G. PULLAIAH COLLEGE OF ENGINEERING AND TECHNOLOGY
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Nandikotkur Road, Venkayapalli, Kurnool – 518452

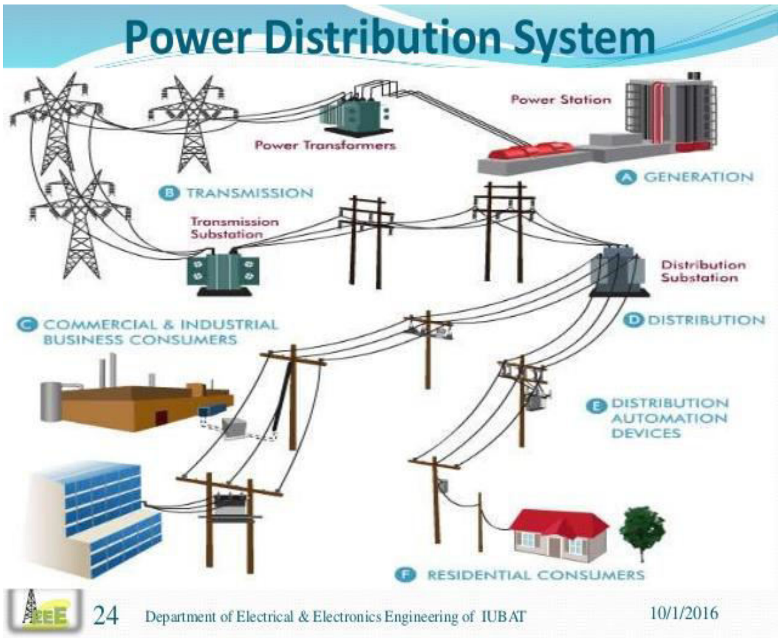
Department of Electrical and Electronics Engineering

Bridge Course

On

Electrical Distribution Systems

(13A02701)



Electrical Distribution Systems

1.Power system:

Power engineering is also called power systems engineering. It is a subfield of electrical engineering that deals with the generation, transmission, distribution and utilization of electric power, and the electrical apparatus connected to such systems.

2.Electrical system:

Electrical system can be as simple as a flashlight cell connected through two wires to a light bulb or as involved as the space shuttle. Electrical systems are groups of electrical components connected to carry out some operation.

3.Electrical power supply system:

An example of an electric power system is the network that supplies a region's homes and industry with power for sizeable regions, this power system is known as the grid and can be broadly divided into the generators that supply the power, the transmission system that carries the power from the generating stations to load centers.

4.Electric supply:

Electric power is the rate, per unit time, at which electrical energy is transferred by an electric circuit. The SI unit of power is the watt, one joule per second. Electric power is usually produced by electric generators, but can also be supplied by sources such as electric batteries.

5.Electrical Network:

An electrical network is an interconnection of electrical components (e.g. batteries, resistors, inductors, capacitors, switches) or a model of such an interconnection, consisting of electrical elements (e.g. voltage sources, current sources, resistances, inductances, capacitances).

6.Electrical Load:

An electrical load is an electrical component or portion of a circuit that consumes (active) electric power. This is opposed to a power source, such as a battery or generator, which produces power. In electric power circuits examples of loads are appliances and lights.

7.Connected load:

The total electric power-consuming rating of all devices (as lamps or motors) connected to a distribution system.

8.Inductive loads:

These type of loads does not allow sudden changes in current and as such, when you measure the current, it lags (is behind) the voltage. Electromagnetic fields are the key to inductive loads, and as such all motors (fans, pumps, etc), solenoids, and relays are inductive in nature. Inductance is measured in Henrys.

9.Resistive Load :

The incandescent light bulb is a commonly-used resistive load. Resistive loads are typically used to convert current into forms of energy such as heat. Unlike inductive loads, resistive loads generate no magnetic fields. Common examples include most electrical heaters, and traditional incandescent lighting loads.

10.Reactive/Capacitive Load:

A capacitive load charges and releases energy. Capacitive reactance resists the change to voltage, causing the circuit current to lead voltage. A capacitive load bank is similar to an inductive load bank in rating and purpose.

