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Multi Objective Economic Emission Load Dispatch Using Quadratic Programming

Dr.T.Govindaraj[1], **R.Thendral**[2]

Professor and Head, EEE Department, Muthayammal Engineering College, Namakkal, India[1]

M.E (Research scholar), EEE Department, Muthayammal Engineering College,Namakkal,India[2]

Abstract- In this paper, an efficient quadratic programming has been used for solving economic dispatch problem. The main aim is to obtain minimum fuel cost and emission. Economic emission load dispatch (EELD) problem is solved to minimize the emission of nitrogen oxides and fuel cost, considering both thermal generators and wind turbines. To find the optimum emission dispatch, optimum fuel cost, best compromising emission and fuel cost, a newly developed optimization technique, called Quadratic Programming Method (QPM) has been applied. QPM is based on the Wolfe Modified Simplex Method and Iteration Process. The bus system having six conventional thermal generators has been considered as test system. After placing the wind power sources, those buses have been considered as generator bus. Minimum fuel cost, minimum emission and best compromising solution obtained by QPM.

Keywords: Economic Emission Dispatch, Quadratic Programming, Wolfe's method.

I. INTRODUCTION

The economic load dispatch (ELD) problem seeks the best generation schedule for the generating plants to supply the required demand plus transmission losses with the minimum production cost.Conventionally, the emphasis on performance optimization of fossil–fuel power systems was on economic operation only, using the ELD approach, as better solutions would result in significant economical benefits[1]. However, due to the pressing public demand for clean air as well as due to the ‘‘global warming’’ concept, new clean air policies and regulations have been forced on the industries, as environmental effect is a direct consequence of industrial advancement.

Thermal power units are responsible in a major way for creating major atmospheric pollution because of high concentrations of pollutants, such as $\mathrm{NO_x}$, $\mathrm{SO_x}$, and $\mathrm{CO_x}$, contained in their emissions. Although those conventional approaches have been effective so far for conventional power systems, a new approach is required in future power systems, where demand patterns are more uncertain and amount of conventional controllable generators are critically decreased. Conventional approaches assumed that the demand is feasible for dispatch and also that generation schedule (GS) does not change much. Hence, there is a need for a method that can address the issue of infeasibility and GS change reliably in a very fast manner in [2]. Thus, the computation speed is the critical issue to deal with the disturbance caused by the renewable energy resources.

EED is an optimization problem that pursues the least emission level of operation of a power system[1]-[16]. But operating either at the absolute minimum cost of generation or at the absolute minimum emission level may no longer be a desirable criterion in [4].The obvious approach is to figure out the optimal amounts of the generated powers for the thermal units in the system by minimizing the emission level and cost of generation simultaneously, which is known as economic emission load dispatch (EELD)

II. PROBLEM FORMULATION

The ED problem may be expressed by minimizing the fuel cost of generator units under constraints. Depending on load variations [4], the output of generators has to be changed to meet the balance between loads and generation of a power system given in equation (1). The power system model consists of n generating units already connected to the system.

The ED problem can be expressed as :

$$\text{Min } \sum_{i=1}^{NG} F_i(P_{Gi}) \qquad (1)$$

$$F_i P_{Gi} = (a_i + b_i P_{Gi} + c_i P_{Gi}^2)$$

Where ai, bi and ci are the cost coefficients of the ith generator and NG is the number of generators including the slack bus. PGi is the real power output of the i-th generator (MW). Fi(PGi) is the operating cost of unit i ($/h).

III. ECONOMIC DISPATCH

Power generation is our main aim to generate the required amount of power with minimum cost. Economic load dispatch means that the generator's real and reactive powers are allowed to vary within certain limits so as to meet a particular load demand with minimum fuel cost. This allocation of loads depends upon constraints. Most electric power systems dispatch their own generating units and their own purchased power in a way that may be said to meet this definition.

There are two fundamental components to economic dispatch:

1. Planning for tomorrow's dispatch
2. Dispatching the power system today

Planning For Tomorrow Dispatch

1) Scheduling generating units for each hour of the next day's dispatch .
2) Based on forecast load for the next day.
3) Select generating units to be running and available for dispatch the next day .
4) Recognize each generating unit's operating limit.
5) Minimum amount of time the generator must run .

