

Stable Planning of Distribution Network

*Thesis submitted in partial fulfillment of the requirements for
the award of degree of*

**Master of Engineering
in
Power Systems & Electric Drives**



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CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled, "Stable Distribution System Planning" in partial fulfillment of the requirements for the award of degree of Master of Engineering in Power System & Electric Drives submitted in Electrical & Instrumentation Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of *Dr. Smarajit Ghosh* and refers other researcher's works which are duly listed in the reference section.

The matter presented in this thesis has not been submitted anywhere for the award of any other degree.



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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.


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ABSTRACT

Planning of distribution substation is an important task to the planning engineer. The main aim of the planning engineer is to reduce the cost as well as the loss of the system. But the two at a time may not be feasible. Hence a compromise has to be made. Literature survey shows that the works reported so far are either optimization of substation to reduce the feeder path or connection of load points to a substation with its location fixed in all possible routes so that the cost is optimal. But till date design of substation with stability has not been proposed.

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CHAPTER 1

INTRODUCTION AND LITERATURE SURVEY

1.0 Introduction

Energy is the basic necessity for the economic development of a country. Energy used per person depends upon the standard of living of people of that country. The higher is the per capita consumption of electricity of a country, higher the standard of living of her people. Energy may be needed as heat, as light, as native power etc. Electrical energy is superior to all other forms of energy in respect of its

- (i) convenient form
- (ii) easy control
- (iii) greater flexibility
- (iv) cheapness
- (v) cleanliness and
- (vi) high transmission efficiency.

The major problems which electric utilities are facing in India are: to improve the quality and reliability of supply and to reduce the cost of production of electricity and to utilize the existing distribution system in a better way. There has been a lot of development in generation and transmission sector. Both these sectors have seen a considerable increase in capital investment but the distribution systems have been neglected.

1.1 Distribution Systems

The distribution system is the vital link connecting the generators that produce electric power to the equipment that uses it. The transmission and distribution systems are similar to circulatory system of a human body. The transmission system may be compared with arteries in the human body and distribution system with its capillaries. They serve the same purpose of supplying the ultimate consumer in the city with the life-giving blood of civilization called electricity. The part of power system which distributes electric power for local use is known as distribution system. In general, the distribution system is the electrical system between the

sub-station fed by the transmission system and the consumer meters. It generally consists of feeders, distributors and the service mains. Figure 1.1 shows the distributor.

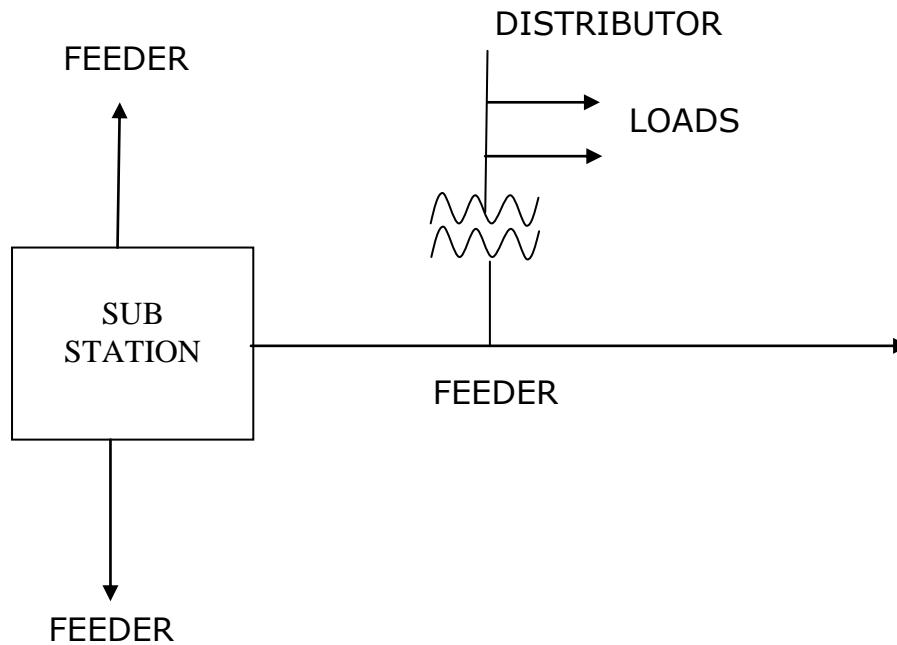


Figure 1.1 Distributors

Electrical energy is generated, transmitted and distributed in the form of alternating current. Alternating current is mostly used and given preference over direct current because of one main reason that it can be conveniently stepped up and down by using transformer. HVDC system of transmission is also gaining popularity because of the development of power electronic devices. Transformer has made it possible to transmit ac power at high voltage and utilize it at a safe potential. High transmission and distribution voltages have greatly reduced the current in the conductors and hence the line losses also.

The ac distribution system is classified into

- (i) primary distribution system and
- (ii) secondary distribution system.

Primary distribution system is part of ac distribution system which operates at voltages somewhat higher than general utilization and handles large blocks of electrical energy than the average low-voltage consumer uses. The voltage used for primary distribution depends

upon the amount of power to be conveyed and the distance of the sub-station required to be fed. The most commonly used primary distribution voltages are 11 kV, 6.6 kV and 2.2 kV. Due to economic considerations, primary distribution is carried out by 3-phase, 3-wire system. The main advantage of using more primary distribution networks is; it allows greater power carrying capability using less current. In addition to the increased capacity, higher voltage also results in

- Less voltage drop
- Decreased losses
- Ability to operate over greater distances, thus decreasing the number of substations required to serve a given area.

The primary distribution system is that portion of the power network between the distribution substation and the utilization transformers. The distribution substation is usually the delivery point of electric power in large industrial or commercial applications.

One disadvantage of the greater reach is that it tends to result in more customer interruptions due to the greater number of customers per protected circuit.

Secondary distribution system is that part of ac distribution system which includes the range of voltages at which the ultimate consumer utilizes the electrical energy delivered to him. The portion of network between the primary feeders and utilization equipment comes under secondary distribution system. The secondary distribution employs 400/230 V, 3-phase, 4-wire system. The voltage between any two phases is 400 V and between any phase and neutral is 230V. The single phase domestic loads are connected between any one phase and the neutral whereas 3-phase 400 V motor loads are connected across 3-phase lines directly. All distribution of electrical energy is done by constant voltage system. In practice, the distribution circuits are radial in nature.

1.1.2 Main requirements of a distribution system

- (i) ***Voltage Constraint:*** Voltage variation at consumer end should be as low as possible. The main reason of voltage variation is the changes in the load of the system. Low voltage occurs due to the variation of load on the system which causes loss of revenue, inefficient lighting and possible burning out of motors. High voltage can cause many problems e.g. insulation of motors can get damaged, lamps filaments may burn out and almost all appliances can get damaged. Therefore, voltage variations at

the consumer end should be in permissible limits. The statutory limit of voltage variations is $\pm 6\%$ of the rated value at the consumer terminals. Thus, if the declared voltage is 230 V, then the highest and the lowest values of the voltage are 244 V and 214 V respectively.

- (ii) **Availability of power:** Power must be available to the consumers in any amount that they may require from time to time. For example, without any prior warning to the electric supply company motors may be switched on or off, lights may be switched on or off. As electrical energy cannot be stored, therefore, the distribution system must be capable of supplying load demands of the consumers. This necessitates that operating staff must continuously study load patterns to predict in advance those major load changes that follow the known schedules.
- (iii) **Reliability:** Reliable service is the need of the hour as almost all the modern industry is dependent on electric power for its operation, homes and office buildings are lighted, heated, cooled and ventilated by electric power. Unfortunately, electric power, like everything else that is man-made, can never be absolutely reliable. However, the reliability can be improved to a considerable extent by
 - a) interconnected system
 - b) reliable automatic control system and
 - c) providing additional reserve facilities.

Good voltage regulation of a distribution network is probably the most important factor and responsible for delivering good service to the consumers. It should be as close to zero as possible. For this purpose, design of feeders and distributors requires careful consideration.

