Upgrading a Digital Hydraulic Switching Valve to Become an Intelligent Hydraulic Equipment

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Abstract: *Digital hydraulics is a recently introduced concept in the field of hydraulics. Some of the solutions used in digital hydraulics have been used for a long time in classical hydraulics, but not at the level at which they can be applied now. The development of the field of digital hydraulics was possible due to the technological advances that the field of electronics has experienced. At present, digital hydraulics intends to offer simpler devices, with less demanding requirements than those of servovalves and with a high reliability and energy efficiency.*
An intelligent system implies a system that is equipped with various sensors and transducers, connected to a Programable Logic Controller (PLC) that gathers all the information and transmits it to a software interface, from where the user can remotely monitor system parameters, can change their values and generate various reports. Another feature of an intelligent system is the fact that an automatic adjustment loop can be made, which allows it to adapt its own parameters according to needs.
In the present paper, the authors started from a digital hydraulic switching valve that they upgraded to become an intelligent hydraulic equipment, which can be controlled, tracked and parameterized remotely via a PLC with Ethernet port and application software.

Keywords: *Digital hydraulics, intelligent, hydraulic switching valve*

1. Introduction

The digital hydraulics [1] is defined by the active control of the system outputs of a hydraulic component (directional valve, pump, actuator). Digital hydraulics is not limited to digital control of analog components, but is based on intelligent control using PWM (pulse width modulation) signals and obtaining flow and speed adjustments, using on/off directional valve, encoded either PNM (Pulse Number Modulation), or PCM (Pulse Code Modulation). [2]
In the realization of the concept described in this paper, we started from a normally closed digital hydraulic switching valve presented in figure 1. Also, in order to realize the concept, flow and pressure transducers and a PLC were used to gather all this information and transmit it to the intelligent system control interface.
Digital hydraulic switching valves are 2-way and two-position on/off directional valves, and the switching signal is a PWM signal [3]. By switching at high frequencies between the closed and the open position of the directional valve, the flow regulation is performed. The flow at the exit of the directional valve is the sum of the closed and open periods.
Intelligent systems are systems that contain sensors and transducers for measuring all the main process parameters, but also process control equipment of PLC type provided with Modbus TCP communication, with the help of which the connection between the system and the software interface is made, where the process parameters can be viewed, the evolution of the system over time can be monitored, but one can also make changes and generate graphs.
With the help of the data obtained from a dedicated software interface, an analysis of the state of the system can be performed in order to be able to consider its introduction during the maintenance period or not. Due to the fact that the main parameters of the process can be viewed at any time, we can also talk about predictive maintenance.
Predictive maintenance refers to the fact that, based on the data collected from the software application, an analysis can be performed to show if the system needs maintenance in order to operate at optimal parameters, thus trying to avoid situations where the equipment fails randomly,

thus unscheduledly stopping the process in which it was involved, which can result in loss of time and money.

2. Hydraulic switching directional valve

The symbol of a digital hydraulic switching valve is represented in figure 1.

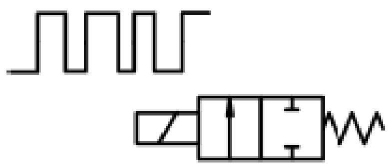

Fig. 1. Hydraulic switching directional valve - symbol

Figure 2 shows a section through the normally closed digital switching valve.
What is of interest to this digital hydraulic switching valve compared to a directional valve, is the fact that its spool switches between the closed and the open position with a frequency of over 100 Hertz and implicitly in order to achieve this both the electromagnet and the spool are made of special materials.

