ELECTRICAL DISTRIBUTION SYSTEMS

IV-B.Tech I- SEM (EEE)

UNIT-I

General Concepts

Introduction to Distribution Systems:

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.

In general, the definition of an electric power system includes a generating, a transmission, and a distribution system. The economic importance of the distribution system is very high, and the amount of investment involved dictates careful planning, design, construction, and operation.

The objective 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.

Factors Affecting System Planning:

The number and complexity of the considerations affecting system planning appears initially to be staggering. Demands for ever-increasing power capacity, higher distribution voltages, more automation, and greater control sophistication constitute only the beginning of a list of such factors. , the planning problem is an attempt to minimize the cost of sub transmission, Substations, feeders, laterals, etc., as well as the cost of losses.

Load Forecasting:

The load growth of the geographical area served by 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.

There are two common Time scales of importance to Load Forecasting:

1. Long- range with time horizons on the order of 15 or 20 years away, and
2. Short-range, with time horizons of up to 5 years distant.

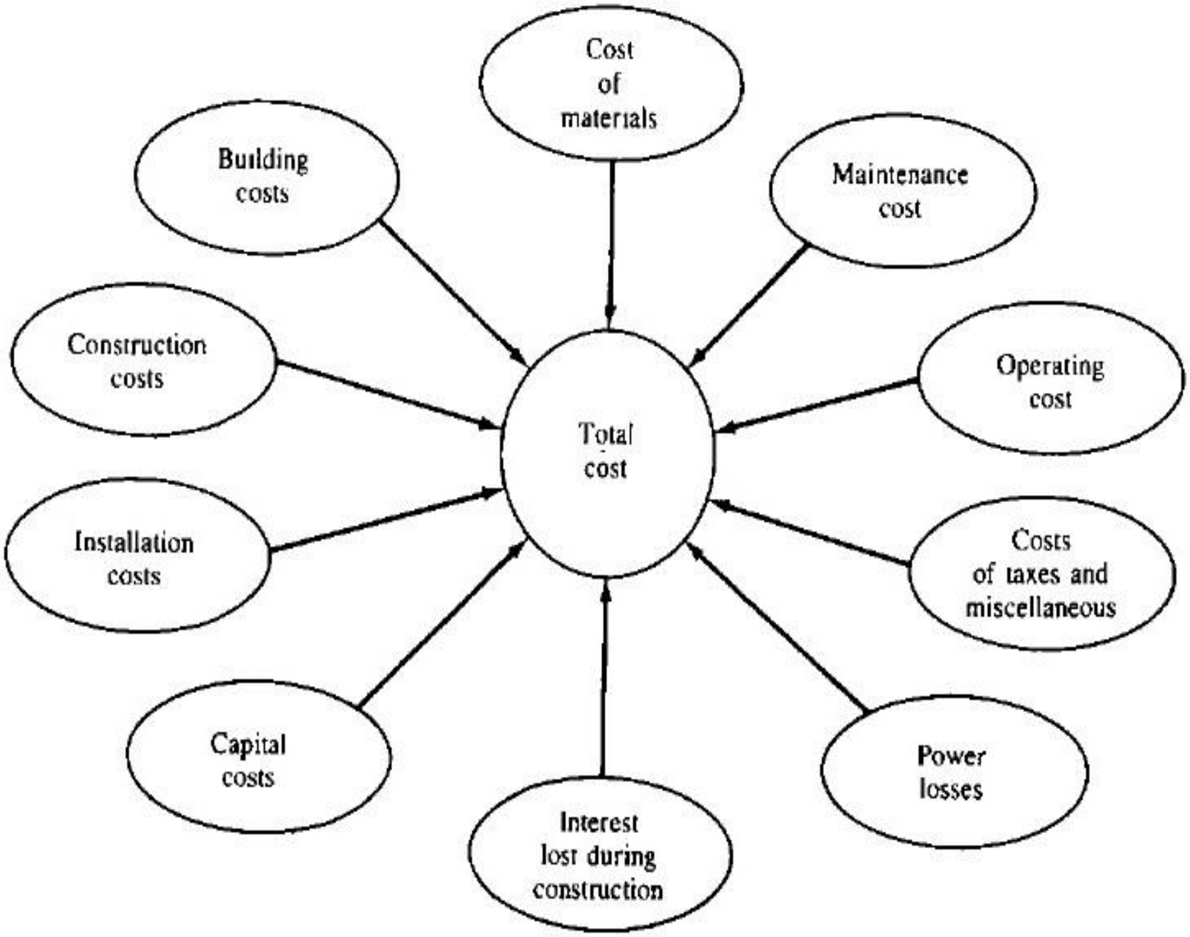


Figure 1-1 Factors affecting load forecast

Factors affecting load forecast

1. Alternative Energy Sources
2. Load density
3. Population growth
4. Historical Date
5. Geographical data
6. Land Use
7. City Plans

8. Industrial Plans
9. Community development plans

Substation Expansion: The planner makes a decision based on tangible or intangible information. In the system expansion plan the present system configuration, capacity, and the forecasted loads can play major roles.

Factors affecting substation expansion

1. Feeder limitations
2. Transmission Voltage
3. Tie Capacity
4. Load Forecast
5. Present capacity & Configurations
6. Projection limitations
7. Physical size and land availability
8. Economic factors
9. Power Losses

