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RESEARCH ARTICLE OPEN ACCESS

Belt Conveyor Control System Using Fuzzy Logic Algorithms Based On the Siemens S7 Controllers

PLC BASED ADAPTIVE FUZZY PID SPEED CONTROL OF DC BELT CONVEYOR SYSTEM

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ABSTRACT:
The paper describes the implementation of the adaptive fuzzy controller for the automated control system (ACS) for the electric drive of a belt conveyor on the example of program logic controllers SIEMENS S7-1200 series. OPC protocol for the data transfer between the Matlab Simulink simulation package and a program logic controller (PLC) is used. Based on the results of the work a comparative analysis of the obtained transition characteristics is given.
Key words: belt conveyor, fuzzy logic, proportional-integral-differentiating controller, electric drive, program logic controller, OLE for Process Control (OPC)

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I. INTRODUCTION

The expansion of the technological capabilities of machine tools and, first of all, multioperational (machining centers), as well as the development of new carbide and high-speed cutting tools made it possible to carry out various technological operations on one machine: milling, drilling and boring [1]. This, in turn, led to the complication of electric drives feeds due to an increase in the torque on the motor shaft, an expansion of the range of working feeds and positioning movements, an increase in the speed of the drive, both under control action and under load disturbance, etc. The use of linear proportional-integral-derivative (PID) controllers in control systems for nonlinear objects often leads to the poor quality of the control process, which is characterized by large overshoot values, static error and / or transition time.

Formulation of the problem

In this paper, we propose a fuzzy adaptation of the tuning parameters of the PID controller, which makes it possible to take into account the nonlinear properties of the object and ensure the required quality of the control on the example of a model of the standard electric drive for a belt conveyor used in the technological processes of transporting bulk materials. As a regulator is taken a program logic controller (PLC) Siemens S7-1 200. Since the internal PLC libraries do not have an implemented fuzzy controller, the implementation of its program model has some peculiarities. So, the entire control system, including the object, is implemented in Simulink, while the controller is made as a hardware device integrated into this system. To implement such a hybrid system, it is necessary to provide software communication between the controller in the PLC and the Simulink model. This communication is implemented using Object Linked and Embedded for Process Control (OPC) communications, widely used in industrial automation.

Improving management efficiency is an urgent problem in the context of the increasing complexity of technological equipment, processes and systems. For the design of control systems for the complex objects, an important role is played the solving the problems of constructing adequate mathematical or simulation models and synthesizing control algorithms that ensure the solution of problems in conditions of uncertainty.

Solution Method

The properties of the fuzzy logic to process incomplete information, to simulate human knowledge and to issue informed decisions make possible of its intensive use for the real-time monitoring of the technological processes, as well as solving problems associated with the practical implementation of technological process control systems [2]. The use of fuzzy logic in control systems allows one to reduce the degree of operator intervention in the control process and, therefore, allows the development of the new control methods, more adapted to the industrial environment. Regulators based on fuzzy logic, in some cases, are able to provide higher quality indicators of transient processes in comparison with classical controllers. In addition, using methods of synthesis of fuzzy control algorithms, it is possible to optimize complex control loops without conducting comprehensive mathematical research.

The difference between PID controller and the controller based on the fuzzy logic from the rest is that the coefficients in the proportional integrating circuits of the controller are not static, i.e., they depend on the state of the system at the current time. This allows one to qualitatively change the control process, to take into account the parameters of the signals in the system (the rate of change of the signal, acceleration), as well as to make the control process more adaptive.

To calculate the coefficients of the PID controller of the speed counter, the Simulink application program with the Nonlinear Control Design (NCD) subroutine package (design of nonlinear control systems) is used, which is intended for parametric optimization of closed-loop systems. This is a program software to solve the optimization problems of the parameter values under the constraints in the form of inequalities and uses sequential quadratic programming as an optimization algorithm.

As a result of the NCD software performance, the following values are obtained for the PID controller coefficients:

Kp=3.62; Ki=0.04; Kd=1.05.

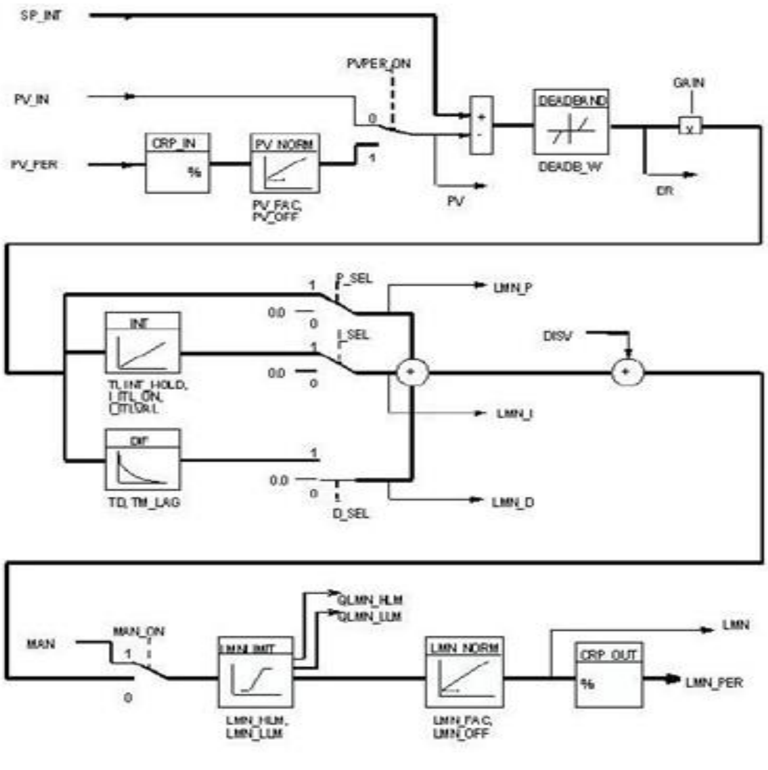
It was determined that this system has 0.8% of overregulation.

