Dynamic Economic Load Dispatch with Emission and Loss using GAMS
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Abstract
Dynamic economic dispatch (DED) is a real time problem of electric power system. DED intends to schedule the online generators outputs with the predicted load demands over a certain period of time in order to operate an electric power system most economically within its security limits. This paper introduces a solution of the dynamic economic dispatch (DED) problem including the loss and emission is participated among all generating units over time interval for a system using General Algebraic Modeling System (GAMS). The objective of the collective problem can be expressed by taking the production cost including emission and losses into account with required constraints for 24 hour time interval of each generating unit. The general algebraic modeling system (GAMS) technique is guaranteed the global optimality of the solution due to its look-further on capability. To validate practicability and robustness of the GAMS, it is tested on six generating unit system with different cases for determine minimum production cost of individual generating unit over a time period. In test case I only production cost without emission and loss, In test case II production cost with loss, In test case III production cost with including emission and without losses and In test case IV production cost including emission and losses for time interval of 24 hours.

Keyword— Dynamic economic dispatch (DED), security limits, general algebraic modeling system (GAMS), production cost etc.

1. Introduction
Economic dispatch problem is one of the most important problems in electric power system operation. Energy management has to perform more complicated and timely system control function to operate a large power system reliably an efficiently.
allowable tolerance in loss and emission taking into account emission constraints and this type of economic load dispatch has been termed emission constrained economic dispatch (ECED) which comes under multiobjective problems [3].

The dynamic economic dispatch (DED), where optimization is done with respect to the dispatchable powers of the committed generation units for time particular given period and formulated as a minimization problem of the total cost over the dispatch period under some constraints [4]. The development of DED is still going on; it has though reached a certain level of development in terms of academic thoughts. Various optimization techniques have been proposed by many researchers to deal with this multiobjective programming problem with varying degree of success. In the recent past, stochastic search algorithms such as genetic algorithm (GA) [5], Particle Swarm Optimization (PSO) [6], evolutionary programming (EP) [7], simulated annealing (SA) [8] and Differential Evolution (DE) [9] and artificial immune system [10] methods are proven to be very effective in solving non-linear DED problems and provide a fast, reasonable nearly optimal solution.

In this paper General Algebraic Modeling System (GAMS) approach has been proposed to solve the objective of the collective problem can be expressed by taking the total production cost, losses and total emission into account with required constraints for 24 hour time interval. General Algebraic Modeling System (GAMS) is a high-level model development environment that supports the analysis and solution of linear, non linear and mixed integer optimization problems [11]. General Algebraic Modeling System is especially useful for handling large dimension and complex problem easily and accurately.

In this paper the effectiveness of the General Algebraic Modeling System (GAMS) is demonstrated using six generating unit system with different cases for determine minimum production cost of individual generating unit over a time period. In test case I only production cost without emission and loss, In test case II production cost with loss, In test case III production cost with including emission and without loss and In test case IV production cost including emission and loss for time interval of 24 hours.

The paper is organized as follows: Section 2 provides a brief description and mathematical formulation of DED problems. The concept of General Algebraic Modeling System (GAMS) is discussed in Section 3. The performance of General Algebraic Modeling System (GAMS) and the simulation studies are discussed in Section 4. Finally, Section 5 presents the conclusions.

2. Dispatch Problem Formulation

The objective of solving the dynamic economic dispatch problem in electric power system is to determine the generation levels for all on-line units which minimize the total fuel cost and minimizing the losses and emission level of the system, while satisfying a set of constraints over a given dispatch period.

It can be formulated as follows:

Minimize \( F_{tc} = \sum_{i=1}^{N} \sum_{t=1}^{T} F_{ti}(P_i) \) \hspace{1cm} (1)

Where

\( F_{ti}(P_i) = F_i(P_i) + h_i \{ E_i(P_i) \} \) \hspace{1cm} (2)

\( F_{tc} \) is the total operating cost over the whole dispatch period,

\( F_{ti}(P_i) \) is the Emission constrained fuel cost of \( 'i^{th} ' \) unit at time \( 't' \),

\( F_i(P_i) \) is the total fuel cost of a \( 'i^{th} ' \) generating unit

\( E_i(P_i) \) is the total emission of a \( 'i^{th} ' \) generating unit

\( h_i \) = cost penalty factor

\( P_i \) is a function of its real power output of \( 'i^{th} ' \) at time \( 't' \),

\( T \) = is the number of hours in time horizon,

\( N \) = is the number of dispatch able units,

The fuel cost \( F_{ti}(P_i) \) of generating unit \( 'i' \) at any time interval \( 't' \) is normally expressed as a quadratic function.

