Optimal Allocation of Multi Renewable DG Integrated with Distribution Network Reconfiguration based on MOFF Approach

Chaitra A S[1]
Assistant Professor,
Department of Electrical and Electronics Engineering,
Sri Krishna Institute of Technology
Bengaluru, Karnataka, India

Dr. H. R. Sudarshana Reddy[2]
Professor
Department of Electrical and Electronics Engineering
Visvesvaraya Institute of Advanced Technology
Muddenahalli, Chikkaballapur

***Abstract*— A novel approach is anticipated in this paper for optimal allocation and sizing of multi renewable DG with reconfiguration based on Multi objective function approach using PSO technique. The objectives of reduction of active power loss, reactive power loss and voltage deviation, also considering reliability enhancement of the system. The proposed work is carried out using MATLAB. The result of the proposed method has been studied and validated on IEEE 33 bus radial distribution system. The proposed approach is considered with different cases which includes optimal DG planning with reconfiguration based on the multi-objective function.**

Keyword- Distributed generation, optimal planning, network reconfiguration, particle Swarm Optimization Technique(PSO)

1. INTRODUCTION

The distribution system is an important part of an electric power system. As stated in [1], the capital investment in the distribution system constitutes a significant portion of the total amount spent in the entire power system. Due to the recent market deregulation, this portion may become even larger. Furthermore, since the distribution systems operate at the low voltage levels, the losses are usually higher compared to those in other parts of the system. Thus, the distribution system rates high in economic importance, which makes careful planning and design most worthwhile. DG placement in distribution system network can diminish numerous problems to a great degree like reduction in power loss, improvement in voltage profile, drop in power demand, power supply to the consumer with improved quality, cost minimization at peak operation, enhanced safety and reliability, reduced greenhouse gas emission, grid strengthening and so on.

In [1] by using mixed integer nonlinear programming (MINLP) based optimization method, the optimal planning of DGs are found and sited in the 33 and 69-bus distribution system network to decrease the losses and improved the voltage profile. Teng et al. [3] and Díaz at el. [4] presented load flow analysis which is used in the presented work. Many researchers have stated that different optimizing techniques [5-11] are available for the determination of optimal planning of renewable DGs which can maintain the performance, operational, economical and reliability issues.

The Genetic Algorithm optimization technique is given in [5-7], while the particle swarm optimization technique is given in [8-10] are used for distribution system planning. In [11] it is discussed that what kind of commonly used technologies are available to harvest the energy by using DGs near to the consumption place and their different type of module size. Prakash et al. [12] presented a comparable study for the optimal placement of DG in IEEE 69-bus Radial Distribution System (RDS) between PSO and bat algorithm (BA). Sedighizdeh et al. [13] presented a work based on reconfiguration with the objective of loss and reliability indices minimization. In [14] depending on the injected power DGs are characterized as four types. Reddy at el. [17] proposed a work namely reconfiguration of IEEE 33 and 69bus RDS using PSO. The DG planning with reconfiguration is a complex target to achieve with a fitness function which is having multi objective function constitutes non-linear constraints. In the presented work, the PSO technique is used in order to evaluate the optimal planning of multi renewable distributed generator with reconfiguration In the used methodology, the radial property of the distribution system network is always maintained for load flow study (LFS). Newton-Raphson method is used for load flow study, which is more superior to basic load flow method for radial systems.

The proposed work is organized in different sections as follows: The Section-1 contains Introduction, Methodology is given in Section-2, In Section-3 Optimization Technique is explained, Section-4 is about Result and Discussion, and Section-5 is about Conclusion. The different cases of proposed work are as follows:

Cases-1: Base Case system
Cases-2: System with reconfiguration
Cases-3: System with single DG
Cases-4: System with multi DG
Cases-5: System with reconfiguration and single DG.
Cases-6: System with reconfiguration and multi DG

2. METHODOLOGY BASED ON MOFF

Multi Objective Based Fitness Function Formulation In this section advanced multi objective fitness function

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 10, October-2021

(MOFF) is introduced, which consists of distinct system performance and reliability assessment parameter. This novel fitness function based problem is utilized for the optimal planning of multi renewable DG with reconfiguration by using PSO technique for different cases.

