NEHRU COLLEGE OF ENGINEERING AND RESEARCH CENTRE

(Accredited by NAAC, Approved by AICTE New Delhi, Affiliated to APJKTU)

Pampady, Thiruvilwamala(PO), Thrissur(DT), Kerala 680 588

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE MATERIALS

EE 405 ELECTRICAL SYSTEM DESIGN

VISION OF THE INSTITUTION

To mould our youngsters into Millennium Leaders not only in Technological and Scientific Fields but also to nurture and strengthen the innate goodness and human nature in them, to equip them to face the future challenges in technological break troughs and information explosions and deliver the bounties of frontier knowledge for the benefit of humankind in general and the down-trodden and underprivileged in particular as envisaged by our great Prime Minister Pandit Jawaharlal Nehru

MISSION OF THE INSTITUTION

To build a strong Centre of Excellence in Learning and Research in Engineering and Frontier Technology, to facilitate students to learn and imbibe discipline, culture and spirituality, besides encouraging them to assimilate the latest technological knowhow and to render a helping hand to the under privileged, thereby acquiring happiness and imparting the same to others without any reservation whatsoever and to facilitate the College to emerge into a magnificent and mighty launching pad to turn out technological giants, dedicated research scientists and intellectual leaders of the society who could prepare the country for a quantum jump in all fields of Science and Technology

ABOUT DEPARTMENT

- Course offered: B.Tech Electrical and Electronics Engineering
- Approved by AICTE New Delhi and Accredited by NAAC
- Affiliated to the University of Dr. A P J Abdul Kalam Technological University.
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DEPARTMENT VISION

To excel in technical education and research in the field of Electrical & Electronics Engineering by imparting innovative engineering theories, concepts and practices to improve the production and utilization of power and energy for the betterment of the Nation.

DEPARTMENT MISSION

- To offer quality education in Electrical and Electronics Engineering and prepare the students for professional career and higher studies.
- To create research collaboration with industries for gaining knowledge about real-time problems.
- To prepare students with sound technical knowledge.
- To make students socially responsible.

Course code	Course Name	L-T-P - Credits	Year of Introduction
EE405	**Electrical System Design**	**3-1-0-4**	**2016**

Prerequisite: Nil

Course Objectives

- To make aware of the Acts and Rules regulating the design of electrical .systems in India.
- To impart knowledge in the design of low voltage and medium voltage electrical installations.
- To give basic knowledge of design of distribution transformer substations, their installations and earthing design for transformer substations
- To familiarise lighting calculations and external lighting.

Syllabus

Electrical system design practices – general awareness of IS Codes, Electricity Acts & Rules, NEC etc. Domestic Installations, Industrial Installations and 11 kV substations. Design features of Recreational buildings and High-rise building. Selection of Standby generators and their Installations. Underground cable installations and their accessories. Design features of external lighting, lightning protection and special requirements for lifts and fire fighting equipments.

Expected outcome

The students will be able to

i. Know the basic Rules and Regulations of electrical systems design.
ii. Design simple electrical systems and prepare the schematic diagram with all the specifications.

Text Books

1. J. B. Gupta, A Course in Electrical Installation Estimating and Costing, S.K. Kataria & Sons; Reprint 2013 edition (2013).
2. K. B. Raina, S. K. Bhattacharya, Electrical Design Estimating Costing, NEW AGE; Reprint edition (2010).
3. M. K. Giridharan, Electrical Systems Design, , I K International Publishers, New Delhi, 2nd edition, 2016

Data Book (Approved for use in the examination):

1. M K Giridharan, Electrical Systems Design Data Hand book, I K International Publishers, New Delhi, 2011
2. N. Rajendran, Electrical System Design Data Book

References:

1. National Electric Code, Bureau of Indian Standards publications, 2011.
2. Relevant Indian Standard – specifications (IS – 732, IS – 746, IS – 3043, IS – 900), etc.
3. S. L. Uppal, Electrical Wiring Estimating & Costing, Khanna Publishers, 2008

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	General awareness of IS Codes (IS 3043, IS 732, IS 2675, IS 5216-P12, IS 2309), The Indian Electricity Act 2003, National Electric Code (NEC **2011**) - scope and safety aspects applicable to low and medium (domestic) voltage installations, Electric services in buildings, Classification of voltages, standards and specifications.	8	15%

II	General aspects of the design of electrical installations for domestic dwellings as per NEC guidelines (low and medium voltage installations)–connected load calculation, sub circuit determination, selection of main distribution board, sub distribution board, MCB, ELCB, MCCB and cables for sub circuits. Pre-commissioning tests of domestic installations.	10	15%
FIRST INTERNAL EXAMINATION			
III	Industrial installations –classifications- Design of distribution systems with light power and motor loads for small and medium industries. Selection of transformer substations, switchgears and protective devices – Design of indoor and outdoor 11 kV substations up to 630 kVA.	10	15%
IV	Short circuit calculations and Design of earthing for 11 kV substation of capacity up to 630 kVA. Pre-commissioning tests of cables and transformers.	8	15%
SECOND INTERNAL EXAMINATION			
V	Design of illumination systems – Average lumen method- lighting design calculations using Coefficient of utilisation (CU) and light loss factor (LLF) - classification and selection of luminaires. Exterior lighting design- road lighting and area lighting. Design requirements for high rise buildings and recreational buildings.	8	20%
VI	Energy conservation techniques in lighting and power. Selection of standby generator –power rating - Continuous, prime power and standby power, installation and its protection, Introduction to Automatic Main Failure (AMF) System. Introduction to Solar PV systems for domestic applications. Simple design projects.	10	20%
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN (End semester exam)

Maximum Marks: 100 Exam Duration: 3 Hourrs.

(Approved data handbook to be permitted inside examination hall)

Part A: Eight compulsory questions. One question from each module of Modules I - IV; and two each from Module V & VI. Student has to answer all questions. (8 x5) = 40

Part B: Three questions uniformly covering Modules I & II. Student has to answer any 2 from the 3 questions: (2 x 10) = 20. Each question can have maximum of 4 sub questions (a, b, c, d), if needed.

Part C: Three questions uniformly covering Modules III & IV. Student has to answer any 2 from the 3 questions: (2 x 10) = 20. Each question can have maximum of 4 sub questions (a, b, c, d), if needed.

Part D: Three questions uniformly covering Modules V & VI. Student has to answer any 2 from the 3 questions: (2 x 10) = 20. Each question can have maximum of 4 sub questions (a, b, c, d), if needed.

Module 1

Power system broadly comprises of generation, transmission and distribution whereas electrical system design involves distribution of electrical energy from the metering point down to the last point or equipment of a building, which is connected to the supply system.

Electrical system design deals from the point of commencement of supply from the utility grid to a premise/ building

Two important aspects of electrical system design are:

- To assure 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

Role of Acts in Electrical system Design

Act: A legal document confiding the result of deliberations of a committee, society or legislative body

Statutes: An Act passed by a legislative body

Rule: In context to an act, **rules** define the guidelines that must be followed for the successful implementation of the act.

An **act** is an official copy of a **statute** or regulation that is initially presented in the form of a **bill** and after being verified it is passed in the process of a legislature

THE ELECTRICITY ACT, 2003

The electricity supply industry in our country was governed by 4 major enactments

1. The Indian Electricity Act , 1910
2. The Electricity Supply Act , 1948
3. The Electricity Regulatory Commission Act, 1998
4. **The Indian Electricity Act 2003**

The Indian Electricity Act, 1910

- Created Basic framework for the development of electric supply industry in India
- This Act envisaged growth of the electricity industry through private licenses
- It created major frame work for laying down of conductors and other work related to supplying electricity

The Electricity supply Act, 1948

- Mandated the creation of state Electricity boards with the responsibility of making available the electricity in the respective states
- The responsibility was handed over to the State Electricity Boards and they undertook rapid expansion programmes by utilizing plan funds
- However there was gradual deterioration in the performance of state electricity boards. They were unable to take decision on tariff in a professional and independent manner
- To address these issues, The Electricity Regulatory Commission act was enacted by the parliament in 1998

The Electricity Regulatory Commission Act 1998

- The Electricity Regulatory Commission act was enacted by the parliament in 1998 with a provision through which the state governments can create State electricity Regulatory Commissions
- Accordingly many states have created State Electricity Regulatory Commissions

The main objectives were:

- Replacing existing laws while preserving the core features
- Introducing new concepts like power trading, open access
- To prevent the requirement of each SEB's to pass their own act
- Give SEBs to develop their own power sector
- Include progressive features and endeavors

- The Indian Electricity Act, 2003 seeks to replace Indian Electricity Act 1910, The Electricity Supply Act 1948, and The Electricity Regulatory Commission Act 1998
- It is an act implemented by the parliament to consolidate the laws relating to generation, transmission, distribution, trading and use of electricity and aims at
    - Promoting measures to the development of electricity industry.
    - Promoting competition
    - Protecting interest of consumers
    - Providing electric supply to all areas
    - Providing transparent policies on subsidies
    - Constitution of Central Regulatory Authority and Regulatory Commission
    - Establishment appellate tribunals
    - For all matters connected to therewith and incidental there to

The salient features of the act are:

- Delicensing of generation
- Liberalization of captive power policy
- Open access to transmission and distribution network
- Stringent penalties for power theft
- Transparent subsidy management
- Constitution of an Appellate tribunal
- Thrust on Rural electrification

Overview of Electricity Act

- The bill seeks to provide a legal frame work for enabling reforms and restructuring of the power sector.

- It simplifies administrative procedures by integrating the Indian electricity Act, 1910, the Electricity (supply) act 1948 and the Electricity Regulatory commission act-1998 into a single Act. 4. The electricity Act 2003, is based on the principles of promoting competition, protecting consumers' interests and providing power to all
- It consolidates the laws relating to generation, transmission, distribution, trading and use of electricity ; take all measures to the development of the sector and empower the existing power sector regulators
- Adequate steps would be taken to encourage conservation & use of non-conventional sources of energy.
- Theft of power, transmission and distribution losses are to be countered more meaningfully.
- Competition will be possible not just in generation, but also in all facets of sectors including distribution

INDIAN STANDARD CODES

IS codes are intended for standardization in the field of electrical power generation, transmission, distribution and utilization equipment & insulating materials, winding wires, measuring and process control instruments and primary and secondary batteries. Major IS codes are

Code	Content
IS 3043	Code for practice for earthing
IS 732	Code for practice for electrical installations
IS 2309	Code for practice for protection of buildings against lightning
IS 2675	Code of practice for enclosed distribution fuse boards and cutouts for voltages not exceeding 1000V AC and 1200V DC
IS 5216 P1	Recommendations on safety procedures and practices in electrical work- General
IS 5216 P2	Recommendations on safety procedures and practices in electrical work- Life saving Techniques

1. IS 3043 Code for practice for earthing:

- Contains guidelines on choosing proper size of various components of earthing system especially earthing conductors and earthing
- Gives guidance on the methods which are adopted to earth and electrical system for limiting the potential of current carrying conductors forming part of the system ie. System earthing and Equipment earthing
- This code applies to land based installation and it does not apply to ships, aircrafts or offshore installations
- It is divided into 11 sections
    - General guidelines
        - Covers terminologies used, influencing factors, system earthing, equipment earthing etc

- Connections to earth
  - Covers details of earth resistance, current density, earthing arrangements, typical schematics etc
- Earth fault protection on consumer's premises power stations, substations and overhead lines industrial premises
- Standby and other private generating plants
- Medical establishment
- Static and lightning protection earthing miscellaneous installations and considerations
  - Earthing of potentially hazardous areas, telecommunication circuits, mines and quarries, maintenance of earth electrodes etc
- Measurements and calculations
  - Covers calculation of earth fault current, earth resistivity, earth electrode resistance etc
- Data processing installations
  - Earthing requirements for installations of data processing equipment

2. **IS 732 Code for practice for electrical installations:**
   - ❖ 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
   - ❖ Applicable to design, selection, erection, inspection and testing of wiring installations whether temporary or permanent
   - ❖ Relates to all wiring installations in non industrial and industrial locations
   - ❖ This code is not applicable to the following:
     - Systems for distribution of energy to the public, or to power generation and transmission for each systems
     - Wiring installations in special locations such as mines or other areas where potentially explosive atmosphere exists
     - Lightning conductors, telecommunications and alarm systems
     - Traction installations, motor vehicles, installations on board ships, aircraft or offshore installations
   - ❖ It is divided into following 5 sections
     - S1. Terminology
       - Explains all terminologies used in the standard
     - S2. Assessment of general characteristics of installations
       - Assessment of general characteristics like purpose of wiring, supply available, maintainability etc

        - Assesses external influences like environmental factors ,construction of building etc, that affects the installation
    - S3. Requirements for protection for safety
        - Requirements for Protection against electric shock
        - Protection Against Thermal Effects in Normal Service
        - Protection Against Overcurrent, Over voltage, Under voltage
        - Precautions against earth leakage and earth fault currents
        - Protection against switching and isolation for maintenance
    - S4. Design of installation, selection and erection of equipment
        - Fundamental Requirements for Design
        - Fundamental Requirements for Selection of Electrical Equipment
        - Fundamental Requirements for Erection and Initial Testing of Electrical Installations
    - S5. Inspection and testing
        - Guidelines for inspection and testing

3. IS 2309 Code for practice for protection of buildings against lightning:

- Outlines the general technical aspects of lightning, illustrating its principal electrical, thermal and mechanical effects
- Offers guidance on good engineering practice and the selection of suitable materials for lightning protection
- This code is divided into 4 sections
    - General and basic considerations
        - Explains the basic definitions related with lightning and lightning protection, technical aspects of lightning, effects of lightning stroke , function of a lightning conductor
    - System design
        - Covers general considerations for design, materials used, corrosion factors etc regarding the design of lightning system design
    - Protection of special structures
        - Explains the protection details of structures exceeding 30m height, buildings with explosive or
        - Highly flammable contents, structures with roofs of high flammability, trees and structures near trees, structures supporting overhead electricity supply, telephone and other lines
    - Miscellaneous provisions and explanatory notes
        - Details about inspection and testing of the system, maintenance and upkeep of system, record keeping etc

4. **IS 2675 Code of practice for enclosed distribution fuse boards and cutouts for voltages not exceeding 1000V AC and 1200V DC:**

- This Indian standard covers enclosed distribution fuse boards for voltages not exceeding 1000V AC and 1200V DC, the current rating in each outgoing circuit not exceeding 100A
- Applies only to distribution fuse boards incorporating different types of fuses
- It does not cover other equipments such as switches, distribution pillars, MCB and instruments
- It is divided into 8 sections
    - S1 scope
        - This standard is intended to cover, fuse boards for use in single phase and three phase ac systems and dc systems
    - Terminology
        - Explains all terminologies used in the standard
    - Service conditions
        - Environmental and atmospheric conditions to be sustained by distribution fuse boards
    - Classification of fuse boards
        - Electrical characteristics of fuse boards design & construction
        - Mechanical design details, protection and earthing aspects of fuse boards
    - Marking
        - Explains about mandatory indications and markings on all fuse boards
    - Testing
        - Pre-commissioning and routine tests to be followed

5. **IS 5216 P1 Recommendations on safety procedures and practices in electrical work-General:**

- Scope
    - Gives recommendations regarding safety procedures and practices which should be followed in all major electrical installations such as generating stations, sub stations, industrial establishments, transmission and distribution lines and cable networks
- Statuary regulations
    - Details of statuary regulations to be followed for electrical installations
- Permit-to-work system
    - All work on major electrical installations shall be carried out under ***permit-to-work*** system unless standing instructions are issued by the competent authority to follow other procedures

- Register of messages
    - All messages and instructions relating to the operation of switches and other important communications concerning the work shall be recorded in the register of messages, preferably by an independent person not directly connected with the work
- Safety instructions for working on low & medium voltage mains and apparatus
- Safety instructions for working on high voltage mains and apparatus
- Workmen's safety devices and appliances
    - Rubber gauntlets, gloves, mats, boots and galoshes, insulated platforms and stools, safety belts, hand lamps, tower wagons and other special insulated devices shall be used, as required, for working on electrical equipment and apparatus as precaution against accidental electric shock
- Fires and fire extinguishers
    - In the event of fire on electrical mains or apparatus, the effected parts shall immediately be isolated completely from its source of supply of electrical energy.
- Training of employees
    - For maximum effectiveness, a sound safety procedure would include in addition to the instructions on the hazards of electricity, thorough training of all employees who work on electrical installations and equipments

6. **IS 5216 P2 Recommendations on safety procedures and practices in electrical work-Life saving Techniques:**

- Objective of this standard is to cover, the DOs and DONTs instructions to be adhered to in the case of an accident and details of the life saving techniques in the event of all accidents to persons, whether minor or major
- Covers in detail the various alternative methods of inducing artificial respiration to a victim of electric shock
- Covers methods of dealing with electrical accidents and techniques for saving the life of a person who is affected

Bureau of Indian standards (BIS)

BIS is the National Standards body of India, established by BIS act 1986. Former name of BIS was Indian Standards Institution (ISI). BIS is a founder member of International Organisation for Standardisation (ISO). BIS represents India in ISO and IEC (International Electro-technical Commission). BIS mark (ISI mark) is mandatory for certifying products to be sold in India like electrical appliances, switches, electric motors, cables etc

NATIONAL ELECTRIC CODE

- Regionally adoptable standard for safe installation of electrical wiring and equipment
- It is a part of National Fire Codes series published by National Fire Protection Association (NFPA)
- NEC unifies practices, procedures and safety requirements to be compiled within the design, execution and inspection/maintenance of electrical installations in the country
- NEC is formulated to elaborate Indian Electricity Rules and serve as a compilation document on electrical practices in our country

Objective of NEC

- To complement Indian Electricity Rules by elaborating and recommending practices to comply with their requirements
- NEC provides information in a consolidated form to the electrical engineers and contractors who are concerned with the design and operation of electrical installations

The information in NEC is presented in 8 parts according to NEC 2011. They are

- General and common aspects
- Electrical installations in standby generating stations and substations
- Electrical installations in non industrial buildings
- Electrical installations in industrial buildings
- Outdoor installations
- Electrical installations in agricultural premises
- Electrical installations in hazardous areas
- Solar photovoltaic power supply system

The information relating to each type of installation identified above is further classified and presented in the following manner

- Assessment of general characteristics
- Heavy current installation in the occupancy
  - Power supply and distribution systems
  - Cables and accessories for power distribution
  - Protective equipment
  - Metering of energy consumption
  - Emergency supply requirements
  - Reactive power compensation
  - Guidance on building services like lighting, air conditioning, lifts etc
- Light current installations in the occupancy
  - Electric bells and clock systems
  - Electrical audio systems
  - Fire protection signaling

  - Cable TV
  - Networking etc
- Specific requirements for protection and safety

NEC takes into account the following

- Classification should be based on skills and capabilities of the occupants utilizing the installations
- Classification should also be based on the degree of sophistication of the electrical installation of the building rather than type of building

Scope of NEC

- Standard good practices for selection of 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
- Additional precautions to be taken for use of electrical equipment for special environmental conditions like explosive and active atmosphere

The Code applies to electrical installations such as

- Standby/emergency generating plants and building substations
- Domestic dwellings
- Office buildings, shopping and commercial centres and 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
- Circuits other than internal wiring of apparatus

The code does not apply to

- Traction, motor vehicles, installations in rolling-stock, on board-ships, aircraft or installations in underground mines
- Lightning protection aspects from structural safety point of view
- Systems of distribution of energy to public
- Power generation and transmission for such systems

- Guidelines on the payment for electrical work done in installations

SAFETY ASPECTS OF ELECTRICAL SYSTEM DESIGN

Two important aspects of electrical system design are:

- 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

Two major risks exposed to end users by every electrical installations

- Electric shock current
- Very high temperature due to sparking which causes burns, fires etc.

When there is a current flow through the human body, the electric current itself is the source of danger which has a negative effect when it passes through the body

Protective measures incorporated in the system

1. **Protection against direct contact**
   - Prevent persons and livestock coming in direct contact with live parts of the installation
   - This is achieved by preventing a current from passing through the body of any person/livestock or by limiting the magnitude of the current passing through the body to a value lower than the perceptible shock current
2. **Protection against indirect contact**
   - Protected against dangers from contact with exposed conductive parts of the electrical installations
   - Protection against indirect contact can be achieved by
     - Preventing fault current from passing through the body of any person/livestock
     - Limiting the magnitude of the fault current which can pass through the body to a low value
     - By automatic disconnection of the supply
3. **Protection against thermal effects**
   - No risk of ignition of flammable material due to high temperature of conductive parts or due to an electric arc
   - During normal operation there shall be no risk of persons suffering from burns due to thermal effects
4. **Protection against overcurrent**
   - Automatic disconnection of the supply in the event of an overcurrent before it reaches a dangerous value taking into account its duration

- By limiting maximum value of overcurrent to a safe value and duration

5. **Protection against fault currents**
   - Faults are likely to occur in an electric systems
   - All parts intended to carry fault current shall be capable of carrying the fault current without reaching excessive temperature levels
6. **Protection against over/under voltage**
   - Causes of overvoltage- lightning, switching or faults between live parts etc
   - These ,ay damage the insulation of various equipments and insulation of power system
   - Over voltage protective devices like rod gap, surge diverter, overhead earth wires are used for protection
   - Causes of undervoltage- overloading of motors, sudden tripping of motor starters etc
   - Undervoltage protective devices are installed in the system

TYPES OF BUILDINGS

Buildings are classified according to their functions like residential and non residential buildings. However a classification is made as per NEC as follows

- **Domestic dwellings/Residential buildings**: includes sleeping accommodation for normal residential purpose with cooking and dining facilities. Such buildings are again classified as
  - One or two private family dwelling: Occupied by members of single family with members not more than 20
  - Living quarters: Occupied by three or more families living independently with each other with independent cooking facilities
- **Office/Business buildings**
  - For the purpose of office transactions, accounts and records, banks, data processing installations etc
- **Shopping/ Commercial buildings**
  - Include buildings such as shops, stores, market etc
- **Educational buildings**
  - Include schools, colleges, day care etc
- **Recreational or Assembly buildings**
  - Any building where group of people gather for amusement, recreation, social, religious, patriotic, civil and similar purpose
  - Eg. Assembly halls, auditorium, exhibition hall museums, restaurants, dance halls etc
- **Other buildings**
  - Hospitals
  - Hotels

- Sport buildings
- Factory buildings

ELECTRIC/BUILDING SERVICES & IT'S CLASSIFICATIONS

- Those aspects of building design that make the building worthy of its purpose for which they are designed are called building services
- Main classification- **Major building services and Minor building services**
- **Major building services-** those services which require high amount of electricity
- Major building services are:
    - Lighting and ventilation
    - Air-conditioning
    - Lifts and escalators
- **Minor building services-** those require less amount of electricity
- Types and number of minor building services depend on type and occupancy of building
- Minor building services are:
    - Electric audio systems
    - Electric call bell systems
    - Electric clock systems
    - Fire alarm systems
    - Closed circuit TV systems
    - Cable TV network
    - Data networking intercom etc.
- Lighting and ventilation services are absolute requirements of any type of buildings
- During day time sufficient amount of natural light and ventilation should be made available inside buildings
- National Building Code (NBC) gives extensive guidelines in the orientation of the building

1. **Design aspects of lighting services**

Good lighting is an absolute necessity and has 3 primary aims

- To promote the work and other activities carried out within the building
- To promote the safety of the people using the building
- To create in conjunction with the structure and decoration, a pleasing environment

Design aspects of good lighting scheme

- Careful planning of the brightness and color pattern within the work space
- Controlling direct and indirect glare
- Minimizing flicker and paying attention to color rendering properties of light sources

- installing emergency lighting systems

Good lighting is also the process of providing the right quantity of light at the right quality. The quantity of lighting or the level of illumination depends on the following factors.

- Adequacy for preventing both strain in seeing and liability to accidents due to poor visibility
- Adequacy for realizing visual comfort
- Adequacy for performance of the task at high efficiency
- Adequacy for pleasantness

The recommended levels of illumination are specified in IS 3646. Therefore we can see that good lighting design will involve

- Planning the brightness pattern from the point of view of visual performance, safety and amenity
- Creating form and texture in the task area and the surroundings
- Controlling glare, flicker and stroboscopic effects
- Selecting the right kind of light sources to provide correct color rendering
- Maintaining right level differences in lighting to prevent accidents
- Providing emergency lighting services
- Including effective maintenance and easy installation features
- Assuring effective energy conservation

2. <u>Design aspects of ventilation</u>

- Provides required quantity of fresh air to improve the general environment of the building
- Proper ventilation means creation of an environment that stimulates the people to higher efficiency levels

Important considerations for ventilation

- To provide fresh air for respiration
- To remove the products of combustion
- To dilute the air inside to prevent vitiation of body odour
- To maintain the heat balance of human body

Ventilation can be arranged in any one of the following methods

- Natural supply and natural exhaust of air
    - Natural wind enters through the building and sweeps through the building providing required level of ventilation
    - Orientation of the building and proper positioning of the doors, windows and ventilators ensure satisfactory level of illumination
- Natural supply and mechanical exhaust of air

  - System of ventilation for forced exhausting of polluted air (kitchen, utility room, bathroom etc.) is introduced
  - The suction created by the exhaust fan pulls fresh air through the openings and provides fair circulation of the fresh air
- Mechanical supply and natural exhaust of air
  - Conventional ventilating systems use circulating fans to provide the required level of ventilation
  - Circulating fans include ceiling fans, table fans, wall fans, pedestal fans etc
  - These fans create an air movement that makes people inside the building more comfortable
  - Ceiling fans are considered to be most effective of all these fans as they effectively circulate the air
- Mechanical supply and mechanical exhaust of air
  - Controlled air flow with a level of purity
  - Balanced air flow is obtained by the use of two fans, one for supply of fresh air and another for exhausting the polluted/stale air
  - Eg. Textile mills, pharmaceutical industry, medical facility etc

IS 3362: Code of practice for natural ventilation for residential buildings
IS 3103: Code of practice for industrial ventilation

3. **<u>Design aspects of climate control</u>**

When the desired temperature and humidity cannot be achieved by proper ventilation, air conditioning is resorted to. The design of air conditioning systems shall be based on the following criteria

- Nature of application
- Type of building construction
- External and internal load patterns
- Desired space condition
- Permissible limits of control
- Energy conservation aspects
- Possibility of heat recovery
- Economic factors

The designer shall also look into the following aspects of load variations before finalizing the design

- Load variations in summer and winter months
- Loading pattern of the intermediate season
- Loading pattern during day and night
- Loading pattern at weekends

- Loading pattern when the electric supply fails and the system operates on standby generators

4. **<u>Design aspects of vertical transportation</u>**

- Lifts and escalators form the major means of vertical transportation
- Following aspects to be taken into account while deciding the electrical requirements for lifts and escalators
    - Number of lifts, its size or passenger carrying capacity and location in the building
    - Number of floors served by the lifts
    - Height between floors
    - Location of the machine room
    - Provision for lighting and ventilation
    - Location where electric supply is required and in what quantity
    - Quantity of electric supply
    - Occupant load factor
    - Control systems used
    - Operation and maintenance

IS 1860: Code of practice for installation, operation and maintenance of passenger and good lifts
IS 4666: Specification for passenger and good lifts

5. **<u>Design aspects of minor building services</u>**

All minor building services like audio systems, fire alarm, electric clock, CC TV systems etc require electric supply in a limited quantity at specific locations in the building. The following Indian Standard specifications are referred

- <u>Audio systems</u>
    - IS 1881: Code of practice for installation of indoor amplifying and sound distribution systems
    - IS 1882: Code of practice for outdoor installation of public address systems
- <u>Fire alarm systems</u>
    - National Building Code, 2005
- <u>Call bell services</u>
    - IS 8884: Code of practice for installation of electric bells and call systems
- <u>Central clock systems</u>
    - IS 8969: Code of practice for installation and maintenance of impulse and electronic master and slave clock system

CLASSIFICATION OF VOLTAGES, STANDARDS AND SPECIFICATIONS

Standard voltages to be used in electrical systems as per NEC are as detailed. The standard distribution voltage for DC system shall be 220/440V.