Dispatching the Power System Today

1) Monitor load, generation and interchange to ensure balance of supply and load.
2) Monitor and maintain system frequency at 60 Hz during dispatch according to NERC standards, using Automatic Generation Control (AGC) to change generation dispatch as needed.
3) Monitor hourly dispatch schedules to ensure that dispatch for the next hour will be in balance.

Frequency of the Dispatch

Performing an economic dispatch more frequently (e.g., 5 or 15 minutes rather than each hour) affects the level of costs. Generation operators, transmission owners, and load serving entities must provide accurate and current information to those performing the planning and dispatch functions. Those performing planning and dispatch must provide accurate and current dispatch instructions to generation operators, transmission operators and load serving entities.

A. Economic Emission Dispatch

The purpose of EELD is to obtain the optimal amount of generated power for the Wind based generating unit. The System is approached to minimizing the fuel and emission costs .To determine the economic distribution of a load amongst the different units of a Plant, the variable operating costs of each unit must be expressed in terms of its power output. The fuel cost is the main cost in a thermal or nuclear unit. Then the fuel cost must be expressed in terms of the power output. Other costs, such as the operation and maintenance costs, can also be expressed in terms of the power output. Fixed costs, such as the capital cost, depreciation etc., are not included in the fuel cost. 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[4]. However, it is realized that the conventional techniques become very complicated when dealing with increasingly complex dispatch problems, and are further limited by their lack of robustness and efficiency in a number of practical applications.

IV. QUADRATIC PROGRAMMING

A linearly constrained optimization problem with a quadratic objective function is called a quadratic program (QP). Because of its many applications, quadratic programming is often viewed as a discipline in and of itself. More importantly, though, it forms the basis of several general nonlinear programming algorithms is given in equation in (2) and (3).

If the optimization problem assumes the form

$$\sum_{I=1}^{NG} P_{Gi} - D - P_L = 0 \qquad (2)$$

$$P_L = \sum_{i=1}^{N} \sum_{i=1}^{N} P_{Gi} B_{ij} P_{Gj} + \sum_{i=1}^{N} B_{0i} P_{Gi} + B_{OO} \qquad (3)$$

D=total demand(MW)
P_L=transmission losses(MW)
P_{Gi}^{max} =maximum generation output of i- th generator
P_{Gi}^{min} =minimum generation output of the i- th generator
B=coefficient of transmission losses.

A.Mathematic Form Of Quadratic Program

The mathematical form of this type of problems is given as follows: Where G1 and G2 is matrix of coefficients with are symmetric matrixesis given in equation (4).
All vectors are assumed to be column vectors unless transposed.

$$\text{Max .z} = \frac{c^T x + \frac{1}{2} x^T G_1 x}{d^T x + \frac{1}{2} x^T G_2 x} \qquad (4)$$

$$Ax \begin{bmatrix} \geq \\ \leq \\ = \end{bmatrix} b$$

$$x \geq 0$$

where ,
a is the dimensional vector of decision variables is,
b is the dimensional vector of constants,
C is dimensional vector of constant.

$$\text{Max } z = \frac{(c_1^T x+\frac{1}{2}x^T G_1^1 x)(c_1^T x+\frac{1}{2}x^T G_1^2 x)}{(d_1^T x+\frac{1}{2}x^T G_2^1 x)(d_2^T x+\frac{1}{2}x^T G_2^2 x)} \qquad (5)$$

B. *Wolfe's Method*

Wolfe's algorithm can be directly applied to solve any quadratic programming problems of the form. With one exception, this is exactly the linear programming..This implies that if is in the basic solution with positive value, then cannot be based with + ve value in equation (6) .

$$\text{Max } z = f(x) =\sum_{j=1}^{n} c_j x_j + \frac{1}{2}\sum_{j=1}^{n}\sum_{k=1}^{n} c_{jk} x_j x_k . \qquad (6)$$

Wolfe has suggested introducing n non negative artificial variable v_j in to the equation representing in equation (7).
We maximize

$$z_v = -\sum_{i=1}^{n} v_i \qquad (7)$$

C. *Algorithm of Wolfe's method*

Step 1: First convert the inequality constraints into equations by introducing slack variables q_1^2 in the I th constraints(i= 1,2….m) and the slack variables r_1^2 in the j th non negativity constraints .

