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Solution of Large Scale Economic Load Dispatch Problem using Quadratic Programming and GAMS: A Comparative Analysis

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Abstract. This paper presents a comparative analysis of efficient and reliable modern programming approach using quadratic programming (QP) and general algebraic modeling system (GAMS) to solve economic load dispatch (ELD) problem. The proposed methodology easily takes care of different equality and inequality constraints of the power dispatch problem to find optimal solution. To validate the effectiveness of algorithm simulations have been performed over four different cases i.e. Crete Island system of 18 thermal generating units, twenty generating units system with losses, practical Taiwan Power Company (TPC) data which consists of 40 generating unit system and a very large system consisting of 110 generating unit. Results obtained with the proposed method have been compared with other existing relevant approaches available in literatures. Experimental results support the claim of proficiency of the method over other existing techniques in terms of robustness and most importantly its optimal search behavior.

Keywords: Economic load dispatch, quadratic programming, general algebraic modelling system, quadratic cost function, operating limit constraints..

1. Introduction

The idea behind economic dispatch problem in a power system is to determine the optimal combination of power output for all generating units which will minimize the total fuel cost while satisfying load and operational constraints. The economic dispatch problem is very complex to solve because of its massive dimension, a non-linear objective function and large number of constraints. Various investigations on the ELD have been undertaken till date. Suitable improvements in the unit output scheduling can contribute to significant cost savings [1, 2]. Also information about forming market clearing prices is provided by it.

To improve the quality of solution, lot of researches have been done and various methods have been evolved so far in the field of economic load dispatch.

Several classical optimization techniques, such as the lambda iteration approach, the gradient method, the linear programming method and Newton's method were used to solve the ELD problem [3]. Lambda iteration method is the most common, which has been applied to solve ELD problems. But for effective implementation of this method, the formulation must be continuous. Though fast and reliable, the main drawback of the linear programming methods is that they are associated with the piecewise linear cost approximation [4].

In order to get the qualitative solution for solving the ELD problems, Artificial Neural Network (ANN) techniques such as Hopfield Neural Network (HNN) [4] have been used. The objective function of the Economic Dispatch problem is transformed into a Hopfield energy function and numerical iterations are applied to minimize the energy function. The Hopfield model has been employed to solve the ED problems for units having continuous or piecewise quadratic fuel cost functions and for units having prohibited zone constraints. In the conventional Hopfield Neural Network, the input-output relationship for its neurons can be described by sigmoid function. Due to the use of the sigmoid function to solve the ED problems, the Hopfield model takes more iteration to provide the solution and often suffers from large computational time.

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Recently, different heuristic approaches have been proved to be effective with promising performance. These include evolutionary programming (EP) [6], genetic algorithm (GA) [7], differential evolution (DE) [8], particle swarm optimization (PSO) [9] etc. Improved fast Evolutionary programming algorithm has been successfully applied for solving the ELD problem [1, 5]. Other algorithms like Biogeography-Based optimization(BBO) [10], Chaotic particle swarm optimization (CPSO) [11], new particle swarm with local random search (NPSO-LRS) [12], Self-Organizing Hierarchical PSO [13], Bacterial foraging optimization [14], improved coordination aggregated based PSO [15], quantum-inspired PSO [16], improved PSO [17], HHS algorithm [18] and HIGA [19] are some of the those which have been successfully applied to solve the ELD problem.

In this paper a comparative analysis of Quadratic programming (QP) and General Algebraic Modeling System (GAMS) approach has been proposed to solve economic load dispatch problems.

Quadratic programming is an effective tool to find global minima for optimization problem having Quadratic objective function and linear constraints. The objective function for the entire test considered here is Quadratic in nature for all cases but the constraints are not linear. Constraints are liberalized by transformation of variable technique and the Quadratic programming is applied recursively till the convergence is achieved [20].

General Algebraic Modeling System (GAMS) [21] is a high-level model development environment that supports the analysis and solution of linear, non linear and mixed integer optimization problems. GAMS is especially useful for handling large dimension and complex problem easily and accurately.

In this paper the effectiveness of the proposed algorithm is demonstrated using four standard test problems (i) Crete Island system of 18 thermal generating units, (ii) 20 generating units system with losses, (iii) practical large scale Taiwan Power Company (TPC) system consisting of 40 generating units and (iv) a very large system consisting of 110 generating units.

The paper is organized as follows: Section 2 provides a brief description and mathematical formulation of ELD problems. The concept of QP and GAMS is discussed in Section 3 and Section 4 respectively. The performance of both proposed approaches and the simulation studies are discussed in Section 5. Finally, Section 6 presents the conclusions.

2. Problem formulation

In a power system, the unit commitment problem has various sub-problems varying from linear programming problems to complex non-linear problems. The concerned ELD problem is one of the different non-linear programming sub-problems of unit commitment. The ELD problem is about minimizing the fuel cost of generating units for a specific period of operation so as to accomplish optimal generation dispatch among operating units and in return satisfying the system load demand considering power system operational constraints.

The objective function corresponding to the production cost can be approximated to be a quadratic function of the active power outputs from the generating units. Symbolically, it is represented as

$$\text{Minimize} \quad F_t^{\cos t} = \sum_{i=1}^{N_G} f_i(P_i) \tag{1}$$

Where

$$f_i(P_i) = a_i P_i^2 + b_i P_i + c_i, \quad i = 1,2,3,\ldots,N_G \tag{2}$$

is the expression for cost function corresponding to i^{th} generating unit and a_i, b_i and c_i are its cost coefficients. P_i is the real power output (MW) of i^{th} generator corresponding to time period t. N_G is the number of online generating units to be dispatched.

The constraints are:

1) Power Balance Constraints: