Chaotic Search Based Genetic Algorithm for Economic Load Dispatch Problem

Snehlata, Mrs. Sanju Saini
Department of Electrical Engineering, Faculty of Engineering and Technology
Deenbandhu Chhotu Ram University of Science and Technology,
Murthal, Sonipat Haryana (India)-131039
snehpanchal89@gmail.com, sanjusaini3669@gmail.com

Abstract— Economic load dispatch is most common optimization problems in power system. Most of power plants operate on strategy of economic load dispatch. In this paper, a hybrid chaotic queue based genetic algorithm has been used for solving this problem. GA is most commonly used optimizing algorithm based on principal of natural evolution. Use of chaotic queue with GA generates several neighbourhoods of near optimal solutions to maintain solution variation. It can prevent the search process from becoming pre-mature. For the purpose of chaotic queue generation, use of tent equation instead of logistic equation results in improvement of iterative speed [4].

Index Terms— Economic load dispatch (ELD), Genetic Algorithm (GA), Chaotic Optimization Technique (COT), improved mutative chaotic optimization algorithm (IMCOA) , mutative chaotic optimization algorithm (MCOA)

I. INTRODUCTION

Recently, electricity demand has grown rapidly, but energy resources have decreased. Therefore, usage of energy must be economized. Main objective of ELD problem is to minimize the fuels cost of generating units, satisfying the equality and non equality constraints [1]. In past decade, many researchers have tried to improve optimization techniques for solving problem of ELD, e.g. partial swarm optimization (PSO) has been proposed to improve the quality of solutions [5]. Dynamic programming has been used to solve ELD problem when incremental rate heat curves are non monotonically increasing. However it has also been realised that conventional techniques becomes very complicated when dealing with dispatch problems. This paper uses a chaotic queue based genetic algorithm for solving ELD problem. The advantages of GA are simple structure; few control parameters and highly reliability [9]. Chaotic optimization directly utilizes chaotic variables to search the optimal solution. The ergodic & regularity properties of chaos make chaotic optimization to obtain global optimal solution more possibly than the methods which have been adapted before [7]. Here, a non-convex ELD problem including various constraints, valve effect and transmission losses, has been efficiently solved using chaotic queue based genetic algorithm.

II. PROBLEM FORMULATION

The main goal of Economic dispatch problem is to allocate the power to be generated from different units so that cost is minimized [1]. Hence, the problem is to minimize the fuel cost of generators units under power balance constraints and power generating constraints.

DOI: 03.AETS.2013.3.142_34
© Association of Computer Electronics and Electrical Engineers, 2013
Mathematically, Total fuel cost function is formulated as [6]:
\[ C = \sum_i C_i = \sum_i (a_i + b_i P_i + c_i P_i^2) \] (1)
Where \( C \) is total fuel cost; \( a_i, b_i, c_i \) are the cost function coefficients of generator \( i \); \( P_i \) is power of generator \( i \)
To minimize the fuel cost, following conditions must be satisfied:
Power balance constraint:
The equality constraints should be satisfied for power balance. The generated power should be equal to load demand and total loss
\[ \sum_i P_i = D + L \] (2)
Where \( \sum_i P_i \) is the total power generated by \( i \) units.
Transmission loss:
Transmission losses are calculated by power flow computation or the B coefficient method. If the B coefficient method is used then the relationship between transmission losses and the generation of units can be expressed as:
\[ P_s = P^T B_{GG} P + P^T B_{go} + B_{00} \] (3)
Here, \( P \) is the active power of \( n \) dimensions & \( B_{GG}, B_{go}, B_{00} \) are B coefficients.
Power output constraint:
Power generation of each generator should be laid between minimum and maximum value.
\[ P_{imin} \leq P_i \leq P_{imax} \] (4)
\( P_{imin} \) & \( P_{imax} \) are the minimum and maximum power generation of unit \( i \)
Valve point effect:
Mathematically, the valve point effect can be expressed as
\[ E_i = |g_i \sin (h_i (P_i - P_{imin}))| \] (5)
Where \( g_i \) & \( h_i \) are constants.
Hence, the actual characteristics of the unit’s fuel consumption can be expressed as
\[ FC = C + E \] Where \( FC \) is total fuel consumption.
Hence, summarizing the above formulations, the economic dispatch problem taking various constraints into account can be expressed mathematically as:
Minimize \[ FC = \sum_i C_i + E_i = \sum_i (a_i + b_i P_i + c_i P_i^2) + |g_i \sin (h_i (P_i - P_{imin}))| \]
Subject to \( \sum_i P_i = D + L \) (6)

