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Optimal DG Location and Size for Power Losses Minimization in Al-Najaf Distribution Network Based on Bee Colony Optimization

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ABSTRACT

The value of Power Losses in distribution system are varied depending on the configuration of the network, the distribution loss can be reduced if the distributed generation (DG) are placed appropriately in the distribution system. The optimum size, location and number of DG units are substantial to avoid the negative effects on electric power system. In this paper, bee colony Optimization (BCO) is used to find the optimal size and locations of DG in order to minimize the active power losses.
Key words : Distributed Generation (DG), BCO, Power Losses.

1. INTRODUCTION

Traditionally, electric power delivered to consumers using transmission and distribution networks after generated at central station power plants. Due to distribution networks in general are of the radial type, the high proportion of R / X would cause great losses in power. So, the most busses which used in distribution are operated with poor voltage profiles. This will likely cause the breakdown voltage resulting in a total power outage [1]. However, recently there was a great revival of interest in the absorption of generating units to the distribution networks, which may be called Distributed Generation (DG). The connection of DG units can make fundamental changes in the network operation, therefore DG new connections must be evaluated to identify and quantify any negative impact on the security and quality of local electricity supplies. Distribution generation in distribution networks has a considerable impact on the network operation. It could lead in bi-directional power flow with the potential to overcome the thermal rating of equipment. As well as reduce voltage regulation, degrading protection operation, increase the contribution of short circuits and fault levels and change the transient stability [1].

The system load variations on the feeders make the operation and control of distribution systems in high load density areas very complex. The network is required to be reconfigured from time to time due to the inability to sustain a loss of power in it at least, even in a fixed network configuration as there are many cases with different loads. Network reconfiguration is done by changing the topology of feeder's structure. This can be reaching by the sectionalizing, as well as changing the status of tie switches (open/closed). The reconfiguration is attempt at keeping the real power loss at a minimum while decreasing of network overload. Generally, system voltage profile will not be successfully brought to the desired level due to nature of the dynamic loads, since the total load of the system is higher than the generating capacity, making it impossible to ease the burden of the feeders. Many researchers focused on the distributed generation because of its importance. The BCO has been applied to treat with this problem for determine the optimum size and location of the desired DG [1, 2].

2. PROBLEM FORMULATIONS

The algorithm is proposed so as to be used for determining the optimal placement and sizing of DG unit.

2.1 Finding Optimal Location of DG

To obtain the optimal location for DG placing, Loss sensitivity factor method will be used.

2.1.1 Loss Sensitivity Factor Method

Loss Sensitivity Factor Method has been used for finding optimal location of DG. It is based on the principle of original non-linear equation around the initial operating point, which helps to minimize the number of solution space. This method is usually used for solving capacitor allocation problem. Applying this method in DG allocation field can be considered new. [3]. The “exact loss” formula (which refers to a system’s real power loss) is:

$$P_{L=\sum_{i=1}^{N}\sum_{j=1}^{N}} \left[\propto_{ij}(P_iP_j+Q_iQ_j)+\propto_{ij}(Q_iP_j-P_iQ_j)\right] \quad ...1$$

where,

$$\propto_{ij}=\frac{r_{ij}}{v_iv_j}\cos(\delta_i-\delta_j) \quad ...2$$

$$\beta_{ij}=\frac{r_{ij}}{v_iv_j}\sin(\delta_i-\delta_j) \quad ...3$$

and

$$r_{ij}+x_{ij}=z_{ij} \quad ...4$$

are ij^{th} the element of $[z_{bus}]$ matrix with

$$[z_{bus}]=[y_{bus}]^{-1} \quad ...5$$

α : mean the sensitivity factor for the real power loss with respect to the power being injected, which calculated by :

$$\propto_i = \frac{\partial P_L}{\partial P_i} = 2\sum_{i=1}^{N}(\propto_{ij} P_j - \beta_{ij} Q_j) \quad ...6$$