MOFF = c_1*APLI + c_2*VolDI + c_3*RPLI + c_4*RLI

Where, c1, c2, c3, and c4, having the values 0.40, 0.20, 0.25 and 0.15 respectively are weight factors which define how much weight we have given to each variable system indices based on priority

APLI- Active Power Loss Index
VolDI- Voltage Deviation Index
RL- Reliability Index

basis [10]. APLI, VolDI, RPLI and RLI are active power loss index, voltage deviation index, reactive power loss index, and reliability index respectively.
In the fitness function we have given priorities to all the important factors that will make our distribution system more efficient and reliable. In the said work with the proposed methodology, active power loss (APL), reactive power loss (RPL) of the system is reduced as shown in table I while the voltage profile and reliability of the system has improved as presented in table-2.

Let us assume that an n-bus power system contains a total number of n_p P-Q buses while the number of P-V (generator) buses be n_g such that $n = n_p + n_g + 1$. Bus-1 is assumed to be the slack bus. The approach to Newton-Raphson load flow is similar to that of solving a system of nonlinear equations using the Newton-Raphson method: at each iteration we have to form a Jacobian matrix and solve for the corrections from an equation of the type given. For the load flow problem, this equation is of the form

$$J\begin{bmatrix}\Delta\delta_2\\ \vdots\\ \Delta\delta_n\\ \dfrac{\Delta|V_2|}{|V_2|}\\ \vdots\\ \dfrac{\Delta|V_{1+n_p}|}{|V_{1+n_p}|}\end{bmatrix}=\begin{bmatrix}\Delta P_2\\ \vdots\\ \Delta P_n\\ \Delta Q_2\\ \vdots\\ \Delta Q_{1+n_p}\end{bmatrix}$$

where the Jacobian matrix is divided into submatrices as

$$J=\begin{bmatrix}J_{11} & J_{12}\\ J_{21} & J_{22}\end{bmatrix}$$

It can be seen that the size of the Jacobian matrix is $(n + n_p - 1) ´ (n + n_p - 1)$.

J_{11}: $(n - 1) ´ (n - 1)$, J_{12}: $(n - 1) ´ n_p$, J_{21}: $n_p ´ (n - 1)$ and J_{22}: $n_p ´ n_p$

RPLI- Reactive Power Loss Index

The submatrices are:-

$$J_{11}=\begin{bmatrix}\dfrac{\partial P_2}{\partial\delta_2} & \cdots & \dfrac{\partial P_2}{\partial\delta_n}\\ \vdots & \ddots & \vdots\\ \dfrac{\partial P_n}{\partial\delta_2} & \cdots & \dfrac{\partial P_n}{\partial\delta_n}\end{bmatrix}$$

$$J_{12}=\begin{bmatrix}|V_2|\dfrac{\partial P_2}{\partial|V_2|} & \cdots & |V_{1+n_p}|\dfrac{\partial P_2}{\partial|V_{1+n_p}|}\\ \vdots & \ddots & \vdots\\ |V_2|\dfrac{\partial P_n}{\partial|V_2|} & \cdots & |V_{1+n_p}|\dfrac{\partial P_n}{\partial|V_{1+n_p}|}\end{bmatrix}$$

$$J_{21}=\begin{bmatrix}\dfrac{\partial Q_2}{\partial\delta_2} & \cdots & \dfrac{\partial Q_2}{\partial\delta_n}\\ \vdots & \ddots & \vdots\\ \dfrac{\partial Q_{1+n_p}}{\partial\delta_2} & \cdots & \dfrac{\partial Q_{1+n_p}}{\partial\delta_n}\end{bmatrix}$$

$$J_{22}=\begin{bmatrix}|V_2|\dfrac{\partial Q_2}{\partial|V_2|} & \cdots & |V_{1+n_p}|\dfrac{\partial Q_2}{\partial|V_{1+n_p}|}\\ \vdots & \ddots & \vdots\\ |V_2|\dfrac{\partial Q_{1+n_p}}{\partial|V_2|} & \cdots & |V_{1+n_p}|\dfrac{\partial Q_{1+n_p}}{\partial|V_{1+n_p}|}\end{bmatrix}$$

Step-1: Choose the initial values of the voltage magnitudes $|V|^{(0)}$ of all n_p load buses and $n - 1$ angles $d^{(0)}$ of the voltages of all the buses except the slack bus.

