



**R. C. Patel College of Engineering and Polytechnic,
Shirpur**

Class: SYEE (EE3K)

Course:

**ELECTRICAL POWER GENERATION,
TRANSMISSION AND DISTRIBUTION**

(Course Code: 313333)

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Unit - V
Distribution Line
Components, Parameters and
Performance
(16 Marks)

Course Outcome:
CO5 - Maintain the functioning and
operation of electric power
distribution system.

* Introduction:

- A distribution line is an important part of the electrical grid used to supply electrical power from substation to consumers.
- For reliable and efficient operation, it is important to understand:
 - Distribution line component
 - Line parameters
 - Distribution scheme.
 - Line performance
 - Distribution substations.

* Components of Distribution Lines:

1. Conductors:

- Materials: - Aluminium - AAC, AACSR
- copper - Cu.
- Types: - overhead: - Bare / Insulated
- underground - Insulated.

2. Poles and Towers

- Materials: wood, steel, concrete, composite.
- Types: - single pole.
- H-frame
- Lattice tower.

3. Insulators:

- Materials: Porcelain, Glass, polymer
- Types: pin, suspension, strain.

4. Transformers:

- Types: - step-up transformer
- step-down transformer
 - Distribution transformer.

- Function:

- used to increase or decrease voltage according to consumer requirements.

5. Switchgear:

- Components - circuit breaker

- Isolator
- lightning arrester
- switches.

- Function: provides protection and control of distribution circuit.

6. Protection Devices:

* Fuse: protects the circuit from overcurrent

* Surge Arrester:

- protects equipment from:
 - lightning surges
 - switching surges.

* Electrical power distribution system: single line diagram:

- The complete electrical system both the generating station and consumers can be divided into:

1. Transmission system
2. Distribution system.

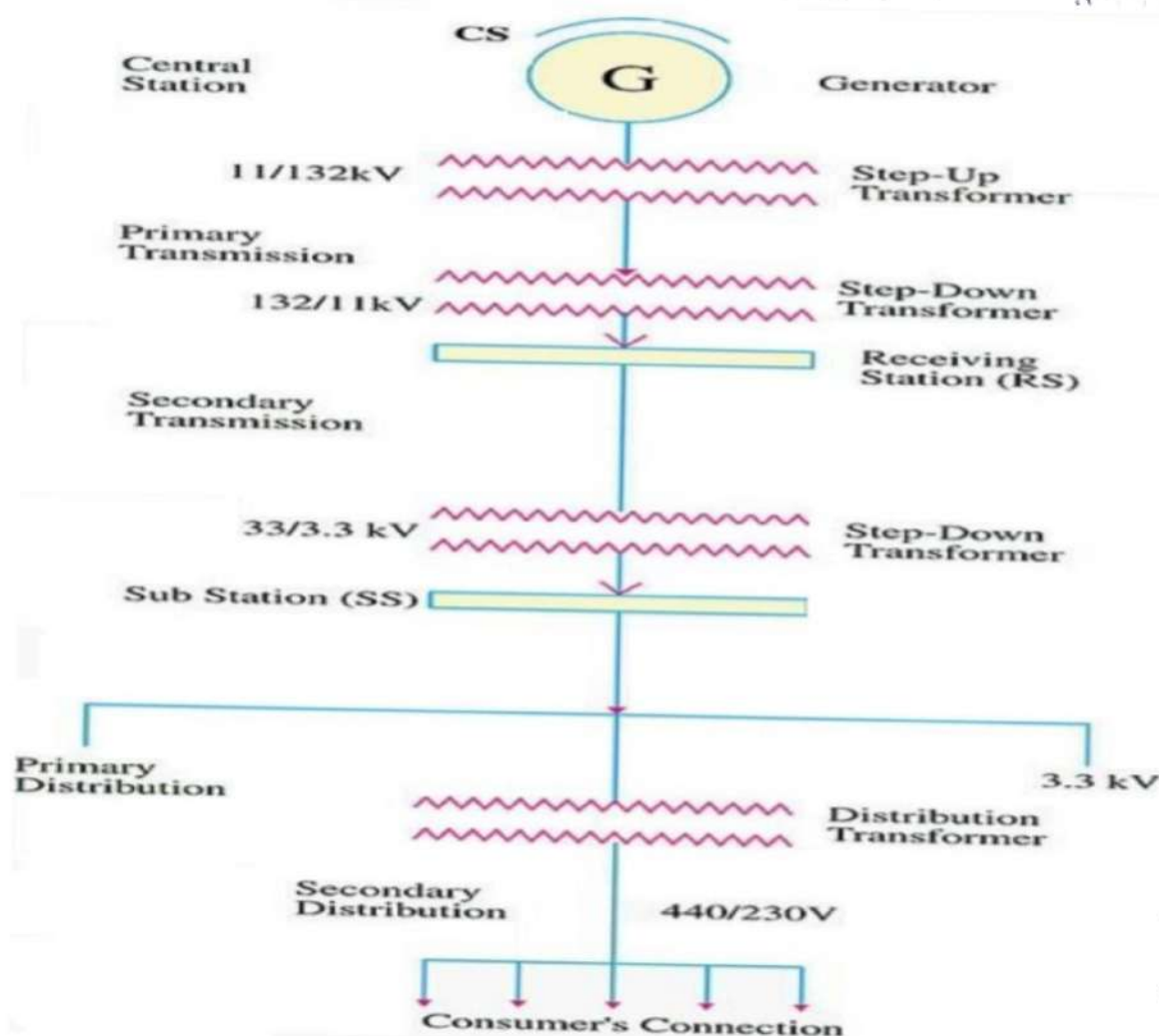
- Both are further divided into:

- Transmission:
 - primary transmission
 - secondary transmission.

- Distribution:
 - primary distribution
 - secondary distribution.

* Electric power Distribution system:- Single line Diagram

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* stages of Electric power Distribution:

i) Generating station:

- Electrical power is generated by 3 ϕ alternator.
- Typical generation voltage = 11 kV.
- A 3 ϕ transformer increases v_{tg} from 11 kV to 132 kV or higher.
- High v_{tg} transmission reduces conductor size/material and improves efficiency.
- Excessively high v_{tg} increases
 - insulation problems
 - switchgear cost
 - transformer cost

i) Primary transmission:

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- Electrical power is transmitted at 132 kV.
- System: 3ϕ , 3-wire overhead system.
- It carries power from generating station towards the receiving station.
- Voltage: 132 kV.

iii) Secondary transmission:

- primary transmission line terminates at the receiving station.
- voltage is stepped down to 33 kV using a step down transformer.
- 33 kV power is supplied to various substations in/near the city.
- system: 3ϕ , 3 wire overhead system.
- voltage: 33 kV

iv) Primary Distribution:

- secondary transmission terminates at the substation. (SS)
- Voltage is stepped down: 33 kV to 11 kV.
- system: 11 kV, 3ϕ , 3 wire.
- 11 kV lines run along important roads.
- Large consumers with demand above 50 kW may receive supply at 11 kV through their own substation.

v) secondary distribution:

- 11 kV primary distribution supply is given to distribution substation. (DS)
- distribution transformer steps down: 11 kV to 400 V.
- system: 400 V, 3ϕ , 4 wire.
- Distribution substations are located near consumers.
- Consumer voltage: - phase to phase = 400 V
phase to neutral = 230 V.
- Loads: - single phase residential load: - connected between phase and neutral.

