Discussion on electric reliability evaluation of hydropower units

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Abstract. This study was based on the problems existing in the hydropower unit reliability assessment. Through the discussion of the ways and methods of hydro turbine reliability evaluation, and the reliability evaluation index, some proposals are provided to improve the reliability management level of hydropower enterprises.

1. Existing problems in current reliability evaluation of hydropower generating units

1.1. The reliability evaluation code is no longer applicable
On March 1, 2012, the national energy administration issued the reliability evaluation code of generating equipment (DL/T793-2012), which is a general and comprehensive code for evaluating the reliability of power generation equipment applicable to thermal power, hydropower, storage hydropower, nuclear power, gas turbine power generation and wind power generation. There is no specific definition according to the characteristics of the hydropower, such as state, evaluation index, statistical evaluation range, basic registration data and so on units. In 2016, the electric power reliability management center of national energy administration formulated the reliability evaluation code of generating equipment (General Regulations Section) and reliability evaluation code of generating equipment part 2: coal-fired units. The reliability evaluation of hydropower generating units can only refer to reliability evaluation code of generating equipment (General Regulations Section). However, with the continuous expansion of the installed capacity of hydropower generating units and the increase of single unit capacity, the types of hydropower generating units now include axial flow, mixed flow, tubular flow, impact type and pumped-storage generating unit [1] and so on, so the original code is no longer applicable.

1.2. The guidance of reliability index to production is not sufficient
At present, the reliability management of hydropower generating units is limited to the reliability statistics submitted to the host and the power transmission and transformation facilities data. Unplanned outage events, unplanned derated of output events, planned maintenance events for hydropower units are not included in the scope of reliability management. Hydropower generation companies do not analyze and calculate the reliability index such as equivalent available factor, unplanned outage factor, unplanned outage times, unplanned outage hours, planned outage factor, etc in real sense. Hydropower generating units not only need to bring basic load during the flood season or power grid accident, but also perform the task of frequency modulation and phase
modulation. Therefore, the reliability management index cannot guide production operations truly and comprehensively.

1.3. Insufficient awareness of reliability management
China's reliability management of hydropower generating unit started late, and coupled with unreasonable statistical evaluation, the reliability management work cannot fully play its role that should be played to a certain extent. Currently, the vast majority of group companies, regional companies, and power generation companies believe that reliability management is limited to reporting statistical reliability data. Reliability management positions are equipped with part-time personnel to manage reliability management work and the personnel rotation is frequent, which is not conducive to the long-term development of the reliability management work. In addition, the absence of supervision and review procedures for the collection, verification, reporting, and leadership review of reliability information lead to much incorrectly reliability information which often needs to be corrected.

1.4. Insufficient assessment of reliability management work
At present, most of the group companies, regional companies, and power generation companies have failed to perform reliability management assessment in the reliability management system. Only in the evaluation of star-rated enterprises or benchmarking units or other types is there a small number of reliability indicators included in the evaluation score. In this way, the emphasis on reliability management is far from enough.

1.5. Reliability management system is no longer applicable
At present, it has been more than 10 years since all of power generation companies such as thermal power [2], hydropower and wind power are using the power generation equipment reliability management information system that uniformly implemented by the Power Reliability Management Center of the China Electric Power Enterprise Association to collect data, statistics, analysis, index calculation and evaluation of reliability management. There are some problems such as delay of information, large deviations in the calculation of indicators, late update of system, and inability to calculate the index of designated interval and other issues. Therefore, it cannot meet the needs of production.

2. Ways and methods for reliability evaluation of hydropower units
The purpose of reliability management of hydropower generating units is to improve equipment reliability and provide services for production. Base on production, serve production and develop on production is the key way to carry out reliability management.

2.1. Formulate a suitable reliability evaluation code for hydropower generating units
It is recommended that the drafting of reliability evaluation code for hydropower units be made at the level of the China Electricity Council. The reliability evaluation, which contains the evaluation indicators, statistical evaluation scope, and basic registration data, should be carry on according to the different types of hydropower units, such as axial flow, mixed flow, tubular flow, impact type and pumped storage units.

2.2. Formulate a reliability management system or rule suitable for the company
Each hydropower plant should formulate a reliability management system or rules considering the characteristics of itself, national and industry reliability regulations, industry evaluation procedures as well as superior unit reliability management systems. The system is the basis and foundation of the specific reliability management work. Thus, the meaning of the guidance will be more targeted.

2.3. Provide timely and valuable reliability information to leaders
Providing complete, accurate, and authentic reliability data and indicators regularly or irregularly to the relevant leaders and superior units can reflect problems and frequency events at production sites or regional companies [3]. Meanwhile, offering constructive suggestions is also proposed to avoid the recurrence of similar problems.

2.4. Attending the accident analysis meetings regularly
According to the principle of “Four Do not Leave” in safety production management, the reliability manager should insist on participating in the accident analysis meeting to understand the entire process of the accident, determine the reliability status of the incident accurately, record the responsibility and technical reasons properly. In this way, the reliability and authority of the unit reliability index would be improved.

2.5. Formulate the unit's annual reliability index target and conduct assessment
The annual reliability index targets should be established according to the annual reliability target plan issued by the group companies and regional companies [4]. At the same time, the completion of the company's previous year's reliability indicators should also be considered. Following the established annual reliability index targets that are decomposed into three levels including plant, department and team, the reliability evaluation can be carried on.

