CHAPTER 6

VOLTAGE AND REACTIVE POWER ESTIMATION FOR CONTINGENCY ANALYSIS

6.1 INTRODUCTION

Contingency analysis is an important component of the security function, which is considered to be an integral part of the modern energy management system at energy control centers. Online steady state security analysis of electric power systems requires evaluation of the effects of a large number of generator unit and transmission line contingencies in order to assess the security of the system. Outages of some of these components may cause several local problems such as voltage magnitude limit violation, active power flow limit violation and complete block out of the system etc. Electric power system operators need to simulate all possible outage scenarios to determine the consequences of such outages and to prepare remedial actions. These simulations aim to estimate post outage voltage magnitudes and power flows.

In this work, an optimization technique based on Genetic Algorithm (GA) is presented for estimation of post contingency voltage and reactive power. Real time implementation of operational problems makes necessary the use of high speed computational methods while requiring reasonable accuracies. On the other hand, accuracy of the results and the speed of calculation depend on power flow technique as well as optimization algorithm
used. The results are tested on the IEEE 14-bus and IEEE 57-bus systems and the results show that the errors due to estimation are significantly reduced.

6.2 GENETIC ALGORITHM (GA)

Genetic Algorithm is composed of three essential operators as follows:

- Reproduction
- Crossover and
- Mutation

6.2.1 Reproduction

It represents a process in which each chain is copied according to the values of the function to optimize \( f_i \) (fitness). The function to be optimized is the final parameter which decides life or death of each chain. It is an operator that obtains a fixed number of copies of solutions according to their fitness value. In fact it is a method of searching among an enormous number of possibilities for solutions. If the score increases, then the number of copies increases too.

A score value is associated with a given solution according to its distance from the optimal solution (closer distances to the optimal solution mean higher scores).

6.2.2 Crossover

A crossing makes it possible to create new chains using a generator of random numbers, the copy of chains, and exchanges partial of chains. It is the primary genetic operator, which explores new regions in the search space. Crossover is responsible for the structure recombination (information
exchange between mating chromosomes) and the convergence speed of the GA and is usually applied with high probability (0.5 – 0.9). The strings to be crossed have been selected according to their scores using the roulette wheel.

6.2.3 Mutation

It is the inversion of a bit in a chromosome. Mutation is used both to avoid premature convergence of the population (which may cause convergence to a local, rather than global, optimum) and to fine tune the solutions.

6.2.4 Algorithm

Step 1: Input data: \(v_{lb}, v_{ub}, P_c, P_m\), the function of adaptation and size of the population. Where, \(v_{lb}, v_{ub}\) - lower and upper bounds. \(P_c, P_m\) - crossover and mutation probabilities.

Step 2:
- To code the variables of the function into binary.
- To choose arbitrary the initial population.
- To decode the chains to calculate the value of the function to be optimized. For that, it is enough to inject the values of chains decoded in the function.

Step 3: To use the three following operators:
- Reproduction
- Crossover
- Mutation

Step 4: If the convergence of GA is reached, then print the optimal values and stop; else go to step 2.

The algorithm has been illustrated using the flow chart shown in Figure 6.1.
Figure 6.1 Flow Chart for Genetic Algorithm

Start

Inputs: Population size, Max. No. of generations, Crossover, Mutation and Reproduction probabilities (P_m and P_c)

Generation = 1

Randomly generate initial population

Find the score of each individual in the current population

Check for convergence

Y

Stop

N

Is Generation = Max. generations

Y

Stop

N

Select parents based on their scores

Produce children by application of genetic operators

Generation = Generation + 1

Replace the current population with children to form next generation
6.3 RESULTS AND DISCUSSION

In this work, the results on the IEEE 14-bus and IEEE 57-bus test systems are presented to illustrate the capabilities of the proposed work. The IEEE 14-bus test system, consists of 5 generator buses (bus 1 is slack bus 2, 3, 6 and 8 are PV buses), 9 load buses and 20 lines in which 3 lines (4-7, 4-9 and 5-6) are with tap changing transformers. The IEEE 57-bus test system consists of 7 generator buses, 50 load buses and 80 lines in which 17 lines are with tap changing transformers. The line parameters and loads are taken from Pai (2006). The results of a single contingency for the proposed test systems are presented.

