Pertanika J. Sci. & Technol. 25 (S): 355 - 362 (2017)

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

Optimisation of Distributed Generation Unit Using Particle Swarm Optimisation Method and Voltage Stability Indicator

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ABSTRACT

Distributed generator is one of the most common sources of electric power as it has many advantages. However, it might cause negative effects to the distribution system if appropriate conditions are undermined. Thus, this paper describes ways to optimise the use of distributed generator in a distribution system in order to reduce total power losses and to improve system performance by increasing stability of the voltage profile. This study focuses on the installation of distributed generator that is installed on 69-bus radial distribution system. Optimisation are done through Particle Swarm Optimization and Voltage Stability Indicator. The findings show that total power loss was reduced by 44.6%, and there was improvement in voltage profile stability.

Keywords: Distributed generator, Particle Swarm Optimization, Voltage Stability Indicator

INTRODUCTION

Distributed generator (DG) is an alternative source of energy to increase efficiency of a distribution system. Installation of DG is aimed at reducing overall power loss and the capability of DG to improve the voltage profile (Gallano & Nerves, 2014). The integration of DG units has contributed to system upgrade. However, emission is a real concern aggravated by climate change. Thus, there is a need for low emission generating unit. As the machine requires a large amount of space (Davis, 2002a, 2002b), DGs can replace the generation station. Hence, the DG unit can serve as a good alternative as it only requires minimal space in the distribution system.

A DG unit is a type of generator that supplies small-scale electricity to consumers.

ARTICLE INFO

Article history:
Received: 28 September 2016
Accepted: 03 February 2017

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ISSN: 0128-7680

It is different from central generation station (Nara, Ishizu, & Mishima, 2005) in terms size, effect on the environment and community, emission level, voltage stability and location. The DG is located at a site nearer to the customers compared with the generating station that has to be located at a certain distance from the consumers for safety reason and comfort issues.

A previous research used fmincon function in Matlab by considering the power demand and availability of the system generating units and equality restrictions. This was tested on three conditions: (i) the DG source connected to the system; (ii) the DG source not connected to the system; and (iii) steady state condition. It uses four generators and one load (Dulau & Bica, 2015). Other research used conventional optimisation techniques such as Genetic Algorithm (GA) to find the size and location of the capacitors, while another used a new method in determining a suitable location in placing the embedded generator. The latter was proposed based on new sensitivity indices that has been derived from the voltage stability improvement with respect to the changes in injected power towards the bus (Rahman, Rahim, & Musirin, 2004).

Installing a DG unit can present several challenges which include causing adverse effects if installed randomly, causing bigger total power loss towards the distribution system. This paper therefore explains how strategically installed DG compares favourably in terms of performance compared with randomly installed DG. Moreover, since the big central generation station needs a long transmission line, the DGs is a better solution. The objectives of this paper are to understand the characteristics of the DG in order to reduce total power losses in 69-bus distribution system and to improve the stability of the voltage profile and for this purpose, the study utilizes Voltage Stability Indicator (VSI) and Particle Swarm Optimization (PSO) algorithm. Both methods were implemented using Matlab (Dulau & Bica, 2015).

This study therefore aims to ensure installed DGs do not contribute to any negative issues, have the appropriate size, and reduce power losses during transmission from the generation part to the distribution part. By reducing the length of transmission lines, the chances of having lower total power losses is higher.

METHOD

The study used two methods to optimise the usage of DG units: which are Voltage Stability Indicator (VSI) and Particle Swarm Optimization (PSO).

Voltage Stability Indicator

The voltage stability indicator (VSI) was proposed by Kayal and Chanda (2013). In this paper, VSI is used to find the optimal location to place the DG units in the distribution network. By using VSI, the stability of the voltage profile will increase. In this way, electricity can be delivered efficiently. The conventional power flow equations of the receiving bus is as follows (Kayal & Chanda, 2013):

$$I^2 = \left(P^2{}_{i+1}/Q^2{}_{i+1}\right)/V^2{}_{i+1} \quad [1]$$

$$I^2 = \frac{P^2{}_{L,i} + Q^2{}_{L,i}}{(V_i - V_{i+1})^2} \qquad [2]$$

$P_{L,i}$ and $Q_{L,i}$ are the active and reactive power losses of the line connected between two nodes respectively. Equation (3) is the power balance equation that needs to be balanced at all time to ensure steady operation.