⑤
- 3 ϕ motor load: Connected to 3 ϕ supply.

* Classification of Distribution Lines:

- Distribution can mainly be classified as:

1. primary distribution
2. Secondary distribution.

* Classification of Distribution system:

- Distribution systems can be classified according to different criteria

A) According to Nature of current:

1. DC Distribution system
2. AC Distribution system.

- AC distribution is universally preferred because it is simpler and more economical than DC distribution.

B) According to Type of construction:

1. overhead distribution system.
2. Underground distribution system.

C) According to scheme of connection:

- Distribution systems are classified according to connection scheme as:

1. Radial system
2. Ring Main system
3. Interconnected system.

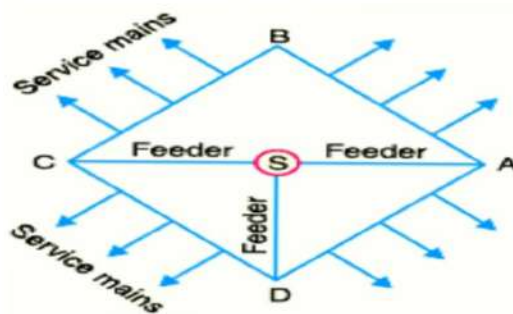


Fig. Distribution System

* AC Distribution:

- Nowadays, electrical power is generally generated, transmitted and distributed in AC form.

* Why AC distribution is preferred?

- AC voltage can be easily increased or decreased using transformer.
- Transformers make AC distribution at high voltage possible.
- High distribution rty reduces the current in conductor.

- lower current results in lower line losses.
- AC system can transmit and distribute power efficiently and economically.
- There is no fixed boundary betn transmission and distribution based only on voltage or power capacity.
- AC distribution is mainly classified into:
 1. primary Distribution system
 2. secondary distribution system.

1) primary Distribution system:

- primary distribution operates at a higher voltage than normal utilization v_{tg} and supplies electrical power to large blocks of low-voltage consumers/load areas.
- standard primary Distribution voltages:
 - 11 kV, 6.6 kV, 3.3 kV
- The selection of primary distribution v_{tg} depends mainly on:
 - Amount of power supplied.
 - Distance from the supply substation.
 - system: 3 phase, 3 wire.
- working: Generating station → high v_{tg} transmission → substation → primary distribution.
- Electrical power is supplied at high v_{tg} from generating station to substation in city, where it is distributed to different load areas.

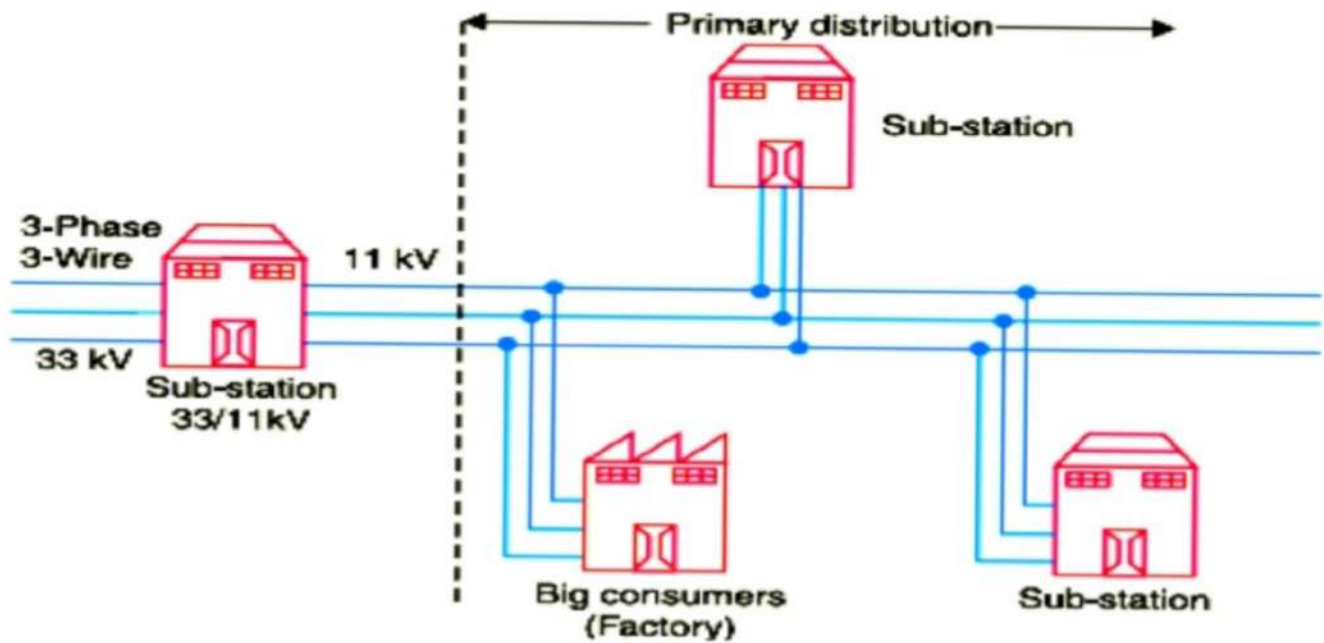


Fig. Primary Distribution System

2) secondary Distribution system:

- Secondary distribution uses 400/230V, 3 ϕ /1 ϕ , 4 wire Ac system.
- primary distribution circuits supply power to distribution substations (DS).
- Distribution substations are located near the consumer load area.
- A step down transformer is installed at the distribution substation.
- voltage is stepped down to 400V.
- power is then distributed through 3 phase, 4 wire Ac system.
- voltage levels:
 - voltage betn any two phases = 400V
 - voltage betn any phase and neutral = 230V.
- Connection of loads:
 - Single phase domestic loads such as lamps are connected betn one phase and neutral.
 - 3 ϕ , 400V motor loads are connected directly across 3 ϕ lines.

