International Journal of Scientific and Technical Advancements

ISSN: 2454-1532

Teaching-Learning Based Optimization for Short Term Scheduling of Multi-Chain Hydrothermal System

Prerna Charak, Sat Dev

Department of Electrical Engineering, Govt. College of Engineering and Technology, Jammu, (J&K)

#prerna.charak@yahoo.com

Abstract- In this scheduling, the hydroelectric and thermal power generation is optimized to minimize the total operating cost (fuel cost) of the thermal plant. This problem of short term hydrothermal scheduling (STHTS) is complex due to consideration of equality and inequality constraints and nonlinearities. In this paper, teaching - learning based optimization (TLBO) algorithm is used to solve the problem of short-term hydrothermal scheduling (STHTS) . The proposed algorithm has been tested on the multi-chain test system having four hydro units and one thermal.

Keywords**:** Hydrothermal scheduling, multi-chain, Power System optimization, Peak load, Base Load and TLBO, valve point loading

INTRODUCTION

Most of the hydro-systems are having different characteristics mainly due to differences in availability of water, control constraints, non-uniform water flow, number of hydro stations and their locations etc. The problem is different when the plant is located on the same stream or on a different stream. To minimize overall cost of system available hydro resources has to be utilized fully. The hydrothermal problem includes long range problem and short range problem

The Short-range hydro scheduling problem involves one day to one week or hour-by-hour scheduling of all generations on a system to achieve minimum production cost for the given time period. A set of starting conditions is given to get the optimized schedule with the minimum cost which is desired. The amount of water to be utilized for short-range scheduling problem is known from the solution of long-range scheduling problem. This problem is classified as: fixed head hydrothermal scheduling and variable head hydrothermal scheduling. Several methods for solving the problem of short-term hydrothermal scheduling have been proposed. The classical methods of solving the scheduling problem are not suitable when the system size increases. Further the computational requirements also increase with the classical methods. Therefore, various evolutionary techniques such as particle swarm optimization (PSO) [1][2][3], constriction factor based particle swarm optimization technique (CFPSO) [4], evolutionary programming (EP) [5], genetic algorithm (GA) [6][7], differential evolution [8] [9] are used for hydrothermal scheduling.

The basic idea for the scheduling of hydrothermal plant is to meet the given load demand for the specified time horizon. The optimal scheduling of hydrothermal plant involves generation of power from hydro as well as thermal plants so as to minimize the total fuel cost of thermal plant.

Thus the problem scheduling problem can be solved by minimizing the fuel cost of thermal plant while considering the various hydro plant constraints. The main constraints of problem include: cascaded nature of the hydraulic network, the time coupling effect of the hydro sub problem where the water inflow of an earlier time interval affects the discharge capability at a later period of time, the varying hourly reservoir inflows, the physical limitations on the reservoir storage and turbine flow rate, the varying system load demand and the loading limits of both thermal and hydro plants [6][10]. In short-term hydrothermal scheduling, the scheduling period is taken as one day to one week and involves hour-by-hour generation of the scheduling horizon to achieve the minimum production cost for the generation of power. The amount of water utilized for the short-range scheduling problem is known from the solution of long-range scheduling problem. A set of reservoirs conditions for hydro plants is given and the optimal hourly schedule of the desired objective i.e. minimizing the fuel cost, while satisfying the hydro system constraints, is obtained [11].

NEED OF HYDROTHERMAL SCHEDULING

Prerna Charak, "Teaching-learning based optimization for short term scheduling of multi-chain hydrothermal system" *International Journal of Scientific and Technical Advancements*, Volume 4, Issue 1, pp. 165-170, 2018.

The idea of hydrothermal coordination is to utilize all energy resources in most economic and efficient manner. The scheduling of hydroelectric plant is more complex than the scheduling of thermal plants. The hydroelectric plants are associated with the water discharge (i.e. water outflow from one plant is the water inflow for one or more downstream plant) from one reservoir to other and plays very significant role for the optimal power generation. It is vital to use the amount of water available by water reservoirs of hydro systems to full extent in hydrothermal integration. In hydro system, there is no fuel cost associated with power generated i.e. the charges are fixed for hydropower regardless of the amount generated. In hydrothermal systems the optimal cost is achieved by utilizing the available water resources for a given time horizon and run the hydro generation units according to the forecasted load demand so that the fuel cost for thermal generation is minimized. Thus the hydrothermal scheduling is important as the operating cost of thermal plant is very high, though their capital cost is low. On the other hand, the operating cost of hydroelectric plant is low, though their capital cost is high. So, it has been economical as well as convenient to have both thermal as well as hydro plants in the same grid. The hydroelectric plant can be started quickly and it has higher reliability and greater speed of response. Hence hydro plants can take up the fluctuating loads. In contrast to hydro plants, starting of thermal plant is slow and their response is slow as well. This is the reason why thermal plants run as base load plants and hydro plants run as peak load plant [2].

PROBLEM FORMULATION

The optimal scheduling of multi-chain hydrothermal system is to meet the load demand over the scheduled horizon of 24 hours with one hour intervals while satisfying the various equality and inequality constraints of hydro and thermal power system network considering valve point loading effect of thermal unit and prohibited discharge zone of hydro units.

A. *Objective Function*

The total fuel cost for the equivalent thermal over the scheduled horizon is given by FC. The objective function with quadratic cost function for thermal units is expressed as:

minimize FC =

$$MinimizeFC = \sum_{i=1}^{nt}\sum_{j=1}^{NH} a_i \times Ps_{i,j}^2 + b_i \times Ps_{i,j} + c_i$$

For more accurate results the fuel cost function, considering valve point effect, is the sum of quadratic function and sinusoidal function and is expressed as:

$$MinimizeFC = \sum_{i=1}^{nt}\sum_{j=1}^{NH} a_i \times Ps_{i,j}^2 + b_i \times Ps_{i,j} + c_i + |d_i * \sin(e_i * (Ps_i^{min} - Ps_{i,j}))|$$

B. *Equality Constraints*

Various equality constraints for solving the problem of STHTS are discussed as

- Power Balance

$$\sum_{i=1}^{nh} Ph_{i,j} + \sum_{i=1}^{nt} Ps_{i,j} = Pd_j + Ploss_j$$

- Power Generation

$$Ph_{i,j} = c_{i,1} \times V_{i,j}^2 + c_{i,2} \times Q_{i,j}^2 + c_{i,3} \times V_{i,j} \times Q_{i,j} + c_{i,4} \times V_{i,j} + c_{i,5} \times Q_{i,j} + c_{i,6}$$

- Hydraulic Continuity Equation

$$V_{i,j}|_{j=0} = V_i^{begin};\ V_{i,j}|_{j=NH} = V_i^{end}$$

- Reservoir End Condition

$$V_{i,j}|_{j=0} = V_i^{begin};\ V_{i,j}|_{j=NH} = V_i^{end}$$

C. *Inequality Constraints*

These constraints are the limits pre specified in the problems and values must satisfies these constraints. The following are the constraints:

- Thermal Generation

$$Ps_i^{min} \le Ps_{i,j} \le Ps_i^{max} \quad ; i = 1, 2, ..., nt; j = 1, 2, ..., NH$$

- Hydro Generation

$$Ph_i^{min} \le Ph_{i,j} \le Ph_i^{max} \quad ; i = 1, 2, ..., nh; j = 1, 2, ..., NH$$

- Water Generation

$$Q_i^{min} \le Q_{i,j} \le Q_i^{max} \quad ; i = 1, 2, ..., nh; j = 1, 2, ..., NH$$

- Reservoir Capacity

$$V_i^{min} \le V_{i,j} \le V_i^{max} \quad ; i = 1, 2, ..., nh; j = 1, 2, ..., NH$$

IMPLEMENTATION OF TLBO TO STHTS

The TLBO algorithm is a population-based algorithm inspired by nature like other algorithms with a pre-defined population size. In all nature-based algorithms, initially the population is generated randomly and an individual in that population represents an optimal solution of the problem [13]. In this algorithm the population refers to the students in a particular class and subjects offered to those students are the design variables of the optimization problem. Thus the objective function value and the design variables constitute the solution representing knowledge of particular students. The teacher for the entire population is the best solution of that population. The design variables are actually the parameters involved in the objective function of the given optimization problem and the best solution is the best value of the objective function [14]. Like genetic algorithm, particle swarm optimization, artificial bee colony and harmony search, teaching-learning based

optimization is also a population-based technique which implements a group of solutions to proceed to the optimum solution.
The TLBO algorithm can be implemented in the following steps as in

