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APPLICATION OF PULSE-WIDTH MODULATOR FOR THERMAL PLANT CONTROL

Abstract. The quality of transient processes in an automatic control loop based on PID controller with PWM is analyzed and compared to the quality in the system based on a switch controller.

Keywords: automatic control, pulse-width modulator, thermal plant, transient process, quality.

Pulse-width modulators are often applied during automation of technological processes, e.g. for controlling the rotation speed of an electric motor, for controlling a thermal plant or for controlling an electric actuator with a constant speed of movement. The goal of this work is to analyze the quality of transient processes in an automatic control loop where PID controller with a pulse-width modulator (PWM) is applied and to compare the quality of these processes to the quality in the system based on a switch controller.

A thermal plant (i.e. an electric oven) is taken for investigation as a controlled plant. One of the features of such a plant is its high inertia and long duration of transient processes in it. That is why a two-point switch controller is usually applied for controlling a thermal plant. This controller is simple and it can be tuned easily. The example of the transient process in an automatic control loop (ACL) with a two-point switch controller is presented in Fig.1. An electric oven (SUOL-0,15.2/12M) with air flow through it is the controlled plant. Electric power at the oven input is the controlling action. And air temperature at the oven output is the process variable. The detailed description of this controlled plant is presented in [1].

The transient process presented in Fig.1 was obtained by applying the mathematical model of the controlled plant [1] in the programmable-logic controller (PLC) MIK-51H of Microl Company. PLC Jazz (JZ10-11-R16) of Unitronics company was the automatic controller. MIK-registrator 1.1.14 software was applied for signals logging. This software provides the possibility of logging a number of signals with the period of 1 s. The two-point switch controller was tuned according to the following condition: it was ON when the temperature was below 59.5 °C and it was OFF when the temperature was higher than 60.5 °C.

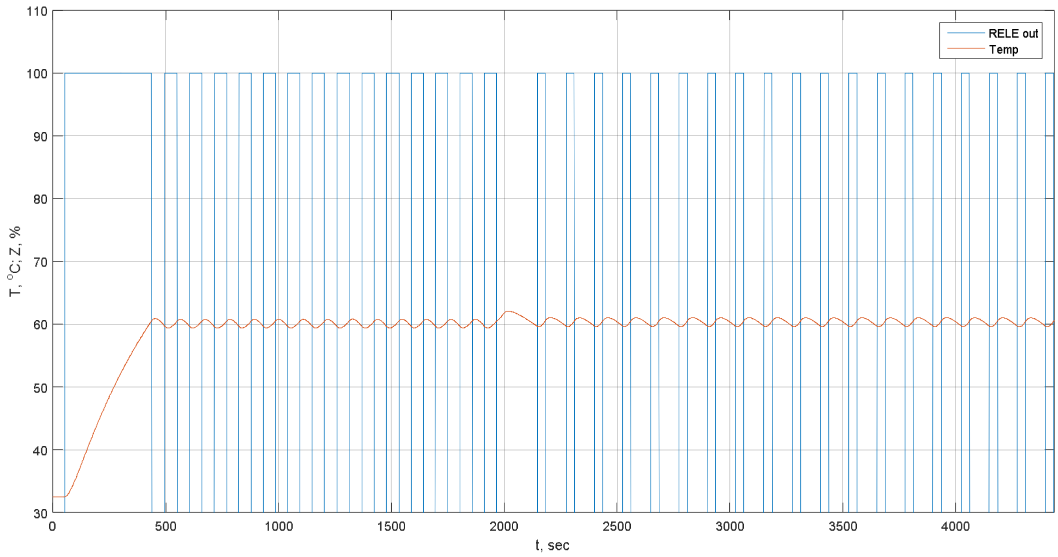

Fig. 1. Transient process in ACL with a two-point switch controller

The transient process presented in Fig.1 consists of two parts. The first part (0 ... 1980 s) is movement of the system to the nominal operating regime. And the second part (1980 s ...) is processing of the disturbance introduced by reducing the air flow rate through the oven. The period of pulses at the end of the first part of the transient process is 107 s, the duty cycle is 50 % and the maximum amplitude of the process variable oscillations is 0.8 °C. At the end of the second part of the transient process the period of pulses is 125 s, the duty cycle is 30 % and the maximum amplitude of the process variable oscillations is 1.0 °C.

