4/4 B.Tech Regular Examination Sub: EPDS
Scheme of Evaluation CODE: 18EE705(A)
EEE Department

1.(a) List any two roles of computers in present distribution system planning.

(A) 1) The System Approach
2) The Database Concept.
3) New Automated tools.

b) Write the factors effecting distribution system planning?

A) 1) Load forecasting
2) Substation expansion
3) Substation site selection.

c) Define Load factor

A) It is the ratio of the average load over a designated period of time to the peak load occurring on that period".

∴ Load factor F_{LD} is the ratio of the average load to the peak load.

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

d) Define regulation of transformer.

A) Regulation is the percent increase in secondary terminal voltage when the load is thrown off

$$\% \text{ Regulation} = V_R \cos\theta + V_X \sin\theta + \frac{(V_X \cos\theta - V_R \sin\theta)^2}{200}$$

(or)

$$\% \text{ Regulation} = \frac{V_{no\,load} - V_{full\,load}}{V_{full\,load}} \times 100$$

e) write two factors to be considered for selecting Substation location.

A) 1) Locate the substation as much as feasible close to the load centre of its service area, so that the addition of load times distance from the substation is minimum.

2) Locate the substations such that proper voltage regulation can be obtainable without taking extensive measures.

3) The selected substation location should provide enough space for the future substation expansion.

f) what are different substation bus schemes?

1) single bus scheme
2) double bus - double breaker (or double main) scheme
3) main and transfer bus scheme.
4) double bus - single breaker scheme
5) Ring bus - scheme
6) breaker-and-a half scheme.

g) what is the purpose of fuse?

A) A fuse is a type of low resistance resistor that acts as a sacrificial device to provide overcurrent protection, of either the load or source circuit.

h) what is the function of sectionalizer?

A) A sectionalizer is a protective device, used in conjunction with a recloser, or breaker and reclosing relay, which isolates faulted sections of lines. The sectionalizer does not interrupt fault current.

List various factors effecting the selection of secondary voltage levels.

A) Type and size of the load to be served. Distance to which power is to be transmitted, Future load Growth., Equipment availability for fault isolation., Permissible voltage regulation cost of utilization and service system equipment.

j) Define power factor.

A) It is the ratio of working power measured in kilowatts (KW) to apparent power, measured in kilovolt Amperes (KVA)

K) List various ways to improve overall voltage regulation?

A) Use of generator voltage regulators, Application of voltage regulating equipment in the distribution substations, Application of capacitors in the distribution substation. Balancing of the loads on the primary feeders, Increasing of feeder conductor size. changing of feeder sections from single-phase to multi-phase. Transferring of loads to new feeders. Installing of new substations and primary feeders. Increase of primary voltage level. Application of voltage regulators on the primary feeders. Application of shunt capacitors on the primary feeders, Application of series capacitors on the primary feeders.

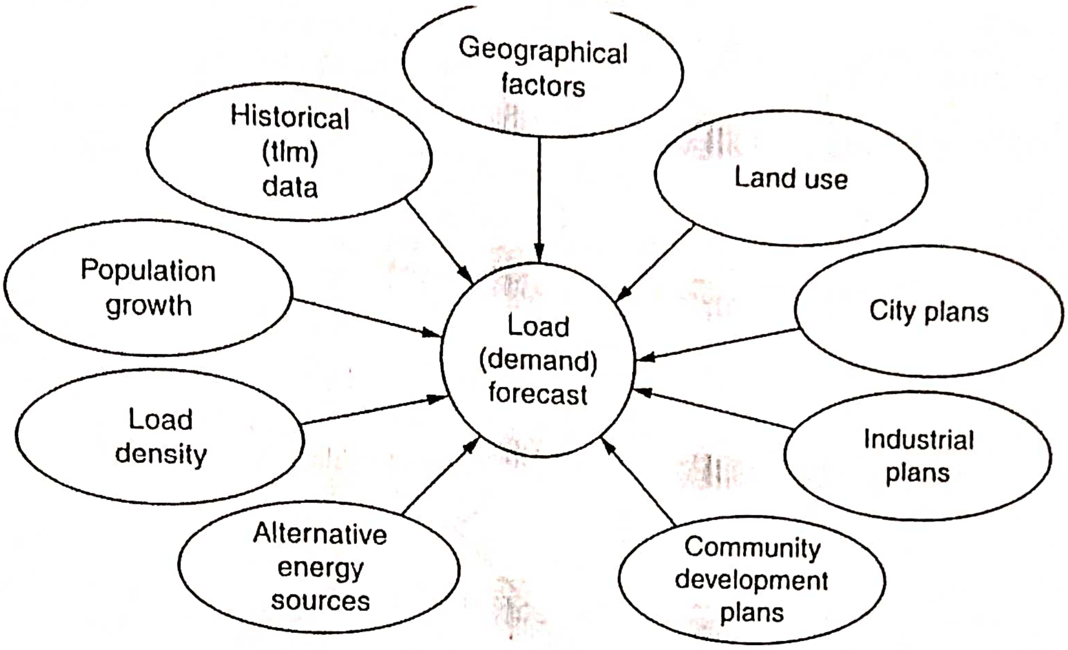
l) what is the use of line drop compensation?

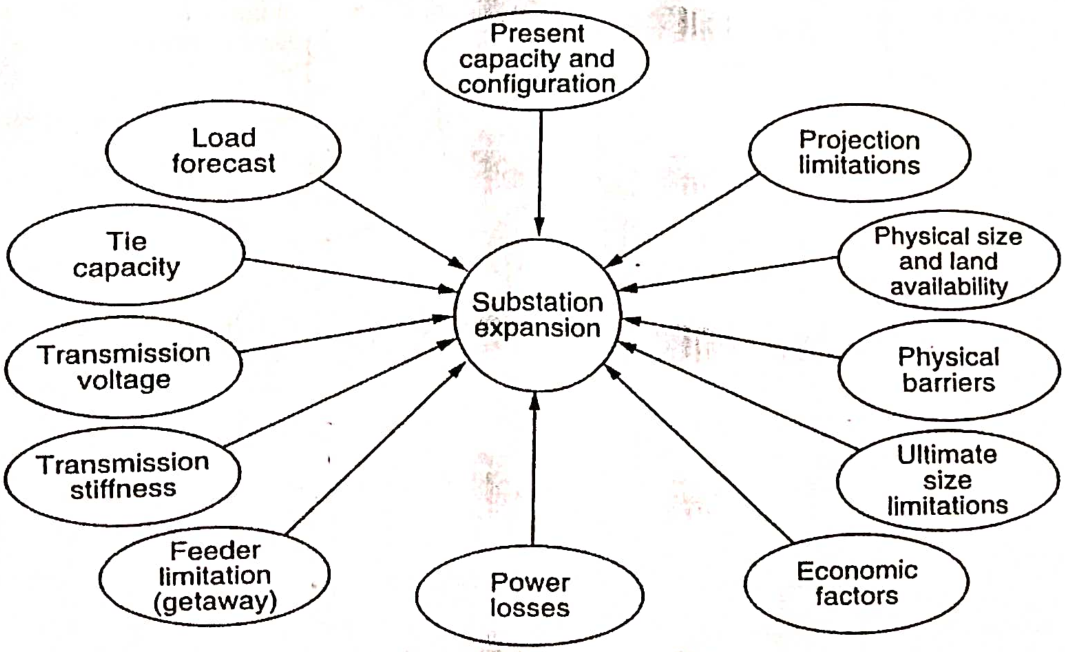
A) The automatic voltage maintaince is achieved by dial settings of the adjustable resistance and reactance element of a unit is called the line drop compensation.

