Abstract – The modern complex power system has conflicting requirements. With heavy load demands and distributed generation, cost of generation becomes the primary casualty with its attendant pollution hazards and increased losses contributing for an inefficient system. The whole generation becomes economical and environmental friendly if coordination is brought between cost, emission and loss. The earlier long iterative procedures are laborious in nature for this pareto-optimal problem. This paper discusses a new Dynamic Programming technique with a novel recursive approach for realizing production cost minimization, with an emission constrained and loss reduced condition. Multi-objective solution is provided by a performance comparison table. The results for the test systems portray the computational efficiency and accuracy of the solution.

Keywords – Economic dispatch, emission dispatch, Emission Constrained Economic Dispatch (ECED), Self Adaptive Dynamic Programming (SADP).

1. INTRODUCTION
In the power driven world, energy demand is predicted to increase 50% by the year 2030, and most of that demand is expected to be met by fossil fuels. Out of 4,055 billion kWh of electricity produced in the entire world during the year 2005, about 2015.335 billion kWh of electricity were obtained through conventional coal fired thermal power generating stations[1]. This generation has to be realized in an optimal, cost effective and environment friendly manner.

Any power system at the initial stages of its inception must have a proper planning after due consideration for the load demand, the transmission circuit, the capacity of generators, the cost of generation and the environmental pollution. In the past three decades, detailed surveys show that conventional methodologies [2]-[4] and optimization techniques using various soft computing methods have been held as the prime solution procedures.

Over the years, several authors have suggested various optimization techniques [5]. These techniques either help in minimizing cost or emission or aid in obtaining a pareto-optimal solution for this multi-objective problem. Reference [6] presents a summary of several techniques intended to reduce emissions into the atmosphere due to electric power generation. A combined handling of economic and minimum emission dispatch by introducing a price penalty factor has been discussed in [7]. Similarly, a fuzzy logic approach for environmental/economic dispatch has been dealt in [8]. Reference [9], [10] demonstrated the usage of neural network method to economic-emission dispatch problems.


Dynamic Programming (DP), because of its non-analytic approach was not given due weight all these days. A well-defined analytic approach is possible with DP and this establishes the aptness of our choice. This fine analytical expression can provide a preliminary footing for the various case studies at the initial stages of planning. If need be, refined and rigorous optimization techniques can be attempted in these systems during operation after the installation of these plants.

2. OPTIMIZED POWER GENERATION
In the initial stages of planning for a given demand, the approximate capacity or rating of the plant can be fixed. They can be planned on optimum generation condition, so that excessive rating of the generators can be avoided. A study involving simple optimization technique is undertaken in this article for fixing up plant capacity by obtaining a pareto-optimal solution format. This establishes the aptness of our choice. This fine analytical expression can provide a preliminary footing for the various case studies at the initial stages of planning. Towards this end, a pareto-optimal solution format is explored for this multi-variable, multi-constraint problem involving cost, emission and loss.

Initial scheduling methods in power system were based on cost criterion. The cost minimum approach relied on equal lambda condition for which analytical methods exist. However, as the system became very large with heavy demands, transmission losses were experienced on a large scale. The coordination equations were developed which solely depended on long iterative techniques. With increased power generation in large thermal power stations, environmental pollution occurred and a cleaner power generation became the casualty. Remedial measures in the form of emission regulations became stringent and the prime requirement was hygiene. This gave way to a scenario where emphasis is given for all the three factors namely cost, emission and loss. This article presents a novel recursive approach in DP, which
considers all the relevant factors for power system generation planning.

In thermal stations, sudden changes in loads cannot be matched by sudden fixing of new optimal generation conditions for the individual generators. The problem considered assumes a longer duration for load continuity. Optimization of power generation for a specific period, even for a day, cannot be considered as a single problem because of variation in power demand from hour to hour. So finding an optimum solution for a day includes finding an optimum allocation for each hour.