11.Parts of power system:

Power systems are comprised of 3 basic electrical subsystems.

- Generation subsystem
- Transmission subsystem
- Distribution subsystem

The sub transmission system is also sometimes designated to indicate the portion of the overall system that interconnects the EHV and HV transmission system to the distribution system.

We distinguish between these various portions of the power system by voltage levels as follows:

- Generation: 1kV-30 kV
- EHV Transmission: 500kV-765kV
- HV Transmission: 230kV-345kV
- Sub transmission system: 69kV-169kV
- Distribution system: 120V-35kV

Our focus in this course is on the distribution system. About 40% of power system investment is in the distribution system equipment (40% in generation, 20% in transmission).

11.1Generation:

Electricity generation is the process of generating electric power from sources of primary energy. For electric utilities, it is the first process in the delivery of electricity to consumers. The other processes as transmission, distribution, energy storage and recovery using pumped-storage

methods are normally carried out by the electric power industry. Electricity is most often generated at a power station by electromechanical generators, primarily driven by heat engines fuelled by combustion or nuclear fission but also by other means such as the kinetic energy of flowing water and wind. Other energy sources include solar photovoltaics and geothermal power.

11.2.Types of generation of electricity:

1.Hydal power plants

2.Thermal power plants

3.Nuclearpower plants

4.Solar electricity

5.Bio-mass electricity

6.Tydal energy

12.Transmission:

Electric power transmission is the bulk movement of electrical energy from a generating site, such as a power plant, to an electrical substation. The interconnected lines which facilitate this movement are known as a transmission network.

12.1.Types of Transmission systems:

Depending upon Operating voltage

1.Primary Transmission (132kv,220kv,400kv,765kv)

2.Secondary Transmission(66kv,33kv)

Depending upon Construction

1.Over Head Transmission system

2.Under Ground Transmission System

13.Grid:

An electrical grid is an interconnected network for delivering electricity from producers to consumers. It consists of generating stations that produce electrical power, high voltage transmission lines that carry power from distant sources to demand centers, and distribution lines that connect individual customers.

14.Electrical Power Distribution System:

The main function of an electrical power distribution system is to provide power to individual consumer premises. Distribution of electric power to different consumers is done with much low voltage level.

15.Electric demand:

Electric demand refers to the maximum amount of electrical energy that is being consumed at a given time. It is measured in both kilowatts and kilovolt amperes, depending on the rate tariff. The difference between the two terms is power factor.

16.Peak Demand:

The peak demand of an installation or a system is simply the highest demand that has occurred over a specified time period . Peak demand is typically characterized as annual, daily or seasonal and has the unit of power. Peak demand, peak load or on-peak are terms used in energy demand management describing a period in which electrical power is expected to be provided for a sustained period at a significantly higher than average supply level. Peak demand fluctuations may occur on daily, monthly, seasonal and yearly cycles. For an electric utility company, the actual point of peak demand is a single half-hour or hourly period which represents the highest point of customer consumption of electricity. At this time there is a combination of office, domestic demand and at some times of the year, the fall of darkness.

Some utilities will charge customers based on their individual peak demand. The highest demand during each month or even a single 15 to 30 minute period of highest use in the previous year may be used to calculate charges.

17. Power factor:

We can define power factor in three different ways.

1.Power factor is defined as cosine angle between voltage and current(cosΦ)

2.Ratio of active power to apparent power

$$\text{Power factor} = \frac{\text{Active Power}}{\text{Apparent Power}} = \frac{KW}{KVA}$$

3.Ratio of Resistance to Impedance in AC Circuits

$$\text{Power factor} = \frac{\text{Resistance}}{\text{Impedance}} = \frac{R}{Z}$$

17.1. Power Triangle:

Power Triangle is the representation of a right angle triangle showing the relation between active power, reactive power and apparent power. When each component of the current that is the active component (Icosφ) or the reactive component (Isinφ) is multiplied by the voltage V, a power triangle is obtained shown in the figure below.