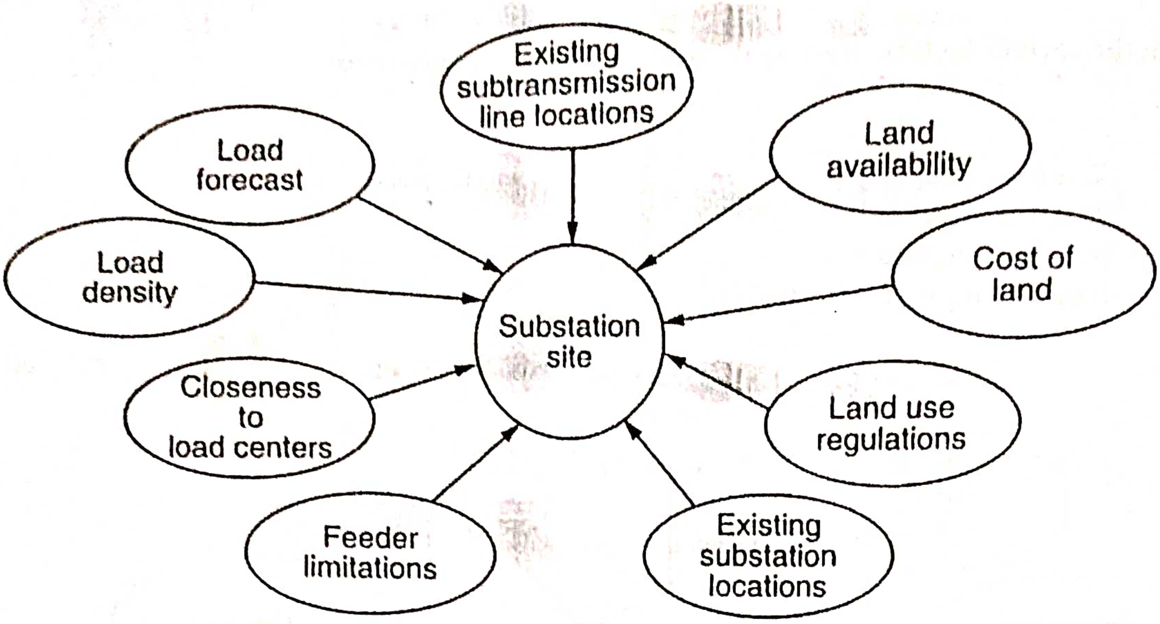
2.

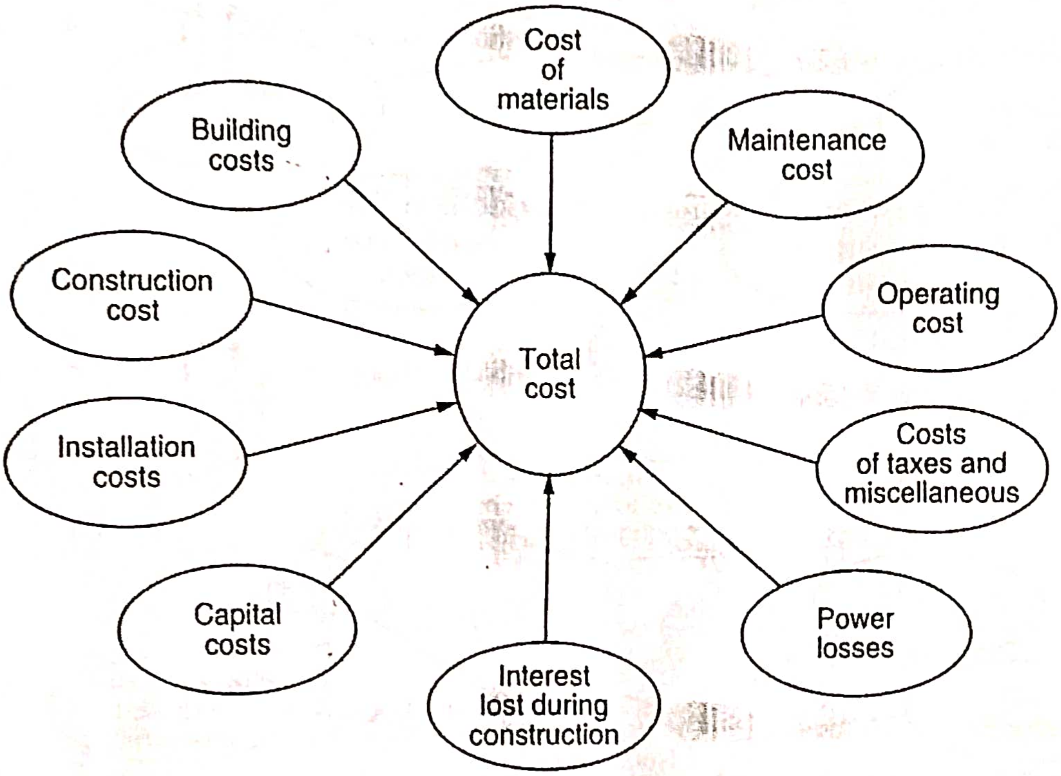
a) Explain the various factors effecting the distribution system planning.

i) Load forecasting
ii) Substation expansion
iii) Substation site selection
iv) Total cost for system expansion









2.

b) Derive relationship between load factor and loss factor for different cases.

In general, the loss factor cannot be determined from the load factor. However, the limiting va of the relationship can be found [3]. Assume that the primary feeder shown in Figure 2.8 is c nected to a variable load. Figure 2.9 shows an arbitrary and idealized load curve. However, it d not represent a daily load curve. Assume that the off-peak loss is $P_{LS,1}$ at some off-peak load P_1 that the peak loss is $P_{LS,2}$ at the peak load P_2. The load factor is

$$F_{LD} = \frac{P_{av}}{P_{max}} = \frac{P_{av}}{P_2}. \quad (2.$$

From Figure 2.9,

$$P_{av} = \frac{P_2 \times t + P_1 \times (T - t)}{T}. \quad (2.$$

Substituting Equation 2.27 into Equation 2.26,

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

or

$$F_{LD} = \frac{t}{T} + \frac{P_1}{P_2} \times \frac{T - t}{T}. \quad (2.$$

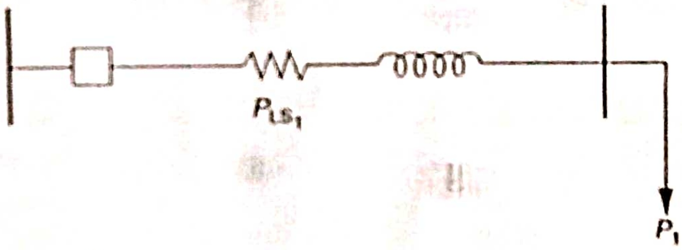


FIGURE 2.8 A feeder with a variable load.

$$F_{LS} = \frac{t}{T} + \left(\frac{P_1}{P_2}\right)^2 \times \frac{T - t}{T}. \quad (2.35)$$

By using Equations 2.28 and 2.35, 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 $P_1 = 0$. Therefore, from Equations 2.28 and 2.35,

$$F_{LD} = F_{LS} = \frac{t}{T}. \quad (2.36)$$

That is, the load factor is equal to the loss factor and they are equal to the t/T constant.

Case 2: *Very short lasting peak.* Here,

$$t \rightarrow 0$$

hence, in Equations 2.28 and 2.35,

$$\frac{T-t}{T} \rightarrow 1.0;$$

therefore,

$$F_{LS} \rightarrow (F_{LD})^2 \quad (2.37)$$

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

Case 3: *Load is steady.* Here,

$$t \rightarrow T.$$

That is, the difference between the peak load and the off-peak load is negligible. For example, if the customer's load is a petrochemical plant, this would be the case. Thus, from Equations 2.28 and 2.35,

$$F_{LS} \rightarrow F_{LD}. \quad (2.38)$$

However, Buller and Woodrow [5] developed an approximate formula to relate the loss factor to the load factor as

$$F_{LS} = 0.3 F_{LD} + 0.7 F_{LD}^2 \quad (2.40a)$$

where F_{LS} is the loss factor (pu) and F_{LD} is the load factor (pu).