Dynamic Programming is a mathematical technique dealing with the optimization of multistage decision process [15]-[16]. The word ‘programming’ has been used in the mathematical sense of selecting an optimum allocation of resources and it is ‘dynamic’ as it is particularly useful for problems where decisions are taken at several distinct stages. Discrete, continuous, particularly useful for problems where decisions are taken

dealing with the optimization of multistage decision

optimization of power generation for a specific period, considered assumes a longer duration for load continuity. The problem

be matched by sudden fixing of new optimal generation

even be extended to higher number of state variables with

Thus each state \( s \) is the function of the input state \( s' \) and it is ‘dynamic’ as it is particularly useful for problems where decisions are taken at several distinct stages. Discrete, continuous, deterministic as well as probabilistic models can be solved by this method.

In contrast to linear programming, there does not exist a standard mathematical formulation for the DP. Therefore, problem solving is in two stages: in developing the functional equations for the problem and in solving functional equations for determining the optimal solution. Increase in the number of states at each stage is the curse of dimensionality in the literature of DP. The result is spectacular in computational savings, if the state variables are three or less. Against this background, it has been established that the format developed in this paper can be nicely demonstrated by the results.

Unlike the DP search technique, the SADP approach presented here does not search through the solution space. The optimum allocation can be obtained directly by substitution of cost, emission coefficients in the equations.

3. DYNAMIC PROGRAMMING

A system in its initial state, described by a vector \( s_N \), finally reaches the state \( s_0 \) as a result of certain decisions denoted by the vector ‘d’. The transformation \( T_N \) can be functionally explained as \( s_0 = T_N(s_N, d) \). Let a real valued function \( \psi_N(s_N, d) \) called the objective or the return function be associated with the transformation \( (T_N) \) which measures the effectiveness of the decisions made and the output that results from these decisions. The objective is to determine a given input \( s_N \) to optimize (minimize or maximize) \( \psi_N \) subject to the constraint \( s_0 = T_N(s_N, d) \).

This multistage problem is decomposed into 'j' stages, where \( 1 \leq j \leq N \), and \( s_j \) represents the input at the \( j \)th stage. Starting from the initial state \( s_N \), the system is considered to pass through successive states \( s_{N-1}, s_{N-2}, s_{N-3}, ... , s_2, s_1 \) before reaching the final state \( s_0 \). Thus each state \( s_{j-1} \) is the function of the input state \( s_j \) and the decision vector \( d_j \), i.e., \( s_{j-1} = T_j(s_j, d_j) \).

There results a stage return function \( f_j(s_j, d_j) \). In addition, the return function \( \psi_N \) is a function of stage returns, i.e. \( \psi_N = \psi_N(f_N, f_{N-1}, ... , f_2, f_1) \). From the above discussion, it would seem to suggest that if \( \psi_N \) is of the form \( \psi_N = f_N \circ f_{N-1} \circ ... \circ f_1 \) where “\( \circ \)” represents a composition operator indicating either addition or multiplication, then \( \psi_N = f_N \circ \psi_{N-1} \), where \( \psi_{N-1} = f_{N-1} \circ f_{N-2} \circ ... \circ f_1 \). It is possible to separate all \( \psi_N, \psi_{N-1}, ..., \psi_2 \) successively in this order, and thus the recursive equation may now be proposed as:

\[
F_j(s_j) = \min_{d_j} \{ f_j \circ F_{j-1}(s_{j-1}) \}, \quad 2 \leq j \leq N
\]

with \( F_1(s_1) = \min_{d_1} f_1 \), subject to \( s_{j-1} = T_j(s_j, d_j), \quad 2 \leq j \leq N \)

This type of approach is called the backward recursion. This backward recursion can be conveniently used only when optimization with respect to a specific input \( s_N \) is needed, because in such case the output \( s_0 \) is not taken into account.

To optimize the system with respect to a prescribed output \( s_0 \), it would naturally be convenient to reverse the direction. Treat \( s_j \) as the function of \( s_{j-1} \) and \( d_{j-1} \), and substitute \( s_{j-1} = T_j(s_j, d_j), 1 \leq j \leq N \). Also express stage returns as functions of stage output and then proceed from stage \( N \) to stage 1. Such a procedure is called the forward recursive approach which is adopted in this work.

4. FORMULATION OF OPTIMIZED POWER GENERATION PROBLEM

This article visualizes the generation planning problem as five different cases involving cost, emission independently and also with loss, in different combinations as presented in Table 1. Each case can be modelled as a mathematical equation involving its own parameters.

