Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Environmental Sciences 11 (2011) 624 – 630

Procedia
Environmental Sciences

The Optimization of Power Dispatch for Hydro-thermal Power Systems

Zhai Rongrong, Bian Jing, Yang Zhiping

School of Energy Power& Mechanical Engineering，North China Electric Power University, Beijing, China,
e-mail:zhairongrong01@163.com.

Abstract

A model in power market for hydro-thermal-nuclear power system has been proposed in this paper. Nuclear units, hydropower units and coal-fired power units are considered to have the renewable energy best used. The model contains two sub-models: Model1 and Model2. Model1 is used to solve the problem of allocating hydro loads and thermal loads, while Model2 is used to solve the problem of optimal power dispatch within hydro units and coal-fired units. Simulation and sensitivity analysis have been done in a case study. The results reveil that the proposed model is correct and the solution approach is effective.

Keywords: Power systems: Optimal power dispatch；MATLAB；Sensitivity analysis

1. Introduction

Up to the end of year 2006, the gross installed capacity of the power systems in China is 62 million kilowatt, which is made up of 70% thermal power, 12% hydropower and a small part of nuclear power and wind power. Nowadays, the research of the optimal power dispatch of our power systems is increasingly important. The optimal power dispatch of power systems means to insure the safe running of all the nuclear-power stations in their determinate dispatch cycles. Given knowing the outputs of hydropower and coal power stations, the model is to achieve the optimal power dispatch with making full use of water power and saving coal [1].

The traditional ways to solve the problem of optimal power dispatch, such as the linear programming method which will lower the calculation accuracy and the dynamic programming method, cannot be well popularized because of their defects,. In recent years, more modern and intellectual solutions have been developed solve to the problem, such as the genetic algorithm (GA), simulated annealing method and artificial neural network method. However, the GA takes a long time to compute and the parameters of the simulated annealing method are difficult to select [2]. Therefore, the problem of optimizing the short term generation schedules of the electric power system needs further discussion.

A model of the problem with the quadratic programming has been built in the paper and software

doi:10.1016/j.proenv.2011.12.097

MATLAB is used to solve the problem.

2. Optimization model for load dispatch in power systems.

There are two optimal methods according to the requirement of different object functions: reduce the cost of production and optimize the use of the primary energy.

Nuclear stations need function in the specified load, and hydropower stations are seriously influenced by seasons and climate. However, coal power stations can work anytime as long as the fuel is adequate. Coal power machines function with primary energy but what hydropower machines consume is renewable energy. In the text, nuclear machines are first considered, and then hydropower machines are considered, and coal power machines are last considered, so renewable energy is best used.

To sum up, the model contains two sub-models: Model1 and Model2. Model1 is used to solve the problem of allocating hydro loads and thermal loads; Model2 is used to solve the problem of optimal power dispatch within hydro machines and coal-fired machines. It is shown in Figure 1,

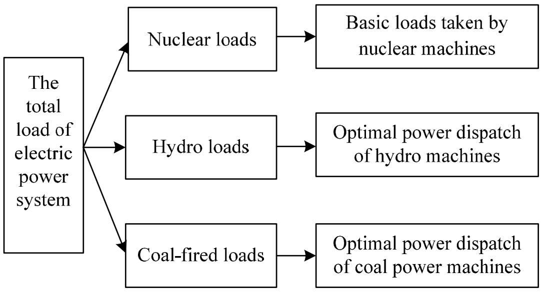

Fig. 1 The flow sheet for load dispatch

2.1 Load Dispatch among Nuclear, Hydro and Coal Power Machine

The basic utility of the nuclear machine should be affording the radical load because of its particularity. If the power of it changing frequently, the nuclear fuel cannot be made the best use of, it means a great waste of fuel and an increase of the radioactive waste, it will also affect the safety of nuclear reactor. Therefore, nuclear machines are first considered. Then are hydropower machines because the motive power of them is water, which is renewable. Arrangement: work out the line of load-water consumption in water grid according to the water resource, and then we'll know how much electrical quantity can we get from a fixed amount of water power, it also means how much water power does a certain amount of electric cost.