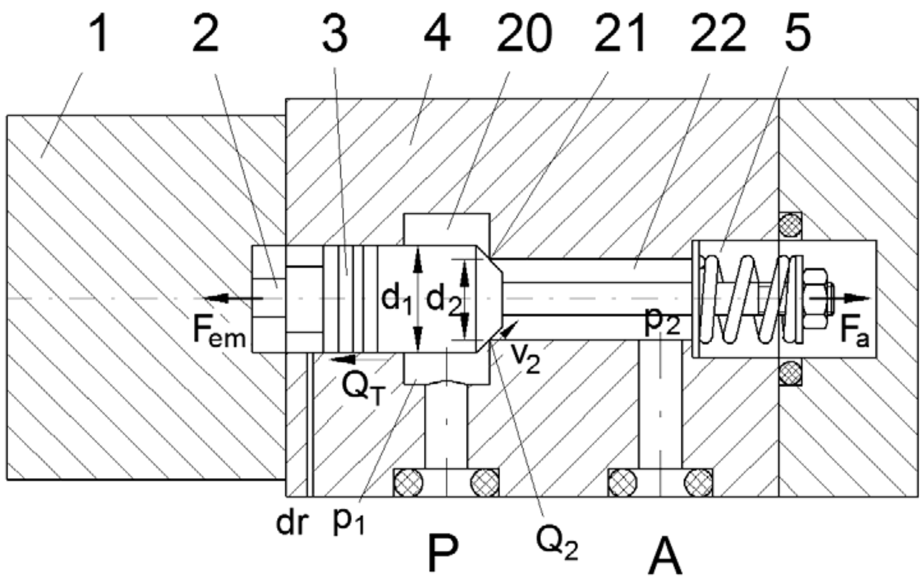

Fig. 2. Normally closed switching valve [4]

The components of interest are:

- High frequency electromagnet (1)
- The electromagnet shaft attached to the spool (2)
- Distribution spool (3)
- Valve body (4)
- Closing spring (5)
- Admission chamber (20)
- Crossing section (21)
- Discharge chamber (22)

When the electromagnet (1) is electrically operated, the distribution spool (3) opens the crossing section 21, so that the hydraulic connection is made between ports P and A. When the signal to the electromagnet is stopped, the closing spring (5) brings the distribution spool (3) in the closed position, so that the hydraulic connection between ports P and A is interrupted. [5]

An example of a step PWM signal can be found in figure 3.

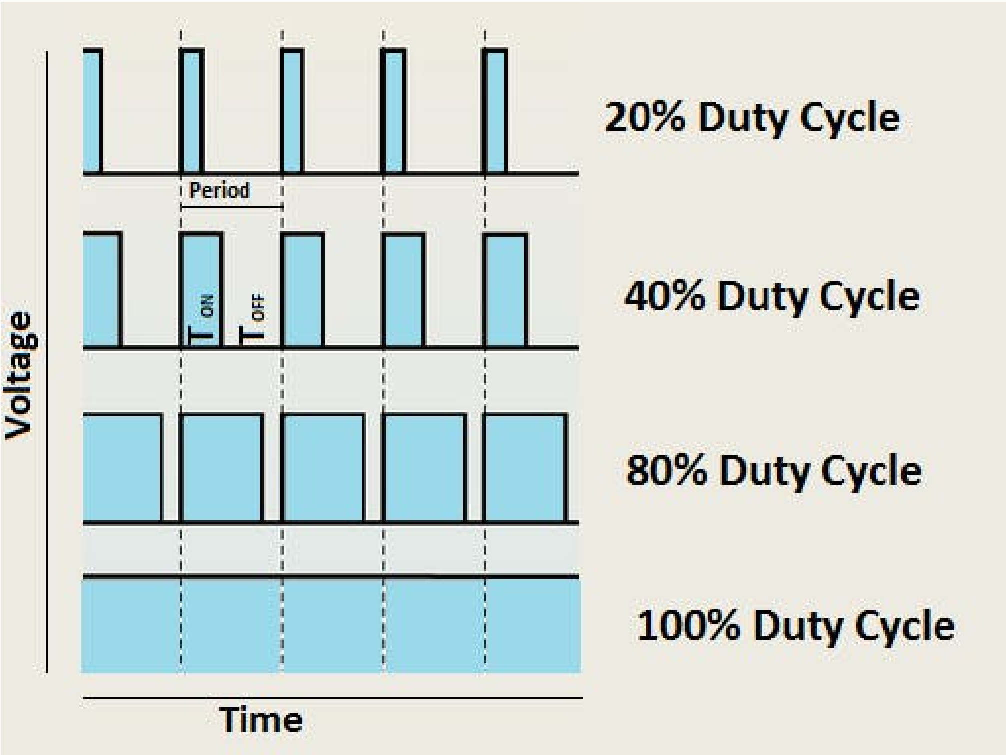

Fig. 3. Example o the PWM signal

The figure above is a graphical representation of a step type PWM signal, and as one can see, 4 actuation variants are represented, modifying the time in which the digital hydraulic switching valve is open and the time in which the digital hydraulic switching valve is closed. The open type, together with the closed type, forms a period. The average between the closing and opening periods of the digital hydraulic switching valve is equal to the flow at the exit of the digital hydraulic switching valve.

3 Electrohydraulic scheme of the system

The software architecture client/server configuration was used; thus, the PLC being configured as a server using the *MODBUS TCP / IP* protocol.