The next stage of this work is the creation of the PID controller based on the of fuzzy logic rules for the above model of the electric drive of the belt conveyor. The process of creating the fuzzy PID controller based on the Siemens S7-1200 PLC is carried out in 2 stages:

1. Creation of a PID controller program in TIA PORTAL (or STEP7) software environment using continuous control block “CONT_C”;

2. Developing the fuzzy PID controller software in TIA PORTAL using LD (Ladder Diagram), FBD (Function Block Diagram) or STL (Structured Text Language) programming language;

The "CONT_C" block (continuous controller) is used in SIMATIC S7 program logic controllers to control the technical processes with continuous input and output variables. The controller can be used as a PID controller with constant set point (SP), or in multi-loop control systems as a cascade controller, ratio controller or proportional controller. The controller functions are based on the PID control algorithm of the digital controller with an analog signal.



Continuous controller block “CONC_C” is shown in Fig. 1.

The main function of the fuzzy controller is the formation of the output control value depending on the current coordinates of the system.

The procedure for processing input information in the controller can be described as follows:

1) The current values of the input variables are converted into linguistic ones (fuzzification);

2) On the basis of the obtained linguistic values and using the controller's rule base, a fuzzy logical decision is made, as a result of which the linguistic values of the output variables are calculated;

3) Defuzzification (Fig. 2) [3,4].

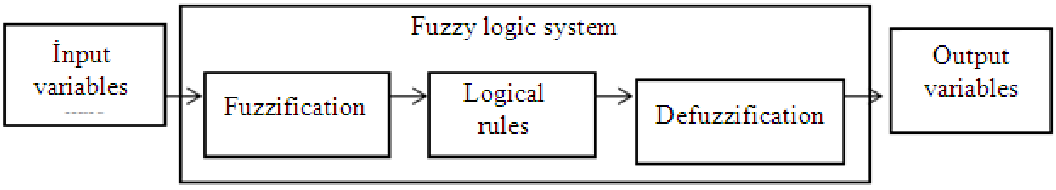


Figure 2. Input processing procedure

The development of the knowledge base of the fuzzy regulator is reduced to solving the following problems:

1) Choice of the input linguistic variables based on the analysis of the behavior of the closed-loop control system in the calculated desired mode;

2) Assignment a set of the linguistic terms for each of the linguistic variables [5];

3) Choice of the approximating fuzzy set for each of the terms.

Fig. 3 shows a comparison results of modeling of the system based on Siemens S7-1200 using a block of PID controller and adaptive fuzzy PID controller.

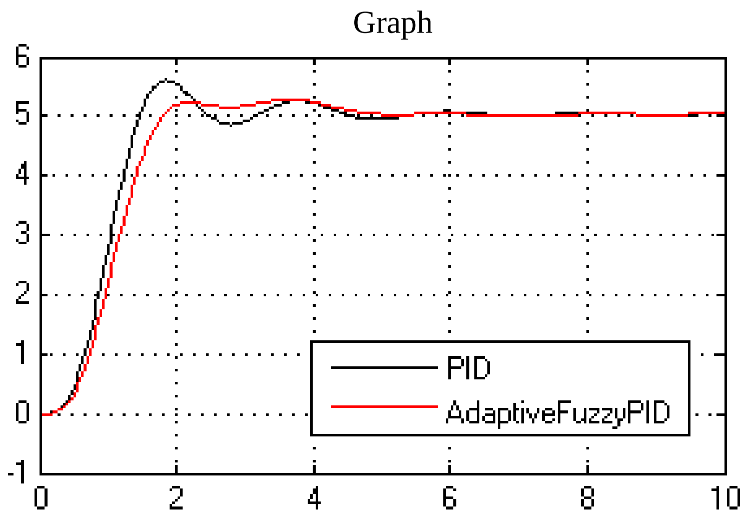


Figure 3. The result of the comparison of the transition process

When comparing the transition characteristics of the transition, using the classic PID controller and the fuzzy controller, there is noticeably less overshoot and a significant improvement in the steady-state time for the model with a fuzzy controller, which is given below.

Table 1: Comparison of system simulation results

	Overregulation, %	Steady-state process period, sec.
PID regulator	0.8	4.8
Fuzzy regulator	0.1	5.7

II. CONCLUSION

Thus, the paper proposes a method for designing a fuzzy PID controller to correct the parameters of the belt conveyor electric drive. A method for the formation of linguistic variables when constructing a fuzzy model is proposed. Rules for the formation of a fuzzy knowledge base of the controller, a software of fuzzy logical inference have been developed, PID and fuzzy PID controllers based on the Siemens S7-1200 PLC have been implemented. The simulation results show that the response of the adaptive fuzzy PID controller is comparatively better than that of the classical PID controller.

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