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Review on solution of Short Term Hydrothermal Scheduling Problem by Using Flower Pollination Algorithm and Particle Swarm Optimization Algorithm

[1]Jagjeet Singh,[2]Er. Ravinder Kumar

[1]M.Tech (EE) , [2]A.P (EE)

AIET Faridkot

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Abstract:

Operation of a system having both hydro and thermal plants is more complicated than the hydro plants which have negligible operating cost but are required to operate under constraints of water available for hydro generation in a given span of time. The main objective of the Hydrothermal Scheduling (HTS) is to minimize the fuel cost of thermal plants with consideration of water availability of hydro plants and various other constraints over a given period of operation. Previously, a wide variety of optimization techniques have applied to solve the Hydrothermal scheduling problems such as simulated annealing (SA), dynamic programming (DP), gradient search differential evolution, evolutionary programming (EP), genetic algorithm (GA), but these methods has drawbacks such as large computation time, algorithm complexity etc. Now we applied particle swarm optimization and flower pollination algorithm to solve particular problem.

Keywords: Overview, Thermal and Hydro Generation, Hydrothermal Scheduling, Need of Hydrothermal Scheduling, Particle swarm optimization, Flower Pollination Algorithm, Objective Function/Cost Function.

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1.1 Overview

Electric power plays a major role in modern society and in the development of various sectors of economy. This trend has led to increase in number of power stations, increase in number of transmission lines, expansion of existing power stations, development of new power stations and many other additions to power system. Even today, major portion of energy required for the world is supplied by fossil-fired units and hence the pollution caused by them is a matter of apprehension. Hence, in order to meet the future demand, immediate attention is to be paid to energy production from hydro, fossil and nuclear resources in the best possible technical, environmental and economic conditions. In the present set-up of large power systems with mainly hydro and thermal (hydro-thermal) system, the integrated operation of them is inevitable with due consideration to economic and environmental aspects. A hydro plant has higher reliability, greater speed of response and can take up fluctuating loads. Since the operating cost of a thermal plant is high but its capital cost is low and the operating cost of a hydro plant is low but its capital cost is high, hence it is economical and convenient to have both thermal and hydro plants on the same grid. Optimum scheduling of hydrothermal plants is more important due to its economical aspect in interconnected power system operation. The main aim of hydrothermal scheduling problem is to minimize the fuel cost of thermal plants as the operating cost of hydro plants is negligible. Thus, the problem of minimizing the operating cost of a hydrothermal system is to minimize the fuel cost of thermal plants subjected to various equality and inequality constraints offered by the operation of power system network. The stochastic nature of water's availability and limited energy storing capacity of water reservoirs makes the solution more difficult for hydrothermal systems as compared to pure thermal systems [1].

1.2 Thermal and Hydro Generation

Thermal power plants convert energy of fuels such as coal, petroleum products, domestic trash/waste, natural gas, agricultural waste, etc. into electricity. Other sources of fuel include biogases and landfill gas. Lignite and coal accounted for about 60% of India's total installed capacity. India's electricity sector consumes nearly about 72% of the coal produced in the whole country. India gestate its projected rapid growth in electricity generation ended the next couple of decades to be largely met by thermal power systems. The operating coal fired power stations required to invest nearly INR 12.5 million per MW capacity for installing pollution control equipment to fulfill the requirement of the latest emission norms notified by the Ministry of Environment and Forests in the year 2016. A large part of Indian coal reserve is similar to Gondwana coal. It is of low calorific value and high ash content. The central and state power generation companies are permitted by Government Of India with flexible coal linkage switch from inefficient plants to efficient plants and from plants situated away from coal mines to pit head to minimize the cost of coal transportation thus leading to decrease in cost of power. The central government has planned to shut down 11,000 MW of thermal power generation capacity that are at least 25 years old and replace with bigger size plants with super critical pressure technology totaling to at least 20,000 MW with the coal being consumed currently by these old and small units. India is the 7th largest hydroelectric power producer in the world.

1.3 Hydrothermal Scheduling

The hydrothermal scheduling is to meet the given load demand for the specified time horizon. The optimal scheduling of hydrothermal plant comprises generation of power from hydro as well as thermal plants so as to minimize the total fuel cost of thermal plant. Thus the scheduling problem can be solved by minimizing the fuel cost of thermal plant while considering the various hydro as well as thermal plant constraints. The main constraints of problem include: cascaded nature of the hydraulic network, the varying hourly reservoir inflows, turbine flow rate, 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, physical limitations on the reservoir storage the varying system load demand and the loading limits of both hydro and thermal plants [6] [7].

1.4 Need of Hydrothermal Scheduling

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.

