A NEW APPROACH BASED ON ANT COLONY ALGORITHM TO DISTRIBUTION MANAGEMENT SYSTEM WITH REGARD TO DISPERSED GENERATION

T. NIKNAM**, A.M. RANJBAR**, A.R. SHIRANI** and A. OSTADI*

*Sharif University of Technology, ** Niroo Research Institute
Iran

INTRODUCTION

Electric power industry has found a way to break and change the old domination by large utilities that had an overall authority over all activities in generation, transmission and distribution of power within its domain of operation. These changes in power system (deregulation) along with environment pollution problems, and technology advancement to make small-scale generators economically, have caused customers to prefer local generation, which do not need transmission lines.

Therefore the usage of DGs is increasing, which leads to necessity of their impacts study on distribution systems. One of the most important problems in distribution system is distribution management system (DMS), which can be affected by DGs. Some DMS algorithms have already developed by researchers [1-9]. The aim of this paper is to present a new approach to distribution management system with regard to Distributed Generations. In the proposed algorithm, DMS is divided two parts:

- State Estimation
- Optimal Operation Management

In other words, at first, state variable of distribution network have been estimated and then optimal operation management has been done based on results of state estimation. In State Estimation part, DGs and Loads that do not have constant outputs, are considered as state variables, the output values of which is obtained by minimizing the difference between measured and calculated values. The target of Optimal Operation Management part is to minimize cost reactive power production of DGs, reactive power cost of capacitors and energy losses with controlling tap of Load Tap Changers Transformers and Voltage Regulators, reactive power of capacitors and reactive power of DGS.

In overall view, Distribution management system is an optimization problem including continuous and discrete variables. Because of existence of DGs, Voltage Regulators (VRs), SVCs, Load tap Changers (LTC) and etc. in distribution system, it is difficult to solve by ordinary and classic methods which objective function and constraints should be continuous and derivative. It is seemed that evolutionary approaches are the best choice for solving these problems. Recently, a new evolutionary global optimization technique known as ant colony optimization (ACO) has become a candidate for many optimization applications. The ant colony optimization has been used to solve several combinatorial optimization problems such as the Traveling Salesman Problem (TSP), Quadratic Assignment Problem (QAP), Job Shop Scheduling Problem (JSP), Single Machine Total Tardiness Problem (SMTTP), Unit Commitment, Economic Dispatch of Power system, Hydroelectric Generation Scheduling, reactive power pricing in deregulated system, voltage and var control in distribution systems and so on[10-18].

The paper is organized as follows. Section II defines Distribution Management System formulation with regard DGs. Section III presents evaluation cost of distributed generation. In section IV ant colony mechanism has been presented Simulation results will be brought in section V. Finally, section VI presents conclusion.

DISTRIBUTION MANAGEMENT SYSTEMS WITH REGARD TO DISTRIBUTED GENERATION

This section presents the proposed approach for formulation of distribution management system with regard to Distributed Generation. As mentioned before, DMS is divided two sub problems State Estimation and Optimal Operation Management sub problem. In overall view, these sub problems are optimization problems including continuous and discrete variables. In following formulation of them are presented.

State Estimation Formulation With Regard to Distributed Generation

The objective function of State Estimation problem is the summation of difference between measurement and calculated values. Distribution State Estimation considering DGs is as follows:

\[
\text{Min } f(X) = \sum_{z=1}^{Nz} \omega_i (Z_i - h_i(X))^2
\]

\[
X = [P_G, P_L]
\]

s.t.

\[
P_{G_{\text{min}}} \leq P_{Gi} \leq P_{G_{\text{max}}} \quad i = 1,2,3,...N_G
\]

\[
P_{L_{\text{min}}} \leq P_{Li} \leq P_{L_{\text{max}}} \quad i = 1,2,3,...N_L
\]

where:

- X: State Variables including Loads & DGs values that varies.
- \(Z_i\): measurement values.
- \(\omega_i\): weighting factor of measurement variable i.
- \(h_i\): state equation of measurement variable i.
- m: number of measurements.
- Ng: number of variable DGs.
- NL: number of variable Loads.

