Realization of an Adaptive Control Algorithm Utilizing a PLC Device

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Abstract: *In this paper the concept of an adaptive control method is presented with the Sobel-Bar-Kauffman algorithm on a practical laboratory example utilizing CJ1 type PLC device. The algorithm and the plant are designed using the MATLAB-SIMULINK programming environment and then realized using a CJ1 type PLC device. The realization results justify the application of this algorithm in industrial circumstances*

Keywords:PLC device, adaptive control mthods

1 Intoduction

Until the 1970s, industrial logical control (sequencing) was realized with electromechanical relays and pneumatic coupling. Starting in 1970, the PLC became more common in industrial applications, initially as a simple replacement for relay sequencing applications. Today, PLCs are the major choice in industrial control applications and are available with increasingly complex functions. In fact, programmable logical controllers (PLCs) are microcomputers developed to handle industrial control applications. Boolean logic and the relay type instructions were the first to be implemented in PLCs. Today, complex functions operating with array structures and a variety of numerical formats, as well as large amounts of memory and high speed of execution, make the development of any control application a relatively simple task when using PLCs.

The concept of adaptation was first introduced in control theory in 1950s. At that time the theory was restricted by insufficient theoretical knowledge and the incapability of the hardware and software resources to handle such a task. During the next decade the theoretical novelty of describing a system in the state space format gave new opportunities in improving the adaptive control theory. In 1970s the appearance of inexpensive microprocessors made it possible to realize very complex control tasks. Nowadays the power of programmable logical controllers makes it possible to implement various adaptive control techniques without the need for great investments.

In this paper a direct model reference adaptive control method will be presented. The results achieved using this method are shown and compared with the results obtained with classical industrial PID controller. An effort was made to prove that the adaptive algorithm is giving better results using a classical PLC device.

2 Model Reference Adaptive Control

The basic configuration of model reference adaptive control systems is presented in Figure 1.

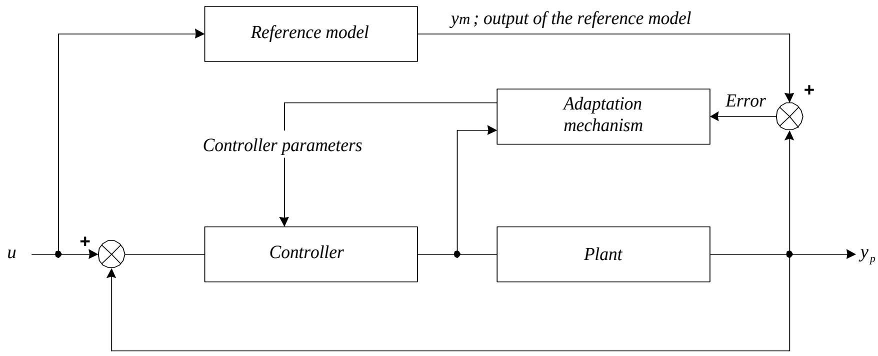

Figure 1: Model reference adaptive control system

The task of adaptive control is either to modify the parameters of the adjustable system or to generate an auxiliary input signal in order to minimize the error signal between the output of the system and the model. The main advance of direct model reference adaptive control is in its relative simplicity. The algorithm does not use parameter identification. An optimally selected dynamical model, the reference model, determines the behavior of the system. The purpose of the design is to find an adaptive mechanism that eliminates the difference between the outputs of the reference model and the adaptively controlled plant. A great number of algorithms are published, developed to meet the above purpose. A relatively simple approach, developed by Sobel, Kauffman, Mabius and Bar-Kana, is chosen for further study. The main advantage of this algorithm is in the guaranteeing stability even in the case when the order of the plant is much greater than that of the reference model.

