Network Reconfiguration in Distribution Power System with Distributed Generators for Power Loss Minimization

Vahid.Rashtchi and Saeed.Pashai

Abstract— This paper uses an ant colony search algorithm (ACSA) to solve the optimal reconfiguration in radial distribution systems with and without distributed resource (DG) for power loss reduction that determine the optimal location and size of DG according to problem constrains. The ACSA is a relatively powerful intelligence evolution method for solving optimization problems. It is a population-based approach that was inspired from natural behavior of the ant colonies on how they find the food source and bring them back to their nest by creating the unique trail formation. The ACSA applies local pheromone updating rule, and global pheromone-updating rule to promote the computation. In this paper ACSA algorithm programmed on Matlab applied to the typical distribution system 3 feeders, 17 buses and one feeder of 33 bus of IEEE distribution system. And results show the effectiveness of ACSA algorithm in solving reconfiguration problems. After that by placing DG units in buses that algorithm determines for minimum losses and sizes are according to problem constrains the effects of DG units in power losses examined.

Keywords— Ant colony search algorithm, distributed generation, distribution system, feeder reconfiguration

I. INTRODUCTION

Distribution systems design are radial systems that tie switches and sectionalizing switches play an important role in forming configuration of this systems.

Because this is the tie switches and sectionalizing switches that by opening and closing change topology of system. This radial systems, themselves are separate into subsystem of radial feeders. By changing the position of switches (on-off) in meshes configuration of distribution system changes and according to different configurations different power losses in distribution system are gained. As amount of power losses is significant so it is important to find configuration that has lowest power loss.

Civanlar et al.[1] and Merlin et al.[2] conducted the early research on feeder reconfiguration for minimum loss reduction. After that, many techniques have been proposed.

Baran and Wu’s [3] offered a method on feeder reconfigurations for loss reduction that was based on branch exchange. In [4],[5], another approach for minimum loss configuration used a genetic algorithm. In [6]–[8], a power flow method based on a heuristic algorithm to determine the minimum loss configuration for radial distribution networks presented by authors. In [9]–[11], the authors proposed a solution procedure which employed simulated annealing to search for an acceptable non-inferior solution.

The authors in [12] outlined and validated a methodology for optimizing the operation of megavolt (MV) distribution networks. In [13], the authors have considered time varying load on the analysis to loss reduction. In [14], the authors employed bidirectional feeder models to simplify calculation for distribution systems. In [15], the authors proposed an EGA-based fuzzy multi objective approach to solve the network reconfiguration problem. In [16], the fuzzy theory and evolutionary programming were employed to solve the problem of feeder reconfiguration. In [18], the authors proposed an economic operation model to solve distribution network configuration. Although the studied problem had been solved by the above methods, either its optimality is not guaranteed or much of computation time is required.

Ant colony search in reconfiguration of distribution system is a novel application of the ant colony search Algorithm to the optimal reconfiguration of distribution systems, with the objective of minimizing the distribution systems losses in the presence of operational constraints. The distribution systems are structurally weakly meshed, but are operated in radial configuration by keeping a number of branches open. The choice of the branches to open in order to minimize losses is a combinatorial problem with high degree of complexity and several local minima.

The characteristics of an ACSA algorithm include positive feedback, distributed computation, and the use of a constructive greedy heuristics. Positive feedback makes sure of a rapid search for a global solution, distributed computation avoids premature convergence, and constructive greedy heuristics helps find acceptable solutions as soon as possible. In this paper ACSA used to solve minimum loss reconfiguration problem and solutions compared with previous findings and then by using ACSA for DG placement one more time power losses compared with system without DG. ACSA used here include global updating and local

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II. PROBLEM FORMULATION

Considering safety operation, the voltage magnitude at each bus must be maintained within its limits. The current in each branch must satisfy the branch’s capacity. These two constraints are expressed below:

\[ V_{\text{min}} \leq |V_i| \leq V_{\text{max}} \]  

\[ |I_i| \leq I_{i,\text{max}} \]  

Where \( |V_i| \) is voltage magnitude of bus \( i \), \( V_{\text{min}} \) and \( V_{\text{max}} \) are minimum and maximum bus voltage limits, respectively. \( |I_i| \) and \( I_{i,\text{max}} \) are current magnitude and maximum current limit of branch \( i \), respectively.