Step 2**:** Then construct the Lagrangian constraints

$$L(x, q, r, \lambda, \mu) =f(x) - \sum_{i=1}^{n} \lambda i[\sum_{i=1}^{n} aii\text{-bj+}qi^2] - \sum_{i=1} \mu i\ [\text{–xj+rj}] \qquad (8)$$

Where,

x =(x1,x2,….x n)

r=(r1,r2,r3….r n),

λ =(λ1, λ2, λ3….. λn)

Step 3: Introduce the non-negative artificial variable j=1, 2… n in equation (9).

$$c_j +\sum_{k=1}^{n} c_{jk}\ x_k -\sum_{j=1}^{n} a_{ij}\,\lambda_i +\mu_j =0 \qquad (9)$$

Step 4: Obtain the initial basic feasible solution to the following linear programming problem in equation (10).
Subject to the constraints

$$\sum_{k=1}^{n} a_{ij}\, x_j + q_i^2 = b_j \qquad (10)$$

Step 5:Now apply 2- phase simplex method to find and optimum solution of Linear Programming problem in step 4.

Step 6: Thus the optimum solution obtained in step 5 is the optimal solution of the given Quadratic programming problem (QPP).

V . MATLAB OUTPUT AND GRAPH

MATLAB is a high-level language and interactive environment for numerical computation, visualization, and programming. Using MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. Using MATLAB, you can analyze data, develop algorithms, and create models and applications.

MATLAB is a high-performance language for technical computing. It integrates Computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. It has since grown into something much bigger, and it is used to implement numerical algorithms for a wide range of applications. The basic language used is very similar to standard linear algebra notation, but there are a few extensions that will likely cause you some problems at first.

A. Algorithm

Step 1**:**
Input the value of load demand, emission factor and the values of cost coefficients, ai, bi, ci where i=1, 2…n.

Step 2:
Allocate the values of Pmax and Pmin values

Step 3:
Update the demand values and find the total demand

Step 4:
Assume the values of Bmin coefficient in all non linear equation and find incremental fuel cost.

Step 5:
Fix the limit for generating plant and solve equation iteratively for $P_{i.}$

Step 6:
Check if test unit 1,2,3,4 converges to load demand at its limit. If not go to step4.

Step 7:
Check if power balance equation is satisfied in 5,6 otherwise go to step4.

Step 8:
Find total fuel cost and emission cost

Step 9:
Stop.

