Steepest Descent Method For Economic Load Dispatch Using Matlab

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Abstract
This paper focuses on the investigation of electrical power systems employing optimization techniques. In this paper steepest descent method with random step size is implemented in parallel to achieve the optimal solution of the non-linear optimization problems satisfying equality and inequality constraints in the context of time expansive evaluation of functions. The exterior penalty function is used to consider the equality and inequality imposed constraints on the system. In this paper, an attempt has been made to solve economic dispatch problem using gradient methods. The validity of the proposed methods has been demonstrated for 3- generator and 6-generator power systems. A comparative study of proposed techniques is carried out to judge the quality of the achieved solution and speed of convergence of the proposed algorithms.

Keywords: Thermal Power System, Steepest Descent method, Mutation, Back Propagation

Introduction
The optimal scheduling of an electric power system is the determination of the generation for every plant such that the total system generation cost is minimum while satisfying the system constrains. However due to operating cost of thermal plants the scheduling problem essentially reduces to minimizing the fuel cost, constrained by the generation limits, and the energy balance condition for the given period of time.

Economic dispatch ranks high among the major economy-security functions in power systems operation. This is a procedure for the distribution of total thermal generation requirements among alternative sources for optimal system economy with due consideration of generating costs, transmission losses, and several recognized constraints imposed by the requirements of reliable service and equipment limitations.

The aim of real power economic dispatch is to make the generator’s fuel consumption or the operating cost of the whole system minimal by determining the power output of each generating unit under the constraint condition of the system load demands. This is also called the classic economic dispatch, in which the line security constraints are neglected. The fundamental of the economic dispatch problem is the set of input - output characteristic of a power - generating unit. Economic dispatch area is classified under one of these four categories.

a) Optimal power flow.
b) Economic dispatch in relation to AGC(automatic generation control).
c) Dynamic dispatch.
d) Economic dispatch with non-conventional generation sources.

The distribution and expansion strategies of electrical utilities have been developed under the premise that all load must be met in full, as when they occur and with very high reliability. Since there are few facilities to store energy, the net production of a utility must closely track its load.

a) Generation planning and production costing
b) Long range fuel planning
c) Transmission and distribution planning
d) Maintenance and production scheduling
e) Real-time operation and fuel scheduling
f) Dispatching

The real life problems to which the techniques of optimization have been applied may be classified as stochastic systems, trajectory systems, and deterministic systems. The first covers the important problem of optimal control in the presence of uncertainty. The second includes winged flight paths but is primarily concerned with the computation of optimum rocket and space flight trajectories. It is the third class, which includes the computations of the performance of mathematical models of designs for particular physical systems [39].
Optimization is the process of obtaining minimum or maximum of an objective function. Study on various optimization problems reveal the fact that the formulation of engineering design problems could defer from problem to problem. Certain problem involves linear term for constrained and objective function but certain other problems involve nonlinear terms for them. Unfortunately, there does not exist a single optimization technique which will work equally well for all optimization problems. Some techniques perform better on one problem, but may perform poorly on other problems. That is why the optimization literature contains a large number of algorithms, each suitable to solve a particular type of problem. For the sake of clarity, the optimization techniques are classified into a number of groups, which are listed [10].

a) Single Variable Optimization Techniques
b) Multi-Variable Optimization Techniques
c) Constrained Optimization Techniques
d) Specialized Optimization Techniques
e) Non-traditional Optimization Techniques

The method of steepest descent is also known as The Gradient Descent, which is basically an optimization algorithm to find the local minimum of a function. It is a method that's widely popular among mathematicians and physicists due to its easy concept and relatively small work steps. This paper introduces the basic concept of the method of steepest descent, the advantage and disadvantage of using such method, and some of its applications. The method of steepest descent is the simplest of the gradient methods. Imagine that there's a function, which can be defined and differentiable within a given boundary, so the direction it decreases the fastest would be the negative gradient of function. To find the local minimum of function, the method of steepest descent is employed, where it uses a zigzag like path from an arbitrary decision point and gradually slide down the gradient, until it converges to the actual point of minimum.

