HIGH VOLTAGE DISTRIBUTION SYSTEM FOR LOSS REDUCTION

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Abstract

Electricity is modern society’s most convenient and useful form of energy. Without it, the present social infrastructure would not all be feasible. The increasing per capita consumption of electricity throughout the world reflects a growing standard of living of the people. The optimum utilization of this form of energy can only be ensured by effective distribution systems. A distribution system is the one from which the power is distributed to various consumers through feeders, distributors and service mains. Feeders are conductors of large current carrying capacity carrying the current in bulk to the feeding points. Distributors are conductors from which the current is tapped off the supply to the consumer premises. Because of lower voltage, and hence higher current, the I^2R loss in the distribution system is significantly high compared to that of a high-voltage transmission system. The pressure of improving the overall efficiency of power distribution has forced the power utilities to reduce the loss, especially at the distribution level. The I^2R loss in a distribution system can be reduced by network reconfiguration. The reconfiguration changes the path of power flow from source to the loads. A program has been developed based on MATLAB program to do the analysis in this project.The perfomance of the proposed method was investigated on distribution system consisting of 33 buses and it was found that a significant loss saving can be achieved by using a of High Voltage Distribution System.

Abstrak

Pada zaman moden, bekalan elektrik merupakan suatu keperluan asas yang penting untuk keselesaan pengguna, tanpanya insfraktrutur sosial tidak akan dapat dilaksanakan. Pertambahan penggunaan bekalan elektrik per kapita di seluruh dunia menggambarkan pertumbuhan taraf kehidupan manusia yang semakin meningkat.Penggunaan optimun tenaga ini hanya dapat dijamin melalui sistem pengagihan yang efektif. Kuasa daripada sistem pengagihan ini diagihkan kepada pengguna melalui penyalur kuasa, pengagih dan servis utama. Penyuap mengkonduk arus yang besar secara pukal dan pengagih merupakan konduktor dan arus seterusnya dibekalkan kepada premis pengguna. Disebabkan voltan yang rendah, arus yang besar, kehilangan kuasa dalam sistem pengagihan adalah lebih tinggi berbanding kehilangan kuasa dalam sistem pencawan voltan tinggi. Peningkatan kecekapan secara keseluruhannya oleh kuasa pengagihan akan mentebabkan berlakunya kehilangan kuasa, terutamanya pada peringkat pengagihan. Kehilangan kuasa dalam sistem pengagihan dapat dikurangkan melalui konfigurasi semula rangkaian. Sistem ini akan mengubah aliran kuasa dari sumber kepada beban. Sebuah program telah dibina berdasarkan program MATLAB untuk menjalankan analisis di dalam laporan ini. Prestasi kaedah yang dicadangkan telah diuji pada sistem pengagihan yang mengandungi 33 bas dan didapati bahawa penjimatan kehilangan yang tinggi boleh dicapai dengan menggunakan Sistem Pengagihan Voltan Tinggi.

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1. INTRODUCTION

1.1 General Description of Distribution systems

Electricity is modern society's most convenient and useful form of energy. Without it, the present social infrastructure would not all be feasible. The increasing per capita consumption of electricity throughout the world reflects a growing standard of living of the people. The optimum utilization of this form of energy can only be ensured by effective distribution systems.

A distribution system is the one from which the power is distributed to various consumers through feeders, distributors and service mains. Feeders are conductors of large current carrying capacity carrying the current in bulk to the feeding points. Distributors are conductors from which the current is tapped off the supply to the consumer premises. A typical distribution system with these elements is shown in figure 1.1

