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Novel Optimization Approach to Distributer Generator Placement for Reducing Loss

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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) with genetic algorithm (GA) 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: Distributed Generation, Grey Wolf Optimization, Genetic Algorithm, Power Distribution Network

I. INTRODUCTION

This section highlights the work of an eminent researcher and concentrates on the challenges which still need to be addressed.

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 DG optimal location. An effective use of BAT algorithm (biologically-inspired) has been done to pinpoint the DG 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.

II. METHODOLOGY

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

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

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 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,

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

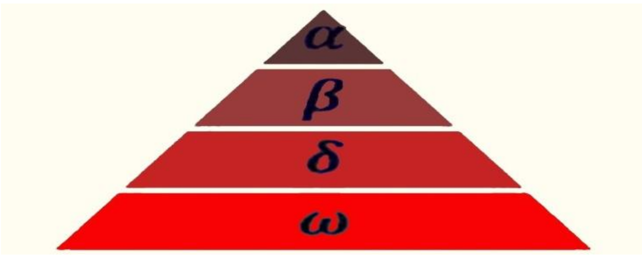

Fig. Hierarchy levels of the wolves

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.

III. PROPOSED METHODOLOGY

Step 1: Initialize the Load/Power.
Step 2: Initialize the generator Load Power.
Step 3: Allocate the generators and calculate the cost.
Step 4: Apply the PSO for optimization.
Step 5: If the output of PSO is optimized then check the convergence otherwise Genetic algorithm starts it working with the following steps.
a. Initialize the chromosomes.
b. Crossover between chromosomes.
c. Apply Roulette Selection.
d. Check Optimization. If optimize then go to convergence Check otherwise loop is running until the Objective form is not obtained.
Step 6: Check the convergence. If converge then check the cost features otherwise again initialize the particles and Repeat the step 5.
Step 7: If the cost is less than Δ C then stop.

IV. RESULTS

This chapter describes the result of the proposed approach on the basis of voltages and bus number. In this chapter the result performed with DG, voltage with PSO and voltages with Proposed is explained in brief.

5.2 Results of Proposed Work

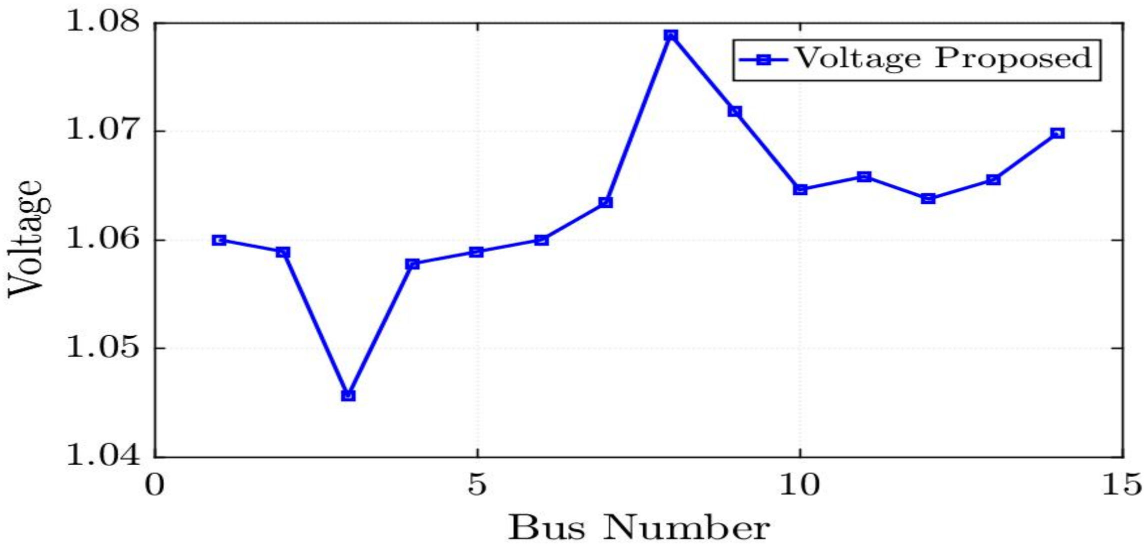

Figure 2 Voltage proposed DG

In figure 2 shows the voltages without DG 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.

