Economic Load Dispatchand Emission Control Using Quadratic Programming

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***Abstract*- Economic load dispatch and Emission control problem is solved to find the optimum emission dispatch, optimum fuel cost,to minimize the emission of nitrogen oxides, considering thermal generator. A 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 Method . The bus system having six conventional thermal generators has been considered as test system. Minimum fuel cost, minimum emission and best compromising solution obtained by QPM.**

Index Terms - Economic Emission Dispatch, Quadratic Programming, Wolfe modified simplex method

NOMENCLATURE

P_{Gi} Real power output of i the generation

P_L Transmission losses

P_{Gi}^{max} Maximum generation Output

V_j Non-Negative Artificial variable

P_{Gi}^{min} Minimum generation output

B Coefficient Of Transmission Losses

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 NO_x, SO_x, and 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 [2]. Thus, the computation speed is the critical issue to deal with the disturbance caused by the renewable energy resources.

ED is an optimization problem that pursues the least emission level of operation of a power system. 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].

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 :

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

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

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of the i-th generator (MW). Fi(PGi) is the operating cost of unit i ($/h).

III-SOLUTION PROCEDURE

A.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

1. 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

2. 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.

B. Economic Dispatch

The purpose of ED 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 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].

C.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 nonlinearprogramming algorithms is given in equation in (1) and (2).
If the optimization problem assumes the form

And G= (g_{ij})n×n is a positive definite orpositive semi-definite symmetric squarematrix,

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

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.

1. Mathematic Form OfQfpp:

The mathematical form of this type of problems is given as follows:Where G1 and G2 is matrix of coefficients with are symmetricmatrixesis given in equation (3). All vectors are assumed to

$$\text{Max .z} = \frac{c^T x+\frac{1}{2}x^T G_1 x}{d^T x+\frac{1}{2}x^T G_2 x} \quad (3)$$

be column vectors unless transposed where an a is the dimensional vector of decision variables is, b is the dimensional vector of constants, C is dimensional vector of constants is expressed in equation (4)

$$\text{Max z} = \frac{(c_1^T x+\frac{1}{2}x^T G_1^1 x)(c_1^T x+\frac{1}{2}x^T G_1^2 x)}{(d_1^T x+\frac{1}{2}x^T G_2^1 x)(d_2^T x+\frac{1}{2}x^T G_2^2 x)} (4)$$

D. *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 (5) . Similarly, and cannot be positive simultaneously.

$$\text{Max z} = \text{f(x)}=\sum_{j=1}^{n} c_j x_j + \frac{1}{2}\sum_{j=1}^{n}\sum_{k=1}^{n} c_{jk} x_j x_k .(5)$$

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Wolfe has suggested introducing n non negative artificial variable v_j in to the equation representing in equation (6).
Now, starting with an initial basic solution v=c,s=b and x=0,λ=0,

We maximize

$$z_v = -\sum_{i=1}^{n} v_i (6)$$

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 variablesr_1^2in the j th non negativity constraints (j= 1,2….n).it will be expressed in equation (7).

Step 2**:** Then construct the Lagrangian constraints L(x, q, r, λ, μ) =f(x) -$\sum_{i=1}^{n} \lambda i[\sum_{i=1}^{n} aii$-bj+$qi^2$] –

$\sum_{i=1} \mu i$ [–xj+rj] (7)

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 the Kuhn Tucker condition in equation (8).
$c_j + \sum_{k=1}^{n} c_{jk}\, x_k - \sum_{j=1}^{n} a_{ij}\, \lambda_i + \mu_j = 0 (8)$
For j=1,2,..n and to construct an objective function.

Step 4: Obtain the initial basic feasible solution to the following linear programming problem in equation (9).
Subject to the constraints
for (j=1,2,….,n)

$$\sum_{k=1}^{n} a_{ij}\, x_j + q_i^2 = b_j \qquad (9)$$

And satisfying the complementary slackness condition in equation (11)

$$\sum_{k=1}^{n} \mu_j x_j - \sum_{i=1}^{m} \lambda_i s_i = 0 \qquad (10)$$

Step 5:Now apply 2- phase simplex method to find and optimum solution of Linear Programming problem in step 4 .The solution must satisfy the above complementary slackness condition.

