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USING TLBO ALGORITHM IN DISTRIBUTED GENERATOR PLACEMENT TO REDUCE POWER LOSS

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ABSTRACT

In this study, we examine optimization of distributed generators (DGs) placement in power distribution system. In addition to the problem of reducing losses in the distribution system, we attempt to reduce the use of DGs in number and capacity each needs for load flow as much as possible. We used Teaching-Learning Based Optimization (TLBO) algorithm for the optimization of cost function. We implemented this algorithm with the placement of 2, 3 and 4 generators in an IEEE 14-bus distribution system. Our study results showed that power loss when using TLBO algorithm, is reduced.

Keywords: TLBO, distributed generators, distribution system, placement, teaching-learning based optimization.

INTRODUCTION

Distribution systems act as an association between transmission and consumption systems that consume electric power with lower voltage and greater current. Rate of loss is the most important factor determining the proper functioning of electricity distribution system (Chiradeja and Ramakumar, 2004). Load flow in common transmission system is influenced by network topology and planning for different plant unit generations. However, the flow network structure and production planning used in many cases cannot be taken as the best situations ever as they do not normally include the lowest losses. In fact, it can be said that by altering network structure in various forms as well as planning for optimal generation, system Load flow can be altered in such a way that less loss from former values remain, which is called optimal power distribution. Normally, for the whole power systems, the highest share of losses is associated with distribution system. However, this issue results from the vast range and a multitude of available utilities in a system along with a bunch of others reasons including single-phase loads and low voltage level. In recent years, the electricity industry has been persuaded to venture into a restructured environment. Therefore, alternatives to use sources of distributed generation (DG) are economically important in order to make such purposes come true. A number of recent year events in the international domain have led to form a new environment to develop electric power. Such events include public objection to new transmission line in the surrounding environment, public awareness of the environmental impacts, electric power generation, rapid increase in the demand for electric power, remarkable benefits in a number of power generation technologies (electricity generated by wind, micro-turbines, cell and photovoltaic), the increase in public demand for promotion of renewable energy sources, and the awareness of DG potential in the improvement of electric power security. All of the above scenarios have given rise to the development and application of DG. The key factor in the new environment is the utilization of several DG units near load centers, instead of building and developing plants far away from consumers (Bayegan, 2001). DG technologies include photovoltaic, internal combustion engines, combustion turbines, wind turbines, micro turbines, and fuel cells. The magnitude of DG in distribution networks may cause technical and security problems. Depending on its place, DG may enhance false flow, voltage fluctuation, interference with voltage control processes, reduction or increase of losses, etc. There are thus a few important factors that should be bore in mind; namely place and function of DG in minimizing losses and voltage sag with respect to distribution network management. In addition to this, it is necessary to examine whether the placement of DG can lead to increase operation and improve distribution network planning. Based on the placement of DG, real and reactive power loss optimization, line load and mega-volt ampere (MVM) absorbed by PSO algorithm contained network have been conducted. A new formulation for optimized distributed generation problem has been proposed by Biswas *et al*. (2012) where a hybrid

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combination of technical factors such as minimization of voltage sags and economic factors such DG installation has been taken into account. Akorede *et al*. (2011), in order to find the location and optimal size of DG in the distribution system, considered maximization of network loading margin as well as the profit of distribution companies as the main Cost function. According to contributing indices in distribution networks as well as on the basis of relevant engineers' experience, Ochoa *et al*. (2006) accomplished the placement. In the present study, with the help of TLBO algorithm, we try to examine the reduction of power loss in distribution systems.

MATERIALS AND METHODS

Load Flow Techniques

With the increasing penetration of distributed generation, distribution network is changing from a passive network (to which loads are only connected) to an active network (which includes loads and producers). This requires us to make some changes in distribution analyses strategies. As a key tool inpower system analysis whether in design and planning stage or in operation stage, load flow scheme is concerned. One of the latest challenges of load flow calculation is the penetration of distributed generation in distribution network. In the presence of distributed generation, common methods of load flow are no longer operable as it is deemed necessary to make some changes in these practices so that DGs can be generally modelled as PQ or PV nodes and introduced to calculation (Ambriz-Perez *et al*., 2000). Load flow study is one of the main studies to determine steady behavior of distribution system.