Step-2: Use the estimated $|V|^{(0)}$ and $\delta^{(0)}$ to calculate a total $n-1$ number of injected real power $P_{calc}^{(0)}$ and equal number of real power mismatch $\Delta P^{(0)}$.

Step-3: Use the estimated $|V|^{(0)}$ and $\delta^{(0)}$ to calculate a total n_p number of injected reactive power $Q_{calc}^{(0)}$ and equal number of reactive power mismatch $\Delta Q^{(0)}$.

Step-4: Use the estimated $|V|^{(0)}$ and $\delta^{(0)}$ to formulate the Jacobian matrix $J^{(0)}$.

Step-5: Solve for $\Delta\delta^{(0)}$ and $\Delta|V|^{(0)}\div|V|^{(0)}$.

Step-6: Obtain the updates from

$$\delta^{(1)}=\delta^{(0)}+\Delta\delta^{(0)}$$

$$|V|^{(1)}=|V|^{(0)}\left[1+\frac{\Delta|V|^{(0)}}{|V|^{(0)}}\right]$$

Step-7: Check if all the mismatches are below a small number. Terminate the process if yes. Otherwise go back to step-1 to start the next iteration with the updates given.

3. OPTIMIZATION TECHNIQUE

The first ever PSO technique was stated by Kennedy and Eberhart in 1995 [9]. PSO is a population based optimization technique [8, 9]. In PSO, in its search area every swarm follows a stated inertia and velocity by associated iterations. Based on the swarm last local best understanding and the past best understanding in its neighborhood the speed and way of the velocity are in tune. The characteristics of the swarm are to fly towards a promising area in the search area. PSO counts each individuals movement in the complete search area with a specific stated velocity which is updated according to its localmovement understanding and its colleagues movement understanding [8–10]. In Fig. 1 the PSO technique algorithm flowchart has shown. In PSO the population of particles are initializes randomly and the corresponding updates in the particles position is totally based upon the local best and neighbor best experience [10].

At every iteration updated new values of the velocity are the deciding factor for updated new value of the population. Swarm updated population is the sum of population of previous iteration and the velocity of current iteration in the next iteration.

Suppose total population is P and respective velocity is v. The velocity and population for i^{th} iteration is v (i+1) and X (i+1) respectively, similarly v and X are the velocity and population for previous iteration. These two equations are given in order to update the values of velocity and population for i^{th}iteration are given as [6,8].

$$\mathbf{V(i+1)=w(i)*v(i)+\ c_1*rand*(X_{localbest}-X)+\ c_2*rand*((X_{gbest}-X))}$$

$$\mathbf{X(i+1)= X(i) + v(i+1)}$$

Where P (i=1, 2, 3….P) is number of population; $X_{local\ best}$ and $X_{gbest}$are the local and global best populations respectively.

v = Velocity, X= Swarm population for PSO

i = i^{th} iteration, w = inertia, rand = random number between 0 and 1 respectively and c1, c2 are the constriction factor these are positive constant numbers [6-8].

The flowchart to determine optimal planning with reconfiguration in IEEE 33-bus RDS is presented in Fig. 1. Five switches (TS1, TS2, TS3, TS4, TS5,) three DG locations (Loc1, Loc2, Loc3) and sizing of DGs areconsidered in the flowchart; these are converted and represented as swarm or (particle).