- (i) **Feeders:** feeders are those conductors in a distribution system that are connected from the distribution sub-stations and that transfer power to the distribution centers. A feeder is designed from the point of view of its current carrying capacity while the voltage drop consideration is relatively not important. It is because voltage drop in a feeder can be compensated by means of voltage regulating equipment at the sub-station.
- (ii) **Distributors:** A distributor is designed from the point of view of the voltage drop in it. It is because a distributor supplies power to the consumers and there is a statutory limit of voltage variations at the consumer terminals which is $\pm 6\%$ of rated value. The size and length of the distributor should be such that voltage at the consumer terminals must be within the permissible limits.

The generated power is stepped up (upto 400 KV) by using transformers installed at power plant premises for transmission through extra–high voltage (EHV) transmission lines. Transmission of electricity at high voltages is efficient and economical that’s why high voltage transmission lines carry electricity to long distances to a substation. A reduction in voltage occurs at transmission substations for distribution to other points in the system through high voltage (HV) transmission lines. Further voltage reductions for commercial and residential customers take place at distribution substations, which connect to the primary distribution network.

Utility transmission and distribution [T&D] systems link electric generators with end users through a network of power lines and associated components. In India, typically the transmission portion of the system is designated operating at 33 kV and above, while the distribution portion operates between 11 kV and 230 V. Industrial and commercial customers with large power demands often receive service directly from the primary distribution system.

Transformers are a crucial link in the electric power distribution system. Utility transformers are high –voltage distribution transformers typically used by utilities to step down the voltage of electricity going into their customer buildings. Distribution transformers are one of the most widely used elements in the electric distribution system. They convert electricity from the high voltage levels in utility transmission systems to voltages that can safely be used in businesses and homes. Distribution transformers are either mounted on an overhead pole or on a concrete pad.

The power distribution systems must provide supply to the consumers without any interruption. The modern power distribution network is constantly being faced with an ever–growing load demand. Distribution networks experience distinct change of load from a lower to higher level everyday. The distribution system experiences voltage collapse above certain critical loading conditions.

1.2 Power System Planning

In power system planning it is necessary to consider the system as a whole and choose the parts in the system so that they give the required technical performance and are also

economically justified. Under such a situation, the effort will be to make the system economical and not only one particular part of the system such as generation, transmission and distribution. It would be necessary to consider stability and reliability of the system. In this respect, load surveys on long term basis and short term basis and their prediction is very essential. Power system planning is divided into three main parts as shown in figure 1.1. All the three problems are taken care of independently and then combined to make the system better.

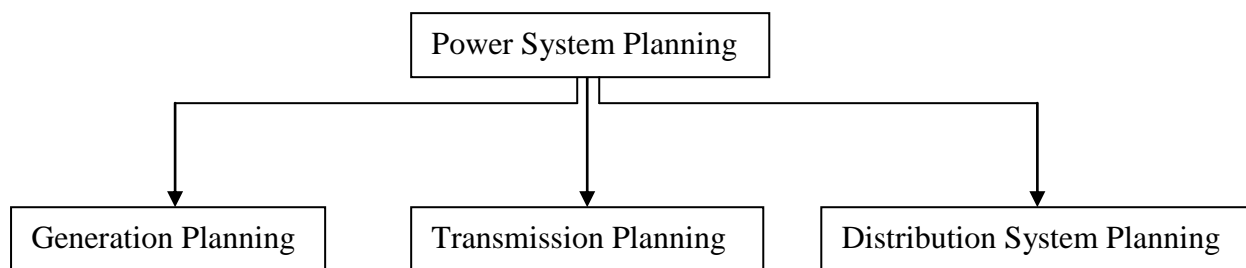


Figure 1.2 Hierarchy of Power System Planning

1.2.1 Objectives of Distribution System Planning

- The distribution system planning goal is to assure that a demand growth can be satisfied in an optimal way from the primary distribution feeders to the substations from where energy must be delivered to the final client complying with several technical specifications.
- To utilize the present assets efficiently.
- To trace an optimal trajectory to energize a node in distribution system so that conductor length and hence losses as well as cost can be reduced.
- To ensure that subject to the availability of adequate generating and transmitting capacity, the system is capable of providing consumers with a safe, reliable, economical and efficient supply of electricity.

1.2.2 Considerations while Planning

- When designing distribution planning, careful consideration should be given to energy consumption, their geographical location, laws regarding the use of soil plus other aspects to come up with the substations dimensioning and location, the maximum efficiency routes, while minimizing the energy loss in the feeders and deployment costs, plus satisfying the reliability of service constraints.
- The planning should be done to conform to the statutory requirements of applicable local and international codes and standards.

1.3 Survey on Planning of Power Distribution System

Power distribution planning is a complex task in which planners must ensure that there is adequate substation capacity (transformer capacity) and feeder capacity (distribution capacity) to meet the load demands. Decisions such as allocation of power flow, installation of feeders and substations, and procurement of transformers are costly ones which must be evaluated carefully.

The cost of power distribution constitutes a significant portion of the overall cost. **Gonen (1986)** proposed a systematic approach to distribution planning to substantially decrease the amount of cost incurred.

Ponnaivaikko and Rao (1981) optimized the configuration of each individual feeder by deciding on the length, conductor size, and gradation, and by addressing the economic, trade off between capital and operating costs. **Mikic (1986)** provided further details of the cost trade off.

Adams and Laughton (1974) was one of the earlier works which developed the above formulation. There were two cost components; the fixed cost and the variable cost of power flow for a particular connection.

Using the transportations model framework, **Crawford and Holt (1975)** provided a procedure, based on analysis of loads and feeders on a grid basis, to determine the optimal substation service boundary. The procedure might be used empirically to identify desirable substation locations and their sizes.

Masud (1974) proposed a two-phase method for power distribution planning. The first phase determined the substation decisions, with consideration on re-distribution of load. The second phase used a transportation model, with substation capacity from the first phase, to determine the optimal power flow for the feeders.

Fawzi and El-Sobki (1983) adopted a similar model while incorporating non-linear variable power cost and voltage drop. A branch and bound algorithm was used to first decide on the substations (with approximate feeders' considerations). This solution then became part of an iterative procedure to determine the optimal feeders' configuration.

Hindi and Brameller (1977) also provided detailed discussions on the dynamics of the power flow along with some computational experience.

Thompson and Wall (1981) presented a branch-and-bound algorithm for this problem. Two major bounding criteria of the algorithm were: (i) minimum incremental cost bound, and (ii) shortest path customer assignment. The former assumed the fixed costs of all potential substations to be zeros and the power flow problem was solved thus giving the lowest incremental cost of power flow. This incremental cost plus the actual fixed cost of the potential substation provided a lower bound cost.

Willis and Northcote-Green (1985) tested the efficiency of some of the above models based on their (i) overall benefit to planning, (ii) capacity to handle large program analysis, (iii) sensitivity to load forecasting error, and (iv) actual level of improvement. Four sets of simulated tests were used. For overall benefit and error sensitivity, the substation feeder models were found to be more superior.

Gonen and Foote (1981) obtained substation locations, substation transformer sizes, additions of incremental capacity, load transfers, and feeder routes and sizes. Detailed procedure on the linearization of the variable concave cost function, using continuous variables, was also included. There were a large number of logical constraints.

Sun et al. (1982) utilized the fixed-charge-transshipment framework of earlier single-period models to develop a procedure to solve the multi-period distribution problem. Their procedure consisted of two phases. The first phase was essentially a static base problem where decisions for substations and flows were first determined. Based on this initial configuration, new inputs (growth and new demand locations) for the next period were incorporated to determine the optimal installation and flow of that period. In turn, the base configuration plus the added configuration then became the basis for the following year's decision and so on until the end of the planning horizon. This procedure would not guarantee an overall optimal solution since current decisions were not related to future ones.

El-Kady (1984) explicitly included time-dependent fixed and variable charges as well as time-dependent cost of losses. Relationships of future-installations were modeled using variables of fixed installation costs incurred only once, while variable costs would be

accounted for throughout the equipment's life. Additionally, voltage drop in feeders were characterized as a step-wise functions of power flow. The overall problem was partitioned into smaller problems where the problem size became more manageable.

Gonen and Ramirez-Rosado (1986) pursued the model framework of **Gonen and Foote (1981)** and provided more explicit considerations. Notable additions such as value of fixed and variable costs and the explicit modelling of voltage drop and radiality constraints were present.

Ramirez-Rosado and Gonen (1991) adopted the two-phase approach of **Sun et al. (1982)** while incorporating more planning details.