One of the most important issues in power systems is the calculation of load flow, which is performed for steady state and symmetric network. The load-flow calculation is one of the most fundamental components in the analysis of power systems and is the cornerstone for almost all other tools used in power system simulation and management, where the given (complex) parameters are the admittance matrix Y_{ik}, the bus shunt admittances Y_i^{sh}, and the bus power injections S_i representing constant-power loads and generators. A power-flow study usually uses simplified notation such as a one-line diagram and per-unit system, and focuses on various aspects of AC power parameters, such as voltages, voltage angles, real power and reactive power. It analyzes the power systems in normal steady-state operation. The goal of a power-flow study is to obtain complete voltage angle and magnitude information for each bus in a power system for specified load and generator real power and voltage conditions (Grainger and Stevenson, 1994).

The solution to the power-flow problem begins with identifying the known and unknown variables in the system. The known and unknown variables are dependent on the type of bus. System buses are invariably classified into three classifications:

- *Reference bus or slack:* the bus which is known as generator bus is considered as reference bus or slack. The angle of the bus is 0° and its voltage is usually 1 per unit. After load flow calculation, generation deficiency and system loss have to be compensated by the bus. The bus is normally called number 1 bus. For this bus |V|and δ are known, and P and Q are unknown.
- *Voltage controlled buses:* the buses have generators and are known as voltage controlled buses or PV buses, because in this type of buses voltage and real power are known. In doing calculations, we are required to find the magnitude of phase and reactive power of the buses.
- *Load buses*: in this type of buses, real and reactive powers are known, and the voltage and phase are unknown and need to be calculated. The buses are also called PQ buses.

There are a number of different mathematical techniques used for load flow study including Newton-Raphson (Tinney and Hart, 1967), Gauss-Seidel (Ward and Hale, 1956) Decoupled, Fast Decoupled (Stott and Alsac , 1974), Probabilistic load flow (Barkowska, 1974), Direct Current Load Flow (DCLF) (Scott *et al*., 2009), and Holomorphic Embedding Load-flow Method (HELM) (Trias, 2009). The important goals of these methods for the analysis of power flow are: applicability of these methods to large and complex real power system, and convergence of the iterations (Ackovski, 1989; Todorovski, 1995; Zhu, 2009; Čepin, 2011).

The most popular method to solve non-linear system is Newton-Raphson method. In this method, we begin with initial guesses. Next, a Taylor series is written for equations, with the higher order terms ignored. The result of this is to convert a nonlinear system into a linear system that can be expressed as:

$$\begin{bmatrix} \Delta\theta \\ \Delta|V| \end{bmatrix} = -J^{-1} \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} \quad (1)$$

Where ΔP and ΔQ are obtained from the following equations which called "mismatch equations":

$$\Delta p_i = -p_i + \sum_{k=1}^{n} |V_i||V_k|(G_{ik}\cos\theta_{ik} + B_{ik}\sin\theta_{ik}) \quad (2)$$

$$\Delta Q_i = -Q_i + \sum_{k=1}^{n} |V_i||V_k|(G_{ik}\sin\theta_{ik} + B_{ik}\cos\theta_{ik}) \quad (3)$$

J is known as Jacobian matrix :

$$J = \begin{bmatrix} H & N \\ J & L \end{bmatrix}, \; J = \begin{bmatrix} \frac{\partial \Delta P}{\partial \theta} & \frac{\partial \Delta P}{\partial |V|} \\ \frac{\partial \Delta Q}{\partial \theta} & \frac{\partial \Delta Q}{\partial |V|} \end{bmatrix} \quad (4)$$

Voltage magnitude and angles for next guess are calculated by the following equation:

$$\theta^{m+1} = \theta^m + \Delta\theta$$
$$|v|^{m+1} = |V|^m + \Delta|V| \quad (5)$$

The iterations continue until ΔP and ΔQ are below a specified tolerance. The flowchart of Newton-Raphson method can be seen in figure 1. In Newton-Raphson method, the number of iteration to reach a solution is low. That is, the number of iteration does not depend on the number of buses and the speed of achieving a solution is high. This is a sustainable method, and is mostly a convergent method as obtained solutions are more accurate in this case.