III. GENETIC ALGORITHM

Genetic Algorithms were first introduced by John Holland in the early 1970s [8]. Nowadays, it has become an important tool in function optimization. Basically, GA is a stochastic method for global optimization based on evolution theory. The algorithm of GA is based on evaluation of set of solutions, called population. The population is initialized by randomly generated individuals. In this paper, initialization of the population has been done using a chaotic series & each individual’s suitability is determined by value of objective function, called fitness function. Further, Roulette wheel selection algorithm is used in this work to select the fittest possible individuals in the population

A. Operators of GA

Then new population is generated by different operations of GA.
Crossover: Crossover is primary operator of GA. The function of crossover is to combine the features of two parent’s structure and to form offspring’s as shown in figure1. Crossover operator produce new chromosomes that is different from their parent’s characteristics [8]. Two different strings share their good quality to produce better string. If the produced string is bad it will die off in the next generation. Strings are selected randomly but proportional to their fitness values in the mating pool. Different type of crossover methods are used like one point crossover, two point crossover etc. The crossover operation occurs in proportion to its probability. Probability of crossover is high, nearly 0.9.
Mutation: Sometimes a desired bit misses in the string at a particular position and this bit may be critical to produce good solutions Crossover may not be able to produce that bit at that particular position. Mutation takes care of this problem. The function of mutation is to take a bit from the string and alter it with some
probability as shown in figure2. But mutation probability is kept very low since mutation rate is very small in natural evolution.

Parent A: 100 | 110
Parent B: 011 | 101

Child A: 100110
Child B: 011110

New child A: 100010

Fig.1 Diagram of simple crossover

Fig. 2. Binary mutation

IV. CHAOTIC QUEUE BASED GA

Chaos states disorder and irregularities within the system. The chaotic system has similar characteristics, such as pseudo-random, parameter sensitivity and the initial condition sensitivity [7]. The hybrid algorithm used here uses a chaos search with genetic algorithm, thus preventing the pre-mature termination of the search process. The basic steps of the algorithm are as follows:

**Step1: Initialization:** Optimal solution from the previous generation is reserved & a population of solutions is generated randomly as [2]:

\[
\text{Initial solution} = [I_{1(0)}, I_{2(0)}, \ldots, I_{i(0)}] \quad (7)
\]

Where, \(i\) is the no. of parameters to be optimized.

***Step2: Normalization:** Transform the \(L_{i(t)}\) to the interval of \([0, 1]\), i.e.

\[
Z_{i(t)} = \frac{L_{i(t)} - P_{i}^\text{min}}{P_{i}^\text{max} - P_{i}^\text{min}} \quad (10)
\]

***Step 3: Generation of chaotic sequence satisfying the constraints.***

Tent equation is formula for approximating the evolution of animal population with time. Tent-Map-Based Chaotic sequences are used to generate variable Solution. It can be expressed mathematically as [4]:

\[
Z_{i+1(t)} = \mu \cdot (1 - 2|Z_i - 0.5|) \quad \text{where} \quad 0 \leq \mu \leq 1 \quad (11)
\]

It is iterated with respect to sub-generation and it can generate several neighborhoods of near optimal solutions.

***Step 4: Perform the reverse transformation to produce the queue.***

Perform the reverse transformation to produce the denormalized values w.r.t. chaotic queue [2].

\[
G_{i(t)}^{(0, a)} = P_{i}^\text{min} + (P_{i}^\text{max} - P_{i}^\text{min}) \times Z_{i(t)}^{(0, a)} \quad (12)
\]

***Step5: Calculate the fitness value of each candidate.***

It includes the solution of the previous generation and the solutions generated by chaos search. Penalty factors have to be associated with violated constraints so that the solutions which do not satisfy the constraints will be rejected in the process of selection.

***Step6: To get optimal solution w.r.t. chaotic queue:** Bubbling method is used to order fitness function values & local minima of these values is used as the initial population for the genetic algorithm.

***Step8: Evaluation process of GA.***

Give selected candidates to genetic algorithm as its initial population, then evaluation process of GA starts by calculation of fitness function of each candidate.

***Step9: If we get optimal solution then go to step12 if not, then selection, crossover, mutation operators have to be used.***
Step 10: Stopping criterion: GA search is stopped if the following condition is satisfied.