For single phase AC: 240V, 50 Hz, 2 wire
For three phase AC: 415V, 50 Hz, 4 wire

- 240V- voltage to neutral
- 415V- line to line voltage
- 3.3kV-HV
- 6.6kV- Thermal Power Stations
- 11kV- Primary distribution
- 22kV- Not in Kerala
- 33kV- EHV
- 66kV
- 110kV
- 132kV- Transmission voltage
- 220kV- Transmission voltage
- 400kV- National Grid voltage

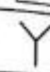
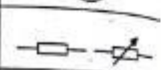
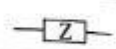
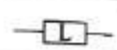
Low voltage- Not exceeding 250V
Medium voltage- Not exceeding 650V
HV- Not exceeding 33kV
EHV-Exceeding 33kV

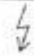
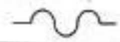
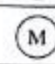
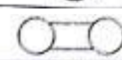
Voltage limits for AC systems

The supply authorities are required to maintain the voltages on the system under normal condition within the tolerances specified below:

- 6% in case of low and medium voltage installations
- 6% on the higher side or 9% on the lower side of high voltage systems
- 12.5% in case of extra high voltage systems
- Under Indian Electricity Rules, the voltage fluctuation may not vary by more than 5% above or below the declared nominal voltage
- Frequency must be within ±1% of the declared frequency of 50Hz ie. 228V to 252V for nominal voltage of 240V & 394.25V to 435.75V for nominal voltage of 415V

GRAPHICAL SYMBOLS

No.	Name	Symbol
1.8.1	Direct Current	—
1.8.2	Alternating Current, General Symbol	~
	a) Alternating Current, Single-Phase 50 Hz	~ 50 Hz
	b) Alternating Current, 3-Phase 415 V 50 Hz	3 ~ 50 Hz 415 V
	c) Alternating Current, 3-Phase with Neutral	3 N ~ 50 Hz
1.8.3	Neutral	N
1.8.4	Positive Polarity	+
1.8.5	Negative Polarity	−
1.8.6	Direct Current, 2 Conductors 110V	2 —— 110 V
1.8.7	Direct Current, 3 Conductors: including Neutral	2 N —— 220 V
1.8.8	Underground Cable	
1.8.9	Overhead Line	
1.8.10	Winding, Delta	
1.8.11	Winding, Star	
1.8.12	Terminals	
1.8.13	Resistance, Resistor, Variable Resistor	
1.8.14	Impedance	
1.8.15	Inductance, Inductor	
1.8.16	Winding	

1.8.17	Capacitance, Capacitor	
1.8.18	Earth	
1.8.19	Fault	
1.8.20	Flexible Conductor	
1.8.21	Generator	
	a) AC Generator	
	b) DC Generator	
1.8.22	Motor	
1.8.23	Synchronous Motor	
1.8.24	Mechanically Coupled Machines	
1.8.25	Induction Motor 3-Phase, Squirrel Cage	
	Induction Motor with Wound Rotor	
1.8.26	Transformers with Two Separate Windings	
1.8.27	Auto-Transformer	
1.8.28	3-Phase T_f with 3 Separate Windings-Star-Star-Delta	
1.8.29	Starter	
1.8.30	Direct-on-Line Starter for Reversing Motor	
1.8.31	Star-Delta Starter	
1.8.32	Auto-Transformer Starter	
1.8.33	Rheostatic Starter	
1.8.34	Switch	
1.8.35	Contactor	
1.8.36	Circuit-Breaker	
1.8.37	Isolator	
1.8.38	Fuse	
1.8.39	Signal Lamp	

1.8.40	Link	
1.8.41	Distribution Board, Cubicle Box, Main Fuse Board with Switches	
1.8.42	Socket Outlet, 5A	Or
1.8.43	Socket Outlet, 15A	
1.8.44	Plug	

Symbols of Lines

Line or cable: existing

planned

Underground cable

Overhead line (general symbol)

Conductors

Conductors or a group of several conductors

Flexible conductor

(a) Single line representation

(b) Multiline representation

Three conductors:

(a) Single line representation

(b) Multiline representation

n conductors: n

Example

Four conductors:

Single line representation 4

Multiline representation

Indication of conductor particulars

(a) *Example:* d.c. circuit, 110 V, two conductors of 125 mm² of aluminium

Single line representation $\frac{-110\text{V}}{2\text{X}125\text{mm}^2\text{Al}}$

Multiline representation $\frac{-110\text{V}}{2\text{X}125\text{mm}^2\text{Al}}$

(b) *Example:* d.c. circuit 220 V (110 V between outer conductors and neutral), two conductors of 50 mm² with neutral of 25 mm²

Single line representation $\frac{2\text{N}-220\text{V}}{2\text{X}50\text{mm}^2+1\text{X}25\text{mm}^2}$

Multiline representation $\frac{2\text{N}-220\text{V}}{2\text{X}50\text{mm}^2+1\text{X}25\text{mm}^2}$

Terminals and Connections of Conductors

Terminal ∘ OR •

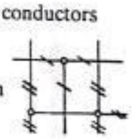
Junction of conductors

Double junction of conductors OR OR

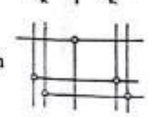
Crossing without electrical connection

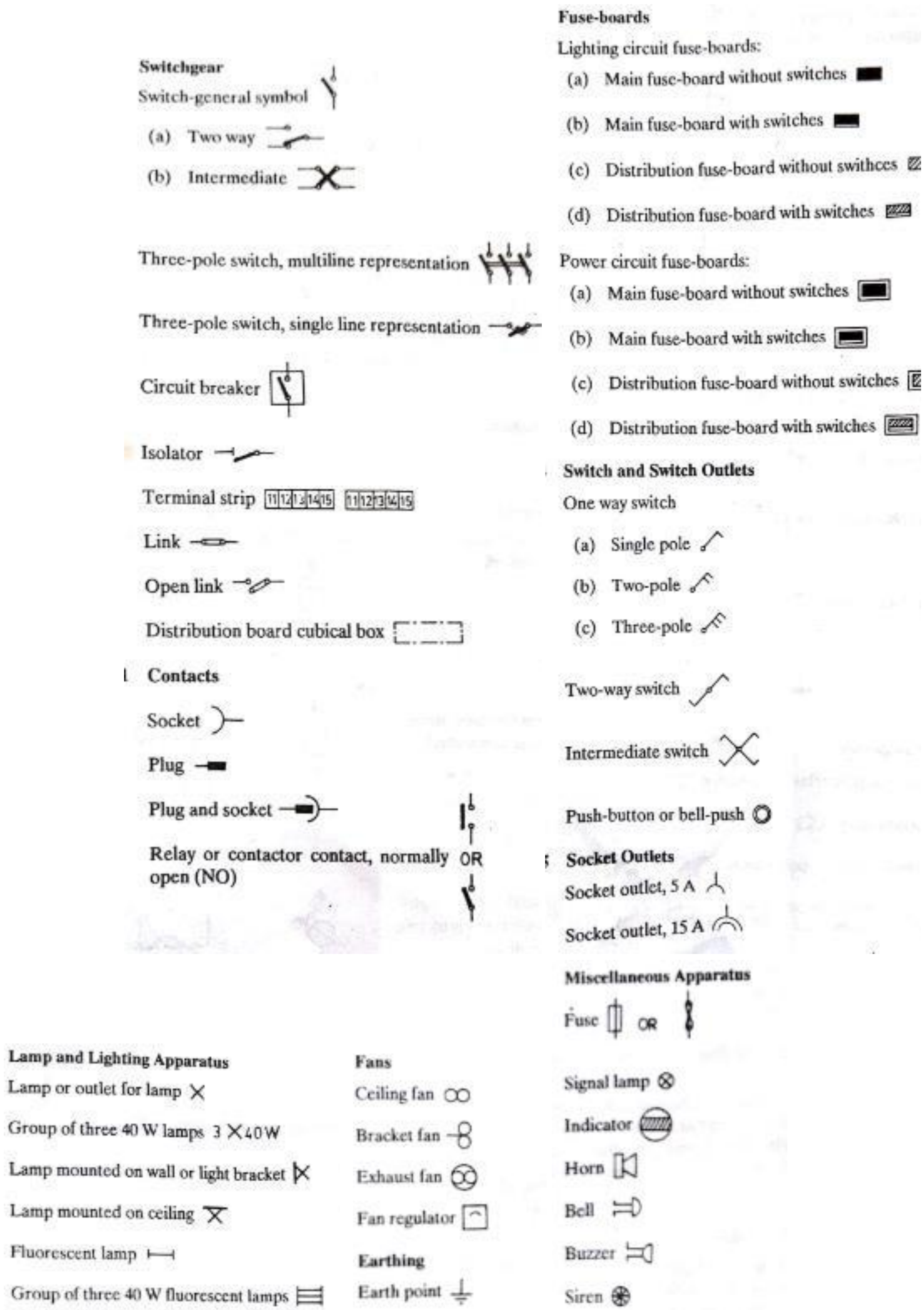
Crossing and connecting conductors

Single line representation



Multiline representation




Switchgear
Switch-general symbol
(a) Two way
(b) Intermediate
Three-pole switch, multiline representation
Three-pole switch, single line representation
Circuit breaker
Isolator
Terminal strip
11 12 13 14 15
11 12 13 14 15
Link
Open link
Distribution board cubical box
Contacts
Socket
Plug
Plug and socket
Relay or contactor contact, normally open (NO)
OR
Fuse-boards
Lighting circuit fuse-boards:
(a) Main fuse-board without switches
(b) Main fuse-board with switches
(c) Distribution fuse-board without swithces
(d) Distribution fuse-board with switches
Power circuit fuse-boards:
(a) Main fuse-board without switches
(b) Main fuse-board with switches
(c) Distribution fuse-board without switches
(d) Distribution fuse-board with switches
Switch and Switch Outlets
One way switch
(a) Single pole
(b) Two-pole
(c) Three-pole
Two-way switch
Intermediate switch
Push-button or bell-push
Socket Outlets
Socket outlet, 5 A
Socket outlet, 15 A
Miscellaneous Apparatus
Fuse
OR
Signal lamp
Indicator
Horn
Bell
Buzzer
Siren
Lamp and Lighting Apparatus
Lamp or outlet for lamp
Group of three 40 W lamps
3 X 40W
Lamp mounted on wall or light bracket
Lamp mounted on ceiling
Fluorescent lamp
Group of three 40 W fluorescent lamps
Fans
Ceiling fan
Bracket fan
Exhaust fan
Fan regulator
Earthing
Earth point

MODULE 2

General aspects of the design of electrical installations for domestic dwellings as per NEC guidelines (low and medium voltage installations)–connected load calculation, sub circuit determination, selection of main distribution board, sub distribution board, MCB, ELCB, MCCB and cables for sub circuits. Pre-commissioning tests of domestic installations.

CLASSIFICATION OF BUILDINGS AND BUILDING SERVICES

Buildings are classified according to their functions like residential and nonresidential buildings. However, a classification is made as per National Electric Code (NEC) is as follows:

1. Domestic Dwellings

Domestic dwellings/Residential buildings include any building in which, sleeping accommodation is provided for normal residential (domestic) purpose with cooking and dining facilities.

Such buildings shall be further classified as follows:

(a) One or two family private dwelling. These shall include any private dwelling which is occupied by members of a single family and has a total sleeping accommodation for not more than 20 persons.

(b) It shall include any building or structure in which living quarters are provided for three or more families living independently of each other and with independent cooking facilities.

2. Office/Business Buildings

These includes for the office transactions, for keeping of accounts and records and similar purposes, professional establishments offices, banks, research establishments, data processing installations etc.

3. Shopping/Commercial Centres /Mercantile Buildings

These include buildings such as shops, stores, market, displays and sale of merchandise, whole sale or retail, departmental stores etc.

4. Educational Buildings

These include buildings used for schools, colleges and day care purposes for more than 8 hours per week involving assembly of people for and education (including incidental recreation etc.).

5. Recreational or Assembly Buildings

These shall include any building where groups of people gather for arnusement, recreation, social religious, patriotic, civil and similar purposes, for example, theatres motion picture (cinema) houses, halls, exhibition halls, museums, restaurants, places of workshops, dance halls, clubs etc.

6. Other Buildings

Hotels
Medical establishments (Hospitals)
Sports buildings
Industrial (factory) buildings

Electric Services in Buildings

In connection with a new building, the following aspects are to be considered to bring an electric supply to premises

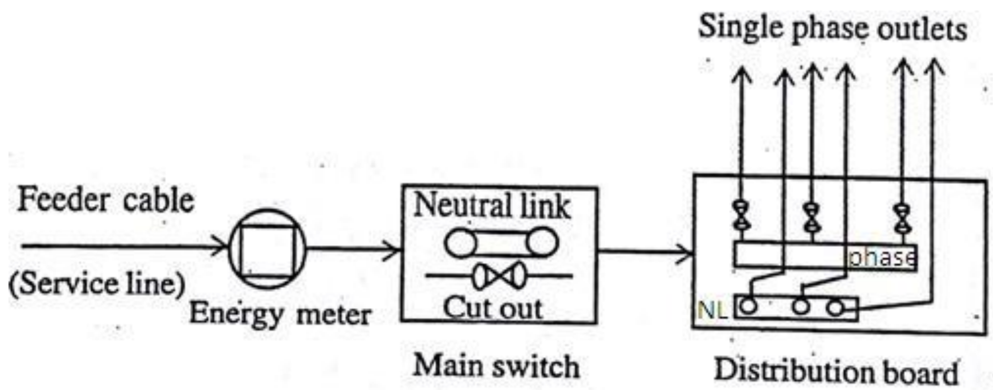
1. The nearness of supply point

2. The position in the building; where the service cable is required to terminate.
3. The characteristic of the supply namely, whether alternating or direct current. If alternating current, number of phases, voltage levels and power rating of equipments and accessories. If direct current number of wires and voltage.
4. Maximum 1oad demand anticipated.
5. In the case of large buildings if alternative supply arrangement is available, change over to alternative supply is to be provided in the event of supply failure.
6. The guide lines of the supply authority for the single phase and three phase supplies are to be observed under their conditions of supply.

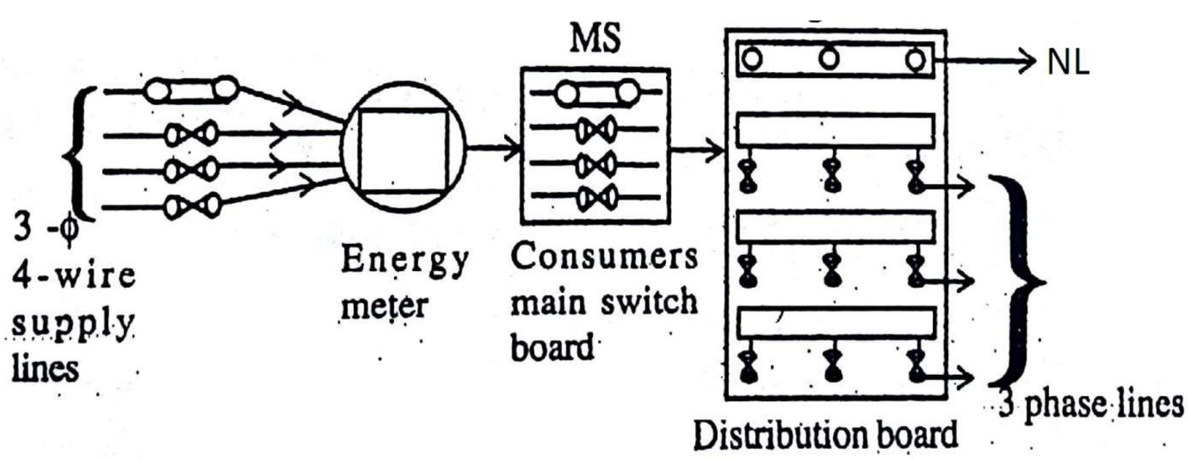
Supply system

According to rules Power supplying Authority give **1 phase (240V, 2wire) supply** for load **less than 5KW** domestic dwellings. **3 phase supply (415V, 4wire)** for load **greater than 5KW.**

A SINGLE PHASE INSTALLATION SHOWING ENERGY METER, MAIN SWITCH (SWITCH FUSE UNIT) AND DISTRIBUTION BOARD



3 PHASE 4 WIRE DOMESTIC DISTRIBUTION SCHEME



INTERNAL DISTRIBUTION

Observing the general aspects of supply system, now it is required to think about the internal distribution system of an electrical installation within the domestic dwelling.

It is this part of the wiring which carries and controls the Current from the supply authority"s cutouts and meters to the fuse boards (distribution boards) feeding the final sub-circuits.

If the installation is small, as for a dwelling house, a standard single phase or two wire supply would be given and after passing through the meters, would be connected to a main switch and fuse board and the local circuits wou1d then run direct from the fuse board.

If however, the installation is a medium voltage (3-phase 415V) one, as for example in a building in which electric heating and cooking, motors for pumping water, air conditioners etc. are present as loads, the supply authority may a require the installation balanced over the three phases and the necessary switch gears for their purpose must be provided.

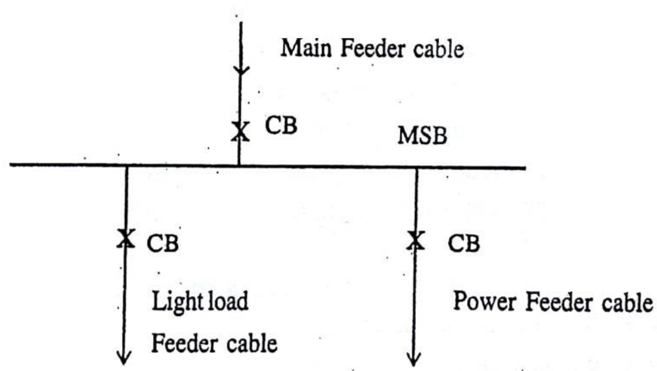
In domestic dwellings total load is divided into two sub circuits, for load calculation and ease to design of circuits. **They are Light sub- circuit and Power sub-circuit**.

Light sub circuit

- The following points may be considered in the distribution of loads
- Light, fan and 5A sockets are connected in a common circuit.
- The load on each sub-circuit shall be restricted to 800 watts or 10 points.
- If a separate circuit is installed for fans only, the number of fans in that circuit should not exceed ten.
- It is advisable to provide at least two lighting sub-circuit in each house so that, in case of a fault in one sub-circuit, the whole house is not plunged into darkness.

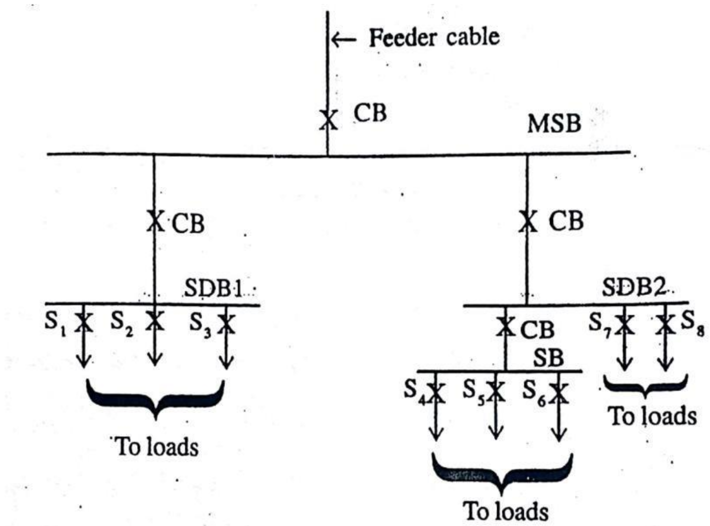
Power Sub-circuit

The load on each power sub-circuit should normally restrict to 3000 watts. In no case it should be not more than two out lets on each sub-circuit.



Load segregation

Following figure showing single line diagram having feeder cable, distribution board, sub-distribution boards and switch boards along with circuit breakers and switches.



GENERAL RULES FOR WIRING

For estimation of internal Wiring it is necessary on the part of estimator that he be fully conversant with the general rules followed for internal wiring. The general rules, which are to be kept in mind in execution of internal wiring work, are:

1. Every installation is to be properly protected near the point of entry of supply cables by *a* two-pole linked main switch and a fuse unit. In a two-wire installation if one pole is permanently earthed, no fuse, switch or circuit breaker is to be inserted in this pole. A 3-pole switch and fuse unit is to be used in 3-phase supply.

2. The conductor used is to be of such a size that it may carry load current safely.
3. The conductor installed is to be safe in all respects.
4. Every sub-circuit is to be connected to a distribution fuse board.
5. Every line (phase or positive) is to be protected by a fuse of suitable rating as per requirements.
6. A switch board is to be installed so that its bottom lies 1.25 meters above the floor.

7. (a) All plugs and socket outlets are to be 3-pin type, the appropriate pin of socket being connected permanently to the earthing system.
   (b) Adequate numbers of socket outlets are to be provided at suitable places in all rooms so as to avoid use of long lengths of flexible cords.
   (c) Only 3-pin, 5 A socket outlets are to be used in all light and fan sub-circuits and only 3-pin, 15 A socket outlets are to be used in all power sub-circuits. All socket outlets are to be controlled by individual switches, which are to be located immediately adjacent to it. For 5 A socket outlets, if installed at a height of 25 cm above the floor level, the switch may, if desired, be installed at a height 1.30 meters above the floor level. In situations where a socket outlet is accessible to children, it is recommended to use shuttered or interlocked socket outlets.

(d) In case an appliance requiring the use of a socket outlet of rating higher than 15 A is to be used, it is to be connected through a double pole switch of appropriate rating. In no case a socket outlet of rating higher than 15A is to be installed.
(e) Socket outlets are not to be located centrally behind the appliances with which these are used. Socket outlets are to be installed either 25 cm or 1.30 m above the floor level as desired.
(f) No socket outlet is to be provided in the bathroom at a height less than 1.30 meters.
(g) Depending on the size of the kitchen, one or two 3-pin 15 A socket outlets are to be provided to plug-in hot plates and other appliances. Dining rooms, bedrooms, living rooms, if required, each is to be provided with at least one 3-pin, 15 A socket outlet.

8. (a) All incandescent lamps, unless otherwise required, are to be hung at a height of 2.5 meters above the floor level.
   (b) Unless otherwise specified, all ceiling fans are to be hung 2.75 meter above the floor.
9. (a) Lights and fans may be wired on a common circuit. Each sub-circuit is not to have more than a total of ten points of lights, fans and socket outlets. The load on each sub-circuit is to be restricted to 800 watts. If a separate circuit is installed for fans only, the number of fans in that circuit is not to exceed ten.
   (b) The load on each power sub-circuit is to be normally restricted to 3,000 watts. In no case more than two socket outlets are to be in one power sub-circuit.
10. No fuse or switch is to be provided in earthed conductor.
11. Every circuit or apparatus is to be provided with a separate means of isolation such as a switch.
12. All apparatus requiring attention are to be provided with means of access to it.
13. In any building, light and fan wiring and power wiring are to be kept separate.
14. In 3-phase, 4-wire installation the load is to be distributed equally on all the phases.
15. No additional load is to be connected to an existing installation unless it has been ascertained that the installation can safely carry the additional load and that the earthing arrangements are adequate.
16. Lamp holders used in bathrooms are to be constructed or shrouded in insulating materials and fitted with protective shield and earth continuity conductor is not to be of size less than 7/0.915 mm.
17. The metal sheaths or conduits for all wiring and metal coverings of all consumer apparatus or appliances is to be properly earthed in order to avoid danger from electricail shock due to leakage or failure of insulation.
18. Each sub-circuit is to be protected against excessive current (that may occur either due to overload or due to failure of insulation) by fuse or automatic circuit breaker.
19. All light conductors are to be insulated or otherwise safeguarded to avoid danger.
20. After completion of work the installations are to be tested before energisation.

DETERMINATIONOF NUMBEROF POINTS (LIGHT, FAN, SOCKET-OUTLETS)

The number of points is determined as per size of the room, illumination level required and the luminous efficiency of the lamps to be used.

The number of fan points is determined as per measure (length, width and height) of the room and size of the fans to be used. The air delivery for fans of different sizes at test voltage and at full speed is given below.

Fan size in mm	*Type*	*Air delivery in m^3/minute*
900 mm	Capacitor ac dc	140 140
1,200 mm	Capacitor ac dc	215 215
1,400 mm	Capacitor ac dc	270 270
1,500 mm	Capacitor ac dc	300 300

As regards the determination of number of socket outlets, recommended schedule of socket outlets as per IS standard is given below

Location	*Number of 5 A Socket outlets*	*Number of 15 A Socket outlets*
Bedroom	2 to 3	1
Living-room	2 to 3	2
Kitchen	1	2
Dining-room	2	1
Garage	1	1
For refrigerator		1
For air-conditioner		1
Verandah	1 per 10 m^2	1
Bathroom	1	1

DETERMINATION OF NUMBER OF SUB-CIRCIUTS

The numbers of sub-circuits are decided as per number of points to be wired and total load to be connected to the supply systems.
In one light and fan sub-circuit the maximum load that can be connected is 800 watts and the maximum number of points, which can be wired, is 10.
In one power sub-circuit the maximum load that can be normally connected is 3,000 watts and the number of socket outlets, which can be provided is 2.

DETERMINATION OF RATINGS OF MAIN SWITCH AND DISTRIBUTION BOARD

The current rating of the main switch is decided as per total current of the circuit to be controlled by it.

The number of ways and current rating of the distribution board is decided as per number of sub-circuits to be connected to it and current of the sub-circuit having highest current rating.

DETERMINATION OF SIZE OF CONDUCTOR

There are three points, which must be taken into account, while determining the size of conductor for internal wiring for a given circuit.

(i) Minimum size mainly for mechanical reasons.

(ii) Current carrying capacity.

(iii) Voltage drop.

Minimum Size of the Cable. The conductor used in domestic wiring (except flexible and fitting wires), according to the regulation in our country, must not be of size less than 1/1. 12 mm in copper or 1/1.40 mm (1.5 mm^2) in aluminium wire. For flexible cords and fitting wires, a smaller size is permissible viz. 14/0.193 mm. Lead-in wires to be not less than one square mm copper or 1.5 square mm aluminium and protected from abrasion.

Current Carrying Capacity. The wire or cable should be of size sufficient to carry the maximum circuit current continuously without overheating. From standard value the size of wire or cable can be determined corresponding to maximum current of the circuit. The following points are noteworthy:
(a) The maximum possible currents are not in exact proportion to the sectional areas of the conductors. The amount of heat developed due to flow of current is proportional to the resistance of the conductor and consequently in inverse proportion to the sectional area, but the temperature rise does not only depend on the quantity of heat developed but also on the rate of dissipation of heat from the surface of conductor. The size of the conductor of the cable increases, the permissible current density decreases.

(b) Paper insulated or lead covered cables are allowed to carry larger currents than VIR cables of the same size (except in the smaller size. in which the maximum permissible currents are the same). This is due to the fact that the impregnated paper insulation can withstand higher temperature than VIR cables without injury. PVC cables are, however, predominantly used.
(c) When there are several cables bunched together in the same conduit or more than one conductor in lead covered cable the current carrying capacity for the same X-sectional area of conductor is less than that of a pair of cables in conduit.

Voltage Drop. Maximum voltage drop from supply terminals to any point. On the installation is not to exceed the prescribed limit 2% of the supply voltage plus one volt for light load wiring and 5 per cent of declared supply voltage for power load wiring.

SELECTION OF DB

Distribution Box can be decided by "way" means how many how many single phase (single pole) distribution. Circuit and Neutral are used.

1) SPN Distribution Board (Incoming+ Outgoing)

- 4way (Row) SPN = 4 X 1SP= 4Nos (Module) of single pole MCB as outgoing feeders.
- 6way (Row) SPN = 6 X 1SP= 6Nos (Module) of single pole MCB as outgoing feeders.
- 8way (Row) SPN = 8 X 1SP= 8Nos (Module) of single pole MCB as outgoing feeders.
- 10way (Row) SPN = 10 X 1SP= 10Nos (Module) of single pole MCB as outgoing feeders.
- 12way (Row) SPN = 12 X 1SP= 12Nos (Module) of single pole MCB as outgoing feeders.
- Normally single phase distribution is mainly used for small single phase loads at house wiring or industrial lighting wiring.

2) TPN Distribution Board (Incoming, Outgoing)

- 4way (Row) TPN = 4 X TP= 4nos of 3pole MCB as outgoing feeders =12 No of single pole MCB.
- 6way (Row) TPN = 6 X TP= 6nos of 3pole MCB as outgoing feeders =18 No of single pole MCB.
- 8way (Row) TPN = 8 X TP= 8nos of 3pole MCB as outgoing feeders =24 No of single pole MCB.
- 10way (Row) TPN = 10 X TP= 10nos of 3pole MCB as outgoing feeders =30 No of single pole MCB.
- 12way (Row) TPN =12 X TP= 12nos of 3pole MCB as outgoing feeders =36 No of single pole MCB

SELECTION OF MCB

Following specifications are required to select appropriate MCB or MCCB.

(A) Current Related:

- Frame Size (Inm): Amp
- Rated current (In/ Ie): Amp
- Ultimate short circuit breaking capacity (Icu): KA
- Rated short-circuit breaking capacity (Ics): % of Icu

(B) Voltage Related:

- Rated voltage (Ue): Volt
- Rated Insulation voltage (Ui): Volt
- Rated impulse withstand voltage(Uimp): KV
- No"s of Pole : SP,DP,TP,TPN,FP

(C) Application Type:

- Utilization Category/ Characteristic : B,C or D curve

(D) Protection Type:

- Protection : Over current / Short circuit
- Trip Mechanism: Thermal / Magnetic / Solid / Microprocessor

- Trip Mechanism adjustment : Fixed / Adjustable

(1) Frame Size (Inm):

- Breaker Frame Size indicates the basic framework of the Plastic shell of MCCB that can hold the biggest rated current.
- It is the maximum current value for which the MCCB is designed (upper limit of the adjustable trip current range) and it also determines the physical dimensions of the device.
- **There are varieties current ratings MCCB for the same series frame Size.**
- For example, DX100 Frame Size MCCB for rated current of 16A, 20A, 25A, 32A, 40A, 50A, 63A, 80A, 100A.
- Same DX225 Frame Size MCCB for rated current of 100A, 125A, 160A, 180A, 200A, 225A.
- In above DX100 and DX225 has two Type of frame Size for rated current of 100A, but the shape and size of breaking capacity of circuit breakers is not the same.

(2) Rated Current (In /Ie):

- It is the current value above which overload protection is tripped.
- For MCB it is fixed while in MCCB the rated current is an adjustable range instead of a fixed value.
- Standard rating of MCB is 1A, 2A, 3A, 4A, 6A, 10A, 13A, 16A, 20A, 25A, 32A, 40A, 50A, 63A, 100A for MCB.

(3) Ultimate short-circuit breaking capacity (Icu):

- Breaking capacity can be defined as the maximum level of fault current which can be safely cleared.
- **It is the highest fault current that the MCCB can trip without being damaged permanently.**
- The MCCB will be reusable after interrupting a fault, as long as it doesn"t exceed this value.
- It is indicate operation reliability of MCCB
- This parameter may increase or decrease the cost, so it should be properly decided. Breaking capacity should be higher than the possible fault level. For domestic application fault level may be 10kA.

(4) Operating short-circuit breaking capacity (Ics):

- It is expressed as a percentage ratio of Icu and tells you the maximum short-circuit current if a circuit breaker can break three times and still resume normal service.
- **The higher the lcs, the more reliable the circuit breaker**
- It is the maximum possible fault current that the MCCB can clear. If the fault current exceeds this value, the MCCB will be unable to trip and another protection mechanism must operate.
- If a fault above the Ics but below the Icu occurs, the MCCB can interrupt it successfully but will need a replacement due to the damage suffered.
- The Main difference between Ultimate Short Circuit (Icu) and Service Breaking Capacity (Ics) that Icu (Ultimate Braking Capacity) means Circuit breaker can remove the fault and remain usable but Ics (Service Braking Capacity) means Circuit breaker can remove the fault, but it may not be usable afterwards.
- For example, if a circuit breaker has an Ics of 25,000 Amperes and an Icu of 40,000 Amperes:
- Any fault below 25kA will be cleared with no problem.
- A fault between 25kA and 40kA will cause permanent damage when cleared.
- Any current exceeding 40 kA can"t be cleared by this breaker.

(5) Rated working voltage (Ue):

- It is the continuous operation voltage for which the MCCB is designed.
- This value is typically equivalent or close to a standard system voltage.
- In three phase it is usually 400V or 415 V. For single phase it is 230V or 240V.

(6) Rated Insulation voltage (Ui):

- It is the maximum voltage that the MCCB can resist according to laboratory tests.
- It is higher than the rated working voltage, in order to provide a margin of safety during field operation.

(7) Rated impulse withstands voltage (Uimp):

- It is the value of transient peak voltage the circuit-breaker can withstand from switching surges or lighting strikes imposed on the supply.
- This value characterizes the ability of the device to withstand transient over voltages such as lightning (standard impulse 1.2/50 μs).
- Uimp = 8kV means Tested at 8 kV peak with 1.2/50μs impulse wave.

(8) Number of Poles:

- No of Pole for MCCB depends on Single Phase & Three Phase Power Controlling/Protection
- **Single Pole (SP) MCB:**
- A single pole MCB provides switching and protection for one single phase of a circuit.
- Used: for Single Phase circuit
- **Double Pole (DP) MCB:**
- A two Pole MCB provides switching and protection both for a phase and the neutral.
- Used: for Single Phase circuit
- **Triple Pole (TP) MCB:**
- A triple/three phase MCB provides switching and protection only to three phases of the circuit and not to the neutral.
- Used: for Three Phase circuit
- **3 Pole with Neutral (TPN (3P+N) MCB):**
- A TPN MCB, has switching and protection to all three phases of circuit and additionally Neutral is also part of the MCB as a separate pole. However, Neutral pole is without any protection and can only be switched.
- Used: for Three Phase circuit with Neutral
- **4 Pole (4P) MCB:**
- A 4 pole MCB is similar to TPN but additionally it also has protective release for the neutral pole. This MCB should be used in cases where there is possibility of high neutral current flow through the circuit as in cases of an unbalanced circuit.
- Used: for Three Phase circuit with Neutral

Difference between TPN and 4P

- TPN means a 4 Pole device with 4th Pole as Neutral. In TPN opening & closing will open & close the Neutral.
- For TPN, protection applies to the current flows through only 3 poles (Three Phase) only; there is no protection for the current flow through the neutral pole. Neutral is just an isolating pole.
- TP MCB is used in 3phase 4wire system. It is denoted as TP+N which will mean a three pole device with external neutral link which can be isolated if required.

- For the 4 pole breakers, protection applies to current flow through all poles. However when breaker trips or manually opened, all poles are disconnected.
- Same type of difference also applies for SPN and DP.

SELECTION OF ELCB

Class of ELCB/RCCB

Type of Load	Class	Sensitivity
Lighting	B Class	I∆n:30ma
Heater	B Class	I∆n:30ma
Drive	C Class	I∆n:100ma
A.C	C Class	I∆n:30ma
Motor	C Class	I∆n:100ma
Ballast	C Class	I∆n:30ma
Induction Load	C Class	I∆n:100ma
Transformer	D Class	I∆n:100ma

Size of MCB/ELCB

Current (Amp)	Lighting Load MCB/ELCB (Amp)	Heating/Cooling/Motor-Pump Load MCB/ELCB (Amp)
1.0 to 4.0	6	16
6.0	10	16
10.0	16	16
16.0	20	20

20.0	25	25
25.0	32	32
32.0	40	40
40.0	45	45
45.0	50	50
50.0	63	63
63.0	80	80
80.0	100	100
100.0	125	125
125.0	225	225
225.0	600	600
600.0	800	800

SELECTION OF CABLES

(i) Copper conductor cable only will be used for submain/ circuit/ point wiring.

(ii) Minimum size of wiring:

Light Wiring : 1.5 sq.mm.

Power Wiring : 4.0 sq.mm.

Power circuit rated : More than 1 KW, Size as per calculation.

(iii) Insulation : Copper conductor cable shall be PVC insulated conforming to BIS Specification.

(iv) Multi stranded : Cables are permitted to be used.

PRE-COMMISSIONING TESTS OF DOMESTIC INSTALLATIONS

On completion of installation, the following tests shall be carried out:-

(1) Insulation resistance test.
(2) Polarity test of switch.
(3) Earth continuity test.
(4) Earth electrode resistance test.

Witnessing of Tests

Testing shall be carried out for the completed installations, in the presence of and to the satisfaction of the Engineer-in-charge by the contractor. All test results shall be recorded and submitted to the Department.

Test Instruments

All necessary test instruments for the tests shall be arranged by the contractor if so required by the Engineer-in-charge.

Insulation Resistance

The insulation resistance shall be measured by applying between earth and the whole system of conductors, or any section thereof with all fuses in place, and all switches closed, and except in earthed concentric wiring, all lamps in position, or both poles of the installation otherwise electrically connected together, a direct current pressure of not less than twice the working pressure, provided it need not exceed 500 volts for medium voltage circuits. Where the supply is derived from a three wire D.C., or a polyphase A.C. system, the neutral pole of which is connected to earth either directly or through added resistance, the working pressure shall be deemed to be that which is maintained between the phase conductor and the neutral.

The insulation resistance shall also be measured between all the conductors connected to one pole, or phase conductor of the supply, and all the conductors connected to the neutral, or to the other pole, or phase conductors of the supply with all the lamps in position and switches in “off” position, and its value shall be not less than that specified in sub-clause 16.2.3.

The insulation resistance in mega ohms measured as above shall not be less than 12.5 mega ohms for the wiring with PVC insulated cables, subject to a minimum of 1 mega ohm.

Where a whole installation is being tested, a lower value than that given by the formula, subject to a minimum of 1 mega ohm, is acceptable.

A preliminary and similar test may be made before the lamps etc. are installed, and in this event the insulation resistance to earth should not be less than 25 mega ohms for the wiring with PVC insulted cables, subject to a minimum of 2 mega ohms.

The term “outlet” includes every point along with every switch, except that a switch combined with a socket outlet, appliance or lighting fitting is regarded as one outlet.

Control rheostats, heating and power appliances and electric signs may, if required, be disconnected from the circuit during the test, but in that event the insulation resistance between the case or frame work, and all live parts of each rheostat, appliance and electric sign, shall be not less than that specified in the relevant Indian Standard Specifications, or where there is no such specification, shall be not less than one mega ohm.

Polarity Test of Switch

In a two wire installation, a test shall be made to verify that all the switches in every circuit have been fitted in the same conductor throughout, and such conductor shall be labeled or marked for connection to the phase conductor, or to the non-earthed conductors of the supply.

In a three wire or a four wire installation, a test shall be made to verify that every non-linked single pole switch is fitted in a conductor which is labeled, or marked for connection to one of the phase conductors of the supply.

The installation shall be connected to the supply for testing. The terminals of all switches shall be tested by a test lamp, one lead of which is connected to the earth. Glowing of test lamp to its full brilliance, when the switch is in "on" position irrespective of appliance in position or not, shall indicate that the switch is connected to the right polarity.

Testing of Earth Continuity Path

The earth continuity conductor, including metal conduits and metallic envelopes of cables in all cases, shall be tested for electric continuity. The electrical resistance of the same along with the earthing lead, but excluding any added resistance, or earth leakage circuit breaker, measured from the connection with the earth electrode to any point in the earth continuity conductor in the completed installation shall not exceed one ohm.

Measurement of Earth Electrode Resistance

Two auxiliary earth electrodes, besides the test electrode, are placed at suitable distance from the test electrode (see Fig. 13). A measured current is passed between the electrode „A" to be tested and an auxiliary current electrode „C", and the potential difference between the electrode „A" and auxiliary potential „B" is measured. The resistance of the test electrode „A" is then given by:

R = V/I

R-Resistance of the test electrode in ohms

V-Reading of the voltmeter in volts,

I- Reading of the ammeter in amps.

(i) Stray currents flowing in the soil may produce serious errors in the measurement of earth resistance. To eliminate this, hand driven generator is used.
(ii) If the frequency of the supply of hand driven generator coincides with the frequency of stray current, there will be wandering of instrument pointer. An increase or decrease of generator speed will cause this to disappear.

At the time of test, the test electrode shall be separated from the earthing system.

The auxiliary electrodes shall be of 13 mm diameter mild steel rod driven up to 1 m into the ground.

All the three electrodes shall be so placed that they are independent of the resistance area of each other. If the test electrode is in the form of a rod, pipe or plate, the auxiliary current electrode „C" shall be placed at least 30 m away from it, and the auxiliary potential electrode „B" shall be placed mid-way between them.

Unless three consecutive readings of test electrode resistance agree, the test shall be repeated by increasing the distance between electrodes A and C upto 50 m, and each time placing the electrode B midway between them.

On these principles, "Megger Earth Tester", containing a direct reading ohm-meter, a hand driven generator and auxiliary electrodes are manufactured for direct reading of earth resistance of electrodes.

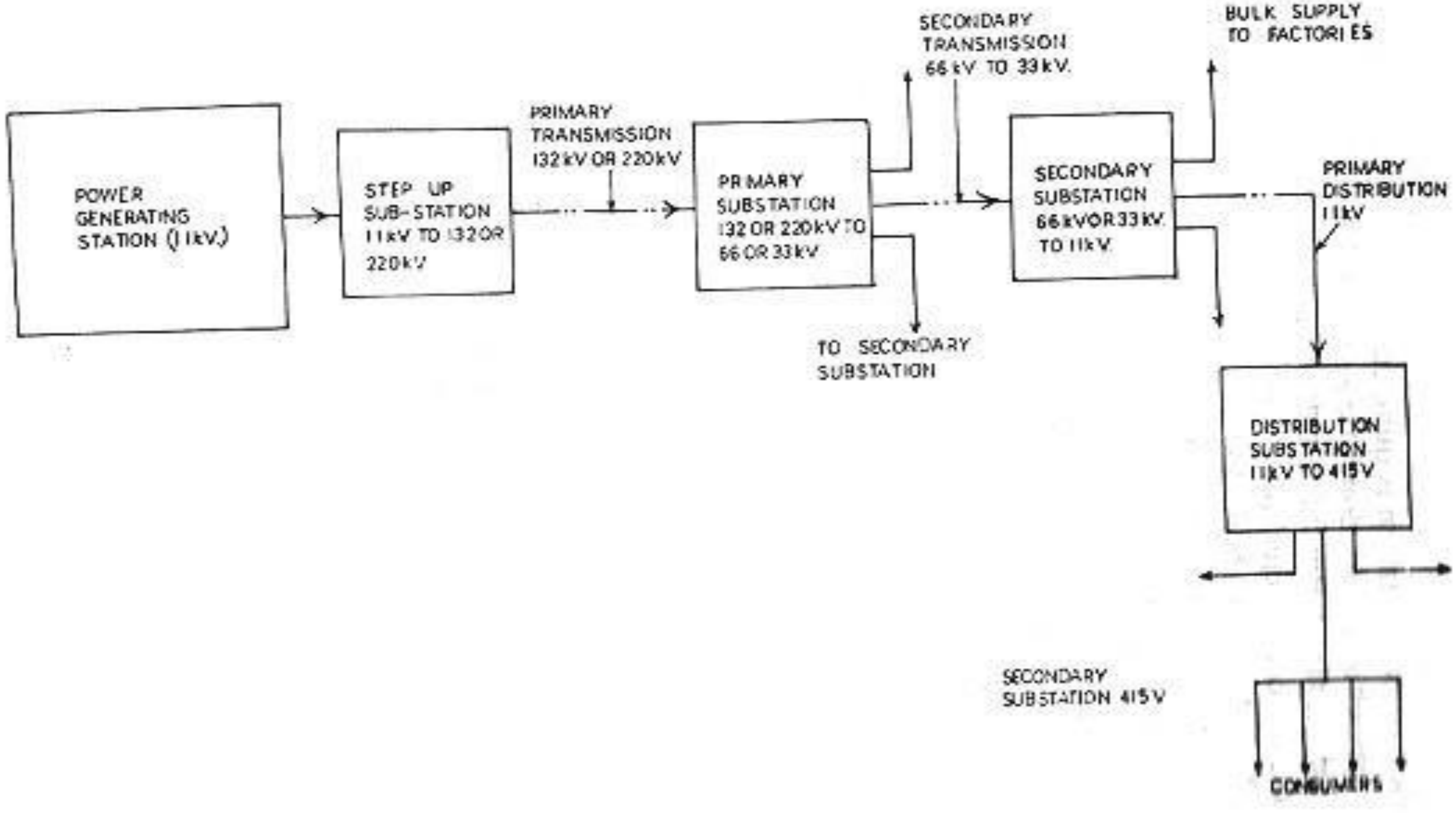
Test Certificate

On completion of an electrical installation (or an extension to an installation), a certificate shall be furnished by the contractor, countersigned by the certified supervisor under whose direct supervision the installation was carried out. This certificate shall be in the prescribed form required by the local Electric Supply Authorities.

EE405
Module 3
SUBSTATIONS

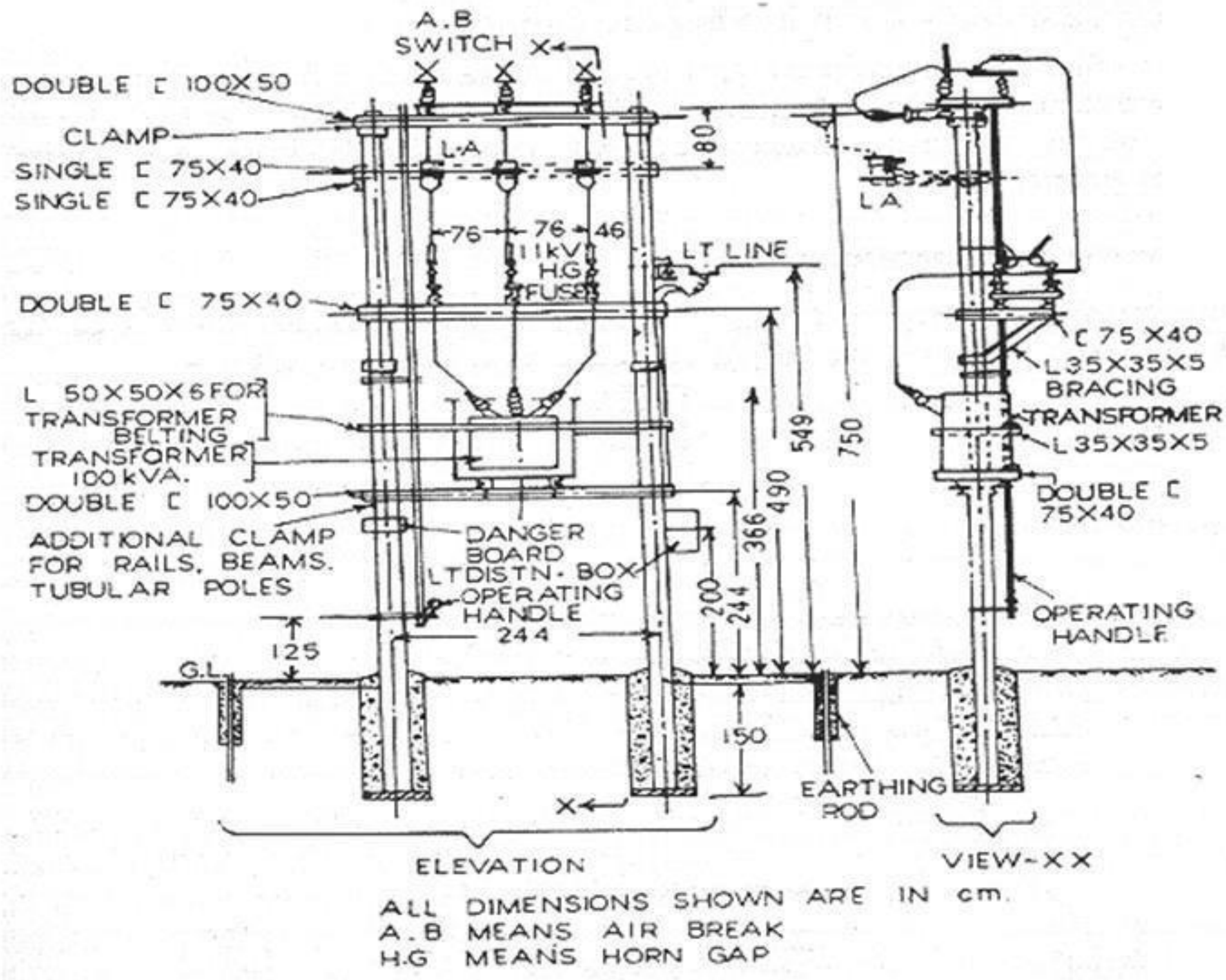
CLASSIFICATION

- Basis of nature of duties
  - Step up or primary substation, Primary grid substation, Step down or distribution substation
- Basis of service rendered
  - Transformer substation, switching substation, converting substation
- Basis of operating voltage
  - HV substation (11-66 kV), EHV substation (132-400 kV), UHV substation (Above 400 kV)
- Basis of importance
  - Grid substation, Town substation
- Basis of design
  - Indoor substation, outdoor substation



Line diagram showing the different substations in a power system.

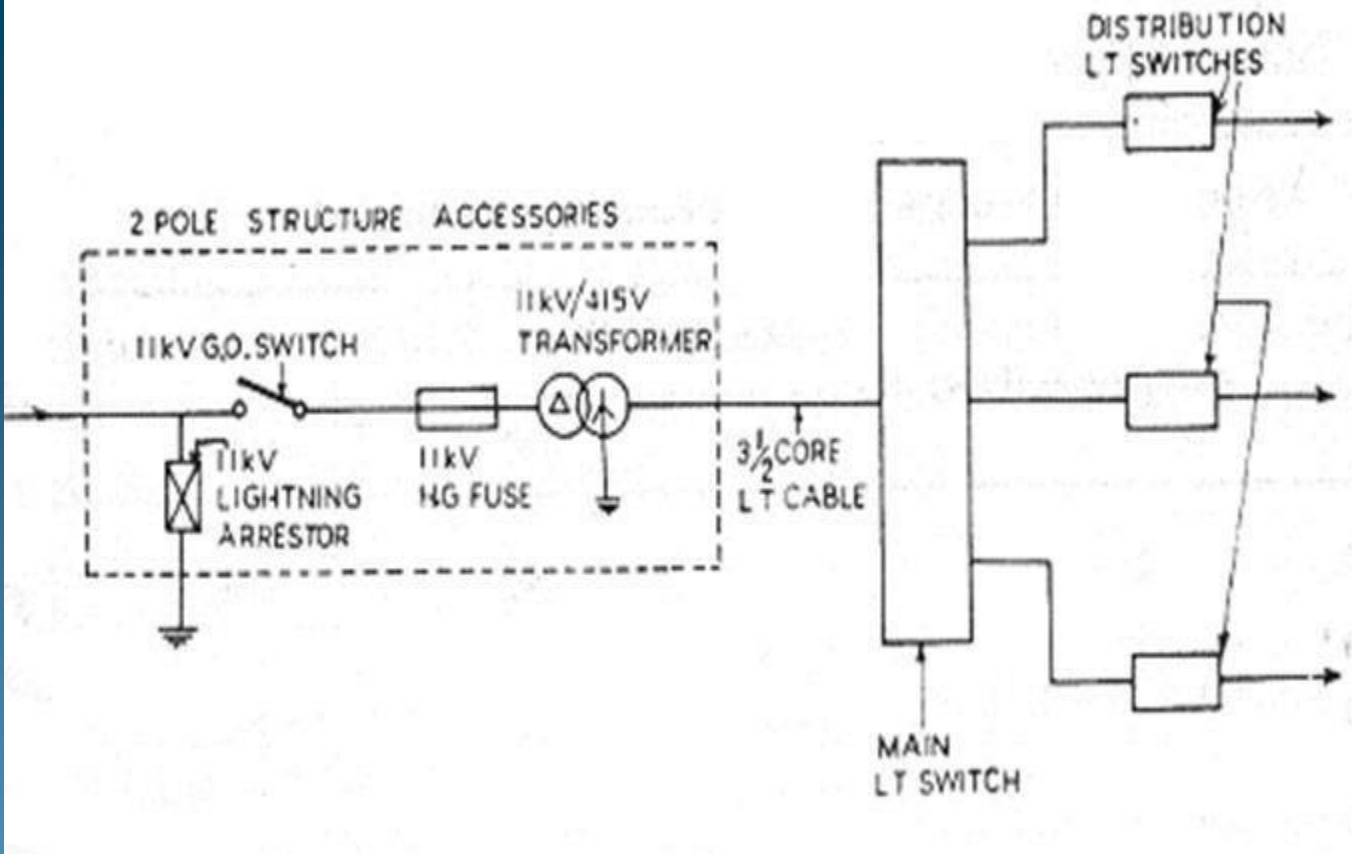
Outdoor substation



H-pole mounted substation with equipment.

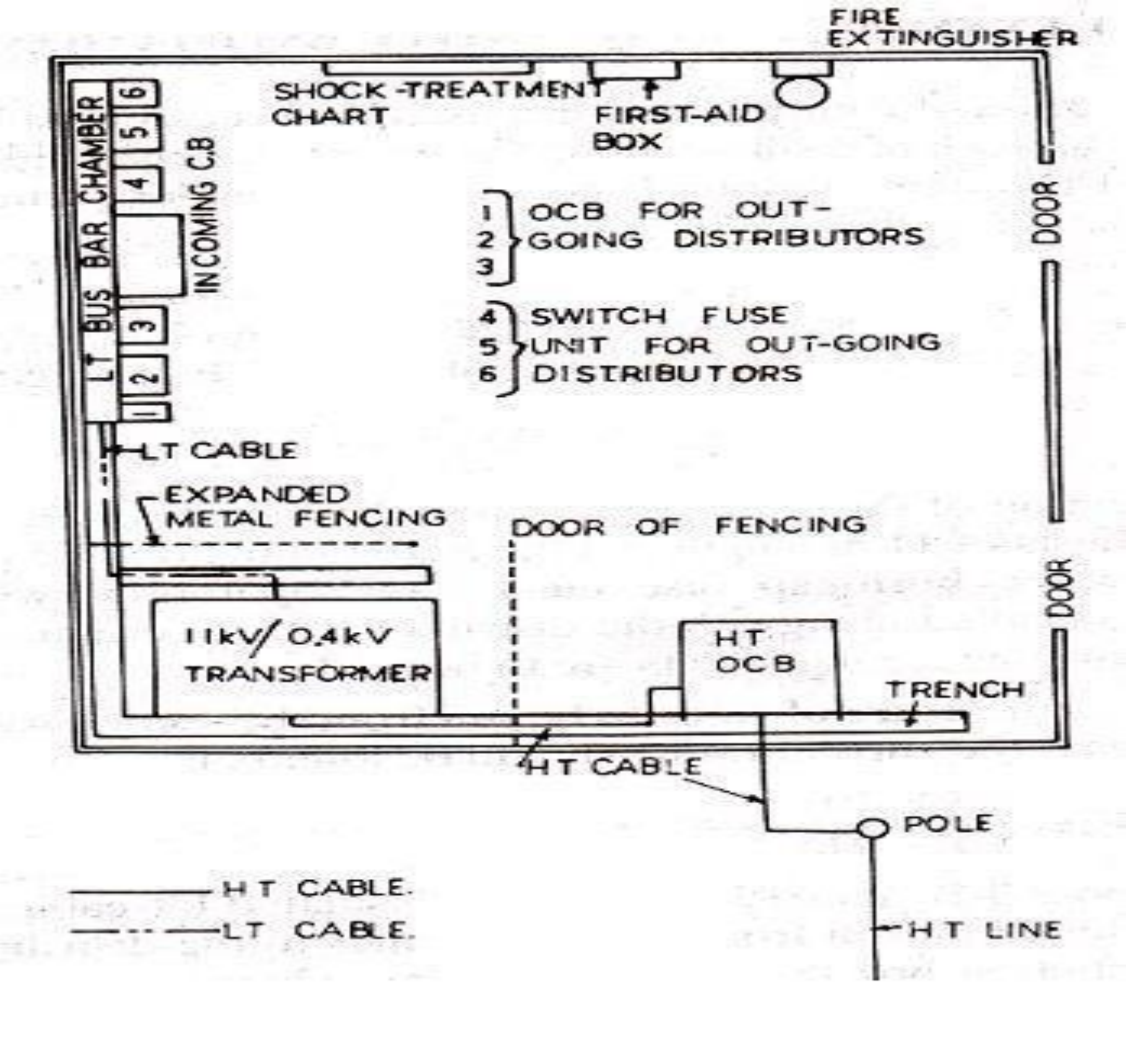
- horn gap fuse

- Gang operated switch

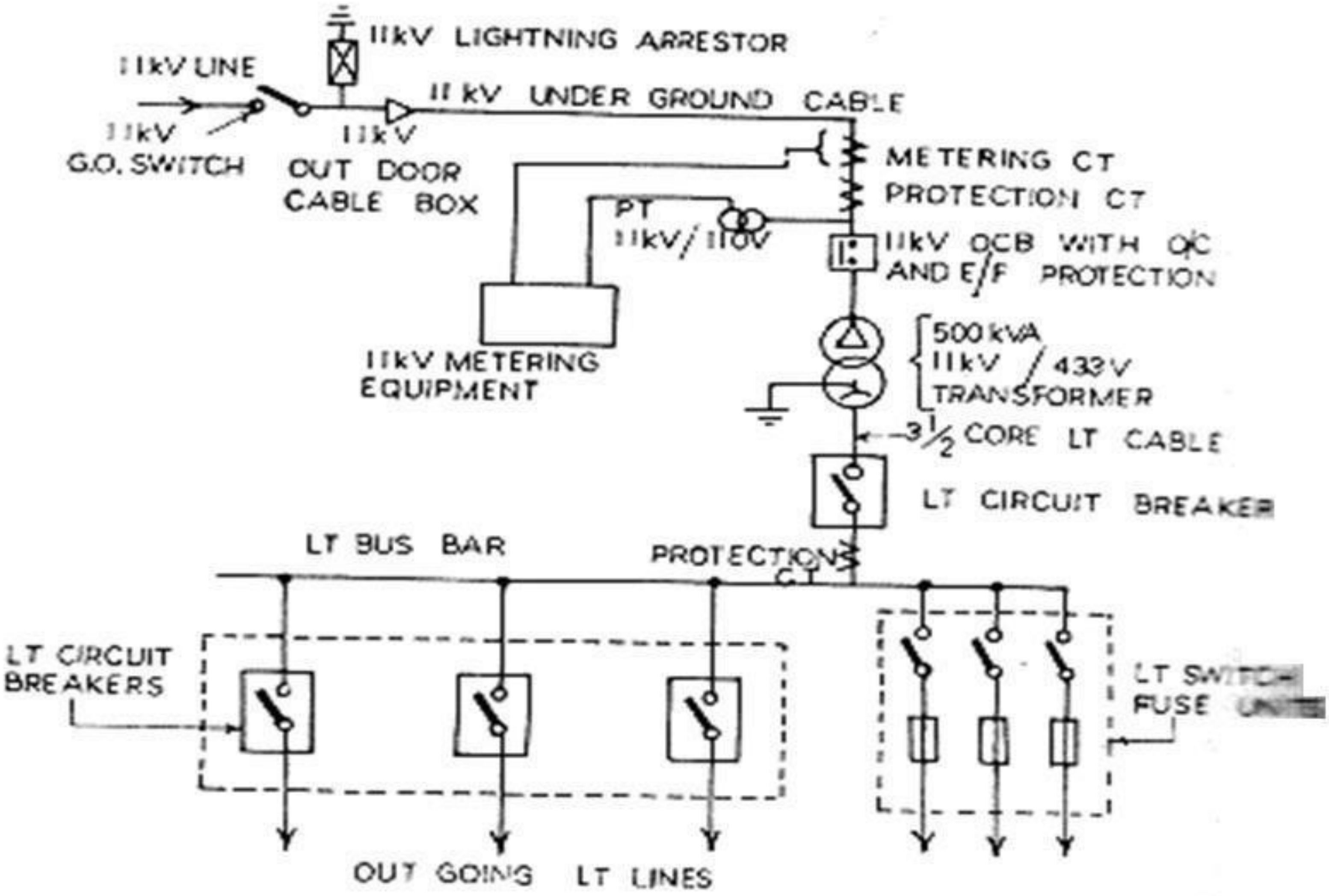


Single line diagram of a pole-mounted distribution substation.

