CHAPTER 6

APPLICATION OF GENETIC ALGORITHM TO DISTRIBUTION SYSTEM RECONFIGURATION FOR LOSS MINIMIZATION

6.1 INTRODUCTION

Electrical distribution networks are built as interconnected meshed networks. However, they are arranged to be radial in operation. Their configurations may be varied with manual or automatic switching operations so that all of the loads are supplied with reduced power loss. Reconfiguration also relieves the overloading of the network components. Feeder reconfiguration is performed by opening sectionalizing (normally closed) and closing tie (normally open) switches of the network. These switchings are performed in such a way that the radiality of the network is maintained and all the loads are energized. A normally open tie switch is closed to transfer a load from one feeder to another while an appropriate sectionalizing switch is opened to restore the radial structure. The problem to be addressed is, to determine the status of the network switches such that the reduction in power loss is achieved.

The loss minimum reconfiguration problem in the open loop radial distribution system is basically one of the complex combinational optimization, since the normal open sectionalizing switches must be determined appropriately. From the limit of the computational burden, methods such as branch and bound can not be applied to even a normal scale distribution problem (Baran 1989).
Genetic Algorithm is a search algorithm based on the mechanics of natural selection and natural genetics. It combines the adaptive nature of the natural genetics or the evolution procedures of organs with functional optimizations. By simulating the survival of fittest among string structures, the optimal string (solution) is searched by randomized information exchange. In every generation, a new set of artificial strings is created using its fittest pieces of the old ones. It efficiently exploits historical information to speculate on a new search point with expected improved performance. It searches from a population of points, not from a single point and the possibility of finding a near optimum in an early generation is very high.

In this thesis work, Genetic Algorithm is successfully applied to the loss minimum configuration problem. In the proposed algorithm, strings consist of sectionalizing switch status or radial configuration and the fitness function consists of total system losses. The loss minimum reconfiguration problem is formulated as mixed integer programming problem [Kochi 1992]. IEEE 16-Bus distribution system is taken as test system. The total losses for the minimum loss configuration are evaluated. The loss reduction demonstrates the validity and effectiveness of the proposed methodology. Genetic algorithm may be efficiently applicable to many kinds of problems in power system planning and operation and in TNEB 20-Bus system.
6.2 RADIAL DISTRIBUTION SYSTEM

Figure 6.1 Schematic diagram of primary circuit of a distribution system

In the Figure 6.1, load points where the transformers are tapped off from the primary circuit is marked by dots. There are two types of switches as shown in the system. Normally Closed switches connect the line switches (CB1-CB6) and Normally Open switches on the tie lines connect either two primary feeders (CB7) or two substations (CB8) or loop type laterals (CB9).

Distribution systems are normally operated as radial networks. However, changing the state of some sectionalizing switches changes the configuration.

The base network can be reconfigured by first closing a tie line switch (CB7). Since this switching will create a loop in the system, a branch in the loop containing a switch has to be opened (CB3) to restore the radial structure of the system. As a result of this, the loads between the branches 8 and 11 will be transferred from one feeder to the other as in Figure 6.2.

The load transfer between different substations can be obtained by branch exchange type switching. By closing the sectionalizing switch (CB8)
and opening (CB6), the loads at branches 18, 19, 20 are transferred from SS2 to SS1.

The network reconfiguration is made

i) To reduce the system power loss.

ii) To relieve the overloads in the network.

The test system consists of three feeders (Figure A3.1), 16 buses and 16 switches. Out of the 16 switches, 13 are normally closed (sectionalizing) and 3 are normally opened (tie) switches. The operation (s12, s15) transfers load 5 from feeder 1 to feeder 2 by opening a sectionalizing switch s12 and closing the tie switch s15. Hence, closing a switch should always follow the opening of a switch. The load at bus 11 can be transferred to feeder 1 by closing the tie switch 15 and opening the sectionalizing switch 19. Similarly, other loads can be transferred from feeder by switching operations.

6.2.1 Formulation of the Problem

In this section, the network reconfiguration problem for loss minimization is discussed in detail.

To simplify the presentation, the system is represented on a per phase basis and the load along a feeder section as constant P, Q loads placed at the end of the lines. It is assumed that every switch is associated with a line in the system. The system of Figure 6.1 can be translated to an equivalent network as shown in Figure 6.2.
In the above figure, solid branches represent the lines that are in service and constitute the base radial configuration; dotted branches (branches 20, 21, 22) represent the lines with open switches.