The least water consumption in water grid Model1:

Objective function: $$\min W_D = \sum_{i=1}^{n}(a_i N_i^2 + b_i N_i + c) \tag{1}$$

Constraint condition： $$\begin{cases} \sum_{i=i}^{n} W_i \le d \\ \sum_{i=1}^{n} N_i - N_{DH} = 0 \\ N_{i\min} \le N_i \le N_{i\max} \end{cases} \tag{2}$$

$i = 1, 2, \cdots, n$

W_D -- total water consumption of the system ; W_i -- water consumption of every hydropower machine; d -- the maximum dispatch capacity of a reservoir of the system, const; N_i -- load of every generating set, N_{DH} -- predicted total load of water grid; $N_{i\min}$ -- the maximum power of the water generating set, $N_{i\max}$ -- the normal rated (the minimum) power of the water generating set[4].

Figure out the relationship between W_D and N_{DH} from Model1, and then we can get the line of load-water consumption in water grid. According to the line and the predicted quantity of water, we can know the predicted total load of water grid N_{DH}.

The relationship among the loads of coal power grid, water grid and nuclear grid, $P_D = P_N + N_{DH} + P_{DT}$. P_D -- predicted total load of system, P_N --basic load taken by nuclear generating set, N_{DH} -- predicted total load of water grid, P_{DT} -- predicted total load of coal power grid.

2.2 Internal Optimal Power Dispatch among Coal Power Units, Hydro Units and Nuclear Units

The consumption characteristic of the thermal power plant means the relationship between the consumption of fuel F (when it functions in the specified load) and output of electric power P. The consumption characteristic of fuel of the generating set can be expressed as $F = F(P)$, which is usually conveyed with conic section.

Optimal power dispatch of coal-fired machines Model2:

Objective function: $$\min F_D = \sum_{i=1}^{n} (a_i P_i^2 + b_i P_i + c) \quad (3)$$

Constraint condition: $$\begin{cases} \sum_{i=1}^{n} P_i - P_D = 0 \\ \sum_{i=i}^{n} (P_{i\max} - P_i) \geq d \\ P_{i\min} \leq P\, i \leq P_{i\max} \end{cases} \quad (4)$$

$$i = 1,2,\cdots,n$$

F_D --total consumption of coal of system, P_i -- load of every generating set, P_D --total load of system, $P_{i\min}$-- the maximum power of the thermal generating set, $P_{i\max}$ -- the normal rated (the minimum) power of the thermal generating set, d --the minimum spinning reserve capacity of system, const. In accordance with the related regulations, the reserve capacity of system includes spare capacity of load and spare capacity of accident. The spare capacity of load should be no less than 2% of the maximum load[4].

3. Realization of the model

Both Model1 and Model2 conform to quadratic programming model. The description as follows[2]:

Objective function： $$\min(\frac{1}{2} x^T H x + f^T x) \quad (5)$$

Constraint condition： $\begin{cases} Ax \le B \\ A_m x = B_{eq} \\ x_m \le x \le x_M \end{cases}$ (6)

It can be solved with function $quadprog()$:

$$[x, f_{opt}, flag, c] = quadprog(H, f, A, B, A_{eq}, B_{eq}, x_m, x_M, x_0) \quad (7)$$

H—the Hessian Matrix of objective function, x_0 --initial searching point. If the constraint condition is nonexistent, it should be covered with empty matrix. The result will be returned in x, and the optimal objective function will be returned in f_{opt} .The result is correct if $flag$ is above zero.

Specific steps:

(1) Make an arrangement of load for nuclear machines according to the situation;

(2) Work out the relationship between W_D and N_{DH} from model1, and we'll get the line of load-water consumption in water grid. Finally, we can know the predicted total load of water grid N_{DH};

(3) After step1 and step2, the load of nuclear and that of hydropower are known. Afterwards, predicted total load of thermal grid is got with the expression of relation, $P_D = P_N + N_{DH} + P_{DT}$;

(4) Work out the problem of optima power dispatch within hydro machines and coal-fired machines.

4. Case study

Some electric fence contains: one nuclear unit of 300MW, six thermal power units (with two of 200MW, two of 300MW and two of 600MW), three hydro units (with one of 150MW, one of 300MW and one of 600MW). The characteristics of thermal units and hydro units are listed in Table 1 & 2. Table 3 shows the load for typical working days. Table 4 shows the water prediction in the system.