“Change of fitness function of GA is less than a particular value for last few generations”

Step 11: If final stopping criterion is fulfilled (difference between maximum fit solution of current & previous iteration is less than a specified value) then stop the optimization process. if not, then extend the search space near optimal solution by performing normalization of optimal solution and generating chaotic series near optimal solution and going for next iteration from step1.

V. SIMULATION RESULTS

The hybrid algorithm is used to determine the solution of economic load dispatch problem taking into account the transmission losses & valve point effect constraints. Parameters of problem have been given in table1 & Results have been shown in table2 A comparison has been made between the results of used algorithm & a number of other search techniques as reported in the literature [3].

Problem: Distribute a total load of 500MW in a power system of three units and optimize the units’ commitment. The B coefficients used for the power system are as follows [3]:

\[
B_{gg} = \begin{pmatrix}
0.676 \times 10^{-3} & 0.953 \times 10^{-3} & -0.507 \times 10^{-3} \\
0.953 \times 10^{-4} & 0.521 \times 10^{-3} & 0.901 \times 10^{-4} \\
-0.507 \times 10^{-4} & 0.901 \times 10^{-4} & 0.294 \times 10^{-3} \\
-7.66 \times 10^{-2} & -0.342 \times 10^{-2} & 1.89 \times 10^{-2} \\
0.00638 & 1.89 \times 10^{-2} & 1.89 \times 10^{-2}
\end{pmatrix}
\]

TABLE I. PARAMETERS OF THE UNITS[3]

<table>
<thead>
<tr>
<th>Units</th>
<th>(a_i)</th>
<th>(b_i)</th>
<th>(c_i)</th>
<th>(g_i)</th>
<th>(h_i)</th>
<th>(P_{l\text{min}})</th>
<th>(P_{l\text{max}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>0.00156</td>
<td>7.92</td>
<td>561</td>
<td>300</td>
<td>0.0315</td>
<td>600</td>
<td>100</td>
</tr>
<tr>
<td>2.</td>
<td>0.00194</td>
<td>7.85</td>
<td>310</td>
<td>200</td>
<td>0.0425</td>
<td>400</td>
<td>100</td>
</tr>
<tr>
<td>3.</td>
<td>0.00482</td>
<td>7.97</td>
<td>78</td>
<td>150</td>
<td>0.0635</td>
<td>200</td>
<td>50</td>
</tr>
</tbody>
</table>

TABLE II. FEASIBLE SOLUTIONS FOUND BY PROPOSED ALGORITHM [3]

<table>
<thead>
<tr>
<th>Algorithm value</th>
<th>(P_1) (MW)</th>
<th>(P_2) (MW)</th>
<th>(P_3) (MW)</th>
<th>(\Sigma P_i) (MW)</th>
<th>Objective function</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSCOA</td>
<td>299.4737</td>
<td>100.5674</td>
<td>99.9595</td>
<td>500.0007</td>
<td>5120.62</td>
</tr>
<tr>
<td>IMSCOA</td>
<td>200.2041</td>
<td>249.7814</td>
<td>50.0145</td>
<td>500.0000</td>
<td>5095.83</td>
</tr>
<tr>
<td>GA</td>
<td>233.6312</td>
<td>180.1787</td>
<td>90.097</td>
<td>503.906</td>
<td>5085.81</td>
</tr>
<tr>
<td>Hybrid algo.</td>
<td>235.1817</td>
<td>181.1090</td>
<td>90.5545</td>
<td>506.98</td>
<td>5076.82</td>
</tr>
</tbody>
</table>

In Table2, MSCOA stands for Mutative Scale Chaos Optimization Algorithm & IMSCOA is Improved Mutative Scale Chaos Optimization Algorithm[3]. From the results obtained, it is clear that the used hybrid algorithm gives the best results by minimizing the objective function value.

VI. CONCLUSION

A chaotic search based genetic algorithm is used for solving a non-convex ELD problem including various constraints, valve effect and transmission losses. It has been observed that the used algorithm improves the global convergence. The hybrid algorithm can’t fall in to local optimal solution trap as the chaotic queue generates several neighborhoods of near optimal solutions to maintain solution variation. It can prevent the search process from becoming pre-mature. Moreover for the purpose of chaos queue use of tent-map, instead of logistic function has further improved the results.

ACKNOWLEDGEMENTS

The authors wish to thank the department of Electrical Engineering, Deenbandhu Chhotu Ram University of Science & Technology, Murthal, Sonepat (Hr.), India, for providing the facilities to complete this work.
REFERENCES