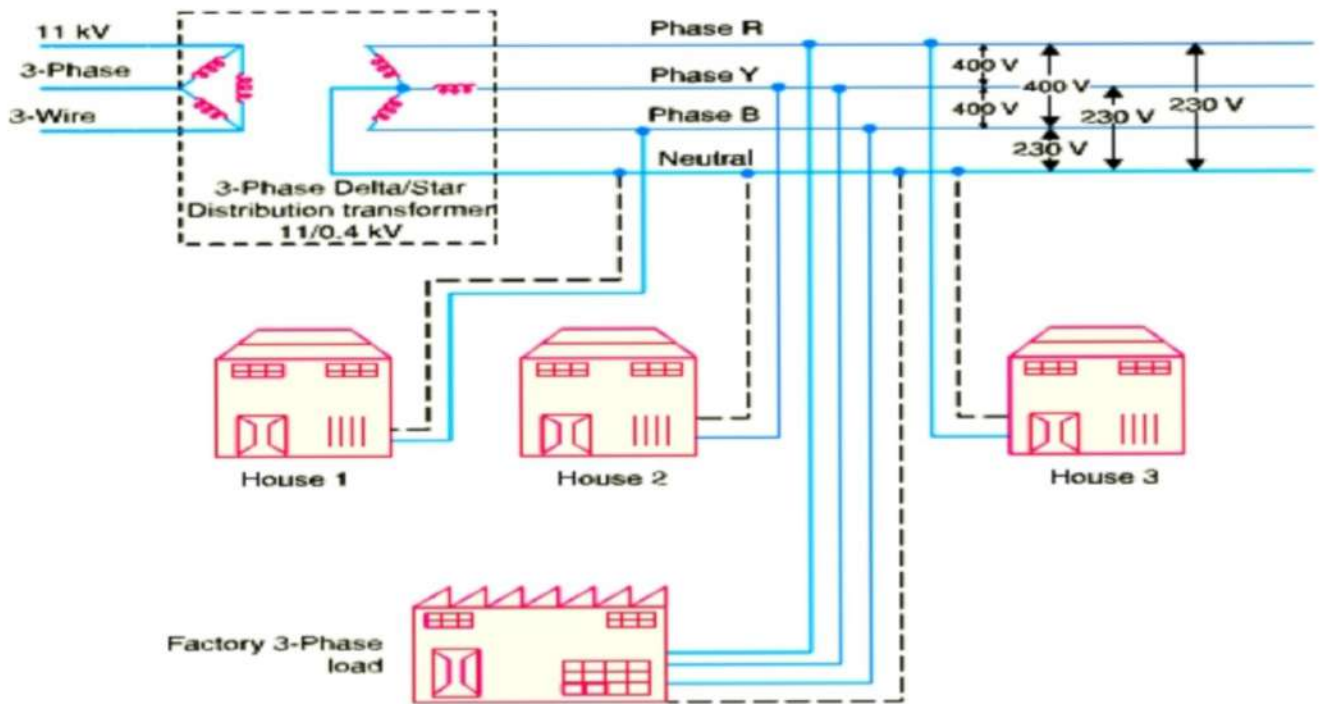


Fig. Secondary Distribution System

* DC Distribution:

- Generally, electric energy is generated, transmitted and distributed in AC form. However, DC supply is required for some special applications:

* Applications of DC supply:

- DC variable speed machinery / DC Motors.
- Electro-chemical processes
- Areas requiring battery reserve storage.
- For DC distribution, AC power is converted into DC at the substation.

- Conversion Equipment:

- Mercury arc rectifier
- Rotary converters
- Motor-generator sets.
- DC power then can be supplied from the DC substation.

i) 2 wire DC system:

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construction:

- 2 wire DC distribution system consist of:

1. positive wire (outgoing)

2. negative wire (return)

- connection: loads such as lamps and motors are connected across the two wires.

- Important point:

- Due to low efficiency, this system is not used for transmission.

- It may be used for DC distribution.

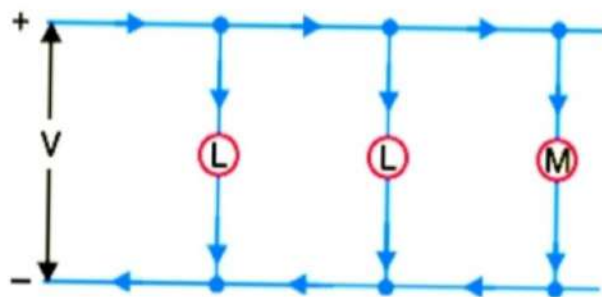


Fig. DC Two Wire System

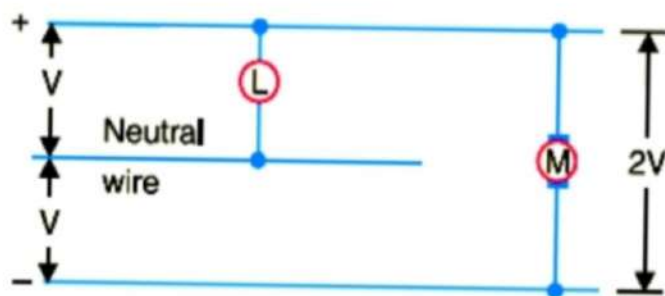


Fig. DC Three Wire System

ii) 3 wire DC system:

construction:

- A 3 wire DC system consists of

1. Two outer wires

2. one neutral wire

- voltage: If V by both outer wire and neutral $= V$:

- outer $\rightarrow$ neutral $= V$

- outer $\rightarrow$ outer $= 2V$

Thus, the system provides two voltage levels at the consumer terminals.

Connection of load:

- High vty loads such as motors $\rightarrow$ connected betn two outer wire.
- low-vty loads such as lamps and heating circuits $\rightarrow$ connected betn outer wire and neutral.

* Distribution line components:

Types of line supports, line insulators and overhead/underground conductors (ACSR) insulator power cables with their function:

* Transmission line components:

- Conductors
- Line supports
- Line Insulators

* (a) Electrical power cables:

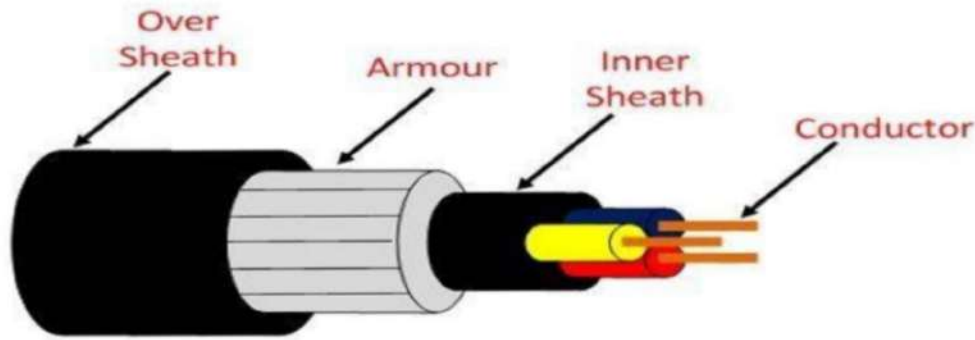
- An electrical power cable is used for transmission and distribution of electrical energy.
- A power cable consists of two or more electrical conductors covered with an outer sheath.