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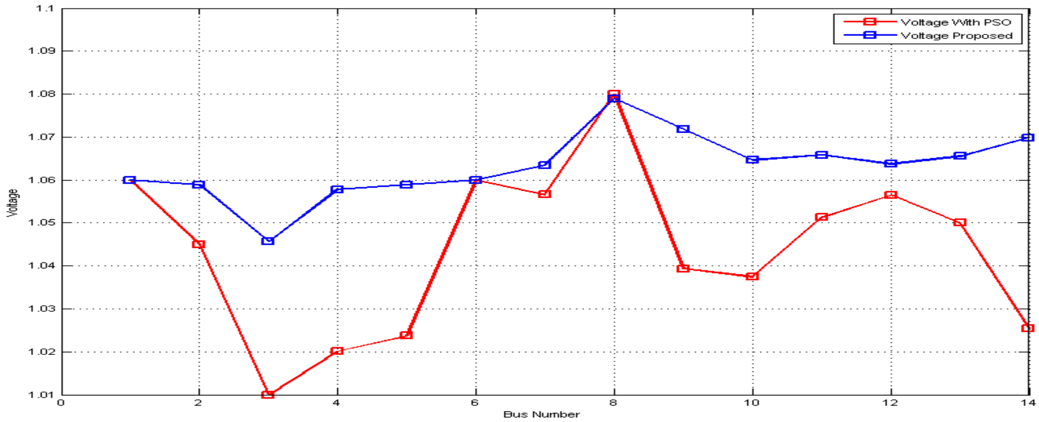

Figure 3 Voltage without Proposed and voltage with PSO

In figure 3 shows the voltages without DG 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 DG 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 DG.

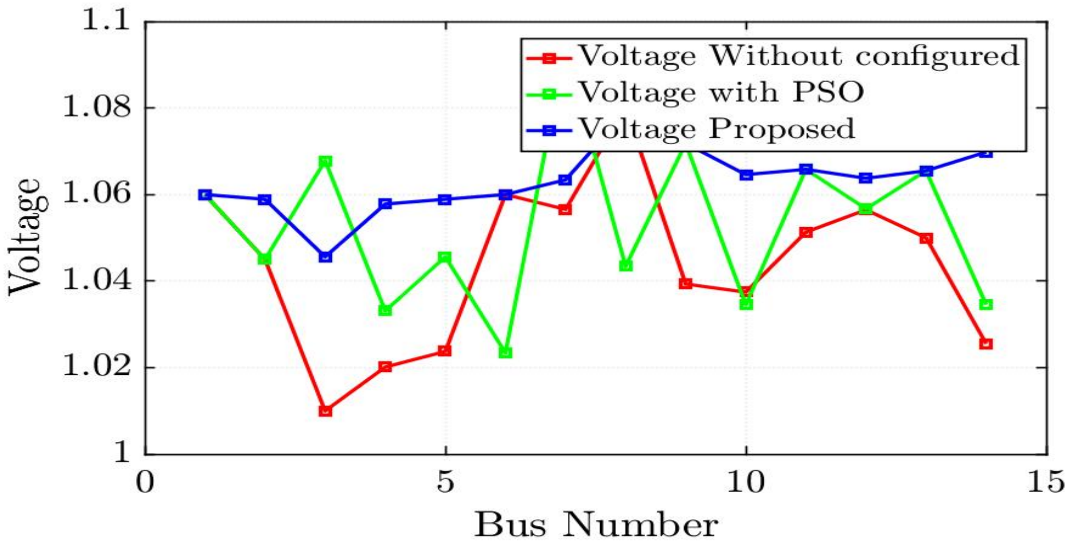

Figure 4 Comparison of voltages with DG, PROPOSED (GWO_GA), PSO

In figure 4 shows the voltages without DG, PROPOSED (GWO_GA) and PSO 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 1 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