Table 1 the characteristics of coal consumption.

Name	MIN Power MW	Normal Power MW	The characteristics of coal consumption（t）
Machines Ⅰ	120	200	$F = 0.0003P^2 + 0.1934P + 17.595$
Machines Ⅱ	120	200	$F = 0.0003P^2 + 0.1934P + 17.595$
MachinesⅢ	200	300	$F = 0.0002P^2 + 0.189P + 19.487$
MachinesⅣ	200	300	$F = 0.0002P^2 + 0.189P + 19.487$
Machines Ⅴ	360	600	$F = 0.000009P^2 + 0.2778P + 14.146$
MachinesⅥ	360	600	$F = 0.000009P^2 + 0.2778P + 14.146$

Table 2 the characteristics of water consunption.

Name	MIN Power MW	Normal Power MW	The characteristics of water consumption（t/h）
Machines Ⅰ	0	600	$W = 0.25N^2 + 0.00375N$
Machines Ⅱ	0	300	$W = 0.6N^2 + 0.0055N$
MachinesⅢ	0	150	$W = 1.225N^2 + 0.007N$

Table 3 the load for typical days.

Time	0	1	2	3	4	5
Load	1850	1800	2050	2000	2250	2250
Time	6	7	8	9	10	11
Load	2310	2380	2450	2550	2620	2690
Time	12	13	14	15	16	17
Load	2700	2680	2610	2600	2350	2410
Time	18	19	20	21	22	23
Load	2390	2280	2330	2150	2200	2050

Table 4 the water prediction.

Time	0	1	2	3	4	5
Amount	390	1540	3470	6170	9640	13880
Time	6	7	8	9	10	11
Amount	18900	24680	31240	38560	46660	55530
Time	12	13	14	15	16	17
Amount	55530	38560	38560	24680	9640	9640
Time	18	19	20	21	22	23
Amount	13880	13880	18900	18900	18900	13880

4.1 The Results of Model

When the basic load of nuclear machines is 300MW, the line of load-water consumption in water grid is shown in Figure2.

