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Effect of Inertia Weight of PSO on Optimal Placement of DG

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Abstract- Integrating Distributed Generation (DG) at appropriate location in distribution system can reduce its real power losses and can also increase the voltage regulation. Optimal allocation of DG has two parts, i) location identification of DG, ii) capacity determination of DG. This article uses loss sensitivity methods for fixing of optimal place of DG and then Particle Swarm Optimization (PSO) technique is implemented for determination of optimal size of DG at that location. During optimization, effect of inertia weight of PSO on the optimal placement of DG is demonstrated in this paper. For detailed study, IEEE 33-bus system is considered and impact of integration DG in the system is also shown.

Index terms- Radial Distribution Network (RDN), Distributed Generation, Particle Swarm Optimization (PSO), Inertia weight, IEEE 33-bus

1. Introduction

Distributed DG can be defined in different ways. In general DG is the electricity generation nearer to the load centres and also connected to the distribution system. DG's are going to play a vital role in realization of smart grid and sustainable energy. Different types of DGs are solar power plant, wind power plant, CHP etc. Use of renewable energy resources as DG has changed the trend of electricity market. Due to several advantaged of renewable DGs, these are becoming more popular day by day. There are numerous advantages of integration of DG in distribution system like flexibility, eco-friendly, improved voltage regulation and reliability and power quality [1]. DGs are often taken as backup for the system or to reduce the usage of grid electricity. DGs can also operate in peak shaving mode.

Integration of DG changes the power flow pattern in distribution system. When DG is not connected the flow of power is usually unidirectional but after the DG is connected the power flow can becomes bidirectional depending on generation and load. Thus bidirectional power flow due to addition of DG creates problems in grid control and protection system. This control of bidirectional flow of power is a major challenge in the interconnection of DG and has to be handled very carefully. Penetration level of DG is also an area of concern during the interconnection. Interconnection of DG in any power system has different impacts on the power system. Impacts of integration of DG can be categorised into Technical Impacts, Economical Impacts and Operational Impacts [2]. In general any DG should be installed on the location of shortage of power or having poor voltage profile. In long radial lines there is a problem of low voltage near end user. If suitable capacity of DG is placed at appropriate place in the system, then voltage profile is improved and this problem can be eliminated.

Actually place of DG and its penetration level decide its effect. If a suitable size DG is integrated at suitable bus location in the distribution system, then only it will be beneficial, otherwise it will adversely affect the system. Therefore Optimal DG Allocation (ODGA) has been the intense focus area power system planners, research engineers, utilities and institutes in the past. ODGA problem may have several objectives such as diminution of power /energy losses, reduction in voltage deviation, maximization of DG capacity, improvement in system reliability etc. If any one objective is selected for the optimization, then optimization problem will be single objective. For creating a multi-objective problem, several objectives can be combined together. For optimization of these single objective or multiobjective

problems, several optimization techniques have been found in the literature. A summary of these techniques is given in [3]. Optimal placement of a fixed size DG is done with the help of an analytical technique [4]. The main aim of this optimization is to reduction of real losses only. Acharya *et al.* [5] have given exact loss formula for ODGA using analytical technique. An improve analytical method is also found suitable for ODGA in literature [6]. ODGA and its effect on the SAIDI and SAIFI of the system is shown in [7]. Similar work is done for the capacitor also [8].

Several other advanced optimization techniques like PSO [9], Improved PSO [10] Genetic Algorithm (GA) [11], Hybrid GA and PSO [12], Artificial Immune System combined with PSO [13], Artificial Bee Colony [14] and Modified Firefly Algorithm [15] are also found their suitability in ODGA. PSO needs few parameters, easily completed and the method is very simple as compared to other algorithm [16]. In this paper PSO is used for ODGA problem for single DG placement in the IEEE 33-bus RDN. PSO Convergence characteristics depend upon the inertia weight of the velocity equation. In this article, effect of the inertia weight on the ODGA is shown by considering different inertia weights during optimization. In section II of the paper, the objective function formulation is explained, in section III PSO technique is discussed. Section IV and V are the results and the conclusion respectively.

