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The algorithm diagram of combustion optimizing of a hydrocarbon fuels variable composition in thermal power plants

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Abstract. In modern power engineering, there is a problem of rational and efficient use of hydrocarbon fuels variable composition. The composition of the fuel can vary in time and from different sources. These changes lead to combustion optimum regime shift in thermal power plants. Previously, an algorithm of combustion optimizing of a hydrocarbon fuel variable composition in thermal power plants was developed. According to the algorithm, the fuel and air flows are regulated depending on the outlet temperature of the heat carrier. In this paper, a diagram of the implementation of this algorithm is presented.

1. Introduction

Due to reduction of fuels reserves and the electricity consumption increasing the problem of energy efficiency and energy saving in combustion processes is topical. The composition of any fuel can vary depending on the time and source. The change in the fuel composition leads to a changes of the fuel characteristics: fuel calorific value, burning temperature, burning velocity, heat release rate, composition of exhaust gases et al. As a result, the stability of the heat power plant is disturbed, that leads to negative effects: blowout, flashback, autoignition, underburning of fuel, change in temperature and composition of combustion products et al. [1].

According to the Government Decree of the Russian Federation since 2009 [2] 95% of produced associated petroleum gases (APG) should be rationally used, for example, as fuel to produce thermal energy. At the same time, the USA Environmental Protection Agency, since 2008, considers any gases generated at the petroleum refinery as fuel gases [3], which also obliges to use these wastes to generate energy.

At this time, special expert organizations are engaged to regulating the operation of thermal power plants in the Russia. However, during the calculations, the expert organization takes the fuel composition as a constant. Thus, regulation of the boiler according to the calculated parameters occurs with an error, when the fuel composition changes.

There are several methods to optimize the combustion process in heat power plants [4-7]. However, the available methods do not allow reacting quickly and efficiently on fuel compositions changes or



requiring a continuous analysis of fuel calorific value or exhausting gas composition. To implement these methods, it is necessary to develop complex automated control systems.

The authors developed a mathematical model of the composition changing effect of the alkane fuels (C_nH_{2n+2}) on the heat release of the combustion process [8]. Conditions for stabilizing the thermal effect of combustion during short-term and long-term changes in the composition of the alkane fuels were obtained. Also, a numerical simulation of the combustion processes of APG various composition in a steam boiler was carried out [9]. As a result of mathematical and numerical modeling an algorithm for stabilizing the boiler's heat release rate was developed [10, 11]. The algorithm includes interrelated changes in fuel and air flows, which ensure established temperature of the heat carrier at the boiler outlet that corresponds to an established heat release rate.

The purpose of this work is the development of the diagram of the combustion optimization algorithm of hydrocarbon fuels variable composition in thermal power plants. The diagram will allow develop the software and the automated control system of fuel and air flow rates in the thermal power plants. Using of the automated system in thermal power plants will improve the efficiency of traditional fuels combustion and reduce their consumption through the use of alternative fuels, such as APG. Optimization of the combustion process will reduce the amount of harmful emissions into the atmosphere and will allow using alternative fuels for their utilization and generation of thermal energy.

2. Diagram of the combustion optimization algorithm.

Earlier, an algorithm for stabilizing the boiler's heat release rate under optimal combustion conditions for fuels variable composition was developed. The stability of the boiler's heat release rate was evaluated by the outlet temperature of the heat carrier. It is established that in case of deviation of outlet temperature from the set value, it is necessary to change fuel and air consumption in order to restore the initial operating mode of the boiler. Two cases were considered: a decreasing and increasing of the fuel calorific value, associated with a change in the fuel composition. In accordance with this, the proposed diagram will have two independent blocks (Figure 1).