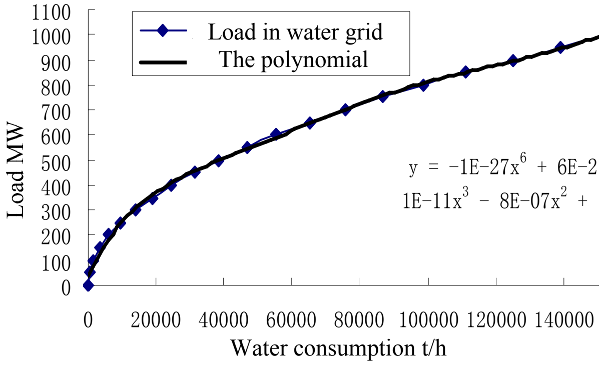

Fig. 2 Load-water consumption in water grid

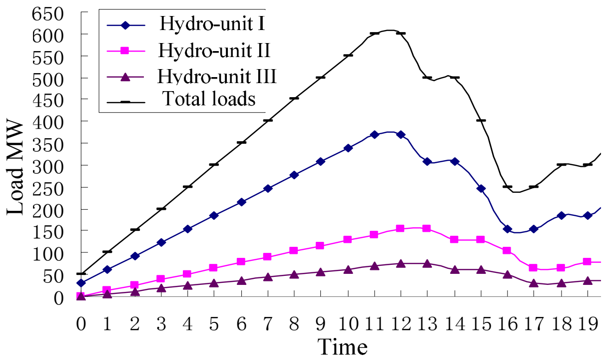

Fig. 3 The load for hydro-units

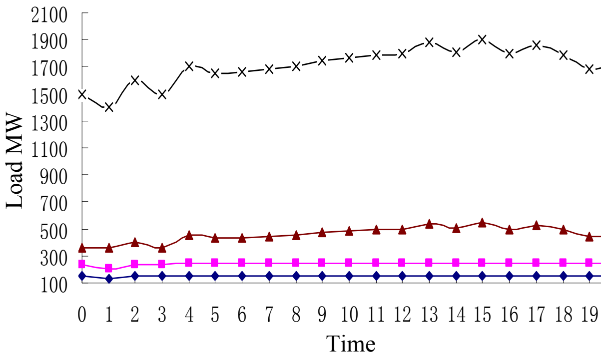

Fig. 4 The load for thermal units

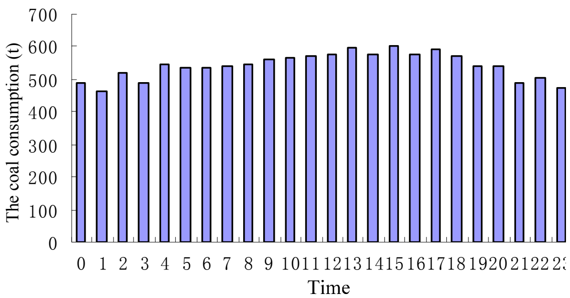

Fig. 5 The coal consumption for hydro-units

4.2 Sensitivity Analysis

The load dispatch for hydro-units, thermal units and thermal machines are got from figure 3, 4 and 5. The sensitivity analysis is necessary because of the uncertainty of hydrological data. This part is based on the running of thermal units, and the quality of water varies from a to b.

$$a = -\min(W^j) \tag{8}$$

$$b = f[\min(P^k) - P_N - \sum_i P_{i\min}] - W^k \tag{9}$$

j=1，2，…24，k=1，2，…24

W^j --the water amount at time j, W^k -- the water amount at time k, the data is shown in table 4; P^k -- predicted load at time k, the data is shown in Table 3. $f(x)$ -- the equation of water amount. In the analysis, a=-390，b=4630. The result is shown in figure 6.

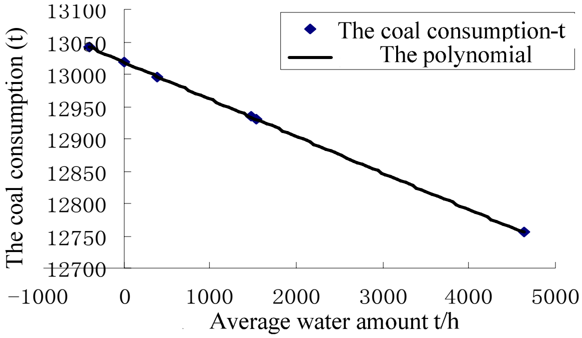

Fig. 6 Sensitivity analysis for average water amount

The sensitivity analysis makes it clear that with the average water amount increases the coal consumption for hydro-units decreases.

5. Conclusions

This paper sets up a model in power market for hydro-thermal-nuclear power system. With the model, the problem of allocating hydro loads and thermal loads and work out the water and coal consumptions will be solved. The computing technique in this text demands accuracy of consumption characteristic of the thermal and water power machines. Conclusion: nuclear machines are first considered in the problem of optimal power dispatch within hydro machines, nuclear machines and coal-fired machines, which will simplify the problem. The computing technique proved correct whit the example.

References

[1]Yuan Xiaohui，Yuan Yanbin，Wang Jinwen，et al. A survey of optimization methods for short-term generation scheduling of hydrothermal power systems[J]. Electric Power，2002，35(9)：33-38(in Chinese).

[2]Wang Xinxing，Zhang Ming. Short-term scheduling optimization of hydro-thermal power systems based on refined particle swarm algorithm[J]. Power System Technology，2004，20(12)：16-19(in Chinese).

[3]Zhu Min，Wang Dingyi. Daily optimal operation of cascade hydroelectric power stations based on artificial neural network[J]. Automation of Electric Power Systems，1999，23(10)：35-40(in Chinese).

[4]Yuan Xiaohui，et al. Application of quasi-gradient genetic algorithm to economic operation of hydropower station[J]. Power System Technology，2000，24(12)：66-69(in Chinese).

[5]Yao Jiangang，Liu Yong，Wu Zhengqiu，Jiang Yuechun. Daily optimal economic dispatch in electricity market[J]. Electric Power Automation Equipment，2001，26(1)：17-20(in Chinese).

[6]Jiang Hui，Peng Jianchun，Yang Qiyu. Study of optimal bi-objective real power dispatch for power markets[J]. Proceedings of the EPSA，2000，12(5)：15-18(in Chinese).