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Research Article

Principle Optimal Placement and Sizing of Single Distributed Generation for Power Loss Reduction using Particle Swarm Optimization

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Abstract: This study presents a methodology using Particle Swarm Optimization (PSO) for the placement of single Distributed Generation (DG) in the radial distribution systems to reduce the power loss. The single DG placement is used to find the optimal DG location and sizing which is corresponded to the maximum power loss reduction. The proposed method is tested on the 26-bus radial power distribution system which modified from the Provincial Electricity Authority system in Thailand. The load flow analysis on distribution system used forward-backward sweep methodology. The simulation results show that PSO can obtain the maximum power loss reductions. The total consumption power is 8.49 MW and 5.97 MVAR and total power loss is 11.68 kW and 26.08 kVAR. This study can be verify that the PSO method can solve the best placement and sizing on the real system.

Keywords: Distributed generation, optimization technique, particle swarm, voltage stability

INTRODUCTION

Photovoltaic (PV) distributed generation systems can make a positive contribution to the sustainability in developing countries that have access to electricity grid. Thailand is a tropical country and has plenty of sunshine which can generate the electricity from sunshine using photovoltaic technology more than 700 W/m^2 (Phuangpornpitak *et al*., 2010). Therefore, the Thailand has abundant of solar resource to generate electricity as the main contribution. Integration of solar photovoltaic system with grid connection would help in supplementing the continually increasing of electricity need in Thailand. Greater use of PV distributed generation systems can also increase reliability of the electricity grid. Many problems exist arising from the operation of PV distributed generators jointly with the grid. Particularly, optimal placement and sizing of such system need to be optimized for improving voltage support in distribution networks. Therefore, it is necessary to take into account that the optimal allocation and sizing of DG grid connected in distribution systems during the design stage.

With the increase of single PV distributed generation systems that are happening nowadays, the application of optimization technique as particle swarm technique which is the useful tool for system design and sizing for an actual feeder are presented in this study. In order to minimize line losses of power systems, it is crucially important to determine the size and location of local generation to be placed. There have been number of studies to define the optimum location of DG.

Several optimization techniques have been applied to DG placement and sizing, such as genetic algorithm, tabu search, heuristic algorithms and analytical based methods. The optimum DG allocation can be modeled as optimum active power compensation. DG allocation studies are relatively new, unlike capacitor allocation that has been studied for many years (Peng *et al*., 2012; Nikzad *et al*., 2011; Abu-Jasser and Husam, 2011). In Prommee and Ongsakul (2008), analytical method to place DG in radial as well as meshed systems to minimize power loss of the system is presented. In this method separate expressions for radial and network system are derived and a complex procedure based on phas or current is proposed to solve the location problem. However, this method only optimizes location and considers size of DG as fixed. In this study, Particle Swarm Optimization algorithm (PSO) is presented as the optimization technique for the allocation and sizing of DG in distribution networks in order to loss reduction in distribution network. The 26-bus test feeder is selected to test proposed method. The results show the best position of DG with minimum economic cost.

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PROBLEM FORMULATION

The real power loss reduction in a distribution system is required for efficient power system operation. The loss in the system can be calculated by Eq. (1) given the system operating condition (Elgerd, 1983):

$$P_L = \sum_{i=1}^{n} \sum_{j=1}^{n} A_{ij}\left(P_i P_j + Q_i Q_j\right) + B_{ij}\left(Q_i P_j - P_i Q_j\right) \quad (1)$$

where,

$$A_{ij} = \frac{R_{ij}\cos\left(\delta_i - \delta_j\right)}{V_i V_j}$$

$$B_{ij} = \frac{R_{ij}\sin\left(\delta_i - \delta_j\right)}{V_i V_j}$$

where,
P_i & Q_i : Net real and reactive power injection in bus *'i'*
R_{ij} : The line resistance between bus *'i'* and *'j'*
V_i & δ_i : The voltage and angle at bus *'i'*

