Stochastic Multi-Objective Short Range Fixed Head Hydrothermal Scheduling Using Classical, PSO & TLBO

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Abstract

This paper presents the multi-objective optimal solution for short range fixed head hydrothermal scheduling using classical method, Newton rapshon method and pso. The problem is formulated as a non-linear constrained multi-objective optimization problem. Considering the scheduling horizon period of 24 hours, hourly generation schedules are obtained for each of both hydro and thermal units for the three cases. The transmission losses are also accounted for through the use of loss coefficients. More no of simulations are carried out to obtain the best solution and the average value considered to improve the behaviour of pso. Numerical simulation of sample test system shows the effectiveness of the proposed algorithms. Index: pso, short range fixed head hydrothermal system, optimization technique, lagrangain relaxation.

1. Introduction

In the present set-up of large systems with hydro and thermal power stations, the integrated operation of these power stations is inevitable and the economic aspect of such an operation cannot therefore be overlooked. The underlying idea of integrated operation is for optimum utilization of all energy sources in the most economical manner, so that an uninterrupted supply can be made available to the consumer. The operating cost of thermal plant is very high, though their capital cost is low. So it has become economical as well convenient to have both thermal and hydro plants in the same grid. The hydroelectric plant can be started quickly and it has higher reliability and greater speed of response. Hence hydroelectric plant can take up fluctuating loads. But the starting of thermal plants is slow and their speed of response is slow. Normally the thermal plant is preferred as a base load plant whereas the hydroelectric plant is run as a peak load plant. The short-term hydrothermal scheduling model has a time horizon of one week or one day with an hourly time interval..

2. HYDROTHERMAL SCHEDULING

Optimal scheduling of power plant generation is the determination of the generation for every generating unit such that the total system generation cost is minimum while satisfying the system constraints. The objective of the hydrothermal scheduling problem is to determine the water releases from each reservoir of the hydro system at each stage such that the operation cost is minimized along the planning period. The operation cost includes fuel costs for the thermal units, import costs from neigh boring systems and penalties for load shedding.

The HTC problem is usually solved by decomposition of the original problem into long, medium and short term problems each one considering the appropriate aspects for its time step and horizon of study.

It is also essential to take into consideration two basic aspects of the hydro system:

- The available water quantity (water inflows) is stochastic in nature.
- The decision for the energy allocated to hydro units is deterministic.

3. Need of Hydrothermal Scheduling

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 become economical as well convenient to have both thermal and hydro plants in the same grid. The hydroelectric plant can be started quickly and it has higher reliability and greater speed of response. Hence hydroelectric plant can take up fluctuating loads.

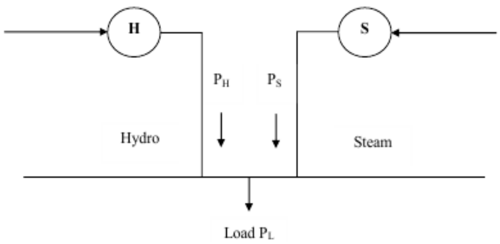
4. Short Range Problem

The load demand on the power system exhibits cyclic variation over a day or a week and the scheduling interval is either a day or a week. As the scheduling interval of short range problem is small, the solution of the short-range problem can assume the head to be fairly constant. The amount of water to be utilized for the short-range scheduling problem is known from the solution of the long-range scheduling problem.

A set of starting conditions (e.g. reservoir levels) is given, and the optimal hourly schedule that minimizes a desired objective, while meeting hydraulic steam, and electric system constraints, is sought.

The short term hydrothermal scheduling problem is classified in to two groups

- Fixed head hydro thermal scheduling
- Variable head hydro thermal scheduling



5. HTS Problem formulation:

5.1. Objective function:

The fixed-head hydrothermal problem can be defined considering the operating cost over the optimization interval to meet the load demand in each interval. Each hydro plant is constrained by the amount of water available for draw-down in the interval. The problem is defined as

Minimize

$$J = \sum_{k=1}^{T} \sum_{i=1}^{N} t_k F_i \left(P_{ik} \right)$$

$F_i \left(P_{ik} \right)$ is the cost function of thermal units in the interval k and is defined by

$$F_i \left(P_{ik} \right) = a_i P_{ik}^2 + b_i P_{ik} + c_i \text{ Rs/h}$$

With a_i, b_i and c_i as the cost coefficients.