This paper focuses on the investigation of electrical power systems employing optimization techniques. In this paper steepest descent method with random step size is implemented in parallel to achieve the optimal solution of the non-linear optimization problems satisfying equality and inequality constraints in the context of time expansive evaluation of functions. The exterior penalty function is used to consider the equality and inequality imposed constraints on the system. In this paper, an attempt has been made to solve economic dispatch problem using gradient methods. The validity of the proposed methods has been demonstrated for 3-generator and 6-generator power systems. A comparative study of proposed techniques is carried out to judge the quality of the achieved solution and speed of convergence of the proposed algorithms.

II. Problem Formulation: To formulate the problem and its solution mathematically, the following notation was introduced:

- Objective function
- jth Inequality Constraint Function
- Lagrange multiplier
- Number of generating units
- Termination parameter
- Optimal step length
- Augmented Lagrange function
- Penalty parameter
- Operating cost coefficients of ith generator
- Real power output of ith generator
- Total demand (MW)
- Transmission losses (MW)
- B-coefficients of transmission losses
- Augmented function using penalty function
- Uniform random number
- Multiplying factor
- Positive multiplying factor

The total demand PD is the sum of all generations. A cost function Fi(Pgi) is assumed to be known for each plant. The problem is to find the real power generation, Pgi for each plant such that the total operating cost F(Pgi) is minimum and the generation remains within the lower generation and upper generation. Suppose there is a station with 'n' generators committed and the active power load demand PD is given, the real power generation Pgi for each generator has to be allocated so as to minimize the total operating cost [23]. The minimization can be therefore stated as

$$ F(P_{gi}) = \sum_{i=1}^{n} F_{i} P_{gi} $$
Subject to:
(i) The energy balance equation
(i=1,2,…,n)

(ii) And the equality constraints

\[ P_{gi}^{\text{min}} \leq P_{gi} \leq P_{gi}^{\text{max}} \]

Where

\( P_{gi} \) is the decision variable, i.e. real power generation

\( P_D \) is the real power demand

\( n \) is the number of generation plants

\( P_{gi}^{\text{min}} \) is the lower permissible limit of real power generation

\( P_{gi}^{\text{max}} \) is the upper permissible limit of real power generation

\( F_i(P_{gi}) \) is the operating fuel cost of the \( i^{\text{th}} \) plant and is given by the quadratic equation

\[ F_i(P_{gi}) = \sum_{i=1}^{n} a_i P_{gi}^2 + b_i P_{gi} + c_i \]

The above constrained optimization problem is converted into an unconstrained optimization problem. Lagrange multiplier is used in which a function is minimized (or maximized) with side conditions in the form of equality constraints. Using the method an augmented function is defined as

\[ L(P_{gi}, \lambda) = F(P_{gi}) + \lambda \left( P_D - \sum_{i=1}^{n} P_{gi} \right) \]

where \( \lambda \) is the Lagrange multiplier.

A necessary condition for a function \( F(P_{gi}) \) subject to energy balance constraint to have a relative minimum at point \( P_{gi}^* \) is that the partial derivative of the Lagrange function defined by \( L = L(P_{gi}, \lambda) \) with respect to each of its arguments must be zero.

Transmission losses may be neglected when transmission losses are very small but in a large interconnected network where power is transmitted over long distances, transmission losses are a major factor and affect the optimum dispatch of generation [23]. The economic load dispatch problem considering the transmission power loss \( PL \) for the objective function is thus formulated as, minimize

\[ F(P_{gi}) = \sum_{i=1}^{n} F_i P_{gi} \]

Subject to;
(i). The energy balance equation

\[ \sum_{i=1}^{n} P_{gi} = P_D + P_L \]

(ii) And the equality constraints

\[ P_{gi}^{\text{min}} \leq P_{gi} \leq P_{gi}^{\text{max}} \]

The general form of the loss formula using B- coefficients is

\[ P_L = B_{00} + \sum_{i=1}^{n} B_{i0} P_{gi} + \sum_{i=0}^{n} \sum_{j=0}^{n} B_{ij} P_{gi} P_{gj} \text{MW} \]

where

\( a_i \), \( b_i \), and \( c_i \) are the operating cost coefficients

\( P_D \) is the load demand

\( P_{gi} \) and \( P_{gj} \) is the real power generation at \( i^{\text{th}} \) and \( j^{\text{th}} \) buses, respectively

\( n \) is the number of generation buses

\( P_L \) is the transmission power loss

\( B_{00}, B_{i0} \) and \( B_{ij} \) are loss coefficients which are constant under certain assumed conditions

\( n \) is the number of generation buses.

