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

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Abstract: *The Power Losses in distribution system are changed depending on the configuration of the network, distributedgeneration (DG) can reduce distribution loss if they are placed appropriately in the distribution system. The optimum location, size and number of DG units are necessary to avoid the negative impacts on electric power system. In this paper, Cuckoo Optimization Algorithm (COA) is used to find the optimal size and locations of DG in order to minimize the active power losses.*
Index Terms: *Distributed Generation (DG), Cuckoo Algorithm, Power Losses*

I. Introduction

Traditionally, electric power is produced at central station power plants and delivered to consumers using transmission and distribution networks. Most of the distribution networks are radial in nature with high R/X ratios causing high power loss. As a result most of the distribution buses are operated with poor voltage profiles which may lead to voltage collapse and gradually total black out of system [1]. However, recently there has been a considerable revival of interest in accommodating generating units to distribution networks which may be called Distributed Generation (DG). Connection of DG units can fundamentally alter the operation of the network, therefore new connections of DG must be evaluated to identify and quantify any adverse impact on the security and quality of local electricity supplies. Distribution generation in distribution networks has a significant impact on network operation. It could result in bi-directional power flow with the possibility of exceeding thermal rating of equipments. As well as reduce voltage regulation, increase the contribution of short circuits and fault levels, degrading protection operation and altering the transient stability [1].

The control and operation of distribution systems in high load density areas are considered very complex due to the variation of system loads on feeders. The network is required to be reconfigured periodically due to the inability to keep the power loss in it at minimum, even in a fixed network configuration as there are many cases with different loads. Network reconfiguration is done changing the feeder's structure topologically. This is achieving by modifying the status of tie switches (open/closed), as well as the sectionalizing. The reconfiguration is aimed at keeping the real power loss at minimum while relieving overload of the network. Generally, the voltage profile of the system will not be successfully brought to the needed level due to the dynamic nature of loads, since the total load of the system is higher than the generation capacity, which makes it impossible to relive the load off the feeders. Many researchers focused on the distributed generation because of its importance. The COA has been applied to deal with this optimization problem for determination of the optimal size and location of the required DG [1, 2].

II. Problem Formulations

The algorithm is proposed in order to be used for determining the optimal location and sizing of DG unit.

2.1 Finding Optimal Location of DG

To find the optimal location for DG placement, the Loss sensitivity factor method will be used.

2.1.1 The loss Sensitivity Factor Method

This method was used to reduce the number of solution space. It is based on the principle of original nonlinear equation around the initial point. This method is commonly used in solving capacitor allocation problem. Appling this method to the DG allocation 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,

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

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

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 : denotes the sensitivity factor for the real power loss with respect to the power injected, it is 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 minimizing the real power loss in the radial distribution network. This should be achieved by locating and sizing of DG in an optimal way. Thus, the losses would be reduced if locating and sizing of DG is done correctly [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

Flowchart shown in Fig. 1 represents thecomputational steps to find minimum power losses

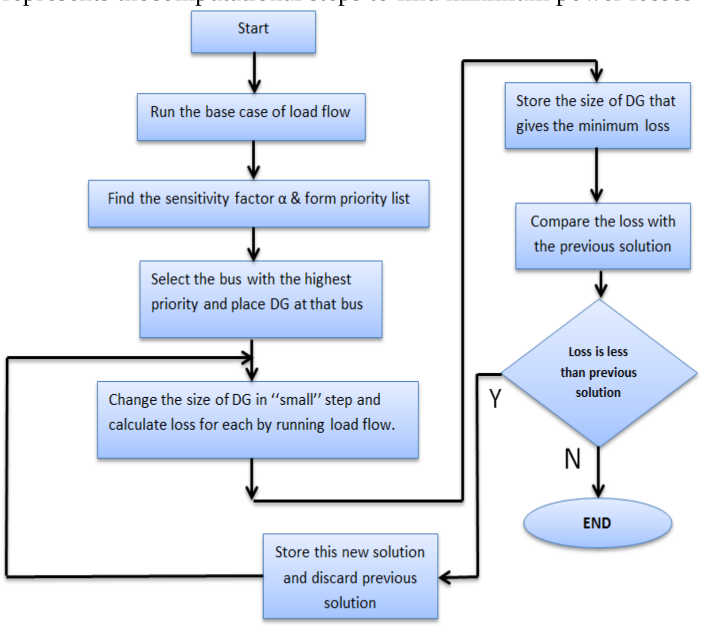

Figure1: Minimum power losses calculation flowchart

III. Cuckoo Optimization Algorithm

This algorithm was devised by observing the life of a bird called cuckoo. The main behaviour that was used to derive this evolutionary algorithm is how this bird would reproduce and lay his eggs in other birds' nests. Cuckoo will be represented by two states. One is the mature cuckoos that lay the other states (eggs) in a number of host birds' nests. When the eggs grow, they will determine whether an area is more suitable in the environment by including more surviving eggs in it, which means there is more profit in that area, and we say that COA can optimize. When solving problems using evolutionary algorithms such as COA and PSO, population of problem variables is initialized in one array. This array of initial population is called habitat in COA and it represents the current positions of living cuckoos [4,5]:

Habitat= [x1,x2,……,xn,……,xN] …10

Where x_n : is the index of each single nest.

