning protection grounding
- Section 9 — Miscellaneous installations and considerations
- Section 10 — Measurements and calculations
- Section 11 — Data processing installations.

Statutory Provisions as per IS 3043

- Earthing shall generally be carried out in accordance with the requirements of Indian Electricity Rules
- All medium voltage equipment shall be earthed by two separate and distinct connections with earth
- Earth electrodes shall be provided at generating stations, substations and consumer premises
- All earth connections shall be visible for inspection
- Each earth system shall be so devised that the testing of individual earth electrode is possible
- It is recommended that a drawing showing the main earth connection and earth electrodes be prepared for each installation
- All materials, fittings, etc, used in earthing shall conform to Indian Standard specifications

Classification of Earthing Systems

- TT
- IT
- TN
  - TN-S
  - TN-C
  - TN-C-S

IS 732

IS : 732 -1989
(Reaffirmed 2005)

Indian Standard

CODE OF PRACTICE FOR
ELECTRICAL WIRING INSTALLATIONS

(Third Revision)

Second Reprint FEBRUARY 1999

SCOPE – IS 732

- Covers the essential requirements and precautions regarding wiring installations for ensuring satisfactory and reliable service and safety from all possible hazards from the use of electricity
- Applies to the design, selection, erection and inspection and testing of wiring installations whether permanent or temporary, in and about buildings
- All wiring installations in non-industrial and industrial locations, whether the electric supply is derived from an external source or from a private generating plant.
- Installations utilizing the following nominal voltage ranges are dealt in this code:
  - Voltages normally not exceeding 50V ac or 120 V dc whether between conductors or to earth
  - Voltages normally exceeding extra-low voltage but not exceeding 1000V ac or 1500 V dc between conductors or 600V ac or 900V dc between conductors and earth.

IS 732 Sections

- Section 1 Terminology
- Section 2 Assessment of General Characteristics of Installations
  - The purpose for which the installation is intended to be used, its general structure, and its supplies, the external influences to which it is to be exposed, compatibility of its equipment, its maintainability
- Section 3 Protection for Safety
  - Protection against Direct Contact, Indirect Contact, Thermal effects in Normal Service, Overcurrent, Fault Currents, Overvoltage
- Section 4 Design of Installation, Selection and Erection of Equipment
- Section 5 Inspection and Testing

IS 2309

IS 2309 : 1989

Indian Standard

PROTECTION OF BUILDINGS AND ALLIED STRUCTURES AGAINST LIGHTNING — CODE OF PRACTICE

(Second Revision)

IS 2675

IS : 2675 - 1983
(Reaffirmed 2001)

Indian Standard

SPECIFICATION FOR ENCLOSED DISTRIBUTION FUSEBOARDS AND CUTOUTS FOR VOLTAGES NOT EXCEEDING 1 000 V AC AND 1 200 V DC

(Second Revision)

IS 5216 (Part 1)

IS : 5216 (Part 1) - 1982
(Reaffirmed 2005)

Indian Standard

RECOMMENDATIONS ON SAFETY PROCEDURES AND PRACTICES IN ELECTRICAL WORK

PART I GENERAL

(First Revision)

IS 5216 (Part 2)

IS : 5216 (Part II)- 1982
(Reaffirmed 2005)

Indian Standard

RECOMMENDATION ON SAFETY PROCEDURES AND PRACTICES IN ELECTRICAL WORK

PART II LIFE SAVING TECHNIQUES

(First Revision)

Acts

- Electricity supply was governed by
  - Indian Electricity Act 1910
  - Electricity Act 1948
  - Electricity Regulatory Commissions Act 1998

Electricity Act 2003

- To transform and develop the electricity sector by distancing Government from the task of regulation
- Objectives
  - Consolidate the laws relating to G-T-D, trading & use of electricity
  - Development
  - Competition
  - Protect interest of consumers & supply of electricity to all areas
  - Transparent policies regarding subsidies
  - Constitute CEA regulatory commission

Features of Electricity Act 2003

- Generation free from licensing
- Captive generation free from control
- Re-structuring of SEBs
- Mandatory establishment of regulatory commission
- Open access in transmission
- Open access in distribution in a phased manner
- Recognition of electricity trading
- Stringent provisions for violation of grid discipline & theft of power

National Electric Code (NEC 2011)

- National Electrical Code is under the scope of Electrical Installations Sectional Committee, ETD 20
- ETD 20 is one of the 37 committees under Electro Technical Division Council of Bureau of Indian Standards
- Members of the Committee are from CEA, CPWD, State Electrical Inspectorates, Installation designers, engineers and contractors
- Standards and Codes are prepared through a process of consultation, consensus and public comment

National Electric Code (NEC 2011)

- Contains guidelines which can be adopted immediately
- Harmonized with corresponding IEC standards
- Code is intended to be advisory and not mandatory
- Should be adopted in interest of safety and economy
- Keep our electrical installation practices at par with the best international practices

Scope of National Electric Code (NEC 2011)

- Standard good practices for selection of various items of electrical equipment forming part of power systems
- Recommendations concerning safety and related matter in the wiring of electrical installations of buildings or industrial structures, promoting compatibility between such recommendations and those concerning the equipment installed.
- General safety procedures and practices in electrical work; and
- Additional precautions to be taken for use of electrical equipment for special environmental conditions like explosive and active atmosphere.