The base network can be reconfigured by closing an open branch, say branch 21 in the figure. Since this switching will create a loop in the system, (composed of branches 1, 2, 3, 21, 11, 10, 9, 8, 7 and 15), a branch in the loop containing a switch has to be opened, say branch 7, to restore the radial structure of the system. As a result of this switching, the loads between the branches 7-11 will be transferred from one feeder to the other.

The network reconfiguration problem for loss reduction involves the load transfer between the feeders or substations by changing the position of the switches.
The radial configuration corresponds to a “spanning tree” of a graph representing the network topology. The minimal spanning tree problem can be stated as follows. Given a graph, find a spanning tree such that the objective function is minimized, while the following constraints are satisfied, (i) voltage constraints, (ii) radiality constraints.

This is a combinatorial optimization problem, since the solution involves the consideration of all possible spanning trees.

### 6.2.2 Mathematical Formulation

The loss reduction in network reconfiguration problem is formulated as

\[
\text{Min } \sum_{i=0}^{N_B-1} r_i \frac{P_i^2 + Q_i^2}{V_i^2} \text{ P.u.} \tag{6.1}
\]

such that \( V_{i\text{min}} < V_i < V_{i\text{max}} \) \tag{6.2}

where

- \( N_B \) = number of buses
- \( r_i \) = Resistance of the \( i^{th} \) branch
- \( x_i \) = Reactance of the \( i^{th} \) branch
- \( P_i \) = Real power flowing through the branch
- \( Q_i \) = Reactive power flowing through the branch
- \( V_i \) = Voltage at the receiving end of the branch.

The network reconfiguration has to obey the following rules:

i) No feeder section can be left out of service

ii) Radial network structure must be retained.
6.2.3 Power Flow Equations

Power flow in a radial distribution network can be described by a set of recursive equations called Distribution Flow Branch Equations that use the real power, reactive power and voltage at the sending end of a branch to express the same quantities at the receiving end of the branch as

\[ P_{i+1} = P_i - r_i \frac{P_i^2 + Q_i^2}{V_i^2} - P_{Li+1} \]  
\[ Q_{i+1} = Q_i - x_i \frac{P_i^2 + Q_i^2}{V_i^2} - Q_{Li+1} \]  
\[ V_{i+1}^2 = V_i^2 - 2(r_i P_i + x_i Q_i) + (r_i^2 + x_i^2) \frac{P_i^2 + Q_i^2}{V_i^2} \]

Distribution Flow Branch Equations can be written backward too, by using the real power, reactive power, voltage at the receiving end of a branch to express the same quantities at the sending end of the branch as

\[ P_{i-1} = P_i + r_i \frac{P_i^2 + Q_i^2}{V_i^2} + P_{Li} \]
\[ Q_{i-1} = Q_i + x_i \frac{P_i^2 + Q_i^2}{V_i^2} + Q_{Li} \quad (6.7) \]

\[ V_{i-1}^2 = V_i^2 + 2 \left( r_i P_i + x_i Q_i \right) + \left( r_i^2 + x_i^2 \right) \frac{P_i^2 + Q_i^2}{V_i^2} \quad (6.8) \]

where \[ P_i' = P_i - P_{Li} \quad (6.9) \]

and \[ Q_i' = Q_i + Q_{Li} \quad (6.10) \]

### 6.2.4 Simplified Distribution Flow Method

The quadratic terms in the Distribution Flow Branch Equations represent the losses on the branches and hence they are much smaller than the branch power terms \( P_i, Q_i \). By dropping the second order terms, the approximate power flow equations are of the form

\[ P_{i-1} = P_i - P_{Li-1} \quad (6.11) \]

\[ Q_{i-1} = Q_i - Q_{Li-1} \quad (6.12) \]

\[ V_{i-1}^2 = V_i^2 - 2 \left( r_i P_i + x_i Q_i \right) \quad (6.13) \]

The power loss in a branch is expressed as

\[ P_{Li} = r_i \frac{P_i^2 + Q_i^2}{V_i^2} \quad (6.14) \]

where \( P_{Li} \) = Power loss in \( i^{th} \) branch
6.2.5 GA Based Algorithm

To implement the genetic algorithm to the solution procedure for the loss minimum problem, the following method is adopted.

