About the task of leveling the "false" operations of the heat load regulator

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Abstract

The effect of a heat load regulator «false» operation is inherent in systems with cross connections (boilers — main steam main — turbine, fast-response PRDS - fast-response pressure-reducing and desuperheating station). The boiler heat load regulator (HLR) is triggered «falsely» to a significant external disturbance from the steam line. The work is devoted to the problem of a boilers HLR response correction solving for the regulator «false» operation leveling for a thermal power plant (TPP) with cross links (or the combined heat and power plant (CHP)). The solution is based on the analysis of the data from measurement sensors in real time.

Keywords: coal thermal power station, combined heat and power plant, steam line, heat load regulator, «false» operations, algorithm of leveling, correction circuit.

Introduction

Thermal power plant with cross connections is a system of boilers and turbines connected by a single heat line. Boilers produce superheated steam, which is collected in the main steam line. Next, steam enters for heating system water and the turbine to produce electricity. In such a unified system, control of each boiler separately is sensitive to external disturbances and to changes in the station load.

To maintain a given level of steam consumption, an automatic control loop is implemented - a heat load regulator (HLR). The difference between the current value of the steam flow and the target flow is supplied to the controller input. In some solutions, a pressure change in the steam collecting chamber is additionally added through the adder.

The scheme and experience of implementing this solution is described in detail in [1]. The heat load regulator of the boiler unit is triggered "falsely" with a significant external disturbance from the steam main. Such a disturbance may be caused by a change in the load of the turbines, that is, the execution of the dispatch schedule and is the normal operation of the station. The situation is accompanied by a change in the load on the boiler and turbines. In the case when a part of the boiler remain with its previous load, then their HLR will "falsely" work out, which will lead to an increase in the total time for reaching the steady state. Since the system of boilers, pipelines and turbines is a system of interconnected vessels, where one affects all, “false” operations introduce additional disturbances to the natural pressure fluctuations in the pipeline and make it difficult to stabilize the entire system. The physical essence of the processes occurring at the time, and the reasons for the appearance of such values of consumption on the sensors were described in detail by A.S. Klyuev in «Installation of Systems for Automatic Regulation of Drum Steam Boilers» [2].

The «false» operation of the regulator effect results are:

- increased risk of pressure fluctuations (higher than desired);
- with regular “false” border operations (feasible area) are observed in a wider range than recommended;
- increase the total time to enter the mode;
- increased equipment wear.

Today the solution of "false" operation problem is to change the HLR task and the raw coal feeder speed by operator in manual mode.

1 Problem formulation

A system of 4 boilers of CHP included in a common steam main is considered as a research object.

Let there is a boiler unit (object of study), which is part of an interconnected system (group of boiler units, the main steam line and turbines).

The boilers structures are the same. Each boiler has a set of regulators (the level in the boiler drum, vacuum, etc.), which have the task of maintaining or controlling certain variables. We should note, that boilers has the heat load regulator (PI controller), that controls its steam capacity.

Let a disturbance occurs in the system (change in turbine load). In the same time the task for the studied object (boiler) does not change.

In this case one of the main control system disadvantages is the false operation of the heat load controller of boiler in the base mode as the reaction to perturbations from the main steam line side.

It is required to form a control action on the object in such a way as to minimize the effect of “false” triggers of the heat load regulator of the considered boiler unit.

2 The false HLR operation leveling algorithm

To solve the problem, an algorithm for leveling “false” heat load regulator operations in automatic mode is proposed.

To do this, we introduce into the control circuit an algorithm (named control unit) that analyzes the general situation of the station load and levels the “false” HLR responses if it is nessasary.

For boilers with constant load it leaves the current number of the raw coal feeder revolutions, that ensuring their load in the steady state. The state stabilization will be the task of the boiler units, which introduce disturbances, that is, change the load.

The integration scheme of the data processing algorithm requires the complete preservation of the existing station control scheme, so that the basic control loop is always included in the work.

The solution scheme is presented in the figure (1).

