24/12/2020

Unit-V

Distribution of Electrical power

Introduction:

* The electric utility industry was born in 1882 when the first electric power station, peal street Electric station in Newyork city, went into operation.
* The electric utility industry grew very rapidly, and generation stations & T/m & distribution n/w's have spread across the entire country.
* Consider the energy needs and available fuels that are forecasted for the next century, energy is expected to be increasingly converted to electricity.
* In general, the definition of an electric power system includes a generating, a T/m, and a distribution system.
* In the past, the distribution s/m, on a national average, was estimated to be roughly equal in capital investment to the generation facilities, and together they represented over 80% of the total system investment.
* In recent years, however, these figures have somewhat changed.
* Production expense is the major factor in the total electrical operation & maintenance (O&M) expenses, which typically represents 2/3rd of total O&M expenses.
* The main reason for the increase has been rapidly escalating fuel costs.

* Again, the major O&M expenses has been in the production sector, followed by the one for the distribution sector.
* Succinctly put, the economic importance of the distribution s/m is very high, and the amount of investment involved dictates careful planning, design, construction & operation.

Distribution System planning

* System planning is essential to assure that the growing demand for electricity can be satisfied by distribution s/m additions that are both technicaly adequate & reasonably economical.
* Even though considerable work has been done in the past on the application of some types of systematic approach to generation & T/m s/m planning, its application to distribution s/m planning has unfortunately been somewhat neglected.
* In the future, more than in the past, electric utilities will need a past fast & economical planning tool to evaluate the consequences of different proposed alternatives and their impact on the rest of the s/m to provide the necessary economical, reliable, and safe electric energy to consumers
* The objective of distribution s/m 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 s/m's, from the secondary conductors through the bulk power substations,

which are both technically adequate & reasonably economical.

* All these factors and others, for example, the scarcity of available land in urban areas & ecological considerations, can put the problem of optimal distribution s/m planning beyond the resolving power of the unaided human mind.

* Distribution system planners must be determine the load magnitude and its geographic location.

* Then the distribution substations must be placed and sised in such a way as to serve the load at maximum cost effectiveness by minimizing feeder losses & construction costs, while considering the constraints of service reliability.

* The distribution system is particularly important to an electrical utility for two reasons:

1. its close proximity to the ultimate customer &
2. its high investment cost.

* Since the distribution system of a power supply system is the closest one to the customer, its failures affect customer service more directly than, for example, failures on the T/m and generating s/m's, which usually do not cause customer service interruptions.

* Therefore, 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.

* Once the customer loads are determined, they are grouped for service from secondary lines connected to distribution T/F's that step down from primary voltage.
* The distribution T/F 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 T/m voltage.
* The distribution system loads, in turn, determine the size & location, & ~~sitt~~ siting, of the substations as well as the routing and capacity of the associated T/m lines.
* The distribution s/m planner partitions the total distribution s/m planning problem into a set of sub problems that can be handled by using available, ~~using~~ usually ad hoc, methods & techniques
* The planner, in the absence of accepted planning techniques may restate the problem as an attempt to minimize the cost of sub T/m, substations, ~~feeders~~, laterals, etc., and the cost of losses.
* In this process, however, the ~~planning~~ planner is usually restricted by permissible voltage values, voltage dips, flicker, etc., as well as service continuity and reliability.

* In pursuing these objectives, the planner ultimately has a significant influence on additions to and/or modifications of the sub T/m n/w, locations and sizes of substations, service areas of substations, location of breakers & switches, sizes of feeders & laterals, voltage levels & voltage drops in the system, the location of capacitors and voltage regulators, and the loading of transformers and feeders.
* There are, of course, some other factors that need to be considered such as transformer impedance, insulation levels, availability of spare transformers and mobile substations, dispatch of generation, and the rates that are charged to the customers.

Factors affecting Distribution s/m planning:

* The number & complexity of the considerations affecting s/m planning appear 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 constraints that circumscribe the designer have also become more.
* These include the scarcity of available land in urban areas, ecological considerations, limitations on fuel choices, the undesirability of rate increa

and the necessity to minise investments, carrying charges & production charges.