Applications:

- Used where overhead lines are not suitable.
- Examples: sea crossing, airports, congested areas etc.
- Used for extra high voltage transmission.
- Underground cables are more expensive than overhead cables for same voltage.

* Construction of power cable:

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Electrical Power Cable

Circuit Globe

* Main parts:

Conductor → Insulation → Inner Cover → protective covering → Armouring → oversheath.

1) Conductor:

- Main path for current flow.
- Usually made of copper or aluminium because of high electrical conductivity.
- Conductors may consist of many stranded wires.
- Common strand arrangement: 7, 19, 37, 61, 91 etc.
- Size may be represented as 7/A, 19/B, 37/C, where the first number represents number of strands.

2) Insulation:

- Common insulating materials:
- Impregnated paper
- Butyl rubber
- PVC
- Polyethylene
- XLPE

* Requirement of good insulation:

1. High insulation resistance
 2. High dielectric strength
 3. Good mechanical strength
 4. Should withstand high temperature.
 5. Low thermal resistance.
 6. Low power factor.
- for underground and damp locations, synthetic dielectrics such as PVC and Polyethylene are preferred because they provide:
- High dielectric strength
 - low power loss
 - low thermal resistance.

3) Inner Cover:

- protects cable from moisture
- protects insulation from damage.
- should be made of non-magnetic material.
- Aluminium sheath may also be used because it is light and has good mechanical strength.

4) Protective Covering:

- protects cable from rust/corrosion and electrolytic action when laid underground.
- Materials such as PVC and bitumin are used.
- provide protection against mechanical damage.

5) Armouring:

- provides protection against mechanical damage.

- usually made using galvanized steel wires or metal tapes.
- steel is preferred because of its high strength.
- Armouring can also provide an earthing path.
- During insulation failure, fault current can flow through armouring.

6.1 oversheath:

- provides mechanical strength to the cable.
- protects against:
 - Moisture, Rust, Abrasion, Dust.
- Made from thermosetting or thermoplastic materials.

* B) ACSR: (Aluminium Conductor steel Reinforced):

characteristic of ACSR:

1. Material:

- Aluminium strands are wound around a steel core.
- Aluminium $\rightarrow$ High conductivity
- steel core $\rightarrow$ mechanical strength and support.

2. Construction:

- outer layer: High-purity aluminium for conductivity.
- inner core: steel for mechanical strength.

3. Strength:

- steel core provides high tensile strength.
- suitable for long spans.

4. Lightweight:

- Lighter than Copper.
- Easy to handle and install.

5. Corrosion resistance:

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- Aluminium has good Corrosion resistance
- steel core requires protection such as galvanization/coating.

* Applications:

- High v_tg overhead transmission lines.
- Transmission and distribution networks
- Areas requiring long spans betⁿ supports.

* C) Insulated power cables:

* Characteristics:

1. Material:

- Conductors are made of:
 - copper or Aluminium
- Insulation materials:
 - PVC
 - XLPE
 - EPR.

2. Insulation:

- protects against:
 - Electric shock
 - short circuit
 - Moisture
 - chemicals.

3. Construction:

Generally consists of:

conductor + Insulation + protective layer + outer jacket.

4. Flexibility:

- More flexible than ACER
- Easy to route in different environments.

5. Safety:

- prevents direct contact with conductor
- safer during handling and installation.

* Applications:

- Underground power lines
- Industrial and Commercial buildings
- substations
- Electrical installations where overhead lines are not permitted.

* Types of line support:

- line support should have:
 - low cost
 - low maintenance
 - long life.

Main types:

1. wood poles
2. concrete pole
3. steel pole
4. Electrical towers.

1) Wood poles:

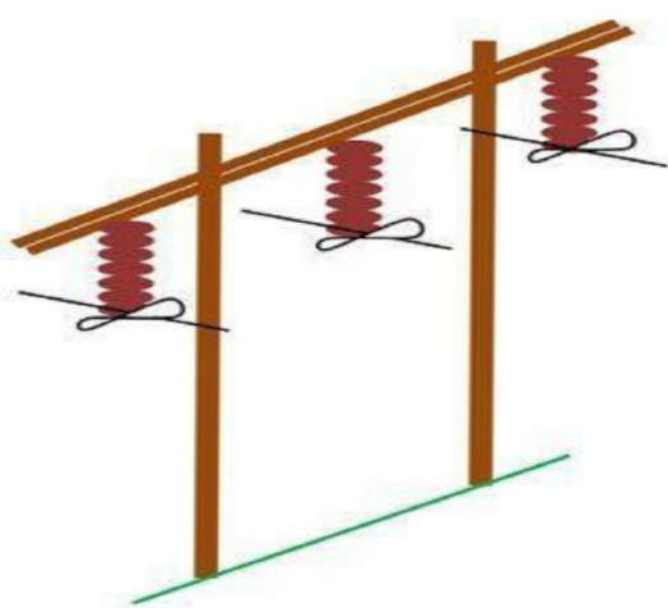
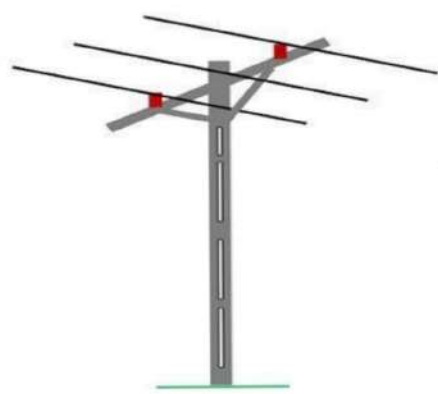


Fig. Wood Pole

- Common and economical line support.
- Used for short span and low tension.
- Have natural insulating properties
- Lower possibility of flashover
- Main disadvantages:
 - strength is uncertain
 - durability is comparatively low.

2) Concrete poles:



- More commonly used than wooden poles
- Longer life than wood poles
- Require low maintenance.
- Disadvantages:
 - very heavy
 - Brittle
 - may be damaged during loading, unloading, transportation and erection.

3) Steel poles:

- Tubular steel poles are used for low and medium voltage lines.
- suitable for long spans
- Require periodic galvanizing or painting to prevent corrosion.
- Maintenance cost is relatively high.

4) Electrical towers:

- used for high voltage transmission lines, generally above 230kV.
- made of steel or aluminium.
- provide sufficient strength to support heavy conductors.

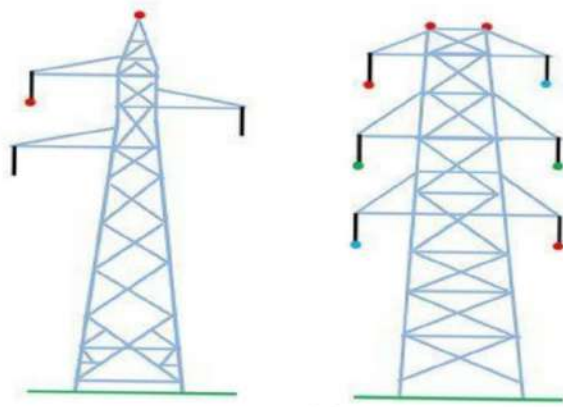


Fig. Electric Tower

* Types OF Electrical Insulators:

- Purpose of Insulator

- An overhead line insulator:

- Electrically separates the line conductor from support structure.
- separates conductors from each other.
- Must have high dielectric strength.
- protects transmission lines against overvoltage due to
 - lightning
 - switching
 - other causes.

