TECHNO-ECONOMIC ASSESMENT FOR DISTRIBUTED GENERATION PLACEMENT IN DISTRIBUTION SYSTEM

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Abstrak

Makalah ini menyajikan fungsi yang diusulkan yang dikenal sebagai model techno-economic untuk penempatan optimal dari sumber daya distributed generation (DG) dalam sistem distribusi dalam rangka meminimalisir kehilangan daya dan meningkatkan profil tegangan. Combined sensitivity factors (CSF), seperti indeks pengurangan kehilangan daya nyata, indeks pengurangan kehilangan daya reaktif, indeks peningkatan profil tegangan, dan biaya siklus hidup, dan particle swarm optimization (PSO) diterapkan pada teknik yang diusulkan untuk mendapatkan persetujuan terbaik pada aspek biaya. Hasil simulasi pada sistem uji IEEE 14-bus disajikan untuk menunjukkan manfaat dari prosedur yang diusulkan.

Kata kunci: *Techno-economic model, renewable DG, CSF, PSO, IEEE 30-bus test system.*

Abstract

This paper presents a proposed function which is known as techno-economic model for optimal placement of distributed generation (DG) resources in distribution systems in order to minimize the power losses and improve voltage profile. Combined sensitivity factors (CSF), such real power loss reduction index, reactive power loss reduction index, voltage profile improvement index, and life cycle cost, and particle swarm optimization (PSO) are applied to the proposed technique to obtain the best compromise between these costs. Simulation results on IEEE 14-bus test system are presented to demonstrate the usefulness of the proposed procedure.

Keywords: *Techno-economic model, renewable DG, CSF, PSO, IEEE 30-bus test system.*

1. Introduction

Renewable Distributed generation (DG) is small-scale power generation that is commonly connected to distribution system. The injections of power from near located of renewable DG units to the loads offer the chance for energy losses reduction and system voltage provision [1-2]. Therefore careful considerations need to be completed when placing DGs in power systems. On the other hand, DG can also have disadvantages, such as frequency and voltage deviations, harmonics on network, and increase of power losses [3-4]. More over The optimal placement of renewable DG assure the lowest investment with a reasonable and full use of the DG.

Renewable DG placement problems of can be described as a single objective (SO) optimization problem or a multi-objective (MO) problem [5-8]. Realization the privatization process in electric industry into account, the economic factors gain importance. The renewable DG units have been then installed and operated not only with having the technical factors got run around, but also for lowering down the total amounts of cost. Far along the importance on both aspects, technical and economic aspects, should be balanced [9]. However, little works has been carried out in the area of integrating technical and economic aspects during design stages. Such a techno-economic model assessment would help determine the size of optimal renewable DG [10].

With the commitment of multiple objectives which is techno-economic model, the optimal placement of renewable DG units in distribution grid can be modelled as a non-deterministic polynomial optimization problem. The heuristic methods are more suitable to decide such complex problems [11]. The intelligent search based population methods, such as Particle swarm optimization (PSO) is proposed to find solutions with faster convergence. Then, the benefits of PSO are easy to implement and only a few parameters to adjust [12].

This paper is organised as follows: A research method is offered on Section 2. Research and analysis is presented on Section 3, while the conclusion followed by the references is described on Section 4.

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2. Research Method

In common, the real power loss reduction proves more consideration for the utilities because of decreasing the proficiency during delivering energy process. But, reactive power loss is seemingly not less important because it makes the possibility for delivering real power through lines to customers. Henceforth the flow of reactive power has to be well-maintained in the system at a guaranteed voltage level [13-15].

The real power flow and reactive power of power system flow in a line connecting two buses and can be described as:

$$P_{ij} = V_i V_j Y_{ij} \cos\left(\theta_{ij} + \delta_{ij}\right) - V_i^2 Y_{ij} \cos\theta_{ij}$$

$$Q_{ij} = V_i V_j Y_{ij} \sin\left(\theta_{ij} + \delta_{ij}\right) - V_i^2 Y_{ij} \sin\theta_{ij} - \frac{V_i^2 Y_{sh}}{2} \tag{1}$$