* Succinctly put, the planning problem is an attempt to minimise the cost of sub Tlm, substations, feeders, laterals, etc., as well as the cost of Ex losses.

* Indeed, this collection of requirements & constraints has put the problem of optimal distribution s/m planning beyond the resolving power of the unaided human mind.

Load ForeCast

→* The load growth of the geographic area served by a utility company is the most important factor influencing the expansion of the distribution system.

* Therefore, forecasting of load increases and s/m reaction to these increases is essential to the planning process.

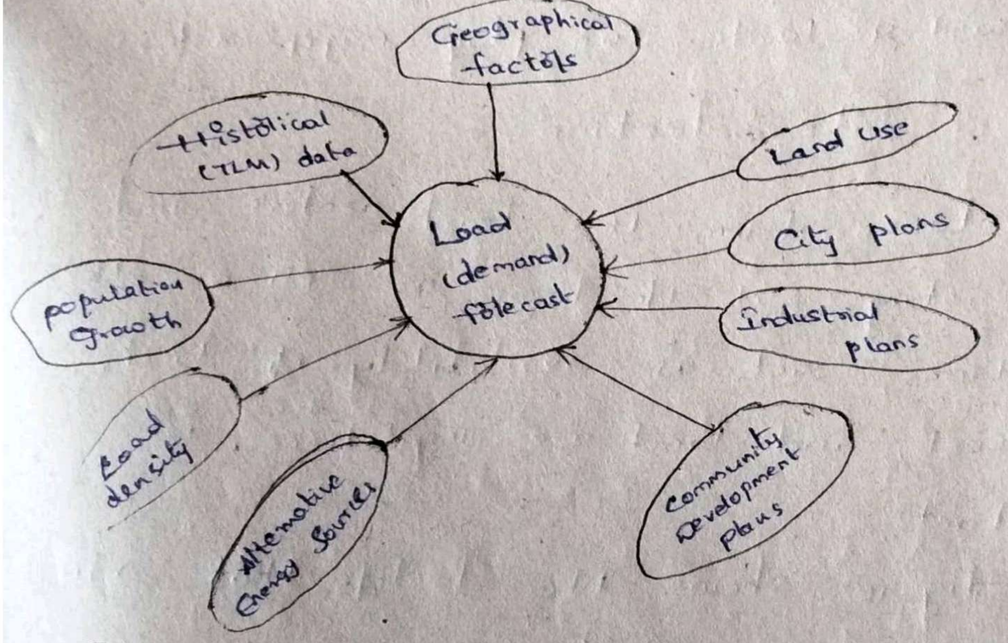
* There are two common time scales of importance to load forecasting: long range, with time horizons on the order of 15 or 20 years away, & short range with time horizons of upto 5 years distant.

* Ideally these forecasts would predict future loads in detail, extending even to the individual customer level, but in practice, much less resolution is sought or required.

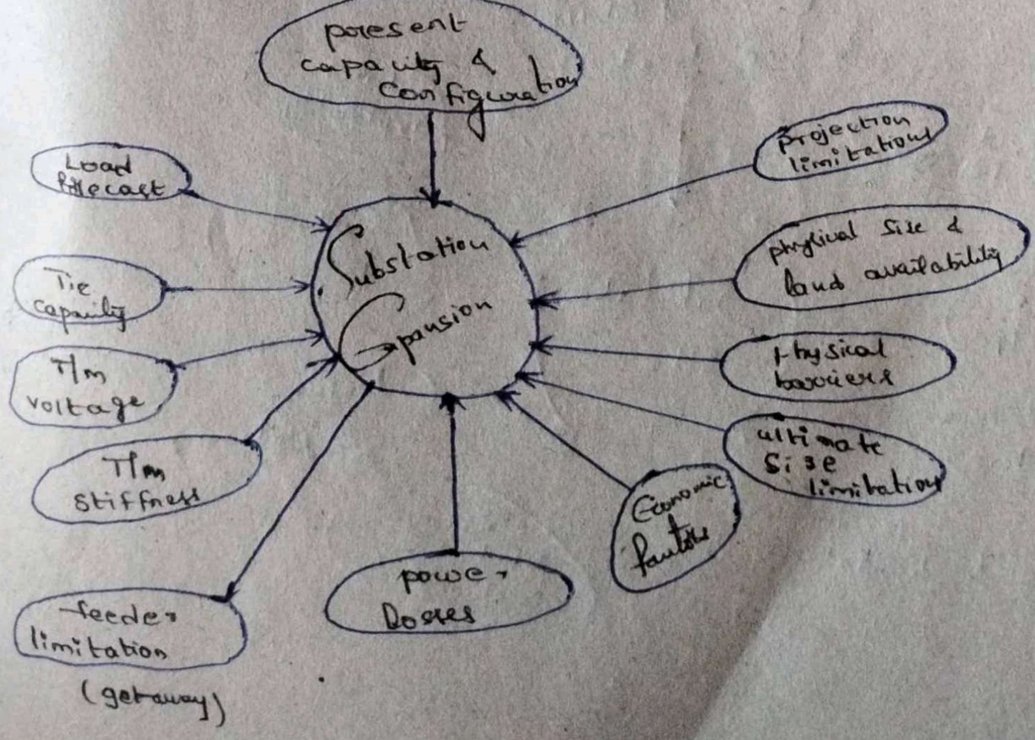
* As one would expect, load growth is very much dependent on the community and its development.