The two-phase approach of **Sun et al. (1982)** and the pseudodynamic planning approach of **Ramirez-Rosado and Gonen (1991)** are both simplifying approaches to reduce the dynamic problem into a static one, thus allowing the problems to be solved more efficiently at the expense of getting an optimal solution.

Aoki et al. (1990) proposed “branch-exchange” algorithm for an approximate optimal solution for single-period distribution planning. It worked as follows:

- Start with a feasible configuration; add a route to form a loop.
- Then, to gain feasibility, a route (with either high installation cost or constraint violation) is an improvement, retain the exchange; otherwise, abandon the exchange.
- Repeat this procedure iteratively until the objective function cannot be improved any further.

The determination of the most sensitive exchange was selected from the information provided by the simplex tableau.

Nara et al. (1991) extended the single-period branch-exchange approximation algorithm of **Aoki et al. (1990)** to a multi period approximation algorithm. The algorithm worked as follows:

- **Forward Path:** At period t , using the branch-exchange method, the approximate optimal expansion plan for $t = t + 1$ was determined. This one-period expansion plan determination was termed the “Forward Path”.
- **Backward Path:** Unlike the two-phase method which proceeds period-by-period into the future, the proposed algorithm would do a “Backward path” after each “Forward Path.” The “Backward Path” was to return to the preceding period to see if the expansion plan P_0 , found up to that period, was indeed the best that could be achieved via branch-exchange. This was done by removing, one preceding period at

a time, the period's facility which were not utilized and by performing branch-exchange on the resulting configuration.

- **Backward/ Forward Path:** If at any period, the plan forming “Backward Path” was not an improvement, the backward process would stop and the forward process would resume with the previous “Forward Path” plan starting period (resulting in a plan P_1), then the algorithm would restart at $t = 1$ with the new period-1 plan as the basis for the next “Forward Path”, the subsequently, developed plan P_2 would be compared to the previously determined backward plan P_1 , with the better plan to replace P_0 for the next “Forward Path” at $t = t + 2$.

Further extending on their previous work, **Nara et al. (1992)** provided a “multi-stage” branch-exchange algorithm. Basically, the proposed algorithm attempted to move away from the local optimum found by the single-stage model by forcing further branch-exchanges with more refined branch selection criteria. Although termed “multi-stage” the algorithm did not address any time-dynamic issues; it was multi-stage in the sense that several series of branch-exchange were pursued.

Quintana, Temraz and Hipel (1993) divided the planning problem into two stages such as clustering and forecasting, and planning. In stage 1, the problem of load growth was solved in two phases. The first phase divided the service area into smaller sub areas with the demand points in each sub area summed to form a single demand node, the second phase assessed the demand forecast per demand node. In stage 2, the planning problem was to determine the overall installations required (without knowing when to install) by solving the problem of meeting projected demand at the horizon year. In the second phase, for each intermediate year between the base and the horizon year, was to determine an optimal intermediate system using only the equipment set from the static optimum problem. This optimization model of the sub-problem was constrained non-linear formulation and was solved using non-linear optimization software.

Development of expert systems for distribution planning had been reported based on PROLOG, an artificial-intelligent programming language.

Wong and Cheng (1987) listed several AI/expert systems for various power-system applications. They presented a set theory based formulation for load allocation in distribution substation. The system first generates all hypothetical solutions.

Chen and Hsu (1989) developed a rule-based system for the load re-allocation in the case of distribution expansion planning. The authors proposed two algorithms, one to minimize

power loss and the other to minimize investment cost. These algorithms formed the basis for the inference engine. The system was implemented on a PC using PROLOG language. The heuristic rules used by the planners were also incorporated in the expert system. The software was also able to calculate the system reliability of developed plan. The system was used to assist the planners in the expansion of a three station, twenty–eight feeder networks.

Hsu and Chen (1990) later designed an expert system for determining substation locations and feeder configuration of a distribution system. The substation locations were determined using an operations research based “location–allocation method.” The method was used to minimize the feeder losses and support the inference engine.

Brauder and Zobel (1994) divided computer based engineering methods developed over the last three decades in three phases. They characterized the knowledge–based methods as the beginning of the third phase. These methods complement the pure algorithmic methods without being part of the algorithm. The knowledge–based systems provide the flexibility needed for analyzing today’s complex distribution networks. They also discussed architecture and components of a knowledge–based programming system. The above model would be repeated for each substation in the service area for existing of unsatisfied load.

Leung et al. (1995) also provided a load reallocation model (additionally expressing the substation–load assignment as transportations type demand–supply constraints set) which sought to re–allocate unsatisfied load under the single–contingency environment.

Under the single–contingency scenario, **Sarada et al. (1995)** proposed a method which could prescribe the least cost feeder expansion plan. The model determined the installation schedule as well as sites of new feeders, while concurrently determined the optional load reallocation to meet load demand.

An approximate algorithm for loss minimum load allocation was developed by **Aoki et al. (1987)** which was extended by **Aoki et al. (1988)**, further refining their work, proposed the following algorithm which quickly restored the emergency load in a distribution system.

Aoki et al. (1989) proposed a procedure of deciding the open positions of switches in order to achieve load balancing of transformers and feeders while subject to their capacity limits. The procedure identified rules to systematically balance two transformers at a time until approximate balance was achieved to all transformers.

Civanlar et al. (1988) presented a scheme, with a simple formula, for determining the open/closed states of the tie and sectionalizing switches to reduce power losses in distribution feeders via feeder reconfiguration.

The issue of the protective device–coordination was incorporated in a feeder reconfiguration algorithm by **Hsu and Jwo–Hwu (1993)**. The algorithm first identified a set of regions in which switch operations were allowed. The protective devices were designed such that proper co–ordination could be attained during load balancing and load reduction where switches were assessed on/ off states.

Nara et al. (1994) provided a multi–year expansion having similar with the models as **Nara et al. (1991)**.

Glamocannin et al. (1993) proposed a method for obtaining optimal location and sizing of substations and network routing for an urban distribution system. The algorithm that they had developed was based on the requirement that each load point should be supplied by at least two feeding points either from the same substation or from other substation. The main limitation of their work was that they had considered the uniform cable size of the feeder segments.

Yeh et al. (1996) proposed a new problem solving environment utilizing different form of resources to approach better substations in the distribution planning domain. They used algorithm for the optimal solutions and this had been demonstrated through an example of street lighting design.

Hongewi et al. (1997) described a method to solve the optimal planning problem of distribution substations automatically selecting the location, size and service area of the distribution substation.

Nahman et al. (1996) suggested a method for selection of main initial parameters and timing of reconstructions of rural distribution networks in long term planning to meet the increasing load demands with minimum total worth cost. Their model incorporated capital and exploitation costs as well as the costs due to undelivered energy and load curtailments.

Goswami (1997) proposed an algorithm for planning of radial system based on the branch exchange technique. He applied the branch exchange between the elements of the networks under adjacent substations. A complete power flow was required after each branch exchange. This model is suitable for small systems.

Singh et al. (1998) proposed a model for optimal sizing and locating distribution substations and feeders in a time dynamic power distribution systems. Their model captured the non–linear costs due to power flow and the effects of harmonics. They used the Bender’s decomposition technique as a solution methodology.

Míguez *et al.* (2002) proposed a method for designing of optimal layout for medium-voltage power networks is a common issue in electrical distribution planning. Technical constraints (radial structure, voltage drops, and equipment capacity), and reliability limits must be fulfilled. The function for minimizing included investments, power losses, and quality of supply costs. We present in this paper an improved algorithm based on a branch-exchange technique to solve large-scale problems.

Nhaman and Peric (2008) presented optimal planning of radial distribution network by optimizing the overall annual cost function. They were silent regarding the stability of the system.

Samui *et al.* (2012) presented a direct approach for feeder routing for radial distribution system. They had considered the same network as considered by Nhaman and Peric (2008) with fixing the end points and their overall cost is more than that of Nhaman and Peric (2008).

Chakravorty and Das(2001) proposed a new voltage stability index for identifying the node which is most sensitive to voltage collapse. He considered composite load modeling for the purpose of voltage stability analysis and showed that the load flow solutions of radial distribution network are unique.

1.4 Research Gaps

Literature survey shows that the works reported so far are either optimization of substation to reduce the feeder path or connection of load points to a substation with its location fixed in all possible routes so that the cost is optimal. But till date design of substation with stability has not been proposed.