Step I: Define the optimization problem and generate random population according to population size (Pn) (students), number of generations (Gn) and number of design variables (Dn) (subjects) within the limits:

$$population = \begin{bmatrix} X_{1,1} & X_{1,2} & \cdots & X_{1,D} \\ X_{2,1} & X_{2,2} & \cdots & X_{2,D} \\ \vdots & \vdots & \ddots & \vdots \\ X_{P_n,1} & X_{P_n,2} & \cdots & X_{P_n,D} \end{bmatrix}.$$

Step II: Teacher Phase

Calculate the mean of the population, i.e. the mean of the subjects of students as:-

$$Mean_{,D} = [m_1, m_2, \ldots, m_D]$$

The best solution of the iteration will act as the teacher. This solution try to change the mean so that the best obtained solution will act as the new mean for next iteration.

$$X_{teacher} = X_{f(X)=min}$$

$$M_{new,D} = X_{teacher,D}$$

The difference between the two means is expressed as

$$Diff_{,D} = r(Mean_{new,D} - T_F * M_{,D})$$

This difference is added to current solution to update its value

$$X_{new,D} = X_{old,D} + Diff_{,D}$$

Step III. Learner's Phase
In this phase, they increase their knowledge by mutual interaction with each other and mathematically explained as

for i=1:popsize
    select two learner randomly X_i and X_l, where i≠l.
If $f(X_i) < f(X_l)$
    $X_{new,i} = X_{old,i} + r_i(X_i - X_l)$
else
    $X_{new,i} = X_{old,i} + r_i(X_l - X_i)$
end if
end for
Accept X_{new} if it gives better function value.

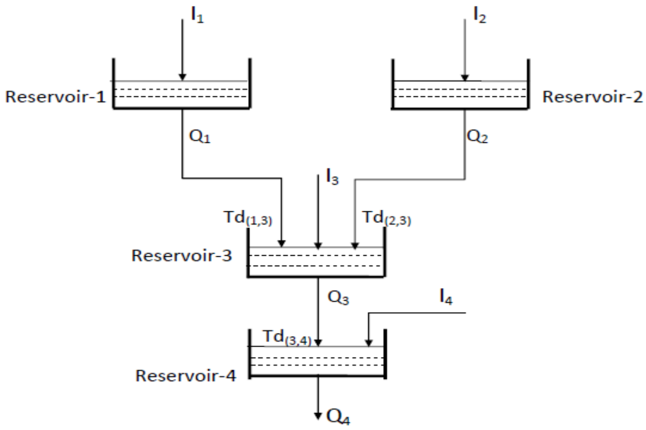
Step 4: Stop if the maximum generation number is achieved; otherwise repeat from Step 2.Two feasible solutions are obtained, i.e. at the end of teacher phase and learner phase, and solution giving better function value (or optimized value) is preferred [16].

RESULTS

TEST SYSTEM

The hydraulic system is characterised by:

- A multi-chain cascaded flow network
- Reservoir transport delay between successive reservoirs
- Variable head hydro plants
- Variable natural inflow rates to each reservoir.
- Variable load demands over scheduling period



The short-term hydrothermal scheduling (STHTS) is studied on the multi-chain system for two cases -

- STHTS with quadratic cost function
- STHTS including the effect of valve point loading

Case I: STHTS with quadratic cost function

Prerna Charak, "Teaching-learning based optimization for short term scheduling of multi-chain hydrothermal system" *International Journal of Scientific and Technical Advancements*, Volume 4, Issue 1, pp. 165-170, 2018.

