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Optimal Dispatching Model Considering the Pumped Storage Power Plant in Hunan

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ABSTRACT

This paper made a research on the Intelligent Optimization Operating Modeling of Pumped Storage Power Station in Hunan Power Grid. First it introduces the characteristics of Hunan power grid and analysis the practical requirement of dispatching. Then it brings forward the intelligent optimization model and set up running model for pumped storage power station of Hei Mi-feng. At last, it introduces the application of pumped storage power station in Hunan power grid and proves the effectiveness of the optimization models.

Keywords: Intelligent Optimization; Dispatching Model; Pumped Storage Power Station

1. Introduction

With the large capacity, high parameters coal-fired power plants are put into operation, especially the development of nuclear power plants, peak shaving, safe and stable operation and reliable power supply face more severe situation. Fully realizing the status and the function of the pumped-storage power stations in the safe and stable operation of the power system[1], researching the pumped storage power plants' related problems of benefits and development and, further researching the pumped storage power plants optimal operation model, have important realistic meaning and theoretical research value to promote the development of the pumped-storage power station and to maintain the safe and stable operation of the grid[2].

This paper combining with the characteristics and actual needs in scheduling of Hunan power grid, studies the intelligent optimization strategy which the Hei Mi-feng pumped storage power plant is in scheduling, and establishes corresponding optimal operation model.

2. The Methods and Problems of Dispatching Peak Shaving in Hunan Grid

At present, to satisfy the peak power demand, Hunan grid system solves the peak[3] shaving problem mainly through the following means:

a) Thermal power: small units such as 50,125,200 MW can pitch peak through start-stop, large units such as 300 MW can output variable load.

b) Hydraulic power: it is very ideal to pitch peak at delivery period, but most of the hydropower plants can only guarantee the output operation at that time.

c) DSM: take measures of lime price to some big users.

Based on the specific characteristics of Hunan power grid, and existing load methods, it can be concluded that there are several problems in Hunan grid as following:

a) The peak shaving capacity of hydraulic power is easily limited in rainy season.

b) Thermal power load does have some disadvantages.

c) The big difference between peak and valley puts forward higher request to power load performance.

The starting of Hei Mi-feng pumped storage power plants will naturally help to solve the problem of Hunan network load. The power station, which is rapid and flexible to start and stop, energy efficiency, economic, environmental protection characteristics, will bring huge benefits for grid. It also helps the power grid to make load of electric decisions of pumped storage units, thermal power unit, and the coexistence of hydro turbine more scientific and reasonable.

3. Hei Mi-feng Pumped Storage Power Plant Profile

Hei Mi-feng pumped storage power station is located in the Qiaoyi town, Wangcheng County, Hunan province. It is close to Hunan grid electricity load center Changsha, Zhuzhou and Xiangtan area, south from Changsha city just 25 km, from Zhuzhou and Xiangtan less than 50 km, the geographical position is superior.

Engineering hub mainly consists by three big building supper reservoir, water power generation system and lower reservoir, which installing four 300 MW each reversible hydraulic pump unit, gross installed capacity is 1200 MW. It is designed to generate peak power, 1.606 billion kW·h, and to consume 2.141 billion kW·h by pumping each year.

4. The Scheduling Strategy of Pumped Storage Power Plant

4.1. Considering the Basic Idea of Pumped Storage Power Plant Grid Dispatching Model

The basic idea of the scheduling model is: start from the whole power system and the reality, fully consider of the technical and economic characteristics of all kinds of power station in the system[4] (including hydropower and thermal power, nuclear power and pumped storage power station, etc.) and relevant operation system constraints under the situation that the load, the installed capacity of power station and hydropower station's hydrological data known. Arrange the working position and capacity of each power station in system typical day (week) month after month in load curves; make full use of hydropower, to reduce the system conventional thermal power unit boot capacity. Make work position and work capacity of pumped storage, thermal power, nuclear power stations and their start-stop by economical efficiency, to meet operation system load demand on the best ways.

The goal is to make the entire units operation cost minimum in the system, and also to make the conventional thermal power unit capacity and the electricity generation least, to achieve the purpose of section coal.

Operation simulation calculation process and procedure roughly as follows:

1) Look for the work position of hydropower, according to the adjustable output and expected power in hydrological years,

2) Get the work position pumped storage power plant,

3) Calculate the generation process, storage capacity, electricity and operation cost, etc., according to the work position.