1.5 Objective of Thesis Work

The aim of this thesis is to give a planning of a substation with voltage stability index so that the stable structure is obtained and the cost will also be minimum.

1.6 Organization of Thesis

Chapter 1 presents the introduction, literature survey , research gaps and objective of research.

Chapter 2 presents the planning of distribution system.

Chapter 3 presents the future scope of research work.

References gives the previous published papers.

Appendix –A presents the coordinate of load points.

Appendix-B presents the data for conductor.

CHAPTER 2

Planning of Distribution System

2.1 Introduction

Planning of distribution substation is an important task to the planning engineer. The main aim of the planning engineer is to reduce the cost as well as the loss of the system. But the two at a time may not be feasible. Hence a compromise has to be made. Literature survey of distribution planning has already been presented in Chapter 1 (Art. 1.3). Literature survey shows that any attempt to make the system stable has not been made yet. The main aim of this thesis work is to make a stable planning.

2.2 Connection of load points to substation

When the location of substation is fixed, it is required to connect all the load points with the help of voltage stability index.

The following heuristic rules are considered before going ahead for connection of load points.

- Existence of residential area or commercial complex between the two load points.
- Existence of commercial plantation area between two load points.
- Existence of any cotton industries between two load points.

If any of the above heuristic rules is violated then the connection of load point (say X) to load point (say Y) is discarded and the previous load point i.e., load point X is connected to its closed neighboring load point (say Z).

The following cases are considered for connecting the load points:

Single Feeder:

Figure 2.1 show the locations of load points and the substation. In this case only one feeder will come out.

Step 1: The stability indices of all load points from the substation are computed. Set $N(0) = \Phi$ and $I=0$.

Step 2: The maximum value of SI is found out which is for load point k.

Step 3: The load point k (say load point 7) is connected to substation i.e., set $I=I+1$,

$$N(I)=N(I-1) \cup k \text{ and } M(I)=M(I-1)-(k)$$

Step 4: The stability indices of all the remaining load-points i.e., set $M(I)$ are calculated from the nodes in $N(I)$.

Step 5: Select the nearest node in set $M(I)$ say k and update set $I=I+1$,

$$N(I)=N(I-1) \cup k \text{ and } M(I)=M(I-1)-(k)$$

Step 6: go to Step 4 if $M(I) \neq \Phi$, else stop.

The load point corresponding to the maximum value of stability index (say load point 4) is connected to load point 7. The distances of all remaining load points will be calculated from the load point 4.

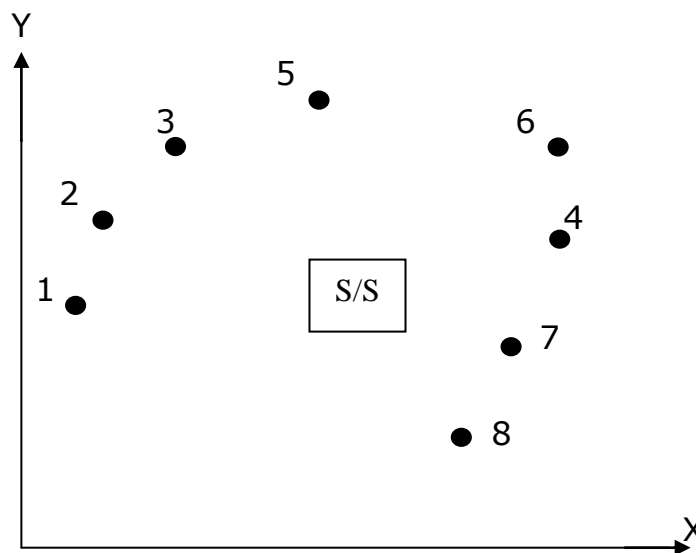


Figure 2.1 Example of Location of Load Points and Substation

Two Feeders:

Figure 2.1 is considered once again. Two feeders will come out from substation.

Step 1: The stability indices of all load points from the substation are calculated. Set $N(0)=\Phi$ and $I=0$

Step 2: The two consecutive maximum value of stability indices are found out, say load point k and k+1.

Step 3: The load points (say load point 7 and 4) corresponding these two consecutive maximum value of stability indices are connected to the substation i.e., set $I=I+1$, $N(I)=N(I-1) \cup k$ and $M(I)=M(I-1)-(k)$.

Step 4: The stability indices of all remaining load points are calculated from load points 5 and 8.

Step 5: The two consecutive maximum value of stability indices with respect to load point 4 and load point 7 are calculated.

Step 6: Say, the load points 6 and 8 are the results for load points 4 and 7. The load points 6 and 8 are connected to load points 4 and 7 respectively.

Now load points 6 and 8 are taken into account to calculate the stability indices of all remaining load points.

Following steps 4, 5 and 6, it is possible to connect all the load points.

Similarly, we can connect all the load points for three and four feeder cases.

The following voltage stability index

$$L(m2) = |V(m1)|^4 - 4.0\{P(m1)X(jj) - Q(m2)R(jj)\}^2 - 4.0\{P(m2)R(jj) + Q(m2)X(jj)\}|V(m1)|^2 \quad (2.1)$$

is used in this paper.

This index had been proposed by Chakraborty and Das(2001).

The load-flow technique proposed by Ghosh and Das (1999) is used in this thesis work.

The main equations in the load-flow method are

$$V(m2) = V(m1) - I(jj)Z(jj) \quad (2.2)$$

The node current is represented by

$$IL(m2) = \frac{PL(m2) - jQL(m2)}{V^*(m2)} \quad (2.3)$$

The real power loss and reactive power loss of each branch is expressed by

$$LP(jj) = |I(jj)|^2 R(jj) \quad (2.4)$$

$$\text{and } LQ(jj) = |I(jj)|^2 X(jj) \quad (2.5)$$

$L(m2)$ Stability index of node $m2$,

$m2$ is the receiving-end node of branch jj ,

$m1$ is the sending-end node of branch jj ,

$P(m2)$ is the real power of node $m2$,

$Q(m2)$ is the reactive power of node $m2$,

$V(m2)$ voltage of node $m2$,

$I(jj)$ current through the branch jj ,

$R(jj)$ is the resistance of branch jj and

$X(jj)$ is the reactance of branch jj .

The equations for branch conductor selection are done using the method proposed by Tram and Wall (1988).

To find the cost of losses the formula proposed by **Tram and Wall (1988)** is used and is given by

$$L(i, k) = 10^{-5} \times C1 \times R(k) \times L(i) \times \{P(i)\}^2 \quad (2.6)$$

where

$C1$ = composite cost of losses (Rs per kW)

$R(k)$ = per unit resistances

$L(i)$ = length of feeder segment i

$P(i)$ = Power flow through segment i (kVA)

To calculate the composite cost of losses ($C1$) the formula proposed by **Tram and Wall (1988)** is used here

$$C1 = D \times 8760 \times LSF \times E \quad (2.7)$$

where

D = levelized annual demand cost of losses per kW

LSF = Loss factor

E = Energy cost of losses (Rs/ kWh)

To calculate the cost of capital [$C(i, k)$], the formula proposed by **Tram and Wall (1988)** is used.

$$C(i, k) = CC \times PP(k) \times L(i) \quad (2.8)$$

where

$PP(k)$ = purchase price of conductor k (Rs/ Unit length)

$L(i)$ = length of feeder segment i

CC = Carrying charge rate (feeders)

The objective function to be minimized is

$$F(i,k) = L(i,k) + C(i,k) \quad (2.9)$$

The current through the feeder is compared with the maximum current carrying capacity of the conductor and proper conductor is selected.

The required steps for the planning are

Step 1: Read the required data

Step 2: Take a particular conductor and calculate the required stability index using the load-flow proposed by Ghosh and Das (1999).

Step 3: Connect all the load points to the substation as discussed above.

Step 4: Select the optimal branch conductor using the method proposed by Tram and Wall (1998).

Step 5: Compute the voltage and stability index of each node, total planning cost and total loss of the system.

2.3 Example

A 24 node graph has been taken as shown in Figure 2.2. The co-ordinates of the load points of Figure 2.2 is shown in Appendix –A. The coordinate of substation is (11.0, 10.3). Base values are 11.0 kV and 100 MVA.

At first the load points are connected in single feeder path. The required connection is shown in Figure 2.3. The voltage of each node is shown in Table 2.1. Table 2.2 shows the voltage stability index of each node. Table 2.3 shows the branch number, sending-end node and receiving-end node of Figure 2.3.