The status of the switches is considered as genes (binary bits). The bit with a value of “zero” (“one”) implies that the corresponding switch is open (close). The sending end and receiving end of the switch is taken into account. To retain a radial network structure, only one switch is opened in each mesh of the distribution system or closed.

The coding scheme is illustrated in Table 6.1. ‘0’ indicates an ‘open’ switch and ‘1’ indicates a ‘closed’ switch. There are 13 sectionalizing switches and 3 tie switches for the 16-bus distribution system. Hence the GA encoding requires 16 bits for a chromosome string as given in Table 6.1. The basic configuration of 16-bus distribution system consists of three normally open tie-switches. Tie switches s15, s21, s26 are coded as ‘0’. The remaining 13 switches are coded as ‘1’.

<table>
<thead>
<tr>
<th>S11</th>
<th>S12</th>
<th>S13</th>
<th>S14</th>
<th>S15</th>
<th>S16</th>
<th>S17</th>
<th>S18</th>
<th>S19</th>
<th>S20</th>
<th>S21</th>
<th>S22</th>
<th>S23</th>
<th>S24</th>
<th>S25</th>
<th>S26</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

The proposed algorithm steps can be summarized as follows.

Step 1: Read the bus data and line data for the distribution test system.

Step 2: Generate number of random variables in 1 and 0’s of 16 bit size as per the population size and also maximum number of iterations for genetic algorithm.
Step 3: Check the radiality, if the distribution network has no loops and when all the loads were connected, the network is radial, otherwise go to step 2.

Step 4: Choose the initial population that obeys the radiality and also check the sending end and receiving end connection for the branches in the network.

Step 5: Calculate the fitness for the population and hence determine the voltage and power loss for the same.

Step 6: Perform crossover operation by taking two chromosomes at a time from the population. Generate a random number for the crossover point. Perform crossover operation by interchanging the bits in the left side for the cross point.

Step 7: Perform mutation operation (after cross over operation) by generating 2 random numbers monitoring the chromosomes and change the bit 1 to 0 or 0 to 1 for the two chromosomes.

Step 8: If the off spring does not obey the radiality, replace it with 1’s.

Step 9: Sort the population and off springs.

Step 10: Choose the best individuals of population size according to their fitness.

Step 11: Steps 6 to 10 are repeated until maximum iteration is reached.

Step 12: The minimum loss, maximum loss, average loss and fitness values are displaced for the given numbers of iteration.
Step 13: The switch status for the minimum loss configuration is also displaced.

Step 14: Stop the process.

6.2.6 Results and Discussion

To illustrate the efficiency of the proposed idea for network reconfiguration, IEEE 16-Bus distribution systems are used as test systems. The numerical data for IEEE 16-Bus distribution system is tabulated in appendix 3. The simulation studies are carried out on Intel Pentium - IV, 3.0 – GHz system in MATLAB 7.0 environment.

The voltages for the system are calculated by the power flow equations. The real power loss for the basic configuration is 0.00615797 p.u. The switches that are opened are tie-switches and they are s15, s21, s26 as shown in Figure A3.1. The minimum voltage level is 0.970051 p.u. The crossover rate and mutation rate are chosen as 0.8 and 0.05. The population size is varied from 10 to 20. The number of iterations is chosen as 200. The real power loss for the loss minimum configuration is 0.00562908 p.u. The minimum voltage level improves to 0.972244 p.u. The switches that are opened for the minimum loss configuration are s17, s19, s26 as shown in Figure 6.4. The fitness values for various population sizes are compared and tabulated in Table 6.3. The relative average fitness decreases gradually, when the number of iterations increases and reaches a constant value as shown in Figure 6.5.

