Russian stationary vibration control and mechanical displacement systems for electric power pumps of thermal power plants

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Abstract. The article discusses the possibility of using Russian stationary vibration and mechanical quantities control systems for electric power boilers of thermal power plants, in particular, the implementation of automated control of absolute vibration bearing, axial shear and speed with the requirements of regulatory documents. A review and analysis of the market of stationary systems for monitoring vibration and mechanical quantities, their technical and metrological characteristics was carried out. The possibility of integrating Russian stationary systems for monitoring vibration and mechanical quantities into automated process control systems of thermal power plants, their application in various subsystems, including the subsystem of technological protection and safety locks, is considered. An assessment was made of compliance with regulatory documents governing the construction of such systems, taking into account the requirements of supervisory authorities.

1. Introduction
The uninterrupted operation of nutrient electropumps (NEPs) of the steam-water path of medium-sized thermal power plants, which supply “feed” water from the deaerator to the boiler through a high-pressure regeneration system, including a group of high-pressure heaters, is an extremely important task.

Terminating the pump for more than 30 seconds triggers the process protection to stop the flow of “feed” water to the boiler and stop it to prevent overheating of the boiler surfaces [1, 2]. This, in turn, makes high demands on the equipment of the NEPs means of controlling mechanical movements and vibrations.

For the first time, the requirement for instrument control of mechanical displacements and vibrations was set forth in the “Guidelines for the volume of technological measurements, signaling and automatic control at thermal power plants” (RD 34.35.101-88) [3]. Later in the regulations, the requirements of supplying electric power pumps with rotor axial-shear protection appeared [1, 2].

It should be noted that at the time of entry into force RD 34.35.101-88 means of continuous measurement of mechanical movements and vibrations could not rely on the capabilities provided by modern stationary systems. Vibration control was carried out using a portable vibrometer, as well as by
feeling the state of the bearing caps of the NEP palm of the hand. The shutdown of the NEPs on the axial shift is carried out upon the fact of a change in the position of the mechanical pointer between the stator and the rotor. These requirements are still included in the operating instructions of the process personnel operating the feed electric pumps designed and manufactured before 1997.

The last twenty years have demonstrated a significant breakthrough in the development of regulatory documentation to determine the requirements for vibration and mechanical movements control systems, as well as in the development and implementation of vibration monitoring systems. In the field of vibration measurement, piezoelectric sensors finally became established, and in terms of measuring mechanical displacements, a transition was made from differential measuring instruments to the now classic instruments with eddy current transducers. At the same time, the first interstate standard, which normalizes the vibration of the feed pumps of thermal power plants, and also defines the requirements for conducting measurements, is being developed and enters into force [4].

Initially, thermal power plants were poorly equipped with automated systems for vibration control and control of mechanical movements of the feed electric pumps in operation. But in recent years, enterprises developing and manufacturing electric motors for the mechanisms of their own needs, including NEPs, begin to specify in the questionnaires the supply of electric motors and pumps with vibration control systems of the most minimal version (vibration sensor plus indicating device).

The use of software and hardware systems with functional group management has led to the improvement of existing automated systems for monitoring mechanical quantities and vibration control [5]. At the same time, the tasks of measuring mechanical quantities (axial shift and speed) were generated with the formation of signals (analog, discrete and digital) in the subsystems of technological protections and interlocks implemented both on the basis of traditional means of instrumentation and equipment, and functional subsystems of automated process control systems.

