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Mitigation of line losses in distribution system using optimised placement of Distributed Generation

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Abstract: **Line losses are the most significant challenge faced by Pakistan's energy department. 6.5% of the country's GDP, a large figure of $1.8 billion is lost every year due to line losses in power generation, transmission, distribution and consumption. In distribution systems, researchers are attracted by the penetration of distributed generation (DG) nowadays. The performance of a distribution network is affected by the significant role of number, capacity and situation of DG units. This study will focus on the distributed generation of a centralised national grid and provide an algorithmic model that implements Improved Particle Swarm Optimization to reduce the system power loss and improve the voltage profiles via optimisation of the locations and sizes of multip1le DG(s). The overall sensitive feature was determined and utilised efficiently to reduce research space for the algorithm. In the case of IEEE 33Bus test system, 10% of candidate buses are selected as possible DG situations. The IPSO methodology produced severe loss reduction and improve the voltage profiles in all the three types of DGs considered using the IEEE 33-Bus system. The percentage decrease in active power losses was reduced 68.10492%, 66.91669% and 58.89211% for DG type -1, DG type-2 and DG type-3 respectively. At the same time, reactive power losses were reduced 53.095%, 53.0922% and 50.4145% for DG type -1, DG type-2 and DG type-3 respectively.**

Keywords: **Distributed Generation (DG), Voltage profile, Power loss, Improved Particle Swarm Optimization (IPSO), Genetic Algorithm (GA)**

I. INTRODUCTION

In Pakistan division of Electrical energy has passed through an era of mal performance and inefficiency. A continuous disbalance in the demand and supply is observed along with inequality of efficiency and sustainability. There is also a great difference between the price of electricity and the users' affordability [1-3]. At present, a severe catastrophe regarding electric power has hit the country that is a consequence of hours-long blackouts in urban and rural areas in terms of load shedding. There are so many reasons for this, but one of the main reasons is the poor distribution system. The grid stations require an operating system that is capable of good maintaining and developing skills along with managing a transmission network of up to 132 KV to deliver electricity in their jurisdiction to the end-user or customer. Typically all these activities are managed under a single term that is the distribution system. The performance of distribution companies of Pakistan is not up to the mark because of a wide range of challenges in the developing atmosphere of the country. These challenges include electricity loss through distribution wires, reduced recovery of electricity charges from consumers, unauthorised use of electricity, underprivileged organisation and supremacy. Consequently, a variable financial loss is observed among different DISCOs. As a specimen, according to NEPRA (2010), average financial loss per annum is 60%, 35%, 20% and 40% of their annual returns collection are recorded in Peshawar Electric Supply Co. (PESCO), Hyderabad Electric Supply Co (HESCO), Quetta Electric Supply Co. (QESCO) and Karachi Electric Supply Co. (KESC)respectively [5-8].

Turbidity Electrical Systems are sprouting from a centralised system to decentralised systems. Decentralised systems represent the use of small generating systems which are linked directly to distribution networks neighboring the load end of the system. Distributed generation system is a term used to illustrate a wind source or a photovoltaic cell connected to a distribution network [9-15]. It is a reliable solution for consistency issues, quality, overloaded lines and load growth problems. Suitable sizing and settlement of distributed generation (DG) system have significant role in reducing loss of electric power in distribution systems. The reduced active power loss saves energy that is technical translated into financial benefits.This research focuses on the ideal placement and sizing of the distributed generation system in Pakistan for a specific locality based on data availability. Optimisation techniques will be used for the available data for evaluating the system using Bus bar regulation of IEEE and examine the outcomes prior &post-employment of these techniques of optimisation.

The Distributed Generation (DG) relates to utilisation of little generators introduced on vital purposes of electrical power framework yet mostly they are favored at burden end of the framework. The innovations which are utilised as DG incorporates yet not restricted to the accompanying: little gas turbines, miniaturised scale turbines, power devices, wind and sunlight-based vitality and so on. Distributed Generation (DG) can be utilised in a secluded manner, providing the purchaser nearby interest or in a coordinated manner or providing vitality to the staying electrical framework. In circulation frameworks, Distributed Generation (DG) can give advantages to the buyer just as for the utilities, particularly in locales where the focal age is unimaginable or where there are inadequacies in the transmission framework.

DG (Distributed Generation) is characterised by little generators normally under 10MW, which are associated with the circulation framework. On the off chance that the framework topology is thought to be perpetual during the arranging time frame, the pinnacle burden request development or the presence of new loads to the system could require the speculation of update. For this situation, distributed generation can be important choice for the arranging architect to limit the speculation for dissemination framework.

Distributed Generation practices have gone through many changes in power production meanwhile from 1980's. Power systems are developed and classified from centralised systems to decentralised systems of power generation. In DG system connectivity is increased among systems, due to these many problems originate concerning to protection of devices, power quality improvements, flexibility and reliability of system and control utility of system. Among these various problems, protection is the main task to overcome the majority problem of the system [15-20].

DGs are imbedded into the current distribution framework when traditional load growth that was forecasted when the system was installed has been reached and there is a need to install additional capacity to the network. The areas and size of DGs have significant impact of voltage profile improvement [3]

Distributed generation (DG) is small scale power generation that is typically associated with distribution frameworks. The Electric Power Research Institute (EPRI) characterises DG as generation from a couple of kilowatts up to 50MW [3]. CIGRE characterise DG as the generation, which has the qualities: it isn't centrally planned; it isn't centrally dispatched at present; it is generally connected to the distribution system; it is smaller than 50-100MW. Ackermann et al. have given the latest definition of DG as: "DG is an electric power generation source connected directly to the distribution network or on the customer side of the meter." [4]

DGs are imbedded into the current distribution framework when traditional load growth that was forecasted when the system was installed has been reached and there is a need to install additional capacity to the network. The primary qualities that are considered for the optimal DG location and size are the minimisation of transmission loss, augmentation of supply reliability and maximum reach. [5].