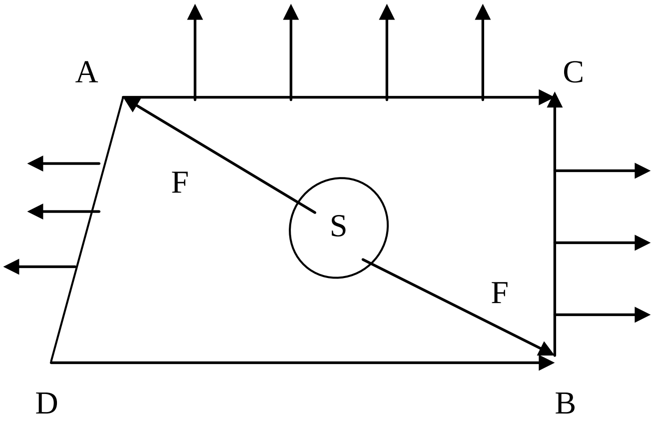

Fig 1.1

In Fig 1.1 SA, SB are feeders radiating from stations, ACB and ADB are distributors. The size of the feeders is determined primarily by the currents, it is required to carry. This is due to the fact that the voltage drop along a feeder can be allowed by regulation and, on the other hand the permissible voltage along a distributor, forms the main basis for the design of a distributor. The size of cross section of distributors and feeders is affected by an increase of supply voltage. Because of lower voltage, and hence higher current, the I^2R loss in the distribution system is significantly high compared to that of a high-voltage transmission system. The pressure of improving the overall efficiency of power distribution has forced the power utilities to reduce the loss, especially at the distribution level. The I^2R loss in a distribution system can be reduced by network reconfiguration. The reconfiguration changes the path of power flow from source to the loads. Adding shunt capacitors to supply part of the reactive power demand can also reduce the loss. Shunt capacitors can be installed in distribution systems to reduce energy and peak demand losses, release the kVA capacities of distribution apparatus, and also improve the system voltage profile.

1.2 Distribution System losses

1.2.1 Introduction:

In the distribution systems so many factors are contributed to the distribution systems losses, some of the factors are discussed in the next section. The distribution system losses form major part of the total system losses. The pressure of improving the overall efficiency of power distribution has forced to take measures to reduce the distribution systems losses by providing remedies to the factors, which contribute to the distribution losses. So, the distribution systems must be properly planned to ensure losses within the acceptability limits.

1.2.2 Factors effecting distribution system losses:

Factors contributing to the increase in the line losses in the primary and secondary distribution system are:

a) Feeder length: In practice, 11kV and 415V lines in rural areas are hurriedly extended radially over long distances to feed loads scattered over large areas. This results in high line resistance, low voltage and high current and therefore leads to high I^2R losses in the line.

b) Inadequate size of conductor: Rural loads are usually scattered and generally fed by radial feeders. The conductor size of the feeders must be adequate. The size of the conductor should be selected on the basis of km-kVA capacity of the stranded conductors.

c) Location of distribution transformers: Often the distribution transformers are not located centrally with respect to the customers. Consequently, the farthest customer receives power at extremely low voltage even though a reasonably good voltage level is maintained at the transformer secondary. This again leads to higher line losses.

d) Use of over rated distribution transformers (Dtr's): Studies on 11kV feeders have revealed that often the rating of distribution transformers is much higher than the maximum kVA demand on the LT feeder. Over rated transformers result in an unnecessary high iron losses.

e**) Low voltage:** Whenever the voltage applied to an induction motor deviates from rated voltage, its performance is adversely affected. A reduced voltage in case of an induction motor results in higher currents drawn for the same output, which leads to higher losses. This can be overcome by adjusting the tap changer at power transformer and at distribution transformer, if available.

f) Low power factor: In most of the LT distribution systems, it is found that the power factor varies from as worse as 0.65 to 0.75. A low power factor contributes towards high distribution losses. For a given load, if the power factor is low, the current drawn is high, consequently the losses goes up significantly.

g) Poor workmanship in fittings: Bad workmanship contributes significantly towards increasing distribution losses, as joints are a source of power losses. So the number of joints should be kept to a minimum and at the same time care must be taken to avoid sparking and heating of contacts.

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2.1.3 Methods for the reduction of distribution system losses:

The following methods are adopted for reduction of distribution system losses

- Feeder reconfiguration
- Reactive power compensation
- HV distribution system
- Grading of conductor
- Reinforcement of the feeder
- Construction of new substation

a) Feeder reconfiguration: Feeder reconfiguration is defined as the process of altering the topological structure of distribution feeders by changing the open/closed status of the sectionalizing and ties switches. Feeder reconfiguration allows the transfer of loads from heavily loaded feeders to less heavily loaded feeders. Such transfers are effective not only in terms of altering the levels of loads on the feeders being switched, but also in improving the voltage profile along the feeders and effective reduction in the overall system losses.

b) Reactive power compensation: It is universally acknowledged that the voltage/reactive power control function has pivotal role to play in the distribution automation. The problem of reactive power compensation can be attempted by providing static capacitors.

The present practice to compensate reactive power component is to increase reactive power by increasing the terminal voltage of the generator (or) by increasing the field current of the synchronous machine in condenser mode at generating stations. Shunt capacitors supply the amount of reactive power to the system at the point where they are connected. This in turn causes a reduction in power flow in the line and the consequent benefits are:

Reduction in losses: If the reactive power Q and the system voltage V are assumed to be constant, the losses are inversely proportional to cosφ and hence improvement in power factor causes reduction in losses.

Voltage profile improvement: As the current flowing in the line is decreased due to flow of less reactive power, the voltage drop (IR) will be decreased and hence improvement in voltage profile.

