COMPARISON OF TWO MATHEMATICAL MODELS FOR CONTROL SYSTEM OF LEVEL IN CONDENSER OF TURBINE IN THE THERMAL POWER PLANT

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COMPARISON OF TWO MATHEMATICAL MODELS FOR CONTROL SYSTEM OF LEVEL IN CONDENSER OF TURBINE IN THE THERMAL POWER PLANT

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Abstract: This paper shows large importance of adequate mathematical modeling of system. Control system of level in condenser of turbine in thermal power plant Gacko is taken into exploration. Here it was presented in two ways, as first-order system and second-order system. Their analysis and comparison were carried out after auto-tuning of PID (proportional-integral-derivative) controller using relay feedback test simulation. Obtained parameters of PID controller were applied into both variations of the system block diagram and its responses have been utilized for giving evaluation of researched models.
Key words:mathematical model, relay feedback test, simulation

INTRODUCTION

All analytical and numerical investigations depend on its appropriate mathematical model. The task is as better as possible presentation of system behavior. In this paper two mathematical model of control system of level in condenser of turbine in thermal power plant Gacko were compared. In first case, condenser was presented as first-order system (using continuity equation) [1] and in second as second-order system (taking into account also transfer function of turbine) [2]. The main aim of this paper was proving better properties of second-order model in order to improve functioning of explored control system. Simulation of auto-tuning of PID controller using relay feedback test was performed in both cases [3]. In the following exposure these two approaches will be shown parallel.

DESCRIPTION OF THE SYSTEM

This system for control level in condenser is one of subsystems in thermal power plant. In order to give closer explanation of the problem, approaches of modeling are presented here.

System structure

Level in condenser depends on the amount of steam which comes from turbine (directly and from heater for regenerative heating), supply of demineralized (DEMI) water, drain condensate and working of vacuum pumps for obtaining vacuum in condenser. Control of level is performing by using two closed-loops, i.e. over valve for condensate drainage from the condenser and valve for demineralized (DEMI) water supply. Accordingly, good dynamic behavior of system and keeping desired level value in steady state is enabled using dumping control method. Schema of this control loops is shown in Fig. 1.

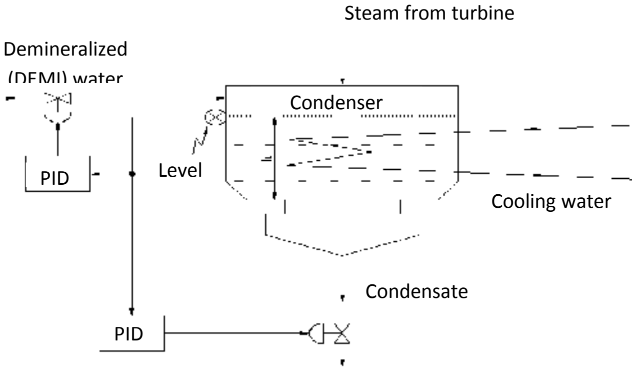


Figure 1. Control system of level in condenser in thermal power plant Gacko [3]

Mathematical model

Mathematical model of all system components leads to its transfer functions and components introduced into structure diagram of system give block diagram [2,4,5,6]. This block diagram is given in Fig. 2.