The objective of the placement technique is to minimize the total real power loss. Mathematically, the objective function can be written as:

$$\text{Minimize } P_L = \sum_{k=1}^{N_{SC}} Loss_k \quad (2)$$

Subject to the power balance constraints:

$$\sum_{i=1}^{N} P_{DGi} = \sum_{i=1}^{N} P_{Di} + P_L \quad (3)$$

Voltage constraints:

$$\left|V_i\right|^{\min} \le \left|V_i\right| \le \left|V_i\right|^{\max} \quad (4)$$

Current limits:

$$\left|I_{ij}\right| \le \left|I_{ij}\right|^{\max} \quad (5)$$

where,
$Loss_k$ = Distribution loss at section k
N_{SC} = Total number of sections
P_L = The real power loss in the system
P_{DGi} = The real power generation DG at bus i
P_{Di} = The power demand at bus i

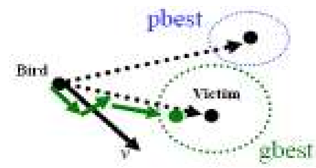

Fig. 1: Birds' food searching with PSO

PARTICLE SWARM OPTIMIZATION (PSO)

Particle Swarm Optimization is an optimization technique based on the movement and intelligence of swarms. PSO applies the concept of social interaction to problem solving. It was developed by Kennedy and Eberhart (1995) (social-psychologist) and Russell Eberhart (electrical engineer). Particle swarm is the system model or social structure of basic creature which make a group to have some purpose such as food searching. It is an important part to take the most of population in a group that has the same activity. The group of creatures has this relative behavior, for example, bee swarm, fish school and bird flock.

Figure 1 shows bird flock hunter that is a bird suspect to a particle (Prommee and Ongsakul, 2008). In victim searching, all bird groups will fly together in the same direction and the bird leader is the nearest food that has the shortest distance as the best fitness and the other birds follow the leader. The particle swarm model will be used by fitness value consideration. The particles represent solutions of fitness value. Moreover the important property in food searching of birds for instance, the particle's velocity of each particle uses to set the direction of particle movement. After that, all particles in the flock would be improved their directions that related with the best fitness of particle direction. The result of this process thus helps to set the most appropriate direction.

PSO consists of a group (swarm) of individuals (particles) moving in the search space looking for the best solution. Each particle is represented by a vector *s* of length *n* indicating the position and has a velocity vector *v* used to update the current position which adjusts its flying according to its own flying experience as well as the flying experience of other particles. Each particle keeps track of its coordinates in the solution space which are associated with the best solution (fitness) that has achieved so far by that particle. This value is called personal best, *pbest*. Another best value that is tracked by the PSO is the best value obtained so far by any particle in the neigh borhood of that particle. This value is called *gbest*. The basic concept of PSO lies in accelerating each particle toward its *pbest* and the *gbest* locations, with a random weighted acceleration at each time step as shown in Fig. 2. Each particle tries to modify its position using the following information with the flowchart of PSO algorithm as depicted in Fig. 3: the current positions, the current velocities, the distance between the current position and the *pbest* and the distance between the current position and the *gbest*.

