Electrical Distribution Systems & Automation

III YEAR B.TECH, EEE-II SEM

Objective:

This course gives the complete knowledge of electrical distribution systems, the design of feeders, substations. It also gives conceptual knowledge on how to determine the performance of a distribution system through its important parameters i.e. voltage drops and power losses and the very important thing that protection of the system by means of protective devices and their co-ordination during the several fault conditions. it also specifies how to improve the voltage profiles and power factors of the system to better value using various voltage control and compensation techniques.

MODULE -I

Introduction & General Concepts:

Introduction to distribution systems: Load modeling and characteristics. Coincidence factor, contribution factor, loss factor - Relationship between the load factor and loss factor.

Classification of loads: Residential, commercial, Agricultural and industrial loads and their characteristics.

MODULE -II

Distribution Feeders & Substations:

Design consideration of Feeders: Radial and loop types of primary feeders, voltage levels, feeder loading, basic design practice of the secondary distribution system.

Substations: Rating of distribution substation, service area with "n" primary feeders. Benefits derived through optimal location of substations.

MODULE -III

Distribution System Analysis:

A) **Power Factor:** . Causes of low power factor- methods of improving power factor-Phase Advancing and generation of reactive KVAR using static Capacitors- Most economical power factor for constant KW and Most economical power factor for constant KVA type loads, Numerical problems. Dependency of voltage on reactive Power flow.

B) Voltage droop and power-loss calculations:

Derivation for voltage droop and power loss in lines, manual methods of solution for radial networks, three phase balanced primary lines.

MODULE -IV

Protection:

Objectives of distribution system protection , types of common faults and procedure for fault calculations.

Protective Devices: Principle of operation of fuses, circuit re-closures and line sectionalizes and circuit breakers.

Co-Ordination of Protective Devices: General coordination procedure.

MODULE -V

Voltage Control & Distribution Automation: Methods of voltage control- shunt capacitors, series capacitors, Synchronous capacitors, Tap changing and Booster transformers, line drop compensation effect of AVB/AVR.

Distribution Automation: Need for DA, Objectives and Functions of DA, SCADA, consumer information service, GIS, automatic reading.

TEXT BOOK:

1. Electrical power distribution systems, V.Kamaraju, TMH.

2. Electrical distribution systems. Dr. S. Siva naga raju, Dr. K. Shankar, Danapathi Rai Publications.

REFERENCE BOOK:

1. Electrical power Distribution Systems Engineering, Turan Gonen, CRC Press.

2. Electrical power Generation, Transmission and Distribution SN. Singh, PHI Publishers.

MODULE-I

INTRODUCTION & GENERAL CONCEPTS

Introduction to Distribution Systems

Introduction

The electric utility industry was born in 1882 when the first electric power station, Pearl Street Electric Station in New York City, went into operation. The electric utility industry grew very rapidly, and generation stations and transmission and distribution networks have spread across the entire country. Considering the energy needs and available fuels that are forecasted for the next century, energy is expected to be increasingly converted to electricity.

In general, the definition of an electric power system includes a generating, a transmission, and a distribution system. In the past, the distribution system, on a national average, was estimated to be roughly equal in capital investment to the generation facilities, and together they represented over 80% of the total system investment.

Distribution System Planning

System planning is essential to assure that the growing demand for electricity can be satisfied by distribution system additions that are both technically adequate and reasonably economical. Even though considerable work has been done in the past on the application of some types of systematic approach to generation and transmission system planning, its application to distribution system planning has unfortunately been somewhat neglected.

The objective of distribution system planning is to assure that the growing demand for electricity, in terms of increasing growth rates and high load densities, can be satisfied in an optimum way by additional distribution systems, from the secondary conductors through the bulk power substations, which are both technically adequate and reasonably economical.

Distribution system planners must determine the load magnitude and its geographic location. Then the distribution substations must be placed and sized in such a way as to serve the load at maximum cost effectiveness by minimizing feeder losses and construction costs, while considering the constraints of service reliability.

Factors Affecting System Planning

Load Forecasting

The load growth of the geographic area served by a utility company is the most important factor influencing the expansion of the distribution system. Therefore, forecasting of load increases and system reaction to these increases is essential to the planning process.

Figure 1.1 indicates some of the factors that influence the load forecast. As one would expect, load growth is very much dependent on the community and its development. Economic indicators, demographic data, and official land use plans all serve as raw input to the forecast procedure.

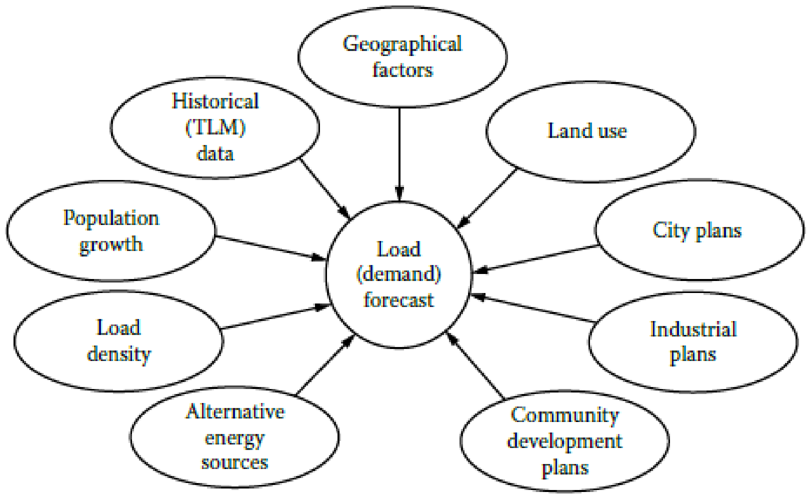


Figure 1.1 Factors affecting load forecast.

Substation Expansion

Figure 1.2 presents some of the factors affecting the substation expansion. The planner makes a decision based on tangible or intangible information. For example, the forecasted load, load density, and load growth may require a substation expansion or a new substation construction. In the system expansion plan, the present system configuration, capacity, and the forecasted loads can play major roles.

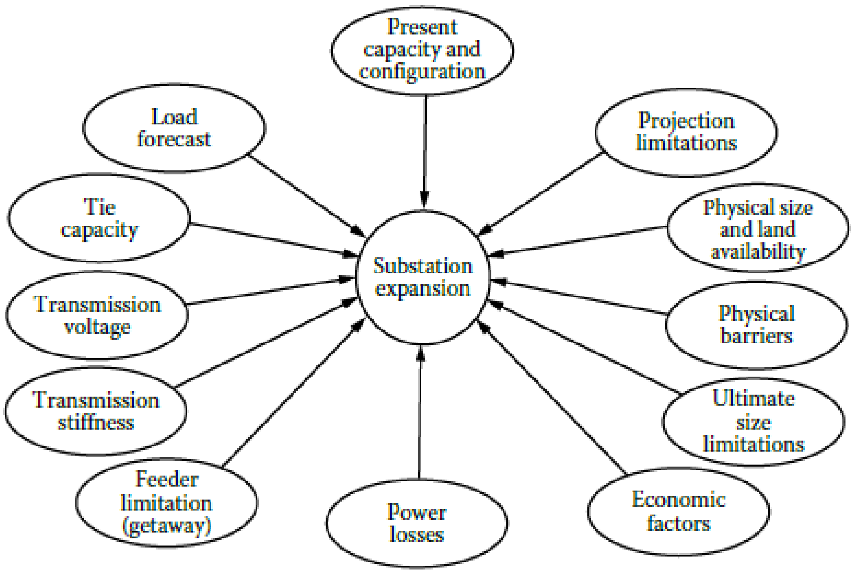


Figure 1.2 Factors affecting substation expansion.

Substation Site Selection

Figure 1.3 shows the factors that affect substation site selection. The distance from the load centers and from the existing sub transmission lines as well as other limitations, such as availability of land, its cost, and land use regulations, is important. The substation siting process can be described as a screening procedure through which all possible locations for a site are passed, as indicated in Figure 1.4. The service region is the area under evaluation. It may be defined as the service territory of the utility.

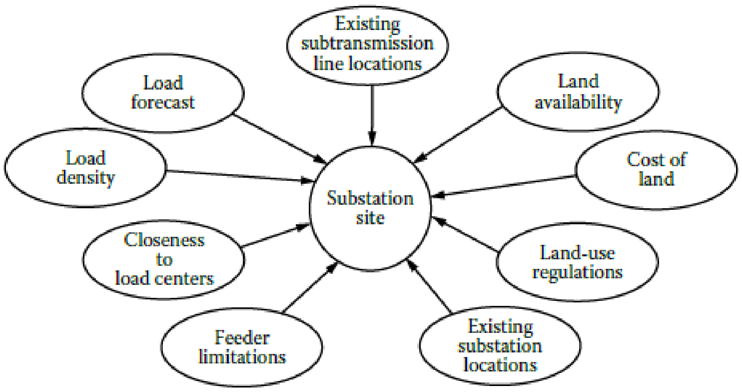


Figure 1.3 Factors affecting substation siting.

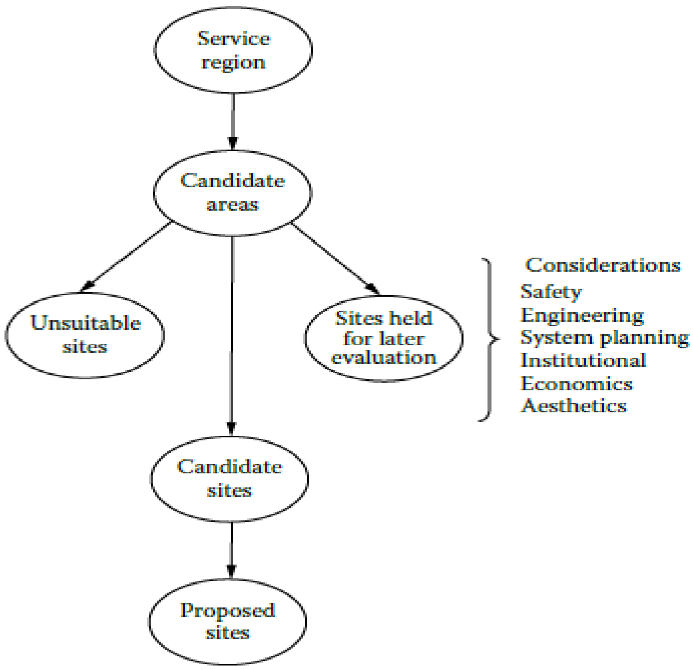


Figure 1.4 Substation site selection procedure.

Other Factors

Once the load assignments to the substations are determined, then the remaining factors affecting primary voltage selection, feeder route selection, number of feeders, conductor size selection, and total cost, as shown in Figure 1.5, need to be considered.

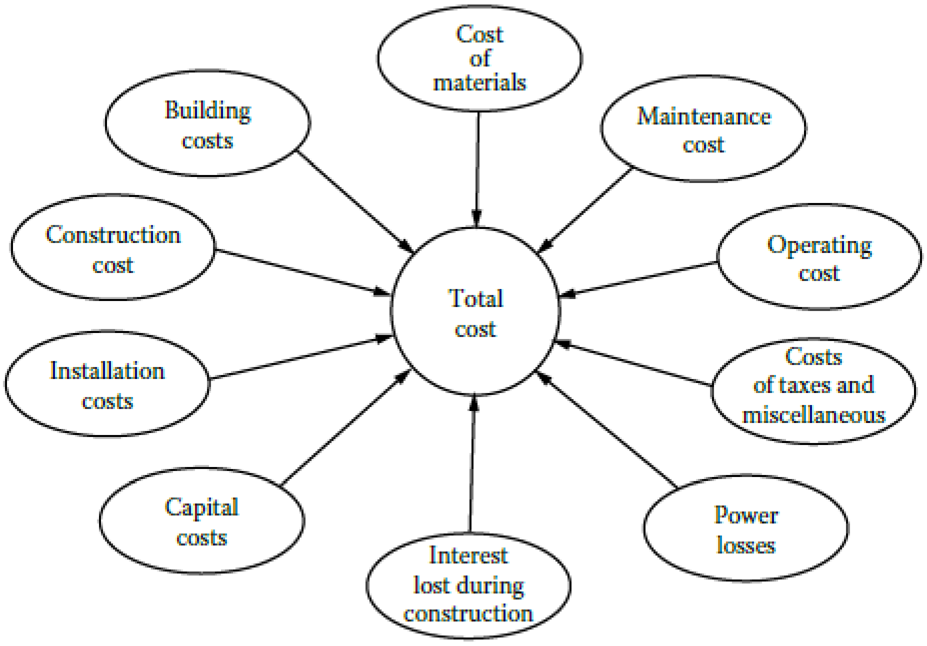


Figure 1.5 Factors affecting total cost of the distribution system expansion.

Present Distribution System Planning Techniques

Today, many electric distribution system planners in the industry utilize computer programs, usually based on ad hoc techniques, such as load flow programs, radial or loop load flow programs, short-circuit and fault-current calculation programs, voltage drop calculation programs, and total system impedance calculation programs, as well as other tools such as load forecasting, voltage regulation, regulator setting, capacitor planning, reliability, and optimal siting and sizing algorithms. Figure 1.6 shows a functional block diagram of the distribution system planning process currently followed by most of the utilities.

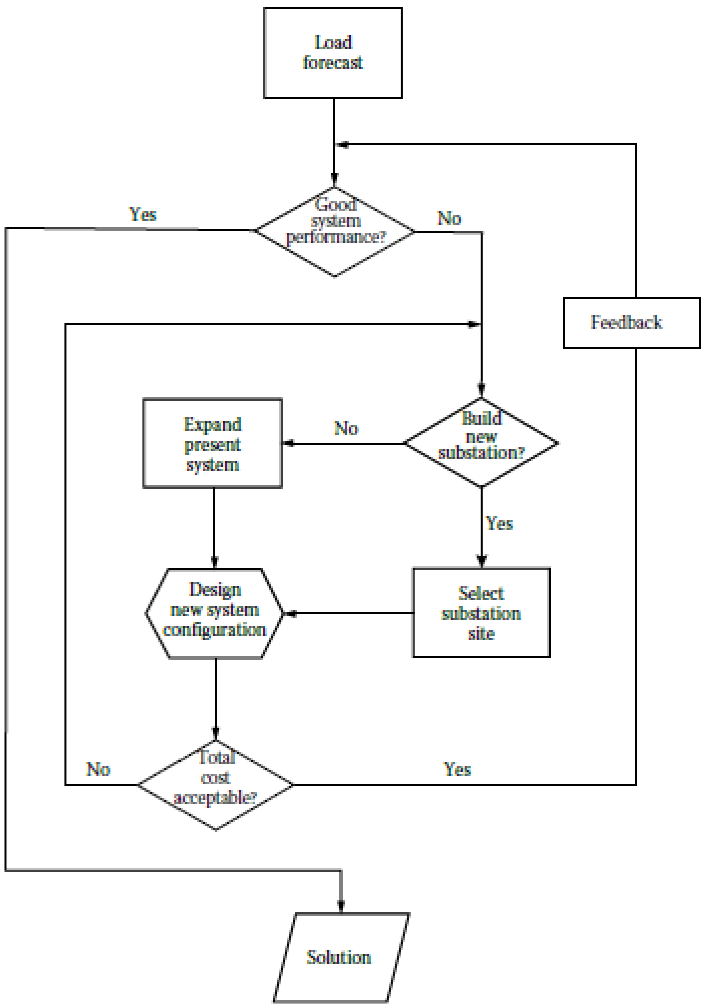


Figure 1.6 A block diagram of a typical distribution system planning process.

The acceptability criteria, representing the company's policies, obligations to the consumers, and additional constraints, can include

1. Service continuity
2. The maximum allowable peak-load voltage drop to the most remote customer on the secondary
3. The maximum allowable voltage dip occasioned by the starting of a motor of specified starting current characteristics at the most remote point on the secondary
4. The maximum allowable peak load
5. Service reliability
6. Power losses

Distribution System Planning Models

In general, distribution system planning dictates a complex procedure due to a large number of variables involved and the difficult task of the mathematical presentation of numerous requirements and limitations specified by system configuration. Therefore, mathematical models are developed to represent the system and can be employed by distribution system planners to investigate and determine optimum expansion patterns or alternatives, for example, by selecting

1. Optimum substation locations
2. Optimum substation expansions
3. Optimum substation transformer sizes
4. Optimum load transfers between substations and demand centers
5. Optimum feeder routes and sizes to supply the given loads subject to numerous constraints to minimize the present worth of the total costs involved.

Some of the operations research techniques used in performing this task include

1. The alternative-policy method, by which a few alternative policies are compared and the best one is selected
2. The decomposition method, in which a large problem is subdivided into several small problems and each one is solved separately
3. The linear-programming, integer-programming, and mixed-integer programming methods that linearize constraint conditions
4. The quadratic programming method
5. The dynamic-programming method
6. Genetic algorithms method

LOAD CHARACTERISTICS

Demand: "The demand of an installation or system is the load at the receiving terminals averaged over a specified interval of time". Here, the load may be given in kilowatts, kilovars, kilovoltamperes, kiloamperes, or amperes.

Demand interval: It is the period over which the load is averaged. This selected Δt period may be 15 min, 30 min, 1 h, or even longer. Of course, there may be situations where the 15 and 30 min demands are identical

Maximum demand: "The maximum demand of an installation or system is the greatest of all demands which have occurred during the specified period of time". The maximum demand statement should also express the demand interval used to measure it. For example, the specific demand might be the maximum of all demands such as daily, weekly, monthly, or annual.

Diversified demand (or coincident demand): It is the demand of the composite group, as a whole, of somewhat unrelated loads over a specified period of time. Here, the maximum diversified demand has an importance. It is the maximum sum of the contributions of the individual demands to the diversified demand over a specific time interval.

Utilization factor: It is "the ratio of the maximum demand of a system to the rated capacity of the system". Therefore, the utilization factor (F_u) is

$$F_u \triangleq \frac{\text{Maximum demand}}{\text{Rated systemcapacity}}$$

Plant factor: It is the ratio of the total actual energy produced or served over a designated period of time to the energy that would have been produced or served if the plant (or unit) had operated continuously at maximum rating. It is also known as the capacity factor or the use factor.

$$\text{Plant factor} = \frac{\text{Actual energy produced or served} * \text{T}}{\text{Maximumplant rating} * \text{T}}$$

$$\text{Annual Plant factor} = \frac{\text{Actual annual energy generation}}{\text{Maximum plant rating} * 8760}$$

Load factor: It is "the ratio of the average load over a designated period of time to the peak load occurring on that period". Therefore, the load factor F_{LD} is o average load.

$$F_{LD} \triangleq \frac{\text{Average load}}{\text{Peak load}}$$

$$\text{Annual load factor} = \frac{\text{Total annual energy}}{\text{Annual peak load} * 8760}$$

Diversity factor: It is "the ratio of the sum of the individual maximum demands of the various subdivisions of a system to the maximum demand of the whole system". Therefore, the diversity factor (F_D) is

$$F_D \triangleq \frac{\text{Sumof individual maximum demands}}{\text{Coincident maximum demand}}$$

$$F_D = \frac{\sum_{i=1}^{n} D_i}{D_g}$$

where
D_i is the maximum demand of load i, disregarding time of occurrence

$D_g = D_{1+2+3+\cdots+n}$ = coincident maximum demand of group of loads

Coincidence factor: It is "the ratio of the maximum coincident total demand of a group of consumers to the sum of the maximum power demands of individual consumers comprising the group both taken at the same point of supply for the same time". Therefore, the coincidence factor (F_c) is

$$F_c = \frac{\text{Coincident maximum demand}}{\text{Sumof individual maximum demands}}$$

$$F_c = \frac{D_g}{\sum_{i=1}^{n} D_i}$$

$$F_c = \frac{1}{F_D}$$

Load diversity: It is "the difference between the sum of the peaks of two or more individual loads and the peak of the combined load". Therefore, the load diversity (LD) is

$$LD \triangleq \left(\sum_{i=1}^{n} D_i\right) - D_g$$

Contribution factor: Manning defines c_i as "the contribution factor of the i^{th} load to the group maximum demand." It is given in per unit of the individual maximum demand of the i^{th} load. Therefore,

$$D_g \triangleq c_1 * D_1 + c_1 * D_2 + c_3 * D_3 + \cdots + c_n * D_n$$

if $C = c_1 = c_2 \ldots . = c_n$

$$D_g \triangleq C \left(\sum_{i=1}^{n} D_i\right)$$

Coincidence factor is

$$F_c = \frac{D_g}{\sum_{i=1}^{n} D_i}$$

$$F_c = C$$

That is, the coincidence factor is equal to the contribution factor.

Loss factor: It is "the ratio of the average power loss to the peak-load power loss during a specified period of time". Therefore, the loss factor (F_{LS}) is

$$F_{LS} \triangleq \frac{\text{Average power loss}}{\text{Power lossat peak load}}$$

Note: is applicable for the copper losses of the system but not for the iron losses.

RELATIONSHIP BETWEEN THE LOAD AND LOSS FACTORS

In general, the loss factor cannot be determined from the load factor. However, the limiting values of the relationship can be found. Assume that the primary feeder shown in Figure 1.8 is connected to a variable load. Figure 1.9 shows an arbitrary and idealized load curve. However, it does not represent a daily load curve.

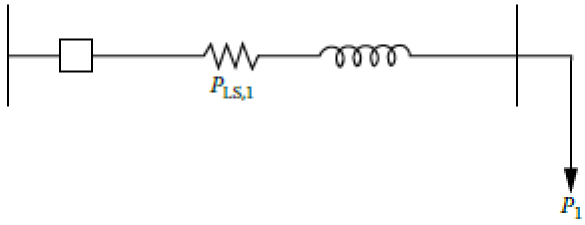


Figure 1.8 A feeder with a variable load.