**Penalty Function Method**

Penalty function method transforms the basic constrained optimization problem into alternative formulations such that the numerical solutions are sought by solving a sequence of unconstrained minimization problems. It is worth mentioning that the inequality constraints of the control variables are self constrained. Generally, the penalty function method is the most popular methods for handling inequality constraints, due to its simple concept and convenience to implementation. However, the penalty function method does suffer from the complication that as the penalty parameter is increased toward infinity; the structure of the unconstrained problem becomes increasing ill-conditioned. Therefore, each unconstrained minimization problem becomes more difficult to solve, which has the effect of slowing the convergence rate of the overall optimization process. On the other hand, if the penalty parameters are too small, the constraint violation will not impose a high cost on the penalty function.
To solve an optimization problem involving both equality and inequality constraints the following form has been proposed

\[ A(P_{gl_i}, r) = \sum_{i=1}^{n} (a_i P_{gl_i}^2 + b_i P_{gl_i} + c_i) + r(P_{gl_i} - P_{g_{min}}^i)^2 + (P_{g_{max}}^i - P_{gl_i})^2 \]

Where \( r \) is a positive penalty parameter, the effect of the second and third terms on the right side is to increase 'A' in proportion to the quadratic power of the amount by which the constraints are violated. Thus there will be a penalty for violating the constraints, and the amount of penalty will increase at a faster rate than will the amount of violation of a constraint. This is the reason why the formulation is called the penalty function method.

**Steepest Descent Method**

Steepest descent is a first order optimization algorithm to find local minimum of a function using gradient descent, one takes steps proportional to the negative of the gradient (or the approximate gradient) of the function at the current point. Steepest descent is also known as gradient descent, or the method of steepest descent. The method of steepest descent is the simplest of the gradient methods. The convergence characteristics of the steepest descent method can be improved greatly by modifying it in to a conjugate gradient method. According to the Powell's method any minimization method that makes use of the conjugate directions is quadratically convergent. This property of quadratic convergence is very useful because it ensures that the method will minimize the quadratic function in given steps. Since any general function can be approximated reasonably well by a quadratic near the optimum point, any quadratically convergent method is expected to find the optimum point in a finite number of iterations. The method of steepest descent is also known as The Gradient Descent, which is basically an optimization algorithm to find the local minimum of a function. The method of steepest descent may appear to be the best unconstrained minimization technique. It is a method that's widely popular among mathematicians and physicists due to its easy concept and relatively small work steps.

The steepest descent method can be summarized by the following steps in the generalized form. Algorithm

1. Start with initial point \( P_{gi} \) where \( (i=1,2,\ldots, n) \)
   Set the iteration number as \( k = 1 \)

2. Find the search direction \( S_i \) as
   \[ S_i^k = -\frac{\partial A}{\partial P_{gi}^k} \quad (i=1,2,\ldots, n) \]

3. Determine the optimal step length \( \alpha^* \) in a direction employing scalar variable optimization technique so that \( f(P_{gi}^k + \alpha^* S_i^k) \) is zero.

4. Update the decision variable
   \[ P_{gi}^{k+1} = P_{gi}^k + \alpha^* S_i^k \]

5. Test the new point, \( P_{gi}^{k+1} \) for optimality
   \[ \sum_{i=1}^{n} \left( \frac{\partial A}{\partial P_{gi}^i} \right)^2 \leq \varepsilon \]
   If then stop the process.

   Else, set new iteration number \( k = k + 1 \) and go to step 2 and repeat.

**Solution Procedure**

Solution procedure to solve economic dispatch problem is given as following. Stepwise procedure to implement steepest descent method has been described in the ensuing section.

Initial Guess: As discussed, \( \lambda \) is calculated using initial data provided in the problem and further generator operating costs \( (P_{gi}) \) are calculated using value of \( \lambda \) and thermal unit coefficients of cost are provided by characteristics equation. Transmission loss PL are calculated using loss equation assuming B00 and B10 to be zero and B-coefficients are provided. Augmented function is formed and stated in equation above.

Gradient of Augmented Function: The gradient of augmented function is obtained by doing partial differentiation with respect to decision variables.