$$\frac{(P^2{}_{i+1}/Q^2{}_{i+1})}{V^2{}_{i+1}} = \frac{P^2{}_{L,i} + Q^2{}_{L,i}}{(V_i - V_{i+1})^2} \qquad [3]$$

P_{i+1} and Q_{i+1} can be found by using these two equations

$$P_{i+1} = P_i - P_{L,i} \qquad [4]$$

$$Q_{i+1} = Q_i - Q_{L,i} \qquad [5]$$

After computing the previous calculation, the VSI is expressed as

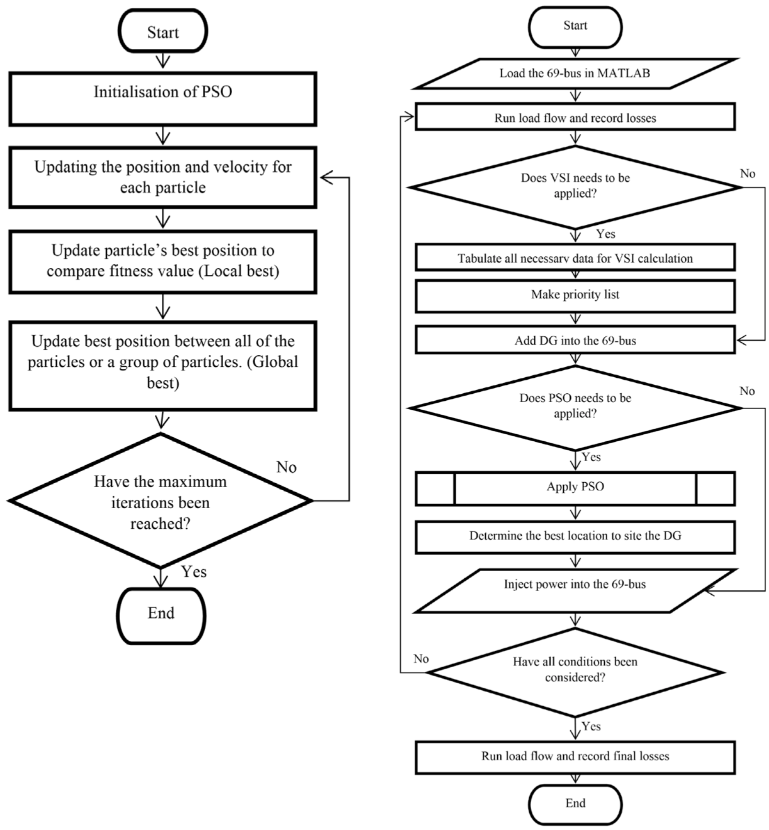
$$L_{i+1} = \frac{4.\sqrt{\left((P^2{}_{i+1} + Q^2{}_{i+1}).(r^2{}_i + x^2{}_i)\right)}}{V^2{}_i} \leq 1 \qquad [6]$$

Where V_i is the voltage magnitude while r_i and x_i is the resistance and impedance of each bus.

Particle Swarm Optimization

Particle Swarm Optimization (PSO) is a technique proposed by Kennedy and Eberhart in 1995. This algorithm is an intelligent-based optimisation that simulates the migration of bird flock when seeking for foods. The PSO actually finds the optimal solution by applying the movement trends of particle population and their interaction. It also finds the particle swarm and parallel global search. Figure 1(a) is the flowchart of PSO algorithm (Kai, Agalgaonkar, Muttaqi, & Perera, 2008; Rugthaicharoencheep, Lantharthong, & Auchariyamet, 2011).

The methods used in this paper are VSI and PSO; the former was used to determine the most suitable bus to install the DGs while the latter was used to obtain the value to be injected to the chosen bus. The ways to implement both methods are shown in Figure 1(b). First, the 69-bus was loaded in the Matlab software. In this simulation, 69-bus was used with the details of the simulation parameters provided in Table 1. Next, load flow analysis was done using the Newton-Raphson method to determine the total power loss of the system. The losses on each bus were recorded. After that, the choice of either to apply the VSI or not was done. If the choice is yes, then data for VSI calculations are recorded. Data was taken from the workspace in the Matlab software and the data were real and reactive power, real and reactive power losses, voltage magnitude, resistance and impedance for each bus. Then, the priority list was made by sorting the VSI value in descending order. The installation of DGs was made according to the priority list. The top four buses will be installed with DGs. The DGs can also be added at any location without applying the VSI calculation.