The furthest distance a cuckoo travels to lay eggs is named "Egg Laying Radius" or simply ELR:

$$ELR = \alpha \times \frac{Number\ of\ current\ cuckoo's\ eggs}{Total\ number\ of\ eggs} \times (var_{hi} - var_{low}) \quad ...11$$

Where α is the maximum ELR (an integer), Var_{hi}: is the upper limit for variables, Var_{low} : is the lower limit for variables.

Where cuckoo's Eggs are laid in the hosts nests, part of the eggs will be destroyed randomly (because they are not very similar to the eggs of the host). Now, any item that got his cuckoo eggs destroyed will be dropped from habitat. A habitat would profit where the number of survived hatched eggs is maximized. The eggs that remained undestroyed will hatch in the host nest and expand. Later cuckoos that mature will move (migrate) to the best habitat after aspect period.

The cuckoos fly λ % of the way only with deviation ϕ radians:

$$\lambda \sim U(0,1),\ \varphi \sim U(-\omega,\ \omega) \quad ...12$$

Where λ is a random number uniformly distributed between 0 and 1. ϕ is a deviation parameter. The author of COA advises: w= (π/6) rad

The basic cuckoo optimization algorithm is represented by flowchart shown in Fig. 2

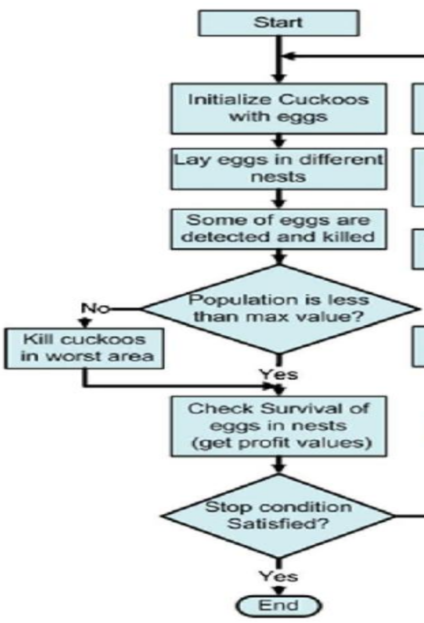

Figure 2: Flowchart of COA (Rajabioun 2011)

IV. Optimization of DG using COA

A COA based approach is proposed to find the optimal locations and size of distributed generation (DG) problem. In this work, the objective function has been considered to minimize the total active power losses .The proposed approach has been tested on IEEE 30-bus distribution system and then applied to part of Iraqi distribution networks (Al-Najaf distribution network 20-bus). The IEEE 30-busdistribution system and Al-Najaf distribution system load data and line data are given in [1,6]. The algorithm is implemented using Matlab program. Fig3 presents the results obtained by IEEE 30-bus without DG units and with DG unit which the location and size of it has been optimized by COA for one, two and three DG units.

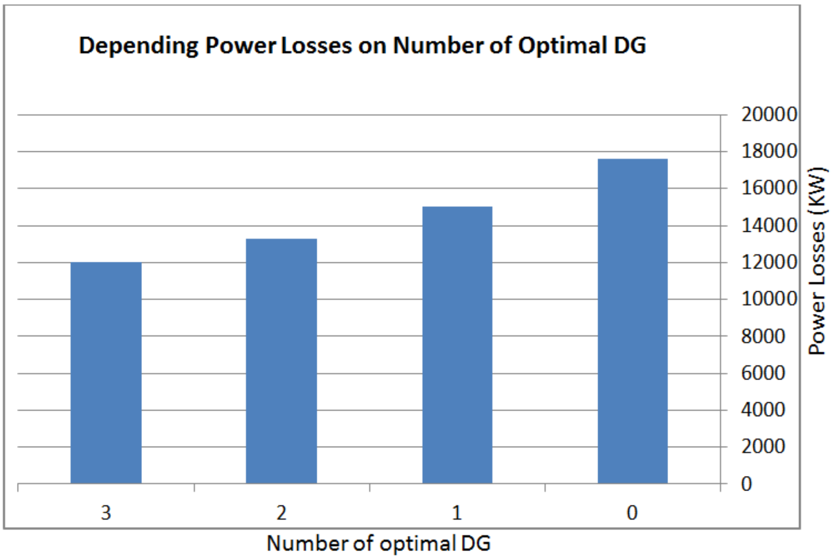

Figure3: Optimal DGUnits with Power Losses for IEEE 30 bus Distribution System

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.Fig.4shows AL-Najaf distribution network which consists of ten transformers substations transform the high voltage (132 KV) to the medium voltage (33 and 11 KV).

