SECURITY CONSTRAINED OPTIMAL GENERATION EXPANSION PLANNING USING HSDE ALGORITHM

M. VEERA KUMARI, K. VAISAKH

1Department of Electrical and Electronics Engineering, Sir CRR College of Engineering Eluru, West Godavari, AP, India
2Department of Electrical Engineering, AU College of Engineering (A), Andhra University, Visakhapatnam, AP, India
E-mail: veerakumari.m@gmail.com, vaishakh_k@yahoo.co.in

Abstract- This paper illustrates OGEP under normal and network contingency with an optimization technique, HSDE algorithm, a Hybrid mutation operator and self adaptive scaling differential evolution (HSDE) algorithm for solving OGEP (Generation Expansion Planning) with Security Constraints. In the first stage, a HSDE algorithm is employed to approximate the set of solutions through an evolutionary optimization process. In the subsequent stage, a multi-criteria decision-making approach like AHP, SAW, WPM are adopted to rank these solutions from best to worst and to determine the best solution in a deterministic environment with a single decision-maker. This hybrid approach is tested on a modified IEEE 30-bus system to illustrate the analysis process. The ranking of solutions is based on entropy weight and the technique for order preference by similarity to ideal solution problem.

Keywords- AHP, HSDE, FLCC, MCDM, OGEP, SAW, And WPM.

I. INTRODUCTION

In OGEP, the objective is to expand the existing generating system to serve the growing load demand in the future by satisfying the reliability criteria. The OGEP determines size, place, technology and the time of installing new generating plants to satisfy forecasted load. As GEP is a highly constrained, nonlinear, discrete [1,2] optimization problem, it is a highly challenging problem for the decision makers. The solution for this GEP problem may be obtained by complete enumeration of each possible combination [3-8] in the entire planning horizon. Since 1950, many optimization techniques such as linear programming, integer programming and dynamic programming (DP) are applied to solve these combinatorial optimization problems [9, 12]. In this paper HSDE is applied to solve the OGEP problem. The Fuzzy Logic Composite Criteria and Multi Criteria Decision Making methods are addressed in the subsequent sections. This algorithm is implemented for modified IEEE 30-bus system with six existing units and 3 new generating units with capacity 40Mw, 60Mw, 30 Mw with 6 years planning horizon.

II. PROBLEM FORMULATION

Main objective of OGEP is to minimize the total investment and operating costs associated with the addition of new units and to satisfy the reliability, fuel mix, and the demand criterion. An innovative Multi Criteria decision making analysis (AHP, SAW, and WPM) was carried out on the Weighted Cost, FLCC, Power loss, \( L_2 \) index in all the three stages. GEP is formulated as three objectives

- Minimizing Total Cost
- Minimizing FLCC
- Minimizing Weighed Sum of Total Cost and FLCC

A. First Objective

It is the Total cost function (objective function) represented by the following expression:

\[
\begin{align*}
\text{Min } CC &= \text{InvC} (N_s) + \text{MaintC} (Y_s) + \text{OutC} (Y_s) - \text{SalvC} (N_s) \\
\text{InvC} (N_s) &= (1 + D)^{-\frac{N_s}{2}} \sum_{i=1}^{N_s} \text{CapInv}_i \times N_{i,s} \\
\text{MaintC} (Y_s) &= \sum_{i=1}^{N_s} \left( 1 + (1 + D)^{-2} \left[ \text{CapInv}_i \times \text{OperC}_i \right] \right) \\
\text{OutC} (Y_s) &= OC \sum_{i=1}^{N_s} \left( 1 + D \right)^{-\frac{\text{OutC}_i}{2}} N_{i,s} \\
\text{SalvC} (N_s) &= (1 + D)^{-T} \sum_{i=1}^{N_s} \text{CapInv}_i \times \text{Salv}_i N_{i,s} \\
\end{align*}
\]

Total cost

Investment cost of the newly added units at stage \( s \)