2. Formulation of Objective Function

In any electrical system the total active power losses depends on the injection of real and reactive powers at different nodes and hence losses can be formulated in terms of these injected powers. For any *N*-node network total active power losses are calculated by the equation (1) [17]. This equation is known as 'exact loss' formula.

$$P_L = \sum_{i=1}^{N} \sum_{j=1}^{N} \left[\alpha_{ij} \left(P_i P_j + Q_i Q_j \right) + \beta_{ij} \left(Q_i P_j - P_i Q_j \right) \right] \tag{1}$$

Where α_{ij} and β_{ij} are the coefficients given as:

$$\alpha_{ij} = \frac{R_{ij}}{V_i V_j} cos(\delta_i - \delta_j),$$

$$\beta_{ij} = \frac{R_{ij}}{V_i V_j} sin(\delta_i - \delta_j),$$

N= Number of Nodes,
P = injected real power
Q = injected reactive power
V = magnitude of voltage
δ = angle of the voltage
i= node number
and $Z_{ij} = R_{ij} + jX_{ij}$ is the *ij*th element of $[Z_{BUS}] = [Y_{BUS}]^{-1}$.

Main aim of the optimization process is to reduce real losses by installing an optimum capacity of DG at optimum node in the system. For this purpose objective function is formed as equation (2).

$$\text{f} = \min(P_{loss}) \tag{2}$$

For this optimization process the constraints are stated below:
Minimum and maximum range of the node voltage can be given as:

$$V_{imin} < V_{i<} V_{imax} \tag{3}$$

Total Active power generation should be within its minimum and maximum limits:

$$P_{DG}^{\min} \leq P_{DG} < P_{DG}^{\max} \tag{4}$$

Total generated power must fulfill power demand (PD) and total losses (T$_L$) of the system.

$$\sum P_G + \sum P_{DG} = PD + T_L \tag{5}$$

3. Particle Swarm Optimization (Pso)

To find the maximum or minimum of any process with least efforts with some constraints is known as optimization. Numerous optimization methods have been proposed by the researchers in the past. PSO is one of them. It is motivated by group activities of birds or fish during the search of food, This algorithm proposed and proposed by Eberhart and Kennedy [19]. There are numerous advantages of the PSO, over other existing techniques. This can also be combined with some other methods to make a hybrid optimization method. In PSO all particles randomly moves in the search space and their initial positions are also randomly generated. In a D-dimensional search space, the *i*th particle of the group of particles is represented by a D-dimensional vector $X_i = (x_{i1}, x_{i2} \dots \dots x_{iD})$ and the best particle of the swarm, is denoted by *g*$_{best}$. The previous best location of the *i*th particle is stored and represented as $P_i =$

$(p_{i1}, p_{i2} ..... p_{iD})$ and the position change (velocity) of the i particle is $V_i = (v_{i1}, v_{i2} ..... v_{iD})$. For each iteration velocity and positions vectors are updated by equations (6) and (7) (the superscripts denote the iteration):

$$V_i^{k+1} = wV_i^k + c_1 r_{i1}^k (P_i^k - X_i^k) + c_2 r_{i2}^k (P_g^k - X_i^k) \qquad (6)$$
$$X_i^{k+1} = X_i^k + V_i^{k+1} \qquad (7)$$

Where i=1, 2,….M .
M = total number of particles
w = the inertia weight
c_1= cognitive parameter
c_2= social parameter
r_{i1} and r_{i2} = random numbers within the range [0, 1].
A general flow chart for PSO is shown in figure 1 [20].
Initial population can be found according the following equation (8):

