Experience in the developing of the laboratory stand for research of the pump operating modes in Kryvyi Rih national university

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Abstract
The laboratory stand for analysis of the centrifugal pump operating modes and building of its pressure and energy characteristics was developed at the Department of Electromechanics. The stand has a closed circuit, which contains a tank with a liquid (water), centrifugal pumps, pipes, pressure and fluid flow sensor. The pump control is possible in two ways: by throttling, using a ball valve with a servodrive and frequency, by changing the rotating speed of the impeller. Stand can be controlled from a PC or operator panel, which are combined into a local network with sensors and a digital multimeter.
The developed software automatically records the parameters of the stand operation and builds pressure and power characteristics of the pump using the SCADA system. Furthermore, the program allows to analyze the regulation method impact of the pump performance on the energy indicators of the system.
The stand is designed for laboratory work and consolidation of the students' theoretical knowledge and for developing of the operation skills of the regulating, controlling and measuring frequency-converter equipment and microprocessor technology.
Key words: LABORATORY STAND; FREQUENCY CONVERTER; PUMP; SCADA SYSTEM; ABB

Introduction

A significant part of the leading home enterprises, using in their work pumping stations, equip them with controlled semiconductor AC drive. The popularity and demand for modern frequency converters is caused by their wide possibilities on the part of energy and resource saving. On the other hand, operation and management of the automated systems of this type requires appropriate knowledge, skills and abilities. View of the foregoing, the task of the university is to give future professionals not only theoretical knowledge concerning the operation of the equipment, but also to teach them to manage this equipment and also to devote considerable attention in the educational process to practical training on the laboratory equipment.

With this in mind, there is a task before the university – to give future professionals not only theoretical knowledge regarding the equipment work, but also to teach them how to manage this equipment, paying significant attention in the educational process to the practical training on laboratory equipment.

The relevance of the work

At present, the Department of Electromechanics of "Kryvyi Rih National University" introduces the new laboratory "Energy-efficient electromechanical systems and technologies". One of the tasks of this laboratory is a research of the turbomechanism work (fans, pumps).

It is known that most of the pumps use the throttle to change productivity, the consequence of which is the excessive energy consumption. The perfect way of turbomechanism productivity regulating is to change the rotational speed of the impellers at the expense of the controlled electric drive, which has a number of indisputable advantages [1-5]. Given the current state of the energy carrier’s use, energy efficiency requirements for the pumps are coming to the fore. The development of the semiconductor elements has led to the appearance on the market quite reliable and relatively inexpensive AC drives based on frequency converters built on modern microprocessor and computer technology. Therefore, an important and relevant issue is the development of the training laboratory stand, which has simple design and low cost and will make it possible to compare different methods of the pump regulation in terms of energy efficiency.

The main purpose is development of the laboratory stand of the pumping unit with the automatic control system. The stand will be used in the educational process for students’ training on a specialty "Electromechanical equipment of the energy-intensive industries", particularly in the laboratory course of the disciplines "Fundamentals of energy literacy" and "Microprocessor and measuring technique". The laboratory stand allows students to carry out experimental evaluation of the pump units operating modes.

The choice of the equipment

There were adopted following conditions by the stand designing:

- the fluid circulation – in a closed loop;
- the stand control – from a personal computer (PC) or operator panels (OP);
- for the sensors survey, the valve control and the information transmission to a PC – programmable logic controller (PLC);
- the internal network pathway– a standard *RS*-485;
- the external network pathway – *Ethernet* and *USB*;
- communication between equipment and PC – *OPC server*;
- the network protocol – *Modbus RTU*.