3 The Sobel-Bar-Kauffman Algorithm

For the purpose of further analysis let us choose a second order reference model determined by the next transfer function:

$$G_m(s)=\frac{y_m(s)}{u_m(s)}=\frac{1}{11s^2+12s+1} \tag{1}$$

Let us describe the adaptive control signal as:

$$u_p(t)=k_e(t)e(t)+k_x(t)y_m(t)+k_u(t)u_m(t) \tag{2}$$

For the sake of simplifying the calculation the adaptive parameters and the states of the system can be described by the means of the following two matrices:

$$k_r(t)=[k_e(t) \quad k_x(t) \quad k_u(t)] \tag{3}$$

$$r(t)=\begin{bmatrix} y_m(t)-y_p(t) \\ y_m(t) \\ u_m(t) \end{bmatrix}=\begin{bmatrix} e_y(t) \\ y_m(t) \\ u_m(t) \end{bmatrix} \tag{4}$$

In this case the adaptive control signal takes the following form:

$$u_p(t)=k_r(t)r(t) \tag{5}$$

The vector of adaptive parameters k_r can be determined as the sum of proportional and integral terms:

$$k_r(t)=k_p(t)+k_I(t) \tag{6}$$

and the structure of the adaptive mechanism is described by the following simple equations:

$$k_p(t) = e_y(t) r^T \overline{T} \tag{7}$$

$$\dot{k}_I(t) = e_y(t) r^T(t) T \tag{8}$$

where T and $\overline{T}$ are positive constants that determine the speed of adaptation, y_m is the output of the reference model, y_p is the output of the plant and u_m the reference input.

4 Laboratory Plant

The plant is a laboratory model that is realized with resistors and capacitors precisely defined in Figure 2.

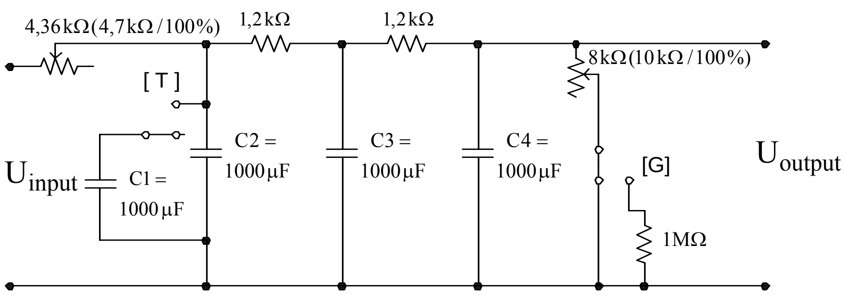

Figure 2 – The laboratory model of the plant

This model corresponds to a third order system, which is designed so that it is possible by the means of two switches to change its gain and time constant. This possibility makes it feasible to test both PID and adaptive algorithms in the case of set point and parameter changes. The algorithms are especially challenged when the gain of the system is altered.

Figure 3 represents the response of the plant when a step change occurs.

