UNIT - 1

Distribution System planning and Automation.

* Introduction.

1) The electric utility industry was born in 1882, when the 1st electric power station, pearl street electric station in New york city, went into operation.

2) The electric power system includes a generating, a transmission, and a distribution s/m.

* Distribution system planning.

1) System planning is essential in order to ensure that the growing demand of electricity which can be satisfied by distribution s/m's which ~~includes~~ are both technically adequate and reasonably economical.

2) The objective of distribution s/m planning is to ensure the growing demand for electricity in terms of increasing growth rates and high load densities, can be classified in an optimum way by additional distribution systems.

3) the scarcity of available land in urban areas and ~~economical~~ ecological considerations, can put the problem of optimal ~~consid~~ distribution s/m planning beyond the resolving power of the unaided human mind.

4) The distribution s/m planner must determine the load magnitude and its geographic location.

5) The distribution s/m is particularly important to an electrical utility for two reasons.

i) its close proximity to the ultimate customer.

ii) its high investment cost.

6) the distribution s/m planning starts at the customer level. the demand, type, load factor, and other customer load characteristics dictate the type of distribution s/m required.

7) The distribution s/m loads, inturn, determine the size and location, or siting, of the substations as well as the routing and capacity of the associated transmission lines. In otherwords, each step in the process provides input for the ~~step that follows~~ next step.

* factors affecting system planning.

1) The number and complexity of the considerations which are affecting s/m planning appear initially to be staggering.

2) ~~Succinctly put~~, the planning problem is an attempt to minimize the cost of subtransmission, substations, feeders, laterals, etc. as well as the cost of losses.

1) Load forecasting.

The load growth of the geographical area served by a utility company is the most important factor influencing the expansion of the distribution s/m. hence 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. long range, with time horizons on the order of 15 or 20 years away. and short range, with time horizons of up to 5 years distant.

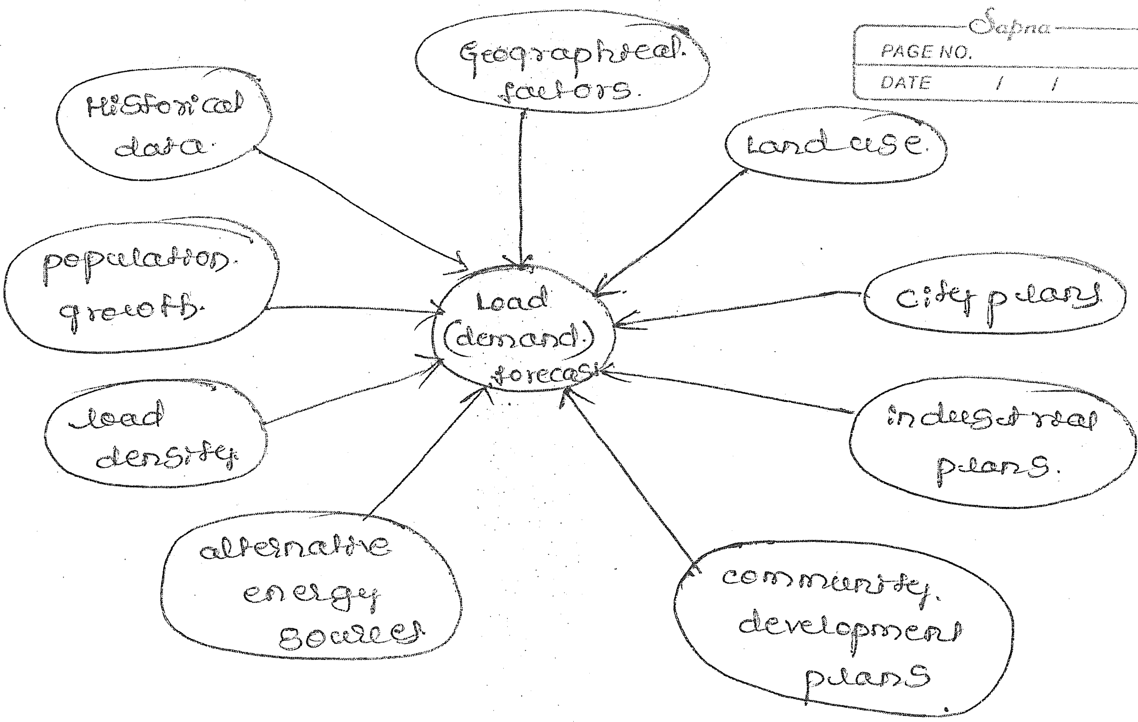

fig - factors affecting load forecast

the above ~~factors~~ fig shows that which factors influence the load forecast. as one would except, the load growth is very much dependent on the community and its development. [2.0 pts: generally] Economic indicators, demographic data, and official land use plans all serve as raw input to the forecast procedure.

~~* Substation expansion~~

~~The below fig shows the some of the factors which affecting the substation expansion. The planner makes a decision based on intangible information. In the s/m expansion plan the present s/m configuration, capacity, and the forecasted loads can play major roles~~

~~* Substation site selection~~

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* Substation expansion.

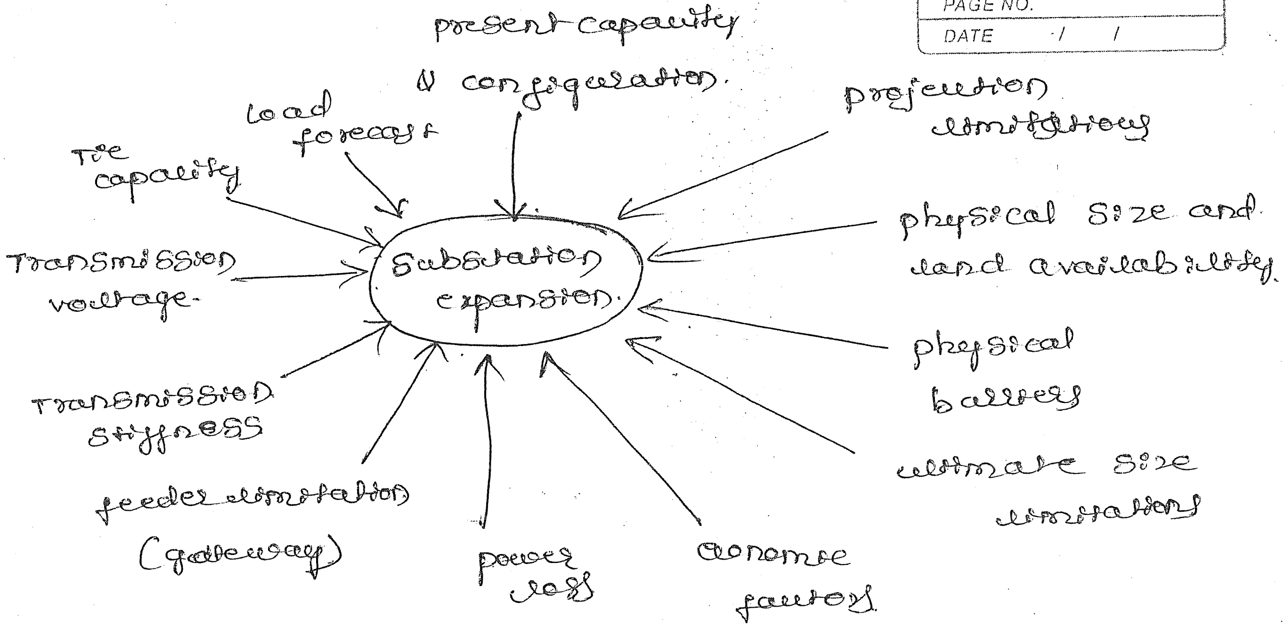


fig - factors affecting the substation expansion.

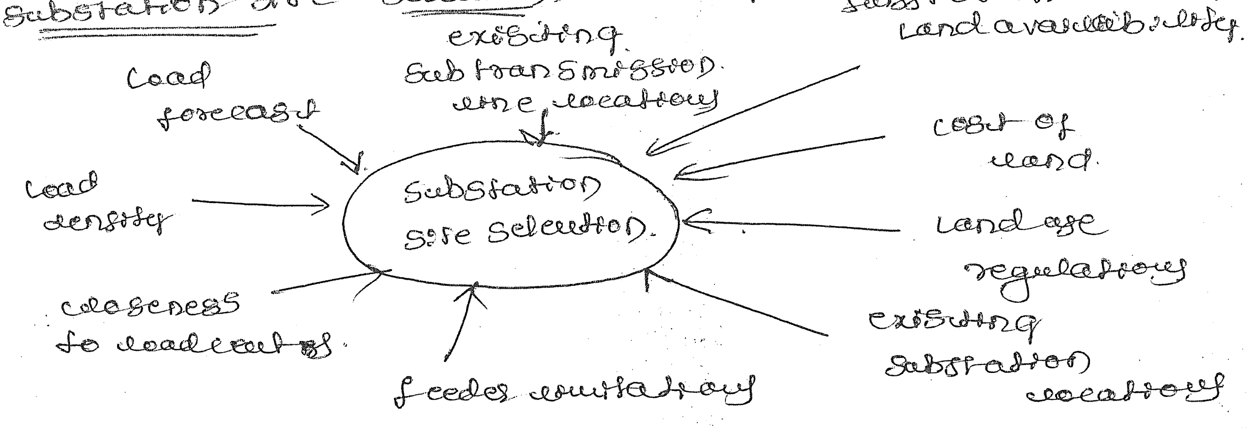
1) The above fig shows the some of the important factors which affects the substation expansion.

2) the planner takes the decissions based on the tangible or intangible information. for example the forecasted load, load density, and load growth require the substation expansion or may be construction of new substation.

3) in the s/m expansion plan. the present s/m configuration, capacity, & forecasted loads play major roles.

* Substation site Selection.

fig - factors affecting substation selection.



1) The above fig shows the factors affecting the substation site selection.

2) the distance b/n the load centers and the existing subtransmission lines as well as other limitations such as availability of land, its cost and land use regulations are important.

3) The substation siting process can be explained with the help of screening procedure which passes through the all possible locations of site as shown below fig.

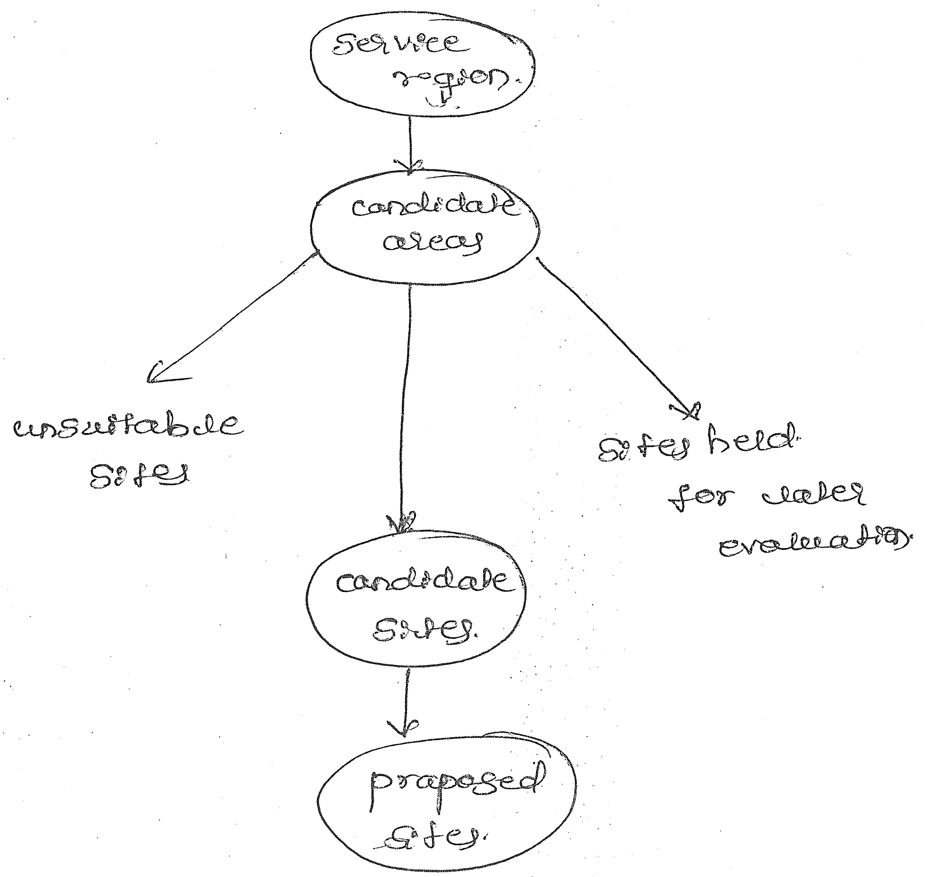


fig - Substation site selection procedure

4) as shown in the above fig the service region is the area under evaluation, which may be defined as the territory of the utility.

5) The initial screening is applied by making certain considerations such as safety, engineering, s/m planning, institutional, economic and aesthetics

* ~~Present distribution~~ S/m ~~planning techniques.~~

6) as shown in the above fig. the ~~service region~~ is screened down to a set of candidate sites for substation construction.

7) the candidate ~~sites~~ areas are subdivided into 3 basic groups they are i) the sites which are unsuitable for the development in the foreseeable future.

ii) the sites which have some promises but even though those sites are not selected for detailed evaluation during the planning cycle.

iii) the candidate sites ~~that~~ which are to be studied in detail.

8) The emphasis which are put on each consideration changes from level to level and from utility to utility.

9) the better eyes of considerations are.

1. quantitative vs qualitative evaluation.
2. adverse vs beneficial effects evaluation.
3. absolute vs relative scaling effects

* other factors.

1) once the load assignments to the substations are determined, then the remaining factors affecting primary voltage selection, feeder route selection, no of feeders, conductor size selection & the total cost is taken into consideration as shown in the below fig.

2) In general, the subtransmission and distribution s/m voltage levels are determined by company policies.