Case A:

In general, an economic dispatch problem starts with a mathematical cost equation, modelled to represent each individual generator in terms of generation and cost coefficients.

\[
F_i(P_i) = \sum_{i=1}^{n} \left( a_i P_i^2 + b_i P_i + c_i \right) \$/hr
\]

where \( P_i \) is the individual generation from unit ‘i’; \( a_i, b_i \) and \( c_i \) are its cost coefficients.

Table 1. Coordination chart

<table>
<thead>
<tr>
<th>Cases</th>
<th>Cost</th>
<th>Emission</th>
<th>Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>✓</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>B</td>
<td>x</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>C</td>
<td>✓</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>D</td>
<td>✓</td>
<td>x</td>
<td>✓</td>
</tr>
<tr>
<td>E</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

✓ Included | x Not included
\[ E_i(P_i) = \sum_{j=1}^{n} \left( d_j P_j^2 + e_j P_j + f_j \right) \text{Kg/hr} \]  \hspace{1cm} (4)

where \( P_i \) is the individual generation from unit ‘i’ and \( d_i, e_i \) and \( f_i \) are their emission coefficients.

**Case B:**

An emission dispatch problem involves an emission equation, modelled to represent each individual generator in terms of generation and emission coefficients.

\[ g_i = \frac{F_i}{P_i} \]  \hspace{1cm} (7)

where \( F_i \) and \( P_i \) are in turn the cost and generation corresponding to \( i \)th generator for specific conditions of generation including the limits of generation and the average costs of generation as given below:

\[ g_{\text{max}} = \frac{F_{\text{max}}}{P_{\text{max}}} ; \quad g_{\text{min}} = \frac{F_{\text{min}}}{P_{\text{min}}} \]

Now the loss-included cost equation is:

\[ f_i = \sum_{j=1}^{n} \sum_{j=1}^{n} \left( g_i \left( P_i P_j^2 + b_i P_j + c_i \right) + g_i \left( P_i B_g P_j \right) \right) \text{$/hr} \]  \hspace{1cm} (8)

**Case C:**

An emission constrained economic dispatch problem starts with mathematical cost equation (3), modelled to represent each individual generator in terms of generation and cost coefficients and mathematical emission equation (4), formulated to relate the emission coefficients with the individual generation.

An appreciable increase in the volume or weight of emission is governed by the magnitude of generation which in turn governs the cost and hence the economical operation of the system. These costs are coordinated with the actual fuel costs by a price factor called the penalty cost of emission (h).

\[ h_i = \frac{F_i}{E_i} \]  \hspace{1cm} (5)

where \( F_i \) and \( E_i \) are the cost and emission corresponding to \( i \)th generator for specific conditions of generation including the limits of generation and the average costs of generation as given below:

\[ h_{\text{max}} = \frac{F_{\text{max}}}{E_{\text{max}}} ; \quad h_{\text{min}} = \frac{F_{\text{min}}}{E_{\text{min}}} \]

\[ h_{\text{ave}} = \left( h_{\text{max}} + h_{\text{min}} \right) / 2 ; \quad h_{\text{com}} = \sum_{i=1}^{n} h_{\text{ave}} / n \]

The emission constrained cost equation for the system can now be formulated as:

\[ f_i = \sum_{j=1}^{n} \left( a_i P_j^2 + b_i P_j + c_i \right) + h_i \left( d_i P_j^2 + e_i P_j + f_i \right) \]  \hspace{1cm} (6)

**Case D:**

In economic dispatch problem under loss-included case, transmission losses are given by \( P_L \), where \( P_L = PBP \)

where \( P \) and \( B \) are in the form of matrices representing generation power and transmission loss coefficients. Also \( P' \) is the transpose of \( P \).