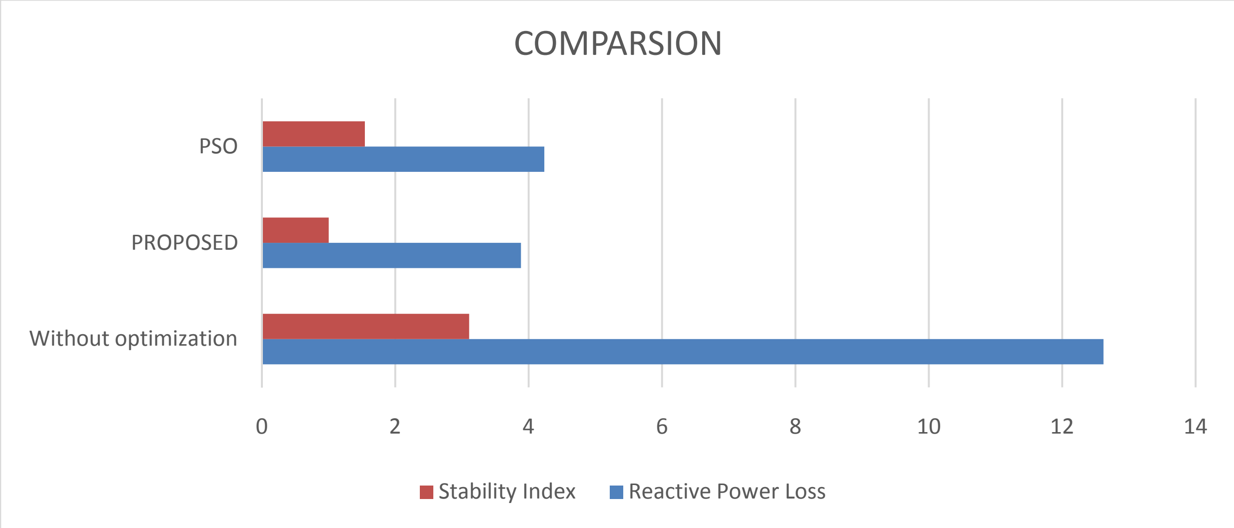

Figure 5 Comparison of reactive Power Loss and stability index

In figure 6 the comparison of three algorithms without optimization, PROPOSED(GWO_GA) and PSO 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 2 DG Size and cost

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

Table 3 DG Location

Approach	**Location**	**Size**
PROPOSED	12,11,10	150,300,600
PSO	14,11,10	300,150, 150

Table 4 Losses on different DG and power factor

LOSSES	7.5MVA	17.5MVA	27.5MVA
REALLOSSES(PF=0.8)	16.34	14.34	12.34
REALLOSSES(PF=0.83)	15.45	13.45	11.23
REALLOSSES(PF=0.86)	14.34	13.23	11.1
REALLOSSES(PF=0.89)	13.23	12.34	10.34
REALLOSSES(PF=0.9)	13.13	12.23	9.23
REACTIVE LOSS(PF=0.8)	67.45	69.34	62.34
REACTIVE LOSS(PF=0.83)	66.23	67.45	60.34
REACTIVE LOSS(PF=0.86)	67	66.34	58.45
REACTIVE LOSS(PF=0.89)	68	65.34	56.45
REACTIVE LOSS(PF=0.9)	66	63.45	67.45

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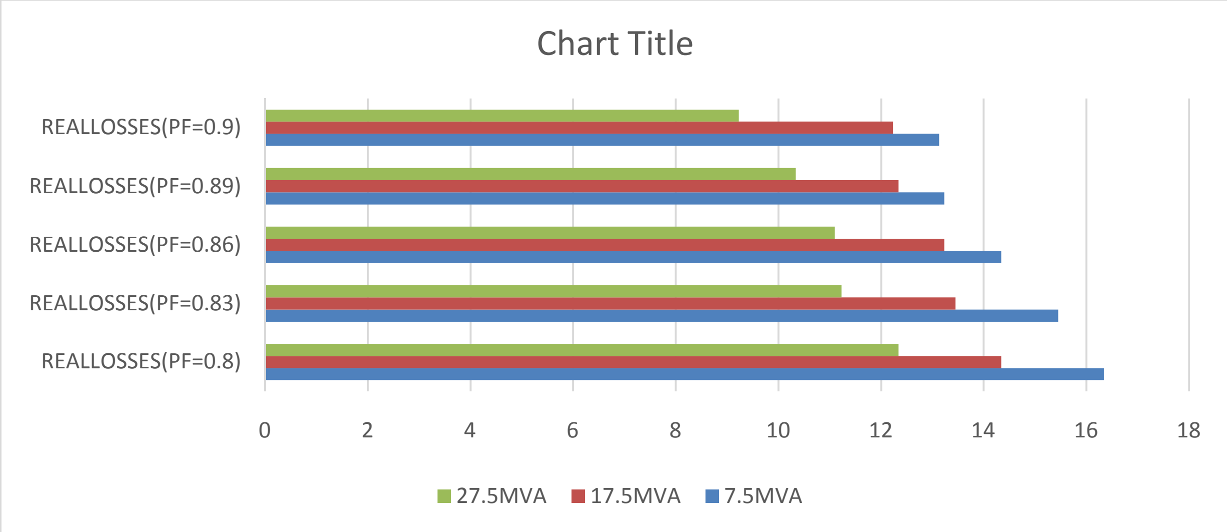