4. RESULTS AND DISCUSSION

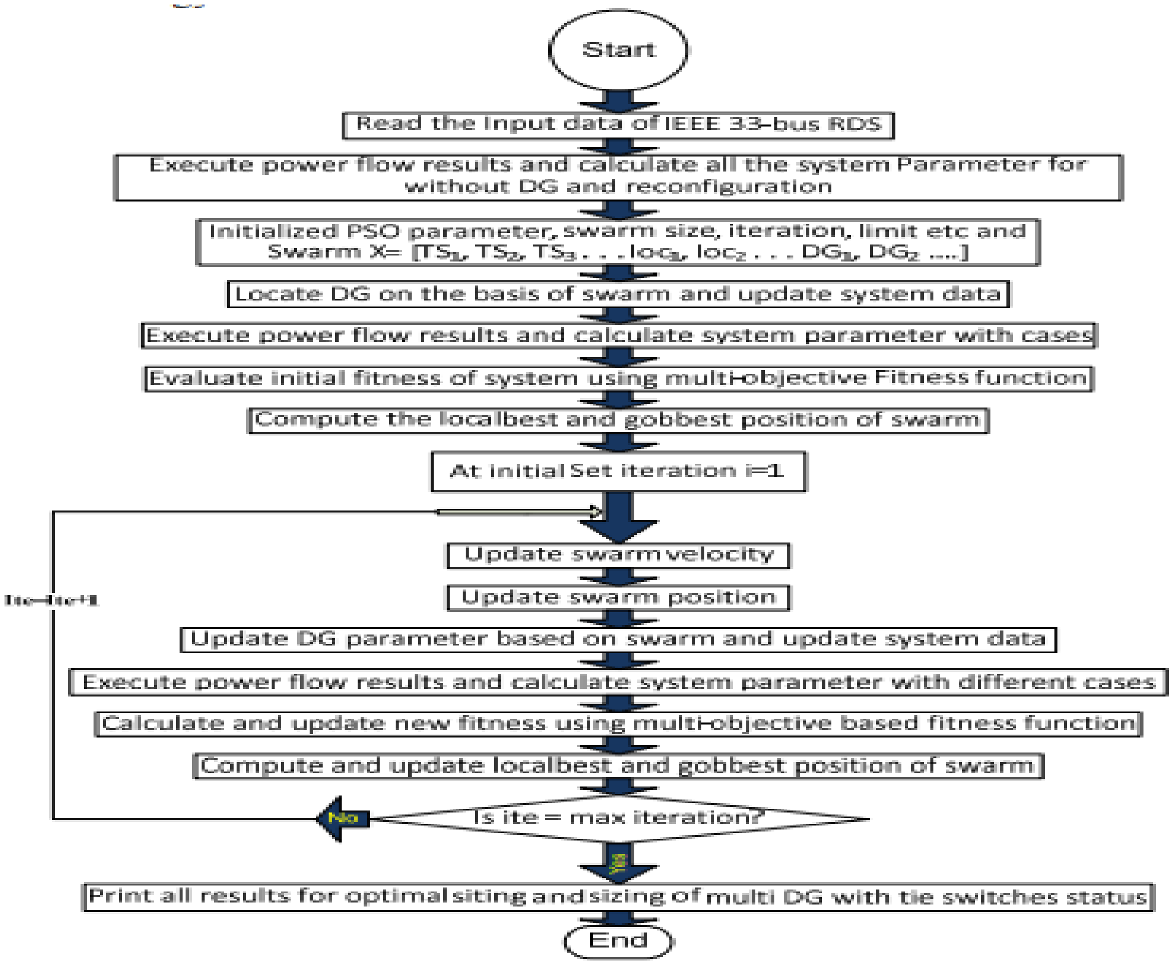

Fig-1: Flowchart for optimal planning of DG with Reconfiguration using PSO.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 10, October-2021

