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ADVANCED AUTOMATIC SYSTEM FOR REMOTE CONTROL IN THE OIL AND GAS INDUSTRY

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ABSTRACT

The purpose of this work is to design and implement a cascade control system of the level with the flow rate, with remote supervision, in an industrial type installation, located in the Laboratory of Measurement Techniques, Department of Automation, Computers & Electronics, within the Faculty of Mechanical and Electrical Engineering. The operating parameters of the installation are as follows: suction pressure: 0 – 2 bar; discharge pressure: 0 -10 bar; water flow: 0-30 m3/h; transported liquid: water.

The automation system is structured on three hierarchical levels: level 1: the instrumentation mounted on the installation (transducers, signaling devices, etc.); level 2: includes the TGA System; level 3: constitutes the upper hierarchical level and includes the HMI (Human Machine Interface).

The TGA system is a computerized system that ensures the monitoring, command and control functions of all the stand's component elements. It contains a programmable logic controller PLC 1214 – Siemens, which communicates via an Ethernet IP network with an operator interface and with the network of the Faculty of Mechanical and Electrical Engineering, which allows remote control of the installation. It also includes the protection system in case of failure, which involves stopping the rotating equipment, isolating the pipes by closing the control valve and alarming the operators.

The HMI (Human Machine Interface) interface presents 3 options on the start page, from where the operator can select which application he wants to test: flow control loop application; level adjustment loop application; cascade adjustment loop application. The HMI equipment integrates SCADA functions, database update, evolution curves of analog quantities, sound and monitor alarm system, keyboard command, periodic records, event records, alarm records and technological schemes at the human-machine interface.

The entire software is made in an open architecture, recommended by ISO norms. The PLC communicates in the network by adopting the protocol TCP/IP. An executable program used for the real-time application program was developed.

Keywords: advanced system, remote control, PLC controller, HMI Interface, SCADA software

INTRODUCTION

For technological installations in the oil and gas industry, the use of automatic control and supervision systems is of particular importance. In the last 50 years, these systems have had a rapid evolution, having the effect of increasing productivity and the quality of the finished product, replacing the human factor in certain situations but, at the same time, reducing the risk of loss of human life.

The earliest gas or oil processing plants were usually manually controlled by opening and closing valves to meet their operating requirements. The monitoring of the parameters in the installation was carried out locally, by monitoring the pressures and temperatures on manometers and thermometers, mechanical equipment produced since the 1800s. In this way, the human operator carried out a local and manual control of the parameters in the installation.

Since the appearance of pneumatic control systems, they have been rapidly integrated. They allowed the use of proportional, integral and derivative (PID) controllers to send pneumatic signals to control valves to change their stroke. The actuation of these devices was done with instrumental air. In certain applications, compressed air is replaced by process gases or hydraulic oils.