Using the system one can monitor the pressure and flow at the entrance of the hydraulic motor and the digital hydraulic switching valve can be controlled via Modbus TCP IP on the intranet using a specific application and can connect to the internet through a router for remote control and parametrization.

The hydraulic system consists of constant pressure and flow source, digital normally closed digital hydraulic switching valve (DHSV), directional valve normally open (DV), Pressure transducer, hydraulic accumulator, hydraulic motor, flow transducer and tank.

When the hydraulic motor has to start, the directional valve is actuated which closes the circuit to the tank and starts operating the digital hydraulic switching valve, so that the flow supplied by the pump is no longer directed to the tank, but enters the system through the digital hydraulic switching valve. The hydraulic accumulator is placed in this system to attenuate the flow pulses produced by the digital hydraulic switching valve. The pressure and flow transducer record the flow and pressure values and send them to the PLC to be displayed in the software application.

The developed client applications are: test signal generator, the parameterization and control application of the digital hydraulic switching valve and motor and the monitoring and data management application.
The control and monitoring scheme of the digital hydraulic switching valve is presented in fig. 4.

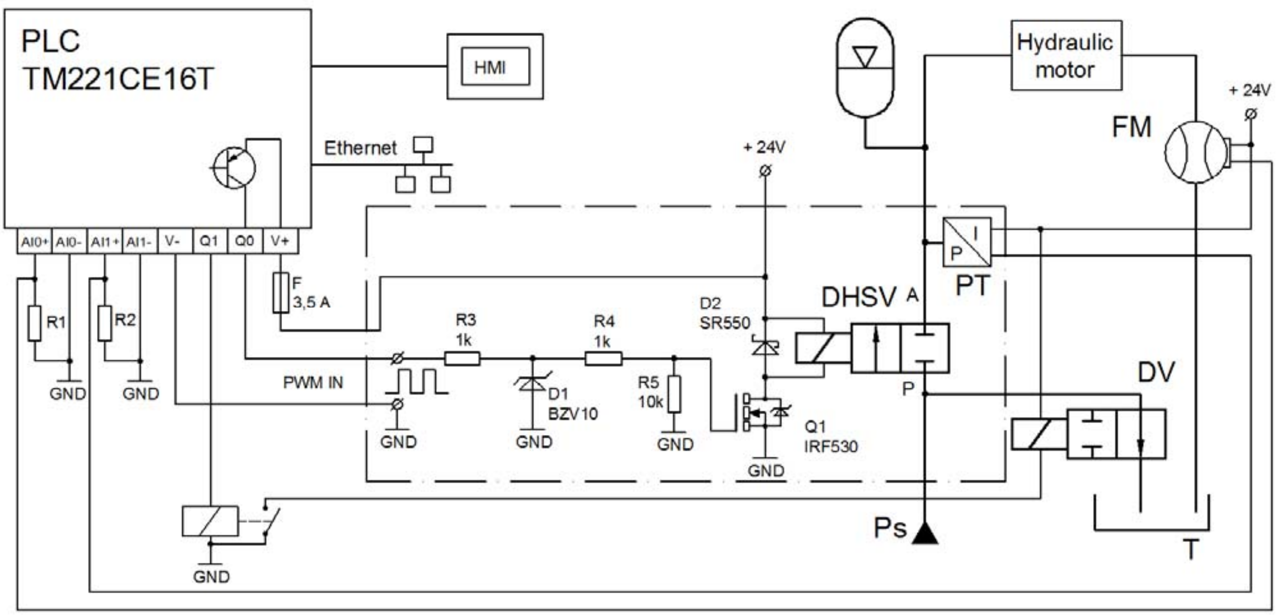

Fig. 4. Switching valve monitoring and control diagram using the PLC

The diagram contains a Mosfet transistor as a driver for the valve solenoid and the connection of the flow and pressure transducer signals to the analog inputs of the PLC. The pressure transducer is positioned before entering the hydraulic motor, and the flow transducer is positioned at the outlet. For the PWM signal control of the digital hydraulic switching valve, the output on transistor Q0 is used. A Human machine interface (HMI) console is used for local monitoring and possible parameterizations. The PLC connection to the network is made through the RJ45 connector located on the front panel of the PLC.

Fig. 5. PLC TM221CE16T from Schneider Electric

The PLC in figure 5 is from the Modicon M221 series, it has 9 discrete inputs where local commands can be connected (buttons, switches), two 0-10V analog inputs where the two pressure and flow transducers are connected, 7 outputs discrete with transistors of which two fast outputs (PWM) where it connects the Digital Hydraulic Switching Valve and Directional valve.

