**Diagnostic tools and monitoring for devices of the hydro generator’s excitation system in the electric power system**

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**Abstract.** The article discusses the need for a diagnostic and monitoring tool for electrical equipment elements in the excitation system devices of hydrogenerators in the electric power system. According to the operating instructions for electrical equipment, which are currently followed, the service life of electrical equipment elements is calculated for 25 years of operation, regulated by technical parameters and performance characteristics guaranteed by the manufacturer. After the expiration of the manufacturer's guaranteed regulated service life, the operating time of the excitation system equipment in the electric power system increases. Due to aging, the technical indicators of the equipment that has worked out its service life gradually begin to deteriorate, the operating characteristics change, the indicators of its operability change, as well as the reliability of the operation of the excitation system devices. Replacing the entire element of the electrical equipment of the excitation system devices of hydrogenerators with new systems and elements in the shortest possible time is impossible and impractical in terms of its technical and economic indicators. Therefore, according to the regulatory document RD34.45-51.300-97, along with the implementation of scheduled restoration work and the replacement of physically worn-out, resource-expired equipment and obsolete elements of electrical equipment, it is necessary to create a means of diagnosing and monitoring elements of electrical equipment of devices of the excitation system of hydrogenerators in the electric power system, which is needed to reliably determine the technical condition of an element of electrical equipment in operation that exceeds the service life regulated by the manufacturer of this product or article.Taking into account these indicators of the technical condition of electrical equipment elements, the role and importance of means of diagnosing and monitoring elements of electrical equipment of devices of the excitation system of hydrogenerators in the electric power system are the most necessary and demanded factor in the operation of equipment of the electric power system.

**INTRODUCTION**

Recently, there has been a global demand for projects such as the “green economy,” “green energy,” and other “green technologies.” It is well known that hydropower also belongs to the category of renewable “green energy.” The Kyrgyz Republic's (KR) electricity system is based on hydropower plants (HPPs), which generate more than 90% of the country's electricity. However, the largest power plants in the Kyrgyz Republic (Toktogul HPP, Kurp-Sayskaya HPP) were built in the 1960s and 1980s. In other words, they are 50 years old or more. Therefore, constant modernization is required, primarily of the “heart” of the plant – the hydro generators and other elements.

To extend or increase the service life of electrical equipment components in hydro generator excitation systems in the power system, it is necessary to create an automated database that takes into account the specific features of each equipment component during operation.

A component is a structural part of a circuit or system that must perform certain functions assigned to it in accordance with its purpose. A component can be a resistor, capacitor, inductance coil, transformer, etc. All of the above components must relate to the electrical equipment of the hydro generator excitation system at power plants [1].

When operating electrical equipment components of hydrogenerator excitation systems in power systems, the following factors and indicators must be taken into account: reliability, durability, repairability, and operational performance of the equipment. At the same time, they must comply with electrical safety, fire safety, explosion safety, and environmental protection requirements, and must also meet the following criteria: repairability and interchangeability of systems, modules, blocks, and block modules in the electric power system [2].

The electrical equipment components of hydrogenerator excitation systems in the power system must have the following properties and parameters when put into operation: completeness of equipment and compatibility with modern systems and devices, including compatibility with protection and automation devices, control of technical parameters and operating mode, diagnostic tools, as well as systems and devices of automated process control systems (APCS) of power plants in the electric power system.

At the same time, they must carry out diagnostics and undergo test control of operating modes in accordance with the technical parameters and operating characteristics of the electrical equipment components of the excitation system devices of hydrogenerators in the power system. The use of diagnostic and monitoring tools for electrical equipment components of hydro generator excitation systems in power systems is necessary for the proper control of devices and the continuous provision of real-time information about all changes occurring during operation, set operating characteristics, and technical parameters of power plant equipment.

Due to the untimely receipt of information about the technical condition of the electrical equipment of the power plant, frequent malfunctions and failures occur in the operation of the equipment of the excitation system of hydro generators in the power system.

Therefore, the introduction of diagnostic and monitoring tools for the timely adoption of measures to ensure the reliable operation of synchronous hydro generator excitation system devices is extremely important.

