

Joint Dispatching of the Reservoirs in the Yuanshui Basin Based on Regime Forecast System and Intelligent Meteorology Forecast

Yujun Mo^{1,a}, Xin Wu¹

¹WULING POWER CORPORATION LTD., Changsha, China

Abstract. This paper briefly introduces the construction of Wuling's automatic monitoring and forecast system of flood regimen, intelligent meteorological system and cascade reservoir dispatching system, and summarizes the joint power generation dispatching and flood control dispatching of cascade reservoirs in Yuanshui basin since 2010. Taking the Yuanshui basin flood in 2017 as an example, the application of joint flood control dispatching for reservoirs is analyzed. The relevant research results of this paper can be used as reference for production technology management personnel.

1 Company and Remote Dispatching Center profile

Wuling Power Corporation Ltd. (Wuling), namely State Power Investment Corporation Limited Hunan Branch, is a comprehensive energy company with hydropower, thermal power, wind power and solar power generation. In 1996, Wuling was authorized by the State Council to take full responsibility for the development, construction and operation of the cascade hydropower plants on Yuanshui in Hunan. By the end of July 2018, Wuling has total installed capacity in operation of 7190MW, including hydropower 4830MW, thermal power 1300MW, wind and solar power 1060MW, excluding 487MW under construction. With 82% generation from clean energy, Wuling is the largest clean energy supplier in Hunan.

With sustainable management innovation, Wuling creates a new power generation dispatch and control mode so as to set up a Remote Dispatching Center. All its 12 hydropower plants (Figure 1) are of remote centralized



Figure 1. Wuling hydropower plant distribution

control under unattended operation with one operator on-call monitoring several plants. Up to date, 54 generator units are connected into the Remote Dispatching Center, with a total installed capacity of 4660MW, which is the largest and at domestic leading level in respect of the number of power plants and generator units under control.

2 Technical Support

Yuanshui flows through three provinces Yunnan, Hubei and Hunan as well as Chongqing municipality. It belongs to the Dongting Lake system, with a basin area of 90000km². The total length of the mainstream is 1050km, with a hydraulic drop of 1035m, and the perennial average annual runoff is 65.3 billion m³. The inter-annual variation of the Yuanshui runoff is large, and the water distribution during the yearly is uneven. The amount of incoming water from May to July in the main flood season accounts for 50% of the whole year.

Wuling continues to research and explore the joint optimal dispatching of cascade reservoirs by combining the regime forecast system and hydro-meteorological forecasting, which exerts great economic and social benefits. At present, a technical support platform based on regime forecast system and intelligent meteorological system and cascade reservoirs dispatching automation system has been built to realize optimal dispatching of cascade reservoirs in the basin.

1. The information of hydrological department shared with the regime forecast system of Wuling. There are 1 central station, 12 sub-central stations, and a total of 289 telemetry stations, including 48 hydrological stations (water level stations) and 241 rainfall stations. Yuanshui has been fully covered. The system adopts GPRS + VHF communication networking mode and self-reporting mode, supplemented by recruitment and measurement, to realize real-time monitoring^[1]. Combined with the

natural characteristics of the tributaries of Yuanshui and the flood forecasting model of each power station, the telemetry station is proposed to be optimized. The average rainfall station area represents 300km²/station. According to the needs of the forecast model, five automatic hydrological stations were built on some tributaries, which make up for the vacancies in the hydrological department station network. The close integration of the telemetry station network with the forecasting model ensures the accuracy of the flood forecasting. The regime forecast system realizes the interaction and sharing between the real-time hydrological data of hydrological departments.

2. Intelligent meteorology system based on GIS technology. The company has carried out long-term, medium-term and short-term meteorological forecast research with technical support of Hunan Professional Meteorological Observatory. Through the integration of meteorological, electric power and hydrological information, we will build a meteorological service system which integrates meteorological monitoring, forecasting and warning with the water and electricity image service and new energy meteorological service as the core, providing the company with full-service of meteorological. The system includes meteorological real-time gathering and monitoring, hydropower meteorological service, wind power meteorological service, solar power meteorological service, auxiliary decision-making meteorological service and other modules to achieve real-time monitoring and early

