DG Planning in Active Distribution Network by hybridization of swarm intelligence using GWO

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Abstract- 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 performance evaluation of the proposed work is done by comparing capacitors and voltages, losses. In BFO, power losses are higher and value of capacitive compensation is less. The values obtained by the BFO is slightly lower and they are in acceptable limits and reasonably good. FPA method gives better reduction in power loss with lesser value of capacitive compensation. It can be concluded that FPA is a superior method than BFO. In future enhance this work by hybrid optimization.

Keywords—*BFO, FPA, optimization, power, loss*

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. 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. 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 [4, 5].

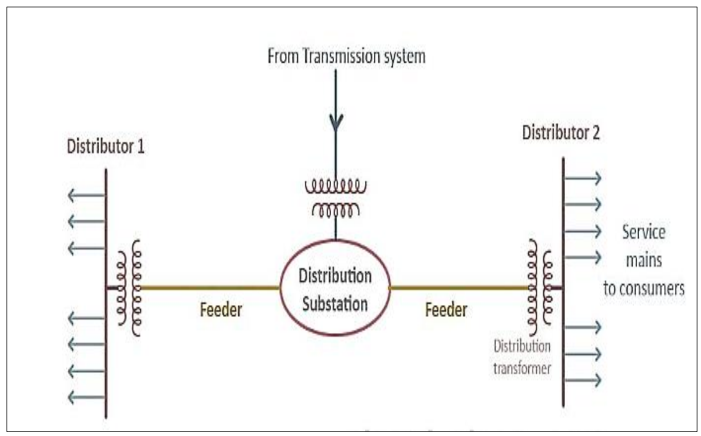

Fig.1 Simple radial AC power distribution system [13]

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. 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.1 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]. 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.

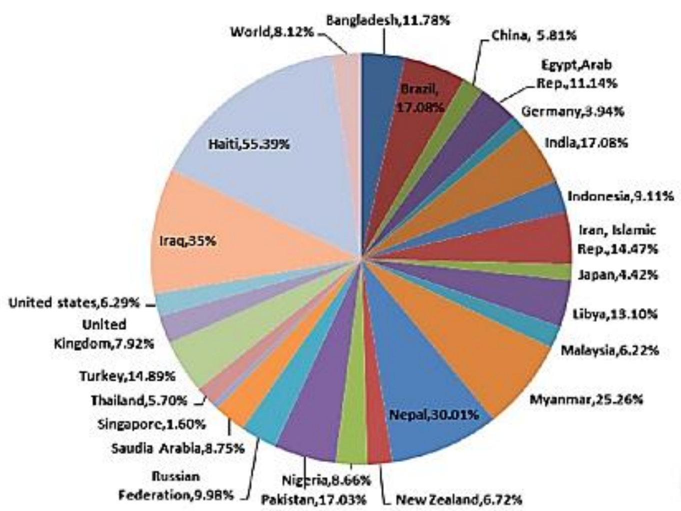

Fig.2 Data Analysis: Transmission and Distribution Losses [14]

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 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 [7]. 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 level description	**Voltage more than % nominal voltage**

-	%
bus bar voltage is ok	≥ 94, ≤ 106
bus bar voltage is to low	< 94

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 [2, 8]. 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 equations [5]. The mathematical representation of voltage stability index based on distribution line model as shown in fig. is presented as follows:

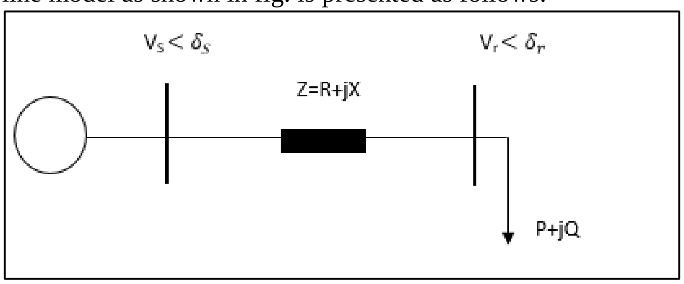

Fig.3 Single Line Diagram: Two bus distribution system

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:

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

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

$$P = -\cos(\emptyset_Z)\,V_r^2 \pm \frac{\sqrt{\cos^2(\emptyset_Z)\,V_r^4 - V_r^4 - |Z|^2Q^2 - 2V_r^2\,QX + V_s^2V_r^2}}{|Z|} \quad \ldots\ldots\ldots 1(a)$$

$$Q = -\sin(\emptyset_Z)\,V_r^2 \pm \frac{\sqrt{\sin^2(\emptyset_Z)\,V_r^4 - V_r^4 - |Z|^2P^2 - 2V_r^2\,PX + V_s^2V_r^2}}{|Z|} \quad \ldots\ldots\ldots 1(b)$$

From equation 1(a) and 1(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: Power Loss Minimization

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 [9, 10]. 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 [11].

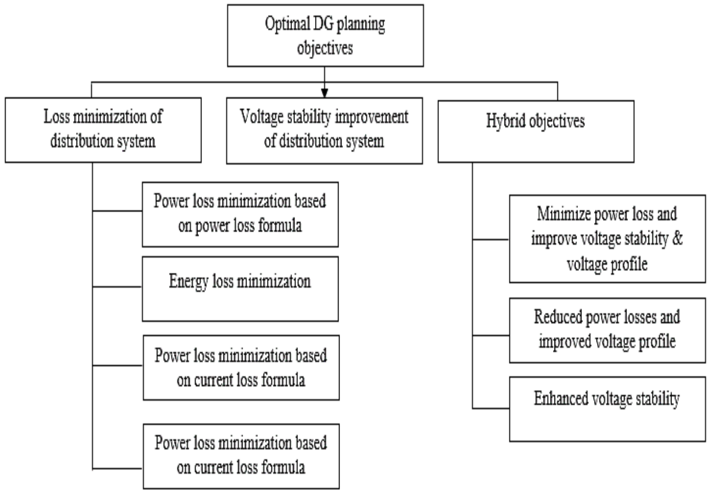

Fig.4 Optimal DG planning objectives

(a) 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 [12]. 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.

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 [8]. 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:

(a) 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.

(b) 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.

(c) 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. Operational Constraints

The multi-objective function (MOF) is reduced/minimized to certain operating constraints in order to fulfill the requirements for the distribution network operation.

(a) Load Balance Constraints

The load regulations of each bus should be satisfied as follows:

$$P_{gni}-P_{dni}-V_{ni}\sum_{j=1}^{N}V_{nj}Y_{nj}\cos(\delta_{ni}-\delta_{nj}-\theta_{nj}) = 0 \ldots\ldots\ldots\ldots 1.30\ (a)$$

$$Q_{gni}-Q_{dni}-V_{ni}\sum_{j=1}^{N}V_{nj}Y_{nj}\sin(\delta_{ni}-\delta_{nj}-\theta_{nj}) = 0 \ldots\ldots\ldots\ldots\ldots (b)$$

Where,

$n_i = 1,2,\ldots, n_n$

(b) Power Generation Limit

This involves the lower and the upper generation limits of real and reactive sources at a given bus i

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max}, i = 1,2,\ldots\ldots, N_g \ldots\ldots\ldots\ldots 1.31\ (a)$$

$$Q_{gi}^{min} \le Q \le Q_{gi}^{max}, i = 1,2,\ldots\ldots, N_g \ldots\ldots\ldots\ldots\ldots\ldots (b)$$

Where,

P_{gi}^{min} *and* P_{gi}^{max} = Generation limits based on real powers

P_{gi}^{min} *and* P_{gi}^{max} = Generation limits based on reactive powers

(c) Voltage Limit

This limit involves the lower and the upper limits of the magnitude i.e. V_i^{min} *and* V_i^{max} at bus-i. In reality the voltage of the generator includes the voltage of the bus/load in addition to line impedance and the line-based power flow. The voltage should be kept within standards maintained as:

$$V_i^{min} \le V_i \le V_i^{max}, i = 1,2,\ldots\ldots, N_b \ \ldots\ldots\ldots\ldots (1.32)$$

