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# Dynamic Economic Dispatch and Emission Control Using Quadratic Programming Method

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**ABSTRACT:** In the Modern world the best generation schedule for the generating plants to supply the required economic benefits. 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. Conventionally, the emphasis on performance optimization of fossil-fuel power systems was on economic operation only regulations have been forced on the industries, as environmental effect is a direct consequence of industrial The economic load dispatch (ELD) problem demand plus transmission losses with the, using the ELD approach, as better solutions would result in advancement.

### I. INTRODUCTION

In the proposed work, 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.

#### 1.1 ECONOMIC DISPATCH

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 economic benefits. 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.

#### 1.2. EXISTING SYSTEM

To find quality solution with good computational efficiency different approaches have been developed.

1. One of the first approaches to solve the EELD problem is using linear and non-linear goal programming techniques.

2. The Next is a new approach based on probability security criteria. Goal programming techniques to solve this multiple criteria decision making problem and evaluate the better environmental marginal cost was

Drawbacks

High fuel cost

High emission

Only using equality constraints

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## II. PROPOSED SYSTEM

In this paper, an alternative approach to the Wolfe's method for Quadratic Programming is suggested. Here we proposed a new approach based on the iterative procedure for the solution of a Quadratic Programming Problem by Wolfe's modified simplex method. The method sometimes involves less or at the most an equal number of iteration as compared to computational procedure for solving EELD. We observed that there is change in the rule of selecting pivot vector at initial stage and thereby for some EELD it takes more number of iteration to achieve optimality. Here at the initial step we choose the pivot vector on the basis of new rules of method described below.

This powerful technique is better understood by resolving a cyclic Existing Economic Dispatch Problem with Emission Control Solution.

### Advantages

Less fuel cost  
High Efficiency  
Maximum emission control

### 2.1. Planning for tomorrow dispatch

Implementation Factors Limiting Effectiveness of Dispatch in Minimizing Customer Costs

### 2.2. 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. Inadequate or incomplete communications affects the level of costs of the economic dispatch.

### 2.3. Economic Emission Dispatch

The proposed algorithm is applied to economic emission load dispatch (EELD) problem. 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 economic dispatch (ED) problem is one of the most important operational functions of the modern energy management 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. The literature of the ED problem and its solution methods are surveyed. 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.

### 2.4. 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 :

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

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

Where ai, bi and ci are the cost coefficients of the i-th generator and NG is the number of generators including the slack bus. P<sub>Gi</sub> is the real power output of the i-th generator (MW). F<sub>i</sub>(P<sub>Gi</sub>) is the operating cost of unit i (\$/h).

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## III. 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. Much like in separable programming, a modified version of the simplex algorithm can be used to find solutions.

If the optimization problem assumes the form

$$\text{Max } z \text{ (or min } z) = \alpha + c^T x + x^T G x \dots\dots\dots(2)$$

Subject to:

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

$$x \geq 0$$

Where  $A=(a_{ij})m \times n$ , matrix of coefficients,  $y_i=1,2,\dots,m$  and  $=1,2,\dots,n$ .

$$B=(b_1, b_2, \dots, b_m)^T, x = (x_1, x_2, \dots, x_N)^T, C^T = (C_1, C_2, \dots, C_N)^T$$

And  $G=(g_{ij})n \times n$  is a positive definite or positive semi-definite symmetric square matrix,

$$P_{Gi}^{min} \leq P_{Gi} \leq P_{Gi}^{max} \text{ For } i=1,\dots,NG$$

$$\sum_{i=1}^{NG} P_{Gi} - D - P_L = 0 \dots\dots\dots(3)$$

Where

$$P_L = \sum_{i=1}^N \sum_{j=1}^N P_{Gij} B_{ij} P_{Gj} + \sum_{i=1}^N B_{Oii} P_{Gi} + B_{OO} \dots\dots\dots(4)$$

$D$ =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

Moreover the constraints are linear and the objective function is quadratic. Such optimization problem is said to be a quadratic programming (QP) problem.