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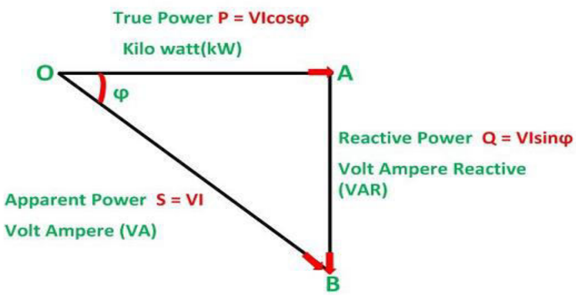

Fig: Power Traingle

The power which is actually consumed or utilized in an AC Circuit is called True power or Active Power or real power. It is measured in kilowatt (kW) or MW. The power which flows back and forth that means it moves in both the direction in the circuit or react upon it, is called Reactive Power**.** The reactive power is measured in kilovolt-ampere reactive (kVAR) or MVAR. The product of root mean square (RMS) value of voltage and current is known as Apparent Power. This power is measured in KVA or MVA.

The following point shows the relationship between the following quantities and is explained by graphical representation called Power Triangle shown above.

- When an active component of current is multiplied by the circuit voltage V, it results in active power.It is this power which produces torque in the motor, heat in heater, etc. This power is measured by the wattmeter.
- When the reactive component of the current is multiplied by the circuit voltage, it gives reactive power. This power determines the power factor, and it flows back and flow in the circuit.
- When the circuit current is multiplied by the circuit voltage, it results in apparent power. From the power triangle shown above the power, the factor may be determined by taking the ratio of true power to the apparent power.

$$\text{Power factor} = \frac{ActivePower}{ApparentPower} = \frac{KW}{KVA}$$

As we know simply power means the product of voltage and current but in AC circuit except pure resistive circuit there is usually a phase difference between voltage and current and thus VI does not give real or true power in the circuit.

17.2. Disadvantages of low power factor:

The undesirable effect of operating a low load at a low power factor is due to the large current required for a low power factor. The important disadvantages of low power factor are

- Higher current is required by the equipment,due to which the economic cost of the equipment is increased.
- At low power factor, the current is high which gives rise to high copper losses in the system and therefore the efficiency of the system is reduced.
- Higher current produced a large voltage drop in the apparatus. This results in the poor voltage regulation.

Since both the capital and running cost are increased, the operation of the system at low power factor (whether it is lagging or leading) is uneconomical from the supplier's point of view.

17.3. Causes of low Power Factor:

A. Inductive Loads:

- 90% of the industrial load consists of Induction Machines (1-φ and 3-φ). Such machines draw magnetizing current to produce the magnetic field and hence work at low power factor.
- For Induction motors, the pf is usually extremely low (0.2 - 0.3) at light loading conditions and it is 0.8 to 0.9 at full load.
- The current drawn by inductive loads is lagging and results in low pf.
- Other inductive machines such as transformers, generators, arc lamps, electric furnaces etc work at low pf too.

B. Variations in power system loading:

- Today we have interconnected power systems. According to different seasons and time, the loading conditions of the power system vary. There are peak as well as low load periods.
- When the system is loaded lightly, the voltage increases and the current drawn by the machines also increases. This results in low power factor.

C. Harmonic currents:

- The presence of harmonic currents in the system also reduces the power factor.
- In some cases, due to improper wiring or electrical accidents, a condition known as 3-φ power imbalance occurs. This results in low power factor too.

17.4. Power Factor Correction:

When the power factor is unity, all the energy supplied by the source is consumed by the load. Power factors are usually stated as "leading" or "lagging" to show the sign of the phase angle. Capacitive loads are leading (current leads voltage), and inductive loads are lagging (current lags voltage).For Power Factor Correction (PFC), note the following points:

- For pure inductance, current lags behind voltage by 90°.
- For pure capacitance, current leads voltage by 90°.
- So, the solution is simple. If we use capacitors to draw leading current, we can cancel the effects of lagging inductive current and hence improve the power factor.