Teaching-learning based optimization (TLBO)

Teaching-learning based optimization (TLBO) is new efficient optimization method proposed by Rao *et al*. (2011 a,b) and Rao and Patel (2012) which simulates the traditional teaching-learning phenomenon of a classroom. It is similar to the ant colony optimizer (ACO) proposed by Dorigo *et al*. (1992), harmony search (HS) developed by Geem *et al*. (2001) and particle swarm

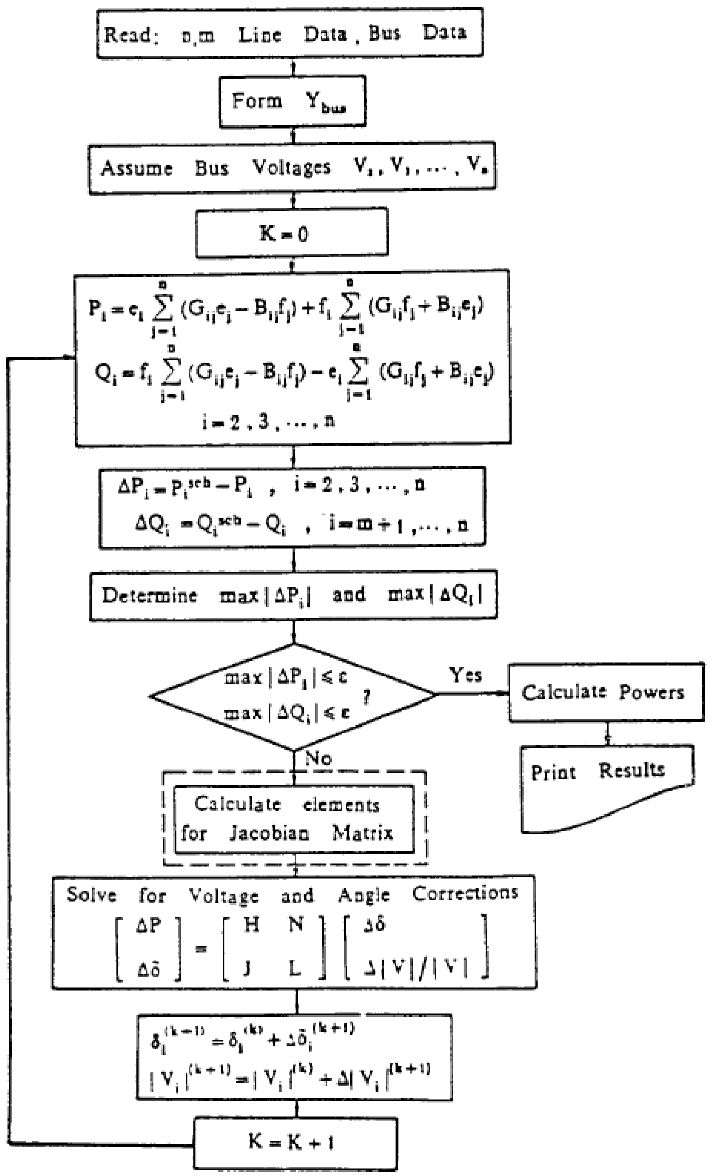

Fig. 1. A Flowchart for Newton-Raphson method (Source: www.motodrive.ir)

optimizer (PSO) created by Kennedy *et al*. (1995). This algorithm simulates two main methods of learning: (a) by teacher (teacher phase) and (b) interaction with other learners (learner phase). TLBO is a population-based algorithm, where a group of students (i.e. learner) is considered the population and the different subjects offered to the learners are analogous with the different design variables of the optimization problem. The best solution in the entire population is considered as the teacher (Rao *et al*., 2011a; Rao and Patel, 2013).