Decrease in kVA loading: Decrease in kVA loading on the source i.e., generators, transformers and line up to the location of capacitors to relieve overloading condition or provide additional capacity for load growth.

Reduces system improvement cost/kVA of load supplied: The effect of shunt capacitors is felt in the circuit from the point of location of the capacitor towards supply only. Hence, the location of shunt capacitor has to be as near the load point as possible for maximum benefits. Thus the location of shunt capacitors at load points which are to be switched on and off along with load is very attractive as the loss reduction is maximum and compensation occurred only when needed.

Demerits of use of shunt capacitors:

- The output of shunt capacitors is proportional to the square of the voltage of the circuit at its location. So the reactive power supplied by shunt capacitor to system gets considerably reduced at the time of peak load conditions due to drop in voltage.
- The shunt capacitor supplies constant reactive power to the system at the location and is independent of the load. Hence optimal compensation provided for peak load condition may result in over compensation at light load, which may result in rise of voltage beyond permissible limits and undesirable operation of system at leading power factor.

- To overcome the overcompensation during light load conditions the automatic switching units can be provided but this switching equipment is costly and this in turn will limit the number of capacitor bank that has to be provided on a feeder.

c) HV distribution system: The low voltage distribution systems contribute about 1/3 of the total losses. The LT distribution system, based on European practice where loads are concentrated in small areas with high load densities and that too with high power factor and load factor is most ill suited to cater to the scattered highly inductive load with very low load densities, low power factor and low load factor prevalent in our country. The situation prevailing is that LV lines are extended irrespective of voltage drops up to full capacity of the distribution transformer, some times over and above the transformer capacity. Hence, no purpose will be served by prescribing low kVA-km loading limits for LV lines when the existing norms are not adhered to at all. The only practice and feasible solution is to eliminate or minimize LV lines by switching over to single-phase high voltage distribution. By adopting HV distribution, the losses in the LV distribution can be reduced by 85%.

Advantages of HV distribution systems:

- It will eliminate losses on lengthy LT lines
- It will have better voltage regulation
- It will improve the power factor as starting and running capacitors are inherently provided to single-phase motors.
- It will improve the supply reliability
- It virtually eliminates pilferage by direct tapping of energy from LT overhead lines.
- Line losses will be reduced by 85% of the LT line losses.

d) Grading of conductor: In normal practice, the conductor used for radial distribution feeder is of uniform cross-section. However the load magnitude at the substation is high and it reduces as we proceed on to the tail end of the feeder. This indicates that the use of a higher size conductor, which is capable of supplying load from the source point, is not necessary at tail end point. Similarly use of different conductor cross sections for inter- mediate sections will lead to a minimum both in respect of capital investment cost and line loss point of view.

The use of larger number of conductors of different cross section will result in increased cost of inventory. A judicious choice can, however be made in the selection of number and size of cross-section for considering the optimal design.

e) Reinforcement of the feeder: Studies on several distribution feeders have indicated that first few main sections (Usually 3 to 5) of the feeder contribute to 60% to 80% of the feeder total losses. This is mainly due to the fact that the conductor size used at the time of erection of feeders is no more optimal with reference to the increased load. The total cost is the sum of fixed cost of investment of the line and variable cost of energy losses in the conductor due to the power flow.

Addition of a new load on existing feeder is limited by its current carrying capacity. So if the existing feeder gets over loaded, the alternative for catering the extra load is only reinforcement of the feeder. This method is considered to be good for short term planning measures.

Reinforcement of conductor is considered necessary as the smaller sized conductors result in high losses due to non-standard planning. However at the time of reinforcement supply interruptions will take place, which leads in loss of revenue.

f) Construction of new substation: If a new substation is to be constructed and connected to an existing network, several possible solutions are to be studied. These solutions may include various connection schemes of the substation and several feasible locations. The number of possible sites are determined by the newly constructed HT (33kV) line and the cost of the substation construction and operation. Due to large number of possible sites, an economical comparison may over look the optimum technical solution. The final decision is usually influenced by additional factors such as topography; land ownership, environmental consideration etc.

The optimum site for a substation is defied as that location which will result in minimum cost of construction with minimum losses. These include both the investments for the 11kV and 33kV voltage systems and the cost of operating the system.

So, by constructing a new substation at load centers, the line losses will be reduced due to improvement in voltage profile and reduction in length of the lines. But for an excess small quantum of load, the decision for construction of new substation cannot be made as the capital investment is high and the substation will run on under load condition for a long time resulting in poor return on the capital. So, in such situations, alternate arrangements can be attempted.