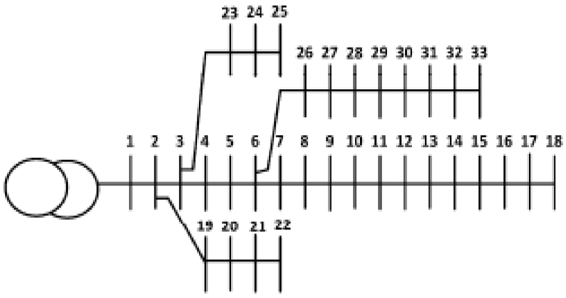

Fig-2: Standard IEEE 33 Bus RDS

In case-1, base case is considered without reconfiguration and DG, and obtained results are active power loss (APL) as 0.2027 p.u., reactive power loss (RPL) as 0.1351 p.u. and maximum voltage deviation (VolD) of the system as 0.0869p.u. with respect to reference voltage. While in case-2, the standard IEEE 33 bus RDS with only reconfiguration is considered by maintaining the radiality of the system, the observed results are APL as 0.102006672 p.u., RPL as 0.065954684 p.u. and maximum VolD of system as 0.040345 p.u. respectively with respect to base case as shown in table-1 & 2. In the same fashion when we have implemented single DG by using PSO technique in Case-3, APL, RPL, and VolD is reduced by 48.69 %, 44.60 % and 44.48% respectively as shown in below three table with respect to Case-1. In Case-4 we have considered multi DG by using PSO technique where we got APL reduction 59.71 %, RPL reduction 58.62%, VolD decrease by 69.96%, and hence the reliability is increased to 96.39% as shown in table-2.

TABLE-1: LOSSES OF THE 33 BUS FOR ALL CASES

CASES	P loss	Q loss	S loss
Case-1	0.2027	0.1351	0.2435
Case-2	0.102006672	0.065954	0.12147
Case-3	0.103985761	0.074844	0.1277
Case-4	0.08165251	0.05589624	0.09896
Case-5	0.0575685	0.0419187	0.07126
Case-6	0.043364024	0.031123	0.05339

TABLE-2: FITNESS FUNCTION OF IEEE 33 BUS RDS FOR ALL CASES

CASES	APLI	VolDI	RPLI	RL in %	FITNESS FUNCTION
Case-1	1	0.0869	1	95.92	0.81738
Case-2	0.5032	0.04035	0.48844	96.25	0.469239
Case-3	0.51306	0.04841	0.55382	96.18	0.469239
Case-4	0.40287	0.03131	0.41364	96.39	0.408789
Case-5	0.28404	0.02281	0.31018	96.6	0.328123
Case-6	0.21395	0.01539	0.23030	96.65	0.277607

Thereafter, we have implemented reconfiguration with DGs placement then better reduction in all indices has noticed, therefore two more cases namely Case-5 & 6 are considered. In Case-5 reconfiguration with single DG by using PSO technique is implemented then the APL reduced by 71.59 %, RPL reduced by 68.97%, and VolD also decrease by 73.36% when it is compared with Case-1. Multi DG with reconfiguration by using PSO technique has implemented in case-6 and considerable reduction is observed in the multi objective function where APL reduced by 78.60 %, RPL reduced by 76.96 %, and VolD decrease by 82.28% hence thereliability is increased upto 96.65 % as given in table-2.

Case-1-Blue Graph
Case-2- Red Graph
Case-3,4- Yellow Graph
Case-5,6- Purple Graph

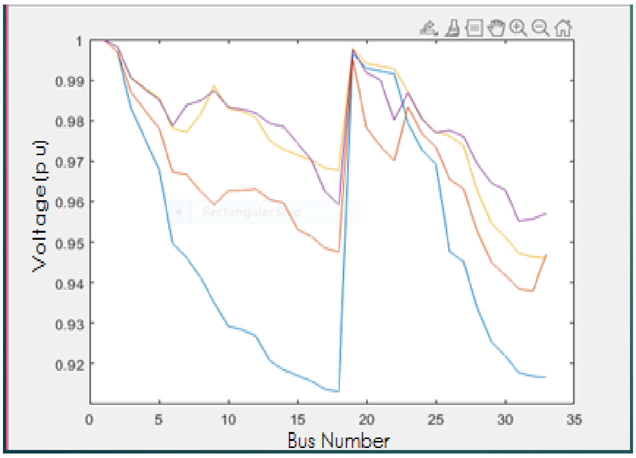

Fig-3:- Improved Volatge profile of 33 Bus RDS for 1,2,3,5 cases.