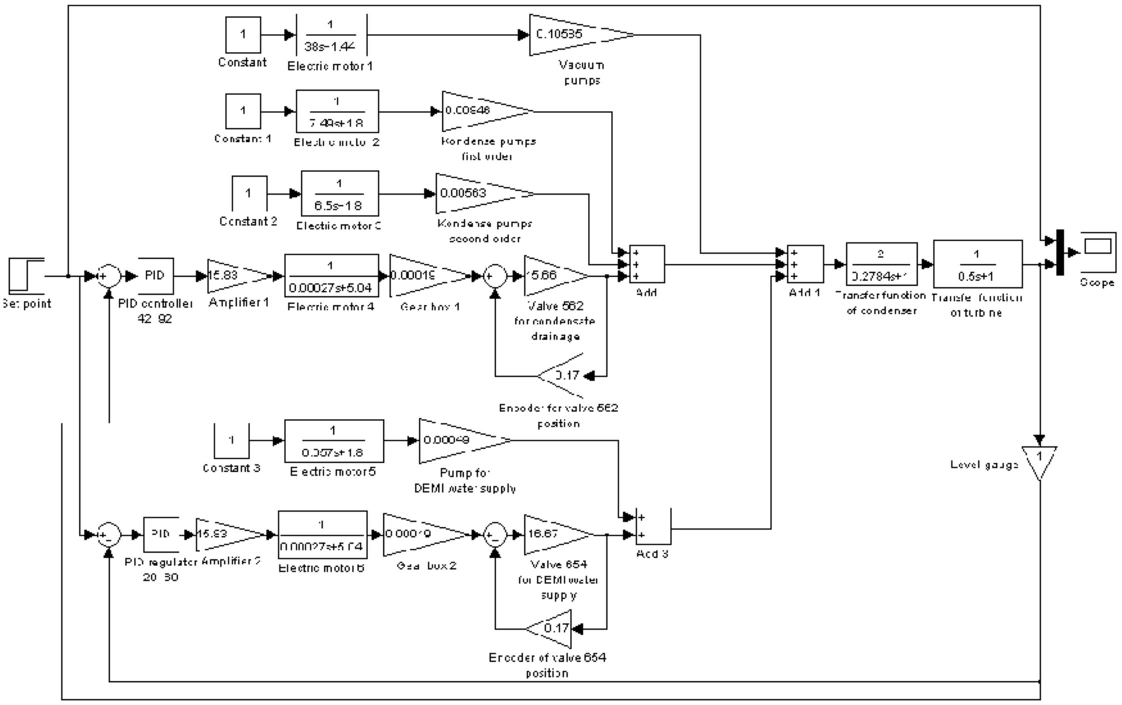


Figure 2. Block diagram of control system of level in condenser in thermal power plant Gacko [2,4,5]

Difference between these two approach is transfer function of process. In the first, transfer function is determined using continuity equation as first-order process (Fig. 2. without transfer function of turbine) [4,5], hence:

$$G_k(s) = \frac{2}{0{,}2784 \cdot s + 1} \tag{1}$$

To improve description of level as function of time, transfer function of turbine was derived, because of vast influence of inlet steam from turbine into condenser [2]. It is given by:

$$G_t(s) = \frac{1}{0{,}5 \cdot s + 1} \tag{2}$$

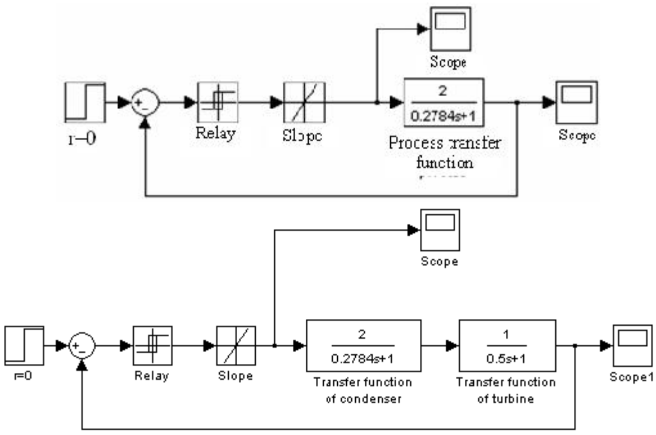
In the second approach, serial connecting of these two transfer function gives second-order process (Fig. 2).

COMPARISON OF SUITABILITY OF MATHEMATICAL MODELS

Usefulness of mathematical models is reflected in good representation of process behavior. A more complete description of the physical principles of the system increases the possibility of more accurate studies of its behavior. Evaluation of these two mathematical models is carried out after finishing two phases: auto-tuning of PID controller and introducing of obtained parameters into block diagram of entire control system of level in condenser. These activities were performed using simulation in the software Matlab.