According to these requirements, the equipment has been selected:

1) basic equipment:

- centrifugal vortical pump *Pedrollo PK60* (voltage U=380/220 V, power P=0.37 kW, n=2900 min^{-1}, flow rate Q=0-40 l/min; head H = 38-5 m)
- AC drive *ABB ACS*-355 (scalar control the *DCU* profile) with the network interface device *RS*-485 *FMBA*-01 and protocol *Modbus* (macro *AC*500 *Modbus*);

2) additional equipment:

- throttle – a ball valve with servodrive *Belimo TR*-24-*SR* (control voltage 0-10);
- fluid pressure sensor *Dwyer* 628*CR*-90 with current output 4-20 mA;
- fluid flow sensor *Sea YF*-S201 with pulse output signal;
- digital Multimeter *Socomec Diris A*10 (measures the current, active and reactive power);
- interface converter *RS*-485/*USB* type *ICP DAS*.

3) equipment for the parameters setting and information displaying:

- OP – *ABB CP*635-*ETH*;
- PLC – *ABB AC*500-*eCo PM*564-*T-ETH*.

The connection between the PC, OP and the PLC is carried out on a standard *Ethernet* using the standard network switch *Ethernet* 100 Mbit/s.

Communication between pressure sensor and servodrive valve control is held in pathway *RS*-485 using built-in PLC, respectively, the ADC and DAC. For measuring of the output pulses frequency of the flow sensor the discrete PLC input is used, which configured to *Fast Counter* mode. The measurement algorithm of the pulse frequency is standard by using the timer. The digital filtering programs are implemented in the PLC to compensate the turbulence impact and the flow non-stationary on the sensors information.

Functional diagram of the laboratory stand is shown in Fig. 1 (we note that the figure shows the real pictures of the selected equipment).

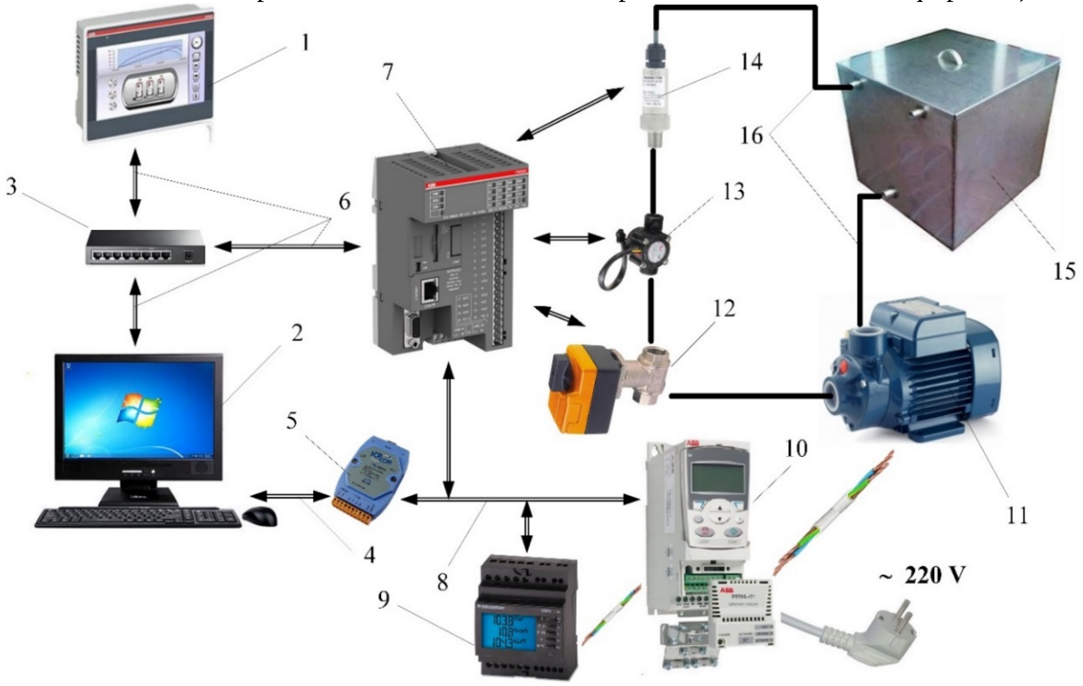


Figure 1. Functional diagram of the laboratory stand

Figure1: 1 – OP; 2 – PC; 3 – network switch; 4 – *USB* pathway; 5 – *RS*-485/*USB* converter; 6 – *Ethernet* pathway; 7 – PLC; 8 – *RS*-485 pathway; 9 – digital multimeter; 10 – AC drive; 11 – pump; 12 – servodrive valve; 13 – fluid flow sensor; 14 – fluid pressure sensor; 15 – tank; 16 – pipeline.