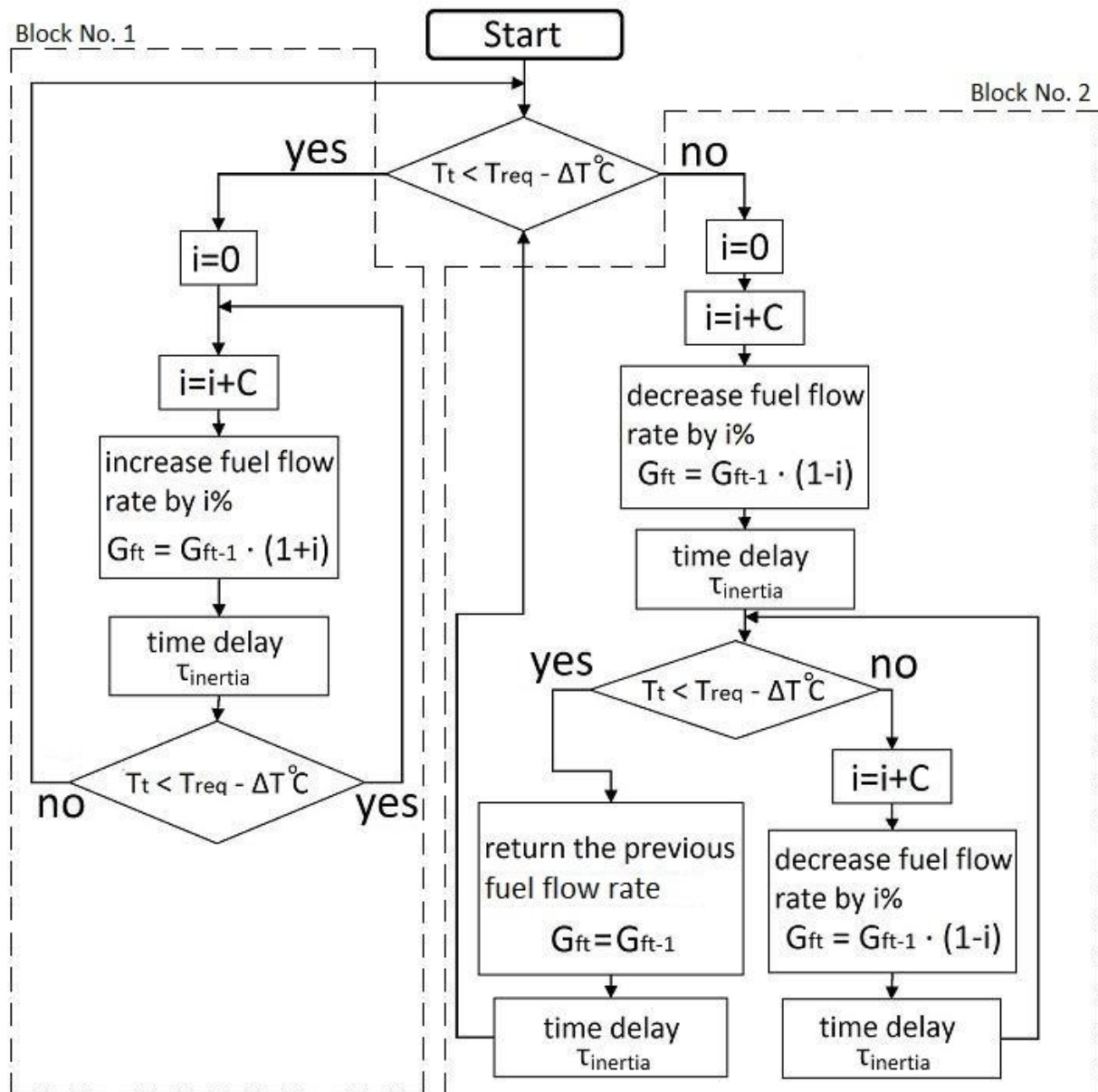


Figure 1. The diagram of optimization. T_t —heat carrier outlet temperature, T_{req} —required heat carrier outlet temperature, ΔT —variation value of heat carrier outlet temperature changing, i —cycle variable, C —variation value of fuel flow rate changing, G_{ft} —fuel flow rate, $\tau_{inertia}$ —boiler inertia time.

Block No. 1 begins to work if the outlet temperature of the heat carrier decreases, which indicates a reduction of fuel calorific value. In this case is necessary to start a gradual increase in the fuel flow rate until the outlet temperature of the heat carrier becomes to the required. After that, the program returns to the initial stage of the work.

Block No. 2 is a test block and it works when the outlet temperature of the heat carrier does not change, which indicates an increasing or stability of fuel calorific value. The test is carried out by reducing the fuel flow rate. After reducing the fuel flow, the program operates based on a change in the outlet temperature of the heat carrier. Decreasing the outlet temperature of the heat carrier means the stability of the fuel calorific value and it is necessary to return to the previous value of fuel flow rate. If the temperature does not change, this means that the fuel calorific value has increased and it is

necessary to continue the further reduction of fuel flow rate until the outlet temperature of heat carrier decreases. When, after fuel flow rate reduction, the heat carrier temperature decreases, it is necessary to return the previous value of fuel consumption. Next, the program returns to the initial mode and checks the work of the algorithm again.

3. Conclusions

So, based on the previously developed algorithm, the diagram of the optimization process of combustion of hydrocarbon fuels variable composition in thermal power plants has been developed. The diagram shows how to stabilize boiler's heat release rate, when fuel calorific value is changing in the case of the fuel composition change.

Based on the algorithm diagram, software to automate the combustion process of fuel variable composition will be developed. Approbation of the optimization algorithm and the corresponding software will be carried out on a laboratory setup. The laboratory setup will consist of a combustion chamber, heat exchangers, automatic fuel and air flow regulators, heat carrier temperature meters at the inlet and outlet of the heat exchanger and an automated system to control digital and analog signals.

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