Auto-tuning of PID controller

Relay feedback test is utilized for auto-tuning of PID controller for both mathematical models of process. Saturation relay is applied instead of ideal relay because of its proved advantages in terms of reducing errors in estimatin ultimate gain (K_u) and ultimate period (T_u). Configuration for saturation relay application into relay feedback test for both explored transfer functions of process is shown in Fig. 3.

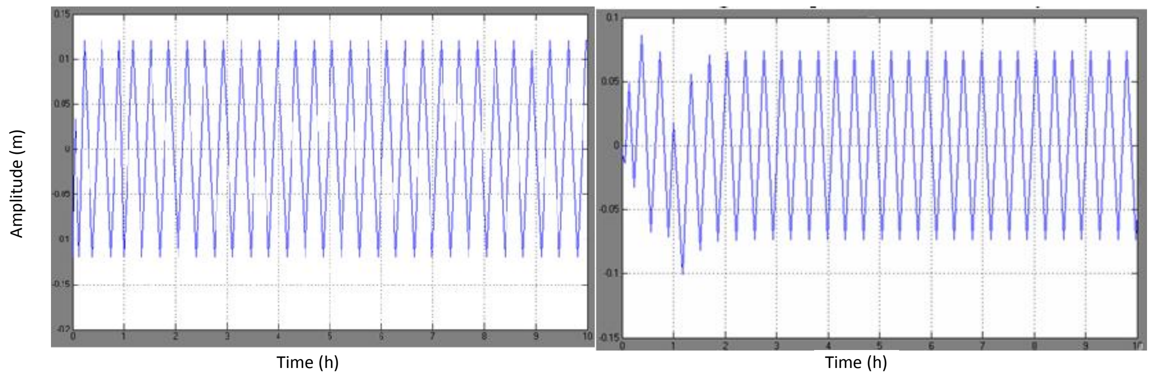


a) b)

Figure 3. Configuration for simulation of relay feedback test using saturation relay: a) without taking into account transfer function of turbine, b) with taking into account transfer function of turbine

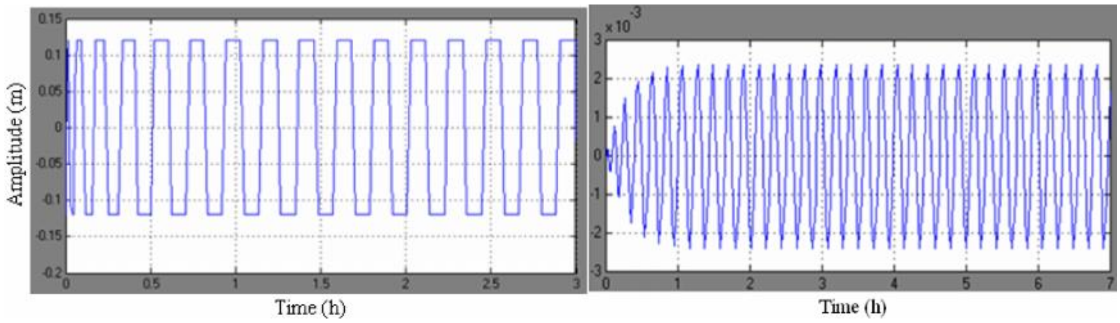
In first case (Fig. 3.a), relevant values are: height of ideal relay$h$=0,12(m), i.e. 10% of set value $h_ž$=1,2(m), the previously completed test with ideal relaygives $k_{min}=4h/\pi a$=2,11, slope of saturation curve$k=1{,}4k_{min}$=2,954 [1]. So, simulation gives oscillatory output of saturation relay (Fig. 4.a) and process response (Fig. 4.b).