1.3 Literature Survey

1.3.1 Load flow solution for radial distribution network:

Kersting and Mendive [1] and Kersting [2] have developed a load flow technique for solving radial distribution networks using ladder-network theory. They have developed the ladder technique from basic ladder-network theory into a working algorithm, applicable to the solution of radial load-flow problems. Stevens et al. [3] have shown that the ladder technique is found to be fastest but did not converge in five out of 12 cases studied. Baran and Wu [5] have obtained the load flow solution in a distribution system by the iterative solution of three fundamental equations representing real power, reactive power and voltage magnitude. They have computed the system Jacobean matrix using chain rule. They have also proposed decoupled, fast decoupled and very fast-decoupled distribution load flow algorithms. Chiang [6] has also proposed three different algorithms for solving radial distribution networks based on the method proposed by Baran and Wu [5]. In fact decoupled and fast-decoupled distribution load-flow algorithms proposed by Chiang [6] are similar to that of Baran and Wu[5]. However, the very fast-decoupled distribution load flow proposed by Chiang [6] is very attractive because it does not require any Jacobean matrix construction and factorization. Goswami and Basu [8] have presented a direct method for solving radial and meshed distribution networks. However, the main limitation of their method is that no node in the network is the junction of more than three branches, i.e. on incoming two out going branches. Jasmon and Lee [9, 10] have proposed a new load flow method for obtaining the solution of radial distribution networks. They have used the three fundamental equations representing real power, reactive power and voltage magnitudes derived in [5]. They have solved the radial distribution network using these three equations by reducing the whole network into a single line equivalent.

In the proposed method a new load-flow technique for solving radial distribution networks has been developed. The charging currents and effect of transformers at the load end also considered in the proposed method which are not considered in previous methods discussed above. Loads in the proposed method can easily be formulated as constant power provided the effect of transformer is neglected. However, the proposed method can easily include composite load modeling, if the composition of the loads is known.

1.3.2 Network Reconfiguration:

For loss reduction, Merlin and Back [15] presented a heuristic method on net reconfiguration, which is latter modified by shirmohammadi and Hong [16]. In reference 3 an optimal load flow analysis is applied, to determine a low loss configuration with all switches closed and then the branches with the lowest current are opened successively to return the radial structure. The optimal load flow solution is determined after each switch is opened and hence, minimum loss configuration is obtained. A reconfiguration algorithm for loss reduction is presented by Civanlar et. al. [21]. In [21] a loss change formula is derived, based on some simplifying assumptions for the estimation of loss reduction with minimum computational effort. This formula can estimate the loss changes for a particular switching option between two feeders. Recently Baran and Wu [22] have developed an attractive loss reduction formula, following the solution approach proposed by Civanlar et. al. An important feature of

Baran and Wu’s method is that it can be applied for the load transfer not only between the feeders, but also between different substations by branch-exchange type switches. In this case substation nodes are considered as a common node.

Among the various methods to reduce the losses,as part of my project High Voltage Distribution System have been considered to incorporate on typical distribution systems.

2. SIMPLIFIED METHOD FOR LOAD-FLOW SOLUTION OF RADIAL DISTRIBUTION NETWORKS

2.1 Introduction

The operation and planning studies of a distribution system requires a study state condition of the system for various load demands. The steady-state condition of a system can be obtained from the load flow solution. Power flow analysis is a very important and basic tool in the field of power system engineering. Some applications, especially in the field of power system engineering optimization of power system and distribution automation, need repeated fast power flow solutions. In these applications, it is imperative that the power flow analysis is solved as efficiently as possible. With the invention and wide spread use of digital computers in the 1950's, many algorithms for solving the power flow problem has been developed, such as indirect Gauss - seidel (bus admittance matrix), direct Gauss-seidel (bus impedance matrix), Newton-Raphson and its decoupled versions. However, these algorithms have been designed for transmission systems, and therefore their application to distribution systems usually does not provide good results, and very often the solution diverges.

One of the reasons why these methods are unsuitable for distribution systems is that they are mostly based on the general meshed topology of typical transmission system. Where as most distribution systems have a radial or tree structure. Methods like the Newton-Raphson method and gauss-seidel method do not exploit the radial structure of the distribution systems and require the solution of a set of equations whose size is of the order of the number of buses. This then results in long computation time. In addition, Y-bus matrix constructed is very sparse and this implies a waste of computer memory storage. Hence it can be seen that the use of conventional power flow methods is not efficient for distribution systems.

Another reason is due to the high R/X ratio of distribution systems. This is a factor, which causes the distribution systems to be ill conditioned for conventional power flow methods, especially the fast- decoupled Newton method, which diverges in most case.