The role of distributed generation system is vital in the reduction of power loss and the placement at optimum location and size shows improved voltages at the feeder side. Many useful algorithms depending on optimal location placement and better size are being proposed for distributed generation system. In a distribution network small sized generating plants placed nearby to load centers are connected directly which are DG units. To upsurge the segment of renewable energy sources and to improve global warming and greenhouse gas emissions we require the integration of large sized DG units at the substation. The total shares for DG system have increased rapidly in the modern electrical power systems and may rise to the 20% of total power production from natural sources in the next decade. But the placement of distributed generation system in an incorrect way causes an increase in losses, operating cost and system capital investment. . DG system also includes a rise in voltage profile at the distribution feeders which can be cured by the assortment of optimal magnitude, location and amount of DG units [6].

In modern years, with prompt increase in capacity of energy sources there is a gain of viable energy based distributed energy resources, such as wind turbines and photovoltaic over the world, these resources play a key role in a micro grid, which could be a group of manageable and distributed generators and loads. But, these distributed energy resources typically interchange power with the grid over the use of converters, and this type of power electronic involved in converters interface to bring a micro grid feature to differentiate it from an outdated synchronous generator based power system, such as small inertia, fast response time, and difficult to stabilise output voltage and frequency. Since the increase in the perception of distributed energy resources in nowadays power grid, these features raise new control challenges in a micro grid, and therefore, have drawn many attentions of the researchers [7].

To overcome the harmonics generation, while integrating to a distribution network, different algorithms are used to resolve this problem. For example, COMBI algorithm and JADE algorithm used for the estimation of harmonics in the distributed generation system [8]. The concept of DG system tells us that it is the generation of electric power which is installed at a small scale in a distributed network.

The practical design concerns while using DG units generally include voltage solidity, service consistency, power quality, protection and control inside the main distribution system [9]. As the time passes the demand of energy is also growing, the DG sources are also adding more and more to the utility network. The addition of DG on distribution feeder interrupts the power excellence in numerous ways, for example voltage variation, flicker, and harmonic inoculations. These effects are essential to be examined and measured after checking that the power eminence of system must fulfil power quality standards. Finally, if the additional distributed generation systems are added, it will have positive effects on the system not the worst one [10].

The most suitable location of DG units and the quantity of generated power by these units is computed in three stages by using two Genetic algorithms (GA) and Neural-network (NN)in paper [11].The GA is implemented in initial and third stage, while second stage is completed by implementing NN. Entire power loss in the system can be decreased by using this method along with the improved system quality and reliability.

The[12] adapted voltage profile and power losses are included in objective function and the IEEE 33-bus system was used to test the suggested method. [13] have anticipated a procedure for ideal arrangement and working of lively delivery grid concerning the setting and sizing of DG units arranged on multiple buses such as 69-bus, 33-bus and 2-bus outspread distribution networks. For decreasing the actual power losses and to augment the voltage profile, a Fuzzy and PSO method for the fitting of DGs in radial distribution system[14].

In present work, the optimal size and location of single and multi-DGs to minimise the power losses and improve the voltage profile are done by IPSO. The proposed technique is tested on IEEE 33-bus system with different scenarios of inserting DG units 1,2 and 3, 10% candidate buses are selected as possible DG situations and the results obtained are compared with DG type-1, DG type-2 and DG type-3 respectively and from these results we shall be concluded that which DG-type is best suited to install keeping in view the active and reactive losses and voltage profile improvement.

II. PROBLEM FORMULATION

Power Flow in Distribution NetworkSimple power distribution is shown in below figure 1, voltage at bus I is shown as Vi, and have current i, branch resistance and reactance are shown as Rj+jXj. Active power at bus is represented by PLi and reactive power at bus i is represented with QLi. Total no of buses in network is nominated as by Nb . Here Rj is resistance, Xj is Reactance and Zj is impedance of the branch j between bus I and bus i+1. The current flowing in branch j between bus i and bus i+1 is termed as Ij.

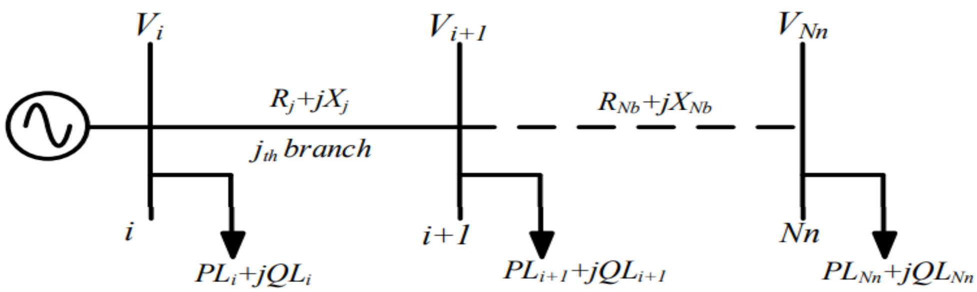

FIGURE 1: Power Distribution sample having N Buses

Total power loss can be calculated from Figure 1 by load flow. The voltages and current at nodes i and i + 1 are $V_i < \delta_i$,$V_{i+1} < \delta_{i+1}$ and Ij, respectively and given in Equations (1), (2) and (3):

$$V_{i+1} = \sqrt{\frac{v_i^2}{2} - \left(PL_{i+1}.R_J + QL_{i+1}.X_j\right) + \sqrt{\left\{\frac{v_i^2}{2} - \left(PL_{i+1}.R_J + QL_{i+1}.X_j\right)\right\}^2 - \left(R_j^2 + X_j^2\right)\left(PL_{i+1}^2 + QL_{i+1}^2\right)}} \quad \text{Eq (1)}$$

$$\delta_{i+1} = \delta_i - \tan^{-1}\left[\frac{P_{i+1}X_j - Q_{i+1}R_j}{V_{i+1}^2 + P_{i+1}R_j + Q_{j+1}X_j}\right] \quad \text{Eq (2)}$$