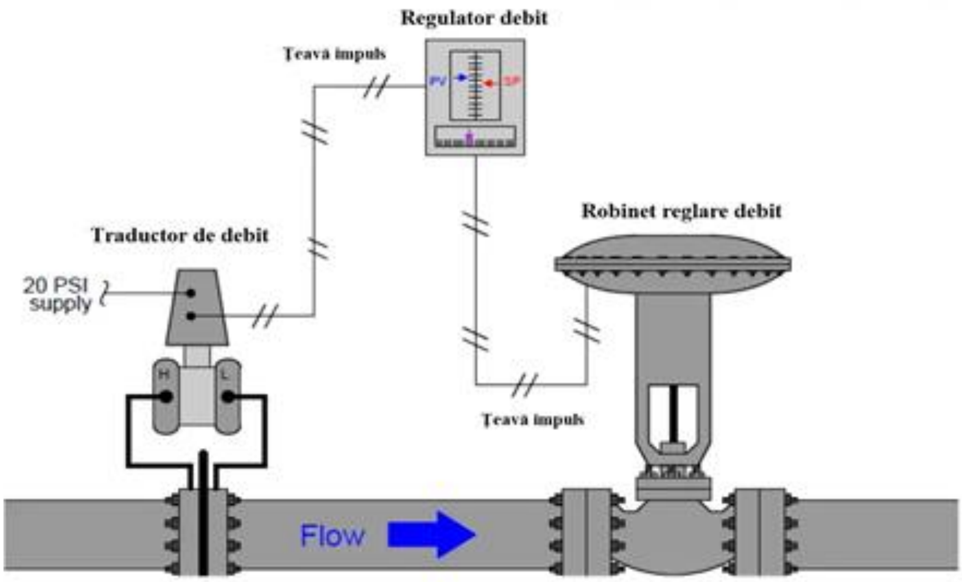

***Figure 1**. Pneumatic flow control loop* [8]

In 1769, James Watt included a speed governor in his steam engine, the first mechanical feedback device with only a proportional function, using for the first time the structure of an automatic adjustment loop after deviation. The governor controlled the speed by applying more steam to the engine when the speed fell relative to a set point and vice versa.

In 1933, Taylor Instruments introduced the first pneumatic controller with a fully adjustable proportional controller. In 1934-1935, Foxboro introduced the first integral (PI) controller. However, PI controllers can overcorrect errors and cause closed-loop instability. This happens when the controller reacts too quickly and too aggressively; it creates a new set of errors, just the opposite of the actual error. In 1940, Taylor Instruments successfully produced the first PID pneumatic controller with derivative action.

Pneumatic equipment had a great impact on control systems that they are still manufactured today [5].

As electronic controls developed, they quickly expanded and replaced pneumatic controls, although some elements of pneumatic control systems are still used today. Most control valves are still pneumatically operated, even though electrically operated valves have been on the market for a long time.

Electronic controllers were quickly accepted due to lower production cost and higher reliability. Thus, electric cables replaced the pneumatic pipes for signal transmission. The pneumatic sensors were replaced by electronic ones.

In industrial process control systems, 4-20 mA analog current loops are frequently used for electronic monitoring of process parameters, with the 4-20 mA range representing 0–100% of the measurement or control range [2]. These loops are used both for transmitting the value measured by a sensor in the process, and for transmitting commands to the execution elements within the technological process, such as regulating valves or frequency converters (Figure 2).

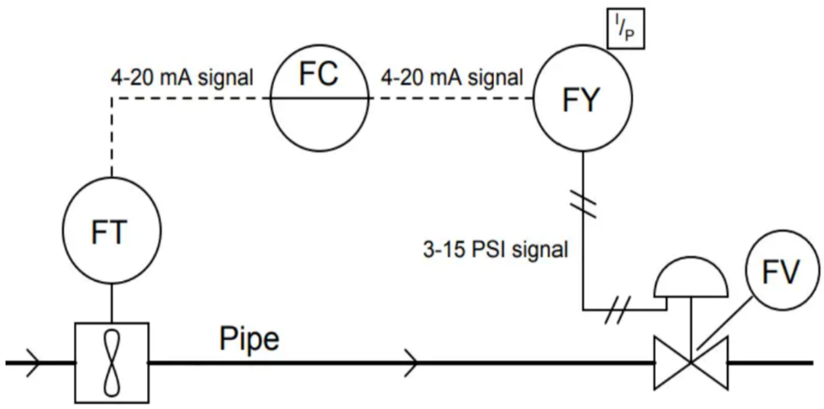

Figure 2. *Analog flow control loop* [9]

In the 1950-1960 period, with the development of electronic equipment and 4-20 mA loops, an extensive modernization of the monitoring and control equipment in the control room began.

The PLC (Programmable Logic Controller) appeared in the late 1960s in the US automotive industry and was designed to replace relay logic systems. This is a digital electronic device with a microprocessor, into whose memory the control instructions for execution and numerous other functions can be loaded. PLCs are widely used in the field of industrial control today [1].

The automatic control of a technological process is based on bringing and maintaining the output quantity of the process close to or equal to the desired value (reference quantity), when the reference quantity changes over time or when the technological process undergoes changes due to the action of disturbances [3].

There are systems that have the property of constantly comparing their current state with the reference state, and when differences between them are detected, they issue commands to eliminate the deviations. These are the control systems after deviation.