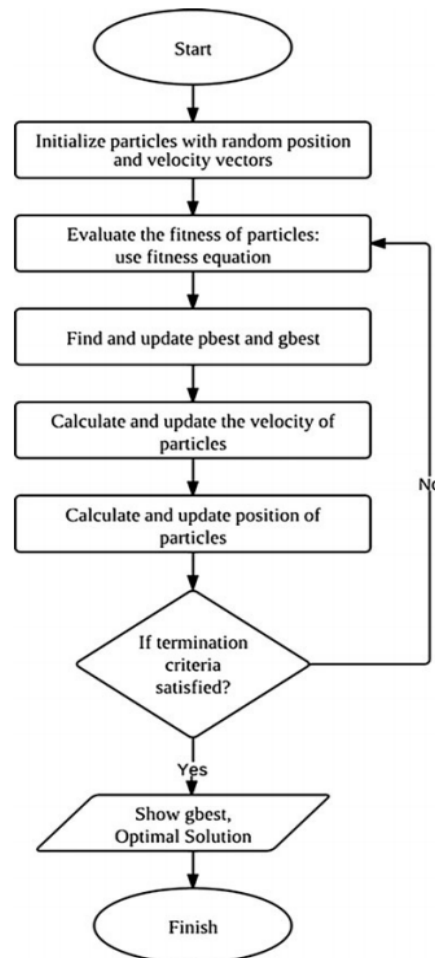$$X_i = X_{min} + rand * (X_{max} - X_{min}) \qquad (8)$$

Fig 1. PSO flow chart [20]

Inertia weight is the deciding factor in the convergence behaviour of the PSO. Large inertia weight results in delayed convergence of the optimization and low inertia weight will result in local trapping. As a result, the inertia weight should be selected for a better searching -utilization trade-off. Different inertia weight settings are proposed in the literature such as: Constant Inertia Weight (CIW), Oscillating Inertia Weight (OIW), Random Inertia Weight (RIW), Global Local Best Inertia Weight (GLBIW), Time Varying Inertia Weight (TVIW) techniques, etc. Some inertia weights and their formula are summarised in Table 1 [21].

Table 1: Different Inertia Weights and Their Formula

S. No.	Name	Formula
1.	CIW	w=c c=0.7
2.	OIW	$w(t) = \frac{(w_{min}+w_{max})}{2} + \frac{(w_{max}-w_{min})}{2}\cos\left(\frac{2\pi t}{T}\right)$ $T = \frac{2S}{3+2k}$
3.	RIW	$w = 0.5 + \frac{Rand()}{2}$
4.	GLBIW	$w_i = (1.1 - \frac{gbest_i}{pbest_i})$
5.	TVIW	$w = (w_1 - w_2)\left(\frac{maxiter-iter}{iter}\right) + w_2$

In this paper above mentioned different inertia weights are considered and their effect on the size optimization of DG is shown.

4. Case Study And Results

PSO with different inertia weights is applied for ODGA in IEEE 33-bus RDN. The system is having 33 nodes, 32 lines. The connected active and reactive load of system is 3.72MW and 2.3MVAR respectively. Base case is without interconnection of DG. In this case active losses in the system are 211.1957 kW and reactive losses are 143.2159 kVAR. Optimal DG placement problem is separated into two parts. One is the regarding decision of optimal place and then determination of optimal size to be placed at that location. For determination of optimal location five random buses are selected and then variation of DG power injection and variation in losses is plotted. Five random selected buses are bus number 6,10,18,22 and 31. This variation is shown in figure 2. Figure 2 also shows that out of these buses, if power injection is done at bus number 6 then the losses in the system will be minimum with variation in DG injected power.
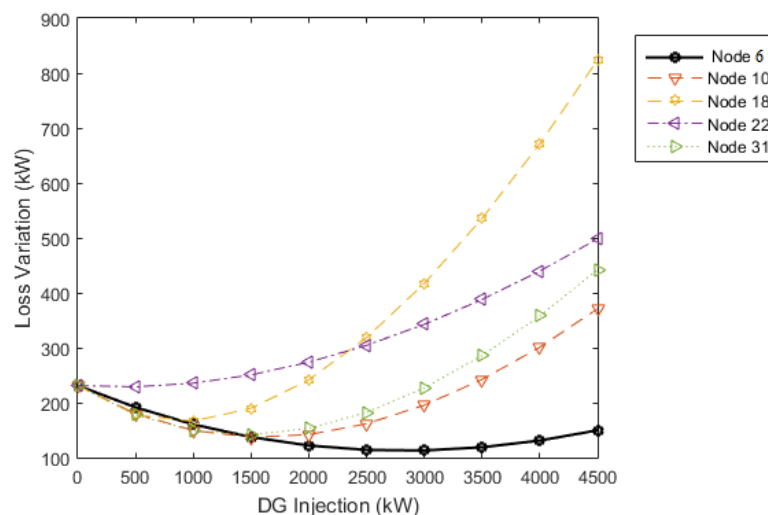

