Review on Transmission Loss Optimization Using Power

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Abstract- The distribution systems must be able to provide energy/electricity to each consumer at an appropriate form of voltage rating. The modern forms of power are complex in nature with multiple load centres and generating stations interconnected through the transmission and distribution networks. The main objective of the energy based power system is energy generation and to deliver the energy/power at to its customers at its rated voltage-based value with minimum losses [3]. In case of heavy loading condition, the reactive form of power flow is the major cause of losses, thus reducing the levels of voltage simultaneously. So, there is occurs a big need to minimize real losses of power and to improve the level of voltage in distribution systems. In such cases, a variation occurs in the network configuration usually varying by the operation based on switching meant for transferring the load among the feeders. Basically there are two switches used in distribution systems; one is normally closed switch that usually connects two line-based sections and the other is the normally open switch placed on tie lines connecting two of the primary feeders in the section.The optimized form of network configuration represents a topological feeder structure by changing the open/closed sectionalizing status and tie-line switches with minimized losses, saving the distribution system radial structure

Keywords- losses, power, optimization, distribution

I. INTRODUCTION

The energy plays a vital role for all the humans as the it can neither be created nor it get destroyed but it can move/transform from one place to other. The modern living has realized the increased importance of energy as the life is moving faster, there is big need for fast communication, fast transport and manufacturing processes. So, energy industry forms one of the biggest consumer market [1, 2]. The use of electric power system requires an alternative generation because of its large demand by the consumers. The electricity cost is calculated based on different proportions such as 50% for fuel consumption, 25% for distribution, 20% for generation, and % for transmission which has created an alert to use or generate the alternative resources of power. For the levels of distribution, the ratio of reactance to resistance (X/R) is low when compared to levels of transmission which has resulted in high power losses and voltage magnitude dip along the distribution (radial) lines. [4, 5]. Generally speaking, the reconfiguration mechanism of network is a basic need to provide service to multiple customers in case of faulty condition or for the purpose of its maintenance, to minimize the real power losses, and to maintain load balance avoiding overloading conditions of network.The electrical power distribution represents the final stage of power delivery. It usually carries power or electricity from the transmission system to its customers on individual basis. When the distribution system gets connected to transmission system, it lowers the transmission voltage to a medium form of voltage lying between 2KV and 35KV with the help of transformers used in the system [6]. The primary lines of distribution carries medium voltage to the transformers in the distribution section placed near customer's location.

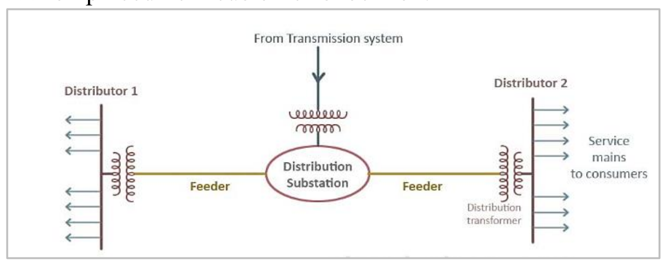

Fig.1: Simple radial AC power distribution system [11]

The distribution transformers again performs the voltage reduction for its utilization process in distinct areas such as household appliances, lighting, industrial equipment etc. Some of the consumers gets the supply from single (one) transformer through secondary-based distribution lines. The residential and the commercial consumers are linked to secondary distribution lines through the service-drop mechanism. The highly demanding consumer may be linked to primary level of distribution or sub-transmission level on direct basis.

The high level of power loss in distribution and transmission system results in reduction of existing system's efficiency [7]. The study has indicated that the losses of distribution power owed or unsettled to Joule effect justifies 13% of the energy generated. The effect defines the lost energy (heat dissipated) in a conducting material. Fig. indicate the losses of transmission and distribution in total power output percentage for several countries including the power theft/ pilferage. The data provided by the World Bank indicates a worldwide study of transmission and distribution losses (annually) that accounts for 8.12% of the transmitted electricity. The loss of transmission and distribution for Haiti carries 55.39% loss which created a huge impact on the financial status of the country including the overall efficiency and performance of the system [9].

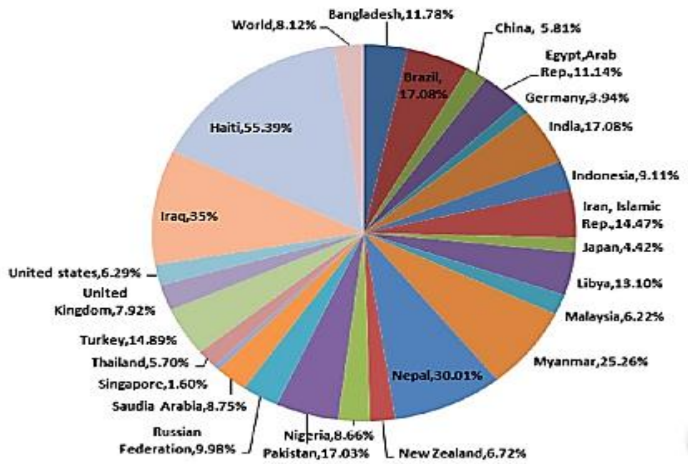

Fig.2: Data Analysis: Transmission and Distribution Losses [12]

Thus the major challenge is to deal and focus upon the present researching methods and areas that would effectively utilize the existing technologies and infrastructure with superior planning.