warning of meteorological elements (rainfall, temperature, wind speed, humidity, etc.), and real-time view of satellite cloud images and related radar echo. The basin meteorological forecast mainly adopts the downscaling method for the basin and establishes the storm forecast model of the reservoir basin to realize the multi-element, high-resolution and high-precision meteorological data gridding, narrow the hydro-meteorological coupled precipitation space matching difference, and carry out the numerical forecast of watershed rainfall with basin runoff and confluence characteristics as subdivisions. It is reported that daily rolling service is provided for forecasting rainfall in 72-hour meeting period and daily rainfall in 15-day meeting period. The results of numerical forecasting should be revised by forecasters in combination with experience and geographical characteristics, assigned to hydrological stations for operation of reservoir dispatching automation system to effectively prolonging flood foreseeing period and improve forecast accuracy^[2].

3. The multi-system interconnected intelligent dispatching automation system. It realizes the seamless connection with the power generation monitoring system of the centralized control power plant, the flood gate control system, the energy metering system, the regime forecast system, and the intelligent meteorological system. The system has the core functions of water affairs calculation, flood forecasting, flood dispatching and

Table 1. The statistics of main power plant performance index in Yuanshui

| Power plant | Installed capacity (MW) | Design power generation (10 ⁸ kWh) | Basin area (km ²) | Runoff (10 ⁸ m ³) | Normal water level (m) | Regulating storage capacity (10 ⁸ m ³) | Regulating performance |
|-------------|-------------------------|---|-------------------------------|--|------------------------|---|--------------------------------|
| Sanbanxi | 1000 | 24.28 | 11050 | 75.96 | 475 | 26.16 | Overyear regulation |
| Baishi | 420 | 12.32 | 16530 | 111.40 | 300 | 1.72 | Seasonal regulation |
| Tuokou | 830 | 21.31 | 24450 | 163.28 | 250 | 6.15 | Incomplete year regulation |
| Wanmipo | 240 | 7.92 | 10420 | 92.00 | 248 | 1.25 | Incomplete Seasonal regulation |
| Wuqiangxi | 1200 | 53.7 | 83800 | 623.29 | 108 | 20.2 | Seasonal regulation |

power generation dispatching. The flood forecasting module adopts the Three-source Xin'anjiang Model to support the forecast of rainfall, so as to effectively prolong the forecasting period of water regime^[3]. At present, the average accuracy of short-term flood forecasting reaches 92%, which is the main basis for flood dispatching decisions. The flood dispatching module can realize "one-button scheduling" and provide preliminary scheduling scheme for reservoirs; it can manually intervene to perform detailed scheduling operations such as peak-shift scheduling, flood interception scheduling, gate scheduling, etc., and provide technical support for flood control scheduling of cascade reservoirs. The power generation dispatching module has three kinds of optimization calculation modes: hybrid control, maximum power generation and maximum power generation revenue. It provides technical support for the economic operation of cascade

power stations.

Aiming at the dispatching characteristics of the run-of-river hydropower plant, Wuling deploys the automatic opening and closing joint function of sluice gates in the control system of the low-head power plant, which can automatically start diesel power generation and open the flood discharge after the machine and flood discharge alarm process in emergency situations such as unit accidents and power loss of the whole plant. This function save about 10 minutes compares with manual operation; it greatly saves valuable time for handling accidents and efficaciously ensures dam safety. After the function was put into operation, the labor intensity of the on-duty personnel was reduced, and through the program was automatically refined and adjusted, the annual running water level was raised by an average of 3 cm and the increase of annual power generation was 420,000 kW·h.

3 Joint operation of reservoirs in Yuanshui basin

3.1 Joint dispatching main object

The dispatching relationship of the substation of Wuling is complex. The power generation dispatch involves the three-level dispatching mechanism of the State Grid Corporation of China (SGCC) for central China power grid, provincial power grid and local power grid. The flood control dispatch involves the provincial and municipal flood control departments of Guizhou and Hunan provinces.

Wuling has five hydropower plants with seasonal regulation and above in Yuanshui basin. It is the main target of joint dispatching of reservoirs. The main performance indicators of each power plant are shown in Table 1. Others are run-of-river hydropower plant, which are dispatched according to the principle of high water level control and the water balance.

3.2 Joint optimal dispatching of power generation

According to the hydrological characteristics, engineering characteristics, power market, power supply and grid structure of each reservoir, comprehensive analysis is made to formulate various reservoir dispatching plans.