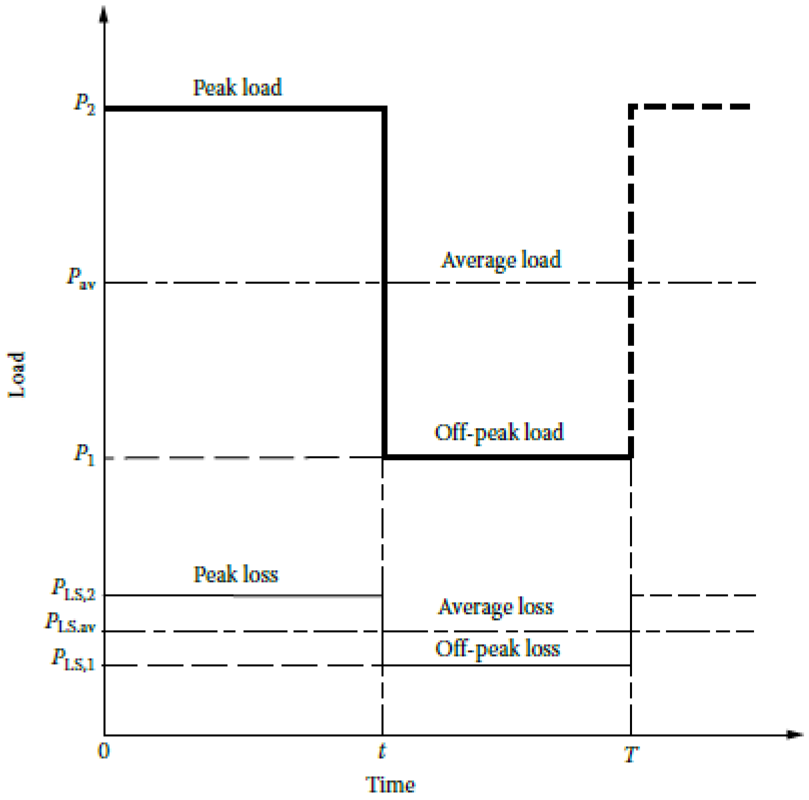


Figure 1.9 An arbitrary and ideal load curve.

Assume that the off-peak loss is $P_{LS,1}$at some off-peak load $P_1$and that the peak loss is$P_{LS,2}$ at the peak load P_2. The load factor is

$$F_{LD} \triangleq \frac{\text{Average load}}{\text{Peak load}} = \frac{P_{av}}{P_2}$$

From Figure 2.9

$$P_{av} = \frac{P_2 * t + P_1 * (T - t)}{T}$$

form that

$$F_{LD} = \frac{t}{T} + (\frac{P_1}{P_2} * \frac{(T - t)}{T})$$

The loss factor is

$$F_{LS} \triangleq \frac{\text{Average power loss}}{\text{Power lossat peak load}} = \frac{P_{LS,av}}{P_{LS,max}} = \frac{P_{LS,av}}{P_{LS,2}}$$

From Figure 2.9,

$$P_{LS,av} = \frac{P_{LS,2} * t + P_{LS,1} * (T - t)}{T}$$

from that

$$F_{LS} = \frac{t}{T} + (\frac{P_{LS,1}}{P_{LS,2}} * \frac{(T - t)}{T})$$

The copper losses are the function of the associated loads. Therefore, the off-peak and peak loads can be expressed, respectively, as

$$P_{LS,1} = k * P_1^2$$

and

$$P_{LS,2} = k * P_2^2$$

so that

$$F_{LS} = \frac{t}{T} + ((\frac{P_1}{P_2})^2 * \frac{(T - t)}{T})$$

The load factor can be related to loss factor for three different cases.

Case 1: Off-peak load is zero. Here$P_{LS,1} = 0$ since $P_1 = 0$.
then

$$F_{LD} = F_{LS} = \frac{t}{T}$$

That is, the load factor is equal to the loss factor, and they are equal to the $\frac{t}{T}$constant.

Case 2: Very short-lasting peak. Here,
t=0 then

$$\frac{(T - t)}{T} = 1$$

$$F_{LS} = F_{LD}^2$$

That is, the value of the loss factor approaches the value of the load factor squared.

Case 3: Load is steady. Here,

t=T then

$$F_{LD} = F_{LS}$$

That is, the value of the loss factor approaches the value of the load factor.

Therefore, in general, the value of the loss factor is

$$F_{LD}^2 < F_{LS} < F_{LD}$$

Therefore, the loss factor cannot be determined directly from the load factor. The reason is that the loss factor is determined from losses as a function of time, which, in turn, are proportional to the time function of the square load.

However, Buller and Woodrow developed an approximate formula to relate the loss factor to the load factor as

$$F_{LS} = 0.3F_{LD} + 0.7F_{LD}^2$$

Figure 1.10 gives three different curves of loss factor as a function of load factor. Relatively recently, the formula given earlier has been modified for rural areas.

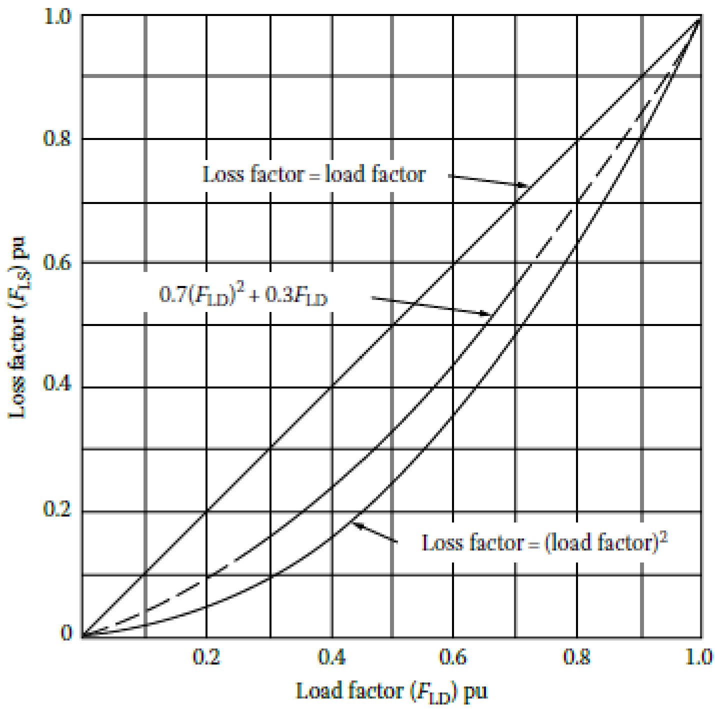


Figure 1.10 Loss factor curves as a function of load factor. (From Westinghouse Electric Corporation, Electric Utility Engineering Reference Book-Distribution Systems, Vol. 3, Westinghouse Electric Corporation, East Pittsburgh, PA, 1965.)

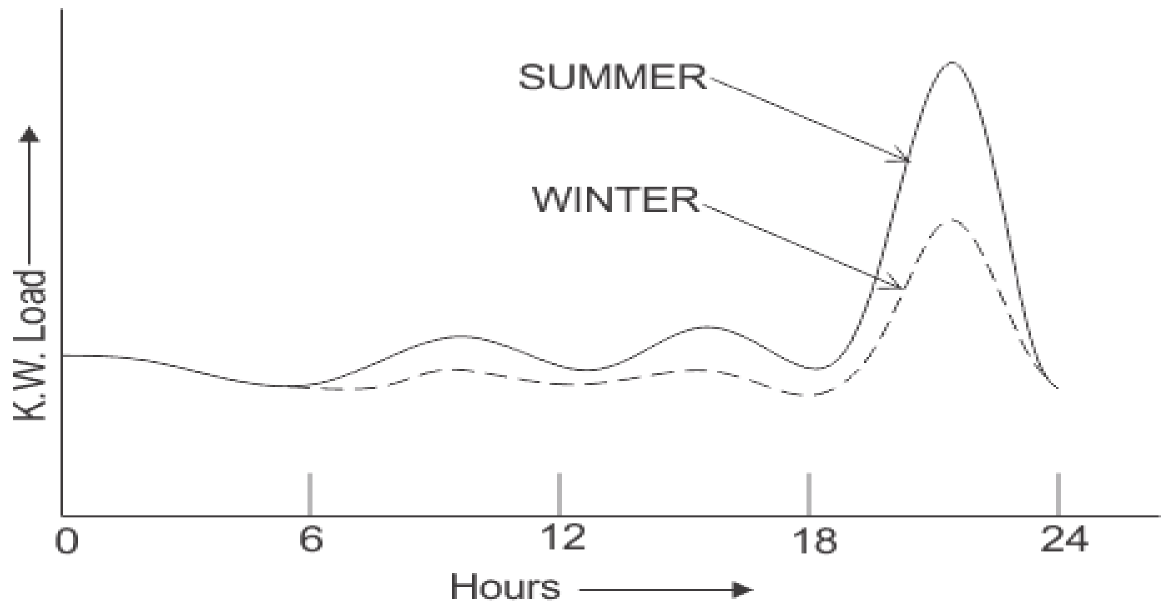
CLASSIFICATION OF LOADS

A device which taps electrical energy from the electric power system is called a load on the system. The load may be resistive (e.g., electric lamp), inductive (e.g., induction motor), capacitive or some combination of them. The various types of loads on the power system are

- Residential Loads
- Commercial Loads
- Agricultural Loads
- Industrial Loads

Residential Loads/ Domestic Loads

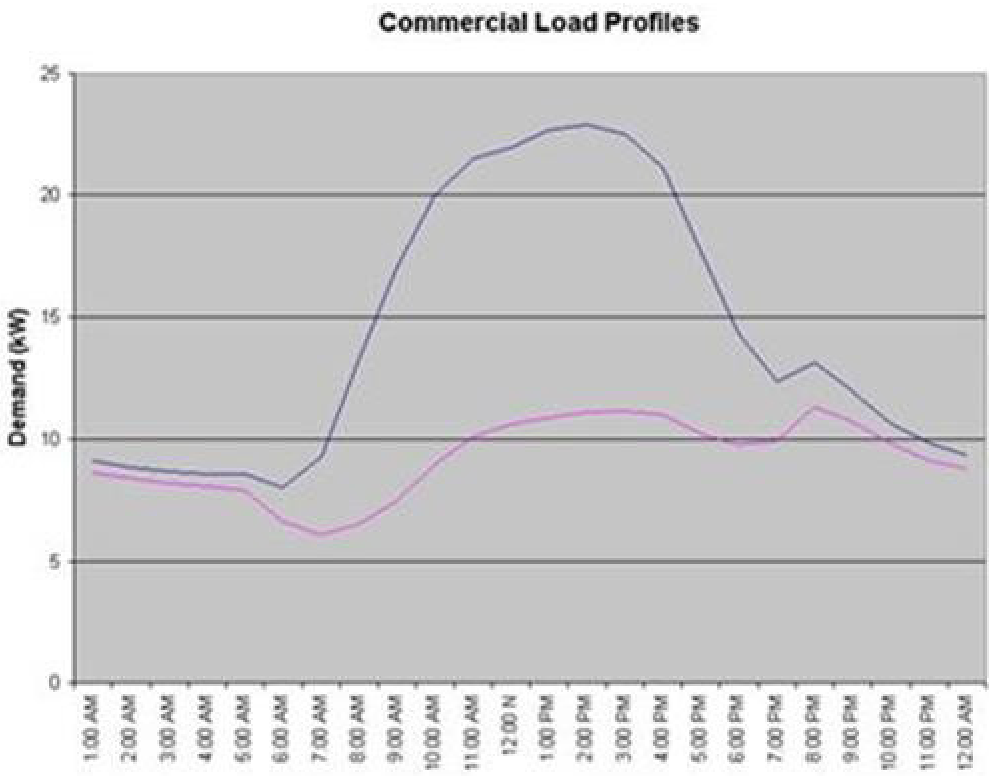
Residential Loads or Domestic load consists of lights, fans, refrigerators, heaters, television, small motors for pumping water etc. Most of the residential load occurs only for some hours during the day (i.e., 24 hours) e.g., lighting load occurs during night time and domestic appliance load occurs for only a few hours. For this reason, the load factor is low (10% to 12%).



Residential Load

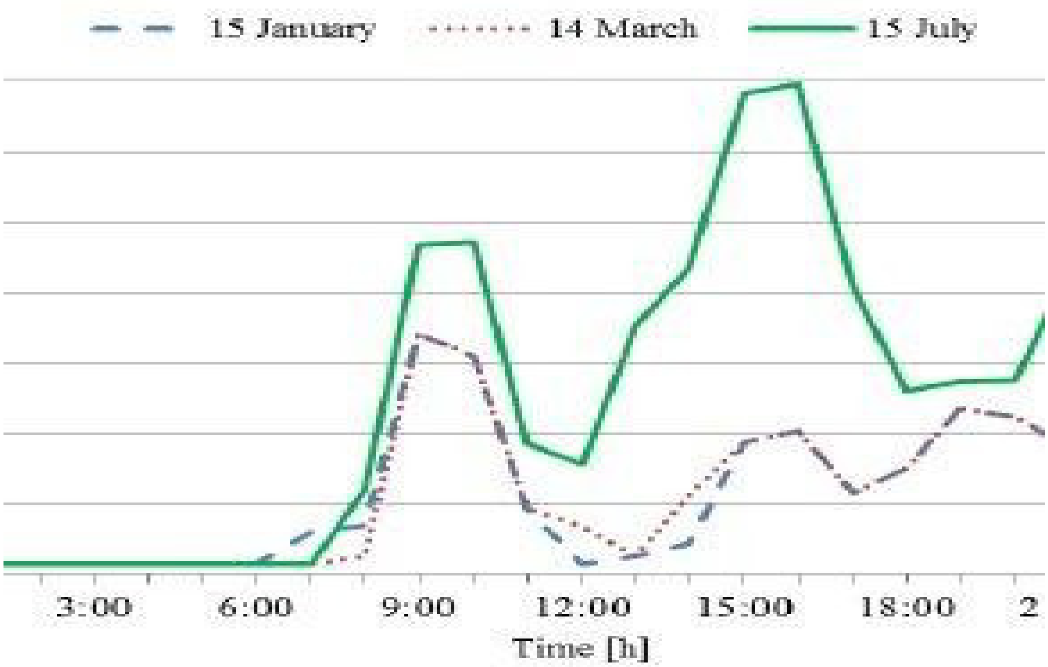
Commercial Loads

Commercial load consists of lighting for shops, fans and electric appliances used in restaurants etc. This class of load occurs for more hours during the day as compared to the domestic load. The commercial load has seasonal variations due to the extensive use of airconditioners and space heaters.



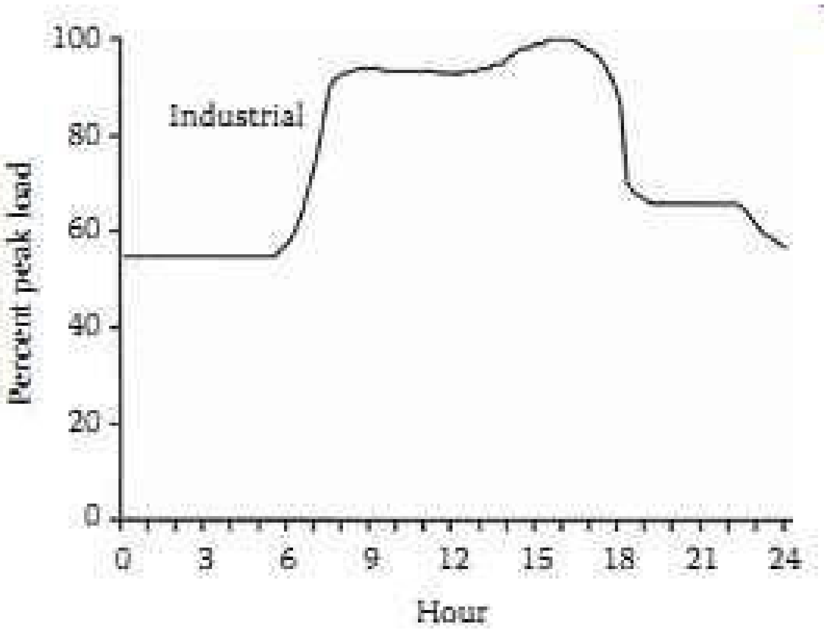
Agricultural Loads/ Irrigation Loads

This type of load is the electric power needed for pumps driven by motors to supply water to fields. Generally this type of load is supplied for 12 hours.



Industrial Loads

Industrial load consists of load demand by industries. The magnitude of industrial load depends upon the type of industry. Thus small scale industry requires load upto 25 kW, medium scale industry between 25kW and 100 kW and large-scale industry requires load above 500 kW. Industrial loads are generally not weather dependent.



Municipal load: Municipal load consists of street lighting, power required for water supply and drainage purposes. Street lighting load is practically constant throughout the hours of the night. For water supply, water is pumped to overhead tanks by pumps driven by electric motors. Pumping is carried out during the off-peak period, usually occurring during the night. This helps to improve the load factor of the power system.

Traction load: This type of load includes tram cars, railways etc. This class of load has wide variation. During the morning hour, it reaches peak value because people have to go to their work place. After morning hours, the load starts decreasing and again rises during evening since the people start coming to their homes.

MODULE -II

DISTRIBUTION FEEDERS & SUBSTATIONS

The part of the electric utility system that is between the distribution substation and the distribution transformers is called the primary system. It is made of circuits known as primary feeders or primary distribution feeders. Figure 2.1 shows a one-line diagram of a typical primary distribution feeder. A feeder includes a "main" or main feeder, which usually is a three-phase four-wire circuit, and branches or laterals, which usually are single-phase or three-phase circuits tapped off the main. Also sublaterals may be tapped off the laterals as necessary. In general, laterals and sublaterals located in residential and rural areas are single phase and consist of one-phase conductor and the neutral. The majority of the distribution transformers are single phase and are connected between the phase and the neutral through fuse cutouts. There are various and yet interrelated factors affecting the selection of a primary-feeder rating. Examples are

1. The nature of the load connected
2. The load density of the area served
3. The growth rate of the load
4. The need for providing spare capacity for emergency operations
5. The type and cost of circuit construction employed
6. The design and capacity of the substation involved
7. The type of regulating equipment used
8. The quality of service required
9. The continuity of service required

The voltage conditions on distribution systems can be improved by using shunt capacitors that are connected as near the loads as possible to derive the greatest benefit.

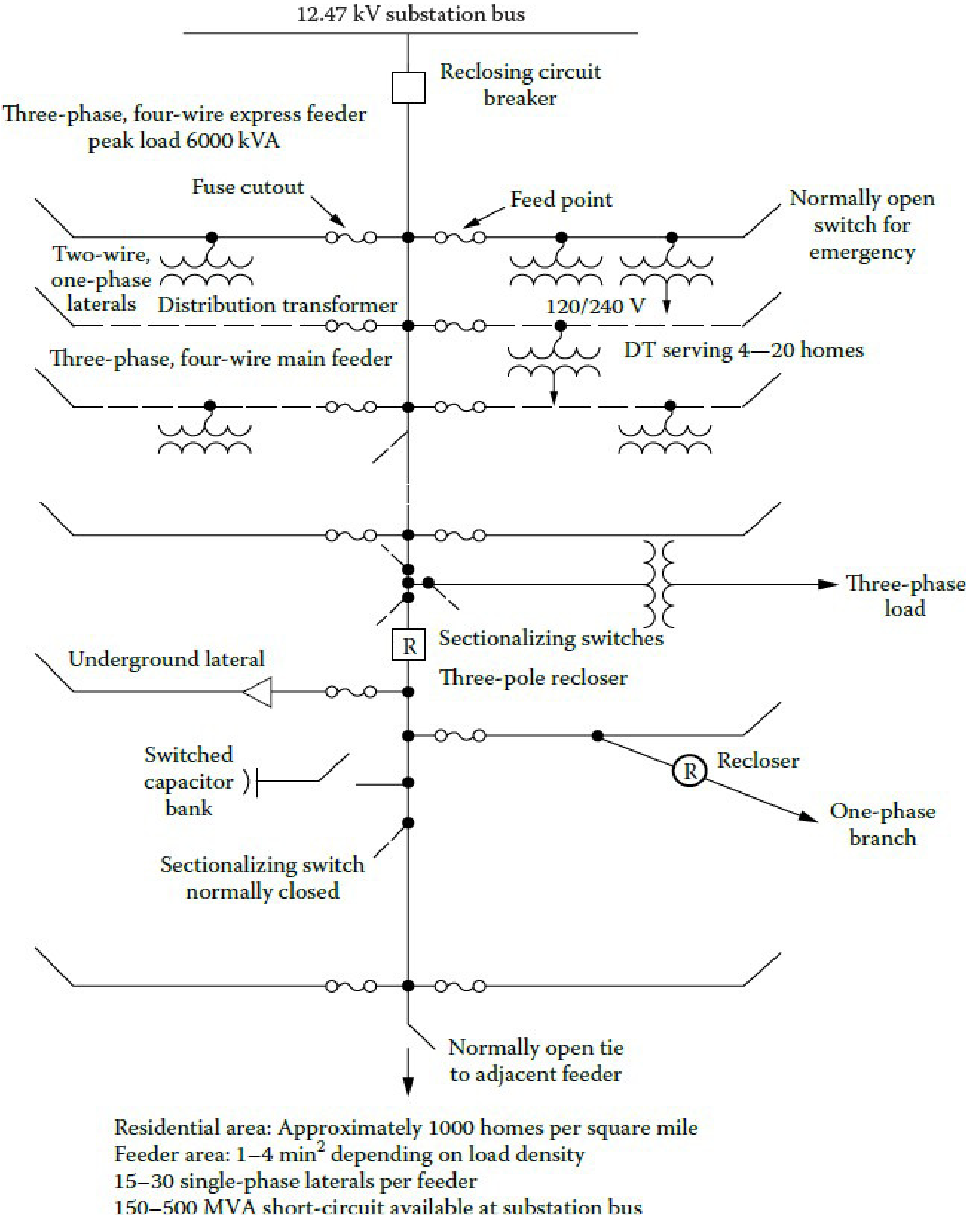


Figure 2.1 One-line diagram of typical primary distribution feeders. (From Fink, D.G. and Beaty, H.W., Standard Handbook for Electrical Engineers, 11th edn., McGraw-Hill, New York, 1978.).