Scope of National Electric Code (NEC 2011)

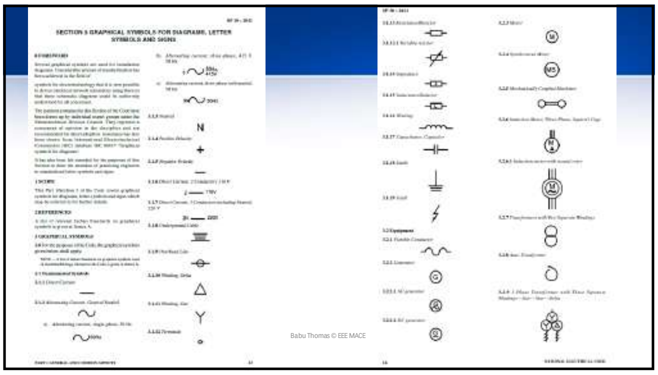
- Standby generating plants
- Building substations
- Domestic dwellings
- Office buildings
- Shopping and commercial centres
- Institutions
- Recreation and other public premises
- Medical establishments
- Hotels
- Sports buildings
- Industrial premises
- Temporary and permanent outdoor installations
- Agricultural premises
- Installations in hazardous areas
- Solar Photovoltaic installations

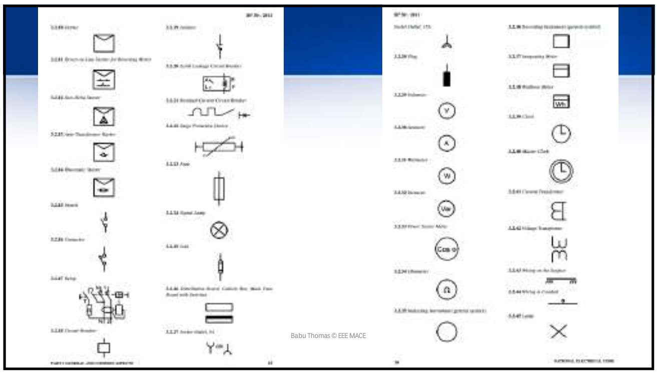
What NOT under NEC

- Traction, motor vehicles, installations in rolling-stock, on board-ships, aircraft or installations in underground mines
- Systems of distribution of energy to public
- Power generation and transmission for such systems
- Guidelines on the payment for electrical work done in installations

NEC 2011 Contents

- Part 1 General and Common Aspects (20 Sections)
- Part 2 Electrical installations in stand by generating stations and captive substations
- Part 3 Electrical installations in non-industrial buildings (7 sections)
- Part 4 Electrical installations in industrial buildings
- Part 5 Outdoor installations (3 sections)
- Part 6 Electrical installations in agricultural premises
- Part 7 Electrical installations in Hazardous area
- Part 8 Solar Photovoltaic (PV) supply systems





Voltage Standard

- IS 12360 : 1988

IS : 12360 - 1988
(Superseding IS : 585 - 1962)
(Reaffirmed 1993)

Indian Standard

VOLTAGE BANDS FOR ELECTRICAL INSTALLATIONS INCLUDING PREFERRED VOLTAGES AND FREQUENCY

(Second Reprint JULY 1998)

UDC 621·3·02 : 621·316·172

Voltage Standard

- Section 6 of NEC 2011

3.1 Standard Declared Voltage

3.1.1 *Single-phase, Two-Wire System*

The standard voltage shall be 240 V(*see* **3.0.2**).

3.1.2 *Three-phase System*

3.1.2.1 The standard voltages for three-phase system shall be as under:

415 V (*see* **3.0.2**)	(Voltage to neutral—240 V) (*see* **3.0.2**)
3.3 kV	66 kV
6.6 kV	110 kV
11 kV	132 kV
22 kV	220 kV
33 kV	400 kV

3.1.3 The standard dc distribution voltage shall be 220/440 V.

Voltage Limit

S.No.	Voltage Class	Abbreviation	Variations Allowed
1	Low	LV	-6% to +6%
2	Medium	MV	-6% to +6%
3	High	HV	-9% to +6%
4	Extra High	EHV	-12.5% to +12.5%

Voltage Classification

S.No.	Voltage Class	Abbreviation	Max. Voltage
1	Low	LV	250 V
2	Medium	MV	650 V
3	High	HV	33,000 V
4	Extra High	EHV	> 33,000 V

Frequency Standard

- The nominal frequency of operation in Indian grid is 50.0 Hz and the permissible frequency band specified by Indian Electricity Grid Code (IEGC) is 49.5 Hz to 50.2 Hz w.e.f 3rd May 2010.

