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Power losses reduction of power transmission network using optimal location of low-level generation

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ABSTRACT

Due to the growth of demand for electric power, electric power loss reduction takes great attention for the power utility. In this paper, a low-level generation or distributed generation (DG) has been used for transmission power losses reduction. Karbala city transmission network (which is the case study) has been represented by using MATLAB m-file to study the load flow and the power loss for it. The paper proposed the particle swarm optimization (PSO) technique in order to find the optimal number and allocation of DG with the objective to decrease power losses as possible. The results show the effect of the optimal allocation of DG on power loss reduction.

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1. INTRODUCTION

Losses reduction has great deals in power systems utility because the rising in cost of delivering electricity due to fuel cost rising to generate more power, and the global warming discomfort [1, 2]. Low-level generation is increasing in the last year because its great effect on improving electric network performance. It is defined as a low-level power generation source connected to the distribution network [3, 4]. It is used as another method to enhance the performance of electric power system [5, 6].

The positive effects of using this technique are as follows [7-11]:

- Decreasing power losses in transmission lines.
- Improving voltage level.
- Improving power quality.
- Short lead time.
- Its location near the load.
- Decreases cost.
- Maximum power demand reduction.
- Improving electric system reliability.
- Efficiency improving of the system.
- Possibility of renewable energy use.
- Reduced environmental impacts.
- Optimization techniques required for best number, size and placement of the low-level generation units [12-15].

In this work, the optimal number and location of low-level generation will be performed by using particle swarm optimization technique. PSO algorithm was incentive by the public behavior of creature such as fish and bird learning. PSO delivers a population-based explore process, in this process the individuals called particles (birds) to transposition their location (state) with time [16, 17]. In a PSO, particles (birds) fly round a multidimensional space. During the flying, each bird regularizes its location according to its private experiment, and the experiment of adjacent birds, making use of the optimal location accomplished by itself and its adjacent birds [18]. The direction of the swarm of a particle is recognized by the set of birds adjacent to the bird that want to optimize its location and its historical experiment [19, 20].

2. KARBALA CITY TRANSMISSION NETWORK DESCRIPTION

Karbala city transmission network shown in Figure 1 is correlating to the Iraqi power grid at three stations (Babylon (400/132/11) KV, Mussayab (400/132/11) KV, Khairat (400/132/11) KV. The Karbala transmission network consists from eleven substations; they are shown as follows:

- Five generation buses 1, 2, 3, 4, 5 that shown in Figure 1.
- Six load buses 6, 7, 8, 9, 10, 11 that shown in Figure 1.
- These substations connected by twelve transmission lines as shown in Figure 1.

Bus data and line data are illustrated in Tables (A.1) and (A.2) are shown in appendix.

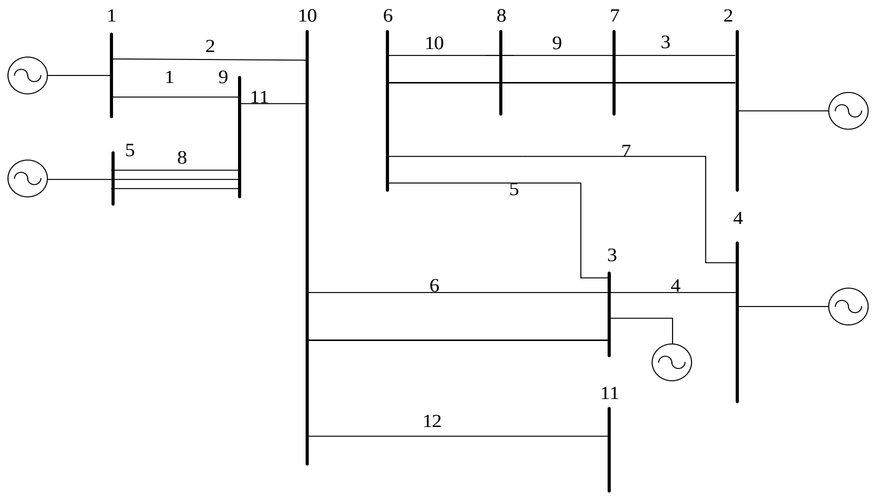

Figure 1. Karbala city transmission network

3. PROBLEM FORMULATION

3.1. Load flow analysis

At this work, both Newton-Raphson power flow method and PSO algorithm were used in the restriction of the optimum number and location of low-level generation units [21]. The Newton-Raphson power flow equation, at any given bus *i* and *j* are given as:

$$P_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \quad (1)$$

$$Q_i = -\sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \quad (2)$$

$$\Delta P_i = P_i^{sp} - P_i \quad (3)$$

$$\Delta Q_i = Q_i^{sp} - Q_i \quad (4)$$

where,

P_i^{sp} , Q_i^{sp} are the specified active and reactive power at the bus *i* respectively.