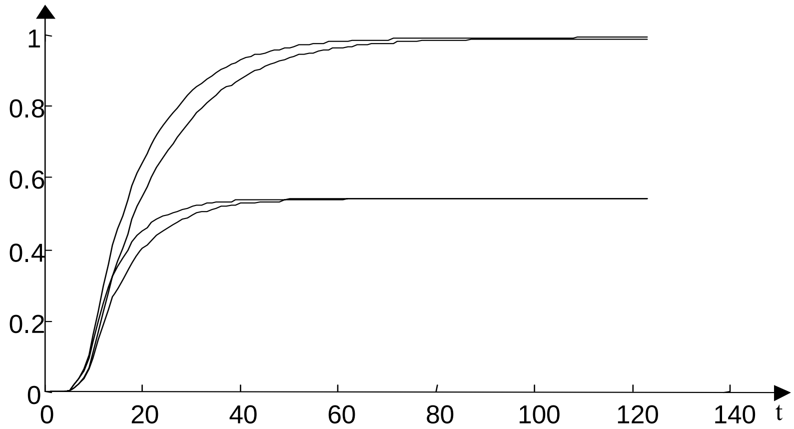

Figure 3 – Response of the plant on a step change

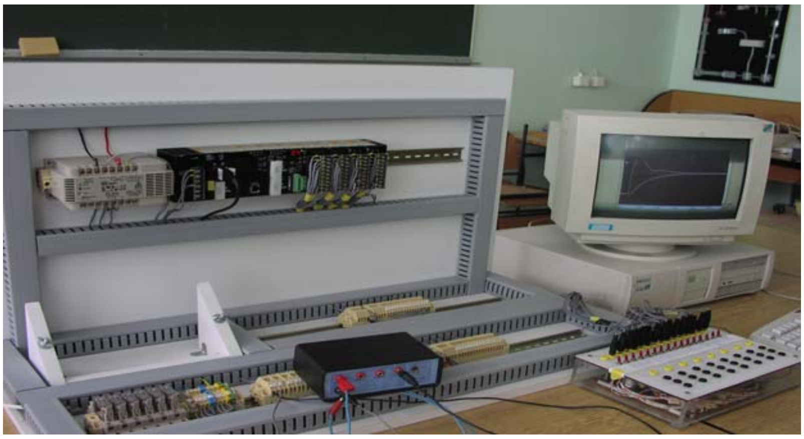

Figure 4 –The physical appearance of the whole system

5 The Pid Algorithm

Consider the ideal PID controller written in the continuous time domain form:

$$u(t) = K_c e(t) + \frac{K_c}{T_I}\int_0^t e(t)dt + K_c T_d \frac{de(t)}{dt} \qquad (9)$$

To discretise the controller, we need to approximate the integral and the derivative terms to forms suitable for computation by a computer. From a purely numerical point of view, it can be used:

$$\frac{de(t)}{dt} \approx \frac{e(t)-e(t-1)}{T_s} \quad \text{and} \quad \int_0^t e(t)dt \approx T_s \sum_{i=0}^{t} e(i) \qquad (10)$$

The discretised PID algorithm as realized by the controller is therefore:

$$u(t) = K_c e(t) + \frac{K_c T_s}{T_I} \sum_{i=0}^{t} e(i) + K_c T_d \frac{e(t)-e(t-1)}{T_s} \qquad (11)$$

It must be denoted that for this case PI controller is chosen because of the unwanted effects derivative action can cause in digital PID algorithms primarily such as inadequate reaction on abrupt set point changes and that amplifies any noise in the error signal. In the next chapter the effectiveness of the PI algorithm is presented on set point and system parameter changes.

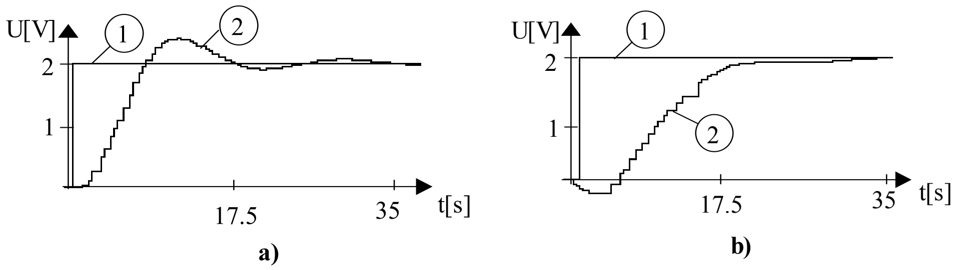

Figure 5 – Response of the plant on a step change. Signal one corresponds to set point while signal two represents the plant output

Picture a) corresponds to gain value 1 while picture b) represents the output of the closed loop transfer function when the gain of the plant is lowered by about 30%. The K_c and T_I parameters are chosen for the situation when the gain equals 1 and are left unchanged when the step change is performed in situation b) which is a normal procedure in industrial circumstances.

It is obvious that a parameter change like the one presented significantly influences the performance of the PI controller. Therefore inevitably a question appears: is PI regulator satisfactory or should some other control method be applied? This problem is characteristic and almost always present in control systems where for example temperature, torque or motor speed must be kept within strict limits.

6 CONCLUSION

Direct model reference output adaptive control method has been shown to be very effective for the control of the plant. It is obvious that it deals with the parameter changes of the plant better than the PI algorithm. However, the relative simplicity and widespread acceptance remains to be the advantage of the PI concept. Unfortunately, this control method is not offered as a single instruction in the PLCs instructions tables as PID is, although, as it has been presented in this paper, it would be justified.

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