Evaluation of Optimal Step Length: The optimal step...
length, $\alpha$ is achieved randomly in the known range of $\alpha$. The mathematical expression is given below

$$\alpha^* = \alpha^{\min} + R(\alpha^{\max} - \alpha^{\min})$$

Where $R$ is a uniform random number varying within $[0, 1]$. $\alpha^{\min}$ and $\alpha^{\max}$ are lower and upper limit of $\alpha$.

Updation of Decision Variable: Updation of decision variable is done in such a way that there is no violation of limits and no divergence occurs.

$$P_{gi}^{new} = P_{gi}^{old} + \alpha \left( -\frac{\partial A}{\partial P_{gi}} \right) \left( \frac{\Delta P_D}{P_D} \right) \xi$$

Where

$$\Delta P_D = P_L + P_D - \sum_{i=1}^{n} P_{gi}$$

$$\xi = \begin{cases} 
\left( P_{gi} - P_{gi}^{\min} \right) ; & \Delta P_D > 0 \\
\left( P_{gi}^{\max} - P_{gi} \right) ; & \Delta P_D < 0
\end{cases}$$

$\alpha$ is step size is multiplying factor which avoids to violate the generation limits during the updation. $\left( \frac{\Delta P_D}{P_D} \right)$ avoids to go out of bound that leads to divergence of the solution.

Convergence Criterion: The convergence is obtained when all the penalty terms become zero. It is achieved by checking the following expression

$$|A(P_{gi}, r) - F(P_{gi})| \leq \varepsilon$$

Penalty Parameter Updation:

$$r = r^* \beta$$

where $\beta$ is an positive multiplying factor.

Having tested the algorithm with various starting values we found that the algorithm has global - like convergence property so that even if the starting values are far away from the optimal region. We get the optimal solution. This paper consists of the testing algorithm for steepest descent method with random step size. Constrained optimization problem is solved by converting it into unconstrained optimization problem by applying penalty to equality and inequality constraints. The algorithms are developed in MATLAB software has been successfully tested on the classical optimization problems. The solution methodology of steepest descent method is given above in the paper and is implemented to solve the classical test problems. In this section, the results obtained are presented. The economic dispatch problem has been solved for 6-generator electrical power system.

Test System

Power system network of six generating units namely Pg1, Pg2, Pg3, Pg4, Pg5 and Pg6 is given in Fig.1. In this system generation buses are connected to their respective generating units. The buses are connected to each other and also with the loads. For this generating system, the fuel cost coefficients are given in Table 1, operating generator limits are given in Table2, and the B-coefficients for transmission loss are given in Table 3. For a given load demand of 700 MW, we have to obtain the optimum generation schedule.

<p>| Table 1. Thermal unit coefficients of cost characteristic equation |
|-----------------------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Gen</th>
<th>Ai (Rs/MW^2h)</th>
<th>bi (Rs/MWh)</th>
<th>Ci (Rs/h)</th>
</tr>
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<tr>
<td>1</td>
<td>0.15247</td>
<td>38.53973</td>
<td>756.79886</td>
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<tr>
<td>2</td>
<td>0.10587</td>
<td>46.15916</td>
<td>451.32513</td>
</tr>
<tr>
<td>3</td>
<td>0.02803</td>
<td>40.39655</td>
<td>1049.99770</td>
</tr>
<tr>
<td>4</td>
<td>0.03546</td>
<td>38.30553</td>
<td>1243.53110</td>
</tr>
<tr>
<td>5</td>
<td>0.02111</td>
<td>36.32782</td>
<td>1658.56960</td>
</tr>
<tr>
<td>6</td>
<td>0.01799</td>
<td>38.27041</td>
<td>1356.65920</td>
</tr>
</tbody>
</table>