Current at the bus can be calculates as under:

$$I_j = \frac{V_i < \delta_i - V_{i+1} < \delta_{i+1}}{Z_j} \quad \text{Eq (3)}$$

Total Active Power Loss of the distribution network is sum of all the resistive loss of the branches Nb , is given as under

$$TPL = \sum_{j=1}^{Nb} R_j I_j^2 \quad \text{Eq (4)}$$

Total Reactive Power Loss of the distribution network is sum of all the reactance loss of the branches Nb , is given as under

$$TQL = \sum_{j=1}^{Nb} X_j I_j^2 \quad \text{Eq (5)}$$

Total Apparent Power loss of the distribution network is sum of all the impedance loss of the branches Nb , is given as under

$$TSL = \sum_{j=1}^{Nb} Z I_j^2 \quad \text{Eq (6)}$$

III. Fitness Function and Constraints

Primary objection of the stud is to reduce the losses of the distribution network using placement of distributed generation at optimum place. In order to find the minim value for the objective function DG is placed at different buses to get minim loss value of the network and maximum average value of the voltage.

$$F(x) = \min\{Total\ Power\ Loss\} \quad \text{Eq (7)}$$

$$x = [B_1, B_2, .. B_i, ; dg_1, dg_2, .. DG_i],$$

Where x is the descion vector variable, B1 is the bus no and dg1 is the size of the DG. So, the minim value for the said function will be the fitness function value.

In the power distribution network, the power flow analysis is done by calculating the voltage of any bus, current flowing on branches between the buses, the active and reactive branch losses of every branch. The limitations and constraints for the any distribution network to get minim losses will be as under:

1. During DG placemen the bus voltages remains in the lower and upper bound . Where V_{imin} is the minimum voltage limit of the bus i, V_{imax} is the maximum voltage limit of the bus i and Nb is the num of buses in the network. Thus, equation becomes as under (8)

$$V_{imin} \leq |V_I| \leq V_{imax} \; ; i = 1,2,3,4, \dots N_b \quad \text{Eq (8)}$$

2. Branch current also remain in the upper limit of the branch conditions, that is over current limit of that branch. Will be given as under (9)

$$|I_I| \leq I_{imax} \; ; i = 1,2,3,4, \dots N_b \quad \text{Eq (9)}$$

3. During the DG placement in the distribution network the network structure remain radial, means determinant of incident matrix A of the network remains 1 or -1.

$$\det(A) = 1 \, or - 1 \, for\ radial\ network$$

$$\det(A) = 0 \;\; for\ non\ radial\ network \quad \text{Eq (10)}$$

The average voltage is given in Equation (11).

$$V_{average} = \frac{\sum_{i=1}^{N_b} V_i}{N_b} \quad \text{Eq (11)}$$

IV. Improved Particle Swarm Optimization (IPSO)

Particle swarm optimisation (PSO) is a population based stochastic optimisation technique which is inspired by social behavior of fish schooling or bird flocking. The method starts from multiple points to obtain a solution which is a near global solution.PSO is visually presented and described in the following figures 2 and figure 3.

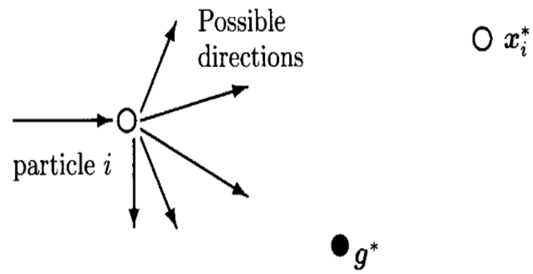

FIGURE 2: Searching point concept in PSO

PSO is initialised with a group of random particles (solutions) and then searches for optima by updating generations. During every iteration every particle value is updated by following the two best values.

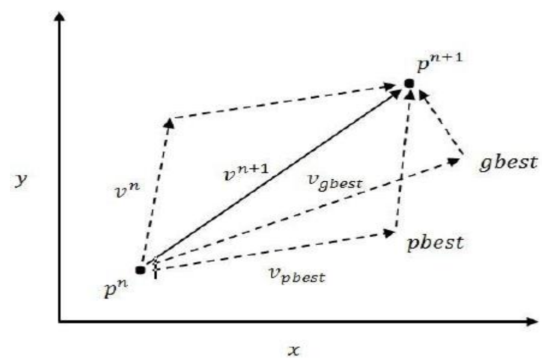

FIGURE 3: updating of Velocity in PSO

The first one pBest value is the best solution achieved by the particle. Whereas gBest value is the global best value achieved by the particle during PSO. After finding the two best values, the particle updates its velocity and positions with following equation (12) and (13).

$$V_{i(u+1)} = C_1 * W * V_{i(u)} * rand(\,x\,) * (pbest_i - P_{i(u)} + C_2 * rand\ (x\ ) * (gbest_i - P_{i(u)}) \quad \text{Eq (12)}$$

$$P_{i(u+1)} = P_{i(u)} + V_{i(u+1)} \quad \text{Eq (13)}$$

In the equation above,

The term $rand(\,x\,) * (pbest_i - P_{i(u)}$ is called particle memory/Personnel influence.

The term $rand\ (x) * (gbest_i - P_{i(u)})$ is called swarm influence.

$V_{i(u)}$ is the velocity of ith particle at iteration 'u' must lie in the range:

$$V_{min} \leq V_{i(u)} \leq V_{max} \quad \text{Eq (14)}$$

The standard particle swarm optimisation uses both the current global best g* and the individual best x_i*. The diversity in the quality solutions is primarily the reason of using the individual best; however, this diversity can be simulated using some randomness. Subsequently, for using the individual best there is no compelling reason, unless the optimisation problem of interest is highly nonlinear and multimodal.