A. Load Flow Analysis

The study of power flow popularly known as load flow helps in determining the bus voltages (steady-state), transformer tap settings, active and reactive power flows, voltage set points for generator exciting regulator, circuit loading, losses in system, and system performance in case of emergency condition. It also determines the initial motor start-up based voltage profile [8]. The power systems operate critically under slow transforming conditions that may be analysed using steady-state operation. This type of analysis provides a starting platform to other type of analysis such as under heavily loaded system, the disturbances that cause instability but it may not have any effect in case of lightly loaded conditions. The analysis of power flow is the major core area for the analysis of power systems like additional planning, facilities of generation, and transmission-based expansions. The problem of such systems can be dictated as follows: a network with critical power loads with some specified restrictions on the voltages and the power generation solving for the un-specified generation, unknown bus voltages, and network components based complex power flow. In addition, the individual component losses in total are evaluated. Further, the conditions of overloads and voltages along with allowable tolerances are checked very often. So, for the study of load flow analysis, generally a balanced three-phase operation is usually assumed. The network planning for medium voltage and Load flow calculation usually involves the following steps:

1. To determine the values of element for the components of passive networks.
2. To determine the values and locations of all power (complex) loads.
3. To determine the generation constraints and its specifications.
4. To develop a mathematical model that particularly describes network power flow.
5. To check constraint violations.
6. To compute all the system bus voltages.
7. To determine the transmission lines based reactive and the real power flows in the network.

The calculations of the load flow are generally carried to maintain system stability while it's running operation and determines optimal or possible selection grid component selection like machine regulators automatic control setting, transformers' voltage regulators etc. The inputs to be determined are the currents and/or voltages and/or the reactive/active power at the generator's port or the customer's port. The cables and the over-head line form the significant elements of the network [10, 11]. To carry simple grid-based calculations, few elements of the circuit are used for a specified task. For low line voltages, mostly there is work done by the ohmic resistance and for high line voltages, the longitudinal impedance is to be considered for the operational purpose and for long lines, the capacitive components must be kept in mind [13]. In order to classify the overloading of the equipment and the voltages at the busbar, the given limit values along with network operator are jointly provides as follows:

Table.1 Network equipment description

Network equipment description	Degree of loading
-	%
rated load	< 80
heavy load	≥ 80, < 100
over load	≥ 100

Table.2 Voltage level description

Voltage leveldescription	Voltage more than % nominal voltage
-	%
bus bar voltage is ok	≥ 94, ≤ 106
bus bar voltage is to low	< 94

The load flow can also be calculated with some of the most commonly used methods such as Newton-Raphson, Extended Newton-Raphson, Gauss-Seidel, Power iteration method, and DC flows.

B. Voltage Stability

It is defined as the power system ability to maintain steady-state system voltage at all the buses in the operating system after the subjection of disturbance from initial condition of operation. It basically carries issues. One is the maximum load ability estimation and the critical power computation leading to voltage collapse. In large typical networks, the load flow analysis is used very commonly [12, 13]. This section carries the analysis of power/load flow with its voltage stability application to understand the concept of voltage stability indices. The voltage stability index helps in computing the bus proximity very sensitive to the mechanism of voltage collapse in distribution systems. The distribution line interchanged power equations active and reactive equations of power is basically used to develop the index for stable process and hence, it only requires solution based on power flow study at its necessary power equation. The mathematical representation of voltage stability index based on distribution line model as shown in fig. is presented as follows:

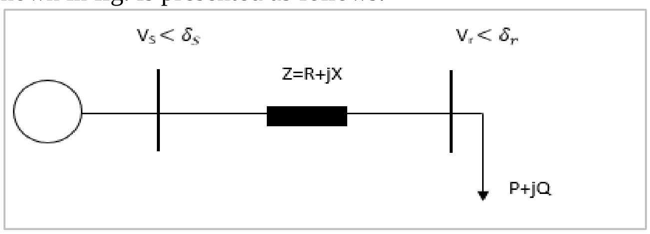

Fig.3: Single Line Diagram: Two bus distribution system

The quadratic equation which is commonly in load flow analysis are used for calculating the sending end line voltages and these can be written in a generalized form given as:

$$V_r^4 + 2V_r^2(PR + QX) - V_s^2V_r^2 + (P^2 + Q^2)|Z|^2 = 0 \ldots\ldots\ldots (1)$$

From equation (1), the active and the reactive power at the line receiving end can be written as

$$P = -\cos(\emptyset_Z)\,V_r^2 \pm \frac{\sqrt{\cos^2(\emptyset_Z)\,V_r^4 - V_r^4 - |Z|^2Q^2 - 2V_r^2\,QX + V_s^2V_r^2}}{|Z|} \ldots\ldots\ldots .2(a)$$

$$Q = -\sin(\emptyset_Z)\,V_r^2 \pm \frac{\sqrt{\sin^2(\emptyset_Z)\,V_r^4 - V_r^4 - |Z|^2P^2 - 2V_r^2\,PX + V_s^2V_r^2}}{|Z|} \ldots\ldots\ldots 2(b)$$

From equation 2(a) and 2(b), the values of real (P) and reactive powers will exist at receiving end based on the following condition.

$$\cos^2(\emptyset_Z)\,V_r^4 - V_r^4 - |Z|^2Q^2 - 2V_r^2\,QX + V_s^2V_r^2 \geq 0 \ldots\ldots\ldots\ldots 3(a)$$

$$\sin^2(\emptyset_Z)\,V_r^4 - V_r^4 - |Z|^2P^2 - 2V_r^2\,PX + V_s^2V_r^2 \geq 0 \ldots\ldots\ldots .3(b)$$

Performing the summation at each side of equation 3(a) and 3(b)

$$2V_s^2V_r^2 - 2V_r^2(PR + QX) - |Z|^2(P^2 + Q^2) \geq 0 \ldots\ldots\ldots\ldots\ldots (4)$$

Thus with the help of equation (4), it is observed that there is some reduction/decrease with increased line impedance and power transferred and thus it can be used for maintaining the bus stability index for the case of distribution network system is given as:

$$SI\ (r) = 2V_s^2V_r^2 - V_r^4 - 2V_r^2(PR + QX) - |Z|^2(P^2 + Q^2) \ldots\ldots (5)$$

The equation (5) is used to find the voltage stability index in radial distribution systems for each of the receiving bus end. Thus after load flow study operation, all the nodal voltage and the branch currents are known which helps in easy calculation of real (P) and the reactive (Q) powers. The position of the node where the stability index value stays minimum is considered to be most sensitive to voltage collapse mechanism.

