Available Online at www.ijcsmc.com

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X
IMPACT FACTOR: 6.199

IJCSMC, Vol. 8, Issue. 9, September 2019, pg.190 – 201

Optimized Siting and Sizing of DG in a HESCO Feeder using Particle Swarm Optimization

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Abstract— Power system is a radial distribution system comprising large number of nodes and branches. Especially in Pakistan, large network causes power loss and voltage drop due to outdated infrastructure. Distributed Generation is one of the emerging solutions to compensate the load demand along with improvement in power quality and voltage profile of electrical power system. Although, proper placement and sizing of DG is still a challenging situation in power system as improper placement and sizing may bring the network more sever situation. This paper analyses a real time 11 kV radial distribution network of HESCO. An artificial intelligence technical named PSO is utilized to identify the optimal placement and size for DG integration. The proposed technique resulted as very effective for reduction in power loss with fast convergence.

Keywords— Distributed Generation, HESCO, Power loss, Artificial Intelligence, Distribution system.

I. INTRODUCTION

Globally, power system has been under stressed condition due to nonlinear behavior of loads [1, 2]. The load is affected by many parameters such as weather change, floating fuel cost etc. Demand for electricity is elevating day by day and this leads the field experts, environmentalist and economists to identify the possible solution to overcome the energy shortfall. Distributed Generation (DG) is widely recommended and deployed by the experts in the distribution system. DG has many benefits over centralized power system such as it reduces overburdening of transmission lines, improves voltage profile and power loss, enhances system capacity and continuity of supply [3-5]. DG is mostly utilized using renewable energy sources that has no any environmental issues like CO2 emissions [6, 7]. Solar PV is the most widely used renewable energy source due to its easy installation, economic benefits and excessive availability especially in Pakistan [8]. Despite of many advantages from DG, optimum configuration of DG in distribution network plays a very crucial as improper placement may cause the system respond more destructively than the conventional system.

DG has become one of the most researched area in power system due to its less environmental effects along with improved power loss and voltage quality. Different authors have worked over proper allocation of DG in the distribution system in order to improve power loss and voltage drop for better performance of the system. Author in [9] formulated an equation to build relation between voltage variation and DG capacity available with the help of analytical approach. Effects of DG over system power loss, voltage drop, and short circuit level is examined by [10] and simulation was carried out on a real time HESCO feeder using PSS SINCAL software. Artificial intelligence technique is deployed by [11] to improve power loss and analyze fast convergence and is tested on IEEE standard 33 bus system. An intelligent decision-making technique is developed by [12] for optimum allocation and sizing of DG using MATLAB additionally another platform is utilized for load analysis of IEEE standard 33 bus system. An 11 KV radial feeder is tested for solar PV integration as a DG in distribution system by [13] using strategic allocation of DG to analyze the extent of power loss reduction using PSS SINCAL software.

Literature suggests that the load is affected by different parameters such as changing weather, elevating fuel prices etc. Technology advancement is elevating day by day. Vehicles are also switching towards electric fueling due to higher fossil fuel cost and lack of availability. This uncertain load variation has caused the distribution system to identify new robust intelligent techniques to cope up with the situation [14]. Although, many researchers have worked on DG and explained its benefits, but the impact of DG varies with varying location and size of DG in the network. Hence this work presents optimum location and size of DG in a real time HESCO radial distribution feeder. Power loss being the objective function for this study avoiding the violation of system constraints.

Further paper is structured as section II gives a brief description about selected model including its modeling and prescribed data set. Section III presents the problem highlight for this study with obtained method structure. Section IV provides methodology used for achieving prescribed goals. Section V delivers the simulation results achieved in this study. And section VI concludes the work with research outcomes and future prospect.

II. DATA ANALYSIS AND NETWORK MODELLING

The model under consideration is a real time radial distribution feeder of one of the Pakistan's distribution company i.e. Hyderabad Electric Supply Company (HESCO), Sindh. The network has a total load of 4,214 kW consisting of 51 busses. Feeder has standard voltage level of 11kV. The feeder is named as Sarfaraz Feeder and it lies at a Latitude of 25.40, Longitude of 68.37 and 38 M above sea level.

A. *Network Load Profile*

The data for load bus is collected by physical visit and has been simulated using MATLAB R2015a version. The active load has been illustrated below in figure (1).