1.5 Particle swarm optimization

Particle swarm optimization (PSO) technique is implemented to determine optimal solution for hydrothermal scheduling [3,4] with cascaded reservoir hydroelectric system in which non-linear relation between water discharge rate, power generation and net head are taken in to account. The water transport delay between connected reservoir, effect of valve point loading, cost characteristic of individual thermal plant are also considered. This algorithm is developed for three thermal and four hydro plants. The proposed algorithm is providing highly near optimal solution as compared with simulated annealing and evolutionary programming. It is found that convergence characteristics of this technique are excellent and superior in term of computation time and cost [3]. To maintain the diversity of population local version of PSO is used [4]. In multi objective Hydrothermal scheduling using PSO short-range fixed head is consider with explicit recognition of uncertainties in production cost, CO2, SO2 and NO2 emissions and load demand. This technique provides efficient solution [8].

1.6 Flower Pollination Algorithm

In this technique various constraints like power balance constraints, reservoir volume limit, and total water discharge constraints, hydro and thermal generation limits are taken into consideration. The relative operation capacity limits of thermal and hydro plant is considered. The main objective of hydrothermal scheduling is to minimize the total fuel cost of thermal plants with consideration of all the constraints and meet the load demand. Reservoir volume constraints and the inequality constraints in langrage multiplier techniques have more difficulties to calculate the schedules and require some special process. FPA is a new met heuristic technique which is used to solve the optimization problem. This technique is based on the pollination process in flowering plants. This technique is applied on the short term hydrothermal [2] as well as thermal scheduling problem and results obtained are found to be better in comparison to GA in case of hydrothermal scheduling and PSO in case of thermal scheduling.

1.7 Objective Function/Cost Function

In the practical power system, it is expected to have losses inside the generator as the generator is placed at a location which has high fuel cost. For example, if the generator is situated at a location which is far away from the load then we may consider that the transmission loss will be significantly affecting the fuel cost. That's why the fuel cost has to be considered as one of the most important part in the economic load dispatch problem compared to other factors [6]. The incremental fuel cost as shown in fig. 1.1.

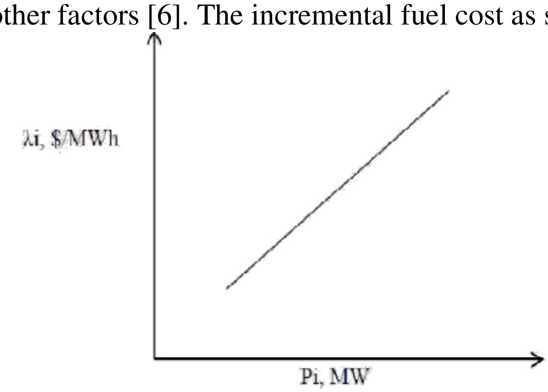

Figure 1.1(Incremental Fuel Cost Curve)

The fuel cost can be written in the form of quadratic equation as:

$$C_i = c_i P_i^2 + b_i P_i + a_i \quad (1.1)$$

$$FC = \sum_{i=1}^{n} (C_i) \quad (1.2)$$

Where,

Ai; bi; ci Cost coefficients for the ith generator

Ci Cost of generation

Pi Generation power of ith generator

FC Total Fuel cost of generation.

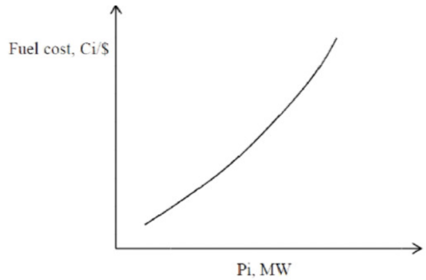

Figure 1.2 (Fuel Cost Curve)

1.7 Experimental Set Up

Objective min or max f(x), x = (x1,x2,...,xn) or f(x1, x2, x3…….xn)
Initialize a population of n flowers/pollen gametes with random solutions
Find the best solution g∗ in the initial population (best value is the minimum value among all the solutions).
Generated random number for switch probability p∈ [0,1] fort= 1: no. of hours or no. of intervals
For i = 1: n (all n flowers in the population)
If rand < p,
Draw a (d- dimensional) step vector L which obeys a Levy distribution Do Global pollination via (xi) t+1= (xi)t + L(g∗ -(xi)t
Else
Draw € from a uniform distribution in [0,1]
Randomly choose j and k among all the solutions
Do local pollination via (xi) t+1= (xi)t + €((xj)t – (xk)t
End if
Evaluate new solutions
If new solutions are better, update them in the population end for
Find the current best solution g∗
End for

Power balance equation

The total active power generation must balance the predicted power demand plus losses, at each time interval over the scheduling horizon i.e.

$$\sum P_{sti}(t) - P_L(t) - P_D(t) = 0$$

Where PL (t) is total transmission losses at time t, PD(t) is total load demand at the time t. Thermal generation capacity. The generators have its own minimum and maximum limits as:-

$P_{stimin} \leq P_{sti}(t) \leq P_{stimax}$

Where;
N = number of thermal unit
Psti(t)= output power of thermal unit i at time t.
ai, bi, ci are cost curve coefficients of thermal unit i.
PL(t) = total transmission losses
PD (t) = total load demand.
Pstimax = lower and upper generation limit for thermal unit i.
t =no. of hours during the study period.