Safety Aspects of Electrical System

- Important Aspects
  - To provide proper functioning of the installation for the use intended by the designer
  - To provide safety to persons, livestock and property against dangers and damages that may arise in the use of electrical installations
- End User Risks
  - Electric shock current
  - Very high temperature due to sparking that can cause burns, fire or other injuries

Safety Aspects of Electrical System

- Incorporate adequate protective measures as below
  - Protection against direct contact
  - Protection against indirect contact
  - Protection against thermal effects
  - Protection against over current
  - Protection against fault current
  - Protection against over/under voltages

Building Services

- Building services are the aspects of building design that make the building worthy of its purpose for which the they are designed
- Major Services
  - Lighting and Ventilation
  - Air conditioning
  - Lifts and escalator
- Minor Services (Functional/Safety)
  - Electric audio system, call bell system, clock system, fire alarm system, CCTV system, Cable TV network, Data networking intercom

Module III Electrical System Design

INDUSTRIAL BUILDING, TRANSFORMER SELECTION, DESIGN OF SUBSTATION

ESD in Industrial Buildings

- Sophisticated procedure
- Diverse load requirements
- Safety and reliability
- Ease of maintenance
- Economic considerations
- Energy consumption

Classification of Industrial Buildings

- Industrial Installations
  - Unique features
  - Variation in electrical load
    - Unified approach not possible
  - Meet the specifications of the Industry
- As per NEC, industries are based on
  - Fire Hazard
  - Power Consumption
  - Pollution Hazard

Based on Fire Hazard

- National Building Code classifies industrial buildings under Group G
  - Group G1- Buildings used for low fire hazard industries
  - Group G2- Buildings of moderate fire hazard
  - Group G3- Buildings with high fire hazard

Based on Power Consumption

- As per NEC

Sl No.	Description[1]	Average Power Requirement	Examples
(1)	(2)	(3)	(4)
i)	Light industries	Up to 50 kVA	Hosiery, tailoring and jewellery
ii)	Average industries	Above 50 kVA up to 2 000 kVA	Machinery, engine fitting, motor cars, aircraft, light pressings, furniture, pottery, glass, tobacco, electrical manufacturing and textile (*see* Note)
iii)	Heavy industries	Above 2 000 kVA	Heavy electrical equipment, rolling mills, structural steel works, tube making, foundries, locomotives, ship-building and repairing, chemical factories, factories for metal extraction from ores, etc.

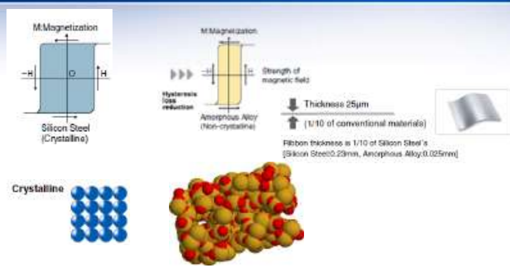
Based on Pollution Level

- Based on Pollution Index
  - Function of the emissions (air pollutants), effluents (water pollutants), hazardous wastes generated and consumption of resources
  - Pollution Index PI of any industrial sector is a number from 0 to 100 and the increasing value of PI denotes the increasing degree of pollution load from the industrial sector
- Red category
  - Pollution Index score of 60 and above
- Orange category
  - Pollution Index score of 41 to 59
- Green category
  - Pollution Index score of 21 to 40
- White category
  - Pollution Index score incl.&upto 20

Selection of Transformer Substations

- Major component
- Technical suitability & economy of operation
- Selection based on long term gains
- Technological Improvements
- Transformer efficiency - 98-99%

Advancement in Transformer



Amorphous Core Transformer

- The amorphous is a non-crystal substance created by rapidly freezing liquids of high temperature

Material	Iron loss (W/kg)	Thickness (mm)
Silicon steel (Crystalline)	0.440	0.23
Amorphous Alloy (Non-crystal line)	0.070	0.025

Factors Deciding Selection of Transformers

- Maximum Demand
- Future Expansion
- Spare Capacity
- Statutory Requirements
- Site Conditions

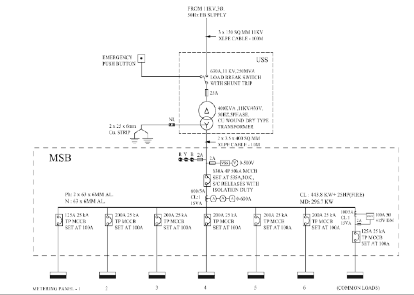
Standard Rating

- 11 kV distribution transformers
  - 10, 16, 25, 63, 100, 160, 200, 250, 315, 400,500, 630, 1000, 1250, 1600, 2000 and 2500 kVA
- 33 kV distribution transformers
  - 100, 160, 200, 315, 400, 500, 630, 1000, 1250, 1600, 2000, 2500 kVA

Cooling

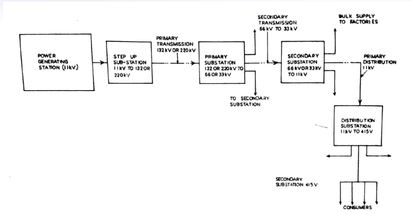
- Indicated in form of 4 Capital letters
- First 2 letters
  - Type of Coolant and manner of circulation of Coolant for windings
- Last 2 letters
  - Coolant and manner of circulation of the coolant for cooling the outside of transformer
- ONAN
  - Oil immersed self cooled (Oil Natural Air Natural)
- ONAF
  - Oil immersed forced air cooled (Oil Natural Air Forced)