C. ***Distribution System:***

a. Power Loss Minimization

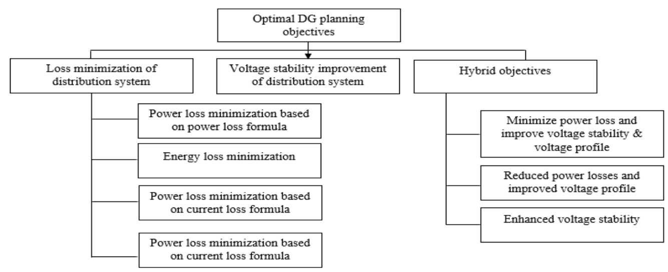

Fig.4: Optimal DG planning objectives

The losses in distribution system cost utilities carries a sizeable profit amount, so it is required to be reduced. Various techniques are used for loss reduction. Some of the techniques are used during the initial design and installation based modelling like choosing optimal location and selecting efficient distribution transformer, selecting low resistive materials and the use of high level voltage profiles [11, 12]. The other type of techniques include the use of harmonic filter placement, shunt capacitor use, demand side management, and load balancing.

b. Losses in Distribution System

The major role of electrical-based distribution system is to provide electricity to its particular customers with the process of completing the mechanism with minimum point of voltage. From bases, the electrical power distribution is complemented at its end level with losses of power at all the times. In distribution systems, the losses of power arise due to Joule's effect affecting economy straightly [18]. Such type of major losses effect the supply utility efficacy in total. There are two types of power distribution losses.

- Technical Losses: The losses that occur technically usually occur natural in form (due to internal action to power system) and consist as the process of power dissipation in electrical power system)

- Non-Technical Losses: These occur basically by external actions such as electricity theft, errors, record-keeping, and customer's non-payment for electricity.

c. Loss Reduction Techniques

Various types of reduction techniques are described in the section below:

*1. Network Reconfiguration:*It is technique or procedure of switches operating to modify the topology of the circuit such that the charges and operational overloads get more concise while sustenance of the stated constraints.

*2. Network Re-conductoring:*In the given network, the technique of re-conductoring in the used (present) conductor on feeder is usually replaced by optimum size conductor for feeder optimum dimension. It is used when the present form of conductor ends it optimum behavior due to system's load growth. This type of technique is excellent for developing nations like India where the annual growing rates are large and the conduction selection is basically done to lower the initial investment on financial basis [2, 8].

3. Distribution Transformers Sizing and Locating: In aspect of clients, the DTs are not located centrally i.e. the main reason for the farthest consumers to have low voltage whereas the high level of voltage gets retained at other transformer. This has contributed to distribution system maximum losses [10]. Here, the DTs must be placed near to load center and the large transformers must be replaced by small rating transformers which serves small consumers in order to maintain optimum level voltage.

*4. Automatic Voltage Booster:*Popularly known asAVB which at point of site increases the voltage in different steps in turn developing the voltage profile and reduce the sectional losses outside its point of location towards its receiving side. The voltage boost done by AVB is approximately 10% in equal steps. So, the minimization of loss is directly proportional to enhancement process of voltage.

*5. Reactive Power Compensation:*It describes the energy management to boost ac energy systemenactment. This kind of technique provides a large area of both the difficulties related to consumer and the system, specifically related to subjects of power superiority as some of the QoS (quality of service) can be easily resolved with reactive power requisite control. In distribution system, there is use of inductive load requiring large reactive power. The shunt based capacitor at its site helps in providing compensation for reactive power i.e. not dependent on load whereas the use of series capacitor contributes to negative reactance [11]. This means that series-based compensation alters the factors or the conductors of distribution system whereas the shunt-based compensation variates the corresponding load impedance.

*6. High Efficiency of Transformers***:** The highly efficient transformers helps in reduction of losses with the use of amorphous core transformers having high magnetic vulnerability, with electrical resistance (maximum) and less coactivity.

7. High Voltage Distribution System: This technique is most effective and efficient in minimizing the technical losses and refining the power quality in distribution system. In this technique, transformation of previous Low Voltage Distribution System to High Voltage Distribution System is done. This technique aims at extending high voltage lines as nearer to the load as possible and replacing large transformers with various small rating transformers. By using high this method, we can reduce the losses as current is low in high voltage systems.

8. Aerial Bunched Cables (ABC): The aerial bunched cables (ABC) provides the best choice in urban areas due to flexible for switching lane. It offers reliability and safety, reduces final system budget and power losses by lowering the repairs, operational cost, and setting up. This kind of technique is used for rural type distribution.

d. Distribution System: Voltage Profile Improvement

In a power system, the operator of the system needs to maintain the level of voltage for each of the consumer bus within specified limit. In distribution system, for ensuring a satisfied profile voltage, distinct standards have been developed to provide recommendations or stipulations [26]. In distribution system, the recommendations by American National Standards Institute (ANSI) {standard C84.1} has specified the voltage variation range lying within -13% to 7%. In practice, various electrical companies, try to control voltage variation within ±6%. The most improved technology adopted was the use of distributed generation (DG) in the distribution systems. The units of DG improve the profile of voltage by transforming the patterns of power flow. The size and location of DGs plays a key role in maintenance of voltage profile. However, in case of medium voltages tie/sectionalizing switches are provided in such a way that the configuration of the network may get altered in order to requirements of operation. The configurational transformation transforms/alters the path of power flow resulting in transformed altered node voltages, degree of unbalances, line currents, and also alters the node voltages distortion level in the presence of harmonics. As the power flow path impedance gets changed because of reconfiguration process, the nodal voltage present in case of voltage sag has the liability to be changed. The problem of tripping of sensitive loads may occur due to process of voltage sag, it is evident that the enhanced voltage sag has the ability to lower the system loss under the condition of voltage sag. The change of nodal voltage harmonic content is resulted by the change in mutually induced voltage and power flow path effective impedance due to transformation in current distribution line. Thus, the task of network reconfiguration can be formulated as:

1. Minimizing the network power losses.

2. Maximizing the network voltage sag in case of switching or fault.
3. Minimizing nodal voltage harmonic distortion.
4. Minimizing the system-based unbalances.

e. Distribution System: Network Configuration

The distribution based network configuration involves the following points:

1. Branch exchanges for loss minimization: The minimized-power loss configuration is basically obtained where there occurs optimum flow pattern with the process of exchanging branch operations. The open tie switch at its normal operation is usually closed for loop formation. The power flow pattern on optimum basis is identified by solving KVL and KCL loop equations, where

KVL is written as resistive voltage drops summation in the loop where it is equal to be zero. This kind of pattern for power flow corresponds to minimized power flow loss.