It was observed that for low population size of 10, the solution may not converge to minimum loss configuration, while a population size of 20 gives minimum loss configuration.
Table 6.2 Loss analysis of the test system

<table>
<thead>
<tr>
<th></th>
<th>Basic Configuration (per unit)</th>
<th>Minimum Loss Configuration (per unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss</td>
<td>0.00615797</td>
<td>0.00562908</td>
</tr>
<tr>
<td>Voltage</td>
<td>0.970051</td>
<td>0.972244</td>
</tr>
</tbody>
</table>

Table 6.3 Fitness value results

<table>
<thead>
<tr>
<th>Population size</th>
<th>Minimum Fitness Value</th>
<th>Average Fitness Value</th>
<th>Maximum Fitness Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.00588718</td>
<td>0.00603241</td>
<td>0.00612974</td>
</tr>
<tr>
<td>20</td>
<td>0.00562908</td>
<td>0.00588718</td>
<td>0.00581715</td>
</tr>
</tbody>
</table>

Table 6.4 Switch status for the minimum loss configuration

<table>
<thead>
<tr>
<th>S11</th>
<th>S12</th>
<th>S13</th>
<th>S14</th>
<th>S15</th>
<th>S16</th>
<th>S17</th>
<th>S18</th>
<th>S19</th>
<th>S20</th>
<th>S21</th>
<th>S22</th>
<th>S23</th>
<th>S24</th>
<th>S25</th>
<th>S26</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Figure 6.4 Minimum loss configuration system

Figure 6.5 Iteration performance for minimum loss configuration
6.3 APPLICATION TO INDIAN TNEB 20-BUS SYSTEM

6.3.1 Introduction

we have collected the data from TNEB-Vijayapuri 110/11KV SS in Kovilpatti (TK) under Tuticorin (Dist). The minimum loss reconfiguration was obtained using Genetic Algorithm as discussed in chapter 6.2.5 for validity.

The corresponding feeders are

Feeder1  $\rightarrow$ Salnaichenpatty

Feeder2  $\rightarrow$ Ketchilapuram

Feeder3  $\rightarrow$ Pandavarmangalam

6.3.2 TNEB 20-Bus System

The base network can be reconfigured by closing an open branch, say branch S15 in Figure 6.6. This switching will create a loop in the system, so branch S14 has to be opened to restore the radial structure of the system. As a result of switching, the loads will be transferred from one feeder to another.

![Figure 6.6 Basic Schematic Diagram of TNEB 20-Bus system](image-url)

Figure 6.6 Basic Schematic Diagram of TNEB 20-Bus system
Table 6.5 Switch status for the basic configuration

<table>
<thead>
<tr>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
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<th>S7</th>
<th>S8</th>
<th>S9</th>
<th>S10</th>
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<th>S14</th>
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<th>S16</th>
<th>S17</th>
<th>S18</th>
<th>S19</th>
<th>S20</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 6.6 Line data for TNEB 20-Bus system