* Four Types of insulator:

1. Pin Insulator

2. suspension Insulator

3. strain Insulator

4. shackle Insulator

1) Pin Insulator:

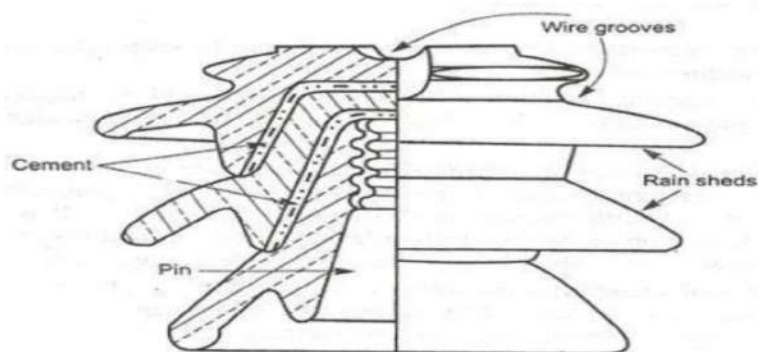


Fig. Pin Insulator

- Used for transmission lines up to 33 kV.
- Mounted on a bolt fixed to the cross-arm of the supporting structure.
- Conductor is attached to the groove at the top.
- For higher voltage, two or more pieces may be joined to obtain sufficient insulation thickness.

2) Suspension Insulator:

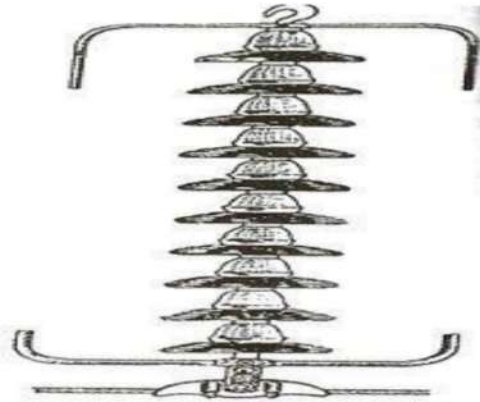


Fig. Suspension Insulator

- Consist of separate insulator units connected by metal links.
- Units form a flexible string.
- Insulator string is suspended from the cross-arm.
- Conductor is connected to the lower unit.

3) Strain Insulator:

- Used at locations where mechanical tension on the line is high.
- Suitable where there is a change in line direction or at the termination of a line.
- For HV lines with long spans and high mechanical loading, suspension insulator strings can be arranged horizontally and act as strain insulators.

4) Shackle Insulator:

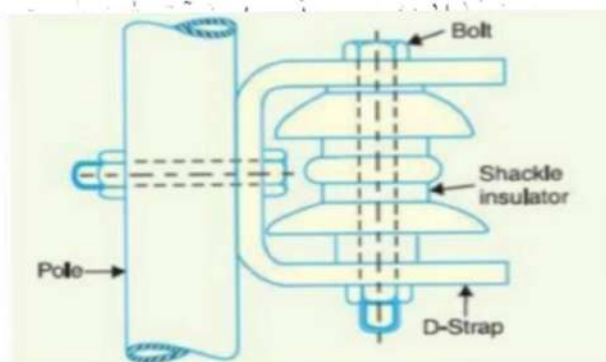
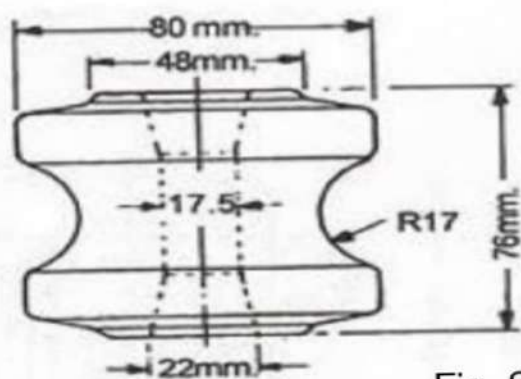


Fig. Shackle Insulator

- Fixed to the cross-arm using a U-clamp, bolt, nut and washer.
- Its main function is to reduce/withstand high mechanical tension on the line.
- Used where the line experiences high tension.
- 11 kV: shackle insulator can be used below 11 kV
- strain insulator is used above 11 kV.

* Method of Distribution line Erection:

- Distribution line erection depends on the voltage level because different voltage levels require different construction methods, materials and safety measures.
- Important vltg levels: 220V $\rightarrow$ 400V $\rightarrow$ 11kV $\rightarrow$ 33 kV.

* General steps for Distribution line Erection:

1. Planning and survey:

a) Route selection:

- select the best route considering:
 - Terrain
 - Accessibility
 - Environmental impact
 - Regulatory requirement.

b) load Assessment:

- Determine the expected electrical load that the line must carry.

c) Right of way:

- Obtain necessary permissions and approvals from:
 - land owners
 - regulatory authorities

2) Design and Engineering:

- structural Design:

- Design poles/towers according to:

- voltage level
- Mechanical strength
- Environmental conditions.

- Electrical Design:

select: - conductor type and size

- Insulators

- other components based on electrical requirement.

3) Material procurement:

- Main materials:

- poles/towers: Wood, Concrete, or steel
- Conductors: Aluminium, ACSR etc.
- Insulators: pin, disc, post etc.
- Hardware: clamps, bolts etc.

4) site preparation:

- clearing: Remove trees, plants and obstacles
- Access: prepare access roads if required for transportation of equipment/materials.

* Erection of 220V & 400V Distribution lines:

1. Pole Installation:

Pole: Generally wooden or concrete poles are used.

Foundation:

- Dig foundation holes to suitable depth.
- Typical depth: 1.5 to 2m
- secure poles using concrete or compacted soil.

2. Stringing of conductors:

- Insulators: Fixed suitable insulators to the poles.
- conductor installation:
 - string conductors between poles
 - maintain proper sag and clearance.
- Tensioning:
 - maintain proper tension to avoid excessive stress on poles.
- Connecting lines:
 - connecting individual consumers using service drops.
- Splicing & joining:
 - proper joints/splices are required for:
 - continuity
 - safety.

3) Safety and Testing:

- Grounding:
 - proper grounding of: poles, equipment must be ensured.
- Testing:
 - perform electrical tests to ensure the line is: - functional and safe.

* 11kV & 33kV Distribution lines:

- These are medium-voltage distribution lines used to supply power over longer distances and to different load centers.