2. Branch exchanges for minimized voltage unbalances: For reduction of voltage unbalances, the process starts with its initial radial configuration. Further the network load flow is performed and the voltage nodal unbalance occurs in the operation. The identification of maximum voltage unbalance occurs at its node and the selection of tie-line takes place where the closing of tie-switch results in loop formation including the node identification. The voltages modified at its node in the loop are evaluated and the power flows are determined through the loop branches. The line having minimum power flow is chosen to be in open form such that nodal voltages are disturbed minimally. This kind of procedure helps in reduction of voltage unbalance due to loop formation, the redistribution of current flow takes place. The maximum branch flows, alternative paths availability get reduced which results in branch voltage drops reduction. It helps in improved quality of node unbalances and node voltages. If the branch with minimum flow is opened in its network, the loop flow pattern is least disturbed and the resulting network is modified or updated.

3. Branch exchanges for compounded problem: The compounded form of reconfiguration problem seek to simultaneously satisfy all the tasks. Thus the procedure of minimizing single task is avoided. The priority is allotted to the task that depends upon its values and its importance in the network prevailed configuration. The loss of power is a critical issue as it carries money wastage repeatedly, so it is called as the highest priority. The main effort is the attempt for system losses reduction. For indices case of power quality, an attempt is generally made for reducing some of the critical violations. Initially, a radial type of configuration, the load flow, harmonic flows are solved and the losses of the system, unbalances of voltage, harmonic distortion are observed or determined. Further voltage sag is performed along with the evaluation of power quality indices and further these are compared with limiting values. In violation case, the severe case is identified and the tie branch is chosen such that a loop gets formed which includes loop problematic node. Thus the updated loop quantities are formed are determined and a chosen branch is opened for the process.

f. Sensitivity Factors & Multi-objective Function

This basically includes the formation is system multi-objective functions and sensitivity based factors. Here, the both the reactive and the real flow of power and the sensitivity factors based on power flow loss are designed using load flow Newton-Raphson based Jacobian matrix whereas the multi-objective function gets formulated considering three major points such as loss reduction using real and reactive power and the improvement of voltage profile [4]. So, both the constraints of equality and inequality are defined.

g. System Power Flow: Sensitivity Factor

The power flow sensitivity of the system is defined as the power flow change in transmission or distribution line linked between two types of buses [bus (i) and bus (j)] due to change in unit in injected power at any system bus.

The power injected of complex form by source into bus say the power system with $i^{t\square}$ bus is represented as:

$$S_i = P_i + jQ_i = V_i J_i^*; i = 1,2 \ldots \ldots, n \ldots\ldots\ldots\ldots\ldots\ldots (1.1)$$

Where;

V_i = Voltage at the bus ($i^{t\square}$) w.r.t ground.

J_i= Source current injected into bus

For load flow to be handled in more convenient for either of the two is encouraged. The result indicate the complex conjugate of the equation written above.

$$S^*{}_i = P_i - jQ_i = V^*{}_i J_i \,; i = 1,2 \ldots \ldots, n \ldots\ldots\ldots\ldots\ldots\ldots (1.2)$$

The current source is given by;

$$J_i = \sum_{j=1}^{n} Y_{ij} V_j; i = 1,2, \ldots \ldots, n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1.3)$$

After, substituting the equation into power injection based complex conjugate equation, we get:

$$P_i - jQ_i = V_j^* \sum_{j=1}^{n} Y_{ij} V_j; i = 1,2, \ldots \ldots, n \ldots\ldots\ldots\ldots\ldots (1.4).$$

Equating real and imaginary parts of the equation above:

$$P_i = Re\left\{V_i \sum_{j=1}^{n} Y_{ij} V_j\right\} \ldots \ldots \ldots \ldots \ldots (1.5a)$$

$$Q_i = -Im\left\{V_j^* \sum_{j=1}^{n} Y_{ij} V_j\right\} \ldots \ldots \ldots \ldots (1.5b)$$

The polar form of V_i and Y_{ij} is expressed as follows:

$$V_i = |V_i| e^{j\delta i} \ldots \ldots \ldots \ldots (1.6)$$

$$Y_{ij} = |Y_{ij}| e^{j\delta i} \ldots \ldots \ldots .. (1.7)$$

The real and reactive powers from the above polar form are expressed as follows:

$$P_i = |V_i| \sum_{j=1}^{n} |V_i| \, |Y_{ij}| \cos(\theta_{ij} + \delta_{ij})\,; i = 1,2, \ldots., n \ldots \ldots \ldots \ldots (1.8a)$$

$$Q_i = -|V_i| \sum_{j=1}^{n} |V_i| \, |Y_{ij}| \cos(\theta_{ij} + \delta_{ij}) \, ; i = 1,2, \ldots, n \ldots \ldots \ldots \ldots (1.8b)$$

1. Change in Real Power Flow Analysis: The real power flow connecting two of the buses in a line *k*, the bus j and i are expressed as follows:

$$P_{ij} = V_i V_j Y_{ij} \cos(\theta_{ij} + \delta_{ij}) - V_i^2 Y_{ij} \cos\theta_{ij} \ldots \ldots \ldots \ldots (1.9)$$

