CHAPTER 4

CUCKOO SEARCH ALGORITHM BASED OPF

4.1  INTRODUCTION

Cuckoo search was first used by Suash Deb & Xin-she Yang (2009). They observed the action of cuckoo to find the other species bird nest to lay their eggs. Cuckoo search the best bird nest to lay their eggs which gives best breeding. The algorithm is idealized by three rules to fit engineering applications. In this research work along with cuckoo search fuzzy logic technique is used to find the best reactive power limits of the generators. IEEE 30 bus system is used in this approach to implement the algorithms.

4.2  FUZZY LOGIC CONTROLLER

In this research fuzzy logic is used to find the reactive power to be delivered by the generator. Then cuckoo search algorithm is used to find optimal real power generation to get minimum losses. Fuzzy logic is a multi-valued logic system. It starts from fuzzy set, it has defined boundary. Fuzzy logic is solved using membership functions. This membership function gives degree of acceptance of the fuzzy set. Fuzzy logic is very effective to select best input for the desired output. It works based on if then rule. Based on the input condition it select best input values from the set of many input combinations. It gives significant input rather than precision input. The main reasons of using fuzzy logic are
• It has simple concepts and easy to understand
• It is flexible and no need to start the process every time from scratch
• It tolerance for less fitness data and give opportunity to them
• It is easy to model non-linear systems
• It may hybrid with any other intelligent techniques
• Fuzzy logic is a convenient way to map an input solution space to an output solution space.

A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The different types of membership functions are 1) Triangular 2) Trapezoidal 3) Gaussian 4) Sigmoid and 4) Polynomial functions. A membership function associated with a given fuzzy set maps an input value to its appropriate membership value.

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. In this research work the value of reactive power generations are calculated using the fuzzy logic system and it is known as fuzzy inference system as given the Figure 4.1.

![Figure 4.1 Fuzzy Inference system](image)
Fuzzy logic controller used in this work as a process of fuzzification, decision making, defuzzification and knowledge base as given the Figure 4.2.

Figure 4.2 Structure of Fuzzy Logic Controller

Based on manner life of Cuckoo bird, one of the new bio-inspired algorithms is the Cuckoo Search (CS). Cuckoos utilize a forceful strategy of reproduction that occupies the female hew nests of other birds to put down their eggs fertilized. Occasionally, the egg of cuckoo in the nest is revealed and the hacked birds throw away or abandon the nest and begin their own offspring somewhere else. Based on the subsequent three idealized rules, the Cuckoo Search was proposed by Yang and Deb (2009) and they are:

- Every cuckoo lays one egg at a time, and deposits it in a erratically chosen nest;
- The top nests with high class of eggs (solutions) will take over to the next generations;
- The number of existing host nests is fixed, and a host can find out an alien egg with a possibility \( pa \in [0, 1] \). In this case, to build an entirely new nest in a new place the host bird can either throw the egg away or discard the nest so as.
An essential advantage of this algorithm is its plainness. There is basically only a single parameter in CS (apart from the population size) comparing with other population or agent based meta-heuristic algorithms such as particle swarm optimization.

4.3 CUCKOO SEARCH ALGORITHM BASED OPF

IEEE 30 bus system is considered for the implementation. In this case 5 real power generation, 6 generator voltage and 4 transformer tap position are used as control variables. To optimize OPF problem the control variables, real power generation, generator bus voltages and transformer tap position are considered. The limits on these control variables form prime constraints in addition to power balance condition.

4.3.1 Encoding

Encoding is the process of converting set of control variables in OPF into optimization problem. Ability of cuckoo is to operate on floating point and mixed integer makes ease of encoding. Final value of vector gives optimal values of control variables is the optimal solution of OPF. For the evolution and better convergence fitness function is most important as follows.

4.3.2 Fitness Function

An appropriate fitness function is vital for evolution and convergence. Losses are taken as objective, which need to be minimized. Objective function value for a vector is called fitness for the cuckoo egg. Egg represents the solution or the values of the real power generation which gives the minimum loss. Placing the egg in the nest is equivalent to find the
objective values of the particular set of control variables the solution which gives minimum loss is the nest very suitable to lay the egg.

4.3.3 Stopping Criteria

Cuckoo search improves problems’ solution iteration by iteration and the iteration has to be stopped either the problem is converged or iteration reached its maximum value. Stopping of iteration is important to provide solution for time complexity. In this research work maximum number of 200 iterations, is considered as stopping criteria.

4.4 IMPLEMENTATION OF CUCKOO SEARCH ALGORITHM FOR SOLVING OPF

Step1: Initialize all the input reactive power limits.

Step 2: To find the fitness of the system using the following the Equation (4.1)

\[ \text{fitness} = \text{Min} \sum_{k=1}^{N_R} P_{Loss} (k) \] (4.1)

Step 3: Determine the better fitness and generate the new solution using the following Equation (4.2)

\[ X_{i+1} = X_i + \alpha \oplus \text{Levy} (\lambda) \] (4.2)

where, \( \alpha > 0 \) is the step size, which should be related to the scale of the problem of interest, the product \( \oplus \) means entry-wise multiplications. In this research work, we consider a Levy flight in which the step-lengths are distributed according to the following probability distribution Equation (4.3)

\[ \text{Levy} (\lambda) = t^{-\lambda}, 1 < \lambda \leq 3 \] (4.3)
**Step 4:** Find the fitness probability rate using \( p_a \in [0,1] \), whereas the best solution can be determined by the minimum power loss which is given in the fitness function.