P_{ik} is the output of thermal and hydro units during the kth interval.

5.2. Constraints:

(i)Load demand equality constraint:

$$\sum_{i=1}^{N+M} P_i \left(t \right) = P_D \left(t \right) + P_L \left(t \right)$$

Where

$P_D(t)$ is the load demand during the sub-interval.

$P_L(t)$ is the transmission loss during the sub-interval.

(ii) Limits are imposed as

$$p_i^{\min} \le P_i \left(t \right) \le p_i^{\max} \quad \text{(i= 1, 2, …, N + M)}$$

5.3. Volume and discharge:

Each hydro plant is constrained by the amount of water available for the optimization interval, i.e.

$$\int_0^T q_j \left(t \right) dt = V_j \qquad \text{(j = 1, 2, …, M)}$$

where V_j is the predefined volume of water available in cubic meters and hydro performance q_j is represented by the conventional quadratic model, i.e.

$$q_j \left(t \right) = x_1 P_{j+N}^2 \left(t \right) + y_j P_{j+N} \left(t \right) + z_j \quad \text{m}^3\text{/h}$$

(j = 1, 2, …, M)

Where x_j, y_j, and z_j and the discharge coefficients of the jth hydro plant.

5.4. Transmission Losses:

A common approach to model transmission losses in the system is to use Kron's approximated loss formula:

$$P_L \left(t \right) = \sum_{i=1}^{N+M} \sum_{j=1}^{N+M} P_i \left(t \right) B_{ij} P_j \left(t \right) + \sum_{i=1}^{N+M} B_{i0} P_i \left(t \right) + B_{00}$$

MW

Where

B_{00}, B_{i0}, and B_{ij} are B-coefficients.

q_{jk} is the rate of discharge from the jth hydro unit in interval k and is defined by

$$q_{jk} = x_j P_{j+N,k}^2 + y_j P_{j+N,k} + z_j \quad \text{m}^3\text{/h}$$

N is the number of thermal units

M is the number of hydro units

T is the overall period for scheduling.

The above objective as augmented by the constraints is given as

$$L\left(P_{ik,} \lambda_{k,} v_j \right) = \sum_{k=1}^{T} \left[\sum_{i=1}^{N} t_k F_i \left(P_{ik} \right) + \sum_{j=1}^{M} v_j t_k q_{jk} + \lambda_k \left[P_{Dk} + P_{Lk} - \sum_{i=1}^{M+N} P_{ik} \right] \right] - \sum_{j=1}^{M} v_j V_j$$

$$t_k \frac{\partial F_i}{\partial P_{ik}} + \lambda_k \left[\frac{\partial P_{Lk}}{\partial P_{ik}} - 1 \right] = 0 \quad \text{(i = 1, 2,..,N; k = 1, 2, …,T)}$$

$$v_j t_k \frac{\partial q_{jk}}{\partial P_{mk}} + \lambda_k \left[\frac{\partial P_{Lk}}{\partial P_{mk}} - 1 \right] = 0 \quad \text{(j = 1, 2, …, M; m = N+ j; k = 1, 2, …,T)}$$

where

λ is the incremental cost of power delivered in the system during the kth interval.

vj are the water conversion factor.

6. HTS methods:

6.1 Classical method:

The problem we wish to set up is the general, short-term hydrothermal scheduling problem where the thermal system is represented by an equivalent unit, Psj. In this case, there is a single hydroelectric plant, PHj We assume that the hydro plant is not sufficient to supply all the load demands during the period and that there is a maximum total volume of water that may be discharged throughout the period of Tmax hours.