A simplified version is to use the global best only which could accelerate the convergence of the algorithm. Thus, in the Improved particle swarm optimisation (IPSO), the velocity vector is generated by a simpler formula

$$v_i^{t+1} = v_i^t \propto \epsilon_n + \beta(g^* - x_i^t) \quad \text{Eq (16)}$$

where ϵ_n is drawn from N(0, 1) to replace the second term. The update of the position is simply

$$v_i^{t+1} = v_i^t + v_i^{t+1} \quad \text{Eq (17)}$$

$$v_i^{t+1} = (1 - \beta)v_i^t + \beta g^* - \propto \epsilon_n \quad \text{Eq (18)}$$

The update of the location in a single step in order to increase the convergence even further is given in equation 18. Comparing with many PSO variants, IPSO is very simpler and uses only two parameters, and the mechanism is simple to understand.

In the IPSO, the randomness reduced as iterations proceed which is a further improvement. This means that we can use a monotonically decreasing function such as

$$\propto = \propto_o e^{-\gamma t} \quad \text{Eq (19)}$$

$$\propto = \propto_o e^{-\gamma t}, \quad (0 < \gamma < 1) \quad \text{Eq (20)}$$

where $\propto_o \approx 0.5 \sim 1$ is the initial value of the

Velocity Update:velocity update of any particle at any moment during the optimisation can be given by

$$V_{11} = V_{11} + c_1r_1(pbest_{11} - x_{11}) + c_2r_2(gbest_{11} - x_{11}) \quad \text{Eq (15)}$$

Position update: position of any particle after iterations can be known by using

randomness parameter. Here t is the number of iterations or time steps. $0 < \gamma < 1$ is a control parameter. For example, in our implementation, we will use,

$$\propto = 0.7^t \quad \text{Eq (21)}$$

where t $\in [0, t_{max}]$ and $t_{max}$is the maximum iterations

V. Implementation of proposed IPSO algorithm

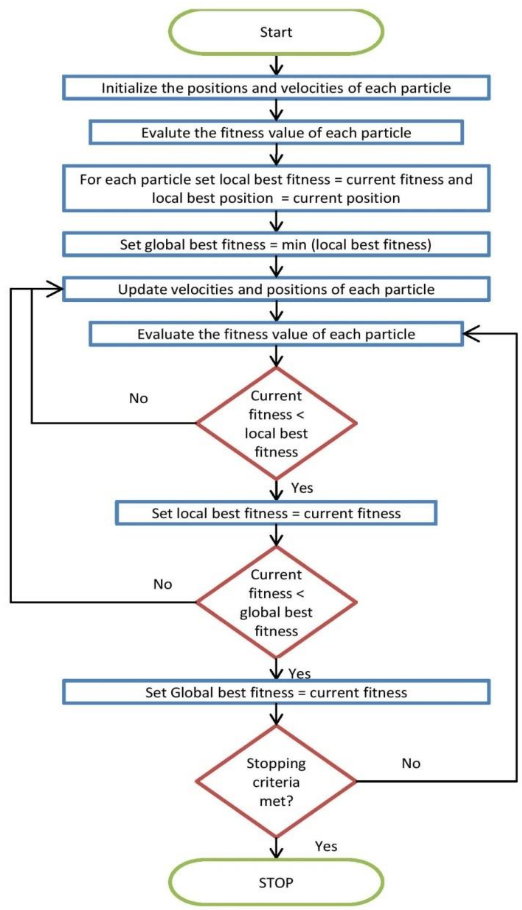

FIGURE 4: Flow diagram of Improved Particle swarm optimisation algorithm (IPSO

IPSO moves towards the best optimal solution and the search process is stopped automatically as shown above in Fig 4.

VI. Results and Discussion

The present part demonstrates the outcomes gotten by Particle swarm Optimisation Algorithm strategy. The calculation examined in the previous segments is customised and executed on MATLAB 2019b. These outcomes are additionally separated into various parts relying upon the test transport framework under thought and the kind of DG being ideally place and estimated. Various correlations have likewise been accomplished for demonstrating the legitimacy of the proposed calculation in reducing receptive and genuine system loses and expanding voltage profiles in relationship with different calculations in open writing. Table 1 shows the initial case before optimal DG placement.

TABLE 1: Initial case before optimal DG placement

	Losses [kW]	**Losses [kVAR]**	**Minimum Voltage [pu]**	**DG location**	**DG size**	**Convergence Curve**		
						DG1	**DG2**	**DG3**
Base Case	208.46	111.67	0.91075	-	-	**113.5157**	**72.6921**	**108.9622**

A. IEEE 33 Bus Test System

To lead this examination study and test purposes 33-Bus testing framework is utilised during the exploration, the power current investigation is finished by utilising the Newton Raphson Method. To ensure fair evaluation, the amount of DGs to be optimally situated and sized was kept constant with the research work under comparison; The DG limit was assumed as given below in order to ascertain similar values for validation;

- 0MW -10MW for real power limit (Type 1, 2 and 3 DGs)
- 0MVar – 10MVar for reactive power limit (Type 2 DG)
- -10MVar – 0MVar for reactive power limit (Type 3 DG)

A.1. Result Considering DG Type-1

The selection of optimal locations for DGs having type 1 and their corresponding optimal sizes was carried out utilising table 2 given below. It was carried out through the selection of the locations that possess minimum fitness values and their respective DG sizes.

This is essential to understand that the incorporation of DG(s) in the power system networks can result to unacceptable voltage levels in certain buses in the system. With that in mind it was important to check the voltage profiles of the 33 Bus system after the inclusion of the DGs for voltage deviation outside the limits and compare it with voltage profiles obtained by other researchers.

When we install DG Type 1, which only delivers the active power on 10% of the total bus, the IPSO algorithm installs DGs as shown in table 2 below. It took 9.9603s for simulation by using 30 iterations and 20 particle size.