2. Russian market of automated vibration control systems and other mechanical parameters

At the moment, Russian developers and manufacturers produce a wide range of automated systems for monitoring vibration and other mechanical parameters in order to equip electric power pumps of power units with direct-flow boilers of thermal power plants. We list the main representatives of this market:

- Scientific-production enterprise “Vibrobit” (Rostov-on-Don) - produces a whole line of automated systems for monitoring vibration and mechanical quantities (Vibrobit 400 equipment; Vibrobit 300 software and hardware systems and Vibrobit 100 equipment).
- Scientific-production enterprise “Measuring Technologies” (Sarov) - produces IT12 / IT14 monitoring, control and diagnostics.
- Group of companies “Diameh” (Moscow) - produces a line of automated vibration control systems (stationary complexes for vibration control and protection of rotary equipment RUBIN-M2 and Basalt; a complex for measuring and monitoring parameters of rotary units ALMAZ-7010).
- LLC “GC ‘Innovation’” (Moscow) - produces a series of vibration control systems under the general name Vector (Vector M; analyzer Vector P).
- LLC “Integra-engineering” (Moscow) - produces the TOR and Vektor-MK systems for monitoring the vibration control systems and the technological parameters monitoring system.
- LLC “Viscount” (Moscow) - produces the Kaskad stationary vibration monitoring system.
- Scientific-production enterprise “TIK” (Perm), specializing in the development and production of instruments and systems for monitoring, diagnostics and emergency protection of industrial equipment on vibration parameters and producing equipment for vibro-measuring IKV-1 and TIK-RVM advanced vibration monitoring system.
- LLC “Elektron” (Rostov-on-Don), which is the developer and manufacturer of the SIVOK equipment for the control of mechanical parameters, which has in its composition the measuring channels of vibration control.
• LLC “Association ‘VAST’” (St. Petersburg), which develops and manufactures complexes KVK-21M of vibration control equipment.
• CJSC “Energopribor” (St. Petersburg), which develops and manufactures LMZ-97.09(04) equipment for technological control of parameters and protection of power turbine sets.
• LLC “Yugenergopribor” (Rostov-on-Don), which is the developer and manufacturer of equipment EP-1000 for controlling the mechanical parameters of turbine units.
• OOO “Eleksir” (Rostov-on-Don), which develops and manufactures equipment AKTIV for controlling the mechanical parameters of turbine units.
• LLC “Vibron” (Moscow), which develops and manufactures the SVKA-2 vibration control equipment.
• The “Baltech” company, which supplies Proton-1000 stationary systems for monitoring the technological parameters.

3. Expert analysis of technical and metrological characteristics of automated systems for monitoring vibration and other mechanical quantities

The task was to analyze the technical and metrological characteristics of automated systems for vibration and other mechanical quantities (axial shift of the NEP rotor and speed measurement) control to determine the possibility of equipping with them electro-pump power units with direct-flow boilers of thermal power plants.

For expert analysis, the following systems were excluded from consideration:

• Use of equipment not included in the Federal Information Fund of Russian Federation for ensuring the uniformity of measurements.
• Use of vibration sensors with fasteners in less than two or three points [6].
• Use of equipment from not-Russian manufacturers.

We have supplemented information on the characteristics of absolute vibration monitoring and protection systems previously published [7] by introducing technical and metrological characteristics of automated vibration monitoring systems and other mechanical quantities (automated monitoring of the axial displacement of the NEP rotor and measuring speed).

It was taken into account that in order to conduct vibration diagnostics and predict the occurrence of malfunctions, additional results are needed for measuring thermal and mechanical parameters: temperature (metal parts of the stator of the electric motor of the PEN, bearings, oil, feed water at the inlet and delivery of the pump), pressure (feed water at the entrance and delivery of the pump, oil for lubrication of bearings; condensate for seals), etc. For which, the systems should be able to measure these parameters or to get them from the subsystems of the industrial control system. [8]

We will analyze the technical characteristics and functionality of stationary automated systems for monitoring vibration and mechanical quantities, selecting only systems that have valid certificates of type approval and are registered in the state register of measuring instruments as of 01.07.2018.