1) Poles/Tower Installation:

* Poles: Uses

- concrete poles
- steel poles
- High towers.

* Foundation:

- Requires deeper and stronger foundation than low-vtg lines.
- Designed for heavy and tall structures.

2) Stringing of conductors:

* Insulators:

Uses high-quality insulators such as:

- pin
- suspension.

For high vtg applications.

* Conductor installation:

- Uses special equipment for stringing
- Properly control high tension and long term loading.

* Sag and tension control:

- Calculate and control sag and tension carefully.
- Ensure stability and safety.

3) Installation of Additional Equipment:

* Transformers:

- Distribution transformers are installed to step down V_{tg} as required.

* Switchgear:

- Used for:
- fault detection
 - Isolation
 - Protection

4) Grounding and Bonding:

* Grounding:

- provides a safe path for high fault current
- strong grounding system is essential.

* Bonding:

- Connect all metallic parts together.
- prevents dangerous potential differences.
- Improves safety.

5) Commissioning:

* Inspection: check - Mechanical integrity

- Electrical integrity.

* Testing:

Important test:

- HV test
- Insulation resistance test
- Commissioning tests.

* Distribution Line Feeder & Distributor schemes:

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- Main distribution schemes:

1. Radial system
2. Ring Main system
3. Inter connected system.

* Connection schemes of Distribution system:

B) Radial system:

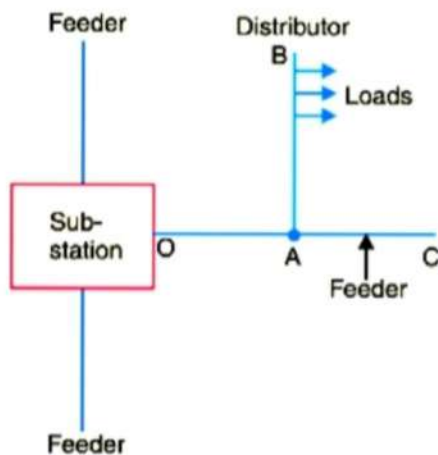


Fig. DC Radial Distribution System

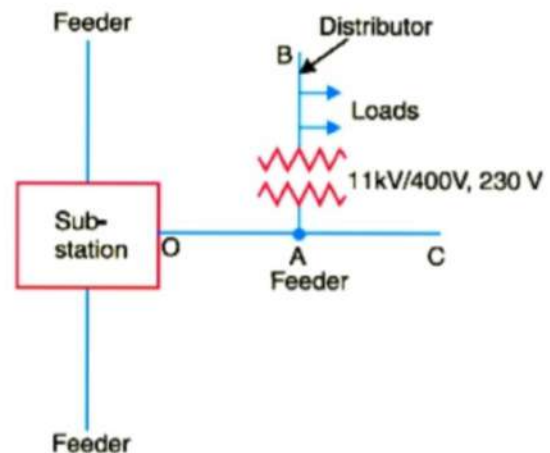


Fig. AC Radial Distribution System

- In a radial distribution system, each distributor receives power from a single Feeder/substation end.

- Basic arrangement:

- Substation $\rightarrow$ Feeder $\rightarrow$ Distributor $\rightarrow$ Consumers.

* Working:

- Feeder supplies the distributor from one end only.
- Commonly used when the generating/substation point is near the center of the load.
- Suitable for low-voltage and short distance distribution.

* Advantages:

- Simple
- Easy to operate
- Low initial cost.

* Disadvantages:

1. Distributor near feeding point may carry very high load.
2. Consumers depends on one feeder and one distributor.
3. Any fault can interrupt supply to consumers beyond the fault.
4. large load variation can cause high vtg fluctuation at the far end.
5. Therefore, generally suitable for short distances.

2) Ring main system:

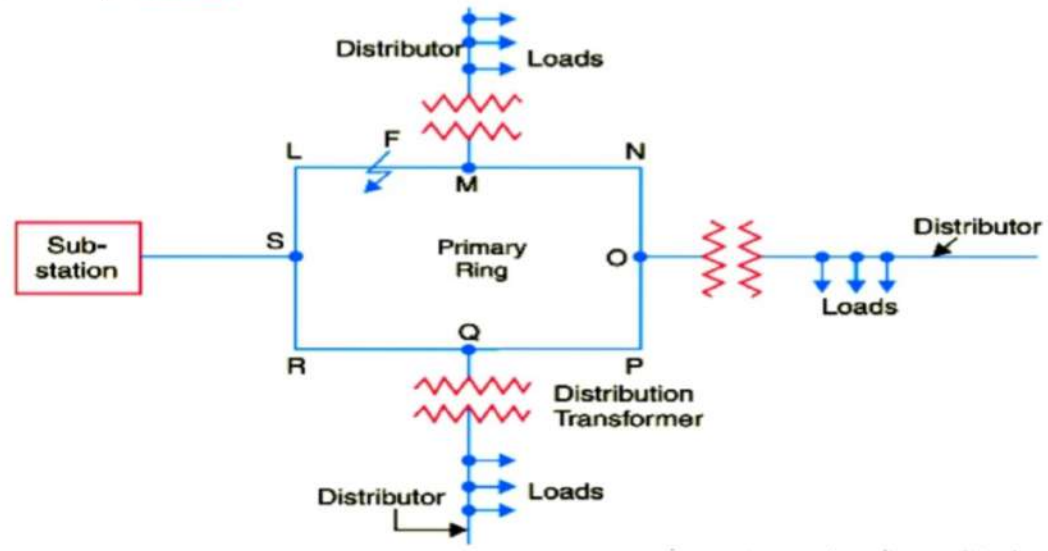


Fig. Ring Main Distribution System

- In a ring-main system, the primary distribution circuit forms a closed loop / ring:
- Ring starts from the substation bus-bar.
- Distribution transformers are connected at different points of the ring.
- A distributor can receive supply from two directions.

* Advantages:

1. Low vtg fluctuation:

- vtg variation at consumer terminals is low.

2. High Reliability:

- Each distributor has supply from two Feeder/directions.

3. Supply Continuity:

- If one section develops a fault, that section can be isolated,
- supply can continue through the other path.