In this method, N is number of learners in a class *i.e*. "class size"; D is number of courses offered to the learners, and *MAXIT* represents maximum number of allowable iterations. The population X is randomly initialized by a search space bounded by matrix of N rows and D columns. The *jth* parameter of the *it* learner is assigned values randomly using following equation: (Satapathy *et al*., 2012)

$$x_{(i,j)}^{0} = x_j^{\min} + rand \times \left(x_j^{\max} - x_j^{\min} \right) \quad (6)$$

Where *rand* is a uniformly distributed random variable within 0 and 1, $x_j^{\min}$ and $x_j^{\max}$ are the minimum and maximum value for *j*th parameter. The parameters of learner for the generation g are given by:

$$x_{(i)}^{g} = \left[x_{(i,1)}^{g}, x_{(i,2)}^{g}, x_{(i,3)}^{g}, \dots, x_{(i,j)}^{g}, \dots x_{(i,D)}^{g} \right] \quad (7)$$

Figure 2 shows flowchart for TLBO. For more information and details, see Rao *et al*., (2011a).

RESULTS AND DISCUSSION

Implementation of TLBO Technique on a Distribution System

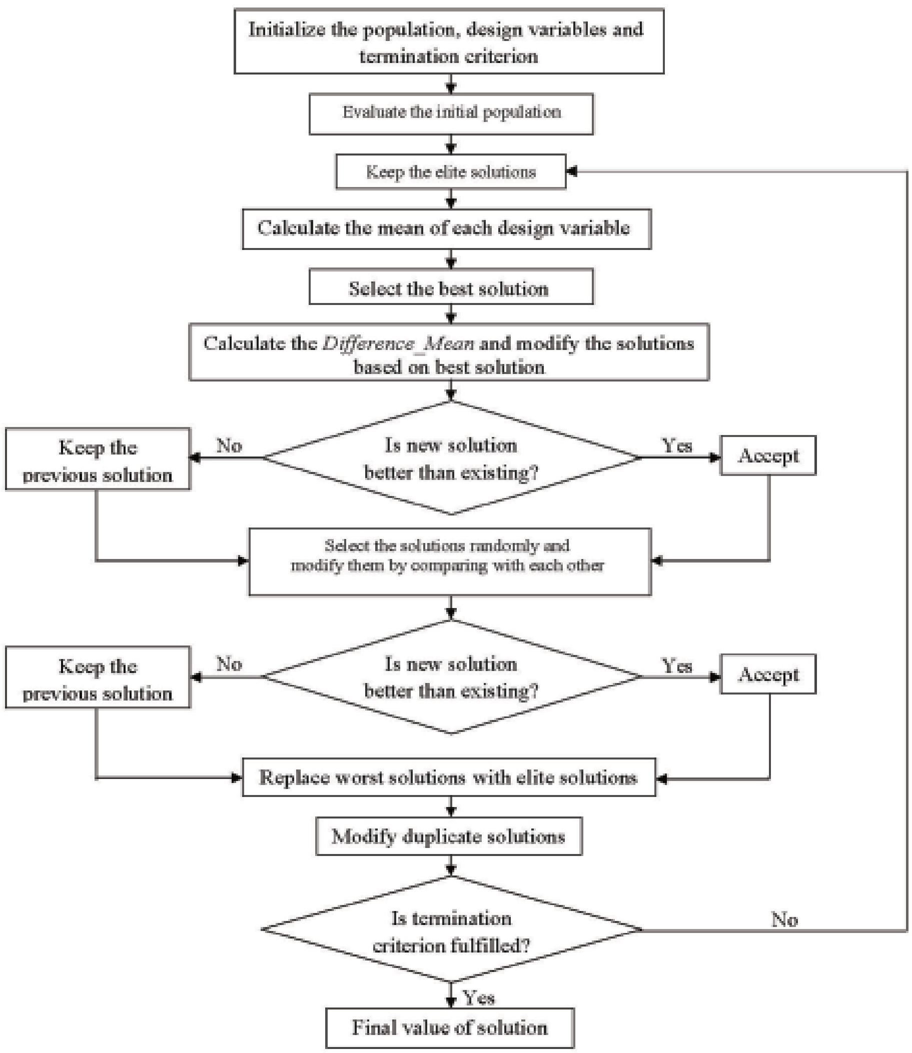

Fig. 2. Flowchart for TLBO (Rao *et al*., 2011a).

In this section, we implement TLBO in an IEEE 14-bus system shown in figure 3. Real and imaginary values of IEEE 14-bus system is presented in table 1. Three different scenarios were used for generator placement.