B. Flowchart

The flowchart of quadratic programming is given by

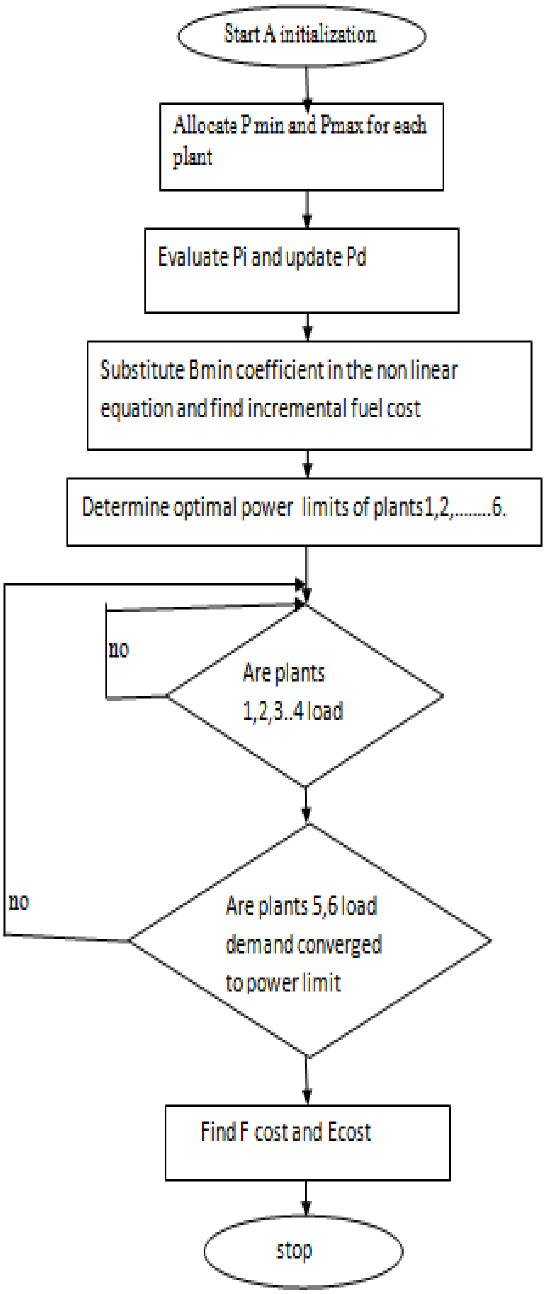


Fig.no.5.1.Flowchart Of Quadratic Method

C.Matlab Output

Economic Emission Dispatch for Power Generation using quadratic programming

```
P =

  36.0497
  21.7086
 124.6406
 123.6278
 211.7041
 200.8878


F cost =

  3.6955e+04


Emi =

 477.2047


Pl =

  18.6186
```

D. Table Of Optimized Power

Power Demand	Optimized Power
500	354.3358
600	274.4185
700	320.9225
800	355.078
900	380.207
1000	406.85

E. Fuel Cost And Emission

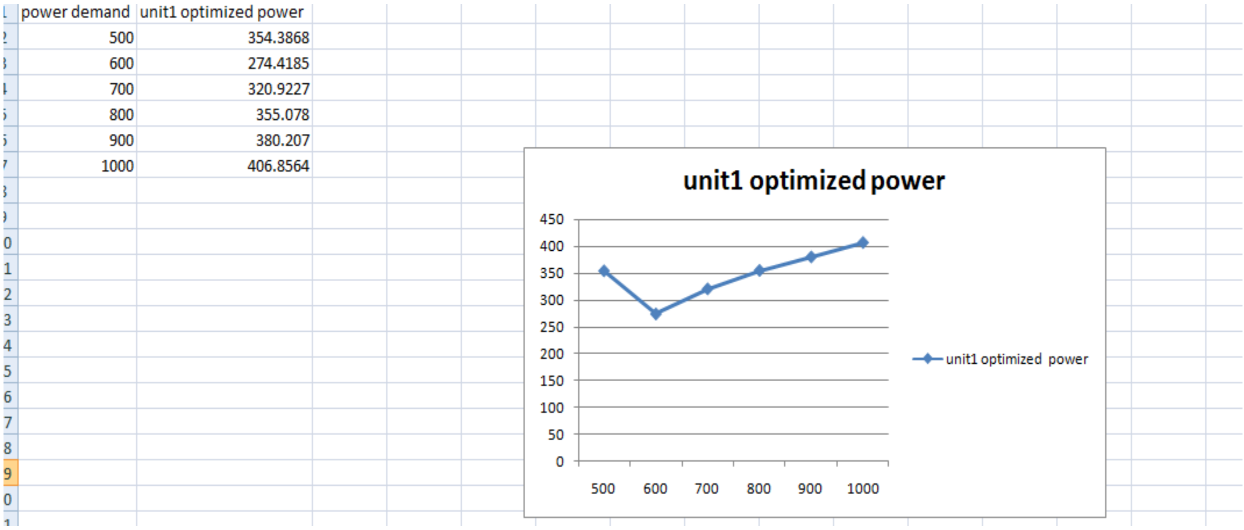
Demand	Fuel Cost	Emission
500	2.744	275.56
600	3.2102	369.44
700	3.692	485.86
800	4.1920	625.88
900	4.7077	791.26
1000	5.2402	982.53