Now the load points are connected in double feeder path. The required connection is shown in Figure 2.4. The voltage of each node is shown in Table 2.4. Table 2.5 shows the voltage stability index of each node. Table 2.6 shows the branch number, sending-end node and receiving-end node of Figure 2.4.

Next the load points are connected in three feeder paths. The required connection is shown in Figure 2.5. The voltage of each node is shown in Table 2.7. Table 2.8 shows the voltage stability index of each node. Table 2.9 shows the branch number, sending-end node and receiving-end node of Figure 2.5.

Table 2.10 shows the total cost, total loss and minimum voltage and total length in each case.

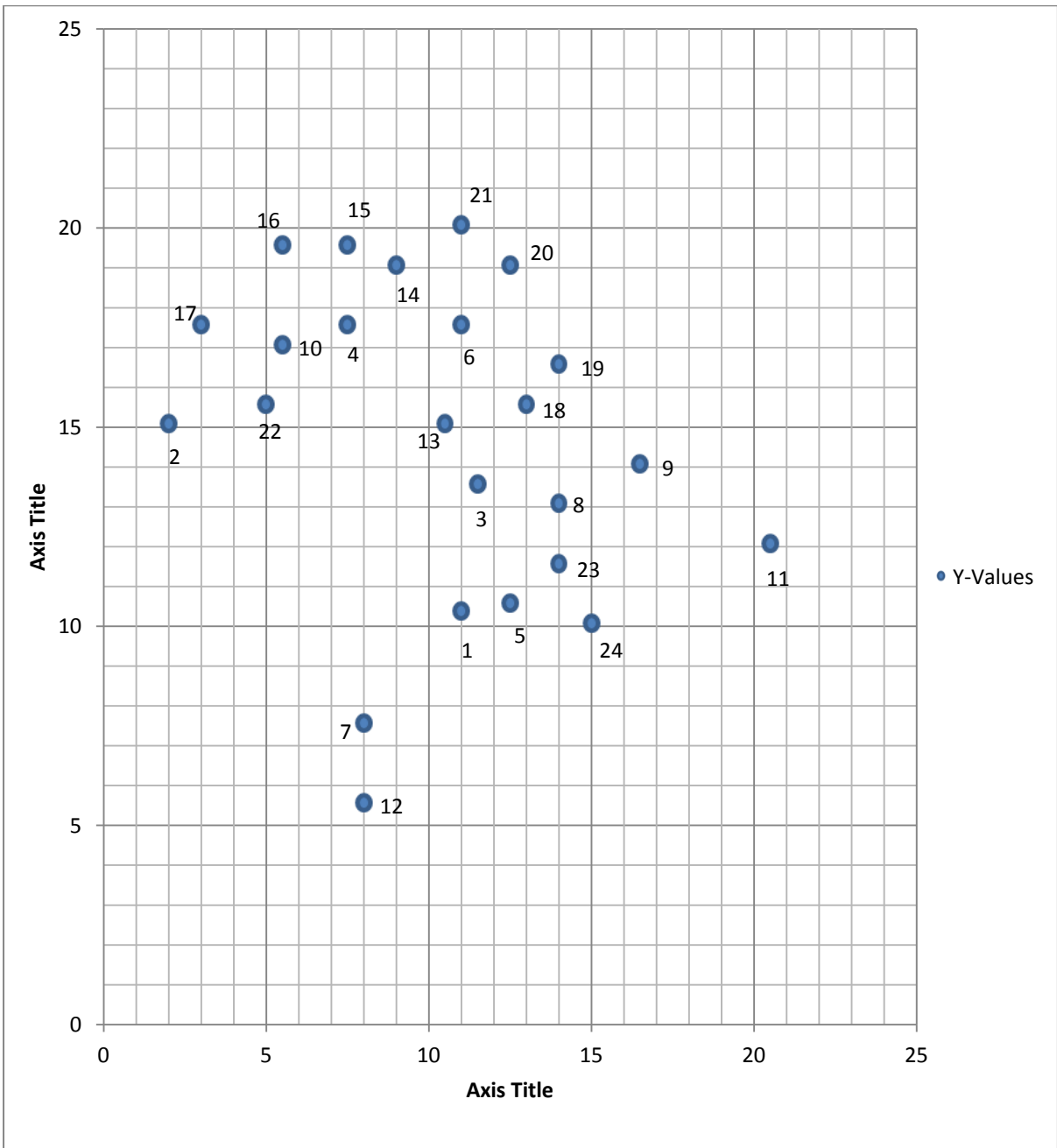


Figure 2.2 24 Load points

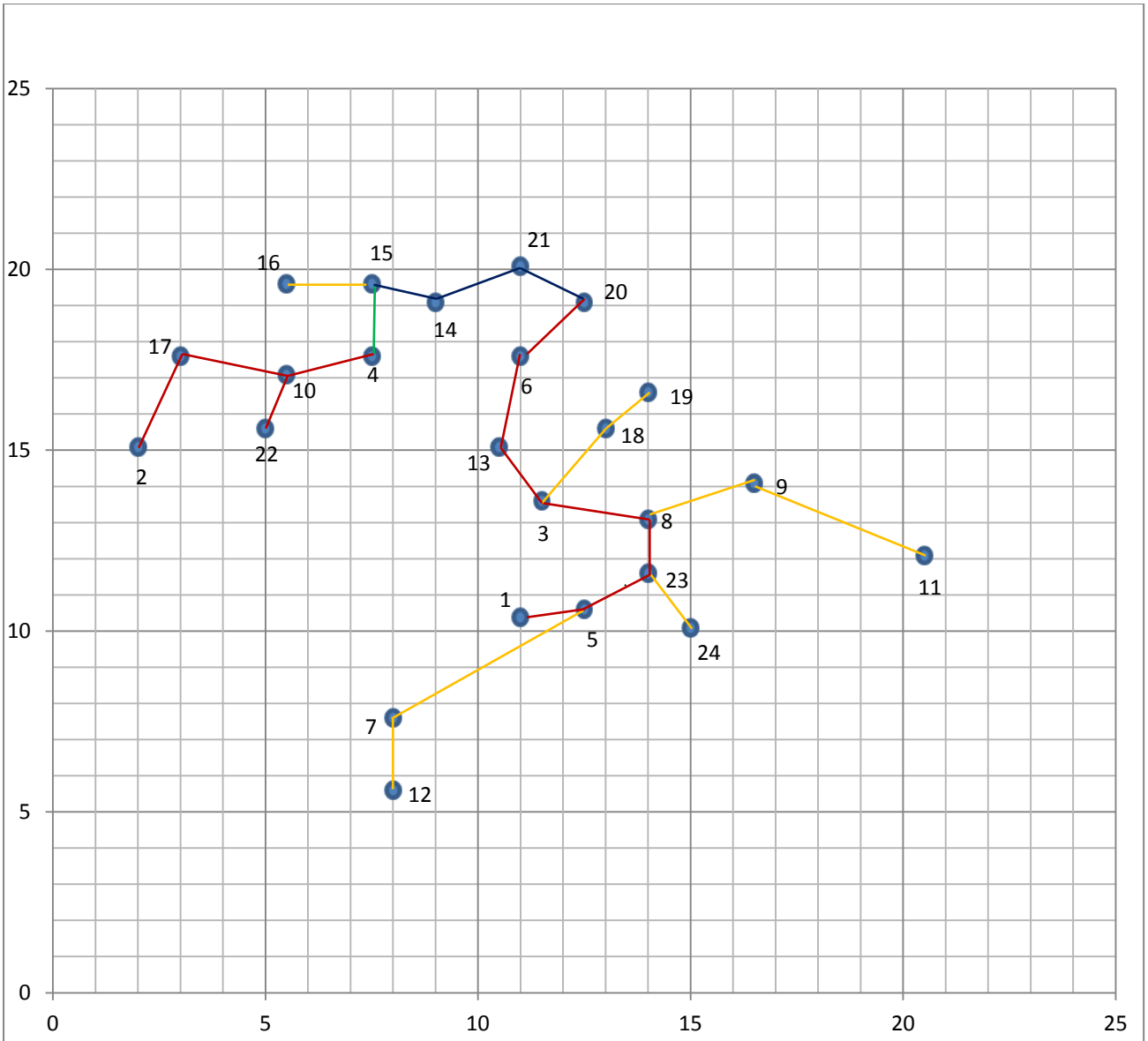


Figure 2.3 Single feeder case

Table 2.1 Voltage of each node of Figure 2.3 in p.u.

