DG Placements in Distribution System for Power Loss Reduction Using grey wolf optimization with genetic algorithm Hybridization

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Abstract: To meet the increasing load demand requirement, the process of distributed generation (DGs) is integrated into distribution systems. The main objective of the system is to minimize the loss caused by the active and reactive power and to boost the overall voltage profile of the system. In power distribution network, the increased load demands is the major cause for the distribution systems to operate very closely to boundaries of voltage instability. When the DG units get integrated into distribution system, the network experiences various impacts based on its parameters such as power quality, power flow, voltage profile, stability, protection, and reliability. The problem of voltage stability and load flow loss are the major challenges for the power industry. In power distribution system, the issue of voltage instability is related to dynamics of the load flow, thus it requires distinct forms of load characteristics to deal with voltage stability as well the losses occurring during its process analysis. In modern electrical power systems, the injection of reactive power plays a significant role in power or load flow analysis and control of voltage stability, thus the losses based on reactive power are required to get incorporated in DG optimization process in order to improve the voltage profile. Many algorithms have been proposed to emphasize load flow losses and improve the voltage profile of the system. The proposed work involves the use of Grey Wolf Optimization (GWO) algorithm employed for obtaining restructured power distribution network (PDS) and helps in identification of optimal switches/transforms corresponding to power (minimum) loss in distribution network systems.

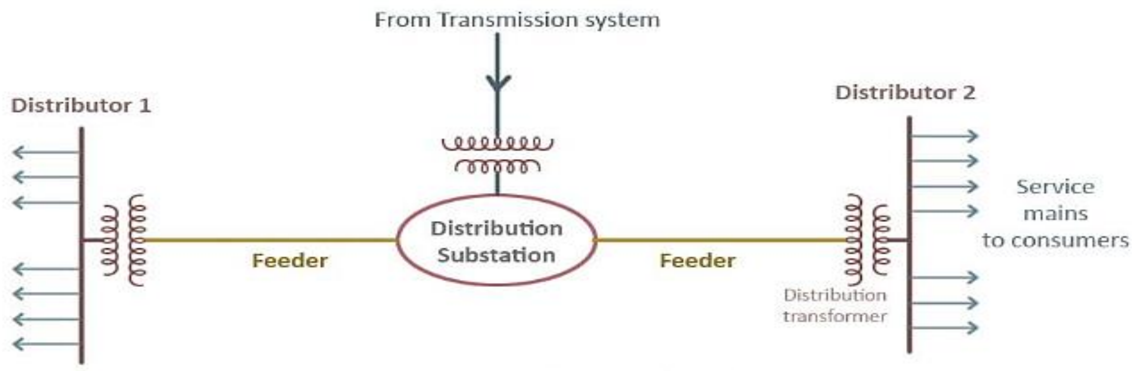
Keywords: gwo, powerloss, placement, optimization

*Index Terms- **DG, optimization, power, replacement***

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. 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 [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.



[30, Fig.1.1] **Simple radial AC power distribution system**

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]. 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.

II. RELATED WORK

Carmen LT, et.al [1] presented an article with a methodology to evaluate the DG units installation impacts on the system reliability, electric losses, and the system's voltage profile in distributed networks. The voltage profile and losses were evaluated based on the method of power flow along with generator representation in the form of PV buses. The evaluation based on the reliability indices relied on analytic methods that was modified to handle or safeguard multiple generation. This type of methodology was used to evaluate DG capacity influence on the system performance for distinct type of generation based expansion with planned alternatives.

Ha, Le Thu, et.al [2] explored the study considering the integrating possibility of two large wind farms into a sub-transmission network. It also analysed the impacts on the voltage stability and network losses considering the impacts when there was an increase in network loading of the system. The study was carried with the help of computer analyses performed on custom-designed radial type of power system.

U. Eminoglu, et.al [3] presented a voltage stability index for identification of voltage collapse attractive sensitive bus in distribution system (radial). The index developed was based on transformed active and reactive power line distribution. The analysis of the index was tested distinct operating conditions of load and voltage levels of sub-station. The results suggested that the index proposed was of reliable nature which was easily applicable to the radial type network distribution.

Wenzhong Gao., et.al [4] presented an approach based on multi-objective optimization methodology for determining distributed generators optimized location in electricity market with deregulated environment as the optimized location of DGs is considered as the most suitable panel or zone which has been identified based on the variations of real and reactive power flow sensitivity variations.