### 3.1. Mathematic form of QFPP

The mathematical form of this type of problems is given as follows:

Where  $G_1$  and  $G_2$  is matrix of coefficients with are symmetric matrixes. All vectors are assumed to

$$\text{Max } z = \frac{c^T x + \frac{1}{2} x^T G_1 x}{d^T x + \frac{1}{2} x^T G_2 x} \dots\dots\dots(5)$$

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

$x \geq 0$  be column vectors unless transposed where an  $n$ -dimensional vector of decision variables is,  $b$  is the dimensional vector of constants,  $C$  is  $n$ -dimensional vector of constants.

In this work the problem that has objective function is tried to be solved as the form.

$$\text{Max } z = \frac{(c_1^T x + \frac{1}{2} x^T G_1 x)(c_2^T x + \frac{1}{2} x^T G_2 x)}{(d_1^T x + \frac{1}{2} x^T G_1 x)(d_2^T x + \frac{1}{2} x^T G_2 x)} \dots\dots\dots(6)$$

### 3.2. Wolfe's Method

Although, the Wolfe's method is not the first method that has been developed for solving quadratic programming problems (QPP), it is one of the most widely used methods for QPP and was developed by P. Wolfe in 1959 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 problem with we can solve by usual simplex method.. Thus, when deciding whether to introduce in the solution, it is a must first to ensure either that is not in the solution or that

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will be removed when enters. This additional check is not difficult to perform by using simplex and routine that has been successfully performed.

The only restriction is that the condition should be maintained all the time. This implies that if is in the basic solution with positive value, then cannot be based with +ve value. Similarly, and cannot be positive simultaneously.

$$\text{Max } z = f(x) = \sum_{j=1}^n c_j x_j + \frac{1}{2} \sum_{j=1}^n \sum_{k=1}^n c_{jk} x_j x_k \dots \dots \dots (7)$$

Subject to the constraints

$$\sum_{j=1}^n a_{ij} x_j \leq b_j, x_j \geq 0 \quad (i=1,2,\dots,m; j=1,2,\dots,n) \text{ where } c_{jk} = c_{kj} \text{ for all } j \text{ and } k, b_j \geq 0 \text{ for all } i=1,2,\dots,m.$$

Wolfe has suggested introducing n non negative artificial variable  $v_j$  in to the equation representing  $\frac{dL}{dx_j} = 0$

$$\sum_{i=1}^n g_{ij} x_i + \sum_{i=1}^m \lambda_i a_{ij} + \mu_j + v_j = c_j \text{ Now, starting with an initial basic solution } v=c, s=b \text{ and } x=0, \lambda=0, \text{ We maximize } z_v = - \sum_{i=1}^n v_i \dots \dots \dots (8)$$

Subject to

$$-\mu + c + g_i x + a_j \lambda - v = 0$$

$$Ax + s = b$$

$$\mu, \lambda, x, s, v \geq 0$$

And the complementary slackness conditions are:

$$\lambda_i s_i = 0, i=1, \dots, m.$$

$$\mu_i x_i = 0, i=1, \dots, m.$$

### 3.3 FLOWCHART

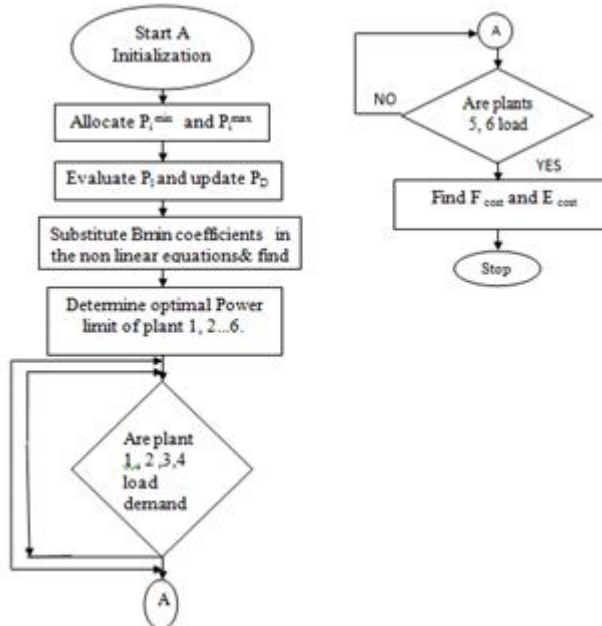


Fig.3.1.Economic Dispatch using quadratic programming

### 3.4. 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 ( $i= 1,2,\dots,m$ ) and the slack variables  $r_j^2$  in the j th non negativity constraints ( $j= 1,2,\dots,n$ ).