Though considerable efforts have been directed to the development of solution algorithm for power flow analysis of transmission system with great success, in contrast, comparatively fewer solution algorithms have been developed for power flow analysis of distribution systems.

2.2 List of symbols

NB = total number of nodes
LN1 = total number of branches
j = branch number, j = 1,2,3,…,LN1
PL[i] = real power load at *i* th node
V[i] = voltage of *i* th node
R[j] = resistance of *j*th branch
X[j] = reactance of *j*th branch
Z[j] = impedance of *j*th branch
I[j] = current that flows through branch *j*
IL[i] = load current of node *i*
LP[j] = real-power loss of branch *j*
LQ[j] = reactive-power loss of branch *j*
IS[j] = sending end node of branch *j*
IR[j] = receiving end node of branch *j*
y_0[i] = charging admittance at node *i*
IC[i] = charging current at node *i*
DVMAX= maximum voltage difference

IK[ip] = The node count (identifies the number of nodes beyond a particular branch)

2.3 Assumption

It is assumed that the three-phase radial distribution networks are balanced and can be represented by their single phase equivalent.

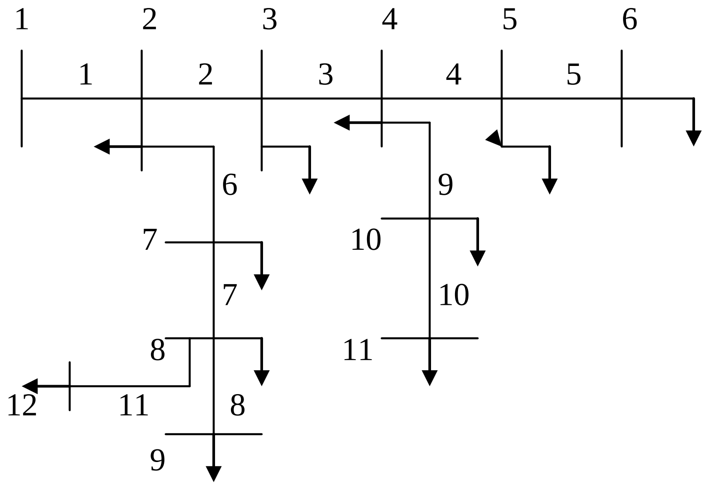

Fig 2.1 single-line diagram of radial distribution network

2.4 Modeling of a Distribution transformer

Distribution transformers must be included in the network modeling procedure since they are quite numerous and contribute to the system losses. Single-phase transformers are represented by series leakage impedance and shunt core loss function on the secondary terminal. Figure 2.2 illustrates the single-phase transformer model.

It is recognized that core loss characteristics vary depending upon the "quality" of the transformer. Tests have indicated that real and reactive power core losses, in per unit, can be approximated as follows [25]:

$$P_{core}\ (\text{p.u}) = \frac{\text{kVA Rating}}{\text{System base}}\left(A\,|V|^2 + B\,e^{C\,|V|2}\right) \tag{2.a}$$

$$Q_{core}\ (\text{p.u}) = \frac{\text{kVA Rating}}{\text{System base}}\left(D\,|V|^2 + E\,e^{F\,|V|2}\right) \tag{2.b}$$