Fig 2. DG power Injection Vs Loss Variation

Comparison of percentage loss reduction with DG power injection is shown in figure 3. This figure also shows that power injection at bus number 6 will give highest loss reduction. Due to this reason, optimum location for injection of power is selected as bus number 6.
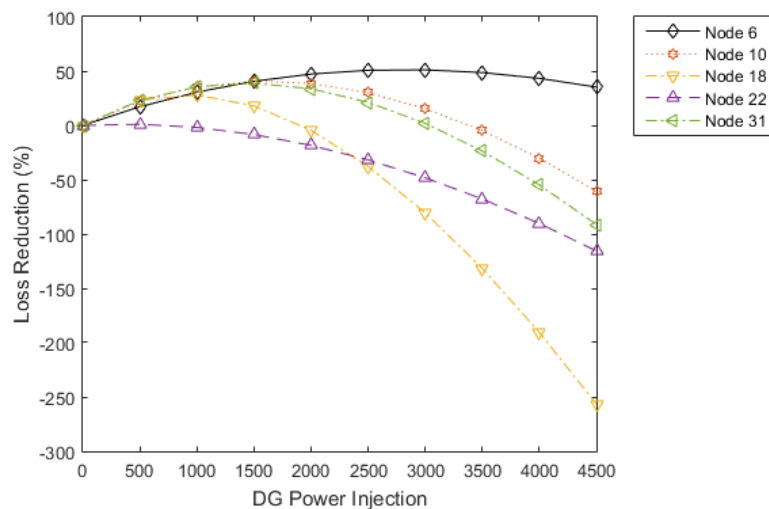
Fig 3. DG power Injection Vs percentage Loss reduction

For fixing of optimal size of DG, PSO is applied and five different inertia weights are selected. In PSO 40 particles are selected and their initial position and velocity are initialized randomly. With different inertia weights results are shown in table 2. For demonstrating the effect of inertia weight on the optimization CIW method is neglected because constant inertia weight will always increase the velocity linearly and in such case the optimization will not converge. Rest other OIW, RIW, GLBIW and TVIW are compared and result shows that time taken by TVIW is least among the compared methods. This time taken is 1.164 seconds. GLBIW gives minimum size of 2.7947 MW for the selected location. Size proposed by the TVIW is 2.8201 MW and system losses by installing this DG will be 112.719 kW. These losses are least among the compared methods and hence it can be said that size proposed by TVIW results in maximum loss reduction. Priorities in speed, size or efficiency will decide the selection of inertia weights.