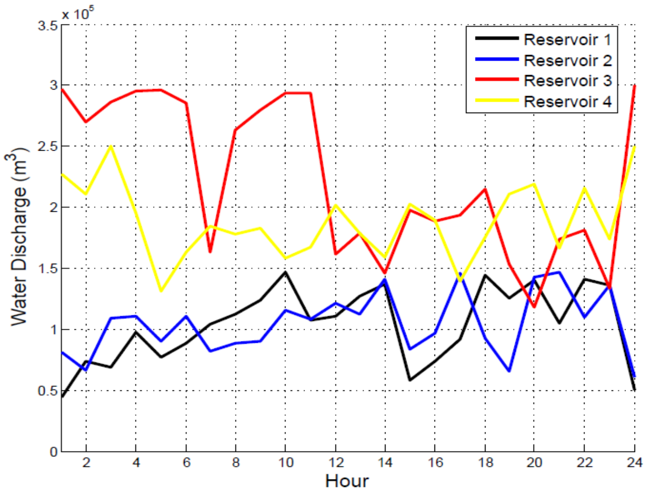


Fig: 1 Water discharge (m3) of the hydro plants for STHTS with QCF

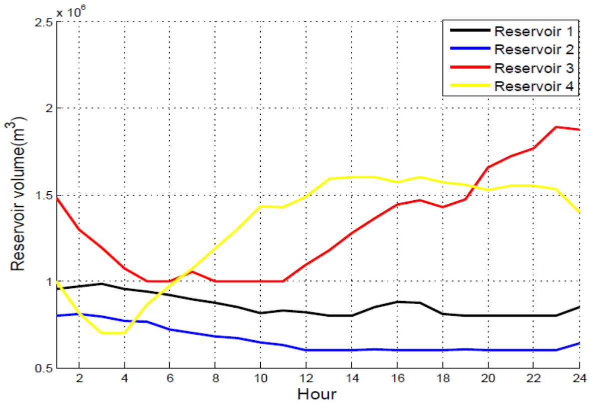


Fig: 2 Reservoir Storage volume (m3) of the hydro plants for STHTS with QCF

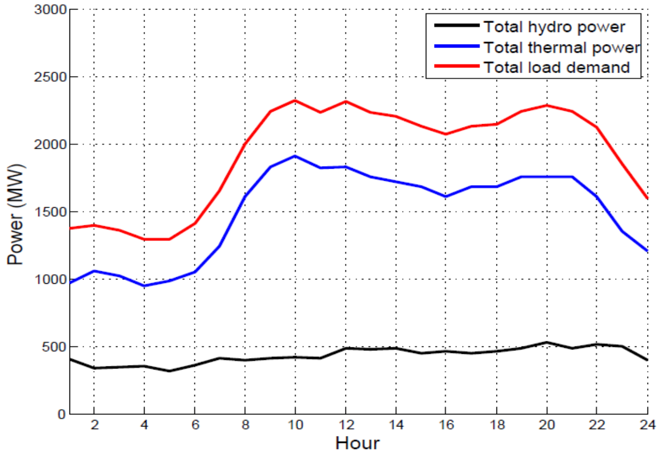


Fig: 3 Hydro generation, thermal generation and total load demand for STHTS with QCF