In second case (Fig. 3.b), relevant values are: height of ideal relay$h$=0,12(m), i.e. 10% of set value $h_ž$=1,2(m), the previously completed test with ideal relaygives $k_{min}=4h/\pi a$=15,44, slope of saturation curve$k=1{,}4k_{min}$=21,62 [2]. So, simulation gives oscillatory output of saturation relay (Fig. 5.a) and process response (Fig. 5.b).



a) b)

Figure 4. Graphics forfirst case of proces transfer function: a) output of saturation relay b) oscillatory process response



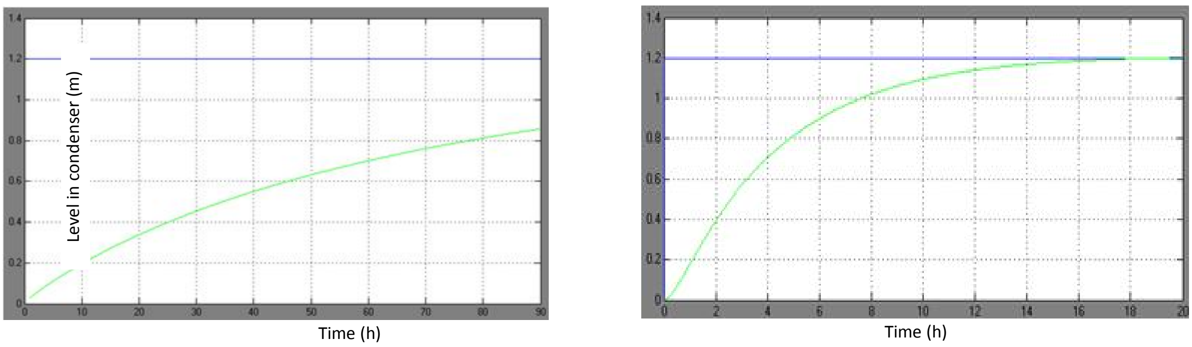
a) b)

Figure 5. Graphs forsecond case of process transfer function: a) output of saturation relay b) oscillatory process response [2]

Parameters of PID controller are calculated according Tyreus-Luyben method in order to enhance system robustness.
According to characteristic values in obtained diagrams (Fig. 4.b) parameters of PID controller (first case of process transfer function) are the following:K_p = 0,89 ; K_i = 1,145 ; K_d = 0,05.
Using values in diagrams (Fig. 5.b) parameters of PID controller (second case of process transfer function) are the following: K_p = 9,83 ; K_i = 20,91 ; K_d = 0,29 [2].
Deviation values of the parameters for PID controller is noticable here.

Evaluation and comparison validity of process response

Difference between parameters in this two cases leads to opinion that transfer function will give different display of system behavior. In order to explore better solution, responses of entire control system of level in condenser are simulated and analyzed. For that purpose, obtained parameters of PID controller are incorporated into appropriate block diagram (Fig. 2.).
Simulated response in Fig. 6.b gives better dynamic behavior of process and it is closer to usual response of level systems. There is no overshoot, output is faster, settling time is shorter, which means corect functioning [2].
Process which was modeled without transfer function of turbine don't reflect appropriate neither dynamic nor static characteristic. Because it doesn't achieve stationary regime in appropriate time, i.e. this is very slow process (Fig. 6.a).
Therefore, lack of information of system causes errors in simulation of auto-tuning of PID controller and bad representation of system behavior.



a) b)

Figure 6. Response of control system of level in condenser with controller`s parameters obtained using saturation relay: a) without taking into account transfer function of turbine, b) with taking into account transfer function of turbine

CONCLUSION

Process which has been modeled as second-order system gives larger possibility for taking information of its behavior. That is concluded after comparison of its responses parameters with parameters of first-order system. It is very important for high-quality analysis and eventual improving of system functioning. Also, auto-tuning of PID controller depends on appropriate derived mathematical model. This means that wrong choice of mathematical model causes errors in simulation of relay feedback test and in display of entire control system.

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