Equation 2.40a gives a reaşonably close result. Figure 2.10 gives three different curves of loss factor as a function of load factor. Relatively recently, the formula given before has been modified for rural areas and expresssed as

$$F_{LS} = 0.16 F_{LD} + 0.84 F_{LD}^2. \quad (2.40b)$$

3.

a) Explain the role of a computer in distribution system planning process.

As suggested in Figure 1.10, the database plays a central role in the operation of such a system. It is in this area that technology has made some significant strides in the past 5 yr so that not only

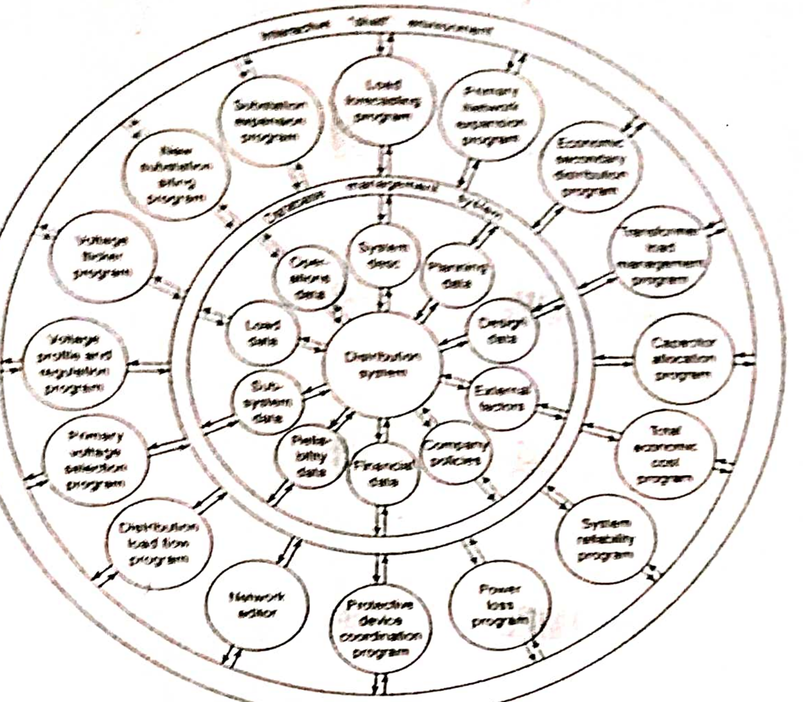


FIGURE 1.10 A schematic view of a distribution planning system.

it is possible to store vast quantities of data economically, but it is also possible to retrieve desired data with access times in the order of seconds. The database management system provides the interface between the process which requires access to the data and the data themselves. The particular organization which is likely to emerge as the dominant one in the near future is based on the idea of a relation. Operations on the database are performed by the *database management system* (DBMS).

3.

b) List different types of tariff and explain about diversified demand method.

Types of Electricity Tariff

- Flat Demand Rate tariff.
- Straight-line Meter rate tariff.
- Block meter Rate tariff.
- Two-part tariff.
- Power factor tariff.
- Peak load tariff.
- Three-part tariff

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.

For example, "if the test locations can, in the aggregate, be considered statistically representative of the residential customers as a whole, a load curve for the entire residential class of customers can be prepared. If this same technique is used for other classes of customers, similar load curves can be prepared" [3]. As shown in Figure 2.4, if these load curves are aggregated, the system load curve can be developed. The interclass coincidence relationships can be observed by comparing the curves.

4.

a) Give the expressions for regulation and efficiency of the transformer.

To calculate the transformer regulation for a kilovoltampere load of power factor $\cos\theta$, at rated voltage, any one of the following formulas can be used:

$$\%\,\text{regulation} = \frac{S_L}{S_T}\left[\%\,IR\cos\theta + \%\,IX\sin\theta + \frac{(\%\,IX\cos\theta - \%\,IR\sin\theta)^2}{200}\right] \tag{3.3}$$

or

$$\%\,\text{regulation} = \frac{I_{op}}{I_{ra}}\left[\%\,R\cos\theta + \%\,X\sin\theta + \frac{(\%\,X\cos\theta - \%\,R\sin\theta)^2}{200}\right] \tag{3.4}$$

or

$$\%\,\text{regulation} = V_R\cos\theta + V_X\sin\theta + \frac{(V_X\cos\theta - V_R\sin\theta)^2}{200} \tag{3.5}$$

where θ is the power factor angle of the load, V_R is the percent resistance voltage = copper loss/output × 100, S_L is the apparent load power, S_T is the rated apparent power of the transformer, I_{op} is the operating current, I_{ra} is the rated current, V_X is the percent leakage reactance voltage $(V_Z^2 - V_R^2)^{1/2}$, and V_Z is the percent impedance voltage.

Note that the percent regulation at unity power factor is

$$\%\,\text{regulation} = \frac{\text{copper loss}}{\text{output}} \times 100 + \frac{(\%\,\text{reactance})^2}{200}. \tag{3.6}$$

The efficiency of a transformer can be calculated from

$$\%\,\text{efficiency} = \frac{\text{output in watts}}{\text{output in watts} + \text{total losses in watts}} \times 100. \tag{3.7}$$

The total losses include the losses in the electric circuit, magnetic circuit, and dielectric circuit. Stigant and Franklin [3] state that a transformer has its highest efficiency at a load at which the iron loss and copper loss are equal. Therefore, the load at which the efficiency is highest can be found from

$$\%\,\text{load} = \left(\frac{\text{iron loss}}{\text{copper loss}}\right)^{1/2} \times 100. \tag{3.8}$$

4.

b) Compare different switching schemes.

Summary of Comparison of Switching Schemes

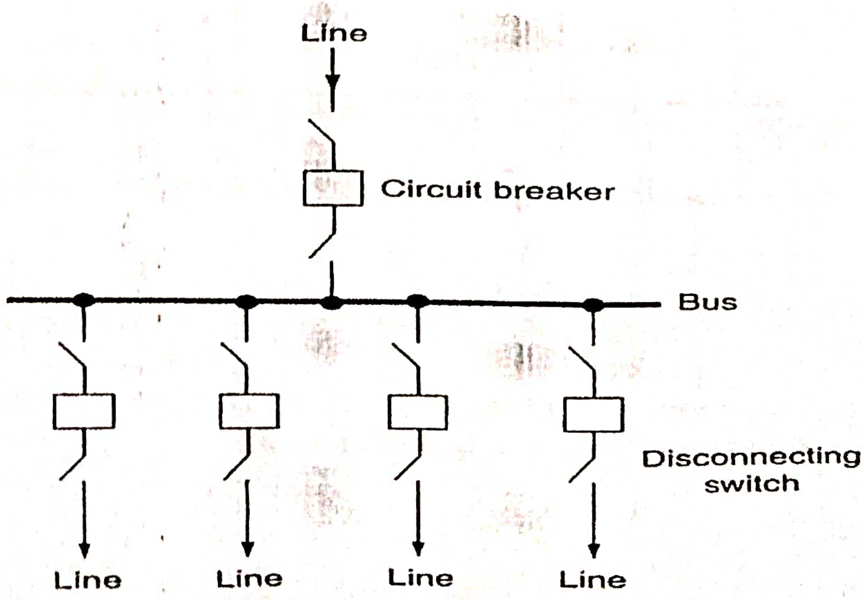
Switching Scheme	Advantages	Disadvantages
1. Single bus	1. Lowest cost.	1. Failure of bus or any circuit breaker results in shutdown of entire substation. 2. Difficult to do any maintenance. 3. Bus cannot be extended without completely de-energizing the substation. 4. Can be used only where loads can be interrupted or have other supply arrangements.
2. Double bus-double breaker	1. Each circuit has two dedicated breakers. 2. Has flexibility in permitting feeder circuits to be connected to either bus. 3. Any breaker can be taken out of service for maintenance. 4. High reliability.	1. Most expensive. 2. Would lose half the circuits for breaker failure if circuits are not connected to both buses.