3) Interconnected system:

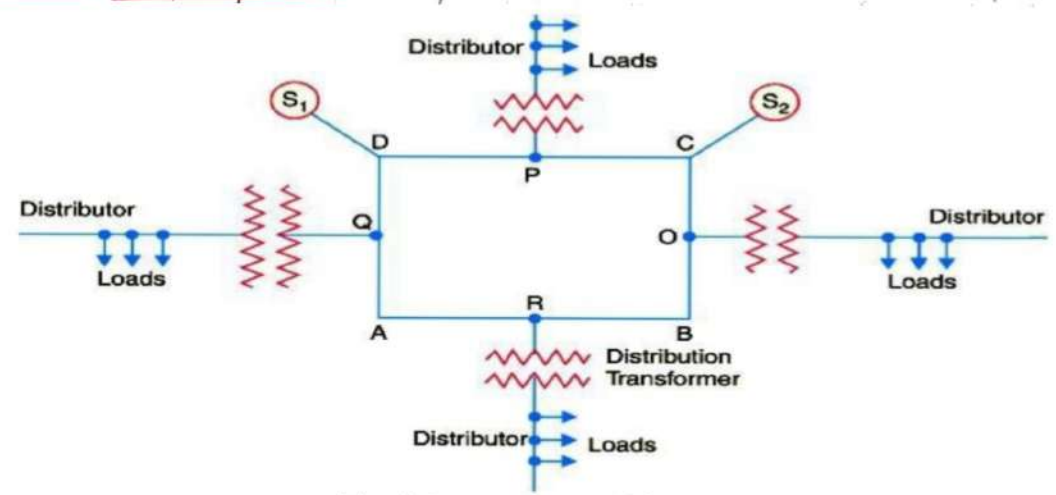


Fig. Interconnected System

- When a ring Feeder is supplied by two or more generating stations or substation, it is called an interconnected system.
- Multiple substations supply the same distribution network.
- Distribution transformers are connected at different points of the ring.
- provides better continuity and reliability of supply.

* Distribution performance of distributor:

- For efficient and reliable power supply, the performance of a distribution system is important, especially
 - voltage drop
 - sending end V_{tg}
 - receiving end v_{tg} .

* Voltage drop

- Defn: Vtg drop is the reduction in vtg along a distribution line due to the resistance and reactance of conductors, transformers and other components.
- When current flows through these components, some electrical energy is lost as heat, causing the voltage to decrease along the length of the distribution line.
- Basic Relation: for resistances

$$\boxed{V = IR}$$

where $V =$ Vtg drop

$I =$ current

$R =$ Resistance.

* Causes of Vtg drop:

1. Resistance of Conductor:

- Conductor / cables have resistance.
- Current flowing through resistance causes Vtg drop.
- According to ohm's law: $\boxed{V = IR}$
- Higher current or resistance $\Rightarrow$ Higher Vtg drop.

2. Reactance of Transformer:

- Transformer has reactance
- This reactance causes a reduction in the output vtg.
- Therefore, transformer reactance contributes to Vtg drop.

3. Load characteristics:

- Vtg drop depends on the type and magnitude of load.
- Imp load types:
 - Resistive load
 - Inductive load
 - Capacitive load.
- Higher load $\rightarrow$ Higher Vtg drop.

4) length and size of conductor:

- longer conductor $\rightarrow$ higher resistance $\rightarrow$ higher V_{tg} drop.
- smaller conductor size $\rightarrow$ higher resistance $\rightarrow$ higher V_{tg} drop.

Therefore:

large conductor size $\rightarrow$ low resistance $\rightarrow$ low V_{tg} drop.

* Effect of Excessive V_{tg} drop:

1. Reduced Efficiency:

- V_{tg} drop causes power/energy losses.
- overall distribution system efficiency decreases.

2. Reduced Load Voltages:

- low V_{tg} at the consumer's end may cause:
 - Improper operation of equipment
 - Reduced performance of electrical appliances
 - Improper brightness of lamps.

3. Overheating and Damage:

- Excessive losses can cause overheating of equipment
- It may result in equipment failure or damage.

* Method to Reduce V_{tg} drop:

1. Use Larger Conductor:

- Increase conductor cross-sectional area.
- Resistance decreases
- Hence, V_{tg} drop decreases.

2. V_{tg} Regulator:

- Install V_{tg} regulator to maintain V_{tg} within permissible limits

3. Tap Changer:

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- Use transformer tap changers for v_{tg} control.

4. v_{tg} Control / Optimization:

- Apply suitable v_{tg} control techniques.
- Improve power factor to reduce v_{tg} drop and improve system performance.

* Receiving End Voltage:

* Defn: Receiving end v_{tg} is the v_{tg} available at the load / consumer end of the distribution line.

* Requirements / Importance:

1. voltage Regulation:

- Receiving end v_{tg} must be maintained within specified / permissible limits for proper operation of electrical equipment.
- v_{tg} regulators and v_{tg}-control devices can compensate for v_{tg} drop.

2. voltage Profile:

- Voltage drop along the distribution line directly affects receiving-end v_{tg}.
- proper design and operation of the distribution system is required to reduce v_{tg} drop and maintain adequate v_{tg}.

3. Load characteristics:

- load reactance and power factor affect receiving end v_{tg}.
- v_{tg} variation depends on the type of load.

4) Quality of supply:

- stable and reliable receiving-end Vtg is essential for providing good quality electrical service to consumers.

* Distribution substation:

Topics:

1. classification
2. site selection
3. Advantages
4. Disadvantages
5. Applications.

* Electrical substation:

* Defn: An electrical substation is a part of the power system where voltage is changed from: High $\rightarrow$ low. for purposes such as;

- Transmission
- Distribution
- Transformation
- switching

* Main Components:

1. power Transformer
2. Circuit Breaker
3. Busbar
4. Insulator
5. Lightning Arrester.

* Classification of substation:

- Substations are mainly classified on two bases:

1. According to service
2. According to construction.

1) According to service:

- substations are used for
 - changing v_{tg} level
 - Improving power level
 - converting AC to DC / DC to AC
 - other specific power system requirements.

(a) Transformer substation:

- Defn: A transformer substation is a substation used to change the v_{tg} level of electrical supply.
- It receives power at one voltage and supplies it at another voltage.
- Transformer is the main component
- most substations in power system are of this type.

(b) switching substation:

- Defn: A switching substation performs switching operations on power lines without changing the voltage level.
- Incoming and outgoing lines have same v_{tg}.
- only switching of power lines is performed.

(c) power factor improvement substations:

Defn: A substation used to improve the power factor of the electrical system is called a power factor improvement substation.

- Generally located at the receiving end of transmission lines.
- Uses power factor improvement equipment.
- synchronous condenser is used for power factor improvement.

(d) Frequency changer substation:

- Defn: A Frequency changer substation is used to change the frequency of electrical supply.
- Applications: Used when a different frequency is required for industrial applications.

(e) Industrial substation:

- Defn: An Industrial substation supplies electrical power to industrial manufacturing processes and facilities.
- steps down high v_tg supply. e.g. 11kV to a suitable lower v_tg for industrial use.

2) According to Construction:

- substation equipment such as:
 - circuit breakers
 - switches
 - fuses
- Other electrical equipment. must be properly arranged to ensure continuous and reliable service.
- According to construction, substations are mainly classified as:
 1. Indoor substation
 2. outdoor substation.

(a) Indoor substation:

- Defn: In an indoor substation, the equipment is installed inside a building / enclosed area.
- Generally used for voltage upto 11kV.
- In areas with polluted atmosphere, indoor substations can be constructed for voltages upto 66kV.