2.2 Objective function

The main objective here is about reducing the loss of real power in the radial distribution network. This should be obtained by locating and sizing of DG in an optimal way. By identifying a suitable locating and sizing of DG the losses will be reduced [3].

$$Min.f = \sum_{i=1}^{n} P_{Loss\ i} \quad ...7$$

Power balance Constraint:

$$\sum_{i=2}^{n} P_{DG,i} \leq \sum_{i=2}^{n} P_i + \sum_{i=1}^{b} P_{loss,i,i+1} \quad ...8$$

Voltage Constraint:

$$|V_1 - V_i| \leq \Delta V_{max} \quad \forall\ i = 1,2..n \quad ...9$$

2.3 Computational procedure

Figure 1 shows flowchart which represents the computational steps to find minimum power losses

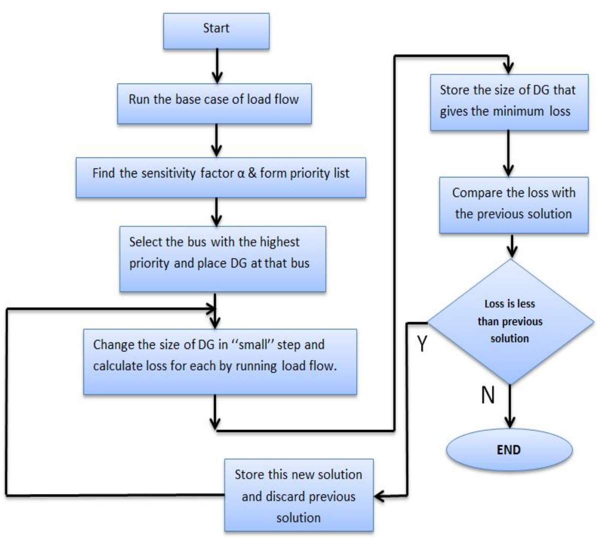

Figure 1: Minimum Power Losses Calculation Flowchart

3. BEE COLONY OPTIMIZATION

Bee colony is the best technology that is based on natural phenomena and find out the best solution in the end. It is self-organizing technique. There are two types of bee available in the beehive. The food collecting technique is depended on these two bees. Scot bee is going outside in search of the food and return to the bee hive when out of energy. Waggle dance is accomplished in shape of digit 8 by the scout bee in the bee hive to communicate with the forager bee. With the communication forager bee came to know about the best quality of food toward sun then follow the same path for the gathering of the food. Scout bees explore the path whereas forager bees exploit the path [4].

Based on this behavior of bees, Bee colony optimization algorithms were proposed. Moreover this concept was extended for the selection and alteration problems. The food source is considered similar to the solution of the problem and the amount of food in the source is similar to the probability of the solution to be the best solution. The BCO algorithms have a fixed number of solutions in the beginning and they are all random solutions. An extensive search is made until obtain optimal solution. At each stage of the algorithm, a new solution is searched in a predefined area and if the solution is better proceeds with the calculation with that schedule. The phases, solutions and stop criteria are dependent on definition of the problem [5].

The probability that a new solution is selected for the next stage depends upon the probability that the new solutions lead to optimal solution. The selection methodology depends on the roulette wheel procedure. The solution which will lead to the global optimum is selected and other treatment. If a solution is not improved by choosing the food source for a predetermined number of times, the algorithm stopped and the solution is proclaimed to be the best solution but not the optimal one. Another solution is created randomly and proceeded to get the new solutions that may lead to a global optimal solution [5].

3.1 Employed Bees Stage

Each of employed bees workers looking in the surrounding areas and generates a new solution V_{ij} representing the j_{th} parameter in the i_{th} solution as

$$V_{ij} = X_{ij} + \varphi_{ij}\left(X_{ij} - X_{kj}\right) \quad i \neq k$$

Where k is a number randomly selected in {1, 2, . . . , SN}, j is the index for the dimension of the optimization problem, and φ_{ij} is an random number between −1 and 1, which affects the disturbance range of X_{ij}. The quality of each solution as well as the nectar amount of the food source is represented by the fitness which could be calculated by

$$\text{Fitness}_i = \begin{cases} \frac{1}{1+f_i} & f_i \geq 0 \\ 1 + abs(f_i) & f_i < 0. \end{cases} \quad ...10$$

Where, f_i corresponding to the i_{th} solution is the value of objective function. Since the goal of linear quadratic regulator

(LQR) controller design is to minimize the performance function J which is equal to f_i , the fitness corresponding to the solution could be expressed as 1/(1+J) [6].