3) due to standardization and economy which are involved the designer ~~will~~ ~~not~~ may not have

Such a freedom in choosing the necessary size and types of the capacity equipment.

for example the designer may have to choose a distribution transformer out of a fixed list of transformers which are presently stocked by the company for voltage levels which are established by the company

4) Any decision regarding addition of a feeder or adding on to an existing feeder will, within limits, depends on the capability of existing s/m and the size, location and timing of the additional load which are need to be served

* present distribution s/m planning techniques

1) Today many electric distribution s/m planners in the industry utilize computer programs, based on ad hoc techniques.
2) The techniques such as load flow programs, radial or loop load flow programs, SC and fault-current calculation programs, voltage drop calculation programs, and total s/m 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.
3) In general the overall concept of using the o/p of each program as input for the next program is not in use
4) The application of computers in the distribution s/m will reduces the calculations accurately than other methods hence reduction in the distribution

engineer work.

5) The below fig shows the functional ~~block diagram~~ of distribution s/m planning process which is currently used by the many utilities

6) this process is repeated for each year of a long range planning period.

7) as shown in the fig. the planning procedure consists of four major activities i) load forecasting ii) distribution s/m configuration design, iii) substation expansion iv) substation site selection.

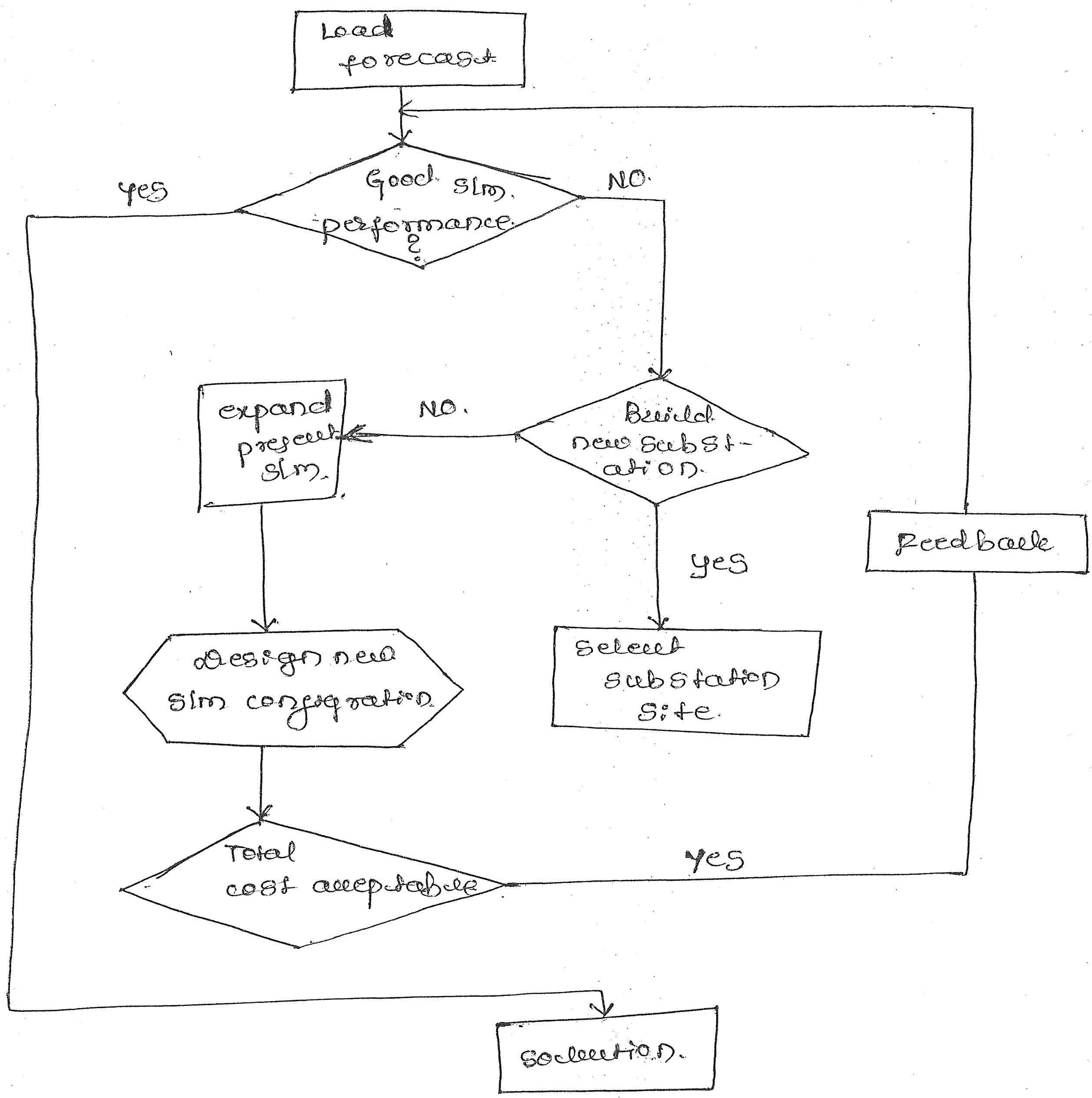


fig - a block diagram of a typical distribution s/m planning process.

As shown in the above if the obtained results of the performance analysis shows that the present s/m is not adequate to meet future demand, then there are two options.

1) the present s/m needs to be expanded by new s/m additions. <u>or</u> a new substation may need to be build to meet the future demand.

2) if the decision is to expand the present s/m with minor additions, then a new additional n/w configuration is designed and analysed for accuracy.

3) in case if the new configuration is found to be inaccurate, another is tried and many more until a satisfactory is to found.

4) The cost of each of the configuration is calculated if the cost is to be found too high <u>or</u> accurate performance can't be achieved then the origional expand or reevaluated.

5). If the resulting decision is to build a new substation, a new placement site must be selected & if the cost of new site is more then the expand <u>or</u> build decision is further evaluated.

6) the continous process ends when satisfactory configuration is attained which provides a solution to existing <u>or</u> future problems at a reasonable cost. & in these procedure many functions are done with computer programs.

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* HVDC, EOCPS
DSDC, SCADA, DE.

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* Distribution System planning Models

1) In general, distribution s/m planning includes a complex procedure due to a large number of variables involved and the difficult task of the mathematical presentation of numerous requirements & limitations specified by s/m configuration.

2) The mathematical models are developed to represent the s/m and can be used by distribution s/m planners to investigate and to determine optimum expansion patterns.

3) Such as optimum substation locations, optimum substation expansions, optimum substation transformer sizes, optimum load transfers b/n substations and demand centres, optimum feeder routes, and sizes to supply the given loads

4) in order to minimize the present worth of the total costs. the s/m is subjected to numerous constraints 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 & the best one is selected

② The decomposition method, in which a large problem is subdivided into a no of small problems and each problem is solved separately.

③ The linear programming and integer-programming methods, which linearize constraint conditions.

④ The dynamic programming method.
⑤ Genetic algorithm method
⑥. The quadratic programming method } Each of these technique has its own advantage & dis-advantage.

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* New planning Tools

in the distribution planning basically there are two types of planning tools 1) network design tools 2) network analysis tools.

* The network analysis tools are more efficient but they are not expected to undergo any major changes, in addition to that the environment in which they are used will change significantly.

* The design tools are expected to show the greatest development since the good planning will have a significant impact on the utility industry.

The result of this development includes the following characteristics such as.

① New design will be optimized cost to many criteria by using different programming methods

② New design will be only one aspect of distribution s/m management which is directed by human engineers using a computer s/m designed for mgt function.

③ The network editors will be available for designing final networks, These network designs in digital form will be passed to extensive simulation programs which will determine whether the proposed new satisfies performance and load growth criteria.

* The central Role of the computer in distribution planning.

1) Since from many years the distribution s/m planners & others using computers to perform the tedious

calculations necessary for sm analysis.

* The system approach

1) A system approach includes the collection of computer programs to solve the analysis problems of a designer does not necessarily constitute an efficient problem-solving sm nor does such a collection even when the output of one can be used as the input of another.

2) The sm approach to the design of a useful tool for the designer begins by examining the types of information required and its sources.

3) The view taken is that this information generates decisions and additional information which pass from one stage of the design process to another.

4) At certain points, it is noted that the human engineer must to evaluate the information generated & add his or her input.

5). Finally, the results must be displayed for use and stored data for later reference. with this conception of the planning process, the sm approach seeks to automate as much of the process as possible.

6) The below fig shows the interface b/w the engineer and the system, The analysis programs forming a part of the sm are supported by a data-base management system which stores, retrieves & modifies the various data on distribution system

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i)
c
2)
c
c
3)
c
*
1)
2)
3)
4)

* The data base concept

1) As shown in the below fig the data base plays a central role in the operation of such a system.

2) In this area of the technology has made some significant improvements since from the last 5 year hence it is helpful to store the large quantity of data along with it is also possible get back the desired data with access times on the order of seconds.

3) The DBMS s/m provides the interface b/w the process which requires access to the data and the data them-selves. The operations on the data base are performed by the data-base mangement system (DBMS)

* New automated tools

1) In addition to the data base management program and the network analysis programs, it is excepted some other tools will exist to assist the designer so that the optimal design is obtained.

2) one such tool is ~~prepared~~ appeared in the literature known as ~~newt~~ a network editor.

3) The network consisting of a graph whose vertices are the network components, such as transformers and loads. The edges will represent the connections among these components.

4) The feature of new editor will include network objects such as feeder line sections, secondary line sections, distribution transformers, variable or fixed capacitors, control mechanisms & command functions.

4) The control mechanisms may provide the planner with natural tools for correct network construction and modification.

* Distribution System Automation. *

1) The main purpose of an electric power system is to efficiently generate, transmit, and distribute electric energy.

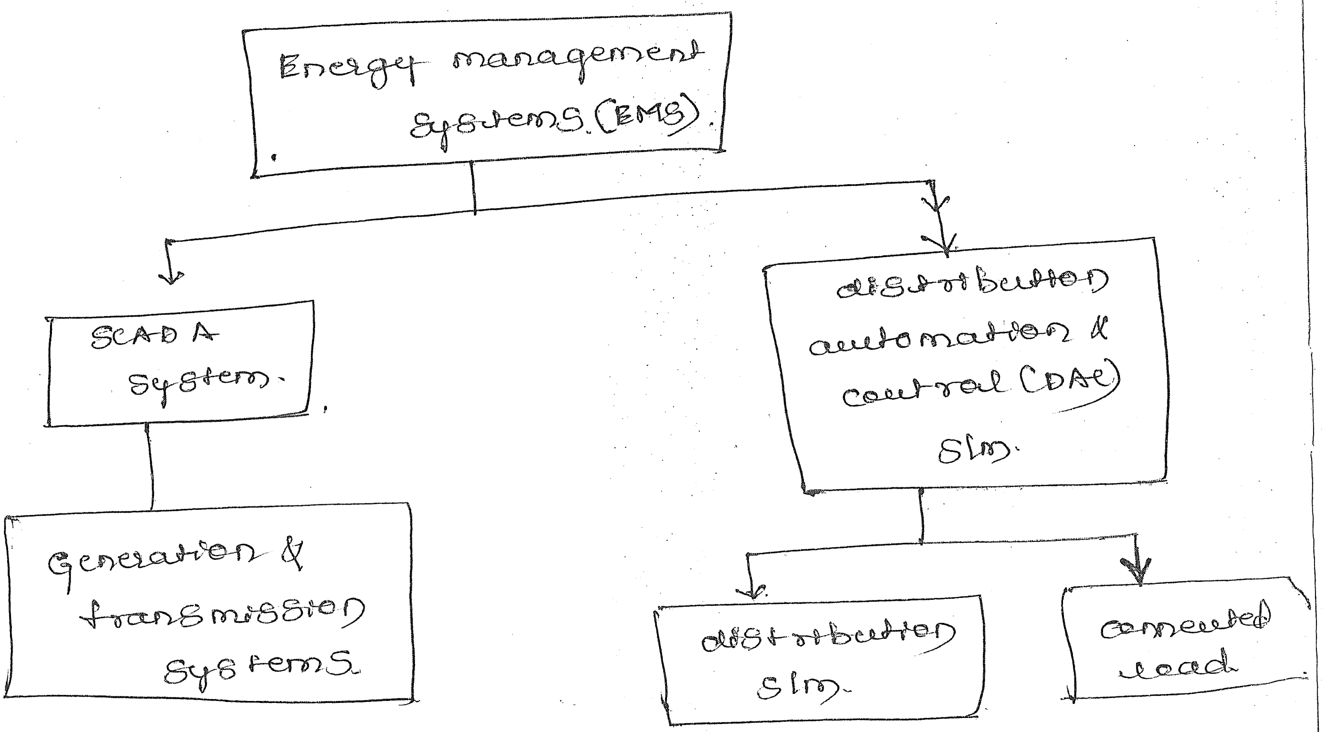

fig - Monitoring and controlling an electric power system

2) as shown in the above fig the energy management system (EMS) exercises overall control over the total system.

3) The SCADA s/m includes the generation & transmission systems.

4) The distribution automation and control (DAC) system includes the distribution system and connected load.

5) More recently automation has become a part of the overall energy management, including the distribution system. The motivating objectives of DAC system are

* improved overall s/m efficiency in the use of both capital and energy.
* increased market demand of coal, nuclear and renewable domestic energy source
* reduced reserve requirements in both transmission and generation.
* increased reliability of service of essential loads

6) The application of inexpensive minicomputers and powerful ~~microcomputers~~ processors have provided the distribution s/m engineers with new tools which are helpful to obtain certain distribution functions achievable.

7) The below fig gives a profile of electric utility industries in the united states in the year 2000. the given data clearly indicate that the future distribution s/m will be more complex than the present s/m.

8) If the systems are developed then those systems must be optimal with respect to construction cost,

capitalization, performance, reliability, operating efficiency better automation and control tools are required.

9) The term distribution automation has a very broad meaning, and ~~too many applications~~ are added to Some people it means that a communication slm at the distribution level that can control the ~~consumer~~ customer load and can reduce peak load generation through load management.

10) The microprocessor located at a distribution sub-station can continuously monitor the slm make operating decisions, issue commands, and report any change in states to distribution dispatch centre.

* a profile of electric utility industry in the united states in the year 2000*

Total us population	250×10^6
No of electric meters	110×10^6
Number of residences	
with central air conditioners	83×10^6
with electric water heaters	25×10^6
with electric space heating	7×10^6
No of electric utilities	3100.