6.1.1 Algorithm:

1. Read the number of thermal units *N*, the number of hydro units M, the number of sub-intervals T, cost coefficients, $a_i, b_i, c_i \ (i = 1, 2, ..., N)$, B-coefficients, $B_{ij} (i = 1, 2, ..., N + M; \ \ j = 1, 2, ..., N + M)$, discharge coefficients, $x_i, y_i, z_i \ (i = 1, 2, ..., M)$, demand $P_{Dk} \ (k = 1, 2, ..., T)$, the pre-specified available water $V_j \ (j = 1, 2, ..., M)$.
2. Calculate the initial guess values of $P_{ik}^0 (i = 1, 2, ..., N + M), \lambda_k^0$ and $v_j^0 \ (j = 1, 2, ..., M)$
3. Consider $v_j^0 \ (j = 1, 2, ..., M)$ as calculated in Step 2.
4. Start the iteration counter, r = 1.
5. Start hourly count, k = 1.
6. Consider $P_{ik}^0 \ (i = 1, 2, ..., N + M)$ and λ_k^0.
7. Calculate $\Delta P_{ik} \ (i = 1, 2, ..., N + M)$ and $\Delta\lambda_k$, using the Newton-Raphson method. Gauss Elimination method is used to solve the following equations.

$$\begin{bmatrix} \nabla_{pp}^k & \nabla_{p\lambda}^k \\ (\nabla_{p\lambda}^k)^T & 0 \end{bmatrix} \begin{bmatrix} \Delta P_{ik} \\ \Delta\lambda_k \end{bmatrix} = \begin{bmatrix} -\nabla_p^k \\ -\nabla_\lambda^k \end{bmatrix}$$

8. Calculate the new values of $P_{ik} \ (i = 1, 2, ..., N + M)$ and λ_k as $P_{ik}^{new} = P_{ik}^0 + \Delta P_{ik}$ and $\lambda_k^{new} = \lambda_k^0 + \Delta\lambda_k$
9. Set limits correspondingly as

$$P_{ik}^{new} = \begin{cases} P_i^{\max} & ; if \ P_{ik}^{new} \geq P_i^{\max} \\ P_i^{\min} & ; if \ P_{ik}^{new} \leq P_i^{\min} \\ P_{ik}^{new} & ; \ \ otherwise \end{cases}$$

Disallow generator to participate, whose limits have been set either to lower or upper limit, in the scheduling by deleting that row and column.

10. Set $P_{ik}^0 = P_{ik}^{new} \ (i = 1, 2, .., N + M)$ and $\lambda_k^0 = \lambda_k^{new}$ GOTO Step 7 and repeat.
11. If $k \geq T$, then GOTO Step 13, else $k = k + t_k$, GOTO Step 6 and repeat.
12. Calculate water withdrawals $V_j \ (j = 1, ..., M)$.
13. If $(|V_j - V_j^s| \leq \varepsilon)$ or if $(r \geq R)$ then GOTO Step 14.

 else $V_j^{new} = v_j^0 + (V_j - V_j^s)/V_j^s$,

 $V_j^0 = V_j^{new} \ (i = 1, 2, ..., M)$

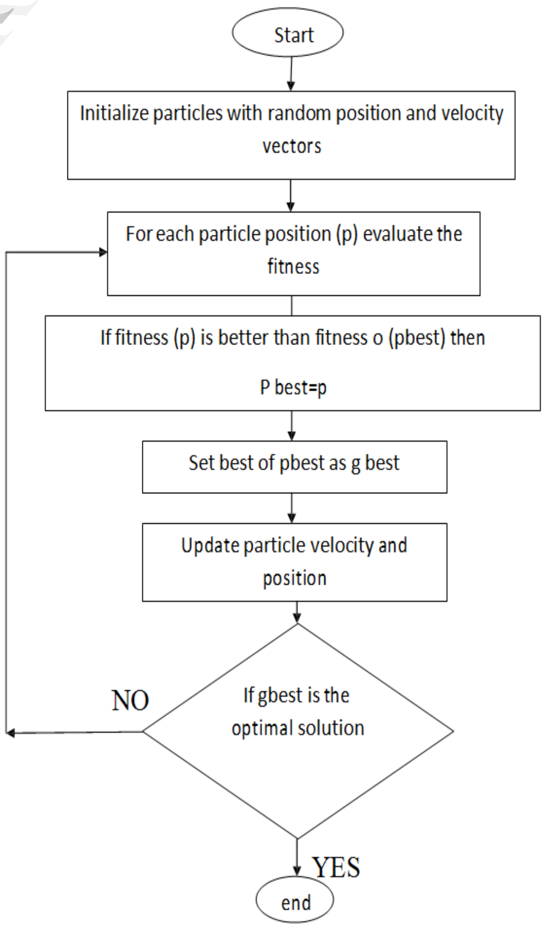
 $r = r + 1;$ GOTO Step 5 and repeat.