INDOOR SUBSTATION



Layout of indoor substation.



Key diagram of a 500 kVA, 11kV/415-V indoor substation.

Recommended current ratings as per IS 3961 (Part II) 1967 Aluminium Conductor PVC Insulated PVC Sheathed Armoured or Unarmoured

Conductor Area	*Laid in Ground*			*In Single Way Duct*			*In Air*		
	Single Core (3 Nos.)	*Twin Single*	*3, $3\frac{1}{2}$ or 4 core Single*	*Single core (3 nos.)*	*Twin Single*	*3, $3\frac{1}{2}$ or 4 core Single*	*Single core (3 nos)*	*Twin Single*	*3, $3\frac{1}{2}$ or 4 core Single*
mm	*amp.*	*amp.*	*amp.*	*amp.*	*amp.*	*amp.*	*amp.*	*amp.*	*amp.*
1.5	17	18	16	17	16	14	15	16	13
2.5	24	25	21	24	21	18	21	21	18
4	31	32	28	30	27	23	27	27	23
6	39	40	35	37	34	30	35	35	30
10	51	55	46	51	45	39	47	47	40
16	66	70	60	65	58	50	64	59	51
25	86	90	76	84	76	63	84	78	70
35	100	110	92	100	92	77	105	99	86
50	120	135	110	115	115	95	130	125	105
70	140	160	135	135	140	115	155	150	130
95	175	190	165	155	170	140	190	185	155
120	195	210	185	170	190	155	220	210	180
150	220	240	210	190	210	175	250	240	205
185	240	275	235	210	240	200	290	275	240
225	260	305	260	220	260	220	320	305	265
240	270	320	275	225	275	235	335	325	280
300	295	355	305	245	305	260	380	365	315
400	325	385	335	275	345	290	435	420	375
500	345	...	365	295	...	315	480	...	420
625	390	...	395	320	...	340	550	...	480

Current Rating For ACSR Conductor For Overhead Lines

Code Word	*Number and Diameter of Wire in mm*	*Diameter of Conductor in mm*	*Approximate Weight of Conductor in kg/km*	*Approximate Ultimate Tensile Strength of Conductor in kg.*	*Approximate Current Carrying Capacity in Amperes*	
					At Ambient Temperature of 45°C	*At Ambient Temperature of 45°C*
Squirrel	6/1 × 2.11	6.33	85	771	115	107
Gopher	6/1 × 2.36	7.08	106	952	133	123
Weasel	6/1 × 2.59	7.77	128	1,136	150	139
Ferret	6/1 × 3.00	9.00	171	1,503	181	168
Rabbit	6/1 × 3.55	10.05	214	1,860	208	193
Mink	6/1 × 3.66	10.98	255	2,207	234	217
Beaver	6/1 × 3.99	11.97	303	2,613	261	242
Raccoon	6/1 × 4.09	12.27	318	2,746	270	250
Otter	6/1 × 4.22	12.66	339	2,923	281	260
Cat	6/1 × 4.50	13.50	385	3,324	305	283
Hare	6/1 × 4.72	14.15	394	3,799	324	300
Leopard	6/1 × 5.28	15.84	493	4,137	375	348
Tiger	30/7 × 2.36	16.52	604	5,758	382	354
Wolf	30/7 × 2.59	18.13	727	6,880	430	398
Panther	30/7 × 3.00	21.00	976	9,127	520	482
Lion	30/7 × 3.18	22.26	1,097	10,210	555	515
Bear	30/7 × 3.35	23.45	1,229	11,310	595	552
Goat	30/7 × 3.71	25.97	1,492	13,760	680	630

A 37 kW connection is to be given to an agriculture field at 415 V, 3-phase, 50 Hz. The connection is to be given from a 3-phase, 11 kV overhead distribution line which is available at a distance of 40 metres. The motor has a full-load efficiency of 85% and power factor 0.8.

Make a neat sketch showing how will you arrange the supply and estimate quantity of material required with cost.

Solution: Consumer load = 37 kW (output) = $\frac{37}{0.85}$ (input) = 43.529 kW

$$\text{Load in kVA} = \frac{\text{Load in kW}}{\text{Power factor}} = \frac{43.529}{0.8} = 54.41 \text{ kVA}$$

Full-load current on primary side of transformer,

$$I_1 = \frac{\text{Output in kVA} \times 1{,}000}{\sqrt{3} \times V_1} = \frac{54.41 \times 1{,}000}{\sqrt{3} \times 11{,}000} = 2.856 \text{ A}$$

Full-load current on secondary side of transformer,

$$I_2 = \frac{\text{Output in kVA} \times 1{,}000}{\sqrt{3} \times V_2} = \frac{54.41 \times 1{,}000}{\sqrt{3} \times 415} = 75.7 \text{ A}$$

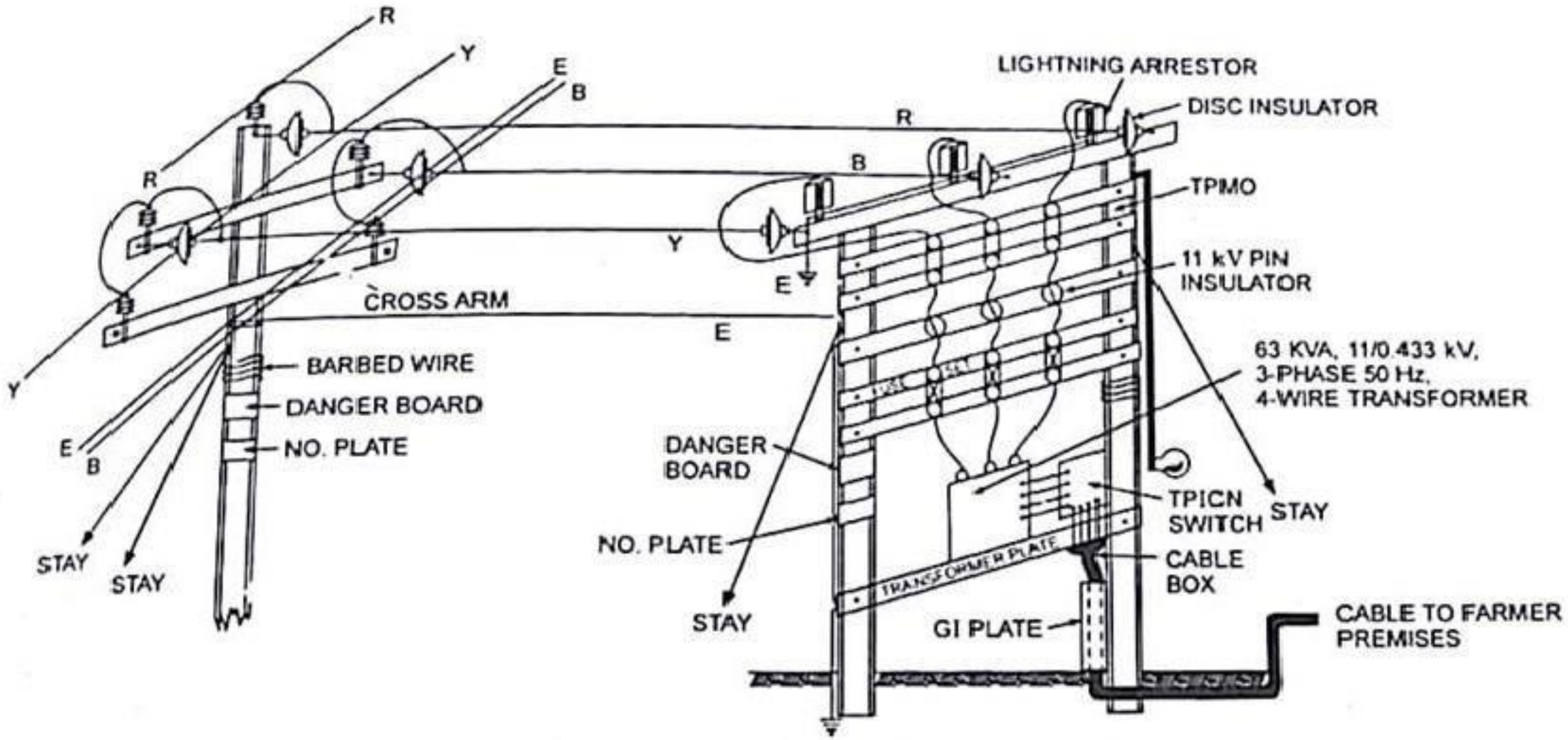
Thus the service connection is proposed to be provided by installing an outdoor pole-mounted 63 kVA, 11/0.433 kV Δ/λ-connected, 3-phase, 50 Hz transformer.

The service connection is proposed to be provided by a $3\frac{1}{2}$-core, 25 mm^2 (7/2.24 mm) aluminium conductor armoured cable

The transformer will be mounted on a two-pole structure 10 metres from the consumer's premises.

ACSR 6/1 × 2.11 mm conductor will be used to connect the transformer to the overhead line. Impedance of the cable is 1.4 Ω/km. Current carrying capacity is 115 A.

[25,40,63,100 ,200 kVA - 2 ~~pole ; 250,300,400 kVA - 4 pole; above~~ 400 - plinth]



Connection Diagram For Pole-Mounted Transformer Substation

Length of ACSR conductor = 3 × 30 + 1 m for sag = 91 m

Length of cable required = Length along pole up to ground + length along trench + length up to cable box + for wastage and connections

= 6 + 10 + 2 + 1 + 1 = 20 metres

A factory has a load of 200 kVA at 415 V 3-phase 50 Hz. The supply to this factory is to be given from an 11 kV, 3-phase, 50 Hz overhead transmission line which terminates at a distance of 15.5 m by installing a 250 kVA, 11/0.435 kV, 3-phase, 50 Hz outdoor type transformer and erecting a substation near the terminal point. Make a neat sketch of the substation and estimate the quantity of materials required and total cost of the project.

Assume cost of the transformer to be ₹ 320,000.00.

Solution: Factory load = 200 kVA

Full load current on the primary (ht) side,

$$I_1 = \frac{\text{kVA} \times 1{,}000}{\sqrt{3} \times V_1} = \frac{200 \times 1{,}000}{\sqrt{3} \times 11{,}000} = 10.5 \text{ A}$$

Full load current on the secondary (lt) side,

$$I_2 = \frac{\text{kVA} \times 1{,}000}{\sqrt{3} \times V_2} = \frac{200 \times 1{,}000}{\sqrt{3} \times 415} = 278.24 \text{ A}$$

10 mm², 3-core XLPE, 11 kV cable is, therefore, proposed to be used for connecting the transformer (ht side) to the existing overhead transmission line. On the lt side $3\frac{1}{2}$ core PVC insulated aluminium conductor 240 mm² is proposed for the connections from transformer (lt side) to the oil circuit breaker.

Different methods of installation (Ref: IEC 60364-5-52)

Item No.	Description	Reference method of installation to obtain current carrying capacity
1	Insulated conductors or single core cables in conduit in a thermally insulated wall	A1
2	Multi-core cables in conduit in a thermally insulated wall	A2
3	Insulated conductors or single core cables in conduit on a wooden or masonry wall or spaced less than 0.3 times diameter of cables from the wall	B1
4	Multi-core cables on a wooden or masonry wall or spaced less than 0.3 times the diameter of the cable from it	B2
5	Single core or multi-core cables fixed on, or spaced less than 0.3 times the cable diameter from the wall	C
6	Cables on non-perforated trays	C
7	Multi-core cables in conduit or in cable ducting in ground / Single core cables in conduit or in cable ducting in ground	D
8	Cables on perforated trays	E or F
9	Bare uninsulated conductors on insulators	G

Current carrying capacity of unburied cables (IEC 60364-5-52)

Reference method	Number of loaded conductors and type of insulation											
A1		2 PVC	3 PVC		3 XLPE	2 XLPE						
A2	3 PVC	2 PVC		3 XLPE	2 XLPE							
B1				3 PVC	2 PVC		3 XLPE					
B2			3 PVC	2 PVC		3 XLPE	2 XLPE		2 XLPE			
C					3 PVC		3 PVC	3 XLPE		2 XLPE		
E						3 PVC		2 PVC	3 XLPE		2 XLPE	
F							3 PVC		2 PVC	3 XLPE		2 XLPE
1	2	3	4	5	6	7	8	9	10	11	12	13
Copper (mm^2)	Current carrying capacity ampere											
1.5	13	13.5	14.5	15.5	17	18.5	19.5	22	23	24	26	-
2.5	17.5	18	19.5	21	23	25	27	30	31	33	36	-
4	23	24	26	28	31	34	36	40	42	45	49	-
6	29	31	34	36	40	43	46	51	54	58	63	-
10	39	42	46	50	54	60	63	70	75	80	86	-
16	52	56	61	68	73	80	85	94	100	107	115	-
25	68	73	80	89	95	101	110	119	127	135	149	161
35	-	-	-	110	117	126	137	147	158	169	185	200
50	-	-	-	134	141	153	167	179	192	207	225	242
70	-	-	-	171	179	196	213	229	246	268	289	310
95	-	-	-	207	216	238	258	278	298	328	352	377
120	-	-	-	239	249	276	299	322	346	382	410	437
150	-	-	-	-	285	318	344	371	395	441	473	504
185	-	-	-	-	324	362	392	424	450	506	542	575
240	-	-	-	-	380	424	461	500	538	599	641	679
Aluminium (mm^2)	Current carrying capacity-ampere											
2.5	13.5	14	15	16.5	18.5	19.5	21	23	24	26	28	-
4	17.5	18.5	20	22	25	26	28	31	32	35	38	-
6	23	24	26	28	32	33	36	39	42	45	49	-
10	31	32	36	39	44	46	49	54	58	62	67	-
16	41	43	48	53	58	61	66	73	77	84	91	-
25	53	57	63	70	73	78	83	90	97	101	108	121
35	-	-	-	86	90	96	103	112	120	126	135	150
50	-	-	-	104	110	117	125	136	146	154	164	184
70	-	-	-	133	140	150	160	174	187	198	211	237
95	-	-	-	161	170	183	195	211	227	241	257	289
120	-	-	-	186	197	212	226	245	263	280	300	337
150	-	-	-	-	226	245	261	283	304	324	346	389
185	-	-	-	-	256	280	298	323	347	371	397	447
240	-	-	-	-	300	330	352	382	407	439	470	530

Current carrying capacity of buried cables (IEC 60364-5-52)

Installation method	Size mm²	No. of loaded conductors and type of insulation			
		Two PVC	Three PVC	Two XLPE	Three XLPE
D			Copper		
	1.5	22	18	26	22
	2.5	29	24	34	29
	4	38	31	44	37
	6	47	39	56	46
	10	63	52	73	61
	16	81	67	95	79
	25	104	86	121	101
	35	125	103	146	122
	50	148	122	173	144
	70	183	151	213	178
	95	216	179	252	211
	120	246	203	287	240
	150	278	230	324	271
	185	312	258	363	304
	240	361	297	419	351
	300	408	336	474	396
D			Aluminium		
	2.5	22	18.5	26	22
	4	29	24	34	29
	6	36	30	42	36
	10	48	40	56	47
	16	62	52	73	61
	25	80	66	93	78
	35	96	80	112	94
	50	113	94	132	112
	70	140	117	163	138
	95	166	138	193	164
	120	189	157	220	186
	150	213	178	249	210
	185	240	200	279	236
	240	277	230	322	272
	300	313	260	364	308

A substation has to be installed for supply to a residential area having a load of 80 kVA , taking supply from a nearby 11kV line. Select a suitable type of substation and estimate the quantity of material required

- **Solution: The distribution transformer to be selected is 100kVA 11kV/415V and can be mounted on H pole structure. On the double pole structure all the necessary accessories like lightning arrester, gang operating switch , disc insulator, horn gap fuse unit are installed.**
- **Current=**

$$\frac{80 \times 10^3}{\sqrt{3} \times 415} = 112 \text{ A}$$

- **Cable size:3-1/2 core 185 sq mm PVC insulated LT cable taking into consideration the factor of safety and future load requirements. From the distribution box, different sizes of cables are run according to the load requirement of each feeder**

[25,40,63,100 ,200 kVA - 2 pole ; 250,300,400 kVA - 4 pole; above 400 – plinth

Table of estimation

O	Description of materials	Qty reqd
1	Rolled steel joists 175mmx100mmx11m long	2 nos
2	11kV lightning arresters	3nos
3	11	3nos
4	11kV gang operating air break switch	1 set
5	11kV horn gap fuse unit	1 set
6	11kV/415V100kVA distribution transformer	1no

Table of estimation

Sl NO	Description of materials	Qty reqd
7	100kVA distribution box	1set
8	3-1/2 core 185 sqmm PVC insulated LT cable	10m
		24kg
10	MS angle 500mmx6mm	24kg
11	Ms channel 75mmx40mmx6mm	22kg
12	MS channel 100mmx75mmx6mm	110kg
13	Stay sets	2 sets
14	Stay wire 7/8SWG	32kg

Table of estimation

Sl NO	Description of materials	Qty reqd
15	Earthing sets	3 sets
16	GI wire No8 SWG	4kg
17	Binding wire	1kg
18	Barbed wire 12x 12x SWG	15kg
1[illegible]		15kg
20	Aluminium paint	2 litres
21	Danger notice plate	1 No
22	Empire tape , pure tin and lead , thimbles and other sundry items required to complete the work	Lumpsum
23	Concreting (for steel pole only)	1.5m

An 11kV/415V 300kVA substation is to be installed in a densely populated area. What type of substation will u select? Make an estimate of the quantity of material required. Assume that the supply is taken from an overhead line running near it. The LT panel consists of an incoming line with OCB and five out going lines with switch fuse units of 1 No.200A, 2 No.100A and 2 No 63A capacity.

- **if preferred. A 11kV/415V 300kVA indoor type distribution transformer with HT and LT cable boxes can be used. The supply is to be taken from an overhead line already running nearby. By taking jumpers from an 11kv line and through the outdoor cable boxes suitable for 2.5sq.mm 11kV cable supply is given to the transformer through the HT OCB .**

- Maximum current in the LT side=300x1000/√3 x415

  =417A

  Taking into account of a factor of safety 2 runs of 3-1/2 core 400sq.mm PVC insulated LT cable can be used. Cable boxes at the LT side of the transformer and at the LT OCB shall be modified such as to take 2 runs of cable.

The LT panel is having

i)One incoming line of 500kVA OCB.

ii)Five outgoing lines of

a) 1 No 200A switch fuse unit

b)2 No 100A switch fuse unit

c)2 No 63 A switch fuse unit along with LT busbars and cable boxes.

- **LT cables:**

i) 3-1/2 core 120 sq mm PVC insulated LT cable to run from 200A switch fuse unit.

ii) 3-1/2 core 95 sq mm PVC insulated LT cable to run from 100A switch fuse unit.

iii) 3-1/2 core 50 sq mm PVC insulated LT cable to run from 63A switch fuse unit.

Table of estimation

Sl NO	Description of materials	Qty reqd
1	Outdoor 11kV box suitable for 25 sqmm 11kV cable with cable jointing materials	1 set
2	11kV jumpers with insulation sleeves	3m
3	11kV paper insulated 3 core 25sqmm	40m
4	11kV 400AOCB rupturing capacity 150 MVA and having metering and protection devices	1 set
5	GI pipe for carrying the 11kV cable along the pole	5m
6	Clamps for fixing the GI pipe and the cable end boxes	1set

Table of estimation

Sl NO	Description of materials	Qty reqd
7	Side cable box suitable for 11kV 25 sqmm cable with jointing material and supporting structure for 11kV OCB	1 set
8	11kV/415V,300kVA distribution transformer indoor type with HT and LT c	1No
9	3-1/2 core 400 sqmm PVC insulated LT cable(2runs)	25 m
10	LT panel having :one incoming line of 500kVA OCB , five outgoing lines and 1 No 200A, 2No 100A, and 2No63A switch fuse units along with LT bus bars and suitable cable and boxes	1 set

Table of estimation

Sl NO	Description of materials	Qty reqd
11	3-1/2 core 120sqmm PVC insulated LT cable	25m
12	3-1/2 core 95sqmm PVC insulated LT cable	50m
13	3-1/2 core 50sqmm PVC insulated LT cable	70m
14		100kg
15	Angle iron 25mmx25mm	50kg
16	Channel iron 50mmx100mm	100kg
17	Earthing sets	2 sets
18	Earthing strips 50mmx6mm,25mmx3mm,No.8 SWG	100kg

19	Fire extinguisher	1No

Table of estimation

Sl NO	Description of materials	Qty reqd
20	First aid box	1 No.
21	Shock treatment chart	1No
22	Danger notice plate	2No
[illegible]		
	Nuts and bolts of required size	Lumpsum
25	Thimbles, jointing materials, trench covers and all other sundry items required to complete the work	Lumpsum

EE405
Module 4
SHORT CIRCUIT CALCULATIONS

Basic equations:

Source

$$\text{Per unit source impedance } (Z_Q) = \frac{\text{Base MVA}}{\text{Short circuit MVA}}$$

$$\text{Source impedance in ohms } (Z_Q) = \frac{cU_{nQ}^2}{S_{kQ}''}$$

where,

c = Voltage factor
= 1 for 230/415 V
= 1.1 for voltages from 1 kV to 230 kV

U_{nQ} = Nominal source voltage-line to line (rms) at Q

S_{kQ}'' = Initial symmetric short circuit apparent power at Q

Transmission line

$$\text{Per unit line impedance } Z_{l(pu)} = \frac{\text{Line impedance}}{\text{Base impedance}}$$

$$\text{Base impedance } Z_b = \frac{\text{Base kV}^2}{\text{Base MVA}}$$

$$\text{Line inductance (sym. spacing) } L = \left(0.5 + ln\frac{d}{r}\right) 10^{-7}\text{H/m}$$

Where,

d = spacing between conductors in metres and

r = radius of conductor in metres.

Inductive reactance of the overhead line $X_l = 0.0628\left(\frac{0.25}{n} + l_n \frac{d}{r}\right) \Omega/km$

Where,

n = number of conductors per phase
d = spacing of overhead line in metres

$$r = \text{mean radius of the conductor} = \frac{1.14}{1000}\sqrt{\frac{q_n}{\pi}}\,\text{m}$$

q_n = area of cross-section of the conductor in mm^2

Transformer

S_{rT} = Rated apparent power of transformers - VA
U_{rT} = Rated voltage of transformer on HV or MV side - V
u_{kr} = Percentage impedance (impedance voltage) of the transformer

$$Z_T = \text{Transformer impedance} - \Omega = \frac{u_{kr}}{100}\frac{U_{rT}^2}{S_{rT}}$$

P_{krT} = Full load loss of transformer - W

$$R_T = \text{Resistance of the transformer} = \frac{P_{krT}}{3I_{rT}^2}$$

$$X_T = \text{Reactance of the transformer} = \sqrt{\left(Z_T^2 - R_T^2\right)}\,\Omega$$

I_{rT} = Full load current of the transformer on HV or MV side-A

$$\text{Soil resistivity } \rho = 2\pi \text{DR ohm} \cdot \text{m}$$

Where,

D = Spacing of the spikes in meter and
R = reading of the earth tester in ohms.

$$\text{Permissible current density of the earth electrode } I_d = \frac{7.57 \text{X} 10^3}{\sqrt{\rho t}} \text{A/m}^2$$

Where,

t = Duration of fault in seconds (3 sec)
ρ= Soil resistivity in ohm · m

$$\text{Initial symmetrical short circuit current} = I_k'' = \frac{cU_n}{\sqrt{3} \times Z_k} A$$

$$\text{And, peak short circuit current} = i_p = k\sqrt{2} \times I_k''$$

$$k = 1.02 + 0.98e^{\left(\frac{-3R_k}{X_k}\right)}$$

$$= 1.02 + 0.98e^{\frac{-3R_k}{X_k}}$$

U_n = Nominal line to line system voltage
Z_k = System impedance up to the fault point 'k'
c = Voltage factor
= 1 for low voltage (240/415)
= 1.05 for other low voltages
= 1.1 for voltages above 1kV up to 230 kV

Electric supply to an industry is provided from the utility substation through an overhead transmission line. The length of the 11 kV line is 2.5 km and the conductor used is MINK with an equilateral spacing of 900 mm. The industry proposes to have a transformer substation with a 750 kVA, 11 kV/433V, delta/star connected transformer. The percentage reactance of the transformer is 4% and the full load copper loss of the transformer is 1.5%. The three-phase short circuit power at the utility substation is 350MVA. The resistance of the line conductor = 0.454 ohm per km. Calculate:

1. Initial symmetrical short circuit current and
2. Peak short circuit current

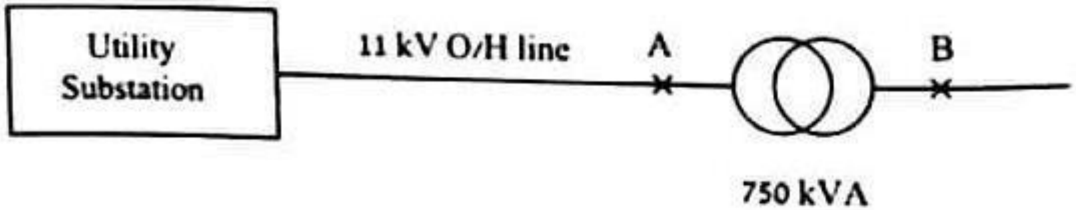
on the primary and secondary terminals of the proposed transformer.

Solution:

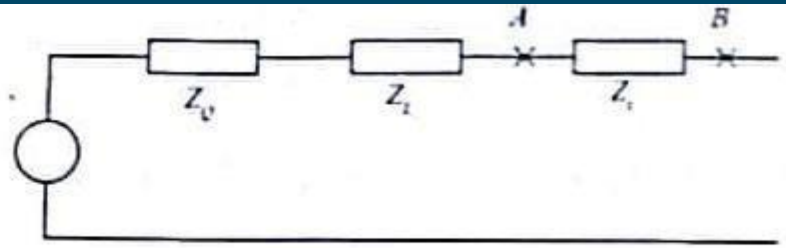
The schematic diagram of the power distribution arrangement is shown in Figure
The equivalent single diagram of the power distribution system is shown below

$$\text{The source impedance } Z_Q = \frac{cU_{nQ}^2}{S''_{kQ}}$$

$$= \frac{1.1 \times 11000^2}{350 \times 10^6} = 0.3803\ \Omega$$



Schematic arrangement of the distribution system



Equivalent single line diagram of example.

The source resistance R_Q	$= 0.1\ Z_Q$
	$= 0.03803\ \Omega$
The source reactance X_Q	$= 0.995\ Z$
	$=0.3784\ \Omega$
The resistance of the line conductor	$= 0.454\ \Omega/\text{km}$
Total resistance of the line R_l	$= 2.5 \times 0.454$
	$= 1.135\ \Omega$

Nominal area of cross section of MINK conductor, $q_\pi = 93.3\ mm^2$

Mean radius of the conductor (r) $= \frac{1.14}{1000}\sqrt{\frac{q_\pi}{\pi}}$

$= 0.0062\ m$

Number of conductors per phase (n) = 1

Inductive reactance of the line x_l $= 0.0628\left(\frac{0.25}{n} + \ln\frac{d}{r}\right)$

$= 0.0628\left(\frac{0.25}{1} + \ln\frac{0.9}{0.0061}\right)$

$= 0.0328\ \Omega/km$

Total inductive reactance X_l $= 2.5 \times 0.0328$

$= 0.0821\ \Omega$

Fault location A (primary side of the transformer)

Total resistance up to the fault point A $-R_A$ $= R_Q + R_l$

$= 0.03803 + 1.135$

$= 1.173\ \Omega$

Total reactance up to the fault point A $-X_A$ $= 0.3784 + 0.0821$

$= 0.4605\ \Omega$

Short circuit up to the fault point A $-Z_A$ $= \sqrt{\left(1.173^2 + 1.1994^2\right)}$

$= 1.26\ \Omega$

Therefore,

Initial symmetrical short circuit current at point A $I''_A = \dfrac{cU_n}{\sqrt{3} \times Z_k}$

$$= \frac{1.1 \times 11{,}000}{\sqrt{3} \times 1.678}$$

$$= 4163 \text{ A}$$

Peak short circuit current at point A i_{pA} $= k\sqrt{2} \times I''_k$

And

$$k = 1.02 + 0.98e^{\left(\frac{-3R_k}{X_k}\right)}$$

$$= 1.02 + 0.98e^{\frac{-3R_k}{X_k}}$$

$$= 1.02 + 0.98e^{\frac{-3\times 1.135}{1.173}}$$

$$= 1.0738$$

Therefore,

$$i_{pA} = 1.0738 \times \sqrt{2} \times 4163$$

$$= 6322 \text{ A}$$

Fault location B (secondary side of the transformer)

In order to calculate the total impedance up to the fault location, first the impedance value of the supply system and the line are converted to the value referred to the secondary side.