(b) Outdoor substation:

- Defn: In an outdoor substation, electrical equipment is installed in open air.
- Generally used for voltages above 66kV.
- At high voltages, large clearances are required both:
 - conductors, switches, circuit breakers, other equipment.
- Therefore, installing such equipment indoors becomes uneconomical.

* Classification of substation:

(c) Underground substation:

- Used when available land is limited and land cost is very high, especially in densely populated areas.
- In such conditions, the substation is constructed underground.

(d) Pole-mounted substation:

- It is an outdoor substation
- Equipment is mounted on an H-pole or 4-pole structure.
- Commonly used for Vtgs upto 11kV, in some cases upto 33kV.
- Mainly used for local / residential area power distribution.

* Selection and location of site for Electrical substation:

- While selecting a substation site, the following factors are considered:

a) Type of substation:

- Depends on the type and size of substation.
- site should be near:
 - load centre or Transmission lines as required.

b) Suitable and sufficient Land:

- sufficient land should be available for
 - substation equipment
 - structures.
 - future expansion.

c) Communication Facility:

- Reliable Communication is required for:
 - operational control
 - Monitoring
 - Emergency response.

eg. Telephone, Internet.

d) Atmospheric pollution:

- site should be away from pollution sources such as:
 - Industrial emissions
 - Highly Congested areas
- This protects sensitive equipment and provides a safe working environment.

e) Essential facilities for staff:

- Adequate Facilities should be available for staff and families, such as: Housing, Healthcare Educational Facilities, Recreation Facilities.

F) Drainage facilities:

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- Proper drainage should be provided.
- Prevents water accumulation during heavy rain / floods.
- Protects the foundation and equipment stability.

* Single line diagram of 11 kv substation:

- Main function of substation:
- An 11 kv substation supplies electrical energy to local area.
- Its main functions are:
 1. Receive high v_tg electrical power transmitted from the generating station.
 2. step down v_tg for local distribution.
 3. provide facilities for switching and control.

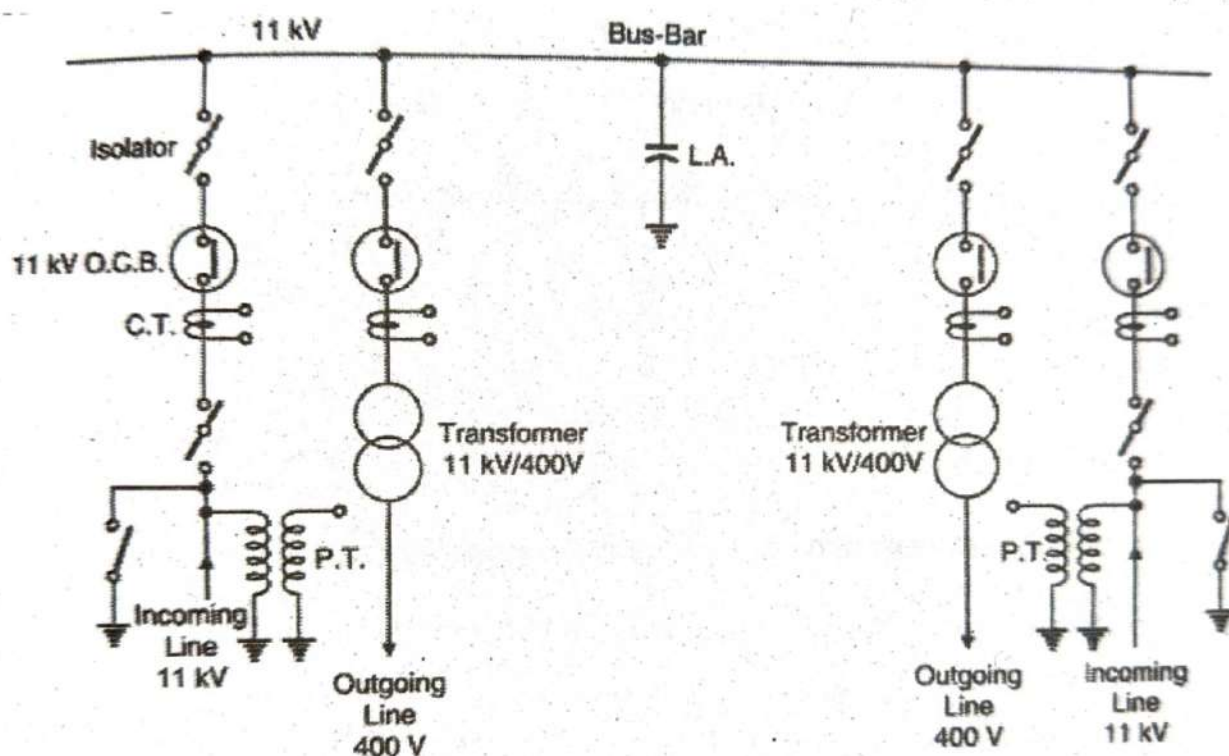


Fig. Single line diagram of 11KV/400V substation

* Types of substation:

1. Switching substation:

- provide different electrical connections betn transmission lines.
- main purpose is switching.

2. Converting substation:

- performs conversion such as:

- AC $\rightarrow$ DC

- DC $\rightarrow$ AC

- High frequency $\rightarrow$ low frequency

- low frequency $\rightarrow$ High frequency.

- Apart from vltg transformation, and switching, a substation also performs the following functions:
 - provides points for installing protective equipment to disconnect the circuit during fault.
 - synchronous condenser may be installed at the end of a transmission line for:
 - power factor improvement
 - Better control / management of power-system operation.
 - street lighting and its switching control can also be provided at the substation.

* Main Components of 11kV substation:

The important components and their functions are:

1. Isolator:

- An isolator ~~consist~~ connects or disconnects the incoming circuit when the supply is already interrupted.
- It is also used to disconnect the charging current of a transmission line.

- It is installed on the supply side of the circuit breaker.
- It provides safe isolation of the circuit breaker from live parts during maintenance.

2. Lightning Arrester:

- It is a protective device used to protect the system from lightning effect/surges.
- It has two terminals:
 - High v_{tg} terminal
 - Ground terminal,
- High v_{tg} terminal is connected to the transmission line.
- Ground terminal carries the high v_{tg} surge safely to earth.

3. CT Metering: (Current Transformer Metering)

- Metering CT measures and records the current flowing in the circuit.
- Its secondary terminals are connected to the metering panel.

4. Step-Down Transformer:

- converts high v_{tg} into low v_{tg}
- In an 11 kV distribution substation; 11 kV is transferred to 400V. (11 kV $\rightarrow$ 400V).

5. Capacitive Bank:

- A capacitive bank consists of several capacitors connected in series or parallel.
- Main function:
 - Reduces reactive component of the circuit.
 - Improve the power factor of the line/system.

6. Circuit Breaker: (CB): A C.B. is an switching device. During fault, it open the circuit and interrupt fault current. It is used for protection and control of the electrical system.