The real power and reactive power losses a line of power system in connecting two buses can be stated as:

$$P_{L(ij)} = g_{ij}\left(V_i^2 + V_j^2 - 2V_i V_j \cos\delta_{ij}\right)$$

$$Q_{L(ij)} = -b_{ij}^{sh}\left(V_i^2 + V_j^2\right) - b_{ij}\left(V_i^2 + V_j^2 - 2V_i V_j \cos\delta_{ij}\right) \tag{2}$$

From these equations, power flow sensitivity factor can be evaluated:

$$\begin{bmatrix} \frac{\partial P_{ij}}{\partial P_n} \\ \frac{\partial P_{ij}}{\partial Q_n} \end{bmatrix} = \begin{bmatrix} F_{P-P} \\ F_{P-Q} \end{bmatrix} = [J^T]^{-1} \begin{bmatrix} \frac{\partial P_{ij}}{\partial \delta} \\ \frac{\partial P_{ij}}{\partial V} \end{bmatrix} \tag{3}$$

$$\begin{bmatrix} \frac{\partial Q_{ij}}{\partial P_n} \\ \frac{\partial Q_{ij}}{\partial Q_n} \end{bmatrix} = \begin{bmatrix} F_{Q-P} \\ F_{Q-Q} \end{bmatrix} = [J^T]^{-1} \begin{bmatrix} \frac{\partial Q_{ij}}{\partial \delta} \\ \frac{\partial Q_{ij}}{\partial V} \end{bmatrix} \tag{4}$$

And power loss sensitivity factor can be assessed:

$$\begin{bmatrix} \frac{\partial P_{L(ij)}}{\partial P_n} \\ \frac{\partial P_{L(ij)}}{\partial Q_n} \end{bmatrix} = \begin{bmatrix} S_{P-P} \\ S_{P-Q} \end{bmatrix} = [J^T]^{-1} \begin{bmatrix} \frac{\partial P_{L(ij)}}{\partial \delta} \\ \frac{\partial P_{ij}}{\partial V} \end{bmatrix} \tag{5}$$

$$\begin{bmatrix} \frac{\partial Q_{L(ij)}}{\partial P_n} \\ \frac{\partial Q_{L(ij)}}{\partial Q_n} \end{bmatrix} = \begin{bmatrix} S_{Q-P} \\ S_{Q-Q} \end{bmatrix} = [J^T]^{-1} \begin{bmatrix} \frac{\partial Q_{L(ij)}}{\partial \delta} \\ \frac{\partial Q_{ij}}{\partial V} \end{bmatrix} \tag{6}$$

Both power flows and power losses can be integrated into the form of factor of combined sensitivity (CSF) as follows:

$$CSF_i = \left(F_{P-P_i} \times F_{Q-P_i}\right) + \left(F_{P-Q_i} \times F_{Q-Q_i}\right) + \left(S_{P-P_i} \times S_{Q-P_i}\right) + \left(S_{P-Q_i} \times S_{Q-Q_i}\right) \tag{7}$$

The performance calculation (MOF) of multi-objective function for renewable DG placement in distribution systems:

$$MOF = 0.3PLRI + 0.2QLRI + 0.2VPI + 0.3LCC \tag{8}$$

Where PLRI is real power loss reduction index, QLRI is reactive power loss reduction index, PVII is voltage profile improvement index, and LCC is life cycle cost.

The planned multi-objective function is reduced subject to various electrical requirements for the distribution grid, such as load regulation, power limits of generators, voltage limits, and power limits of distributed generations. The load regulations for every bus should be achieved.

$$P_{gni} - P_{dni} - V_{ni} \sum_{j=1}^{n} V_{nj} Y_{nj} \cos(\delta_{ni} - \delta_{nj} - \theta_{nj}) = 0 \tag{9}$$

The upper and lower real and reactive power generation limits of generators at bus-i;

$$P_{gi}^{min} \leq P_{gi} \leq P_{gi}^{max}, \; i = 1,2,\dots,N_g \qquad Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max}, \; i = 1,2,\dots,N_q \tag{10}$$

The voltage could be reserved within standard limits at every bus;

$$V_i^{min} \leq V_i \leq V_i^{max}, \; i = 1,2,\dots,N_b \tag{11}$$

The upper and lower real and reactive power generation limits of renewable DG connected at bus-i;

$$P_{DGi}^{min} \leq P_{DGi} \leq P_{DGi}^{max}, \; i = 1,2,\dots,N_{DG} \qquad Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max}, \; i = 1,2,\dots,N_q \tag{12}$$

The proposed PSO based method for optimal placement of renewable DG in distribution system is shown in Fig. 1.

