Research on Intelligent Operation and Maintenance Technology of Pumped Storage Power Plant Based on 5G

Meng Ye(✉), Guan-jin Huang, Peng Gao, Miao-geng Wang, and Xu-hui Zhang

CSG Peak Shaving and Frequency Modulation Power Generation Co., Ltd., Guangzhou 511400, China
ym42856@163.com

Abstract. Due to the poor data communication transmission effect of the current power station operation and maintenance technology, the equipment failure rate is high. To solve this problem, the intelligent operation and maintenance technology of pumped storage power plant based on 5G is designed. The technical design process is completed by constructing the operation state estimation model of pumped storage power plant, setting up the inspection contents and 5G operation and maintenance platform. Through comparison, it can be seen that the application effect of 5G technology is better than current technology.

Keywords: 5G network · Pumped storage power plant · Operation and maintenance management · Virtual reality technology

1 Introduction

The rapid development of mobile communication industry has led to the rapid development of communication technology, which has brought great convenience to people's communication and provided high quality communication services for people. In recent years, with the improvement of people's requirements on the service quality of the communication industry, 5G mobile communication network technology has achieved rapid development. Compared with 4G communication technology, 5G mobile communication technology brings people a good network experience, greatly improves the network transmission speed, and meets people's needs for high-quality network use. 5G mobile communication itself shows a high data rate, and in the actual use process, it meets the bandwidth requirements of IGHZ [1, 2].

With the continuous progress of society and the enhancement of scientific and technological strength, the development of power grids is also changing with each passing day. Power customers have raised higher standards for the demand for reliability of power supply and the diversification of services. In order to optimize the allocation of resources and adapt to the development process of the current power grids, the State Grid Corporation has put forward a new strategic goal, namely, to build a unified, strong and smart power grid [3, 4]. With a large number of innovative technologies injected into the intelligent construction of power grids, further promote

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the development of power plant grid management model by leaps and bounds. Pumped-storage power plant is the core of the power transmission process, which means the operation and maintenance of its intelligent equipment become an important part of the smart grid development strategy.

At present, the installed capacity and power generation capacity of power plants has ranked first in the world. With the progress of power generation technology and the support of power information technology, power plants are moving from centralized control and information management to intelligent, environment-friendly and efficient. Safe, efficient and clean operation is an inevitable trend of the development of power plants. In this context, as a traditional power generation enterprise, in order to ensure production safety, improve management quality and promote energy conservation and consumption reduction, we must make use of digital and information technology to promote the innovative development of enterprises, adjust the production mode and management mode, promote the refined management of power plants, achieve the integration of management and control of the whole life of power plants, ensure the safe production and operation of power generation enterprises and maximize the operating benefits of units in the whole life. With the construction scale and quantity of pumped-storage power station increasing year by year, the problems of construction quality and safety of pumped-storage power station break out frequently, and more and more photovoltaic power stations face the problems of operation and maintenance, design defects, equipment quality defects, construction non-standard and so on, which bring severe challenges to the operation and maintenance of pumped-storage power station. The operation efficiency and management quality of pumped-storage power station will directly affect the operation stability and power generation capacity of the power station. In general, the research and application of operation and maintenance technology of pumped-storage power plants at home and abroad are relatively not diversified in data collection types, especially the serious lack of resource data, detection data and fault data; the functions realized are relatively simple, mainly the viewing, browsing and statistical analysis of the operation information of the equipment of pumped-storage power plants, and the intelligent operation and maintenance function has not been realized yet and needs to be optimized and improved [5, 6].

In order to complete the operation data communication of pumped storage power stations with higher efficiency, 5G technology is applied to the operation and maintenance of pumped storage power stations. Therefore, this research uses 5G network as the core technology of intelligent operation and maintenance, and designs the intelligent operation and maintenance technology of pumped storage power plant based on 5G.

2 Intelligent Operation and Maintenance Technology Design of Pumped Storage Power Plant Based on 5G

By studying the related theories of pumped storage power plants, this study analyzes in detail the architecture of “three layers and two networks” in intelligent pumped storage power plants, the characteristics of intelligent equipment, technical characteristics and equipment operation, maintenance and maintenance [7]. Through these analyses, the operation technology, overhaul technology and operation and maintenance management

mode of intelligent pumped storage power plant are studied. In order to meet the higher requirements of pumped storage power plant technology for its management and maintenance, this paper puts forward some suggestions and opinions on the operation and maintenance of pumped storage power plant from the aspects of technical framework, inspection management, maintenance management, equipment risk assessment, defect management, operation and safety control, etc.