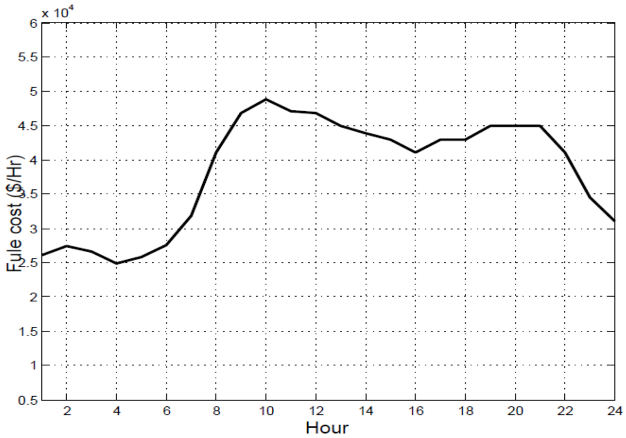


Fig: 4 Fuel cost per hour for STHTS with QCF

- Case-II: STHTS including the effect of valve point loading

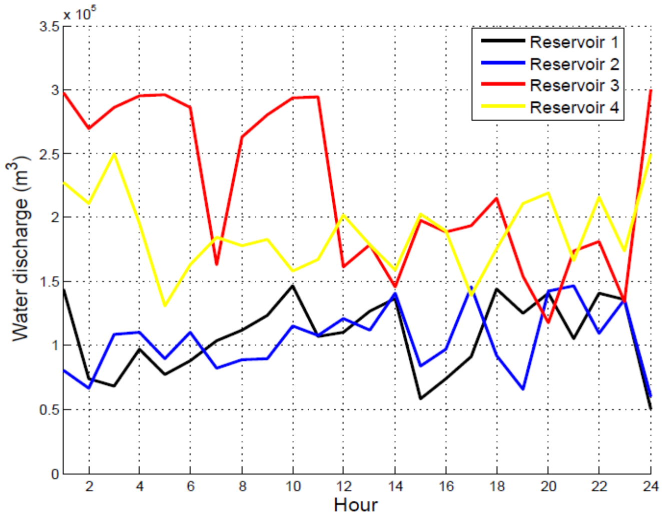


Fig: 5 Water discharge (m3) of the hydro plants for STHTS with VPL

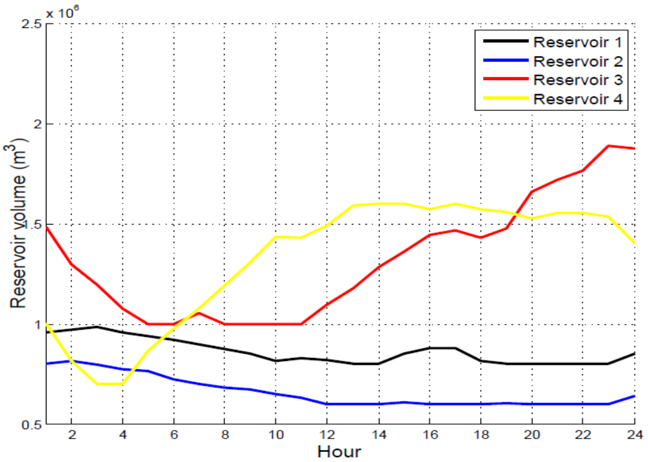


Fig: 6 Storage volume of reservoirs (m3) of the hydro plants for STHTS with VPL

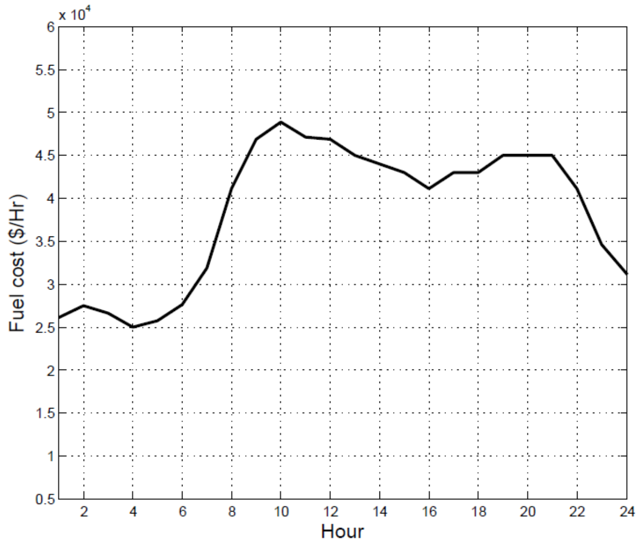


Fig: 8 Fuel cost per hour for STHTS with VPL

TABLE 1: COMPARATIVE FUEL COST

CASE- I WITH QCF	CASE-II WITH VPLE
$ 896840.323	$ 921168.06

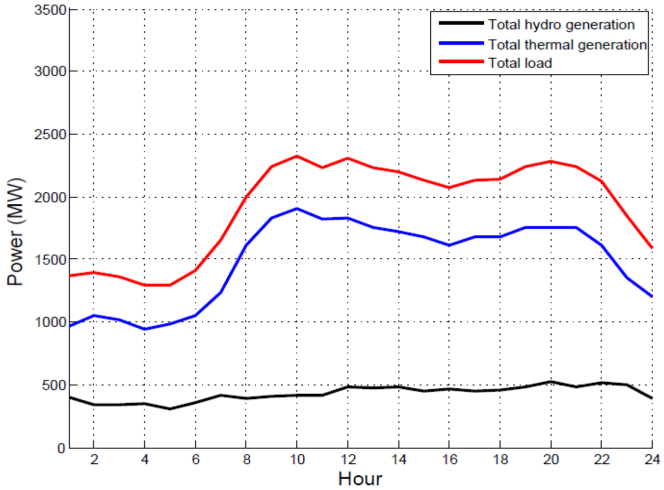


Fig: 7 Hydro generation, thermal generation and total load demand for STHTS with VPL