SLD of Transformer Substation



Types of Substation

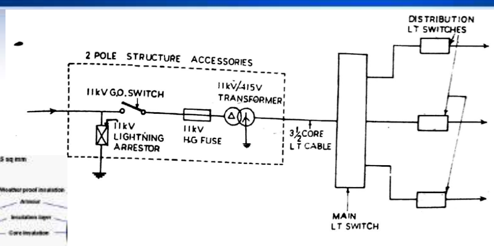
❖ Classified based on the service

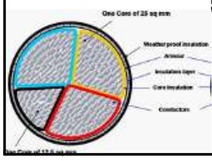


Indoor & Outdoor Substation

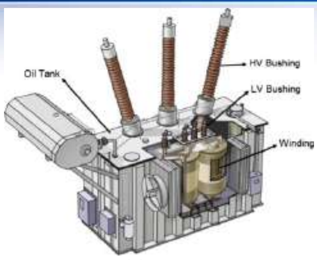
- ❖ **Indoor**
  - ❑ Transformer and associated equipment inside the building
  - ❑ Safety
- ❖ **Outdoor**
  - ❑ Pole mounted
    - ➢ 2 Pole (H Pole) Structure – upto 200kVA
    - ➢ 4 Pole Structure – 200 to 400kVA
    - ➢ On foundation – above 400kVA
  - ❑ Floor mounted
    - ➢ High Voltage SS – 33kV, 66kV, 132kV, 220kV

Outdoor SS





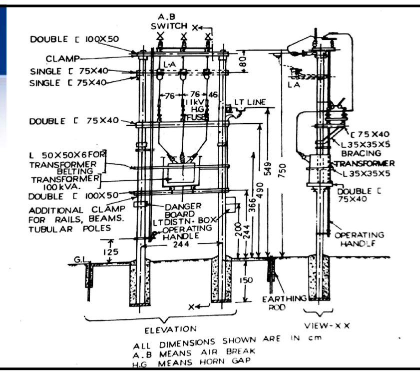
Transformer Bushings



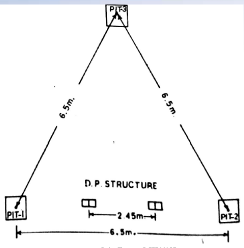
Air Break (AB) Switch

Horn Gap (HG) Fuse

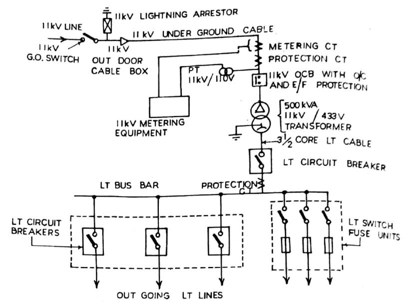
Outdoor SS



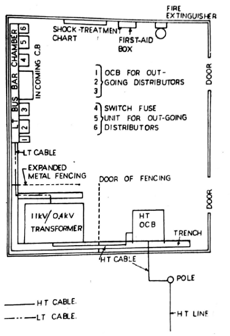
Earthing Arrangement



Indoor Sub Station



Layout of Indoor SS



Average Lumen Method

$$\text{Illuminance } E = \frac{L}{A}$$

$$E = \frac{L \times CU}{A}$$

$$E = \frac{L \times CU \times LLF}{A}$$

$$E = \frac{L_n \times N \times CU \times LLF}{A}$$

N = Number of luminaire
L_n = Initial lumen output per luminiare.

$$N = \frac{A \times E}{L_n \times CU \times LLF}$$

DESIGN CONSIDERATIONS FOR A GOOD LIGHTING SCHEME

- Intensity of illumination
  - Intensity of illumination depends on place of work and type of work
  - Refer Table : 4,5,6,7,8 in hand book (M K Giridharan)
- Selection of lamps or selection of luminaires
  - The choice of lamps for different types of application differs
  - Fluorescent lamps and LED lamps are used when lighting is needed in small areas
  - In large areas, the lighting can be provided by high intensity lamps such as mercury or discharge lamps
  - Depending upon the type of illumination required, the type of luminaire is decided

DESIGN CONSIDERATIONS FOR A GOOD LIGHTING SCHEME

- Size of the room
  - The lumen output of the source or lamp is not fully utilized at the work place
  - A part of the light is lost in the fittings and some part is directed to the walls and ceilings where a part will be absorbed and a part will be reflected
  - This is taken into account by a factor known as Coefficient of Utilization (CU).
  - The ratio of lumens reaching the working plane to the total lumens given out by the lamps is known as CU or Utilization factor.

DESIGN CONSIDERATIONS FOR A GOOD LIGHTING SCHEME

- Mounting height and spacing of fitting
  - Governed by the type of the building and the type of lighting scheme employed
  - The distance of the light source from the wall should be equal to half of the distance between the two adjacent light sources.
  - The distance between lighting fitting should not exceed 1.5 times the mounting height

DESIGN CONSIDERATIONS FOR A GOOD LIGHTING SCHEME

- Condition of use
  - For different types of buildings, the condition of use of light varies.
  - Dust and dirt particles of the surroundings get deposited on the light fitting and hence deteriorate the lamp efficiency.
  - Light Loss Factor or Maintenance Factor

Laws of Illumination

- Inverse Square Law
- Cosine Law

- Applicable to point sources

INVERSE SQURAE LAW

- States that the illumination (E) of a surface is directly proportional to the luminous intensity and inversely proportional the square of the distance between the source and the illuminated surface, as long as the source remains the same.
- $E = I/D^2$
- I= luminous intensity (unit is Candela (Cd))
- E- illumination of the surface
- D- distance between the source and surface to be illuminated
- This is true only when the surface to be illuminated is placed normal to the direction of the light beam.

COSINE LAW

- When the plane to be illuminated may not be normal to the direction of luminous flux, and is inclined by an angle θ, where θ is the angle between the line of flux and the normal to the illuminated plane.
- The law states that the illumination on a surface is proportional to the cosine of the angle between the normal to the surface and the line of flux and also to power of the source. E is inversely proportional to D^2.
- $E = I \cos \theta / D^2$
- These laws are applicable only to point sources (no reflecting surfaces)

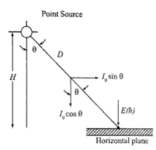
Formulas

Source directly above the point.

$$\text{Illuminance } E = \frac{I}{D^2}$$

When light arrives at the point on a horizontal surface at an angle.

$$\text{Illuminance } E_h = \frac{I_\theta \cos \theta}{D^2}$$

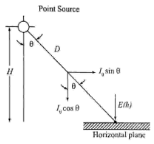


Problem

A point source produces 3000 cd in the direction of interest. The angle of incidence with respect to the vertical is 30°. Determine the illuminance at a point 5 m away from the light source.

Solution:

$$\text{The illuminance } E = \frac{I_\theta \cos\theta}{D^2} = \frac{3000}{5^2}\cos 30 = 103.92 \text{ lux}$$



Lighting Design Procedure

Step-1 Study the site plan and elevation of the … consultation with standards and the end …

Step-2 Select the light sources and luminair… nature of visual task and energy criteria…

Step-3 Calculate the ceiling, room and floor c… effective ceiling and floor cavity reflect…

Step-4 Use the given chart for coefficient o… reflectances and RCR; find out the valu…

Step-5 Select the light loss factor (LLF), t… maintenance factor (MF). Generally, acc…

A/C rooms, clean rooms, etc
Industrial environment
Dusty areas

$$\text{Cavity ratio} = \frac{2.5 \times h \times (\text{perimeter})}{\text{Area}}$$

where, $h = h_{cc}$ for Ceiling Cavity Ratio (CCR)

Table of coefficient of utilisation
(20% effective floor cavity reflectance)

Effective ceiling cavity reflectance	80%			50%		
Wall reflectance	50	30	10	50	30	10
RCR						
10	0.33	0.26	0.22	0.31	0.26	0.22
9	0.43	0.35	0.27	0.40	0.35	0.29
8	0.58	0.42	0.35	0.48	0.42	0.36
7	0.58	0.50	0.42	0.55	0.48	0.42
6	0.64	0.57	0.49	0.61	0.54	0.47
5	0.72	0.65	0.59	0.65	0.60	0.56
4	0.77	0.71	0.64	0.71	0.65	0.60
3	0.82	0.76	0.70	0.74	0.69	0.63
2	0.87	0.82	0.77	0.78	0.74	0.70
1	0.91	0.87	0.83	0.81	0.78	0.75

Lighting Design Procedure

Step-6 Use the formula to arrive at the quantity of luminaires (fixtures)

$$\text{Number of Luminaires} = \frac{\text{Area} \times \text{Illumination}}{\text{CU} \times \text{LLF} \times \text{Lumen output of luminaire}}$$

Step-7 Arrange the luminaires symmetrically giving due considerations to spacing criterion to achieve uniformity of illumination.

$$\text{Area per luminaire (fixture)} = \frac{\text{Room area}}{\text{Number of fixtures}}$$

$$\text{Therefore, fixture spacing} = \sqrt{\text{Area per fixture}}$$

Spacing should not be more than the mounting height (MH) for high bay fixtures and 1.5 times the mounting height for low bay fixtures. Check for conformity. If the spacing is too large, go back to step-2 and start again with a lower lamp rating.

EXAMPLE 3.2

A classroom measuring 6.5 m × 8 m is to be provided with an illumination level of 300 lux. The height of the ceiling is 4.5 m. The height of the ceiling is 4.5 m. The height of the working plane is 1.0 m above floor level. The ceiling/wall/floor reflectances are 70/50/20.