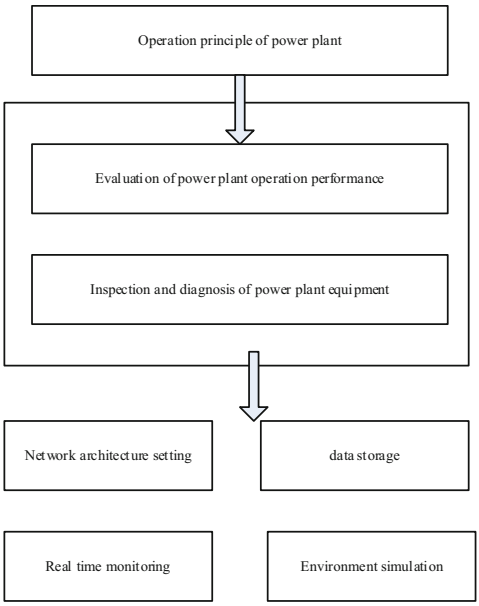

Fig. 1. Research route of intelligent operation and maintenance technology for pumped storage power plants

In this study, the overall technical design process will be completed according to the content set in the Fig. 1 above. 5G network and virtual reality technology are mainly applied as the core technologies in this research [8]. On the premise of controlling the cost of power plant intelligent operation and maintenance, the application effect of power plant operation and maintenance technology is improved [9]. To provide impetus and technical support for the development of pumped storage power plant.

2.1 The Operating State Estimation Model of Pumped Storage Power Plant is Established

In this study, the operating state data of the pumped storage power plant will be collected at first. Data acquisition is the center of data input and output of operation and maintenance management, and also the bridge between operation and maintenance service support platform and other scheduling and control systems [10, 11]. Data collection is also a process of collecting, identifying and selecting data from data

sources. After data collection is completed, it will be used to analyze the operating state of the power plant.

Considering the development trend of the pumped storage power plant degradation in condition assessment is worth more than an absolute standard, according to power plant operation to get the forecast of scores is divided into dynamic and static, in the form of a'_{ii} and a'_{ij}, respectively, the two grades respectively according to the proportion of α'_{ii} and α'_{ij} coefficients calculated cable one pilot test score information:

$$a_{ii} = a'_{ii}\alpha'_{ii} + a'_{ij}\alpha'_{ij} \tag{1}$$

After the calculation results of single pre-test information are given, all pre-test information a_{ij} of the power plant shall be calculated according to different importance degrees of each in the state evaluation and different proportions of each information α_{ij}. Calculate the score of all the pre-test information [12]:

$$b_1 = \sum_{i=1}^{j} a_{ii}\alpha_{ii} / \sum_{i=1}^{j} a_{ij} \tag{2}$$

where, b_1 is the score of all the pre-test information.

The scoring principle of on- line monitoring information content can be similar to that of pre-test information content. If there is on- line monitoring information, it can be regarded as some items in the above formula. Since on- line monitoring is not a necessary amount in a state assessment, it defaults if no online information is available at the time of the assessment. Based on the above assumptions, the operational status of the pumped storage power plant can be preliminarily estimated, and the operational status can be analyzed using approximate entropy [13–15] in order to improve the analysis results.

Let the data with length n be represented by $B = [b(1), b(2), ..., b(n)]$, and the specific algorithm of approximate entropy of data b is as follows:

The Takens embedding theory is used to construct B into a group of m-dimensional vectors, such as:

$$B(i) = [b(i), b(i+1), ..., b(i+m-1)] \tag{3}$$

The distance between $B(i)$ and $B(j)$ is defined as the maximum of the difference between the corresponding elements of two vectors, namely:

$$d[B(i)B(j)] = max[|b(i+k) - b(i+k)|] \tag{4}$$

Given the threshold value u, count the number of distances between each row and other rows less than the threshold value u, i.e., $d[B(i)B(j)] < u$, denoted by $n_i^m(u)$, i.e.:

$$n_i^m(u) = \sum_{j=1}^{m} G(d[B(i)B(j)] - u) \tag{5}$$

where $G(b)$ is A Heaviside function. By comparing $n_i^m(u)$ with the total distance $n-m$, we get:

$$V_i^m(u) = \frac{n_i^m(u)}{n-m} \tag{6}$$

Take the logarithm sum of $V_i^m(u)$, and then take its mean value, which is:

$$\beta^m(u) = \frac{1}{n-m+1} \sum_{i=1}^{n-m+1} \ln V_i^m(u) \tag{7}$$

Increase the dimension, change the original m vector into $m+1$ dimension, repeat the above several processes to get $V_i^m(u)$ and $\beta^{m+1}(u)$. The approximate entropy of this sequence is obtained:

$$S(m,u,N) = \beta^m(u) - \beta^{m+1}(u) \tag{8}$$

From the above discussion, it can be seen that the approximate entropy value is related to dimension m, threshold u and signal length n. For parameter setting, according to practice Pincus [16, 17], m is suggested to be 1 and E is suggested to be 0.1–0.2 times of signal standard deviation. In order to ensure the reliability of the data, it is normalized. Normalization is an important method in data preprocessing, that is, the dimensionless data is transformed into dimensionless data. Min-Miax standardization, also known as deviation standardization, is a linear change of the original data. Where $B_{\min}$ is the minimum value of sample B and $B_{\max}$ is the maximum value of sample. The original value of sample B is mapped to the value B' in the interval [O, 1], and its formula is as follows:

$$B' = \frac{B - B_{min}}{B_{max} - B_{min}} \tag{9}$$

According to this formula, the estimated results of operation state are verified, and the verified results are used as the basis of operation and maintenance management.

2.2 Power Plant Operation Inspection Content Setting

After analyzing the operation status of the power plant, the patrol inspection technology is used to complete the operation management of the power plant equipment [18]. Through literature study, it can be seen that inspection tours refer to timely recording, judging and reporting the equipment defects or abnormal operating conditions found in the inspection process by regularly or irregularly inspecting the operating conditions and health conditions of various types of equipment in power plants, and handling them in accordance with the relevant provisions, inspecting the existing hidden safety dangers, and notifying the relevant departments to rectify them after discovering them, so as to effectively guarantee the safe and stable operation of the power system through the inspection tours [19].

The periodical inspection mode of pumped-storage power plant can be divided into two categories: normal inspection and overall inspection. Normal patrol refers to the inspection and patrol of the directly observable parts such as the signals of the secondary equipment and the appearance and operation status of the primary equipment, which shall be periodically inspected by the operation and maintenance personnel according to the voltage level of the pumped-storage power plant [20]. In general, the patrol of the pumped-storage power plant shall be conducted once every four days and the patrol of the voltage level equipment with the value of 110 kV or below shall be conducted once every eight days [21]. The comprehensive patrol shall be conducted once every quarter by the relevant personnel of the operation and maintenance department and the transformer substation operation and maintenance room together with the operation and maintenance personnel. Various monitoring equipment are used to monitor the operation condition of the equipment. Carry out seasonal safety inspection; check whether the contents such as false locking, station electricity are in good condition, etc. In this design, the contents of the inspection shall be set as follows (Table 1):

Table 1. Inspection content of pumped storage power plant

Involving parts	Project number	The project content
Electrical storage protection device	1	The device and the shell of the collector are clean and complete without damage and well sealed
	2	The indicator lights of the device are normal and correct without flicker
	3	Whether the optical fiber interface of the device is loose
Core control unit	4	The appearance of the device is clean and complete without damage
	5	The secondary terminal connection should be reliable and firm, no loosening off phenomenon
	6	Check whether there is abnormal sound or smell during the operation of the equipment, and whether there is vibration phenomenon
Network signal transceiver device	7	Check the monitoring background computer telemetry data indicating normal, no abnormal alarm signal
	8	Check that all kinds of indicator lights of network switch and its intelligent terminal are normal without flicker and the communication status is normal
	9	Check that the network is working properly

The on- line monitoring device of electrical equipment can collect real-time information of all kinds of equipment for comprehensive processing and analysis, and the calculation results can analyze the trend of equipment status change, evaluate the reliability of equipment, find out the hidden safety trouble existing in equipment as soon as possible, and provide the basis for predicting the maintenance of power grids, which can change the preventive maintenance or fault maintenance into predictive maintenance, reduce the times of power cut of equipment, shorten the time of power cut, and improve the operation and maintenance efficiency of power grids [22].