CONCLUSION

THE algorithm presented in this paper has been applied to short-term hydrothermal scheduling problem over the time horizon of 24 hours with one hour time interval. The optimum solution for the fuel cost has been given by the algorithm. The test system used for this algorithm have four hydro units and one thermal unit and these units are arranged in multi-chain arrangement. The analysis has been extended for thermal unit considered to have quadratic cost function and cost function with valve point loading. It is concluded that the cost increases if valve point loading effect is considered.

REFERENCES:

[1]. K.K. Mandal and N. Chakraborty. Optimal scheduling of cascaded hydrothermal systems using a new improved particle swarm optimization technique. Smart Grid and Renewable Energy, 2:282–292, 2011.

[2]. G. Sreenivasan, C.H. Saibabu, and S. Sivanagaraju. Pso based short-term hydrothermal scheduling with prohibited discharge zones. (IJACSA) International Journal of Advanced Computer Science and Applications, 2(9):97–105, 2011.

[3]. P.K. Hota, A.K. Barisal, and R. Chakrabarti. An improved pso technique for short-term optimal hydrothermal scheduling. Electric Power Systems Research, 79:1047–1053, 2009.

[4]. M. M. Salama, M. M. Elgazar, S. M Abdelmaksoud, and Henry H. A. Short term optimal generation scheduling of multi-chain hydrothermal system using constriction factor based particle swarm optimization technique (cfpso). International Journal of Scientific and Research Publications, 3(4), April 2013.

[5]. N. Sinha, R. Chakrabarti, and P.K. Chattopadhay. Fast evolutionary technique for short-term hydrothermal scheduling. IEEE Transactions on Power Systems, 18(1):214–220, 2003.

[6]. S.O. Orero and M.R. Irving. A genetic algorithm modeling framework and solution technique for short-term optimal hydrooptimal scheduling. IEEE Transactions on Power Systems, 13(2):501–518, 1998.

[7]. S. Kumar and R. Naresh. Efficient real coded genetic algorithm to solve the non-convex hydrothermal scheduling problem. Electrical Power and Energy Systems, 29:738–747, 2007.

[8]. K.K. Mandal and N. Chakraborty. Differential evolution technique-based short-term economic generation scheduling of hydrothermal systems. Electric Power Systems Research, 78:1972–1979, 2008.

[9]. L. Lakshminarasimman and S. Subramanian. Short-term scheduling of hydrothermal powe system with cascaded reservoirs by using modified differential evolution. IEE Proceedings Generation Transmission Distribution, 153(6):693–700, 2006.

[10]. V.H. Hinojosa and C. Leyton. Short-term hydrothermal generation scheduling solved with a mixed-binary evolutionary particle swarm optimizer. Electrical Power Systems Research, 92:162–170, 2012.

[11]. A.J. Wood and B.F. Wollenberg. Power Generation Operation And Control. John Wiley & sons, 2009.

[12]. D.P. Kothari and J.S. Dhillon. Power System Optimization. PHI Learning Private Limited, 2011.

[13]. P.K. Roy. Teaching learning based optimization for short-term hydrothermal scheduling problem considering valve point effect and prohibited discharge constraint. Electrical Power and Energy Systems, 53:10–19, 2013.

[14]. R.V. Rao and Vivek Patel. An elitist teaching-learning-based optimization algorithm for solving complex constrained optimization problems. International Journal of Industrial Engineering Computations, 3:535–560, 2012.

[15]. R.V. Rao, V.J. Savsani, and D.P. Vakharia. Teaching-learning based optimization: A noval method for constrained mechanical design optimization problems. Computer Aided Design, 43:303–315, 2011.

[16]. R.V. Rao, V.J. Savsani, and J. Balic. Teaching-learning based optimization algorithm for unconstrained and constrained real-parameter optimization problems. Engineering Optimization, 44:1447–1462, 2012

Prerna Charak, “Teaching-learning based optimization for short term scheduling of multi-chain hydrothermal system” *International Journal of Scientific and Technical Advancements*, Volume 4, Issue 1, pp. 165-170, 2018.