14. Calculate the optimal cost and loss and stop.

6.2 PARTICLE SWARM OPTIMISATION:

Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Dr.Ebehart and Dr.Kennedy in 1995, inspired by social behaviour of bird flocking or fish schooling. PSO shares many similarities with evolutionary computation techniques such as Genetic Algorithms (GA). The system is initialized with a population of random solutions and searches for optima by updating generations. In PSO, the potential solutions, called particles, fly through the problem space by following the current optimum particles. PSO has been successfully applied in many areas: function optimization, artificial neural network training, fuzzy system control, and other areas where GA can be applied. It mainly consists three operations mutation, de acceleration and migration

Flow chart:



TLBO:

The TLBO algorithm is a newly developed meta-heuristic optimization algorithm [17]. It is a population-based optimization algorithm that is modelled based on the transfer of knowledge to the classroom environment, where learners first gain knowledge from a teacher (Teacher Phase) and then from fellow-students (Learner Phase). TLBO is a population based algorithm, where a group of students (i.e. learner) is considered the population and the different subjects offered to the learners are analogous with the different design variables of the optimization problem. The results of the learner are analogous to the fitness value of the optimization problem. The best solution in the entire population is considered as the teacher. The operation of the TLBO algorithm is explained below with the teacher phase and learner phase.

The structure of the proposed algorithm can be explicated as follows:

Step 1: Initializing the problem and algorithm parameters

Step 2: Establishing the initial population learners.

Step 3: Compute the objective function.

Step 4: Compute the mean of the population.

Step 5: Determine the best solution (Teacher).

Step 6: Modify solutions based on the teacher knowledge according to teacher phase.

Step 7: Update solutions according to learner phase and Steps 3.

Step 8: Go to Step 4 until the iteration number arrives at the maximum iteration number.

Table-I. Analysis of cost & discharge values for these methods**.**

	Classical method		PSO method		TLBO method	
Load Mw	COST Rs/h	Q Mm^3/h	COST Rs/h	Q Mm3/h	COST Rs/h	Q Mm3/h
75	501.70	493.8	504.3	346.0	506.33	346
190	523.40	536.1	526.0	346.0	529.71	346
220	572.40	620.8	578.6	346.0	582.02	346
280	694.20	790.9	706.0	559.1	722.66	346
320	794.60	902.9	801.0	642.6	809.96	592.5
360	911.70	1015.8	910.4	724.1	913.74	688.5
390	1011.2	1100.5	984.8	883.3	972.48	1036.0
410	1083.5	1156.9	1054.7	1010.3	1024.6	1136.2
440	1201.1	1241.5	1156.3	1734.2	1114.3	1635.4
475	1353.4	1340.3	1267.3	2108.0	1252.3	1690.6
525	1600.9	1481.4	1502.3	2036.9	1368.0	2309.3
550	1739.0	1551.9	1595.4	2294.3	1478.7	2436.9
565	1826.8	1594.2	1664.4	2736.1	1513.0	2581.1
540	1682.6	1523.7	1526.7	2064.1	1489.9	2151.4
500	1472.5	1410.8	1427.0	1879.2	1369.9	1756.9
450	1242.9	1269.8	1181.7	1241.4	1204.2	1306.1
425	1140.9	1199.2	1135.8	1106.3	1124.3	1096.8
400	1046.7	1128.7	1049.6	529.8	1051.2	878.2
375	960.20	1058.1	959.4	429.5	959.48	589.6
340	851.00	959.4	884.8	428.0	904.67	346.00
300	742.40	846.5	758.3	415.6	773.42	346.00
250	629.20	705.4	634.0	346.0	658.83	346.00
200	538.90	564.3	542.5	346.0	550.09	346.00
180	508.70	507.9	510.0	346.0	513.60	346.00