The on- line monitoring platform of pumped-storage power plant is also an important technical means to realize the state operation and maintenance management of transmission and transformation equipment and enhance the level of lean production and operation management of transmission and transformation specialty. The system realizes real-time sensing, monitoring and early warning, analyzing, diagnosing, evaluating and predicting of all kinds of transmission and transformation equipments by various sensor technology, wide-area communication technology and information processing technology [23]. The construction and popularization of the system have positive and far-reaching significance for improving the intelligence level of power grid and realizing the operation management of transmission and transformation equipments. Therefore, a 5G operation and maintenance platform will be constructed to provide the operation basis for the operation inspection and the operation state estimation model of pumped storage power plant.

2.3 5G Operation and Maintenance Platform Construction

More and more pumped storage power plants entrust professional automation plants to complete the daily operation and maintenance of power plant equipment. These include on-site power plant on duty, provide owners can query the data of the plant anytime, anywhere mobile monitoring client software. With the continuous development of science and technology, looking for more favorable personnel training methods and interactive experience advantages, virtual on-site simulation technology came into being. In order to save cost and concentrate excellent technical backbone to manage more power stations, remote monitoring and unmanned unmanned monitoring have developed into an important value-added service item in operation and maintenance system, providing data original collection and storage for each user engineering project and data release service through Internet, and will provide various directional services based on monitoring data in the future, bringing more convenient and more secure monitoring system for users, so as to provide users with satisfactory 7 * 24-h service. In this study, remote monitoring is equipped with virtual reality simulation technology and mobile phone monitoring, which can quickly complete the operation and maintenance management of power plants. At the same time, we use the network communication platform to complete the round-the-clock remote monitoring of the power plant, based on the digital information platform of water conservancy and hydropower, construct the digital and information management to realize the centralized monitoring and control of several power plants.

In this design, the virtual reality simulation technology will be used as the core technology of the platform. In order to ensure the smooth operation of the platform in

5G network, the virtual reality technology is used to simulate the pumped storage power plant. Virtual reality technology makes use of modern computer technology such as modern computer simulation technology, high sensitivity sensor, artificial intelligence, graphics and image technology and various human-computer interface technology to create human-computer interaction experience with "real scene, real action and real feeling". In order to apply it to the platform design, we need to keep the safe and stable running state of the management platform, so we need high-quality maintenance and management personnel. Pumped-storage plants involve a wide range of areas, so it is difficult to fully understand a Pumped-storage plant in operation, and it is impossible to realize the familiarity with the functional relationships of various devices and switches by on-site control. Therefore, the use of virtual reality technology in the pumped storage power plant personnel training and field understanding of the situation has a considerable practical significance. The 5G operation and maintenance platform designed in this study can be used to solve the problems of difficult comprehension, monitoring and personnel training, and to optimize the dispatching and personnel training.

The platform uses 3D modeling software to model the whole environment of the hydropower station, and defines the key components such as equipment and switch, etc. By combining the monitoring technology, collecting the field signal, combining the operation situation of the specific power station and the use characteristics, the platform completes the simulation of various operation actions of the valves, buttons and knobs in the operation of the power station, simulates the operation and maintenance of the hydropower station by linkage remote simulation and assists the management, and makes the operation and maintenance of the pumped-storage power station more intuitively. The above design content is connected in order, so far, the intelligent operation and maintenance technology design based on 5G pumped storage power plant is completed.

3 Experimental Demonstration and Analysis

3.1 Experimental Environment Design

In this study, an intelligent operation and maintenance technology based on 5G is proposed for pumped storage power plants, in order to confirm that this technology has a certain application effect. In this study, the current operation and maintenance technology and 5G operation and maintenance technology are applied to the same pumped storage power plant, corresponding experimental comparison indexes are set, and the application effects of the current technology and 5G operation and maintenance technology are analyzed. In order to avoid the external environment has a certain influence on the experimental results. Set the parameters of the experimental platform in this experiment, and complete the processing process of the experimental platform according to the result of setting the parameters of the platform. 5G technology and current technology will be introduced into this platform to complete the technology application test.

3.2 Experimental Control Indexes

In this study, the experimental comparison indexes are set as three parts: the failure rate of power plant equipment, the time of power plant patrol inspection and the time of power plant fault information transmission. During the experiment, the number of experiments was set as 50 times, and a group of average values were taken for every 10 times as the experimental results. According to this average value, the application of 5G technology is analyzed and the comparison process between 5G technology and current technology is completed.

In the collection of experimental data, attention should be paid to the accuracy of experimental data to avoid abnormal experimental results caused by data collection errors. In view of this situation, the experimental data were kept to two decimal places to ensure the authenticity and accuracy of the data (Fig. 2).