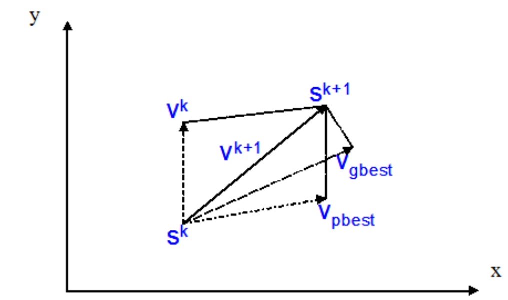

Fig. 2: Concept of modification of a searching point by PSO

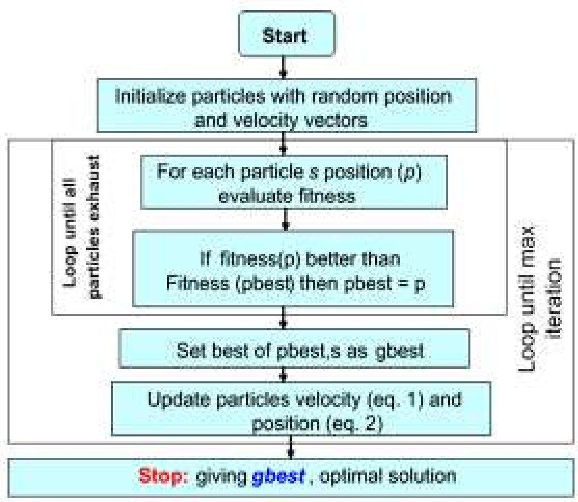

Fig. 3: Flowchart of PSO algorithm

The modification of the particle's position can be modelled by using Eq. (6) and (7):

$$v_i^{k+1} = wv_i^k + c_1r_1 (pbest_i - s_i^k) + c_2r_2 (gbest - s_i^k) \quad (6)$$

$$s_i^{k+1} = s_i^k + V_i^{k+1} \quad (7)$$

where,

c_1, c_2 = The weighting factor
r_1, r_2 = The random numbers between 0 and 1
w = The weighting function
v_i^k = The current velocity of particle i at iteration k
v_i^{k+1} = The modified velocity of particle i
s_i^k = The current position of particle i at iteration k
s_i^{k+1} = The modified position of particle i
$pbest_i$ = The personal best of particle i
$gbest$ = The global best of the group

The literature (AlRashidi and El-Hawary, 2009) has noted the advantages of PSO technique over other optimization techniques as follows: It is easy to implement and program with basic mathematical and logic operations, It can handle objective functions with stochastic nature, like in the case of representing one of optimization variables as random and it does not require the good initial solution to start its iteration process.

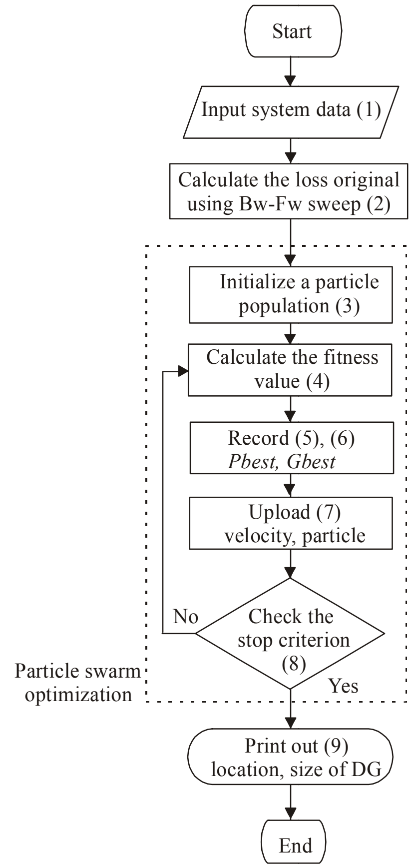

Fig. 4: PSO-OPDG computational procedure

However, the drawbacks of PSO technique still exist as follows (AlRashidi and El-Hawary, 2009): More parameters tuning is required and Programming skills are required to develop and modify the competing algorithm to suit different optimization problems.

DESIGN PROCEDURE

The flowchart of the proposed algorithm is illustrated in Fig. 4 (Krueasuk, 2007). The PSO-based approach for solving the optimal placement of distributed generation problem to minimize the loss takes the following steps:

Step 1: Input line and bus data and bus voltage limits.
Step 2: Calculate the loss using distribution load flow based on backward-forward sweep.
Step 3: Randomly generates an initial population (array) of particles with random positions and velocities on dimensions in the solution space. Set the iteration counter $k = 0$.
Step 4: For each particle if the bus voltage is within the limits, calculate the total loss using Eq. (1). Otherwise, that particle is infeasible.