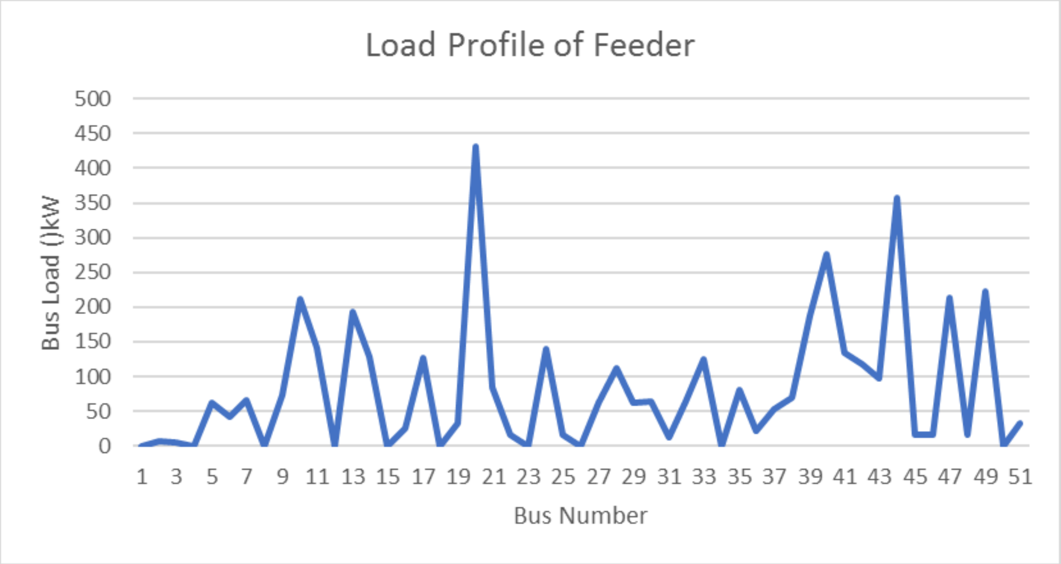


Figure 1: Load Data of HESCO Radial Feeder

B. *Solar Radiation Potential*

Pakistan is one of the countries with high solar irradiance throughout the year [15]. Sindh and Balochistan have highest solar irradiance availability in Pakistan and considered in best availability in the world as well [16-18]. Solar irradiance data is simulated for selected feeder using PVsyst V6.70 software. PVsyst is a software tool that is used for solar modeling and designing. The data is collected on the monthly basis to analyze the availability of solar energy generation for the reliability and continuity of system supply. Following table (1) can clearly illustrate the Global Horizontal Irradiance on monthly basis for the feeder location.

TABLE 1: MONTHLY SOLAR IRRADIANCE

Month	**Global Irradiance W/m²**	**Temperature**
January	180.6	20.6
February	211.8	23.2
March	251.2	28.2
April	280	32.1
May	294.9	35
June	285.8	33.8
July	253.4	32.2
August	255.8	30.9
September	245.6	29.4
October	225.1	30.8
November	186.7	26.7
December	168.4	21

III. PROBLEM STATEMENT

Overall aim of this paper is to reduce active power loss component in the real time radial power distribution network. Voltage limit is set as the constraint for the system that needs to be satisfied for the quality and security purpose.

Mathematical expression for objective function is described as:

$$min\ f = min(T_{active\ (loss)}) \quad \text{i}$$

Where, $T_{active\ (loss)}$ *is active power loss*

Active and reactive power injected by the system can be expressed as:

$$P_{DG,M} = P_{loss} + \sum P_{D,M} \quad \text{ii}$$

$$Q_{DG,M} = Q_{loss} + \sum Q_{D,M} \quad \text{iii}$$

Where

$P_{DG,M}$ and QDG,M

are active and reactive power inject by DG at bus 'M'

Whereas

$\sum P_{D,M}$ and

$\sum Q_{D,M}$ are total active and reactive power at bus 'M'

A. *Position of DG in the system:*

As Bus-1 is assumed as slack bus so it cannot be considered for DG therefore the upper and lower bound for DG is as follows

Voltage on load bus

$$V_M^{min} \le V_M \le V_M^{mac}$$

B. *Load Flow Analysis*

Variety of load flow methods have been used by different authors in different type of application ranging from industrial automation, bio-medical industries to the power electronic applications and many others [19].

Traditional techniques were previously utilized in electrical power transmission system, but distribution system is not being broadly exploited for load analysis. Distribution system possess high R/X ration and radial network topology [20]. In this research work, ‘Backward-Forward sweep method’, is utilized for load analysis of a real time electrical power distribution system. This method is based on a bidirectional process i.e. forward and backward. Let’s consider a two-bus system starting at bus K and ending at bus M as illustrated in figure (2).

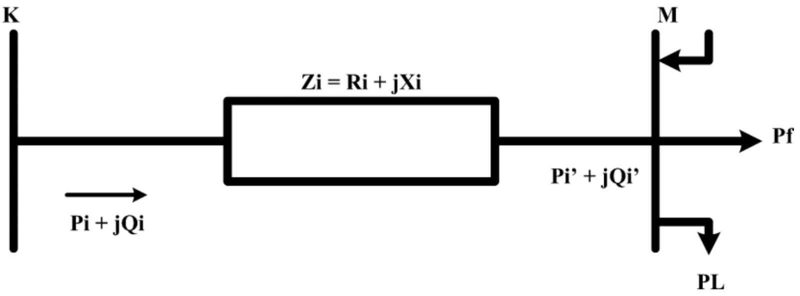


Figure 2: Two bus representation of radial distribution system

Following recursive equations are used to calculate power flow studies of radial distribution system.

$$P_i = P_L + P_f - P_{in} + R_i * \frac{(P_i'^2 + Q_i'^2)}{|V_i^2|} \tag{iv}$$

$$Q_i = Q_L + Q_f - Q_{in} + X_i * \frac{(P_i'^2 + Q_i'^2)}{|V_i^2|} \tag{v}$$

$$V_m = V_k - I_i(R_i + jX_i) \tag{vi}$$

$$V_m = V_k - \left\{P_i - j\left(Q_i + \frac{V_k^2 y_i}{2}\right)\right\} * \frac{R_i + jX_i}{V_k} \tag{vii}$$