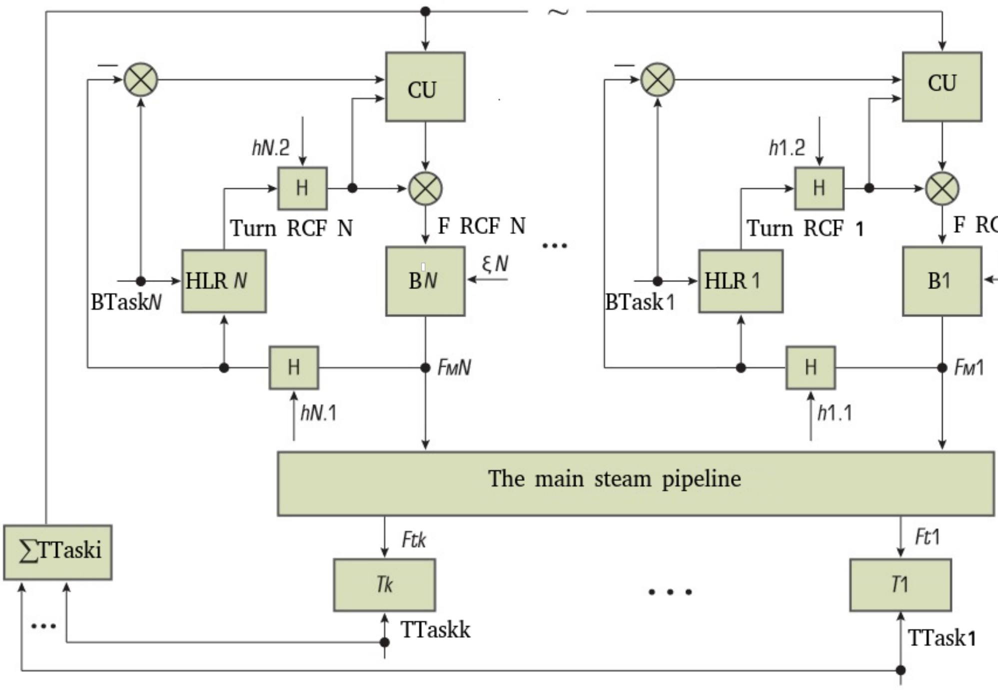

Figure 1: The scheme of the rpm number of raw coal feeder correction (by the proposed control unit) with the HLR enabled

The following notation are used in the diagram: $B(1, \ldots, N)$, $T(1, \ldots, k)$ – boilers and turbines; control unit (CU) – the proposed algorithm for calculating the raw coal feeder (RCF) rpm number in the boiler , taking into account the load change throughout the station; HLR$(1, \ldots, N)$ – classical proportional-integral (PI) regulator of heat load (for each boiler); BTask$(1, \ldots, N)$ – steam consumption task in each boiler; TTask$(1, \ldots, k)$ – steam consumption task for each turbine; ΣTTaski - total task for turbines; Ft$(1,\ldots, k)$ – measuring steam consumption turbines; Turn RCF $(1, \ldots, N)$ – rpm number of raw coal feeder from boiler HLR; F RCF $(1, \ldots, N)$ – corrected raw-coal feeder turnover values; $\xi(1, \ldots, N)$ – uncontrolled disturbances (changes in fuel quality, air regime, thermal properties of feed water, the operation of the superheated steam temperature controller, etc.); hN.1, (N – boiler number) – steam flow fluctuations, measurement accuracy; hN.2, (N – boiler number) – the conversion of the output signal in the RCF rotation frequency.

In the base control scheme PI regulators control the values of the steam flow by changing the input influences (rpm number of raw coal feeder).

The proposed control unit (CU) monitors the current situation according to the process data and, if necessary, includes an algorithm for leveling “false” operations.

The leveling algorithm is activated in the boiler where an external disturbance by other boilers is detected when the station load changes. It works only for boilers where HLR task remains unchanged.

The leveling "false" regulator operations [4] algorithm consists of the following steps:

1. Fix a change of the turbine task;
2. Trace changes of the task to boiler units;
3. If the boiler has not received a change in steam flow task, then switch off it HLR
4. The control unit supplies the input of the boiler with the value of the RCF revolutions from the previous step (before the turbine load changes).
5. After the end of the transient processes in boilers with a modified load, the control unit turns on the RCF in the boiler without changing the load with zero value of the integrating component.