(a) (b)

Figure 1. (a) PSO algorithm; and (b) Flowchart of DG Optimisation

Table 1
Simulation parameters of 69-Bus

Bus	Voltage magnitude (V)	Load		Power loss		Resistance (Ω	Impedance (℧)
		(MW)	(Mvar)	(MW)	(Mvar)		
1-23	1.0000 to 0.9674	0.0000 to 0.0000	0.0000 to 0.0000	0.0000 to 0.0000	0.0000 to 0.0000	0.0003 to 0.3153	0.0007 to 0.1043
24-34	0.966 to 1.768	0.0280 to 0.0195	0.0200 to 0.0140	0.0010 to 0.0510	0.0000 to 0.0510	0.6832 to 1.9853	0.2259 to 0.6563
35-46	1.736 to 0.972	0.0060 to 0.0392	0.0040 to 0.02630	0.0480 to 0.0010	0.0480 to 0.0000	0.9197 to 0.6245	0.3040 to 0.3127
47-64	0.9997 to 0.9593	0.0000 to 0.2270	0.0000 to 0.1620	0.0030 to 0.0000	0.0070 to 0.0000	0.0552 to 1.0928	0.1352 to 0.5566
65-69	0.9612 to 0.9719	0.0590 to 0.0280	0.1620 to 0.0200	0.0000 to 0.0000	0.0000 to 0.0000	1.2734 to 0.0029	0.6428 to 0.0010

A decision needs to be made whether to apply or not to apply the PSO algorithm. If yes, then the PSO program is run using Matlab and results analysed. From the result, the appropriate sizes of DGs are determined. Next, the DGs are added into the 69-bus. If the previous decision is no, the DGs can be added in random sizes. Finally, the last decision is made where, either all the conditions have been considered or not. If yes, the last step is to run the load flow and the final losses recorded. However, if decision is no conditions were considered, then the next step is to run the load flow analysis and record the losses but after that, again, the consideration of VSI calculation needs to be made. Four cases were used in this paper. Those cases are as follows:

a) Apply both VSI and PSO
b) Apply only VSI
c) Apply only PSO
d) Without applying both PSO and VSI

Referring to Figure 2, the DGs are located at four chosen buses. The program then calculates the suitable size for each chosen bus. Each bus might have similar or different values which is determined by the program. Next, the total power loss in this system was calculated and displayed. The latest values were assumed as better than the values from the previous iteration(s). The current iteration number was checked in order to know whether the maximum iteration has been reached or not. If the maximum iteration has not been reached, it will repeat Step 2, if it has been reached, it will end the program.

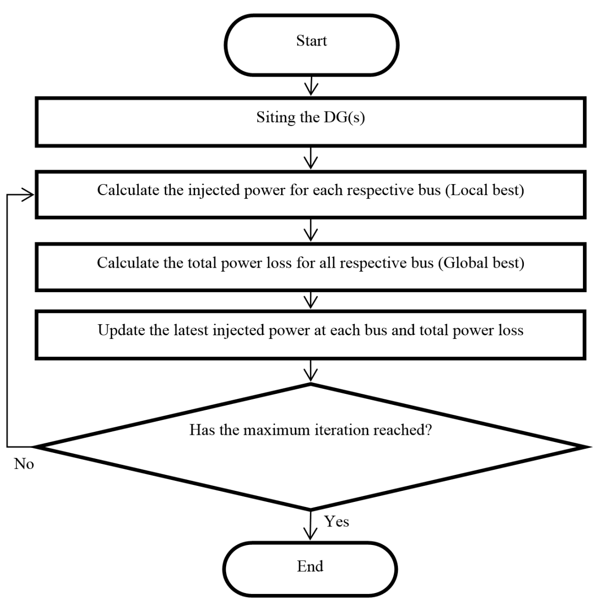


Figure 2. Flowchart of PSO implementation

RESULTS AND DISCUSSION

Table 2 presents the result of the total loss of 69-bus distribution system before and after the installation of DG units. The results showed that the total loss before installation of DG units is 0.166 MW. The total loss after DG units installation by using both PSO and VSI methods are the least compared with the other three conditions where it conserves the power by 74 kW. The least power conservation, which is 10 kW, was demonstrated by the system with installed DG units that inly applied PSO method. The other two conditions that applied VSI only or neither algorithm in the installation of DG units both decreased the power loss by 69 kW and 52 kW respectively. This proved that the system that installed DGs by applying both PSO and VSI successfully reduced 74 kW compared. This gives the system 44.6% reduction of total power loss.