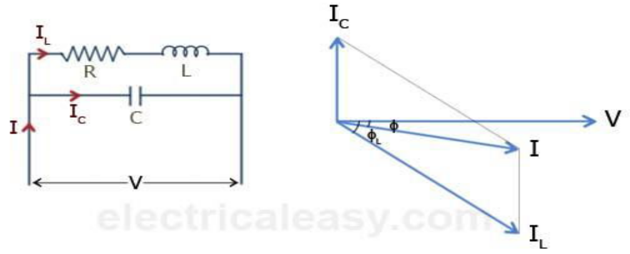

Fig: power factor correction

17.5. Methods of Power Factor Correction or Improvement:

There are three methods for improving power factor. They are

1. Synchronous Condenser
2.Capacitor Bank
3. Phase Advancers

18.Load Factor:

In electrical engineering the load factor is defined as the average load divided by the peak load in a specified time period.[1] It is a measure of variability of consumption or generation; a low load factor indicates that load is highly variable, whereas consumers or generators with steady consumption or supply will have a high load factor.

$$\text{Load Factor} = \frac{AverageDemand}{MaximumDemand}$$

An example, using a large commercial electrical bill:

- peak demand = 436 kW
- use = 57200 kWh
- number of days in billing cycle = 30 d

Hence: load factor = { 57200 kWh / (30 d × 24 hours per day × 436 kW) } × 100% = 18.22%

It can be derived from the load profile of the specific device or system of devices. Its value is always less than one because maximum demand is always higher than average demand, since facilities likely never operate at full capacity for the duration of an entire 24-hour day. A high load factor means power usage is relatively constant. Low load factor shows that occasionally a high demand is set. To service that peak, capacity is sitting idle for long periods, thereby imposing higher costs on the system. Electrical rates are designed so that customers with high load factor are charged less overall per kWh. This process along with others is called load balancing or peak shaving. The load factor is closely related to and often confused with the demand factor.

The major difference to note is that the denominator in the demand factor is fixed depending on the system. Because of this, the demand factor cannot be derived from the load profile but needs the addition of the full load of the system in question.

19. Demand Factor:

Demand factor is the ratio of the sum of the maximum demand of a system (or part of a system) to the total connected load on the system (or part of the system) under consideration. Demand factor is always less than one.

$$\text{Demand Factor}=\frac{Sumof\ \max imumDemandofaSystem}{TotalConnectedLoad}$$

20. Diversified Load :

The diversified load is the total expected load (power) to be drawn during a peak period by a device or system of devices. The diversified load is the combination of each devices full load capacity, Utilization Factor, Diversity Factor, Demand Factor and the Load factor(electrical)| load factor.

21.Diversity Factor :

It is a measure of the probability that a particular piece of equipment will turn on coincidentally to another piece of equipment. For aggregate systems it is defined as the ratio of the sum of the individual non-coincident maximum loads of various subdivisions of the system to the maximum demand of the complete system.

The diversity factor is almost always greater than 1 since all components would have to be on simultaneously at full load for it to be one. The aggregate load is time dependent as well as being dependent upon equipment characteristics. The diversity factor recognizes that the whole load does not equal the sum of its parts due to this time interdependence (i.e. diverseness). For example, we might have ten air conditioning units that are 20 tons each at a facility. In Florida we typically assume that the average full load equivalent operating hours for the units are 2000 hours per year. However, since the units are each thermostatically controlled, we do not know exactly when each unit turns on. If the ten units are substantially bigger than the facility's actual peak A/C load, then fewer than all ten units will likely come on at once. Thus, even though each unit runs a total of 2000 hours a year, they do not all come on at the same time to affect the facility's peak load. The diversity factor gives us a correction factor to use, which results in a lower total kW load for the ten A/C units. If the energy balance we do for this facility comes out within reason, but the demand balance shows far too many kW for the peak load, then we can use the diversity factor to bring the kW into line with the facility's true peak load. The diversity factor does not affect the kWh; it only affects the kW.

22.Loss Load Factor (LLF)

Load Factor (LF) is defined as the ratio of the average demand over a period of time to the maximum demand within that period for the particular network Loss Load Factor (LLF) is defined as average power losses over a period of time to the losses at the time of peak demand.

$$\text{Loss Factor} = \frac{AveragePowerLosses}{LossesatPeakDemand}$$

23.Load Curve:

In a power system, a load curve or load profile is a chart illustrating the variation in demand/electrical load over a specific time. Generation companies use this information to plan how much power they will need to generate at any given time. A load duration curve is similar to a load curve.