TABLE 2: Optimal placement of DG type 1

DG location at 10%buses	**Active power [MW]**	**Reactive power [MVAR]**	**Losses reduction[kW]**	**%losses reduction**	**%voltage improvement**
3	1.1344	-	66.4882	68.1049	3.467309245
6	2.1754	-			
4	0.0868	-			
5	0.12144	-			

Below Figures highlights the graph of the above comparison of voltage in Fig.5, active power losses in figure 6, reactive power losses in Fig. 7 and the convergence curve of the IPSO in Fig. 8.

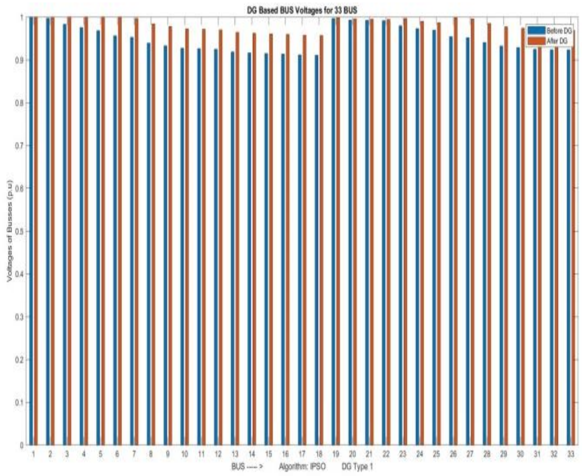

FIGURE 5: Initial and Final Voltages on IEEE-33 Bus Network after placing DG

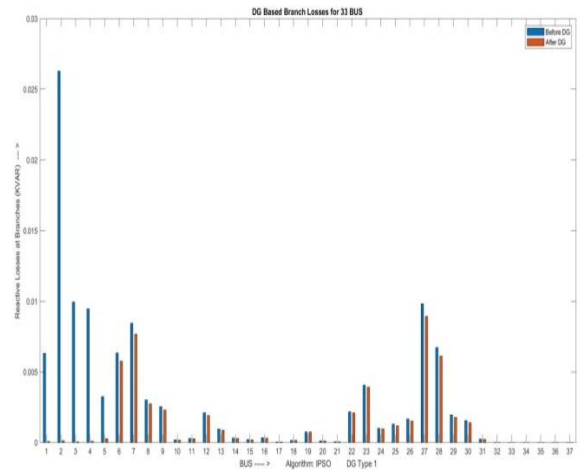

FIGURE 6: Initial and Final Reactive Power losses IEEE-33 Bus Network after placing DG Type-1

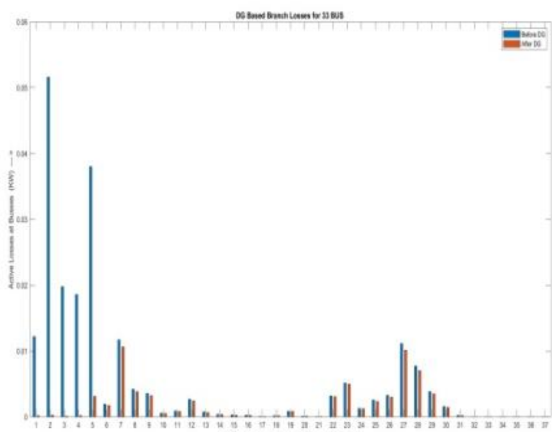

FIGURE 7: Initial and Final Active Power losses on IEEE-33 Bus Network after placing DG Type-1

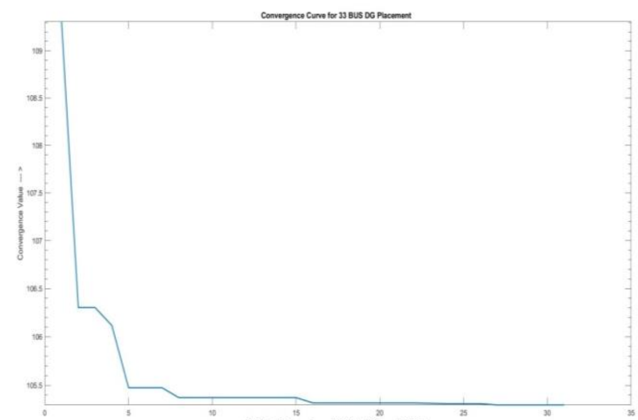

FIGURE 8: Convergence Curve of IPSO for IEEE-33 Bus Network after placing DG Type-1

A.2. Result Considering DG Type-2

Similarly, the seven ideal areas for the DGs of sort 2 and their individual ideal sizes were picked utilising the separate segments for wellness and DG size in table 3. The areas which gave the base wellness esteems and their separate DG sizes were chosen. The chosen candidate buses were expected, and a heap stream study was finished utilising Newton Raphson technique in order to decide the related energy losses and levels of voltage. The correlation of the outcomes got for the energy loses is given in the table below.

When we install DG Type 2, which only delivers the active power as well as reactive power on 10% of the total buses, the IPSO algorithm installs DGs as shown in table 3.It took 9.4202s for simulation by using 30 iterations and 20 particle size.

TABLE 3:Optimal placement of DG type 2

DG location at 10%buses	Active power [MW]	Reactive power [MVAR]	Losses reduction[kW]	%losses reduction	%voltage improvement
3	1.0124	0.38312	66.9652	66.9167	3.467329425
6	2.2033	1.4402			
4	0.14991	0.0012			
5	0.005	0.23494			

The voltage comparison on the candidate buses is compared and shown in the below figure 9, this highlight voltage profiles of candidate buses prior to and after the DG placements in the 33 Bus standard. Similarly, active power losses comparison and reactive power losses comparison is shown in figure 10 and figure 11. Whereas IPSO convergence curve for DG Type 2 is shown in figure 13.