Where,
$V_i and\ V_j$= voltage magnitude at i and j buses
$\delta_i and\ \delta_j$ = voltage angles at i and j buses
Y_{ij}= $ij^{t\square}$element based magnitude of Y_{bus} matrix
θ_{ij}= $ij^{t\square}$ element based angle of Y_{bus} matrix
The mathematical representation of real power sensitivity is given as:

$$\begin{pmatrix} \frac{\Delta P_{ij}}{\Delta P_n} \\ \frac{\Delta P_{ij}}{\Delta Q_n} \end{pmatrix} \ldots \ldots \ldots \ldots . (1.10)$$

With Taylor expansion methodology, the real line flow change (excluding higher order terms) is expressed as:

$$\Delta P_{ij} = \frac{\partial P_{ij}}{\partial \delta_i} \Delta\delta_i + \frac{\partial Q_{ij}}{\partial \delta_j} \Delta\delta_j + \frac{\partial Q_{ij}}{\partial V_i} \Delta V_i + \frac{\partial Q_{ij}}{\partial V_j} \Delta V_j \ldots \ldots \ldots \ldots \ldots (1.11)$$

The appearing coefficients of equation (11) are obtained using real power flow based partial derivatives given as:

$$\frac{\partial P_{ij}}{\partial \delta_i} = V_i V_j Y_{ij} \sin(\theta_{ij} + \delta_{ij}) \ldots \ldots \ldots \ldots \ldots .. 1.12(a)$$

$$\frac{\partial P_{ij}}{\partial \delta_j} = -V_i V_j Y_{ij} \sin(\theta_{ij} + \delta_{ij}) \ldots \ldots \ldots \ldots \ldots \ldots \ldots (b)$$

$$\frac{\partial P_{ij}}{\partial V_i} = V_j Y_{ij} \cos(\theta_{ij} + \delta_{ij}) - 2V_j Y_{ij} \cos\theta_{ij} \ldots \ldots (c)$$

$$\frac{\partial P_{ij}}{\partial V_j} = V_j Y_{ij} \cos(\theta_{ij} + \delta_{ij}) \ldots \ldots \ldots \ldots (d)$$

2. Change in Reactive Power Flow Analysis: The change is reactive power flow connecting two of the buses of the line k are expressed as:

$$Q_{ij} = -V_i V_j Y_{ij} \sin(\theta_{ij} + \delta_{ij}) + V_i^2 Y_{ij} \sin\theta_{ij} - \frac{V_i^2 Y_{s\square}}{2} \ldots \ldots \ldots .. (1.13)$$

Where,
$V_i\ and\ V_j$ = voltage magnitude at *i*and *j* buses.
$\delta_i\ and\ \delta_j$ = voltage angles at *i*and *j* buses.
$Y_{s\square}$ = shunt charging admittance (line k)
The mathematical representation of reactive power sensitivity is given as:

$$\begin{pmatrix} \frac{\Delta Q_{ij}}{\Delta P_n} \\ \frac{\Delta Q_{ij}}{\Delta Q_n} \end{pmatrix} \ldots \ldots \ldots \ldots . (1.14)$$

With Taylor expansion methodology, the reactive line flow change (excluding higher order terms) is expressed as:

$$\Delta Q_{ij} = \frac{\partial Q_{ij}}{\partial \delta_i} \Delta\delta_i + \frac{\partial Q_{ij}}{\partial \delta_j} \Delta\delta_j + \frac{\partial Q_{ij}}{\partial V_i} \Delta V_i + \frac{\partial Q_{ij}}{\partial V_j} \Delta V_j \ldots \ldots \ldots \ldots \ldots (1.15)$$

The appearing coefficients of equation (11) are obtained using reactive power flow based partial derivatives given as:

$$\frac{\partial Q_{ij}}{\partial \delta_i} = V_i V_j Y_{ij} \cos(\theta_{ij} + \delta_{ij}) \ldots \ldots .. 1.16(a)$$

$$\frac{\partial P_{ij}}{\partial \delta_j} = -V_i V_j Y_{ij} \cos(\theta_{ij} + \delta_{ij}) \ldots \ldots \ldots .. (b)$$

$$\frac{\partial P_{ij}}{\partial V_i} = -V_j Y_{ij} \sin(\theta_{ij} + \delta_{ij}) + 2V_j Y_{ij} \cos\theta_{ij} - V_j Y_{s\square} \ldots \ldots (c)$$

$$\frac{\partial Q_{ij}}{\partial V_j} = -V_j Y_{ij} \sin(\theta_{ij} + \delta_{ij}) \ldots \ldots \ldots \ldots \ldots \ldots \ldots (d)$$

h. System Power Loss: Sensitivity Factor

The circuit below shows both the real and the reactive power loss based on the sensitivity factors which helps in calculation of the power losses [29].

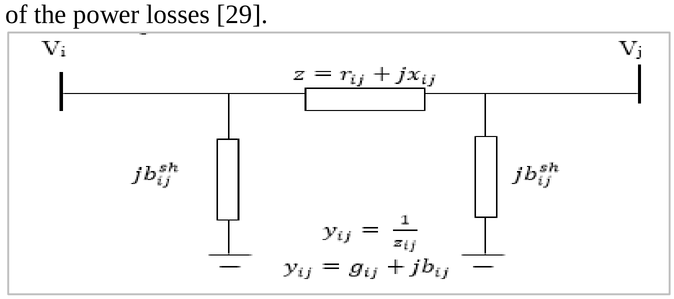

Fig.5: Line lumped circuit model

1. Change in Real Power Loss Analysis: The line lumped circuit model loss in case of active power shown in the circuit is represented as:

$$P_{L(ij)} = g_{ij}(V_i^2 + V_j^2) - 2\,V_i V_j \cos\delta_{ij} \ldots \ldots \ldots \ldots \ldots \ldots . (1.17)$$

The active power loss in total is evaluated as:

$$P_{L(total)} = \sum_{i=1}^{nl} [g_{ij}(V_i^2 + V_j^2) - 2\,V_i V_j \cos\delta_{ij}] \ldots \ldots \ldots \ldots (1.18)$$