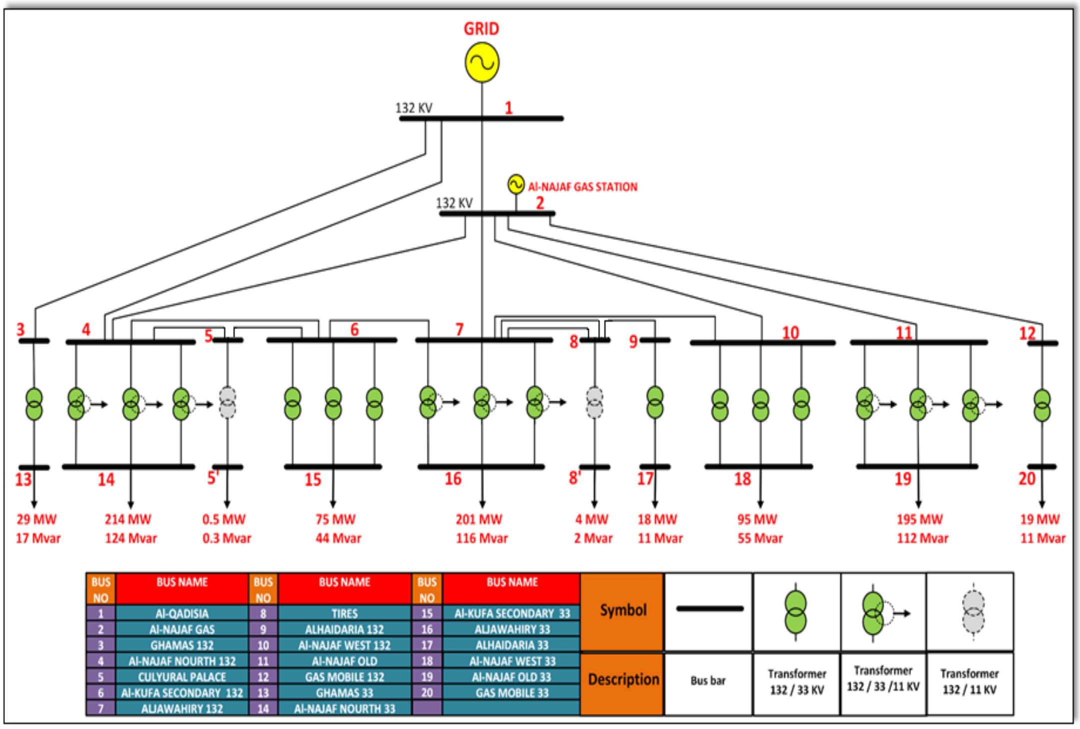

Figure 4: Al-Najaf Distribution Network

Fig 5presents 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 COA for one, two and three DG units.

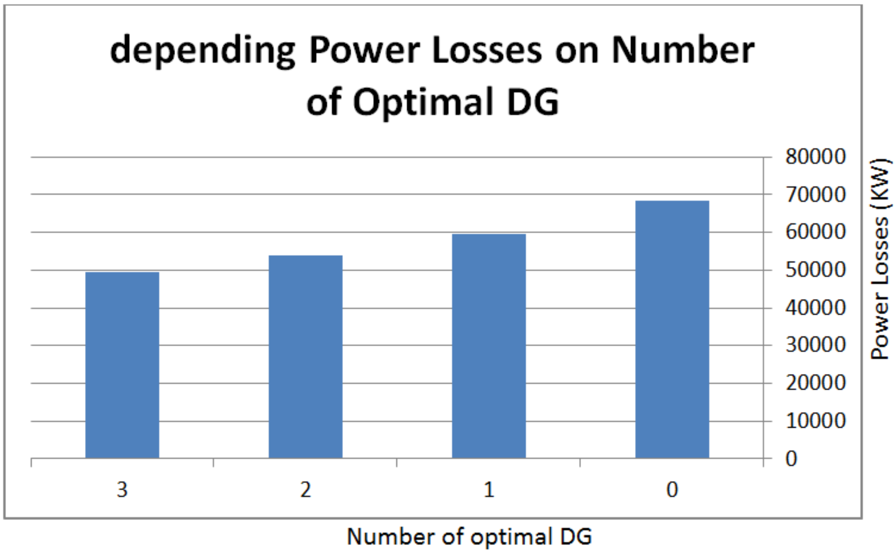

Figure5: Optimal DG units with Power Losses for Al-Najaf Distribution System 20-bus

V. 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 reduce the system dependency on the centralized generation leading to reduction in the power flow through the transmission line which ensures its survival within thermal limit, furthermore, the load on transformers is reduced.
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 COA.

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