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AUTOMATIC WATER-LEVEL REGULATING INVARIANT SYSTEM IN THE BOILER SHELL

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The main task of the power industry is a reliable supply of industry and the population with electric and thermal energy. In this case, the main danger associated with reliability is the aging of thermal power plants (TPP).

The ability of automated heat and power equipment to perform its functions is usually expressed by the concepts of “reliability” and “durability” (“service life”) of both process equipment and the technical means of automated process control systems (ACS TP). Reliability is characterized by an average number of shutdowns, such as a boiler, per unit of time that occurred primarily due to sudden failures, caused by the presence of weakened metal elements (due to metal defects, corrosion, improper operation) that had exhausted their resources much earlier regulatory deadline. After such shutdowns, the damaged element is replaced, and the operability is restored. The economic effect of the modernization of the automatic control system (ACS) of the water level in the boiler drum is determined primarily by reducing the damage caused by failures and accidents, due to the increased reliability of the main equipment. At the same time, an accident at one TPP disrupts the normal operation of the entire power grid. Improving the quality of regulation reduces the number of failures and accidents, increases the availability of the main equipment, reduces the reserve of installed power in the system, reduces the number of accidents caused by the boiler over-flow and level drop, and also partially prevents damage to the boiler and turbine.

Durability is characterized by the service life of the elements of the boiler to their full replacement, caused by the exhaustion of the service life of the main mass of the metal due to the accumulation of irreversible destruction processes. Since the replacement of some sections (elements) of the boiler with new ones in the elimination of sudden failures refers only to a small fraction of the total metal, the service life of the metal before the replacement is not associated with the average number of sudden failures. This allows the analysis of reliability and durability separately.

In addition to failures of technological equipment of thermal power plants, they also take into account failures of technical means of automated process control systems, for example, elements of the automatic control system, the quality of which has the greatest impact on efficiency, reliability and durability of technological equip-

ment of thermal power plants. At the same time, the boiler enters the closed loop of the ACS as its main element. It should be noted that in the analysis of sudden failures it is almost always possible to establish the cause of the failure and the failed device.

At the same time, when analyzing the reliability of ACS, gradual failures are also taken into account, affecting both the reliability and the durability of the boiler. The elimination of gradual failures is carried out by changing the settings of the ACS with the help of organs specially designated for this purpose, and they are considered as a failure of the ACS as a whole. As studies have shown, for analog ACS gradual failures more (59%) than sudden (41%).

The transition to more reliable microprocessor automation reduces the number of sudden failures of ACS to 38%. Extremely stringent requirements are imposed on the quality of regulation of modern drum boilers. At the same time, the zone of operation of the power supply automatic control system is usually limited to the limits of the protection settings against lowering the water level in the boiler drum and opening the emergency drain. These limits determine the safety of the boiler, exceeding them causes an emergency situation. Exceeding the upper emergency limit may result in water being thrown into the superheater, a sharp drop in the temperature of hot steam, hydraulic and thermal shock, and damage to the turbine. A drop in the level beyond the lower alarm limit may result in a violation of the circulation in the screen tubes and their burnout. Changing the water level in the boiler drum within the allowable limits has practically no effect on the operation of the boiler. The durability of the metal of the drum and the water economizer, as well as the consumption of electrical energy by the feed pumps depend on the quality of control of the flow of feed water. The sharp fluctuations in the consumption of the latter contribute to the appearance of fatigue phenomena in the metal of the drum, reducing its reliability. Therefore, the deviations between steam production and feed water supply should be minimal. Improving the quality of maintaining the water level in the boiler drum in a typical three-pulse ACS and its modifications when the load changes is usually achieved due to sharp deep changes in feedwater consumption, which is unacceptable due to fatigue stresses in the metal. Therefore, the ACS supply of the drum boiler must ensure that the water level is kept within permissible limits:

- in stationary mode (in the absence of sharp disturbances on the load), the maximum allowable level deviations should not exceed ± 20 mm;
- with a discontinuous disturbance on the load by 10% (initial load is nominal), the maximum permissible level deviations should not exceed ± 50 mm;
- in the normal stationary mode of operation of the boiler, the number of switch-ons of the regulator should not exceed six per minute.

In modern boilers with high thermal voltage level fluctuations with sharp and significant changes in load reach significant values.

With deep internal and external disturbances, typical power regulators of nuclear power plants (NPP) are not able to maintain the water level within the normal operating limits, which leads to unloading or complete shutdown of the power unit and the emergence of economic losses, as well as to reduce the reliability of the steam generator. The automatic regulator of the water level of the steam generator of

the NPP maintains an overestimated level of water at workloads, which leads to an increase in the moisture content of steam and increased wear of the turbine blade apparatus. This reduces the reliability and service life of the turbine.

At the same time, the replacement of old technical means of the ACS of heat and power processes with modern microprocessors using standard control algorithms and traditional structural schemes does not significantly improve the quality of maintaining the heat and power parameters of TPPs operating in a wide range of loads. In this connection, the tasks of modernization of the ACS TPPs based on innovative methods of structural and parametric optimization of dynamic systems that significantly affect the efficiency, reliability and durability of the TPP operation, and the development of a methodology for calculating the economic efficiency of their implementation become relevant. First of all, it concerns the ACS of the water level in the boiler drum, since the latter belong to the first group of the most complex and responsible ACSs, the reliability and maintainability indicators of which are given in [2].

To eliminate these drawbacks, an invariant ACS of the power supply of the drum boiler has been developed. The invariant system with the allocation of an equivalent external disturbance differs from the typical one in that the structure of the stabilizing regulator is selected on the basis of the transfer function of the optimal regulator, the structure and parameters of the dynamic adjustment of the correcting device are based on the transfer function of the optimal regulator taking into account the dynamics of the equivalent control object including the inner loop of the stabilizing regulator.

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СИСТЕМА АВТОМАТИЧЕСКОГО РЕГУЛИРОВАНИЯ ПАРАМЕТРОВ НАСТРОЕК РОБАСТНЫХ ТИПОВЫХ РЕГУЛЯТОРОВ

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Приведены рекомендации по расчету настроек робастных типовых регуляторов с использованием критерия максимальной степени устойчивости. Отмечено, что в отличии от других критериев данный критерий в совокупности с гарантирующим подходом придает методике расчета безытерационный характер.