Table 1. Real and imaginary values of IEEE 14-bus system.

From bus	To bus	R(pu)	X(pu)	B/2(pu)	X'mer TAB (a)
1	2	0.01938	0.05917	0.0264	1
1	5	0.05403	0.22304	0.0246	1
2	3	0.04699	0.19797	0.0219	1
2	4	0.05811	0.17632	0.017	1
2	5	0.05695	0.17388	0.0173	1
3	4	0.06701	0.17103	0.0064	1
4	5	0.01335	0.04211	0	1
4	7	0	0.20912	0	0.978
4	9	0	0.55618	0	0.969
5	6	0	0.25202	0	0.932
6	11	0.09498	0.1989	0	1
6	12	0.12291	0.25581	0	1
6	13	0.06615	0.13027	0	1
7	8	0	0.17615	0	1
7	9	0	0.11001	0	1
9	10	0.03181	0.0845	0	1
9	14	0.12711	0.27038	0	1
10	11	0.08205	0.19207	0	1
12	13	0.22092	0.19988	0	1
13	14	0.17093	0.34802	0	1

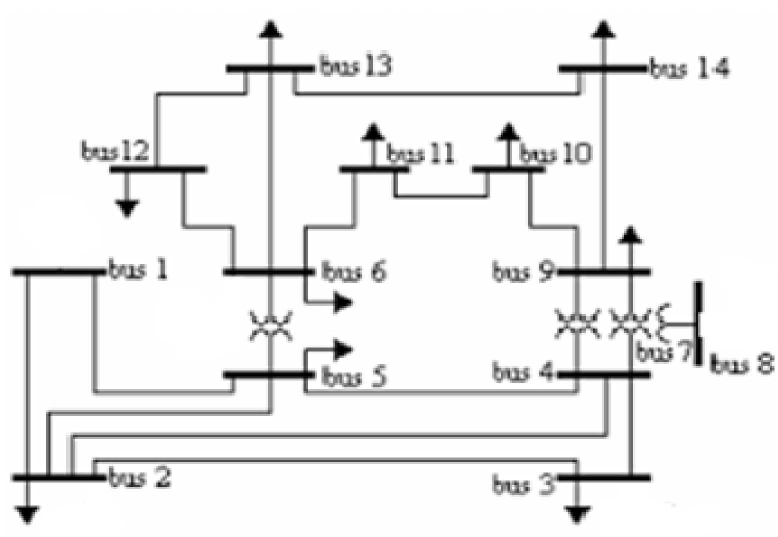

Fig. 3. IEEE 14-bus system.

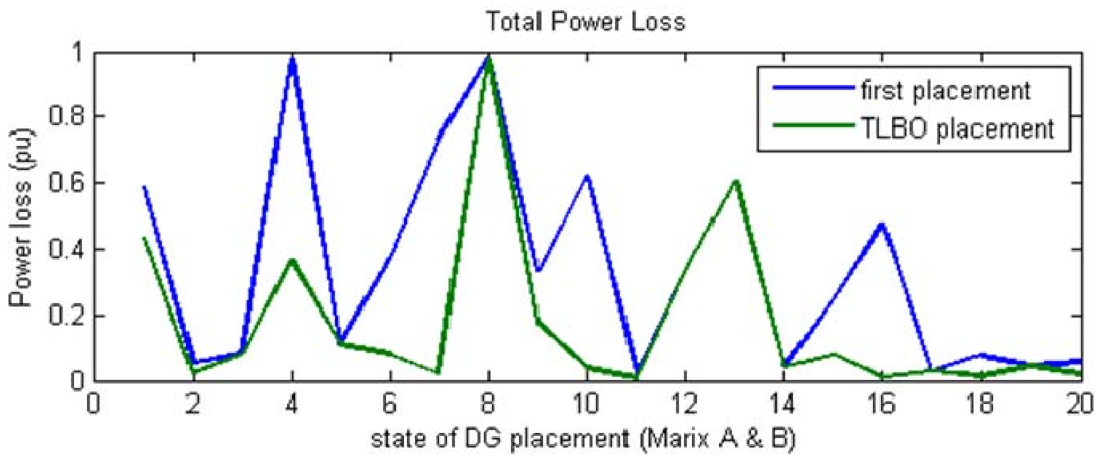

Fig. 4. State of DG placement using TLBO (Matrix A, and B).