3. Main-and-transfer	1. Low initial and ultimate cost. 2. Any breaker can be taken out of service for maintenance. 3. Potential devices may be used on the main bus for relaying.	1. Requires one extra breaker for the bus tie. 2. Switching is somewhat complicated when maintaining a breaker. 3. Failure of bus or any circuit breaker results in shutdown of entire substation.
4. Double bus-single breaker	1. Permits some flexibility with two operating buses. 2. Either main bus may be isolated for maintenance. 3. Circuit can be transferred readily from one bus to the other by use of bus-tie breaker and bus selector disconnect switches.	1. One extra breaker is required for the bus tie. 2. Four switches are required per circuit. 3. Bus protection scheme may cause loss of substation when it operates if all circuits are connected to that bus. 4. High exposure to bus faults. 5. Line breaker failure takes all circuits connected to that bus out of service. 6. Bus-tie breaker failure takes entire substation out of service.
5. Ring bus	1. Low initial and ultimate cost. 2. Flexible operation for breaker maintenance. 3. Any breaker can be removed for maintenance without interrupting load. 4. Requires only one breaker per circuit. 5. Does not use main bus. 6. Each circuit is fed by two breakers. 7. All switching is done with breakers.	1. If a fault occurs during a breaker maintenance period, the ring can be separated into two sections. 2. Automatic reclosing and protective relaying circuitry rather complex. 3. If a single set of relays is used, the circuit must be taken out of service to maintain the relays (common on all schemes). 4. Requires potential devices on all circuits since there is no definite potential reference point. These devices may be required in all cases for synchronizing, live line, or voltage indication. 5. Breaker failure during a fault on one of the circuits causes loss of one additional circuit owing to operation of breaker-failure relaying.
6. Breaker-and-a-half	1. Most flexible operation. 2. High reliability. 3. Breaker failure of bus side breakers removes only one circuit from service. 4. All switching is done by breakers. 5. Simple operation; no disconnect switching required for normal operation. 6. Either main bus can be taken out of service at any time for maintenance. 7. Bus failure does not remove any feeder circuits from service.	1. 1½ breakers per circuit. 2. Relaying and automatic reclosing are somewhat involved since the middle breaker must be responsive to either of its associated circuits.

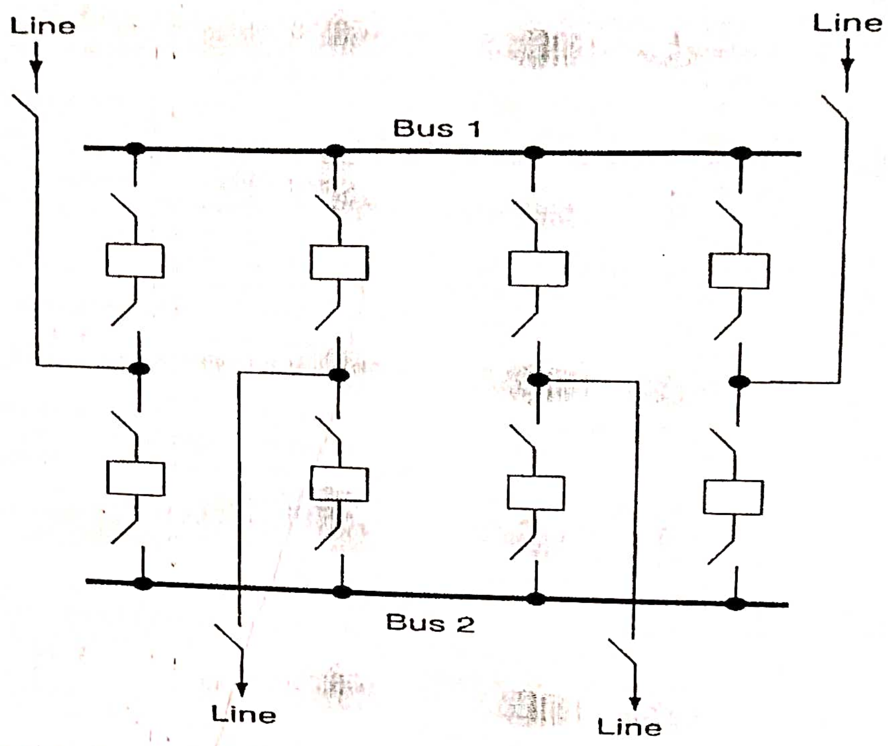
5.

a) Illustrate substation bus schemes with neat diagrams.

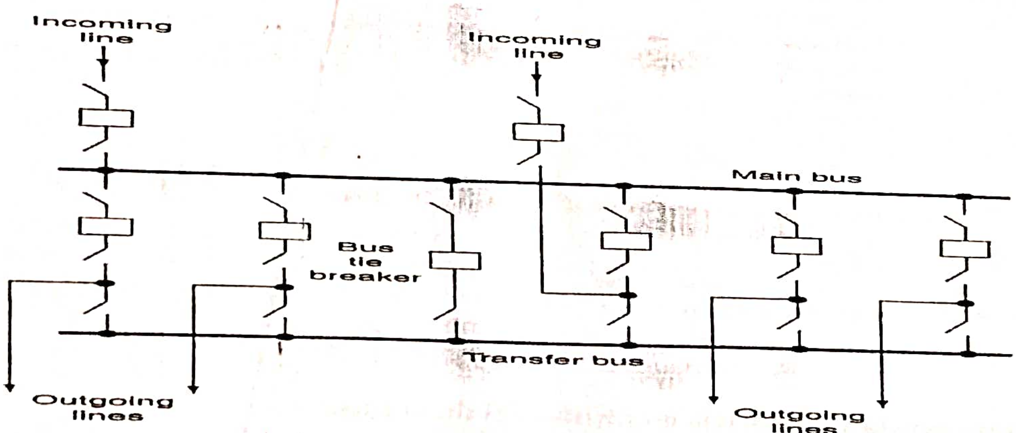
The most commonly used substation bus schemes include: (*i*) single bus scheme; (*ii*) double bus-double breaker (or double main) scheme; (*iii*) main-and-transfer bus scheme; (*iv*) double bus-single breaker scheme; (*v*) ring bus scheme; and (*vi*) breaker-and-a-half scheme.



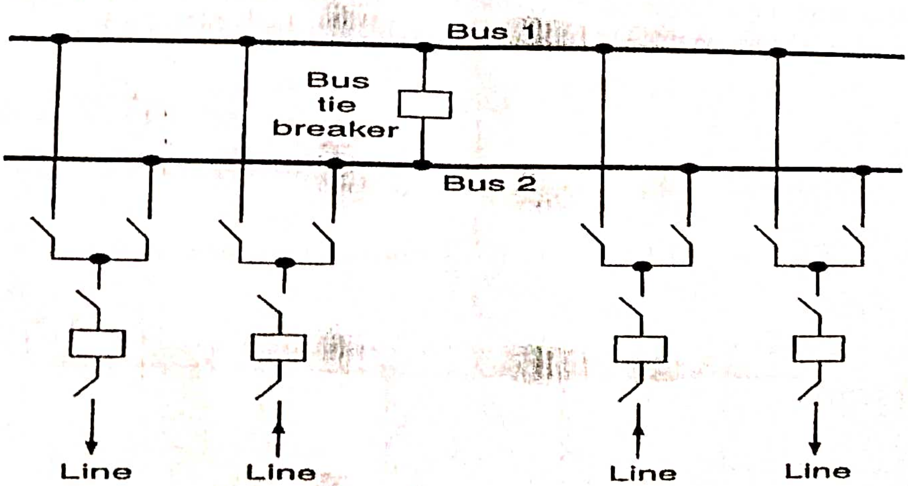
A typical single-bus scheme.