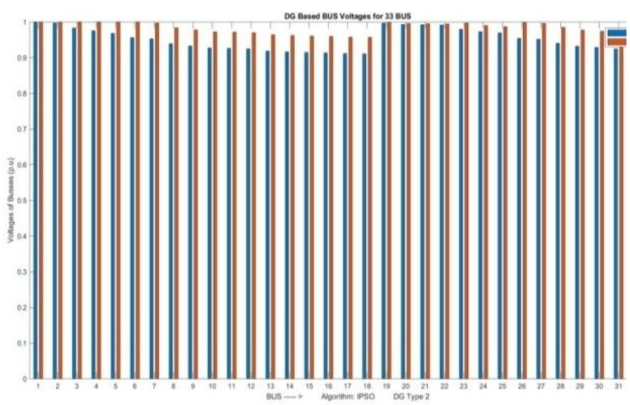

FIGURE 9: Initial and Final Voltages on IEEE-33 Bus Network placement

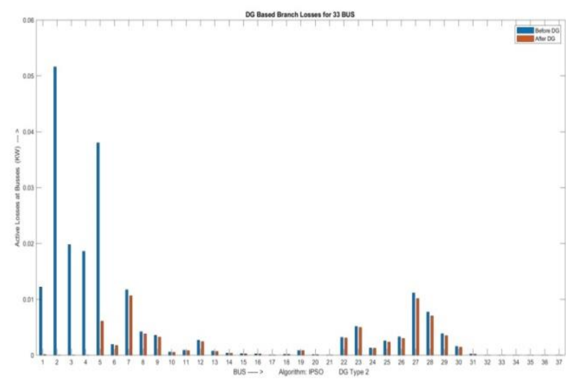

Figure 10: Initial and Final Active Power losses on IEEE-33 Bus Network after placing DG Type-2

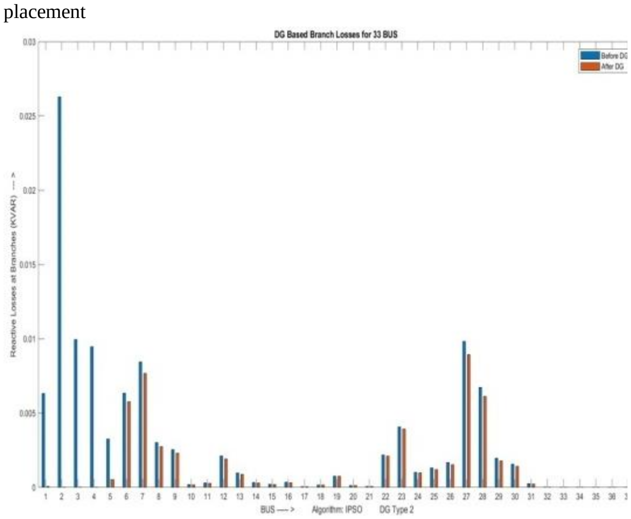

FIGURE 11: Initial and Final Reactive Power losses IEEE-33 Bus Network after placing DG Type-2

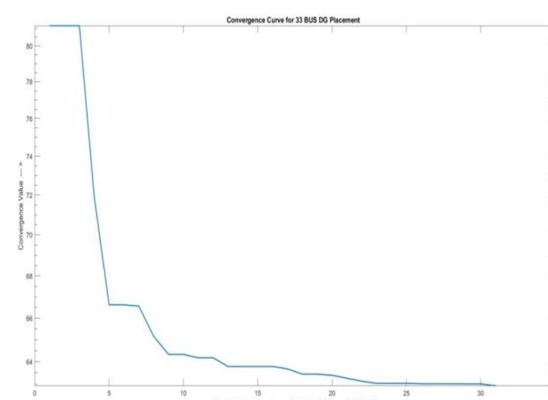

FIGURE 12: Convergence Curve of IPSO for IEEE-33 Bus Network after placing DG Type-2

A.3. Result Considering DG Type-3

Similarly, the best suited placements for the Distributed Generators of type 3 and their related best suited sizes were designated utilising the related columns for suitability and Distributed Generator size in table 4. The placements that gave the least suitability values and their related Distributed Generator magnitudes were selected. The chosen candidates DG sizes were assumed to be in their respective locations and a study of load flow was performed utilising Newton Raphson technique to ascertain the related energy losses and levels of voltage.

When we install DG Type 3, which only delivers the active power as well as absorb reactive power on 10% of the total buses, the IPSO algorithm installs DGs as shown in table 4.It took 9.216s for simulation by using 30 iterations and 20 particle size.

TABLE 4: Optimal placement of DG type 3

DG location at 10%buses	Active power [MW]	Reactive power [MVAR]	Losses reduction[kW]	%losses reduction	%voltage improvement
3	0.7378	-0.001	85.6931	58.8921	3.467307874
6	1.9522	-0.001			
4	0.85676	-0.001			
5	0	-0.001			

The voltage comparison on the candidate buses is compared and shown in the below figure 13, this highlight voltage profiles of candidate buses prior to and after the DG placements in the 33 Bus standard.

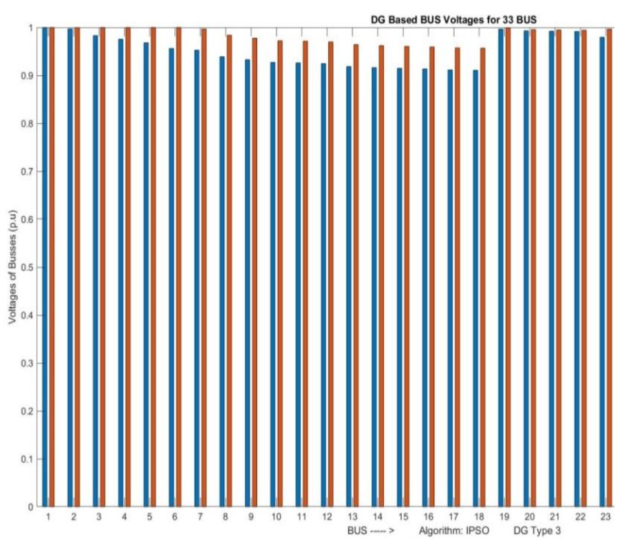

FIGURE 13: Initial and Final Voltages on IEEE-33 Bus Network after placing DG Type-3

Similarly, active power losses comparison and reactive power losses comparison is shown in figure 14 and figure 15. Whereas IPSO convergence curve for DG Type 2 is shown in figure 16.