Table 2
Result of the total power loss before and after installation of DGs

Conditions of Distribution System	Total Power Loss	
	Real Power (MW)	Reactive Power (Mvar)
Without DGs	0.166	0.132
With DGs (Considering VSI and PSO)	0.092	0.081
With DGs (Considering PSO)	0.156	0.119
With DGs (Considering VSI)	0.097	0.085
With DGs (Without considering VSI and PSO)	0.114	0.092

The first bar chart (see Figure 3) shows the system voltage profile without DGs installation and after DGs were installed using both VSI and PSO techniques. Bus 1 to 4 and 28 to 30 do not show any difference while Bus 4 displays a slight difference. This condition is due to the selection of location of installed DG. It can affect only the buses. The other buses display quite clear differences between these two states. The highest difference was shown at bus 27 which is 0.024 pu.

Figure 4 shows the difference between part of the system without DG installed and with the DG installed after only using PSO method to determine the amount of power that needs to be injected into the system while the location of the DGs was selected randomly. The pattern of this bar chart is quite similar to Figure 3. Bus 1 to 4 and 28 to 30 once again does not show any differences. The same goes to Bus 5 that only shows a slight difference. However, in this case, the voltage profiles are quite wavy and show higher differences between both conditions compared with the previous figure. Moreover, the largest difference of voltage magnitude is shown by Bus 16 which is 0.033 pu.

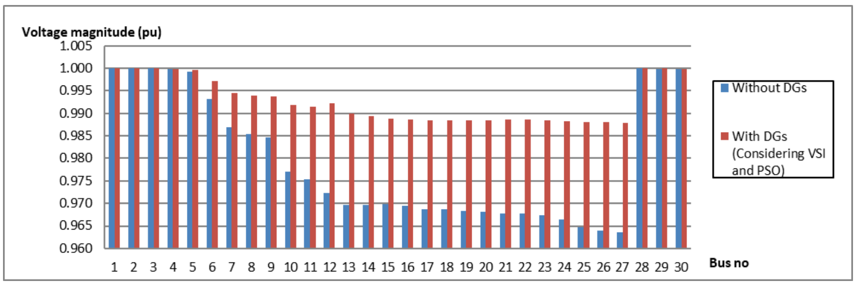


Figure 3. Voltage profile for the first thirty buses before and after installing the DG using VSI and PSO

As seen in Figure 5, the voltage profile after adding the DG units are also better, as shown in Figure 3 and Figure 4. The voltage profile shown in Figure 5 is pre-and post DG units installation but by only using the VSI method. Figure 5 shows quite similar patterns to Figure 3. However, there is a slight difference between these figures where the highest difference between both states was shown with Bus 12 by 0.023 pu.

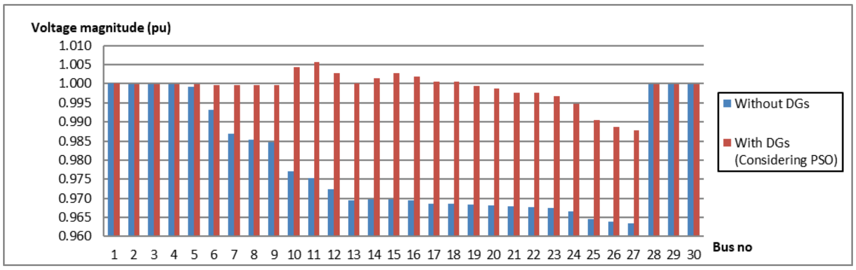


Figure 4. Voltage profile for the first 30 buses before and after installing the DG using PSO

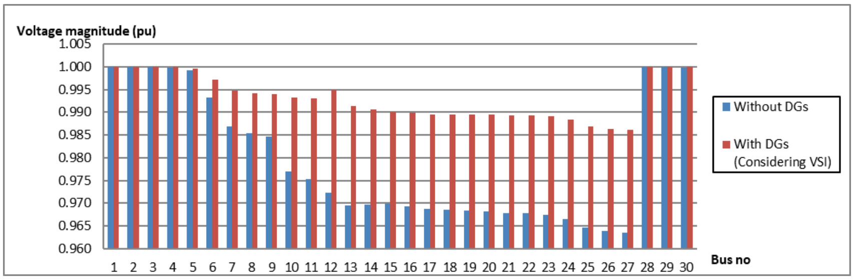


Figure 5. Voltage profile for the first 30 buses before and after installing the DG using VSI