We know that the number of measurements in distribution system is less than state variables. In order to have almost a
In this paper, state equations of measurement variables are obtained through unbalanced three-phase load flow.

**Optimal Operation Management of Distribution Networks with Regard to Distributed Generation**

The objective function of Optimal Operation Management of Distribution systems is the summation of reactive cost of DGs, reactive cost of capacitors and active power cost of substation as follows:

\[ f(x) = C_{\text{Sub}}(P_{\text{Sub}}) + \sum_{i=1}^{n} Q(Q_i) + \sum_{i=1}^{n} Q(Q_i) + \sum_{j=1}^{n} P_{\text{loss}} * MCF \]  \hfill (2)

where:

- \( C_{\text{Sub}} \) is substation active energy cost.
- \( C(Q_i) \) is reactive cost of DGs.
- \( C(Q_c) \) is reactive cost of capacitors.
- \( P_{\text{loss}} \) is branch loss.
- \( N_c \) is number of capacitors.
- \( N_g \) is number of DGs.
- \( N_b \) is number of branches.

Constraints are defined as follows:

- Active and reactive power constraints of DGs:
  \[ Q_{\text{min}} < Q < Q_{\text{max}} \]  \hfill (3)

- Transmission line limits:
  \[ P_{\text{max}} < P_{\text{loss}} \]  \hfill (4)

- Reactive power of capacitors:
  \[ 0 < Q < Q_{\text{max}} \]  \hfill (5)

- Tap of Transformers:
  \[ Tap_{\text{min}} < Tap < Tap_{\text{max}} \]  \hfill (6)

- Load flow equations.

**DISTRIBUTED GENERATION MODELING**

Depending on the contract and control status of a generator, it may be operated in one of the following modes:

1. In “parallel operation” with the feeder, i.e., the generator is located near and designed to supply a large load with fixed real and reactive power output. The net effect is the reduced load at a particular location.
2. To output power at a specified power factor.
3. To output power at a specified terminal voltage.

The generation nodes in the first two cases can be well represented as PQ nodes. The generation nodes in the third case must be modeled as a PV node. An approach to model the generator as PV node based on compensation method has been presented by T. Niknam and A.M. Ranjbar, [19]. In this paper DGs are considered as PQ nodes.

**EVALUATION DISTRIBUTED GENERATION COST**

Generally, costs of distributed generation to customers include the installed cost of the equipment, fuel costs, nonfuel operation and maintenance (O&M) expenses, and certain costs that the customers’ utility imposes.

Table (1) shows comparison of different cost of some distributed generations.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Capacity (kW)</th>
<th>Capital Cost ($/kW)</th>
<th>Fuel Cost ($/kWh)</th>
<th>O&amp;M Cost ($/kWh)</th>
<th>Service Life (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro turbine</td>
<td>100</td>
<td>1485</td>
<td>0.075</td>
<td>0.015</td>
<td>12.5</td>
</tr>
<tr>
<td>Micro turbine-CHP</td>
<td>100</td>
<td>1765</td>
<td>0.035</td>
<td>0.015</td>
<td>12.5</td>
</tr>
<tr>
<td>Gas ICE-Power Only</td>
<td>100</td>
<td>1030</td>
<td>0.067</td>
<td>0.018</td>
<td>12.5</td>
</tr>
<tr>
<td>Gas ICE-CHP</td>
<td>100</td>
<td>1491</td>
<td>0.027</td>
<td>0.018</td>
<td>12.5</td>
</tr>
<tr>
<td>Fuel Cell-CHP</td>
<td>200</td>
<td>3674</td>
<td>0.029</td>
<td>0.01</td>
<td>12.5</td>
</tr>
<tr>
<td>Solar Photovoltaic</td>
<td>100</td>
<td>6675</td>
<td>0</td>
<td>0.005</td>
<td>20</td>
</tr>
<tr>
<td>Small Wind Turbine</td>
<td>10</td>
<td>3866</td>
<td>0.005</td>
<td>0.005</td>
<td>20</td>
</tr>
<tr>
<td>Large Wind Turbine</td>
<td>1000</td>
<td>1500</td>
<td>0</td>
<td>0.005</td>
<td>20</td>
</tr>
<tr>
<td>Combustion Turbine-Power Only</td>
<td>100000</td>
<td>715</td>
<td>0.067</td>
<td>0.006</td>
<td>20</td>
</tr>
<tr>
<td>Combustion Turbine-CHP</td>
<td>100000</td>
<td>921</td>
<td>0.032</td>
<td>0.006</td>
<td>20</td>
</tr>
<tr>
<td>Combined-Cycle System</td>
<td>1000000</td>
<td>690</td>
<td>0.032</td>
<td>0.006</td>
<td>20</td>
</tr>
</tbody>
</table>