The cost of transmission losses in between the plants are accounted with the actual fuel costs by a price factor (g).

\[ g_i = \frac{F_i}{P_i} \]  \hspace{1cm} (7)

\[ g_{\text{max}} = \frac{F_{\text{max}}}{P_{\text{max}}} ; \quad g_{\text{min}} = \frac{F_{\text{min}}}{P_{\text{min}}} \]

Now the loss-included cost equation is:

\[ f_i = \sum_{j=1}^{n} \sum_{j=1}^{n} \left( g_i \left( P_i P_j^2 + b_i P_j + c_i \right) + g_i \left( P_i B_g P_j \right) \right) \text{$/hr} \]  \hspace{1cm} (8)

**Case E:**

In emission constrained economic dispatch problem under loss-included case, modified form of cost equation is:

\[ f_i = \sum_{j=1}^{n} \sum_{j=1}^{n} \left( a_i P_j^2 + b_i P_j + c_i \right) + h_i \left( d_i P_j^2 + e_i P_j + f_i \right) \]  \hspace{1cm} (9)

where \( a_i = (a_i + h_i d_i) \), \( b_i = (b_i + h_i e_i) \) and \( c_i = (c_i + h_i f_i) \)

A load balance equation will impose constraint over generation as:

\[ \sum_{i=1}^{n} P_i - P_L - P_d = 0 \]  \hspace{1cm} (10)

where \( P_d \) is the total system load demand and \( P_L \) is the transmission loss.

A generation limit will also be a constraint over the operating range of individual generators

\[ P_{\text{min}} \leq P_i \leq P_{\text{max}} \]  \hspace{1cm} (11)

Now the cost formula for the first generator can be modified as:

\[ P_L = P_i B_{11} P_i = P_i B_{11} P_i + P_i B_{12} P_i + P_i B_{13} P_i = P_i^2 B_{11} \]  \hspace{1cm} (12)

where \( B_{11} \) is the modified form of self-coefficient.

Using this, cost equation for the first generator can be rewritten as:

\[ f_i = \left( a_i P_i^2 + b_i P_i + c_i \right) + g_i \left( P_i B_{11} \right) \]  \hspace{1cm} (13)

Similar cost equations can be arrived for second and third generators.

This whole formulation has turned out to be purely analytic in nature with high possibility for accurate solutions. A best choice was chosen for penalty cost of emission and price factor of loss.

A penalty cost of emission and a price factor for transmission loss have helped the suggested recursive technique to achieve this simple analytical form. A triangularization has been adopted for the loss coefficient matrix, which has made the discussed DP approach also
suitable for loss-included condition.

Since the procedures of applying SADP to these situations are similar in nature, Case E which involves all the three objectives has been considered in this paper. The methodology and the cases undertaken are figuratively presented in Figure 1.

5. IMPLEMENTATION OF RECURSIVE APPROACH

Let \( s_i \) be the output from the \( i^{th} \) stage of this multistage problem. For a generation planning problem involving three generations, \( s_3 \) is the output from the 3\(^{rd} \) stage and it equals \( P_i + P_j + P_k \). Outputs from earlier stages are \( s_2 = P_i + P_j = s_3 - P_k \) (for the second stage) and \( s_1 = P_i = s_2 - P_j \) (for the first stage).

Now

\[
 f_1(s_j) = \min_{0 < P_i < s_j} \left( a_i^2 P_i^2 + b_i P_i + c_i \right) \text{$/hr} \quad (14)
\]

Since \( c_i \), \( c_j \) and \( c_k \) are constants, they are removed from the respective equations and their sum can be added to the cost equation at the end.

\[
 f_2(s_2) = \min_{0 < P_i < s_2} \left( a_i^2 P_i^2 + b_i P_i + f_1(s_i) \right) \text{$/hr}
\]

\[
 = \min_{0 < P_i < s_2} \left( a_i^2 P_i^2 + b_i P_i + f_1(s_2 - P_j) \right) \text{$/hr}
\]

\[
 = \min_{0 < P_i < s_2} \left( a_i^2 P_i^2 + b_i P_i + a_i^2 (s_2 - P_j)^2 + b_i (s_2 - P_j) \right) \text{$/hr}
\]

\[
 (15)
\]

For the second generator, minimum is attained when the above equation (15) is differentiated with respect to \( P_j \) and equated to 0. This gives the value of \( P_j \) in terms of \( s_2 \) and constant,

\[
i.e., \quad P_j = A_2 s_2 + B_2 \quad (16)
\]

where, \( A_2 = 2a_i^2(2a_i^2 + 2a_j^2) \) and \( B_2 = (b_i - b_j)(2a_i^2 + 2a_j^2) \)