* <u>distribution</u> <u>automation</u> and <u>control functions</u>

The various distribution ~~and~~ automation & control functions are as follows

① <u>discretionary</u> <u>load</u> <u>switching</u> :- discretionary load switching function is also called customer load management, it includes the direct control of loads at individual customer sites from a remote control location.

customer loads that are appropriate for control are water pumping, air conditioning, space heating thermal storage heating etc.

(2) peak load pricing :- This function allows the implementation of large blocks of load, under certain conditions according to an established priority basis.

(3) Load shedding :- The load shedding includes the rapid dropping of large blocks of load, under certain conditions, according to the established priority

(4) cold load pickup :- This function is a corollary to the load shedding function. it includes the controlled pickup of dropped load.

(5) load reconfiguration :- i) the load reconfiguration includes the remote control of switches and breakers to permit routine daily weekly or seasonal reconfiguration of feeders or feeder segments for the purpose of taking of advantage of load diversity among feeders

ii) it enables the sim to effectively serve larger loads without requiring feeder reinforcement or new construction.

iii) it also enables routine maintance on feeders without any customer load interruptions

(6) voltage regulation :- voltage regulation allows the remote control of selected voltage regulators within the distribution network, together with network capacitor switching, to effect co-ordinated system

wide voltage control from a central facility.

(7) transformer load mangement (TLM) :- this function enables the monitoring and continous reporting of transformer loading data and core temperature to prevent overloads, abnormal operation by timely reinforcement, replacement or reconfigration.

(8) feeder load management (FLM) :- this function is similar to the Transformer load mangement, but in this case the loads are monitored and measured on feeders and feeder segments, this function permits loads to be equalized over several feeders.

(9) capacitor control :- it includes the selective and remote controlled switching of distribution capacitors.

(10) dispersed storage and generation :- storage and generation equipment may be located at strategic places throughout the distribution system. and they may be used for peak shaving, it includes the co-ordinated remote control of these sites.

(11) fault detection, location and isolation :- i) sensors located throughout the distribution network can be used to detect and report abnormal conditions.
ii) this information in turn can be used to automatically locate faults, isolate the faulted segment, and initiate proper sectionalization and circuit reconfiguration.

(12) load studies :- i) this function involves the automatic on line gathering and recording of load data for special off line analysis

ii) the data may be stored at the collection pt, at the substation or transmitted to a dispatch center.

(13) condition and state monitoring :- this function includes the real time data collection and status reporting from which minute by minute status of the power system can be determined.

(14) Automatic customer meter reading :— this function allows automatic remote reading of customer meters for total consumption, peak demand, and necessary man-hours involved in meter reading.

(15) Remote service connect or disconnect :- this function permits remote control of switches to connect or dis-connect an individual customers electric service from a central control location.

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2nd unit – Load characteristics.

* **Demand** :- The demand of a s/m is defined as the load at the receiving terminals averaged over a specified interval of time. The load may be expressed in terms of kilowatts, kilovoltamperes, kiloamperes or amperes

* **Demand interval** :- it is the period over which the load averaged this selected Δt period may be 15 min, 30 min, 1hr or even longer. there exists the certain situation when 15 and 30 min demands are identical.

The curve constructed by selecting the maximum peak points and connecting them by a curve. Such a curve is called as load duration curve.

The load duration curves may be daily, weekly monthly or annual

forexample => if the curve is plot of all the 8760 hours loads during the year it is called an annual load-duration curve.

* **Maximum demand** :- the maximum demand of an s/m is the greatest of all demands which have occured during the specified period of time.

* **diversified demand** or (coincident demand) :- it is a demand of the composite group, as a whole, of some-what unrelated loads over a specified period of time.

* **Non coincident demand** :- Noncoincident demand is defined as the sum of the demands of a group of loads with no restrictions on the interval to which each demand is applicable.

* **Demand factor** :- demand factor is defined as the ratio of maximum demand of the s/m to the total

connected load of the s/m.

∴ demand factor (DF) ≜ $\frac{\text{maximum demand}}{\text{total connected demand}}$

the demand factor is usually less than (1)

* **connected load** :- it is the sum of the continuous ratings of the load-consuming apparatus, connected to the s/m or any part of the s/m.

When the maximum demand and the total connected demand have the same units, the demand factor is dimensionless.

* **utilization factor** :- it is the ratio of maximum demand of a system to the rated capacity of the system.

∴ utilization factor F_u ≜ $\frac{\text{maximum demand}}{\text{rated s/m capacity}}$

* **plant factor** :- it is the ratio of the total energy produced over a designated period of time to the energy that produced or served if the plant had operated continuously at maximum rating. plant factor is also called as capacity factor or the use factor

∴ plant factor = $\frac{\text{actual energy produced or served} \times T}{\text{maximum plant rating} \times T}$

or

Annual plant factor = $\frac{\text{actual annual energy generation}}{\text{maximum plant rating} \times 8760}$

* **Load factor** :- it is the ratio of the average load over a designated period of time to the peak load occurring on the period.

F_{LD} = average load / peak load.

or load factor = $\frac{\text{average load} \times T}{\text{peak load} \times T}$

= $\frac{\text{units served}}{\text{peak load} \times T}$

Where T is time in days, weeks, month or year.

The annual load factor is given by.

Annual load factor = $\frac{\text{total annual energy}}{\text{annual peak load} \times 8760}$

* **diversity factor** :- it is the ratio of sum of the individual maximum demands of the various subdivisions of a sim to the maximum demand of the whole sim.

∴ diversity factor F_D = $\frac{\text{sum of individual maximum demands}}{\text{coincident maximum demand}}$

or $F_D = \frac{D_1 + D_2 + D_3 + \text{———} + D_n}{D_g}$

or $F_D = \sum_{i=1}^{n} D_i / D_g$ ——— (1)

where D_i = maximum demand of load i,

D_g = $D_{1+2+3} \text{———} + D_n$

= coincident maximum demand of group of n loads.

The diversity factor can be equal to or greater than 1.0.

DF = maximum demand / total connected load.

∴ maximum demand = DF × total connected load. ——— (2)

put eqn ② in eqn ①. ∴ the diversity factor can also be given as.

$$F_D = \frac{\sum_{i=1}^{n} TCD_i \times DF_i}{D_g}$$

where TCD_i = total connected demand of group or class i load,

DF_i = demand factor of group or class i, load

* **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 the individual consumers.

∴ coincidence factor $F_C \triangleq \frac{\text{coincident maximum demand}}{\text{sum of individual maximum demands}}$

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

∴ the coincidence factor is the reciprocal of diversity factor ie $\boxed{F_C = 1/F_D}$.

* **Load diversity** :- it is the difference b/n the sum of the peaks of two or more individual loads and the peak of the combined load.

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

* **contribution factor** :- (●) it is defined as the contribution factor of the ith load to the ~~group~~ maximum demand of group.

$$\therefore D_g \triangleq C_1 \times D_1 + C_2 \times D_2 + C_3 \times D_3 + \text{———} + C_n \times D_n. \text{ — ①}$$

put the eqn ① in case of contribution factor equation in contribution factor equation

$$\therefore F_C = \frac{C_1 \times D_1 + C_2 \times D_2 + C_3 \times D_3 + \dots + C_n \times D_n}{\sum_{i=1}^{n} D_i}$$

or

$$F_C = \frac{\sum_{i=1}^{n} C_i \times D_i}{\sum_{i=1}^{n} D_i}$$

Special cases.

* case-1 :- $D_1 = D_2 = D_3 = \text{———} = D_n = D$.

$\therefore$ we have $F_C = \sum_{i=1}^{n} C_i \times D_i \Big/ \sum_{i=1}^{n} D_i$. $n \times D$.

$$\therefore F_C = \frac{D \cdot \sum_{i=1}^{n} C_i}{n \times D}.$$

$$\boxed{\therefore F_C = \frac{\sum_{i=1}^{n} C_i}{n}}$$

coincidence factor = Avg contrn factor

* case-2 $C_1 = C_2 = C_3 \text{———} = C_n = C$

$\therefore F_C = C \times \sum_{i=1}^{n} D_i \Big/ \sum_{i=1}^{n} D_i$.

coincidence factor = contn factor

$$\boxed{\therefore F_C = C}$$

* Loss factor :- it is defined as the ratio of the average power loss to peak load power loss during a specified period of time.

$\therefore$ Loss factor $F_{LS} \triangleq \dfrac{\text{average power loss}}{\text{power loss at peak load}}$

* Substation location.

The location of a substation is decided by the voltage levels, voltage regulation considerations, subtransmission costs, substation costs, and costs of primary feeders, mains and distribution transformer.

* The location of substation is selected by the following factors.

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

2. Locate the substation such that proper voltage regulation can be obtained 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 location for substation must be such that it must provide enough space for the future substation expansion.

5. The selected substation location should not be opposed by the land use regulatory.

6. The selected substation location should help to reduce the number of customers which are affected by the service discontinuity.

7. Other considerations such as adaptability, emergency etc.

* The rating of a distribution substation

The additional capacity requirements of a S/D with increasing load density can be met by.

① either holding the service area of a given substation constant and increasing its capacity

② developing new substations and thereby holding the rating of the given substation constant

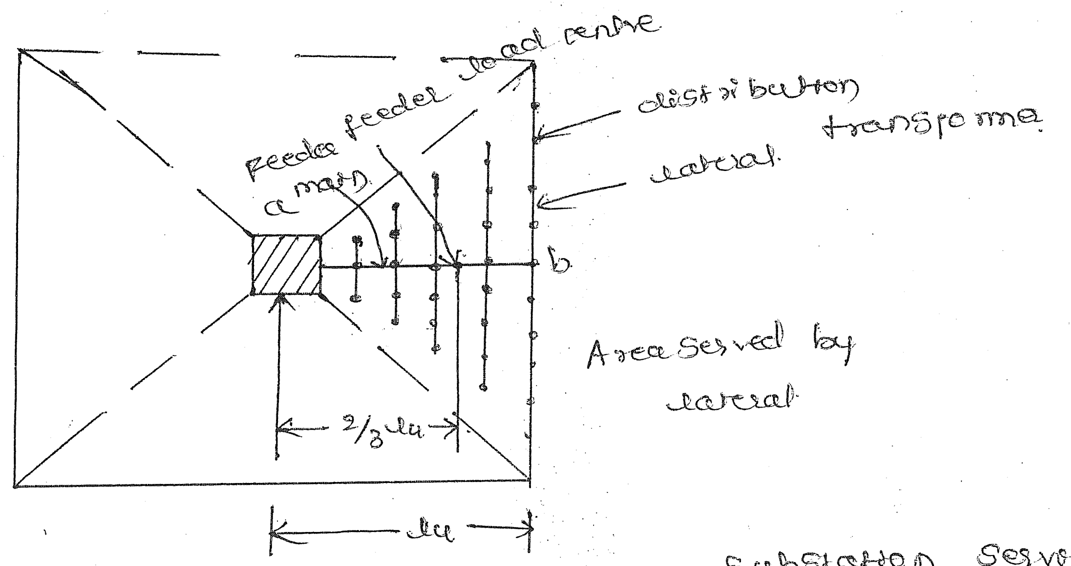


fig - square shaped distribution substation service area.

Lets consider a square shaped distribution substation service area as shown in the above fig. representing a part of or the entire service area of a distribution substation. as shown in the above fig a square area is served by 4 primary feeders from a central feed point,

* Each feeder and its laterals are three phase, dots will represent balanced 3-ϕ loads lumped at that location and feed by distribution transformers

the present voltage drop from the feed pt a to the end of the last lateral pt C is

% VDae = % VDab + % VDbc.

~~[Simplify the above voltage drop calculation by introducing the constant k which can be defined]~~

The above voltage drop equation can be simplified by considering constant k, which can be defined as percent voltage drop per kilovoltampere-mile.

As shown in the above fig each feeder serves a total load of $S_4 = A_4 \times D$ kVA. ——— (1)

~~where~~ the above equation can be rewritten as $S_4 = l_4^2 \times D$ kVA ——— (2)

where $l_4^2 = A_4$ & l_4 is the linear dimension of the primary feeder service area in miles

Assuming the uniformly distributed load i.e equally loaded and spaced distribution transformer, the voltage drop in the primary feeder main is

$\% VD_4 main = 2/3 \times l_4 \times k \times S_4$. ——— (3)

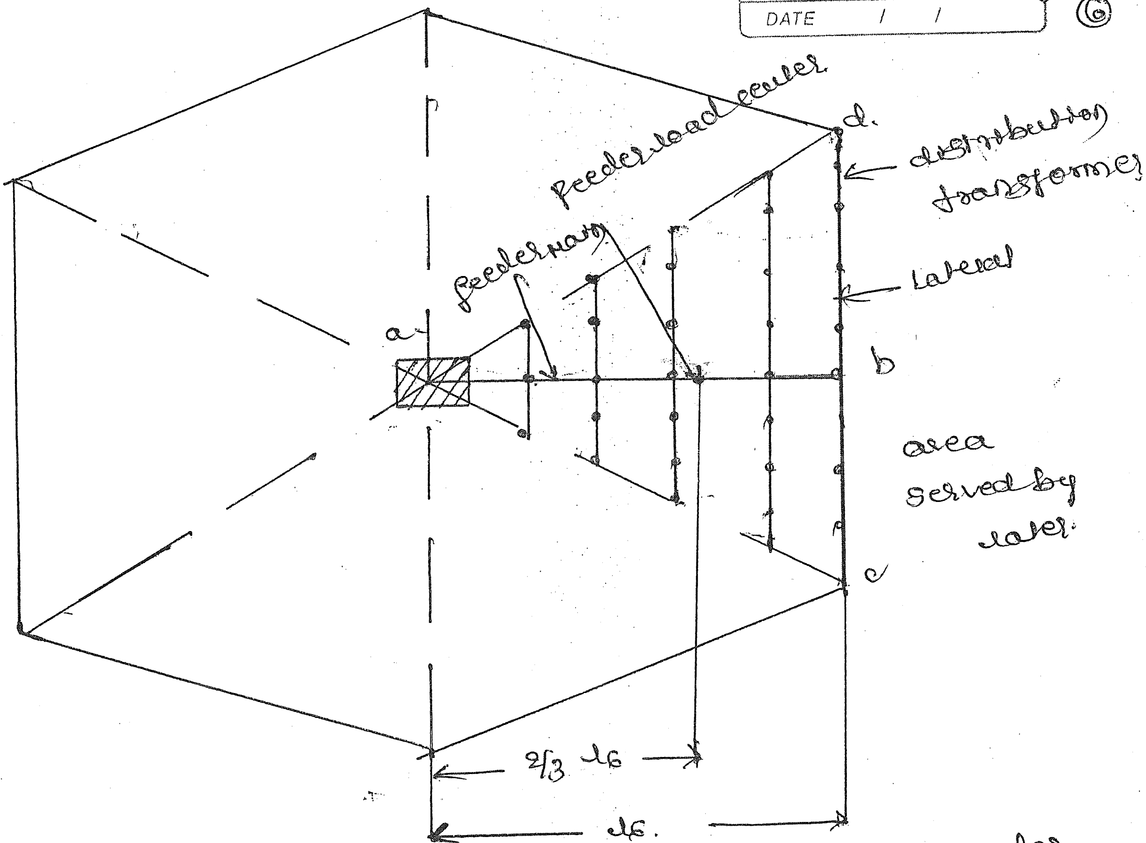
put eqn (2) in equation (3)

$\% VD_4 main = 0.667 \times k \times D \times l_4^3$. ——— (3a)

in the equation (3) & (3a) it is assumed that the total load is located at a point on the main feeder at a distance of $2/3 \times l_4$ from the feed point a.