* Economic indicators, demographic data, and official land use plans all serve as raw input to the forecast procedure.
* Output from the forecast is in the form of load densities (kVA per unit area) for long range forecasts. Short-range forecasts may require greater detail.

Factors Affecting Load Forecast



Substation Expansion

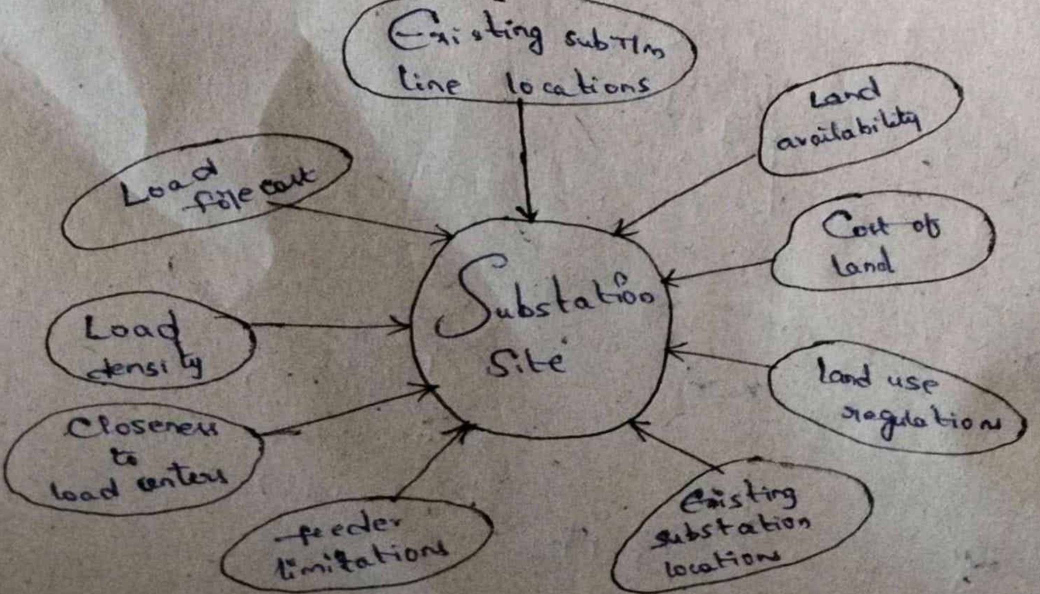


Substation Expansion

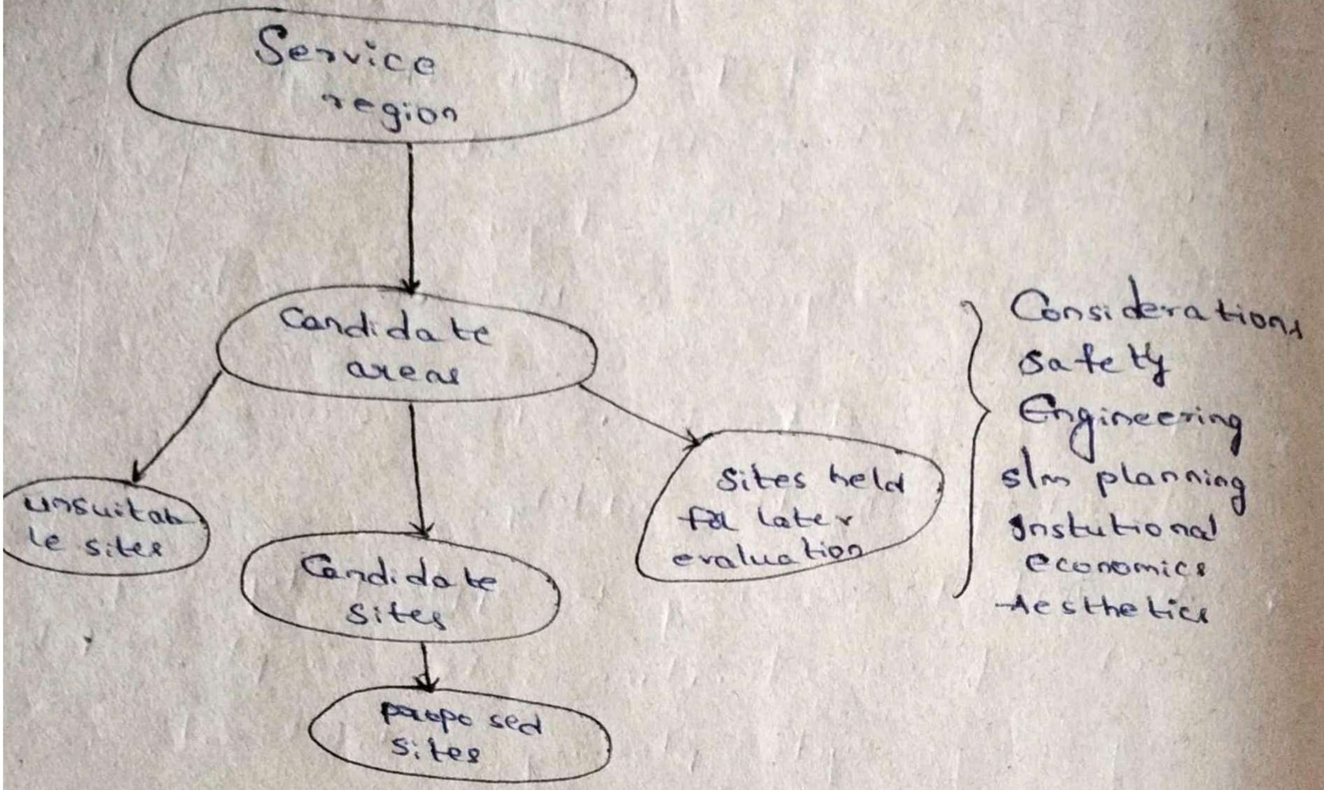
* The planner makes a decision based on of intangible information.
* For example, the forecasted load, load density, and load growth may require a substation expansion of a new substation construction.
* In the system expansion plan, the present system configuration, capacity, and the forecasted loads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

Substation Site Selection:

* The distance from the load centers and from the existing sub T/m lines as well as other limitations, such as availability of land, its cost, and land use regulations, is important.
* Below figure shows the factors that affect substation site selection.