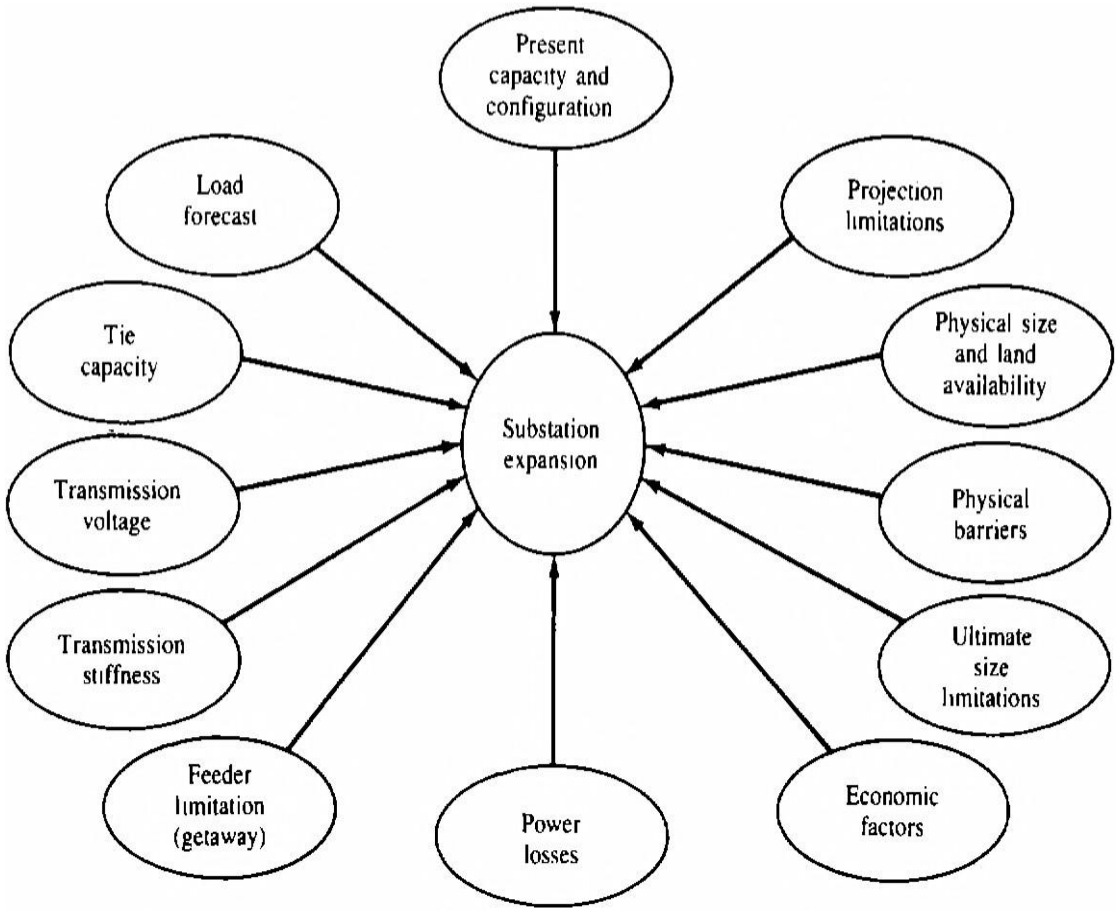


Figure 1-2

Factors affecting substation expansion

Substation Site Selection:

The substation sitting process can be described as a screening procedure through which all possible locations for a site are passed. An initial screening is applied by using a set of considerations, e.g., safety, engineering, system planning, institutional, economics, aesthetics. This stage of the site selection mainly indicates the areas that are unsuitable for site development. Thus the service region is screened down to a set of candidate sites for substation construction.