The main feature of the solution is the use of current information, that is, the latest measurements from sensors throughout the station to correct the reaction of each boiler, which is expected to have a “false” operation of the regulator. In this regard, it is important to ensure the flow of raw data from sensors with reliable values into the algorithm, that requires the information-measuring system and instrumentation stability.

In developing and testing the HLR operation correction algorithm, raw data archives were used. Data was written to the file in increments of 30 seconds.

The initial archive was the unloading of process control parameters, in *.mbd, MS Access format. Data acquisition time: from june 4, 2017 to december 14, 2017. The data processing period is taken from June 5 to June 27, 2017.

List of the thermal power plant variables [3]:

- the coal consumption in boiler: 0-6000 a rpm number of raw coal feeder.
- the steam pressure in the drum is in range 120-150 kgf/cm^2;
- the steam flow from boiler: 0-600 t/h
- the steam pressure in the manifold (main line): 120-150 kgf/cm^2;
- the steam flow in the manifold (main line): 0-1700 t/h ;
- the heat load regulator task (flow task) in boiler: 0-600 t/h. (the max value of flow task for different boilers is 350 or 500 t/h)
- the total number of fuel turns for monitoring the task change process: 0-24000 rpm.

Some computational studies of the imitation object are carried out in the paper.

3 Test experiments on the object model

To test the proposed algorithm of the HLR false operations correcting, an experiment was conducted. On the ABB (Asea Brown Boveri Ltd.) platform a prototype of the station with 4 boilers combined into a single steam main was created (see in figure (2)).

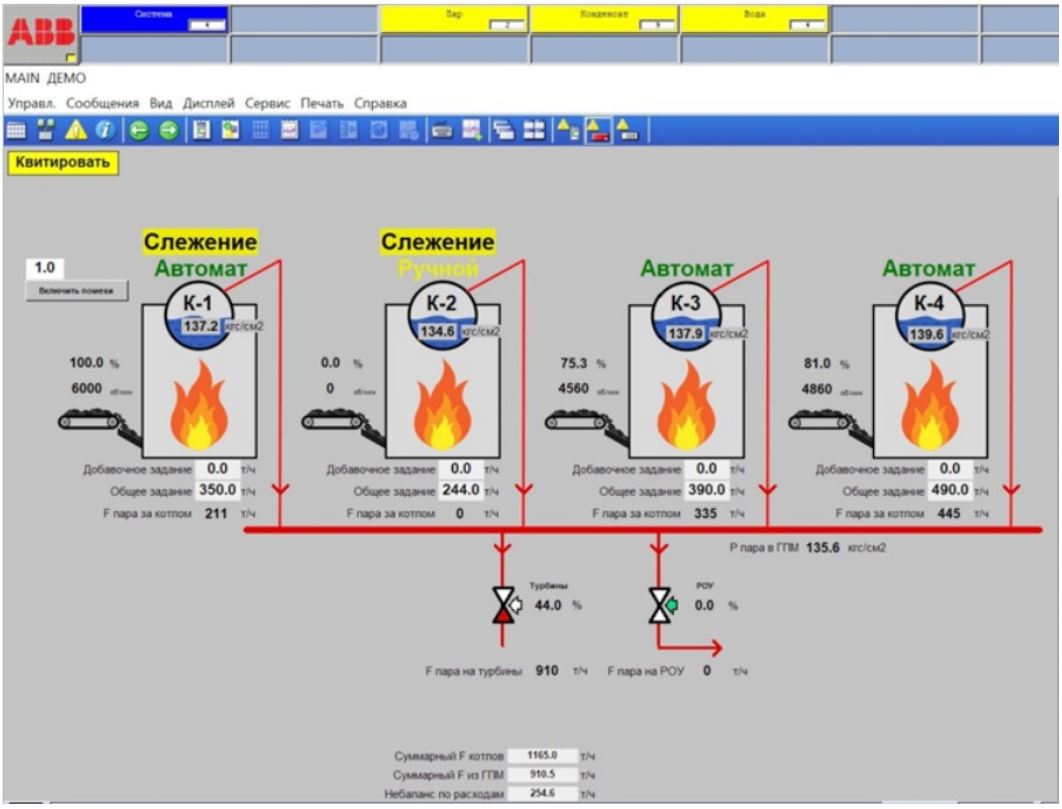

Figure 2: Imitation model of the station with 4 boilers

The simulation model is based on the following dependencies derived from real data:

1. Main steam line pressure is calculate as:

$$P_{MSL} = ((F1 + F2 + F3 + F4 - Ft - F_{PRDS})40e^{-st}\frac{1}{(Ts+1)}\frac{1}{5Ts}) + 125. \quad (1)$$

where P_{MSL} - steam pressure in the main steam line, $F1$ – steam flow of boiler 1; $F2$ – steam flow of boiler 2; $F3$ – steam flow of boiler 3; $F4$ – steam flow of boiler 4, Ft - turbine steam flow, F_{PRDS} – pressure-reducing station flow.

2. To calculate the pressure of each boiler separately the following formulas are used:

$$P_{drm1} = (3.7V1^2 0.0000001\frac{1}{(Ts+1)(Ts+1)}) + \frac{P_{MSL}}{(Ts+1)}. \quad (2)$$

where P_{drm1} – drum pressure 1, $V1$ - a rpm number of the heat load regulator 1;

$$P_{drm2} = (3.8V2^2 0.0000001\frac{1}{(Ts+1)(Ts+1)}) + \frac{P_{MSL}}{(Ts+1)}. \quad (3)$$

where P_{drm2} – drum pressure 2, $V2$ - a rpm number of the heat load regulator 2;

$$P_{drm3} = (3.9V3^2 0.0000001 \frac{1}{(Ts+1)(Ts+1)}) + \frac{P_{MSL}}{(Ts+1)}. \quad (4)$$

where P_{drm3} – drum pressure 3, $V3$ - a rpm number of the heat load regulator 3;

$$P_{drm4} = (4V4^2 0.0000001 \frac{1}{(Ts+1)(Ts+1)}) + \frac{P_{MSL}}{(Ts+1)}. \quad (5)$$

where P_{drm4} – drum pressure 4, $V4$ - a rpm number of the heat load regulator 4.

3. To calculate the steam flow of each boiler separately the following formulas are used:

$$F_1 = 170\sqrt{P_{drm1} - P_{MSL}}, \quad (6)$$

$$F_2 = 170\sqrt{P_{drm2} - P_{MSL}}, \quad (7)$$

$$F_3 = 223\sqrt{P_{drm3} - P_{MSL}}, \quad (8)$$

$$F_4 = 223\sqrt{P_{drm4} - P_{MSL}}. \quad (9)$$

4. To calculate the steam flow of turbines and pressure-reducing station flow the following formulas are used:

$$F_T = 177.7K_{VFC.Turb}\sqrt{P_{MSL}}. \quad (10)$$

$$F_{PRDS} = 9K_{VFC.PRDS}\sqrt{P_{MSL}}. \quad (11)$$

where $K_{VFC.Turb}$ - valve flow coefficient of turbine, $K_{VFC.PRDS}$ - valve flow coefficient of pressure-reducing station.

5. The proportional-integral regulator for HLR imitation is described as:

$$W(s) = \frac{Kp(Ts+1)}{Ts}. \quad (12)$$

where Kp, Ts - parameters of PI regulator.

It should be noted that the efficiency of the control with the use of PI regulator depends on when and how accurately it is set. Since over time some characteristics of the object may change, which will require the setting of the PI controller parameters.

Next, we show the result of the experiment with the leveling Control unit turned on and without it on the imitation model (figures (3), (4)).

We compare the results of steam flow control in the main line with the use of the PI-regulator and the proposed controller that corrects the reaction of the boiler heat load controller. It is required to bring the system to the setpoint state when changing the target for steam flow in the pipeline, by controlling the heat load controller of the one boiler. The remaining boilers of the CHP plant are in the base mode (and their regulators react to the pipeline pressure changes).

Figure (3) shows the difference in the rpm number of raw coal feeder (RCF) with the control unit turned on (algorithm for leveling “false” operations) and without it.