N-R load flow is expressed as:

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} \frac{\partial P}{\partial \delta} & \frac{\partial P}{\partial V} \\ \frac{\partial Q}{\partial \delta} & \frac{\partial Q}{\partial V} \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta |V| \end{bmatrix} \quad (5)$$

The power loss required for the optimal location and size of the low-level generation units determination given in equation below:

$$P_{Loss} = \sum_{i-1}^{n} \sum_{j=1}^{n} (\frac{R_{ij} \cos(\delta_i - \delta_j)}{V_i V_j})(P_i P_j + Q_i Q_j) + (\frac{R_{ij} \sin(\delta_i - \delta_j)}{V_i V_j})(Q_i P_j - P_i Q_j) \quad (6)$$

where,
P_i , P_j, Q_i, Q_j: Active and reactive power of buses *i* and *j* respectively.
R_{ij} : Resistance of line between bus *i* and *j*.
V_i , V_j : The magnitude of bus voltage *i* and *j* respectively.
δ_i, δ_j : Voltage angle of bus *i* and bus *j* respectively.

3.2. PSO formulation

As discuss earlier; in a PSO, birds get about round a multi- dimensional space expecting to optimal solution. During the flying, each bird regularizes its location according to its own experiment, and the experiments of adjacent birds, best location accomplished by itself and its adjacent birds has been used. According to that two significant best values results, one of these values is called $pbest$ (personal best) and another best value is the $gbest$ (global best) [22]. These values are the optimal values that has realized by any birds in the swarm. Each bird tries to change its location to a better location depending on the information listed below:
- The current positions and velocities.
- The distance between current position and $pbest$
- The distance between current position and $gbest$

The position *(xi)* and velocity *(vi)* of particle *i* can be updated using (7) and (8) respectively:

$$v_i^{k+1} = \omega v_i^k + c_1 rand \times (pbest_i - s_i^k) + c_2 rand \times (gbest_i - s_i^k) \quad (7)$$

$$x_i^{k+1} = x_i^k + v_i^{k+1} \quad (8)$$

where,
c_1, c_2 : Positive constants.
$rand$: Random number in the range of 0 and 1.
ω : Weight inertia.
The target of the optimal location algorithm is to decrease the total power loss of the power system, P_{Loss} in (6). Flowchart of PSO shown in Figure 2.

3.3. Active power loss index P_{L_index}

The active power loss index is defined as:

$$P_{L\_index} = \left(\frac{P_{L\_wDG}}{P_{L\_woDG}}\right) \times 100\% \quad (9)$$

where;
P_{L_wDG} is the active power loss with DG.
P_{L_woDG} is the active power loss without DG.
The lower value of this index indicates better operation of the power system in terms of active power loss reduction happened according to DG positioning and sizing [23-25].