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

$$L(x, q, r, \lambda, \mu) = f(x) - \sum_{i=1}^m \lambda_i [\sum_{j=1}^n a_{ij} x_j - b_j + q_i^2] - \sum_{j=1}^n \mu_j [-x_j + r_j] \dots \dots \dots (9)$$

$$\text{Where } x = (x_1, x_2, \dots, x_n)$$

$$r = (r_1, r_2, r_3, \dots, r_n),$$

$$\lambda = (\lambda_1, \lambda_2, \lambda_3, \dots, \lambda_m),$$

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Differentiating L partially with respect to the components of and equating the first order partial derivatives to zero, Kuhn-Tucker conditions are obtained.

**STEP 3:** Introduce the non-negative artificial variable  $j=1, 2, \dots, n$  in the Kuhn Tucker condition

$$c_j + \sum_{k=1}^n c_{jk} x_k - \sum_{j=1}^n a_{ij} \lambda_i + \mu_j = 0 \dots\dots\dots (10)$$

For  $j=1, 2, \dots, n$  and to construct an objective function

$$z_v = v_1 + v_2 + \dots + v_n$$

**STEP 4:** Obtain the initial basic feasible solution to the following linear programming problem min. subject to the constraints

$$\sum_{k=1}^n c_{jk} x_k - \sum_{k=1}^n c_{jk} x_k - \sum_{k=1}^n a_{ij} \lambda_i + \mu_j + v_j = -c_j \text{ for } (j=1, 2, \dots, n)$$

$$\sum_{k=1}^n a_{ij} x_j + q_i^2 = b_j \text{ Where } i=(1, 2, \dots, m), v_j, \lambda_i, \mu_j, x_j \geq 0 \text{ (} i=1, 2, \dots, m; j=1, 2, \dots, n)$$

And satisfying the complementary slackness condition:

$$\sum_{k=1}^n \mu_j x_j - \sum_{i=1}^m \lambda_i s_i = 0 \text{ where } (s_i = q_i^2) \lambda_i s_i = 0 \text{ and } \mu_j x_j = 0$$

$$(i=1, 2, \dots, m; j=1, 2, \dots, n)$$

**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).

### 3.5. Solving Technique for Power Demand

#### Integration with supervisory system

- Plant Information Systems - MIS
- Regional Dispatch Centres

## IV. MATLAB SIMULATION RESULT

P=  
41.9917  
30.3025  
144.4392  
140.5510  
238.2159  
228.7617  
Fcost=  
4.1952e+04  
Emi =  
613.0715  
P1 =  
24.2621

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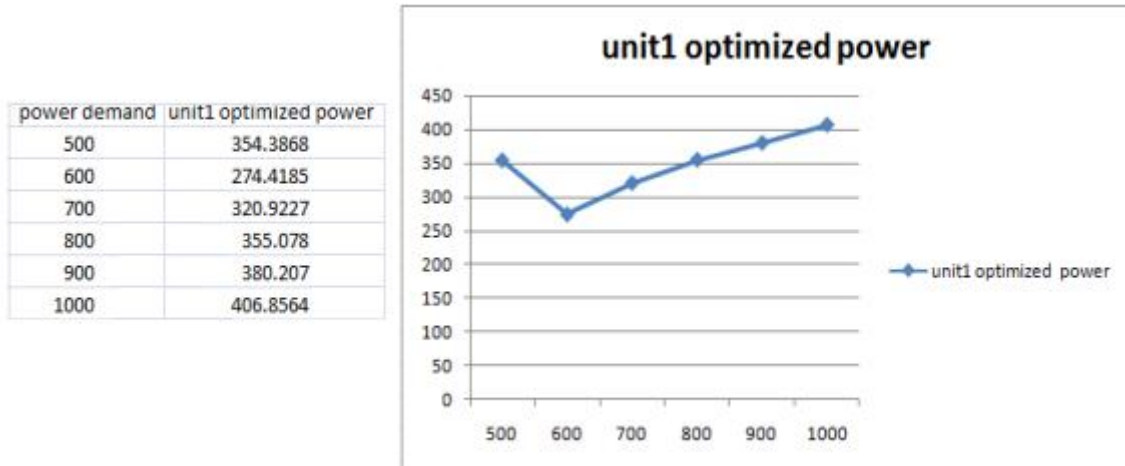