For the IEEE-14 bus test system, the outage of line 2–4 is presented in detail. The post-outage voltage is given in Table 6.1. From test results, it is found that the estimated post-outage voltages are larger than or equal to the corresponding results from linear estimate (Pablo Ruiz et al 2007). The post-outage reactive power generations and flows are given in Tables 6.2 and 6.3. Comparing to Pablo Ruiz et al 2007, the proposed linear estimation method gives accurate results.

For the IEEE-57 bus test system, the outage of line 12–13 is presented in detail. The post-outage voltage is given in Table 6.5. The reactive power generations and flows are given in Tables 6.6 and 6.7.

Estimation errors for IEEE 14-bus and IEEE 57-bus systems are presented in Tables 6.4 and 6.8. The improved accuracy is due to the fact that this technique takes into account of VAR limits, which are ignored in estimates in Ozdemir et al 2005. The obtained mean error and standard deviation are less compared to the results presented in the literature (Pablo Ruiz et al 2007) except for the mean error of Post-Outage MVAR Flows for the IEEE 57-bus systems.
Table 6.1 Post-Outage Voltage Magnitudes (p.u.) for IEEE 14-bus system

<table>
<thead>
<tr>
<th>Bus No</th>
<th>Exact value</th>
<th>Linear Estimate (Pablo Ruiz et al 2007)</th>
<th>Proposed Method (GA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0600</td>
<td>1.0600</td>
<td>1.0600</td>
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Table 6.2 Post-Outage MVAR Generations for IEEE 14-bus system

<table>
<thead>
<tr>
<th>Bus No</th>
<th>Exact value</th>
<th>Linear Estimate (Pablo Ruiz et al 2007)</th>
<th>Proposed Method (GA)</th>
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<tr>
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### Table 6.3 Post-Outage MVAR Flows for IEEE 14-bus system

<table>
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<th>Line and Direction</th>
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<th>Linear Estimate (Pablo Ruiz et al 2007)</th>
<th>Proposed Method (GA)</th>
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Table 6.4 Estimation Errors for IEEE14-bus system

<table>
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<tr>
<th>Error</th>
<th>Linear Estimate (Pablo Ruiz et al 2007)</th>
<th>Proposed Method (GA)</th>
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Table 6.5 Post-Outage Voltage Magnitudes (p.u) for IEEE 57-bus system

<table>
<thead>
<tr>
<th>Bus No</th>
<th>Exact Value</th>
<th>Outage of Line 12-13</th>
<th>Linear Estimate (Pablo Ruiz et al 2007)</th>
<th>Proposed Method(GA)</th>
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### Table 6.6 Post-Outage MVAR Generations for IEEE 57-bus system

<table>
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<th>Bus No</th>
<th>Exact Value</th>
<th>Linear Estimate (Pablo Ruiz et al 2007)</th>
<th>Proposed Method(GA)</th>
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### Table 6.7 Post-Outage MVAR Flows for IEEE 57-bus system

<table>
<thead>
<tr>
<th>Line and Direction</th>
<th>Exact Value</th>
<th>Linear Estimate (Pablo Ruiz et al 2007)</th>
<th>Proposed Method (GA)</th>
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Table 6.8 Estimation Errors for IEEE 57-bus system

<table>
<thead>
<tr>
<th>Error</th>
<th>Linear Estimate (Pablo Ruiz et al 2007)</th>
<th>Proposed Method (GA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
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<tr>
<td>Flows [MVAR]</td>
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</tr>
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6.4 CONCLUSION

- The estimation of post contingency voltages, reactive power generations and flows are based on Genetic Algorithm is presented.

- The results on the IEEE 14-bus and IEEE 57-bus test systems show that the estimation errors are significantly reduced with the proposed technique compared to the techniques in the literature (Pablo A. Ruiz et al 2007).

- The linear estimation method is useful in power system operation and control, where contingency studies are needed.