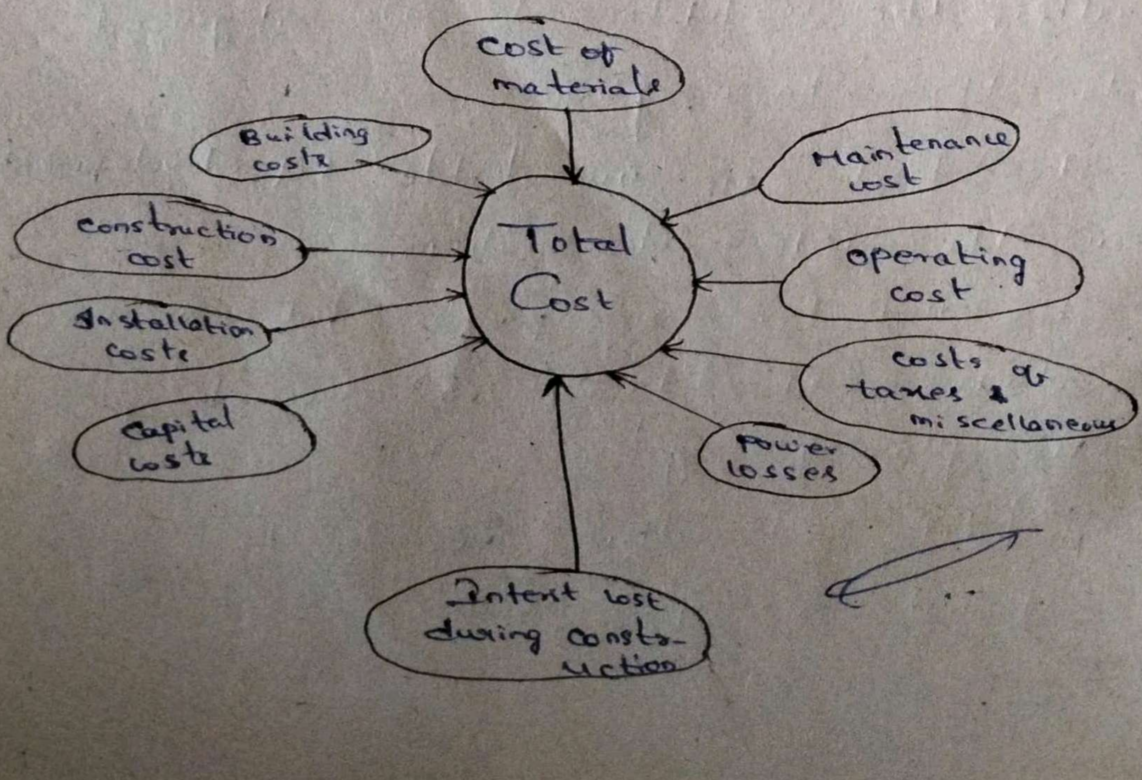


* The substation siting process can be described as a screening procedure through which all possible locations for a site are passed, as indicated in below figure.
* The service region is the area under evaluation.
* It may be defined as the service territory of the utility.
* An initial screening is applied by using a set of considerations, for example, safety, engineering, system planning, institutional, economics, and 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.
* Further, the candidate sites are categorised 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,
  3) Candidate sites that are to be studied in more detail.



Other Factors:

* 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, and total cost, as shown in below figure, need to be considered.



Distribution System planning Models

* In general, distribution s/m planning ~~indicates~~ dictates a complex procedure due to a large no. of variables involved and the difficult task of the mathematical presentation of numerous requirements & limitations specified by s/m configuration.
* Therefore, mathematical models are developed to represent the s/m & can be employed by distribution s/m planners to investigate and determine optimum expansion patterns or alternatives, for example, by selecting

1. Optimum Substation locations.
2. Optimum substation expansions.
3. Optimum substation T/F sizes.
4. Optimum load transfers b/w substations and demand centers.
5. Optimum feeder routes & sizes to supply the given loads subject to numerous constraints to minimize the present worth of the total costs involved.

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

1. The alternative - policy method, by which a few alternatives policies are compared and the best one is selected.
2. The decomposition method, in which a large problem is subdivided into several small problems & each one is solved separately.

3. The linear-programming, integer-programming and mixed-integer programming methods that linearize constraint conditions
4. The quadratic programming method
5. The dynamic-programming method
6. Genetic algorithms method.

→* Each of these techniques has its own advantages and disadvantages.

→* Especially in long-range planning, a great no. of variables are involved, and thus there can be no. of feasible alternative plans that make the selection of the optimum alternative a very difficult one

→* The distribution s/m costs of an electric utility company can account for up to 60% of investment budget and 20% of operating costs, making it a significant expense.

→* Minimizing the cost of distribution s/m can be a considerable challenge, as the feeder system associated with only a single substation may present a distribution engineer with thousands of feasible design options from which to choose.

* Finding the overall least cost plan for the distribution system associated with several neighboring substations can be truly intimidating task.