Candidate sites are categorized into three basic groups:

1. Sites that are unsuitable for development in the foreseeable future

2. Sites that have some promise but are not selected for detailed evaluation during the planning cycle, and

3. Candidate Sites that are to be studied in more detail.

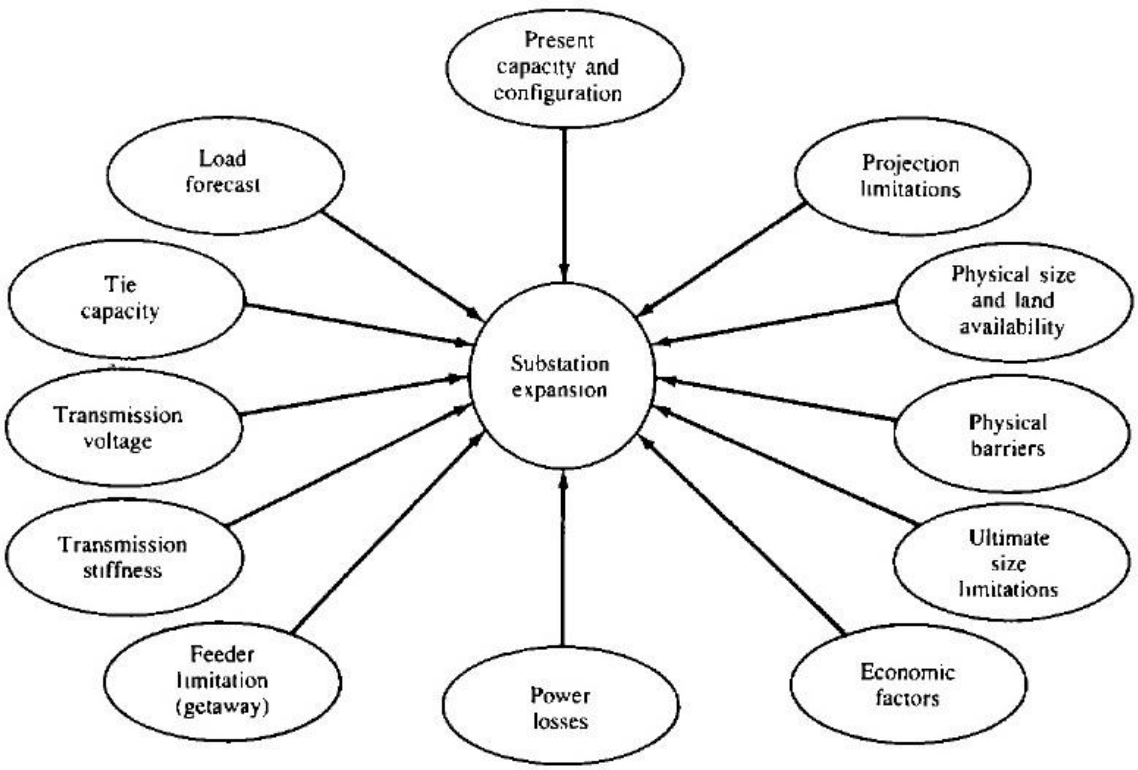


Figure 1-3 Factors affecting Site Selection

Total Cost: The substation planning must be within the cost limits and distribution of power in the large amount with low losses.