Now, the power loss equations can be expressed as follows:

$$P_{i\,loss} = R_i * \frac{(P_i'^2 + Q_i'^2)}{|V_i^2|} \tag{viii}$$

$$Q_{i\,loss} = X_i * \frac{(P_i'^2 + Q_i'^2)}{|V_i^2|} \tag{ix}$$

Where,

$P_{i\,loss}$ *is active power loss of branches*

$Q_{i\,loss}$ *is reactive power loss of branches*

Hence, the total power loss of all branches can be calculated by the total sum of all branches’ active and reactive power losses as given in below equation:

$$T_{loss} = \sum_1^{i=n-1} P_{i\,loss} + j \sum_1^{i=n-1} Q_{i\,loss} \tag{x}$$

IV. METHODOLOGY

A. Algorithm

PSO is an evolutionary optimization algorithm initiated by Dr. Eberhart and Dr. Kennedy in 1995[21, 22]. This algorithm is an was inspired by the flocking of bird in search of food. The technique is being widely used in various fields of science and engineering due to its efficient problem solving ability[23]. The stochastics evolutionary algorithm consists group of ‘n’ number of particles and fitness function’s possible solution is represented by each particle’s position in ‘D’ dimensional space. Particle’s velocity and position can be update with the help of following equations and the process continues till the criteria for stopping is met.

$$V_{id}^{k+1} = \omega * V_{id}^{k} + c_1 * r_1^k \left(pbest_{id} - x_{id}^k\right) + c_2 * r_2^k \left(gbest_{id} - x_{id}^k\right) \tag{xi}$$

$$x_{id}^{k+1} = x_{id}^{k} + v_{id}^{k+1} \qquad \text{xii}$$

Where

V_{id}^{k+1} *is velocity of particle i at k iteration*

x_{id}^{k} *position of particle i at k iteration*

n is number of particles

m is number of particl e′members

d is dimetional space

k is kth iteration k is kth iteration

c1 and c2 are acceleration constants

ω *is intertial weight factor*

r is uniform random values in range f 0 *and* 1

Moreover, proper selection of inertial weight assigned to previously grasped position of particle maintains a perfect balance amongst local and global search and it can be described with the help of following equation.

$$\omega = \omega_{max} - \frac{\omega_{max} - \omega_{min}}{k_{max}} * k \qquad \text{xiii}$$

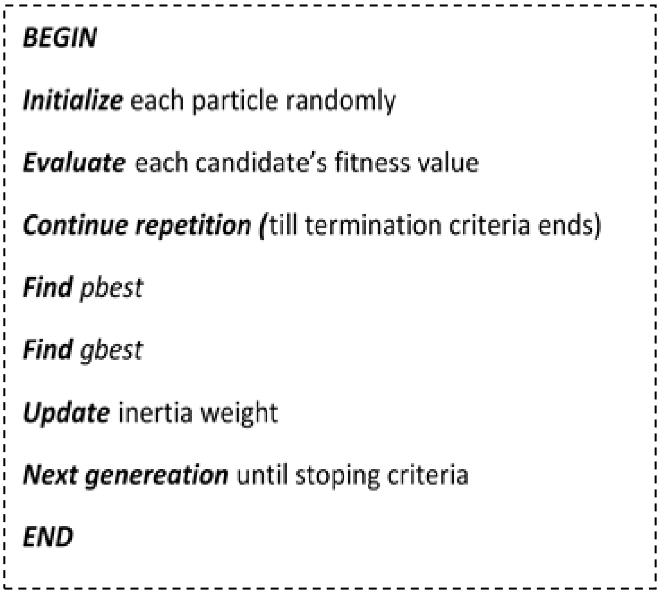
Where

ω_{min} *is minimum number of intertia weight*

ω_{max} *is maximum number of intertia weight*

B. *Implementation of PSO*

The optimum size and location for DG is identified using PSO. Figure (3) describes the basic structure of the optimization technique.



```
BEGIN
Initialize each particle randomly
Evaluate each candidate's fitness value
Continue repetition (till termination criteria ends)
Find pbest
Find gbest
Update inertia weight
Next genereation until stoping criteria
END
```

Figure 3: General Pseudocode of PSO

Moreover, the optimized DG siting and sizing in radial distribution network involves multiple steps that are requisite. Figure (4) illustrates the flow chart of PSO implementation in order to obtain optimized results of the system.

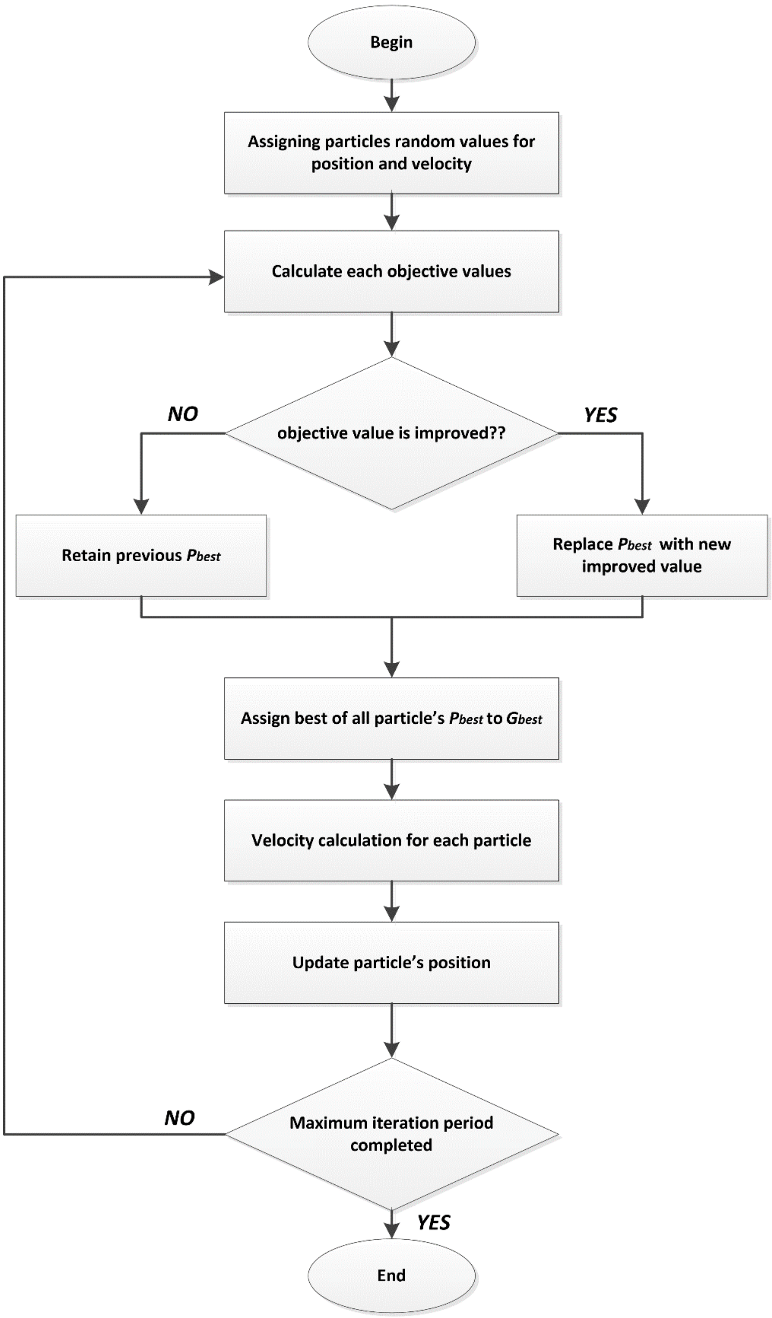


Figure 4: Flow chart of Particle Swarm Optimization

V. SIMULATION RESULTS

This study is attained for a real time 11kV radial electrical power distribution system named as Sarfaraz Baba figure (5) to observe the power loss reduction using optimized sizing and allocation of DG. Feeder consists of 51 buses with a total load of 4214 kW. Simulation is done on a personal computer with core m3 processor, 8GB RAM and Microsoft windows 10 updated.

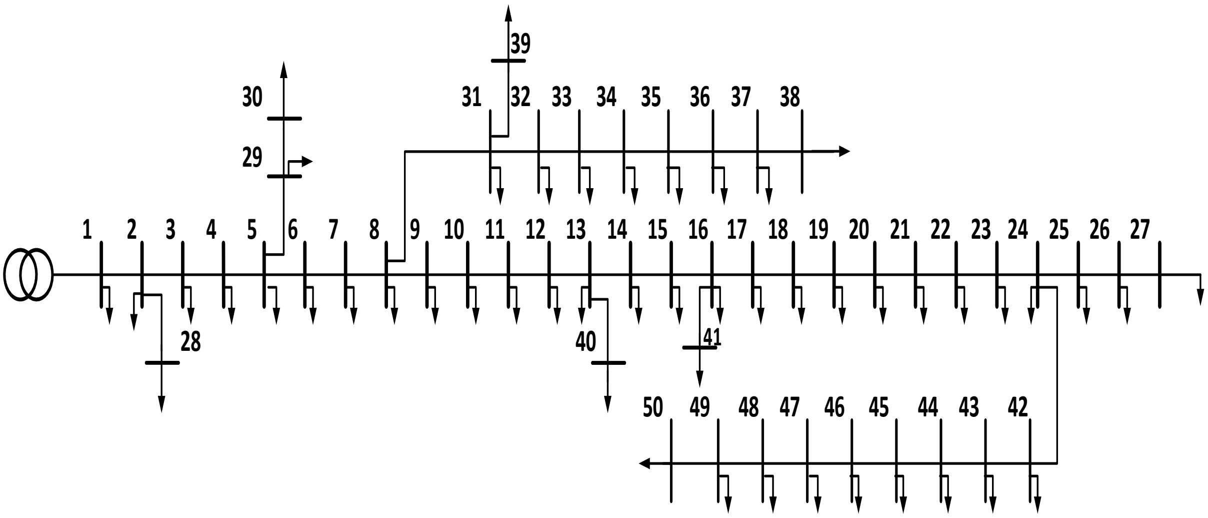


Figure 5: One-line diagram of 11kV Sarfaraz Baba Feeder

The object function for this research work is active power loss and Solar PV is considered as a DG source to be installed in order to compensate the loss occurring in distribution network. Upper and lower bound of voltage for optimization are set as 1.05 and 0.95 respectively. Bus-1 in the network is assumed as slack bus. Slack bus voltage is selected as 1.02 V and MVA is standard as 11kV.

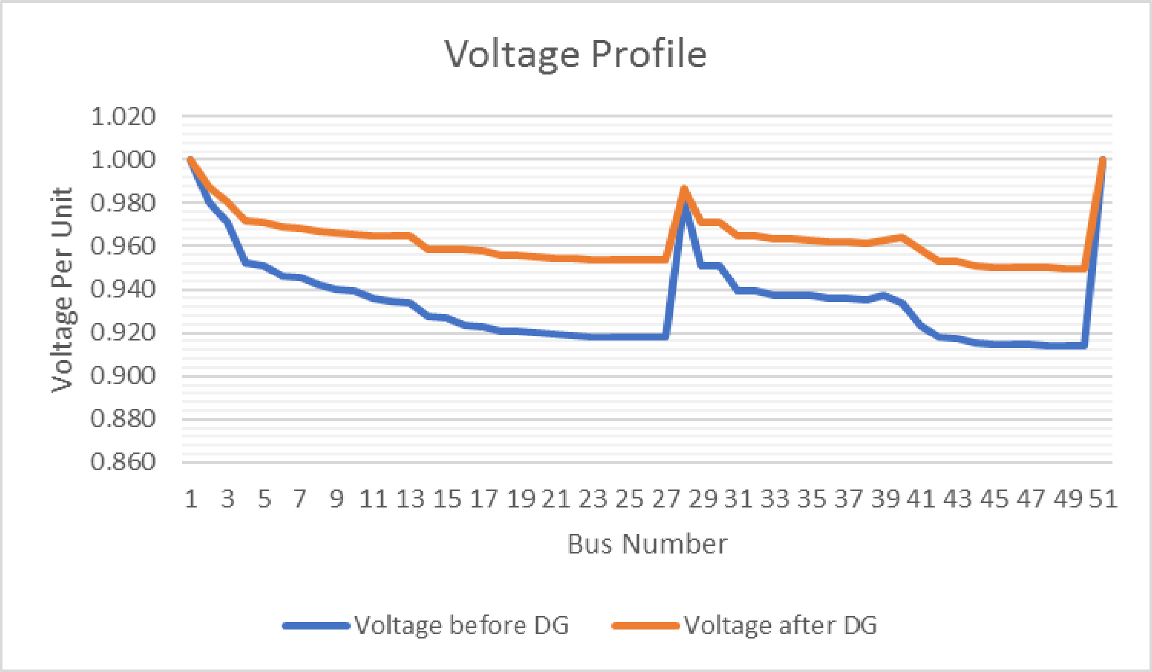


Figure 6: Voltage profile of 11kV Sarfaraz Baba Feeder

Figure (6) illustrates the voltage profile of a real time 11 kV Sarfaraz feeder of Hyderabad Sindh, Pakistan. The graph clearly illustrates that the DG installation affects the network positively and the bus voltage is improved on almost every bus. Below is the table that clearly shows the comparison of bus voltage keeping in view the constraint limit.

TABLE 1: VOLTAGE COMPARISON OF 11 KV SARFARAZ FEEDER

Voltage (*p.u*)			
Base Case		After DG Integration	
Minimum	Maximum	Minimum	Maximum
0.914 @ Bus 47	1.00 @ Bus 1	0.950 @ Bus 47	1.00 @ Bus 1

Minimum system voltage before installation of DG is found to be 0.914 p.u. whereas DG installation has improved this voltage to 0.950, keeping the minimum acceptable voltage satisfied. Table (2) clearly states the satisfactory improvement in the voltage level on each bus after DG installation to the system.