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Table-I. Analysis of generations, losses and lamda values for these methods**.**

	CLASICALMETHOD						PSO METHOD					TLBO METHOD				
Load Mw	PG1 Mw	PG2 Mw	PG3 Mw	PH4 Mw	PL Mw	λ	PG1 Mw	PG2 Mw	PG3 Mw	PH4 Mw	PL Mw	PG1 (Mw)	PG2 (Mw)	PG3 (Mw)	PH4 (Mw)	PL (Mw)
175	66.90	36.10	61.80	16.8	6.60	1.6	53.34	40.00	75.00	10.0	3.34	56.51	40.00	69.84	10.0	1.35
190	72.40	39.40	67.30	18.8	7.80	1.7	55.98	80.00	50.00	10.0	5.98	71.09	40.00	71.88	10.0	2.98
220	83.60	46.10	78.40	22.5	10.5	2.0	60.00	75.71	74.50	10.0	8.26	90.68	40.00	82.58	10.0	3.26
280	176.3	60.30	100.8	29.8	17.3	2.6	60.00	117.8	92.18	19.7	10.6	105.9	76.16	93.48	10.0	5.63
320	121.7	70.50	116.0	34.6	22.8	3.1	75.00	131.9	99.09	27.0	12.5	112.9	91.79	101.4	21.2	7.54
360	137.4	81.30	131.4	39.2	29.3	3.6	70.00	84.90	159.4	33.7	15.0	139.2	99.16	104.1	25.4	8.04
390	149.3	89.80	143.0	42.6	34.7	3.9	134.0	105.2	123.7	38.9	18.2	145.9	103.8	112.4	40.0	12.2
410	157.3	95.70	150.7	44.8	38.6	4.2	186.4	63.92	80.19	48.1	21.8	154.8	105.1	119.9	44.0	13.8
440	169.4	105.0	162.4	48.1	44.9	4.6	207.3	103.9	94.98	66.4	26.2	156.2	121.3	123.7	62.9	24.2
475	183.7	116.3	176.1	51.9	53.0	5.2	138.9	88.50	170.4	77.0	29.0	170.0	133.9	133.1	64.8	27.0
525	204.4	133.7	195.7	57.2	66.0	6.0	250.0	60.56	190.9	79.4	38.1	175.0	145.0	145.0	86.1	36.1
550	214.8	142.9	205.5	59.8	73.1	6.4	199.7	69.03	214.7	85.6	47.1	189.0	151.0	152.0	91.3	46.1
565	221.1	148.7	211.3	61.4	77.5	6.7	250.0	72.13	142.9	99.8	51.9	192.0	152.0	157.0	94.9	48.9
540	210.6	139.2	201.6	58.8	70.2	6.2	234.1	141.0	122.0	77.9	46.6	194.0	148.0	155.0	90.6	47.6
500	194.0	124.8	185.9	54.6	59.3	5.6	248.9	145.6	92.10	71.5	41.2	186.0	136.0	149.0	67.2	38.2
450	173.5	108.1	166.3	49.2	47.2	4.8	50.00	144.0	178.0	42.8	36.5	172.3	122.7	134.0	50.6	31.5
425	163.4	100.3	156.6	46.5	41.7	4.4	119.4	82.14	204.9	23.4	25.2	162.7	118.1	125.3	42.4	21.2
400	153.3	92.80	146.8	43.7	36.6	4.1	201.3	41.78	143.0	18.4	21.2	152.1	113.1	119.0	33.5	19.2
375	143.3	85.50	137.2	40.9	31.9	3.8	50.00	122.7	130.7	13.8	18.4	139.7	105.8	111.1	21.1	15.4
340	129.5	75.80	123.7	36.9	25.9	3.3	61.49	66.01	164.3	13.8	14.5	132.5	98.50	109.4	10.0	10.5
300	114.0	65.30	108.4	32.2	19.9	2.9	50.00	116.9	123.0	13.2	11.3	121.7	74.44	102.1	10.0	8.33
250	94.90	53.10	89.50	26.2	13.7	2.3	50.00	122.0	64.16	10.0	9.78	112.5	61.49	73.75	10.0	7.78
200	76.10	41.60	71.00	20.0	8.7	1.8	50.00	82.75	57.25	10.0	8.30	84.19	40.00	71.11	10.0	5.30
180	68.70	37.20	63.60	17.5	7.0	1.6	50.00	40.00	80.00	10.0	6.50	70.50	40.00	62.00	10.0	2.50