**Step 5:** Terminate the process

### 4.5 SIMULATION RESULTS

In this research work IEEE 30 bus system is considered and shown in Figure 4.3. For the loss minimization the Equation given in the chapter 2, (2.10) is considered as objective function. The system has 6 generators, 4 transformers and 41 transmission lines. In this case 5 real power generation, 6 generator voltage and 4 transformer tap position are used as control variables. This is the standard test case and used in most of the research papers.

(Source: Power Systems Test Case Archive – University of Washington Electrical Engineering)

*Figure 4.3 IEEE 30 bus system Single line diagram*
The Fuzzy logic can be producing the reactive power generation limits depending on the expert knowledge rules base. The optimal reactive power limit has been identified using the cuckoo search algorithm. It is optimization algorithm, which determines the minimized power loss of the bus system and corresponding reactive power limits of the generators. The real power generation, Loss and Total generation Cost of the system is given in the Table 4.1. The real power loss is reduced as compared the system which is not optimized. Voltage profile of all the bus is given in the Figure 4.4. From this plot it is clear that, all the buses voltage level more than 0.97.

![Voltage stability of the proposed system](image)

**Figure 4.4 Voltage level at all the buses**
Table 4.1 Optimal Power Generation given by Cuckoo Search Algorithm

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Variables</th>
<th>$P_{\text{min}}$ (MW)</th>
<th>$P_{\text{max}}$ (MW)</th>
<th>Taker Niknem et al. (2011)</th>
<th>Ranjit Roy et al. (2015)</th>
<th>Ouafa Herbadji et al. (2016)</th>
<th>CS - OPF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$P_{G1}$ (MW)</td>
<td>50</td>
<td>200</td>
<td>179.1929</td>
<td>177.236</td>
<td>176.611</td>
<td>173.08</td>
</tr>
<tr>
<td>2</td>
<td>$P_{G2}$ (MW)</td>
<td>20</td>
<td>80</td>
<td>48.9804</td>
<td>48.701</td>
<td>48.624</td>
<td>47.01</td>
</tr>
<tr>
<td>3</td>
<td>$P_{G5}$ (MW)</td>
<td>15</td>
<td>50</td>
<td>20.4517</td>
<td>21.353</td>
<td>21.523</td>
<td>22.34</td>
</tr>
<tr>
<td>5</td>
<td>$P_{G11}$ (MW)</td>
<td>10</td>
<td>30</td>
<td>11.5897</td>
<td>11.898</td>
<td>12.170</td>
<td>12.26</td>
</tr>
<tr>
<td>6</td>
<td>$P_{G13}$ (MW)</td>
<td>12</td>
<td>40</td>
<td>11.9579</td>
<td>12.00</td>
<td>12.271</td>
<td>12.61</td>
</tr>
<tr>
<td>7</td>
<td>Total Power Generation, MW</td>
<td>---</td>
<td>---</td>
<td>293.0991</td>
<td>292.322</td>
<td>293.024</td>
<td>291.55</td>
</tr>
<tr>
<td>8</td>
<td>Total Demand, MW</td>
<td>---</td>
<td>---</td>
<td>283.4</td>
<td>283.4</td>
<td>283.4</td>
<td>283.4</td>
</tr>
<tr>
<td>9</td>
<td>Real Power Loss, MW</td>
<td>---</td>
<td>---</td>
<td>9.6991</td>
<td>8.934</td>
<td>9.624</td>
<td>8.15</td>
</tr>
<tr>
<td>10</td>
<td>Generating Cost ($/hr)</td>
<td>---</td>
<td>---</td>
<td>802.287</td>
<td>800.0963</td>
<td>802.721</td>
<td>799.031</td>
</tr>
</tbody>
</table>

Minimization of loss versus iterations is given in the Figure 4.5. The loss converged at 24th iteration and the loss is reduced to the minimum value of 8.15MW. The Generation cost converged in 799.031$/hr at 20th iteration. For the generating cost minimization the quadratic cost function without valve point loading effect and 100% loading condition is considered. The convergence curve for that is given in the Figure 4.6. Time taken to get convergence result is 22 seconds.
Figure 4.5 Real Power loss convergence curve

Figure 4.6 Fuel cost minimization for the iterations
Total generation and demand for the base case and proposed method comparison is graphically given in the Figure 4.7. Total power generation is reduced to 291.55 MW and which intern reduces the losses in the system. Figure 4.8 gives the real power loss comparison between existing and proposed algorithm. It shows that loss is reduced to 8.15MW. Figure 4.9 explains about the fuel cost comparison between existing and proposed algorithm also it shows that fuel cost is reduced to 799.031 $/hr.

![Figure 4.7 Comparison of total power generation and demand versus various algorithms](image)

![Figure 4.8 Comparison of real power losses versus various algorithms](image)
Figure 4.9 Comparison of fuel cost versus various algorithms

To take care of different initial condition the algorithm is executed for 50 trails and the worst, average and best results are given in the graphical representation as below. Fuel cost and Real Power Loss for IEEE 30 bus system is optimized using the Cuckoo Search Algorithm. Figure 4.10 and 4.11 shows the Fuel Cost optimization for 50 trails and Real Power Loss optimization for 50 trails respectively.

Figure 4.10 Fuel Cost optimization for 50 trails.
4.6 CONCLUSION

This chapter discussed the applications of Fuzzy Logic and Cuckoo search algorithm to solve OPF problems. Fuzzy logic gives the best limits for the reactive power of the generators and the cuckoo search used to find best real power generation for the minimum loss and generating cost for without valve point loading effect. The obtained simulation results shows reduction in generating cost losses, and improvement of voltage profile for standard IEEE 30 bus system. The real power loss is reduced by 8.15MW and the fuel cost is reduced by 799.031$/hr in this approach. In this proposed method real power loss are reduced by 15.92% and the fuel cost is reduced by 1%.