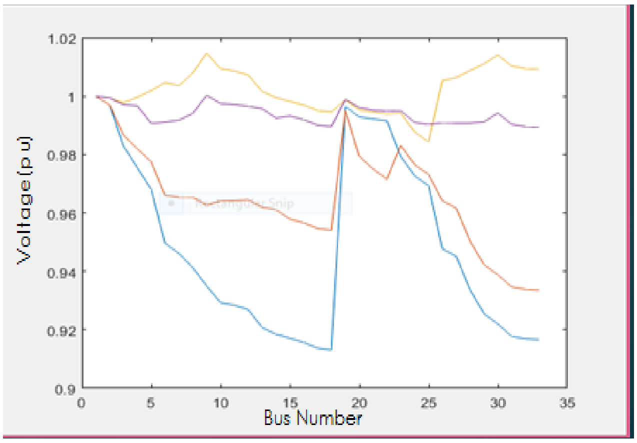

Fig-4:- Improved Voltage Profile for 33 Bus with 1,2,4,6 cases.

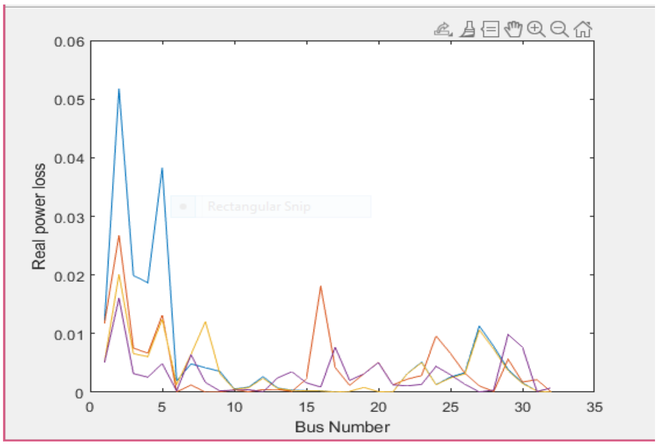

Fig-5:- IEEE 33 Bus RDS Active Power Loss with 1,2,3,5 cases.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 10, October-2021

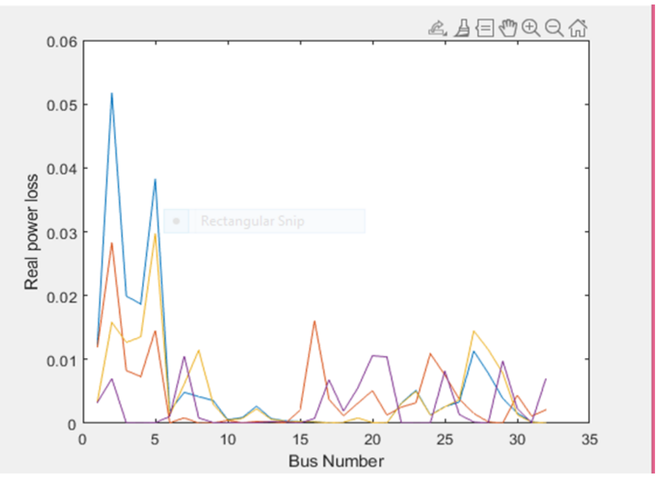

Fig-6:- IEEE 33 Bus RDS Active Power Loss with 1,2,4,6 cases.