Basically, this PLC in the system is the one that monitors and controls all the process that this system has to perform.
An example of a software application related to the digital intelligent switching system is shown in figure 6. This type of application can be installed on most existing PCs at this time and can work with minimal hardware and software requirements of the operating system on which it is installed.

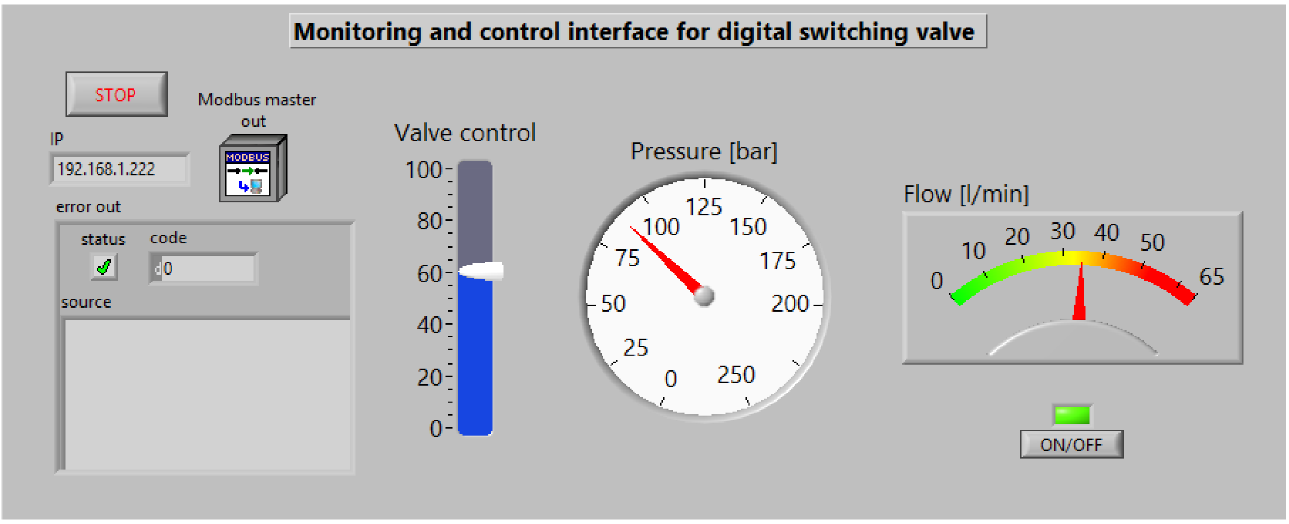

Fig. 6. Software application for intelligent digital switching system.

From the window in fig. 6 of the control software application of the intelligent digital hydraulic switching system, it is possible to monitor the pressure in bars, the flow in liters per minute and the bar (slider) for manual control of the switching valve.
Also, in the application there is the STOP button that closes the application, but also the on/off button which, when activated (the indicator above it is green) activates the manual control bar (valve control) of the digital hydraulic switching valve. When the button is off (the indicator has the LED off) the manual control bar cannot be changed and the system works automatically in the set parameters.

4. Conclusions

The system consisting of a constant pressure and flow source, a digital hydraulic switching valve, a flow transducer, a pressure transducer, a hydraulic accumulator, a hydraulic motor, a PLC for driving the whole process and a software application, becomes an intelligent digital hydraulic system, so that the parameters of the process can be followed remotely and can be modified to optimize the process.
Intelligent systems also bring with them the concept of predictive maintenance, which is very beneficial both for the life of hydraulic components and for the one who exploits the systems.
Intelligent systems are equipment with great prospects for the future and both production technologies and much easier interconnection of more such equipment.
For the system described in this paper, simulations will be made and later an experimental model will be developed on which laboratory tests will be performed, and this will be the subject of a new paper.

Acknowledgments

This paper has been funded by the Romanian Ministry of Research and Innovation under NUCLEU Programme, Financial Agreement no. 18N/2019, Ad 11/2020, Project code PN 19-18.01.01, Phase 17 "Comparative study of energy losses between current hydraulic systems, with classical and proportional equipment, and digital hydraulic systems". European funding has also been granted, under Competitiveness Operational Programme POC 2014-2020, call POC-A1-A.1.1.3-H-2016, Financial agreement no. 253/02.06.2020, signed between INOE 2000 and the Ministry of Education and Research for the project titled "Horizon 2020 Support Center for European project management and European promotion PREPARE", MYSMIS2014 code 107874.

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