COMPARISON OF COST OF DIFFERENT METHODS:

The operating costs of classical, PSO and TLBO-method for 24 hours for given load demand. Cost obtained for TLBO less as compared with PSO and Classical methods. Comparison of cost for 24 hours

Table-III. Cost analysis for these methods.

Classical	PSO	TLBO
Rs. 24630.00	Rs. 23477.00	Rs. 23387.00

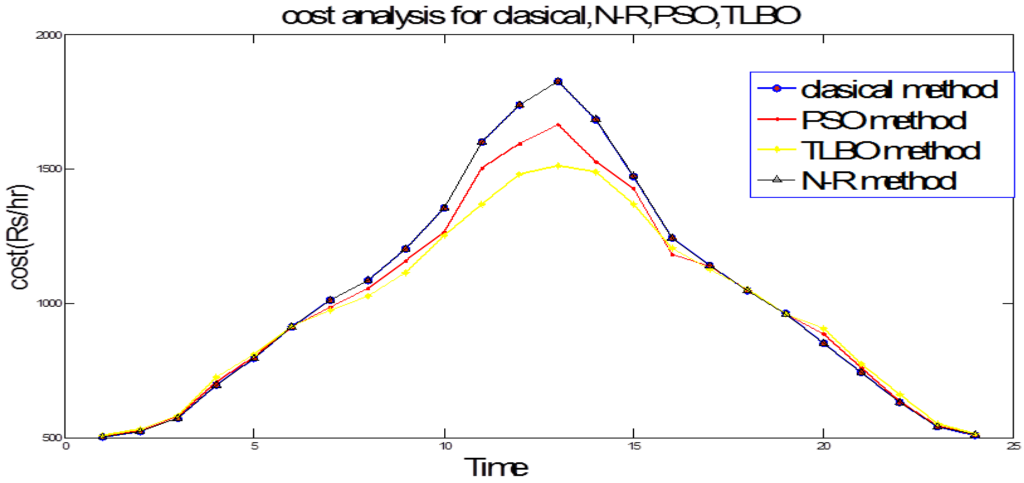

Fig: cost analysis for these methods.

CONCLUSION AND FUTURE WORK:

The scheduling of electrical power from hydro and thermal plants has been done using PSO and classical methods. The optimization of cost is obtained mainly by employing three basic approaches. The optimization of thermal costs has been done by three methods employing programming technique. Finally the results of optimization by both the methods are tabulated and analysed. Numerical results show that highly near-optimal solutions can be obtained by TLBO. So it is clear that with the help of TLBO based algorithm it is possible to find a more nearly optimal solution to the existing hydrothermal scheduling problem.

Future works:

Hydro thermal scheduling problem with valve point loading can also be solved using EP. The valve point effect is modelled in two forms one is in the form of prohibited operating zones and the other is by including rectified sinusoidal component in the fuel cost function.

REFERENCES:

1). Power System Optimization by J.S.Dhillon & D.P.Kothari