Where,

V_i^{min} *and* V_i^{max}= min and max voltage limits

II. RELATED WORK

Azra Zaineb, et.al [1] 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 [2] 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 [3] 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 [4] 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. Josep M. Guerrero, et.al [5] presented the use of battery energy storage (BES) systems in order to overcome the problem of voltage rise during the process of PV generation peak and the drop of the voltage at the meet time of the peak load hours. The method proposed a coordinated control strategy which regulates the mechanism of BESs charging or discharging along with the scheme named local droop based control ensuring the feeder voltage within specified limit. Hence two distinct algorithms have been used. The first algorithm helps in determining the participation of BES in the process of voltage regulation relating to the capacity installed. The second algorithm helps in modification of BES performance in SOC i.e. state of charge terms which prevents large battery depletion and saturation process. The controller proposed enables the storage capacity use effectively in distinct condition of operation. In the final stage, the results based on simulation relies on radial distribution feeder data validating the effectiveness of the strategy used. Hasibuan, A., S. Masri, et.al [6] presented a study with an objective to analyze the distributed generation inpact 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. 27.27%. Giampaolo Buticchi, et.al [7] 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. Sanjay R. Vyas, et.al [8] presented an effective study of network reconfiguration based on power losses in case of distribution system. The technique was restructured with an objective of power quality improvement. The general task of power quality, minimization of losses along with objectives like voltage sag and voltage unbalance have been identified for the reconfiguration of the network. Each objective was solved using a technique named Branch exchange which worked effectively to improve distribution system power quality operations. Mohamed Zellagui, et.al [9] proposed a new method of optimization popularly known as Grey Wolf Optimizer (GWO) algorithm for the process of optimized power flow of two-terminal based HVDC power system. For pure AC power system, the OPF problem basically involves reduction of overall cost under the inequality and equality constraints. Hence, the issue of OPF related to integrated AC-DC power system gets updated for incorporation of HVDC links on account of control characteristics of power transfer using GWO algorithm. This algorithm was usually inspired by hunting and leadership behaviour of the wolves. The algorithm proposed was implemented over two distinct study-cases. One is the WSCC 9-bus and the other is the modified 5-bus system test. The algorithm validity was demonstrated the obtained result comparative study along with the results explained in the literature survey other types of techniques by optimization methods. The results obtained have shown that the algorithm proposed achieved shorter CPU timing along with minimization of the total cost on comparing it with existing techniques of optimization which proved high efficiency of GWO algorithm. Mitesh G. Patel, et.al [10] presented the research using an intelligent technique tool named Grey Wolf Optimizer (GWO) for dealing with the issues related to Optimal Power Flow (OPF). The OPF represents a problem based on non-linear optimization where the optimization of the controlled parameters was done for a particular task. The sub-problem of optimal power flow is usually known as Optimal Reactive Power Dispatch (ORPD). The Grey wolf optimizer (meta-heuristic tool) was tested on two of the test cases, one is the IEEE-118 bus system and the other is IEEE-30 bus system for minimizing the voltage deviation and active power Losses.Shao, Hua, et.al [11] analysed the voltage profile in distribution based networks for distinct type of installations for DG based on its capacity and location of the DGs. The back/forward sweep method was implemented to the calculation of the load flow and the distribution network simulation was performed along with distributed generation. The proposed method resulted in analysing the impact of DG connection over the voltage profile.

III. THE PROPOSED METHOD

In this section, we discussed the proposed approach and the methodology used to achieve the results.