Factors affecting total Cost:

1. Capital Costs
2. Installation Costs
3. Construction Cost
4. Building Costs

5. Cost of materials
6. Maintenance Cost
7. Operating Cost
8. Cost of taxes
9. Power losses
10. Interest lost during Construction

Present Distribution System Planning Techniques:

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

Figure 1-3 shows a functional block diagram of the distribution system planning process

The planning procedure consists of four major activities: load forecasting, distribution system configuration design, substation expansion, and substation site selection.

Configuration design starts at the customer level. The latter provides the reduction from primary voltage to customer-level voltage. The distribution transformer loads are then combined to determine the demands on the primary distribution system. The primary distribution system loads are then assigned to substations that step down from sub transmission voltage. The distribution system loads, in turn, determine the size and location (siting) of the substations as well as the route and capacity of the associated sub transmission lines.

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

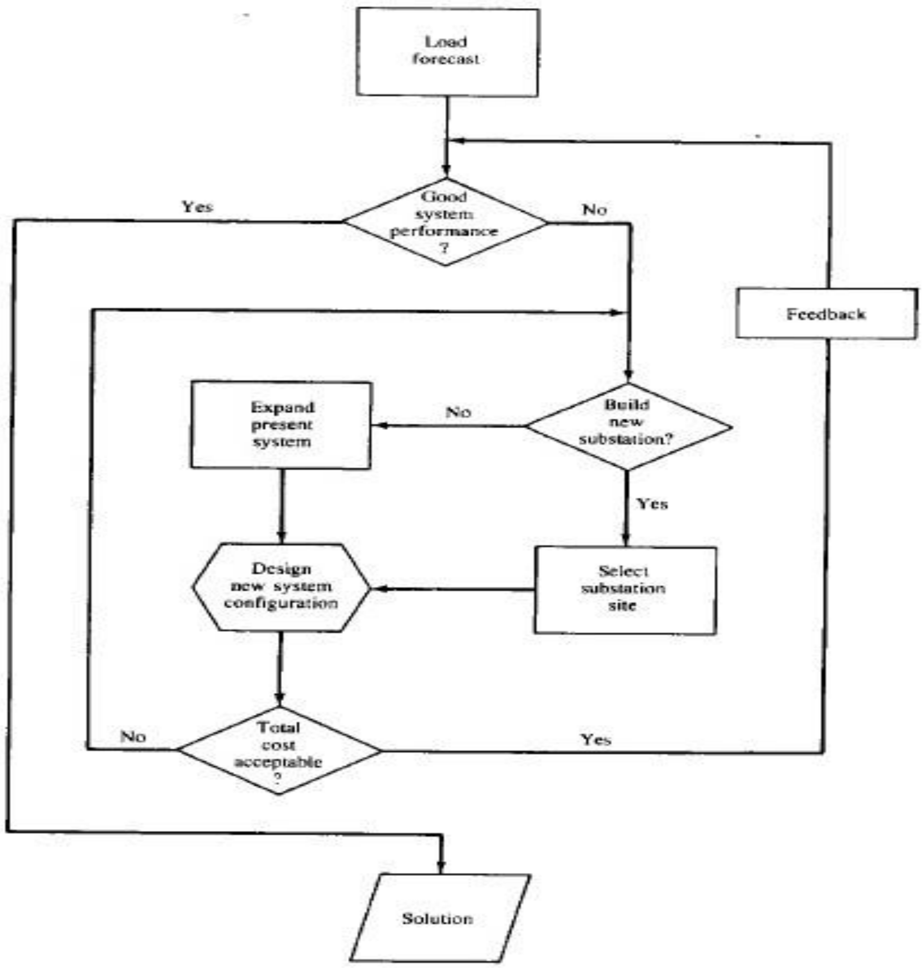


Figure 1-3 Factors affecting Site Selection

Load Characteristics:

1. **Demand:** The demand of a system is the load at receiving end over a specified time interval.
2. **Maximum Demand:** The maximum demand of a system is the greater of all the demands within the time interval specified.