The proposed method uses a set of simplified feeder-line flow formulations for power flow analysis to prevent complicated computation. Referring to Fig. 1, this set of simplified formulations can be described as [2].

\[ P_i = P_{i+1} + P_{i+1} + R_{i,i+1} \frac{P_i^2 + Q_i^2}{|V_i|^2} \]  

\[ Q_i = Q_{i+1} + Q_{i+1} + X_{i,i+1} \frac{P_i^2 + Q_i^2}{|V_i|^2} \]  

\[ |V_{i+1}| = |V_i|^2 - 2(R_{i,i+1}P_i + X_{i,i+1}Q_i) + (R_{i,i+1}^2 + X_{i,i+1}^2) \frac{P_i^2 + Q_i^2}{|V_i|^2} \]  

Where \( P_i \) and \( Q_i \) are the real and reactive line powers flowing out of bus \( i \), respectively, \( P_{i+1} \) and \( Q_{i+1} \) are the real and reactive load powers at bus \( i \). The resistance and reactance of the line section between buses \( i \) and \( i+1 \) are denoted by \( R_{i,i+1} \) and \( X_{i,i+1} \), respectively. The power loss of the line section connecting buses \( i \) and \( i+1 \) can be computed as (6).

\[ P_{\text{loss},i+1} = R_{i,i+1} \frac{P_i^2 + Q_i^2}{|V_i|^2} \]  

The power loss of the feeder \( P_{\text{loss}} \) may then be determined by summing the losses of all line sections of the feeder, as (7).

\[ P_{\text{loss}} = \sum_{j=0}^{n-1} P_{\text{loss},i+1} \]  

The total system power loss \( P_{\text{loss}} \) is the sum of power losses of all feeders in the system.

III. ACSA PARADIGM

The ACSA imitates behavior of the ants while searching for food. Each ant leaves a pheromone trail on the path from nest to food. The pheromone evaporates with time, so that the other ants can reach the food by following the “shortest” paths marked with strong pheromone quantities.

Some ACS applications recently proposed in the distribution system area concern feeder restoration and optimum switch adjustments for distribution system planning.

Real ants are able to find the shortest path between a food source and their home colony. They also have the ability to adapt to the environmental changes, for example, finding the new and shortest path once the old one is no longer feasible due to a new obstacle. The studies of real ants reveal that they communicate via pheromones. The ant deposits a certain amount of pheromone when it walks. An ant tends to choose a path positively correlated to the pheromone intensity of found trials. The pheromone trail evaporates over time (i.e., it loses intensity if other ants lay down no more pheromone).

If many ants choose a certain path and lay down pheromones, the intensity of the trail increases and thus this trail attracts more and more ants. The environment changes, the ants that are just in the front cannot continue following the pheromone trail.

Therefore, those ants will choose the paths randomly; it means that the ants will choose the path to point C or D with the same probability in Fig. 2. Later on, those ants that choose the shorter path around the obstacle will move faster than the ants that choose the longer path. The pheromones on the shorter Path will be reconstructed more rapidly and this will cause more ants to choose the shorter path. After all, all ants will choose the same path due to the positive feedback.

The full procedures of the ACSA algorithm can be summarized as follows.

A. Probability

From the Fig. 3, each mesh shows one group of tie switches so totally there are three group of switch. At first iteration selection of switches are random with equal chance of selection for each switch in a group. But in next iterations chance of selecting a switch is depend on intensity of pheromone that relates to each switch according to (8).

\[ T_i = T_0 \]
Where $T_0$ is the initial pheromone that is determined in first tour and probability for selection of switch number $i$ is:

$$P_i^*(i,j) = \frac{T_i}{\sum_{i=0}^{n} T_i}$$  \hspace{1cm} (9)

Where $T_i$ is pheromone that is belong to switch number $i$.

**B. Evaporation**

When one group of ants finish their tour, ant will have its location list and fitting evaluation. At this point, all trail intensity can be updated according to the following evaporation formula:

$$T_i = (1 - \rho)T_i$$  \hspace{1cm} (10)

Where $\rho$ is a heuristically defined parameter.

**C. Global updating rule**

The ant with the best solution at this iteration will provide the greatest amount of pheromones to the edges. For example if the $k$ ant has the best result in this tour, then the pheromones of those edges can be modified by:

$$T_i = T_i + (x - y)a$$  \hspace{1cm} (11)

Where $x$ is best cost in resent tour, $y$ is best cost in previous tour of ants and $a$ is a heuristically defined parameter.