Node number	Voltage (p.u.)
1	1.000000
2	0.947636
3	0.974746
4	0.950119
5	0.993390
6	0.966272
7	0.989012
8	0.981366
9	0.978783
10	0.948935
11	0.977564
12	0.987933
13	0.970776
14	0.955555
15	0.953244
16	0.952886
17	0.947936
18	0.972938
19	0.972690
20	0.962756
21	0.959452
22	0.948759
23	0.986476
24	0.985501

Table 2.2 Stability Index of each node of Figure 2.3 in p.u.

Node number	Stability Index
2	0.001264
3	0.026802
4	0.013073
5	0.026267
6	0.018474
7	0.017558
8	0.020614
9	0.010500
10	0.004980
11	0.004977
12	0.004360
13	0.016223
14	0.016183
15	0.009649
16	0.001502
17	0.004208
18	0.007408
19	0.001019
20	0.014502
21	0.013681
22	0.000742
23	0.027646
24	0.003950

Table 2.3 Branch number, Sending-end node, receiving-end node and length of each branch of Figure 2.3

Branch Number	Sending-end node	Receiving-end node	Length of each branch (km)
1	1	5	1.513275
2	5	23	1.802776
3	23	8	1.500000
4	23	24	1.802776
5	8	3	2.549510
6	3	13	1.802776
7	3	18	2.500000
8	18	19	1.414214
9	13	6	2.549510
10	6	20	2.121320
11	20	21	1.802776
12	21	14	2.236068
13	14	15	1.581139
14	15	4	2.000000
15	15	16	2.000000
16	4	10	2.061553
17	10	22	1.581139
18	10	17	2.549510
19	8	9	2.692582
20	17	2	2.692582
21	9	11	4.472136
22	5	7	5.408327
23	7	12	2.000000

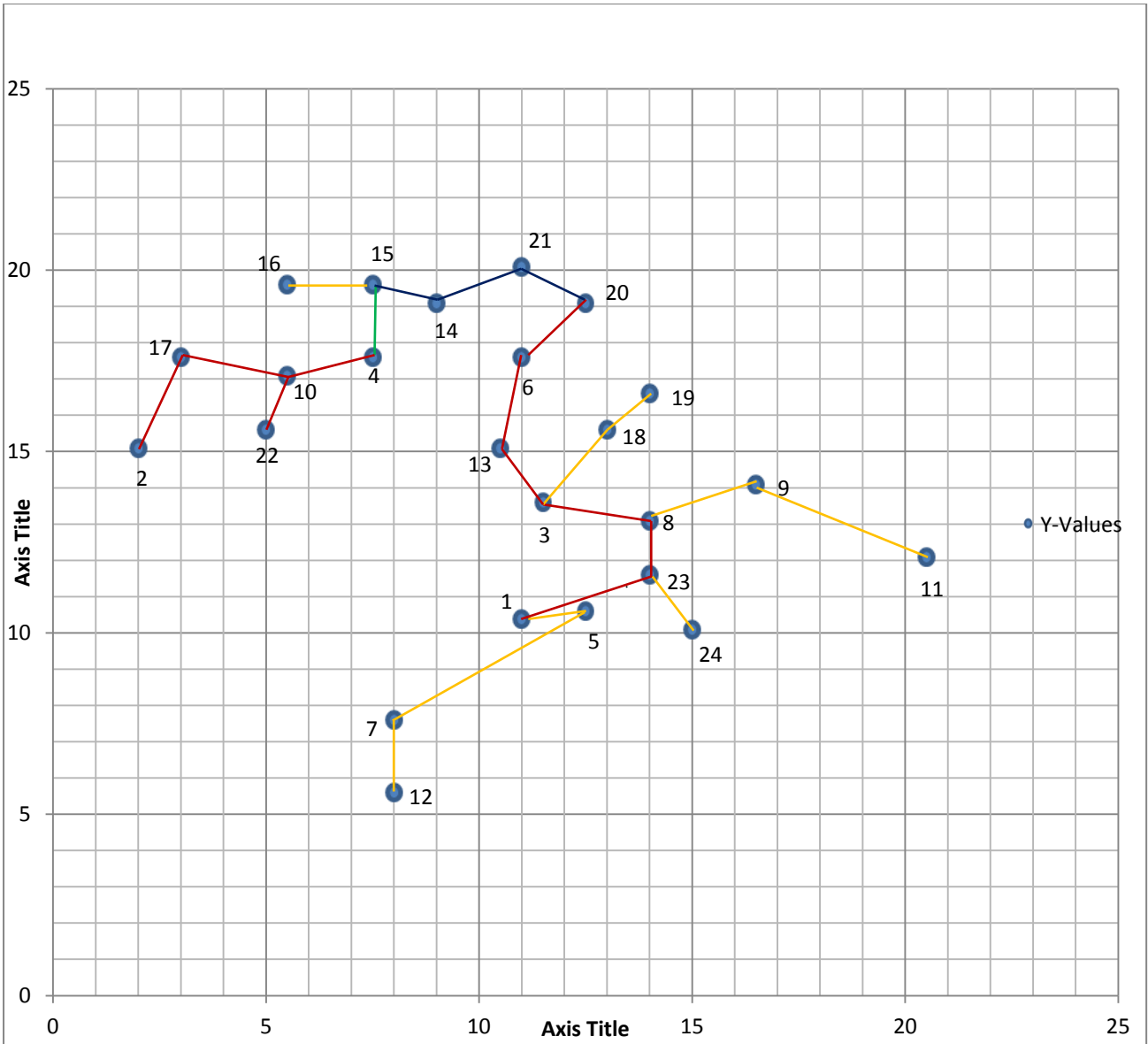


Figure 2.4 Double feeder case

Table 2.4 Voltage of each node of Figure 2.4 in p.u.

Node number	Voltage (p.u.)
1	1.000000
2	0.948831
3	0.975907
4	0.951311
5	0.997972
6	0.967444
7	0.993614
8	0.982519
9	0.979940
10	0.950128
11	0.978722
12	0.992540
13	0.971943
14	0.956740
15	0.954432
16	0.954075
17	0.949130
18	0.974101
19	0.973854
20	0.963932
21	0.960632
22	0.949953
23	0.987623
24	0.986649

Table 2.5 Stability Index of each node of Figure 2.4 in p.u.

Node number	Stability Index
2	0.001261
3	0.026738
4	0.013041
5	0.008099
6	0.018429
7	0.017397
8	0.020565
9	0.010476
10	0.004967
11	0.004965
12	0.004320
13	0.016184
14	0.016143
15	0.009625
16	0.001498
17	0.004197
18	0.007390
19	0.001017
20	0.014467
21	0.013648
22	0.000740
23	0.048896
24	0.003941

Table 2.6 Branch number, Sending-end node, receiving-end node and length of each branch of Figure 2.4

Branch Number	Sending-end node	Receiving-end node	Length of each branch (km)
1	1	5	1.513275
2	1	23	3.231099
3	23	8	1.500000
4	23	24	1.802776
5	8	3	2.549510
6	3	13	1.802776
7	3	18	2.500000
8	18	19	1.414214
9	13	6	2.549510
10	6	20	2.121320
11	20	21	1.802776
12	21	14	2.236068
13	14	15	1.581139
14	15	4	2.000000
15	15	16	2.000000
16	4	10	2.061553
17	10	22	1.581139
18	10	17	2.549510
19	8	9	2.692582
20	17	2	2.692582
21	9	11	4.472136
22	5	7	5.408327
23	7	12	2.000000