2.1 Objective Functions

2.1.1 Fuel Cost Objective

The classical economic dispatch problem of finding the optimal combination of power generation, which minimizes the total fuel cost of a generating unit is usually described by a quadratic function of power output \( P_i \) while satisfying the total required demand can be mathematically stated as follows:

\( F_i(P_i) = a_i P_i^2 + b_i P_i + c_i \) \hspace{1cm} S/\text{Hr} \hspace{1cm} (3)

Where

\( a_i, b_i \) and \( c_i \) are the cost co-efficient of unit \( i \).

2.1.2 Emission Objective

The minimum emission dispatch optimizes the above classical economic dispatch including emission...
objective of a generating unit is usually described by a quadratic function of power output \( P_i \) as [12]:

\[
E_i (P_i) = d_i P_i^2 + e_i P_i + f_i \quad \text{Kg/Hr} \quad (4)
\]

Where

d\(_i\), \( e\)\(_i\), and \( f\)\(_i\) are the emission co-efficient of unit \( i \).

2.1.2 Emission constrained cost equation

Economic and emission dispatch problem is converted into single optimization problem by introducing price penalty factor \( h \) [13]:

The Emission constrained cost equation can now be formulated as:

\[
F_{Ti} (P_i) = a_i P_i^2 + b_i P_i + c_i + h_i (d_i P_i^2 + e_i P_i + f_i) \quad \text{S/Hr} \quad (5)
\]

Where

\[
h_i = F_{i \text{max}} (P_{i \text{max}})/E_{i \text{max}} (P_{i \text{max}}) \quad (6)
\]

\[
F_{i \text{max}} (P_{i \text{max}}) = a_i P_{i \text{max}}^2 + b_i P_{i \text{max}} + c_i \quad \text{Rs/Hr} \quad (7)
\]

\[
E_{i \text{max}} (P_{i \text{max}}) = d_i P_{i \text{max}}^2 + e_i P_{i \text{max}} + f_i \quad \text{Kg/Hr} \quad (8)
\]

The price penalty factor \( h_i \) unifies the emission with the normal fuel costs and the total operating cost of the system (i.e., the cost of fuel + the implied cost of emission). Once the value of price penalty factor is determined, the problem reduces to a simple economic dispatch problem. By proper scheduling of generating units, comparative reduction is achieved in both total fuel cost and emission.

2.2 Transmission Loss

The transmission losses \( P_L \) can be found using \( B_{mn} \) coefficients

\[
P_L = \sum_{i=1}^{n} \sum_{j=1}^{n} P_{ij} B_{ij} P_i + \sum_{i=1}^{n} B_{oo} P_i + B_{oo} \quad (9)
\]

Where

\( B_{ij}, B_{oo} \) and \( B_{oo} \) are the transmission line coefficients

2.3. Constraints

2.3.1 Power Balance Constraints

The real power balance between generation and the load must be maintained at all times, while assuming the load at any time to be constant. The total supply must be equal to power demand.

\[
\sum P_i = P_o + P_L \quad (10)
\]

Where

\( P_o \) is the load demand

Each generating unit is constrained by its lower and upper limits of real power output to ensure stable operation. The power generation of unit ‘\( n \)’ should be between its minimum and maximum limits.

\[
P_{i \text{min}} \leq P_i \leq P_{i \text{max}} \quad (11)
\]

Where

\( P_{i \text{min}} \) is the minimum generation limit of unit \( i \)

\( P_{i \text{max}} \) is the maximum generation limit of unit \( i \)

3. General Algebraic Modeling System (GAMS)

General Algebraic Modeling System provides a high-level (algebraic) language for the representation of large and complex models. It allows for unambiguous statements of algebraic relations that define an abstract system of variables and equations. It also provides several mechanisms for data management. The system performs appropriate data transformations to create a specific instance of the model. The General Algebraic Modeling System (GAMS) is a high-level model specially designed for modeling linear, nonlinear and mixed integer optimization problems [11]. GAMS can easily handle large and complex problems. It is especially useful for handling large complex problems, which may require much revision to establish an accurate model. Conversion of linear to nonlinear optimization is also very simple. Models can be developed, solved and documented simultaneously, maintaining the same GAMS model file. The basic structure of a mathematical model coded in GAMS has the components: sets, data, variable, equation, model and output [14] and the solution procedure are shown below in Figure 1.