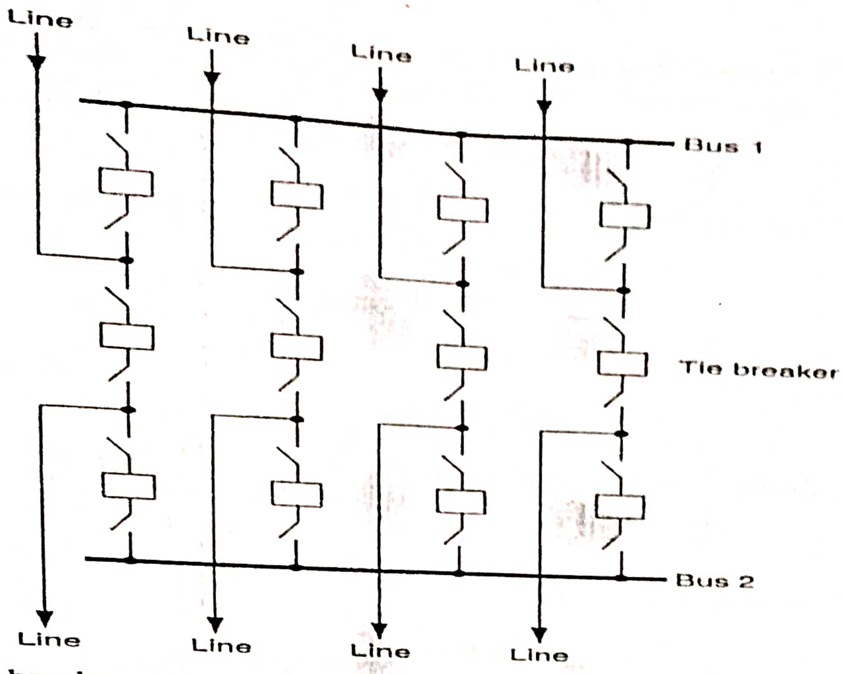
A typical double bus-double breaker scheme.



A typical main-and-transfer bus scheme.



A typical double bus-single breaker scheme.



A typical breaker-and-a-half scheme.

5.

b) Explain different factors to be considered for substation location.

The location of a substation is dictated by the voltage levels, voltage regulation considerations, subtransmission costs, substation costs, and the costs of primary feeders, mains, and distribution transformers. It is also restricted by other factors, as explained in Chapter 1, which may not be technical in nature.

However, to select an ideal location for a substation, the following rules should be observed [2]:

1. Locate the substation as much as feasible close to the load center of its service area, so that the addition of load times distance from the substation is minimum.
2. Locate the substation such that proper voltage regulation can be obtainable without taking extensive measures.
3. Select the substation location such that it provides proper access for incoming subtransmission lines and outgoing primary feeders and also allows for future growth.
4. The selected substation location should provide enough space for the future substation expansion.
5. The selected substation location should not be opposed by land use regulations, local ordinances, and neighbors.
6. The selected substation location should help to minimize the number of customers affected by any service discontinuity.
7. Other considerations, such as adaptability, emergency, etc.

6.

a) Compare four and six feeder patterns in distribution substation.

For a square-shaped distribution substation area served by four primary feeders, that is, $n = 4$, the area served by one of the four feeders is

$$A_4 = l_4^2 \text{ mi}^2. \tag{4.22}$$

The total area served by all four feeders is

$$\begin{aligned} TA_4 &= 4A_4 \\ &= 4l_4^2 \text{ mi}^2. \end{aligned} \tag{4.23}$$

The kilovoltampere load served by one of the feeders is

$$S_4 = D \times l_4^2 \text{ kVA}. \tag{4.24}$$

Thus, the total kilovoltampere load served by all four feeders is

$$TS_4 = 4D \times l_4^2 \text{ kVA}. \tag{4.25}$$

The percent voltage drop in the main feeder is

$$\%VD_{4,\text{main}} = \frac{2}{3} \times K \times D \times l_4^3. \tag{4.26}$$

The load current in the main feeder at the feed point a is

$$I_4 = \frac{S_4}{\sqrt{3} \times V_{L-L}} \tag{4.27}$$

On the other hand, for a hexagonally shaped distribution substation area served by six primary feeders, that is, $n = 6$, the area served by one of the six feeders is

$$A_6 = \frac{1}{\sqrt{3}} \times l_6^2 \text{ mi}^2. \tag{4.29}$$

The total area served by all six feeders is

$$TA_6 = \frac{6}{\sqrt{3}} \times l_6^2 \text{ mi}^2. \tag{4.30}$$

The kilovoltampere load served by one of the feeders is

$$S_6 = \frac{1}{\sqrt{3}} \times D \times l_6^2 \text{ kVA}. \tag{4.31}$$

Therefore, the total kilovoltampere load served by all six feeders is

$$TS_6 = \frac{6}{\sqrt{3}} \times D \times l_6^2 \text{ kVA}. \tag{4.32}$$

The percent voltage drop in the main feeder is

$$\%VD_{6,\text{main}} = \frac{2}{3\sqrt{3}} \times K \times D \times l_6^3. \tag{4.33}$$

The load current in the main feeder at the feed point a is

$$I_6 = \frac{S_6}{\sqrt{3} \times V_{L-L}} \tag{4.34}$$

For Thermally Limited Feeder Circuits. For a given conductor size and neglecting voltage drop,

$$I_4 = I_6. \tag{4.36}$$

Substituting Equations 4.28 and 4.35 into Equation 4.36,

$$\frac{D \times I_4^2}{\sqrt{3} \times V_{L-L}} = \frac{D \times I_6^2}{3 \times V_{L-L}} \tag{4.37}$$

from Equation 4.37,

$$\left(\frac{I_6}{I_4}\right)^2 = \sqrt{3}. \tag{4.38}$$

Also, by dividing Equation 4.30 by Equation 4.23,

$$\frac{TA_6}{TA_4} = \frac{6/\sqrt{3}I_6^2}{4I_4^2}$$
$$= \frac{\sqrt{3}}{2}\left(\frac{I_6}{I_4}\right)^2. \tag{4.39}$$

Substituting Equation 4.38 into Equation 4.39,

$$\frac{TA_6}{TA_4} = \frac{3}{2} \tag{4.40}$$

or

$$TA_6 = 1.50\ TA_4. \tag{4.41}$$

Therefore, the six feeders can carry 1.50 times as much load as the four feeders if they are thermally loaded.

6.

b) Discuss any two over current protective devices.

Fuse:-

A *fuse* is an overcurrent device with a circuit-opening fusible member (i.e., fuse link) directly heated and destroyed by the passage of overcurrent through it in the event of an overload or short-circuit condition. Therefore, the purpose of a fuse is to clear a permanent fault by removing the defective segment of a line or equipment from the system. A fuse is designed to blow within a specified time for a given value of fault current. The time-current characteristics (TCC) of a fuse are represented by two curves: (*i*) the minimum melt curve and (*ii*) the total clearing curve. The minimum melt curve of a fuse is a plot of the minimum time versus the current required to melt the fuse link. The total clearing curve is a plot of the maximum time versus the current required to melt the fuse link and extinguish the arc.