Cost of DGs (per kWh/$), based on above table, can be defined as follows:

\[ C(P) = a + b \times P \]  \hfill (7)

In mentioned equation a & b coefficients can be evaluated as follows:

\[ a = \frac{\text{CapitalCost} \times \text{t}\text{\$/kW} \times \text{Capacity}\text{\(kW\)} \times \text{Gr}}{\text{LifeTime}\text{\(\text{Year}\)} \times \text{365} \times \text{24} \times \text{LF}} \]  \hfill (8)

\[ b = \text{FuelCost}\text{\$/kWh} + \text{O\&MCost}\text{\$/kWh} \]

where Gr and LF are yearly rate of benefit and DG loading factor.

The cost of reactive power produced by generators is called opportunity cost. Opportunity cost depends on demand and supply in market, so it is hard to determine its exact value. In simplest form opportunity cost can be considered as follows:

\[ c_m(Q_i) = c_{am}(S_{g,i,max}) - c_{am}(S_{q,i,min} - Q_{gi}) \times k \]  \hfill (9)

Where:

- \( S_{g,i,max} \) : Maximum apparent power in \( i \text{th} \) bus
- \( Q_{gi} \) : Reactive power of generator in \( i \text{th} \) bus
- \( K \) : Reactive power efficiency rate

**TABLE 1 COMPARISON OF SELECTED ELECTRICITY GENERATION TECHNOLOGIES[20]**

**Session No 4**
ANT COLONY SYSTEM MECHANISM

Ants are insects, which live together. Since they are blind animals, they find the shortest path from nest to food with aid of the pheromone. The pheromone is the chemical material deposited by the ants, which serves as critical communication media among ants, thereby guiding the determination of next movement. On the other hand, ants find the shortest path, based on intensity of pheromone deposited on different paths. For better understanding, assume that ants want to move from A to B and vice versa, to obtain food (Fig1).

At first, if there is no obstacle, all of them will walk to the straight path (Fig 1.a). Now, assume that there is an obstacle, in this case, ants will not be able to follow the original trial in their movement. Therefore, randomly, they turn to left (ACB) and to right (ADB) (Fig 1.b). Since ADB path is shorter than ACB, the intensity of pheromone deposited on ADB is more than the other. So ants will be increasingly guided to move on the shorter path (Fig 1.c). This behavior forms the fundamental paradigm of ant colony system.

As it was indicated in Fig.1, the intensity of deposited pheromone is one of the most important factors for ants to find the shortest path. Therefore, this factor should be used to simulate behavior of ants. Generally, the following factors are used to simulate ant systems:

- Intensity of pheromone
- Length of path

To select the next path, state transition probability is defined as follows:

\[ P_{ij} = \frac{\tau_{ij}^\gamma (1/L_{ij})^{\gamma_2}}{\sum \tau_{k}^\gamma (1/L_{kj})^{\gamma_2}} \]  

(9)

After selecting the next path, trail intensity of pheromone is updated as:

\[ \tau_{ij}(k+1) = \rho \tau_{ij}(k) + \Delta \tau_{ij} \]  

(10)

Where:
\( \tau_{ij} \): intensity of pheromone between nodes i and j, \( L_{ij} \): length of path between nodes i and j,
\( \rho \): a coefficient such that (1-\( \rho \)) represents the evaporation of trail between time k and k+1.
\( \gamma_1 \) and \( \gamma_2 \): control parameters for determining weight of trail intensity and length of path.