A. Proposed methodology: Flowchart

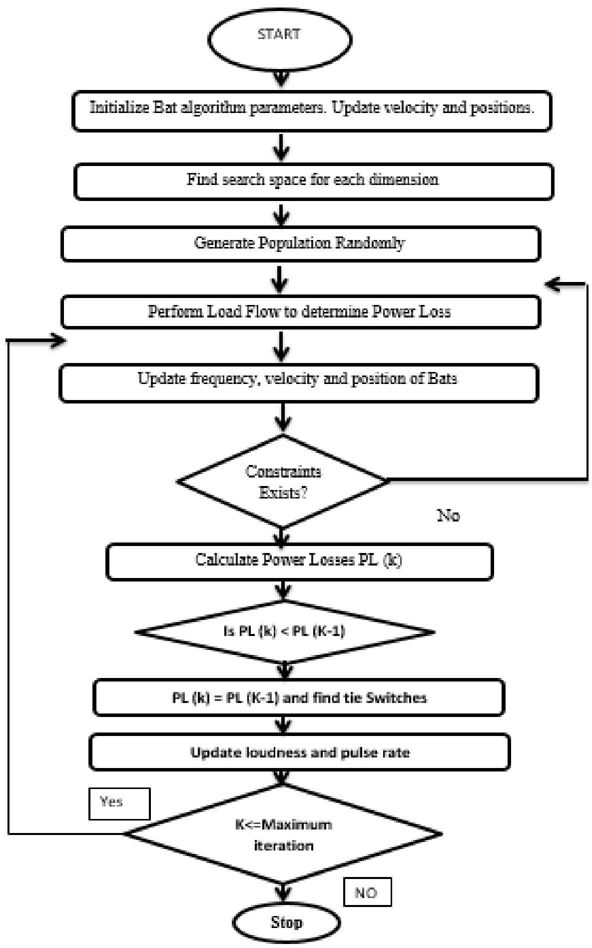

Fig.5 Proposed Flowchart

B. Description of the Algorithms Used: The following is the detail of the different algorithms used in the present work.

(a) 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. 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 (α) is the best solution, the second optimal solution is beta (β) and the third optimal solution is delta (δ). Omega (ω) 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.

Encircling prey: Prey encircled by the grey wolves during their hunt. Encircling behavior in the mathematical model, below equations is utilized [37].

$$\vec{A}(T+1) = \overrightarrow{A_P}(T) - \vec{X}.\vec{Z}$$

$$\vec{Z} = \left|\vec{Y}.\overrightarrow{A_P}(T) - \vec{A}(T)\right|$$

Where,

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

T←iterative number

$\vec{A}$←grey wolf position

$\overrightarrow{A_P}$←prey position

$$\vec{X} = 2x.\overrightarrow{r_1} - x$$

$$\vec{Y} = 2\overrightarrow{r_2}$$

Where

$\overrightarrow{r_1}$and$\overrightarrow{r_2}$←random vector range[0,1]

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

$\vec{Y}$←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 $\alpha, \beta,$ and δ have better knowledge about possible prey location. The three best solutions are firstly considered and then ω (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]:

$$\vec{A}(T+1) = \frac{\overrightarrow{A_1}+\overrightarrow{A_2}+\overrightarrow{A_3}}{3}$$

Where $\overrightarrow{A_1}, \overrightarrow{A_2}, and\ \overrightarrow{A_3}$ are determined,

$$\overrightarrow{A_1} = \left|\overrightarrow{A_\alpha} - \overrightarrow{X_1}.Z_\alpha\right|$$

$$\overrightarrow{A_2} = \left|\overrightarrow{A_\beta} - \overrightarrow{X_2}.Z_\beta\right|$$

$$\overrightarrow{A_3} = \left|\overrightarrow{A_\delta} - \overrightarrow{X_3}.Z_\delta\right|$$

Where $\overrightarrow{A_\alpha}, \overrightarrow{A_\beta}, and\ \overrightarrow{A_\delta}$← first three best solution at a given iterative T

Z_α, Z_β, and Z_ω are determined,

$$\overrightarrow{Z_\alpha} \leftarrow \left|\overrightarrow{Y_1}.\overrightarrow{A_\alpha} - \vec{A}\right|$$

$$\overrightarrow{Z_\beta} \leftarrow \left|\overrightarrow{Y_2}.\overrightarrow{A_\beta} - \vec{A}\right|$$

$$\overrightarrow{Z_\delta} \leftarrow \left|\overrightarrow{Y_3}.\overrightarrow{A_\delta} - \vec{A}\right|$$

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

1) 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.
2) 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.
3) 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. RESULTS

A. Proposed Work Results: This section describes the result of the proposed approach on the basis of voltages and bus number. In this section the result performed with capacitor, voltage with FPA and voltages with BFO is explained in brief.