The difference of these three modes is related to the number of placed generators. In the first scenario, only 2 generators were used, in the second scenario, 3 generators, and in the last scenario 4 generators were employed for placement. At each scenario, we consider a matrix with 20 rows, and columns equal to the number of desired generators. Each element of the matrix contains numbers from a 1 to 14 set. Each row contains two to four numbers which indicate the initial placement of generators on each bus the number of which is given in the mentioned matrix. Having placed generators on each foresaid buses, load flow process is undertaken based on Newton-Raphson technique. Having obtained the voltage of the buses and the loss power of the lines derived from load flow output, we proceed with the work by reaching the teacher phase in TLBO algorithm. In teaching phase, the mean of the mentioned matrix is calculated in the column by teacher. Next, we decide which line is related to the best solution to the placement of generators. The decided line for the placement of generators can carry on load flow process with the lowest rate of loss compared to other lines. Afterward, with respect to the rest of the algorithm procedure, modifying the values of the matrix is executed considering the mean value and decided line with the lowest rate of loss. After each time, altering the value of load flow matrix elements is undertaken and the rate of loss is calculated. For each line, if the value of loss is reduced compared to the former scenario, the line under consideration will be replaced with new values. After this stage, we arrive at the learner phase where we randomly select one of the levels, comparing other lines with the selected line in terms of power loss. Due to the difference the values make, we use different formula given above. If new obtained values have less power loss for the matrix elements, i.e. the same place where distributed generations are placed, then the values are replaced in the relevant line. After this, the implementation of the algorithm is accomplished. In this implementation, the cycle generated is reiterated 500 times so that the best value can be obtained for the placement of generators with respect to the value of their capacitors. The initial matrix is called A, and the final matrix is called B. The power calculated for each matrix if three 500 KW generators be placed, is as following:

$$A = \begin{bmatrix} 5 & 1 & 2 & 4 & 2 & 12 & 9 & 10 & 6 & 6 & 9 & 5 & 4 & 7 & 9 & 7 & 11 & 11 & 10 & 11 \\ 12 & 11 & 3 & 6 & 3 & 7 & 2 & 6 & 5 & 8 & 5 & 7 & 6 & 5 & 11 & 5 & 12 & 2 & 11 & 13 \\ 6 & 7 & 12 & 10 & 5 & 3 & 12 & 4 & 7 & 6 & 6 & 13 & 11 & 10 & 12 & 2 & 14 & 7 & 5 & 7 \end{bmatrix}$$

$$B = \begin{bmatrix} 7 & 1 & 1 & 1 & 2 & 12 & 8 & 7 & 6 & 5 & 9 & 3 & 1 & 7 & 2 & 5 & 10 & 11 & 10 & 6 \\ 12 & 8 & 2 & 2 & 3 & 7 & 1 & 2 & 5 & 6 & 5 & 5 & 2 & 5 & 7 & 2 & 9 & 1 & 9 & 5 \\ 5 & 4 & 11 & 6 & 5 & 3 & 11 & 1 & 7 & 4 & 6 & 11 & 6 & 10 & 8 & 1 & 11 & 6 & 3 & 9 \end{bmatrix}$$

Figure 4 shows diagram of power loss for each A, and B matrix. As can be seen, power loss when using TLBO algorithm, is reduced. The minimum amount of loss in matrix A is for row 5 which is 10.62 KW, and the lowest power loss in matrix B is for the row 4 with 4.9 KW.

CONCLUSION

In this paper, we tried to examine optimization when placing distributed generators in a radial Distribution system when we use TLBO algorithm. In this regard, we implemented TBLO algorithm in three scenarios with 2, 3 and 4 generators on IEEE 14-bus system. For each scenario, in addition to the reduction of loss with placement of DG in new buses, we observed the improvement of voltage profile in each scenario. As a consequence, we can conclude that TLBO algorithm could appropriately conduct the placement of generators at distribution system and reduce power loss.

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