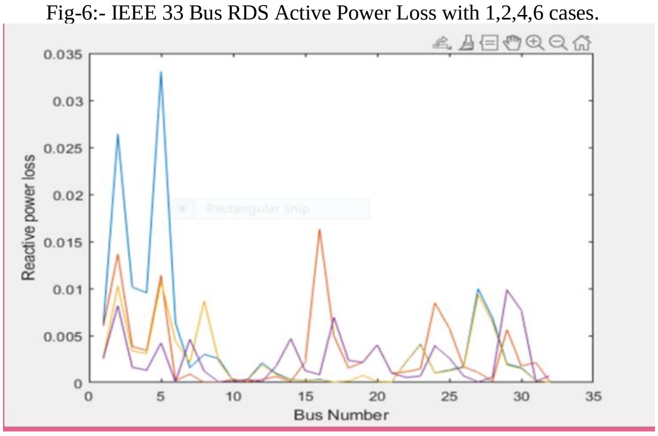

Fig-7:- System Reactive Power Loss for 1,2,3,5 cases.

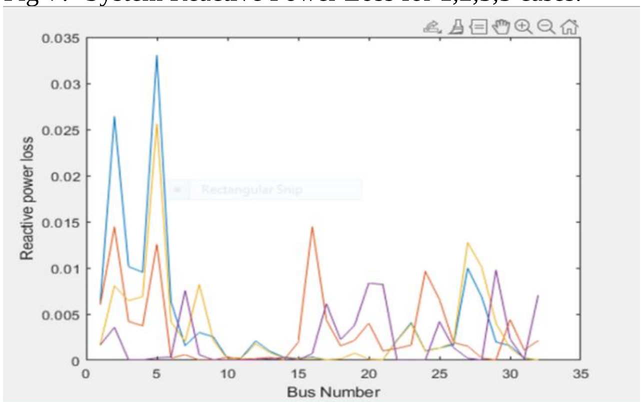

Fig-8:- System Reactive Power Loss for 1,2,4,6 cases.

After analyzing the obtained result it can be concluded that the Optimal planning of multi Renewable Distributed Generator with Reconfiguration using PSO Technique is an effective approach to minimize the multi objective based fitness function.
Through this proposed work we achieved our target with 78.60 % APL reduction and improved reliability of 96.65 % along with better-quality voltage profile as shown in table-1 & 2 and all graphs.

TABLE-3: COMPARATIVE ANALYSIS OF 33 BUS RDS EXISTING WORK WITH PROPOSED WORK

Existing/Proposed Work	Optimization Technique	Power Loss (kW)	Voltage Deviation
Alam *et al.* [1]	MINLP	72.95	----
Prakash *et al.* [14]	PSO	74.09	----
Reddy *et al.* [17]	PSO	148.30	0.1605
Proposed Work	PSO	43.36	0.0869

In the comparison table, literature [1] and [14] presented optimal DG placement using MINLP Technique and PSO Technique of the IEEE 33-bus RDS respectively, whereas in [17] reconfiguration using PSO for the same has been carried.

For the said cases in table-3 the reduced active power losses are 72.95 kW, 74.09 KW and 148.30 kW but in the proposed work of this paper the active power loss is reduced to 43.36 kW also the voltage profile is improved with reference to the base case as given in table I.

5. CONCLUSION

The optimal planning of DG with reconfiguration based on a multi-objective fitness function, which includes several system parameters using PSO is evaluated on IEEE 33-bus RDS. Finally, network reconfiguration with multi DG is implemented using PSO technique with MOFF. In the observed outcomes, APL, RPL, & VolD are decreased by 78.60 %, 76.96 %, and 82.28% as shown in table-1. Correspondingly the overall reliability is enhanced upto 96.65% along with improved voltage profile as illustrated in result analysis with respect to the first case i.e., with the base case. The outcomes are analyzed for different cases and also compared the results of finally implemented case i.e., reconfiguration with multi DG (Case-6) with the existing work as illustrated in table-3. It is concluded that the presented approach is effective for the decrease in apparent power. Therefore, the power losses (active & reactive) and the voltage deviation reduce significantly. Moreover, the system reliability and voltage profile of the system is enhanced.