To apply ant colony algorithm for solving optimization problems, at first, it should find global and local movement based on equation 9. In other words, determination of next path for each colony of ants depends on the direction of global and local paths as follows:

\[ X_i(k+1) = X_i(k) + \text{rand}(X_i(k) - X_{global}(k)) + \text{rand}(X_i(k) - X_{local}(k)) \]  

(11)

Fig 2 shows flowchart of Ant Colony Algorithm.

SIMULATION

In this section the proposed method is applied to distribution management system with regard to Distributed Generation. In sub problem of state estimation, it is assumed the following information is available:

- Value of output for constant loads and constant DGs.
• Average value and standard deviation for variable DGs and variable loads.
• Value of measurement points
• Power factor of Loads and DGs

Fig 3 shows the flowchart of distribution management system.

<table>
<thead>
<tr>
<th>TABLE 2 DGS CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>G1</strong></td>
</tr>
<tr>
<td>Maximum Active Power (kW)</td>
</tr>
<tr>
<td>Maximum Reactive Power (Kvar)</td>
</tr>
<tr>
<td>Minimum Reactive Power (Kvar)</td>
</tr>
<tr>
<td>Average of Active Power (kW)</td>
</tr>
<tr>
<td>Standard Deviation (%)</td>
</tr>
<tr>
<td>Power factor</td>
</tr>
<tr>
<td>Location</td>
</tr>
<tr>
<td>Kind of DG</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Table 6 gives the comparison of results the proposed method with Genetic Algorithm.

<table>
<thead>
<tr>
<th>TABLE 3 CHARACTERISTIC OF VARIABLE LOADS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>L1</strong></td>
</tr>
<tr>
<td>Average of Active Power (kW)</td>
</tr>
<tr>
<td>Standard Deviation (%)</td>
</tr>
<tr>
<td>Power factor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 4 COMPARISON RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Method</strong></td>
</tr>
<tr>
<td>G2</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>G3</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>L1</td>
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<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>L2</td>
</tr>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

As shown in Tables 4, 5 & 6, the proposed method can be used to estimate state variables in distribution networks. The results of these Tables can be summarized as follows:

1. The execution time of proposed method is sufficiently short (with regard to GA and NN) and will give a general idea that the method can be implemented without any restriction in realistic networks.
2. The execution time of Neural Network is less than the proposed method, however neural Networks are dependent on training patterns, which may cause a main problem. The proposed algorithm requires only network data and measurement point values.
3. The simulation results show that estimation error is in an acceptable level.
4. The method can estimate the appropriate target system condition even with measurement errors.
5. The proposed algorithm can estimate appropriate loads and DGs output values at each node with limited measurement points in distribution networks.
6. The method can be applied to a wide variety of similar optimization problems. On the other hand, this method
can be used to non-differential and non-continuous objective function and constraints.
7. Objective function value and active power losses in the proposed method is less than GA.
8. Because most of dispersed generations owned and controlled by private sections, necessary mechanisms must be applied for supervision and control of optimal operation in power systems. In this paper costs pertaining to reactive power generation offered by owners of dispersed generations have been used as a decisive factor for optimal control of them. Results achieved in last sections show that we can apply these methods to control dispersed generations and be sure that high benefits will be gained from them.

CONCLUSION

As the number of DGs will be increasing, their impacts on power system to be studied. One of the most important issues in distribution system is distribution management system (DMS), which can be affected by DGs. In this paper a new approach for distribution management system with regard to DGs presented. The simulation result showed that the method could be implemented in practical distribution networks. The execution time of proposed method is sufficiently short and will give a general idea that the method can be implemented without any restriction in realistic networks. Since the most of DGs owned by private section, active and reactive power generation costs of DGs considered as optimal parameter control of them.

REFERENCE