Assume that each feeder service area is equal to one-sixth of the hexagonally shaped total area.

fig - Hexagonally shaped distribution substation area.



* S_6 = kVA load served by one of the six feeder from the feeding end.

A_6 = area served by one of the 6 feeder from feeding point in mi^2 or km^2

D = kVA/mi^2

l_6 = linear dimension of a primary feeder service area mi

area of Δle abc. $= \frac{1}{2} ab \times bc$

length ab $= l_6$.

bc $= ab \tan 30^\circ$ $= l_6/\sqrt{3}$

$= ab \, 1/\sqrt{3}$

$\therefore A_6 = 2 \times$ area of Δle

$= 2 \times \frac{1}{2} l_6 \times l_6/\sqrt{3}$ $= l_6^2/\sqrt{3}$ $= 0.578 \, l_6^2$

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S_6 = load density kVA/mi²

× area of service in mi²

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$S_6 = DA_6$

$S_6 = D \times 0.578 l_6^2$

$$S_6 = 0.578 D l_6^2$$

it is assumed that total or lump sum is located at a point on the main feeder at a distance of $\frac{2}{3} \times l_6$ from the feed point.

∴ The percentage vtg drop in the main feeder is

$\% VD_6 \text{ main} = \frac{2}{3} l_6 [k \times S_6]$

$= \frac{2}{3} k l_6 \times 0.578 D l_6^2$

$$\% VD_6 \text{ main} = 0.385 k D l_6^3$$

* derive an expression for percentage voltage drop in the main feeder ① a square shaped series are supplied by a feeder ② Hexagonal area supported by 6 feeders

Imp

* Substation service area with n number of feeders

Consider a substation service area consisting of n no of primary feeders from the point.

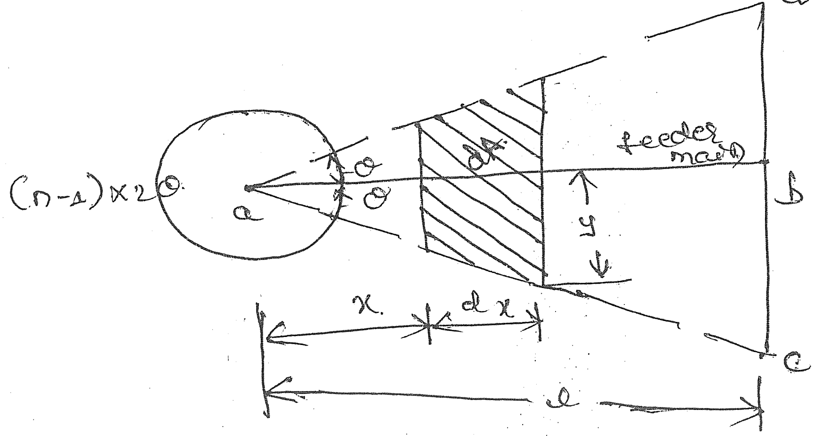


fig - distribution substation service area served by n primary feeders

Let us consider a small elemental area dA, having a distance x, at a distance.

Let dS = differential load served in kVA for the differential area dA.

$dS = D\,dA$ kVA —— (1)

D = load density, kVA/m²

$\tan\theta = y/(x+dx)$ —— (2)

$y = (x+dx)\tan\theta$

$\simeq x\tan\theta$ —— (3)

∴ the total service area of the feeder.

$A_n = \int_{x=0}^{l_n} dA = l_n^2 \times \tan\theta$ —— (4)

the total load served by one of the n feeder

is $S_n = \int_{x=0}^{l_n} dS$

$= D \times l_n^2 \times \tan\theta$ —— (5)

the total load located at a lump sum load, at the main feeder is —— (6)

$\% VD_n = 2/3 \times l_n \times k \times S_n$

put eqn eqn (5) in eqn (6) —— (7)

$\% VD_n = 2/3 \times k D l_n^3 \tan\theta$

from the fig we have.

$n \times 2\theta = 360°$ or $360/2n$ put in (7)

$$\left[\therefore \% VD_n = 2/3 \times kD\, l_n^3 \tan(360/2n) \right]$$ —— (8)

the above eqn holds good if $n \geq 3$ then different values can be obtained.

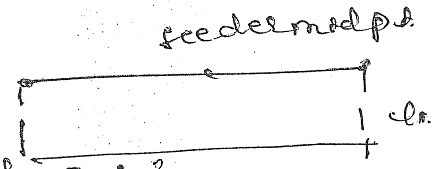
ie when $n = 1$, the voltage drop in the feeder main

$\therefore VD_1 = \frac{1}{2} kD l_1^3$.

when $n = 2$.

$\therefore VD_2 = kD l_2^3 \times \frac{1}{2}$.

when $n = 1$



Area $A_1 = l_1 \times l_1 = l_1^2$.

$S_1 = DA_1 = D l_1^2$

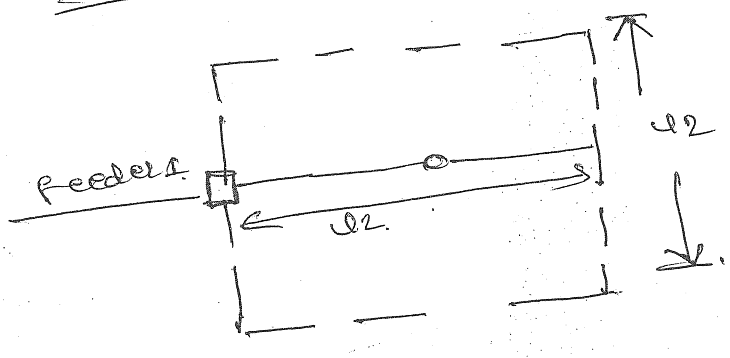
$\therefore$ VD at midpt

$VD_1 = \frac{1}{2} k l_1 \times S_1$.

$= \frac{1}{2} k l_1 \times D l_1^2$.

$\therefore VD_1 = \frac{1}{2} k D l_1^3$

at $n = 2$.



$A = l_2 \times l_2 = l_2^2$

$S_2 = DA_2 = D l_2^2$.

$\therefore VD_2 = \frac{1}{2} k l_2 \times S_2$

$= \frac{1}{2} k l_2 \times D l_2^2$

$\therefore VD_2 = \frac{1}{2} k D l_2^3$

the application of above equations in square & Hexagonal services when n>3 is used

n	θ	tan θ	% VD
4	45°	1.0	$\frac{2}{3}kDl_4^3$
6	30	$1/\sqrt{3}$	$\frac{1}{\sqrt{3}}\left(\frac{2}{3}kDl_6^3\right)$

4/4/13

* derive the relationships b/n the 4 and 6 feeder serving the distribution substation areas when the feeder ckts are thermally limited, ② vtg drop limited.

* thermally limited :- ckt for a given conductor size

Soln:- By neglecting the voltage drop, by comparing the load currents in a 4 feeder & 6 feeder i.e

$I_4 = I_6$

$$\frac{D l_4^2}{\sqrt{3}\, V_{LL}} = \frac{D l_6^2}{3 V_{LL}}$$

$$\frac{\text{total area served by all 6 feeders}}{\text{total area served by all 4 feeders}}$$

$$\frac{TA_6}{TA_4} = \frac{3\sqrt{3}\, l_6^2}{2\, l_4^2}$$

$$= \frac{3}{2\sqrt{3}}\left(\frac{l_6}{l_4}\right)^2$$

$$\boxed{\frac{TA_6}{TA_4} = 1.5}$$

it is clear that 6 feeder can carry the 6 times as much load as 4 factors if they are thermally loaded.

* vtg drop limited feeder ckts

for a given conductor size & assuming equal % voltage drop i.e. % VD4 = % VD6

$$\frac{2}{3} K D l_4^3 = \frac{2}{3\sqrt{3}} K D l_6^3$$

$$l_4^3 = \frac{1}{\sqrt{3}} l_6^3$$

$$\boxed{l_4 = 0.833\, l_6}$$

$$\frac{TA6}{TA4} = \frac{6/\sqrt{3}\, l_6^2}{4 l_4^2} = \frac{3}{2\sqrt{3}} \left(l_6/l_4\right)^2$$

$$= \frac{3}{2\sqrt{3}} \left(l_6/0.866\, l_6\right)^2$$

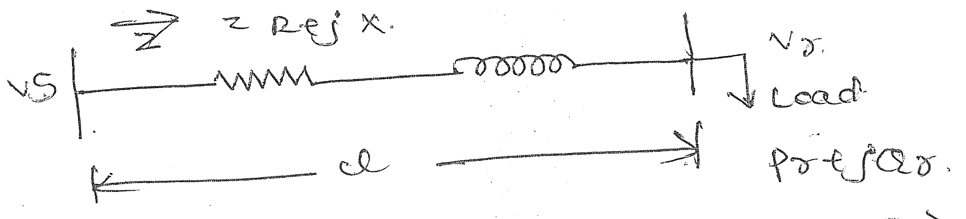
$$\frac{TA6}{TA4} = 1.25$$

∴ 6 feeder can carry only 1.25 times as much load as the 4 feeder if they are vtg drop limited.

Derivation of K concept.

* From the fundamentals derive an expression for constant K of a conductor & explain how it is useful in the calculation of % regulation — question paper.

Considering the primary feeder main shown in fig, as below.



Let the effective impedance Z, when the entire load is connected at the end of the main let Z be the impedance l = length of the feeder in miles

then effective impedance $\vec{Z} = 3 \times l$. ~~per phase~~

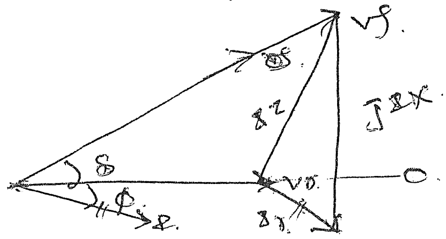
Suppose load is uniformly distributed

Suppose when ~~the load~~ has an increase in its load density

$Z = \frac{2}{3} Z l$.

taking receiving end voltage $\bar{V_R}$ $V_r = |V_r| \angle 0^\circ$

and sending end voltage $\bar{V_S} = |V_S| \angle \delta$



on I is lagging by V_r by ϕ.

then when the real power P and the reactive power Q flows in opposite direction then the pf is leading

∴ the % p, the p.u. voltage regulation

$$V_{R\,pu} = \frac{V_S - V_r}{V_r}$$

6931.82

$$\% V_R = \frac{V_S - V_r}{V_r} \times 100$$

$$\% V_R = V_{R\,pu} \times 100$$

% drop.

$$\% V_D = \frac{V_S - V_r}{V_b}$$

V_b is the base voltage

$$\% V_D = \frac{V_S - V_r}{V_b} \times 100$$

$$V_{D\,pu} = V_D \times 100$$

6/9/13 *** Derivation of k constant ***

*** Construction:-**

From the vector diagram, sending end voltage.

$$\vec{Vs} = \vec{Vr} + \vec{IZ}$$

$\therefore$ $Vs(\cos\delta + j\sin\delta) = Vr\angle 0^\circ + I(\cos\theta - j\sin\theta)(R + jX)$ —— ①

the unit is pu or mks (SI unit)

Now let us consider $R \simeq X$ & δ is nearly equal to zero

or $0 \leq \delta \leq 4^\circ$

Hence $X \gg R$ & in typical dr-line $\delta \cong 0^\circ$

$\therefore$ for a typical distribution ckt $\sin\delta$ is neglected

$\therefore$ $Vs \cong Vs\cos\delta$ $\therefore$ the equation ① becomes

$Vs \simeq Vr + IR\cos\theta + IX\sin\theta$ —— ②

$\therefore$ pu voltage drop for a lagging pf is.

$$V_{D pu} = \frac{IR\cos\theta + IX\sin\theta}{V_b}$$ —— ③

if V_D pu is -ve leading pu is -ve X, due to series capacitors installed in the circuits

the complex power is given by

$P_r + jQ_r = \vec{Vr}\,\vec{I}^*$ —— ④

$\therefore \vec{I} = \frac{P_r - jQ_r}{\overline{Vr}}$ —— ⑤ $\overline{Vr} = Vr\angle 0^\circ$

put equation ⑤ in equation ① where δ is neglected.