<p>| Table 2. Power generation limits |
|-----------------------------|----------------|</p>
<table>
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<tr>
<th>Unit</th>
<th>Minimum Limit (MW)</th>
<th>Maximum Limit (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>125</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>150</td>
</tr>
<tr>
<td>3</td>
<td>35</td>
<td>225</td>
</tr>
<tr>
<td>4</td>
<td>35</td>
<td>210</td>
</tr>
<tr>
<td>5</td>
<td>130</td>
<td>325</td>
</tr>
<tr>
<td>6</td>
<td>125</td>
<td>315</td>
</tr>
</tbody>
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<p>| Table 3. B-coefficients of the power system network |
|-----------------------------|----------------|</p>
<table>
<thead>
<tr>
<th>I</th>
<th>B11</th>
<th>B12</th>
<th>B13</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.002022</td>
<td>-0.000286</td>
<td>-0.000534</td>
</tr>
<tr>
<td>2</td>
<td>-0.000286</td>
<td>0.003246</td>
<td>0.000016</td>
</tr>
<tr>
<td>3</td>
<td>-0.00533</td>
<td>0.000016</td>
<td>0.002085</td>
</tr>
<tr>
<td>4</td>
<td>-0.000565</td>
<td>-0.000307</td>
<td>0.000831</td>
</tr>
</tbody>
</table>
Load Dispatch of thermal generating unit problem having six thermal units has been solved using steepest descent method with random step-size. Other different parameters such as maximum iterations are set to 1000, penalty parameter $r$ is taken 0.75 and updated by a multiplying factor $\beta=2.225$ whereas $R$ is uniform random number. $\alpha$ is the step-size and it avoids to violate the generation limits during updating. The obtained value of objective function using steepest descent method algorithm is Rs 38585.9068 and obtained generation schedule is given in Table 4.

<table>
<thead>
<tr>
<th>B_{i4}</th>
<th>B_{i5}</th>
<th>B_{i6}</th>
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<tbody>
<tr>
<td>-0.000565</td>
<td>-0.000454</td>
<td>-0.00103</td>
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<tr>
<td>-0.000307</td>
<td>-0.000422</td>
<td>-0.000147</td>
</tr>
<tr>
<td>0.000831</td>
<td>0.000023</td>
<td>-0.000270</td>
</tr>
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<td>0.001129</td>
<td>0.000460</td>
<td>-0.000153</td>
</tr>
<tr>
<td>-0.000295</td>
<td>-0.000153</td>
<td>0.000898</td>
</tr>
</tbody>
</table>

Optimum Solution for Test System: The Economic

Table 4. Generation schedule for 6-generator system for load demand PD is 700MW: steepest descent method

| Iter | $P_{g1}$ (MW) | $P_{g2}$ (MW) | $P_{g3}$ (MW) | $P_{g4}$ (MW) | $P_{g5}$ (MW) | $P_{g6}$ (MW) | $F$ (Rs/h) | $P_L$ (MW) | $P$ | $| \nabla |$
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>0</td>
<td>25.32</td>
<td>0.483</td>
<td>104.6</td>
<td>112.1</td>
<td>235.2</td>
<td>222.1</td>
<td>35993.6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1</td>
<td>52.56</td>
<td>34.90</td>
<td>61.57</td>
<td>100.9</td>
<td>253.8</td>
<td>206.9</td>
<td>36801.6</td>
<td>44.306</td>
<td>0.025</td>
<td>0.911</td>
</tr>
<tr>
<td>2</td>
<td>54.36</td>
<td>37.03</td>
<td>62.78</td>
<td>104.4</td>
<td>260.5</td>
<td>212.0</td>
<td>37774.6</td>
<td>46.376</td>
<td>0.025</td>
<td>0.897</td>
</tr>
<tr>
<td>3</td>
<td>55.19</td>
<td>37.97</td>
<td>63.43</td>
<td>105.9</td>
<td>263.4</td>
<td>214.5</td>
<td>38219.4</td>
<td>47.369</td>
<td>0.025</td>
<td>0.879</td>
</tr>
<tr>
<td>4</td>
<td>55.57</td>
<td>38.50</td>
<td>63.92</td>
<td>106.6</td>
<td>264.5</td>
<td>215.5</td>
<td>38421.8</td>
<td>47.815</td>
<td>0.025</td>
<td>0.742</td>
</tr>
<tr>
<td>5</td>
<td>55.76</td>
<td>38.84</td>
<td>64.30</td>
<td>106.9</td>
<td>264.8</td>
<td>215.9</td>
<td>38512.5</td>
<td>48.010</td>
<td>0.025</td>
<td>0.685</td>
</tr>
<tr>
<td>6</td>
<td>55.84</td>
<td>38.93</td>
<td>64.39</td>
<td>107.0</td>
<td>265.0</td>
<td>216.1</td>
<td>38553.8</td>
<td>48.101</td>
<td>0.025</td>
<td>0.691</td>
</tr>
<tr>
<td>7</td>
<td>55.88</td>
<td>39.00</td>
<td>64.47</td>
<td>107.1</td>
<td>265.1</td>
<td>216.2</td>
<td>38572.2</td>
<td>48.141</td>
<td>0.025</td>
<td>0.599</td>
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<tr>
<td>8</td>
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<td>64.50</td>
<td>107.1</td>
<td>265.1</td>
<td>216.3</td>
<td>38580.5</td>
<td>48.159</td>
<td>0.025</td>
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<td>9</td>
<td>55.90</td>
<td>39.04</td>
<td>64.51</td>
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<td>48.167</td>
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<tr>
<td>10</td>
<td>55.91</td>
<td>39.04</td>
<td>64.51</td>
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<td>265.1</td>
<td>216.3</td>
<td>38585.5</td>
<td>48.170</td>
<td>0.025</td>
<td>0.568</td>
</tr>
</tbody>
</table>
Table 6. Comparison: total cost computed using steepest decent method and conventional economic thermal power dispatch method