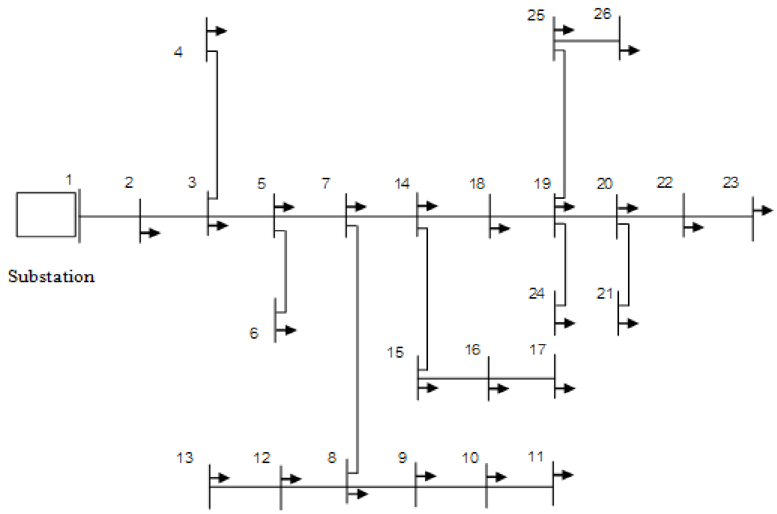

Fig. 5: A 26-bus radial distribution system

Step 5: For each particle, compare its objective value with the individual best. If the objective value is lower than *Pbest*, set this value as the current *Pbest* and record the corresponding particle position.

Step 6: Choose the particle associated with the minimum individual best *Pbest* of all particles and set the value of this *Pbest* as the current overall best *Gbest*.

Step 7: Update the velocity and position of particle using Eq. (6) and (7) respectively.

Step 8: If the iteration number reaches the maximum limit, go to Step 9. Otherwise, set iteration index $k = k + 1$ and go back to Step 4.

Step 9: Print out the optimal solution to the target problem. The best position includes the optimal locations and size of DG and the corresponding fitness value representing the minimum power loss.

The PSO algorithm is able to reach a good solution by finite steps of evolution steps performed on a finite set of possible solutions. The objective function for the optimization is the power loss reduction as shown in Eq. (1). The PSO algorithm sets in the core of this optimization problem. This routine is programmed by MATLAB M-File program.

SIMULATION RESULTS

The proposed micro-grid distribution system is used as a test system which was selected from one part of the PEA central station distribution network. The single line diagram of the network is illustrated in Fig. 5. The 26-bus system has 25 sections with the total load of 8.49 MW and 5.28 MVAR. The original total real and reactive power losses of the system are 11.68 kW (0.14%) and 26.08 kVAR (0.49%), respectively. The base MVA is 10 MVA and the base kV is 12.66 kV. For PSO parameters, population size is equal to 100 and maximum generation (k_{max}) is equal to 50. Following analysis is performed with the test system and results are presented accordingly.

Table 1: Simulation results of a 26-bus test system

Bus number	DG size (MW)	P loss (kW)	Q loss (kVar)
2	8.5068	10.3580	23.6760
3	8.2344	7.1198	16.1569
4	4.6531	9.0117	18.2691
5	7.9300	5.0661	11.3894
6	7.5522	5.3662	12.1020
7	7.8500	4.7659	10.6897
8	6.7758	5.3157	11.7930
9	6.4996	5.5243	12.2208
10	5.8028	6.0993	13.4124
11	5.6693	6.2192	13.6618
12	5.6600	6.2339	13.6948
13	5.2773	6.5771	14.4206
14	6.9486	4.5639	10.2018
15	6.8565	4.6432	10.3937
16	6.7195	4.7710	10.6880
17	6.6535	4.8367	10.8430
18	5.9930	4.8258	10.7728
19	5.8276	4.8788	10.8882
20	4.4188	5.9701	13.3300
21	4.1434	6.2939	14.0584
22	3.0214	7.4594	16.6576
23	3.0127	7.4705	16.6838
24	5.4783	5.2687	11.7739
25	4.1968	6.5990	14.7698
26	3.2110	7.7178	17.2749

The proposed methodology was run on a 26 bus test system. The impact of installing DG in the case study network with optimal allocation and sizing is presented Table 1. The decrease in total power loss depends on the location and size of DG.