<table>
<thead>
<tr>
<th>Bus</th>
<th>Section Resistance (p.u.)</th>
<th>Section Reactance(p.u.)</th>
<th>Bus Load MW</th>
<th>P</th>
<th>Q</th>
<th>MVAR</th>
<th>End Bus Capacitance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4</td>
<td>0.77266</td>
<td>0.510989</td>
<td>0.01294</td>
<td></td>
<td></td>
<td>0.009708</td>
<td>0.00315</td>
</tr>
<tr>
<td>4-5</td>
<td>0.9646</td>
<td>0.359645</td>
<td>0.010032</td>
<td></td>
<td></td>
<td>0.007524</td>
<td>0.00153</td>
</tr>
<tr>
<td>5-6</td>
<td>0.4331311</td>
<td>0.16155</td>
<td>0.006016</td>
<td></td>
<td></td>
<td>0.004512</td>
<td>0.00108</td>
</tr>
<tr>
<td>6-8</td>
<td>0.86638</td>
<td>0.32312</td>
<td>0.001408</td>
<td></td>
<td></td>
<td>0.001056</td>
<td>0.00027</td>
</tr>
<tr>
<td>8-9</td>
<td>0.30132</td>
<td>0.11229</td>
<td>0.000904</td>
<td></td>
<td></td>
<td>0.000678</td>
<td>0.00018</td>
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<tr>
<td>2-10</td>
<td>0.953585</td>
<td>0.53552</td>
<td>0.00591</td>
<td></td>
<td></td>
<td>0.004434</td>
<td>0.00108</td>
</tr>
<tr>
<td>10-11</td>
<td>0.3377042</td>
<td>0.205746</td>
<td>0.0084</td>
<td></td>
<td></td>
<td>0.0063</td>
<td>0.00135</td>
</tr>
<tr>
<td>11-14</td>
<td>0.29568</td>
<td>0.180097</td>
<td>0.0116</td>
<td></td>
<td></td>
<td>0.0087</td>
<td>0.00171</td>
</tr>
<tr>
<td>3-15</td>
<td>0.683307</td>
<td>0.560993</td>
<td>0.013008</td>
<td></td>
<td></td>
<td>0.009756</td>
<td>0.00262</td>
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<tr>
<td>15-16</td>
<td>0.58239</td>
<td>0.422629</td>
<td>0.00372</td>
<td></td>
<td></td>
<td>0.00279</td>
<td>0.00072</td>
</tr>
<tr>
<td>16-18</td>
<td>0.791048</td>
<td>0.295024</td>
<td>0.027352</td>
<td></td>
<td></td>
<td>0.002178</td>
<td>0.00063</td>
</tr>
<tr>
<td>18-19</td>
<td>0.94171</td>
<td>0.351231</td>
<td>0.01704</td>
<td></td>
<td></td>
<td>0.001578</td>
<td>0.00045</td>
</tr>
<tr>
<td>19-20</td>
<td>0.678018</td>
<td>0.252868</td>
<td>0.008632</td>
<td></td>
<td></td>
<td>0.002106</td>
<td>0.00054</td>
</tr>
<tr>
<td>6-7</td>
<td>0.33756</td>
<td>0.1748</td>
<td>0.005671</td>
<td></td>
<td></td>
<td>0.002145</td>
<td>0.00078</td>
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<tr>
<td>17-18</td>
<td>0.76816</td>
<td>0.28661</td>
<td>0.004578</td>
<td></td>
<td></td>
<td>0.00452</td>
<td>0.000417</td>
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<tr>
<td>10-12</td>
<td>0.1474</td>
<td>0.1605</td>
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<td></td>
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<td>0.004672</td>
<td>0.005671</td>
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<tr>
<td>11-13</td>
<td>0.1216</td>
<td>0.23499</td>
<td>0.004621</td>
<td></td>
<td></td>
<td>0.004685</td>
<td>0.005774</td>
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<tr>
<td>7-13</td>
<td>0.8663</td>
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</tr>
</tbody>
</table>
6.3.3 Reconfigured TNEB 20-Bus System

The voltages for the system are calculated by the Power flow equations. The real power loss for the basic configuration is also calculated and given in Table 6.8. The reconfiguration obtained by closing switch S15 and S20 and opening switch S14 and S16 to maintain Radiality as shown in Figure 6.7.

Figure 6.7 TNEB 20-Bus System for Best Configuration

This is the diagrammatic representation of the switch status for the best configuration of the Indian TNEB 20-Bus system.

Table 6.7 Switch status for the Best Configuration

<table>
<thead>
<tr>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
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<th>S6</th>
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<th>S10</th>
<th>S11</th>
<th>S12</th>
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<th>S14</th>
<th>S15</th>
<th>S16</th>
<th>S17</th>
<th>S18</th>
<th>S19</th>
<th>S20</th>
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</tr>
</tbody>
</table>

Thus the Minimum loss value for the best configuration is: 0.00686595.
The relative fitness decreases gradually, when the number of iteration increases and reaches a constant value as shown in Figure 6.9.

![Figure 6.8](image1.png)  
**Figure 6.8** Convergence of minimum fitness value with respect to generations

![Figure 6.9](image2.png)  
**Figure 6.9** Convergence of maximum fitness value with respect to generations
6.3.4 Loss Analysis for the Test System

After reconfiguration the minimum loss and voltage were calculated and compared with basic configuration as given in Table 6.8.

Table 6.8 Loss Analysis for the TNEB 20-Bus test system

<table>
<thead>
<tr>
<th>Loss Minimum/ Voltage Improvement</th>
<th>Basic Configuration (p.u.)</th>
<th>Minimum Loss Configuration (p.u.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss</td>
<td>0.00842813404987</td>
<td>0.00686595</td>
</tr>
<tr>
<td>Voltage</td>
<td>0.86749626435207</td>
<td>0.877894521</td>
</tr>
</tbody>
</table>
6.3.5 Fitness Value Results

The fitness values for various population sizes are compared and tabulated in Table 6.9.