Fuses designed to be used above 600 V are categorized as *distribution cutouts* (also known as *fuse cutouts*) or *power fuses*. Figure 10.1 gives detailed classification for high-voltage fuses.

The liquid-filled (oil-filled) cutouts are mainly used in underground installations and contain the fusible elements in an oil-filled and sealed tank. The expulsion-type distribution cutouts are by far the most common type of protective device applied to overhead primary distribution systems. In these cutouts, the melting of the fuse link causes heating of the fiber fuse tube which, in turn, produces deionizing gases to extinguish the arc. Expulsion-type cutouts are classified according to their external appearance and operation methods as: (*i*) enclosed-fuse cutouts, (*ii*) open-fuse cutouts, and (*iii*) open-link-fuse cutouts.

The ratings of the distribution fuse cutouts are based on continuous currentcarrying capacity, nominal and maximum design voltages, and interrupting capacity. In general, the fuse cutouts are selected based on the following data:

1. The type of system for which they are selected, for example, overhead or underground, delta or grounded-wye system.
2. The system voltage for which they are selected.
3. The maximum available fault current at the point of application.
4. The *X/R* ratio at the point of application.
5. Other factors, for example, safety, load growth, and changing duty requirements.

Automatic circuit breakers:-

Circuit breakers are automatic interrupting devices which are capable of breaking and reclosing a circuit under all conditions, that is, faulted or normal operating conditions. The primary task of a circuit breaker is to extinguish the arc that develops due to separation of its contacts in an arc-extinguishing medium, for example, in air, as is the case for air circuit breakers, in oil, as is the case for oil circuit breakers (OCBs), in SF_6 (sulfur hexafluoride), or in vacuum. In some types, the arc is extinguished by a blast of compressed air, as is the case for magnetic blow-out circuit breakers. The circuit breakers used at distribution system voltages are of the air circuit breaker or oil circuit breaker type. For low-voltage applications molded-case circuit breakers are available.

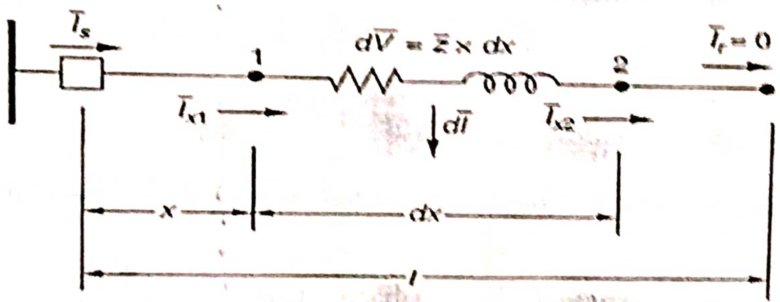
Oil circuit breakers controlled by protective relays are usually installed at the source substations to provide protection against faults on distribution feeders. Figures 10.13 and 10.14 show typical oil and vacuum circuit breakers, respectively.

Currently, circuit breakers are rated on the basis of RMS symmetrical current. Usually, circuit breakers used in the distribution systems have minimum operating times of five cycles. In general, relay-controlled circuit breakers are preferred to reclosers due to their greater flexibility, accuracy, design margins, and esthetics. However, they are much more expensive than reclosers.

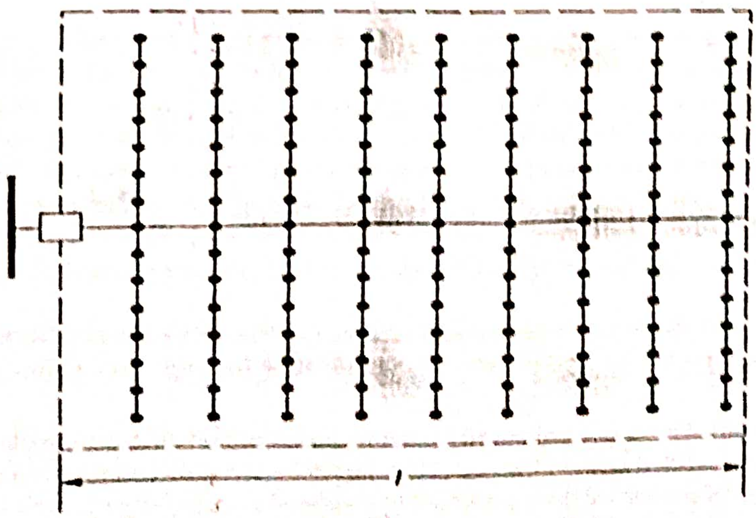
The relay, or fault-sensing device, that opens the circuit breaker is generally an overcurrent induction type with inverse, very inverse, or extremely inverse TCC, for example, the overcurrent (CO) relays by Westinghouse or the inverse overcurrent (IAC) relays by General Electric. Figure 10.15 shows a typical IAC single-phase overcurrent relay unit. Figure 10.16 shows typical TCC of overcurrent relays.

7.

a) Summarize radial type feeder with uniformly distributed load.



A radial feeder.



A uniformly distributed main feeder.

As the total load is uniformly distributed from $x = 0$ to $x = l$,

$$\frac{dI}{dx} = k, \tag{5.8}$$

which is a constant.

Therefore $\bar{I}_x$, that is, the current in the main of some x distance away from the circuit breaker, can be found as a function of the sending-end current $\bar{I}_s$ and the distance x. This can be accomplished either by inspection or by writing a current equation containing the integration of the $d\bar{I}$. Therefore, for the dx distance,

$$\bar{I}_{x1} = \bar{I}_{x2} + d\bar{I} \tag{5.9}$$

or

$$\bar{I}_{x2} = \bar{I}_{x1} - d\bar{I}. \tag{5.10}$$

From Equation 5.10,

$$\begin{aligned} \bar{I}_{x2} &= \bar{I}_{x1} - d\bar{I}\,\frac{dx}{dx} \\ &= \bar{I}_{x1} - \frac{d\bar{I}}{dx}\,dx \end{aligned} \tag{5.11}$$

$$\bar{I}_{x2} = \bar{I}_{x1} - \bar{k}dx \tag{5.12}$$

where

$$\bar{k} = \frac{d\bar{I}}{dx}$$

or, approximately,

$$\bar{I}_{x2} = \bar{I}_{x1} - kd\bar{l} \tag{5.13}$$

and

$$\bar{I}_{x1} = \bar{I}_{x2} + kd\bar{l} \tag{5.14}$$

Therefore, for the total feeder,

$$I_r = I_s - k \times l \tag{5.15}$$

and

$$I_s = I_r + k \times l. \tag{5.16}$$

When $x = l$, from Equation 5.15,

$$I_r = I_s - k \times l = 0$$

hence

$$k = \frac{I_s}{l} \tag{5.17}$$

and since $x = l$,

$$I_r = I_s - k \times x. \tag{5.18}$$

Therefore, substituting Equation 5.17 into Equation 5.18,

$$I_r = I_s\left(1 - \frac{x}{l}\right). \tag{5.19}$$

For a given x distance,

$$I_x = I_r$$

thus Equation 5.19 can be written as:

$$I_x = I_s\left(1 - \frac{x}{l}\right). \tag{5.20}$$

Therefore, the differential series voltage drop can be found as:

$$d\bar{V} = I_x \times z dx \tag{5.21}$$

or substituting Equation 5.20 into Equation 5.21,

$$d\bar{V} = I_s \times z\left(1 - \frac{x}{l}\right)dx. \tag{5.22}$$

Also, the differential power loss can be found as:

$$dP_{LS} = I_x^2 \times r dx \tag{5.23}$$

or substituting Equation 5.20 into Equation 5.23,

$$dP_{LS} = \left[I_s\left(1 - \frac{x}{l}\right)\right]^2 r dx \tag{5.24}$$

7.

b) Discuss the coordination procedure between fuse and fuse.