1. Lowering the water level before the flood season. At the end of a year, The State Grid Huazhong Branch and Hunan Branch convened a special meeting to communicate the water level control scheduling ideas and reached a consensus, and the next year's "Water Level Control Plan before Flood Season for the Key Reservoirs of the Yuanshui" will be prepared. By reasonable controlling the sequence and the speed of the variation in water level of each reservoir, the reservoir group plays the role of the water compensation and the head benefit before the flood season, and reserves the storage capacity for the flood season^[4].

2. According to the specific hydrological regime, making the full exploitation performance of each reservoir, and taking priority water utilization as the principle we can reduce the abandonment water of each water reservoir and improve the utilization ratio of water by carrying out several measures in flood season. Such as vacating the reservoir before the flood, dynamic controlling the flood limit level, intercepting the flood tail, transferring load between plants, and utilizing the reservoir action in upstream.

Table 2. Statistical of reservoir optimization

| Year | Power generation (10 ⁸ kW·h) | Increased power generation (10 ⁸ kW·h) | Increased rate (%) |
|------|---|---|--------------------|
| 2010 | 98.827 | 1.83 | 1.85% |
| 2011 | 75.377 | 0.951 | 1.26% |

| | | | |
|----------|----------|--------|-------|
| 2012 | 106.694 | 5.7 | 5.34% |
| 2013 | 116.376 | 2.85 | 2.45% |
| 2014 | 155.907 | 9.5 | 6.09% |
| 2015 | 170.364 | 8.3 | 4.87% |
| 2016 | 165.348 | 5.813 | 3.52% |
| 2017 | 155.808 | 4.78 | 3.07% |
| In total | 1044.701 | 39.724 | 3.80% |

3. Water storage after the flood season. We strengthen the communication with the authority of flood control, meteorological and power grid dispatching. Taking advantage of the last flood and controlling the water level properly in the flood season, the high water level operation can be realized and the utilization efficiency of the head of the hydropower plant can be increased during the dry season.

According to statistics, since Wuling launched hydropower centralized control, the reservoir optimization dispatched increased power generation by 3.97billion kW·h, equivalent to an increase of 1.2 billion RMB. The increased rate of optimized dispatching power in Yuanshui is about 3.8%.

3.3 Joint dispatching of flood control

3.3.1 Statistics on flood since 2010

The Yuanshui basin is relatively long and narrow, and it is generally rarely to encounter the heavy flood throughout the basin. During the period from 2010 to 2017, the heavy flood throughout the main stream of basin occurred in 2017, regional floods occurred in other years, and only medium and small floods occurred in the upper reaches of the main stream.

Taking Wuqiangxi reservoir as an example, there were 48 times with the flood peak flow more than 6000m³/s in the Yuanshui basin. Among them, medium and small flood (peak flow between 6000 m³/s to 20000 m³/s) occurred 41 times, heavy flood (peak flow more than 20000m³/s) occurred 7 times.

3.3.2 Main flood dispatching

Yuanshui was in the low water during 2010 to 2013. Due to the low water level control operation of the Sanbanxi reservoir during the flood season and the construction of Baishi reservoir and Tuokou reservoir, there was no serious flood in the upper reaches of Yuanshui. From 2014 to 2016, Baishi reservoir and Tuokou reservoir successively stored water for power generation. For the problem of reservoir area immigration, Baishi and Tuokou reservoir controlled the low water level operation, and regulating storage of Sanbanxi reservoir in flood season, there was no design standard flood occurred in the upstream, and it ensured the safety of immigration in flood season.

Wuqiangxi reservoir can independently undertake the

flood control tasks which the flood is less than 20-year for downstream of Yuanshui basin. But it is necessary to joint Wuqiangxi reservoir and Fengtan reservoir to undertake the flood control tasks which the flood is more than 20-year for downstream of Yuanshui basin. Wuqiangxi reservoir has a great peak effect on flood interception for short time. The peak flow of the largest flood in the past years is above 7500m³/s, the peak clipping rate is above 25%, and reduce of the water level of the downstream is more than 1.5m.