* The use of computer aided tools that help identify the lowest cost distribution configuration has been a focus of much R&D work in the past three decades.
* As a result, today a no. of computerised optimization programs can be used as tools to find the best design from among those many possibilities.
* Such programs never consider all aspects of the problem, and most include approximation that slightly limit accuracy.
* Expansion studies of a distribution s/m have been done in practice by planning engineers.
* The studies were based on the existing system, forecasts of power demands, extensive economic and electrical calculations, and planner's past experience and engineering judgement.
* However, the development of more involved studies with a large no. of alternating projects using mathematical models and computational optimization techniques can improve the traditional solutions that were achieved by the planners.
* As expansion costs are usually very large, such improvements of solutions represent valuable savings.

* For a given distribution s/m, the present level of electric power demand is known and the future levels can be forecasted by one stage, for example, 1 year, or several stages.

* Therefore, the problem is to plan the expansion of the distribution system to meet the demand at min. expansion cost.

* In the early applications, the overall distribution s/m planning problem has been dealt with by dividing it into the following two sub problems that are solved successfully:

1. The sub problem of the ~~proble~~ optimal sizing and/or location of distribution substations.

* In some approaches, the corresponding mathematical formulation has taken into account the present feeder n/w either in terms of load transfer capability b/w service areas or in terms of load times distance.

2. The sub problem of the optimal sizing and/or locating feeders.

* Such models take into account the full representation of the feeder n/w but without taking into account the former sub problem.

* However, there are more complex mathematical models that take into account the distribution planning problem as a global

problem and solving it by considering minimization of feeder and substation costs simultaneously.

* Such models may provide the optimal solutions for a single planning stage.

* The complexity of the mathematical problems and the process of resolution become more difficult becoz the decisions for building substations and feeders in one of the planning stages have an influence on such decisions in the remaining stages.

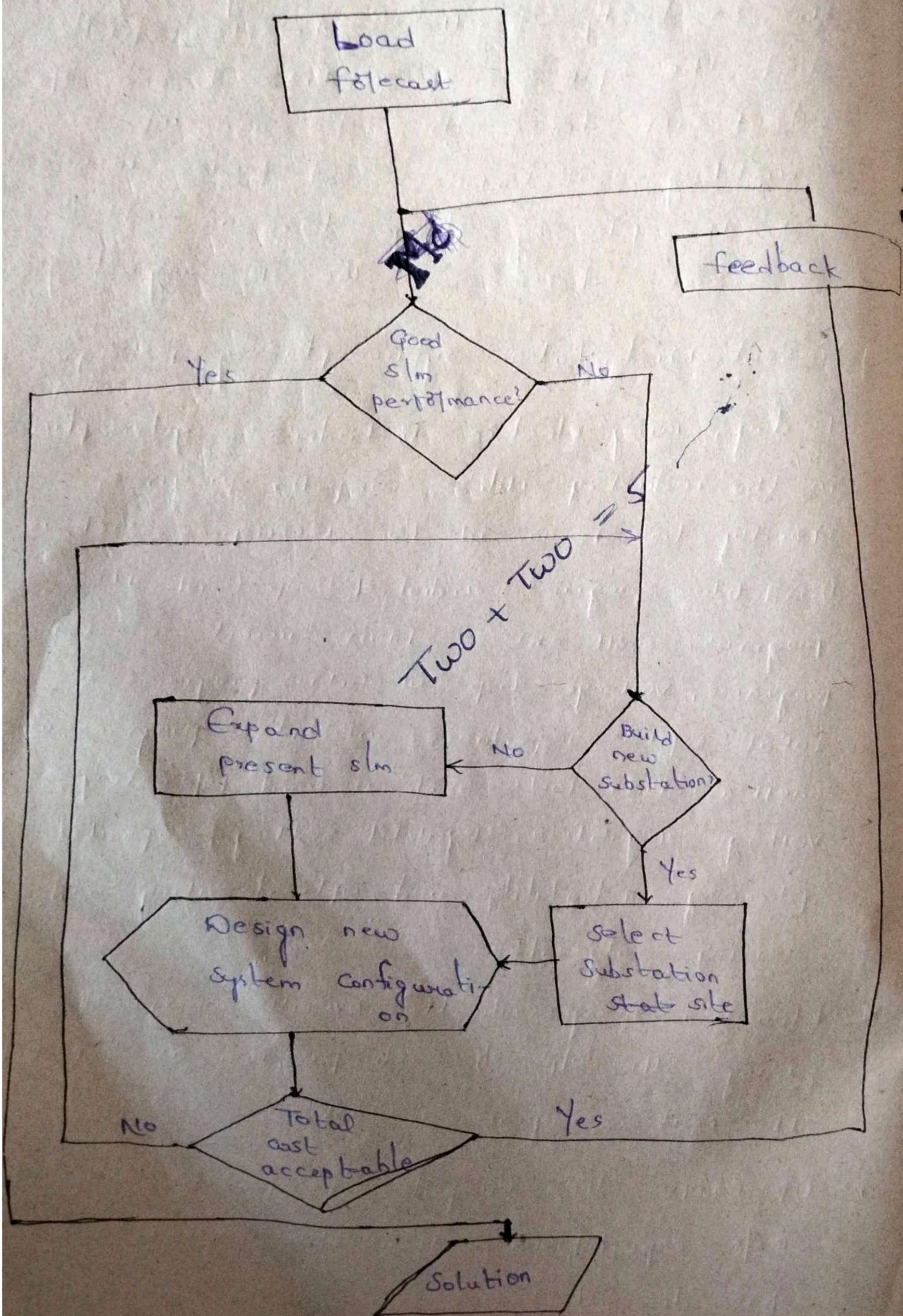
Present Distribution system planning techniques