F. Fuel Cost Data

Economic	Fuel cost
3	3.2119
5	3.2117
6	3.2101
7	3.2105
8	3.2104
9	3.2101

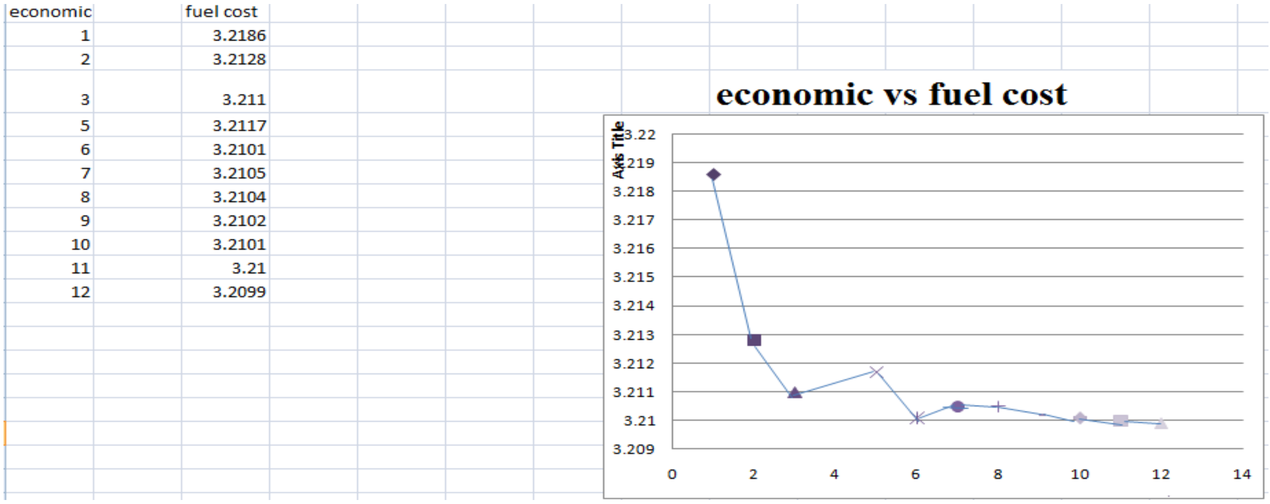
G. Emission Cost Data

Emission	Emission Cost
15	349.77
18	347.98
20	347.01
22	346.19
25	345.16
28	344.33



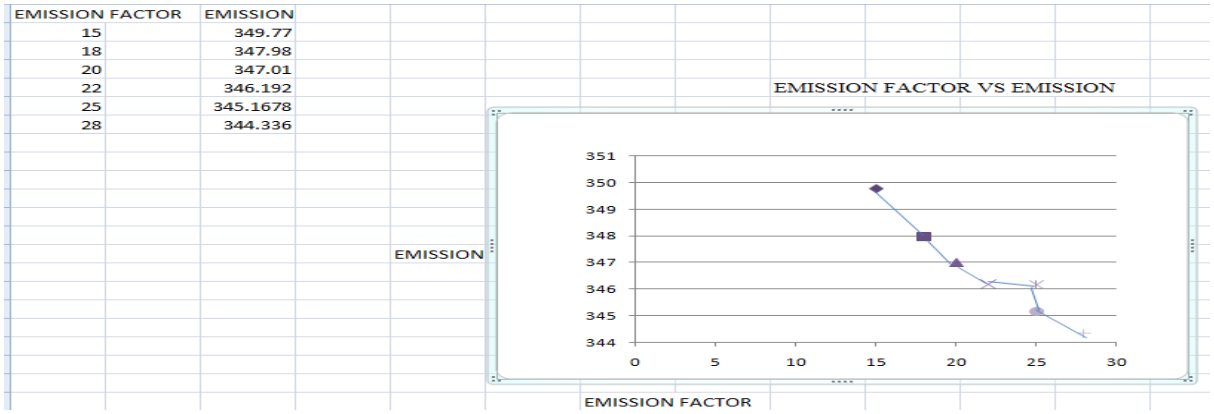
power demand	unit1 optimized power
500	354.3868
600	274.4185
700	320.9227
800	355.078
900	380.207
1000	406.8564

