Analysis of approaches to assessing the actual condition, residual life and reliability of hydraulic turbines

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Abstract. In order to increase the resource and reliability of power equipment, reduce downtime and repair costs, modern methods of monitoring and resource diagnostics are used to build an equipment maintenance system based on the actual technical condition of the equipment. The main content of the work performed with different prevention strategies is considered. The current situation with the wear of the main power equipment in the country and the results of research indicate the need to create and develop more advanced methods for assessing the resource of power equipment both in hydropower and in the energy sector as a whole.

1 Introduction

To date, for a sufficiently large number of hydraulic turbines in Russia, there is an excess of the design resource characteristics of hydraulic units (HA), often by two or more times, which creates a potential danger of an accident with large economic losses in case of prolonged failure of the damaged unit [1-2]. Therefore, the development of new methods for assessing the actual condition as well as the improvement of the existing methods are an urgent task, the solution of which will ensure the safety of power equipment.

The service life of hydro turbine installations operated at Russian hydroelectric power plants is limited by the requirements of the regulatory document SRT 17330282.27.010.002–2008 "Conformity assessment in the electric power industry" [3], which states that after reaching the service life specified in the regulatory and technical documentation (NTD), further operation of the equipment is not allowed without work to assess its residual resource. The industry standard SRT RusHydro02.03.77-2011 [4] establishes the service life for hydraulic turbines (GT) manufactured before 01.01.91–30 years, after 01.01.91–40 years, if a longer period is not set by the equipment manufacturer.

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2 Materials and methods

Figure 1 shows the structure of operational maintenance that has developed in practice today [5-9]. This structure is quite general and typical for all countries. The difference in them usually lies in the fact that different accents are made on one or another type of repair.

Modern methods of monitoring and resource diagnostics make it possible to leave scheduled preventive maintenance (PPR) and build a new equipment maintenance system, relying on the actual technical condition of the equipment (RTS). This will help to increase the reliability and resource of equipment, reduce downtime and repair costs.

The advantages of such a transition are obvious. With the PPR, a large amount of repair work is carried out, including defect-free equipment, i.e. such equipment, the condition of which at the time of the PPR does not require urgent repair, but is subject to maintenance to ensure trouble-free operation during the overhaul period. Often, the residual resource of the equipment withdrawn for repair turns out to be significant. Statistical data show that during the implementation of the PPR, from 30 to 50% of the work carried out in accordance with the regulations is carried out without their actual need. Special types of repairs remain outside the PPR system: restorative and post-emergency.

The main content of the work carried out with different prevention strategies is given in Table 1.

Trends on an international scale are aimed at finding economic efficiency [9].

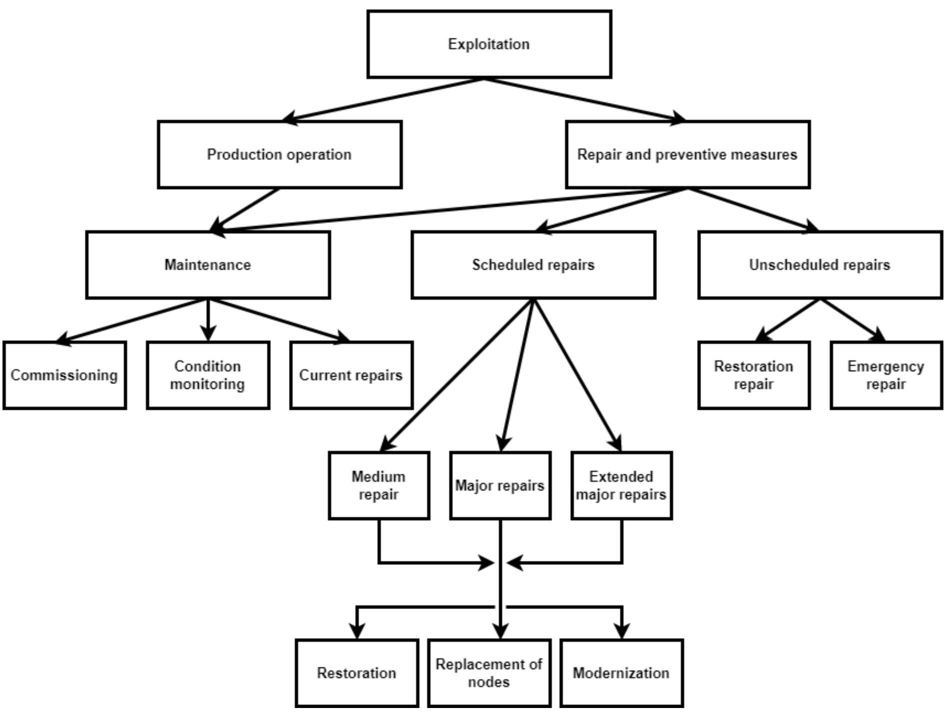

Fig. 1. Structure of equipment maintenance.

As the equipment ages, the individual characteristics of hydraulic units (HA) become more and more pronounced, which are associated both with the actual conditions of manufacture, installation and operation of hydraulic turbine equipment, and with both incipient and developing defects, which are often individual in nature. This leads to certain problems in the process of accumulating the necessary statistical base for comparing aggregates during operation and predicting changes in their technical condition over time.

