Active Power Dispatch Planning Using Differential Evolution Algorithm

Navpreet Singh Tung
Department of Electrical Engineering, CT Group of Institutions, Jalandhar India
Email: icenitj@gmail.com

Sandeep Chakravorty
Department of Electrical Engineering, Baddi University, Baddi, India
Email: sandeep@baddiuniversity.ac.in

Abstract—Economic Load Dispatch is an integral part of power system generation planning and it is of utmost importance for the electrical utilities and power engineers to explore this area in short and long term planning scenarios. Load demand requirements subjected to economic feasible solutions matching voltage profile, power demand, minimization of losses, voltage stability and improve the capacity of the system is the need of the hour. Optimization techniques based on evolutionary computing, artificial intelligence, search method finds their applications in the area of economic load dispatch planning to reach global optimal solution for this multi-decision, multi-objective combinatorial problem subjected to different constraints. In this paper, Differential Evolution based algorithm has been proposed to solve economic dispatch problem. Unlike other heuristic algorithms, Differential Evolution possesses a flexible and well-balanced mutation operator to enhance and adapt the global and fine tune local search. The Differential Evolution algorithm starts by initialization in first iteration. The next step is mutation where addition, subtraction and multiplication are done to achieve target population from donor population starting with initial count. Mutation operator in general works well within bandwidth of 0 to 1. Similarly, crossover is benchmarked in this slab to promote the promising results. Exponential cross over is chosen for recombination. Recombination results in trial version of generated population vector for next generation. The suggested technique is tested on IEEE 25 bus system. Test results are compared with other techniques presented in literature. Test results appeals for further investigation of differential evolution in active load dispatch problem.

Index Terms—differential evolution (DE), Unit commitment (UC), economic dispatch (ED)

I. INTRODUCTION

The economic dispatch (ED) problem is one of the most important areas of today’s power system. The purpose of the ED is to find the optimum generation among the existing units, such that the total generation cost is minimized while simultaneously satisfying the power balance equations and various other constraints in the system. Below are the suggested techniques in the literature.


II. PROBLEM FORMULATION

The ED problem may be expressed by minimizing the fuel cost of generator units under constraints. Depending on load variations, the output of generators has to be changed to meet the balance between loads and generation of a power system. The power system model consists of n generating units already connected to the system.

The ED problem can be expressed as.

A. Fuel Cost Model

\[ C(P_{Gt}) = \sum (a_i P_{Gt}^2 + b_i P_{Gt} + c_i)Rs \] where \( i = 1, \ldots, N \)

B. Constraints
- \( \sum P_{Gt} - P_{D_{t}} = 0 \)
- \( P_{G_{\text{min}}} \leq P_{G_{t}} \leq P_{G_{\text{max}}} \) where \( i = 1, 2, \ldots, N \)

C. Minimization

Total Operating Cost=C

D. Transmission Losses

\[ P_L = \sum_{i=1}^{N} \sum_{j=1}^{N} P_{ij} B_{ij} P_{ij} + \sum_{i=1}^{N} B_{i0} P_{i0} + B_{00} \]

III. DIFFERENTIAL EVOLUTION

The Differential Evolution (DE) [45] algorithm was introduced by Storn and Price in 1995. DE is a version of an evolutionary algorithm which operates in continuous search spaces. DE is based on four main steps:

- Initialization, mutation, recombination and selection. While the initialization step is only compiled in the initial iteration, the other three steps take place in each iteration.
- All individuals pass through these operations.
The chromosomes of an individual are built up of real valued genes, \( X_{p,q} \) (where \( q \) is the index of the parameter, \( p \) is the index of the individual and \( r \) shows the generation number), each of which maps to the parameters of the problem to be optimized.

All individuals in the population, called the target vectors, go through the phase of mutation and recombination. There are several mutation operators. One of the most commonly used forms of these operators, the DE/rand/1 method, chooses three different vectors from the population and creates a mutant vector from these, called the donor vector, through the equation given below:

\[
V_{i,g} = X_{i,g} + Q(X_{r1,g} - X_{r2,g})
\]

\( Q \) (step size) takes values in the range \((0, 1)\). Next Step is recombination. The aim of the recombination operation is to create a different vector based on the donor and the target vectors.

The parameters of this vector are taken from the target vector when a uniformly distributed random number is greater than a predefined \( Cr \) or \( j = j_{rand} \) otherwise, it is taken from the donor vector [45] as shown:

\[
U_{j,i,g} = \begin{cases} V_{j,i,g} & \text{if } \text{rand} \leq Cr \text{ or } j = j_{rand} \\ X_{j,i,g} & \text{otherwise} \end{cases}
\]

There are two proposed ways to implement this step: binomial and exponential. The binomial crossover operation evaluates each parameter in a vector separately; whereas in the exponential crossover operation after \((\text{rand} \leq Cr) \) becomes true for the first time, the remaining parameters are taken from the donor vector as a block. The exponential crossover operator is chosen in this study. \( Cr \) (crossover) takes values in the range \([0, 1]\).

The vector that is created through the recombination step is called the trial vector. In the selection step, either the target vector or the trial vector is chosen for the next generation as shown below.

\[
X_{i,g+1} = \begin{cases} U_{j,i,g} & \text{if } \text{fitness}(V_{j,i,g}) \leq \text{fitness}(X_{j,i,g}) \\ X_{j,i,g} & \text{otherwise} \end{cases}
\]

These steps continue until an optimal solution is found or a predefined number of maximum iterations has been reached.