Typical values of A, B, C, D, E, F are

$A = 0.00267$, $B = 0.734 \times 10^{-9}$, $C = 13.5$

$D = 0.00167$, $E = 0.2683 \times 10^{-13}$, $F = 22.74$

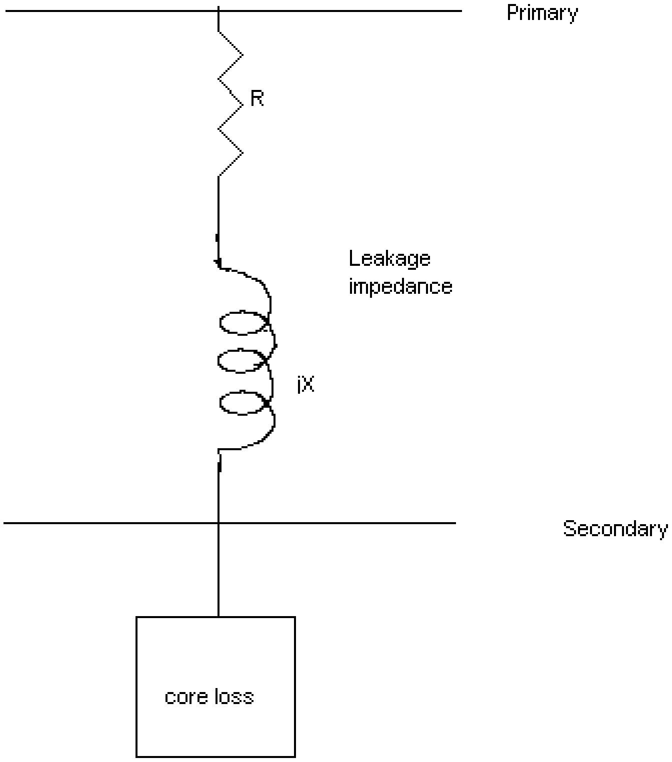

Fig. 2.2 Modelling of single phase transformer

2.5 Solution methodology

Fig.2.1 shows single-line diagram of a distribution feeder. The branch number sending-end and receiving-end node of this feeder are given in Table 1. Consider branch 1. The receiving-end node voltage can be written as

$V(2) = V(1) - I(1)\,Z(1)$ (2.1)

Similarly for branch 2,

$V(3) = V(2) - I(2)\,Z(2)$ (2.2)

As the substation voltage V (1) is known, so if I (1) is known, i.e. current of branch 1, it is easy to calculate V (2) from eqn. 2.1.

Once V (2) is known, it is easy to calculate V (3) from eqn. 2.2, if the current through branch 2 is known. Similarly, voltages on nodes 4, 5, …. NB can easily be calculated if all the branch currents are known. Therefore, a generalized equation of receiving-end voltage, sending-end voltage, branch current and branch impedance is

$V(m2) = V(m1) - I(j)\,Z(j)$ (2.3)

Where j is the branch number

$m2 = IR(j)$ (2.4)

$m1 = IS(j)$ (2.5)

Eqn. 2.3 can be evaluated for j = 1, 2, …. , LN1 (LN1 = NB – 1 = number of branches). Current through branch 1 is equal to the sum of the load currents of all the nodes beyond branch 1 plus the sum of the charging currents of all the nodes beyond branch1, i.e.

LN1 LN1

$$I(1) = \sum_{i=2} IL(i) + \sum_{i=2} IC(i) \qquad (2.6)$$

The current through branch 2 is equal to the sum of the load currents of all the nodes beyond branch 2 plus the sum of the charging currents of all the nodes beyond branch 2, i.e.

$$I(2) = IL(3) + IL(4) + IL(5) + IL(6) + IL(10) + IL(11) + IC(3) + IC(4) + IC(5) + IC(6) + IC(10) + IC(11) \qquad (2.7)$$

Therefore, if it is possible to identify the nodes beyond all the branches, it is possible to compute all the branch currents. Identification of the nodes beyond all the branches is realized through an algorithm [13] as explained in Section 2.6.

The load current of node i is

$$IL(i) = \frac{PL(i) - jQL(i)}{V^*(i)} \qquad i = 2, 3, \ldots NB \qquad (2.8)$$

The charging current at node 'i' is

$$IC(i) = y_0(i)\, V(i) \qquad i = 2, 3, \ldots NB \qquad (2.9)$$

Load currents and charging currents are computed iteratively. Initially, a the sending end (or source voltage) voltage at all the nodes is assumed and load currents and charging currents of all the loads are computed using eqns. 2.8 and 2.9. A detailed load-flow-calculation procedure is described in Section 2.7.

The real and reactive power loss of branch j is given by:

$$LP(j) = |I(j)|^2 R(j) \qquad (2.10)$$

$$LQ(j) = |I(j)|^2 X(j) \qquad (2.11)$$

Table 1: Branch number (j), sending-end (m1 = IS (j)) node, receiving-end node (m2 = (IR (j)) and nodes beyond branches 1,2,3, ….11 of Fig.2.1

Branch number (j)	Sending end m1 = IS[j]	Receiving m2 = IR[j]	Nodes beyond branch j N(j)	Total nodes beyond branch j
1	1	2	2,3,4,7,8,5,10,9,12,6,11	11
2	2	3	3,4,5,10,6,11	6
3	3	4	4,5,10,6,11	5
4	4	5	5,6	2
5	5	6	6	1
6	2	7	7,8,9,12	4
7	7	8	8,9,12	3
8	8	9	9	1
9	4	10	10,11	2
10	10	11	11	1
11	8	12	12	1

2.6 Identification of nodes beyond all branches

Before the detailed algorithm is given, the details of the methodology do identifying the nodes beyond all branches will be discussed. This will help in finding the exact current flowing through all the branches.

j = 1, 2, 3… LN1 (j indicates branch of Fig. 2.1, see also Table 1);

IK (ip) is the node count (identifies the number of nodes beyond a particular branch);

N (j) is the total number of nodes beyond branch j; and IE (j, ip + 1) is the receiving-end node for the 'j' th branch.