A shortcoming of a two-point switch controller is that there is a self-oscillating transient process in the ACL. The amplitude of the process variable oscillations may be reduced by making a smaller hysteresis loop width in the two-point switch controller. However there is a minimum value below which the hysteresis loop width may not be set. And this value is defined by the measurement error of the transducer of the process variable (temperature transducer in our case).

In order to remove the self-oscillations in ACL a PID controller with PWM is applied [2]. In this case the period of pulses at the input of the controlled plant is much smaller than that in case of a two-point switch controller application. The period of pulses is set to a specific value during adjustment of PWM algorithm. And the duty cycle is defined by the PID controller output signal. The transient process in ACL based on the PID controller with PWM is presented in Fig.2. PLC Jazz (JZ10-11-R16) was applied for implementation of PID controller with PWM. The period of pulses was 20 s. The tuning parameters of the PID controller correspond to the following values: proportional gain coefficient K_P=30 %/°C, reset time T_I=200 s, differentiation time T_D=0 s. It can be seen from Fig.2 that there are no self-oscillations in ACL based on PID controller with PWM.

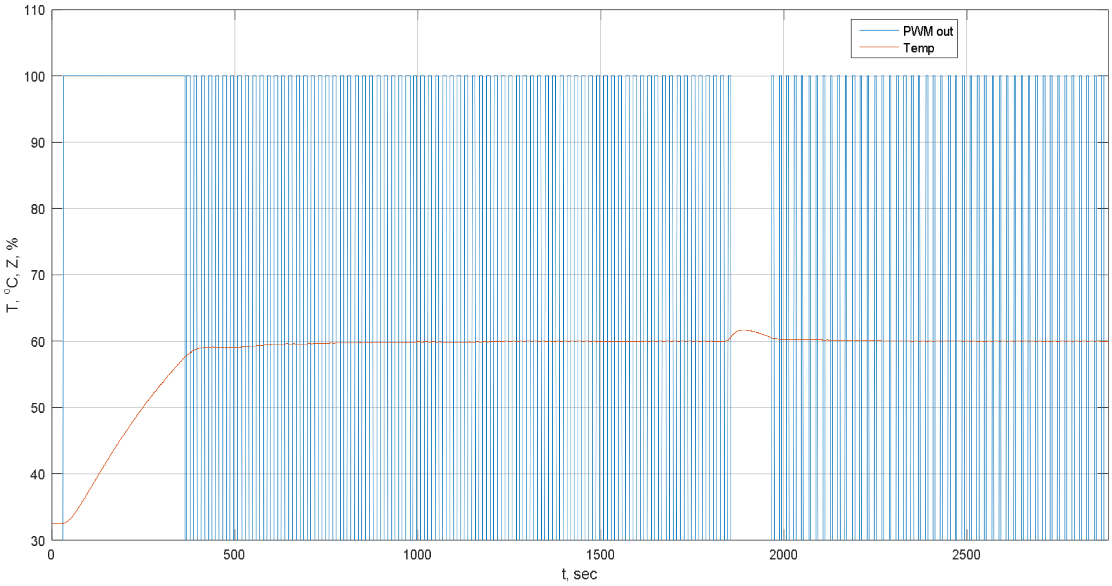

Fig. 2. Transient process in ACL based on the PID controller with PWM

The transient process presented in Fig.2 consists of two parts. The first part (0 ... 1860 s) is movement of the system to the nominal operating regime. And the second part (1860 s ...) is processing of the disturbance introduced by reducing the air flow rate through the oven. The period of pulses at the end of the first part of the transient process is 20 s and the duty cycle is 50 %. At the end of the second part of the transient process the period of pulses is 20 s and the duty cycle is 30 %.

Thus by applying the PID controller with PWM the self-oscillations in ACL are eliminated in comparison to the system based on a switch controller.

References

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