3. **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.
4. **Demand factor:** It is the "ratio of the maximum demand of a system to the total connected Load. It is dimension less.

   Demand factor is usually less than 1.0.

   Demand factor = Maximum demand/ Total connected demand
5. **Non-coincident demand:** It is "the sum of the demands of a group of loads with no restrictions on the interval to which each demand is applicable."
6. **Connect ed load :** It is "the sum of the continuous ratings of the load-consuming apparatus connected to the system"
7. **Utilization factor:** It is "the ratio of the maximum demand of a system to the rated capacity of the system "

   F_u = Maximum Demand/ rated system capacity

8. **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.**

   Plant Factor = actual energy production (or) served * time/ maximum plant rating

9. **Load factor** It is "the ratio of the average load over a designated period of time to the peak load occurring on that period"

   F_{LD} = average load/ peak load

   Annual load factor = total annual energy/ annual peak load*8760

10. **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"

$$F_D = \frac{D_1 + D_2 + D_3 + \cdots + D_n}{D_g}$$

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

$$F_D = \frac{\sum_{i=1}^{n} \mathrm{TCD}_i \times \mathrm{DF}_i}{D_g}$$

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"

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

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"

Contribution factor: The contribution factor of the ith load to the group maximum demand." It is given in per unit of the individual maximum demand of the i_{th} load

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

$$D_g = c_1 \times D_1 + c_2 \times D_2 + c_3 \times D_3 + \cdots + c_n \times D_n.$$

Substituting Equation 2.18 into Equation 2.15,

$$F_c = \frac{c_1 \times D_1 + c_2 \times D_2 + c_3 \times D_3 + \cdots + c_n \times D_n}{\sum_{i=1}^{n} D_i}$$

Loss factor: It is " the ratio of the average power loss to the peak-load power loss during a specified period of time"

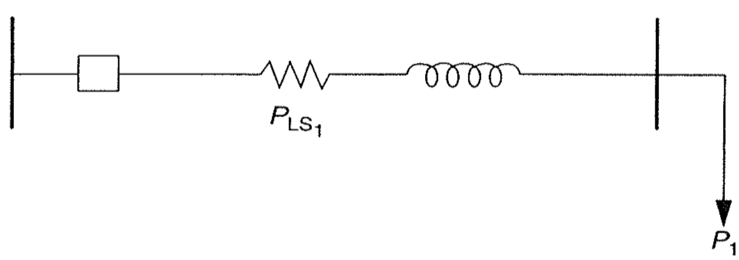
Relationship between Load & loss factors:

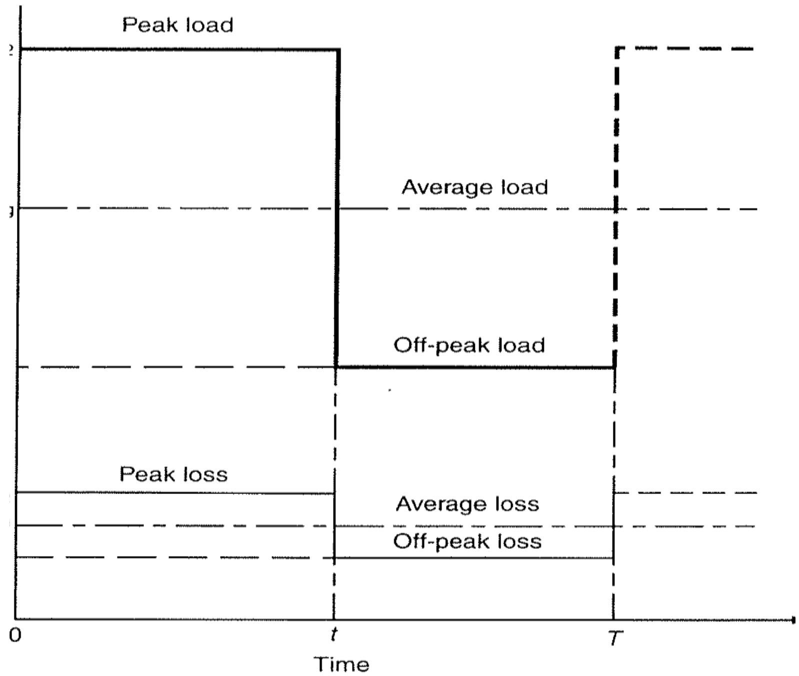
$$F_{LD} = \frac{P_{av}}{P_{max}} = \frac{P_{av}}{P_2}.$$