3.2 Onlooker Bees Phase

After all employed bees complete searching process, they share the fitness of each food source with the onlookers, each of whom selects a food source according to the probability as shown in (11) which is proportional to the nectar amount of food source. Consider

$$P_i = \frac{\text{Fitness}_i}{\sum_{j=1}^{SN} \text{Fitness}_j} \qquad \ldots 11$$

At that point, better food source around its chosen food source will be searched randomly according to the fitness [6].

3.3 SCOUTS BEES PHASE

If a solution does not improve for a multiple of iterations, the food source will be ignored, and the associated employed bee becomes scout bee. Random search will accomplished and new solutions will be generated as

$$X_{i,j} = X_{\min,j} + \text{rand}(0,1)\left(X_{\max,j} - X_{\min,j}\right) \qquad \ldots 12$$

Where, (X^j_{min}, X^j_{max}) are the bound of j_{th} dimension.

As mentioned above, the flow chart of BCO algorithm is presented in Figure 2 [6].

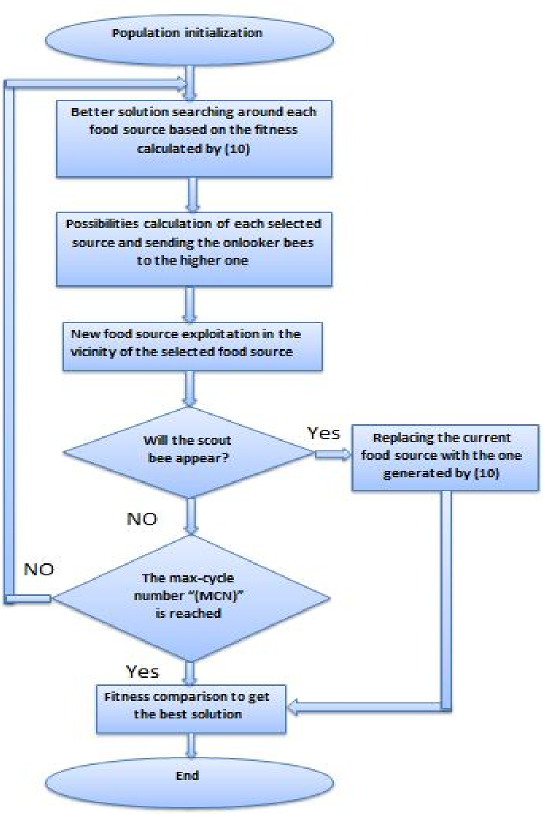

Figure 2: Flowchart of BCO

4. OPTIMIZATION OF DG USING BCO

In this work, it was proposed to create a BCO model for finding location and size optimizations of distributed generation (DG) problem. The target function has been considered to reduce the total active power losses .The proposed model has been tested on distribution system IEEE 30-bus and then applied to (Al-Najaf distribution network 20-bus) which is the part of Iraqi distribution networks. The IEEE 30-bus distribution system and Al-Najaf distribution system load data and line data are given in [1,7]. The algorithm is implemented using Matlab R2011b program. Figure 3 presents the results obtained by IEEE 30-bus with and without DG units which the location and size of it has been optimized by BCO for one, two and three DG units.

