Approaches to improving the efficiency and safety of the TPP gas economy based on internet of things technologies

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Abstract. This paper describes the design features and characteristics of the "Fast-acting shut-off and control ball valve" proposed for possible replacement of the existing natural gas supply control systems of boilers and other gas-dispersing plants at the power plant. Application of FSCBV provides improvement of reliability and efficiency of gas economy of TPP due to design features, as well as application of technology of Industrial Internet of Things, which allows on the basis of statistical data to perform qualitative regulation, as well as prediction of possible failures.

1. Introduction
The implementation of the national project "Digital Economy" in the concept of energy development until 2035 requires the creation of new approaches for energy companies to modernize and introduce digital transformation programs.

Control of natural gas supply to burners of power boilers is usually carried out according to schemes involving the use of expensive gas units using fast-acting shut-off valves. At the same time, the installation of gas units requires complete dismantling of the gas equipment and pipelines used, which leads to high material and time costs. Also, the boiler load control circuits remain with a common gate control valve, which in turn prevents the quality control of gas flow in accordance with the required heat load of the boiler, both in the boring and in the operating mode.

It is proposed to use "Fast-acting shut-off and control ball valve" (FSCBV) for gas supply schemes of boilers and other gas-dispersing plants [1].

2. Materials and methods
The FSCBV consists of electric drive, fast-action insert and ball valve.

Design version of FSCBV using electromagnetic coupling in shaft release mechanism is shown in Figure 1. Drive shaft 1 and driven shaft connected by electromagnetic coupling 3 are arranged in body 2 of fast-action insert. When the coupling is disengaged, the power spring 4 is released to turn the driven shaft and close the valve.

The consumption characteristic of FSCBV has a smoothly increasing character at the beginning of opening and is close to linear on the main part. This characteristic provides better control of the flow rate of the natural gas supplied to the boiler in the boring mode.
Modularity of FSCBV design makes it possible to complete the product for a specific task with the required characteristics, varying the used components: ball valve, electric drive, power spring of fast-action insert.

Each type and design of ball crane has its own mechanical characteristics. The main characteristic in this case is the dependence of the resistance moment on the rotation angle of the ball locking element.

The figure shows the characteristics of the valve DU 150 with cantilever attachment of the ball element and fluoroplastic seal.

At the same time change of characteristics of torque moment of fast-action insertion to correspond to characteristics of ball crane and electric drive is performed in wide range by means of variation of angle of spring pre-fixation, as well as selection of type size of spring.

According to the system reliability requirements [2], the CAS availability shall be at least 0.99 for a maintenance period of 1 month (approximately 700 hours). As a result of calculations probability of failure-free operation of the system with FSCBV equal to 0.991 is determined.

Design of FSCBV is characterized by possibility of installation of device for control of position of locking ball element, at the same time feature of design of fast-action insert is constant connection of driven shaft with spindle of ball valve. This provides continuous monitoring of ball shut-off element position at any operation modes of FSIV. Such a solution increases the reliability of the device and makes it possible to use an electric drive of simpler design - multi-turn without an integrated position control device.

Figure 1. Diagram of FSCBV with electromagnetic coupling.

Figure 2. Account characteristic of FSCBV.

Figure 3. Ball valve shaft torque.
Control of FSCBV is performed by complete control device, which performs the following functions:
- current control/adjustment (PI, position regulator as part of cascade gas flow ACS)
- calculation of a resource
- diagnostics
- calibration
- Additional protection link, if necessary.

Additional functionality enhancement is achieved by implementing industrial Internet of Things (IoT) IIoT in a control device. At the same time, in the control device, the architecture layers are implemented as follows:
- Sensor level - lower level, represented by integrated sensors: angle of rotation of spindle of ball shutoff member, extreme positions of spindle, temperature of electromagnetic coupling.
- Network layer - for combining control devices into the network and transmitting measurement information and control commands. Implemented on a wired Ethernet interface. Additionally, to improve reliability, the main signals are duplicated by unified analog and discrete signals from the PLC. The use of wire interfaces is due to the higher noise immunity and the need for wire connection of the FSCBV on part of the lines, including power supply.
- The management layer is implemented using PLC and cloud storage technology. Measurement information from control devices is transmitted by PLC to cloud storage, which provides further analysis of data using technologies of operation with large data sets to predict reliability indicators of FSCBV.

Structural diagram of FSCBV control subsystem is given in Figure 4. Electric drive of ED changes position of shut-off element SE through fast-action insert FI. Sensors S measure values of main parameters of FSCBV operation. Measuring information from sensors is transmitted to measuring module MM of control device, and also partially - to PLC. Control module ConM performs switching of electromagnetic coupling of fast-action insert. The ComM communication module performs information interaction with the PLC and other devices.

The FSCBV control device based on the microcontroller provides implementation of data monitoring, diagnostics and archiving functions with the possibility of flexible reconfiguration to different parameters of electric drives and shut-off elements, as well as the possibility of integration into most software and technical complexes of boiler units control.
3. Conclusion
Thus, application of FSCBV as a whole provides improvement of reliability and efficiency of gas economy of TPP, and implementation of technology IIoT control device of FSCBV provides continuous measurement of all important parameters of device operation, including operating time and reliability prediction indicators, and allows to realize advantages of IIoT for complex collection and transmission of measurement information and control signals of decentralized interaction of devices between each other and external environment.

The mechanical tests of the prototype showed the efficiency of the device and compliance of the parameters with the requirements of the current regulatory documents.

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