IV. ACTIVE POWER DISPATCH USING DIFFERENTIAL EVOLUTION

A. Variables

Power Generation (PG) and cost coefficients \((a, b, c)\) of units with objective function as fuel cost, quadratic in nature. Power Generation variable should be initialized as starting point for DE algorithm.

B. Constraints

Equality Constraints: Power Generation-Power Demand-Power losses=0\((P_G-P_d-P_L)\)

In-Equality Constraints: Power Generation should be between minimum and maximum limit of power generation.

Variables in constraints should be incorporated in differential evolution algorithm.

C. Stopping Criteria

It can be maximum limit of iterations or any other benchmark for optimum solution.

V. SIMULATION RESULTS

This proposed approach is tested on IEEE 25 bus system [44]. Simulation results are achieved and compared with other techniques presented in literature.

| TABLE I. POWER GENERATION, TOTAL COST AND COMPUTATIONAL TIME USING DE |
|------------------|----------------|----------------|----------------|----------------|
| PG1(MW)          | 212.2441       | 213.68         | 206.71         | 211.30         |
| PG2(MW)          | 122.7887       | 127.46         | 121.64         | 126.30         |
| PG3(MW)          | 140.3052       | 141.93         | 151.82         | 151.29         |
| PG4(MW)          | 27.258         | 29.53          | 33.21          | 71.24          |
| PG5(MW)          | 268.3662       | 258.86         | 258.05         | 211.31         |
| Cost($/hr)       | 2009.3145      | 2010.8         | 2011.0         | 2029.3         |
| Time(Sec)        | 7              | 1.6            | 4.78           | 0.0            |

| TABLE II. RESULTS COMPARISON WITH OTHER TECHNIQUES [44] |
|------------------|----------------|----------------|----------------|----------------|
| Parameters       | DE             | RCGAs          | BCGAs          | BFGS           |
| PG1(MW)          | 212.2441       | 213.68         | 206.71         | 211.30         |
| PG2(MW)          | 122.7887       | 127.46         | 121.64         | 126.30         |
| PG3(MW)          | 140.3052       | 141.93         | 151.82         | 151.29         |
| PG4(MW)          | 27.258         | 29.53          | 33.21          | 71.24          |
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| Cost($/hr)       | 2009.3145      | 2010.8         | 2011.0         | 2029.3         |
| Time(Sec)        | 7              | 1.6            | 4.78           | 0.0            |

| TABLE III. DE ALGORITHM PARAMETER SETUP FOR OPTIMAL SOLUTION |
|------------------|----------------|----------------|----------------|----------------|
| Iterations       | Step Size      | Cross Over     | Number of Populations | Best Value     |
| 10               | 0.8            | 0.8            | 20              | 2009.5464      |
| 20               | 0.8            | 0.8            | 20              | 2009.3383      |
An application of evolutionary techniques in economic load dispatch planning optimization has been inherently evolving for last few decades. Different evolutionary methods whether stand alone or hybrid in nature have been developed and successfully applied to economic load dispatch area. In the current research, an application of DE algorithm has been applied successfully for economic load dispatch problem. Proposed technique is tested on IEEE 25 bus system. Test results reveal the minimum operating cost, optimum power generation and high speed convergence of solution. A comparison has been made other techniques presented in literature. It outperforms other techniques presented in literature. Hence, DE algorithm is more robust and lead to optimal solution in economic dispatch problem.

**VI. CONCLUSION**

Future studies involve the extension of DE leads to the formulation of hybrid algorithm to polish the search capacity of the proposed technique as well as fast convergence for optimal solution with incorporation of more constraints.

**REFERENCES**


NOMENCLATURE

N  Number of units
P_D  Power Demand
P_Gmax  Maximum limit of Unit
P_Gmin  Minimum Limit of Unit
P_G  Power Generation
C  Total Cost
P_L  Power Losses
a,b,c  Cost Coefficients
B  Loss Coefficients

Sanddeep Chakravorty is serving as a Dean and Professor in Department of Electrical Engineering, Baddi University, India.He did his BE in Department of Electrical and Electronics Engineering, Sikkim Manipal Institute of Technology, Sikkim and ME in Software Engineering from Birla Institute of Technology, Mesra,Ranchi. He obtained his PHD in Power System Planning from Sikkim Manipal University. He served in different capacities in Sikkim Manipal University,Lovely Professional University. He has a long stint of teaching and research career in Electrical Engineering. He authored and co-authored many research papers in the area of Power system in leading International Journals and Conferences. His area of expertise is Power System Planning, Power system Optimization and application of artificial intelligence in Power System.

Navpreet Singh Tung is serving as an Assistant Professor in Department of Electrical Engineering, CT Group of Institutions. India. He holds his B-Tech in Instrumentation and Control Engineering from National Institute of Technology, Jalandhar. He obtained his M-Tech in Electrical Engineering with specialization in Power System from Lovely Professional University. He is a member of reviewer board of International Journals. He authored and co-authored many papers in leading international proceedings and journals in Power System. His area of interest is Power System Planning, Power System Optimization.