Similarly for the third generator,

\[
 f_3(s_3) = \min_{0 < P_i < s_3} \left( a_i^2 P_i^2 + b_i P_i + f_2(s_2) \right) \text{$/hr}
\]

\[
 = \min_{0 < P_i < s_3} \left( a_i^2 P_i^2 + b_i P_i + f_2(s_3 - P_k) \right) \text{$/hr}
\]

\[
 (17)
\]

Solving further we arrive at the value of \( P_k \) as:

\[
 P_k = \left( \begin{array}{c}
 2a_j^2 + 2a_i^2 A_j^2 - 4a_i A_j A_k + 2a_j A_k^2 b_3 \\
 2a_i A_j B_j - 2a_i A_k + b_1 - b_i A_j + 2a_j A_k B_k + b_2 A_j - b_3 \\
 2a_i^2 + 2a_i A_j^2 - 4a_i A_j A_k + 2a_j A_k^2 + 2a_j A_k^2 + 2a_j^2 \\
 \end{array} \right)
\]

\[
 (18)
\]

i.e. \( P_k = A_3 s_3 + B_3 \)

Substitution of cost coefficients, emission coefficients and the total load on the system in the above equation will provide the optimum generation for the third generator.

Proceeding in this fashion and expanding sequentially as per the equations \( P_i(P_i) = (a_i^2 P_i^2 + b_i P_i + c_i) \) and \( s_{i+1} = s_i - P_i \) where ‘i’ varies from 1 to 6, we can arrive at the equations for all the six generators in the given test system.

2. Substitution of cost, emission and loss coefficients and the load in the equation for \( P_i \) will yield the generation of \( i^{th} \) generator under optimum condition. This procedure can also be extended to any ‘n’ generator system and this brings out the efficacy of SADP.

While attempting to attain the objective, a suboptimal point using the above technique was found for the emission constrained economic dispatch condition, which neglected loss. Then the same procedure was applied for emission constrained economic dispatch condition with loss, using modified form of B-coefficient matrix. In the subsequent approach, a few iterations were required so that the same format suits the total generation with loss inclusion. Thus, an all round satisfactory performance forms the basis of system planning. The best performance addresses to all the three objectives mentioned in this paper, to be at their best possible values. Since simultaneous realization of their minima is impossible, a near optimal solution satisfying multi-objective criterion, with a small deviation from their individual minima has been realized in this paper.

6. RESULTS AND DISCUSSIONS

Test System 1:

A three-generator system [17] with cost, emission coefficients and power limits as listed in Table 2 and loss coefficients as in Table 3 was considered for our study.

The results of various cases from A to E are entered in Table 4. The best configuration arrived at corresponds to fine optimization approach. A single penalty factor (g) does not provide a solution for the best configuration, where all the three objectives are at their best possible values. It necessitates a comprehensive study about various penalty factors \( g_{\text{min}}, g_{\text{max}}, g_{\text{ave}} \) and \( g_{\text{com}} \). Table 4 also helps to identify the price factor \( g_{\text{ave}} \) with which compromise between the objectives is satisfied. While attempting to find a best suited price factor (g), a comparison among various penalty costs of emission (h) should be attempted. Table 4 clearly projects \( h_{\text{max}} \) as a well-suited one.

Test System 2:

An IEEE six-generator, 30-bus test system [7], [9], [10] with cost and emission coefficients and power limits as given in Table 5 and loss coefficients taken from Table 6 was considered as our next test system. The results of various case studies are entered in Table 7.

Results obtained for 700 MW using recursive approach have been compared with that arrived through conventional method and quick method [10], in Table 8. Accuracy of the proposed algorithm has been endorsed with this table, where the results of the proposed algorithm match with that of the conventional and score over the method in [10].