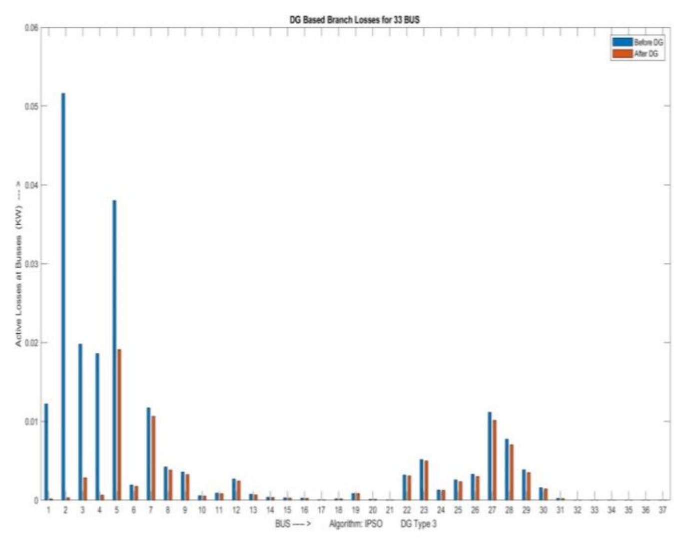

FIGURE 14: Initial and Final Active Power losses on IEEE-33 Bus Network after placing DG Type-3

The Active power comparison on the candidate buses is compared and shown in the above figure 15, this highlights active profiles of candidate buses prior to and after the DG placements of Type-3 in which the

DGs as well as generation of real power in the IEEE-14bus standard.

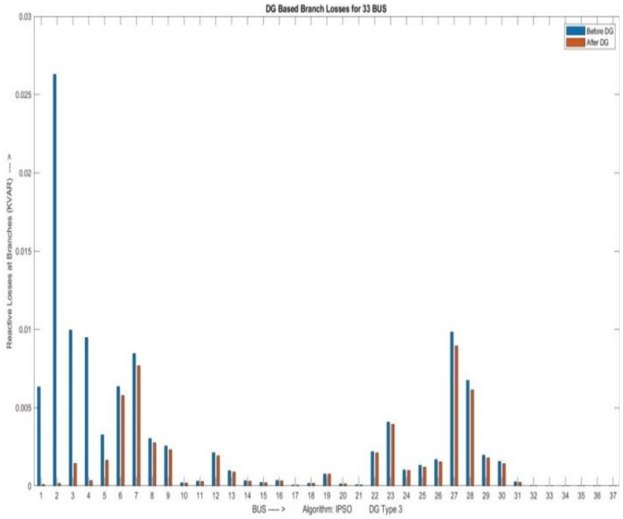

FIGURE 15:Initial and Final Reactive Power losses IEEE-33 Bus Network after placing DG Type-3

The reactive power losses comparison on the candidate buses is compared and shown in the above figure 16, this highlights power profiles of candidate buses prior to and after the DG placements of Type-3 in which the reactive power is being absorbed but the DGs as well as generation of real power in the IEEE-33 bus standard.

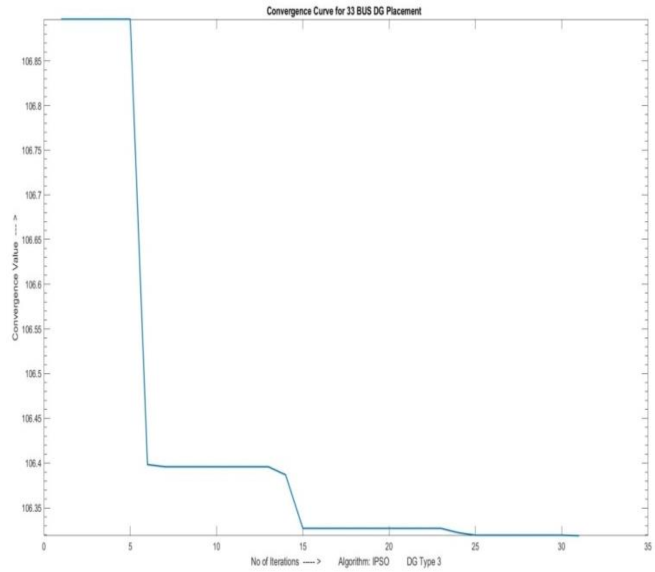

FIGURE 16: Convergence Curve of IPSO for IEEE-33 Bus Network after placing DG Type-3

A.4. Results Comparison for All type DGs

To implement in this case the DG(s) was presumed to be situated in a 33-bus test system. Here Improved Particle Swarm Optimization (IPSO) is used to optimise the locations and size of a multi-type DG. Since the major goal of the research study was to improve voltage profile and minimise real power losses. Table 5 and 6 shows the summary of voltage and losses comparison for IEEE-33 bus for all type DGs.