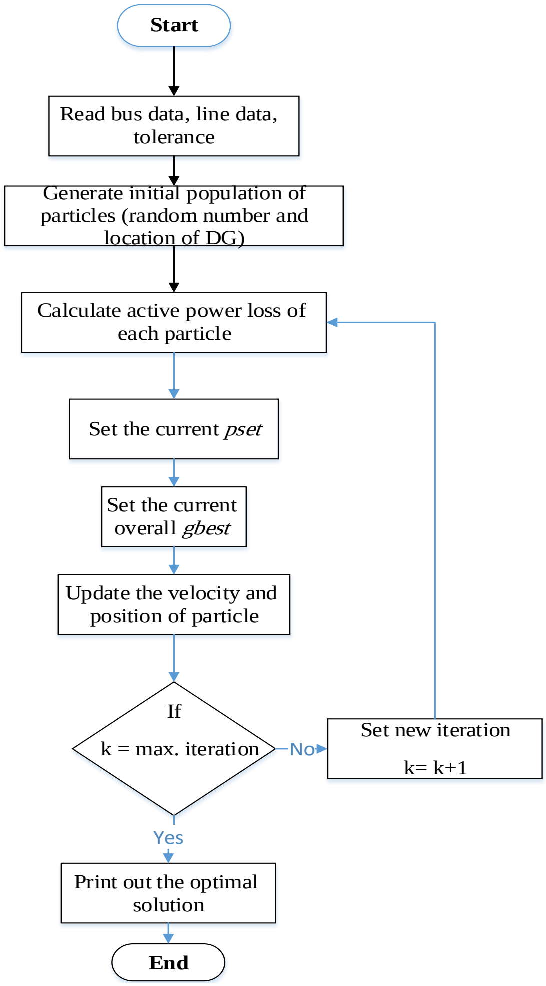

Figure 2. Flowchart for PSO of low-level generation optimal installation

4. RESULTS AND ANALYSIS

Karbala city transmission network has been analyzed by using MATLAB m-file to show the effect of using low-level generation in the transmission network. In the program the constrains for optimal size and location of low –level generation to be added to the network is selected as:

- The size of low–level generation not exceed 30 MW.
- It located at the load busses 6, 7, 8, 9, 10, 11 of the transmission networks.

PSO technique used to show optimal location for low-level generation installation as illustrated in the Table 1. From Table 1, the results show that the total losses for the system without low-level generation unitsis bigger than the total losses with low-level generation units; it is 39.507 MW without DG while it becomes less when a low-level generation unit used. Also, using PSO helps to select an optimal number and location of low-level generation units used to decrease the power losses as possible. It's obvious from the results that the optimal number is one low-level generation unit with a size of 30 MW and located at the bus no. 7 which is a heavy loaded bus as shown in Appendix A Table (A.1). Table 2 lists the real power loss index for the system at different cases of DG insertion.

Table 1. Total power losses with and without using of low-level generation units

No. of DG	Size of DG (MW)	Location	Total loss (MW)
Without DG			39.507
3	10, 10, 10	6, 7, 10	30.067
2	15, 15	6, 7	29.564
1	30	7	26.549

Also, using of low-level generation units in optimal location helps to decrease the losses in active power and that is affect the real power loss index. The results show that a lower real power index is achieved in case 3 (witch is indicate an optimal location and size for the low-level generation unit), where the index becomes 0.671 while it is 0.7609 in case 1, this indicates that optimal location of low-level generation units insertion helps to decrease the active power loss.

Table 2. Real power loss index

Case	No. of DG	Size of DG (MW)	Location	P_{L_index}
1	3	10, 10, 10	6, 7, 10	0.7609
2	2	15, 15	6, 7	0.7107
3	1	30	7	0.671

5. CONCLUSION

PSO technique used to show optimal number location and size of low-level generation for a transmission network to reduce the total loss of the power system. The proposed optimization algorithm was applied to Karbala city (132/33) Kv. From the analysis and results shows above, it's clear that using of low-level generation helps to improve the performance of the transmission network and decreases the total losses for the system. Also, the selection of optimal location for low-level generation units is near the heavy loaded bus and this installation helps to decrease the total losses and improving the performance.

APPENDIX

Bus data and line data are illustrated in Tables (A.1) and (A.2).

Table (A.1). Karbala 132KV bus data

Bus no.	Bus Name	Type	V(pu)	δ	Pg (Mw)	Qg (Mw)	PL (Mw)	QL (Mw)
1	Mussayab	1	1.0	0	0	0	0	0
2	Babylon	2	1.0	0	135	65.383	0	0
3	alghazia	2	1.0	0	96.3	46.545	0	0
4	Khairat	2	1.0	0	135	65.383	0	0
5	STX	2	1.0	0	99	47.85	0	0
6	West of Karbala	3	1.0	0	0	0	154	74.585
7	Hindia	3	1.0	0	0	0	198.5	96.137
8	South of Karbala	3	1.0	0	0	0	164	79.428
9	East of Karbala	3	1.0	0	0	0	123	
10	North of Karbala	3	1.0	0	0	0	150.8	73.03
11	Al- Okhaider	3	1.0	0	0	0	16.3	7.89

Table (A.2). Karbala 132KV line data

Line no.	From Bus	To Bus	R(pu)	X(pu)
1	1	9	0.016367	0.091959
2	1	10	0.021934	0.123238
3	2	7	0.005479	0.030788
4	3	4	0.009600	0.053939
5	3	6	0.012024	0.067561
6	3	10	0.015810	0.088831
7	4	6	0.020985	0.117908
8	5	9	0.007126	0.040038
9	7	8	0.007744	0.043514
10	8	6	0.005941	0.033380
11	9	10	0.005567	0.031278
12	10	11	0.039592	0.222454

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