~~$Vs = Vr\angle 0^\circ + I(\cos\theta - j\sin\theta)(R + jX)$ pu~~

$$\overline{V_S} = V_r\angle 0^\circ + \frac{RP_r + XQ_r}{V_r\angle 0^\circ} - j\frac{RQ_r - XP_r}{V_r\angle 0^\circ} \quad (6)$$

$$\text{or } V_S \cong V_r + \frac{(RP_r + XQ_r)}{V_r} \quad (7)$$

Substitute eqn (7) into $V_{Dpu} = \frac{V_S - V_r}{V_b}$

$$\therefore V_{Dpu} = \frac{\cancel{V_r}\, RP_r + XQ_r}{V_r V_b} \quad (8)$$

$$\text{or } V_{Dpu} \cong (S_r/V_r)\, R\cos\theta + (S_r/V_r)\, X\sin\theta \quad (9)$$

pu voltage.

$$\text{or } V_{Dpu} \cong \frac{S_r \times (R\cos\theta) + S_r \times (X\sin\theta)}{V_r V_b} \quad (10)$$

Since $P_r = S_r\cos\theta$ watts (10)

$Q_r = S_r\sin\theta$ var (11)

equation (9) & (10) can also be derived from some equation (8) & (10) are in pu, nearly using line to neutral voltage values and perphase values for the constant P_r & Q_r & S_r to determine

$$\text{ie } V_{Dpu} \cong \frac{RP_r + XQ_r}{V_r V_b} \text{ pu - V}$$

$$V_{Dpu} \cong \frac{\left[S_{3\phi} \times S\,(r\cos\theta + x\sin\theta)\,(1/3 \times 1000)\right]}{V_r V_b} \quad (14)$$

$$V_{Dpu} = S \times k \times S_{3\phi} \text{ pu} \quad (15)$$

$$\text{or } V_{Dpu} = S \times k \times S_n \text{ pu - volts} \quad (16)$$

$$\text{where } k \cong \frac{(r\cos\theta + x\sin\theta)\,(1/3 \times 1000)}{V_r V_b} \quad (17)$$

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$k = f$ (conductor size, spacing, $\cos\theta$, V_b)

& it has the unit of

$= \frac{VDpc}{\text{arbitrary no of kVA in miles}}$

to obtain the percentage voltage drop

$$k = \frac{(r\cos\theta + x\sin\theta)(1/3 \times 1000)}{V_T V_b} \times 100$$

which has the unit of % VD. / arbitrary no of kVA mi

which has totaly the equation ke to 46, sis the effective length of feeder main which depends upon the nature of the load for example, when the load is connected at the end of the main as lumped sum

∴ the effective feeder length is $S = l$ unit length

when the load is uniformaly distributed along the main $S = 1/2 \times l$ unit length

when the load is increasing the load density

$S = 2/3 \times l$ unit length

* problem (4.2) in equations

a) % voltage drop in the main

$\% VD = S \times k \times S_D$

$= 1.0 mi \times \frac{0.01\ \% VD}{(kVA \times mi)} \times 500 kVA$

$= 5.0\%$

example 4.3 :-

8/4/13

* Substation application curves

$$\% VD_D = \frac{(2/3 \times l_D)\, k\, (n \times D \times A_D)}{n}$$

$$\% VD_D = \frac{TS_D^{3/2}}{n^{3/2} \times D^{1/2}} \times \frac{2/3 \times k}{(\tan\theta)^{1/2}}$$

* interpretation of the percent - vtg - drop formula

$$\% VD_D = \frac{(2/3 \times l_D \times k)\, n \times D \times A_D}{n}$$

$$= (2/3 \times l_D \times k)\, TS_D$$

$$= (2/3 \times l_D \times k)\, S_D$$

% VD_D = percent vtg drop in primary feeder
k = ... 2/3 × l_D = effective length primary feeder

TS_D = n × D × A_D = ~~total kv~~ ampere supply

* case - 2 => if load density is doubled. it causes TS_D & S_D is doubled ∴ % VD_D increases by (2) times

* case - 3 :- when a new feeder is added (feeder is doubled ∴ % VD reduces ~~by~~ 1/2, feeder reconducting

4) if k constant reduced by 1/2 then % VD reduced by half.

5) by converting Δ to grounded star, voltage reduced by 1/√3 times, also current reduces k/√3, then VD reduces 1/3rd of previous value

Q - How interrupt various factors of the percent vtg drop formula for different cases

* Assume that the annual peak load of primary feeder is 2000kw, at which the power loss ie the total copper loss or ΣI^2R loss is 80kw per 3-ϕ. Assume an annual loss factor of 0.15 determine a) The avg annual power loss b) The total annual energy loss due to the copper losses of the feeder circuits.

→ given peak load = 2000kw I^2R loss = 80kw.
Loss factor = 0.15.

we have Loss factor = $\frac{\text{avg power loss}}{\text{peak load power loss}}$

∴ avg power loss = 0.15 × 80kw
= 12kw

b) The total annual energy loss is
= avg power loss × 8760hr/yr.
= 12kw × 8760.
= 105120 kwh

* There are six residential customers connected to a DT as shown below. Assume that the connected load is 9kw per house & that the demand factor and diversity factor are 0.65 & 1.10 respectively. determine the diversified demand of group of six houses on DT.

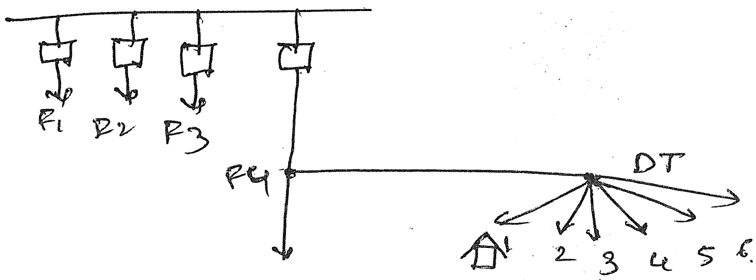
$$D_g = \frac{\sum_{i=1}^{n} TCD_i \times DR}{FD}$$

$DR = 0.65$

$FD = 1.1$

$$= \frac{\left(\sum_{i=1}^{6} 9\,kW\right) \times 0.65}{1.1}$$

$$= \frac{6 \times 9\,kW \times 0.65}{1.1} = 31.9\,kW$$



* ASS.

* Assume that

* idealized Load data for No light & No power company primary feede Load kw

Time	Street lighting	Residential	Commercial
12 A.M	100	200	200
1	100	200	200
2	100	200	200
3	100	200	200
4	100	200	200
5	100	200	200
6	100	200	200
7	100	300	200
8		400	300
9		500	500
10		500	1000
11		500	1000
12 Noon		500	1000
1		500	1000
2		500	1200
3		500	1200
4		500	1200
5		600	1200
6	100	700	800
7	100	800	400
8	100	1000	600
9	100	1000	400
10	100	800	200
11	100	600	200
12	100	300	200

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Load forecasting.

* The ~~a~~ load growth of the geographical ~~area~~ served by the utility company is most important factor influencing the expansion of the distrib slm

→ hence forecasting of load will influences the factor for ~~expansion~~ of ~~distribution~~ ~~slm~~ planning process

→ forecasting of load can be expressed with the help of equation $y_t = ab^x$ —— (1)

this expression is known as growth equation

this equation is used to explain the phenomenon of growth through ~~time~~.

→ for example if the load growth rate is known, then the load at the end of the nth year is given by

$$P_n = P_o(1+g)^n \quad —— (2)$$

Where P_n = is the load at the end of nth year

P_o = initial load g = annual growth rate.

& n = number of years.

→ Now if we set $P_n \rightarrow y_t$

$P_o \rightarrow a$

$(1+g) = b$ $n = x$.

then the equation (1) & (2) becomes similar

for such a equation we can write MATLAB computer program to forecast ~~dem~~ future demand values if past demand values are known ~~known~~.

→ In order to plan the resources which are required to supply future load demand within the area, it is much more necessity to forecast the ~~as~~ accurately as possible the magnitude & distribution of these loads.

→ However certain adjustments are to be made for load transfer into and out of the area.

→ Methods which forecast the future demand by location will divide utility service area into a set of small area forecasting the load growth in each.

→ In order to plan T&D Sm it is ~~not~~ necessary to study not only overall load on a region, but we need to study & forecast load on a "spatial basis ie "analyzing it on total and on a local area" basis throught the sm.

→ define how much, where, the load growth.

→ Trend or regression analysis. — it is the study of behavior of time series or a process in the past and its mathematical modeling so that the future demand can be defined.

→ Trend analysis are.

1) fitting of continous mathematical function through actual data in order to achieve ~~at~~ the least overall error, known as regression analysis

2) the fitting of a sequence on discontinuous lines or curves to the data.

The second concept is most commonly used is short term ~~small~~ -forecasting.

* distribution sim load can be divided into following major 4 components

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a) Basic trend.
2) seasonal variation, ie monthly or yearly variation of load,

3) cycle variation which influences of period longer than the above & causes the load pattern to be repeated for 2 or 3yr or even more.

4) Random variations which occur ~~on~~ due to day to day changes.

→ The principle of regression theory is any fcn $y = f(x)$ can be fitted to set ~~of~~ points (x_1, y_1), (x_2, y_2) to minimize the sum of errors squared to each point

ie $\varepsilon^2 = \sum_{i=1}^{n} [y_i - f(x_i)]^2 = \text{min.}$

→ Typical regression curves used in PS forecasting.

Linear = $y = a + bx$

exponential $y = a(1+b)^x$

power $y = ax^b$

polynomial $y = a + bx + cx^2$

Gompertz $y = ae^{-be^{-cx}}$

Unit 3&4 - System planning

→ planning is a process of taking careful decision. It involves selecting the vision, values, mission and objectives and deciding what should be done to attain them.

→ The objective of distribution planning is to provide satisfactory service at the lowest possible cost.

→ The various components of planning process is as shown below

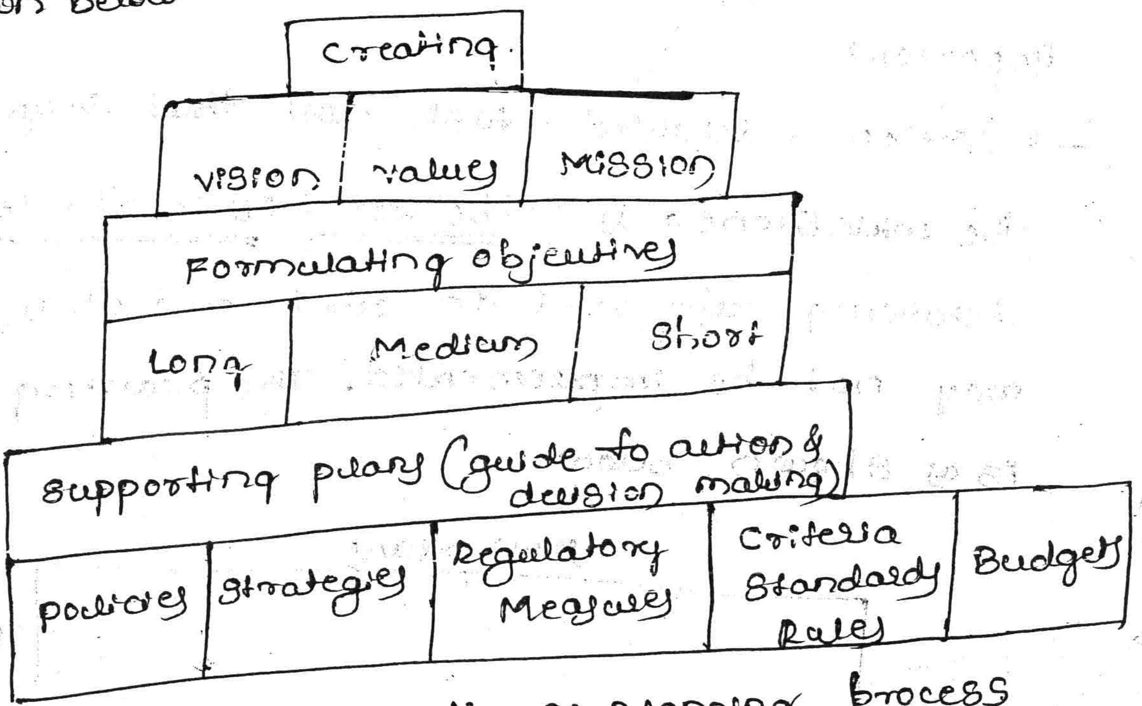

fig - components of planning process

The above fig shows various components of planning process & the different steps involved in the planning process are →

① Feasibility studies are carried out to identify, evaluate and finalise the best plan.

Define the problem → find the alternatives → evaluate the alternatives, → ~~evaluate the~~ select the best one

ii) A detailed project report for long, medium and short term works along with action plan/ pert chart/ bar chart for each activity/ work is prepared.

iii) Final approval is accorded after financial and economic appraisal.

iv) once the best plan has been selected, the next process of implementation begins.

While executing the plan, monitoring is important.

→ develop a detailed task list that ~~supplies~~ supports the mile stones as " the devil is in the detail", without detailing who will do, what and when, the plan may not be implemented. The planning action is as shown below.