Radial-Type Primary Feeder

The simplest and the lowest cost and therefore the most common form of primary feeder is the radial-type primary feeder as shown in Figure 2.2. The main primary feeder branches into various primary laterals that in turn separates into several sublaterals to serve all the distribution transformers.

In general, the main feeder and subfeeders are three-phase three- or four-wire circuits and the laterals are three phase or single phase. The current magnitude is the greatest in the circuit conductors that leave the substation. The current magnitude continually lessens out toward the end of the feeder as laterals and sublaterals are tapped off the feeder. Usually, as the current lessens, the size of the feeder conductors is also reduced. However, the permissible voltage regulation may restrict any feeder size reduction, which is based only on the thermal capability, that is, current-carrying capacity, of the feeder.

The reliability of service continuity of the radial primary feeders is low. A fault occurrence at any location on the radial primary feeder causes a power outage for every consumer on the feeder unless the fault can be isolated from the source by a disconnecting device such as a fuse, sectionalizer, disconnect switch, or recloser.

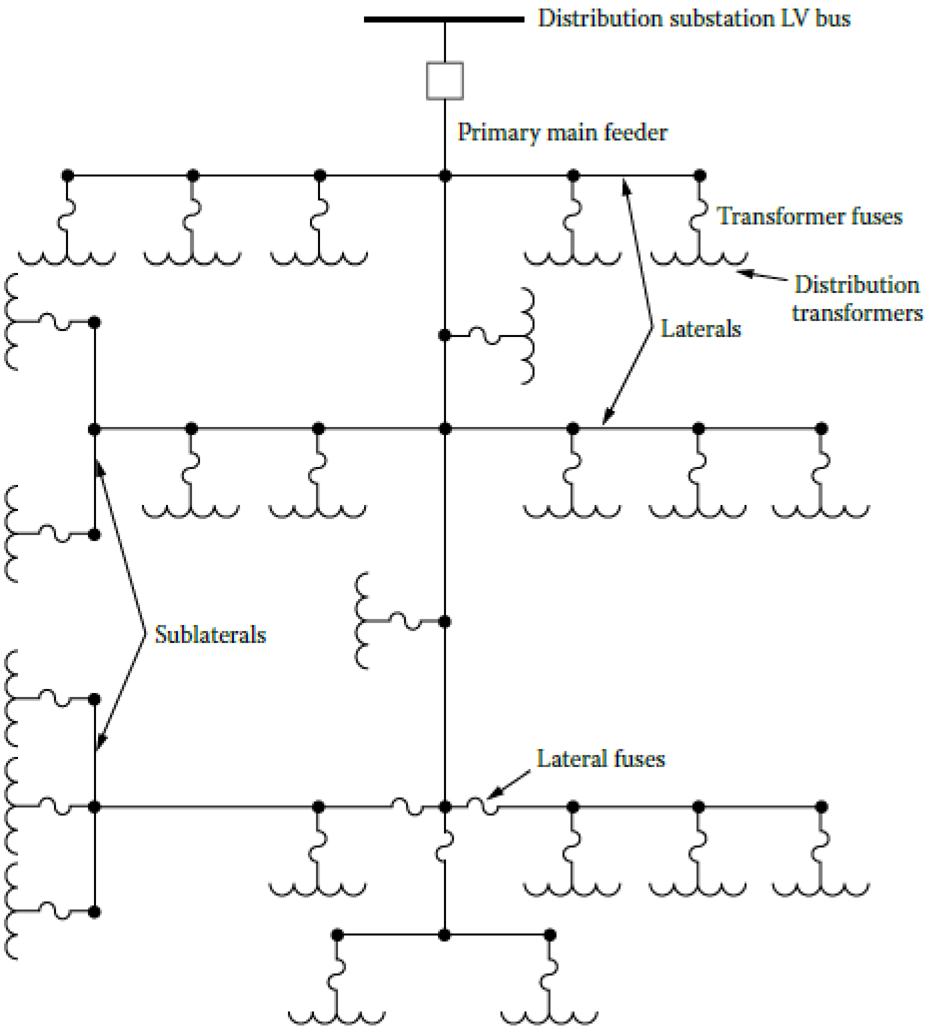


Figure 2.2 Radial-type primary feeder.

Radial-type primary feeder with tie and sectionalizing switches

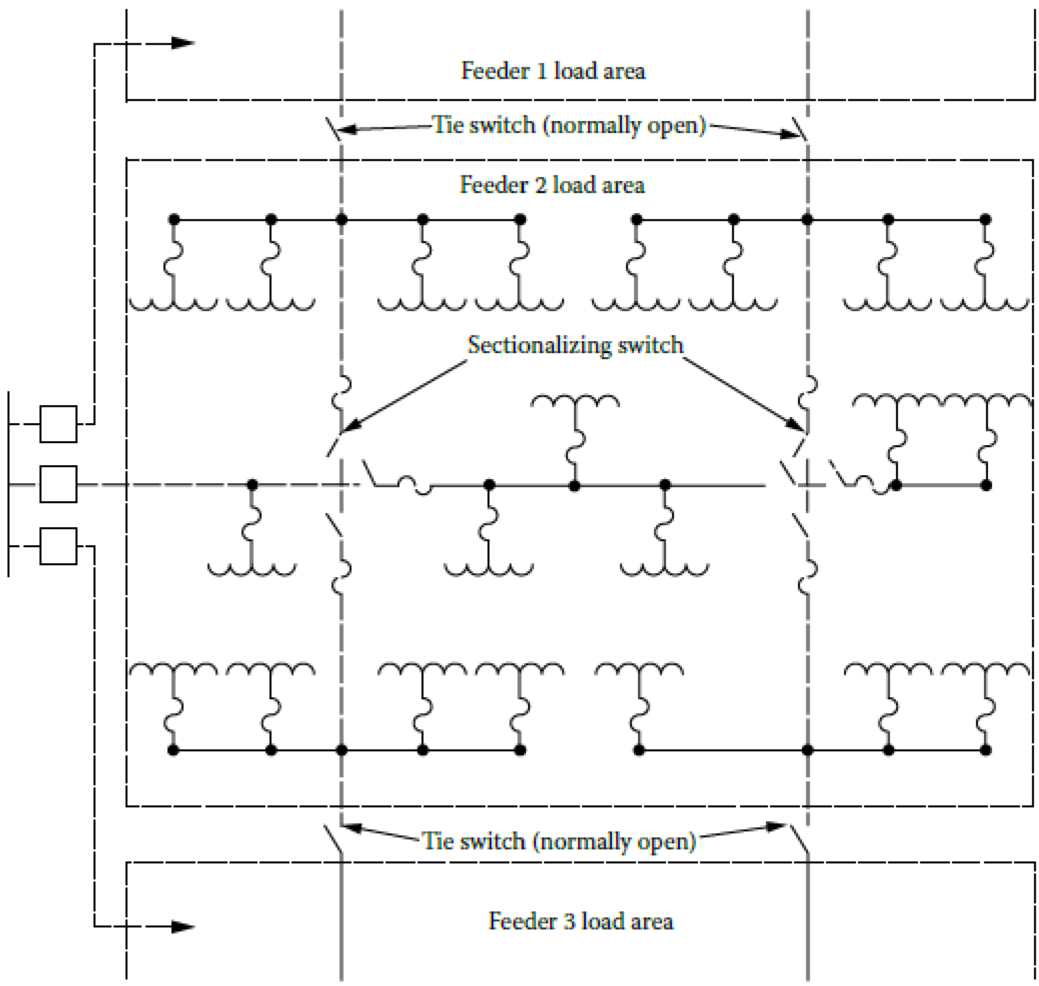


Figure 2.3 Radial-type primary feeder with tie and sectionalizing switches.

Figure 2.3 shows a modified radial-type primary feeder with tie and sectionalizing switches to provide fast restoration of service to customers by switching unfaulted sections of the feeder to an adjacent primary feeder or feeders. The fault can be isolated by opening the associated disconnecting devices on each side of the faulted section.

Radial-type primary feeder with express feeder and backfeed

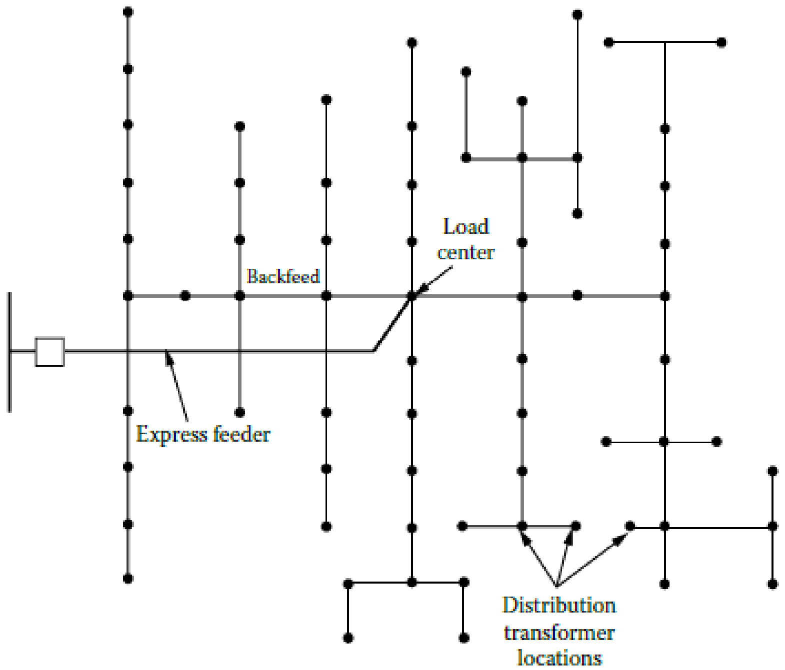


Figure 2.4 Radial-type primary feeder with express feeder and backfeed.

Figure 2.4 shows another type of radial primary feeder with express feeder and backfeed. The section of the feeder between the substation low-voltage bus and the load center of the service area is called an express feeder. No subfeeders or laterals are allowed to be tapped off the express feeder. However, a subfeeder is allowed to provide a backfeed toward the substation from the load center.

Radial-type phase-area feeder

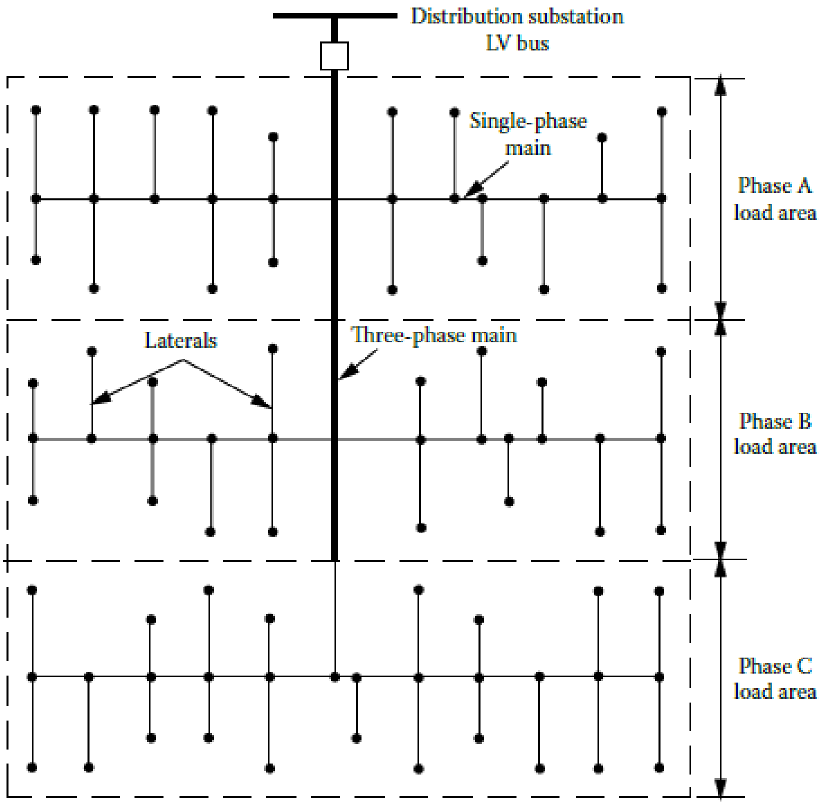


Figure 2.5 Radial-type phase-area feeder.

Figure 2.5 shows a radial-type phase-area feeder arrangement in which each phase of the three phase feeder serves its own service area.

Loop-Type Primary Feeder

Figure 2.6 shows a loop-type primary feeder that loops through the feeder load area and returns back to the bus. Sometimes the loop tie disconnect switch is replaced by a loop tie breaker due to the load conditions. In either case, the loop can function with the tie disconnect switches or breakers normally open (NO) or normally closed. Usually, the size of the feeder conductor is kept the same throughout the loop. It is selected to carry its normal load plus the load of the other half of the loop. This arrangement provides two parallel paths from the substation to the load when the loop is operated with NO tie breakers or disconnect switches.

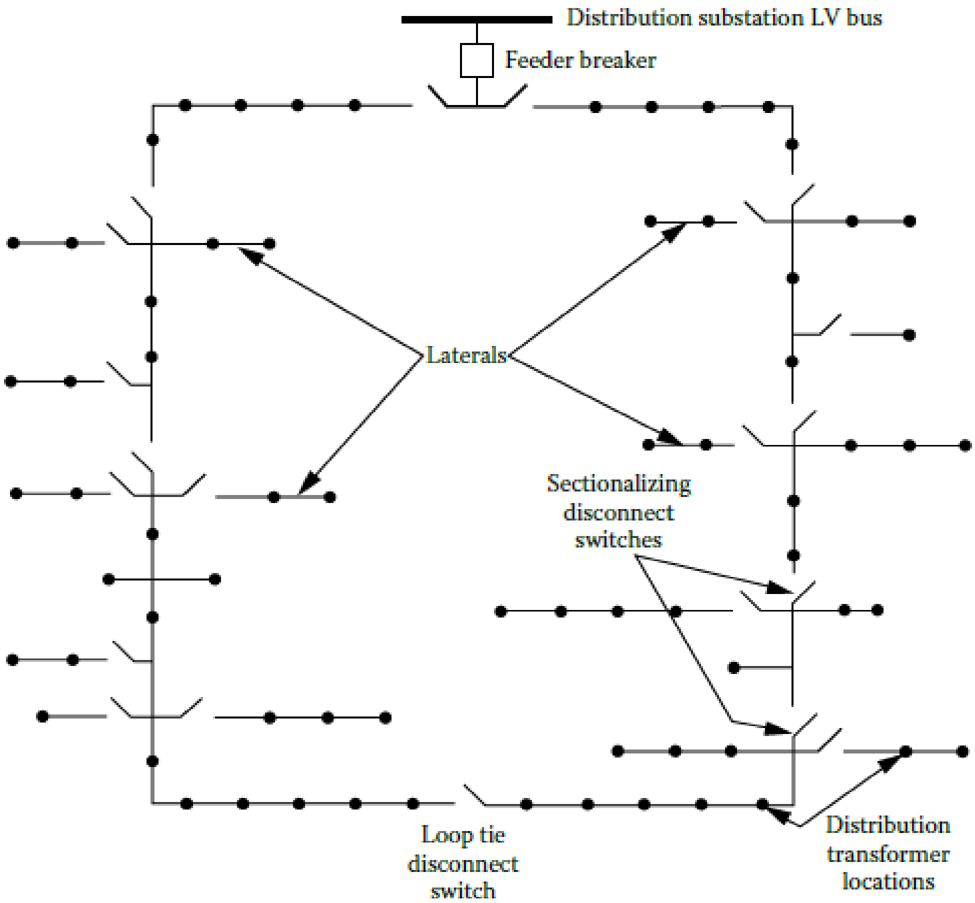
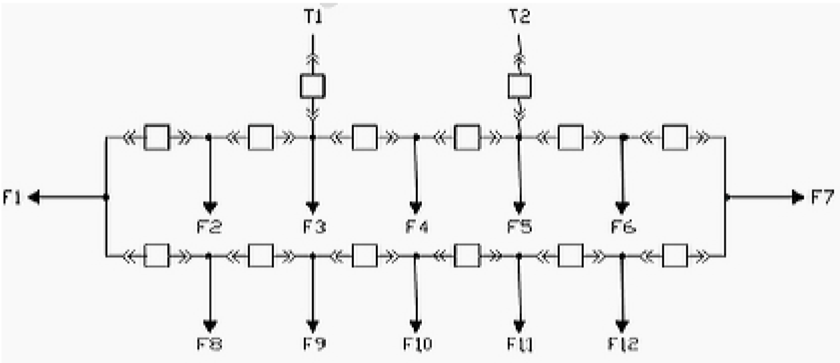


Figure 2.6 Loop-type primary feeder.

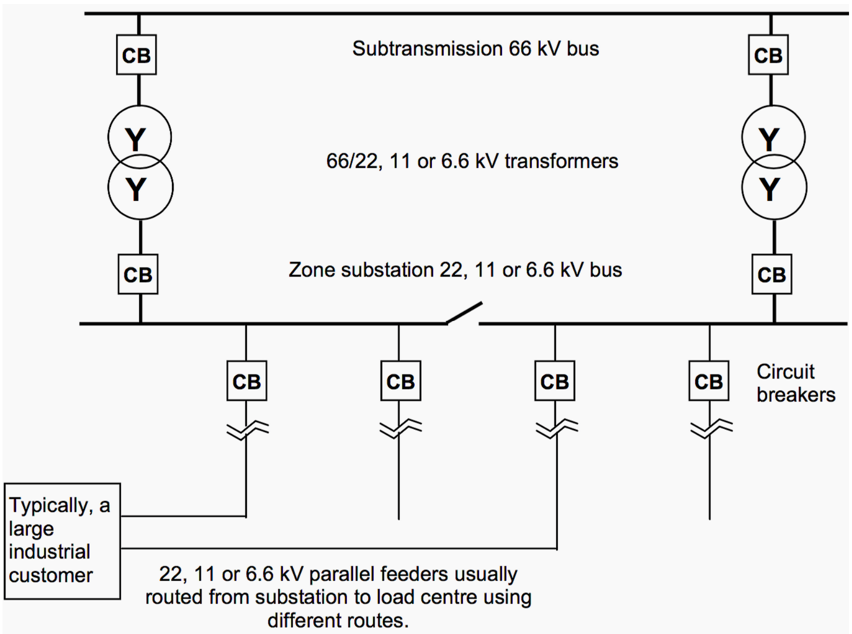
MESHED SYSTEMS

In transmission and sub-transmission systems, usually parallel, ring or interconnected (mesh) systems are used. This ensures that alternative supply can be made to customers in the event of failure of a transmission line or element. The general rule is that where large loads or numbers of customers are involved, then some form of standby, in the form of deliberate redundancy, is built into the network design, through the use of parallel, meshed or ring type feeders.



PARALLEL FEEDERS

A greater level of reliability at a higher cost is achieved with a parallel feeder. To improve the reliability factor it may be possible to have the separate sets of cables follow different routes. In this case the capital cost is double that of a radial feeder but there is a greater reliability factor for the line. This may be justified if the load is higher, more customers are being supplied, or there are loads such as hospitals which require high levels of reliability



SECONDARY DISTRIBUTION SYSTEMS

Present Design Practice

The part of the electric utility system that is between the primary system and the consumer's property is called the secondary system. Secondary distribution systems include step-down distribution transformers, secondary circuits (secondary mains), consumer services (or SDs), and meters to measure consumer energy consumption.

Generally, the secondary distribution systems are designed in single phase for areas of residential customers and in three phase for areas of industrial or commercial customers with high-load densities.The types of the secondary distribution systems include the following:

1. The separate-service system for each consumer with separate distribution transformer and secondary connection
2. The radial system with a common secondary main, which is supplied by one distribution transformer and feeding a group of consumers
3. The secondary-bank system with a common secondary main that is supplied by several distribution transformers, which are all fed by the same primary feeder
4. The secondary-network system with a common grid-type main that is supplied by a large number of the distribution transformers, which may be connected to various feeders for their supplies

The separate-service system is seldom used and serves the industrial- or rural-type service areas. Generally speaking, most of the secondary systems for serving residential, rural, and light-commercial areas are radial designed. Figure 2.12 shows the one-line diagram of a radial secondary system. It has a low cost and is simple to operate.

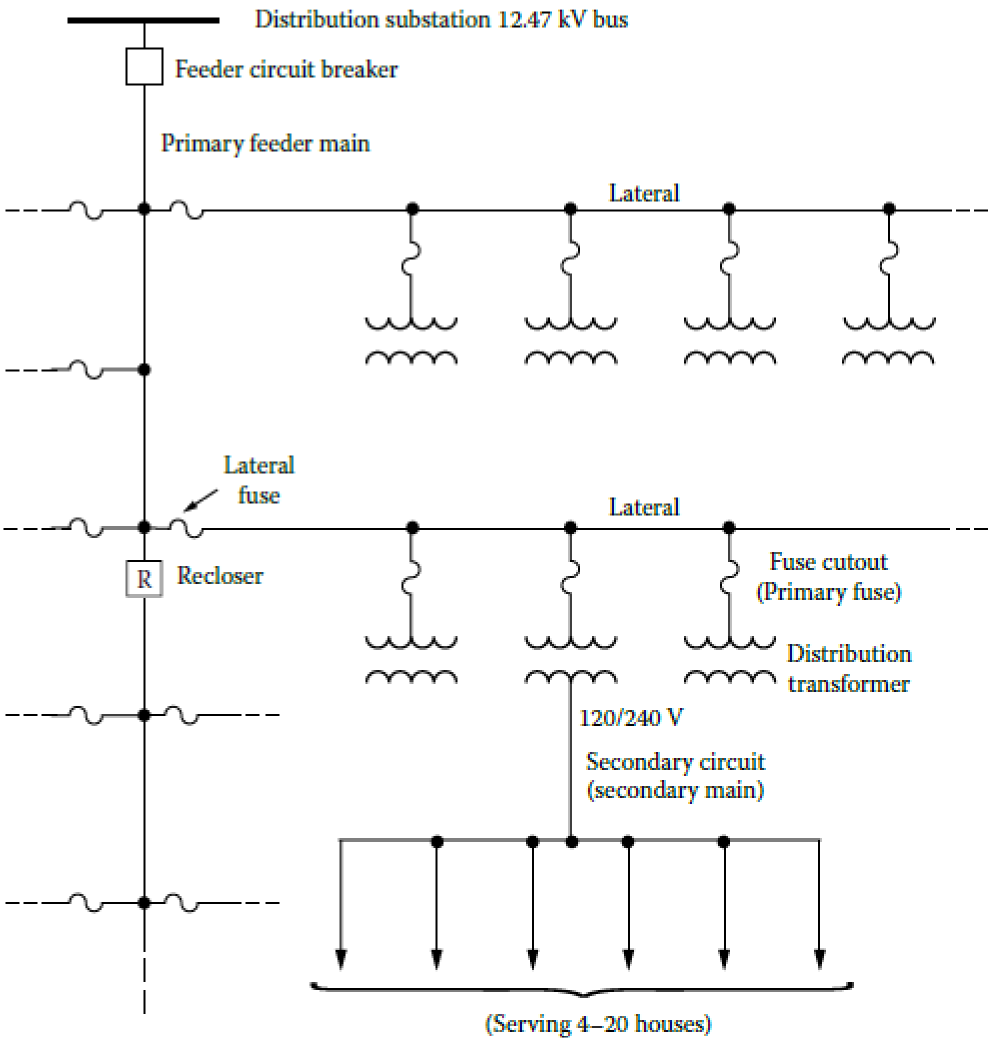


Figure 2.12 One-line diagram of a simple radial secondary system.