Alonso, M, et.al [5] presented a methodology for DG unit's optimal placements in the power networks to assure the maximum load-ability conditions, voltage profile. This type of strategy aims to find system based components configuration meeting the required system reliability considering the limits of stability. The study indicates that the formulations proposed have shown the best way to find out the best buses where the distributed generator units (additionally) enhance the voltage stability and the capability of power transfer under certain contingencies.

Viswanadh, M. M. G., et.al [6] studied an Optimization technique using Particle Swarm Optimization and an analytical approach used to determine the size of the wind generator and its placement optimally. A backward forward sweep load flow conventional method was used for the calculation purpose. The results obtained from two of the approaches were compared and voltage profile of different buses such as 69-bus, 13-bus and 33-bus in the distribution network was obtained.

Gagandeep Kaur, et.al [7] proposed a work which determines the optimized DG capacity to be connected to the system existing. A line based voltage stability index (VSI) which was obtained by a load flow method (conventional) solution which accurately calculated the operating point proximity to the voltage collapsing point and hence it validates the proposed method significance. The optimised DG value obtained boosted the system's maximum load ability. The method proposed was tested on standard bus system IEEE-14 bus system and the simulation was done using C++. This type of method contains a good methodology for identification of DG rating and the best location.

D. Sattianadan, et.al [8] presented a study on minimizing the process of power loss with the placement of distributed generators (DGs) in distribution-based network. The DG location is generally found using voltage stability index and the corresponding calculation of power loss is done by the running process of power flow and the results were obtained using Particle Swarm Optimization. The simulation was performed over 33 bus Distribution System by analysing distinct load models.

Q. S. Chua, et.al [9] considered the real time system implementation methods of monitoring that was able to provide power system based time warning before the occurrence of voltage collapse. In this work, different types of line voltage stability indices (LVSI) have been differentiated to overcome the effectuality which determines the power system weakest lines. The LVSI have been accessed using IEEE 14-Bus and IEEE 9-Bus system for practicability validation. This paper work also contributed real-time voltage stability monitoring implementation using Artificial Neural Network (ANN). The results demonstrated the indices evaluation using ANN methodology for predicting the system based voltage collapse.

K.R. Devabalaji, et.al [10] proposed the work with the main objective to reduce the power loss in total along with maintenance and satisfaction of all the constraints. The implementation of LSF i.e. Loss Sensitivity Factor was done to pre-determine the capacitor optimal location. An effective use of BAT algorithm (biologically-inspired) has been done to pinpoint the capacitor banks optimal location. The method proposed was tested on IEEE 34-bus distribution system to observe the effectiveness and performance of the proposed technique.

Chaw Su Hlaing, et.al [11] presented an approach based on voltage stability index utilizing an analogy of combined sensitivity factor to optimally place and size a DG multi-type using 48-bus Belin distribution test system with the objective of power losses reduction and the improvement of voltage profile with the placement of type 2 DG than the type 1 based DG placement i.e. DG generation using both real and reactive powers. It reaches a point where the increment in DG number results in improving voltage profiles and minimizing the power losses of the system.

Pyone Lai Swe, et.al [12] considered for types of DGs in their proposed work. With its types, one DG was installed at location to reduce the total losses i.e. the real and the reactive power losses occurred during the operation. The main objective was to evaluate the size and to observe or identify the Dg optimum corresponding location to reduce the real and reactive losses and to improve the primary distribution voltage profile. With this type of method, it was able to obtain maximum reduction of losses for optimally placed DGs in the network.The DG based optimized sizing was calculated an exact type of loss formula along with an efficient approach to determine the DG optimized placement. The performance of the proposed method was demonstrated in Belin Substation in Myanmar on a 36-bus radial type distribution system which was validated with different sizes of the DGs in the network.

Yorukoglu, Sinan, Fuad Nasibov, et.al [13] conducted a study of distinct distribution system losses, Turkish electricity distribution network based privatization process, and percentage of current losses. In SYSTEM distribution network topology, possible alternations decreased the losses (non-technical) using analytical methods and the best form of strategy against losses was determined for distinct customer characteristics and network topologies with the help of AHP method.

Salah Kamel, et.al [14] this paper investigated the DSTATCOM impact over the performance of Upper Egypt electrical realistic network. The analysis was done using NEPLAN commercial software and the network was selected using 20 buses with 22/0.4 kV distribution transformers (20) and two of the voltage (medium) distribution points. The network was studied with and without forms of D-STATCOM showing the impact over the performance of the network regarding voltage magnitude control, total reduction active power losses, and the stability of the voltage.

Sultana, U., et.al [15] 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.