1.8 Results

The FPA technique is used to solve the economic load dispatch problem considering a test system consists of 3 thermal generator units and 6 thermal generator units [5].

Case 1: 3 Unit Systems

The thermal generators minimum and maximum limits along with the cost curve coefficients of 3 generating units are shown in Table 5.1 are taken from [5].

The results obtained using the FPA technique without considering the transmission losses are shown in Table-5.2. The results are calculated at different load demand ranging from 250MW to 400M.

Case -2: 6-units system

Here an IEEE 30 bus system with 6 generating units system is used to check the effectiveness of the proposed FPA technique. All the inputs i.e. cost coefficients of all thermal units and minimum and maximum power generation limits as shown in Table-5.3 are taken from [5].

The results obtained are shown in Table-5.4 with load demand of 600MW, 700MW and 800MW.It is found that the proposed FPA is effective in reducing the operating cost of thermal plants while satisfying all the equality and inequality constraints.

Table-5.1: Generating unit capacity and coefficient

Unit	P_i^{min}(MW)	P_i^{max} (MW)	a_i ($/MW^2)	b_i ($/MW)	c_i ($)
1	50	250	328.13	8.663	0.00525
2	5	150	136.91	10.04	0.00609
3	15	100	59.16	9.76	0.00592

Below table with load demand of 600MW, 700MW and 800MW. It is found that the proposed FPA is effective in reducing the operating cost of thermal plants while satisfying all the equality and inequality constraints.

Table 5.2 Best Power Output for 3-Unit system (without consideration of transmission loss)

P_{demand} (MW)	P1 (MW)	P2 (MW)	P3 (MW)	Fcost (FPA) ($/hr) (Proposed method)	Fcost (PSO) ($/hr) [44]
250	164.8052	31.4382	53.7586	2958.0	2959.98
275	175.5852	37.0932	62.3219	3219.2	3219.23
300	182.2811	46.9701	70.7517	3482.9	3483.73
325	193.1064	50.6625	81.2326	3749.0	3749.95
350	201.2165	62.5674	86.2203	4017.4	4017.52
375	208.8795	70.5767	95.5449	4288.3	4288.92
400	222.5766	77.5744	99.8518	4561.5	4563.00

Table 5.3 (Generating unit capacity of six thermal units and their coefficients)

Unit	P_i^{min} (MW)	P_i^{max} (MW)	a_i ($/MW^2)	b_i ($/MW)	c_i ($)
1	10	125	756.79886	38.53973	0.15240
2	10	150	451.32513	46.15916	0.10587
3	35	225	1049.9977	40.39655	0.02803
4	35	210	1243.5311	38.30553	0.03546
5	130	325	1658.5596	36.32782	0.02111
6	125	315	1356.6592	38.27041	0.01799

Table 5.4 (Best Power Output of 6 unit-systems (without consideration of transmission loss)

Power Demand	PD=600MW		PD=700MW		PD=800MW	
Unit Output	PSO	FPA	PSO	FPA	PSO	FPA
P1(MW)	23.84	21.3655	28.28	31.6310	32.67	31.2448
P2(MW)	10.00	10.0906	10.00	12.5372	14.45	19.9516
P3(MW)	95.57	93.0332	119.02	93.1158	141.73	120.7122
P4(MW)	100.52	73.5055	118.67	121.2348	136.56	139.3915
P5(MW)	202.78	206.1072	230.78	225.9551	257.37	249.8387
P6(MW)	181.52	195.9118	212.56	215.5355	242.54	238.8664
Total generation cost ($/hr)	32094.69	31466.78	36912.16	36024.09	41896.66	40707.89

Conclusion

In short term hydrothermal scheduling , the complexity is introduced by cascaded nature of the hydraulic network, nonlinear relationship among the hydro power generation, water transport delay time, varying hourly reservoir inflows, varying load demand and loading limits of both hydro and thermal power plants. These factors have made the system more complex and are difficult to solve with the help of conventional technique. So hybrid intelligence technique is used to solve this problem and effectively handling the constraints. Flower Pollination Algorithm (FPA) technique provide better result as comparison GA. The test performed on one thermal and four cascaded hydro power plants with multi reservoir and scheduling horizon has been kept on twenty four hours with one hour time interval. Algorithm is applied for each and every time intervals and results are demonstrated.

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