FIG 4.1.Power Demand versus Optimized power.

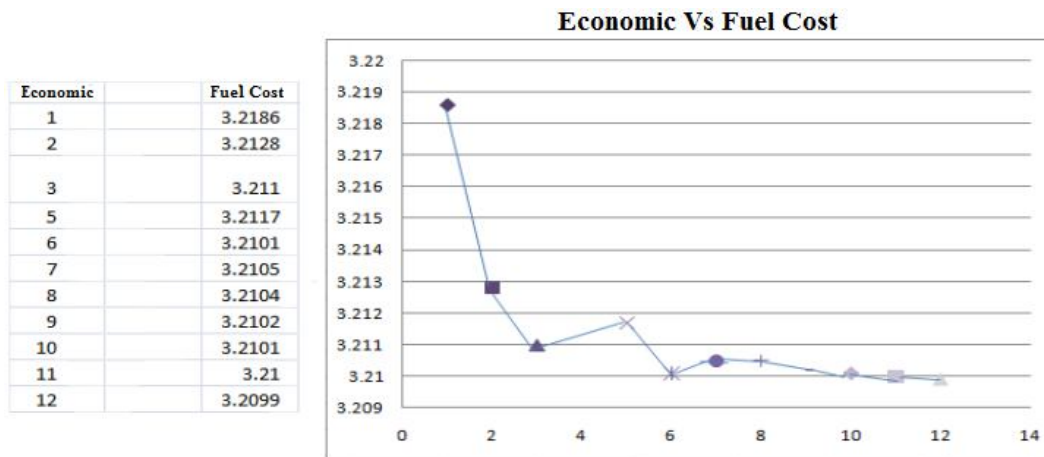


FIG 4.2.Economic versus Fuel cost

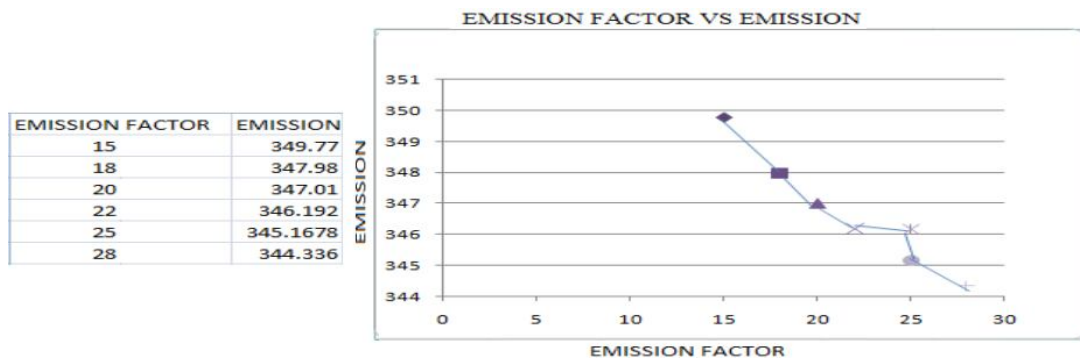


FIG 4.3.Emission factor versus Emission

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## V. CONCLUSION

The QPM has been successfully implemented to solve both single and multi-objective EELD problems. 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.

It is also clear from the results of different trials that the implementation of this new QPM approach can eliminate the shortcoming of premature convergence, exhibited by other optimization techniques. 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.

## FUTURE WORK

The simulation for the economic emission dispatch using quadratic programming is done and the simulation for the economic emission dispatch using improved PSO will be produced in phase II

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