A graphical plot showing the variation in demand for energy of the consumers on a source of supply with respect to time is known as the load curve. If this curve is plotted over a time period of 24 hours, it is known as daily load curve. If its plotted for a week, month, or a year, then its named as the weekly ,monthly or yearly load curve respectively.

24. Load Duration Curve(LDC):

A load duration curve (LDC) is used in electric power generation to illustrate the relationship between generating capacity requirements and capacity utilization. A LDC is similar to a load curve but the demand data is ordered in descending order of magnitude, rather than chronologically.

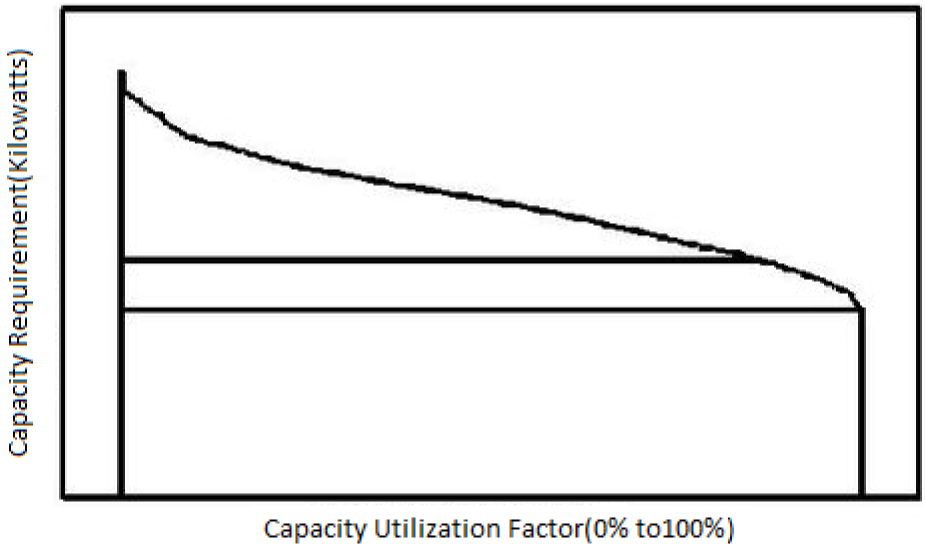

Fig:Load Duration Curve

25. Substation:

A substation is a part of an electrical generation, transmission, and distribution system. Substations transform voltage from high to low, or the reverse, or perform any of several other important functions.

26.Equipments of Substation:

26.1. Transformer:

A transformer is an electrical device that transfers electrical energy between two or more circuits through electromagnetic induction. A varying current in one coil of the transformer produces a varying magnetic field, which in turn induces a voltage in a second coil. Power can be transferred between the two coils through the magnetic field, without a metallic connection between the two circuits.

26.2. Types of Transformers:

- Step-down transformer
- Step-up transformer
- Power transformer
- Single-phase or three-phase transformer
- Instrument transformer

- Potential transformer
- Current transformer

27.Circuit Breaker:

A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by excess current, typically resulting from an overload or short circuit. Its basic function is to interrupt current flow after a fault is detected.

27.1.Different Types of Circuit Breakers:

The different types of high voltage circuit breakers which includes the following

- Air Circuit Breaker
- SF6 Circuit Breaker
- Vacuum Circuit Breaker
- Oil Circuit Breaker
- Air Circuit Breaker

28.Fuse:

In electronics and electrical engineering, a fuse is an electrical safety device that operates to provide over current protection of an electrical circuit including the source of power and the load. Its essential component is a metal wire or strip that melts when too much current flows through it, thereby interrupting the current. It is a sacrificial device and once a fuse has operated it is an open circuit, and it must be replaced or rewired, depending on type.

29.Relay:

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

29.1. Different Types of Relays:

The different types of relays that are used in power system are

- Electromagnetic Relays
- Solid State Relays
- Hybrid Relay

- Thermal Relay
- Thermal Relay