Table 2. Performance Comparison of PSO with Different Inertia Weights

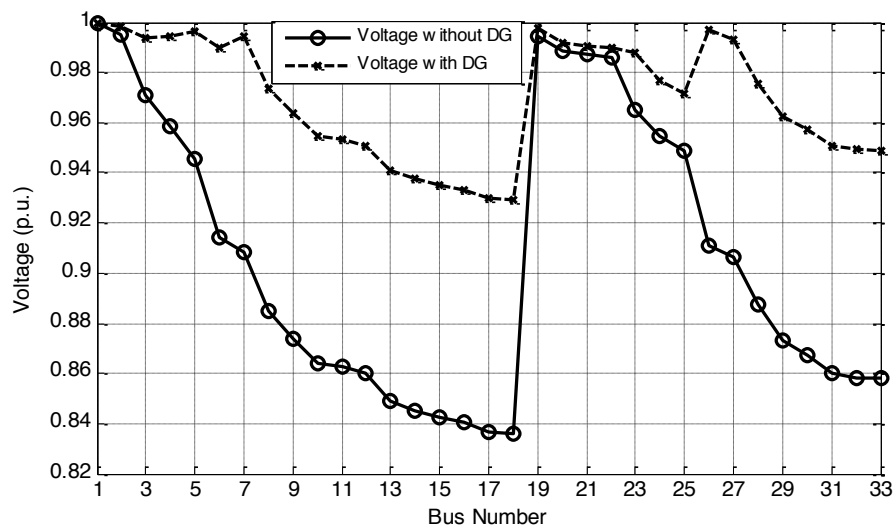|	OIW	RIW	GLBIW	TVIW
Average DG Injection (in MW)	2.8171	2.9109	2.7947	2.8201
Average Loss (in kW)	112.691	112.558	112.719	112.534
Average time taken (in sec)	1.175	1.526	2.817	1.164

Fig 4. Voltage Profile comparison in base case and with DG

Voltage profile of the test system for with and without DG case is demonstrated in Figure 4. Since prime purpose of this optimization problem is to reduce the real losses and hence for the voltage profile comparison size corresponding to least system losses is taken into consideration. Figure 4 also demonstrates that in RDN, optimal capacity DG placed at optimal bus number for minimization of losses only, also improves its voltage profile. Effect of DG varies with the distance of the load point from the DG.

5. Conclusion

In this article initially the optimal bus number of the DG is decided and then PSO is applied for the fixation of optimal capacity of the DG. Location of this optimal size DG is already predefined. Optimal capacity of DG is calculated to decrease the real losses occurring in the system. During optimization different inertia weight methods are selected and their effect on the optimal capacity of DG is shown. It can be concluded that TVIW is the fastest among the compared methods. Also the size proposed by the TVIW method gives minimum losses of the system. However GLBIW gives minimum size of DG for the minimization of losses, although this size gives losses higher than that of the TVIW. Thus selection of the inertia weight depends on the priority of the size or losses. Effect of the inertia weight on the size and location optimization can also be shown for the same system or for any other system. This analysis will help in decision making at the planning stages. Effect of inertia weight on the both size and location can also be studied.

References

[1] S. N. Singh, J. Ostergaard and N. Jain, 2009 *Distributed Generation in Power Systems: An Overview and Key Issues*, Indian Engineering Congress,

[2] Bhadoria, Vikas Singh, Nidhi Singh Pal, and Vivek Shrivastava. 2013 *A review on distributed generation definitions and DG impacts on distribution system.* Proc. Int. Conf. Advanced Computing and Communication Technologies (ICACCT™-2013), Vol. 7. DOI: 10.13140/RG.2.1.4439.4328

[3] Adefarati, T., and R. C. Bansal 2016. Integration of renewable distributed generators into the distribution system: a review. IET Renewable Power Generation 10.7: 873-884.

[4] Bhadoria, Vikas Singh, Nidhi Singh Pal, and Vivek Shrivastava. 2014 *Installation of DG for optimal demand compensation.* International Conference on Issues and Challenges in Intelligent Computing Techniques (ICICT). **DOI:** 10.1109/ICICICT.2014.6781385.

[5] Acharya N, Mahat P, Mithulananthan N. 2006 An analytical approach for dg allocation in primary distribution network. Int J Electr Power Energy Syst;28:669–78.

