ENHANCING RELIABILITY BY RECONFIGURATION OF POWER DISTRIBUTION SYSTEMS CONSIDERING LOSS

Jency Sara John¹, S.T. Suganthi².

¹ Department of Electrical and Electronics Engg, SNS College of Tech, Coimbatore
² Department of Electrical and Electronics Engg, SNS College of Tech, Coimbatore
jencysara@gmail.com, suganthi_thangaraj@yahoo.co.in

Abstract- The paper describes an effective method to reconfigure a power distribution system using optimization techniques. Here genetic algorithm is used for the reconfiguration to enhance reliability and to reduce losses. The reliability at the load points is evaluated using probabilistic reliability approach. Finding minimal cut sets and losses different algorithms are used. To maximise the reliability and to reduce the losses, the status of the switch is controlled using genetic algorithm. The effectiveness of the system is tested in 33 bus distribution system.

Keywords- Reliability, power losses, reconfiguration, genetic algorithm.

I. INTRODUCTION

As the demand for electrical energy is increasing day by day, the transmission and distribution lines are heavily loaded. From the recent blackouts, we can see that most of failures occurs at the distribution level will result in cascading effect[1]. So reliability evaluation of distribution system gains significance in planning and operating stage of power system. Here the reliability at loads points and reducing the total losses of the system is considered as objectives. The optimal status of the switches considering reliability and power losses was done by particle swarm optimisation[2]. To find the reliability at the load points , minimal cut set for the network has to be found out. [3] suggests an algorithm to find minimal cut sets.

The subject of minimizing distribution losses become important due to the rising prices of electrical energy. By reducing the losses, system acquires longer life span and high reliability.[4] presents a systematic feeder reconfiguration technique that develops an optimal switching scheme to achieve a maximum reduction of losses in a distribution network by restructures the distribution feeders by changing the open/closed status of the sectionalizing and tie switch. [5] presents an algorithm for loss minimization by using an automatic switching operation in large scale distribution systems by simulated annealing. In this paper, probabilistic models of the distribution system components are considered while evaluating the reliability at the load points. Minimal cut sets between the source and the load points are first determined, and then the expected availability of power is computed by using the joint failure probability distribution of the components involved in the cut set. The genetic algorithm technique is used to determine the optimal reconfiguration of switches in the network in order to maximize the reliability at the load points, and minimize the real power loss in the system.

II. RELIABILITY ASSESSMENT AT THE LOAD POINTS

For the reconfiguration of power distribution system, one of the objective is the reliability taken between source and load point. For that , minimal cut sets and minimal paths has first to be for the given network. In order to evaluate the reliability at various load points, probabilistic reliability models of various components are considered.

A.MINIMAL CUT SETS

The minimal cut set effectively describes the combinations of component failure the top event to occur.
The minimal cut set method consists of minimal number of components, the outage of any of which will render the corresponding load point out of power.

B. COMPONENT RELIABILITY

Failure models can be categorized into 4 basic groups. 1. Passive failure events 2. Active failure events. 3. Stuck-condition of breakers 4. Overlapping failure events.

Passive failure events are component failures that do not activate the protection system such as unknown open circuit conditions or unintentional operation of a circuit breaker. As expected, if a passive failure does not activate the protection system, an active failure is an event that causes the protection system to operate and isolate a failed component. A simple example of an active failure event would be a fault on a bus and the subsequent operation of breakers to “seal off” the area from the rest of the station. If during the above fault one of the primary breakers failed to operate and a backup or secondary breaker had to operate to isolate the faulted area, this would be termed a ‘stuck-condition of breakers’ failure mode. The station may still remain in operation, but a larger portion has become inoperable than in the active failure mode. An overlapping failure is when a failure has occurred and before the failure has been fixed, another failure occurs.

The final step is to list all system failures by the probability of occurrence. This will provide a clear picture of scenarios that will cause the most problems. To find the system reliability, combine the system failure probabilities and frequencies. Each failure state is an exclusive state, so the probability of occurrence of system failure is the sum of all the failure event probabilities. The product of occurrence of failure event and the duration can be used to determine the probability of the failure state.

The reliability of a component can be described as

\[ P = \frac{\text{MTTF}}{\text{MTTF} + \text{MTTR}} = \frac{\sum 1/\lambda_i}{\sum 1/\lambda_i + \sum 1/\mu_i} \]  

(1)

Where \( \lambda_i \) is the different outages and \( \mu_i \) is the repair times for the various outages.

Generator, Transformer and Circuit Breaker model: It includes two failure modes 1) active 2) passive. Maintainence outage and End of life probabilities are also included in this model.

Bus Model: This model includes maintainence and failure modes.

Distribution Line and Switch Model: The model includes the two failure modes and maintainence outage.