3.3 Analysis of Experimental Results

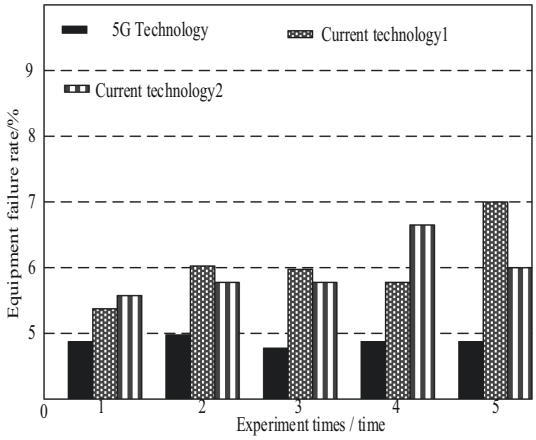

Fig. 2. Failure rate of power plant equipment

According to the above experimental results, after the use of 5G technology, the failure rate of power plant equipment has changed, showing a trend of gradual decline, indicating that this technology has a better equipment management ability. The current technology is less effective than 5G. After using this technology, the failure rate of the equipment did not change significantly, and the failure rate increased in some tests. Through the analysis, it can be seen that the equipment state estimation module is added in 5G technology, which improves the management ability of power plant equipment to a certain extent. Based on the above analysis results, it can be seen that 5G technology has a high device control capability (Table 2).

Table 2. Time of power plant inspection

Method of use	Compare the content of	Specific results/min
5G technology	Maximum patrol time	5.14
	Minimum patrol time	4.74
	Average patrol time	5.07
Current technology 1	Maximum patrol time	6.74
	Minimum patrol time	5.89
	Average patrol time	6.57
Current technology 2	Maximum patrol time	6.15
	Minimum patrol time	5.71
	Average patrol time	6.07

According to the above experimental data, both 5G technology and current technology will consume a lot of time in the inspection of power plants. However, 5G technology has smaller fluctuation and shorter time, which has certain advantages in the management of large power plants. Compared with 5G technology, the current technology takes longer time to conduct inspection on power plants and has greater volatility. The experimental results show that the current technology has poor control over time. Unable to carry out equipment inspection and maintenance in a short time for large power plants (Table 3).

Table 3. Time of transmission of fault information in power plant

Method of use	Compare the content of	Specific results/s
5G technology	Maximum message transmission time	10.15
	Minimum information transmission time	8.17
	Average information transfer time	9.54
Current technology 1	Maximum message transmission time	11.25
	Minimum information transmission time	10.58
	Average information transfer time	10.85
Current technology 2	Maximum message transmission time	11.65
	Minimum information transmission time	10.54
	Average information transfer time	11.06

According to the experimental data, after the use of 5G technology, the time of transmission of fault information in power plants has significantly decreased, indicating that 5G technology has improved the intelligence of power plant operation and maintenance management. Compared with 5G technology, the current technology takes a long time in data transmission, which has a certain impact on equipment maintenance. In the future research, this part of performance will be optimized.

The comprehensive analysis of the experimental results of power plant equipment failure rate, power plant inspection time and power plant fault information transmission time shows that the use effect of 5G technology is better. In the future power plant management process, this technology can be used as the main power plant management.

4 Conclusion

This paper analyzes the history and present situation of power plant operation and maintenance, and points out the existing problems. Based on the situation that big data and cloud computing technology have been mature and widely used in various industries, this paper studies the intelligent operation and maintenance technology of power plant based on 5G network. In-depth study on the functions of the operation and maintenance platform, further study on VR display technology, enrich the display functions of 5G operation and maintenance technology, and improve the display efficiency and effect.

Compared with 3G and 4G communication technologies, 5G technology has more obvious advantages. As a product of the new era, it is developed on the basis of science and technology, with higher communication security, communication quality and transmission efficiency, and can provide better communication services. In order to promote the application of 5G technology in the intelligent operation and maintenance of pumped storage power stations, it is necessary to increase the full application of high-frequency transmission technology, MIMO technology and multi-carrier technology, clarify the conditions for the intelligent operation and maintenance of pumped storage power stations, and further optimize the operation and maintenance effect. Through this study, it can be seen that the application of 5G technology in the intelligent operation and maintenance of pumped storage power station is feasible and has an ideal application prospect.

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