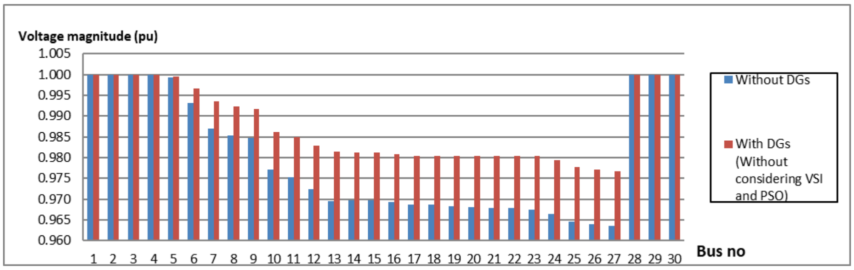


Figure 6. Voltage profile for the first 30 buses before and after installing the DG randomly

As for Figure 6, the DGs were added but at random locations and sizes. This figure shows the least difference of voltage magnitude for the two conditions between all four figures explained previously. Although the same bus as Figure 3 shows the highest difference of voltage magnitude, the value of the difference differs. For Figure 6, the difference is only 0.132 pu. This is the lowest difference shown by all four conditions.

CONCLUSION

This paper has presented two ways to optimise the installation of DGs in the 69-bus distribution system which is by using PSO and VSI. It can be concluded that the implementation of both methods improves the performance of the system with installed DGs. The total power loss was successfully reduced by 44.6%. At the same time, the voltage profile of the system has also improved in the aspect of stability as the system installed with DGs by applying both PSO and VSI showed more consistency. This paper proves that the use of both methods provides the most stable distribution system and the least total power loss. For future research, it is recommended to include a few systems for comparison. Moreover, comparing these methods to others is also good for the development of a better distribution system.

REFERENCES

Davis, M. W. (2002a). Distributed resource electric power systems offer significant advantages over central station generation and T & D power systems. I. I*EEE Power Engineering Society Summer Meeting*, 25-25 July 2002, Atlanta, USA.

Davis, M. W. (2002b). Distributed resource electric power systems offer significant advantages over central station generation and T & D power systems. II. *IEEE Power Engineering Society Summer Meeting*, 25-25 July 2002, Atlanta, USA.

Dulau, L. I., & Bica, D. (2015). Optimization of a power system with distributed generation sources. *13th International Conference on Engineering of Modern Electric Systems (EMES)*, 11-12 June 2015. Bucharest, Romania.

Gallano, R. J. C., & Nerves, A. C. (2014). Multi-objective optimization of distribution network reconfiguration with capacitor and distributed generator placement. *IEEE Region 10 TENCON 2014 Conference*, 22-25 Oct. 2014. Bangkok, Thailand.

Kai, Z., Agalgaonkar, A. P., Muttaqi, K. M., & Perera, S. (2008). Optimisation of distributed generation units and shunt capacitors for economic operation of distribution systems. *Australasian Universities Power Engineering Conference*. 14-17 Dec. 2008, Sydney, Australia.

Kayal, P., & Chanda, C. K. (2013). A simple and fast approach for allocation and size evaluation of distributed generation. *International Journal of Energy and Environmental Engineering, 4*(1), 1-9.

Nara, K., Ishizu, S., & Mishima, Y. (2005). Voltage control availability of distributed generators in power distribution system. *2005 IEEE Russia Power Tech.* 27-30 June 2005, St. Petersburg, Russia.

Rahman, T. K. A., Rahim, S. R. A., & Musirin, I. (2004). Optimal allocation and sizing of embedded generators. *National Power and Energy Conference*. 29-30 Nov. 2004, Kuala Lumpur, Malaysia.

Rugthaicharoencheep, N., Lantharthong, T., & Auchariyamet, S. (2011). Optimal operation for active management of distribution system with distributed generation. *International Conference on Clean Electrical Power*. 14-16 June 2011, Ischia, Italy.