If all the component reliabilities have been calculated between the source and the load, then the overall reliability of the system can be calculated using the following equation.

\[ Q_{SA} = \frac{1}{L} \sum_{i=1}^{L} Q_i(\text{load point}) \]  

(2)

III. DISTRIBUTION SYSTEM POWER LOSS ANALYSIS

The power losses for each configuration of the distribution system has to be calculated using load flow solution. The system topology will be changed each time, while reconfiguring the network thereby changing the sending end and receiving ends of each branch. The algorithm proposed in [8] is used in this paper. This can be explained with the help of a simple distribution feeder given in figure 2.
Let the voltage phasors at bus1 and bus 2 be \( V_1 \angle \delta_1 \) and \( V_2 \angle \delta_2 \) respectively. The current flowing through the impedance \( R + jX \) be \( \tilde{I} \).

\[
\tilde{I} = \frac{(V_1 \angle \delta_1 - V_2 \angle \delta_2)}{(R + jX)}. \quad (3)
\]

The load power consumption (power flowing through bus 2) is given by

\[
P_2 - jQ_2 = V_2 \tilde{I}. \quad (4)
\]

Where \( P_2 \) and \( Q_2 \) are total real and reactive power loads fed through node 2. The real power loss in the branch is therefore given by

\[
P_{\text{loss}} = R \left( \frac{P_2^2 + Q_2^2}{V_2^2} \right). \quad (5)
\]

The real power loss in all branches can be evaluated in the same manner. The system real power loss is taken to be the sum of the real power loss in all branches.

![Modified 33 bus radial distribution network](image)

**Fig. 2. Modified 33 bus radial distribution network**

**IV. CASE STUDIES**

The proposed methodology is applied in a 33 bus distribution system[6]. All of the buses, except the substation bus, are treated as load points. The line data and load data of this system are given in [7] is shown in Table1. The possible locations of switches are shown in Fig.3. Each switch can be either open or close. In the base case all the switches that were shown in the tie lines is kept open and the remaining switches are closed. The value of reliability and power losses calculated for the network is shown in Table 2.

![Flow chart for GA implementation in reconfiguration of power distribution systems](image)

**Fig 3. Flow chart for GA implementation in reconfiguration of power distribution systems**
Table 1. Component Reliability Data

V. RECONFIGURATION OF DISTRIBUTION SYSTEM.

The optimal status of switches is determined by the binary coded genetic algorithm. The switches in the distribution system reconfiguration problem can remain only in two states: open or close. Assigning a value of 1 to the “close” state, and 0 to the “open” state, the switch status can be described by a binary vector. GA is an algorithm that searches for such binary vectors as the solution of a problem and, therefore, is found to be suitable to the present state. Fig 3. shows flow chart for GA implementation in reconfiguration of power distribution systems.

<table>
<thead>
<tr>
<th>Component</th>
<th>( \lambda_t )</th>
<th>( \lambda_{f1} )</th>
<th>( s_1 )</th>
<th>( s_2 )</th>
<th>( \lambda_m )</th>
<th>( s_m )</th>
<th>( \lambda_{eo1} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transformer</td>
<td>0.0588</td>
<td>0.05555</td>
<td>144</td>
<td>144</td>
<td>1</td>
<td>16</td>
<td>0.00</td>
</tr>
<tr>
<td>Circuit breaker</td>
<td>0.1</td>
<td>0.14283</td>
<td>20</td>
<td>20</td>
<td>0.4</td>
<td>12</td>
<td>0.00</td>
</tr>
<tr>
<td>Busbar</td>
<td>0.0045</td>
<td>-</td>
<td>24</td>
<td>-</td>
<td>0.5</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Distribution</td>
<td>0.13</td>
<td>0.13</td>
<td>5</td>
<td>5</td>
<td>0.2</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Switch</td>
<td>0.2</td>
<td>0.2</td>
<td>5</td>
<td>5</td>
<td>0.2</td>
<td>4</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2. Solution for the base case

A. GENETIC ALGORITHM

Genetic algorithm mimic the metaphor of natural biological evolution. GA maintains population of individuals that represent candidate solutions. Each individual is evaluated to give some measure of its fitness to the problem from the objective function. In each generation, a new population is formed by selecting the more fit individuals based on a particular selection strategy. Some members of the new population undergo genetic operations to form new solutions. Fitter chromosomes have higher probabilities of being selected for the net generation. After several generations, the algorithm converges to the best chromosome, which represents the optimum or near optimum solution. The flowchart is given in Fig.4.

Flowchart of genetic algorithm.

Genetic algorithm has following four major components: 1. A means of encoding solutions to the problem chromosome. 2. A function that evaluates the “fitness” of a solution. 3. A means of obtaining an initial population of solutions. 4. Genetic operators.
IV. CONCLUSION

This paper presents a methodology for the reconfiguration of distribution systems in order to maximize the reliability of the power supplied to the load points and to minimize the system power loss. The distribution system load flow is used to evaluate the system power loss. Probabilistic reliability models of components involved in the cut sets are then used to evaluate the joint probability of the event of power outage at the load points, and subsequently, the reliability at the load points. For a 33 bus radial distribution system, reliability and power losses have been calculated. The reconfiguration of the distribution system is going to be performed by closing or opening a set of switches using genetic algorithm as my future work.

REFERENCES