2.6. Strengthen the evaluation and maintenance of quality management
The quality of maintenance is evaluated by using the reliability management index before and after the unit large, medium, and minor repairs, the load capacity of the unit and the operational stability. The equipment maintenance plans should be established based on the reliability index and the change of the reliability index should be taken as an important basis for evaluating the quality of the maintenance and the effect of the technical transformation [5].

2.7. Strengthen reliability management training
Organize or participate in the reliability management training of the power reliability management centers of factories, regional companies, group companies and China Electric Power Enterprise Association, and promote the exchange of reliability management among different units. Concerted efforts should be made to improve the reliability of the business level, which is not only limited to the reliability management professional. Extension to the boiler, steam turbine, thermal control, electrical, metal and other professional should also take into account to help improve the timeliness, completeness and accuracy of reliability information, and to make sure that production personnel accurately determine the equipment reliability status and record correctly. By all these means, the reliability of business management can be improved.

2.8. Upgrade of Reliability management system
The reliability management system has the status of collecting hydropower units in real time. Registered unit data according to the different types of hydropower generating units, the reliability indicators of different periods such as flood season can be calculated selectively, the same type of units can be calculated with two overhaul intervals, the reliability index can be calculated during the life cycle, and add the detection of the dam water level.

2.9. Ensure that the reliability basis and operational information are true, reliable and accurate
Through the advanced reliability management information system, the equipment status can be identified and obtained, which ensure that the equipment reliability basis and operation information is true, reliable and accurate. Accurately calculation of the reliability indexes for availability, maintenance and outage of each main equipment, auxiliary equipment and power transmission and transformation facilities, combines putting forward reasonable suggestions for overhaul of large, medium and small maintenance of the unit can reduce unit operating costs for hydropower enterprises
and improve economic efficiency.

3. **Hydropower unit reliability evaluation index**

#### 3.1. Equivalent available factor

EAF (equivalent available factor) = \( \frac{AH - EUNDH}{PH} \times 100\% \).

The equivalent available factor is the ratio at which the reaction device is at a usable level. Whether or not the unit is available is determined by whether or not the power generation function can be achieved, and it can be seen intuitively that the unit can operate at full output. To make the unit safe and long-term operation, the unit needs to be overhauled, and the equivalent availability factor can reflect the optimal inspection interval. It can be calculated over many years, years, quarters, months, or other selected intervals. The equivalent available factor of two overhaul intervals can be calculated for the same type of unit to evaluate the overhaul quality of the last overhaul. In addition, the equivalent available life factor is calculated over the entire life cycle.

#### 3.2. Planned outage factor

POF (planned outage factor) = \( \frac{POH}{PH} \times 100\% \).

The planned outage factor is the ratio of reactive equipment at the level of unavailable (planned outages). The planned outage factor can be calculated through years, years, quarterly, monthly or other selected intervals, and the outage factor of the same type of unit can also be calculated and analyzed. In addition, calculate the planned outage factor over the life cycle.

#### 3.3. Unplanned outage factor

UOF (unplanned outage factor) = \( \frac{UOH}{PH} \times 100\% \).

The unplanned outage factor is the ratio of reactive equipment at the level of unavailable (unplanned outage) [6]. The unplanned outage factor can be calculated through multi-year, annual, quarterly, monthly or other selected interval, or the unplanned outage factor of the same type of unit with two overhaul intervals can be calculated to evaluate the quality of overhaul of the last overhaul. In addition, calculate the unplanned outage factor over the life cycle.

The unplanned outage factor is one of the important reliability indicators for evaluating the hydropower enterprise's power production management, and it directly reflects the operation level, maintenance quality, and equipment management level of the equipment. For non-planned outage incidents, identify the regular and frequent occurrence of technical and liability reasons, etc., to avoid the recurrence of similar problems.

#### 3.4. Unit derated factor

UDF (unit derated factor) = \( \frac{EUNDH}{PH} \times 100\% \).

The unit derated factor is the ratio of the reaction equipment to the operating level of the reduction force. This indicator can show the running time of the unit under abnormal conditions. Operation of the unit under abnormal conditions will lead to further deterioration of the reliability of the unit. The computer group can be used to reduce the output coefficient through many years, annual, quarterly, monthly or other selected intervals, and it can also be used to calculate and reduce the unit derated factor of the same type of unit. In addition, calculate the unit decrease factor over the life cycle.

#### 3.5. Output factor

OF (output factor) = \( \frac{GAAG}{SH \times GMC} \times 100\% \).

The output factor is the ratio of the actual operating level of the reaction equipment to the rated operating level. The lower the unit load rate, the higher the water consumption rate and the worse the economy. Therefore, the operating personnel need to operate in the safest and most economical way.
The coefficient of force can be calculated through years, years, quarters, months, or other selected intervals, and the output coefficient of the same type of generator can also be calculated and analyzed. In addition, calculate the output factor over the life cycle.

3.6. Successful start rate
SSR (successful start rate) = SST (successful start times)/(SST(successful start times)+ UST(unsuccessful start times))×100%.

Hydropower generating units must meet the needs of the power grid at any time. Successful start rate is an important indicator reflecting reliability of hydropower generating units. The impact of unsuccessful start-up is much greater than that of failure to shut down. The impact of unsuccessful start-up will cause unplanned outage of hydropower generating units.

4. Conclusions
By analyzing the problems existing in the reliability management of hydropower generating units, this article provides several ways and methods for evaluating the reliability of hydropower generating units and reliability evaluation indicators [7-10] for hydropower generating units. It transforms the reliability management of hydropower generating units from extensive model to refined form. This will help to improve the level of reliability management of hydropower companies.

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