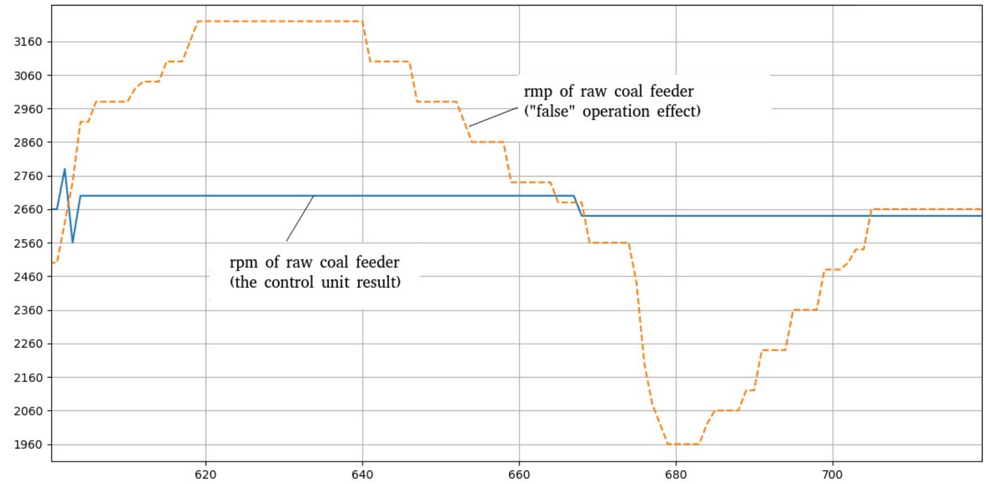

Figure 3: An example of the RCF speed change with control unit operation and without it

Figure (4) illustrates the difference in the operation of the boiler with the leveling algorithm turned on and without it.

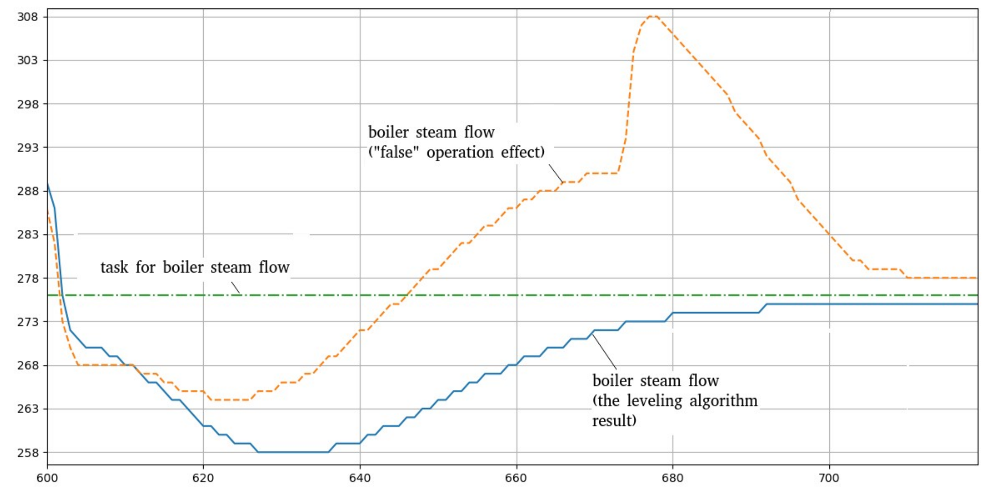

Figure 4: The Boiler steam flow with and without control unit operation

As we can seen from the figure (4), variations in steam flow at the output of the boiler with the leveling algorithm turned on are much lower. Thus, the use of the leveling algorithm allows us to avoid additional pressure fluctuations introduced into the system under consideration in the presence of “false” regulator operations, as well as to reduce the time for the entire system to achieve the specified performance.

Conclusions

The introduction of the proposed algorithm in the control system at the plant will allows correcting the false reaction of the heat load regulator of boilers in order to achieve the setpoint.

The proposed algorithm allows to avoid the effect of "false" operation, calculates the required value of the control action. It blocks the control signal from the heat load regulator by transferring the calculated values, then returns control to it, zeroing the integrating component. As a result of all the above actions, the control unit helps prevent unwanted pressure fluctuations in the main steam line.

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