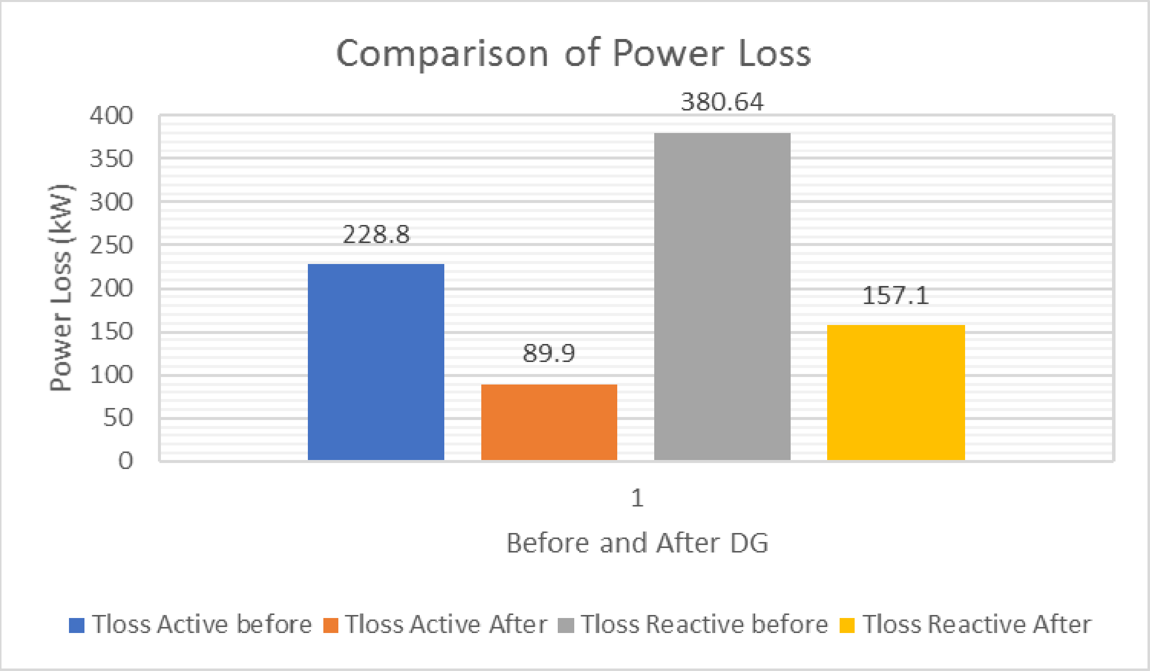


Figure 7: Comparative analysis of Power loss

Figure (7) shows a comparative analysis of total power loss i.e. both active and reactive, of the system. Illustrated data is a comparison of conventional system's power loss and the power loss after DG integration. The comparison clearly shows a good amount power loss reduction after optimum sizing and sitting of DG in the network.

TABLE 2:COMPARATIVE STUD OF POWER LOSS

Before DG		After DG		Loss reduction (%)	
Loss Active (KW)	Loss Reactive (KVar)	Loss Active (KW)	Loss Reactive (KVar)	Active	Reactive
228.8	380.64	89.9	157.1	60.7	58.7

The main object of this research work intends to reduce power loss in the HESCO feeder by DG integration with the help of artificial integration technique. Table (3) describes the extent of power loss reduction i.e. both active and reactive. The table illustrates comparative statistic of conventional system and optimized network. The DG considered here is solar PV for active power compensation. The optimal placement and size of DG integration is identified as 3.8441 at 16th bus. The active power loss of system was 228.8 kW and it reduced to 89.9 kW after installation showing 60.7% of loss reduction in the system. Similarly, the reactive power loss reduced from 380.64 kVAR to 157.1 kVAR with a 58.7% of loss reduction.