4.2. The Mathematics Model of the Pumped Storage Power Station's Scheduling Planning

4.2.1. The Objective Function

The objective function of operation simulation of pumped storage power plant is the minimized operation cost in research period

$$C = \min \sum_{t=1}^{T} (F_t + R_t + D_t) \tag{1}$$

C: the total cost of operation every week in the system, ten thousand;

F_t is the fixed operation cost at t period in the system; R_t is the fuel cost at t period in the system; D_t is the variable cost at t period in the system, including the start-stop losses and the operation cost of the hydropower and pumped-storage units, ten thousand; T is the number of operation cycle time, this paper take T = 168 h.

Hydropower units with no coal consumption, so fuel costs can be neglected[5]; the pumped-storage units replace other units to generate power in power generation condition, its power benefit is the operating costs of the replaced units, when the pumped-storage unit in pumping condition, the pumping cost equals the increased supply of pumping thermal power unit of power operation costs. So the objective function for the plan is practical calculation and pumped storage power station in valley of pumping after thermal power unit system operation cost and the pumped-storage unit to substitute other unit's load the fixed cost saving the minimum sum.

4.2.2. Constraint Condition

a) The related constraints of pumped storage

1) Pumped storage capacity constraints

Power generation capacity constraint

$$0 \le P_g(t) \le P_{g,\max} \tag{2}$$

Pumping capacity constraint

$$0 \le P_{pu}(t) \le P_{pu,\max} \tag{3}$$

Without other restrictions, to make full use of the unit capacity, generally think $P_{g,\max}$, $P_{pu,\max}$ equal to the pumped storage power plant capacity.

2) Power balance constraints

Under the restricted constraints ①, get week pumping power:

$$\sum_{i=1}^{7} Epu(i) = \sum_{t=1}^{168} P_{pu}(t) \tag{4}$$

The biggest generating capacity constraints on i day:

$$0 \le Eg(i) \le \eta \sum_{1}^{i} Epu(i) \sum_{1}^{i-1} Eg(i) \tag{5}$$

Eg (0) = 0.

3) Capacity constraints

Set pumped storage power station as a reference for processing agricultural products on power C, then

$$\max(Es(i)) \le C \tag{6}$$

4) Work position constraints

To avoid the position overlap of pumped storage position and generation position, it must satisfy the follow:

$$P_{pu,up} \le P_{g,down} \quad (7)$$

Pumping work position also can't overlap with hydropower work position, it must satisfy the follow:

$$P_{pu,up} \le P_{H,down} \quad (8)$$

5) Water balance constraints

$$W_{S_{168}} = W_{S_0} \quad (9)$$

$$W_S(i) = W_S(i-1) + Wpu(i) - Wg(i) \quad (10)$$

while $P_g(t)$ is the power generation capacity of pumped storage power station at t period; $P_{pu}(t)$ is the pumping capacity at t period; $P_{g,\max}$ is the max power generation capacity; $P_{pu,\max}$ is the max pumping capacity; $P_{pu,up}$ is the upper pumping limit of pumped storage power station, $P_{g,down}$ is the lower; $P_{H,down}$ is the lower limit of hydropower; Eg (i) is the day power generation of pumped storage power station;

Epu (i): the day pumping power consumption of pumped storage power station, MWh;

H: the pumped-storage unit pumping-power efficiency;

Wg: he power generation water consumption;

Wpu:the quantity of pumping, m^3.

b) The related constraints of thermal power units

1) Thermal power unit output constraint

$$P_{i\min} \le P_i(t) \le P_{i\max} \quad t = 1,2,\cdots,168 \quad (11)$$

In it $P_i(t)$: the output of the i thermal power unit at t period, MW;

$P_{i\min}$: The minimum technological output of the I thermal power unit at t period, MW;

$P_{i\max}$: The maximum technological output of the *i* thermal power unit at t period, MW.

2) Unit climbing constraint

The climbing constraint should be decided based on the units' output at t moment, the units' output upper and lower limit and the allowable adjustment step length, shown below:

$$\Delta P_i^{\min} \le P_i(t) - P_i(t-1) \le \Delta P_i^{\max} \quad (12)$$

When the output is increasing:

$$\begin{cases} \Delta P_i^{\max} = \min(P_{i\max} - P_i(t), r_{ui}) \\ \Delta P_i^{\min} = 0 \end{cases} \quad (13)$$

When the output is decreasing:

$$\begin{cases} \Delta P_i^{\max} = 0 \\ \Delta P_i^{\min} = \max(P_{i\min} - P_i(t), -r_{di}) \end{cases} \quad (14)$$

r_{ui}: The maximum climbing speed allowed by output in the unit time of the i kind thermal power unit, MW;

r_{di}: The minimum climbing speed allowed by output in the unit time of the *i* kind thermal power units, MW;

$\Delta P_i^{\min}$: The lower limit of the i kind thermal units' power, MW

$\Delta P_i^{\max}$ r_{ui}: The maximum climbing speed allowed by output in the unit time of the i kind thermal power unit, MW;

r_{di}: The minimum climbing speed allowed by output in the unit time of the i kind thermal power units, MW;

$\Delta P_i^{\min}$: The lower limit of the i kind thermal units' power, MW

$\Delta P_i^{\max}$: The upper limit of the i kind thermal units' power, MW.