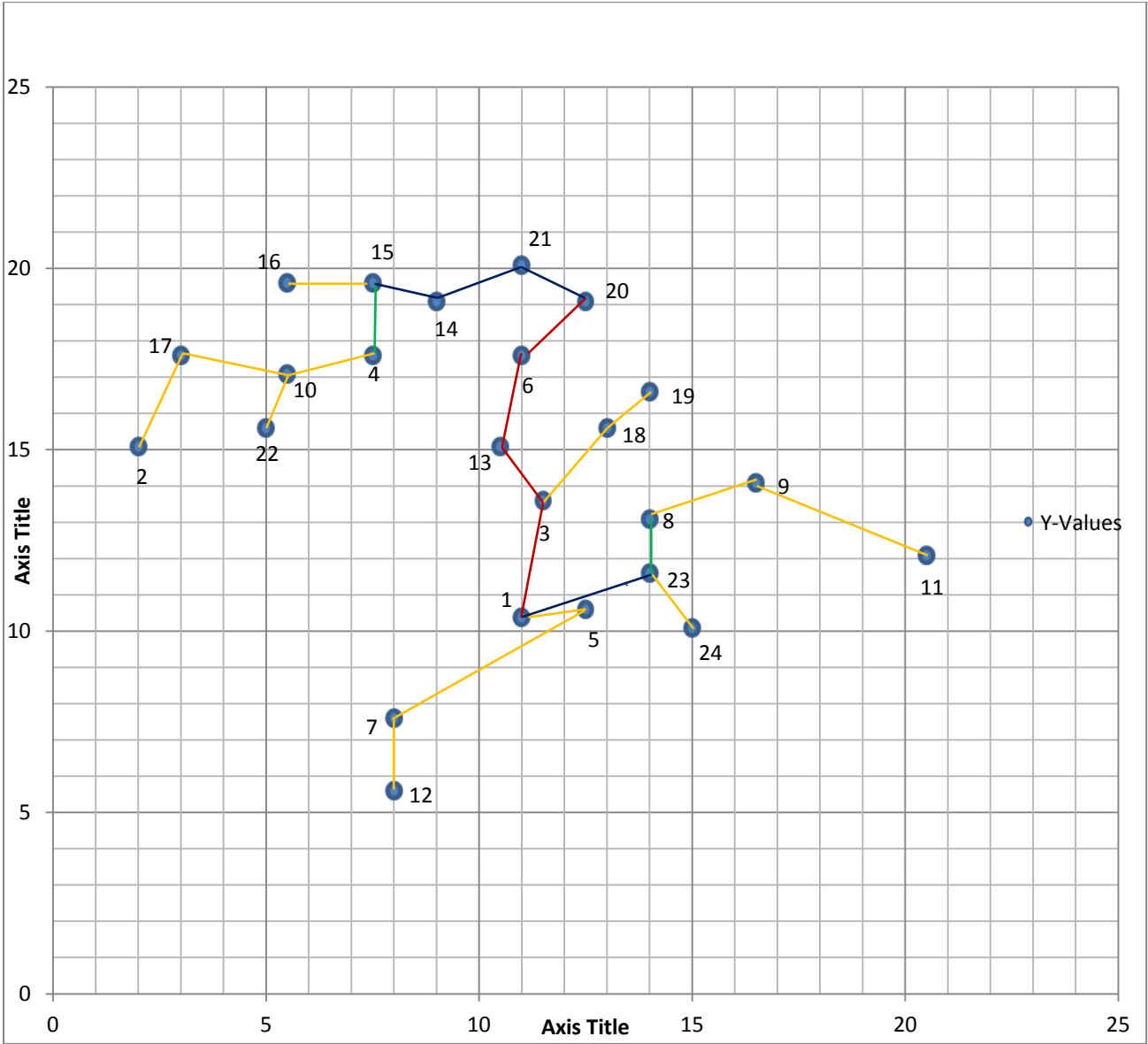


Figure 2.5 Triple feeder case

Table 2.7 Voltage of each node of Figure 2.5 in p.u.

Node number	Voltage (p.u.)
1	1.000000
2	0.961335
3	0.991733
4	0.967514
5	0.997972
6	0.983403
7	0.993614
8	0.992757
9	0.990205
10	0.964567
11	0.989000
12	0.992540
13	0.987831
14	0.972864
15	0.970591
16	0.970239
17	0.962081
18	0.989956
19	0.989712
20	0.979946
21	0.976697
22	0.964130
23	0.994954
24	0.993988

Table 2.8 Stability Index of each node of Figure 2.5 in p.u.

Node number	Stability Index
2	0.003100
3	0.032796
4	0.012642
5	0.008099
6	0.017851
7	0.017397
8	0.008814
9	0.010260
10	0.012150
11	0.004863
12	0.004320
13	0.015676
14	0.015636
15	0.009324
16	0.001448
17	0.010289
18	0.007156
19	0.000984
20	0.014011
21	0.013219
22	0.001812
23	0.020081
24	0.003883

Table 2.9 Branch number, Sending-end node, receiving-end node and length of each branch of Figure 2.5

Branch Number	Sending-end node	Receiving-end node	Length of each branch (km)
1	1	5	1.513275
2	1	23	3.231099
3	1	3	3.238827
4	23	8	1.500000
5	23	24	1.802776
6	3	13	1.802776
7	3	18	2.500000
8	18	19	1.414214
9	13	6	2.549510
10	6	20	2.121320
11	20	21	1.802776
12	21	14	2.236068
13	14	15	1.581139
14	15	4	2.000000
15	15	16	2.000000
16	4	10	2.061553
17	10	22	1.581139
18	10	17	2.549510
19	8	9	2.692582
20	17	2	2.692582
21	9	11	4.472136
22	5	7	5.408327
23	7	12	2.000000

Table 2.10 Total cost, total loss and minimum voltage and total length in each case

Cases	Total cost	Real power loss (kW)	Reactive power loss (kVAr)	Minimum voltage	Total length (km)
Single feeder	77084.10	23.28	21.05	0.947636 (Node 2)	52.64
Double feeder	75470.55	22.16	19.78	0.948831 (Node 2)	54.06
Triple feeder	52185.37	13.76	10.52	0.961335 (Node 2)	54.75

2.4 Conclusion

A stable planning is proposed in this thesis work. The load points are connected through voltage stability index instead of connection the nodes through optimum path or minimizing any cost function. The proposed work gives stable planning. The connections are done in single feeder, double feeder or triple feeder . The comparison of cost, losses and minimum voltage has been shown. The utility may use the three feeder case.

CHAPTER 3

Future Scope of Research Work

Planning of distribution system can also be done with joint optimization of cost function and reliability indices with hybrid optimization technique. The effect of fuzzy logic can also be taken into account to incorporate the uncertainty.

The cases of unbalanced effect of the distribution network can also be taken into account.

REFERENCES

1. Adams, R.N. and M.A. Laughton (1974), “Optimal Planning of Power Networks Using Mixed-Integer Programming”, Proceedings IEE, Part C (GTD), Vol.121, No.2, pp. 139-148.
2. Aoki, K., Ichimori T., and M. Kanezashi (1987),“ Normal State Optimal Load Allocation in Distribution Systems”, IEEE Transactions on Power Delivery, Vol.2, No.1, pp.147–155.
3. Aoki, K., Kuwabara, H. Satoh, T. and M. Kanezashi (1988), “An Efficient Algorithm for Load Balancing of Transformers and Feeders by Switch Operation in Large Scale Distribution Systems”, IEEE Transactions on Power Delivery, Vol.3, No.4, pp. 1865–1872.
4. Aoki, K., Nara, K., Itoh., M., and H. Kuwabara (1989), “A New Algorithm for Service Restoration in Distribution Systems”, IEEE Transactions on Power Systems, Vol.4, No.3, pp.1832–1842.
5. Aoki, K, Nara, K, Satoh, T., Kitagawa, M. and K. Yamanaka (1990),“New Approximate Optimization Method for Distribution System Planning”, IEEE Transactions on Power Systems, Vol.5, No.1, pp.126–132.
6. Braunder, G. and M. Zobel (1994), “Knowledge Based Planning of Distribution Networks”, IEEE Transactions on Power Systems, Vol.9, No.2, pp.942–948.
7. Chakravorty.M. and Das.D.(2000), “Voltage Stability Analysis of Radial Distribution Networks”, Electrical Power and Energy Systems, Vol 23, No.2, pp.129-135
8. Chen, J. and Y. Hsu (1989), “An Expert System for Load Allocation in Distribution Expansion Planning”, IEEE Transactions on Power Delivery, Vol.4, No.3, pp.1910–1917.
9. Civanlar, S., Grainger, J.J. and S.H. Lee (1988), “Distribution Feeder Reconfiguration for Loss Reduction”, IEEE Transactions on Power Delivery, Vol.3, No.2, pp.1217–1223.
10. Crawford, D.M. and Jr. S.B. Holt (1975), “A Mathematical Optimization Technique for Locating and Sizing of Distribution Substations, and Deriving their Optimal Service