A GAMS model is a collection of statements in the GAMS language. This statement define the variables of the model, specify the symbolic relationships between them in the form of equations specify data structures and assign values to them and instructs the computer to generate and solve the model. Other GAMS statements are used to handle output [14].
Figure 1. GAMS modeling and solution procedure

STEPS FOR PROBLEM Formulation WITH GAMS
GAMS formulation follows the basic format as given below:
1. SETS
   Declaration
   Assignment of members
2. Data (PARAMETERS, TABLES, SCALARS)
   Declaration
   Assignment of values
3. VARIABLES
   Declaration
   Assignment of type
   Assignment of bounds and/or initial values (optional)
4. EQUATIONS
   Declaration
   Definition
5. MODEL and SOLVE statements
6. DISPLAY statements (optional)

4. Result and Discussion
The GAMS approach has been tested on four different test cases of a single six unit system of the dynamic economic dispatch problem. In test case I only production cost without taking loss and emission, In test case II production cost with loss and without emission, In test case III production cost with including emission and without loss and In test case IV total production cost including emission and loss for hourly time interval of 24 hours. The implementation model on GAMS with system configuration Core 2 Duo processor and 3GB RAM.

Table I. Cost and emission coefficient of six unit system

Table II. The optimal solution of total generation cost of each unit

Linear Coefficient of B losses are:

\[ B_{0j} = [0.00003, 0.00009, 0.00012, 0.00007, 0.000085, 0.0001] \]

4.1. Test case I
The generator cost coefficients and generation limits of six units system are taken from Table I. For this test case emission coefficients and losses coefficients are not considered. In this test case production cost of six-unit system is calculated at different power demand over time period of 24 hours using GAMS. Table II shows the optimal solution of power output and production cost of each generator at different power demand over time period of 24 hours obtained using GAMS.

Table II. The optimal solution of total generation cost of each unit

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The generator cost coefficients, loss coefficients and generation limits of six units system are taken from Table I of six-unit system. For this test case emission coefficients are not considered. In this test case production cost with losses of six-unit system is calculated at different power demand over time period of 24 hours using GAMS. Table III shows the optimal solution of power output and production cost of each generator at different power demand over time period of 24 hours obtained using GAMS.

Table III. The optimal solution of total generation cost with power loss of each unit

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<th>P_G4</th>
<th>P_G5</th>
<th>P_G6</th>
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4.4. Test case IV

The generator cost coefficients, emission coefficients and generation limits of six units system are taken from Table I of six-unit system. In this test case production cost including emission with power losses of six-unit system is calculated at different power demand over time period of 24 hours using GAMS. Table V shows the optimal solution of power output and production cost of each generator at different power demand over time period of 24 hours obtained using GAMS.

4.5. Conclusion

In this paper, General Algebraic Modeling System (GAMS) for optimization have been used for solving
Table V. The optimal solution of total generating cost including emission and power loss of each unit

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dynamic power dispatch problems. Three different test cases of a single six unit system of the dynamic economic dispatch problem are taken. In test case I only production cost without emission and loss, In test case II production cost with loss, In test case III production cost with including emission and without loss and In test case IV production cost including emission and loss for time interval of 24 hours. An efficient economic dispatch algorithm for dealing with nonlinear functions such as the thermal cost, transmission loss and emission constraint is developed. The quality of the solutions generated by the General Algebraic Modeling System (GAMS) offers excellent approach to solve the dynamic thermal power dispatch problem. The solution is analytic in nature with high accuracy and it is used for any online application. The result shows that GAMS performs better so far for the above mentioned test cases. The GAMS algorithm has superior features, including quality of solution and good computational efficiency. Therefore, this results shows that GAMS is a promising technique for solving complicated problems in power system.

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References