Module-III

A) Power Factor

Introduction

The electrical energy is almost exclusively generated, transmitted and distributed in the form of alternating current. Therefore, the question of power factor immediately comes into picture. Most of the loads (e.g. induction motors, arc lamps) are inductive in nature and hence have low lagging power factor. The low power factor is highly undesirable as it causes an increase in current, resulting in additional losses of active power in all the elements of power sys- tem from power station generator down to the utilisation devices. In order to ensure most favourable conditions for a supply system from engineering and economical standpoint, it is im- portant to have power factor as close to unity as possible. In this chapter, we shall discuss the various methods of power factor improvement.

Power Fa ctor the cosine of angle between voltage and current in an a.c. circuit is known as power factor.

In an a.c. circuit, there is generally a phase difference φ between voltage and current. The term cos φ is called the power factor of the cir- cuit. If the circuit is inductive, the current lags behind the voltage and the power factor is referred to as lagging. However, in a capacitive circuit, current leads the volt- age and power factor is said to be leading.

Consider an inductive circuit taking a lagging current I from sup- ply voltage V; the angle of lag being φ. The phasor diagram of the circuit is shown in Fig. 6.1. The circuit current I can be resolved into two perpendicular components, namely ;

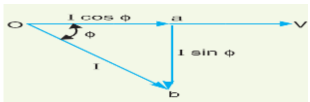


Fig. 6.1

I cos Φ in phase with V

I sin Φ90o out of phase with V

The component I cos φ is known as active or wattful component, whereas component I sin φ is called the reactive or wattless component. The reactive component is a measure of the power factor. If the reactive component is small, the phase angle φ is small and hence power factor cos φ will be high. Therefore, a circuit having small reactive current (i.e., I sin φ) will have high power factor and vice-versa. It may be noted that value of power factor can never be more than unity.

It is a usual practice to attach the word 'lagging' or 'leading' with the numerical value of power factor to signify whether the current lags or leads the voltage. Thus if the circuit has a p.f. of 0·5 and the current lags the voltage, we generally write p.f. as 0·5 lagging.

Sometimes power factor is expressed as a percentage. Thus 0·8 lagging power factor may be expressed as 80% lagging.

Power Triangle

The analysis of power factor can also be made in terms of power drawn by the a.c. circuit. If each side of the current triangle oab of Fig. 6.1 is multiplied by voltage V, then we get the power triangle OAB shown in Fig. where

OA = VI cos □ and represents the active power in watts or kW AB = VI sin □ and represents the reactive power in VAR or kVAR OB = VI and represents the apparent power in VA or kVA

The following points may be noted form the power triangle :

The apparent power in an a.c. circuit has two components viz., active and reactive power at right angles to each other.

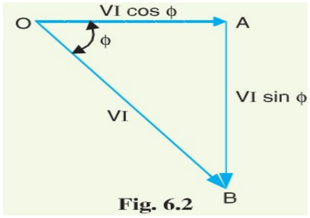


Fig. 6.2

OB2 = OA2 + AB2

Or (apparent power)2 = (active power)2 + (reactive power)2 or

(kVA)2 = (kW)2 + (kVAR)2

Power factor, cos Φ = OA Φ active power kW

OB apparent power kVA

Thus the power factor of a circuit may also be defined as the ratio of active power to the apparent power. This is a perfectly general definition and can be applied to all cases, what- ever be the waveform.

The lagging* reactive power is responsible for the low power factor. It is clear from the power triangle that smaller the reactive power component, the higher is the power factor of the circuit.

kVAR = kVA sin Φ = kW sin Φ

Disadvantages of Low Power Fa ctor:

The power factor plays an importance role in a.c. circuits since power consumed depends upon this factor.

P = V I cos Φ (For single phase supply)

I = P/V cos Φ

It is clear from above that for fixed power and voltage, the load current is inversely proportional to the power factor. Lower the power factor, higher is the load current and vice-versa. A power factor less than unity results in the following disadvantages

Causes of Low Power Fa ctor

Low power factor is undesirable from economic point of view. Normally, the power factor of the whole load on the supply system in lower than 0·8. The following are the causes of low power factor:

1) Most of the a.c. motors are of induction type (□and 3 □nduction motors) which have low lagging power factor. These motors work at a power factor which is extremely small on light load (0·2 to 0·3) and rises to 0·8 or 0·9 at full load.

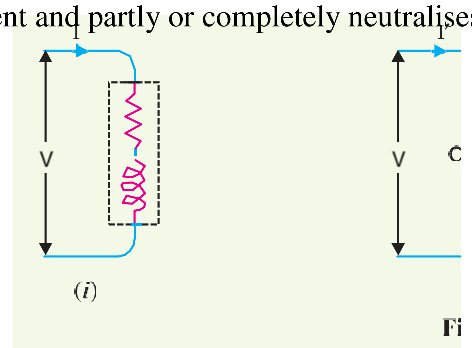
2) Arc lamps, electric discharge lamps and industrial heating furnaces operate at low lagging power factor.

3) The load on the power system is varying ; being high during morning and evening and low at other times. During low load period, supply voltage is increased which increases the magnetisation current. This results in the decreased power factor.

Power Factor Improvement

a) Static Capacitance

The low power factor is mainly due to the fact that most of the power loads are inductive and, there- fore, take lagging currents. In order to improve the power factor, some device taking leading power should be connected in parallel with the load. One of such devices can be a capacitor. The capacitor draws a leading current and partly or completely neutralises the lagging reactive



component of load current. This raises the power factor of the load.

Illustration.:

To illustrate the power factor improvement by a capacitor, consider a single *phase load taking lagging current I at a power factor cos Φ 1 as shown in Fig. 6.3.

The capacitor C is connected in parallel with the load. The capacitor draws current IC which leads the supply voltage by 90. The resulting line current I Φ is the phasor sum of I and I and its angle

of lag is Φ 2 as shown in the phasor diagram of Fig. 6.3. (iii). It is clear that Φ 2 is less than Φ 1, so that cos Φ 2 is greater than cos Φ 1. Hence, the power factor of the load is improved. The following points are worth noting :

The circuit current I Φ after p.f. correction is less than the original circuit current I.

The active or wattful component remains the same before and after p.f. correction because only the lagging reactive component is reduced by the capacitor.

I cos Φ 1 = I 1 cos Φ 2

The lagging reactive component is reduced after p.f. improvement and is equal to the differ- ence between lagging reactive component of load (I sin Ɒ) and capacitor current (IC) i.e.,

I 1 sin Φ 2 = I sin Φ 1 * IC

As $I \cos \Phi_1 = I_1 \cos \Phi_2$

□ $VI \cos \Phi_1 = V I_1 \cos \Phi_2$ [Multiplying by V]

Therefore, active power (kW) remains unchanged due to power factor improvement.

$I_1 \sin \Phi_2 = I \sin \Phi_1 * I_C$

$V I_1 \sin \Phi_2 = VI \sin \Phi_1 V I_C$ [Multiplying by V]

i.e., Net kVAR after p.f. correction = Lagging kVAR before p.f. correction ⁻ leading kVAR of equipment.

b) Phase Advencers

Phase advancers are used to improve the power factor of induction motors. The low power factor of an induction motor is due to the fact that its stator winding draws exciting current which lags be- hind the supply voltage by 90o. If the exciting ampere turns can be provided from some other a.c. source, then the stator winding will be relieved of exciting current and the power factor of the motor can be improved. This job Static Capacitor is accomplished by the phase advancer which is simply an a.c. exciter. The phase advancer is mounted on the same shaft as the main motor and is connected in the rotor circuit of the motor. It provides exciting ampere turns to the rotor circuit at slip frequency. By providing more ampere turns than required, the induction motor can be made to operate on leading power factor like an over-excited synchronous motor.Phase advancers have two principal advantages. Firstly, as the exciting ampere turns are sup- plied at slip frequency, therefore, lagging kVAR drawn by the motor are considerably reduced. Sec- ondly, phase advancer can be conveniently used where the use of synchronous motors is unadmissible. However, the major disadvantage of phase advancers is that they are not economical for motors below 200 H.P.

Calculations of Power Factor Correction

Pb) A single phase motor connected to 400 V, 50 Hz supply takes 31·7A at a power factor of 0·7 lagging. Calculate the capacitance required in parallel with the motor to raise the power factor to 0·9 lagging.

Solution:

The circuit and phasor diagrams are shown in Figs. 6.8 and 6.9 respectively. Here motor M is taking a current I_M of 31·7A. The current I_C taken by the capacitor must be such that when combined with I_M, the resultant current I lags the voltage by an angle □ where $\cos \Phi = 0·9$.

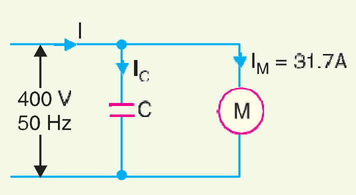


Fig. 6.8

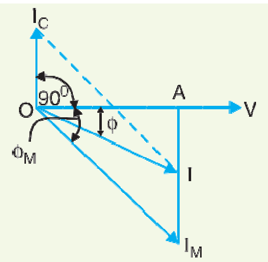


Fig. 6.9

Referring to the phasor diagram in Fig. 6.9,

Active component of $I_M = I_M \cos \Phi_M = 31·7 \times 0·7 = 22·19A$

Active component of $I = I \cos \Phi = I \times 0·9$

These components are represented by OA in Fig. 6.9.

I = 22 ×19 = 24·65A

Reactive component of IM = IM sin Φ M = 31·7 □ 0·714* = 22·6A

Reactive component of I = I sin Φ = 24·65

= 24·65 □ 0·436 = 10·75 A

It is clear from Fig. 6.9 that :

IC = Reactive component of IM □ Reactive component of I= 22·6 ×10·75 = 11·85A

I_c= V ×2×3.14 f C

or 11·85 = 400 ×2×3.14×50 × C

C = 94·3 μF

MODULE -IV
Protection

1 Objective of Distribution System Protection

The main objectives of distribution system protection are:

I. To minimize the duration of a fault
II. To minimize the number of consumers affected by the fault

The secondary objectives of distribution system protection are:

I. To eliminate safety hazards as fast as possible
II. To limit service outages to the smallest possible segment of the system
III. To protect the consumers' apparatus
IV. To protect the system from unnecessary service interruptions and disturbances
V. To disconnect faulted lines, transformers, or other apparatus.

Overhead distribution systems are subject two types of electrical faults, namely, transient (or temporary) faults and permanent faults. Depending on the nature of the system involved, approximately 75–90% of the total number of faults are temporary in nature. Usually transient faults occur when phase conductors electrically contact other phase conductors or ground momentarily due to trees, birds or other animals, high winds, lightning, flashovers, and so on. Transient faults are cleared by a service interruption of sufficient length of time to extinguish the power arc. Here, the fault duration is minimized and unnecessary fuse blowing is prevented by using instantaneous or high-speed tripping and automatic reclosing of a relay-controlled power circuit breaker or the automatic tripping and reclosing of a circuit recloser. The breaker speed, relay settings, and recloser characteristics are selected in a manner to interrupt the fault current before a series fuse (i.e. the nearest source-side fuse) is blown, which would cause the transient fault to become permanent.

Permanent faults are those which require repairs by repair crew in terms of:

I. Replacing burned-down conductors, blown fuses, or any other damaged apparatus
II. Removing tree limbs from the line
III. Manually reclosing a circuit breaker or recloser to restore service

Here, the number of customers affected by a fault is minimized by properly selecting and locating the protective apparatus on the feeder main, at the tap point of each branch, and at critical locations on branch circuits. Permanent faults are cleared by fuse cutouts installed at submain and lateral tap points. This practice limits the number of customers affected by a permanent fault and helps locate the fault point by reducing the area involved. In general, the only part of the distribution circuit not protected by fuses is the main feeder and feeder tie line.

The substation is protected from faults on feeder and tie lines by circuit breakers and/or reclosers located inside the substation.

Most of the faults are permanent on an underground distribution system, thereby requiring a different protection approach. Although the number of faults occurring on an underground system is relatively much less than that on the overhead systems, they are usually permanent and can affect a larger number of customers. Faults occurring in the underground residential distribution (URD) systems are cleared by the blowing of the nearest sectionalizing fuse or fuses. Faults occurring on the feeder are cleared by tripping and lockout of the feeder breaker.

2 Equipment

A wide variety of equipment is used to protect distribution networks. The particular type of protection used depends on the system element being protected and the system voltage level, and, even though there are no specific standards for the overall protection of distribution networks, some general indication of how these systems work can be made.

The devices most used for distribution system protection are:

I. Overcurrent Relays
II. Reclosers
III. Sectionalizers
IV. Fuses

The coordination of overcurrent relays was dealt with in detail in class, and this report will cover the other three devices referred to above.

Reclosers

A recloser is a device with the ability to detect phase and phase□to□ground overcurrent conditions, to interrupt the circuit if the overcurrent persists after a predetermined time, and then to automatically reclose to re□energise the line. If the fault that originated the operation still exists, then the recloser will stay open after a preset number of operations, thus isolating the faulted section from the rest of the system. In an overhead distribution system between 75 to 95 per cent of the faults are of a temporary nature and last, at the most, for a few cycles or seconds. Thus, the recloser, with its opening/closing characteristic, prevents a distribution circuit being left out of service for temporary faults. Typically, reclosers are designed to have up to three open□close operations and, after these, a final open operation to lock out the sequence. One further closing operation by manual means is usually allowed. The counting mechanisms register operations of the phase or ground□fault units which can also be initiated by externally controlled devices when appropriate communication means are available. The operating time/current characteristic curves of reclosers normally incorporate three curves, one fast and two delayed, designated as A, B and C, respectively. Figure 1 shows a typical set of time/current curves for reclosers. However, new reclosers with microprocessor□based controls may have keyboard□selectable time/current curves which enable an engineer to produce any curve to suit the coordination requirements for both phase and ground□faults. This allows reprogramming of the characteristics to make an arrangement to a customer's specific needs without the need to change components.

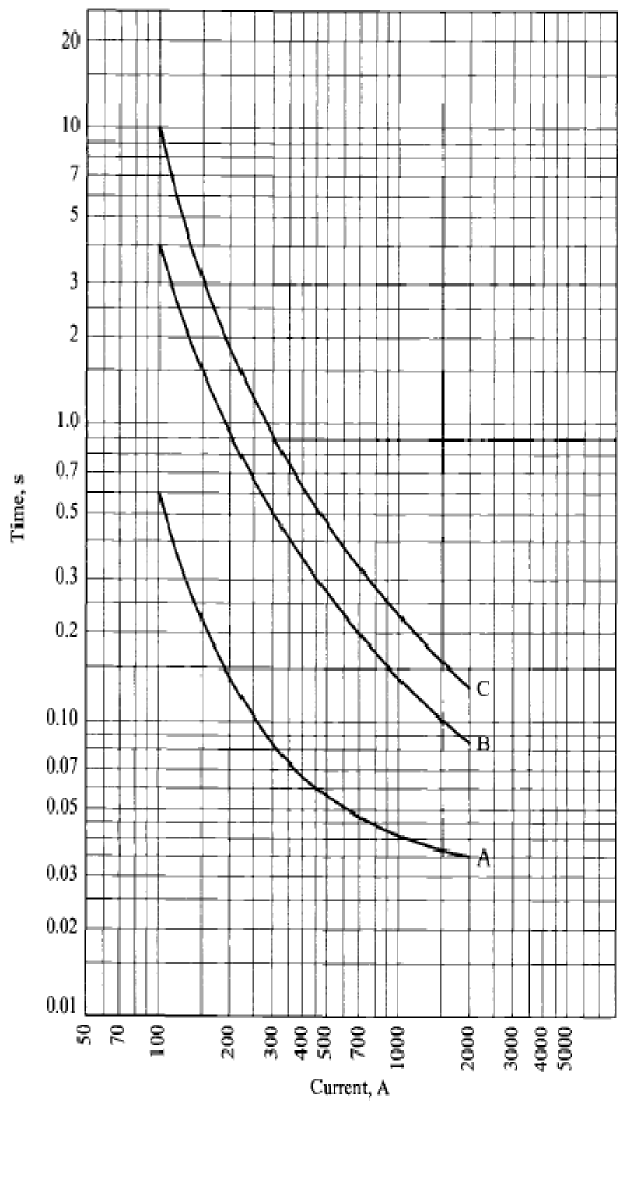


Figure 1: Time/Current Curves for Reclosers

Coordination with other protection devices is important in order to ensure that, when a fault occurs, the smallest section of the circuit is disconnected to minimise disruption of supplies to customers. Generally, the time characteristic and the sequence of operation of the recloser are selected to coordinate with mechanisms upstream towards the source. After selecting the size and sequence of operation of the recloser, the devices downstream are adjusted in order to achieve correct coordination. A typical sequence of a recloser operation for a permanent fault is shown in Figure 2. The first shot is carried out in instantaneous mode to clear temporary faults before they cause damage to the lines. The three later ones operate in a timed manner with predetermined time settings. If the fault is permanent, the time-delay operation allows other protection devices nearer to the fault to open, limiting the amount of the network being disconnected.

Ground faults are less severe than phase faults and, therefore, it is important that the recloser has an appropriate sensitivity to detect them. One method is to use CTs connected residually so that the resultant residual current under normal conditions is approximately zero. The recloser should operate when the residual current exceeds the setting value, as would occur during ground faults.

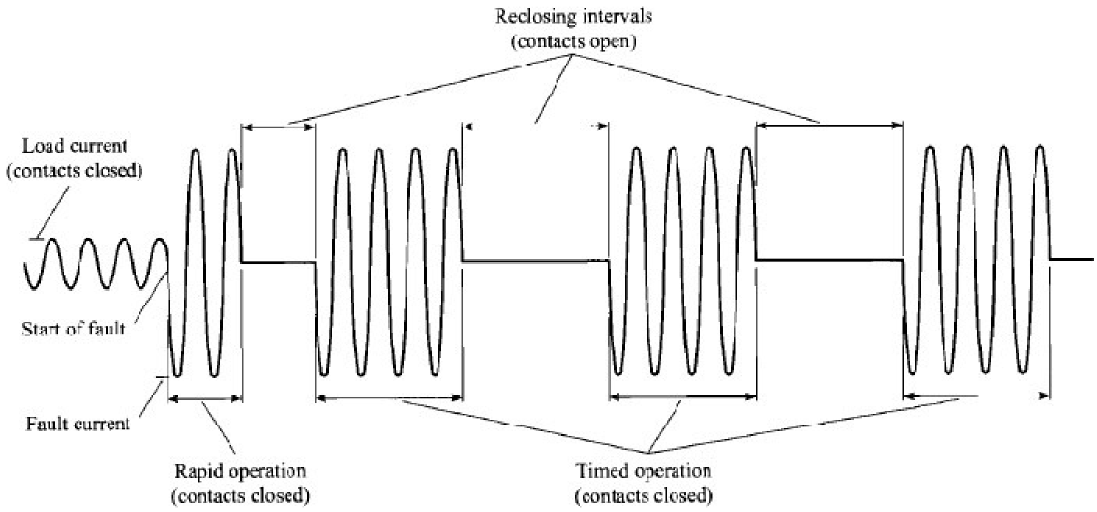
Reclosers can be classified as follows:

I. Single-phase and three-phase;
II. Mechanisms with hydraulic or electronic operation;
III. Oil, vacuum or SF6.

Single-phase reclosers are used when the load is predominantly single-phase. In such a case, when a single-phase fault occurs the recloser should permanently disconnect the faulted phase so that supplies are maintained on the other phases. Three-phase reclosers are used when it is necessary to disconnect all three phases in order to prevent unbalanced loading on the system. Reclosers with hydraulic operating mechanisms have a disconnecting coil in series with the line. When the current exceeds the setting value, the coil attracts a piston that opens the recloser main contacts and interrupts the circuit. The time characteristic and operating sequence of the recloser are dependent on the flow of oil in different chambers. The electronic type of control mechanism is normally located outside the recloser and receives current signals from a CT-type bushing. When the current exceeds the predetermined setting, a delayed shot is initiated that finally results in a tripping signal being transmitted to the recloser control mechanism. The control circuit determines the subsequent opening and closing of the mechanism, depending on its setting. Reclosers with electronic operating mechanisms use a coil or motor mechanism to close the contacts. Oil reclosers use the oil to extinguish the arc and also to act as the basic insulation. The same oil can be used in the control mechanism.

Vacuum and SF6 reclosers have the advantage of requiring less maintenance.

Figure 2: Typical Sequence for Recloser Operation



Reclosers are used at the following points on a distribution network:

I. In substations, to provide primary protection for a circuit;
II. In main feeder circuits, in order to permit the sectioning of long lines and thus prevent the loss of a complete circuit due to a fault towards the end of the circuit;
III. In branches or spurs, to prevent the tripping of the main circuit due to faults on the spurs.

When installing reclosers it is necessary to take into account the following factors:

I. System voltage.
II. Short-circuit level.
III. Maximum load current.
IV. Minimum short-circuit current within the zone to be protected by the recloser.
V. Coordination with other mechanisms located upstream towards the source, and downstream towards the load.
VI. Sensitivity of operation for ground faults

The voltage rating and the short□circuit capacity of the recloser should be equal to, or greater than, the values that exist at the point of installation. The same criteria should be applied to the current capability of the recloser in respect of the maximum load current to be carried by the circuit. It is also necessary to ensure that the fault current at the end of the line being protected is high enough to cause operation of the recloser.

Sectionalizers

A sectionalizer is a device that automatically isolates faulted sections of a distribution circuit once an upstream breaker or recloser has interrupted the fault current and is usually installed downstream of a recloser. Since sectionalizers have no capacity to break fault current, they must be used with a back-up device that has fault current breaking capacity. Sectionalizers count the number of operations of the recloser during fault conditions. After a preselected number of recloser openings, and while the recloser is open, the sectionalizer opens and isolates the faulty section of line. This permits the recloser to close and re-establish supplies to those areas free of faults. If the fault is temporary, the operating mechanism of the sectionalizer is reset.

Sectionalizers are constructed in single- or three-phase arrangements with hydraulic or electronic operating mechanisms. A sectionalizer does not have a current/time operating characteristic, and can be used between two protective devices whose operating curves are very close and where an additional step in coordination is not practicable.

Sectionalizers with hydraulic operating mechanisms have an operating coil in series with the line. Each time an overcurrent occurs the coil drives a piston that activates a counting mechanism when the circuit is opened and the current is zero by the displacement of oil across the chambers of the sectionalizer. After a prearranged number of circuit openings, the sectionalizer contacts are opened by means of pretensioned springs. This type of sectionalizer can be closed manually. Sectionalizers with electronic operating mechanisms are more flexible in operation and easier to set. The load current is measured by means of CTs and the secondary current is fed to a control circuit which counts the number of operations of the recloser or the associated interrupter and then sends a tripping signal to the opening mechanism. This type of sectionalizer is constructed with manual or motor closing.

The following factors should be considered when selecting a sectionalizer:

I. System voltage.
II. Maximum load current.
III. Maximum short-circuit level.
IV. Coordination with protection devices installed upstream and downstream.

The nominal voltage and current of a sectionalizer should be equal to or greater than the maximum values of voltage or load at the point of installation. The short circuit capacity (momentary rating) of a sectionalizer should be equal to or greater than the fault level at the point of installation. The maximum clearance time of the associated interrupter should not be permitted to exceed the short-circuit rating of the sectionalizer. Coordination factors that need to be taken into account include the starting current setting and the number of operations of the associated interrupter before opening.

Fuses

A fuse is an overcurrent protection device; it possesses an element that is directly heated by the passage of current and is destroyed when the current exceeds a predetermined value. A suitably selected fuse should open the circuit by the destruction of the fuse element, eliminate the arc established during the destruction of the element and then maintain circuit conditions open with nominal voltage applied to its terminals, (i.e. no arcing across the fuse element).

The majority of fuses used in distribution systems operate on the expulsion principle, i.e. they have a tube to confine the arc, with the interior covered with de-ionising fibre, and a fusible element. In the presence of a fault, the interior fibre is heated up when the fusible element melts and produces de-ionising gases which accumulate in the tube. The arc is compressed and expelled out of the tube; in addition, the escape of gas from the ends of the tube causes the particles that sustain the arc to be expelled. In this way, the arc is extinguished when current zero is reached. The presence of de-ionising gases, and the turbulence within the tube, ensure that the fault current is not re-established after the current passes through zero point. The zone of operation is limited by two factors; the lower limit based on the minimum time required for the fusing of the element (minimum melting time) with the upper limit determined by the maximum total time that the fuse takes to clear the fault.

There are a number of standards to classify fuses according to the rated voltages, rated currents, time/current characteristics, manufacturing features and other considerations. For example, there are several sections of ANSI/UL 198-1982 standards that cover low voltage fuses of 600 V or less. For medium and high voltage fuses within the range 2.3-138 kV, standards such as ANSI/IEEE C37.40, 41, 42, 46, 47 and 48 apply. Other organisations and countries have their own standards; in addition, fuse manufacturers have their own classifications and designations.

In distribution systems, the use of fuse links designated K and T for fast and slow types, respectively, depending on the speed ratio, is very popular. The speed ratio is the ratio of minimum melt current that causes fuse operation at 0.1 s to the minimum melt current for 300 s operation. For the K link, a speed ratio (SR) of 6-8 is defined and, for a T link, 10-13. Figure 3 shows the comparative operating characteristics of type 200 K and 200 T fuse links. For the 200 K fuse a 4400 A current is required for 0.1 s clearance time and 560A for 300s, giving an SR of

For the 200T fuse, 6500A is required for 0.1 s clearance and 520A for 300s; for this case, the SR is 12.5.

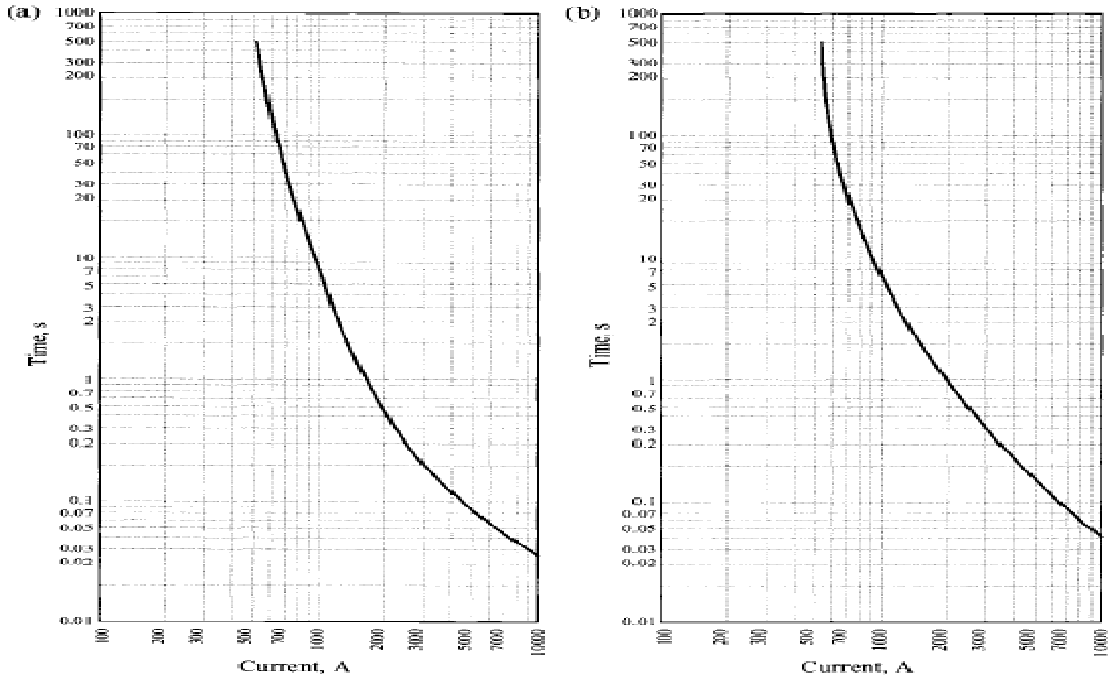


Figure 3: Time/Current Characteristics of Typical Fuse Links: (a) 200K Fuse Link; (b) 200T Fuse Link

The following information is required in order to select a suitable fuse for use on the distribution system:

I. Voltage and insulation level.
II. Type of system.
III. Maximum short-circuit level.
IV. Load current.

The above four factors determine the fuse nominal current, voltage and short circuit capability characteristics.

3 Criteria for Coordination of Time/Current Devices in Distribution Systems

The following basic criteria should be employed when coordinating time/current devices in distribution systems:

1. The main protection should clear a permanent or temporary fault before the backup protection operates, or continue to operate until the circuit is disconnected. However, if the main protection is a fuse and the back-up protection is a recloser, it is normally acceptable to coordinate the fast operating curve or curves of the recloser to operate first, followed by the fuse, if the fault is not cleared.
2. Loss of supply caused by permanent faults should be restricted to the smallest part of the system for the shortest time possible.

In the following sections criteria and recommendations are given for the coordination of different devices used on distribution systems.

Fuse•Fuse Coordination

The essential criterion when using fuses is that the maximum clearance time for a main fuse should not exceed 75 per cent of the minimum melting time of the backup fuse, for the same current level, as indicated in Figure 4. This ensures that the main fuse interrupts and clears the fault before the back□up fuse is affected in any way. The factor of 75 per cent compensates for effects such as load current and ambient temperature, or fatigue in the fuse element caused by the heating effect of fault currents that have passed through the fuse to a fault downstream but were not sufficiently large enough to melt the fuse.

The coordination between two or more consecutive fuses can be achieved by drawing their time/current characteristics, normally on log□log paper as for overcurrent relays. In the past, coordination tables with data of the available fuses were also used, which proved to be an easy and accurate method. However, the graphic method is still popular not only because it gives more information but also because computer□assisted design tools make it much easier to draw out the various characteristics.

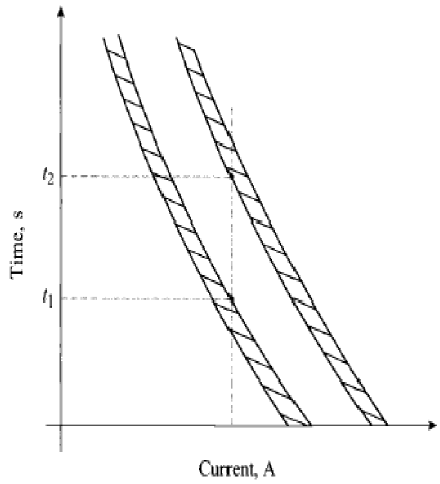


Figure 4: Criteria for Fuse-Fuse Coordination: t1<0.75 t2

Recloser•Fuse Coordination

The criteria for determining recloser□fuse coordination depend on the relative locations of these devices, i.e. whether the fuse is at the source side and then backs up the operation of the recloser that is at the load side, or vice versa. These possibilities are treated in the following paragraphs.

Fuse at the Source Side

When the fuse is at the source side, all the recloser operations should be faster than the minimum melting time of the fuse. This can be achieved through the use of multiplying factors on the recloser time/current curve to compensate for the fatigue of the fuse link produced by the cumulative heating effect generated by successive recloser operations. The recloser opening curve modified by the appropriate factor then becomes slower but, even so, should be faster than the fuse curve. This is illustrated in Figure 5.

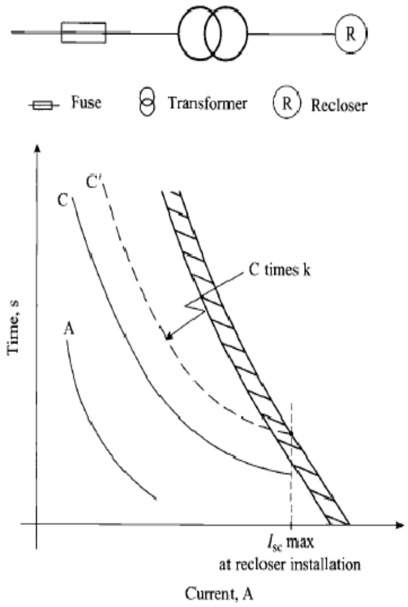


Figure 5: Criteria for Source-Side Fuse and Recloser Coordination

The multiplying factors referred to above depend on the reclosing time in cycles and on the number of the reclosing attempts. Some values proposed by Cooper Power Systems are reproduced in Figure 6. It is convenient to mention that if the fuse is at the high voltage side of a power transformer and the recloser at the low voltage side, either the fuse or the recloser curve should be shifted horizontally on the current axis to allow for the transformer turns ratio. Normally it is easier to shift the fuse curve, based on the transformer tap that produces the highest current on the high voltage side.

Reclosing time in cycles	Multipliers for:		
	two fast, two delayed sequence	one fast, three delayed sequence	four delayed sequence
25	2.70	3.20	3.70
30	2.60	3.10	3.50
50	2.10	2.50	2.70
90	1.85	2.10	2.20
120	1.70	1.80	1.90
240	1.40	1.40	1.45
600	1.35	1.35	1.35

The *k* factor is used to multiply the time values of the delayed curve of the recloser.

Fuses at the Load Side

The procedure to coordinate a recloser and a fuse, when the latter is at the load side, is carried out with the following rules:

1. The minimum melting time of the fuse must be greater than the fast curve of the recloser times the multiplying factor, given in Figure 7 and taken from the same reference as above;
2. The maximum clearing time of the fuse must be smaller than the delayed curve of the recloser without any multiplying factor; the recloser should have at least two or more delayed operations to prevent loss of service in case the recloser trips when the fuse operates.

Reclosing time in cycles	Multipliers for:	
	one fast operation	two fast operations
25–30	1.25	1.80
60	1.25	1.35
90	1.25	1.35
120	1.25	1.35

The *k* factor is used to multiply the time values of the recloser fast curve.

Figure 7: k Factor for the Load-Side Fuse Link

The application of the two rules is illustrated in Figure 8.

Better coordination between a recloser and fuses is obtained by setting the recloser to give two instantaneous operations followed by two timed operations. In general, the first opening of a recloser will clear 80 per cent of the temporary faults, while the second will clear a further 10 per cent. The load fuses are set to operate before the third opening, clearing permanent faults. A less effective coordination is obtained using one instantaneous operation followed by three timed operations.

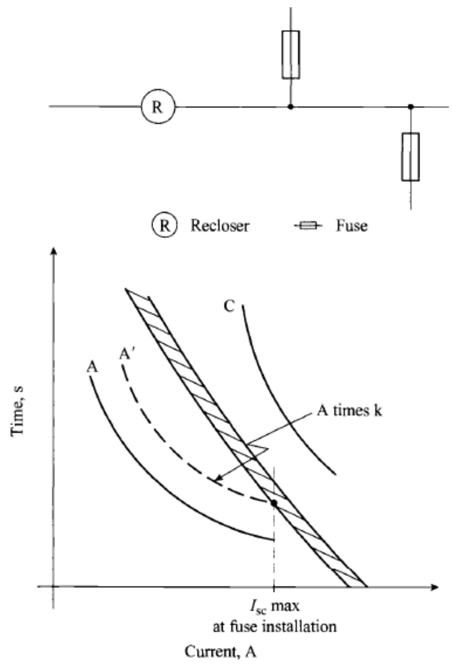


Figure 8: Criteria for Recloser and Load-Side Fuse Coordination

Recloser•Recloser Coordination

The coordination between reclosers is obtained by appropriately selecting the amperes setting of the trip coil in the hydraulic reclosers, or of the pick□ups in electronic reclosers.

Hydraulic Reclosers

The coordination margins with hydraulic reclosers depend upon the type of equipment used. In small reclosers, where the current coil and its piston produce the opening of the contacts, the following criteria must be taken into account:

I. Separation of the curves by less than two cycles always results in simultaneous operation;
II. Separation of the curves by between two and 12 cycles could result in simultaneous operation;
III. Separation greater than 12 cycles ensures non-simultaneous operation.

With large capacity reclosers, the piston associated with the current coil only actuates the opening mechanism. In such cases the coordination margins are as follows:

I. Separation of the curves by less than two cycles always results in simultaneous operation;
II. A separation of more than eight cycles guarantees non-simultaneous operation.

The principle of coordination between two large units in series is based on the time of separation between the operating characteristics, in the same way as for small units.

Electronically-Controlled Reclosers

Adjacent reclosers of this type can be co□ordinated more closely since there are no inherent errors such as those that exist with electromechanical mechanisms (due to overspeed, inertia, etc.). The downstream recloser must be faster than the upstream recloser, and the clearance time of the downstream recloser plus its tolerance should be lower than the upstream recloser clearance time less its tolerance. Normally, the setting of the recloser at the substation is used to achieve at least one fast reclosure, in order to clear temporary faults on the line between the substation and the load recloser. The latter should be set with the same, or a larger, number of rapid operations as the recloser at the substation. It should be noted that the criteria of spacing between the time/current characteristics of electronically controlled reclosers are different to those used for hydraulically controlled reclosers.

Recloser•Relay Coordination

Two factors should be taken into account for the coordination of these devices; the interrupter opens the circuit some cycles after the associated relay trips, and the relay has to integrate the clearance time of the recloser. The reset time of the relay is normally long and, if the fault current is re□applied before the relay has completely reset, the relay will move towards its operating point from this partially reset position.

For example, consider a recloser with two fast and two delayed sequence with reclosing intervals of two seconds, which is required to coordinate with an inverse time□delay overcurrent relay that takes 0.6 s to close its contacts at the fault level under question, and 16 s to completely reset. The impulse margin time of the relay is neglected for the sake of this illustration. The rapid operating time of the recloser is 0.030 s, and the delayed operating time is 0.30 s. The percentage of the relay operation during which each of the two rapid recloser openings takes place is (0.03 s/0.6 s) x 100 per cent= 5 per cent. The percentage of relay reset that takes place during the recloser interval is (2 s/16 s) x 100 per cent □□ 12.5 per cent. Therefore, the relay completely resets after both of the two rapid openings of the recloser.

The percentage of the relay operation during the first time□delay opening of the recloser is (0.3 s/0.6 s) x 100 per cent=50 per cent. The relay reset for the third opening of the recloser□□12.5 per cent, as previously, so that the net percentage of relay operation after the third opening of the recloser = 50 per cent□ 12.5 per cent = 37.5 per cent. The percentage of the relay operation during the second time delay opening of the recloser takes place = (0.3 sec. /0.6 sec) x 100 per cent = 50 per cent, and the total percentage of the relay operation after the fourth opening of the recloser = 37.5 per cent + 50 per cent = 87.5 per cent.

From the above analysis it can be concluded that the relay does not reach 100 per cent operation by the time the final opening shot starts, and therefore coordination is guaranteed.

Recloser•Sectionalizer Coordination

Since the sectionalizers have no time/current operating characteristic, their coordination does not require an analysis of these curves.

The coordination criteria in this case are based upon the number of operations of the back-up recloser. These operations can be any combination of rapid or timed shots as mentioned previously, for example two fast and two delayed. The sectionalizer should be set for one shot less than those of the recloser, for example three disconnections in this case. If a permanent fault occurs beyond the sectionalizer, the sectionalizer will open and isolate the fault after the third opening of the recloser. The recloser will then re-energise the section to restore the circuit. If additional sectionalizers are installed in series, the furthest recloser should be adjusted for a smaller number of counts. A fault beyond the last sectionalizer results in the operation of the recloser and the start of the counters in all the sectionalizers.

Recloser•Sectionalizer•Fuse Coordination

Each one of the devices should be adjusted in order to co-ordinate with the recloser. In turn, the sequence of operation of the recloser should be adjusted in order to obtain the appropriate coordination for faults beyond the fuse by following the criteria already mentioned.

MODULE –V
Voltage Control & Distribution Automation

REACTIVE POWER AND VOLTAGE CONTROL

A power system is said to be well designed if it gives a good quality of reliable supply. Voltage level maintained within reasonable limits is referred as good quality. If variation is more than specified valve, the performance of equipment suffers and also the life of equipment is scarified.

When the load on the system increases, the voltage at the consumer terminals falls due to the increased voltage drop in alternator synchronous impedance, transmission line, transformer impedance, feeders and distributors.

Power is supplied to load through transmission line, keeping sending end voltage constant. The higher load we have smaller the power factor. Service voltage are usually specified by a nominal valve.

For examples 220 volt. residential supply circuit, the voltage might normally vary between limits 210 V and 230 V. The picture on a television starts rolling is the

voltage is below certain level. While sudden drips or rapid fluctuations of less that 1 or 1.5% produce annoying eight fluctuations, they are called as eight flickers.

The methods for controlling voltage are tap changing transformers. Regulating transformers etc synchronous condenser. Static shunt capacitors, shunt reactors are common source of reactive power.

REQUIREMENTS OF VOLTAGE & REACTIVE POWER CONTROL

For efficient & reliable operation of power system should have the following:

a) All the machines and equipments are designed to operate at a certain voltage. Operation above or below the allowable range could damage them.
b) System stability in increase to maximize utilization of the transmission system. Voltage and reactive power control have a significant impact on system stability.
c) The reactive power flow is minimized so as to reduce I^2R and I^2X losses and to operate the transmission system efficiently (IP) mainly for active power transfer.

The reactive power cannot be transmitted over long distance; voltage control has to be affected by using special devices dispersed throughout the system. This is in contrast to the control of frequency which depends on the overall system active power balance. The problem of maintain voltage constant is that the loads keep on changing over a wide range, when the load varies, the power requirement also varies.

IMPORTANCE OF VOLTAGE CONTROL

The variations of Voltage at load will affect the consumer terminals. So , we should maintain the voltage within prescribed limits for the following reasons.

1. In lighting load, the lamp characteristics are very sensitive to change of voltage.

If the supply voltage decrease, then the illumes acting power may decrease. If the supply voltage increase, the of the lamp reduces.

2. In induction motors, the voltage variations may cause erratic operation. If the supply voltage increase, the motor may operate with a saturated magnetic circuit and produce heating, thereby low power factor. If the voltage decrease. The starting torque of the motor may reduce.
3. In distribution transformers, the voltage variations may cause excessive heating and thereby rating of transformer.

Location of voltage control equipment.

The voltage control equipments are connected between the generating station and the consumers. It is used at more than one point in any part of power system because, the power network is very large and there is a considerable voltage drop in transmission distribution load characteristics.

Voltage control equipment is located at .