Resistance up to point A referred to the secondary side of the transformer

$$R'_A = 1.173\left(\frac{433}{11{,}000}\right)^2 = 0.00182\ \Omega$$

Similarly

$$X'_A = 0.464\left(\frac{433}{11{,}000}\right)^2 = 0.00071\ \Omega$$

Impedance of the transformer Z_T $= \dfrac{u_{kr}}{100}\dfrac{U_{rT}^2}{S_{rT}} = \dfrac{4 \times 433^2}{100 \times 750000} = 0.01\ \Omega$

Power loss in the transformer P_T $= \frac{1.5 \times 750000}{100}$

$= 11{,}250 \text{ W}$

Full load current on the secondary side $= \frac{750000}{\sqrt{3} \times 433}$

$= 1000 \text{ A}$

Resistance of the transformer R_T $= \frac{P_{krT}}{3I_{rT}^2}$

$= \frac{112500}{3 \times 1000^2}$

$= 0.00375\ \Omega$

Reactance of the transformer X_T $= \sqrt{(0.01^2 - 0.00375^2)}$

$= 0.00927\ \Omega$

Total resistance up to the fault point B R_B $= 0.00182 + 0.00375$

$= 0.00557\ \Omega$

Total reactance up to the fault point B X_B $= 0.0018 + 0.00927$

$= 0.01107\ \Omega$

Total impedance up to the fault point B Z_B $= \sqrt{(0.00557^2 + 0.01107^2)}$

$= 0.0124\ \Omega$

Therefore

Initial symmetrical fault current at B $I''_B = \dfrac{cU_n}{\sqrt{3} \times Z_B}$

$$= \frac{1.05 \times 433}{\sqrt{3} \times 0.0124}$$

Voltage factor $c = 1.05$ for a voltage of 433 V)

$= 21.167$ kA

Peak short circuit current at point A i_{pB} $= k\ \sqrt{2} \times I_k''$

And $k = 1.02 + 0.98e^{\left(\frac{-3R_k}{X_k}\right)}$

$= 1.02 + 0.98e^{\left(\frac{-3\times 0.00552}{[illegible]}\right)}$

$= 1.237$

$i_{pB} = 1.237 \times \sqrt{2 \times 21.167}$

$= 37.03$ kA

Summary of short circuit currents

Fault location	**Initial symmetrical short circuit current (I_k'')**	**Peak short circuit current i_p**
Point A	4.163 kA	6.322 kA
Point B	21.167 kA	37.03 kA

Design of earthing for 11 kV substation

Earth electrode resistances are given by the equations:

Plate electrodes $R = \frac{\rho}{4}\sqrt{\frac{\pi}{A}}$ ohm

Pipe or rod electrodes $R = \frac{100\rho}{2\pi l}\ln\frac{2l}{d}$ ohm

Strip or conductor $R = \frac{100\rho}{2\pi l}\ln\frac{4l}{t}$ ohm

Where, ρ = soil resistivity in ohm.m

A = area of both sides of the plate electrode-m^2

l = length in m

d = diameter of pipe or rod in m

t = thickness of strip conductor or twice the diameter of circular conductor

The number of earth electrodes can be calculated based on the fault level on the H.T side of the consumer transformer.

Permissible current density of an electrode $= \frac{7.57 \times 10^3}{\sqrt{\rho t}} = I_d$

Where t = duration of fault (3s)

Assuming ρ = 100 ohm.m

$$I_d = \frac{7.57 \times 10^3}{\sqrt{100 \times 3}}$$

$$= 437 \text{ A/m}^2$$

Area of earth plates required $= \frac{I''_A}{I_d} \times 1000 \text{ m}^2$

$$= \frac{4.163}{437} \times 1000$$

$$= 9.526 \text{ mm}^2$$

Standard size of earth electrodes is $= 1.2 \times 1.2 \times 0.012$ m

Hence, the area of a plate electrode $= 2\,(1.2 \times 1.2) \text{ m}^2$

$$= 2.88 \text{ m}^2$$

Hence, number of earth electrodes required $= \frac{9.526}{2.88}$

$$= 3.36 \text{ say } 4$$

Determination of earthing conductor size

(Assume that copper is used as earthing conductor)

Permissible current density of copper = 118 A/mm^2

$$\text{Area of earth conductor on H.T side} = \frac{I''_A}{118}\ \text{mm}^2$$

$$= \frac{4163}{118}$$

$$= 35.28\ \text{mm}^2$$

From the Table given below, choose the nearest standard size on the higher side. (Choose the nearest standard section, say 25 × 3 mm on the HT side)

$$\text{Area of earth conductor on the LT side} = \frac{I_B''}{118} \text{ mm}^2$$
$$= \frac{21167}{118}$$
$$= 180 \text{ mm}^2$$

(Choose the nearest standard section such as 32 × 6 mm on the LT side)

Standard sizes of rectangular copper conductors for earthing	
25 × 3 mm	copper strip tinned at the points of contacts
25 × 6 mm	-do-
32 × 3 mm	-do-
32 × 6 mm	-do-
40 × 3 mm	-do-
40 × 6 mm	-do-
50 × 3 mm	-do-
50 × 6 mm	-do-
65 × 3 mm	-do-
65 × 6 mm	-do-

A cement factory is supplied from a Utility substation 5km away from the factory through an over head line. The cement factory has two numbers of 630kVA, 11kV/ 433V, 3 phase transformers with a percentage reactance of 6% operating in parallel. If the 3 phase fault level on the 11 kV side of the substation is 500 MVA, determine the number of earthing stations required using plate electrodes for the transformer station. The O/H line conductor (AAC-Grasshopper) has a cross section of 84.1 mm^2 and a spacing of 900 mm. Assume a soil resistivity of 65 Ωm.

Design of overhead and underground distribution system

Main materials:

- Poles and fitting
- Conductors and their accessories
- Earth wire and its accessory
- Stay or guy wire and its arrangement
- Insulators and their fittings
- Danger sign board
- Guarding wires
- Anti climbing devices

- Poles and fittings:
  - Wooden poles, Steel tubular poles, Steel rails, Reinforced Cement Concrete(RCC) and pre stressed cement concrete (PCC) poles
  - PCC poles maximum height 8m to9m
- Cross arms can be of wood or steel. Dimensions are
  - 1.52mx125mm125mm(11kV)
  - 2.14mx125mmx125mm(33kv)
- MS channel iron sizes 75mm x 37mm and 100mm x 50mm are usually used as steel cross arms
- MS flat boards- 60mmx8mm is used to fix the pin insulator
- Conductors and accessories: Upto 67m AASC, beyond 67m ACSR, Galvanized steel wires are used in telecommunication circuits, earth wires, guard wires, guy wires etc

- **Accessories required for conductor to be installed on poles-**
  1. **Binding tape - For binding conductors to pin insulators**
  2. **Binding wire - For binding conductors to pin insulators**
  3. **Parallel grove clamp – To connect parallel run lines**
  4. **Jointing sleeve – To join two conductors**
  5. **Repair sleeve – Reinforcement of ACSR/ AAC when few conductors are damaged**
  6. **Tension clamp**
  7. **Suspension clamp – Used for suspending disc insulators**
- **Earth wire: A continuous earth wire is run over the supports and then connected to earth at 4 points every 1.6km.Double earth wire is provided in the case of 3 phase system. Otherwise every pole is earthed.**
- **Insulators and their fittings :In order to prevent short circuit between the different phase conductors of the line and also to prevent leakage of current to earth through cross arms on poles and towers insulators are provided. Normally pin/shackle insulators are used.**

- **Guys(Stays):In the case of an overhead line using poles, unlike intermediate poles a terminal pole experience a pull on one side only and tends to tilt the pole in the direction of line. To prevent this a stay or guy wire is provided.**

- **Anticlimbing devices: Barbed wire is wrapped on poles at a height of about 2.5m above ground level.**

- **Danger sign boards: As a warning indicating the working voltage and the word' danger'.**

- **Guarding wires: For the safety of life, installations and of the communication circuits.**
  - **Cradle guard - LT lines with horizontal formation**
  - **Cage guard –LT lines with vertical formation**

UNDERGROUND CABLES

- **Low tension cables : 250-440V**
  650-1100V
- **High tension cable : upto 3.3kV**
  upto 11kV
  22kV and 33kV cables
- **Extra High tension cables: 66kV and 132kV oil filled and gas filled cables**

- **Construction of cables:**
  - Conductors of power cables may be made of copper or aluminium.
  - Copper conductors are used only for cables required in control circuit wiring
  - In other applications aluminium is used. The aluminum conductors up to 10 sqmm are circular and solid and above that size are circular and stranded.
  - Insulation may be of Vulcanized India Rubber, Paper or Polyvinyl chloride.

- Estimate the main material requirement for a 750m , 415/240 V 3 phase line with 4 wires in vertical configuration. The lines emanate from a substation to feed a load of 30 kW . Take the span between two poleas 50m.The size of the conductor is ACSR 6/1 x 2.59mm (code Weasel).

Solution:

Total length of line=750m

Length of span between two poles=50m

No of poles required=750/50=15

Total = 15+1=16(including the starting pole)

- **Insulators :**
- LT shackle insulators for all the poles.(4 for each pole)=16 x 4=64
- Earth knob for carrying the earth wire=16
- D-clamps are made from MS flats of suitable sizes
- **Conductor:**
- Length of ACSR conductor = 750x4+ 5% for sag and wastage

  = 3150m = 31.5 km
- No.8 SWG GI wire for earthing=0.75x1.05 [5% for sag and wastage]
- =0.7875 km

  = 78.7kg(say 85kg including gaurding)
- **Miscellaneous:**
- Guy sets(complete)one for each end pole and 2 for 5th , 10th and 15th poles as wind guys= 6
- Guy wire=7/20 SWG =35kg
- Earthing sets:4
- Aluminium binding wire and binding tape = 1.5kg each.

Table of estimation

Sl NO	Description of materials	Qty reqd
12	Aluminium binding tape	1.5 kg
13	Aluminium paint	1 litre
14	Sundries to compete the job	Lumpsum

Design a 11kV 3 core underground cable feeder for 750 kVA transformer. The length of the feeder up to substation is 1km where the feeder gets terminated. Estimate the materials reqd.

Transformer rating = 750kVA

Voltage = 11kV

Line current = 40A

We can take the higher size 3 core 25 sqmm PILC screened armoured cable

Total length of cable =1000m

1 drum of the cable carries 250m. Therefore straight through joint boxes for three core 25 sqmm HT cables=1000/250=4

Cable for the joints and bends,5m/bend =4x5=20

On the starting pole the cable is jointed to the outdoor cable box and taken along the pole through GI pipe to the trench and they run through the trench to the transformer. the GI pipe is mounted on the pole by means of clamps.

Cable for mounting on the starting pole=10m

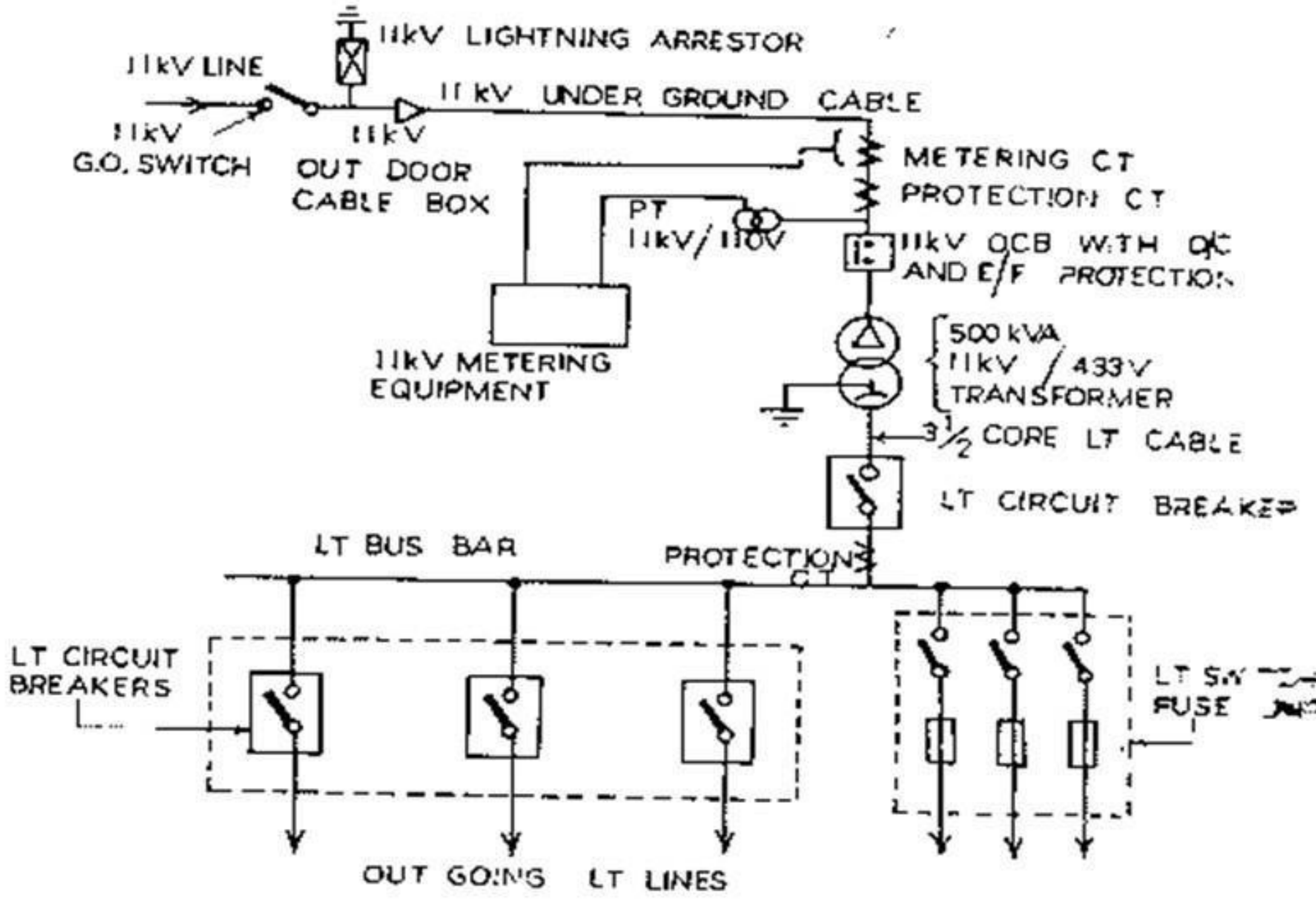
Total length of cable required=1000+20+10=1030m

Outdoor pole mounting cable end box and the joint material=1 No

Cable joints should be marked properly

Preparing the trench: The bottom of the trench is usually covered with sand. The cable is then provided with a wall of bricks on either side and on the top. The space between the cable and enclosed bricks is filled with sand. After that the trench is filled and made compact.

For crossing of roads, stone - ware pipe is to be used in trenches.



Key diagram of a 500 kVA, 11kV/415-V indoor substation.

Touch Potential

- Touch potential is the touch voltage between the energized object and the feet of a person in contact with the object. It is equal to the difference in voltage between the object and a point some distance away. The touch potential or touch voltage could be nearly the full voltage across the grounded object if that object is grounded at a point remote from the place where the person is in contact with it. For example, a crane that was grounded to the system neutral and that contacted an energized line would expose any person in contact with the crane or its uninsulated load line to a touch potential nearly equal to the full fault voltage.

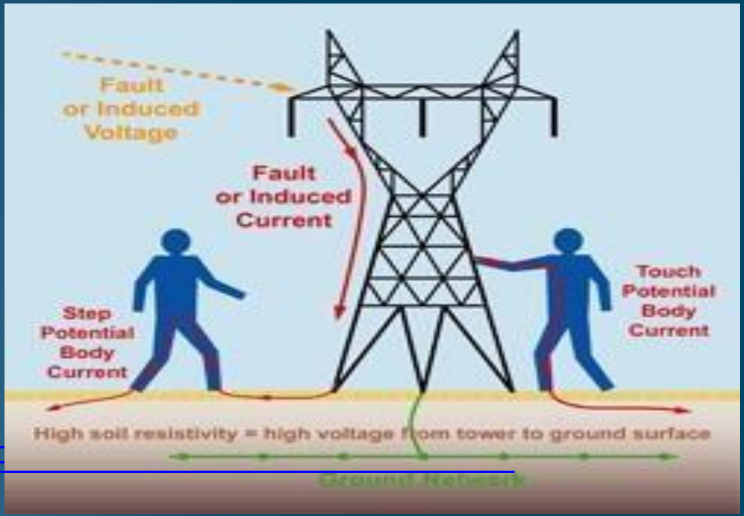
Step Potential

- Step potential is the step voltage between the feet of a person standing near an energized grounded object. It is equal to the difference

  curve, between two points at different distances from the electrode. A person could be at risk of injury during a fault simply by standing near the grounding point.

- When a fault occurs at a tower or substation, the current will enter the earth. Based on the distribution of varying resistivity in the soil (typically, a horizontally layered soil is assumed) a corresponding voltage distribution will occur. The voltage drop in the soil surrounding the grounding system can present hazards for personnel standing in the vicinity of the grounding system. In the case of Step Potentials or step voltage, electricity will flow if a difference in potential exists between the two legs of a person. Calculations must be performed that determine how great the tolerable step potentials are and then compare those results to the step voltages expected to occur at the site.

- Ref - http://www.esgroundingsolutions.com/what-is-step-and-touch-potential/



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Transfer Potential

- Any metallic object of significant length may bridge locations that may be at different potential with respect to the earth. As such, the object may transfer a voltage difference with respect to earth potential arising from passage of earth fault current to ground or flowing through earthed metallic paths. The metal objects may be fences, pipes cable sheaths and metal conductors, which are referenced to earth or safety earthed at one or more points. A transferred voltage may introduce risk of danger, damage or malfunctioning of equipment. Danger includes electric shock, fire or explosion, damage may be caused by overstressed insulation of equipment and voltages may be a noise to interfere with proper functioning of equipment.
- Ref- http://www.ground-perfect.com/transfer.htm

Ground (earth) mat

- In an electrical substation a ground (earth) mat is a mesh of conductive material installed at places where a person would stand to operate a switch or other apparatus; it is bonded t the local supporting metal structure and to the handle of the switchgear, so that the operator will not be exposed to a high differential voltage due to a fault in the substation.
- In the vicinity of electrostatic sensitive devices, a ground (earth) mat or grounding (earthing) mat is used to ground static electricity generated by people and moving equipment

- There are two types used in static control: Static Dissipative Mats, and Conductive Mats.
- A static dissipative mat that rests on a conductive surface (commonly the case in military facilities) are typically made of 3 layers (3-ply) with static dissipative vinyl layers surrounding a conductive substrate which is electrically attached to ground (earth). For commercial uses, static dissipative rubber mats are traditionally used that are made of 2 layers (2-ply) with a tough solder resistant top static dissipative layer that makes them last longer than the vinyl mats, and a conductive rubber bottom. Conductive mats are made of carbon and used only on floors for the purpose of drawing static electricity to ground as quickly as possible. Normally conductive mats are made with cushioning for standing and are referred to as "anti-fatigue" mats.
- In computer repair shops and electronics manufacturing workers must be grounded before working on devices sensitive to voltages capable of being generated by humans. For that reason static dissipative mats can be and are also used on production assembly floors as "floor runner" along the assembly line to draw static generated by people walking up and down.

- A factory has the following connected loads:
  - Machine shop – 50kW
  - Air conditioning load – 150kW
  - Furnace load – 60kW
  - Welding transformer – 50kW
  - Light and fans – 10kW
- Design an indoor substation and draw the schematic diagram showing details of switchgear and cable sizes. Assume a diversity factor of 1.5

- Connected load = 50+150+60+50+10 kW

  =320kW
- Assume efficiency of 85% and pf =0.85
- Therefore Connected load in kVA = 320/(0.85*0.85) = 442.9 kVA
- Anticipated connected load = 1.2 * 442.9 = 531.48 kVA
- Maximum demand = 531.48/1.5 = 354.32 kVA
- From databook std transformer chosen is 400 kVA, 11/.433 kV, delta star

- FL current on secondary side of transformer is 533 A – Choose 4 pole 630 A, MCCB
- Choose suitable value of cable from data book for secondary side of transformer
- Machine shop
- Anticipated connected load = 60 kW
- Maximum demand = 40 kW or 58.36 kVA
- FL current = 58.36 k/(root3*415) =77.02A
- Choose suitable cable
- Rated MCB- 3P – 100A

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- Air conditioning load
- kVA at MD = 166.09 kVA
- FL Current at MD= 231.07A
- Nearest std MCB available is 3 pole 250 A
- Choose suitable cable size
- Furnace load
- Assume pf = 0.5 and consider all day efficiency
- Input power = 60/0.5 = 120 kVA
- DF will be one and no chances of future expansion, so MD in kVA = 120 kVA
- FL current drawn at MD= 170 A
- Nearest std MCB available is 3 pole 200 A
- Choose suitable cable size

- Welding transformer
- Assume pf = 0.5, DF will be one and no chances of future expansion, so MD in kVA = 50/.5= 100 kVA
- FL current at MD = 140 A
- Nearest std MCB available is 3 pole 160 A
- Choose suitable cable size
- Lighting load
- Assume pf = 0.8, DF will be one and no chances of future expansion, so MD in kVA= 10/0.8= 12.5kVA
- FL current at MD = 20 A
- Nearest std MCB available is 4 pole 25 A
- Choose suitable cable size

DESIGN OF 11kV/433V TRANSFORMER SUBSTATION

Transformer is required if total load ≥63KW

Total Load in KVA=Total Load in KW / pf, where pf=0.8

Maximum demand in KVA=Total Load in KVA/ Diversity factor, Diversity factor=1.5

Consider 20% extra for future expansion.

Check: Transformer rating ≥ 2.5*HP rating of highest capacity motor

Use Oil cooled Transformer for outdoor substation and Resin cast Dry type transformer for indoor substation. Winding connection should be delta Star (DYN11) with star side neutral double earthed.

TRANSFORMER RATING	PRIMARY CURRENT I_1	SECONDARY CURRENT I_2	HT side DO Fuse	LT PROTECTION (To be set at I_2)	LT Cable Size (AYFY or A2XFY)	Neutral earthing conductor
KVA	Amps	Amps	Amps	Amps	mm sqr	mm sqr
63	4	84	10	100A MCCB	50	25 x 3
100	6	134	16	160A MCCB	95 or 2x50	25 x 3
160	9	214	16	250A MCCB	185 or 2x95	25 x 3
200	11	267	25	400A MCCB	300	25 x 3
250	14	333	32	400A MCCB	2x185	25 x 3
315	17	420	40	630A MCCB	2x300 or 3x185	25 x 4
400	22	533	40	630A MCCB	3x300 or 2x400	38 x 3
500	27	667	50	800A Draw out type ACB	3x400 or 4x240	25 x 6
630	34	840	63	1000A Draw out type ACB	4x400	31 x 6

SELECTION OF DO FUSE

based on primary current I_1

$$I_1 = \frac{transformer\ kVA\ rating*10^3}{\sqrt{3}*V_1}; V_1 = 11kV = 11*10^3 V$$

SELECTION OF HT CABLE

based on HT side fault MVA (minimum of 150 MVA as per KSEB Rules, usual value is 250MVA)

HT fault current $I_S = \frac{fault\ MVA*10^6}{\sqrt{3}*V_1}$

Area of cross section XLPE (A2XFY) cable = 11.11* I_S*$\sqrt{t}$

I_S=fault current in kA

=13.12kA for 250MVA

t= fault duration =1 sec

3*150 mm square XLPE Cable is selected if fault MVA is 250.

SELECTION OF CT AND PT FOR HT METERING

CT : ratio-multiple of 10 next to primary current/5A, CT burden-15VA, Class-1(1% error)

PT: ratio-11kV/110V, Burden-100VA, Class-1(1% error)

Available classes for measuring CT/PT -1,0.5,0.2,0.2s (which indicate accuracy of measurement)

SELECTION OF HT SIDE CONTROL SWITCH

For outdoor substation-630A,250MVA HT Air Break Switch

For indoor substation-630A,250MVA HT ABSFU with HRC fuse as per primary current (ref table).

HT ABSFU is also called LBS (Load Break Switch). Instead of LBS ,VCB with 2 o/c and 1 E/F relay with DC trip may be used, is economy is not a constrain.

SELECTION OF LT SIDE CONTROL SWITCH

Based on full load secondary current (I_2)

$$I_2 = \frac{transformer\ VA\ rating}{\sqrt{3} * V_2}$$

For transformer rating<400kVA: __(ref table for Ampere rating)MCCB set at I_2 having isolation duty and E/F release and standby low set earth fault release using CT at neutral conductor.

For transformer rating between 400kVA and 630kVA: __(ref table for Ampere rating) Draw out type ACB set at I_2 with 3 O/C& 1 E/F release and standby low set earth fault relay, using CT at neutral conductor.

SELECTION OF LT SIDE CABLE

Size of AYFY Cable for LT side= $\frac{full\ load\ secondary\ current\ (I_2)}{current\ density\ of\ aluminium}$, Current density of Al=0.8A/sq mm

Considering de rating factors choose 3.5 core__sq mm(ref table) AYFY Cable

SELECTION OF MSB BUS BAR SIZE

Size of Aluminium Bus Bar = $\frac{full\ load\ secondary\ current\ (I_2)}{current\ density\ of\ aluminium}$

Area	Size of Al Bus bar for phase	Size of Al Bus bar for neutral
150	25 x 6	25 x 6
240	40 x 6	25 x 6
300	50 x 6	25 x 6
390	65 x 6	32 x 6
500	50 x 10	50 x 6
600	2x 50 x 6	50 x 6
780	2x 65 x 6	65 x 6
1000	2x 50 x 10	50 x 10
1300	2x 65 x 10	65 x 10

SELECTION OF STARTERS, CABLES AND FUSES FOR INDUCTION MOTORS

Motor full load current (for 1 phase motors) = HP*746/240*PF*efficiency

Motor full load current (for 3 phase motors) = HP*746/$\sqrt{3} * 415$*PF*efficiency

= HP *1.5(efficiency=85%,pf=.8)

Motor starting current=K * Full load current

MOTOR RATING	TYPE OF STARTER	Value of K
Less than 5HP	DOL	2.5
5 to 100HP	STAR DELTA	1.5
100 to 250HP	AUTO TRANSFORMER	1.5

- An industry consists of following loads-
  - 7.5kW, 3 phase squirrel cage induction motor – 1 No
  - 10 kW, 3 phase squirrel cage induction motor – 2 No
  - 22.2 kW, 3 phase squirrel cage induction motor – 1 No
  - Power sockets – 15 No.s
  - Lighting Loads – 40 Nos of 2x28 W LED lamps
  - Exhaust fans, 300mm, 1420 rpm – 4No.s
- **Design the electrical system for the industry**, if the industry is located in a village and also determine :

i. Transformer capacity required and type off substation.

ii. Draw the single line diagram showing details of cable sizes, starters, switchgears etc of the substation, distribution boards (power and lighting)

Assume DF – 1.5

Selection of Transformer

Total motor load (o/p) $= 7.5\times1 + 10\times2 + 22.2\times1$

$= 49.7\,kw$

Total input Power to motors $= \dfrac{o/p}{\eta}$

$= \dfrac{49.7}{.8}$ (Assume efficiency of 80%)

$= 62.125\,kw$

P.S LED Exhaust fan

Total connected load $= 62.125 + \dfrac{15\times1000}{1000} + \dfrac{40\times2\times28}{1000} + \dfrac{4\times45}{1000}$

$= 79.545\,kw$

Total connected load in KVA $= \dfrac{79.545}{.8}$ (Assume Pf = .8)

$= 99.43\,KVA.$

Max demand in KVA $= \dfrac{\text{C.L in KVA}}{\text{Diversity factor}}$

$= \dfrac{99.43}{1.5}$ (Assume D.f = 1.5)

$= 66.28$ KVA.

Considering 20% extra for future expansion

$\Rightarrow 66.28 \times 1.2$

$\Rightarrow 79.54$ KVA

Select 100 KVA 11kV/433V, Resin Cast dry type transformer, DYN 11

Indoor Substation Selected.

Selection of DO fuse

Based on primary current of transformer.

$$I_1 = \frac{S}{\sqrt{3}\, V_1} = \frac{100 \times 10^3}{\sqrt{3} \times 11 \times 10^3} = 5.25\,A.$$

But as per table (Page 25) 16A DO fuse is selected.

Selection of HT Side Cable

Based on fault MVA. (Assume fault MVA = 250 MVA, minimum specified by KSEB)

$V_1 = 11\,kV$

$$I_S = \frac{\text{fault MVA}}{\sqrt{3}\, V_1} = \frac{250 \times 10^6}{\sqrt{3} \times 11 \times 10^3}$$

$$= 13.12\,kA.$$

$$\text{Size of XLPE Cable} = 11.1 \times I_S \times \sqrt{t}$$

$t = 1\,sec$

$$= 145\,mm^2$$

3 core, 150 mm² XLPE cable is selected.

