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THE AUTOMATED ADAPTIVE CONTROL SYSTEM FOR THE CONSTANT SPEED DRIVE

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Abstract: *This project is concentrated at the design of the automated control system for the hydraulic drive with a constant rotary speed of output shaft. On stream the power part is being designed and the software is being developed. The power part of the system consists of Silicon Laboratories C8051F041 controller, signal amplifier, sensors. The software is the program for PLC, based on PID-control concept. The system must match the following criteria: high performance of output signal working out, accuracy and quality of constant speed maintenance, output signal prediction, low cost, compactness. Also a test bench for the control system is being constructed.*
Key words: *alternative energy sources, hydraulic drive, control system, PID control*

1. INTRODUCTION

Today, the creation of alternative energy sources becomes more and more important. Particularly, there are alternative energy sources which use the energy of moving air masses. Due to this reason a complex scientific problem appears. We need to transform the variable speed of the working motor at a constant speed of the consumer motor. Also we should keep high performance and low mass-dimensional parameters. The hydraulic constant-speed drive (CSD) is used to solve this problem. The main objective of this study is making it possible to set up and maintain the rotary speed of output shaft. The adaptive control system, consisting of PLC and sensors should be used to accomplish this task.

On stream the control system of a hydraulic drive with constant rotary speed will be designed and realized. The system structure includes the hardware, based on the PLC and the software, which is represented by the program for the controller, based on PID control.

All researches take place at the International Scientific Educational Center BSTU-FESTO "Synergy" of Baltic State Technical University “VOENMEH” named after D. F. Ustinov (Saint-Petersburg, Russia). Technical equipment, which is manufactured by FESTO, is being used to construct the test bench (valves, sensors, etc).

2. PROJECT DESCRPTION

The research is concentrated at solving of the following problems:

- Investigation of main parameters of the power part of the CSD
- Designing the adaptive control system based on PID-control concept, which makes it possible to set up and maintain the rotary speed of output shaft.
- Analyzing its main parameters and its influence on the quality of the drive control.

Several stages of the research should be differentiated:

- Investigation of different sources and patent search
- Main schemes and concepts of hydraulic drives with constant rotary speed structure and functioning analysis.
- Investigation of the power part of the CSD, its structure and parameters
- Developing of the mathematical model of the CSD.
- Using Mathlab for modelling future control system.
- Choosing components for memory hardware of control system
- Developing software for PLC, based on PID-control concept (using C).
- Designing test bench for the control system and analyzing parameters of the system (using technical equipment, which is manufactured by FESTO).
- Mounting the control system, commissioning the complex and doing test operation.
- Economic analysis of the developing and testing effort and its comparison with analogs if they exist.
- Investigation of the new ranges of application of the CSD, appeared as a result of mounting a new control system.

2.1 Constant speed drive

The scheme of the power part, which exists at the moment, is shown at the Figure 1. The power part of the *CSD* is represented by the hydromechanical two-loop transmission. It consists of actuating motor *AM*, three-link differential *D* and consumer motor (e.g., a direct-current generator) *CM* which are linked by the kinematical gears (Babaev et al., 2000). During the working process of the drive, variable moment of the motor *AM* is converted by the differential D to the constant moment which is transferred to the motor *CM* shaft by the gear. The differential *D*, thanks to its kinematical scheme, has a variable reduction ratio. This parameter should vary depending on the value of the input moment for the purpose to maintain the constant moment at the output. The hydraulic drive, which consists of the fixed displacement hydraulic motor FDM and of the variable displacement hydraulic motor VDM is designated for regulation of the reduction ratio of the differential D (Kopaev,1985).