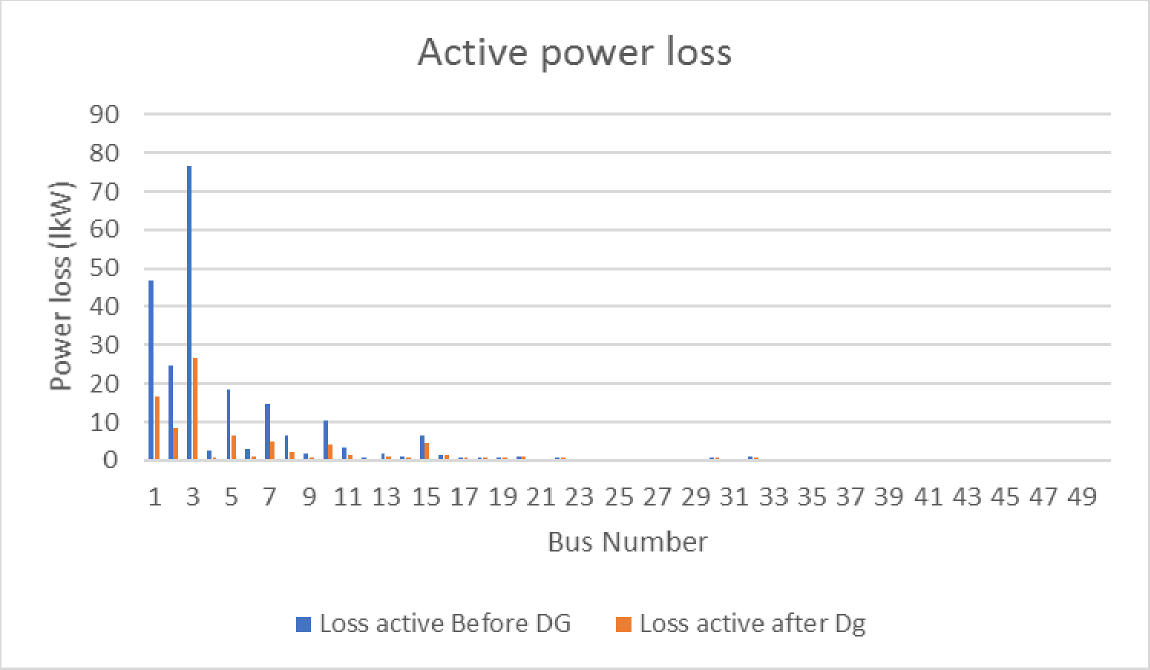


Figure 8: Active power loss at each bus

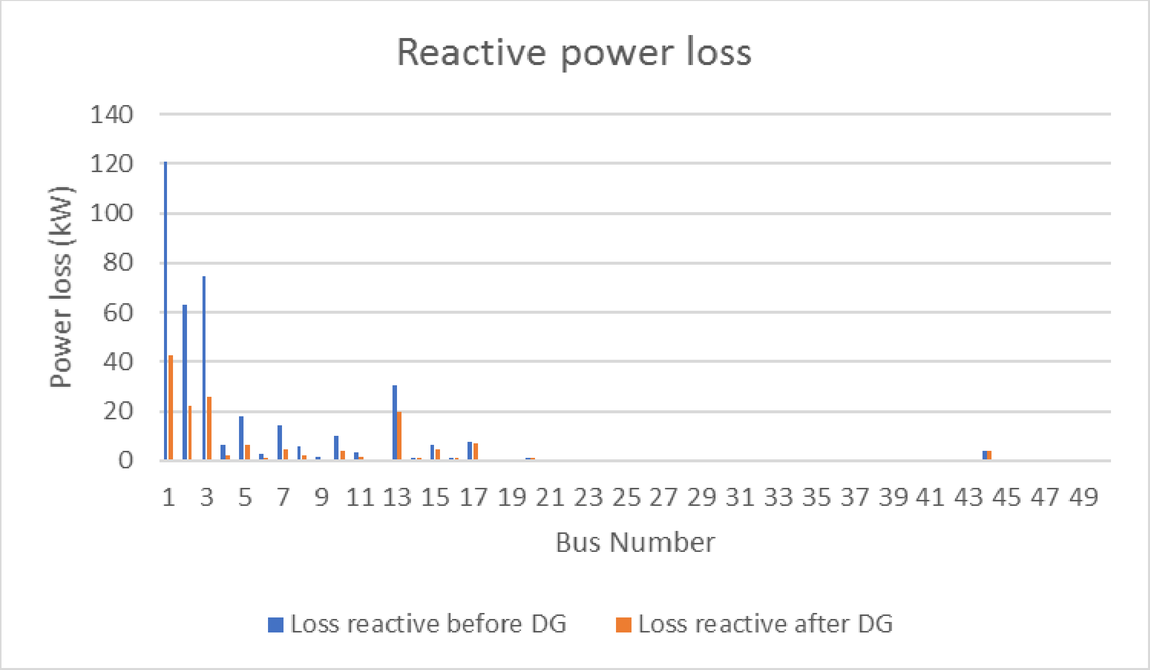


Figure 9: Reactive power loss at each bus

It can be clearly observed from Figure (8) and Figure (9) that the active and reactive power loss is maximum at bus number 1,2,3 and 5 and has experienced a significant power loss reduction by DG integration with optimal size and location.

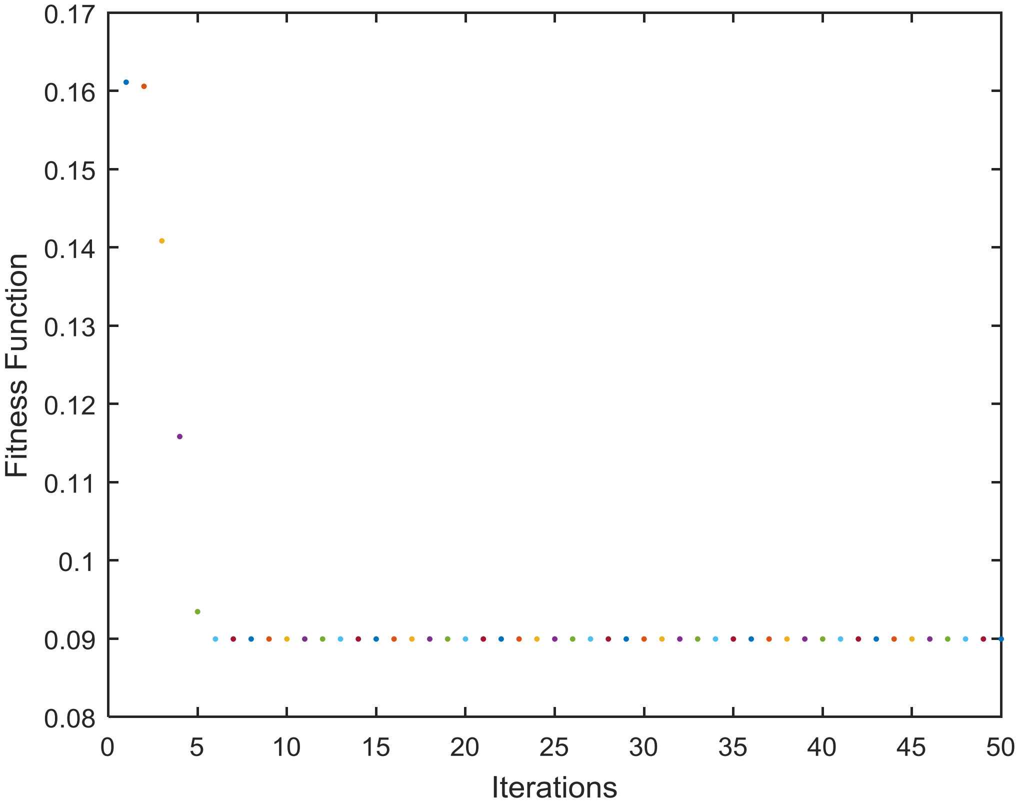


Figure 10: Convergence of PSO with 50 iterations

PSO is one of the most widely used stochastic algorithm in distribution system and its higher efficiency with fast convergence. Figure (10) represents the convergence curve for the 11 kV Sarfaraz Baba Feeder. Above simulation results suggests that PSO, in comparison with other AI technique has faster convergence i.e. converges within a few iterations.