- Areas”, IEEE Transactions on Power Apparatus and Systems, Vol.94, No.2, pp.230-234.
11. El-Kady, M.A (1984), “Computer-Aided Planning of Distribution Substation and Primary Feeders”, IEEE Transactions on Power Apparatus and Systems, Vol.103, No.6, pp. 1183–1189.
 12. Fawzi, T.H. and S.M. El-Sobki (1983), “A New Planning Model for Distribution Systems”, IEEE Transactions on Power Apparatus and Systems, Vol. 102, No. 9, pp.3010–3017.
 13. Glamocannin, V. (1993),” Optimal Loss Reduction of Distribution Networks”, IEEE Transactions on Power Delivery, Vol.5, No.3, pp.774 –782
 14. Gonnem, T. (1986), “Electric Power Distribution System Engineering”, McGraw Hill.
 15. Gonen, T. and B.L. Foote (1981), “Distribution System Planning Using Mixed Integer Programming”, Proceedings IEE Part C (GTD), Vol.128, No.2, pp.70 –79.
 16. Goswami, S.K. (1997), “Distribution System Planning Using Branch–Exchange Technique”, IEEE Transactions on Power Systems, Vol. 19, No.8, pp. 549 –556.
 17. Hindi, K.S. and A. Brameller(1977), “Design of Low–Voltage Distribution Networks: A Mathematical Programming Method”, Proceedings IEE Part C, Vol. 24, No.1, pp.54 –58.
 18. Hongewi, Dai et. al. (1997), “Optimal Planning of Distribution Substation Locations and Sizes Model and Algorithm”, Electrical Power and Energy Systems, Vol.18, No.6, pp.353 –357.
 19. Hsu, Y. and J. Chen (1990), “Distribution Planning Using a Knowledge-Based Expert System”, IEEE Transactions on Power Delivery, Vol.5, No.3, pp. 1514 –1519.
 20. Hsu, Y. and Y. Jwo-Hwu (1993), “Planning of Distribution Feeder Reconfiguration with Protective Device Coordination”, IEEE Transactions on Power Systems, Vol.6, No.3, pp.1340 –1347.
 21. Leung, L.C. Thatore, S.K. and I. Schnepf (1995a), “Planning Substation Capacity Under the Single Contingency Scenario”, IEEE Transactions on Power Systems, Vol.10, No.3, pp. 1442 –1447.
 22. Masud, E. (1974), “An Interactive Procedure for Sizing and Timing Distribution Subtractions–using Optimization techniques”, IEEE Transactions on Power Apparatus and Systems, Vol.93, No.5, pp. 1281 –1286.

23. Míguez , E. et al. (2002), “An Improved Branch-Exchange Algorithm for Large-Scale Distribution Network Planning”, *IEEE Transactions on Power Systems*, Vol. 17, No. 4, pp. 931-936.
24. Mikic, O.M. (1986), “Mathematical Dynamic Model for Long-term Distribution System Planning”, *IEEE Transactions on Power Systems*, Vol.1, No.1. pp. 40 –46.
25. Nahman, J. et al.(1996), “Optimal Planning of Rural Medium Voltage Distribution Networks”, *Electric Power Systems Research*, Vol.19, No.8, pp.549 –557.
26. Nahman , J.M. and Peric D.M. (2008), “Optimal planning of Radial Distribution Networks by Simulated Annealing Techniques”, *IEEE Transactions on Power Systems*, Vol. 23, No. 2, pp. 790-795.
27. Nara, K. Satoh, T., K., Kitagawa, M. and K. Yamanaka (1991), “Multi-Year Expansion Planning for Distribution Systems”, *IEEE Transactions on Power Systems*, Vol.6, No.3, pp. 952 –958.
28. Nara, K., Santoh, T., Kuwabara, H. Aoki, K. Kitagawa, M. and T. Ishihara (1992) “Distribution Systems Expansion Planning By Multi-Stage Branch Exchange”, *IEEE Transaction Power Systems*, Vol.7, No.1, pp.208 –214.
29. Nara, K., Kuwabara, H., Kitagawa, M. and K. Ohtaka (1994), “Algorithm for Expansion Planning in Distribution Systems Taking Fault into Consideration”, *IEEE Transactions on Power System*, Vol.9, No.1, pp.324 –330.
30. Ponnavaikko, M. and K.S. Prakasa Rao (1981), “Optimal Distribution System Planning”, *IEEE Transactions on Power Apparatus And Systems*, Vol.100, No.6, pp.2969 –2976.
31. Quintana, W.H., Temraz, H.K. and K.W. Hipel(1993), “Two–stage Power System Distribution Planning Algorithm”, *Proceedings IEE Part C*, No.1, pp. 17–29.
32. Ramirex-Rasado, I.J. and T. Gonen (1991), “Review of Distribution System Planning Models: a Model for Optimal Multi –stage Planning”, *IEEE Transactions on Power Systems*, Vol.6, No.1, pp.245 –253.
33. Samui, A *et al.*(2012), “ A direct approach to optimal feeder routing for radial distribution system,” *IEEE Transactions on Power Delivery*, Vol. 27, No. 1, pp. 253-260.
34. Sarada, A., Khator, S.K. and L.C. Leung (1995), “Substation Feeder Configuration at a Large Utility”, *Computer and IEEE*, Vol.28, No.2, pp.329 –339.

35. Singh, P. et al. (1998), "A New Techniques for Optimal Time – Dynamic Distribution Substation and Feeder Planning", *Electric Power System Resaerch*, Vol. 47, pp. 197–204.
36. Sun, D.I., Farris, D.R., Cote, P.J. Shoults, R.R. and S.S. Chen (1982), "Optimal Distribution Substation and Primary Feeder Planning via the Fixed Charge Network Formulation", *IEEE Transactions on Power Apparatus And Systems*, Vol.101, No.2, pp.602–608.
37. Thompson, G.L., and D.L. Wall (1981), "A Branch and Bound Model for Choosing Optimal Substation Locations", *IEEE Transactions on Power Apparatus And Systems*, Vol. 100, No.5, pp.2683 –2687.
38. Willis, H. Lee and J.E.D. Northcote-Green (1985), "An Optimization Model for Planning Radial Distribution Networks", *IEEE Transactions on Power Apparatus and Systems*, Vol.104, No.1, pp.233 –240.
39. Wong, K.P. and H. N. Cheng(1987), "Artificial Intelligence Approach to Load Allocation in Distribution Substations", *IEE Proceedings Part C (GTD)*, Vol.134, No.5, pp.357 –364.
40. Yeh, E–C, et al. (1996), "Improved Distribution System Planning Using Computational Evolution", *International Journal of Electric Power System Research*, Vol. 11, No. 2, pp. 668 – 674.

Appendix-A

Table A1 : Coordinates and load of the load points

Load Points	X coordinate (km)	Y coordinate (km)	Load (kVA)
2	2.0	15.0	25.0
3	11.5	13.5	25.0
4	7.5	17.5	63.0
5	12.5	10.5	50.0
6	11.0	17.5	25.0
7	8.0	7.5	25.0
8	14.0	13.0	100.0
9	16.5	14.0	63.0
10	5.5	17.0	16.0
11	20.5	12.0	25.0
12	8.0	5.5	50.0
13	10.5	15.0	100.0
14	9.0	19.0	50.0
15	7.5	19.5	50.0
16	5.5	19.5	16.0
17	3.0	17.5	63.0
18	13.0	15.5	50.0
19	14.0	16.5	16.0
20	12.5	19.0	50.0
21	11.0	20.0	16.0
22	5.0	15.5	25.0
23	14.0	11.5	50.0
24	15.0	10.0	50.0

Base kV = 11.0, Base MVA=100, pf = 0.8

Appendix-B

Table B1 Data for conductors

Type of Conductor	Area of cross section (mm ²)	Resistance (Ω/km)	Reactance (Ω/km)	Maximum Current carrying capacity(Amp)	Cost of conductor (Rs/km)
Squirrel	12.90	1.3760	0.3896	70.0	2880
Weasel	19.35	0.9810	0.3797	100.0	4338
Rabbit	32.26	0.5441	0.3673	148.0	7306
Raccon	48.39	0.3657	0.3579	200.0	10950
LSF = 0.20 CC = 0.10 V _{min} = 0.95					

Appendix-C

Biography

PERSONAL INFORMATION

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