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

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

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





$$F_{LS} = \frac{P_{LS,av}}{P_{LS,max}} = \frac{P_{LS,av}}{P_{LS,2}},$$

Where $P_{Ls,avg}$ the average power loss, $P_{LS,max}$ is the maximum power loss, and $P_{LS,2}$ is the peak loss at peak load.

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

Substituting

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

Where $P_{LS,1}$ is the off-peak loss at off-peak load, t is the peak load duration, and $T - t$ *is* the off-peak load duration.

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

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

$$P_{LS,2} = k \times P_2^2$$

Where k is a constant. Thus, substituting Equations 2.32 and 2.33 into Equation 2.31, the loss factor can be expressed as

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

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

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, = 0. Therefore, from Equations 2.28 and 2.35,

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

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,

$$t \longrightarrow 0$$

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

$$F_{LS} \longrightarrow (F_{LD})^2$$

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

Case 3: Load is steady. Here,

$$t \longrightarrow T.$$

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

$$F_{LS} \longrightarrow F_{LD.}$$

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, is 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

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

Where FLS is the loss factor (pu) and FLD is the load factor (pu).

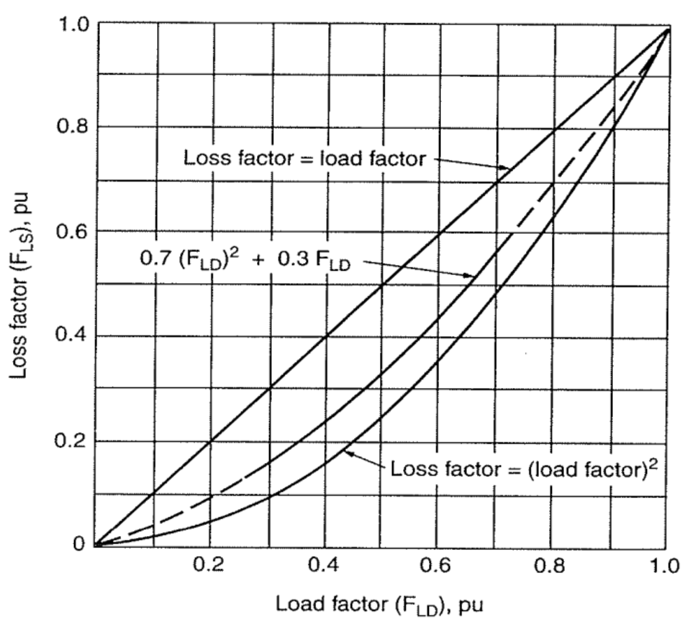
Equation 2.40a gives a reasonably close result. Figure 2.10 gives three different curves of loss factor as a function of load factor. Relatively recently, the formula given before has been modified for rural areas and expressed as

$$F_{LS} = 0.16\,F_{LD} + 0.84\,F_{LD}^2.$$

1. The average load factor of a substation is 0.65. Determine the average loss factor of its feeders, if the substation services:

(a) An urban area.

A rural area



Solution:

(a) For the urban area,

$$FLS = O.3F_{LD} + {}^{O.7}({}^{F}LD)^2$$

$$= 0.3(0.65) + 0.7(0.65)^2$$

$$= 0.49.$$

(b) For the rural area,

$$FLS = 0.16F_{LD} + {}^{0.84}({}^{F}LD)^2$$

$$= 0.16(0.65) + 0.84(0.65)^2$$

$$= 0.53.$$