Where,
nL= network lines
g_{ij}= line i-j conductance
V_i = nodal voltage at bus-i
V_j = nodal voltage at bus-j
δ_{ij}= phase angle difference at busses i and j
Mathematically, the real power loss sensitivity is given as:

$$\begin{pmatrix} \frac{\Delta P_{L(ij)}}{\Delta P_n} \\ \frac{\Delta P_{L(ij)}}{\Delta Q_n} \end{pmatrix} \dots\dots\dots\dots(1.19)$$

The taylor expansion ignoring second and higher order term is given as:

$$\Delta P_{L(ij)} = \frac{\partial \Delta P_{L(ij)}}{\partial \delta_i}\Delta\delta_i + \frac{\partial \Delta P_{L(ij)}}{\partial \delta_j}\Delta\delta_j + \frac{\partial \Delta P_{L(ij)}}{\partial V_i}\Delta V_i + \frac{\partial \Delta P_{L(ij)}}{\partial V_j}\Delta V_j \dots\dots\dots\dots\dots(1.20)$$

Where,

$$\frac{\partial \Delta P_{L(ij)}}{\partial \delta_i} = 2\, g_{ij}\, V_i V_j \sin\delta_{ij} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..1.21(a)$$

$$\frac{\partial \Delta P_{L(ij)}}{\partial \delta_j} = -2\, g_{ij}\, V_i V_j \sin\delta_{ij} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(b)$$

$$\frac{\partial \Delta P_{L(ij)}}{\partial V_i} = g_{ij}\left(2\,V_i - 2V_j\cos\delta_{ij}\right) = 2\, g_{ij}\left(2\,V_i - 2V_j\cos\delta_{ij}\right) \dots\dots\dots\dots\dots\dots\dots\dots\dots(c)$$

$$\frac{\partial \Delta P_{L(ij)}}{\partial V_j} = g_{ij}\left(2\,V_j - 2V_i\cos\delta_{ij}\right) = 2\, g_{ij}\left(2\,V_j - 2V_i\cos\delta_{ij}\right) \dots\dots\dots\dots\dots\dots\dots\dots\dots(d)$$

2. Change in Reactive Power Loss Analysis: The power loss based on the reactive power connecting the buses i and j in a line l is designed as follows:

$$Q_{L(total)} = \sum_{i=1}^{nl}\left[-b_{ij}^{s}\left(V_i^2 + V_j^2\right) - b_{ij}\left(V_i^2 + V_j^2 - 2\,V_i V_j\cos\delta_{ij}\right)\right] \dots\dots\dots\dots(1.22)$$

Where,

b_{ij}^{s}= shunt susceptance at bus i and j

b_{ij}= susceptance at bus i and j

Mathematically, it is represented as:

$$\begin{pmatrix} \frac{\Delta Q_{L(ij)}}{\Delta P_n} \\ \frac{\Delta Q_{L(ij)}}{\Delta Q_n} \end{pmatrix} \dots\dots\dots\dots(1.23)$$

The taylor expansion ignoring second and higher order term is given as:

$$\Delta Q_{L(ij)} = \frac{\partial \Delta Q_{L(ij)}}{\partial \delta_i}\Delta\delta_i + \frac{\partial \Delta Q_{L(ij)}}{\partial \delta_j}\Delta\delta_j + \frac{\partial \Delta Q_{L(ij)}}{\partial V_i}\Delta V_i + \frac{\partial \Delta Q_{L(ij)}}{\partial V_j}\Delta V_j \dots\dots\dots\dots\dots(1.24)$$

Where,

$$\frac{\partial \Delta Q_{L(ij)}}{\partial \delta_i} = -2\, b_{ij}\, V_i V_j \sin\delta_{ij} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..1.25(a)$$

$$\frac{\partial \Delta Q_{L(ij)}}{\partial \delta_j} = 2\, b_{ij}\, V_i V_j \sin\delta_{ij} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..\dots\dots(b)$$

$$\frac{\partial \Delta Q_{L(ij)}}{\partial V_i} = -2b_{ij}^{s} V_i - b_{ij}\left(2\,V_i - 2V_j\cos\delta_{ij}\right) = -2\left[b_{ij}^{s} V_i + b_{ij}\left(V_i - 2V_j\cos\delta_{ij}\right)\right] \dots\dots\dots\dots\dots(c)$$

$$\frac{\partial \Delta P_{L(ij)}}{\partial V_j} = -2b_{ij}^{s} V_j - b_{ij}\left(2\,V_j - 2V_i\cos\delta_{ij}\right) = -2\left[b_{ij}^{s} V_j + b_{ij}\left(V_j - 2V_i\cos\delta_{ij}\right)\right] \dots\dots\dots\dots\dots\dots(d)$$

i. Objective Function Parameters

The following section below describes the method of calculating the multi-objective index of distribution system with load models [7].

j. Real Power Loss Reduction Index: It is basically defined as the ratio of real power loss reduction (percent basis) to the base case when the installation of DG is done at bus i and the real power loss reduction index (PLRI) is usually expressed as:

$$PLRI = \frac{P_{L(base)} - P_{L(dgi)}}{P_{L(base)}} \dots\dots\dots\dots(1.26)$$

Where,

$P_{L(base)}$= active power loss before installing DG

$P_{L(dgi)}$= Real power loss after installing DG

k. Reactive Power Loss Reduction Index: For determining the DG effect in case of (reactive) power losses, the reactive Power Loss Reduction Factor Index consist of incorporating the objective-based function. The Reactive Power Loss Reduction Index is expressed as:

$$QLRI = \frac{Q_{L(base)} - Q_{L(dgi)}}{Q_{L(base)}} \dots\dots\dots\dots(1.27)$$

$Q_{L(base)}$= reactive power loss before installing DG

$Q_{L(dgi)}$= reactive power loss after installing DG

l. Voltage Profile Improvement Index: The voltage of the power system should be kept within specified range and the line flow within its limits. These limits are significant as the system-based DG integration does not cause any increase regarding replacement or voltage control of the lines (existing). The Voltage Profile Improvement Index (VPII) is given as:

$$VPII = \frac{1}{\lambda + \left|\left(1 + V_{dgi}\right)\right| max_{i=2}^{n}} \dots\dots\dots\dots(1.28)$$

Where,

V_{dgi} = Voltage value after the installation of DG

λ = Scaling factor

m. Multi-objective Function Formulation: For achieving better performance of distributed systems for proper location and size of DG, the Multi-objective Function (MOF) is defined as:

$$MOF = w_1 PLRI + w_2 QLRI + w_3 VPII \ldots\ldots\ldots (1.29)$$

Where, $\square_1, \square_2, \square_3$ are the weights assigned. The weights absolute value summation is given as:

$$|\square_1| + |\square_2| + |\square_3| = 1$$

The used weights may vary depending upon the choice of an engineer. The benefits and importance is allotted with larger weight.