Flow chart for identifying the nodes beyond branch 'j' is in fig. 2.3.

2.7 Load-flows calculation

Once all nodes beyond each branch are identified, it is very easy to calculate the current flowing through each branch as described in Section 2.5. For this purpose, the load current and charging current of each node are calculated by using eqns. 2.8 and 2.9. Once the nodes are identified beyond each branch, the expression of branch current is given as

$$I(j) = \sum_{i=1}^{N(j)} IL\{IE(j,i)\} + \sum_{i=1}^{N(j)} IC\{IE(j,i)\}$$

Initially, a constant voltage at all the nodes is assumed and load currents and charging currents are computed using eqns. 2.8 and 2.9. After load currents and charging currents have been calculated, branch currents are computed using eqn. 2.12. The voltage of each node is then calculated by using eqn. 2.3 with eqn.2.4. Real and reactive power loss of each branch is calculated by using eqns. 2.10 and 2.11, respectively. Once the new values of the voltages at all the nodes are computed, convergence of the solution is checked. If it does not converge, then the load and charging currents are computed using the most recent values of the voltages and the whole process is repeated.

The convergence criterion of this load flow method is that if, in successive iterations the maximum difference in voltage magnitude (DVMAX) is less than 0.0001 p.u., the solution has then converged.

3. HIGH VOLTAGE DISTRIBUTION SYSTEM FOR LOSS REDUCTION

3.1 Introduction

The two widely prevalent distribution practices in vogue across the world are:

Low voltage distribution system (LVDS): This is based on European practice, where three-phase transformer of considerable capacity is installed and LV lines are extended to cater to a group of loads. This system is best suited to meet the concentrated loads of high load density incident in European countries.

High voltage Distribution System (HVDS): This is based on North American practice where three phase or single phase HV line is taken as near the load as possible and a distribution transformer of appropriate capacity is installed to feed one or small group of loads, such that the length of the LV lines is minimum or eliminated altogether. This system is best suited to meet the scattered loads of low load density, incident in developing countries like Malaysia.

3.2 Power losses scenario

The LVDS, which was in vogue in metropolitan and large cities at the time of independence, was adopted to extend supply to remote villages, energize agricultural pump sets and intensive electrification of small urban towns, without reckoning the characteristics of the loads and the cost of losses. As a result, the energy losses, which were 15% in 1960, have risen to 22 to 25% by 1980 and continue to increase further. During the same period two other Asian countries namely South Korea and Japan, which were having 25 to 30% of losses in 1960, have brought it down to 6% by 1980 by switchover to HVDS. This situation is true in respect of number of developing countries in Asia.

The design and investment in transmission and distribution system and to a large extent generating system is related to the maximum demand incident on the system. The annual energy losses of 20 to 25% correspond to peak power loss of 35 to 40%, considering the load factors prevailing at various voltage levels. In generation of 4000MW, power loss in the auxiliaries is of the order of 400MW and 1600 MW is lost as peak power loss in T&D system and only 2000 MW is left to meet demand of consumers. With increasing cost of generating plant and transmission and distribution system utilities can no more afford to burn the power on the distribution lines. The average energy losses in various elements of the power system of Malaysia and the corresponding tolerable maximum limit and the target level are shown in table 2.

Table 2: Review of System Losses

System Element	Existing Level %	Max. Tolerable limit %	Target Level %
Transmission	4.0	4.0	2.0
Sub Transmission	4.0	4.5	2.25
High Voltage Distribution	6.0	5.0	3.0
Low Voltage Distribution	8.0	2.0	1.0

Total	22.8	15.5	8.25

On review of table, it could be seen that losses in the Distribution network is the principle contribution factor for high losses scenario in the power system. Therefore, the utilities in the developing countries like Malaysia, felt the need to switch over to HVDS wherever applicable to reduce the losses in the Distribution Systems.

3.3 Technical features

The important drawbacks of LVDS and the way in which these are automatically solved by adopting HVDS are described below:

a) Line losses

LVDS: The long LV lines of small conductor sizes cause high line losses. The low voltage network energy losses alone are estimated to be 8% to 10% of total energy handled or in other words the low voltage network contributes about 30% of total energy losses. The international norms for energy losses in the low voltage network are 1% to 2%. Thus the energy losses of low voltage network of LVDS are 5 to 6 times the international norms.