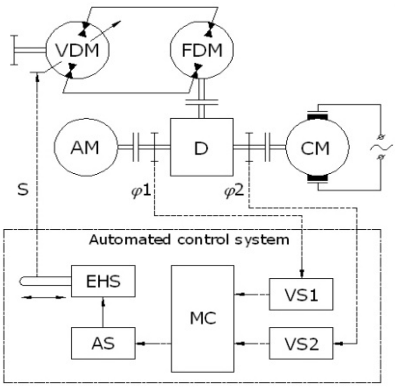

Fig.1. The CSD with the control system

2.2 PID control

The PID controller is the most common form of feedback. It was an essential element of early governors and it became the standard tool when process control emerged in the 1940s. (Aström, 2002) The "textbook" version of the PID algorithm is described by equation 1.

$$u(t) = K(e(t) + \frac{1}{T_i}\int_0^t e(\tau)d\tau + T_d \frac{de(t)}{dt}) \qquad (1)$$

where y is the measured process variable, r is the reference variable, u is the control signal and e is the control. The reference variable is often called the set point. (Dingyu Xue et al, 2008) Thus, the control signal is a sum of three terms: the P-term, (which is proportional to the error), the I-term (which is proportional to the integral of the error), and the D-term (which is proportional to the derivative of the error). The controller parameters are proportional gain K, integral time Ti, and derivative time Td. The integral, proportional and derivative part can be interpreted as control actions based on the past, present and the future. (Denisenko, 2006) In this project, designing of software, based on PID-control concept is being planned.

2.3 CSD with the control system

The scheme of the workable system is shown at the figure 1. This system contains

- Two velocity sensors VS1 and VS2 measuring rotation of the motor shaft and generator shaft
- The main controller MC, which is based on the Silicon Laboratories microcontroller. Software for it is based on PID control concept
- The amplifier AS of the control signal.
- Electrohydraulic converter EHC, which regulates the rotary speed of the hydraulic machine.

The value of the motor speed and the generator speed is fixed by velocity sensors VS1 and VS2. Then, electrical analog signal from the sensors is transferred to the controller MC. The controller returns control signal, worked by the PID-control-based program. This signal comes to the electrohydraulic converter EHC after passing through the amplifier AS. In the EHC the signal is transformed to the movement of the rod, which regulates the speed of hydraulic machine. In this project, designing of software, which is based on the PID-control concept, is being planned. Also, it is necessary to analyze the following parameters of the system: performance of output signal working out, accuracy, sensibility, robustness, possibility of output signal prediction; and to compare them with the parameters of similar systems, which could be used to accomplish a similar task. After that it is planned to research into parameters of hydraulic control and power elements.

3. RESULTS

The following results have already been obtained at the present point in time:

- Main schemes and concepts of hydraulic drives with constant rotary speed have been analyzed
- Parameters of the power part which are significant for the control system design have been analyzed (dead zone, influence of the force of friction, hydrodynamic force)
- A number of important experiments with the power part of the CSD have been carried out (investigation of the dead zone, neutralization of the dead zone etc.)
- Structure chart of the control system and the test bench has been designed

The mathematical model of the power part and the model of the control system are in process of developing.

These results are very important. They enable experiment to be proceeded to the next stage – control system design.

The obtaining of the following results is being planned during this stage:

- Obtain the mathematical models of the power part and the control system
- Develop the software for the calculation of CSD output parameters, based on its mathematical model.
- Design the memory hardware of the control system, based on Silicon Laboratories C8051F041 PLC, velocity sensors and the electrohydraulic converter.
- Develop the software for the control system. The software consists of the program for PLC and bases on PID control concept.
- Design and construct a test bench for the control system
- Design and construct completed complex of CSD, based on engineered control system and bring it into service.

4. PROBABLE APPLICATION AREAS

Workable innovative control system is intended for hydraulic constant speed drives. Drives could be used to transform the variable speed of the working motor at a constant speed of the consumer motor (e. g. electric generator). Today, very important problem is alternative energy sources creation. Energy sources, which use a power of moving air masses, have prospects. In other words, wind power is very prospective.

Also, the hydraulic constant-speed drive is becoming more widely used in the transportation and industrial systems (seaborne machinery, aeronautical engineering, etc).

Designed control system perfectly matches objectives, which are defined by such wide range of application: high performance of control signal working out, accuracy and quality of constant speed maintenance, or, in other words, minimization of the output and input shaft speeds mismatch, low mass-dimensional parameters and low cost against the hydromechanical control systems, high reliability and longevity.

In addition, usage the microprocessor technology and a new, highly efficient software, will make it possible to adapt (e.g., to expand and complicate) the control system to the various industrial hydraulic drives and plants.

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