1) Generating stations
2) Transformer stations
3) Feeders

GENERATION AND ABSORPTION OF REACTIVE POWER

1. **Synchronous generators**

It can generate or absorb reactive power. Reactive power (q) is supplied by synchronous generators depending upon the short circuit ratio (SCR).

$SCR=1/X_S$

Where X_S = synchronous reactance.

An over excited synchronous machine operating on no load condition, generates reactive power. An under excited synchronous machine absorbs reactive power. It is undesirable to transmit large amount of KVAR over transmission lines as this produces excessive voltage droop.

2. **Shunt capacitors:**

It offers the cheapest means of reactive power supply.

3. **Shunt reactors:**

It offers the cheapest means of reactive power absorption and these are connected in the transmission line during light load conditions.

4. **Transformers:**

It always absorb reactive power regardless of their loading.

At no load – shunt magnetizing reactance effect is predominant. At full

load – series leakage inductance effect is pre-dominant.

$$P.U\ reactance, X_T = \frac{Actual\ X}{Base\ value} = \frac{Actual\ X}{\frac{V}{I}}$$

$$Actual\ X = X_T \frac{V}{I} = X_T \frac{KV}{I} \times 1000$$

$$I_{ph} = \frac{KVA}{\sqrt{3}\ KV}$$

$$X = \frac{X_T}{KVA} \times \sqrt{3} \times KV^2 \times 1000$$

$$Reactive\ power\ absorbed\ or\ loss[Q_T] = 3 \times |I^2| \times VAR$$

$$= 3 \times |I^2| \times \frac{X_T}{KVA} \times \frac{X_T}{KVA} \times 1000$$

$$= \frac{3KVA^2}{3KV^2} \times \frac{X_T}{KVA} \times \sqrt{3} \times KV^2 \times 1000$$

$$= \sqrt{3} \times KVA \times X_T \times KVAR$$

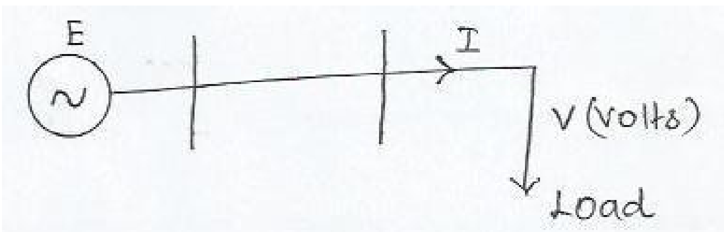
1. Cables:

Cables generate more reactive power than transmission lines because the cables have high capacitance.

2. Overhead lines:

Transmission lines are considered as generating KVAR in their shunt capacitance and consuming KVAR in their series inductance. The inductive KVAR Vary with the line current, where as the capacitive KVAR vary with the system potential.

Consider transmission line be loaded such that load current be 'I' amperes and load



voltage 'V' volts as shown in figure.

If we assume the transmission line to be lossless, the reactive power absorbed by the line will be

$$\Delta Q_L = |I|^2 \times X_L$$

$$= |I|^2 \omega L$$

Due to the capacitance of the line, the reactive power generated by the line will be

$$\Delta Q_c = \frac{|V|^2}{X_c} = |V|^2 \omega C$$

$$\Delta Q_L = \Delta Q_c$$

Suppose

$$|V|^2 \omega C = |I|^2 \omega L$$

$$= \left|\frac{V}{I}\right|^2 = \frac{\omega L}{\omega C} = \frac{L}{C}$$

$$Z_n = \frac{V}{I} = \sqrt{\frac{L}{C}}$$

Where Zn is called surge impedance of the line

A line is said to be operating as its surge impedance loading when it is terminated by a resistance equal to its surge impedance. The power transmitted under to its impedance. The power transmitted under this condition is called natural or surge power.

In general,

$$P = \frac{|E||V|}{X} sin\delta$$

$\delta = 90°$, max $power\ can\ be\ transfered.$

$$P = \frac{|E||V|}{X} MW$$

By varying X, , , $|V|$ we can get the control power. Case (i)

$$\Delta Q_L > \Delta Q_c$$

$$|V|^2 \omega C < |I|^2 \omega L$$

The voltage sags if the voltage at the two ends are maintained constant. The variation of voltage along the line is as shown in fig 2.

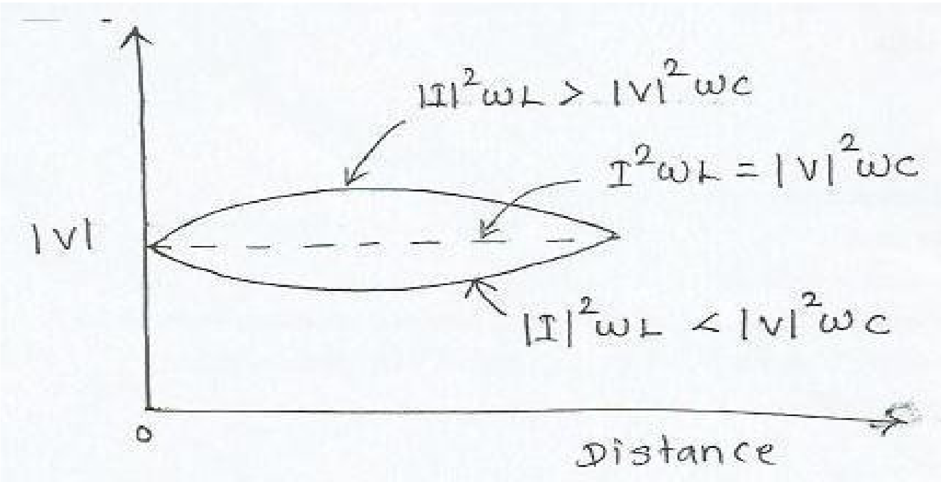
Here the line is loaded below Zn (ie) light load condition. The net effect of the line will be

absorbed reactive power.
Case (ii)

$\Delta Q_L < \Delta Q_c$

$|V|^2\omega C > |I|^2\omega L$

The variation of voltage along the line is as shown in fig 5.2 and we find that the voltage rises and maintains constant voltage at the ends. Under light load conditions the effect of shunt capacitors is predominating and the line will generate reactive power.



5. LOADS:

It absorb reactive power load change occurs depending on the day, season and weather conditions. Both active and reactive power of the composite loads vary as a function of voltage magnitudes load operating at L.P.F give voltage drop in the line and is uneconomical. Industrial consumers improve the p.f. using shunt capacitors.

METHOD OF VOLTAGE CONTROL

Voltage level control is accomplished by controlling the generation, absorption and reactive power flow at all levels in the system.

1. Shunt Capacitors:

Shunt capacitors banks are used to supply reactive power at both transmission and distribution levels, along lines or sub-stations and loads. Capacitors are either directly connected to a bus bar or to the tertiary winding of a main transformer. They may be switched on and off depending on the changes in load having a lagging power factor, the capacitors supply reactive power.

Shunt capacitors are extensively used in industrial and utility systems at all voltage levels. By developing higher power density, lower cast improved capacitors and an increase in energy density by a factor of 100 is possible. These present a constant impedance type of load and the capacitive power output varies with the square of voltage.

$K_{Var},V_2 = K_{Var},V_1[V_2/V_1]^2$

Where Kvar, V1 is output at voltage V1 Kvar, V2

is output at voltage V2

As the voltage reduces, so does the reactive power output, when it is required the most. This is called the destabilizing effect of power capacitors. Capacitors can be switched in certain discrete steps and do no not provide a stepless control. As a reactive power demand increases voltage falls.

Advantages:

1. These are less costly.
2. Flexibility of installation and operation.
3. Power factor improvement.
4. Efficiency of transmission and distribution of power is high.
5. Single or multiple banks industrial distribution at low and medium voltage substation.
6. Essential elements of SVC & Facts controllers and HVDC transmission.
7. Reactive power compensation

Disadvantages:

1. They cannot be overloaded.
2. The reactive power supplied by static capacitors tends to decrease in case of voltage dip on the bus because KVAR α V^2

Problems Associated with shunt capacitors:

- Switching inrush currents at higher frequencies and switching over voltage.
- Harmonic resonance problems.
- Limited overvoltage withstands capacity.
- Limited of harmonic current loadings
- Possibility of self-excitation of motors when improperly applied as power factor improperly applied as power factor improvement capacitors switched with motor.

Applications:

- improve power factor
- improve feeder voltage control

2.Series capacitors

It is connected in series to compensate the inductive reactance of line. This reduces the transfer reactance between the fuses to which the lines is connected. It increases maximum power that can be transmitted and reduce reactive power loss. The reactive power produced by the series capacitor increases with increase in power transfer, a series capacitor is self regulating in this regard.

Under fault conditions, the voltage across the capacitor rises and unlike a shunt capacitor, a series capacitor experiences many time its rated voltage due to fault currents.

A Zinc oxide varistor in parallel with the capacitor may be adequate to limit this voltage**.**

For locations with high fault currents a parallel fast acting triggered gap is introduced which operates for more severe faults. When the spark gap triggers it is followed by closure of the bypass breaker.

The drainage reactor limits the frequency and magnitude of the current through the capacitor when the gap sparks.

The schematic diagram of a series capacitor installation is shown in figure.

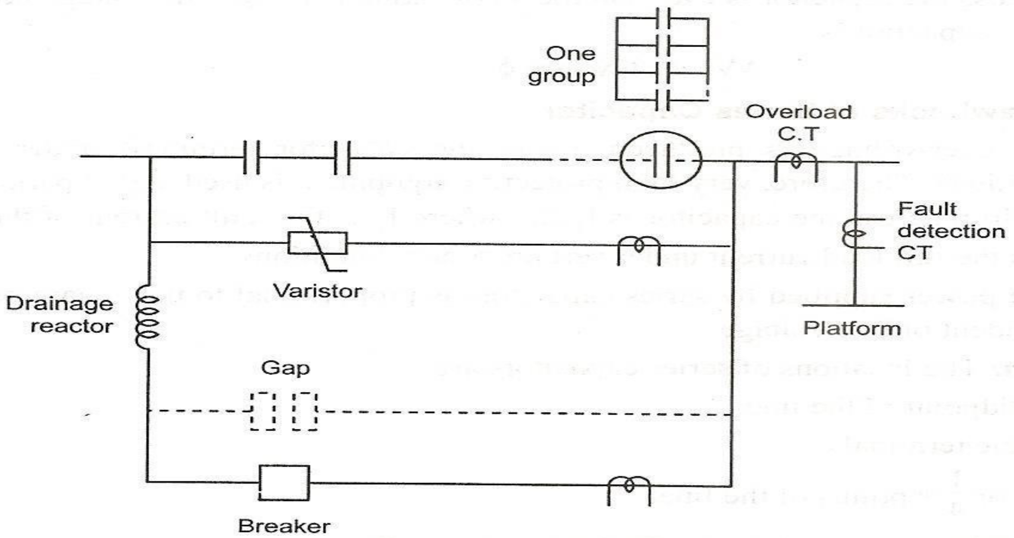
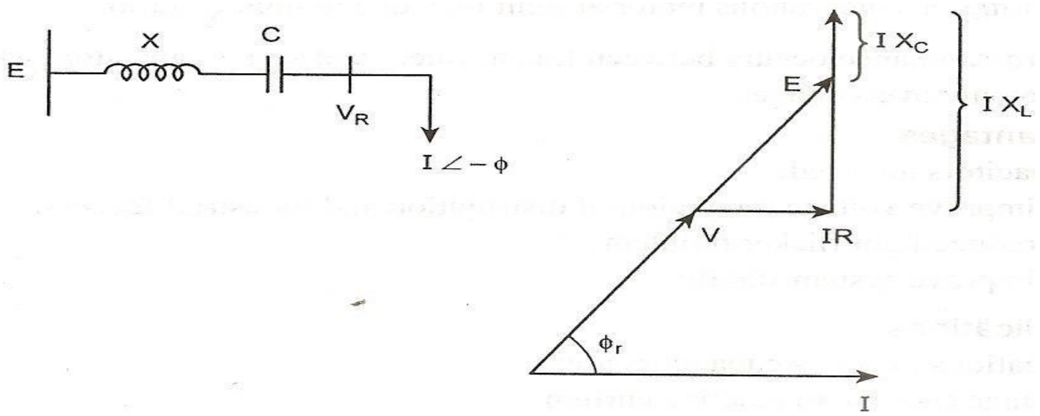


Figure 5.3 Series capacitor



Phasor diagram when series capacitor is connected on a line.

The voltage drop Across the line is IR cos

ϕ_r + I (X_L-X_C) sin ϕ_r

It is clear from the vector diagram diagram shown in figure that the voltage drop produced by an inductive load can be reduced particularly when the line has a high X/R ratio.

In practice X_C may be so chosen that the factor (X_L-X_C) sinϕ_r becomes negative and numerically equal to R cos ϕ_r so that the voltage drop becomes zero. The ratio X_C/X_L pressed as a percentage is usually referred to as the percentage compensation.

If I is the full load current, and X_C is the capacitive reactance of the series capacitor, then the drop across the capacitor is IX_C and the VAR rating is $I^2 X_C$. The voltage boost produced by the series capacitor is $V= IX_C \sin \phi_r$.

Drawbacks of series capacitor:

1. High over-voltage is produced across the capacitor terminals under short curcuit conditions. Therefore, very high protective equipment is used. E.g., spark gap.
2. The drop across the capacitor is if Xc, where if is the fault current of the order of 20 times the full load current under certain circuit conditions. Reactive power supplies capacitor is proportional to the square of line current and independent of line voltage.

Location:

The location of series capacitors au:

1.Midpoint of the line.

2. Line luminal

/3 or ¼ th point of the line.

Problems associated with series capacitors:

Locking of synchronous motor during stating .

- Hunting of synchronous motor at light load due to high R/x ratio
- ✓ Ferro resonance occurs between transformers and series capacitors which produces harmonic over voltages.

Advantages:

Series capacitors are used

- To improve voltage regulation of distribution and industrial feeders
- To reduce light flicker problems
- To improve system stability

Applications:

The applications of series capacitors are

- Voltage rise due to reactive current
- By passing the capacitor during faults and reinsertion after fault clearing

3.Shunt reactors:

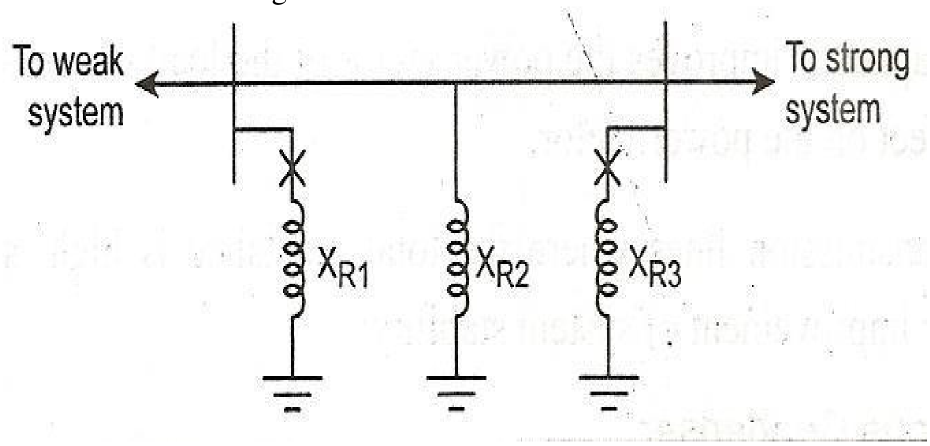
The shunt reactor au used to reduce (or) limit rise due to circuit (or) light load, shunt reactor absorbs reactive power are usually used for EHV lines longer than and when the far end line is opened, the large source inductive reactance will cause a rise in voltage at the receiving end of the line. Ferranti effete will cause a feather rise in receiving end voltage. During heavy loads some of the reactors may have to be disconnected.

Advantages:

- ✓ Shunt reactors of sufficient sixe is permanently connected to the line to limit fundamental. Frequency temporary over voltages
- ✓ To limit switching transients
- ✓ To maintain normal voltage under light load conditions
- ✓ During heavy load conditions, some of the reactors are disconnected by using switching reactors and circuit breakers.

Location:

Shunt reactors added to maintain normal voltage under light load may be connected to EHV bus as shown in fig 5.5.



EHV bus Shunt reactors connected to EHV bus:

XR1, XR3 – switchable reactors.

XR2 – permanently connected reactor

shunt reactors connected to the tertiary windings of adjacent transformers as shown in fig 5.6

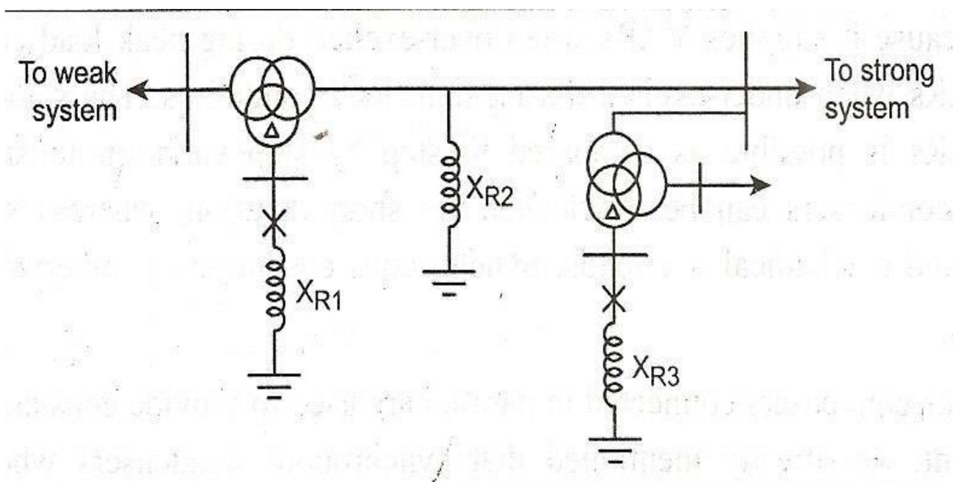


Figure 5.6 Shunt reactors connected to tertiary winding of transformers.

In short transmission lines, no need connecting shunt reactors permanently, so switchable reactors may be connected to EHV bus or tertiary winding of transformers but in some applications, tapped reactors with on load tap changer is used in fig 5.7

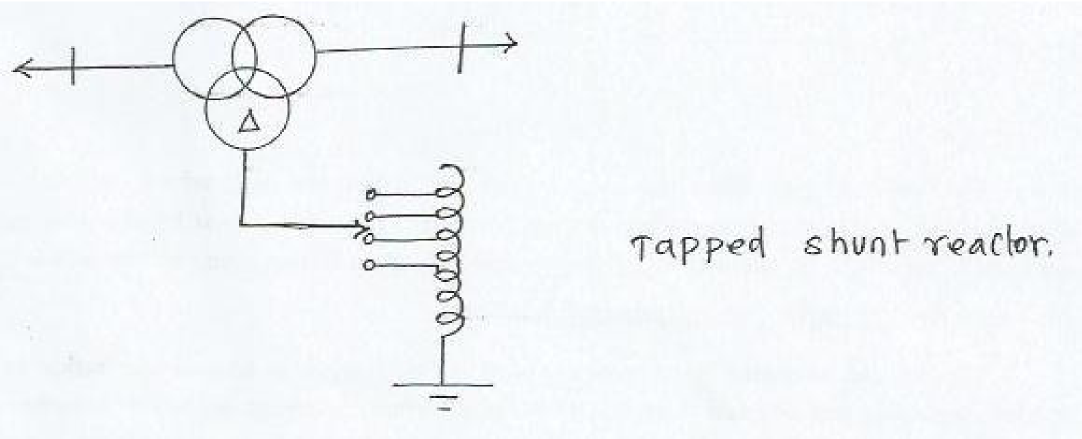


Figure 5.7 Tapped reactors with on load tap changer

Comparison between series & shunt capalitors:

- The voltage boost due to a shunt capacitor is evenly distributed over the transmission line whereas the change in voltage between the two ends of a series capacitor where it is connected in sudden. The voltage drop along the line is unaffected.
- For the same voltage, the reactive power capacity of a shunt capacitor is greater than that of a series capacitor.
- The shunt capacitor improves the power factor of the load whereas the series capacitor has little effect on the power factor.
- For long transmission lines where the total reactance is high, series capacitors are effective for improvement of system stability.

4. Tap changing transformer:

All power transformers on transmission lines an provided with traps for control of secondary voltage. The tap changing transformers do not control voltage by regulating the flow of active VARs but by changing transformation ratio.

There are two types of tap changing transformer:

a) Off-load tap changing transformers.
b) On load (under-load) tap changing transformers.[OLTC]

5. Off-load tap changing transformer:

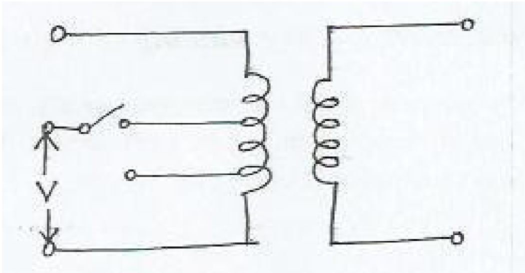
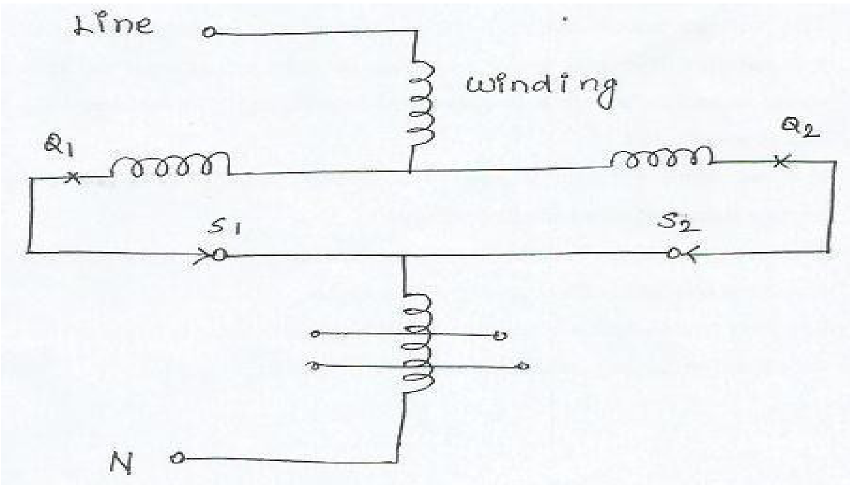


Figure 5.8 Off load Tap changing transformer

The off-load tap changing transformer as shown in fig 5.8. which requires the disconnection of the transformer when the tap setting is to be changed off load tap changers are used when it is to be operated in frequently due to load growth or some seasonal change.