Deviations that intervene in the state of the system are due to the continuous action of disturbances on it. In the process of eliminating the observed deviation, the system will finally reach a new permanent state, characterized by the complete or only partial removal of the deviation, depending on the degree of complexity of the internal structure of the respective system.

There are also systems that have the property of permanently observing the evolution of disturbances and when their changes are detected, they issue commands to compensate for the effect of disturbances, simultaneously with their action, so that the current state of the system does not change in relation to the state of reference [4]. These are the control systems after the disturbance.

In industrial processes, control systems with multiple loops are also used, which, although they use a single control agent, have internal structures that allow substantial improvements in their performance. One such system is the cascade control system, used in the control of both fast and slow processes.

Eliminating the effect of certain disturbances and improving the dynamic performance of the main control loop are the objectives pursued by using these systems: P1, P2 – controlled processes; T1, T2 – transducers; TI1 – transducer for the reference size; R1, R2 - controllers; EE – execution element (Figure 3).

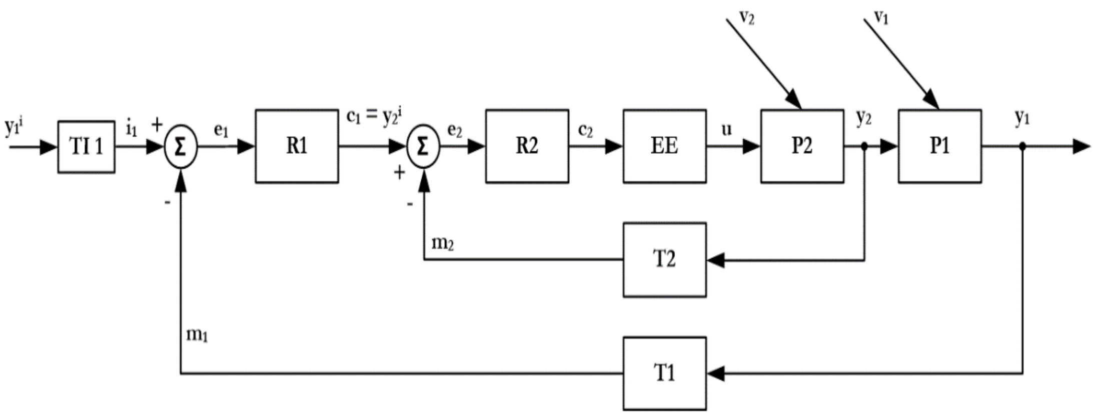

Figure 3. *Block diagram cascade control system* [3]

DESCRIPTION OF THE TECHNOLOGICAL INSTALLATION

The description of the technological process is presented in the technological scheme of the laboratory installation, similary with an oil& gas industrial installation (Figure 4).

The water recirculation pump 10-PA-01 is connected with the suction to the water tank 10-RA-02;