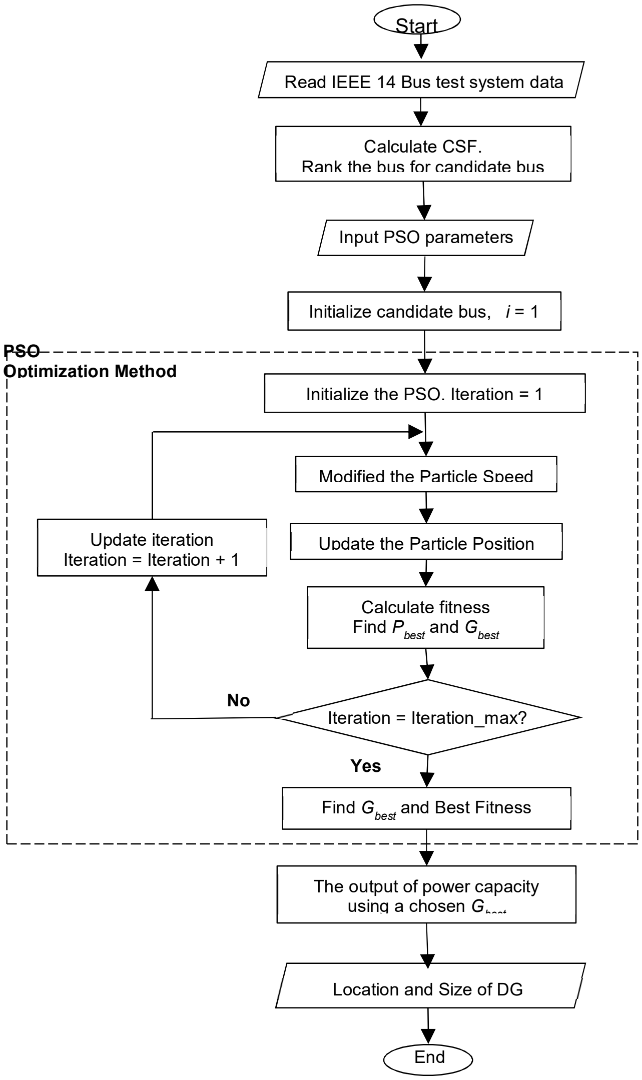

Fig. 1. Flowchart of proposed algorithm

Research Results

The single line diagram of IEEE 14 Bus test system is shown in Fig. 2. While grid data and line data are shown in Table 1 and 2.

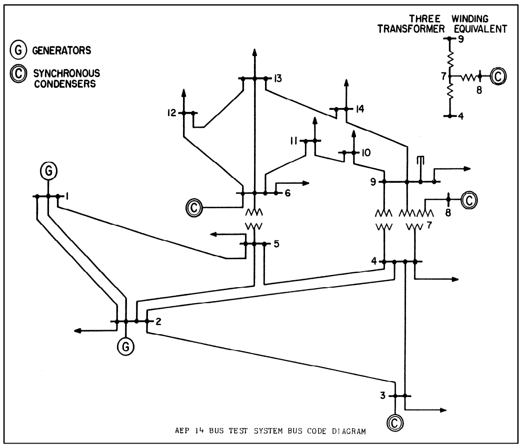

Fig.2. Single line diagram of Test System [16]

Table 1: Bus Data of IEEE 14 Bus System

No. Bus	Tipe	Bus Voltage		Generation		Load		Reactive Power Limit	
		Mag (pu)	Angle (°)	Active Power (pu)	Reactive Power (pu)	Active Power (pu)	Reactive Power (pu)	Q $_{min}$ (pu)	Q $_{max}$ (pu)
1.	Swing	1,060	0	0	0	0	0	0	0
2.	PV	1,043	0	40	42,4	21,7	12,7	-40	50
3.	PQ	1,01	0	0	23,4	94,2	19,1	0	40
4.	PQ	1,06	0	0	0	47,8	0	0	0
5.	PQ	1,00	0	0	0	7,6	1,6	-40	40
6.	PV	1,07	0	0	12,2	11,2	7,5	-6	24
7.	PQ	1,00	0	0	0	0,0	0,0	0	0
8.	PV	1,09	0	0	17,4	0,0	0,0	-6	24
9.	PQ	1,00	0	0	0	29,5	16,6	0	0
10.	PQ	1,00	0	0	0	5,8	2,0	0	0
11.	PQ	1,00	0	0	0	0,9	5,8	-6	0
12.	PQ	1,00	0	0	0	6,1	1,6	0	0
13.	PV	1,00	0	0	0	13,5	5,8	-6	24
14.	PQ	1,00	0	0	0	`14,9	5,0	0	0