HVDS: The HV line is taken as near the load as possible and a LV service cable is run to feed loads. The losses in HV system for the distribution of same amount of power is less than 1% that of LV line. Thus the line losses in the LV network are negligible bringing down the total energy losses considerably.

b) Voltage drop

LVDS: The voltage drop in the LVDS is very high as the lines are long and conductor sizes are small. The sample studies made on Andhra Pradesh Distribution system indicated that 50% of LV feeders have more than 10% voltage drop and another 25% have more than 5% and less than 10% voltage drop. The maximum permissible voltage drop on the LV feeders is 5%.

HVDS: The voltage drop for distribution of same power is less than 1 % that of LVDS and this ensures proper voltage profile at all customer points.

c) System power factor

LVDS: The Power Factor (PF) of three phase motors of Agricultural pumps, which is main load in rural areas is as low as 0.7. This low power factor is the most important cause for high energy losses, poor voltage profile and over loading of the power system. The terms and conditions of supply have been amended making it obligatory on the part of the consumer to provide capacitors for Power Factor correction but this could not be enforced as a motor can be run without a capacitor and the tariff is not based on Power Factor of service.

HVDS: The single phase motors can be used for all Agricultural services. The single-phase motors have built in capacitors and the PF is more than 0.95 and almost nearer to unity. Further the motor cannot be run without a capacitor and hence PF of the load is high. Thus system power factor is always maintained high.

d) Failure of distribution transformers

LVDS: The present failure rate of three phase distribution transformers is 15 to 20%. The major contributing factors for this high failure rate are LT line faults and indiscriminate loading of transformers over and above its capacity. The lengthy LT lines in LVDS coupled with poor construction standards is the cause for large number of LT faults. Further the fault current due to a fault at tail end of lengthy feeders may not be adequate enough to cause protective device operation and it reflects as a load on the network. Thus these faults cause frequent failure of transformers. The overloading of transformers could not be effectively checked as it serves large number of consumers spread over a wide area.

HVDS: The length of LT lines is minimum. Further the AB cables are used for LT lines, as the current ratings are low and as AB cable is cheaper than bare conductor construction at low current ratings. Thus the failure of transformers due to LV line faults is eliminated. The loading of transformer over and above its capacity will be externally prevented by consumers whom it serves, as its failures will affect their supply.

e) Theft of energy

LVDS : Theft of Energy by direct tapping of long LT lines passing through Agricultural fields in rural area and colonies in Urban area has become a menace in recent years. It is estimated that the number of direct tapping for pump sets is estimated to be as high as 20 to 25% of total number of services connected. These unauthorized tapings are mainly responsible for overloading of the system and consequential failure of transformers, high energy losses and high voltage drop.

HVDS: The LT lines are virtually eliminated and even the short LT lines required will be of AB cable. This makes direct tapping of lines a very difficult task. Each transformer caters 2 or 3 consumers and they can be made responsible to prevent any unauthorized connection on the transformer.

f) End use equipment efficiency

LVDS: The high voltage drops in the LV network results in low voltages at customer premises particularly agricultural pump sets. This has resulted in large scale burning of pump sets motors. It is estimated that motors are rewound once in two years and the efficiency of rewound once in two years and efficiency of rewound motor is generally lower than that of new motor. Further efficiency of motors is lower than rated efficiency, when operated at voltages lower than rated voltage. Thus the end use equipment efficiency is low resulting in wastage of energy.

HVDS: The voltage drop for distribution of same amount of power is less than 1% that of LVDS and thus the voltages at the consumer premises can be maintained satisfactorily. This will avoid burning of motors. The efficiency of end use equipment is also kept high, bringing in considerable benefits by way of energy conservation.

g) Reliability of supply

LVDS: The frequent faults on LT lines cause blowing off fuses at distribution transformers or failure of transformers resulting in interruption of supply to the consumers. This interruption will not come to the notice of substation operator unless it is reported by the affected consumers. Further failure of transformer will affect supply to large number of consumers served by it. Thus the reliability of power supply is poor.

HVDS: The LT lines are short and insulated, avoiding all LT faults. The faults on HT line will come to the notice of the operator immediately due to tripping of substation breaker. The reliability of HV system can easily be improved by providing sectionalizors with auto reclosures on the line. The failure of transformer will affect a very small number of consumers served by it. Thus the reliability of power supply is very high.

h) Voltage fluctuations

LVDS: Due to high voltage drop on LV lines the consumers are subjected to wide voltage fluctuations with variation of load. All the modern electrical and electronic equipment are sensitive to voltage variations and the consumers are forced to use stabilizers to provide stable supply. The voltage stabilizers draw reactive power from the system causing associated reactive power management problems on the upstream side of the power system.

HVDS: The voltage drop on the LT line is negligible. The additional drop due to extension of HV line up to consumer premises is also negligible. Thus, the voltage profile is very stable and there will be no need to use voltage stabilizer. Further, any