Selection of LT Side Control Switch

Based on secondary current of Transformer

$$I_2 = \frac{S}{\sqrt{3}\,V_2} = \frac{100 \times 10^3}{\sqrt{3} \times 433} = 133.3A$$

Choose 160A MCCB set at 134A (having isolation duty & E/f release and stand by low set E/f release using CT at neutral earthing conductor)

Selection of LT Side CABLE

Size of AYFY cable for LT side = $\frac{I_2}{\text{Current density of Al}}$

$= \frac{133.3}{.8 \text{ A/mm}^2}$

$= 166.6 \text{ mm}^2$

(ref. Page 23) ⇒ select 2×50 mm² 3.5 core AYFY Cable

[100mm² area is sufficient due to derating factors)

Selection of MSB Bus bar Size

Size of Al bus bar = $\frac{I_2}{\text{Current density of Al}} = 166.6 \text{ mm}^2$

(ref. Page 26) 38.1×6.35 Al bus bar (3 Nos) ⇒ for phase &

25.4×6.35 Al bus bar (1 No) → for Neutral.

Motor Calculation

Assume efficiency $\eta = 88\%$, P.f = .8. (Ref. page 21)

Motor rating (Kw)	Rated current $I = \frac{Kw \times 10^3}{\sqrt{3} \times 415 \times Pf \times \eta}$	Starter	Starting current $I_s = I \times K$	Protection	Cable Size (Al)	Earthing Cond.	Capacitors for pf correction
22.2 kw	45. A	S-D (k=1.5)	68 A	100A MCCB set 63A	25 mm²	6 SWG	8 KVAR
10 kw	20. A	S-D	30 A	63A SFU with 32A fuse	10 mm²	10 SWG	5 KVAR
7.5 kw	15. A	S-D	23 A	32A SFU with 25A fuse	6 mm²	10 SWG	4 KVAR

Design of SSB (Sub Switch Board)

2

Load on SSB other than motor $= 15 + \frac{40 \times 2 \times 25}{1000} + \frac{4 \times 45}{1000}$

$= 17.4\,kw$

$I = \frac{17.4 \times 10^3}{\sqrt{3} \times 415 \times .8} = 30.25A$

63A MCCB set at 32A. is used.

cable ⇒ 25 mm² XLPE (Page 43)

busbar $= \frac{54}{.8} = 68\,mm^2$ ⇒ $25 \times 6\,mm^2$ Selected

Design of PDB

Number of Power Sockets = 15

2 pp per Subckt, So 8 Subckts

A 3ϕ, 4way DB can be selected as it can accomodate 12 Subckts.

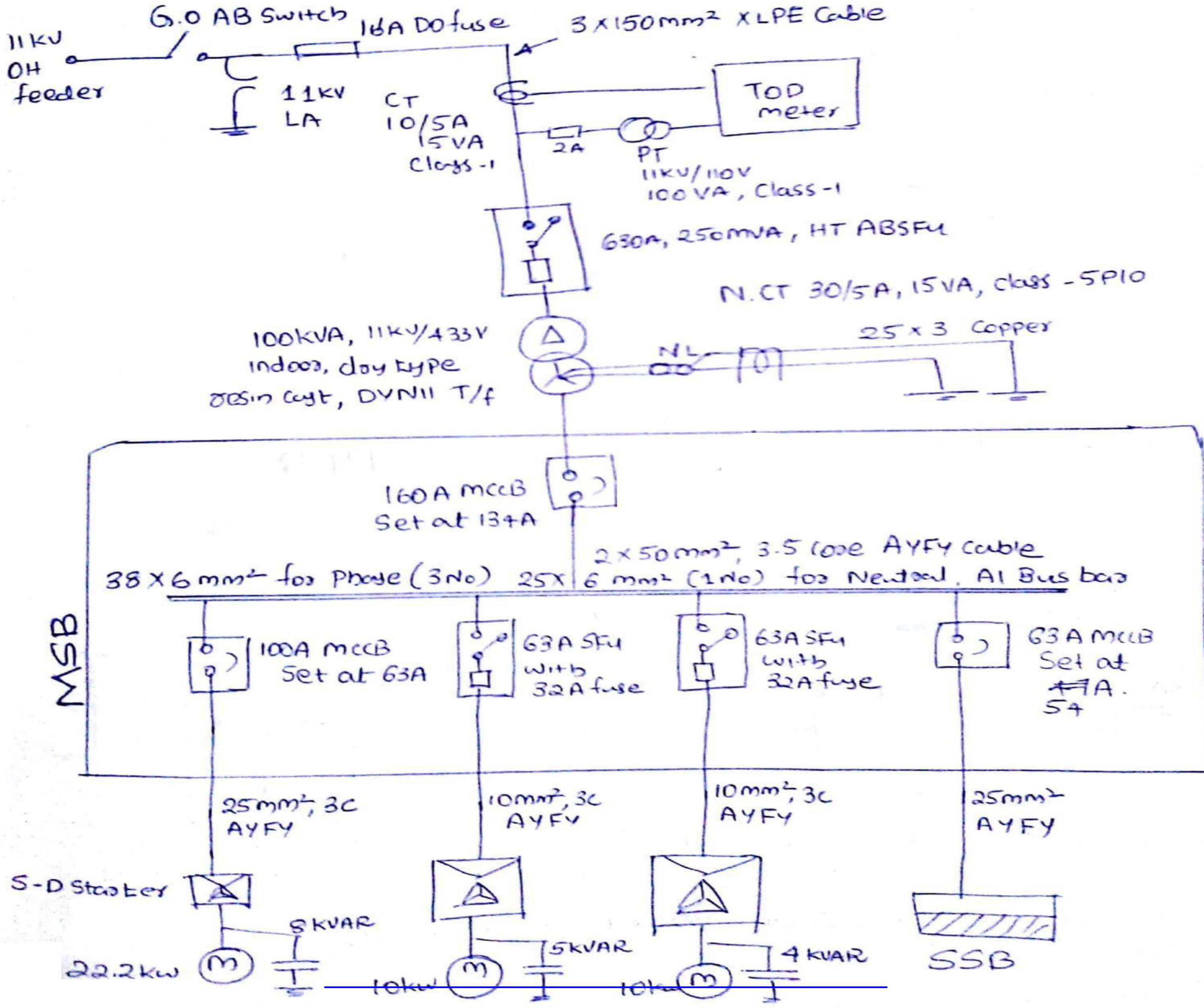
Design of LDB

No of light points = 44.

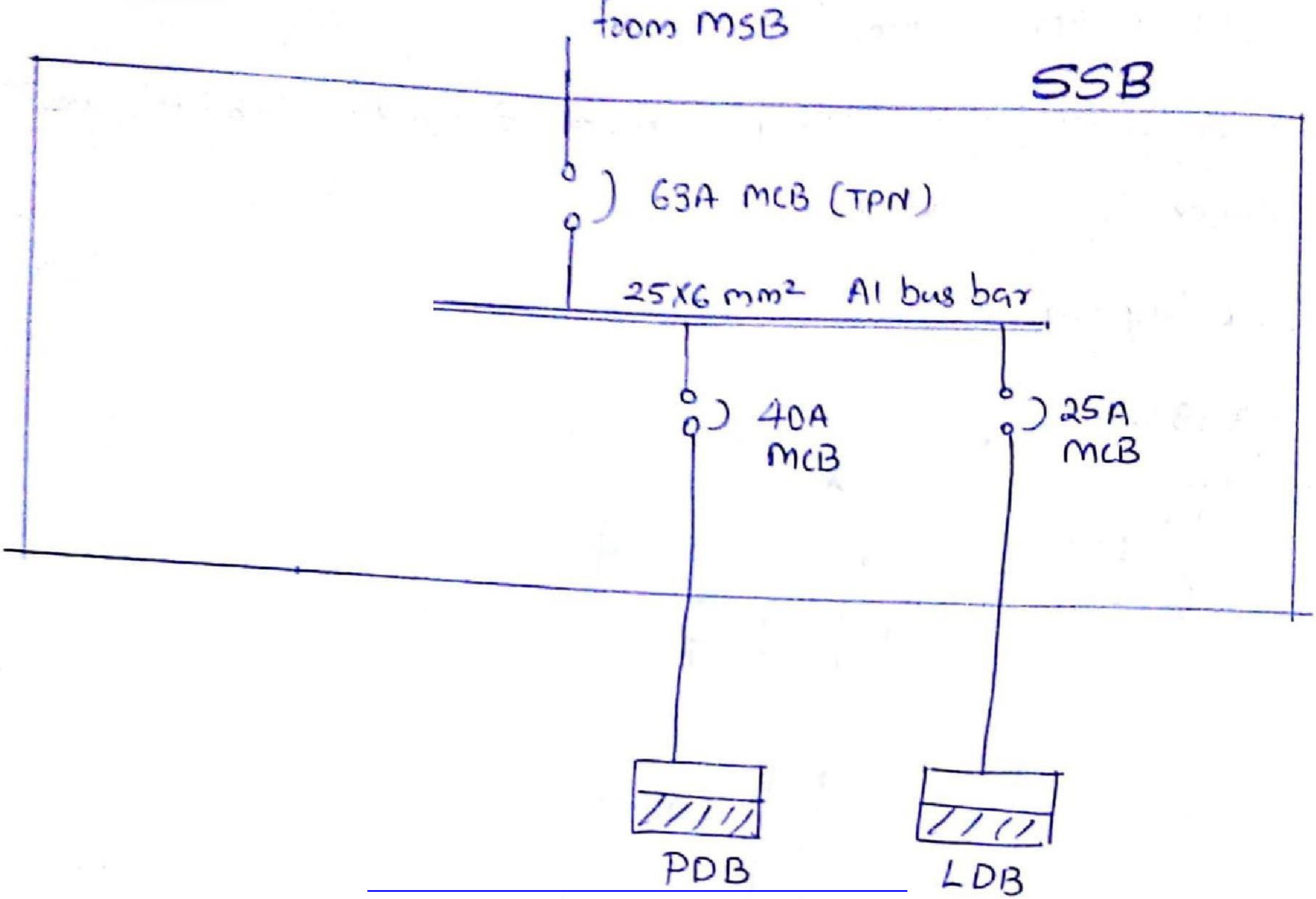
assuming 6 points in a lighting Sub ckt 8 lighting Sub ckts are there.

3ϕ, 4way, DB is Selected.

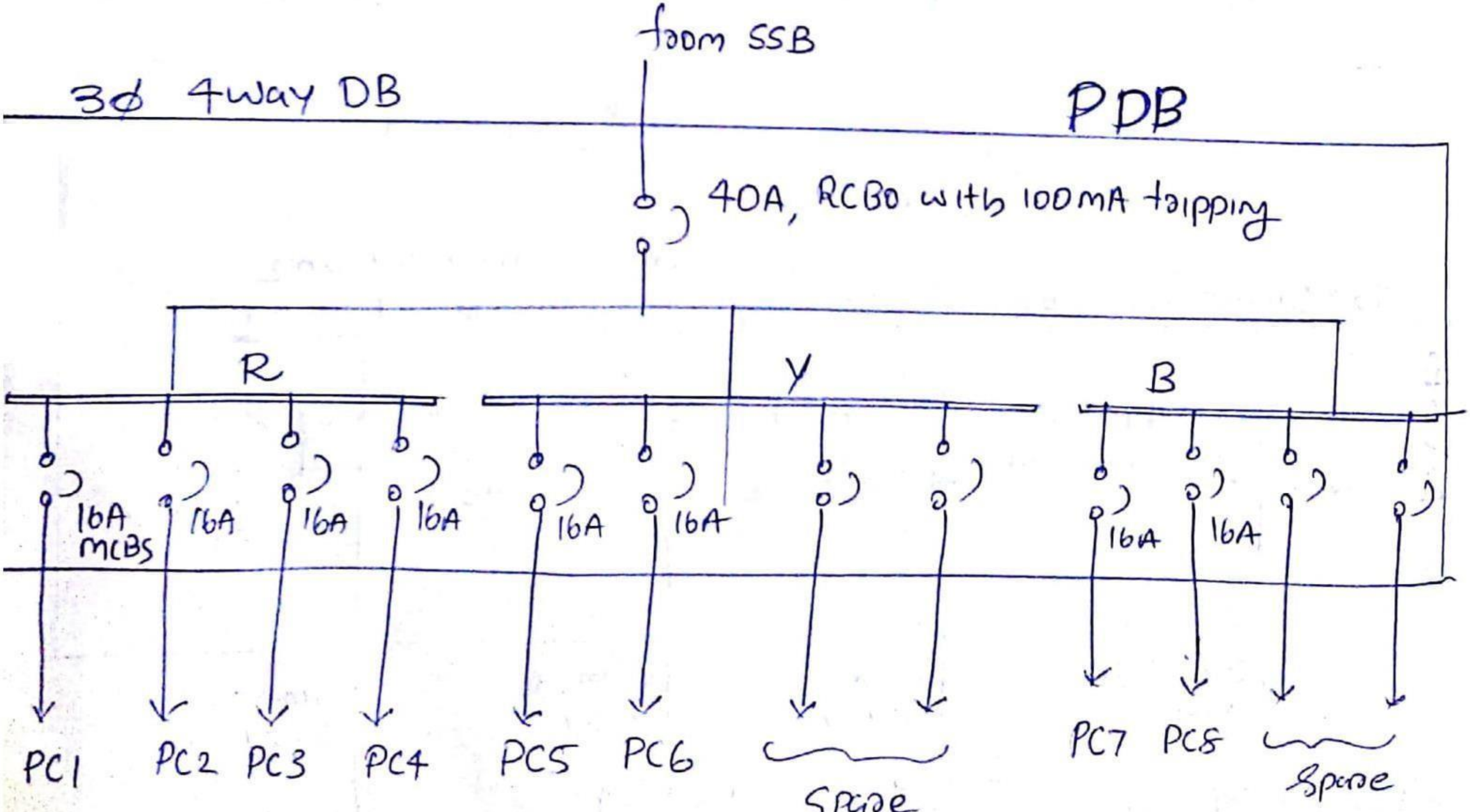
Single Line Digram



Subswitch board

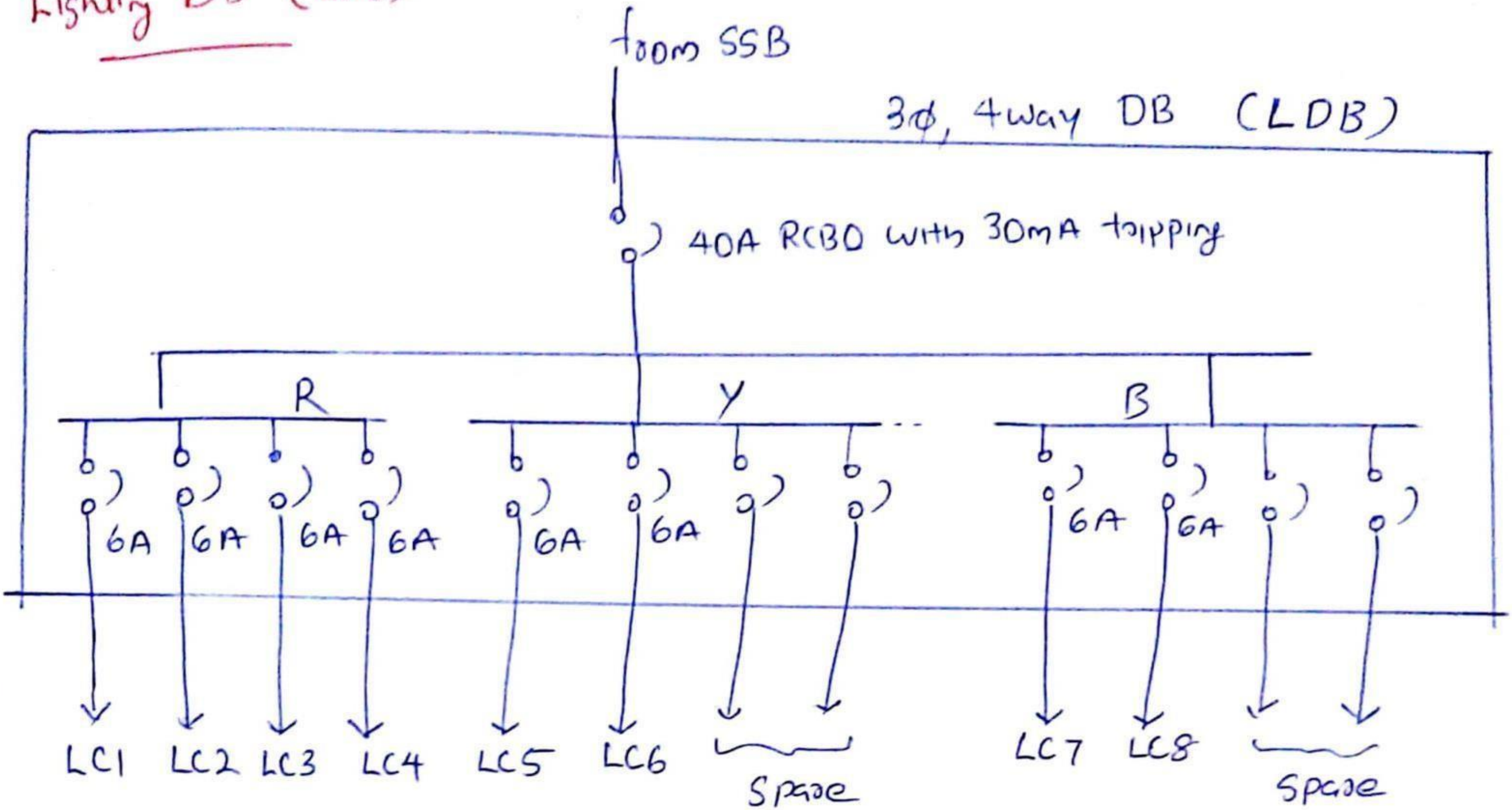


Power DB (PDB)



Cable Size → 2.5mm² for all Power Circuits

Lighting DB (LDB)



Cable Size ⇒ 1.5mm2 for all Light Sub Circuits.

REFERENCES

- Electrical Design Estimating and Costing – K B Raina, S K Battacharya
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EE405
MODULE 5
DESIGN OF ILLUMINATION SYSTEMS

BASIC DEFINITIONS

- **Light : T**hat part of radiant energy from a hot body which produce visual sensation on human eye
- **Luminous intensity (I) :**The power or strength of the source of light is known as **luminous intensity (I)** and is measured in **Candela**.
- **Luminous Flux (L)** : From the light source, energy is radiated in the form of light waves. This flow of light from the source is known as **Luminous Flux (L)** and unit is **lumen**
- **Lumen :** One lumen is the luminous flux emitted per unit solid angle from a point source of one candle power

- **Illuminance (E)** : When the light emitted by a source falls on a surface, it is illuminated. Illuminance (E) is the amount of light falling on a surface measured in **lux**.
    - 1lux=lumen/area= 1lumen/m^2
- **Luminaire** (light fitting): It is the apparatus which distributes, filters or transforms the light given by a lamp. It includes all the items necessary for fixing and protecting the lamps and for connecting them to the supply circuit.

- **Candle power**: Number of lumens given out by a source per unit solid angle in a given direction is called candle power
    - Total flux= CP*4π lumens
    - CP is the unit of luminous intensity

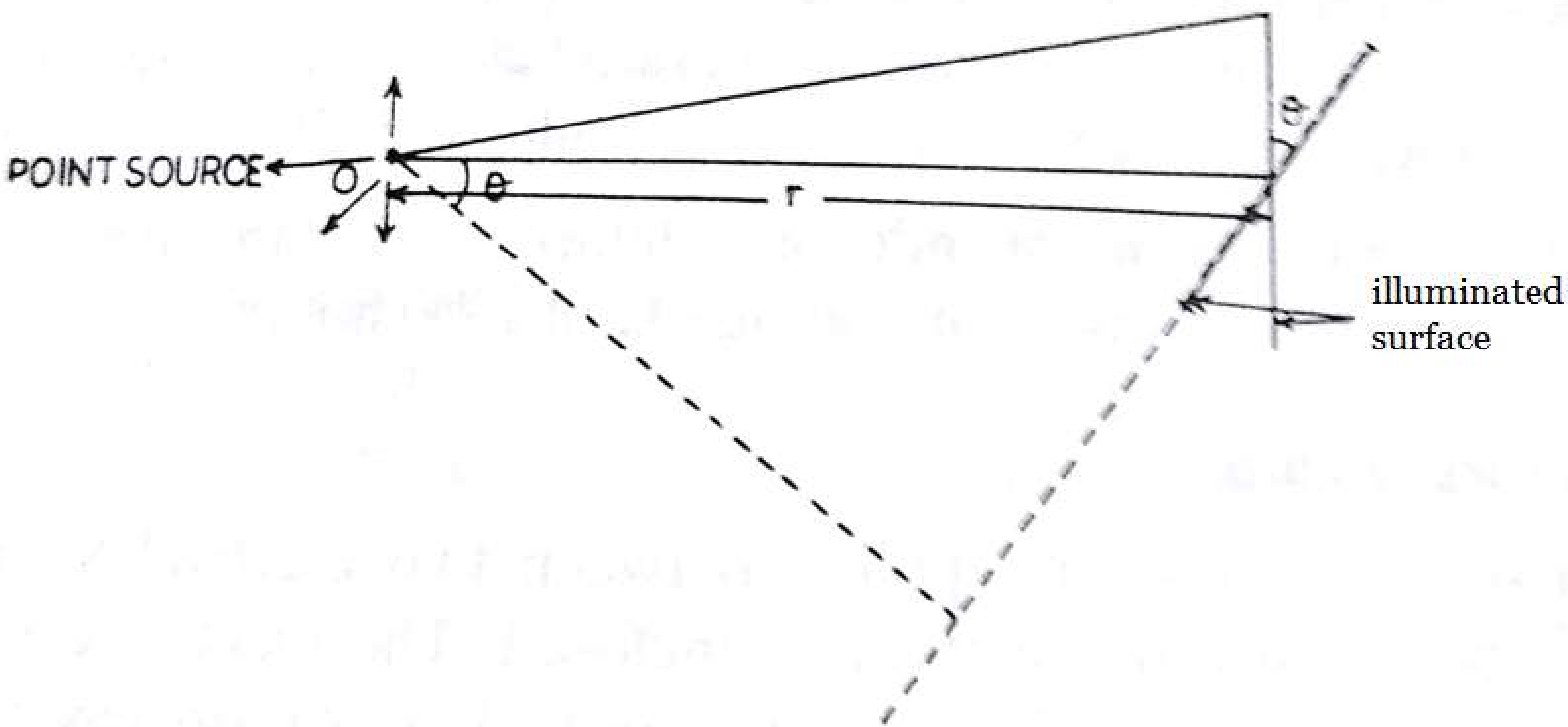
LAWS OF ILLUMINATION

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.
    - $E = I/r^2$
    - I= luminous intensity
    - E- illumination of the surface
    - r- 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 r^2.
    - $E = I \cos \theta / r^2$
- These laws are applicable only to point sources(no reflecting surfaces)


POINT SOURCE
O
θ
r
φ
illuminated
surface

DESIGN CONSIDERATIONS FOR A GOOD LIGHTING SCHEME

- **Intensity of illumination**
  - Intensity of illumination required for different types of work differ from place to place.
  - Refer Table : 4,5,6,7,8 in hand book.
- **Selection of lamps or selection of luminaires**
  - The choice of lamps for different types of application differs
  - Fluorescent lamps and tungsten filament 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 illuminatiom required, the type of luminaire is decided

- **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.

- CU depends on the following factors
  - Lumen output of the fitting
  - Shape of the room
  - Reflection factors of walls and ceilings
  - Height of the ceiling
  - Arrangement of the fittings etc

- **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. Also distance between lighting fitting should not exceed 1.5 times the mounting height

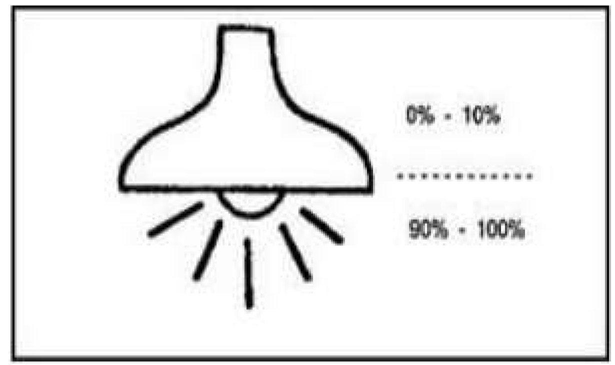
- **Condition of use**
  - For different types of buildings, the condition of use of light varies.
  - Dust and dirt particles of the surroundings get deposited on the light fitting and hence deteriorate the lamp efficiency.
  - If regular periodic cleaning is adopted and assuming good atmospheric condition, the maintenance factor (MF) is taken as 0.8 , but for dirty and dusty atmosphere, the MF is taken as 0.4.
- **Depreciation factor (DF) =1/Maintenance Factor**

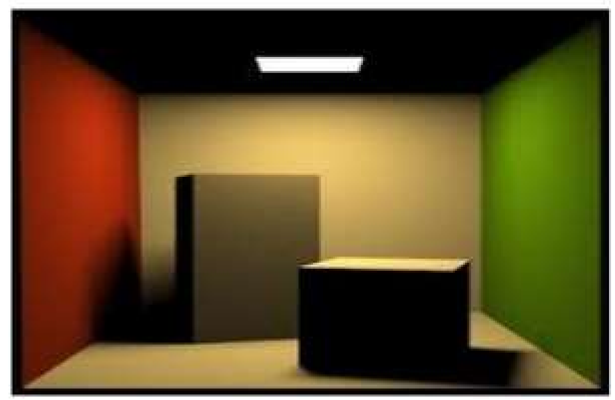
TYPES/CLASSIFICATION OF LUMINAIRE OR LIGHTING ARRANGEMENTS

- Classified according to proportion of light directed upward or downward from the fittings
  - Direct
  - Indirect
  - Semi direct
  - Semi indirect
  - General diffusing

DIRECT LIGHTING

- Commonly used type of lighting scheme
- More than 90 percent of total light falls directly on the working plane with the help of deep reflectors
- Though it is most efficient it causes hard shadows and glare
- It is mainly used for industrial and general out-door lighting





SEMI DIRECT LIGHTING

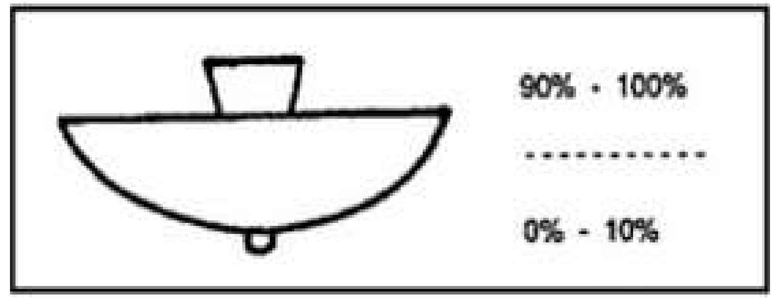
- 60 to 90 percent of the total light flux is made to fall downwards directly, remaining light is used to illuminate the ceiling and walls
- Best suited to rooms with high ceilings where a high level of uniformally distributed illumination is desirable
- Good for stairways, corridors, and storage areas

INDIRECT LIGHTING

- More than 90 percent of total light flux is thrown upwards to the ceiling
- Resulting illumination is softer and more diffused, the shadows are less prominent and the appearance of the room is much improved
- Used for decoration purposes in cinemas theatres and hotels

SEMI INDIRECT LIGHTING

- Most of the light produced by the fittings is directed upwards and a certain amount of light is directed downwards
- Soft shadows and glare free
- Used for indoor light decoration purposes



GENERAL DIFFUSING

- Light produced is equally distributed upwards and downwards

LIGHTING DISTRIBUTION

CLASSIFICATION	% UPWARDS	%DOWNWARDS
DIRECT	0-10	90-100
INDIRECT	90-100	0-10
SEMI DIRECT	10-40	60-90
SEMI INDIRECT	60-90	10-40
GENERAL DIFFUSING	40-60	40-60

SELECTION OF LIGHT SOURCES

- The choice of source for public lighting is guided by the following considerations
  - Luminous flux
  - Economy
  - Dimensions of the light sources
  - Colour characteristics
- The sources normally used in public lighting are
  - Incandescent lamps
  - Fluorescent lamp
  - High Intensity Discharge lamp
  - Mercury vapour lamps
  - Metal halide lamps
  - High pressure sodium vapour lamps
  - Low pressure sodium vapour lamps

Incandescent lamps

- Produce light by heating tungsten filament
- Lowest efficacy (lumens/watt)
- Shortest life
- Limited in practice
- Used for residential streets
- Initial cost is low
- Most common types are Pear shaped, reflector type and tungsten halogen lamp (quartz)

- Energy saving incandescent lamps
  - Krypton filled lamps
    - Use Krypton instead of Argon inside the bulb
    - Consume 5-10% less wattage compared to normal incandescent lamps
    - Available in the range 36-143W
  - Ellipsoidal reflector lamps
    - Works on the principle of elliptical reflector such that when a point source is placed at first focal point of an elliptical reflector, all reflected lights emerge through the second focal point
    - Reduces wastage of light

Fluorescent lamps

- Produce light by creating an arc between two electrodes in atmosphere of low pressure mercury vapour and some inert gas in a glass tube
- Requires a ballast to initiate an arc in the tube
- Efficient than incandescent lamps (50-70 lumens/watt)
- Energy efficient fluorescent lamps are CFL
  - CFL- A 9W CFL can replace 60W incandescent lamp saving 80% of energy
  - Life of CFL- 7500 hrs
  - Small luminaire, compact and preferred for domestic applications

High Intensity Discharge Lamps (HID)

- Used to designate 3 distinct type of lamp- mercury vapour, metal halide and high pressure sodium
- Produce light by establishing an arc between two electrodes, the electrodes being few centimetres apart enclosed in a transparent arc tube
- Arc tube is then enclosed in an outer bulb that is filled with nitrogen and an inert gas

Mercury vapour lamps (MV)

- Outer tube is filled with nitrogen and inner tube contains mercury and argon gas
- Consists of starting electrode and main electrode
- When voltage is applied to starting electrode, an argon arc is produced by main electrodes adjacent to it which heats up and vaporises mercury
- These ionised mercury atoms decrease the resistance between the main electrodes and produces arc to strike
- Available from 40-1000W

Metal Halide lamps (MH)

- Contains metallic additives in addition to argon and mercury in the arc tube which produces different colour rendering in the overall light output
- Higher efficacy (66-100 lumens/watt) than metal vapour lamps
- Better colour rendering

High pressure sodium vapour lamps (HPS)

- Produce energy in all wavelengths
- Light produced is golden white colour
- Has highest efficacy of all lamps (60-127 lumens/watt)
- Available in 35-1000W size
- Life is 24000 hours
- Best energy savers in HID lamps

Low pressure sodium vapour lamps

- 183 lumens/watt
- Monochromatic light output (yellow)
- Life of 18000 hours
- Used in street lighting and outdoor area & security lighting

Factors considered for choice of luminaire

- Nature and power of the source
- Nature of optical arrangements and light distribution which they provide
- Light output ratio
- Whether the luminaire is open or closed type
- Resistance to heat, soiling and corrosion
- Protection against collection of dust and insects
- Resistance to atmospheric conditions
- Ease of installation and maintenance
- Presence or absence of auxiliaries
- Fixing arrangements, weight and area exposed to wind pressure

METHODS OF LIGHTING CALCULATIONS

- Watts per square meter method
- **Average lumen or light flux method**
- Point to point method or inverse square law method

1. <u>Watts per square meter method</u>

- This is principally a “rule of thumb” method
- It consists in making an allowance of watts per square meter of area to be illuminated according to the illumination desired on the assumption of an average figure of overall efficiency of the system

2. Average lumen method

- Simplified way of calculating an average uniform illuminance level on a plane in interiors
- Takes into account the effects of surface reflectance
- Simplified and accurate method of quantity evaluation for interiors
- This method is developed from the basic definition of lux, which states that one lux is the illuminance on a surface of one square metre having a light flux of one lumen
- Illuminance $E = L/A$ where L = lumens produced by all the luminaires in room and A = area in sq.m.