In the frequency range when measuring the parameters of absolute vibration, the best indicators (minimum frequency - maximum frequency) of the IT-14 monitoring, control and diagnostics system with both models of vibration sensors (developed and manufactured by “Measuring Technologies” (Sarov)) vibration measurements at higher frequencies up to 7000 Hz (for vibration acceleration) and 100 Hz (for vibration velocity) and a minimum frequency of 2 Hz (for vibration acceleration and vibration velocity as a whole), which greatly expands the possibilities of nutrient pumps measurement and diagnostics.

It is necessary to note a wide range of vibration measurements in the high frequency range up to 10,000 Hz (for vibration acceleration) and 1000 Hz (for vibration velocity) for the TIK-RVM advanced vibration monitoring system (JSC “TIK” (Perm)). At the same time, the border of vibration measurements in the low-frequency region is determined to be 3 Hz (for vibration acceleration) and 10
Hz (for vibration velocity), which does not allow for diagnostics at the stage of starting the feeding electric pump when giving the command to turn on the electric motor.

In general, all the considered stationary systems for measuring vibration and mechanical quantities satisfy the requirements for vibration measuring instruments (frequency range is from 10 to 1000 Hz) [9, 10].

The widest range of vibration acceleration and vibration velocity measurement (from 0.0 to 2000 m/s² and from 0.1 to 100.0 m/s) with the ability to control it at the initial stages of the feeding electric pump movement has IT-14 system. This equipment provides the ability to measure the vibration acceleration and vibration velocity of the nutritious electric pumps bearings, including performing diagnostics at the initial stage of movement, immediately after the command to turn on.

Despite a number of differences, all the stationary automated systems for measuring and controlling vibrations and mechanical movements of nutrient electro-pumps meet the requirements for measuring vibration accelerations set forth in regulatory and technical documents.

Of particular interest is the stationary information-measuring system of extended vibration monitoring “TIK-RVM”. It has a wide range of vibration acceleration and vibration velocity.

It should be noted that the recalculation function for vibration acceleration is implemented in the Vibrobit-400 automated machine control system for vibration and in the TIK-RVM stationary information-measuring advanced vibration monitoring system. This function can be implemented in the IT-14 monitoring, control and diagnostics system as an additional option if it is defined in the customer’s technical assignment [7].

Analysis of the data provided by the manufacturers makes it possible to state that the widest range of axial displacement measurements (from 0 to 1.9; 3.0; 4.5; 6.0) with the possibility of its control at the initial stages of movement along the rotor axis of the feed pump possesses the IT-14 monitoring, control and diagnostics system.

All stationary automated systems for measuring and controlling vibrations and mechanical movements of electric feeding pumps meet the requirements of regulatory and technical documents in terms of measuring the axial displacement of the rotor.

If we turn to the measurement of the rotational speed of the feed pumps engines, then the widest range (from 1 to 12000 rpm) is in “Vibrobit-400”.

All stationary systems of measurement and control of vibration and mechanical movements of feed electro-pumps also meet the requirements of regulatory documents for the range of rotational speed measurements.

The lowest error of vibration measurement from the stationary systems of vibration and mechanical displacements control considered for nutrient electro-pumps is ±2.5% on a digital indicator and ±3.0% on a unified current output at Vibrobit-400 [10]. The rest of the considered systems, in terms of their metrological characteristics when measuring vibrations, also do not go beyond the requirements of regulatory documents [10].

At the moment there are no regulatory documentation governing the measurement error of the axial shift of the nutrient electro-pumps rotor. Therefore, to conduct a comparative analysis, we used documents obliging to equip nutritious electro-pumps with axial-shear protection for the rotor and axial-shear protection for the turbine rotor [1, 2]. On the basis of the “Rule of the technological parameters error measurement for thermal power plants and substations” (RD 34.11.321-96), we limit the error of axial shift measurement as ± 5%.

Comparing the above measurement error with the values of axial shift measurement errors by stationary vibration control systems and mechanical displacements, we conclude that all systems satisfy this requirement, however, the highest metrological characteristics of the minimum of axial shear measurement error (± 2.0%) are in the IT-14 monitoring, control and diagnostics system.