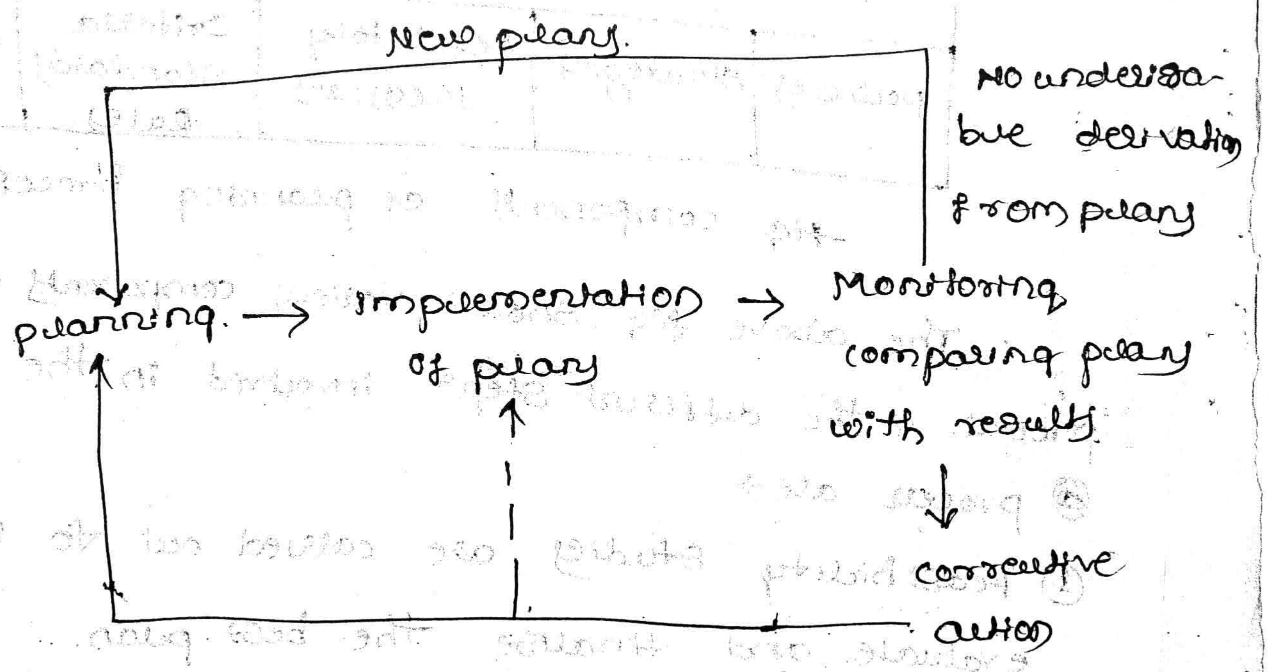

fig - planning actions

* Basic principles in distribution s/m planning

Any distribution system planned is used to transport a certain amount of power to maximum capability from source point to another location.

→ planning determines the routing of lines, locations of new, substations, distribution transformers

→ The transformation of electricity from one bulk power location to the consumer site, & x-ers change voltage level of the power by considering the following basic principles

1) It is more economical to transport power at a high voltage. The higher voltage reduce the cost/ kW to transport power to a distant point.

2) Electricity travels as per KCL & KVL laws. It follows least resistance path.

3) power must be delivered in relatively small quantity at a low voltage level. (400V / 230V)

4) voltage drop occurs from source point to end location

5) equipment & labour come at cost.

6) operation & maintenance add to service cost.

7) Future growth of load is accounting is much more needed.

8) When power is used for any purpose by the

consumer, the responsibility lies on the consumer to share the degradation of environment on this account.

* Nominal ~~s/m~~ rated system voltage is most efficient voltage for equipment operation. If the voltage rise above this voltage then their is a reduction of Pf of equipment.

* electricity market :- Wholesale, retail, bi-lateral contracts will cut down the cost of supply.

The main steps in planning power distribution are as shown below. The goal is to provide electricity at the lowest possible economic & social cost.

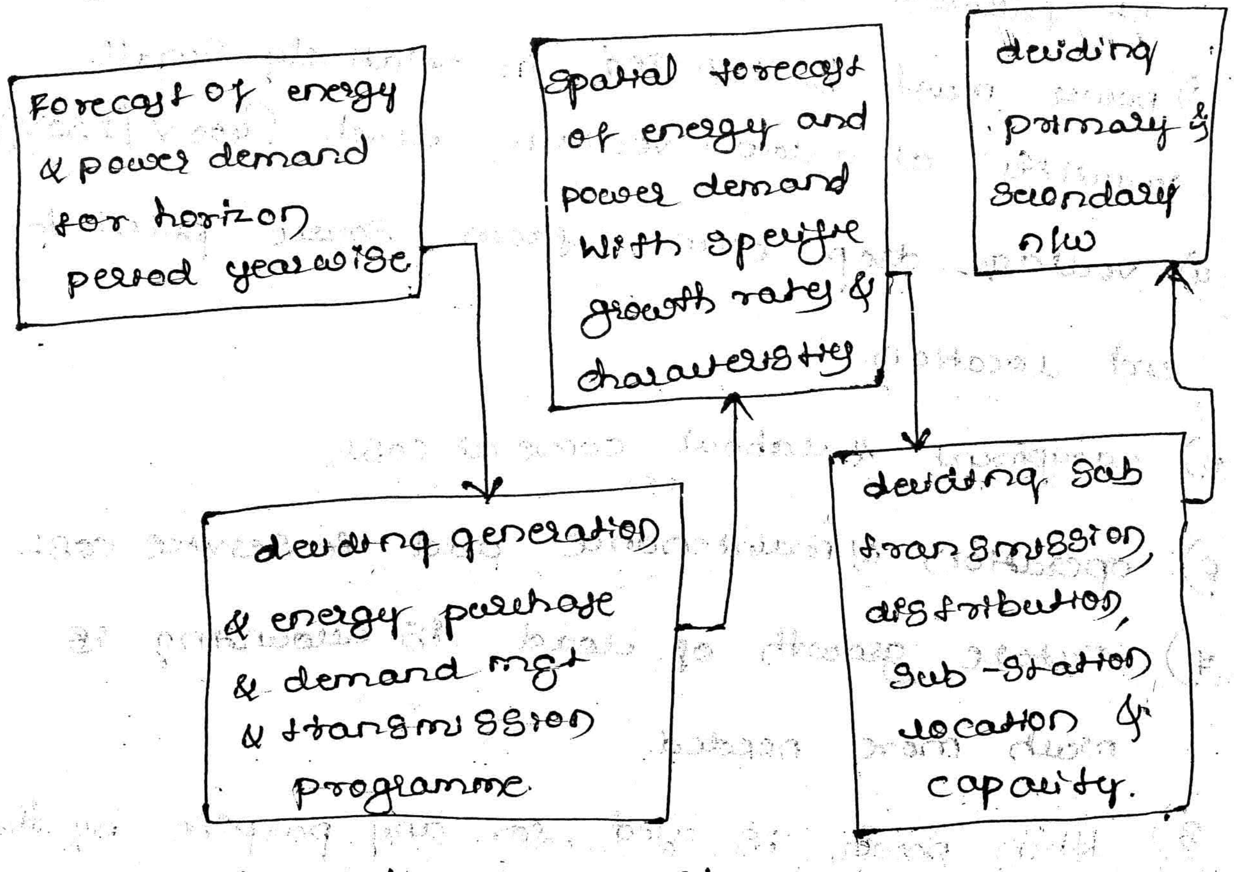

fig- steps for power s/m planning.

* planning method.

The planning of integrated resources requires the following two methods.

i) Traditional least cost planning
ii) demand side Management (DSM)

* Traditional least cost planning :- It is a process which minimises the cost of electricity supply

→ It is the method of acquiring the resources at the lowest cost, taking into account of all possible needs to meet the electricity needs and all the resource costs including construction, operation, subtransmission, distribution, consumer & environment costs.

* 1stly the existing s/m inadequacies are identified as →

1) poor voltage regulation
2) Higher s/m losses.
3) Higher equipment failure/ breakdown/ higher line breakdowns /trippings
4) Bad quality of power supply.
5) No scope for future load growth.

However initial investment to improve such a s/m is cost effective in removing all the above mentioned difficulties.

∴ There are two options →

a) s/m improvement

b) expansion of the existing n/w

* **s/m improvement** :- Augmentation and strengthening of the existing s/m, improve reliability and quality of supply. reduction of commercial and technical losses.

* **expansion of existing n/w** :- The least cost optimal solution from various cost of proposed works and present values of the kW and energy losses ~~are~~ over the excepted life of equipment while expansion of n/w.

* **Demand Side Management (DSM)**

It is a planning, implementation and evaluation of utility activities designed to encourage consumers to modify their electricity consumption patterns.

→ DSM has the potential to modify the energy cost to consumers & it also minimise the adverse environmental impacts — reduction of GHG emissions

→ The report of "National development council committee" on power has indicated the potential of energy consumption as follows

Industrial → 20%

Agriculture → 80%

Domestic & Residential → 20%

* Monitoring and evaluation :- A detailed benefit cost analysis include identifying the avoided supply cost for the utility via the total programme cost for the utility and benefits to the consumer including the reduced bills or incentives to the end users

* DSM benefits households, industry, agriculture, and society in the following ways.

1) Reduced consumer energy bills
2) Reduces the need for power plant & transmission & distribution construction.
3) Stimulates the economic development.
4) creates the long term jobs that benefit the economy.
5) can reduce the equipment replacement cost & maintenance cost.
6) Reduces local air pollution.
7) Enhances national security by dependence on foreign energy resources.
8) it will increase the comfort and quality of work spaces, which in turn increases worker productivity

with the help of different techniques.

utility DSM programme generally fall into three main category they are

1) conservation programme
2) Load management programmes
3) strategic load growth programmes

* **conservation programme** :- these programmes helps to reduce energy use with to improve the efficiency of equipment, buildings & industrial processes as per Energy conservation Act, 2001

* **Load - Management programme** :- They help to redistribute energy demand to spred it more easily throughout the day.

Some of the ways to achieve this is

1) load - shifting programme,
2) time of use rates (charging more at peak load demand)
3) interruptible rates → providing discounts in exchange for the right to reduce consumers

* **Strategic load growth programme**

Increased use of energy during some periods for example encourage cost-effective electrical technologies which operate mainly

~~operate~~ during the time period of low electricity demand for this the different approaches are used They are →

1) General information programmes to inform consumers about general energy efficient options.

2) Site specific information programmes which provide information about specific DSM measures appropriate for a particular ~~frequency~~ industry, agriculture or home.

3) Financing programmes to assist consumer to pay for DSM measures including loans, shared saving programmes

4) Direct installation programmes ~~to assist consumers to pay for DSM measures including loans,~~ that provide complete services to design, finance & install a package of efficiency measures.

5) alternative tariff programme such as time-of-use tariff, interruptible tariff and load-shifting tariff. However these programmes will not reduce the energy usage but they are effective ways to shift loads during off-peak periods.

6) Market information programmes that helps to change market for a particular technology or the services so that efficient technology can be preferred.

* **Load limiters** are effective in demand side management, as they helps to limit the maximum power that the consumers draw from supply.

* Encourage captive / co-generation power and distributed generation.

The process of designing and implementing DSM programmes generally consists the following steps ⇒

1) Identifying sectors, end-uses and efficiency measures to target.
2) developing programme design.
3) conducting cost effective screening
4) preparing an implementation of plan
5) Implementating programmes.
6) evaluating the programmes

* **System development**

Large amounts of power is generated at power plants and sent to a n/w of high voltage (220, 132, 110, 66 or 33 kV) sub-transmission lines

→ These sub-transmission lines supply power to distribution centres feeding primary distribution s/m, which supply power to the still lower voltage 0.415 kV distribution

Secondary S/m.

∴ The total n/w is a complex grid of interconnected lines.

* The n/w has a function of transmitting power from the points of generation to the points of consumption.

* However the power utilities should plan their investment programmes to 5 to 10 years in advance through annual plans with detailed list of investement.

* However the location of subtransmission lines and distribution substation is made after conducting computer based load flow studies of varies alternatives.

* distribution s/m is much more important to an electrical utility for two reasons.

1) Its proximity to the ultimate consumer & its high investment cost.

2) The objective of distribution s/m planning is to ensure that the growing demand of electricity with growing rates can be satisfied in an optimum way.

* Therefore the distribution s/m planner divides the whole problem of ~~planning~~ total distribution system into a set of subproblems and they can be handled with the help of different technologies.

* Sub-transmission :-

1) The sub-transmission designates the circuits which deliver energy from the transmission system to the primary distribution system.

2) Increased load growth and demand results in the reduction of transmission voltage.

3) as a result voltages from 220kv is down to 33kv which are found in sub-transmission systems.

3) distribution system is connected with four elements ie sub transmission, substation, feeder system and consumers.

4) The system augmentation/strengthening is then worked to meet the proposed demand as well as to identify the constrains in the backup system. The various options are →

① Augmentation of power transfer capacity at the existing distribution sub-station.

② Re-arranging or Re configuration of the sub-transmission feeders from the new trans-mission sub-station nearby, augmenting the line conductors.

③ Establishing new 66/11 kv or 33/11kv sub-station nearer to the load centres and re-distributing the load b/n existing & sub-stations s/m

⟹ Load flow analysis helps to compare the losses for vary alternatives.

⟹ However power utility should prepare a code of practice for New expansion & DSM to meet the increased demand & to improve the stability & quality of supply.

⟹ The s/m expansion for the purpose of releasing of power connection is done as per the distribution code. The other considerations are - i) designs as per the ~~distribution~~ code

ii) construction standards.

* **Distribution substations - siting**

planning of the substation is done by considering the impact of any siting or sizing decision on all four levels.

The main criteria for selecting a substation site is as follows ⟹

i) proximity of load :- some sites are close to the existing transmission line or can be reached at a low cost. Some other sites require lengthy or underground access, leads to addition of cost

ii) out-going feeder space :- getting a feeder out of a substation requires right-of-way.

iii) geographic :- Nearby terrain or public facility may constrain feeder routing and increases costs.

iv) Site preparation :- The slope, drainage and underlying soil or rock determine the cost of preparing the site for a substation & building the foundation etc.

v) cost of land :- Some site costs more than others.

vi) Weather exposure :- The some sites on hilltops are more exposed to lightning and adverse weather, increasing some operation & maintenance costs.

* Service area location

The service area for a substation should be as far as practical, circular. The consumer should be served from the nearest substation. which will make the supply line distance as short as possible to reduce losses, costs & service interruption exposure.

⇒ in order to apply the concept the best approximation is made by per bisector rule.

⇒ The per bisector rule consists of following steps →

i) Draw a straight line b/n a proposed substation site and each of the substations surrounding it.

ii) Then draw a perpendicular bisect of each of these lines.

iii) The area enclosed by the ⊥er bisectors around the proposed substation will be the service area as shown in below figure.