Table.3 Voltage without capacitor

Bus Number	Voltage
1	1.6
2	1.045
3	1.01
4	1.035
5	1.034
6	1.06
7	1.095
8	1.08
9	1.072
10	1.065
11	1.068
12	1.065
13	1.068
14	1.07

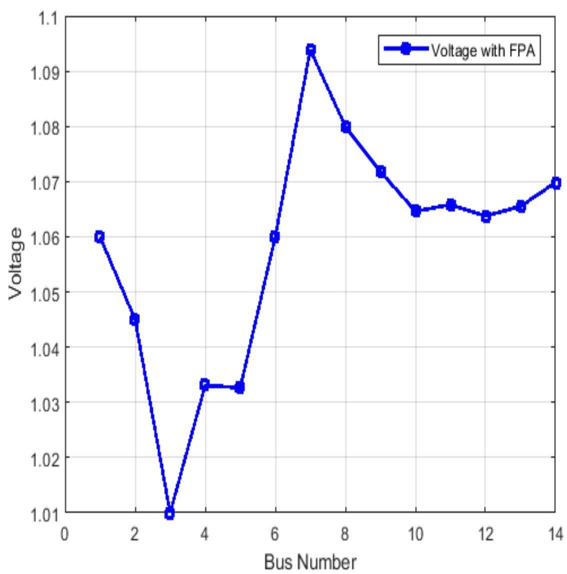

Fig.6 Voltage without capacitor.

In fig.6 shows the voltages without capacitor on the different buses. The x-axis represents the bus number and y axis represents the voltage. The ups and down in the blue line on the graph shows the changes in the voltages according to the bus. The maximum voltage is on bus number 9 where the voltage is 1.072. The minimum voltage is at bus number 3 which is 1.01.

Table.4 Voltage without FPA and voltage with BFO

Bus Number	Voltage without capacitor	Voltage with BFO
1	1.6	00
2	1.045	1.045
3	1.01	1.068
4	1.035	1.036
5	1.034	1.046
6	1.06	1.023
7	1.095	1.095
8	1.08	1.044
9	1.072	1.073
10	1.065	1.036
11	1.068	1.067
12	1.065	1.058
13	1.068	1.068
14	1.07	1.035

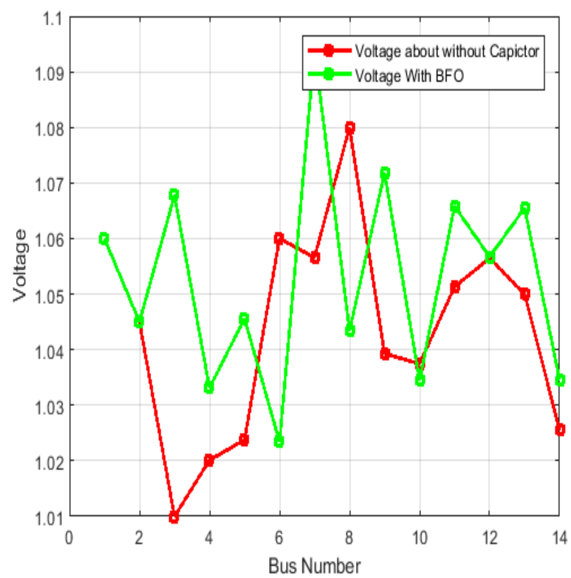

Fig.7 Voltage without FPA and voltage with BFO

In fig.7 shows the voltages without capacitor on the different buses. The x-axis represents the bus number and y axis represents the voltage. The ups and down in the blue line on the graph shows the changes in the voltages according to the bus. The maximum voltage is on bus number 9 where the voltage is

1.09. The minimum voltage is at bus number 3 which is 1.01. The green line show the voltage without capacitor and the minimum voltage in this is on bus number 6 which is 1.023 and maximum is on bus number 9 which is similar to voltage without capacitor.

Table.5 Comparison of voltages with Capacitor, FPA, BFO

Bus Number	**Voltage with FPA**	**Voltage with BFO**	**Voltage without capacitor**
1	1.6	1.06	00
2	1.045	1.045	1.045
3	1.01	1.068	1.01
4	1.035	1.036	1.02
5	1.034	1.046	1.024
6	1.06	1.023	1.06
7	1.095	1.095	1.058
8	1.08	1.044	1.08
9	1.072	1.073	1.039
10	1.065	1.036	1.038
11	1.068	1.067	1.051
12	1.065	1.058	1.059
13	1.068	1.068	1.05
14	1.07	1.035	1.026