**D. Local updating rule**

While constructing its tour, each ant modifies the pheromone by the local updating rule. propose for local updating is, in each tour three switch is selected but some of these three switches may help in reaching global minima some not so helpful selections should gain more pheromone than restricting selections. This can be written below:

$$T_i = T_i + (x - y)b$$  \hspace{1cm} (11)

Where $b$ is a heuristically defined parameter.

**IV. SIZING AND PLACEMENT OF THE DG WITH ACSA**

According to papers and references total amount of DG in a system often is between 15 to 20 percent of total amount of system power consumption [19]. in this paper steps for 13 bus test system is 5 unit that each one delivers 1mw of active power and 33 IEEE bus system 5 unit that each one delivers of active power. Constrain for ACSA here is that installed DG power in a bus should not exceed 50 percent active power of end bus load.

**V. CASE STUDY**

**A. 33 Case I**

The typical distribution network is used for reconfiguration problem included 3 feeders, 17 buses and 16 switches as shown in Fig.3.

**B. Case II**

An other illustration is applied for a 33 IEEE standard system shown in Fig. 4 and results are shown in Table II.

**TABLE I RESULTS FOR 13 BUS TEST SYSTEM**

<table>
<thead>
<tr>
<th>Tie switches</th>
<th>Original Config</th>
<th>SA</th>
<th>GA</th>
<th>ASCA</th>
<th>ASCA With DG</th>
</tr>
</thead>
<tbody>
<tr>
<td>15,21,26</td>
<td>19,17,26</td>
<td>19,17,26</td>
<td>19,26,17</td>
<td>19,26,17</td>
<td></td>
</tr>
<tr>
<td>19,17,26</td>
<td>19,17,26</td>
<td>19,26,17</td>
<td>19,26,17</td>
<td>19,26,17</td>
<td></td>
</tr>
<tr>
<td>19,26,17</td>
<td>19,26,17</td>
<td>19,26,17</td>
<td>19,26,17</td>
<td>19,26,17</td>
<td></td>
</tr>
<tr>
<td>(DG bus)</td>
<td>7,8,9,12</td>
<td>7,8,9,12</td>
<td>7,8,9,12</td>
<td>7,8,9,12</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE II RESULTS FOR 33 IEEE BUS**

<table>
<thead>
<tr>
<th>Tie switches</th>
<th>Original Config</th>
<th>SA</th>
<th>GA</th>
<th>ASCA</th>
<th>ASCA With DG</th>
</tr>
</thead>
<tbody>
<tr>
<td>33,34,35</td>
<td>36,37</td>
<td>6,9,14,</td>
<td>6,9,14,26,</td>
<td>32,14,9,</td>
<td>32,14,9,</td>
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<td>36,37</td>
<td>6,9,14,26,</td>
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<td>37,7</td>
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<td>31</td>
<td>37,7</td>
<td>28,7</td>
<td>28,7</td>
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<td>28,7</td>
</tr>
<tr>
<td>(DG bus)</td>
<td>7,17,23,</td>
<td>7,17,23,</td>
<td>7,17,23,</td>
<td>7,17,23,</td>
<td>7,17,23,</td>
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<td>27,31</td>
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<td>27,31</td>
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</tbody>
</table>

With this case study, ACSA has been compared to the Classical method, the result optimal configuration of distribution network is found and compared with previous answers and results are shown in Table I.
VI. CONCLUSION

In this paper, the ACSA algorithm has been proposed to reduce distribution system losses. The effectiveness of ACSA has been demonstrated by a 13 bus test system and a 33-bus distribution system respectively. The merits of the ACSA are parallel search and optimization capabilities, and this method was inspired by observation of the behaviors of ant colonies. As in each ant tour from each switch group one switch is selected and some of this switch may help in finding global minima and some not, the local updating rule makes ACSA to give helpful selections more pheromone than the others. Finally, it applies the global updating rule to make the search more directed and to enhance the capability of finding the optimal solution in the problem solving process. The rules make the ACSA become an extremely powerful method for optimization problems. From the results of this paper, it can be seen that DG has the improvement effects on loss reduction and can increase the system power quality. The computational results of the 33 bus system show that the ACSA method is better than the GA one. It can be observed that a 137 KW of loss reduction can be achieved by the ACSA comparing with a 136.49 by the GA when distributed generators are installed in the system; the results are shown in Table 2. For a large scale distribution system it can decrease the current of main transformer and avoid the overload and load difference among the feeders no matter whether the system is with or without DG.

REFERENCES