Table 6.9 Fitness value results

<table>
<thead>
<tr>
<th>Population Size</th>
<th>Minimum fitness value</th>
<th>Average fitness value</th>
<th>Maximum fitness value</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
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<td>0.00812265</td>
<td>0.00857356</td>
</tr>
<tr>
<td>20</td>
<td>0.00686595</td>
<td>0.01046243</td>
<td>0.00887202</td>
</tr>
</tbody>
</table>

6.3.6 Conclusion

This chapter discusses the distribution systems loss, configuration methodology using Genetic Algorithm. The solution methodology employs a search over different radial configurations by considering branch exchange type switching. GA was able to produce a near optimal solution by adopting the adaptive nature of natural genetics. From the numerical example, it was observed that the proposed method is computationally efficient and the loss reduction is achieved by this algorithm. This result demonstrates the validity and effectiveness of the proposed methodology.
CHAPTER 7

CONCLUSION AND FUTURE WORK

7.1 INTRODUCTION

This chapter reviews the result obtained and scope for further research on this topic. The objective of the thesis stated in the first chapter is recalled.

The primary objective of this thesis is to propose an Evolutionary Computation approach to Combined Economic and Emission Dispatch Problems in power system where the plants are having quadratic fuel cost functions and with valve-point loading. This approach has also been demonstrated for CEED problems with multi-objectives.

By suitably applying Genetic Algorithm to Distribution system reconfiguration and by introducing FACTS devices in EHV lines, the losses are reduced. The validity was verified to an Indian TNEB 20-Bus system.

7.2 REVIEW OF THE WORK DONE

The work has been carried out in two phases.

i) Optimizing the fuel cost and emission output using Evolutionary Programming

ii) Loss minimization in transmission and distribution using Genetic Algorithm
7.2.1 Optimization of the Fuel Cost and Emission Output

The mathematical formulation for ELD and CEED problems were developed. For ELD problem quadratic, non-converse and non-differentiable forms were considered. The transmission losses were determined using $B_{mn}$ coefficients. A modified penalty factor was developed and tested to CEED problem in MATLAB 7.0 environment. The results were presented for six unit system. The results of the proposed method was compared with the standard method and gives fairly lesser power loss with lesser emission output with marginal increase in fuel cost.

Evolutionary Programming was developed with weighted sum method for six generator systems having quadratic fuel cost equation for a load of 490, 522 and 598 MW. The results were compared with already published results with Genetic Algorithm and Micro Genetic Algorithm applications. The proposed EP algorithm gives fairly lesser power loss and fuel cost.

The same algorithm was applied to valve-point loading. The results show that the EP algorithm is a powerful optimization tool when compared to a complete enumeration method for the same fuel cost.

The proposed MOEP algorithm was tested for a three unit system with quadratic fuel functions and emission functions and was compared with the weighted sum method. The global Pareto optimal solutions are obtained in a single run. It is matching exactly with the 81 optimal solutions point of the weighted sum method. The time required is only 6.39sec.
7.2.2 Loss Minimization in Transmission and Distribution

When GA has been applied to an EHV line by introducing FACTS devices in suitable places, the transmission losses were fairly reduced. By proper reconfiguration of the radial feeder a minimum loss configuration was obtained. The proposed method was tested to an IEEE 16-Bus system and it was found that the loss was reduced from the basic reconfiguration with a raise in voltage level. The same algorithm was tested to Indian TNEB 20-Bus system and the results are encouraging. Hence the validity of the proposed algorithm was verified.

In Genetic Algorithm binary coding is effectively used in the distribution system reconfiguration and FACTS allocation. Two operators such as cross over and mutation are easily used in this problem. Where as, these operators are difficult to implement in real coded GA. In case of EP, only one operator mutation is used. Hence EP and GA are suitably applied in the respective problems. In all, the EC method (EP and GA) were found to be a useful tool for optimization related to power system problems.

7.3 RECOMMENDATIONS FOR FUTURE WORK

Evolutionary Computation and hence Evolutionary Programming Algorithm were mostly used for single objective function and in multi-objective, a maximum of two objectives alone were tested. More than two objectives may be tried in future. In the loss reduction, GA has been used as a tool. This may be applied to very large system, (i.e.) more than 20-Bus systems. So it may be more useful for the Electricity companies.

The application and comparison of Evolutionary Computation methods to small standard, proven test system is carried out. However it can be attempted for large scale system in future.