Figure 6 shows the suitable DG size of a 26-bus test system and Fig. 7 shows the power loss of a 26-bus test system. The minimum power loss occurs in bus 14

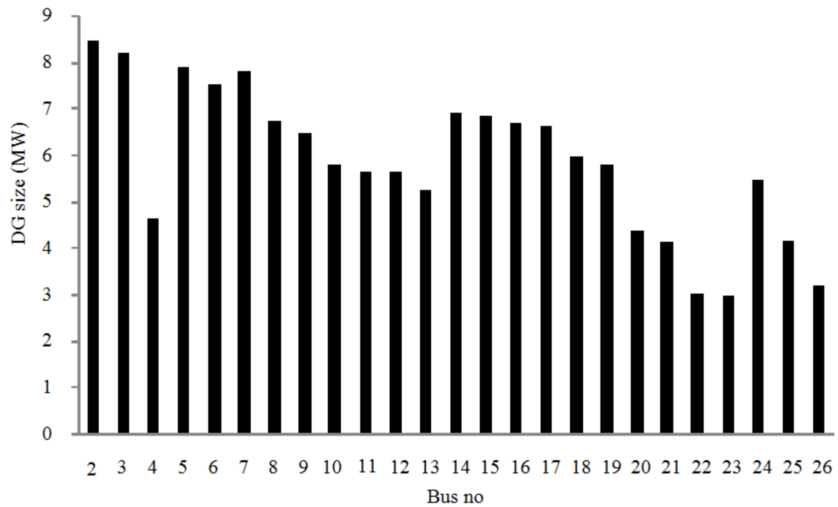

Fig. 6: Suitable DG sizing of a 26-bus test system

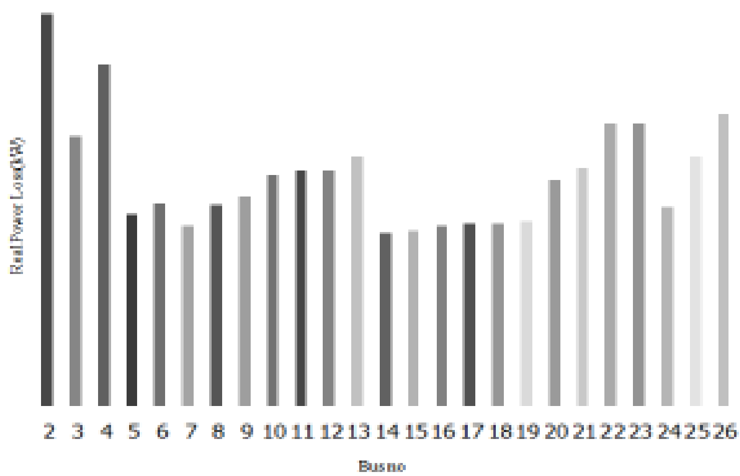

Fig. 7: Power loss of a 26-bus test system

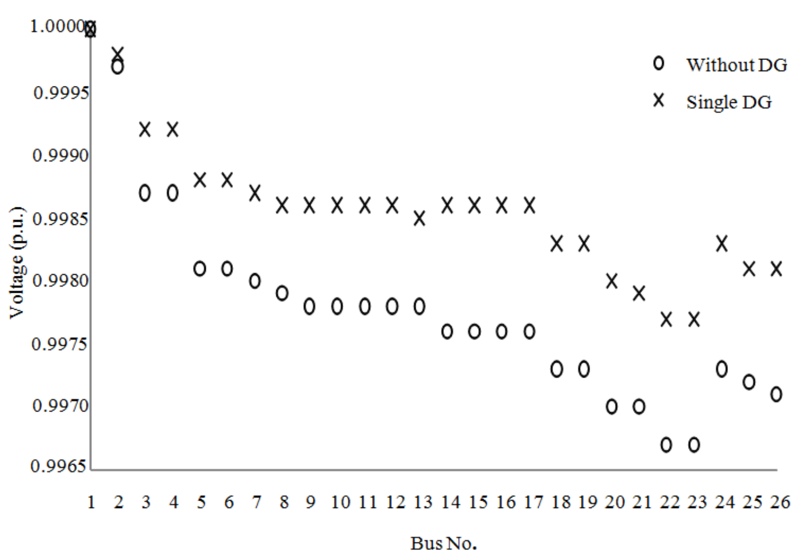

Fig. 8: Voltage level comparison on the 26-bus system

(4.56 kW and 10.20 kVAR). The proposed method can reduce loss by 61% of its original loss.

