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Adaptive Neuro-fuzzy Regulating System of the Temperature Mode of the Drum Boiler

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ABSTRACT: The aim of the work is to upgrade the existing methods of regulating the parameters of the heat and power boiler. Mathematical models are constructed by an analytical method using equations that describe the physical properties of an object. The synthesis of the regulatory system is carried out on the basis of the localization method using various switching circuits for regulators. Developed new mathematical models of the gas-air path by the analytical method. These include linear, non-linear and non-linear with electric drive. Each of the models can be used for the synthesis of control systems, depending on the required accuracy of the description of the object. The research results of this work can be applied to real technological objects. As the object of regulation considered ACS temperature superheated steam drum boiler thermal power station.

KEYWORDS: Automatic control system, integral controller, PID controller, tuning methods, PID algorithm efficiency.

I.INTRODUCTION

The algorithms of functioning of automated control systems developed at the design stage, as a rule, differ significantly from the optimal values of the parameters of traditional regulators. This is due to the imperfection of mathematical models of objects. It is known that obtaining mathematical models of experimental control systems for operating complex objects is a difficult task. These difficulties are associated with the influence of external and parametric perturbations, some of which are non-stationary in nature and are not subject to control.

In connection with the above, the need to use adaptive intelligent control systems for complex multi-mode dynamic objects becomes relevant and necessary measure to improve the efficiency of production management in general.

II. REVIEW OF EXISTING MANAGEMENT METHODS

The task of controlling the superheated was to provide a predetermined temperature in the steam path of the boiler [1, 2]. The steam temperature was varied by increasing or decreasing the amount of water injected into the superheated to stabilize the set value of the steam temperature at the superheated outlet (Fig. 1).

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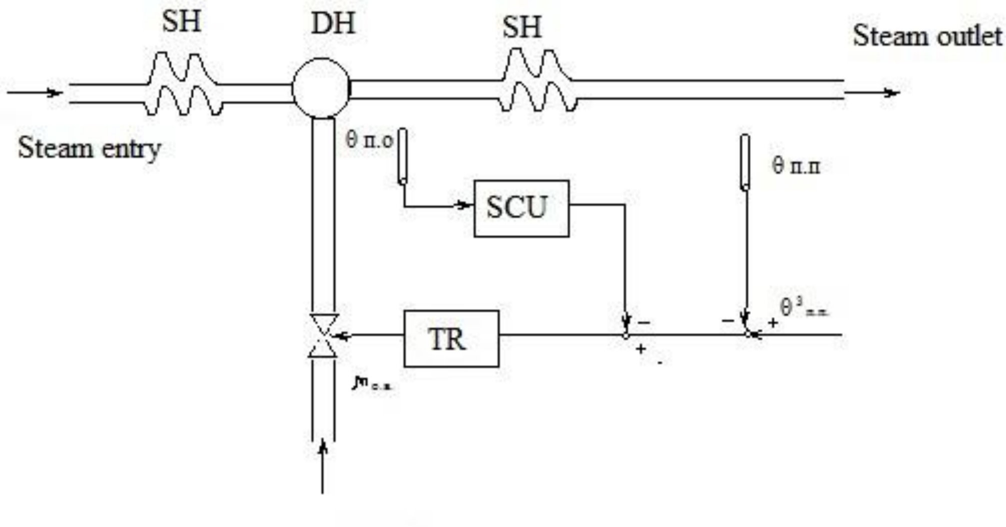

Fig. 1. ACP temperature of superheated steam:

SH - superheater, DH - desuperheater, SCU - signal conditioning unit (differentiator), TR - temperature regulator, θ *n.o.*- steam temperature after the desuperheater, θ *n.n.* - steam temperature after the superheater, θ ^{3}*n.n.* – task

In the existing heat and power facilities, a typical cascade system for superheated steam temperature control is used, which include the control circuit of the PI controller and an additional measurement circuit of an auxiliary controlled variable formed in the SCU unit.

Analysis of the operating characteristics of the superheater shows that the control object has a variable transport lag, its dynamic properties substantially depend on the oxygen content in the outgoing gases, contamination of heating surfaces, and also on regime factors - load, type and grade of combusted fuel, condition of heating surfaces, excess air, etc. In addition, obtaining a mathematical model of steam superheat temperature is usually associated with approximation of acceleration curves obtained experimentally. cial, whereby the mathematical description of a priori becomes inaccurate.
The study of scientific publications in the field of adaptive ASR in dynamic systems [1-3] led to the conclusion that the traditional methods of active identification and the associated algorithms for calculating the optimal settings for PI and PID controllers for analyzing the CFR of objects or the mode of self-oscillations are widely used. It should be noted that for the considered SAR temperature of steam, the self-oscillation process is unacceptable due to the requirements of the technological regulations, since the deviation of the temperature of steam from the norm can lead to premature wear of the turbine equipment. Thus, the scientific problem arises of finding the optimal methods for identifying an object in cases of changes in its load and algorithms for calculating PI controller settings to ensure the expected transition process (by overshoot *G*<30%, attenuation degree, $\psi = (0{,}75 - 0{,}95)$ with minimal control time T_p).

III. SOLUTION METHODS

Nowadays, scientific approaches associated with the use of intelligent systems [4-6], based on the hybrid application of neural regulators and neural networks, have become widely popular in the theory of adaptive control, which prompted the emergence of a new scientific direction - hybrid, or neuro-fuzzy networks (HS NFN) [4]. Consideration of this technology in relation to the identification and adaptation of the ASR temperature of superheated steam is an important scientific task.

The structure proposed in the article of the neuro-fuzzy adaptive regulatory system is shown in Figure 2.

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The structure of the transfer function consists of several inertial units with a delay of the form: $W(S) = \frac{K}{(T(s)+1)}e^{\tau(s)}$ with values varying over time in a certain range depending on the type of load or the mode of operation of the steam boiler. The identifier determines the values of the parameters of the object and its structure.
The neuro-fuzzy controller model is a multilayer neural network without feedback, in which the inputs (K, T, τ) are presented in the form of linguistic variables. To approximate the dependence representing the causal relationship between K, T, τ and K_p, T_u was chosen and the type of membership function (trapezoidal and triangular), describing the input values. Thus, the neuro-fuzzy model was implemented to display the parameters of the PI controller according to the characteristics of the control object: $S^k = f(x^k) = f(x_1^k, x_2^k, \cdots, x_n^k), k = 1,2,\cdots,n$in the presence of a training set $\left((x^1, y^1), \cdots, (x^n, y^n)\right)$.

To model an unknown function f , Sugeno's algorithm is used with a knowledge base of the following type: P_i IF $x_1$is $A_{i1}$and x_2 is A_{i2} and x_1 is A_{in}, THAT $T_{u=}S_i, i = 1,2,\cdots,m$,where$A_{ij}$ are fuzzy triangular sets describing the statements of the expert (small (M), medium (C), large (B)), S_i - output values of the regulator. The degree of truth μ of the rule i is determined using the conjunction operation. Output fuzzy system was determined by the method of center of gravity [3]:

$$T_{uk} = \frac{\sum_{i=1}^{m} \mu_i S_i}{\sum_{i=1}^{m} \mu_i}$$

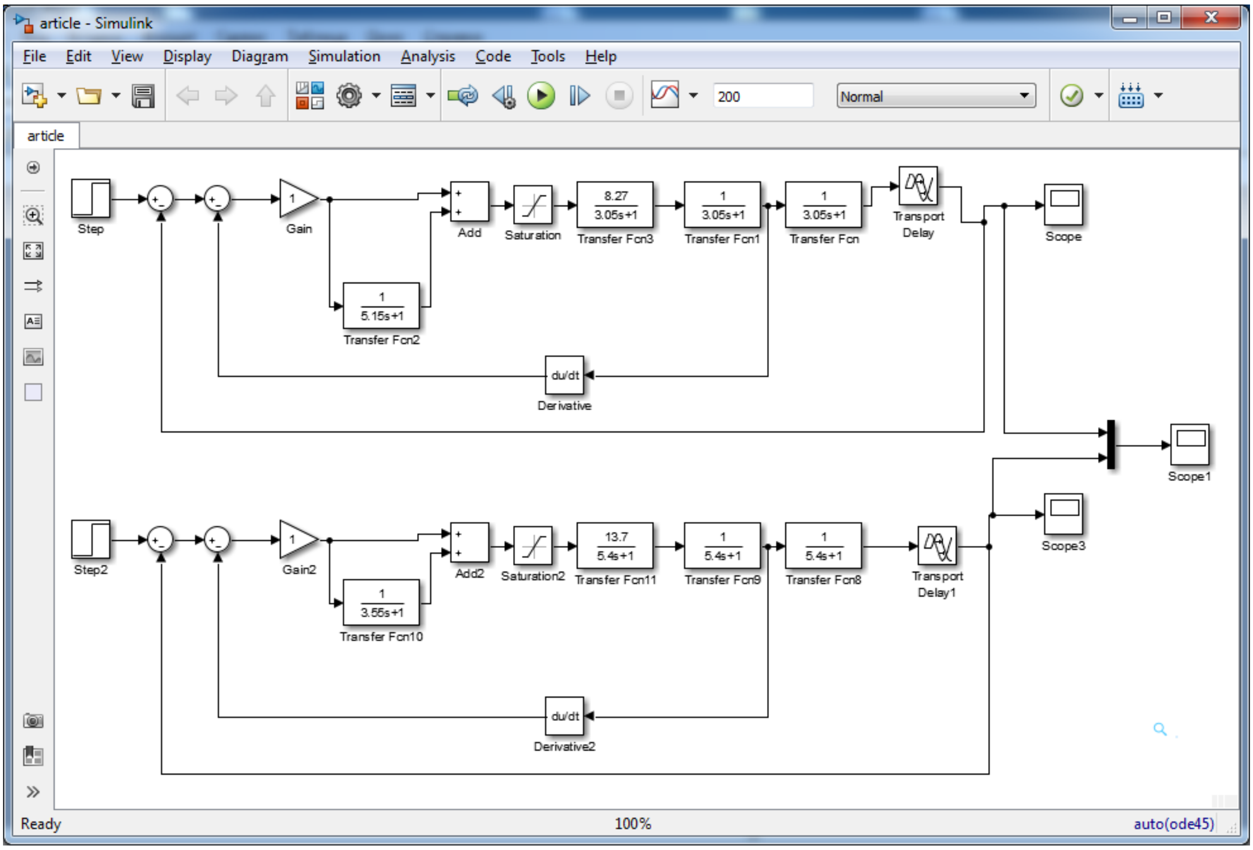

Fig. 2. Diagram of adaptive ASR with PI controllers and nonlinear elements

IV. RESULTS

From the analysis of transients (Fig. 3), we can conclude that, with the influence of parametric perturbation (1,2), the hybrid system has a shorter regulation time ($T_{p1} = 138\ s$) compared to the traditional adaptive ASR ($T_{p2} = 163\ s$), as

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well as reregulation of the hybrid ASR $G^{tr} = 28\%$, traditional $G^{tr} = 50\%$, the degree of attenuation of the hybrid, traditional, i.e. the proposed hybrid billing system is optimal and energy efficient.

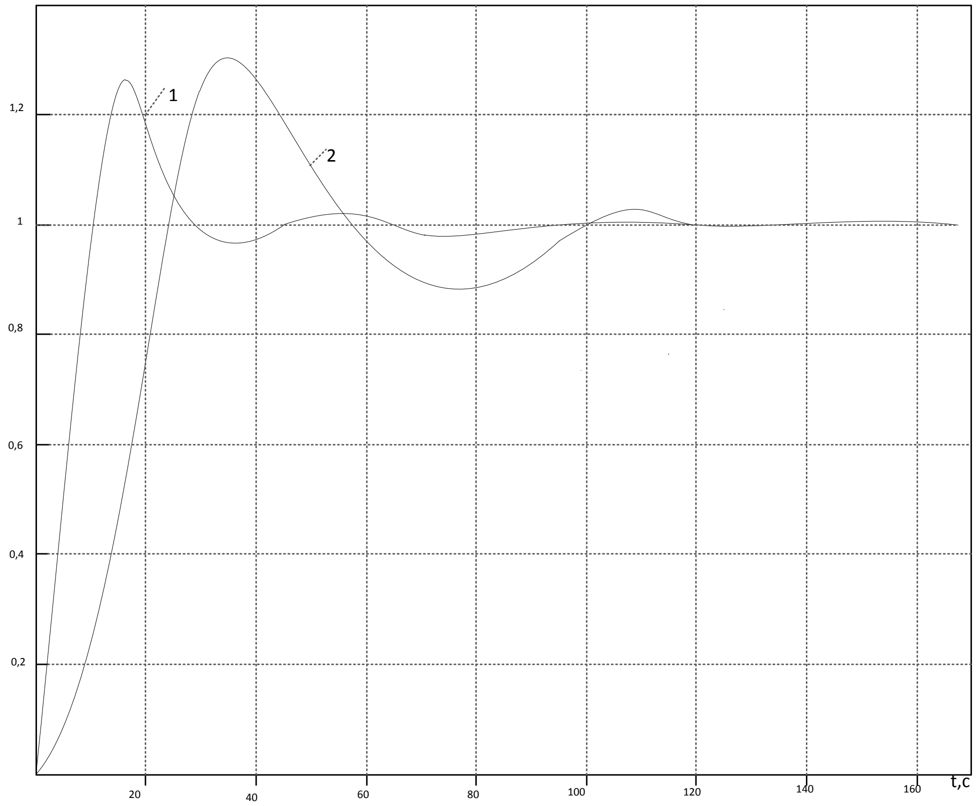

Fig.3 Transients along the control channel: 1-neurofinar ASR (at nominal load), 2 - neuronet of ACS (when the load changes)

V. CONCLUSION

Based on the obtained results, it can be concluded that the proposed intelligent adaptive ASR temperature of superheated steam has the following advantages:

1. the speed of the process of finding the optimal settings of the PI controller of a cascade ASR with the possibility of their approximation and extrapolation, as well as under the action of indefinite perturbations;
2. smaller first deviation and improve the time of the transition process regulation;
3. the possibility of optimal functioning of the cascade ASR in all modes of the steam drum boiler;
4. the ability to use in the processes of adaptation of various ACS TP and ASR with PD and PID-regulators in thermal power.

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