Design a lighting scheme for the classroom using general purpose 2 × 40 W fluorescent fixtures whose coefficient of utilisation chart is given below. Assume that the luminaires are suspended from the ceiling at 1.0 m below the ceiling level. The light loss factor (LLF) may be taken as 0.70. Spacing of lamps shall not exceed the mounting height. Initial lamp lumens = 4000.

Table of coefficient of utilisation
(20% effective floor cavity reflectance)

Effective ceiling cavity reflectance	80%			50%		
Wall reflectance	50	30	10	50	30	10
RCR						
10	0.33	0.26	0.22	0.31	0.26	0.22
9	0.43	0.35	0.27	0.40	0.35	0.29
8	0.58	0.42	0.35	0.48	0.42	0.36
7	0.58	0.50	0.42	0.55	0.48	0.42
6	0.64	0.57	0.49	0.61	0.54	0.47
5	0.72	0.65	0.59	0.65	0.60	0.56
4	0.77	0.71	0.64	0.71	0.65	0.60
3	0.82	0.76	0.70	0.74	0.69	0.63
2	0.87	0.82	0.77	0.78	0.74	0.70
1	0.91	0.87	0.83	0.81	0.78	0.75

Solution:

Step-1: Ceiling cavity height h_{cc} = 1.0 m

Floor cavity height h_{fc} = 1.0 m

Room cavity height h_{rc} = 2.5 m

Step-2: Ceiling cavity ratio (CCR) $= 2.5\, h_{cc} \times \frac{\text{perimeter}}{\text{area}}$

$$= 2.5 \times 1.0 \times \frac{(6.5+8)2}{6.5 \times 8}$$

$$= 1.40$$

Similarly,

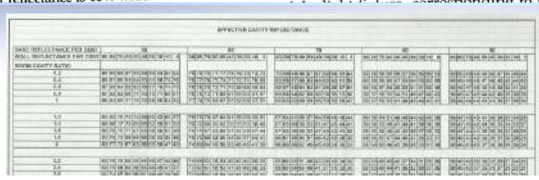
Floor cavity ratio (FCR) $= 1.40$

Room cavity ratio (RCR) $= 2.5 \times 2.5 \times \frac{(6.5+8)2}{6.5 \times 8}$

$= 3.48$ (say 3.50)

Step-3: By referring to Table 3.3

Corresponding to ceiling/wall reflectance of 70%/50% and CCR of 1.4, the effective ceiling cavity reflectance is 55%. Similarly, with a floor/wall reflectance of 20%/50% and FCR of 1.4, the effective floor reflectance is 18% which can be rounded to 20%.



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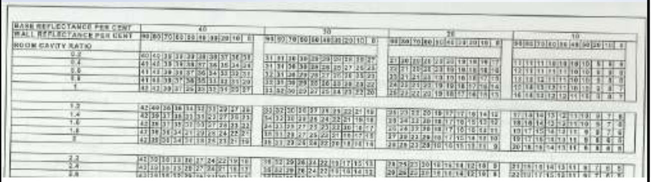

Step-4: From the Coefficient of Utilisation table of the light fixture, corresponding to a RCR of 4 and 3 we get the CU values as shown below.

RCR	CU value 80%/50%/20%	CU value 50%/50%/20%
4	0.77	0.71
3	0.82	0.74

Table of coefficient of utilisation

(20% effective floor cavity reflectance)

Effective ceiling cavity reflectance	80%			50%		
Wall reflectance	50	30	10	50	30	10
RCR						
10	0.33	0.26	0.22	0.31	0.26	0.22
9	0.43	0.35	0.27	0.40	0.35	0.29
8	0.58	0.42	0.35	0.48	0.42	0.36
7	0.58	0.50	0.42	0.55	0.48	0.42
6	0.64	0.57	0.49	0.61	0.54	0.47
5	0.72	0.65	0.59	0.65	0.60	0.56
4	0.77	0.71	0.64	0.71	0.65	0.60
3	0.82	0.76	0.70	0.74	0.69	0.63
2	0.87	0.82	0.77	0.78	0.74	0.70
1	0.91	0.87	0.83	0.81	0.78	0.75

RCR	CU value 80%/50%/20%	CU value 50%/50%/20%
4	0.77	0.71
3	0.82	0.74

We have to calculate the required CU value for an effective ceiling reflectance of 55% and an RCR = 3.5. For RCR = 3.0, the CU value for 55% effective ceiling reflectance can be calculated as,

$$CU = \frac{0.82 - 0.74}{30} \times 5 + 0.74$$
$$= 0.753$$

Similarly, for RCR = 4.0 and effective ceiling reflectance = 55%,

$$CU = \frac{0.77 - 0.71}{30} \times 5 + 0.71$$
$$= 0.720$$

Therefore, we have the CU values as,

RCR	Ceiling/wall/floor reflectance 55%/50%/20%
4	0.72
3	0.753

$$CU_{;} = 0.753 - (0.753 - 0.720)\ 0.5$$
$$= 0.7365$$

RCR	Ceiling/wall/floor reflectance 55%/50%/20%
4	0.72
3	0.753

= 0.7365

Step-5: The number of luminaires required

$$= \frac{\text{Area} \times \text{Lux}}{\text{CU} \times \text{LLF} \times \text{Lumens}}$$
$$= \frac{6.5 \times 8 \times 300}{0.7365 \times 0.7 \times 4000}$$
$$= 7.564 \text{ (say 8 nos.)}$$

$$\text{Area per luminaire (fixture)} = \frac{\text{Room area}}{\text{Number of fixtures}}$$
$$= \frac{6.5 \times 8}{8} = 6.5 \text{ m}^2$$