Operation and maintenance cost of existing and newly introduced units

Outage cost of the existing and newly introduced units

Salvage value of the newly added unit at stage \( s \)

B. Upper Construction limit

If \( N_s \) be the units to be committed, in the expansion plan at stage \( s \), \( N_s \) must satisfy the maximum construction capacity of the units to be committed.

\[
0 \leq N_s \leq N_{max,s}
\]

Where \( N_{max,s} \) is the maximum construction capacity of the units in stage \( s \)
C. Reliability Criteria
The selected units along with the existing units must satisfy the reliability criterion, Loss of Load Probability (LOLP).

\[ LOLP (X_i) \leq \varepsilon \]  \hspace{1cm} (7)

\( \varepsilon \) is the Reliability criterion expressed in LOLP.

D. Reserve Margin
The selected units must satisfy the minimum and maximum reserve margin.

\[ (1-R_{\min}) \times D_t \leq \sum \text{R}_a \leq (1 + R_{\max}) \times D_t \]  \hspace{1cm} (8)

where,
- \( R_{\min} \): Minimum reserve margin in MW
- \( R_{\max} \): Maximum reserve margin in MW
- \( D_t \): Demand at stages in MW
- \( V_{R,i} \): Cumulative capacity of unit i at stage t in MW

III. IMPLEMENTATION OF HSDE TO OGEPE

The following steps describe detailed procedure of proposed APSODV [39-42] method.

Step1: Generate randomly initial population with size \( (N_{pop} \times N) \) and store them in archive X

\[ X = [x_{11} \ x_{12} \ \ldots \ x_{N1} \ \ldots \ x_{1N} \ x_{21} \ \ldots \ x_{N2} \ \ldots \ x_{2N} \ \ldots \ x_{NN}]_{N_{pop} \times N} \]

where \( x_{ij} = [R_{ij} \ V_{R,i} \ Tap \ \theta_{ij}]_{T} \)

All elements of vector \( x \) is set of decision variables called as particles.

Step 2: Randomly generate velocities for all the elements \( \mathbf{v}_{xy} = [v_{x_1} \ v_{x_2} \ Tap \ \theta_{xy}]_{T} \) of which should be within the limits.

Step3: Set iteration Count \( it=0 \).

Step4: Run NR load flow program for particles and calculate the line flows (SFF), voltage stability index (VS), Bus Voltages (VP) and Reactive Powers (QP) of Generators. Check the severity of SFF, VS, VP and QP using Fuzzy rule base (Fuzzification and Defuzzification).

Step5: Calculate the optimum fuel cost which is considered in maintenance cost calculation of GEP.

Step6: Evaluate the objective function values (any one at a time)
- Cost Function CC (GEP) using (1).
- FLCC objective using (9).
- Weighed CC and FLCC objective using (10).

Step7: Sort out the local best and global best solutions and best fitness.

Step8: Select three random individuals which are mutually different from each other and update the velocity \( (P_G, V_G, Tap, Q_C) \) using the following equation

\[ \eta_i = \begin{cases} x_{0i} + f_i + f_{i_0} \left( f_{i_0} > f_{i_1} \right) \left( f_{i_1} > f_{i_2} \right) > f_{i_3}, & \text{if } f_i > f_{i_1} > f_{i_2} \left( f_{i_0} > f_{i_1} \right) \left( f_{i_1} > f_{i_2} \right) > f_{i_3}, \\ x_{0i} + f_i + f_{i_3} \left( f_{i_0} > f_{i_1} \right) \left( f_{i_1} > f_{i_2} \right) = 0, & \text{otherwise} \end{cases} \]

Step 9: Check for limit violations \((P_G, V_G, Tap, Q_C)\).

Step10: Check for stopping criteria, if iterations reach maximum, go to next step else go to step 4. Repeat the steps 5 to 10 again.

Step11: Obtain the global best solution.

IV. RESULTS

The algorithm FAPSODV was implemented using MATLAB version 7.10, on a laptop with Intel Core i3 processor having 3.10GHz speed and 4 GB RAM.

