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Short term hydro–wind–thermal scheduling based on particle swarm optimization technique

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ABSTRACT

Hydro–wind–thermal scheduling is one of the most important optimization problems in power system. An aim of the short term hydrothermal scheduling of power systems is to determine the optimal hydro, wind and thermal generations in order to meet the load demands over a scheduled horizon of time while satisfying the various constraints on the hydraulic, wind and thermal power system network. In this paper we present optimal hourly schedule of power generation in a hydro–wind–thermal power system applying PSO technique. The simulation results inform that the proposed PSO approach appears to be the powerful to minimize fuel cost and it has better solution quality and good convergence characteristics than other techniques.

Introduction

Hydrothermal scheduling plays an important role in operation and planning of power system. Maximum power demand is fulfilled by thermal power. If a part of the demand power is fulfilled by another energy source, then cost of the thermal power will be reduced. In hydrothermal scheduling technique, demand power is fulfilled by thermal and hydro power plant. Now a day, non conventional energy source is very effective and essential energy source. Non conventional energy source is a reliable energy source by which we can produce electrical energy at 24 h in a day. It does not produce any pollution. Wind energy is the most important non conventional energy source to generate power. This technology is used in many practical purposes like power generation, pumping water etc. The operating cost of thermal power plant is very high compared to the operating cost of hydro power plant and wind power plant. Wind and hydro plant has more initial cost than thermal plant but has not any running cost. The integrated operation of the hydro, wind and thermal plants in the same grid has become more economical.

In short-term hydro–wind–thermal scheduling, an aim is to determine the optimal hydro, wind and thermal generations in order to meet the load demands over a scheduled horizon of time while satisfying the various constraints on the hydraulic, wind and thermal power system network.

The hydro–wind–thermal generation scheduling is mainly concerned with hydro unit scheduling, wind unit scheduling and thermal unit dispatching. The hydro–wind–thermal generation scheduling problem is more difficult than the scheduling of thermal power systems. Since there is no fuel cost associated with the hydro power generation and wind power generation. The problem of minimizing the total production cost of hydro–wind–thermal scheduling problem is achieved by minimizing the fuel cost of thermal power plants under the constraints of water available for the hydro power generation in a given period of time. In short term hydro–wind–thermal scheduling problem, the reservoir levels at the start and the end of the optimization period and the hydraulic inflows are assumed known. In addition, the generating unit limits and the load demand over the scheduling interval are known. In this article, four hydro power plants, ten wind power plants and three thermal power plants have been considered. Valve point effect has been considered.

Different performances of stochastic techniques have been studied in the literature. In recent years, many type of optimization algorithm has been applied to solve hydrothermal scheduling problem.

Wong and Wong [1,2] proposed a short term hydrothermal scheduling algorithm based on simulated annealing technique. Yang et al. [3] presented a novel evolutionary programming based

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Nomenclature

P_{sim} output power of ith thermal unit at time m
$P_{si}^{\min}, P_{si}^{\max}$ lower and upper generation limits for ith thermal unit
$a_{si}, b_{si}, c_{si}, d_{si}, e_{si}$ cost curve coefficients of ith thermal unit
P_{Dm} load demand at time m
P_{hjm} output power of jth hydro unit at time m
P_{wkm} output power of kth wind unit at time m
$P_{hj}^{\min}, P_{hj}^{\max}$ lower and upper generation limits for jth hydro unit
Q_{hjm} water discharge rate of jth reservoir at time m
V_{hjm} storage volume of jth reservoir at time m
$Q_{hj}^{\min}, Q_{hj}^{\max}$ minimum and maximum water discharge rate of jth reservoir
$V_{hj}^{\min}, V_{hj}^{\max}$ minimum and maximum storage volume of jth reservoir
$C_{1j}, C_{2j}, C_{3j}, C_{4j}, C_{5j}, C_{6j}$ power generation coefficients of jth hydro unit
I_{hjm} inflow rate of jth reservoir at time m
R_{uj} number of upstream units directly above jth hydro plant
S_{hjm} spillage of jth reservoir at time m
T_{1j} water transport delay from reservoir l to j
N_s number of thermal generating units
N_h number of hydro generating units
N_w number of wind power generating units
m, M time index and scheduling period

algorithms for the short term hydrothermal scheduling problem. Chen and Chang [4] described an efficient approach to the 24-h ahead generation scheduling of hydraulically coupled plant based on genetic algorithms. Orero and Irving [5] presented short term optimal hydrothermal scheduling using genetic algorithm. Hota et al. [6] proposed short term hydrothermal scheduling through evolutionary technique. Sinha et al. [7] developed evolutionary programming based algorithms with Gaussian and other mutation techniques which is tested on a multi-reservoir cascaded hydro-electric system having prohibited operating zones and a thermal unit with the valve point loading. Gil et al. [8] presented short term optimal hydrothermal scheduling using genetic algorithm. Basu [9] presented an interactive fuzzy satisfying method based on evolutionary programming technique for short-term multi-objective hydrothermal scheduling. Yuan and Yuan [10] proposed a new cultural algorithm to solve the optimal daily generation scheduling of hydrothermal power systems. Yu et al. [11] proposed short-term hydrothermal scheduling based on different particle swarm optimization techniques. Kumar and Naresh [12] proposed a simple and efficient optimization procedure based on real coded genetic algorithm for the solution of short term hydrothermal scheduling problem continuous and non smooth/non convex cost function. Lee [13] presents multi-pass iteration particle swarm optimization to solve short term hydroelectric generation scheduling of a power

Table 1
Load demand.

Hour	P_D (MW)
1	750
2	780
3	700
4	650
5	670
6	800
7	950
8	1010
9	1090
10	1080
11	1100
12	1150
13	1110
14	1030
15	1010
16	1060
17	1050
18	1120
19	1070
20	1050
21	910
22	860
23	850
24	800

Table 2
Hydropower generation coefficient.

Plant	C_1	C_2	C_3	C_4	C_5	C_6
1	−0.0042	−0.42	0.030	0.90	10.0	−50
2	−0.0040	−0.30	0.015	1.14	9.5	−70
3	−0.0016	−0.30	0.014	0.55	5.5	−40
4	−0.0030	−0.31	0.027	1.44	14.0	−90

Table 3
Reservoir inflows ($\times 10^4$ m^3).

Hour	Reservoir			
	1	2	3	4
1	10	8	8.1	2.8
2	9	8	8.2	2.4
3	8	9	4	1.6
4	7	9	2	0
5	6	8	3	0
6	7	7	4	0
7	8	6	3	0
8	9	7	2	0
9	10	8	1	0
10	11	9	1	0
11	12	9	1	0
12	10	8	2	0
13	11	8	4	0
14	12	9	3	0
15	11	9	3	0
16	10	8	2	0
17	9	7	2	0
18	8	6	2	0
19	7	7	1	0
20	6	8	1	0
21	7	9	2	0
22	8	9	2	0
23	9	8	1	0
24	10	8	0	0

Table 4
Reservoir storage capacity limits, plant discharge limits, reservoir end conditions ($\times 10^4$ m^3) and plant generation limits (MW).

Plant	$V^{\min}$	$V^{\max}$	V_{ini}	V_{end}	$Q^{\min}$	$Q^{\max}$	$P_h^{\min}$	$P_h^{\max}$
1	80	150	100	120	5	15	0	500
2	60	120	80	70	6	15	0	500
3	100	240	170	170	10	30	0	500
4	70	160	120	140	6	20	0	500