Fig.no.5.2. Optimized Power output



economic	fuel cost
1	3.2186
2	3.2128
3	3.211
5	3.2117
6	3.2101
7	3.2105
8	3.2104
9	3.2102
10	3.2101
11	3.21
12	3.2099

Fig.no.5.3.Optimized Fuel Cost



EMISSION FACTOR	EMISSION
15	349.77
18	347.98
20	347.01
22	346.192
25	345.1678
28	344.336

Fig.no.5.4.Emission Cost

VI CONCLUSION

In this paper, we have derived the mathematical formulation for the Economic dispatch problem in power systems using quadratic programming techniques. A basic EELD model is used to coordinate the power generated from thermal and wind generators. The model used in this case is very simple where fuel cost characteristics of thermal generators are assumed as quadratic in nature; effect of valve point loading is not included in the problem formulation. Similarly operating limit and power balance constraints are considered at the time of problem formulation only. The new exploration ability of gravitational attraction model of QPM handles the problem of premature convergence in an effective manner compared to other existing algorithm. Due to these features, in the future, the QPM seems to become an important tool for solving complex power system optimization problems in search of better quality results.

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BIOGRAPHY

Dr.Govindaraj Thangavel born in Tiruppur , India , in 1964. He received the B.E. degree from Coimbatore Institute of Technology, M.E. degree from PSG College of Technology and Ph.D. from Jadavpur University, Kolkatta, India in 1987, 1993 and 2010 respectively. His Biography is included in Who's Who in Science and Engineering 2011-2012 (11th Edition). Scientific Award of Excellence 2011 from American Biographical Institute (ABI).

Outstanding Scientist of The 21st century by International Biographical centre of Cambridge, England 2011.

Since July 2009 he has been Professor and Head of the Department of Electrical and Electronics Engineering, Muthayammal Engineering College affiliated to Anna University, Chennai, India. His Current research interests includes Permanent magnet machines, Axial flux Linear oscillating Motor, Advanced Embedded power electronics controllers,finite element analysis of special electrical machines,Power system Engineering and Intelligent controllers.He is a Fellow of Institution of Engineers India(FIE) and Chartered Engineer (India).Senior Member of International Association of Computer Science and Information. Technology (IACSIT). Member of International Association of Engineers(IAENG), Life Member of Indian Society for Technical Education(MISTE). Ph.D. Recognized Research Supervisor for Anna University and Satyabama University Chennai. Editorial Board Member for journals like *International Journal of Computer and Electrical Engineering*,International Journal of Engineering and Technology,International Journal of Engineering and Advanced Technology (IJEAT).International Journal Peer Reviewer for Taylor &Francis International Journal "Electrical Power Components & System"United Kingdom,Journal of Electrical and Electronics Engineering Research,Journal of Engineering and Technology Research (JETR),International Journal of the Physical Sciences,Association for the Advancement of Modelling and Simulation Techniques in Enterprises,International Journal of Engineering & Computer Science (IJECS),Scientific Research and Essays,Journal of Engineering and Computer Innovation,E3 Journal of Energy Oil and Gas Research,World Academy of Science, Engineering and Technology,Journal of Electrical and Control Engineering（JECE),Applied Computational Electromagnetics Society etc.. He has published 132 research papers in International/National Conferences and Journals. Organized 40 National / International Conferences/Seminars/Workshops. Received Best paper award for ICEESPEEE 09 conference paper. Coordinator for AICTE Sponsored SDP on special Drives,2011.Coordinator for AICTE Sponsored National Seminar on Computational Intelligence Techniques in Green Energy, 2011.Chief Coordinator and Investigator for AICTE sponsored MODROBS - Modernization of Electrical Machines Laboratory. Coordinator for AICTE Sponsored International Seminar on "Power Quality Issues in Renewable Energy Sources and Hybrid Generating System", July 2013.

R.Thendral is pursuing her M.E. Power Systems Engineering in Muthayammal Engineering College,India. Her area of interest are Economic Dispatch,Distributed Generation FACTS and REPS.