Table 2: Line Data of IEEE 14 Bus System

No. Bus	Tipe	Bus Voltage		Generation		Load		Reactive Power Limit	
		Mag (pu)	Angle (°)	Active Power (pu)	Reactive Power (pu)	Active Power (pu)	Reactive Power (pu)	Q $_{min}$ (pu)	Q $_{max}$ (pu)
1.	Swing	1,060	0	0	0	0	0	0	0
2.	PV	1,043	0	40	42,4	21,7	12,7	-40	50
3.	PQ	1,01	0	0	23,4	94,2	19,1	0	40
4.	PQ	1,06	0	0	0	47,8	0	0	0
5.	PQ	1,00	0	0	0	7,6	1,6	-40	40
6.	PV	1,07	0	0	12,2	11,2	7,5	-6	24
7.	PQ	1,00	0	0	0	0,0	0,0	0	0
8.	PV	1,09	0	0	17,4	0,0	0,0	-6	24
9.	PQ	1,00	0	0	0	29,5	16,6	0	0
10.	PQ	1,00	0	0	0	5,8	2,0	0	0
11.	PQ	1,00	0	0	0	0,9	5,8	-6	0
12.	PQ	1,00	0	0	0	6,1	1,6	0	0
13.	PV	1,00	0	0	0	13,5	5,8	-6	24
14.	PQ	1,00	0	0	0	`14,9	5,0	0	0

The CSF all buses of test system were calculated based on Eq. 7. Candidate buses were chosen by selecting CSF values more than 0.8. The optimal placements of the renewable DGs could be able to select by cautiously looking at all the candidate buses, shown in Table 3.

Table 3: Resuls for CSF, Fitness, and optimal DG sizes for candidate buses

Candidate Bus	CSF	Fitness	DG size (MW)
8	0,9180	0,8817	1,8447
9	0,8437	0,8821	1,9407
10	0,9112	0,8820	1,9097
14	0,8171	0,8815	1,7891

The results obtained for the real power losses and voltage levels was completed using Newton-Raphson load flow. It can be got in Table 4 that the presence of the DGs does not effect to deviation of voltage levels outside the acceptable limits [17]. Obviously, all of the bus voltages were in the range of 1.0 pu to 1.1 pu. And Renewable DG gave obvious real power loss reduction, shown in Table 5.

Table 4: Comparison of Bus Voltage using DG

Bus No.	Voltage without DG (pu)	Voltage with DG (pu)
1	1,0600	1,0600
2	1,0350	1,0350
3	0,9957	0,9961
4	1,0023	1,0031
5	1,0067	1,0074
6	1,0500	1,0500
7	1,0335	1,0341
8	1,0700	1,0700
9	1,0162	1,0169
10	1,0167	1,0178
11	1,0297	1,0302
12	1,0295	1,0294
13	1,0200	1,0200
14	0,9992	1,0011

Table 5: Comparison of Results using DG

Bus No.	DG size (MW)	Power Losses (MW)	Power Loss Reduction (MW)	Power Loss Reduction Percentage (%)
10	1.9097	12.5173	0.4202	3.25
14	1.7891			

3. Conclusion

This paper showed implementation of Techno-economic model based on PSO algorithm for system loss reduction and voltage profile improvement in distribution system by optimizing the location and size of renewable DG units. The combined sensitivity factors were used effectively in reducing the amount of candidate placements for renewable DG. As results, this optimization technique gave obvious loss reduction considered using this distribution system. The percentage real power loss reduction was 0.4202 MW or 3.25 %. Meanwhile all of bus voltages after integrating renewable DGs was maintained at acceptable limits.

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