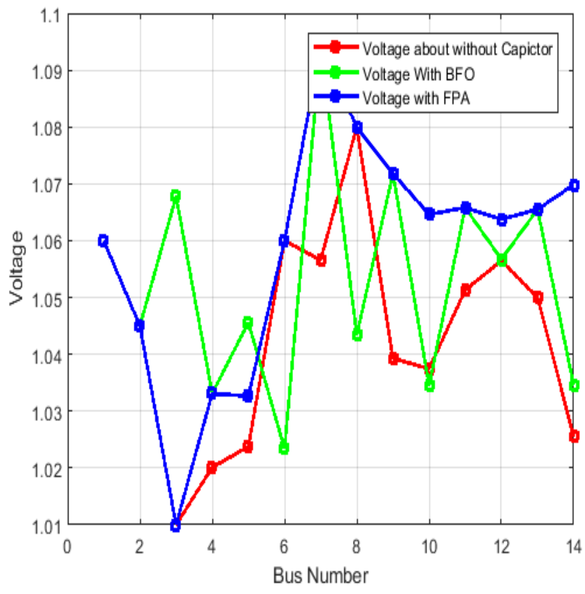

Fig.8 Comparison of voltages with Capacitor, FPA, BFO

In fig.8 shows the voltages without capacitor, FPA and BFO on the different buses. The x-axis represents the bus number and y axis represents the voltage. The ups and down in the red, green, and blue line on the graph shows the changes in the voltages according to the bus.

Table.6 Comparison of reactive Power Loss and stability index

Algorithm	Reactive Power Loss	Stability Index
Without optimization	12.6210	3.1061
FPA	3.886	1.0032
BFO	4.2340	1.5432

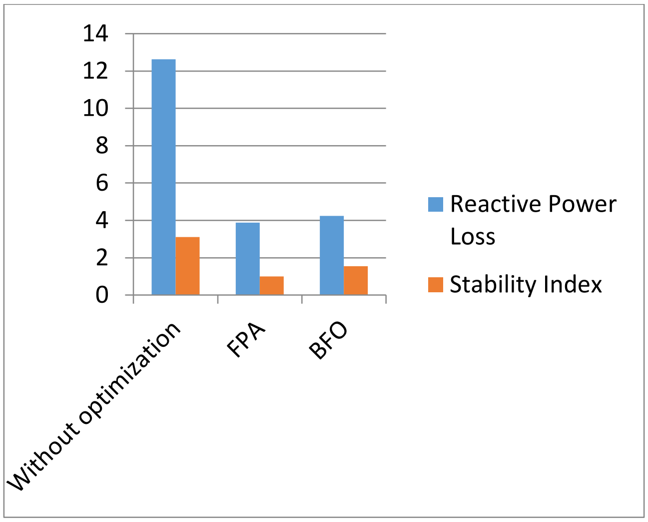

Fig.9 Comparison of reactive Power Loss and stability index

In fig.9 the comparison of three algorithms without optimization, FPA and BFO is presented on the basis of reactive power loss and stability index. The blue bar in the graph presents reactive power loss and blue represents the stability index. The Flower Pollination Algorithm gives better results among all because it has low reactive power loss and stability index.

Table.7 Capacitor Size and cost

Size K Var	150	300	450	600	900
Cost (Rs)	750	975	1140	1320	1040

Table.8 Capacitor Location

Approach	Location	Size
BFO	12,11,10	150,300,600
FPA	14,11,10	300,150, 150

V. CONCLUSION

The objective of the proposed research is to reduce the power and voltage loss and also work on reducing the cost. The investment cost of the network is the finite number of capacitors sizes that are multiple of the smallest size capacitor. The cost in this work represented per kVar which changes according to size because large sizes are less in price and smaller which are optimal in size is costly. The index method and size of the capacitor is used for the optimal placement of the capacitor which is given by the proposed method and classical method BFO. The performance evaluation of the proposed work is done by comparing capacitors and voltages, losses. In BFO, power losses are higher and value of capacitive compensation is less. The values obtained by the BFO is slightly lower and they are in acceptable limits and reasonably good. FPA method gives better reduction in power loss with lesser value of capacitive compensation. It can be concluded that FPA is a superior method than BFO. In future enhance this work by hybrid optimization.

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