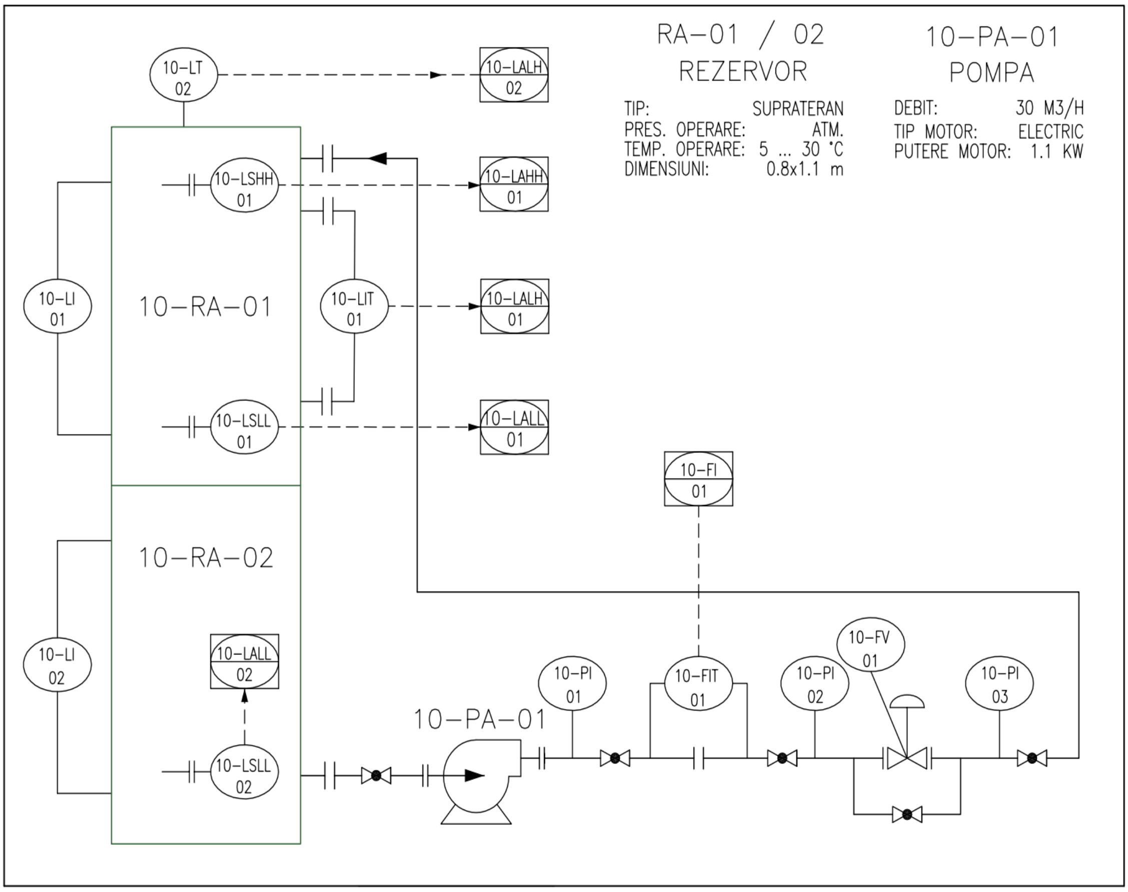

Figure 4. *Technological diagram (P&ID) of the installation*

The pump discharge is connected by a DN50 pipe to the water tank 10-RA-01. Between the two water tanks there is a valve that opens during the operation of the installation, to facilitate the recirculation of the liquid between the tanks.

On the discharge of the recirculation pump is the pressure gauge 10-PI-01.

The 10-FIT-01 flow transducer is mounted on the DN50 pipe on the discharge route. This flow transducer is composed of a diaphragm and a differential pressure transducer.

On the pipe, after 10-FIT-01, the 10-PI-02 pressure gauge is mounted, which helps, together with the 10-PI-01 pressure gauge, to monitor the pressure drop on the measuring diaphragm.

After 10-PI-02, the flow regulating valve 10-FV-01 is mounted on the pipe.

The 10-PI-03 pressure gauge helps, together with the 10-PI-02 pressure gauge, to monitor the pressure drop on the regulating valve.

A local level indication system is mounted on each water tank using glass tubes.

Two level transducers 10-LIT-01 and 10-LT-02 are mounted on the water tank 10-RA-01, which work according to different measurement principles. The level transducer 10-LIT-01 is an immersion level transducer with an external measuring chamber, this chamber is connected to the vessel by means of two flanged connections. The level transducer 10-LT-02 is of the radar type with antenna and is mounted on the upper part of the vessel, it does not come into contact with the working fluid. These level transducers are also used for alarming the minimum and maximum level to the operator.

Two level indicators 10-LSLL-01 and 10-LSHH-01 are also mounted on the water vessel 10-RA-01, which are equipped with floats. These level indicators are used to alarm the minimum minimorum and maximum maximorum level to the operator. At the same time at the maximum maximorum level, stop the water recirculation pump and close the flow control valve.

A level indicator 10-LSLL-02 is mounted on the water tank 10-RA-02 which detects the minimum level by means of a vibrating fork. This level indicator is used to alarm the minimum level to the operator and to stop the water recirculation pump.