6. On load tap changing transformer (OLTC):

On-load tap changing transformer is used when changes in transformer ration to be needed frequently and no need to switch of the transformer to change the top of transformer. It is used on power transformers, auto transformers and bulk distribution transformers and at other points of load service.



The modern practice is to use on load tap changing transformer which is shown in fig.5.9. In the position shown, the voltage is maximum and service the currents divide equally and flow in opposition through the coil between Q1 and Q2, the resultant flux is zero and hence minimum impedance.

To reduce the voltage the following operations an required in sequence:

i) Open Q1
ii) Move selector switch S1 to the next contact
iii) Class Q1
iv) Open Q2
v) Move selector switch se to the next contact
vi) Close Q_2

Thus, six operations are required for one change in tap position. The voltage change between taps is often 1.25% of the nominal voltage.

Applications of tap-changing transformers:

Auto transformers used to change voltage from one sup-system to another are often furnished with under-load or on-load tap changing facilities (ULTC). They may be controlled either automatically or manually. These are usually present throughout the network interconnecting transmission systems of different levels. The taps on these transformer provide a convenient means of controlling reactive power flow between subsystems. This in turn can be used to control line voltage profiles and reactive power losses. The control of single transformer will cause change in voltages at its terminals. In addition, it influences the reactive power flow through the transformer. During high system load conditions, the network voltages are kept at the highest practical level to maximize reactive power requirement and increase the effectiveness of shunt capacitors and line-charging.

During lightly loaded condition, it is usually required to lower the network voltage, to reduce line charging and avoid under excited operation of generators.

Transformers with off-load tap changing facilities can also help to maintain satisfactory voltage profile, while transformers with VLTC can be used to take care of daily, hourly and minute-by-minute variation in system conditions setting of off-load tap changing transformers have to be carefully chosen depending on long term variation due to system expansion, load growth or seasonal changes.

MALLA REDDY ENGINEERING COLLEGE (AUTONOMOUS)

III B.Tech II Semester I Mid Question Bank

Subject: EDSA **Branch: EEE**

Name of the Faculty: B Sampath kumar

OBJECTIVE QUESTIONS

1. The common voltage adopted for low voltage electrical distribution is_____________[ ]
A)220v DC B) 230v AC 1ph
C) 400 3ph 3 wire D) 400 3ph 4 wire

2. The usual voltage level adopted for high voltage distribution network in Indian is [ ]
A)132kv B) 11kv
C) 16kv D) 400v

3. Demand factor is theratio of [ ]
A)max demand to connected load B) total load to max demand
C) max demand to rated capacity D) none of the above

4. The coincidences factor for lighting loads in domestic/residential loads is about [ ]
A) 0.1 B) 0.5
C) 1.0 D) 0.9

5. The estimation of load inadvance is commonly known as……… [ ]
A)load approach B) load forecasting
C) both a and b D) none

6. Load duration curveis between [ ]
A|)load and time duration over whichit occurs B) load and time of occurrence
C) units consumed and duration in days D) power supplied and time

7. For commercial loads, the diversity factor is usually……. [ ]
A) 1.3 – 1.5 B) 1.1 – 1.2
C) 2 – 4 D) 3.2 – 3.5

8. The load factor of agriculture load is generally……. [ ]
A) 25 – 30% B) 10 – 15%
C) 20 – 25% D) 70 – 80%

9. Load factor of a power station is defined as [
A) maximum demand/average load B) average load x maximum demand
C) average load/maximum demand D) (average load x maximum demand)172

10. Load factor of a power station is generally [ ]
A) equal to unity B) less than unity
C) more than unity D) equal to zero Diversity factor is always

11. The load factor of domestic load is usually [ ]

A) 10 to 15% B) 30 to 40%
C) 50 to 60% D) 60 to 70%

12. Demand factor is defined as [ ]
A) average load/maximum load B) maximum demand/connected load
C) connected load/maximum demand D) average load x maximum load

13. High load factor indicates [ ]
A) cost of generation per unit power is increased
B) total plant capacity is utilised for most of the time
C) total plant capacity is not properly utilised for most of the time
D) none of the above

14. A load curve indicates [ ]
A) average power used during the period
B) average kWh (kW) energy consumption during the period
C) either of the above D) none of the above

15. Which plant can never have 100 percent load factor ? [ ]
A) Peakload plant B) Base load plant
C) Nuclear power plant D) Hydro electric plant

16. The area under a load curve gives [ ]
A) average demand B) energy consumed
C) maximum demand D) none of the above

17. Diversity factor has direct effect on the [ ]
A) fixed cost of unit generated B) running cost of unit generated
C) both (a) and (b) D) neither (a) nor (b)

18. Power plant having maximum demand more than the installed rated capacity will have utilisation
factor [ ]
A) equal to unity B) less than unity
C) more than unity D) none of the above

19) Which of the following is usually not the generating voltage- [ ]

A) 6.6 kV B)9.9 kV
C) 11kV D)13.2kV

20) A 3 phase 4 wire system is commonly used for- [ ]

A. Primary distribution B. Secondary distribution
C. Primary transmission D. Secondary transmission

21) The rated voltage of a 3 phase power system is given as [ ]

A. rms phase voltage B. peak phase voltage
C. peak line to line voltage D. rms line to line voltage

22)Demand interval is usually-------- [ ]

min B.5 min C.30 min D.3 hours

23) Demand factor is the ratio of----- [ ]
A.maximum demand to connected load B.total load to maximum demand
C.maximum demand to rated capacity D.none of the above

24) Load-duration curve is between-------- [ ]

A)load and time of occurrence B)load and time duration over which it occurs
C)units consumed and duration in day D)power supplied and time

25) Utilization factor is the ratio of------- [ ]

A) maximum demand to total connected load
B) maximum demand to rated capacity of the system
C) Any demand occurring in a day to maximum demand
D) Total load to maximum demand

26) The empirical relation used between load factor(l.f) and loss factor is,loss factor= [ ]

A)0.7(l.f)+0.3(l.f)² B)0.3+(l.f) C) 0.3(l.f)+0.7(l.f)² D)0.7+(l.f)

27) The coincidence factor for lighting loads in domestic/residential loads is about[]

A)0.1 B)0.5 C)1.0 D)0.9

28) power factor of domestic appliances like fans,washing machines,mixies etc in the range [ ]

A)0.75 to 0.85 B)0.4 to 0.75 C)0.4 to 0.8 D)0.6 to 0.75

29) Load growth follows-----------law [ ]
A.power law B.compound interest law C.both D.none

30) A load in an area has a load factor 0.6.The approximate loss factor may be[ ]
A.0.432 B.0.7 C.0.85 D.0.92

31) Load diversity is the difference between -------------and----------- [ ]
A.sum of the peak demands of individual loads and concident maximum demand
B. Maximum demand and connected loads
C. Total connected load and Demand D.none

32) For large power loads,Distribution voltage is-------- [ ]
A.500 V dc B.400 V 3 phase ac C.11 KV 3-ph 3-wire ac D. 11 KV 3-ph

4-wire ac

33) Single-phase ac with mid point earthing is used for------ [ ]
A.bulk load distribution B.domestic loads
C.rural and agricultural loads D.industrial loads

34) For typical urban loads,peak demand can occur-------- [ ]
A.once in a day B.twice in a day C.more than twice in a day
D.cannot be predicted

35) The time interval taken for estimation of maximum demand for billing is[ ]A.15 min or 30 min (in AP state) B.1 hour C.50 min D.none

36) Diversified demand also termed as-------- [ ]
A.coincident demand B.non coincident demand C.Maximum demand D.none

37) Plant factor is also known as the------------- [ ]A.capacity factor B.use factor C.both D.none

39) The ratio of average power loss to the peak load power loss during a specific period of time is-------- [ ]
A.Loss factor B.Load factor C.Diversity factor D.Utilization factor

40) When the power cuncumption is high in residentioal loads [ ]
A. 3am-9am B.9am-2pm C.2pm-6pm D.7pm-12am

41) When the power cuncumption is high in commercial loads [ ]
A. 3am-9am B.9am-2pm C.2pm-6pm D.7pm-12am

42) When the power cuncumption is high in agricultuer loads [ ]
A. 3am-9am B.9am-2pm C.2pm-6pm D.7pm-12am

43) Load decrease follows-----------law [ ]

A.power law B.compound interest law C.both D. None

44) The primary distribution system is known as [ ]
A.sub transmission line to substation B. Sub station to sub transmission line
C. substation to Transformer D. None

45) The secondary distribution system is known as [ ]
A.sub transmission line to substation B. Sub station to sub transmission line
C. substation to Transformer D. None

46) Three-phase ac with mid point earthing is used for------ [ ]

A.bulk load distribution B.None

C.rural and agricultural loads D.industrial loads

47) Load factor is the ratio of----- [ ]
A.maximum load to average load B.total load to maximum load
C.maximum demand to rated capacity D.none of the above

48) Loss factor is the ratio of----- [ ]
A.maximum loss to average loss B. average load to maximum loss
C.maximum demand to rated capacity D.none of the above

49) Contribution factor is the ratio of----- [ ]
A.maximum loss to average loss B. average load to maximum loss
C.maximum demand to rated capacity D.none of the above

50) Coincident factor is the ratio of----- [ ]
A.maximum loss to average loss B. average load to maximum loss
C.maximum demand to rated capacity D.none of the above

51) Feeder is designed mainly from the point of view of- [ ]
A. Its current carrying capacity B. Voltage drop in it
C. Operating voltage D. Operating Frequency

52) Distributors are designed from the point of view of - [ ]
A. Its current carrying capacity B. Operating voltage
C. Voltage drop in it D. Operating frequency

53) Transmission and distribution of electric power by underground system is superior to overhead system in respect of- [ ]
A. Apperance and public safety B. Maintenance cost
C. Frequency of faults, power failure and accidents D. All of the above

54) The main drawbacks of underground system over overhead system is/are- [ ]

A. Exposure to lighting B. Heavy initial cost
C. Exposure to atmospheric hazards such as smoke, ice, wind etc.
D. Inductive interference between power and commuication circuit

55) The main drawback of ovehead system over underground system is-[ ]
A. Underground system is more flexible than overhead system
B. Higher charging current
C. Surge problem D. High initial cost
56) For the same voltage drop, increasing the voltage of a distributor n time-[ ]
A. Reduces the x section of the conductor by n times
B. Increases the x section of the conductor by n times
C. Reduces the x section of conductor by n^2 times
D. Increases the x section of the conductor by n^2 times

57) The volume of copper required for an ac transmission line is inversely proportional to [ ]
A. Current B. Voltage C. Power factor D. Both b and c
58) In a transmission system the feeder supplies power to- [ ]

A. Transformer substations B. Service mains C. Distributors D. All
59) The most suitable practical value of primary distribution is? [ ]
A. 66 Kv B. 6.6 kV C. 230 V/ 400 V D. 22 kV
60) A ring main distributor fed at one end is equivalent to ------- fed at both ends with equal voltages. [ ]
A.straight distributor B.Ring feeder C.both D.none

61)A distributor is designed from------ considerations. [ ]
A.voltage drop B.Current C.power factor D.none

62) The dc interconnector is used to ------------the voltage drops in the various sections of the distributor. [ ]
A.increase B.reduce C.Both D.None

63) The most common system for secondary distribution is 400/------V,3-phase,----wire syste [ ]

A.230,4 B.440,3 C.230,2 D.440,2

64)Distribution transformer links the--------and ------- systems [ ]
A.balanced and unbalanced B.primary and secondary C.both D.none

65)3-phase,4-wire ac system of distribution is used for -------- load. [ ]A.unbalanced B.balanced C.both D.none

66) For purely domestic loads, --------- ac system is employed for distribution. [ ]
A.3-phase 3-wire B.single phase 2-wire C.Both D.None

67) A ring main system of distribution is -------reliable than the radial system. [ ]
A.less B.more C.Equal D.none

68) The interconnected system -------------the reserve capacity of the systems. [ ]
A.increases B.decreases C.slightly decreases D.none

69) The statutory limit for voltage variations at the consumer's terminals is -------------% of rated value. [ ]
A.8 B.9 C.6 D.10

70) The service main connect the -----------and the------- [ ]
A.distributor,consumer's terminal B. feeder,consumer's terminal

C.Both D.None

71) Isolator switch in a substation is used for [ ]
A. disconnecting supply under fault condition
B. connecting the equipment and disconnecting it under no-load conditions

C. operating the switch only on load conditions
D.none of the above

72) The gas used in Gas insulated substation is [ ]
A. nitrogen B. oxygen C. air D. SF6

73) For distribution transformers %Z will be usually [ ]
A. 4 to 6% B. 10% C. 8% D. 9%
74) Breaker and a half scheme uses -------- breakers per bay and two buses together [ ]

A 2 B.1 C.3 D.4

75) Gas insulated substation operates at [ ]
A.high pressure above 10 atmospheres B.5-6 atm

C.2-3 atm D.less than one atm

76) Which one of the following is not a component of Gas insulated substation [ ]
A.earth switch B.transformer C.Circuit breaker D.current transformer

77) Controlling of the Gas insulated substation is done by…… [ ]
A.control panel at remote place B.control panel placed locally
C.both B & A D.none of the two A & B

78) Substations are located in open space and conductors and equipment is mounted on insulators. [ ]
A. outdoor B.Indoor C.Both D.none
79) Busbars are used in Gas insulated substation to connect------- [ ]
A.to connect components that are not directly connected to each other
B. not to connect components
C. not to connect components that are not directly connected to each other
D.None
80) Outdoor substation requires-----------space [ ]
A.more B.less C.Both D.none
81) The possibility of fault escalation is ---------- in outdoor sub-station than that of indoor sub-station. [ ]
A.more B.less C.Both D.none

82) Majority of distribution substations are of--------type. [ ]
A.polemounted B.outdoor C.indoor D.GIS

83) Power factor correction sub-stations are generally located at the ------ end of a transmission line. [ ]
A. sending B. receiving C.Both D.none

84) Underground substations are generally located in------------- [ ]

A.thickly populated areas B. villages C.Both D.none

85) An ideal location for the substation would be at the -------of load. [ ]
A.centre of massB.centre of gravity C.Both D.none

86) Pole-mounted substations are used for--------distribution. [ ]
A. secondary B. primary C.Both D.none

87) The voltage rating of the transformer in a pole-mounted sub-station is---[ ]
A.11 KV/400V B.33 KV/11 KV C.400V/11 KV D.11 KV/33KV

88) Single bus-bar arrangement in sub-stations is used for voltages less than----[ ]
A.33 KV B. 11 KV C.400V D.230 V

89) For voltages greater than 33 KV,----------busbar arrangement is employed. [ ]
A.single B.duplicate C.Both D.none

90) The KVA rating of transformer in a pole-mounted sub-station does not exceed
[ ]
A.300 KVA B.100 KVA C.200 KVA D.400 KVA

91) Reactive power compensated, when p.f is improved from cosθ1 to cos θ2 is given by(P=power and S=kva) [ ]
A) P(tan θ1-tan θ2) B) S(tan θ1-tan θ2)
C) P(sin θ1-sin θ2) D) S(cos θ1-cos θ2)

92) Series capacitor compensation is used to [ ]
A)improve p.f B)reduce line reactance
C) reduce fault levels D)compensate for reactive power of load

93) Hospitals, commercial locations etc will have p.f of------ [ ]
A)0.75-0.85 lagging B)0.65 lagging C) 0.95 lagging D)0.55 lagging

94) series capacitors are located at---- [ ]
A)sending end of the line B)middle of the line
C)receiving end of the line D)all the above

95) Multiplying factor to determine KVAR of capacitor banks is---[ ]
A)(sin θ1-sin θ2) B) cos θ1-cos θ2 C) θ1- θ2 D) tan θ1-tan θ2

96) The most suitable and best location for capacitors is---- [ ]
A)Either at the load end or at the distribution bus B)sending end

C)receiving end D)none

97)Lighting loads such as fluorescent lamps have a p.f of------- [ ]
A) 0.2 B) 0.5 to 0.6 C)0.8 to 0.9 D)1.0

98)The disadvantage of a series capacitors is------------- [ ]

A) Fault current or fault MVA is increased due to decrease of line reactance.
B) Fault current or fault MVA is decreased due to increase of line reactance
C) Fault current or fault MVA is increased due to increase of line reactance
D) Fault current or fault MVA is decreased due to decrease of line reactance

99) Series capacitors in distribution lines are protected against over voltage by-------- and--------- [ ]
A) Surge arrester, HRC fuse in series B) Surge diverter, HRC fuse in series
C) Both D) Surge arrester, Surge diverter

100) The power factor of an a.c circuit is given by------power divided by---------- power [ ]
A) active, apparent B) apparent, active C) active, reactive D) reactive, active

101) The lagging power factor is due to-----power drawn by the circuit. [ ]
A) lagging reactive B)leading reactive C)both D)none

102)Power factor can be improved by installing such a device in parallel with load which takes------------ [ ]
A) lagging reactive power B) leading reactive power C) both D) none

103)The major reason for low lagging power factor of supply system is due to the use of------------motors [ ]
A) synchronous B) stepper C) D.C D) induction

104)An over-excited synchronous motor on no load is known as----[ ]
A) synchronous condenser B) over-excited motor C) synchronous machine D) none

105) The maximum value of power factor can be--------- [ ]
A)0.5 B)0.9 C)1 D)0.4

106)By improving the power factor of the system, the kilowatts delivered by the generating station are-------- [ ]
A) decreased B) increased C)not changed D)none
107)The most economical power factor for a consumer is generally------[ ]
A) 0.7 lagging B)0.95 lagging C) unity D)0.8 leading

108)KVAR=---------tanØ [ ]
A)KW B)KVAR C)KVA D)KV

109) Phase advancers are used to improve the ------------of induction motors. [ ]
A) efficiency B)KVAR C)power factor D)KVA

110) If power factor is more, maximum KVA demand will be------and [ ]
If power factor is less, maximum KVA demand will be-------
A)more, more B)less, less C)less, more D)more, less
111) System which suffers from maximum voltage fluctuations is [ ]

a) Ring type b) Mesh type c) Radial type d) None of these

112) Light points available in the houses are [ ]
a) Voltage source b) Current source c) Power source d) All of these

113) Systems getting supply from one end only are [ ]
a) Ring type b) Mesh type c) Radial type d) All of these

114) Outdoor sub-station are preferred for voltages above [ ]
a) 3.3 kV b) 11 kV c) 33 kV d) 66 kV

115) Which of the following system is preferred for good efficiency and high economy in distribution system? [ ]
a) Single phase system
b) 2 phase 3 wire system
c) 3 phase 3 wire system
d) 3 phase 4 wire system

116) For most reliable distribution supply, the configuration used is [ ]
a) Radial main b) Ring main c) Parabolic main d) Balancing main

117) Feeder is designed mainly from the point of view of- [ ]
A. Its current carrying capacity B. Voltage drop in it
C. Operating voltage D. Operating Frequency

118) A distributor is designed from------ considerations. [ ]
A.voltage drop B.Current C.power factor D.none

119) Majority of distribution substations are of--------type. [ ]
A.polemounted B.outdoor C.indoor D.GIS

120) Diversified demand also termed as-------- [ ]
A.coincident demand B.non coincident demand C.Maximum demand D.none

121) Plant factor is also known as the------------- [ ]
A.capacity factor B.use factor C.both D.none

122) While designing the distribution to locality of one lac population with medium dense load requirement, we can employ ____________ [ ]
a) radial system
b) parallel system
c) ring main system
d) any of the mentioned

123) A__________distribution system is more reliable than the_______ [ ]

distribution system.
a) parallel, radial
b) parallel, ring
c) radial, parallel
d) ring, parallel

124) While designing the distribution sub stations by the designer, it is required to use the________for the discrete power tapping. [ ]
a) distributor
b) power transformer
c) distribution transformer
d) feeder

125) A transmission and distribution engineer needed to design the sub transmission substation. The tapping component needed will be____ [ ]
a) feeder
b) distributor
c) transmitter
s) tap-changing transformer

QUESTION BANK

MODULE-I

1. i) Give the classification of loads and draw their characteristics
   ii) Obtain the relationship between the load factor and loss factor

2. i) List out and explain the various control functions in distribution automation.

   ii) Write in detail about commercial and agricultural loads and their respective characteristics.

3. i. Derive relationship between load factor and loss factor.
   ii. What are the different types of loads? Discuss their characteristics.

4. Why loads are classified in distribution systems and how they are classified? Also explain their different characteristics.

5. i. The total annual copper loss of the feeder is 20000kWh and load factor is 0.32. Then find average power loss of the feeder.
   ii. Show that load factor = loss factor = t/T for zero off - peak load. i. Assume that a load of 100kW is connected at the riverside substation. The 15min. weekly maximum demand is given as 75kW, and the weekly energy consumption is 4200kWh. Assuming a week is 7 days, fine the demand factor and the 15min. weekly load factor of the substation.
   ii. Classify different types of distribution loads and specify their voltage levels.