**EXPERIMENTAL RESEARCH**

Means of diagnosing and monitoring electrical equipment components of hydrogenerator excitation systems in power systems must perform the following basic functions and tasks:

– early detection of malfunctions;

– identification of the causes of malfunctions;

– assessment of the possible consequences of equipment failure;

– assessment of technical condition and performance parameters;

– development of recommendations and instructions for equipment maintenance;

– creation of a timely database to improve the reliability of power plant electrical equipment devices and components.

The means of diagnosing and monitoring the electrical equipment components of the excitation system devices of hydro generators in the power system must continuously and periodically monitor the condition of the equipment, identify early signs of malfunction, and conduct test control and monitoring of the condition of the equipment.

Based on the reliable data obtained on early signs of malfunctions occurring in the initial period, appropriate measures should be taken to localize malfunctions and maintain the equipment in working order during operation [2].

The service life of electrical equipment is the calendar duration of operation of the excitation system and its components until the onset of the limit state specified by the technical parameters of the manufacturer, concern, or company that manufactures the product or electrical engineering industry product [3].

The aging of electrical products and materials is also subject to the Van't Hoff-Arrhenius law [3].

Diagnostic tools are a field of knowledge that covers the theory, methods, and means of monitoring to determine the technical condition of the excitation system, which is characterized by the operational values of the technical parameters of the equipment specified in the technical documentation and the operating characteristics of the excitation system devices [4].

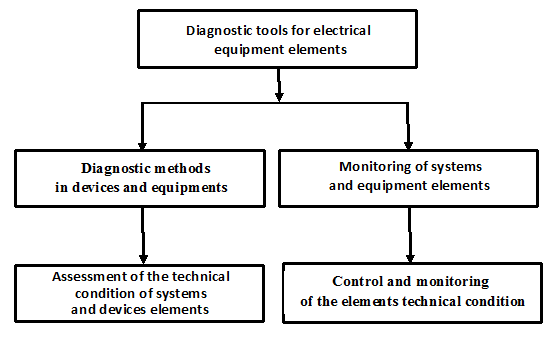
In digital microprocessor terminals of hydrogenerator excitation system devices, continuous monitoring of the condition of equipment in operation (in working mode) is a means of diagnosis and monitoring.

Diagnostic and monitoring tools are necessary for diagnosing (monitoring) the technical parameters and operating characteristics of hydrogenerator excitation systems, as specified in the technical documentation for this equipment.

The diagnostic tools are shown in Figure 1. The technical diagnostic system can be classified in the following areas: technical diagnostic methods and monitoring tools for hydrogenerator excitation system equipment components.

When selecting diagnostic tools for technical parameters, the following basic principles should be followed. Each value of the tested parameter of the hydrogenerator excitation system components must have a single diagnostic parameter to ensure uniqueness.

The diagnostic parameter of the hydrogenerator excitation system components must be accessible and convenient for measurement. The diagnostic parameter of the excitation system devices of hydrogenerators must have a sufficient measurement limit for changes in the monitored parameter occurring during the operation of electrical equipment components, which must ensure the requirements for measurement accuracy and diagnostic reliability when a wide range of changes is required.



**FIGURE 1.** Qualification of diagnostic tools for electrical equipment components

**RESEARCH RESULTS**

Modern digital microprocessor terminals of excitation system devices at power plants currently lack sufficiently advanced methods, tools, and systems for analyzing faults based on diagnostic information. Therefore, it is necessary to eliminate these shortcomings in the processing of information obtained through monitoring [4].

The purpose of diagnostics is to detect and localize faults during equipment operation [5]. An automatic diagnostic system must perform the following functions: maintainability and interchangeability of elements in a block, module, or block-module, which must be used to improve the performance of the excitation system of hydrogenerators.

Monitoring (from the English word monitor – to control, to check). Specially organized, systematic observation of the state of devices, phenomena, processes, assessment of their performance, control, and forecasting [6].

Monitoring is a system of continuous observation of phenomena and processes occurring in electrical networks and equipment, the results of which are used to justify decisions on ensuring the safety of equipment in the electric power industry.