- In reality, all the luminous flux generated by the lamps will not fall on the work plane
- Factors like luminaire candle power distribution, efficiency, room size and shape and luminaire height, will affect the total number of lumens reaching the work plane
- The formula is multiplied by a coefficient of utilisation (CU) to take into consideration all above factors. Therefore, $E=(L*CU)/A$

- The luminaire, lamp and even the surface will accumulate dust over a period of time and the lamp lumen output will depreciate with time
- To obtain the maintained illuminance level, the formula now must be multiplied by a “light loss factor(LLF) to account for the depreciation in light output
- E=(L*CU*LLF)/A

- The formula can be modified as

  E=(Ln*N*CU*LLF)/A where Ln, = Initial lumen output per luminaire and N= total number of luminaires

  - N=(A*E)/(Ln*Cu*LLF)
- From the above, it is obvious that for a given level of illuminance and area, the only means or reducing the number of luminaires is by using the highest values of Ln, CU and LLF
- The lower the number of luminaires, the less the power consumption.

LIGHT LOSS FACTOR (LLF)

- Periodic schedule and appropriate maintenance is very essential in maintaining the initial lighting level
- An LLF would not be required if light output remains constant throughout the useful life.
- Inherent light loss characteristics of the luminaire and unfavourable ambient conditions will force the net output to deteriorate with time
- An LLF is introduced in lighting calculations to make up for expected loss of light in the lighting system

- The various factors that contribute to light loss are of two types.
  - Recoverable
  - Non-recoverable.
- **The recoverable factors include**:
  - Luminaire dirt depreciation (LDD)
  - Room surface dirt depreciation (RSDD)
  - Lamp lumen depreciation (LLD) and
  - Lamp burn out (LBO)

Luminaire dirt depreciation (LDD)

- The greatest loss of light output is due to the dirt accumulation on lamps and luminaire reflecting surface
- Proper selection of maintenance is essential
  - Air-conditioned spaces - Once in two years
  - Non A/C offices, School, etc - Once in a year
  - Industrial areas- 3-6 times a year
  - Food preparation area - every week

Room surface dirt depreciation (RSDD)

- This factor takes into account the dirt or dust accumulation on surfaces
- A proper schedule for cleaning the reflecting surface must be followed to maintain the reflectance

Lamp lumen depreciation and lamp burn out (LLD and LBO)

- Lamp lumen depreciation is an inherent characteristic of all lamps.
- Two types
  - Spot re-lamping
  - Group re-lamping.
- Spot re-lamping refers to changing of lamps as and when a lamp burns out
- Group re-lamping is the process of replacing all the lamps in an installation after the useful life period of the lamps irrespective of the fact whether the lamps are in working condition or not

- **Non-Recoverable factors**

These include:

  - Luminaire ambient temperature (LAT)
  - Voltage variation (VV)
  - Ballast factor (BF)
  - Luminaire surface depreciation (LSD)

- These factors present those conditions of a lighting system that reduce the light output, where nothing in terms of periodic maintenance can recover the losses

- **Luminaire ambient temperature (LAT)**
- A variation in the ambient temperature does not have much effect on the incandescent and HID lamps
- Fluorescents are affected by a change in ambient temperature
- Fluorescent produces a peak output at about 25 °C
- **Voltage variation factor (VV)**
- For incandescent lamps a variation of 1% voltage may cause as much as 3% variation in light output
- For HID and fluorescents also variation in voltage affects their output

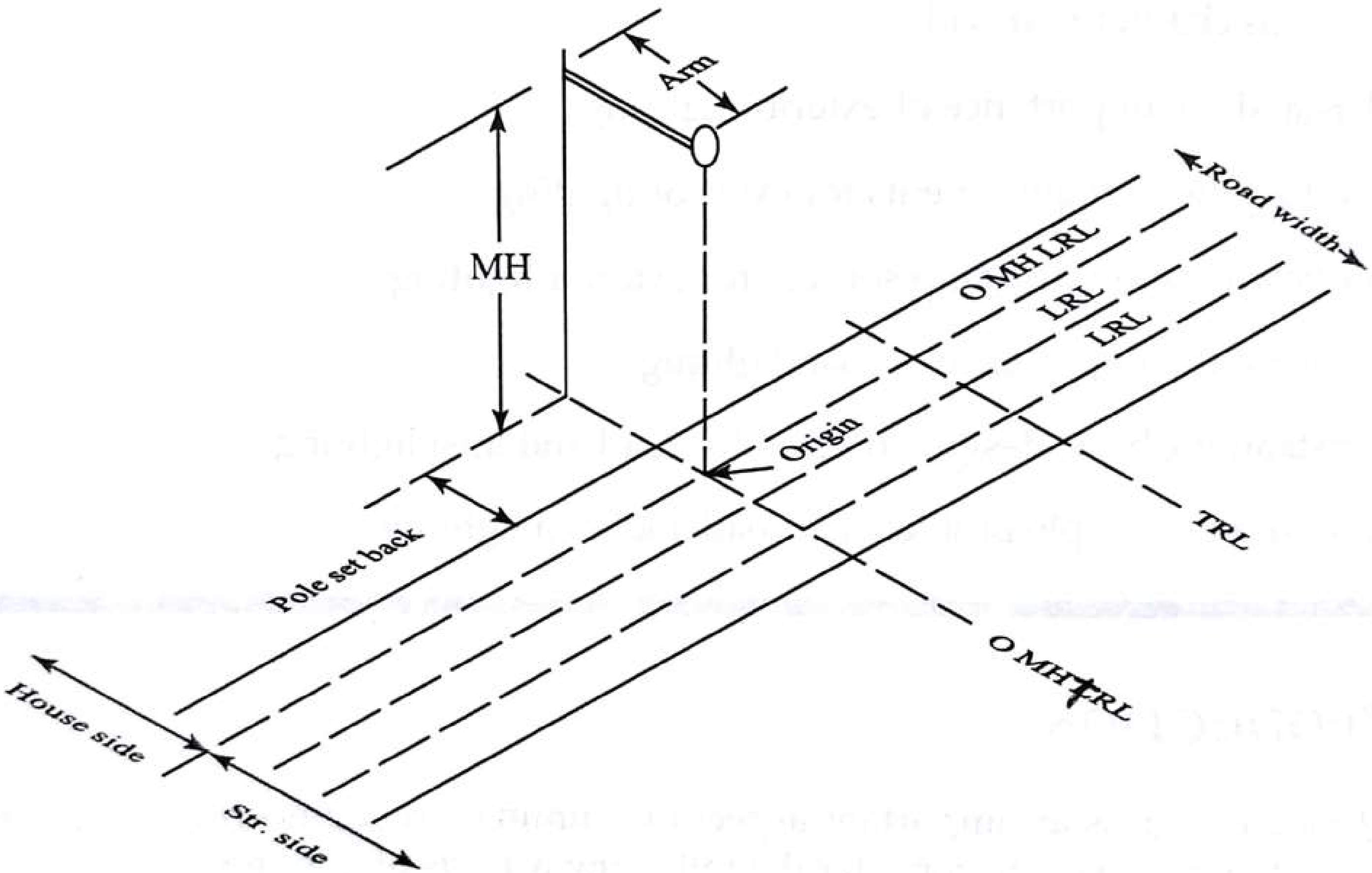
- **Ballast Factor (BF)**
- Ratio of light output by a commercial ballast to that by reference ballast
- **Luminaire surface depreciation factor (LSD)**
- Changes in the various components used in the manufacture of luminaires can cause reduction in the light output
- Due to aging, polished surface will have reduced reflectance
- All four non-recoverable factors will depreciate the output permanently and nothing can be done to recover them

EXTERIOR LIGHTING

- Lighting design for exterior application will have to consider the following aspects:-
- Functional lighting-Road lighting, yard lighting (area lighting), flood lighting
- Decorative lighting- Monumental lighting, façade lighting and special lighting for festivals

General consideration

- Primary aim of exterior lighting :- Safety and Security
- Luminaires used for exterior lighting can be classified into :-
  - **Static luminaries**-Luminaries fixed on top of a pole, to produce light in a predetermined manner.
  - **Adjustable luminaries** - Luminaries mounted with adjustable brackets are referred to as adjustable luminaries. Mostly used for flood lighting and area lighting


Arm
MH
Road width
O MH LRL
LRL
LRL
Origin
TRL
Pole set back
O MH TRL
House side
Str. side

Photometric Report

- Luminaries used for external lighting are always supplied with a photometric report by the manufactures.
- The most important features are:-
- Luminaire identification and depreciation
- Luminarie Classification
- Utilisation Curve

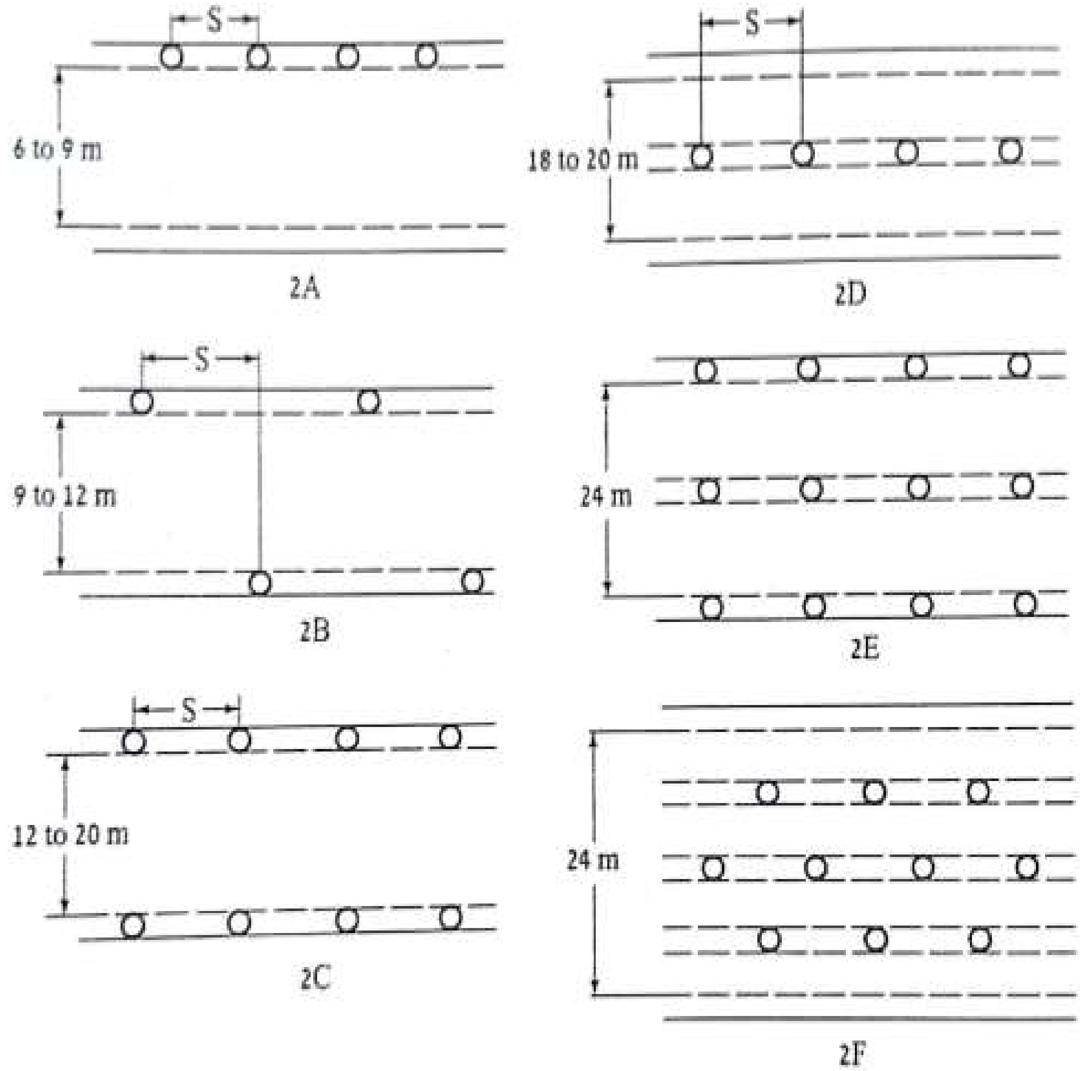
ROAD LIGHTING

- Main requirement is to provide driver of a moving vehicle the exact information continuously and accurately from the road
- Objects should be present with clear contrasts with their surroundings
- Dangerous objects shall be seen and recognized in time
- The scene should have adequate brightness, at the same time it should not appear to be so bright to cause discomfort or disability
- The patterns created by the road lights shall not be confusing to the driver

Classification of roads

- Classified based on the volume of traffic, speed and composition of the traffic
- For roads with width ranging from 6-9m, lamp posts are arranged on side of the roads
- For roads with width 9-12m, zig zag spacing is recommended
- For roads with width 12-20m, face to face spacing of lamp posts on both sides of the road becomes necessary
- For multi-lane roads, spacing of lamp posts on the median or on the median plus the curbs on both sides may have to be chosen depending upon the number of the lanes of traffic, planned on the road

Group	Description
A1	Very important roads with rapid and dense traffic, where safety, speed of traffic and comfort to drivers are the only consideration
A2	Other main roads with considerable mixed traffic like main city streets, arterial roads etc.
B1	Secondary roads of considerable traffic such as principal local traffic routes, shopping streets etc.
B2	Secondary roads with comparatively light traffic
C	Residential and unclassified roads not included in group A and B
D	Grade separated junctions, bridges and elevated roads
E	Town and city centres and areas of civic importance
F	Roads with special requirements
G	Road tunnels


S
6 to 9 m
2A
S
18 to 20 m
2D
S
9 to 12 m
2B
24 m
2E
S
12 to 20 m
2C
24 m
2F

Selection of light sources

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

Design considerations

- 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)

- It is necessary that the illuminance directly under the luminaire be the same as the midway between the poles
- 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

ELECTRICAL INSTALLATIONS IN HIGH RISE BUILDINGS

- Buildings of height 15m and above are treated as high rise buildings

Transformer Installations in high rise buildings

  - If the building is a residential one, dry type transformers shall be installed inside the building (indoor substation) at ground level itself
  - In corporation areas, outdoor transformer with overhead lines is not allowed
  - There should not be any inflammable materials stored in the transformer room
  - The walls, ceilings and other fittings shall be fire resistant
  - The transformer shall be installed in clean and dry locations
  - Air Break SFU or VCB is used depending on the capacity of the transformer. Oil filled switch gears shall be avoided

Installation of Standby Generator

- **The minimum rating of the generator selected should be able to feed at least 20 % of the total connected load**
- The following points shall also be noted
  - A generator shall be installed at the periphery of the building
  - Fuel tank of the generator shall be kept outside the building
  - Sufficient clearances and ventilations shall be provided with respect to walls and ceilings
  - Exhaust pipe of DG sets shall be brought above roof top for venting out smoke
  - Sound proof arrangements shall be provided to DG sets

RECREATIONAL/ ASSEMBLY BUILDINGS

- Recreational/ Assembly buildings are those which are used for recreational, amusement, social or religious activities.
- It also includes cinema hall, theatre, auditorium etc.
- **Control of Circuits**
  - **Power Load -** Stage machinery**,** Ventilation and air conditioning installation**,** lifts etc
  - **(b) Lighting Loads -** General lighting of outdoor, corridors and stairs and auditorium and in the rear of the assembly hall for stage, workplace, dressing rooms, workshops and store houses
  - **(c) Emergency supply -** cabin, passageways, stairways, 'EXITS' and parts of the building open to the public

- **Substation Facility**
  - The assembly building must have its own electrical substation. The location of substation is decided based on the following aspects.
  - The substation should be located away from the area
  - The substation should not be in the way of people and fire fighting vehicles and personnel
  - It is desirable that the transformer which contains a large quantity of oil is not located in the basement as there is risk of fire

Miscellaneous Provisions

(i) Emergency Supply

– Standby supply either from generator or battery system shall be installed or the generator set shall be installed in the ground floor.

(ii) Stage lighting

– The stage may require a number of spot lights, border lights, projectors etc for illumination

– Sufficient number of lights and power sockets shall be fitted in the stage to feed such loads.

(iii) Group control

– Group control facility inside auditorium

– Good view of the stage in order to follow the performance inside stage

(iv) Audio visual system

– Provision for the installation of amplifying and sound distribution systems shall be provided in the stage and these equipments must be earthed independently

EE405
MODULE 6

SOLAR PV SYSTEMS FOR HOUSEHOLD APPLICATIONS

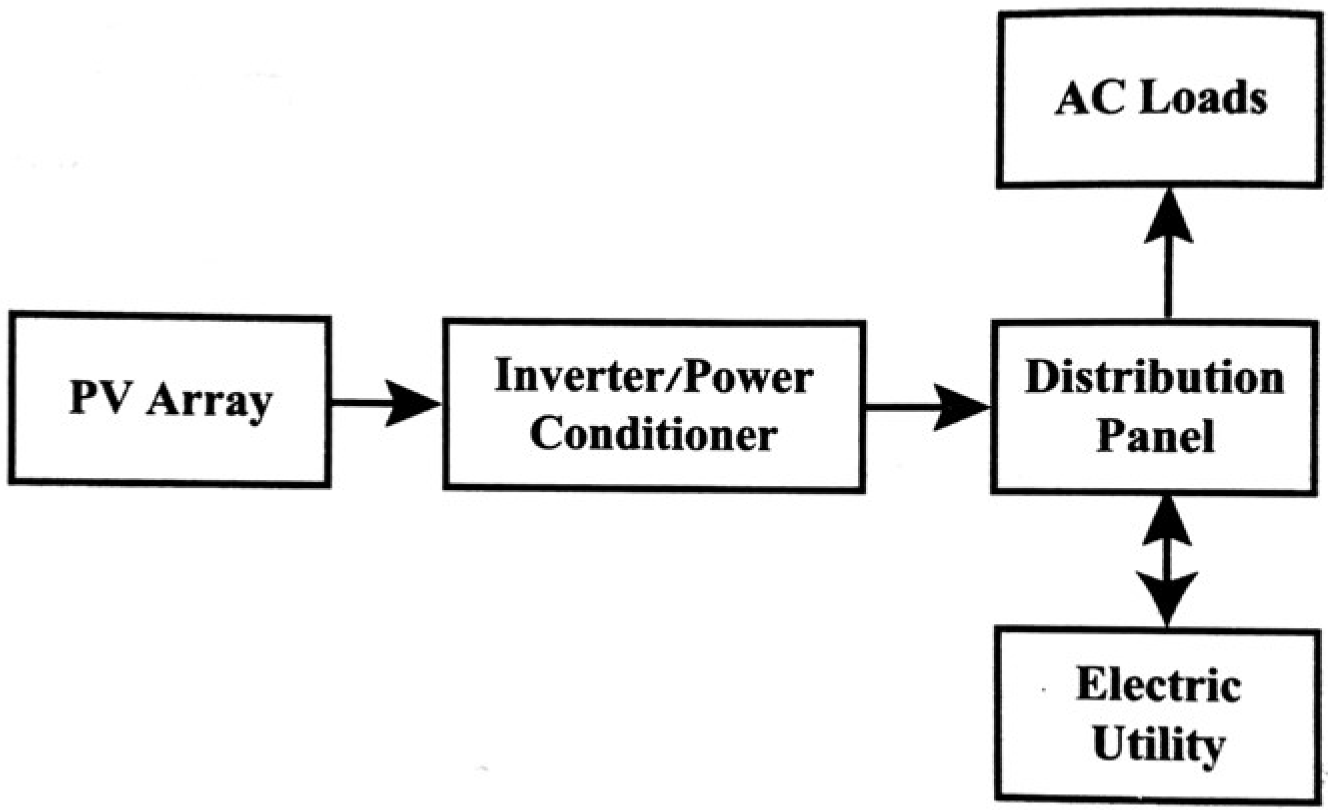
INTRODUCTION

- PV systems – generate electricity directly from sunlight
- Electricity can be used directly or can be stored in batteries/fed to grid
- Most suitable for homes with a flat roof or with slanting roof facing south

Types of PV electrical systems

- 2 general types of design for PV power systems are
  - Grid connected or utility interactive systems
  - Stand-alone or off grid PV systems

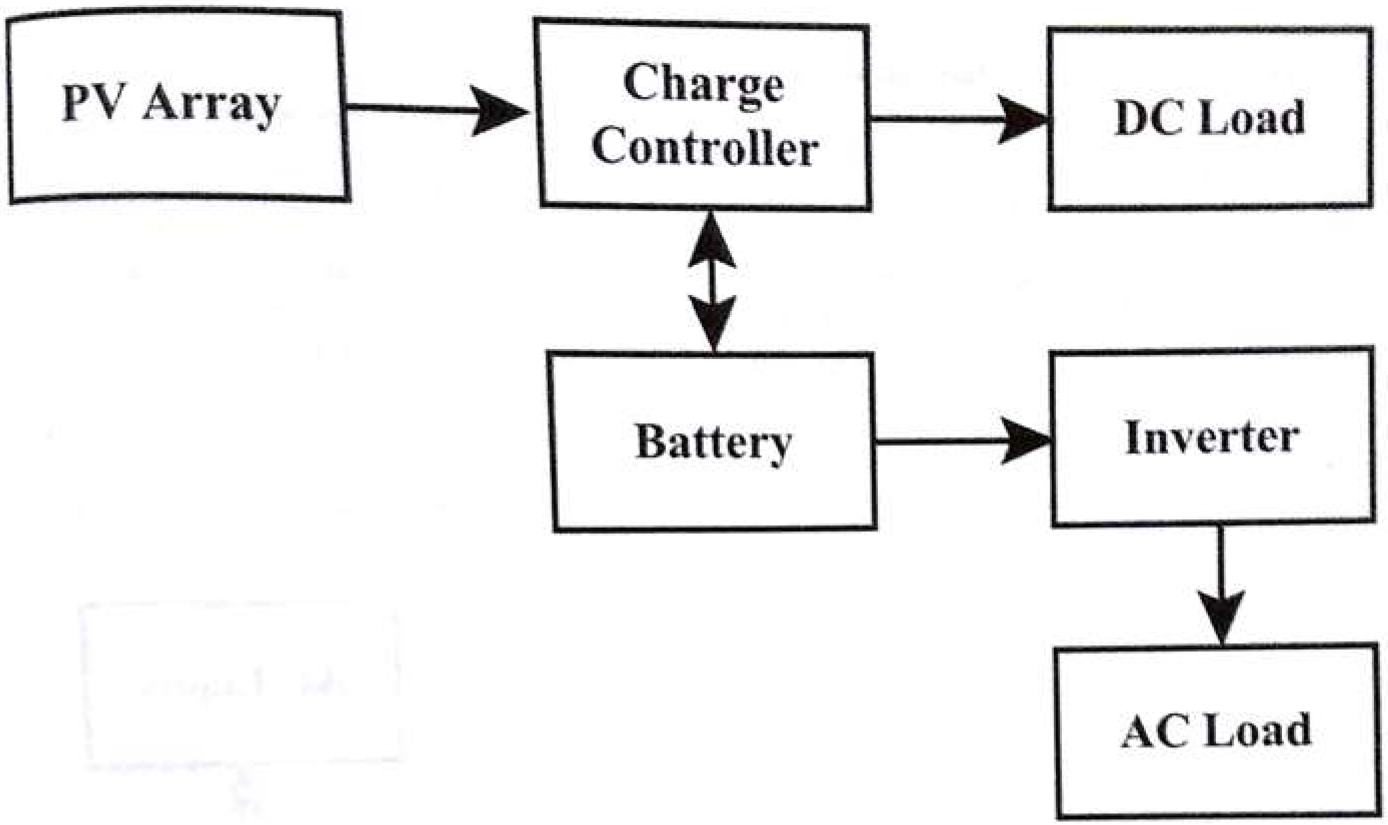
Grid connected system



- Designed to operate in parallel with and interconnected with the utility grid
- Primary component is the inverter or power conditioning unit (PCU)
- Inverter converts DC power produced by the PV array into AC power consistent with the voltage and power quality required by the utility grid
- Bidirectional interface is made between PV system AC output circuits and the electric utility network

- This allows PV system to either supply on site electrical loads or to feed the grid when the PV output is greater than the on site load demand
- When electrical demand is greater than the PV system output, the balance of power required is drawn from the electric utility
- Safety feature to consider is that PV system should not operate feed to utility grid when grid is down for service or repair

Stand-alone system



- Designed to operate independent of the electric utility grid
- Supply DC/AC loads
- Most suited for remote locations where there is no utility supply
- Use batteries to store electricity but they wont last forever
- Need replacement every 5-6 years

- Next drawback is wastage of surplus energy
- A grid tied solar system can feed power to utility grid when generation is excess and load demand is met, creating an energy credit
- This is not possible with stand alone systems
- System maintenance and trouble shooting are also serious issues

PV system components

- Basic components are
  - Solar PV modules
  - Array mounting racks
  - Grounding system
  - Junction box
  - Surge protection
  - Inverter
  - Meters
  - Disconnector
  - Battery bank
  - Charge controller
  - Battery disconnect

Solar and modules

- Solar cell – basic building block
- Many cells wired together form PV module (10W-300W) and many modules form PV array
- Rating of a module is the maximum power the module can produce under standard test conditions with 1kW of sunlight per sq.meter at a temperature of 25° C in air

Types of solar modules

- Mono crystalline- high performance solar cells (efficiency 15-19%)
- Poly-crystalline- standard solar cells (efficiency 11-15%)
- Amorphous – thin film solar cells(efficiency 5-8%)
- Hybrid solar modules (combines two technologies for manufacture)

Array mounting racks

- Orientation of PV array affects its performance
- Best location of PV system is south facing roof
- Flat roofs also work well for solar electric systems
- On roof mounted systems, PV array is mounted on fixed racks parallel to the roof and lifted off few centimeters above the roof surface to allow airflow that will keep the surface cool

- Solar modules can also be placed on the ground either on a fixed pole or a tracking mount
- Mounting racks are adjustable such that angles can be set for PV modules to follow the sun
- Tracked PV arrays can increase system’s daily energy output by 25%-40%
- Tracking systems are not recommended for home solar applications

Grounding system

- Provides low resistance path from PV system to ground to protect the system from current surges, lightning strikes or equipment malfunctions
- Stabilises the voltage and provides common reference point
- Provides protection from shock caused by ground fault
- All system components and any exposed metal including equipment boxes, frames and PV mounting equipment should be properly grounded

Junction box

- Output wires from individual PV modules are run to the junction box
- Junction box includes safety fuse or circuit breaker for each string and also includes a surge protector

Surge protection

- Protect the system from power surges due to lightning
- Lightning surge is a sudden increase in voltage above the design voltage

Inverter

- Converts DC power of PV to AC power to feed domestic loads
- Also takes function of power conditioning
  - Reduce voltage fluctuations
  - Ensuring pure sinusoidal wave for grid connected systems
  - Ensuring 50 Hz frequency of electricity

  Criteria for selecting a grid connected inverter: The following factors should be considered for selection
  - DC voltage of PV module
  - Quality of inverter such as efficiency, voltage regulation and good frequency
  - Manufacturer warranty
  - MPPT capability

