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SYNTHESIS OF HEAT AND POWER UNIT AUTOMATIC CONTROL SYSTEMS

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Abstract. The process of synthesis of heat and power unit automatic control systems is studied in the article. A review of works and publications showed that implementation of management theory modern methods in relation to heat and power units is restrained by sophisticated workflow mathematical models in power units' elements. Different types of automatic control are delineated using a steam boiler as an example.

Keywords.

Introduction. Modern water heating units for heating energy generating in heat and power systems are known to be complex technical systems. That's why it is difficult to control their parameters automatically for optimum operation mode control [1]. Various approaches, methods and means are used to work out this engineering task nationally and internationally.

It is extremely important to conduct theoretical and practical research in physical and mathematical stimulation to develop power industry. Theory and principles of power equipment models' organization and their regulation systems were worked out to enable workflow stimulation in large power systems.

Most heat power stations display concern about automatic control and management systems modernization whose hardware equipment has exhausted technical resources, is out of date and should be replaced as soon as possible. Current regulators do not meet up-to-date requirements and, therefore, their further maintenance without being replaced or improved will be economically unsound.

The aim of the paper is to analyze the automatic control system synthesis methods for power and substance transformation in heat and power units using mathematical models.

The issue of boiler unit automatic control, management automatic system synthesis and heat and power units' mathematical models development is justified by a great number of respectful national and international scientists [1-18].

Introducing computer equipment on the basis of microprocessors has had a great impact on a general approach to organization and tasks of boiler units and hot water boilers maintenance. This issue is investigated in the works of I.V. Plachkov, A.K. Shydlovskyi, B.S. Stohni, M.M. Kulyk, O.S. Dupak. For instance, level control systems in a boiler barrel have undertaken great transformations from a simple level float regulator and single-pulse regulator with hydrostatic level control to the widespread regulator with impulse circuit. Microprocessors allowed level regulating using a mathematical model. Such mathematical models for boiler units and hot water boilers include description of combustion behavior and heat exchange characteristics as well as the boiler's general dynamic linking.

In this paper we will consider current approaches, methods and means of heat and power unit automatic control.

The analysis of current methods and means of heat and power unit automatic control gives grounds to create an approach for workflow control tasks in heat and power industry.

Materials and Methods. The synthesis of heat and power unit automatic control systems is studied in the paper.

Expert system of control algorithms for power generation units has been developed by Moscow engineering institute scientists. Also hot water boilers control systems have been investigated as well as their optimization, having little information about unit models [2]. The authors argue that recent works on automatic control theory are focused upon so called Fuzzy-control with unknown mathematical model. Such type of control is based on L.A. Zade's fuzzy-set theory [3], having expert evaluation as basic material. However, the authors state that the above-mentioned approach is limited in use in power industry. Hence, they considered an alternative complex of automatic control methods for units with unknown mathematical model. They approved the efficiency of expert evaluation which is based on modified adaptative methods.

The exercise of requirements for energy saving and heat and power unit environmental improvement is displayed in the paper [4]. Furthermore, mathematical models of continuous and discrete control systems of efficiency and ecological cleanness of power and hot water boilers are investigated in more detail. It is proved that under essential delay in optimum parameter measurement circuit (i.e. incomplete combustion constituents in flue gases) the use of the discrete system in order to adjust the "fuel" and "air" correlation provides higher dynamic accuracy in the field of real disturbing frequencies than the continuous one. Although, high control stability and a boiler's economic and environmental indices optimization are attained.

The authors study the grapho-analytical method to design an optimum algorithm for hot water boilers automatic control working for overall load [5]. The analysis begins with a simple case of load sharing between two similar boilers and comes to a general case for different boilers. Basic data is the dependence of the boilers' coefficient of efficiency on their loads. The formula of fuel economy estimate using discrete control optimum algorithm is given in the paper. The formula is used for different boiler units working at full capacity.

There is a description of Boilermizer scheme in the paper [6] developed by Energy Technology Control (Great Britain) with microprocessors for "air" and "fuel" correlation control in hot water boilers having heat production of (0,63-6,3) GJ per year and being liquid fuel or gasoline-based.

The authors [7] also study combustion automatic control system in hot water boilers, which was developed in Great Britain, with keeping CO in flue gases. Besides, the authors state that combustion control in terms of oxygen is imprecise since it is difficult to define the representative point of gas samples screening. The scheme studied, automatic control discrete algorithms and testing data for the three boilers working on oil and natural gas are elaborated in the paper. It is shown that the boilers' coefficient of efficiency has increased up to 0, 5-3%, oxygen content in flue gases has decreased from 4-5 % to 1,4-2,8%, emissions have decreased by 25%.