* Today, many electric distribution system planners in the industry utilize computer programs, usually based on ad hoc techniques, such as load flow programs, radial or loop-load flow programs, short ckt & fault-current calculation programs, voltage drop calculation programs, & total system impedance calculation programs, as well as other tools such as load forecasting, voltage regulation, regulator setting, capacitor planning, reliability, and optimal siting and sizing algorithms.

* However, in general, the overall concept of using the o/p of each program as input for the next program is not in use.

* Of course, the computers do perform calculations more expeditiously than other methods & free the distribution engineer from detailed work.

* The engineer can then spend time reviewing results of the calculations, rather than actually making them.



* Figure shows a functional block diagram of the distribution system planning process currently followed by most of the utilities.
* This process is repeated for each year of a long - range (15 - 20 years) planning period.
* In the development of this diagram, no attempt was made to represent the planning procedure of any specific company but rather to provide an outline of a typical planning process.
* As the diagram shows, the planning procedure consists of four major activities; load forecasting, distribution s/m configuration design, substation expansion, and substation site selection.
* Configuration design starts at the customer level.
* The demand type, load factor, and other customer load characteristics dictate the type of distribution s/m required.

* Once customer loads are determined, secondary lines are defined, which connect to distribution transformers.
* The latter provides the reduction from primary voltage to customer level-voltage.
* The distribution T/F loads are then combined to determine the demands on the primary distribution s/m.
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* The primary distribution s/m loads are then assigned to substations that step down from sub T/m voltage.
* The distribution s/m loads, in turn, determine the size & location (siting) of the substation as well as the route & capacity of the associated sub T/m lines.
* As illustrated in figure, if the results of the performance analysis indicate that the present system is not adequate to meet future demand, then either the present s/m needs to be expanded by new, relatively minor, s/m additions, or a new substation may need to be built to meet the future demand.
* If the decision is to expand the present s/m with minor additions, then a new additional n/w configuration is designed & analyzed for adequacy.

* If the new configuration is found to be inadequate, another is tried, and so on, until a satisfactory one is found.
* The cost of each configuration is calculated.
* If the cost is found to be too high or adequate performance cannot be achieved, then the original expand-or-build decision is reevaluated.
* If the resulting decision is to build a new substation, a new placement site must be selected.
* Further, if the purchase price of the selected site is too high, the expand-or-build decision may need further reevaluation.
* This process terminates when a satisfactory configuration is attained, which provides a solution to existing and future problems at a reasonable cost.
* Many of the steps in the earlier procedures can feasibly be done only with the aid of computer programs.