3.4 Study Case

From June 22rd to July 2rd, 2017, a basin-wide flood occurred in Yuanshui. The rainstorm process is characterized by “wide rainfall range, strong precipitation intensity, long duration, large accumulated rainfall, and heavy rain center swinging back and forth”. Under the unified dispatch of the flood control departments of Hunan and Guizhou, Wuling Company fully exerted the joint flood control dispatching function of the Yuanshui cascade reservoirs, and gradually intercepted flood, then the pressure of the flood control reduced obviously in downstream. The floods and main dispatching conditions of each power plant are as follows:

- 1、 The peak discharge of Sanbanxi was 6140m³/s (5-year). Sanbanxi power plant had stopped generation before the flood subsidence in the downstream area. It intercepted the flood to 1.06 billion m³, and reduced the peak flow for Baishi by 5350 m³/s.
- 2、 The peak discharge of Baishi was 5970m³/s

(20-year). It intercepted the flood to 120 million m³, and reduced the peak flow for Tuokou by 870 m³/s, and shifted the peak flood in Tuokou for 12 hours.

3、 The peak discharge of Tuokou was 9570m³/s (20-year). It intercepted the flood to 225 million m³, and shifted the peak flood in downstream for 16 hours. It ensured that Tuokou and the Anjiang didn't break the design safety flow of which the corresponding was 13900m³/s and 16600m³/s respectively.

4、 The peak discharge of Wuqiangxi was 32400 m³/s (Over 20-year). It had released 966 million m³ before the flood, and intercepted the flood to 1.547 billion m³. Wuqiangxi reservoir maximum outflow was 22500m³/s, which clipped the peak by 9900m³/s and delayed the downstream peak for 30 hours.

5、 Through the combined flood control dispatching of the cascade reservoirs, a total of 3 billion m³ of floods was intercepted, and the downstream water level was lowered by 2m-2.5m. It ensured flood control safety in the area of the Yuanshui, and making an important contribution to the goal of safety proposed by the Hunan Provincial Government. According to the preliminary analysis, if there is no Sanbanxi, Baishi and Tuokou reservoirs combined flood control dispatching, the flood peak flow of Wuqiangxi would increase to over 38000m³/s, and the maximum 3-day flood volume would increase to 7.41 billion m³. The flood similar to the 1996 would be re-emerged, and severe flood damage would be occurred in the downstream area.

The actual situation of flood control dispatching of each power plant is shown in figure 2(a)-(e).

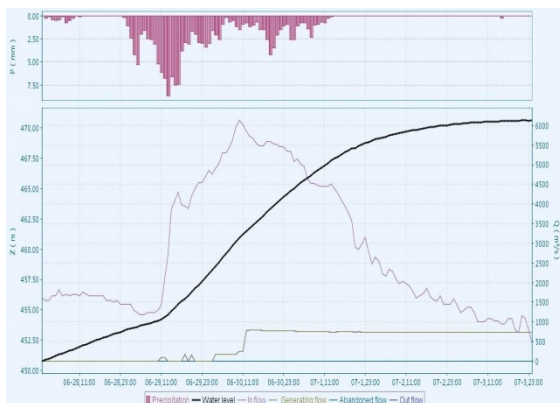


Figure 2(a). Integrated water regime of Sanbanxi reservoir



Figure 2(c). Integrated water regime of Tuokou reservoir



Figure 2(b). Integrated water regime of Baishi reservoir



Figure 2(d). Integrated water regime of Wuqiangxi reservoir

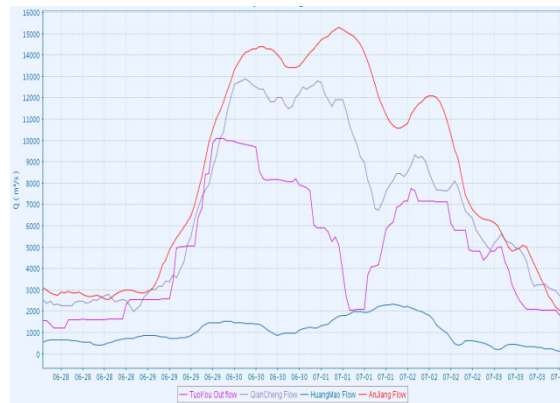


Figure 2(e). Joint flood control dispatching curve of Sanbanxi, Baishi, Tuokou reservoir

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