II. RELATED WORK

Sultana, U., et.al [1] conducted a comprehensive study for optimized DG placement by considering minimized power/energy losses, voltage profile improvement, and voltage stability enhancement. The researchers made an attempt to provide a summary of existing methods and presented a deep analysis helping the energy planners to decide what type of objectives and factors of planning were required for optimum allocation of DG.YalishoGirmaLoaena [2] provided a deep study on the issues related to power system like distribution system based on energy loss and its reduction techniques, reactive power flow along with its compensation, indicators of voltage quality such as regulation of voltage and voltage unbalance. In order to achieve the tasks, the existing form of distribution system based on study site has been designed using a Power Factory Software named DIgSILENT and the process of simulation was performed under balancing and unbalancing operating conditions. The measurement using Clamp-on meter was done to find the line to line voltages and the load demand.Patel, J. S., R. R. Patel, et.al [3] conducted a novel approach utilizing generated power with the help of distributed generation in case of primary distribution network such that the DG incorporation installed with capacity reduce the losses occurring in the overall system. The method of DG location and sizing using Genetic Algorithm was presented. A very simple load flow technique for accuracy was described and technique proposed was implied over two of the systems. One is the 2. 69 Bus Distribution System and the other is the IEEE 34 Bus distribution System using a software MATLAB tool.A. V. Sudhakara Reddy, et.al [4] proposed an algorithm popularly known as a Grey Wolf Optimization (GWO) algorithm to overcome the issues related to feeder reconfiguration with the help of fitness function corresponding to power distribution systems based optimized switch combination to overcome the issues related to reconfiguration including the real power loss reduction.AzraZaineb, et.al [5] discussed the siting and sizing problems related to DG placement in radial-type distribution system. The main objective was to minimize the power loss in both the reactive and the active power cases and enhanced the voltage profile of the whole system. A methodology for optimized DG sizing and location in distribution network systems. The addition of DG units was to minimize the losses with acceptable voltage profile. The testing was performed over IEEE 33 bus (radial) distribution system using software and the results were found to be very impressive.Dr.K.Lenin [6] presented the use of Aeriform Nebula Algorithm (ANA) for solving the optimal reactive problem of power dispatch. The Aeriform Nebula Algorithm was stirred from cloud based deeds. It helps in initiating the behaviour of creation, modified the behaviour, and expands the deeds of cloud. The projected form of this algorithm was tested on IEEE 30 (standard form) bus system test and the simulation based results shows a clear and superior performance of the system proposed with the use of ANA which further provided voltage stability and real power loss reduction.Mohammad Darvishi, et.al [7] proposed an algorithm used in the problem of optimization. The algorithm designed a flowchart and after the flowchart extraction process in optimized placement of power plants in distribution systems. The computer based program was firstly developed and implemented over the network and it was firstly implemented on IEEE bus system. The results obtained from program implementation and its merits and de-merits were obtained which stated that the losses were reduced with reduced congestion and voltage was improved in the network lines. Amandeep, et.al [8] presented a study on two of the essential motivations to reconfigure typical method of operation using a dispersion organize amid methodology. The variables relied on current conditions of stacking. The , reconfiguration strategy aims to remove over-loading burdens on the specific framework segments, for example, line areas or transformers which was called as load adjusting. The paper describes the framework stacking conditions noticeably profitable to reconfigure in order to diminish the misfortunes done to the power system.GiampaoloButicchi, et.al [9] proposed two application. One is the smart overload-control which involves the controlling action of the voltage. On the other hand, the the Soft Load Reduction method helps in reduction of load consumed by avoiding the problem of load-disconnection. These type of services basically depends upon voltage with proper load dependency identification mechanism which was evaluated using Smart Transformer in real-time analysis on the on load-based measurements. The distributed generation effect on total load sensitivity has been demonstrated and derived with control hardware In Loop technology by means of a Digital Simulator on real time basis. Hasibuan, A., S. Masri, et.al [10] presented a study with an objective to analyze the distributed generation impact over the losses of the distribution system. Some of the power system issues could be solved with DG installation where one such method was used in this study to lower the power losses in transmission system line. The simulation results were obtained on standard system IEEE 30 bus that shows that the power losses of the system were decreased from 5.7781 MW to 1,5757 MW i.e. 27.

Table.1Existing Scheduling Model.

Author's Name	Year	Method/Algorithm Used	Proposed Work
Sultana, U., et.al	2016	Optimum allocation	Conducted acomprehensive study for optimized DG placement by considering minimized power/energy losses, voltage profile improvement, and voltage stability enhancement.
YalishoGirmaLoaena	2016	Power Factory Software named DIgSILENT	Provided a deep study on the issues related to power system like distribution system based on energy loss and its reduction techniques, reactive power flow along with its compensation, indicators of voltage quality such as regulation of voltage and voltage unbalance.
A. V. Sudhakara Reddy, et.al	2017	Grey Wolf Optimization	Proposed an algorithm popularly known as a Grey Wolf Optimization (GWO) algorithm to overcome the issues related to feeder reconfiguration
Dr.K.Lenin	2017	Aeriform Nebula Algorithm	Presented the use of Aeriform Nebula Algorithm (ANA) for solving the optimal reactive problem of power dispatch. The Aeriform Nebula Algorithm was stirred from cloud based deeds.
Mohammad Darvishi, et.al	2017	Flowchart extraction process	Proposed an algorithm used in the problem of optimization. The algorithm designed a flowchart and after the flowchart extraction process in optimized placement of power plants in distribution systems.
Amandeep, et.al	2017	Reconfiguration strategy	Presented a study on two of the essential motivations to reconfigure

			typical method of operation using a dispersion organize amid methodology.
Hasibuan, A., S. Masri, et.al	2018	DG installation	Presented a study with an objective to analyze the distributed generation impact over the losses of the distribution system.