TABLE 5: Summary of Voltage Comparison for IEEE-33 Bus for All Type DGs

Detail	**Vm DG Type 1**	**Vm DG Type 2**	**Vm DG Type 3**
Average Voltage	0.982606563	0.982606755	0.98260655
Vmin	0.956801476	0.956801476	0.956801476
Vmax	1	1	1
%age Improvement	3.467309245	3.467329425	3.467307874

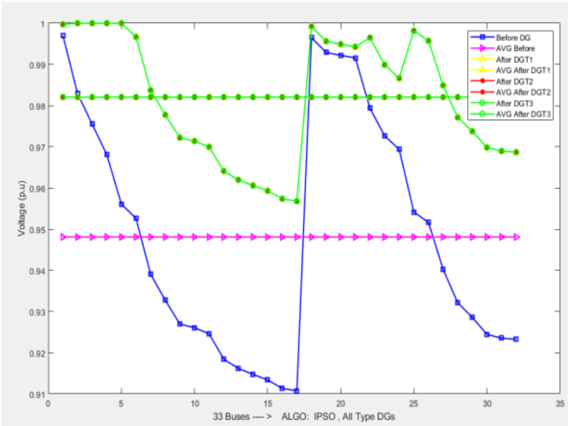

FIGURE 17: Voltage Comparison for IEEE-33 Bus Network for All Type DGs

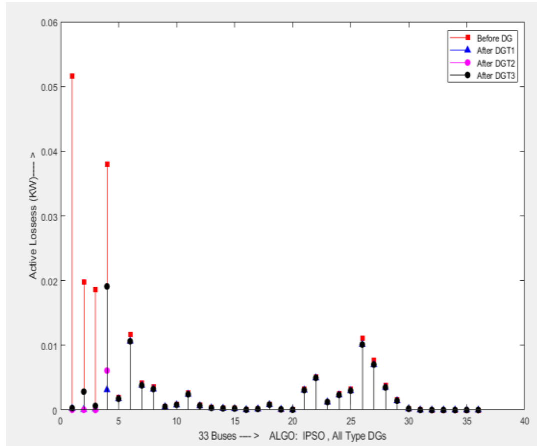

FIGURE 18: Active Power Loss Comparison for IEEE-33 Bus Network for All Type DGs

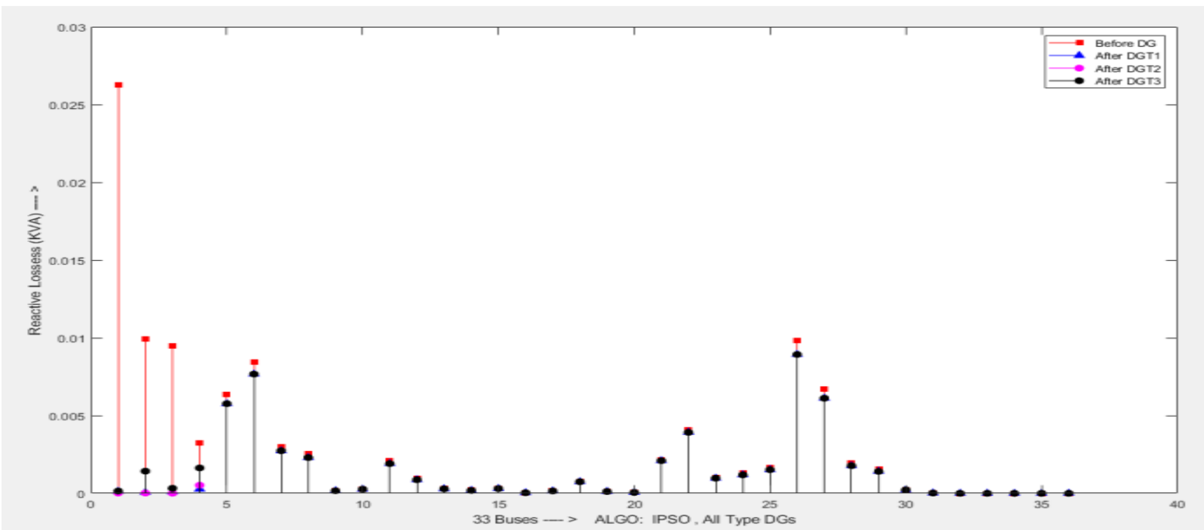

FIGURE 19: Reactive Power Loss Comparison for IEEE-33 Bus Network for All Type DGs

TABLE 6: Summary of Active and reactive power Comparison for IEEE-33 Bus for All Type DGs

DG Type	**Ploss before DG**	**Ploss After DG**	**% Ploss Reduction**	**Qloss before DG**	**Qloss after DG**	**% QLoss Reduction**
Before DG	208.46	-	-	111.673	-	-
DG Type 1	208.46	66.4882	68.104927	111.673	52.38005	53.09503305
DG Type 2	208.46	68.9652	66.916698	111.673	52.383193	53.09221845
DG Type 3	208.46	85.6931	58.892117	111.673	55.373468	50.41450575

Above table show the cooperative summary of DG Types and their impact on the percentage loss reduction. Active power loss reduction varies from 68%, 66% and 58% for DG Type-1, 2 and 3 respectively. Similarly, for reactive power losses of all DG types are 53,53, and 50% respectively. As shown from active and reactive power comparison table above, best result obtained from DG type 1.So, DG type-1 is well suited for optimal placement for mitigation of losses from economic point of view

VII. CONCLUSIONS

Improved PSO algorithm used in helping to reduce the system power loss and improve the voltage profiles via optimisation of the locations and sizes of multiple DG(s). The overall sensitive feature was determined and utilised efficiently to reduce research space for the algorithm. In the case of IEEE 33-Bus test system, 10% of candidate buses are selected as possible DG situations. As seen from the results, the IPSO methodology produced a severe loss reduction in all the three types of DGs considered using the IEEE 33-Bus system. The percentage decrease in active power losses was reduced 68.10492%, 66.91669% and 58.89211% for DG type -1, DG type-2 and DG type-3 respectively. At the same time, reactive power losses were reduced 53.095%, 53.0922% and 50.4145% for DG type -1, DG type-2 and DG type-3 respectively. The IPSO technique also produces good results to reduce the loss and improve the voltage profiles of the IEEE 33-Bus test systems. This methodology also enhanced the lowermost bus voltage 0.91075pu from value to 0.9568pu.

By comparing the results of DG type-1, DG type-2 and DG type-3, it is concluded that DG type-1 shows the best efficiency with active power losses reduced to 68.10492% whereas reactive power reduced to 53.095% and improve the voltage profile to 3.467309245%. Hence, DG type-1 is best suited to install to minimise losses and improve voltage profile.

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