Economical Operation of Hydro-Thermal Power System based on Multi-path Adaptive Tabu Search

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Abstract—An economic operation scheduling problem of a hydro-thermal power generation system has been properly solved by the proposed multipath adaptive tabu search algorithm (MATS). Four reservoirs with their own hydro plants and another one thermal plant are integrated to be a studied system used to formulate the objective function under complicated constraints, eg water managements, power balance and thermal generator limits. MATS with four sub-search units (ATSs) and two stages of discarding mechanism (DM), has been setting and trying to solve the problem through 25 trials under function evaluation criterion. It is shown that MATS can provide superior results with respect to single ATS and other previous methods, genetic algorithms (GA) and differential evolution (DE).

Keywords—Hydro-thermal scheduling problem, economic dispatch, adaptive tabu search, multipath adaptive tabu search

I. INTRODUCTION

THE general short-term hydro-thermal generation scheduling problems investigated under a general hypothesis that the hydro units do not pose any cost constraints on the generation of electric power [1] have the objective function to minimize the operation cost of thermal units in given period of time while preserving all constraints, prohibited operating zone, valve-point loading, power balance, water discharge rate limit, water storage volume limit, reservoir end limit and capacity limit in both hydro plants and thermal plants. Under these constraints, the difficulty to bring optimal solution for this problem has arisen and meta-heuristic search methods have been applied to solve this problem, [1],[2],[6]-[8].

This paper is composed of five topics, firstly introduction, problem formulation, proposed multipath adaptive tabu search algorithm, computational results and finally conclusion.

II. PROBLEM FORMULATION

A. Hydropower plants

This paper has studied an hydraulic network depicted in Fig.1. It consists of four reservoirs which act as huge energy storages, both receiving water from four channels, I1- I4, and discharging water, Q1- Q4, into each turbine of hydro power generators to produce electricity.

Output power from hydropower plant, \( P_{h,i}(t) \) of \( i \)th hydro power plant, can be obtained by the frequently used equation (1) in terms of reservoir volume, \( V_{h,i} \) and water discharge, \( Q_{h,i} \).

\[
P_{h,i}(t) = c_{h,i}V_{h,i}(t) + c_{h,i}Q_{h,i}(t) + c_{h,i}V_{h,i}(t)Q_{h,i}(t) + c_{h,i}Q_{h,i}(t) + c_{h,i}
\]

where \( c_{h,i} \) are coefficients of hydro power plants given by [2].

B. Thermal power plant

The aim for solving this problem is to minimize the fuel cost of the only one thermal plant in this system. But the cost has highly complex relation with hydraulic network management [2] through the hydro power plants which has been described in previous topic. The thermal power generation, \( P_s(t) \), can be archived from power demand, \( P_d(t) \), hydro power generation, \( P_h(t) \) and power loss, \( P_L(t) \) within this equation,

\[
P_s(t) = P_d(t) + P_h(t) - P_L(t)
\]

\( P_d(t) \) is assigned to zero here. \( P_s(t) \) is bounded the range 500 to 2500 MW. The fuel cost in dollars ($) from a thermal power plant can be written in the general quadratic form,

\[
F_s(P_s(t)) = \gamma + \beta P_s(t) + \alpha P_s^2(t)
\]

where \( \gamma \) is 5000, \( \beta \) is 19.2 and \( \alpha \) is 0.002.

C. Objective function

The main scheme of this problem is to find what set of hourly water discharge over 24 hour interval to meet power demand under restricted constraints. The objective function
has been formulated as optimization problem in equation (4)

$$
\begin{align*}
\min & \quad J(Q_1, Q_2, Q_3, Q_4, t) \\
\text{subject to} & \quad 5 \leq Q_1 \leq 15 \\
& \quad 6 \leq Q_2 \leq 15 \\
& \quad 10 \leq Q_3 \leq 30 \\
& \quad 13 \leq Q_4 \leq 25 \\
\end{align*}
$$

where

$$
J = P_1(Q_1, Q_2, Q_3, Q_4, t) + \sum_{i=1}^{4} \sum_{j=1}^{4} \alpha_i L_i(t)
$$

The $P_i$ is an thermal power output which indirectly depend upon all water discharge $Q_i$. Penalty terms- $L_i$ and weighting factors-$\alpha_i$ can be described as follows,

1) Discharge rate limit can be represented in equation (6)

$$
L_1 = \sum_{i=1}^{4} \sum_{j=1}^{4} \left( |Q_{i,j} - Q_{\min}| - (Q_{i,j} - Q_{\min}) \right) + \left( |Q_{\max} - Q_{i,j}| - (Q_{\max} - Q_{i,j}) \right)
$$

2) Storage volume limit can be calculated by equation (7)

$$
L_2 = \sum_{i=1}^{4} \sum_{j=1}^{4} \left( |V_{i,j} - V_{\max}| - (V_{i,j} - V_{\max}) \right) + \left( |V_{\max} - V_{i,j}| - (V_{\max} - V_{i,j}) \right)
$$

3) Capacity of hydro plant limit can be formulated here,

$$
L_3 = \sum_{i=1}^{4} \sum_{j=1}^{4} \left( |P_{i,j} - P_{\min}| - (P_{i,j} - P_{\min}) \right) + \left( |P_{\max} - P_{i,j}| - (P_{\max} - P_{i,j}) \right)
$$

4) Capacity of thermal plant limit can be formulated here,

$$
L_4 = \sum_{i=1}^{4} \sum_{j=1}^{4} \left( |P_{i,j} - P_{\max}| - (P_{i,j} - P_{\min}) \right) + \left( |P_{\max} - P_{i,j}| - (P_{\max} - P_{i,j}) \right)
$$

5) Reservoir end limit can be calculated by equation (10)

$$
L_5 = \sum_{i=1}^{4} \sum_{j=1}^{4} \left( |V_{storage,j} - V_{start,i}| + |V_{storage,j} - V_{stop,i}| \right)
$$

These weighting factors are $\alpha_1 = \alpha_3 = 10^4$, $\alpha_2 = 10^5$ and $\alpha_5 = 10^6$.

The objective function is hard to solve problem via classical method, many meta-heuristic search methods have been applied to solve it [1],[2],[7],[8]. As an alternative search method, the proposed multipath adaptive tabu search algorithm is described in next topic [5].
Alternative pattern to demonstrate the comparative results between ATS and MATS in histogram has been elaborated through in Fig. 2. Obviously, if we count the number of trials which is less than 9.44x10^5 $. There are fifteen trials (80%) of MATS and only three trials (12%) of ATS. It means that the solution from MATS is probably superior than of ATS’s do.

Let’s the left MATS#4 go on searching until the maximum function evaluation limit (150,000) found. Finally MATS#4 has reported the final solution, J=9.395x10^5 $, at the 9,000\textsuperscript{th} iteration within 422.1219 seconds.

V. CONCLUSION

Multi-path adaptive tabu search (MATS) approach is applied to solve the complicated hydro-thermal scheduling problem. The problem characterized by four reservoirs with hydro generators and a thermal generator have been described. Computational tests are based on 150000 FES limit. MATS with four sub-ATSs and suitable parameters can obtain better results, mean than of the single ATS and other previous methods, GA and DE.

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REFERENCES