Therefore,

Spacing between fixtures = $\sqrt{6.5} = 2.55$ m

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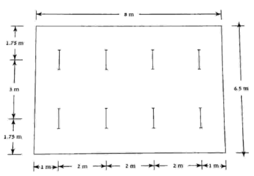
For low bay fixtures (mounting height below 6 m), spacing can be upto 1.5 times the mounting height. In this case, mounting height is equal to 2.5 m and therefore the spacing should be below 1.5 ×2.5 = 3.75 m. Hence the design is satisfactory.

A typical layout of the lamps is shown below.



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Factors to Consider When Designing a Road Lighting Project

- The main purpose of road lighting is to provide an appropriate level of visibility to motorists to ensure safety in driving.
- In cities, road lighting plays an additional role of creating a more inviting and safe environment.
- The ability of road lighting to illuminate an object – expressed as RP – is affected by the quality of light and other physical factors such as traffic level and road surface. A good road lighting system will ensure visual detection of an object at greater distances.

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Factors to Consider When Designing a Road Lighting Project

Factors to Consider When Designing a Road Lighting Project

- **Road Luminance**
  - Its a measure of how visible the road is to a motorist. Luminance is dependent on the light distribution of the luminaires, the lumen output of the lamps, the installation design of the road lighting, and the reflection properties of the road surface. The higher the luminance level, the better the lighting. Based on industry standards, a 75% RP is considered sufficient in most road conditions

Factors to Consider When Designing a Road Lighting Project

- **Uniformity**
  - Its a measure of how evenly distributed the light on the road is, which can be expressed as Overall Uniformity (UO) and Longitudinal Uniformity (UL). A good overall uniformity ensures that all spots and objects on the road are sufficiently lit and visible to the motorist. The industry accepted value for UO is 0.40.

Factors to Consider When Designing a Road Lighting Project

Overall Uniformity. The picture on the left shows a road with good U_O while the picture on the right has low level of U_O. The box is more visible in the road with higher U_O. Having higher U_O allows the motorist to see the road clearly and anticipate potential road hazards (e.g. open manholes, road excavations, sharp objects on the road, people crossing the street).

Factors to Consider When Designing a Road Lighting Project

On the other hand, a good level of longitudinal uniformity ensures comfortable driving conditions by reducing the pattern of high and low luminance levels on a road (i.e. zebra effect). It is applicable to long continuous roads.

Longitudinal Uniformity. The picture on the right shows a road with low level of U_l demonstrating the 'zebra effect' while the picture on the left has high level of U_l. The 'zebra effect' can cause discomfort to motorists, posing a risk to road safety. Ensuring good level of uniformity can reduce the luminance level needed.

Factors to Consider When Designing a Road Lighting Project

❖ **Glare**

- **Its the blinding sensation when the brightness of the light exceeds the adaptation level of the human eye to light. It produces discomfort and reduces road visibility. It is measured in Threshold Increment (TI), which is the percentage increase in required luminance to compensate the effect of glare (i.e., make the road equally visible as in the absence of glare). The industry standard for glare is 10% TI.**

Factors to Consider When Designing a Road Lighting Project

Glare. The pictures above demonstrate the effect of glare. High levels of glare can make the road appear hazy (less visible) which poses a safety risk to motorists and pedestrian alike.

Factors to Consider When Designing a Road Lighting Project

Surround Ratio (SR): Road lighting should light up not only the road, but also the adjacent areas so motorists can see objects in the periphery and anticipate potential road obstructions (e.g., a pedestrian about to step onto the road). The SR is the visibility of the road's periphery relative to that of the main road itself. As per industry standards, SR should be at least 0.50, as this is ideal and sufficient to create a proper adaptation to the eyes.

Surround Ratio: (Left) A schematic diagram of how road lighting should illuminate both the main road and its periphery. (Right) A real-life example of a road with good SR.

Factors to Consider When Designing a Road Lighting Project

Color Rendering Index measures the ability of the artificial light to show or reproduce the colors of the road or objects on the road, relative to a natural light source. The natural light source (the sun) has CRI of 100. The higher this index the better the visibility will be. For all types of road CRI ≥ 70 is recommended.

Color Rendering Index: Road under natural light (left), HPSV (middle), and LED (right).