6. REFERENCES

[1] Alam, Afroz, Abhishek Gupta, ParthBindal, Aiman Siddiqui, Mohammad Zaid. "Power loss minimization in a radial distribution system with distributed generation." IEEE International Conference on Power, Energy, Control and Transmission Systems (ICPECTS).,pp 2125, 2018.
[2] Ackermann, Thomas, GöranAndersson, and LennartSöder. "Distributed generation: a definition."Electric power systems research, vol. no. 57(3), pp. 195-204, 2001.
[3] Teng, Jen-Hao. "A direct approach for distribution system load flow solutions." IEEE Transactions on Power delivery, vol no. 18(3), pp. 882887, 2003.
[4] Díaz, Guzmán, Javier Gómez-Aleixandre, and José Coto. "Direct backward/forward sweep algorithm for solving load power flows in AC droop-regulated microgrids." IEEE Transactions on Smart Grid, vol. no. 7(5), pp. 2208-2217, 2015.
[5] Holland, John H. "Adaptation in natural and artificial systems." The University of Michigan Press, pp. 275, 1975.
[6] Goldberg, D. E. "Genetic Algorithms in Search. Optimization and Machine Learning.Addism1—Wesley." Reading, MA, 1989.
[7] Haupt, Randy L., and Sue Ellen Haupt. "Practical genetic algorithms."A John wiley& sons, Inc., Publication, 2004.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 10, October-2021

[8] Kennedy, J., and R. Eberhart. "Particle swarm optimization (PSO)." Proc. IEEE International Conference on Neural Networks, Perth, Australia.pp.1-6, 1995.

[9] Eberhart, Russell, and James Kennedy. "A new optimizer using particle swarm theory." MHS'95.Proceedings of the Sixth IEEE International Symposium on Micro Machine and Human Science, pp. 1-6, 1995.

[10] Bohre, Aashish Kumar, Ganga Agnihotri, and ManishaDubey. "Optimal sizing and sitting of DG with load models using soft computing techniques in practical distribution system." IET generation, transmission & distribution, vol. no. 10 (11), pp. 2606-2621, 2016.

[11] Dulau, Lucian Ioan, Mihail Abrudean, and DorinBică. "Distributed generation technologies and optimization."Procedia Technology, vol. no. 12, pp. 687-692, 2014.

[12] Prakash, Ram, and B. C. Sujatha. "Optimal placement and sizing of DG for power loss minimization and VSI improvement using bat algorithm." IEEE National Power Systems Conference (NPSC)., pp. 1-6,2016

[13] Sedighizadeh, M., M. Esmaili, and M. M. Mahmoodi. "Reconfiguration of distribution systems to improve reliability and reduce power losses using Imperialist Competitive Algorithm."Iranian Journal of Electrical and Electronic Engineering, vol. no. 13(3), pp. 287-302, 2017).

[14] Prakash, D. B., and C. Lakshminarayana. "Multiple DG placements in distribution system for power loss reduction using PSO Algorithm. "Procedia Technology, vol. no. 25 (2016), pp. 785-792, 2016.

[15] Zimmerman, R.D., Murillo-Sanchez, C.E.: 'Matpower4.1', December 2011. Available at: http://www.pserc.cornell.edu//matpower/

[16] Swarnkar, Anil, Nikhil Gupta, and K. R. Niazi. "A novel codification for meta-heuristic techniques used in distribution network reconfiguration." Electric Power Systems Research, vol. no. 81(7) , pp. 1619-1626, 2011.

[17] Reddy, A V Sudhakara, and M. Damodar Reddy. "Optimization of network reconfiguration by using particle swarm optimization."IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES), pp.1-6, 2016.

[18] Mohammd Bakhshipour, Esmaeil rokrok, "Optimal DG and capacitor allocation along with network reconfiguration using swarm robotics search and rescue algorithm" IEEE 5th Conference on knowledge based engineering and innovation, Iran university of science and technology, Tehran, Iran, 2019

[19] Mina G Naguib, Walid A omran, Optimal Reconfiguration and DG allocation in active distribution network using a probabilistic Approach" IEEE conference, 2017

[20] Alireza Lorestani and Mostafa Mohammadian. "A Novel Analytical –Heuristic Approach for Placement of Multiple Distributed Generator in Distribution Network", Smart grid conference, graduate university of Advanced technology, Kerman, Iran, pp 20-21, Dec 2016