The selection of a fuse rating to provide adequate protection to the circuit beyond its location is based on several factors. First of all, the selected fuse must be able to carry the expanded load current, and, at the same time, it must be sufficiently selective with other protective apparatus in series. Furthermore, it must have an adequate reach; that is, it must have the capability to clear a minimum fault current within its zone in a predetermined time duration.

A fuse is designed to blow within a specified time for a given value of fault current. The TCCs of a fuse are represented by two curves; the minimum melting curve and the total clearing curve, as shown in Figure 10.19. The minimum melting curve of a fuse represents the minimum time, and therefore it is the plot* of the minimum time versus current required to melt the fuse. The tota

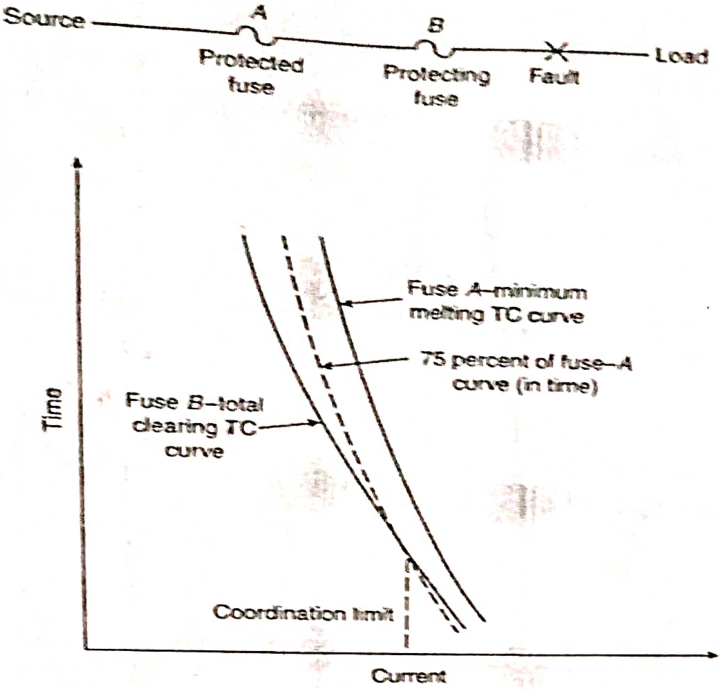


FIGURE 10.19 Coordinating fuses in series using time-current characteristic curves of the fuses connected in series.

clearing (time) curve represents the total time, and therefore it is the plot of the maximum time versus current required to melt the fuse and extinguish the arc, plus manufacturing tolerance. It is also a standard procedure to develop "damaging" time curves from the minimum melting time curves by using a safety factor of 25%. Therefore the damaging curve (due to the partial melting) is developed by taking 75 percent of the minimum melting time of a specific-size fuse at various current values. The time unit used in these curves is seconds.

Fuse-to-fuse coordination, that is, the coordination between fuses connected in series, can be achieved by two methods:

1. Using the TCC curves of the fuses.
2. Using the coordination tables prepared by the fuse manufacturers.

Furthermore, some utilities employ certain rules of thumb as a third type of fuse-to-fuse coordination method.

In the first method, the coordination of the two fuses connected in series, as shown in Figure 10.19, is achieved by comparing the total clearing time-current curve of the "*protecting fuse*," that is, fuse *B*, with the damaging time curve of the "*protected fuse*," that is, fuse *A*. Here, it is necessary that the total clearing time of the protecting fuse not exceed 75% of the minimum melting time of the protected fuse. The 25% margin has been selected to take into account some of the operating variables, such as preloading, ambient temperature, and the partial melting of a fuse link due to a fault current of short duration. If there is no intersection between the aforementioned curves, a complete coordination in terms of selectivity is achieved. However, if there is an intersection of the two curves, the associated current value at the point of the intersection gives the coordination limit for the partial coordination achieved.

8.

a) Explain the effect of shunt and series capacitor on power factor and voltage profile improvement.

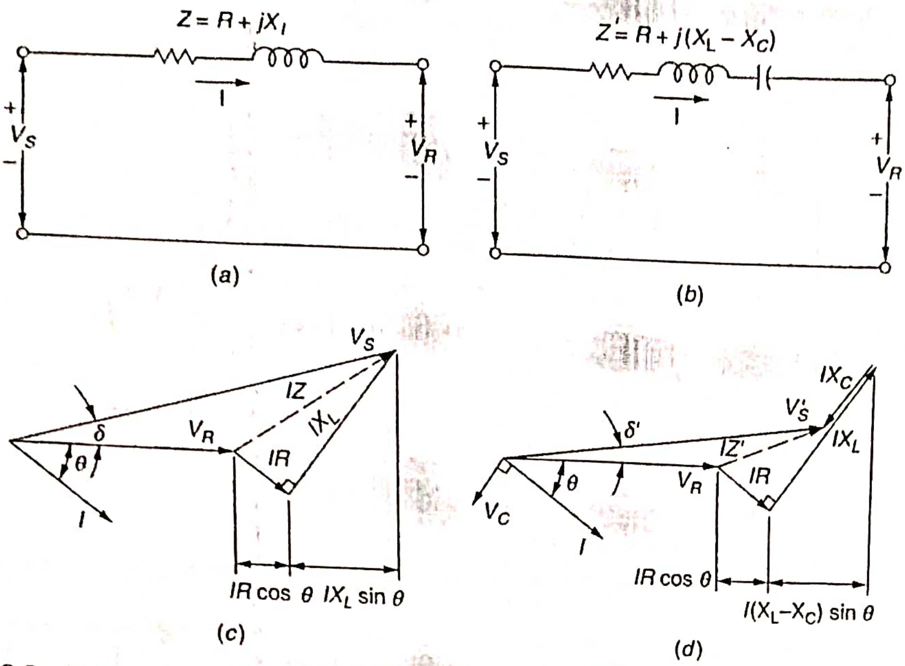


FIGURE 8.3 Voltage-phasor diagrams for a feeder circuit of lagging power factor: (*a*) and (*c*) without and (*b*) and (*d*) with series capacitors.

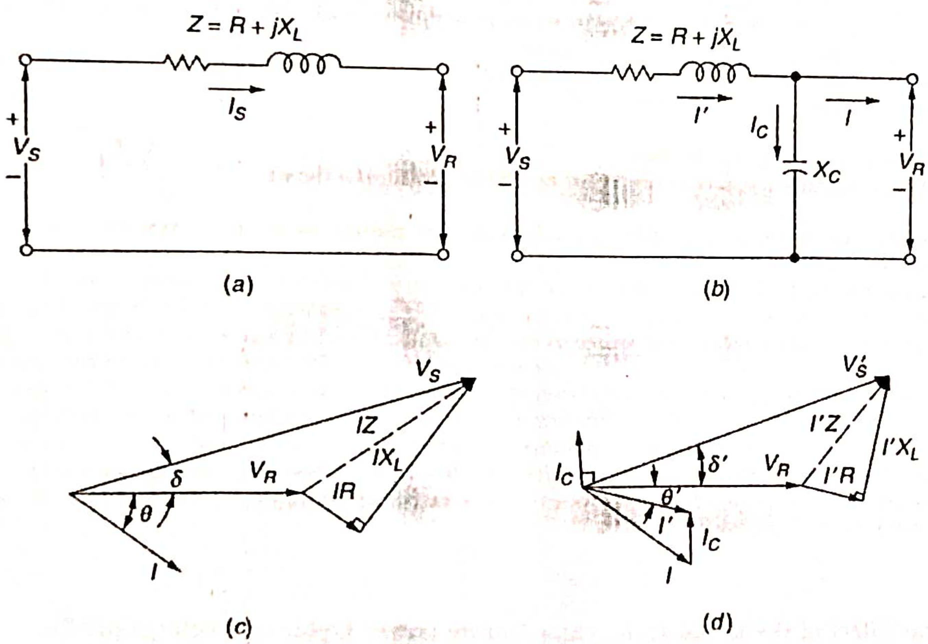


FIGURE 8.6 Voltage-phasor diagrams for a feeder circuit of lagging power factor: (*a*) and (*c*) without and (*b*) and (*d*) with shunt capacitors.