Comparison of iterations in Table 9 portrays the superiority in computational speed of SADP in comparison with conventional method in terms of the number of iterations required to arrive at the solution.
Fig. 1. SADP algorithm
Table 2. Cost, emission coefficients, and power limits for three generator system

<table>
<thead>
<tr>
<th>Unit</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>Min load (MW)</th>
<th>Max Load (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.03548</td>
<td>38.385</td>
<td>112.531</td>
<td>0.00453</td>
<td>0.5455</td>
<td>48.269</td>
<td>35</td>
<td>210</td>
</tr>
<tr>
<td>2</td>
<td>0.02111</td>
<td>36.32782</td>
<td>150.569</td>
<td>0.00046</td>
<td>0.2116</td>
<td>42.95583</td>
<td>130</td>
<td>325</td>
</tr>
<tr>
<td>3</td>
<td>0.01799</td>
<td>38.27041</td>
<td>135.6392</td>
<td>0.00046</td>
<td>0.2116</td>
<td>42.95583</td>
<td>125</td>
<td>325</td>
</tr>
</tbody>
</table>

Table 3. Loss coefficients for three generator system

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
<th>h</th>
<th>i</th>
<th>j</th>
<th>k</th>
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<tr>
<td>0.00000771</td>
<td>0.0004030</td>
<td>0.0000069</td>
<td>0.0000032</td>
<td>0.0000025</td>
<td>0.000000080</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Table 4. Performance comparison table with results for various cases of three generator system (for a load of 700MW)

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
<th>Emission</th>
<th>Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic Dispatch</td>
<td>3.2092</td>
<td>639.905</td>
<td></td>
</tr>
<tr>
<td>Emission Dispatch</td>
<td>3.3336</td>
<td>606.377</td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Cost, emission coefficients, and power limits for six generator system

<table>
<thead>
<tr>
<th>Unit</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>Min load (MW)</th>
<th>Max Load (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.15247</td>
<td>38.5973</td>
<td>756.7986</td>
<td>0.0429</td>
<td>0.1200</td>
<td>13.86</td>
<td>10</td>
<td>125</td>
</tr>
<tr>
<td>2</td>
<td>0.19387</td>
<td>46.15916</td>
<td>451.2513</td>
<td>0.0420</td>
<td>0.3300</td>
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<td>10</td>
<td>150</td>
</tr>
<tr>
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</tr>
<tr>
<td>4</td>
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<td>1243.5311</td>
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<td>-0.5455</td>
<td>40.267</td>
<td>35</td>
<td>210</td>
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<tr>
<td>5</td>
<td>0.02211</td>
<td>36.32782</td>
<td>1698.9696</td>
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<td>-0.5112</td>
<td>42.9</td>
<td>130</td>
<td>325</td>
</tr>
<tr>
<td>6</td>
<td>0.01799</td>
<td>38.27041</td>
<td>1356.692</td>
<td>0.0460</td>
<td>-0.5112</td>
<td>42.9</td>
<td>125</td>
<td>315</td>
</tr>
</tbody>
</table>

Table 6. Loss coefficient for six generator system

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
<th>h</th>
<th>i</th>
<th>j</th>
<th>k</th>
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<tbody>
<tr>
<td>0.000014</td>
<td>0.000017</td>
<td>0.000015</td>
<td>0.000019</td>
<td>0.000026</td>
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Table 7. Performance comparison table with results for various cases of six generator system (for a load of 800MW)

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<th>Cost</th>
<th>Emission</th>
<th>Loss</th>
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</thead>
<tbody>
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<td>Economic Dispatch</td>
<td>4.9878</td>
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<tr>
<td>Emission Dispatch</td>
<td>4.9299</td>
<td>523.627</td>
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</table>

Table 8. Comparison of results of ECED (loss included) for six generator system (for a load of 700MW)

<table>
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<tr>
<th></th>
<th>Cost</th>
<th>Emission</th>
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</table>

7. CONCLUSION

The paper as a whole has suggested an integrated approach to optimized generation planning by addressing all the three issues cost, emission, and loss. The regular conventional method involving common Lambda was totally eliminated. A novel form of recursive approach involving SADP was presented as an alternative to the conventional iterative method. Simple analytic solution procedure has been made possible and its results were at par with the one obtained using conventional approach.

The performance comparison table portrays the conclusive picture. Case A, cost minimum condition, is of theoretical interest with high emission, while Case B is with minimum emission and high cost. Case C corresponds to the loss neglected ECED while Case D discusses loss inclusion with emission neglected. Case E brings out a total integrated solution that provides an
economical condition with less loss and restricted emission.

The method proposed is straightforward and elegant. This schema might serve as a boon for optimum power generation of any thermal power system.

REFERENCES