6. i. A small city experiences an annual peak load of 3500kW. The total annual energy supplied to the primary feeder circuits is 10x106 kWh. The peak demand occurs in July/August and is due to air conditioning load:
      a. Find the annual average power demand
      b. Find the annual load factor
      c. Find the annual loss factor.
   ii. Explain the characteristics of commercial and agricultural loads. i. For what contribution factor, the coincident factor is equal to contribution factor. Also define contribution and coincident factor
   ii. The annual peak load of substation is 3500kW. The annual energy supplied to the primary feeder circuit is 20 x 106 kWh. Find:

a. The annual average power demand

b. The annual load factor. i. Give the classification of loads and draw their characteristics.

ii. A load of 100 kW is connected at the riverside substation. The 15 min. weekly maximum demand is given by 75 kW and the weekly energy consumption is 4200kWh. Find the demand factor, the 15 min. weekly load factor of the substation and its associate loss factor. (May 11, Nov 10)

7. Discuss the following factors of the distribution system:

i. Demand factor
ii. Plant factor
iii. Load factor
iv. Diversity factor
v. Contribution factor
vi. Coincident factor
vii. Loss factor. i. A 50MW hydro generator delivers 320 million kWh during the year. Calculate the plant load factor.

ii. Explain the load characteristics of distribution system.

Discuss different types of loads present in distribution system and explain their characteristics.

13\.

i. What is meant by load modeling and give their characteristics?

ii. Define the following:

a. Coincidence factor
b. Load factor
c. Loss factor

Contribution factor.

Explain about load modelling and characteristics of different types load models.

Explain the characteristics of residential, industrial and commercial loads.

14\. i. Explain load modeling and their characteristics.

ii. The annual peak load of a substation is 5000KW and the total annual energy supplied to the feeder is 15 × 105

KWh. The peak demand occurs is demand due to A-C load then find

a. Annual average power demand
b. Annual load factor
c. Annual loss factor using approximate formula.

ii. Obtain the relationship between loss factor and load factor.

iii. What is a distribution system? What are the different types of load that are connected to this system?

iv. What is the significance of diversify factor and demand factor with respect to distribution system?

15\. Why loads are classified in distribution systems and how they are classified? Also explain their different characteristics.

16. Draw a block diagram in flow chart form for a typical distribution system planning process and explain the techniques for distribution planning.

17. i. Explain how the load growth in a distribution system can be obtained.

ii. A distribution substation experiences an annual peak load of 3,500 kW. The total annual energy supplied to the primary feeder circuits is 107 kWh. Find

a. the annual average power

18. the annual load factor

19. Explain the different control functions used for distribution automation.

20. Write in detail about commercial and agricultural loads and their respective characteristics. (May 09)

21. The annual peak load input to a primary feeder is 2000 Kw. A computer program which calculates voltage drops and copper looses shows that the total copper loss at the time of peak load is ?2R= 100 Kw. The total annual energy supplied to the sending end of feeder is 5.61x106 Kwh, Then

i. Determine the annual loss factor

ii. Calculate the total annual copper loss energy and its value at $ 0.03/Kwh.

22. i. Define coincidence factor and contribution factor.

ii. Obtain the relation between the load factor and loss factor.

23. i. Prove that approximate formula for loss factor(FLS) = 0.3FLD + 0.7F2 , where F = load factor.

ii. The annual average load is 1241 kW and monthly peak load is 3600kW. Find the load factor and loss factor by using approximate formula.

24. i. Discuss the effect of load factor and diversity factor on the cost of generation in a power system.

ii. Assume that the annual peak-load input to a primary feeder is 2000 kW. The total copper loss at the time of peak- load is 100 kW. The total annual energy supplied to the sending end of the feeder is 5.61 × 106 kWH. Determine

a. the annual loss factor

b. the total annual copper loss energy and its value at Rs.1.5 per kWh.

27. Discuss the objectives of distribution system planning.

28. Explain briefly the classification of Loads.

i. A power supply is having the following loads.

ii.

i. If the overall system diversity factor is 1.35, determine maximum demand

ii. connected load of each type

29. i. Derive the relationship between the load and loss factors.

ii. The input to a sub transmission system is 87.6 × 106 kWh annually. On the peak-load day of the year, the peak is 25, 000kW and the energy input that day is 3 × 105 kWh. Find the load factors for the year and for the peak-load day.

30. i. What is meant by the term load? How loads can be classified?
ii. Define: Demand, load duration curve and Annual load duration curve.
ii. Explain how maximum demand and average demand can be obtained from daily demand variation curve.

31. Examine the present trend for the future distribution system planning.

32. i. Explain the following terms
a. maximum demand
b. coincident demand and
c. non - coincident demand

ii. Explain following factors
a. Contribution factor
b. load diversity
c. loss factor
d. Explain the characteristics of different types of Load models.

ii. Assume that the annual peak load of a primary feeder is 2,000 kW, at which the power is 80kW per three phase.

Assuming an annual loss factor of 0.15, determine
a. the average annual power loss
b. the total annual energy loss due to the copper losses of the feeder.

33. Explain: Load factor and diversity factor.

34. Explain the various factors affecting the distribution system planning.

35. i. What is the need for mathematical models to represent the system? Name the different operations research techniques used by planners, for planning a distribution system.

ii. Discuss about the three factors which affect the distribution system planning in the near future.

36. i. What informations can be obtained from the load duration curve?

ii. Explain the following factors:

a. Demand factors b. Connected load c. Utilization factor d. Plant factor.

37. Draw the schematic view of a distribution system planning, and explain the role of computer in distribution system planning.

38. i. Explain how a load duration curve is plotted. What is its age?

ii. A distribution substation supplies the following loads: 15,000 kW, 8,500 kW, 6,000 kW and 450 kW. The station has a maximum demand of 22,000 kW. The annual load factor of the station is 48%. Calculate

a. the energy supplied annually b. the diversity factor and c. the demand factor

Write the importance of electrical distribution systems and their applications?

ii. What are the different types of supply systems that are adopted for transmission of electrical power.

MODULE-II

1. i) Assume that feeder has a length of 2 miles and that the new feeder uniform loading has increased to 3 times the old feeder loading. Determine the new maximum length of the feeder with the same percent voltage drop if the new feeder voltage level is increased to 34.5kV from the previous voltage level of 12.47kV.

ii) Explain basic design practice of secondary distribution system and also discuss about secondary banking.

2. i) Compare the various switching schemes by clearly mentioning the advantage and the disadvantages of earthing.

ii) Explain the rectangular type development and radial-type development in case of feeders

3. i. Explain the basic design practice of secondary distribution systems.

ii. A 300m distributor fed from both ends F1 and F2 is loaded uniformly at the rate of 2A/m run. The resistance of loop is
0.2 ?/km. Find the minimum voltage and the point where ? occurs, if the feeding F1 and F2 are maintained at 225V and 220V respectively. Also find the currents supplied from the feeding points F1 and F2.

i. Distinguish between a feeder, distributor and service mains in a secondary distribution scheme.

ii. Show that with an increase in working voltage to ‘n times, the cross section of a feeder and a distributor would be reduced to 1/n and 1/n2 of their respective values.

4. i. Explain the basic design practice of secondary distribution system.

ii. Mention different standard voltage levels of secondary distribution system.

5. Find the new load and area that can be served with the same percent voltage drop if the new feeder voltage level is increased to twice the previous voltage level of the feeder.

6. Give comparison between four and six feeder patterns.

7. i. Draw and explain secondary network supplied by three primary feeders.

ii. Discuss how number of feeders are decided by given primary feeder loading.

i. Assume that the service area pf a given feeder is increasing as a result of new residential developments. Determine the new load and area that can be served with the same percent voltage drop if the new feeder voltage level is increased to 34.5 kV from the previous voltage level of 12.47kV.

ii. Discuss in detail the factors which influence the selection of primary feeder rating.

8. i. Draw and explain one line diagram of typical primary distribution feeder.

ii. Draw and explain one line diagram of secondary network of the distribution feeder.

9. Give the various loading and voltage level factors that influence the design and operation of primary feeders.

10. i. Classify different types of primary feeders and give their merits and demerits.

ii. Explain basic design practice of secondary distribution system and also discuss abou secondary banking.

11. Assume that a star connected three phase load is made up of three impedances of 506 250 ohms each and that the load is supplied by a three phase four wire primary express feeder. The balanced line to neutral voltages at the receiving end are van = 7630 ?0V, vbn = 7630 24?0V, vcn = 7630 120?V. Determine the following:

i. The phase currents in each line
ii. The line to line phasor voltages
iii. The total active and reactive power supplied to the load.
iv. What is meant by primary feeder loading? Give some of the factors which will affect the design loading of a feeder.

12. i. Classify the types of primary feeders and give the applications of each type primary feeder.

ii. Draw and explain one line diagram of secondary distribution system and explain the parts of itExplain single line diagram of a simple radial secondary distribution and explain design practice of this system.

13. i. Explain various factors that influences the number of conductors and size of conductor of primary feeder.

ii. Distinguish between a feeder, distributor and service mains in a secondary distribution system.

14) i. Explain the basic design consideration of primary feeders.

ii. State the different voltage levels of secondary distribution system.

15) How do you optimally locate the substations and explain the benefits derived from optimal location.

16) i. Explain radial type primary feeder with neat diagram.

ii. Assume that feeder has a length of 2 miles and that the new feeder uniform loading has increased to 3 times the old feeder loading. Determine the new maximum length of the feeder with the same percent voltage drop if the new feeder voltage level is increased to 34.5kV from the previous voltage level of 12.47kV.

17) i. What is meant by express feeder and give its importance in operation of radial type primary feeder?

ii. Explain different connection diagrams of radial primary feeder.

What are the various factors that are to be considered in selecting a primary feeder rating? Describe the arrangement with suitable diagram.

A 3 phase radial express feeder has a line to line voltage of 22.0 kv at the receiving end, a total impedance of 5.25 + j10.95ohm/phase, and a load of 5 MW with a lagging power factor of 0.90. Determine the following:

a. The line to neutral and line to line voltages at the sending end.
b. The load angle.

18) i) How do you analyze a substation service area with `n' primary feeders.

ii) Discuss the benefits, which are derived through optimal location of substations i. What are the factors considered when selecting a location for a substation?

ii. Explain the procedure for optimal location of substation.

19) Calculate the % voltage drop in the main if load 500kVA is uniformly distributed along the feeder main, is shown in figure Consider k = 0.01%VD/(kVA.mi).

ii. Explain the rules to be considered to locate the substation.

iii. Define `k' constant and give its importance.

iv. i. A 3 -�, 4.16kV wye grounded feeder main has 4 copper conductors with an equivalent spacing of 1.0 m between phase conductors and a lagging load power factor of 0.9. Determine the `k' constant of the main feeder. Let r = 1.503�/m and x=0.7456 �m. Also calculate the percent voltage drop in the main if a lumped sum load of 500 kVA with a lagging p.f. of 0.9 is connected at the end of 1m long feeder main.

ii. List out the benefits obtained from optimal location of substations.

20) i. Draw the primary network which is supplied by number of substations.
ii. Define secondary banking and explain different connections of secondary banking.

21) Obtain the percentage voltage drop of substation service area served with `n' primary feeders and each feeder serves an area of triangular shape.

22) Compare the four and six feeder patterns of substation service area if they are voltage drop limited.

23) i. Explain the procedure to fix the rating of a substation.
ii. Calculate the percent voltage drop in the main of given 3 - phase feeder of 4.16 kV having r = 1/3 ohms/mi, x = 0.8 ohms/mi and 560 kVA load is uniformly distributed along the feeder main of length 1 mile. Assume p.f. = 0.92.

MODULE-III

1. i) What is the justification for power factor improvement and what are the benefits.
   ii) A 3-phase,50Hz, 2200V induction motor develops 400H.P at a power factor 0.8lag and effciency 90% .The power factor is to be raised to unity by connecting a bank of condensers in delta across supply mains. If each of the capacitance unit built up of 4 similar 550V condensers, calculate the required capacitance of each condenser and its KVA rating
2. i) Write short note an power factor correction.

   ii) Explain the practical procedure to determine the Best capacitor location.

3. i) List and explain any four disadvantages of low power factor.

   ii) Compare the merits and demerits of various methods of power factor improvement methods.

4. i. Compare and explain the role of shunt and series capacitors in P.F. correction.
   ii. A 400V, 50 cycles three phase line delivers 207KW at 0.8p.f. (lag). It is desired to bring the line p.f. to unity by installing shunt capacitors. Calculate the capacitance if they are
      a. star connected delta connected.
5. A 37.3KW induction motor has a p.f 0.9 and efficiency 0.9 at full load , power factor 0.6 and efficiency 0.7 at half load. At no load, the current is 25% of the full load current and p.f 0.1. capacitors are supplied to make the line power factor 0.8 at half load. With these capacitors in circuit , Find the line power factor at :
   i. Full load and
   ii. no load

6. Explain how reduction in line current and hence power losses are obtained with p.f. improvement.

7. A 3-phase,50Hz, 2200V induction motor develops 400H.P at a power factor 0.8lag and efficiency 90% .The power factor is to be raised to unity by connecting a bank of condensers in delta across supply mains. If each of the capacitance unit built up of 4 similar 550V condensers, calculate the required capacitance of each condenser and its KVA rating.

8. i. Explain power factors?
   ii. What is the justification for p.f. improve and what are the benefits?

9. Discuss the basic features of applicapability of compensation through shunt and series capacitors in radial distribution systems.
10. i. How is economical power factor arrived at for a given distribution system with different loads?
ii. Explain shunt capacitors compensation.

VOLTAGE DROP CALCULATIONS:

1. A 1-phase feeder circuit has total impedance (1+j3) ohms, receiving end voltage is 11kV and current is 50∟-300 A. Determine:
   a) Power factor of load
   b) load p.f. for which the drop is maximum
   c) load p.f. for which impedance angle is maximum and derive the formula used.

2. i) Explain single phase two wire uni grounded levels to calculate voltage drop and power loss.

   ii) Consider three phase two wire 240V secondary system with balanced loads at A,B and C .Determine the following

      a) Calculate total voltage drop

      b) Calculate real power per phase for each load.

      c) Reactive power per phase

      d) KVA O/P and load power factor of distribution transformer.

3. i) What are the disadvantages of constant voltage transmission?
   ii. Derive an expression for the power loss in a uniformly - loaded distributor fed at one end.

4. i. In terms of line parameters, derive the equation for load p.f. for which voltage drop is minimum.
   ii. An unbalanced 3 - phase delta connected load is connected to a balanced 3-phase, 3-wire source. The load impedances ZA = 60/_300Ω/ph, ZB = 80/_-450 Ω/ph and ZC = 50/_650Ω/ ph respectively. The line voltage of A phase is 12.6 kV. Use the A phase to phase voltage as reference and determine the line currents and total real and reactive powers.

5. i. Derive the expression for voltage drop and power loss in 3-phase balanced system.
   ii. An unbalanced 3-phase star connected load is connected and balanced 3-phase, 4-wire source, the load impedance Za, Zb and Ac are given by 70/_300 Ω/phase,

85/_400Ω/phase, 50/_350 Ω/phase respectively. The phase `a' line voltage has an effective value of 13.8kV. Use the line to neutral voltage of phase `a' as the reference and determine the following:

a. Line to neutral currents

b. Total power delivered to the load.

6. i. Consider a balanced three phase circuit shown in figure R + jX represent the total impedance of the line. The power factor of the load is cosθ = cos (θ V R–θr). Find the load power factor for which the voltage drop is maximum?

ii. Prove the power loss due to load currents in the conductors of the 2 phase, 3-wire lateral with multi - grounded neutral is approximately 1.64 times larger than the one in the equivalent three phase lateral. Also show that VDpu;2Φ= 2 x VDpu;3 Φ

7. Illustrate the computation of the voltage drop of a balanced three phase feeder, supplied at one end in terms of the load and the line parameters.

8. A single phase radial network is shown in fig. The resistance and reactance of each wire is 0.2 ohms and 0.3 ohms per meter respectively. The receiving end voltage is 220∠0V. Then calculate:

i. The voltage drop of each section of the line

ii. Total voltage drop of the line

iii. Total real power and real power and reactive power of the line.

9. i. Derive the expressions for volt drop and power loss in lines.

ii. Explain the manual method of solution for radial distribution systems.

10. i. Give detailed analysis of three phase balanced primary lines

ii. Consider a balanced 3 phase circuit having Vs and Vr are the sending and receiving end voltages respectively. R+jX is the total impedance of lines and I is the total current passing through the circuit. Find the load power factor for which the voltage drop is maximum?

11. i. Derive the expression for voltage drop and power loss for non-three phase system.

ii. Show that power loss due to load currents in the conductors of equivalent three phase lateral is approximately 1/1.64 times the two phase 3 wire lateral with multigrounded neutral.

12. Draw and explain typical four - wire multi - grounded common neutral distribution system.

MODULE-IV

1. i) Discuss the procedure for fault current calculation in following faults:

a) Double Line-Ground fault. b) Line - Line fault

ii) Explain the principle of operation of fuse

2. i) What are automatic line sectionalizers? Explain the purpose and advantages of using

them.

ii) What is the main objective of distribution system protection? Explain in detail.

3. A single phase 3 wire distribution line 120 V - 0 - 120 V, feeds a load of 10 KVA line to line and 3 KVA on each line to ground. The transformer is 7620V/240V 25KVA with 5% impedance. The line impedance is j0.05 ohm per wire. Calculate the fault current and fault MVA for:
   i. L-L fault 1km from the transformer
   ii. L-G fault 1km from the transformer.

4. i. What are the objectives of Distribution system protection.
   ii. What is the data required for selecting a protective device.

5. Explain different types of over current protective devices with neat diagrams?

6. Describe the principle of operation of:

   i. fuses
   ii. Circuit breakers
   iii. Line sectionalizer
   iv. circuit recloser.

7. What are the various factors considered while selecting a over current protective device. Explain the operation of circuit recloser and circuit breaker.

8. What are the common types of faults in a single phase 2-wire and 3-wire systems. Explain how fault current is computed with proper single line diagrams.

9. A single phase 3 wire distribution line 600 V - 0 - 160 V, feeds a load of 10 KVA line to line and 3 KVA on each line to ground. The transformer is 7620V/240V 25kva with 5% impedance. The line impedance is j0.15 ohm per wire. Calculate the fault current and fault MVA for: (Nov 10)

   i. L-L fault 1km from the transformer
   ii. L-G fault 1km from the transformer.

10 . i. Discuss the procedure for fault current calculation in following faults:

   a. 3-phase fault.
   b. Single Line-Ground fault

   ii. Explain about the operation of a circuit breaker.

MODULE-V

1. Define:

   a. Voltage Regulation
   b. Voltage drop
   c. Nominal voltage
   d. Rated voltage.

   ii) Explain about step type regulators (May 13)

2. i) How an AVB Can control voltage ? With the aid of suitable diagram its function.
   ii) Explain the methods to calculate the voltage dips due to voltage fluctuations in distribution systems.(Dec 12(R07))
3. Why is voltage control required in power system? Mention the different methods of voltage control employed in a power system. Explain one method of voltage control in detail giving a neat connection diagram.(Dec 12)

4. i. Explain the basic function of booster transformer and how it increases the line voltage.
   ii. Describe the operation of AVR/AVB with neat diagram.

5. i. Define:
   a. Voltage Regulation
   b. Voltage drop
   c. Nominal voltage
   d. Rated voltage
   ii. Explain about step type regulators.

6. i. Define:
   a. Voltage Regulation
   b. Voltage drop
   c. Nominal voltage
   d. Rated voltage
   e. Utilization voltage
   f. Maximum voltage
   g. Minimum voltage
   h. Voltage spread.
   ii. Describe different types of equipment for voltage control with neat diagrams.

7. Explain the line drop compensation on voltage control.

8. Explain control and rating of voltage regulators.

9. i. Briefly explain the line drop compensation and voltage control.
   ii. How an AVB can control voltage? With the aid of suitable diagram explain its Function.

10. i. Explain the use of induction regulator and voltage control.
    ii. Discuss the effect of series capacitors on voltage control.

11. i. Write short notes on any two methods of voltage control?
    iii. Voltage control and p.f. correction are necessary in power systems? Explain. What are the disadvantages of low voltage and low p.f. of the system?
    iv. What is series capacitor compensation in feeder lines? How does it improve the regulation of the lines. Discuss with suitable examples.

12. Explain different methods of voltage control in power system with neat diagrams.

13. i. What is series capacitors compensation in voltage in feeder lines? How does it improve the regulation of the lines?
    ii. Explain about the Induction type regulator.

15. Explain the operation of AVR/ AVB with neat diagram.
    i. Why do we need to control the voltage of a power system?
    ii. Explain in detail?

16. Write short notes on:
    a. Power factor correction b. Effect of AVB/AVR c. Line drop compensation

17. How an AVR can control voltage? With the aid of suitable diagram
    i. explain its function. Briefly explain about line drop compensation.
    ii.

18. What are the different methods for voltage control? Briefly explain them.

19. Write the ways to improve the distribution system overall voltage regulation?

20 . Why we need to control the voltage of power system?

i. Explain in detail. Compare and explain the role of shunt

ii. and series capacitor in voltage control.

21. With the help of a phasor diagram, show how a series capacitor boosts the voltage? What are the drawbacks of this method?

22. Discuss how voltage profile of a long feeder can be improved by connecting shunt capacitor banks at the end of the feeders.

23. What is a line drop compensator? How is it used along with tap changer of transformer for voltage control?

24. Discuss the different components of distribution system that require optimization.

25. How do the shunt capacitor and reactors control the voltage.

26. List the disadvantages of using a shunt capacitor for voltage control.

27. Explain calculation of power factor correction.

28. Define nominal voltage, rated voltage, service voltage, base voltage, voltage spread, voltage regulation.

29. What is the main in voltage control. What are the methods adopted.

30. Explain about transformer tap changing method in voltage control.

31. A 33kV/ 11kV 5MVA substation has two 3 MVA transformers with impedance 0.025+j0.06 p.u. There are four feeder lines of length 15 km each with uniformly distributed load of 50 kVA/km and a concentrated load of 0.5 MVA at feeder end. If the voltage is to be maintained at 11 kV at feeder end.

i. What is the voltage boost needed at substation?

ii. The transformer has taps of 2% of normal voltage. What is the tap setting to be used? Line impedance is 0.8 + j0.6 ohm/km and load p.f. may be taken as 0.8 lag.