Figure 8 shows the voltage level comparison for the 26-bus system with and without installation of DG system. In order to have a clear comparison, bus voltages in the base case and also after installation of DG units are illustrated in Fig. 8. The outcomes represent that installation of DG units considerably improves the voltage profile. Note that installation of DG units give better average voltage levels (0.9985 per unit) compared with the original system (0.9977 per unit). In the system without DG units, the lowest voltage level is 0.9967 per unit. After the PV units are installed, the voltage level is improved (0.9977 per unit).

CONCLUSION

In this study, a particle swarm optimization for optimal placement of DG is efficiently minimizing the total real power loss satisfying transmission line limits and constraints. The methodology is fast and accurate in determining the sizes and locations. The methodology is tested on a 26 bus systems. The total consumption power is 8.49 MW and 5.97 MVAR and total power loss is 11.68 kW and 26.08 kVAR. By installing DG at all potential locations, the total power loss of the system has been reduced drastically and the voltage profile of the system is also improved.

NOMENCLATURE

PV = Photovoltaic
DG = Distributed generation
PSO = Particle swarm optimization
P_i = Net real power injection in bus *'i'*
Q_i = Net reactive power injection in bus *'i'*
R_{ij} = The line resistance between bus *'i'* and *'j'*
V_i = The voltage at bus *'i'*
δ_i = The angle at bus *'i'*
$Loss_k$ = Distribution loss at section k
N_{SC} = The total number of sections
P_L = The real power loss in the system
P_{DGi} = The real power generation DG at bus i
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REFERENCES

Abu-Jasser, A. and S. Husam, 2011. Multi-objective solution based on various particle swarm optimization techniques in power systems. Res. J. Appl. Sci. Eng. Technol., 3(6): 519-532.

AlRashidi, M.R. and M.E. El-Hawary, 2009. A survey of particle swarm optimization applications in electric power systems. IEEE T. Evolut. Comput., 13(4): 913-918.

Elgerd, I.O., 1983. Electric Energy System Theory: An Introduction. Tata McGraw-Hill Education, New Delhi, pp: 533.

Kennedy, J. and R. Eberhart, 1995. Particle swarm optimization. Proceeding of the IEEE International Conference on Neural Networks. Perth, Australia, pp: 1942-1948.

Krueasuk, W., 2007. Particle swarm optimization for optimal DG placement in distribution system. Proceeding of the ECTI International Conference. Chiang Rai, Thailand, pp: 210-216.

Nikzad, M., S. Shams Shamsabad Farahani, M. Bigdeli Tabar, M. Ghasemi Naraghi and A. Javadian, 2011. Using particle swarm optimization method for supplementary STATCOM stabilizer tuning in electric power system. Res. J. Appl. Sci. Eng. Technol., 3(8): 824-831.

Peng, G., C. Wenming and L. Jian, 2012. Particle swarm optimization for gantry crane scheduling with interference constraints. Res. J. Appl. Sci. Eng. Technol., 4(9): 1117-1123.

Phuangpornpitak, N., S. Tia, W. Prommee and W. Phuangpornpitak, 2010. A study of particle swarm technique for renewable energy power systems. Proceeding of the International Conference on Energy and Sustainable Development: Issues and Strategies (ESD), pp: 1-6.

Prommee, W. and W. Ongsakul, 2008. Optimal multi-distributed generation placement by adaptive weight particle swarm optimization. Proceeding of International Conference Control, Automation and Systems (ICCAS), pp: 1663-1668.