<table>
<thead>
<tr>
<th>S.no.</th>
<th>Method</th>
<th>Cost (Rs/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Steepest decent method</td>
<td>38585.8847</td>
</tr>
<tr>
<td>2</td>
<td>Conventional economic thermal dispatch method</td>
<td>39993.0681</td>
</tr>
</tbody>
</table>

Comparison of the total operating cost obtained using steepest descent method and conventional economic thermal power dispatch method is given. The total cost obtained from the steepest descent method is less than that of conventional economic thermal power dispatch method. Thus, it can be concluded that steepest descent method provides optimum results than conventional economic thermal power dispatch method. While implementing steepest descent method there is no need of initial guess of power. Hence it is better to use steepest descent method.

Conclusions

Economic load dispatch in electric power sector is an important task, as it is required to supply the power at the minimum cost which aids in profit-making. Optimization deals with selecting the best of many possible decisions in real-life environment, constructing computational methods to find optimal solutions, exploring the theoretical properties, and studying the computational performance of numerical algorithms implemented based on computational methods. With the rapid development of high performance computers and progress of computational methods, more and more large-scale optimization problems have been studied and solved. In this paper, steepest descent method with random step-size has been applied for solving the optimization classical test problems and economic dispatch problem. In present work the unconstrained multivariable optimization problem viz. economic load dispatch problem with equality constrained, is solved. Penalty method is applied to convert constraint optimization problem into unconstrained optimization problem. Then steepest descent method is used to solve equality constrained optimization problem.

In present work multivariable optimization test problems and economic load dispatch problem for 6-generator power system, for given load, has been solved. Algorithms are developed in MATLAB for the solution of economic dispatch problem. It has been observed from the results that steepest descent method shows faster convergence and gives better results. In case of 6-generating unit system total operating cost obtained by classical method is more than the total cost obtained by steepest descent method. So it is better to implement steepest descent method with random step-size because in this method step-size is taken care in such a manner that penalty parameter remain fix and solution is avoided to diverge. Inequality constraint is taken care during updating the decision variable. Moreover, it is seen that steepest descent method with random step-size gives better results when implemented on large systems having large generating units, as we have tested on 6-generating unit system.

Scope For Future Work

Here the loss co-efficient are given in the problem. The work may be extended for the problem where transmission loss co-efficient are calculated by performing load flow analysis. In that case, the loss co-efficient can be calculated by solving the load flow problem. Prohibited operating zones can also be considered as constraints. Multiple fuels can also be incorporated in the economic dispatch problem formulation. The method applied in this work is giving better results than classical and conventional economic thermal power dispatch method. So, both these methods can be combined with steepest descent method to find a better solution. Any other method like direct search method, gradient method and population methods can be applied to improve the performance. This work may be extended for new optimization techniques. This may be used to compare and find out the better optimization technique. Steepest descent method with random step-size can be hybridized with evolutionary programming as an approach to optimization that combines features of gradient strategies with ideas from evolutionary computation. The future scope includes utilization of particle swarm optimization, biologically based optimization or genetic algorithm based techniques to solve the multi-objective optimization problems. Self tuning of control parameters can be the next step for future work in steepest descent method with random step-size.

References


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