Different strategies of US boilers automatic control systems organization in terms of their optimized efficiency are investigated in the paper. Key factors for ACS design are dynamic properties of a unit and closed-loop system. There is a description of a typical boiler's ACS and its separate circuits in the paper. In-depth analysis of excess oxygen control in order to minimize air excess and flue gases temperature at zero underburning is given. The methods to determine flue gases content and parameter choice are considered in the paper which characterizes combustion process and fuel burnout rate. The most appropriate scheme for optimization is the one that uses O_2 and CO analyzing.

The automation system of heavy oil boiler houses developed in France is investigated in the paper [9]. To increase the coefficient of efficiency, to reduce costs and to decrease environment pollution level the author suggests the following ways of boilers' automation: using of application-specific logic blocks (schemes) in programmed automatic units in multiple control systems; applying of adaptive or remote viewing systems which allow full or partial excluding a person's involvement in a boiler house; installing some water-fuel slurry automated devices on a burner fuel feedline to decrease carbon loss.

The authors reviewed English industrial systems applied to automatically control gas fuel and flame loss in hot water boilers [10]. Those systems allow determining gas and oxidizing agent loss. They are used to automate continuous heat generation under variable gas mixture combustion.

In this paper the authors study the design and functions of the Japanese low-mass and hot water boiler computer-driven control system [11]. The system which is based on conventional detectors like combustion detectors, pressure switches, is provided with some additional functions. Moreover, there is an opportunity to detect a boiler's status and the system of control, processing, data storage, data printing release and its transfer via data channel to a maintenance panel.

Optimum algorithm determination method to control boilers in a boiler house grounded on dynamic programming methods is suggested by the authors [15] and is successfully employed in Russia. The method given is based on optimum correlations of the efficiency coefficient and boiler house production acquired by statistical analysis. It is of general usage and can be adapted to any kind of boilers. Besides, it can be used to control boiler production manually and automatically considering any operating boiler design.

Gain in hot water boiler performance by means of air feed automatic control system using the "fuel" and "air" correlation is of great importance. The paper gives the description of such system [16] which, according to their authors from Australia, is thought to save up 2% of the fuel. Although the system is designed for shell boilers with rotary burners, it can be used for hot water boilers as well. The system uses a zirconium oxide based detector which measures O2 content in flue gases with given values referring to unit loads, an executing mechanism changing air feed. In case of inability to measure O2 content (under essential air inflow), air-flow and fuel detectors connected to a comparison unit are used.

The Swiss design shows that gas saving in central heating boiler units the burners should have two- or multistep control and to decrease the number of their ons and offs there should be a heat accumulator between a boiler and a circuit [17]. To use flue gas heat there should be a heat exchanger behind a boiler to heat water for hot water supply. Boiler load control should be done in accordance to the temperature of the water having passed through a boiler. Applying the above-mentioned measures of saving in terms of a test boiler showed 37% of gas saving.

Results. The analysis of the above-mentioned and some other current approaches, methods and means of boiler house parameters automatic control at hot water and combined plants revealed that, in spite of their diversity, all of them are focused on temperature or hot water (steam) pressure automatic control; optimum correlation between burnt fuel amount and air losses; exhaust in a combustion chamber and behind a boiler and CO abatement decrease. The last matters very much for the decline of harmful matters in the products of combustion and contamination of environment.

One of effective methods of improvement of quality of smoke gases and energy-savings there is automation of processes of burning of fuel in boiler rooms. Perfection of process of burning of fuel is determined by the economy of work of the caldron setting and instrumental in protecting of environment from contamination. It is known that the serve of fuel and air in heating of caldron must be carried out in certain correlation both insufficient and surplus, serve of air reduces an output-input of caldron ratio [13]. In order that processes of burning, which take place in the caldron settings, as least contaminated an atmosphere, it is necessary to equip the system of the automated management a subsystem for the improvement of quality of smoke gases. For solving of the noted task CAS must additionally execute the followings functions [13]:

- automatic collection of values of parameters of processes of burning, which influence on quality of smoke gases;
- analysis of the got values of the controlled parameters of technological processes of burning;
- automatic control parameters which provide necessary nedopal;
- determination of supernumerary situations, that exceeding of possible maintenance of the harmful pluggings is in smoke gases.

Automation of caldron aggregates foresees the equipment of every caldron facilities of automatic control and measuring of his parameters, automatic defence, in case of occurring of emergency situations and providing of the automated management a separate aggregate.

Conclusion. Requirements for hot water unit energy saving and environmental improvement are directly connected with current production processes improvement based on modern control theory methods. To bring in modern control theory methods by means of multilink systems one should have an adequate production process mathematical model to converse energy in the form of a conventional differential equations system. Dynamic mathematical model design is complicated both by the distribution of most separate subprocesses in hot water units and by difficult choice of physical parameters being a part of differential equations.

The discussed structures, approaches and boiler automatic control systems can be used to develop the projects of their automation using a wide range of mathematical methods of process parameters control.

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