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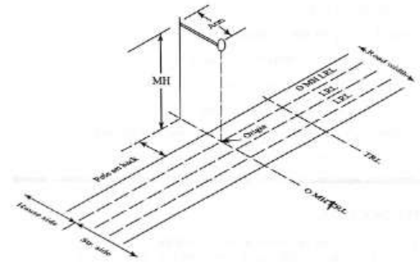

Terminologies

- Origin
  - The point on the road directly under the luminaire
- Longitudinal Road Line (LRL)
  - Imaginary line running parallel to the curb (a concrete margin along edge of a road) expressed as a multiple of mounting height (MH).
- Transverse road Line (TRL)
  - Imaginary lines perpendicular to the curb or LRL, expressed in terms of MH.
- Reference Line (0MH LRL and 0 MH TRL)
  - Reference line passing through the origin.
- Street Side (SS)
  - The space located on the street side of 0 MH LRL.
- Longitudinal Distance (LD)
  - A distance measured between two TRL in a direction parallel to the curb.
- Transverse Distance (TD)
  - A distance measured between two LRL in a direction perpendicular to the curb

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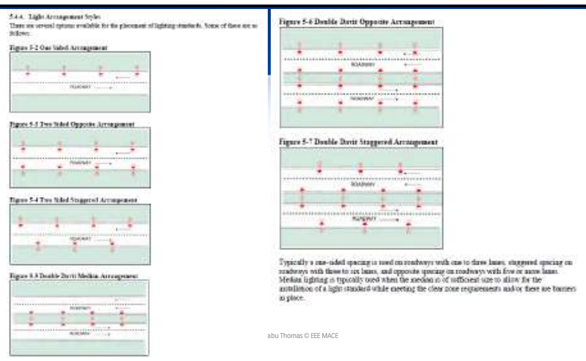

5.4.4. Light Arrangement Styles

There are several options available for the placement of lighting standards. Some of these are as follows:

Figure 5-2 One Sided Arrangement

Figure 5-3 Two Sided Opposite Arrangement

Figure 5-4 Two Sided Staggered Arrangement

Figure 5-5 Double Davit Median Arrangement

Figure 5-6 Double Davit Opposite Arrangement

Figure 5-7 Double Davit Staggered Arrangement

Typically a one-sided spacing is used on roadways with one to three lanes, staggered spacing on roadways with three to six lanes, and opposite spacing on roadways with five or more lanes. Median lighting is typically used when the median is of sufficient size to allow for the installation of a light standard while meeting the clear zone requirements and/or there are barriers in place.

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Selection of Lamps

- Incandescent lamps- Obsolete
- Fluorescent lamps
- Mercury vapour lamps
- Metal halide lamps (MH)
- High pressure sodium vapour lamp
- Low pressure sodium lamps
- LED Lamps

Design Formula

- Initial lumen Ln = (E*A)/(LLF*CU)
- Area of the road = Width* Spacing between lamp poles
- LLF= LLD* LDD
  - LLD- lamp lumen depreciation
  - LDD- lamp dirt depreciation
- Spacing = (Ln*LLF*CU)/(E*W)

Design Considerations

- It is necessary that the illuminance directly under the luminaire be the same as the midway between the poles
- Spacing to mounting height ratio should be between 3 and 5
- The ratio of average to minimum illuminance should not be greater than 3
  - For residential areas the ratio can be as high as 6
- Three popular models of the pole placement along the roadway are
  - Spaced continuously on the road side with a spacing of S meter (least expensive and less wiring)
  - Staggered spacing on both sides of the road with spacing of S meters between consecutive poles
  - Spacing on opposite sides of the road with a spacing of 2S meter between two consecutive poles on the same side

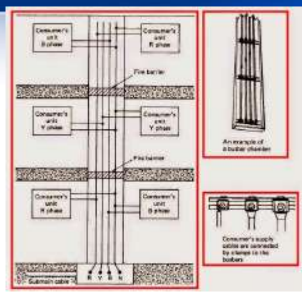
Area Lighting

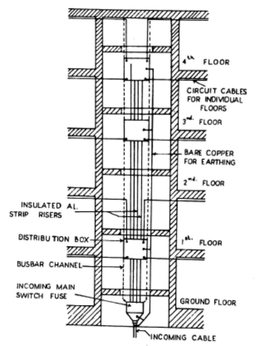
- Illumination of large area with average level of lighting
  - Examples are airport parking space, railway yards, vehicle parking space etc
- All luminaires used for road lighting can be used for area lighting
- Limiting factors for area lighting are
  - Mounting height
  - Colour rendering property of light source
  - Spacing limitations
- Spacing between poles shall not be more than 4.5 times the height of the poles
- Spacing between the edges of the area and the nearest pole shall not be greater than 2.25 times the mounting height
- A minimum of two lights per pole shall be employed for even distribution of lighting

Rising Mains

- For a large multi-storeyed building where there are several floors and having many circuits, the main switch board controls the circuit to each floor or section.
- Sub-distribution boards are placed in convenient positions on different floors and all sub-circuits are taken from them. Such a system of wiring which resembles a tree is known as the tree system of wiring. In a tree system, conductors are taken from the point of supply to the various load points.
- At each load point, branches with conductors of smaller sizes are taken off or a pair of fuse is inserted. This is necessary at every place where the sectional area of the conductor is reduced. The conductors constituting the main branch are known as rising mains or risers

Rising Mains





Rising Mains