III. ALGORITHM

1. Grey Wolf Optimizer (GWO): It is a meta-heuristic algorithm which simulates the leadership hierarchy and hunting behavior of wolves. The fitness of the wolves measured in the form of alpha, beta and delta. The figure 1.2 given below shows the hierarchy level of the wolves.

Grey wolves have the ability of memorizing the prey position and encircling them. The alpha as a leader performs in the hunt. For simulating the behavior of grey wolves hunting in the mathematical model, it is assumed that the alpha (□) is the best solution, the second optimal solution is beta (□) and the third optimal solution is delta (□). Omega (□) is assumed to be the candidate solutions. Alpha, beta and delta guides the hunting while position is updated by the omega wolves by these three best solutions considerations [37]. **Encircling prey:** Prey encircled by the grey wolves during their hunt. Encircling behavior in the mathematical model, below equations is utilized [37].

$$\vec{\square}(\square + 1) = \vec{\square_{\square}}(\square) - \vec{\square}.\vec{\square}$$

$$\vec{\square} = \left|\vec{\square}.\vec{\square_{\square}}(\square) - \vec{\square}(\square)\right|$$

Where,

$\vec{Z}$ and $\bar{X}$ are vectors that are calulated by above given equation.

T← iterative number

$\vec{\square}$← grey wolf position

$\vec{\square_{\square}}$← prey position

$$\vec{\square} = 2\square.\vec{\square_1} - \square$$

$$\vec{\square} = 2\vec{\square_2}$$

Where

$\vec{\square_1}$ and $\vec{\square_2}$← random vector range[0,1]

The x value decrease from 2 to 0 over the iteration course.

$\vec{\square}$← random value with range [0,1] and is used for providing random weights for defining prey attractiveness.

Hunting

For grey wolves hunting behavior simulation, assuming □, □, and □ have better knowledge about possible prey location. The three best solutions are firstly considered and then □ (other search agents) are forced for their position update in accordance to their best search agent position. Updating the wolve's positions as follows [37]:

$$\vec{\square}(\square + 1) = \frac{\vec{\square_1} + \vec{\square_2} + \vec{\square_3}}{3}$$

Where $\vec{\square_1}, \vec{\square_2}$, □□□ $\vec{\square_3}$ are determined,

$$\vec{\square_1} = \left|\vec{\square_{\square}} - \vec{\square_1}.\square_{\square}\right|$$

$$\vec{\square_2} = \left|\vec{\square_{\square}} - \vec{\square_2}.\square_{\square}\right|$$

$$\vec{\square_3} = \left|\vec{\square_{\square}} - \vec{\square_3}.\square_{\square}\right|$$

Where $\vec{\square_{\square}}, \vec{\square_{\square}}$, □□□ $\vec{\square_{\square}}$← first three best solution at a given iterative T

$\square_{\square}$, $\square_{\square}$, and $\square_{\square}$ are determined,

$$\vec{\square_{\square}} \leftarrow \left|\vec{\square_1}.\vec{\square_{\square}} - \vec{\square}\right|$$

$$\vec{\square_{\square}} \leftarrow \left|\vec{\square_2}.\vec{\square_{\square}} - \vec{\square}\right|$$

$$\vec{\square_{\square}} \leftarrow \left|\vec{\square_3}.\vec{\square_{\square}} - \vec{\square}\right|$$

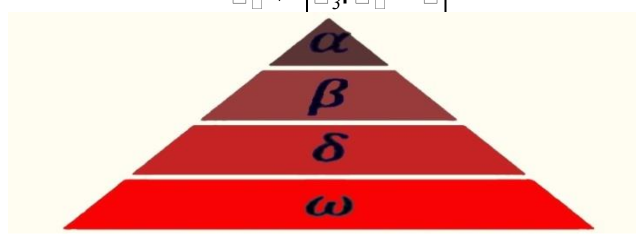

Fig.6 Hierarchy levels of the wolves.

1. The first level wolver are called are alpha wolves which are dominant in nature and all other wolves follow their orders. Alpha are the best decision makers having the best fitness value in the whole pack and are also the leaders of the pack

The second level wolves are the beta wolves and also called as subordinate wolves which help in decision making in alpha and also the other members of the pack.

3. The third level wolves are the delta wolves which work after the beta wolves. Delta wolves are considered when the beta wolves are not working properly. These wolves are also called as scouts.

4. The fourth and the last level of the hierarchy are related to the omega wolves. Omega wolves have low fitness value and are considering at the last. Omega wolves are also known as scapegoats.

IV. CONCLUSION

The one major advantage of distribution system is the process of power loss reduction in the system line. In normal, the power loss based on real power generates more attention for the connected utilities as it is helpful in reducing the transmitted energy efficiency to the consumers. The reactive loss of power is not of greater importance as it is required to be maintained at a specific amount for adequate level of voltage [12]. Hence, the reactive power (Q) enable transfer of the real power (P) through transmission and distribution lines to the consumers. The loss reduction in the system by strategical planning of DG along its network is considered to be very useful if decision analyzer is strictly committed to lower the system losses and to improve the performance of the network i.e. on losses and reliability level, maintenance of low level reasonable investments. This kind of methodology is very impressive in case recovered revenue by the DISCOs (distribution companies) that not only depend upon the value of assets but also depend upon the performance of the network [17].

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