3) Related constraints to the system

1) Balance constraints of electric system capacity

$$\begin{aligned} &P_D(t) + P_{LOSE}(t) \\ &= \sum_{i \in G} U_i(t) P_i(t) + PS(t) + P_H(t) + \sum P_{ot} \end{aligned} \quad (15)$$

2) System spares constraints

$$\sum_{i \in G} U_i(t) P_{\max i} \ge P_D(t) + P_R(t) \quad (16)$$

In it $P_D(t)$: system load at t moment, MW;

$P_{LOSE}(t)$: network loss at t moment, MW;

$U_i(t)$: 0,1 integer variable,0 means stop,1 means start, at t moment ;

$PS(t)$: boot capacity of pumped storage power plant at t moment, MW;

$P_H(t)$: generated output of hydropower at t moment, MW;

P_{ot}: The total boot capacity of other types of units, except thermal, storage units, MW

$P_R(t)$: spins reserve of the electric system at t moment, MW.

5. Pumped Storage Power Plant Operation Mode

5.1. Model State

According to load characteristics, the system may stay at a low load for several days in a week there, and increase to a high load for other days, so the weekly regulation pumped storage power station may adjust the focus on the continuously pumping without power in a few days and adjust the focus on the continuously power without pumping in other few days. In this way, the weekly regulation pumped storage power station has stricter demand of the storage capacity than the diurnal one. Differently from the diurnal one, the storage capacity of the weekly regulation pumped storage power station is based on the weekly capacity. Thus there are many differences between the weekly one and the diurnal one no matter in power plant capacity, water capacity or even the role the weekly one played on and the benefit it gained.

From consideration of the operational model pumped storage power station characteristic, it can not only take the minimum running costs of its economic indicators as the objective function to run the simulation, but also take into account the peak of its good performance. The determining of the location of utilities should be arranged after the cramps working position, and it should reduce coal consumption as much as possible when filling the valley to meet the peaking needs of the system. The goal is to make full use of pumped storage power plant capacity, and to meet weekly cycle power plant operating characteristics.

5.2. Mathematical Model

This paper, based on the work of the output after deducting hydropower station system fixed weeks load curve, establish pumped storage power plant operation simulation objective.

Function is as follows:

$$\begin{cases} P_{g,up} - P_{g,down} \le P_{g,\max} \\ \sum_{t=1}^{168} P_g(t) = \eta \sum_{t=1}^{168} P_{pu}(t) \\ P_{pu,up} - P_{pu,down} \le P_{pu,\max} \end{cases} \quad (17)$$

$P_{g,up}$, $P_{g,down}$: top and bottom limitation of power position of the pumped-storage power station in fixed weeks load curve , MW;

$P_{pu,up}$, $P_{pu,down}$: top and bottom limitation of pumping position in pumped-storage power station, MW;

$P_{g,\max}$: The maximum capacity of pumped-storage power station, MW;

$P_{pu,\max}$: The maximum pumping power capacity of pumped-storage power station, MW;

$\sum_{t=1}^{168} P_g(t)$: week power generation of pumped-storage power station, MWh;

$\sum_{t=1}^{168} P_{pu}(t)$: week pumping power consumption of pumped-storage power station, MWh;

η: pumping-generation efficiency of pumped-storage power units.

6. The Role of Synchronize and Close

Hei Mi-feng pumped storage power station mainly use low power consumption or the amount of abandoned water pumping to pump water in the lower reservoir into the reservoir on the store. When the peak comes, water drive turbine power generation will be run in the potential energy of the water flow from high reservoir to the low. The way of making the abandoned or low reservoir water volume become high quality of peak processing power, reduce and avoid energy waste effectively. Construction of the Hei Mi-feng power plant optimized the structure of power in Hunan Province greatly, solving the load imbalance season problems. Especially in the flood season, the pumped storage hydroelectric power plants take advantage of other diarrhea flood of abandoned water pumped storage power generation, in the summer peak period, and then water to generate electricity, in order to address the province's electricity "excess flood, lack Xuzhou's situation.

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