Monitoring the technical condition of the excitation system involves observing the technical condition of the excitation system equipment in order to determine and predict the moment when it reaches its limit state under operating parameters.

During the diagnostic process, it is established

The term “diagnostics” comes from the Greek word “diagnosis,” which means recognition or determination.

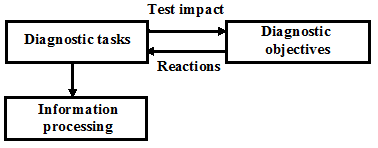
Diagnostics is one of the important measures for ensuring and maintaining the reliability of technical systems.

Automatic diagnostic tools can be divided into two types: test diagnostics and functional diagnostics. A test is a task with a known solution designed to verify the correct operation of the excitation system devices based on the data embedded in the software of these systems [5].

Test diagnostics are used to analyze the serviceability or search for defects (malfunctions) in the operation of electrical equipment in the excitation system of hydrogenerators. Functional diagnostics is used to check and determine the correctness of their functioning and to identify defects (malfunctions) in the excitation system of hydrogenerators that can lead to failure, i.e., disruption of the operability of equipment elements in the process of their operational parameters of the system when operating in the electric power system [5].

Testing and functional diagnostics of the hydrogenerator excitation system are necessary for the timely adoption of appropriate measures to ensure reliability, trouble-free operation, durability, and maintainability during the operation of equipment in the power system.

Test diagnostics tools can be represented as a block diagram shown in Figure 2 [5].

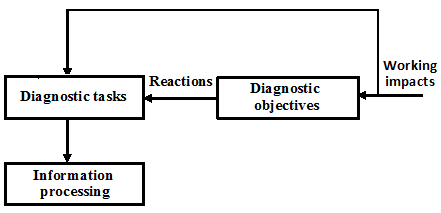


**FIGURE 2.**Block diagram of the test diagnostic tool.

A test diagnostic tool is a process that affects diagnostic targets (DT) that come from the diagnostic tool. A test impact is a set of codes (commands) that affect diagnostic targets to locate the place of a malfunction (defect) during operation in excitation systems.

Functional diagnostics are influences on diagnostic targets that are set by the working algorithm of the excitation system devices shown in Figure 3 [5].

The diagnostic process consists of elementary checks, each of which is characterized by a test or working impact and removed after information processing. These information processing operations (signal values at control points) are the result of an elementary check [5].



**FIGURE 3.**Structural diagram of the functional diagnostics algorithm for the excitation system.

An elementary test object is a device required for testing technical parameters and operating characteristics, for which a diagnostic impact (test or operational) must be calculated.

The algorithm for diagnosing electrical equipment elements is a sequence of rules and elementary checks when evaluating data processing after receiving the necessary information from the operating equipment of the hydrogenerator excitation system in the electric power system [5].

**CONCLUSIONS**

1. The implementation of this device is necessary to improve the parameters of diagnostic and monitoring tools, as well as to determine the operating characteristics and technical condition of electrical equipment components (blocks, modules, block modules) in the excitation system of hydrogenerators in operation.

2. Early detection of: signs of malfunction (defect); the extent of damage; location and position; causes of these signs of malfunction (defects). All this is necessary for a correct (reliable) analysis and decision-making on the subsequent operation of devices in service (removal for repair and restoration work, as well as for extending the service life of equipment after receiving a conclusion on its technical condition and performance characteristics).

3. The use of data obtained from diagnostic and monitoring tools is necessary to determine the period of subsequent operation of the equipment and to assess the remaining service life of electrical components in the excitation system of hydrogenerators, in accordance with the guaranteed technical parameters, operating characteristics, and values specified by the manufacturers.

4. To prevent the formation of signs of malfunctions (defects) or to detect them at an early stage, to maintain operational parameters and the service life of 25 years of equipment operation as stipulated by operational values, operating characteristics and technical parameters of electrical equipment components, it is necessary to use complete, reliable (accurate) information about the condition and control (diagnostics) of electrical equipment components.

To this end, as well as to maintain the components of the power system equipment in working order, it is necessary to create systems and devices with improved technical parameters, operating characteristics, values, and properties based on the latest achievements in innovative engineering and technology.

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