Diagnostics of equipment within the design service life today is reduced to periodic monitoring of the technical condition of the hydraulic turbine. Monitoring is based on the requirements of regulatory and technical documentation. The assessment of the technical condition consists of visual and measuring control, technical inspection and other routine tests. The main task of diagnostics when the equipment reaches the estimated service life is to identify the feasibility of continuing its operation.

Table 1. The nature of work with different prevention strategies.

Type of preventive effect	**Organization of work on the strategy**		
	Emergency	**Planned preventive**	**According to the technical condition**
Maintenance	Episodic	Periodic	Periodic according to technical condition
Diagnosis	Not carried out	Episodic	Periodic and permanent
Average maintenance	After refusal	Periodically	According to the technical condition
Major repairs	After refusal	Periodically	According to the technical condition
Emergency repairs	After refusal	After refusal	After refusal

3 Results and Discussion

When considering the main approaches, methods, and opinions of scientists and experts, the authors divided them into two groups.

The first group of methods for assessing the resource of hydraulic turbines is based on statistical analysis of operational experience data. Such methods include the following:

- Evaluation based on the calculation of the failure rate [10-11].
- Assessment of the reliability of the HA on the basis of the readiness coefficient (or operational readiness coefficient) and their modifications, characterizing the ratio of the duration of the HA operation under various operating modes and downtime [12-13].

An important advantage of such techniques lies in the simplicity of their practical application and the prospect of comparing the resources of different HA, taking into account the specified parameters (failure rate, operational readiness coefficient) from the side of integral reliability characteristics. They are applicable at the stage of the design life of the equipment, however, statistical models are not applicable for unique powerful HA beyond this period. They can only be used as auxiliary assessment methods.

In the second group of methods, the calculated estimation of the hydraulic turbine resource, which depends on fatigue damage, is taken as a basis. Such approaches are described in regulatory industry documents [14-15], which is necessary at the design stage to ensure the required level of equipment reliability. The following main stages of computational approaches can be distinguished[16-23]:

- Construction of a mathematical model of the object under study.
- Calculation of the current value of the resource-determining parameter.
- Forecast of changes in the resource-determining parameter for the period of operation.

In various branches of energy, petrochemical industry and mechanical engineering, similar approaches are also used to assess the resource of critical facilities. They are specified in the industry NTD. It specifies the main criteria for limit states, calculation and values of coefficients.

The Russian hydropower industry has not yet developed a unified, normative approach to the issue of resource estimation, therefore, various specialized expert organizations use their own, based on their own experience, knowledge and capabilities, methods described in [24].

The authors [25] presented the concept of reliability of a hydraulic unit, based on statistical data, complex reliability indicators for hydraulic units with axial and radial-axial turbines were obtained, recommended for use as basic analogues of the reliability of newly created equipment.

The authors [14] made a deep analysis of foreign literature devoted to the analysis of the GT resource. The paper concludes that, unlike other widely publicized issues of hydropower devoted to optimization, modernization, monitoring, etc., there are practically no works devoted to the GT resource.

The current situation with the wear of the main power equipment in the country and the results of research indicate the need to create and develop more advanced methods for assessing the resource of power equipment both in hydropower and in the energy sector as a whole. The choice of methods, techniques, means of control and diagnostics at the stage of the developed design service life is determined by the need to obtain such initial information that will allow you to build a reliable forecast of the operation of power equipment for an extended period and ensure the reliability of its operation. It is necessary to develop computational and experimental models, possibly digital counterparts of existing unique equipment with verification of the computational model based on experimental data for specific equipment. This will allow us to get a real assessment of both the residual life of this equipment and the reliability of the station as a whole.

In [26-28], the authors proposed an approach to evaluating ITS based on Order 676 using neural network models. The proposed approach has a number of advantages, in particular, it provides a transfer from a piecewise linear to a continuous function of ITS dependence on diagnostic parameters, the possibility of a comprehensive analysis of ITS changes from any number of diagnostic values, forecasting changes, etc. Also, the use of INS to assess the technical condition provides the possibility of supplementing or replacing discrete diagnostic parameters with continuous ones from the composition of constantly monitored ones. Based on this hypothesis, the authors proposed a set of universal indicators, evaluated without stopping the equipment, characterizing the technical condition. Approaches to the formation of training and validation templates that provide high-quality neural network training are described. The algorithms of the functional evaluation system are proposed and a universal representation of the relations between the objects of the mathematical model for determining the residual resource of generating equipment is formed. The obtained results of the scientific research allow us to further apply the proposed comprehensive system for assessing the technical condition of generating equipment using neural network modeling to assess the current residual resource of generating equipment based on available diagnostic data.

4 Conclusion

The joint application of a comprehensive system for assessing the technical condition of generating equipment using neural network modeling to assess the current residual resource of generating equipment based on available diagnostic data, developments in the field of artificial intelligence and computer technologies will allow for the processing of big data for their further application in the management decision support system at enterprises to ensure the safety of power equipment in the energy sector.

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