Yalisho Girma Loaena [16] 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 [17] 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 [18] 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.

III. THE PROPOSED METHOD

4.2 Algorithm

Grey Wolf Optimization: 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 (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 [37].

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

$$\vec{X} = 2x.\vec{r_1} - x$$
$$\vec{Y} = 2\vec{r_2}$$

Where

$\vec{r_1}$and$\vec{r_2}$←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 α, β, 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,

$$\overrightarrow{Z_\alpha} \leftarrow \left|\overrightarrow{Y_1}.\overrightarrow{A_\alpha} - \vec{A}\right|$$
$$\overrightarrow{Z_\beta} \leftarrow \left|\overrightarrow{Y_2}.\overrightarrow{A_\beta} - \vec{A}\right|$$
$$\overrightarrow{Z_\delta} \leftarrow \left|\overrightarrow{Y_3}.\overrightarrow{A_\delta} - \vec{A}\right|$$

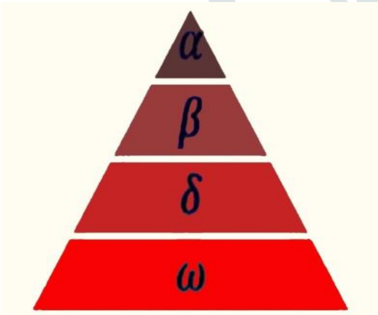


Figure 4.2: Hierarchy levels of the wolves.

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
2) 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.

GWO: Modified Version

The normal grey wolf optimizer is of very flexible nature and provides good results during the operation of testing on benchmark functions and other issues mentioned in literature. The operators such as crossover and mutation are very well known operators i.e.population-based. These operators are used for designing the modified version of GWO by implementing them in its simplified version for achieving better results.

(a) Crossover: It provides improvement in the process by the method of interchanging the values that occur between two of the arrays or strings which is done by selecting cross-site and then performing the function of swapping among two parts of strings or arrays. It helps in obtaining two types of new strings. The mechanism of crossover act as first operator i.e. applied on Grey wolves' population and the probability of crossover is firstly defined for each population. The cross-site is randomly chosen from population size matrix and after that the values get swapped. This process is repeated for each of the population.

(b) Mutation. It is performed after the crossover process is done. It completely nullifies some of the values by making them to reach its initial form or zero state. It acts as a second operator to be applied over matrix based on the mechanism of grey wolf. Generation of mutation matrix based on zeroes and ones is formulated in accordance to mutation probability i.e. multiplied with matrix of grey wolf i.e. from one element to other where some of the values may vary.

IV. RESULTS

Table 5.1 Voltage with Proposed

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

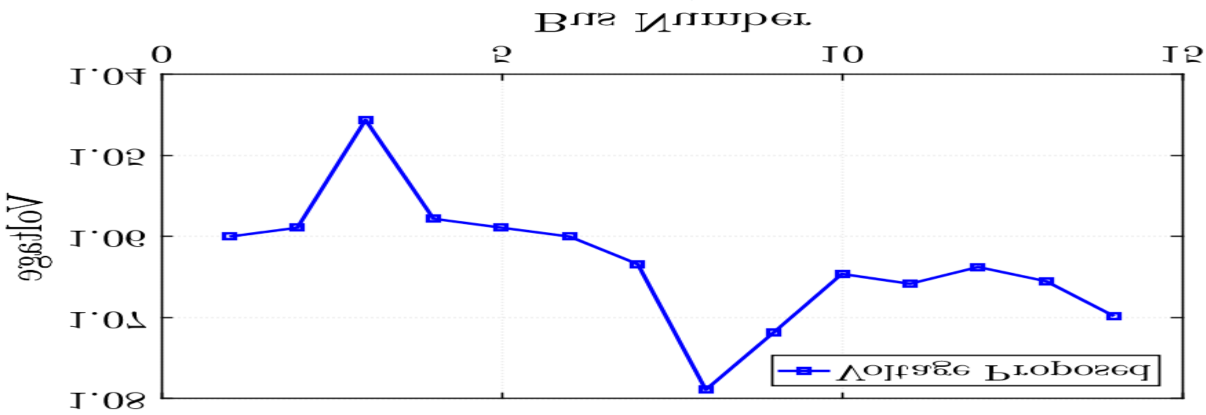


Figure 5.1 Voltage proposed DG.

In figure 5.1 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.

Figure 5.2 Voltage without FPA and voltage with BFO

In figure 5.2 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.

In figure 5.4 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.