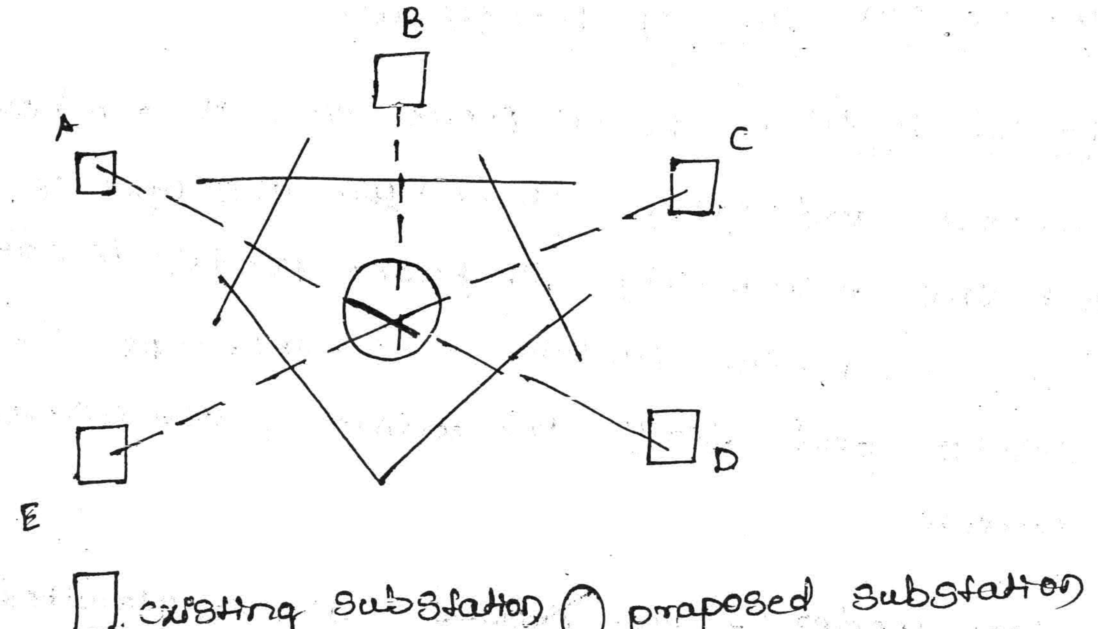

fig - process of substation siting.

iv) The shifting of the load nearby substations can be determined from the area falling within the polygon.

v) Therefore the 'optimal site' for a new substation is determined by an iterative process.

★ Feeder system

Feeder is a part of the distribution s/m connected to load locations and needs.

Voltage drop, power flow, power quality & cost are more important point of consideration. In the

* feeder system

* More than 80% of the distribution world wide is accomplished with the help of radial feeder in which one path is b/n consumer & substation.

* The various types of feeders are

1) Radial feeder :- Radial feeder circuits are having low cost and easy to analyze and operate. But the reliability of Radial feeder is low

=> any equipment failure will interrupt the service and leads the consumers downstream from it.

2) Loop feeder :- Two feeders are constructed and operated as a loop feeder circuits & they are tapped for consumers as show in below fig.

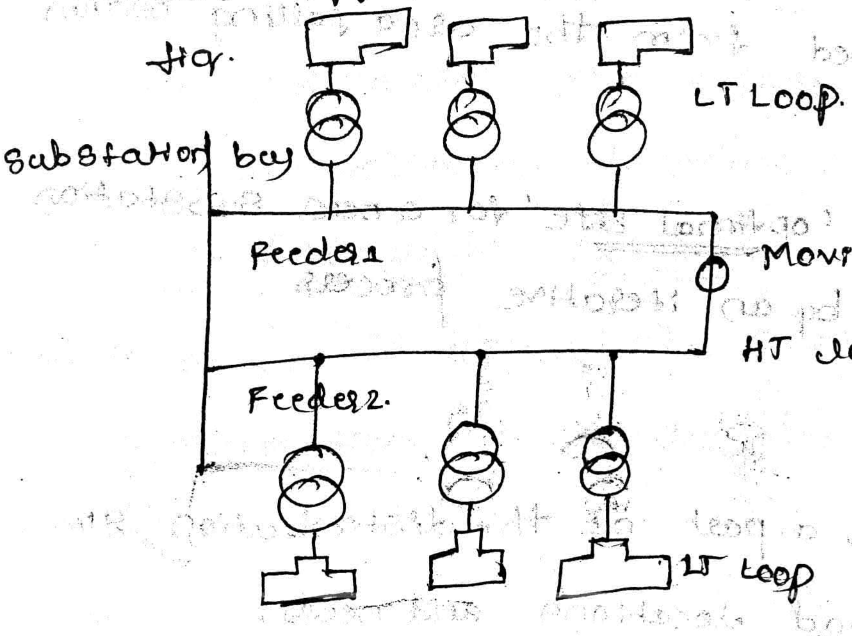

fig - HT & LT loop feeders

→ This is basically a dynamic radial circuit with an open point (null point) shifting as the load changes.

⇒ When such type of loops are constructed & protected properly, it provides a high level of reliability for the consumer.

* **Feeder N/w** :- feeder N/w consists of a group of feeders which are interconnected ∴ there is always more than one route b/n any two points in the feeder N/w.

This s/m gives high level of reliable power to the consumer & cost of such a s/m is very high compare to radial s/m.

→ The voltage drop, fault behaviour & load flow studies are little bit complicated.

* **planning criteria and standards.**

⇒ planning criteria and standards together form a set of requirements against which the planning process can compare alternating in the evaluation & final choice.

⇒ A distribution plan must provide good economy and it should also satisfy various criteria and standards.

⇒ Criteria are rules or procedures. Standards are the specifications to ensure that the system is built with compatible equipment that will fit and function together when installed and maintained in the economical manner.

* The following steps describe the typical criteria for planning.

1) A perspective plan must be prepared for next 15 years to meet the anticipated load growth & forecast load centres. However the plan will ~~must~~ be reviewed yearly on the basis of annual plans wrt to the targets achieved.

2) A detailed project reports must be formed to identify strengthening of the work on long term and short term basis

   i) Feeders having poor performance :- for which reconfiguration of feeder or augmentation of line conductors & distribution transformers must be performed.

   ii) New technology can be adopted for system improvement.

   iii) Loss minimization plans are to be adopted

3) DSM project reports are to be undertaken based on pay back period financial analysis to achieve tangible reduction in demand and energy consumption in the planned horizon year.

4) Security ➡ i) In industrial cities, alternative source of supply is provided by using sub transmission open ring circuit of 33 or 66kv or 132 or 220kv.

ii) In all urban estates 11kv open ring main s/m is to be provided.

iii) In case of rural area, separate feeders to be provided.

5) The following voltage levels to be used for release of power connections to consumers

i). The connected load upto 10kw to be supplied at 240v, single phase two-wire.

ii) connected load b/n 10kw and 50kW to be supplied at 415/240v, 3-ϕ four wire.

iii) load demand b/n 50 kW and 5MW to be supplied at 11kv.

iv) Load demand b/m 5MW & 30MW to be supplied at 33 or 66kv.

6) power utility would create and use load research facilities in order to identify consumer load profiles in the respective geographical area of the s/m to forecast changes in the load.

7) the no of 11kv outgoing feeders at the distribution sub-station should not exceed 10.

8) Loss minimization could be achieved by

a) LT line not exceed 0.8 km. In city area, the aerial bunched cables to be used for LT.

b) Improved metering. ie electronic meters to be provided for all types of consumers

9) Total harmonic distortion at any voltage level should be within 5 percent.

10) 3-ϕ fault levels should not exceed 2000 MVA and 750 MVA respectively at 66kV and 33kV level.

* The different planning standards are as follows

1) Development of a standard cost structure for material and labour rates for different voltage systems to be considered in the estimation.

2) Standards for S/m voltage as per Indian Standards and voltage as per IE regulation.

3) The load growth of at least 10 years will be taken into account to prepare new or S/m improvement schemes.

4) Fixed LT capacitors on the distribution transformers shall be installed.

5) One mobile substation to replace fixed substations when such substations are out

of service due to abnormal conditions.

* **distributed generation/dispersed generation**

distributed /captive generation as per section 9 & 14 of the electricity act 2003 are freely permitted without any licence.

* Microgrids integrate wind, solar energy and in some cases, diesel generators or storage s/ms can provide can provide power from a mix of resources to typically a village or cooperative.

* distributed generation with local ^radial distribution n/co will play an important role in the 21st century.

* distributed generation is generally from local renewable resources, which saves environment degradation compared to conventional thermal generation. The most promising technologies are →

1. Fuel cells
2. Solar photovoltaics
3. wind power
4. Tidal and wave power from ocean
5. Small hydro
6. Geo-thermal
7. Bio - mass
8. Muncipal and industrial waste

* there are certain issues considered while connection to grid & it requires careful analysis

1) voltage unbalance is not more than 3% at 33 kV and 3.5% of 11 kV.

2) voltage rise
3) Island operation
4) Increase in short circuit level
5) Impact on power quality.

A typical grid connection of distributed generation is as shown below.

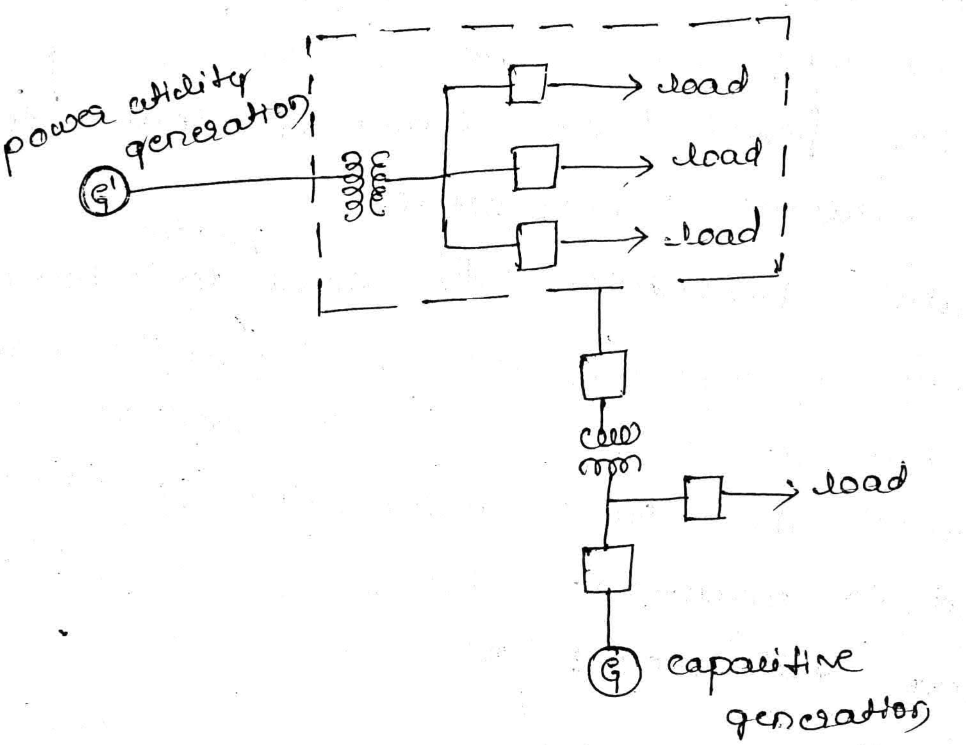

fig - capacitive power connection to grid supply

* On the basis of life cycle costs, including social cost of environmental degradation, DG has to be found cost-effective.
* power factor at connection to grid should not be less than 0.98 lagging as per CEA regulations of grid - connectivity 2007.
* Net metering :- The kWh meter can be used to accurately register the flow of electricity in

either direction.

∴ The netting process associated with net metering happens automatically. The meter is normal direction when consumer needs more electricity than is being produced & spins backward when consumer producing more electricity than is needed in the house or building.

* Studies and estimates undertaken (2001) by the Ministry of Nonconventional sources reveal that India has potential for generating 45,000 MW wind, 15000 MW from Small hydro, 19500 MW from biomass, 2700 MW from waste, 10,000 MW from geo-thermal, & 15000 MW from ocean tides.

* There is a need to attract developers to the country renewable potential of power generation on the basis of a tariff based bidding system.

* Distribution System economics and finance

Economic analysis is carried out to determine low cost plan among various alternatives.

⇒ Financial analysis determine the rate of return and risk involved on the investment which is to be made on plan.

* The investment made on distribution s/m includes

1) Annual expenses → obtained from operating revenue.

2) Capital expenditure → obtained from financing

reinvested reserve, reinvested earnings, consumers contribution for service connections.

* 3) Both annual expenses and capital expenditure.

For an investment to be worthwhile the estimated return on capital must be greater than the cost of capital. However investment decision is made on alternative proposals with the following methods

* **Economic Analysis.**

* **Minimum Revenue requirement:-**

A choice is made on the basis of the present value of all future annual costs. i.e the economic choice is the one with the lowest present value of all future costs. The economic comparison b/n alternatives involve two steps

① for each alternative, estimate the annual cost for each year.

② If the annual costs are not uniform, then calculate the present value.

* **Time value of Money:-** Money has time value & interest on its use to be paid.

→ However the rate of interest is determined by the RBI according to the economic conditions at that time.

* there is a similar mechanism is used to determine the interest rate at the international

level also.

* If the current interest is 10% then RS 100 today is equivalent to RS 100 (1+0.10) or RS 110 at the end of year.

* for n no of years in future this amount computed by the factor is $(1+i)^n$ and future value is RS 100 after n' years will be $100(1+i)^n$

The process of taking money and finding its equivalent value at some future date is called <u>future value</u> calculation. & the process of finding the equivalent value at some earlier time is called <u>present value calculation</u>.

* <u>Revenue requirement</u> of <u>Investment</u> :- The total revenue requirement of investement is the sum of the <u>annual charges</u> extending over the service life

It includes →

1) Return on investment
2) depreciation
3) Insurance expenses
4) operating & maintenance expenses
5) Interest on loan capital & working capital
6) Taxes etc.

However the above charges can be conveniently estimated as a % of the original investment.

* Three formats are given below to calculate

the present value.

* Cumulative present worth method.
* Levelised Annual cost method.
* uniform series present worth method.

* **Cumulative present worth method** :- When the annual revenue requirement are non-uniform, the sum of the present value of the revenue requirements for each alternative is calculated.

The most economical alternative will have the min present value of the revenue requirement.

→ In case the annual revenue requirements are uniform throughout the service life or steady period, the alternative with the minimum annual revenue requirements will be the most economical.