VI. CONCLUSION

This paper presented a new technique to tackle power loss problem with real time networks in Pakistan. PSO is new artificial intelligence technique used to identify the optimum location and size of DG to be installed in the distribution network. The main theme of this work was to analyze the reduction in power loss and improvement in voltage profile of a 11 kV HESCO radial feeder. Results suggests that optimum size and location plays a vital role for power loss reduction as 60.7% of active and 58.7 % of reactive power loss is reduced with DG installation. Moreover, simulation results show that the proposed algorithm has fast convergence as compared to other techniques.

Moreover, simulation results show that the algorithm has fast convergence. Furthermore, results also validate effectiveness of the method for power loss and voltage profile improvement of the system.

VII. ACKNOWLEDGMENT

Authors are thankful to Mehran University of Engineering and Technology Jamshoro, Pakistan for untired efforts and non-ending support to accomplish this work

REFERENCES

[1] Angarita, O.F.B., et al. Power loss and voltage variation in distribution systems with optimal allocation of distributed generation. in 2015 IEEE PES Innovative Smart Grid Technologies Latin America (ISGT LATAM). 2015. IEEE.

[2] SAHITO, A., et al., Unbalanced Loading; An Overlooked Contributor to Power Losses in HESCO. Sindh University Research Journal-SURJ (Science Series), 2015. 47(4).

[3] Kumar, M., P. Nallagownden, and I. Elamvazuthi, Optimal placement and sizing of renewable distributed generations and capacitor banks into radial distribution systems Energies, 2017. 10(6): p. 811.

[4] Davda, A.T., et al., Dispersed generation enable loss reduction and voltage profile improvement in distribution network—Case study, Gujarat, India. IEEE Transactions on Power Systems, 2013. 29(3): p. 1242-1249.

[5] Sahito, A., et al., Voltage Profile Improvement of Radial Feeder through Distributed Generation. Sindh University Research Journal-SURJ (Science Series), 2016. 48(3).

[6] Rupa, J.M. and S. Ganesh, Power flow analysis for radial distribution system using backward/forward sweep method. International Journal of Electrical, Computer, Electronics and Communication Engineering, 2014. 8(10): p. 1540-1544.

[7] Ghanghro, S., et al., Network Reconfiguration for Power Loss Reduction in Distribution System. Sindh University Research Journal-SURJ (Science Series), 2016. 48(1).

[8] Adnan, S., et al., Solar energy potential in Pakistan. Journal of Renewable and Sustainable Energy, 2012. 4(3): p. 032701.

[9] Mahmud, M.A., M.J. Hossain, and H.R. Pota, Voltage variation on distribution networks with distributed generation: Worst case scenario. IEEE Systems Journal, 2013. 8(4): p. 1096-1103.

[10] Sahito, A.A., et al., Analyzing the impacts of distributed generation integration on distribution network: A corridor towards smart grid implementation in Pakistan. Wireless Personal Communications, 2015. 85(2): p. 545-563.

[11] Mahesh Kumar, P.N., Irraivan Elamvazuthi, Optimal Placement and Sizing of Renewable Distributed Generations and Capacitor Banks into Radial Distribution Systems. Energies, 2017.

[12] Vita, V., Development of a decision-making algorithm for the optimum size and placement of distributed generation units in distribution networks. Energies, 2017. 10(9): p. 1433.

[13] Mari, M.A., et al., Analyzing the Impacts of Solar PV Generation Integration on Radial Distribution Feeder International Journal of Computer Science and Information Security 2018. 16(1).

[14] SAHITO, A., et al., Distribution System Power Loss Reduction through Distributed Generation. Sindh University Research Journal-SURJ (Science Series), 2017. 49(1).

[15] Harijan, K., M.A. Uqaili, and U.K. Mirza, Assessment of solar PV power generation potential in Pakistan. Journal of Clean Energy Technologies, 2015. 3(1): p. 54-56.

[16] Irfan, M., et al., Solar Energy Development in Pakistan: Barriers and Policy Recommendations. Sustainability, 2019. 11(4): p. 1206.

[17] Muhammad, F., et al., Different solar potential co-ordinates of Pakistan. Innovative Energy & Research, 2017. 6(2).

[18] Kamran, M., Current status and future success of renewable energy in Pakistan. Renewable and Sustainable Energy Reviews, 2018. 82: p. 609-617.

[19] Mahmoud, K., N. Yorino, and A. Ahmed, Optimal distributed generation allocation in distribution systems for loss minimization. IEEE Transactions on Power Systems, 2015. 31(2): p. 960-969.

[20] Shahbaz Ahmed, M.K., Abdul Hakeem, Zubair Ahmed Memon, Anwar Ali Sahito, Aamir Mahmood Soomro, Analysis of a radial distribution network and mitigating losses by strategic allocation of Distributed Generation. International Journal of Computer Science and Network Security, 2019. 19(3): p. 157-161.

[21] Juneja, M. and S. Nagar. Particle swarm optimization algorithm and its parameters: A review. in 2016 International Conference on Control, Computing, Communication and Materials (ICCCCM). 2016. IEEE.

[22] Badar, A., B. Umre, and A. Junghare, Study of artificial intelligence optimization techniques applied to active power loss minimization. IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) e-ISSN, 2014: p. 2278-1676.23.

[23] Kumar Mahesh, P.N., Irraivan Elamvazuthi, Optimal Configuration of DG in Distribution System: An Overview, in MATEC Web of Conferences. 2016, EDP Sciences.

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