Minimum error of speed measurement (0.1%) is at the TIK-RVM tachometer sensor. The remaining stationary systems for measuring and controlling vibration and mechanical movements Vibrobit-400 and IT-14 also meet the requirements for speed measurement errors of 3%, according to RD 34.11.321-96.
The widest ranges of operating temperatures (from -40 to +70 °C) for the Vibrobit-400 and IT-14 systems, which correspond to the RD 153-34.1-35.137-00 “Technical requirements for the subsystem of technological protection performed on the basis of microprocessor technology” (from -10 to +45 °C).

Obviously, the stationary information-measuring systems of advanced vibration monitoring TIK-RVM, which have a working temperature range from -20 to +40 °C, do not satisfy the requirement of the above regulatory document.

Considering the ranges of external working temperatures for vibration transducers, it should be noted that vibration transducers of not all stationary vibration monitoring systems and mechanical quantities meet the requirements for working conditions at temperatures above 250 °C [11].

The best in terms of resistance to external temperatures (+400 °C) is the IT-14 control and diagnostic control system with vibration sensors of the MV-44 series. In the event of an emergency (in particular the appearance of fistulas on the pipeline at the exit of the feed pump), the temperature can rise up to 170 °C. Vibrobit-400 of PS400 series can be used without restrictions when monitoring vibrations on nutritious electro-pumps.

It should be noted that the National Standard of the Russian Federation “Machine condition monitoring and diagnostics. Vibration machine condition monitoring” (GOST R ISO 13373-1-2009) laid down clearly overestimated requirements for external temperature conditions for mechanical displacement sensors - for both axial-shift sensors and for tachometer sensors (+200 °C).

According to the working conditions of the ambient temperature, the above-mentioned sensors are inferior to the axial shift sensors and speed sensors DS-1 and DS-2 at TIK-RVM’ (from -50 to +135 °C) and (from -50 to +70 °C), respectively. This system for measuring axial shear and speed can be used in normal conditions only with the guaranteed exception of the extremely high ambient temperatures occurrence.

As already indicated, for a comparative analysis, stationary systems were selected that have valid certificates of the measuring instrument type approval.

The interesting interval for Vibrobit-400 and IT-14 is 24 months with the use of all types of sensors (vibration sensors, axial shift sensors, tachometer sensors) [12]. The stationary information-measuring system extended vibration monitoring TIK-RVM verification interval is 12 months.

The highest average time to failure is 200,000 hours for axial shift sensors and tachometer sensors in stationary systems for monitoring vibration and mechanical quantities (Vibrobit-400 and IT-14). The stationary information-measuring system of extended vibration monitoring TIK-RVM has an average time between failures of 10,000 hours.

All three considered stationary systems for monitoring vibration and mechanical displacements have the same assigned service life of 10 years.

In the stationary vibration and mechanical quantities monitoring systems considered in this article, the documentation reflects the function of the application in systems affecting safety: in the operating manual, for Vibrobit-400; in the catalog, for IT 14. TIK has a certificate of compliance for TIK-RVM with the requirements of the system's compliance with the SIL2 safety levels.

### 4. Conclusion

An expert analysis of the technical and metrological characteristics of Russian stationary vibration and mechanical movements control systems for nutrient electro-pumps of the average power units boilers shows that the most preferable, including from the point of view of emergency protection, are IT-14 and Vibrobit-400. Their capabilities are superior to other Russian counterparts in most characteristics.

When creating integrated automated process control systems for the power units of thermal power plants, which include stationary vibration and mechanical quantities control systems for turbine units, along with stationary systems for monitoring vibration and mechanical movements of nutrient electric pumps, it makes sense to dwell on the complex choice of the above systems of one particular manufacturer, taking into account the features of the specific technological equipment and the requirements of the reviewed regulatory documents.
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