* **Levelised annual cost method** :- The level annual carrying charge is the %, by which capital investment (P) can be multiplied in order to determine its annual ~~cost~~ capital cost on uniform basis.

* It is desirable to calculate the annual capital costs investment made for each alternative scheme.

* The capital investment (P) made today is converted to an equivalent annual annuity (R) using the uniform capital recovery factor, $i(1+i)^n / (1+i)^n - 1$ as shown in below fig

$\therefore R = P.i(1+i)^n / (1+i)^n - 1$

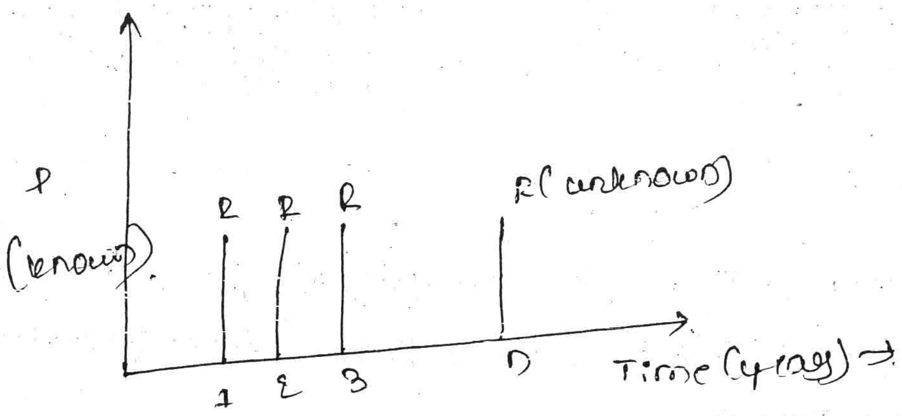

fig - uniform annual charge.

* <u>uniform series present worth method</u> :- In economic analysis, there exist a uniform series of annual costs or payment (R') that extend to next n no. of years. In order to compare the present worth (p') for the uniform annual series of payments, the formula is given below. $p' = \frac{R'(1+i)^n - 1}{i(1+i)^n}$

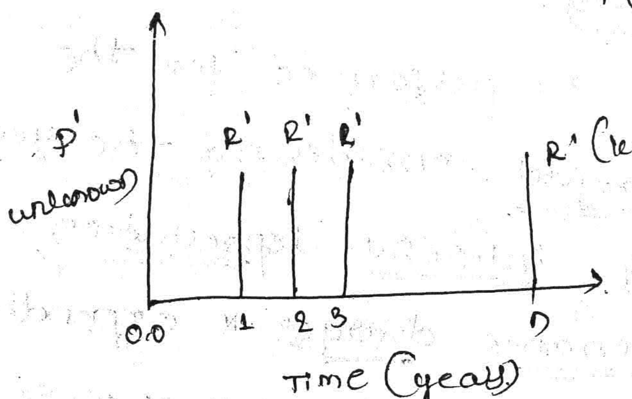

fig - uniform series present worth.

These three revenue requirement methods all are equivalent.

* Financial analysis

1) Benefit/cost Ratio :- This method ranks a project by the ratio of present value of revenue (income) and benefits earned to the present value of the costs.

* System improvement works are generally evaluated based on a benefit cost basis by the Rural electrification corporation of India

* The central electricity Authority (CEA) uses this method for such schemes to evaluate cost - benefits.

* The work proposed for strengthening, upgradation and improvement of sub-transmission & distribution s/m help in reducing technical & commercial losses by the year.

* However the s/m is also be able to meet the load demand in the horizon year with a resultant increase in sale of energy.

* The financial analysis is performed for the year-wise time of the project considering the year wise costs including interest, depreciation, operation and maintenance charges & expenditure made for additional sale of energy. & year wise gross benefit including the income from additional energy & saving done due to saving in losses.

* However a project is acceptable if Benefit cost ratio exceeds one ⇒

* ① go on increasing s/m energy efficiency until the cost saved energy reaches the cost of supply and delivery of electricity.
② An optimal level of n/w losses reaches, when the cost of further reduction would exceed the cost of supplying the losses.

* **Life-cycle cost** :- It is the total cost including initial purchase, installation cost, maintenance cost & disposal of project cost, with all costs adjusted or discounted to reflect the time value of Money

* The design which provides long life with low total cost it is to be selected; alternatives of new constructions, retrofit, HVAC etc. are selected based on lowest total cost.
* This method helps to calculate the rate of interest or discount rate which is to be needed for the present value of the return, to be same as the present value of the investment needed.
* A project is acceptable if its internal rate of return exceeds the capital cost.

* **Payback period**.

The length of time period required to recover the initial investment cost is computed for each alternative.

→ However this method does not consider the time value of money and the use of investment after the payback period.

* The alternative which is having lowest payback period is to be selected. acceptable payback period for utility project range from 1 to 5 years

Mapping

1) **Global positioning system (GPS)**

GPS is a system in which earth orbiting satellites provide precise information on time and position is enabled with GPS receiving devices to compute position on earth.

* The signals must be received from atleast 3 satellites in order to establish the latitude & longitude of the receiver, while 4th satellite is required to calculate altitude.
* There are certain rules for sharing the use of GPS satellites for Geographical information system (GIS)
* GIS deals with spatial information and it require following.

i) 24 US Naval GPS satellites in different orbits about 17,700 km above the earth. The orbits are such that any time, atleast 4 satellites are above the horizon for an observer

ii) portable mobile GPS receivers.

iii) Base receiver station positioned at a known geographical area.

GPS technology is used to locate tap-off points, transformers and other facilities of power distribution network and concertly to map the system with an accuracy of upto one meter.

* GPS can be used to capture network data for 11kV and above voltage level distribution / sub transmission lines and substations / distribution xTers for mapping.

Background Maps

Background paper maps with the ~~largest~~ latest geographical information are necessary to draw correct digital n/w.

* Geographical information of various states is usually maintained by agencies like Survey of India, the aerial survey and satellite imagery departments of National Remote Sensing agency (NASA)
* the topological sheets covering each state are available from the Survey of India at Rs 20-25 per sheet.

Digital mapping

* Digital mapping software can be used to create an integrated and automated facility model in which paper maps are digitized 1st & then suitably linked
* A digitizer board is used for digitizing nodes wrt to the a reference point which is prefixed on the map.

* one person is able to read co-ordinates on the digitized board and other person can feed it into a computer.

* once digitization is completed, the software numbers the nodes, draws the network diagram & calculates the length

* computer processing centre will issue prescribed format to obtain electrical loading data of feeders, transformer capacity, size/type of the feeder for the concerned data.

* The following steps should be taken to prepare the maps →

a) The complete area should be covered & duplication avoided.

b) The 132-33kV S/S to be digitized 1st followed by 11kV and finally the 415/240V network.

c) differential survey with GPS instruments and VHF sets may be required for dense urban areas to capture various attributes of the S/S.

d) oracle RDBMS is suitable for data storage.

The process of digitally mapping the n/w is as shown above.

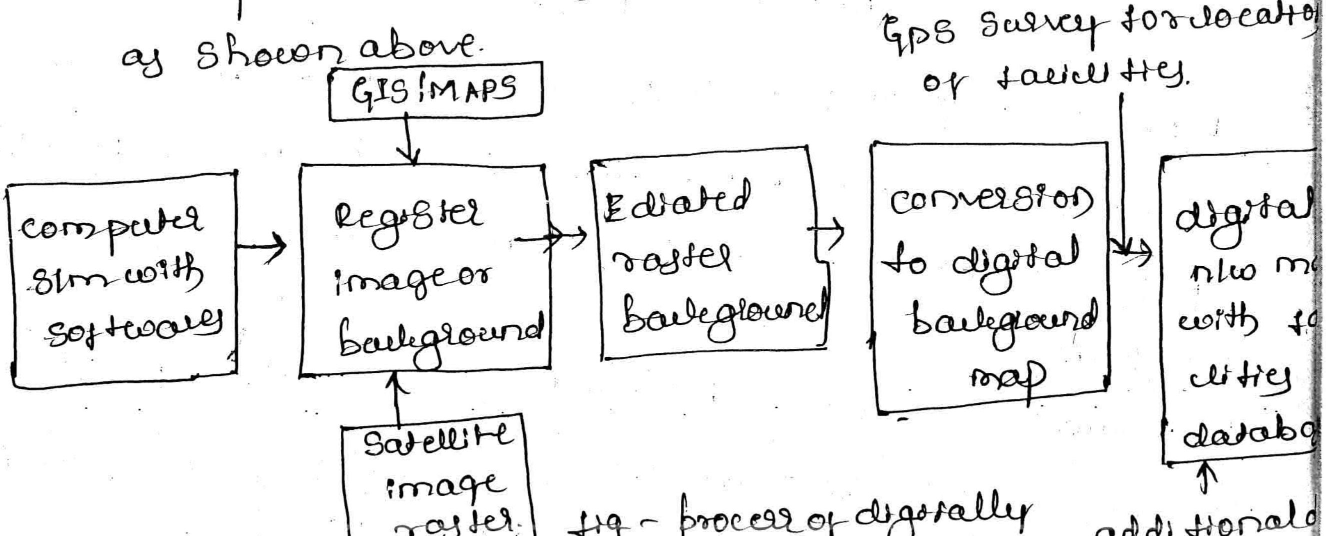

fig - process of digitally mapping n/w.

* Automated Mapping (AM) / Facilities Management / Geographical Information System (GIS)

Every transaction, whether it is a work order, billing, operation system improvement or maintenance is tied to a location.

* AM & FM provide an integrated tool to create an automated facilities model and helps to convert paper maps into digital environment where sl/m details & its changes are fed and stored in a graphic and tabular database.

* FM software links the graphic n/w map to tabular and non-graphic data associated with the databases, work orders, drawings etc.

* The Role of GIS.

GIS is a sl/m of mapping of complete electrical n/w including low voltage sl/m and consumer meter. Database plays a central role in the operation of planning, where analysis program form a part of the sl/m supported by database management system which stores, retrieves and modifies various data on the distribution system.

* Electrical utility companies need two types of geographical information. →

1. Details on the location of facilities and information on the spatial interrelations b/n them.
2. The integration of geographically referenced database, analytical tools & in house software

Software tools will allow the s/m to be designed more economically and operated closer to its limits resulting in more efficient, low cost power distribution systems

* different additional benefits such as improved material management, inventory control, maintenance & s/m performance can be accomplished in systematic & cost-effective manner.

* all information s/ms are built around relational data base management (RDBMS) and constantly updated.

* However establishing the relationship b/n these information system & GIS is only, in defining a relationship b/n objects in two systems

* The ultimate aim of AM/FM/GIS is to integrate the dynamic side of the operation with the relatively static side of the utility facility record for effective utilisation by all functional departments.

* The different features of the AM/FM/GIS s/m are

1. explicit spatial representation of the facilities network linked to related data.
2. Integrated facility database & its management with multi-user-access.
3. Management of different assets.
4. optimum data for facility applications

* The software platform with database and document warehouse may include the following →

1) Installed facility records

2) change orders : pending, implemented.
3) Standard equipment costs
4) Standards, practices & criteria for design, operation & maintenance.
5) Land use
6) Maintenance and inspection records
7) equipment, operations, trouble history & records
8) Facility operating data

* Applications

i) The planning department requires field data of land records. Load growth is based on population growth and demand, existing n/w layout and general land base data.

ii) Estimation & costing :- For a planning engineer to develop estimates and prepare costing reports, bill of materials etc. based on standard costs, energy audit.

iii) **Management reports** :- Management reports are the reports like ongoing works, failures in operation, damaged replaced or newly-commissioned during a certain period.

iv) **Design / operational logistics** :- The operational requirements may need re-configuration of the electrical s/m during abnormal conditions and during electrical system analysis.

v) **Maintenance** :- To perform maintenance, testing & fault root-cause analysis.

vi) **Troubleshooting** :- To support help desks &

improve consumer services.

* **GIS process**

① create a digitised background map of the area fro Survey of India maps.

② Carry out GPS survey with GPS receiver to locate the substations / transformers / poles / consumer points etc. GPS receiver figure out the distance to each satellite and use this information to figure out its own locat

③ Attribute data of each pole and other facilities collected during the survey - such as asset data, transformer details, cables, line poles, services, type of use, load, consumer details etc.

④ preparation of N/w in GPS package.

⑤ Layers of information are contained in these map representations.

i) The 1st layer corresponds to the distribution N/w coverage

ii) The 2nd layer corresponds to the land back ground containing roads, landmarks, buildings rivers, railway crossings etc.

iii) The next layer could contain equipment namely poles, conductors, transformers etc.

* **Network analysis.**

The electrical database of the N/w can be imported from the GIS/AM/FM into various analysis runs for carrying out studies

① voltage profile / load flow analysis

② Fault flow analysis.

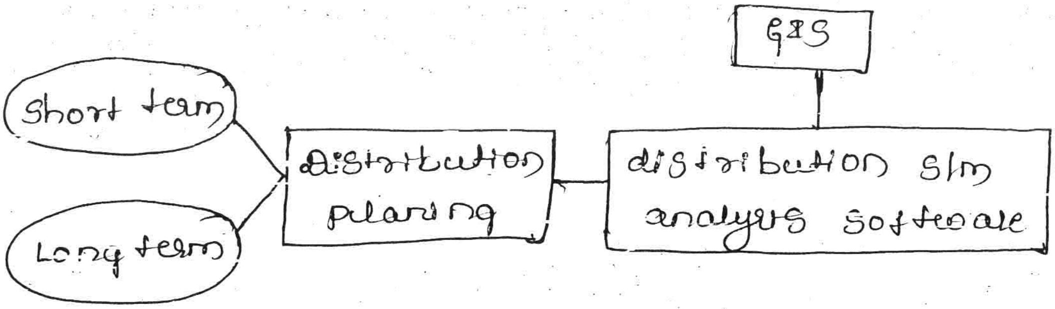

fig - GIS based distribution s/m analysis.

③ capacitor placement

④ contingency analysis

⑤ For separating the s/m losses into technical losses and commercial technical.