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

2.FLOWCHART

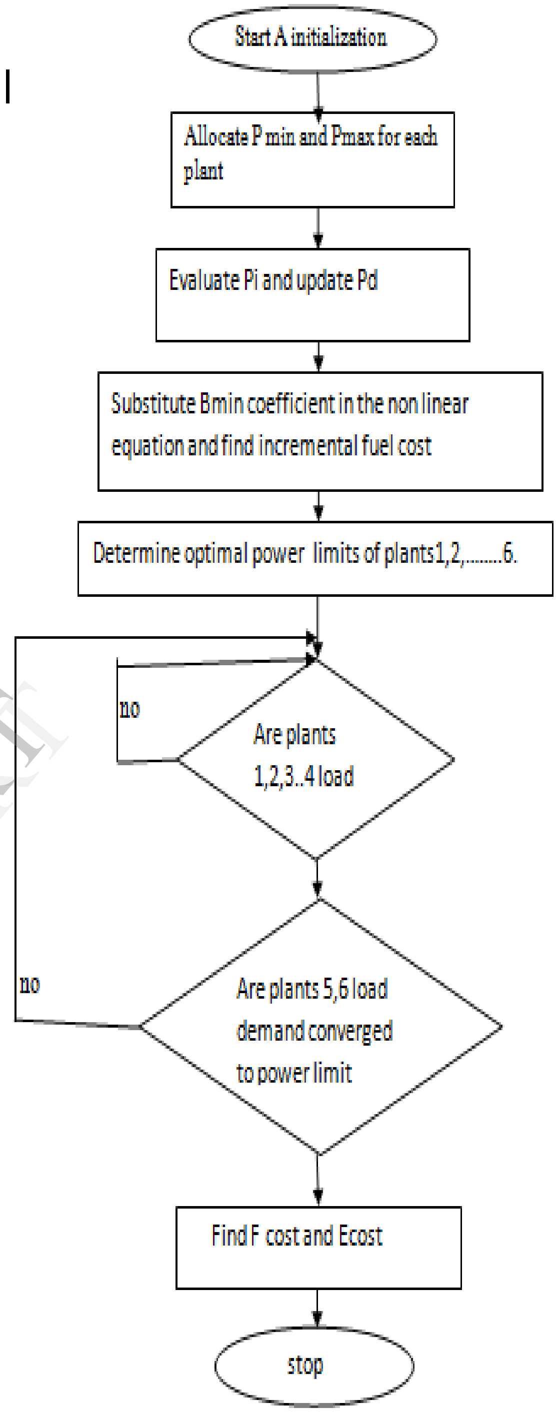

Fig.1.Flowchart Of QuadraticMethod

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3. 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

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

FUELCOST DATA

ECONOMIC	FUELCOST
10	4.7065
11	4.7062
12	4.7059
13	4.7058
14	4.7056
15	4.7055

EMISSION COST DATA

EMISSION	EMISSION COST
12	797.10
13	795.40
14	793.75
15	792.14
16	790.47
17	789.03

IV-SIMULATION RESULT

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Optimization terminated.

P =

   56.5320
   51.7838
  184.3993
  175.1106
  287.9904
  281.8721


Fcost =

   5.2484e+04


Emi =

  957.0486


Pl =

   37.6882
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Fig.2.Output of Economic Emission Dispatch

COMPARISON CHART

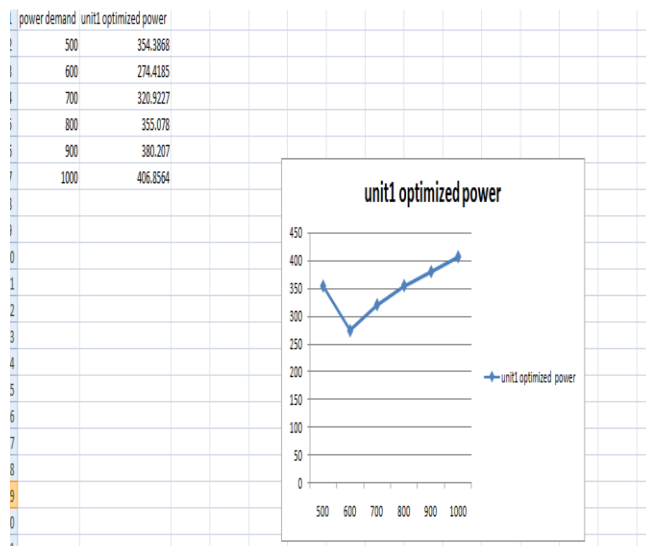

Fig.3. Optimized Power

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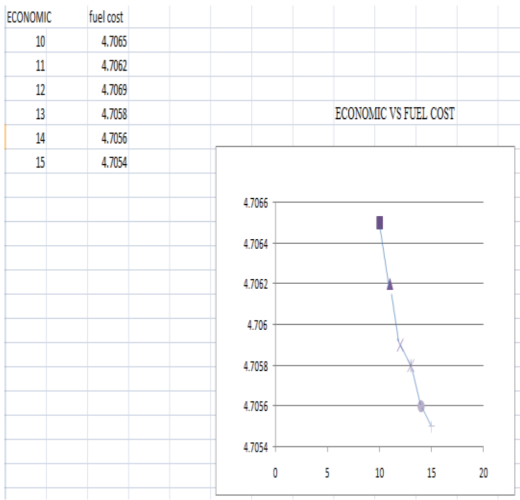

Fig .4.Optimized Fuel Cost

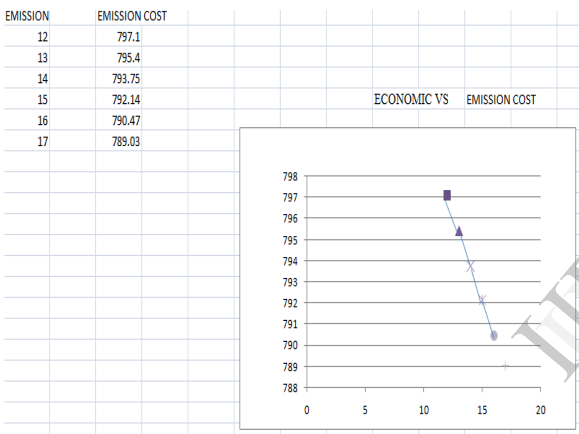

Fig.5.Emission Cost

V-CONCLUSION

A basic Economic load dispatch and emission control model is used to coordinate the power generated from thermal generators. The model used in this case is very simple where fuel cost characteristics of thermal generators are assumed as quadratic in nature. Similarly operating limit and power balance constraints are considered at the time of problem formulation only. The 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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