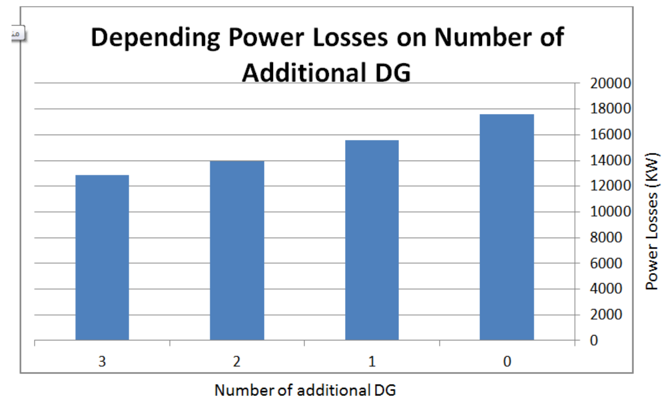

Figure 3: Optimal DG Units with Power Losses for IEEE 30 bus Distribution System

Al-Najaf distribution network is connected to the Iraqi power grid at Al-Qadisia bus bar to the southeast of Al-Najaf city, there is another connection at Al-Najaf gas station (generating station) which is connected to Al-Qadisia bus bar too. Figure 4 shows distribution network of Al-Najaf city which consists of ten transformers substations transform the high voltage (132 KV) to the medium voltage (33 and 11 KV).

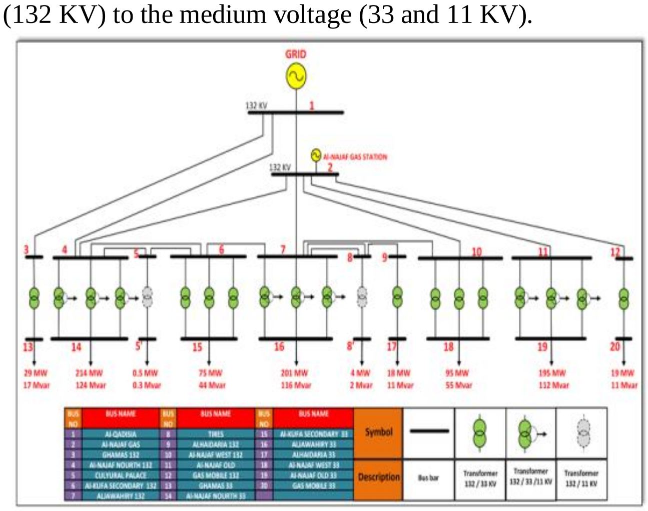

Figure 4: Al-Najaf Distribution Network

Figure 5 represents the results obtained by Al-Najaf distribution network 20-bus without DG units and with DG unit which the location and size of it has been optimized by BCO for one, two and three DG units

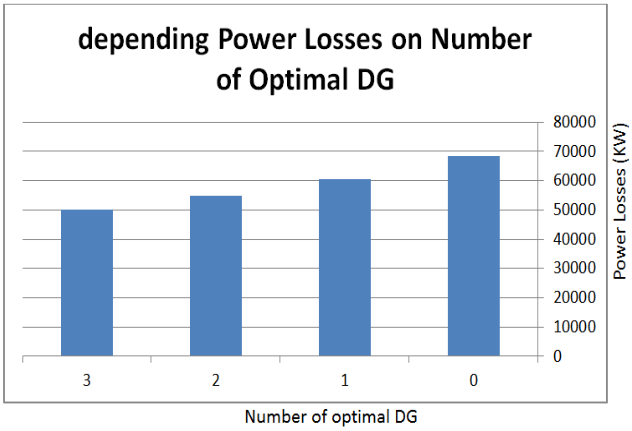

Figure 5: Optimal DG units with Power Losses for Al-Najaf Distribution System 20-bus

5. CONCLUSIONS

The conclusions from this work can be summarized as follows:

1. The optimal locations of DG are near the buses that carry more loads.
2. DG contributes significantly to the reduction in power losses.
3. DG units minimize the system dependency on the centralized generation leading to the minimization in the power flow through the transmission line which ensures its survival within thermal limit, moreover, the load on transformers is minimizes.
4. Power Losses can be reduced in a large percentage whenever we add the appropriate number and size of DG unit and put it in the optimal location selected by BCO.
5. In proposed system, the power losses have been reduced to 27% after adding three optimal DG units.

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