Metering

- Provides easy access to various parameters of the system and allows us to check whether the system is operating properly or not
- Digital instruments are provided for measurement

Disconnector

- Automatic and manual type
- Protects the wiring and components of a PV system from power surges and other malfunctions
- Ensure proper shut down of system for repair and maintenance

Battery bank

- Store DC power of PV system during daytime for later use
- Batteries increase cost and complexity of the system
- Reduces efficiency and output of PV system
- Different types of batteries used in solar system are
  - Lead acid batteries
    - Flooded- least expensive but distilled water has to be added once in a month
    - Sealed- spill proof and do not require maintenance
      - Absorbent glass mat- maintenance free, suited for grid tied systems
      - Gel cell- overcharging will damage it permanently
  - Alkaline batteries- high cost, used for extremely cold temperatures

Charge controller

- Necessary for systems with battery back up
- Prevents overcharging and over discharging of batteries
- Prevent charge from draining back to solar modules at night
- Selection based on
  - PV array voltage – The controller's DC voltage input must match the nominal voltage of the solar array
  - PV array current – The controller must be sized to handle maximum current produced by the PV array

  The charge controller must be selected such that it does not interfere with the proper operation of the inverter

Typical design for home application

- Design steps
  - Determine the load to be served in watt-hours/day
  - Determine the average solar energy available on at least a month by month basis
  - Calculate the size of solar panel that is required to meet the load demand under the worst month conditions
  - Calculate the size and type of battery that is needed to provide the required reliability of power
  - Determine the type of charge controller
  - Determine the inverter capacity

- System sizing is the process used for determining the minimum PV panel, inverter, battery and charge controller sizes needed to deliver the required electrical energy under solar conditions that exists at site
- The following points are required to do the system sizing
  - Solar energy available in kW/m2/day at the site for the lowest solar energy month of the year
  - Average Wh/day required by the user to operate the desired appliances
  - Losses that reduces the energy available to the user

Determining load to be served in watt-hours per day

- Determine the power rating in watts of each of the appliances to be used in the household
- Estimate the number of hours per day that each appliance will be used
- For each appliance multiply the power rating in watts by the hours of use to get watt-hour/day
- Calculate the total watt hour per day for all appliances taken together

Determining average solar energy available on at least a month by month basis (TVM, Kerala)

January	5.8 kWh/m2/day
February	6.46
March	6.83
April	6.24
May	5.57
June	4.83
July	4.91
August	5.26
September	5.74
October	5.24
November	4.94
December	5.3

Size of solar panel required to meet the load

- Solar panels should produce 30% more energy that is required by the user
- Watt – hour /day to be generated by the solar panel is about 130% of the watt hour needed by the equipment in the household
- Panel generation factor (PGF) is an important component used in deciding solar panel size
- There are several factors that influence performance of the solar panels and we need to apply corrections for the same

- Corrections include
  - 15% for ambient temperature above 25°C (85% derating)
  - 5% loss due to sunlight not striking straight on the panel (95%)
  - 10% for loss due to not receiving energy at MPP (not present if there is a MPPT charge controller) 90% derating
  - 5% allowance for dirt collected on the solar panel (95% derating)
  - 10% allowance for the panel being below specification and for ageing (90%)

- Therefore panel generation factor is obtained by multiplying the lowest Wh/day by the derating factor
- Number of PV modules required is calculated
- Number=(Panel size required/rated Wp of the PV module)

Battery sizing

- Deep cycle battery is preferred for PV systems
- Shall be large enough to operate the appliances at night and cloudy days
- Depth of discharge of the battery should not be large to have good life of battery
- The following assumptions are made for selecting the capacity of the battery bank

- Battery efficiency is assumed to be 85%
- Depth of discharge is assumed to be 50%
- Cloudy days are assumed to be 2
- Battery voltage levels are chosen based on the wattage capacity of the plant
  - 12V for up to 500W capacity
  - 24V for up to 1000W capacity
  - 48V for up to 2000W capacity

Selection of charge controller

- Basic functions include
  - Block reverse flow of current
  - Prevent battery over charging
  - Prevent battery over discharging
  - Protect battery from overload
  - Display battery status and flow of power

  The charge controller is specified in terms of current and voltage

  It is selected to match the voltage of the PV array and batteries

  Should operate at 30% more than the short circuit current of the array

Selection of inverters

- Basic qualities of inverter for PV applications are
  - Power quality- "Utility Interactive"
  - Voltage input- inverter's DC input should match the PV array
  - AC power output
  - Surge capacity
  - Frequency and voltage variation
  - Efficiency
  - Integral safety disconnects
  - MPPT
  - Inverter –chargers (inverter integrated with charge controller)
  - Automatic load shedding
  - Warranty

Emergency and standby generation

- Intended to provide an alternate source of power if the normal source of power fails
- Classified as follows
  - Emergency power systems
  - Standby power systems

- **Emergency power system**: an independent reserve source of electric energy that, upon failure or outage of the normal source, automatically provides reliable electric power within specified time to critical devices and equipment whose failure to operate satisfactorily without jeopardise the health and safety of personnel or result in damage to property

- **Standby power system**: an independent reserve source of energy that, upon failure or outage of the normal source provides electrical power of acceptable quality so that the user’s facilities may continue in satisfactory operation

General considerations

- Engine driven AC generator sets are used for industrial and commercial buildings as a source of power
- Main prime movers used in engine driven type generators are diesel engines, gas turbines and steam turbines
- Turbines are used for production whereas diesel engines can be used for both production and standby sets

- Gas turbine generators are lighter in weight than diesel engine sets, run more quietly and require less cooling and combustion air leading to lower installation costs
- Gas turbine generator sets are more expensive than diesel engine generator sets, require more starting time
- Another factor is fuel supply
- If fuel is stored in tanks, it should be stored away from the generators

Ratings of standby generator sets

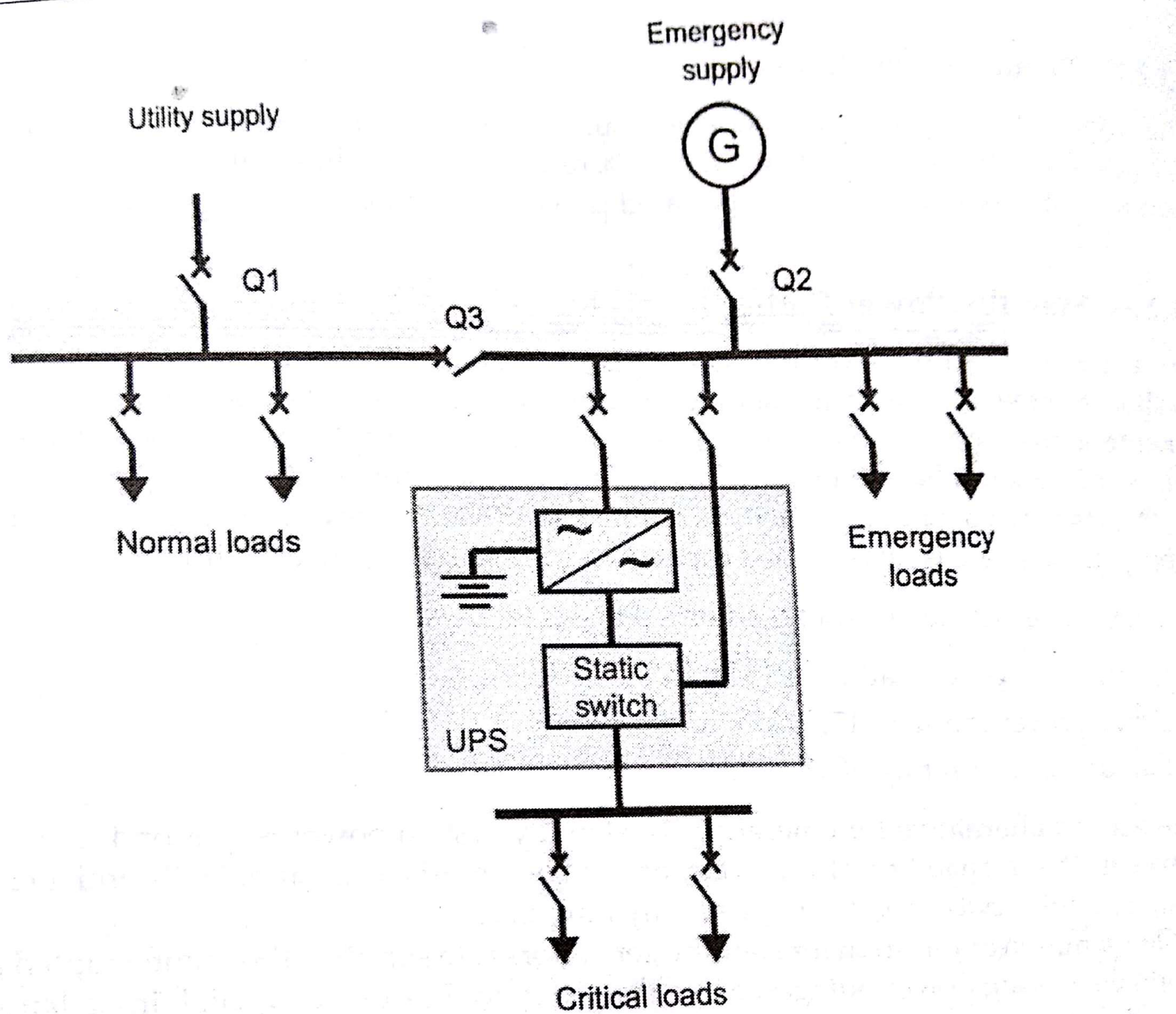
- **Continuous power rating**-engine can supply rated power for an unlimited time
- **Prime power rating**: engine can supply a base load for an unlimited time, and 100% rated power for a limited time
- Typical values are a base load of 70% of the rated power, 100% rated power during 500 hours per year

- **Standby power rating**: Maximum power that the engine can deliver and is limited in time, less than 500 hours per year
- Applied to generator sets which are used exclusively for emergency power
- Typical example of a diesel engine set is as follows
  - Continuous power rating of 15.5kW
  - Prime power rating of 17.6kW
  - Standby power rating of 18.8kW

- One common application for standby generators is to supply UPS equipment during power outages
- When generator sets are used as a primary source of electrical energy, the following points should be considered
  - Provide for parallel operation with other sets/utility
  - Allow for long maintenance periods
  - Ensure starting capability of generator sets without presence of a utility supply
  - Long life

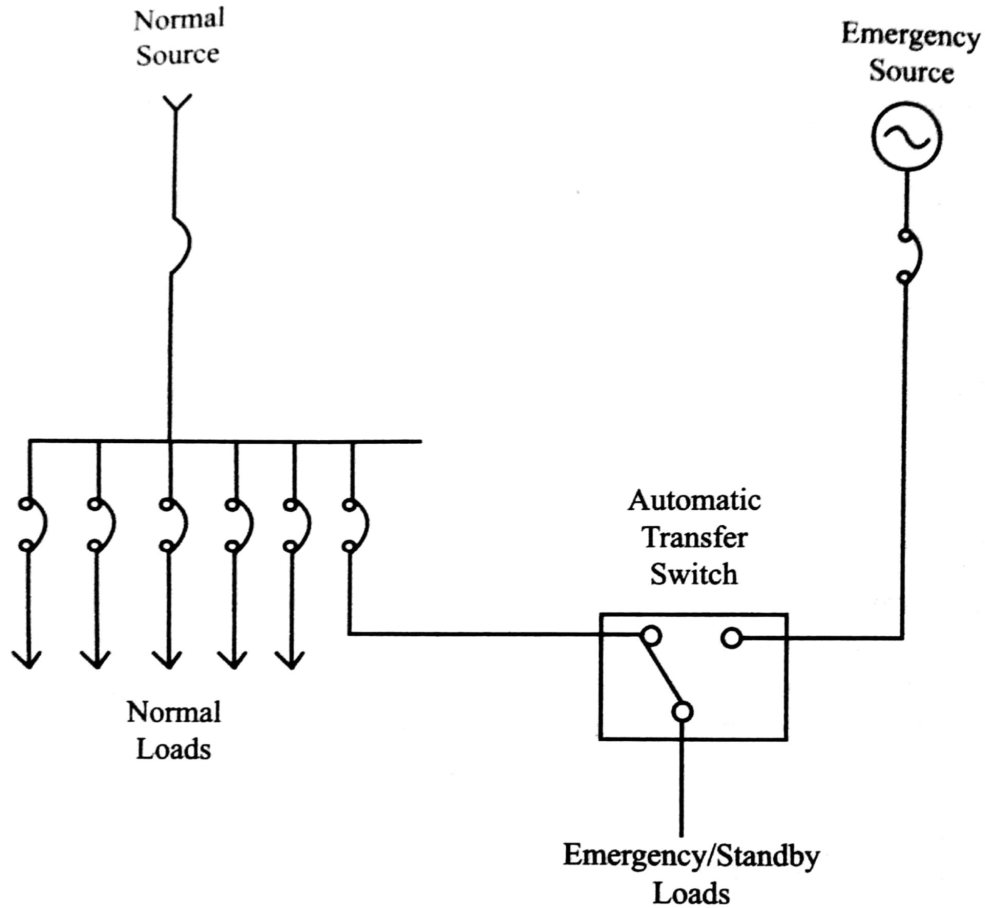
- When used as a standby source
  - Quick and reliable start up and loading
  - Reliable load shedding to avoid overloading
  - Allow for periodic testing under load
  - Provide for parallel operation with utility

Arrangement of standby generating system



- Normal operating conditions- load supplied from utility supply
- Upon loss of this supply Q3 is tripped, the generator set is started and load is supplied by the standby generator set by closing the CB Q2
- Critical loads are supplied from UPS
- UPS is equipped with static switch which will bypass the rectifier/inverter module in case of an internal fault in the UPS and ensure continuous supply of electric power to the critical loads

Emergency/standby power supply arrangement



Installation requirements of standby generators

- Minimum 1m clearance shall be provided on three sides of the generator set, minimum 2m clearance shall be provided between them
- Fuel tank of DG sets shall be installed outside the generator room
- Exhaust pipe of DG sets shall maintain a minimum height of 1.8m clearance from the floor level
- Voltmeters and frequency meters shall be connected before the circuit breaker in the generator control panel

- Watt hour meter and ammeters in each phase shall be provided
- For generators of 500kVA and above, kVA/kW meter and pf meter shall also be provided
- Changeover switches of approved makes is permitted for capacities up to and including 800A
- Undervoltage coil may be provided at grid side, ACB/MCCB on respective switchboards at installations where generators are installed for preventing chances of back feeding from generators to grid side

- Provide thermal O/L relay in the generator circuit
- Generator room shall be made of non inflammable materials
- Standard size of earthing cables and conductors for generators shall be provided
- Proper protection schemes should also be provided for generators

Generator capacity kVA	Full load current rating Amps	Cable size AYFY mm^2	Earth conductor size mm^2/SWG	Protection	Panel instruments
5	7	4	8.3/10	MCB	AM, VM & FM
7.5	10.5	4	8.3/10	MCB	
10	14	4	8.3/10	MCB	
12.5	17.5	6	8.3/10	MCB	AM, VM, FM & EM
15	21	10	8.3/10	MCB	
20	28	10	8.3/10	MCB	
25	35	16	18.6/6	MCB	
30	42	16	18.6/6	MCB	
35	49	25	18.6/6	MCB	
40	56	35	27.27/4	MCB	
45	63	35	27.27/4	MCB	
50	70	35	27.27/4	MCCB	
63	88	50	27.27/4	MCCB	
82.5	115	95	25 × 3	MCCB	
100	140	120	25 × 3	MCCB+ Stand by low Set earth fault Relay using CT in neutral Earthing conductor	AM, VM, FM & EM
125	175	150	25 × 3		
160	224	185	25 × 3		
180	252	300	25 × 3		
200	280	2 × 120	25 × 3		
225	315	2 × 225	25 × 3		
250	350	2 × 185	25 × 3		
320	448	2 × 300	25 × 3		
400	560	2 × 400	25 × 3		
500	700	3 × 400	25 × 3	ACB with Overload and E/F release	AM, VM, FM EM, PFM, kVAM
625	875	4 × 400	25 × 3		
750	1050	Bus-Bar Trunking	25 × 3		
For 1000 kVA and above, ACB with thermal O/L, voltage controlled O/C relay, over voltage, under voltage, negative sequence, low set stand by earth fault relays and REF/Different relay with fuel shutoff facilities. Overspeed protection shall be provided for the engine.					

Automatic Mains Failure

- An **uninterruptible power supply (UPS) system** is your bridge between mains power and your backup generators. Automatic mains failure (AMF) panels – also referred to as automatic transfer switch (ATS) panels – make the power, switch to emergency standby generators in the event of a significant loss of mains power or total blackout

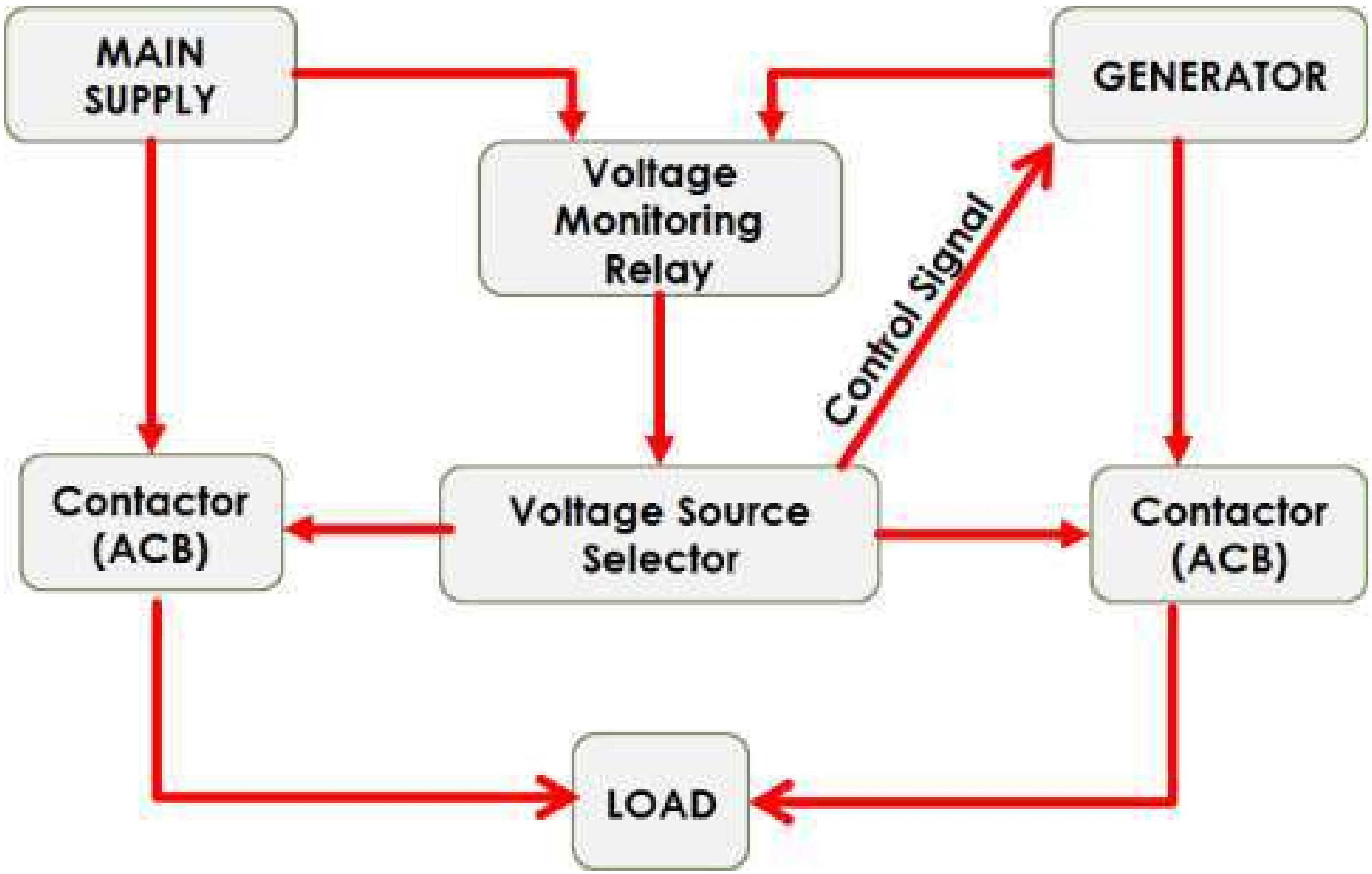
There are three main types of AMF units

- Using Microcontroller in the unit itself
- Using PLC (Programmable Logic Control) for control action
- With the help of Relay Mechanism

  A relay based system is described for control action. Elements which are used are voltage monitoring relay/phase failure detector (PFD), Overload Relay and Air Circuit Breaker.

- The system is continuously monitoring the voltage level from the mains
- If the voltage is dropped below the allowed level, this system will switch the Load to Generator (auxiliary supply) and switch back to the mains when the voltage is back to nominal required normal level
- An interlocking of both the ACB is done to avoid any mal-operation of switching of ACB
- Continuity of supply to load is achieved with the help of AMF unit

Block diagram of AMF



- Power from mains supply is continuously monitored by PFD with the help of relay unit
- It gives signal to the ACB for its operation / protection
- When fault occurs in the mains supply PFD detects the fault and disconnect the mains supply form the load side by tripping the ACB
- Generator will start automatically
- When generator runs at rated RPM & frequency then the ACB will operate & supply is given to the load form the generator

- **Phase Failure Detector:** Protects a load from damage due to failure in any of the phases supplying power to the load
- It automatically cuts off the load from supply
- Phase Failure Detector will operate in following conditions;
- i) Unbalanced Voltage
- ii) Single Phase or Phase loss
- iii) Overload Condition
- iv) Power Outage
- v) Phase Reversal

- It monitors both Generator as well as Mains side parameter
- Any above mentioned condition will cause PFD to operate & give signal to ACB as well as control signal is generated ne of the individual phase becomes faulty
- **Air circuit breaker** is a device used to provide Over current and short circuit protection

Energy conservation techniques in lighting

- Electric lighting is a major energy consumer.
- Enormous energy savings are possible using energy efficient equipment, effective controls, and careful design
- Electric lighting design also affects visual performance and visual comfort by maintaining adequate and appropriate illumination while controlling reflection and glare.

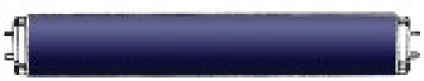
Techniques implemented

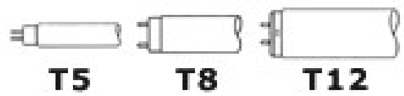
Installation of CFL in place of incandescent lamps

- CFLs use about 2/3 less energy than standard incandescent bulbs, give the same amount of light, and can last 6 to 10 times longer

Installation of energy-efficient fluorescent lamps in place of "conventional" fluorescent lamps

- There are a few styles worth noting; these models are simply labeled as "T-12", "T-8", or "T-5"
- The names come from the size of their diameter per eighth inch. For example, a T-12 lamp is 12/8 inch in diameter (or 1 1/2 inch); a T-8 lamp is 8/8 inch in diameter (or 1 inch); a T-5 lamp is 5/8 inch in diameter





- The recommended style of fluorescent lighting is a T-8
- T-8 lights are the most cost effective
- More efficient than standard T-12 fluorescent lamps, which have poor color rendition and cause eye strain
- T-8 lamps provide more illumination, better color, and don't *flicker*
- T-5 lamps are the most energy efficient and also tend to transmit the best color; however, they are expensive

- Installation of occupancy/motion sensors to turn lights on and off where appropriate
  - Lighting can be controlled by occupancy sensors to allow operation whenever someone is within the area being scanned
  - When motion can no longer be detected, the lights shut off

Use an automated device, such as a key tag system, to regulate the electric power in a room

- The key tag system uses a master switch at the entrance of each guest room, requiring the use of a room key-card to activate them
- Using this technique, only occupied rooms consume energy because most electrical appliances are switched off when the keycard is removed (when the guest leaves the room)
- Along with lighting, the heating, air-conditioning, radio and television may also be connected to the master switch

Offer nightlights to prevent the bathroom lights from being left on all night

- A nightlight can be used at night to provide light during sleep
- One model can be use of **Light Emitting Diodes (LEDs)** in the panel of a light switch to provide light at night

Replace all exit signs with light emitting diode (LED) exit signs

- Multiple LEDs, properly configured, produce equivalent lighting and consume 95% less electricity than incandescent bulbs and 75% less than energy-efficient compact fluorescent lamps
- 20 year life cycle and eliminates maintenance
- LED exit signs are the most expensive, but are also the most efficient exit signs available

Use high efficiency (HID) exterior lighting

- include mercury vapor, metal halide and high pressure sodium
- HID lighting is mostly utilized in floodlight, canopy, area fixtures outdoors etc
- The best type for any application depends on the area being lit and mounting options

Add lighting controls such as photo sensors or time clocks

- Photo sensor controls monitor daylight conditions and allow fixtures to operate only when needed
- Photo sensors detect the quantity of light and send a signal to a main controller to adjust the lighting
- Time controls save energy by reducing lighting time of use through preprogrammed scheduling.

Star certification

- **Earning the ENERGY STAR** certification means the product meets strict energy efficiency guidelines set by the US Environmental Protection Agency
- Lighting products that have earned the ENERGY STAR label deliver exceptional features, while using less energy
- Saving energy helps you save money on utility bills and protects the environment by reducing greenhouse gas emissions.

- **ENERGY STAR Certified Light Bulbs:**
- Use about 70-90% less energy than traditional incandescent bulbs
- Last at least 15 times longer and saves electricity costs over its lifetime
- Meet strict quality and efficiency standards that are tested by accredited labs and certified by a third party
- Produce about 70-90% less heat, so it’s safer to operate and can cut energy costs associated with home cooling

- **ENERGY STAR certified ceiling fan/light combination units**:
  - Are 40% more efficient than conventional fan/light units
  - Use improved motors and blade designs
  - Provide quality, cutting edge design, and the latest in efficient technology

Energy conservation in power

- **ENERGY STAR certified room air conditioners** come with better materials and clearer instructions to improve sealing and insulation around the unit, so uncomfortable air leaks are minimized.
- Offer additional convenience, comfort and energy-savings, including the ability to:
  - turn off the unit remotely using your phone or computer;
  - schedule changes to temperature settings based on your needs
  - receive feedback on the energy use of the product
  - use 10 percent less energy and saves electricity cost

- An **ENERGY STAR certified solar water heating system** can cut your annual hot water costs in half
- Installing a certified solar water heater will prevent 4,000 pounds of carbon dioxide from entering the atmosphere annually. This is equivalent to not driving your car for four months every year
- Life expectancy of certified solar water heating systems is 20 years

Energy conservation in motors

- Motors and drives constitute two third of the energy consumed by manufacturing industry.
- The efficiency of conversion of this electrical energy , is of the order of 85%
- There are three important losses in motor, the largest being the resistive loss of windings(I^2R loss)
- The next loss is that of magnetic circuit(known as iron loss) which varies with both voltage and frequency
- Third is windage and friction loss which varies with motor speed

Energy efficiency-Induction motors

- Induction motors have long been the workhorses of industry for fixed speed applications
- They are applied to variable speed duties through the use of variable frequency inverters.
- These electronic equipment allow the voltage and frequency supplied to the motor to be accurately controlled and hence very effective variable speed performance can be achieved over a wide operating range.
- The efficiency of standard induction motors can be significantly improved by using more materials in the motor, namely extra copper in the winding to reduce current density and hence copper loss and extra iron to reduce flux density and hence iron loss

- Energy efficient motors are
  - more expensive than standard motors
  - lower noise and vibration
  - lower operating temperature
  - greater ability to accelerate high inertia loads
  - Less affected by voltage variations
- An alternative method of reducing losses in the motor would be to use low magnetic loss materials such as silicon iron, which have losses of about one-fifth of those in conventional material

- Improvements to increase efficiency of motors include
  - use of lower loss steel, longer core, thicker wire, thinner laminations smaller air gap between stator and rotor , copper instead of aluminum bars in the rotor, superior bearings and a smaller fan
- Energy efficient motors now available in India, have 3-4% of higher efficiency than standard motors.
- B.I.S stipulates that energy efficient motors are to operate without loss of efficiency at loads between 75% and 100% of rated capacity
- The power factor is to be the same or higher than standard motors.

Energy management opportunities with motors

Operational improvements:

- Supply of rated voltage with proper balance between phases
- Improve controls : turn motor off when not in use
- Schedule regular maintenance of motor and provide regular lubrication
- Provide adequate cooling
- Reduce peak demand by rescheduling motor operation

Retrofit improvements

- Improve power factor
- Improve cooling
- Replace old inefficient motor with efficient ones
- size motors to run at full load

New installation or designs

- Purchase more efficient motors, evaluated on a life cycle cost basis
- Consider using variable speed motors, if different motor speeds are required
- Use higher voltage for motor drives & single phase rather than 3 phase motors

Economy in using energy efficient motors

- Cost of energy efficient motor is higher than that of standard motors
- The high cost will be paid back rapidly by the saving in operating cost, particularly in new applications and end-of-life motor replacements

However energy efficient motors are not available for certain applications such as :

- High torque and intermittent duty applications such as cranes, hoists, punch presses, machine tools ,centrifuges and traction drives.
- Flame proof operations in oil fields or fire pumps or very low speed operations(below 750 rpm).
- Most energy efficient motors today are designed for continuous duty cycle operations