The choice of the software

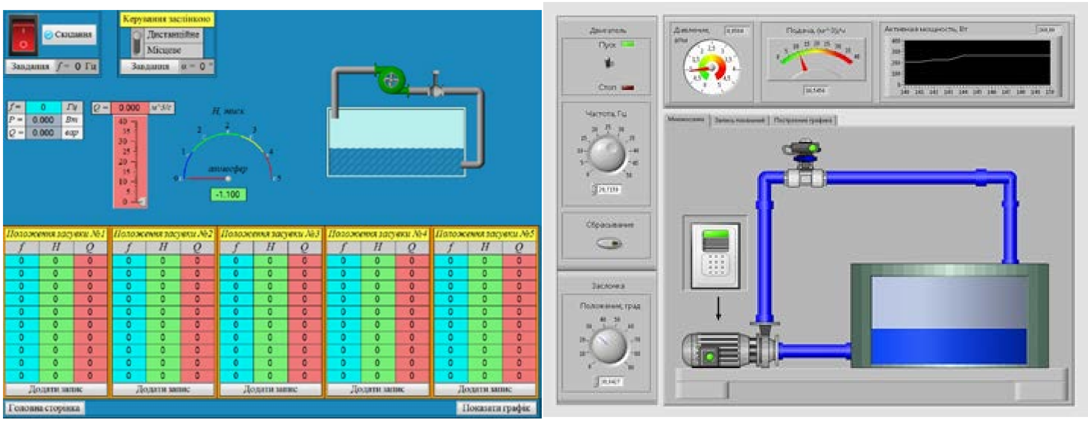
As noted above, for the stand managing and the research automatization it is envisaged the use of a PC or OP. Creating of the modern management systems is based on the development and application of adaptive intelligent systems, whose functioning is impossible without the use of advanced computer network, including a PC, a microcontroller and a set of I/O modules. [6] As an example, SCADA system (Supervisory Control And Data Acquisition) can be used intended for the design, operation, supervisory control and data acquisition. Ease of SCADA systems is that they allow in real-time visually to obtain information about the process run or monitor, as well as to collect all its parameters into a single database for archiving.

In the software market there are many versions of SCADA systems, mostly foreign manufacturers, for example, Simatic WinCC (Windows Control Center), DataRate, KRUG-2000, Master SCADA, TRACE MODE and others.

Technological process of the laboratory stand is simple, that is why selection criteria of SCADA system served its relative simplicity, visibility, versatility, low PC resource requirements and availability of enhanced documentation. These conditions are met SCADA system TRACE MODE, which is an integrated environment for the development of human-machine interfaces (HMI) and supports animation, graphics, historical trends and trends in real time, it has built in programming language, functions library, and also provides a link with a wide controllers range of home and foreign production through the driver controller or OPC server [7].

In order to familiarize students with different types of SCADA systems as an alternative to TRACE MODE it was selected LabVIEW environment (Laboratory Virtual Instrumentation Engineering Workstand). LabVIEW is a multifunctional development environment and platform for running programs written in visual programming language of the National Instruments Company. The purpose of this language is the use automation of the computer and measuring laboratory equipment. Ideologically LabVIEW is very close to the SCADA systems, but unlike them focus more on problem of solving rather than in the field of automated technological process control systems, as in the field of automated research systems [8].