Figure 6 Comparison of reactive Active or real Power Loss

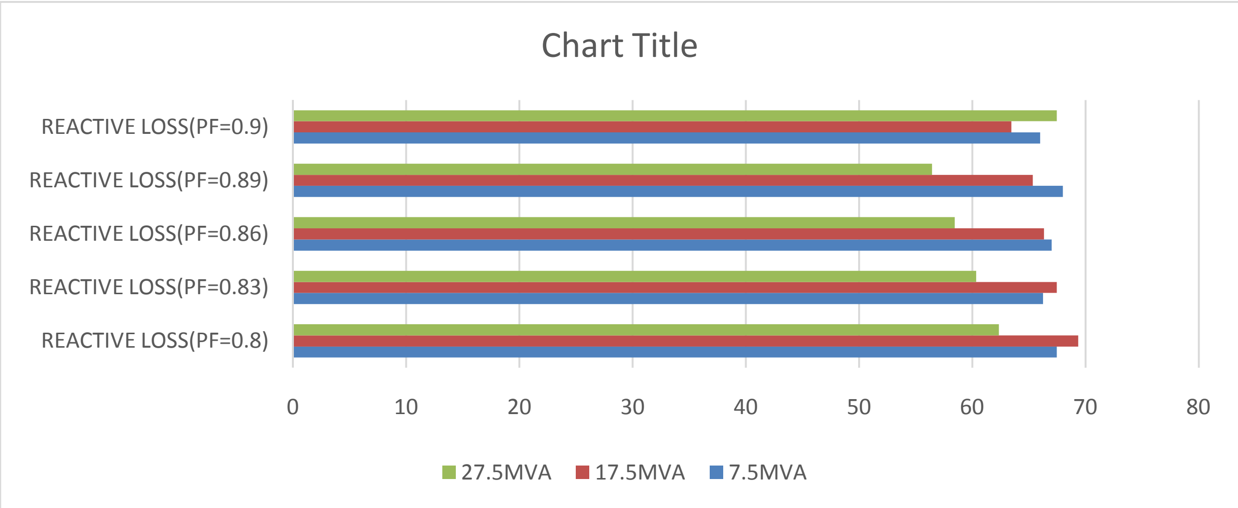

Figure 7 Comparison of reactive Power Loss

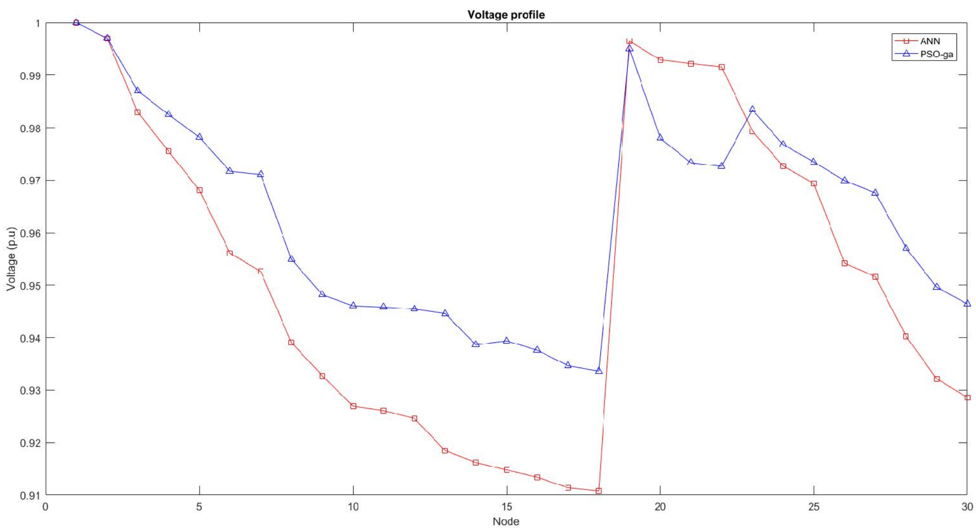

Figure 8 Comparison of Voltage profile

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Figure 9 Comparison of real Power Loss

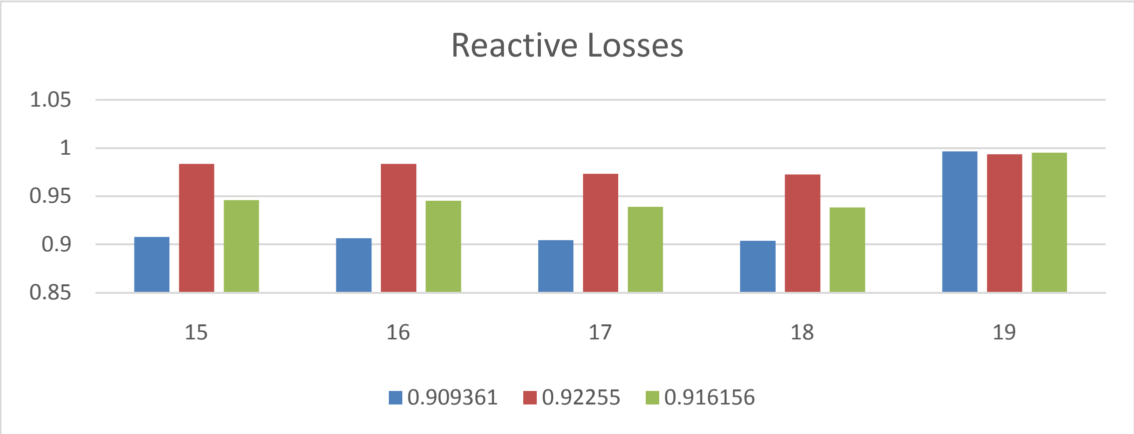

Figure 10 Comparison of reactive Power Loss

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 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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