A. Test System Description
The forecasted peak demand and other technical data of modified IEEE 30 bus system are taken from [9]. The test system consists of 6 existing power plants and 3 candidate plants are considered for 6-years planning horizon. The planning horizon comprises of 3 stages each with 2-year interval.

B. Parameter of OGEPE
The Construction limit is set as 1. The lower and upper boundaries for reserve margin are set as 20\% and 40\%. LOLP limit is set to 0.001. Discount factor is chosen as 0.1. Cost of EENS is assumed as 0.05 Rupees per kilo watt hour. Investment cost is calculated at starting of the planning period, maintenance cost is calculated in the middle of the
planning period, salvage cost is calculated at the end of the planning period.

C. Parameters of HSDE

<table>
<thead>
<tr>
<th>Parameter</th>
<th>HSDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population size</td>
<td>50</td>
</tr>
<tr>
<td>Number of iterations</td>
<td>150</td>
</tr>
<tr>
<td>Differentiation Constant</td>
<td>0.1</td>
</tr>
<tr>
<td>Crossover Constant</td>
<td>0.8</td>
</tr>
</tbody>
</table>

D. Discussion

The best parameters of HSDE are given in Table I. Comparison of three objectives in Cost in all three stages in Normal Case and Network Contingency are given in Table II. The test system results for three objectives are given in Table III, IV, V. To meet the forecasted load demand, OGEP is essential, either expansion of existing units or addition of new generator units without expansion of transmission network.

In Optimal Generation expansion planning problem, the strategy we followed is addition of one new generator of 40 Mw (unit with minimum investment Cost) capacity at bus 7 to meet the additional load demand (120%) in stage 1. Fuel cost is calculated with the inclusion of this new unit for the optimal Pg values. In the second stage, one more unit of 40 Mw (next unit with minimum investment cost) is added at the same bus 7 to meet the demand of 140%.

The fuel cost is calculated by considering the average of two newly added units. To meet the Demand in the third stage (160%) an additional unit of capacity 60 Mw (next unit with minimum investment cost) is added at the same bus 7. Fuel cost is calculated by considering the weighed sum of three newly added units (40, 40, and 60). As shown in Table III, IV, V the ranks are assigned to the alternatives in all the three stages using all the three methods of MCDM.

AHP, WPM, SAW have matched for the normal case whereas top rank for alternative is same in all the three methods and three stages, however ranking order is slightly changed in network Contingency of Stage 1 whereas in the remaining stages the ranking order is same in the network Contingency Case. The ranking order is dependent on the priority matrix.

CONCLUSION

Though there are several optimization method implemented (PSO, DE, SFLA, TS, ES, EA), Hybrid optimization method are not implemented in literature for GEP. In this paper the methodology of HSDE algorithm implementation for the GEP is illustrated. In each stage (2years=1stage) the three objectives Total Cost (Investment Cost, Maintenance Cost, Outage Cost, Salvage Cost) FLCC objective and weighed sum of Total Cost and FLCC for both cases (normal operation, network contingency) are evaluated.
The Total Cost in the three objectives is less in normal operation case when compared to the network contingency case. Comparing the real power loss in the Total cost objective, increase in the network Contingency Case than the normal case.

The feasibility of the proposed approach was tested on Modified IEEE 30-bus system with three different objective functions. Several cases were investigated to test and validate the robustness of the proposed method in finding the optimal solution. We consider five alternatives of four attributes where these attributes are Total Cost, FLCC, Power Loss, $L^2$ Index. For the study conducted, shifting the weight of one attribute can affect the weight of other attributes and the final score of all alternatives also changed. Normally, the attributes chosen for decision making are conflicting; it’s implied that the improvement at one attribute may result in the deflation of other attributes. Also, weight can be assigned considering the relative importance of attributes. The change in the value of weight one attributes leads to change in ranking alternatives.

REFERENCES


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