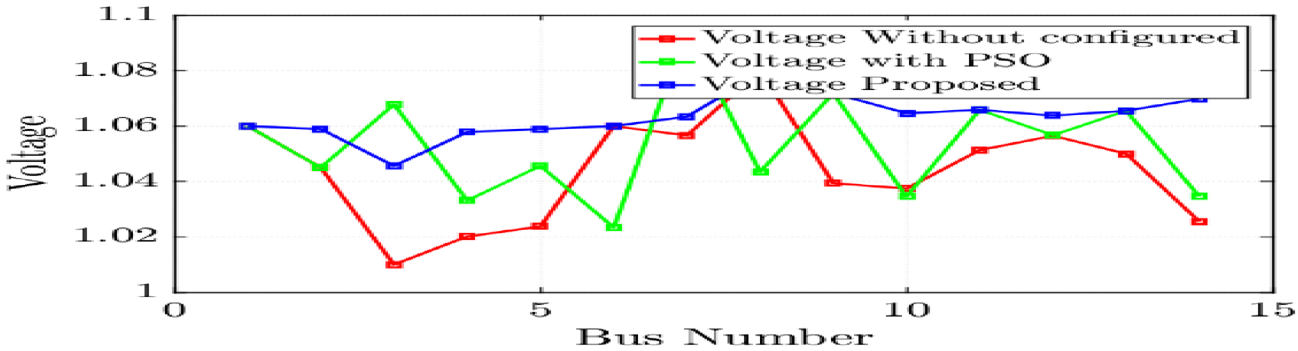


Table 5.4 Comparison of reactive Power Loss and stability index

Algorithm	**Reactive Power Loss**	**Stability Index**
Without optimization	12.6210	3.1061
PROPOSED	3.886	1.0032
PSO	4.2340	1.5432

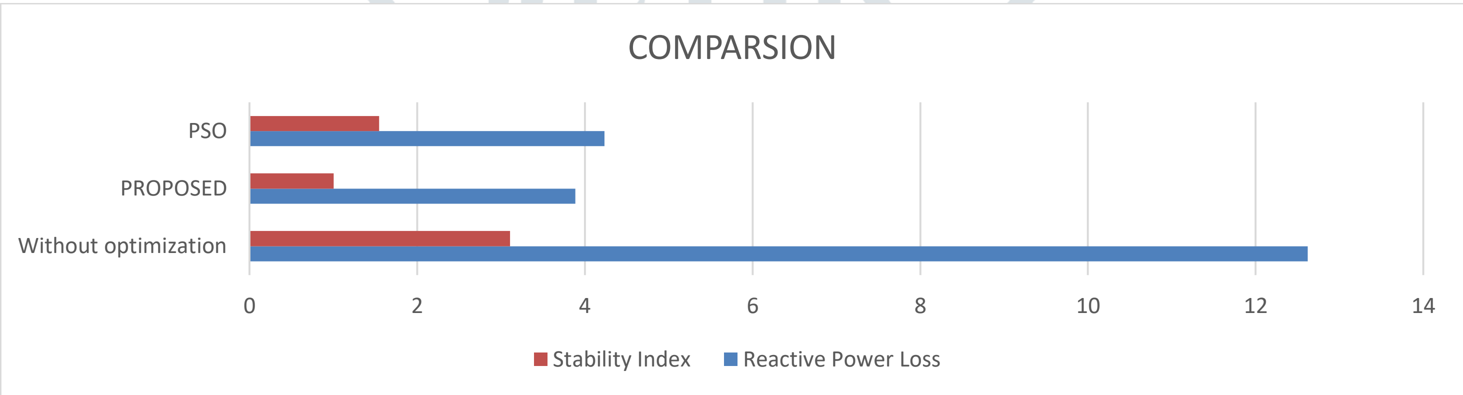


Figure 5.5 Comparison of reactive Power Loss and stability index

Figure 5.5 Comparison of reactive Power Loss and stability index

In figure 5.5 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 5.5 Capacitor Size and cost

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

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 DGs sizes that are multiple of the smallest size DG. 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 DG is used for the optimal placement of the DG which is given by the proposed method and classical method PSO. The performance evaluation of the proposed work is done by comparing DGs and voltages, losses. In PSO, power losses are higher and value of capacitive compensation is less. The values obtained by the PSO is slightly lower and they are in acceptable limits and reasonably good. PROPOSED(GWO_GA) method gives better reduction in power loss with lesser value of capacitive compensation. It can be concluded that PROPOSED(GWO_GA) is a superior method than PSO. In future enhance this work by hybrid optimization.

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