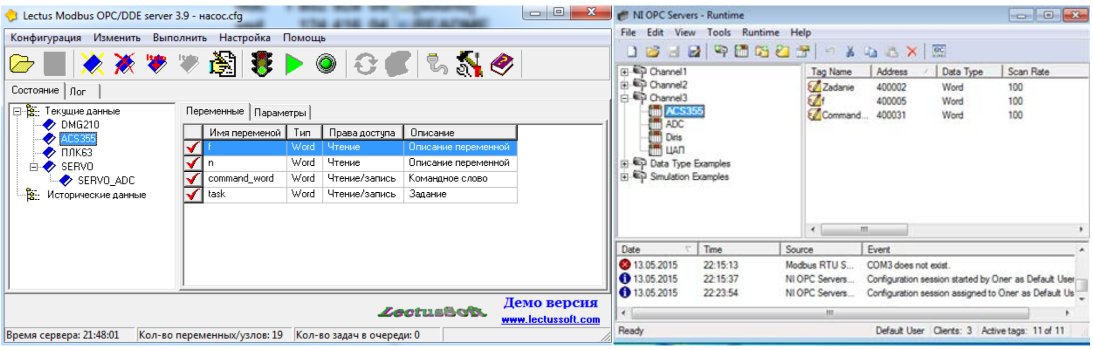
Exterior projects complex laboratory work, created in environments TRACE MODE and LabVIEW, are shown in Fig. 2.



a *b*

Figure 2. Graphic screens for the parameters withdrawal and record of the pump unit:
a – in the environment of TRACE MODE; *b* – in an environment of LabVIEW.

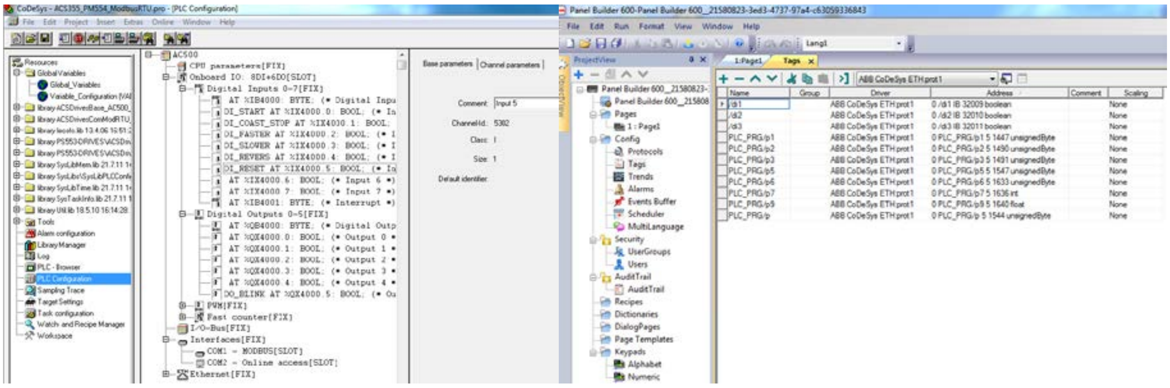
For communication with external equipment for lack of the appropriate drivers, the OPC server configured to protocol *Modbus* is used. For built in the TRACE MODE environment system the variant with using the exterior OPC server Lectus [9] was designed and for LabVIEW its own OPC server of National Instruments was used [8]. *Modbus* server addresses were selected according to the documentation, COM ports addresses were selected according to the System Settings Driver of the interface converter RS485/USB. The structure of the projects OPC servers is shown in Fig. 3.



a *b*

Figure 3. OPC-server project properties:
a – Lectus; *b* – National Instruments.

For programming the PLC and the OP the configurator programs PS501 Control Builder Plus (with tool software package CoDeSys for industrial automation) and PB610 Panel Builder 600 respectively was used. Control Builder Plus and Panel Builder are truly revolutionary products, which combines all of the tools you require for configuring, programming, debugging and maintaining your automation project from a single, intuitive interface. Their feature is that the configuration chosen for stand PLC and OP latter can be connected to any network node *Ethernet* [10]. Screenshots windows PLC and OP configurations are shown in Fig. 4.



a *b*

Figure 4. PLC and OP Settings:
a – in Control Builder Plus program; *b* – in Panel Builder program.

Conclusion

To improve the professional training of the future electrical engineers, the laboratory stand was developed using the hardware and software that meets the needs of modern production and makes it possible to carry out a number of laboratory and experimental studies.

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