$$\cos \theta_1 = \frac{P}{S_1}$$

$$\cos \theta_1 = \frac{P}{(P^2 + Q_1^2)^{1/2}}.$$

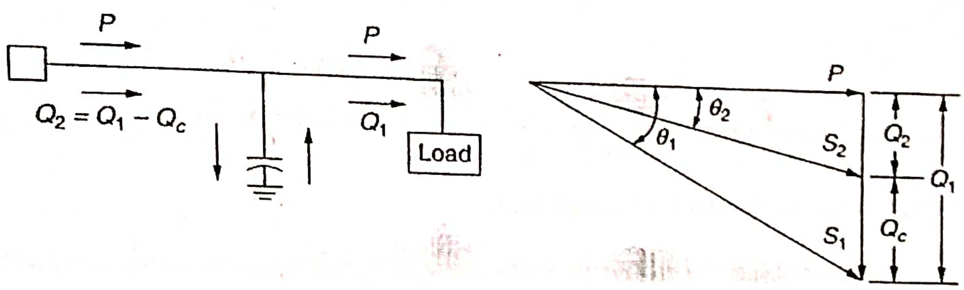
When a shunt capacitor of Q_c kVA is installed at the load, the power factor can be improved from $\cos\theta_1$ to $\cos\theta_2$, where

$$\cos\theta_2 = \frac{P}{S_2}$$

$$= \frac{P}{(P^2 - Q_1^2)^{1/2}}.$$

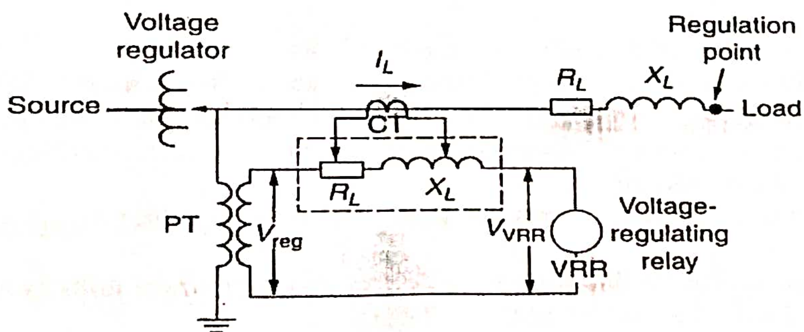
or

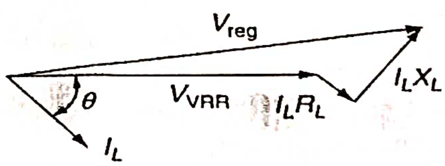
$$\cos\theta_2 = \frac{P}{\left[P^2 + (Q_1 - Q_c)^2\right]^{1/2}}. \tag{8.9}$$



8.

b) Explain the method of line drop compensation.





If no load is tapped off the feeder between the regulator and the regulation point, the R dial setting of the line-drop compensator can be determined from

$$R_{set} = \frac{CT_P}{PT_N} \times R_{eff}\ \Omega, \tag{9.2}$$

where CT_P is the rating of the current transformer's primary, PT_N is the potential transformer's turns ratio = V_{pri}/V_{sec}, and R_{eff} is the effective resistance of a feeder conductor from regulator station to regulation point (Ω).

$$R_{eff} = r_a \times \frac{l - s_1}{2}\ \Omega, \tag{9.3}$$

where r_a is the resistance of a feeder conductor from regulator station to regulation point (Ω/mi per conductor), s_1 is the length of three-phase feeder between regulator station and substation (mi) (multiply length by 2 if feeder is in single-phase), and l is the primary feeder length (mi).

Also, the X dial setting of the LDC can be determined from

$$X_{set} = \frac{CT_P}{PT_N} \times X_{eff}\ \Omega, \tag{9.4}$$

where X_{eff} is the effective reactance of a feeder conductor from regulator to regulation point, Ω

$$X_{eff} = x_L \times \frac{l - s_1}{2}\ \Omega \tag{9.5}$$

and

$$x_L = x_a + x_d\ \Omega/\text{mi} \tag{9.6}$$

9.

a) Determine the step by step procedure to determine the best capacitor location.

1. Collect the following circuit and load information:

   (*a*) Any two of the following for each load: kilovoltamperes, kilovars, kilowatts, and load power factor,
   (*b*) Desired corrected power of circuit,
   (*c*) Feeder circuit voltage,
   (*d*) A feeder circuit map which shows locations of loads and presently existing capacitor banks.

2. Determine the kilowatt load of the feeder and the power factor.
3. From Table 8.1, determine the kilovars per kilowatts of load (i.e., the correction factor) necessary to correct the feeder circuit power factor from the original to the desired power factor. To determine the kilovars of capacitors required, multiply this correction factor by the total kilowatts of the feeder circuit.
4. Determine the individual kilovoltamperes and power factor for each load or group of loads.
5. To determine the kilovars on the line, multiply individual load or groups of loads by their respective reactive factors that can be found from Table 8.1.
6. Develop a nomograph to determine the line loss in watts per thousand feet due to the inductive loads tabulated in steps 4 and 5. Multiply these line losses by their respective line lengths in thousands of feet. Repeat this process for all loads and line sections and add them to find the total inductive line loss.
7. In the case of having presently existing capacitors on the feeder, perform the same calculations as in step 6, but this time subtract the capacitive line loss from the total inductive line loss. Use the capacitor kilovars determined in step 3 and the nomograph developed for step 6 and find the line loss in each line section due to capacitors.
8. To find the distance to capacitor location, divide total inductive line loss by capacitive line loss per thousand feet. If this quotient is greater than the line section length

   (*a*) Divide the remaining inductive line loss by capacitive line loss in the next line section to find the location;
   (*b*) If this quotient is still greater than the line section length, repeat step 8a.

9. Prepare a voltage profile by hand calculations or by using a computer program for voltage profile and load analysis to determine the circuit voltages. If the profile shows that the voltages are inside the recommended limits, then the capacitors are installed at the location of minimum loss. If not, then use engineering judgment to locate them for the most effective voltage control application.

9.

b) what are the various ways to improve the overall voltage regulation?

To keep distribution circuit voltages within permissible limits, means must be provided to control the voltage, that is, to increase the circuit voltage when it is too low and to reduce it when it is too high. There are numerous ways to improve the distribution system's overall voltage regulation. The complete list is given by Lokay [1] as:

1. Use of generator voltage regulators
2. Application of voltage-regulating equipment in the distribution substations
3. Application of capacitors in the distribution substation
4. Balancing of the loads on the primary feeders
5. Increasing of feeder conductor size
6. Changing of feeder sections from single-phase to multiphase
7. Transferring of loads to new feeders
8. Installing of new substations and primary feeders
9. Increase of primary voltage level
10. Application of voltage regulators on the primary feeders
11. Application of shunt capacitors on the primary feeders
12. Application of series capacitors on the primary feeders

Signature of the HoD

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