[6] Duong Quoc H, Mithulananthan N, Bansal RC. 2010 *Analytical expressions for dg allocation in primary distribution networks.* IEEE Trans Energy Convers;25:814–20.

[7] V. Bhadoria, N. Pal, V. Shrivastava and S. Jaiswal, 2017 *Reliability Improvement of Distribution System by Optimal Sitting and Sizing of Disperse Generation*, International Journal of Reliability, Quality and Safety Engineering, vol. 24, no. 06, p. 1740006. doi.org/10.1142/S021853931740006X

[8] Bhadoria, Vikas Singh, et al. 2018 *Optimal Sitting and Sizing of Capacitor Using Iterative Search Method for Enhancement of Reliability of Distribution System.* Advances in Energy and Power Systems. Springer, Singapore, 123-129. doi.org/10.1007/978-981-13-0662-4_11.

[9] El-Zonkoly AM. 2011 Optimal placement of multi-distributed generation units including different load models using particle swarm optimization. Swarm Evolut Compute 1:50–9.

[10] Singh RK, Goswami SK 2009. Optimum siting and sizing of distributed generations in radial and networked systems. Electr Power Compon Syst;37:127–45.

[11] M. H. Moradi and M. Abedini, Jan. 2012 A combination of genetic algorithm and particle swarm optimization for optimal DG location and sizing in distribution systems, Int. J. Electr. Power Energy Syst., vol. 34, no. 1, pp. 66–74,.

[12] W. Prommee and W. Ongsakul, Jan. 2011 Optimal multiple distributed generation placement in microgrid system by improved reinitialized social structures particle swarm optimization Euro. Trans. Electr. Power, vol. 21, no. 1, pp. 489–504,.

[13] M. Gomez-Gonzalez, A. López, and F. Jurado, Mar. 2012 *Optimization of distributed generation systems using a new discrete PSO and OPF* Elect. Power Syst. Res., vol. 84, no. 1, pp. 174–180.

[14] F. S. Abu-Mouti and M. E. El-Hawary Oct. 2011 Optimal distributed generation allocation and sizing in distribution systems via artificial bee colony algorithm IEEE Trans. Power Del., vol. 26, no. 4, pp. 2090–2101.

[15] A.Y. Abdelaziz, Y. G. Hegazy, W. El-Khattam, W. and M.M. Othman 2015 *Optimal Planning of Distributed Generators in Distribution Networks Using Modified Firefly Method* Electric Power Components and Systems, vol. 43, no. 3, pp. 320-333.

[16] Q. Bai 2010 *Analysis of Particle Swarm Optimization Algorithm* Computer and Information Science, vol. 3, no. 1.

[17] Bhadoria, V. S., Pal, N. S., & Shrivastava, V. 2016. *Comparison of Analytical and Heuristic Techniques for Multiobjective Optimization in Power System* (pp. 264-291). Hershey, PA: IGI Global. DOI: 10.4018/978-1-4666-9885-7.ch013

[18] O. Elgerd, 1971 Electric energy systems theory: an introduction. New York: McGraw-Hill.

[19] J. Kennedy and R. C. Eberhart, 1995 *Particle Swarm Optimization*, Proc. IEEE International Conference on Neural Networks, vol. IV, pp. 1942-1948.

[20] D. Armaghani, M. Hajihassani, E. Mohamad, A. Marto and S. Noorani, 2013 Blasting-induced flyrock and ground vibration prediction through an expert artificial neural network based on particle swarm optimization, Arabian Journal of Geosciences, vol. 7, no. 12, pp. 5383-5396.

[21] Bansal, J.C., Singh, P.K., Saraswat, M., Verma, A., Jadon, S.S., & Abraham, A. 2011. *Inertia Weight strategies in Particle Swarm Optimization.* 2011 Third World Congress on Nature and Biologically Inspired Computing, 633-640.