DESIGN OF THE CONTROL SYSTEM IN THE LEVEL-FLOW CASCADE

The hardware structure of the system is presented with the help of the technological diagram (P&ID) of the cascade regulation loop of the level with the flow in figure 5.

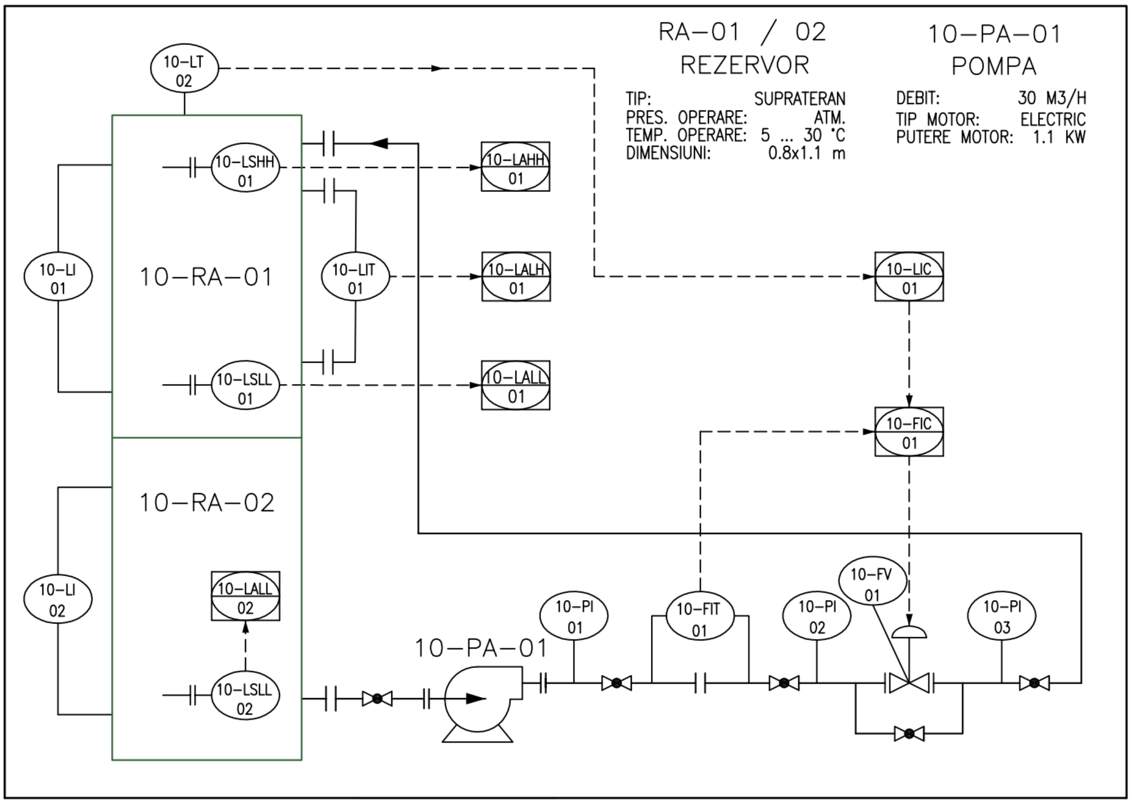

Figure 5. *P&ID diagram for the level and flow cascade control loop*

To create the flow control loop, the flow transducer 10-FIT-01, the software controller 10-FIC-01 and the control valve 10-FV-01 are used. To create the level control loop, the level transducer 10-LT-02 and the software controller 10-LIC-01 are used, the command of the level controller representing the setpoint for the flow controller.

ADVANCED AUTOMATION SYSTEM IMPLEMENTATION

The automation system is structured on three hierarchical levels: level 1: the instrumentation mounted on the installation (transducers, signaling devices, etc.); level 2: includes the TGA System; level 3: constitutes the upper hierarchical level and includes the HMI (Human Machine Interface).

The TGA system is a computerized system that ensures the monitoring, command and control functions of all the stand's component elements. It contains a programmable logic controller PLC 1214 – Siemens, which communicates via an Ethernet IP network with an operator interface and with the network of the Faculty of Mechanical and Electrical Engineering, which allows remote control of the installation. It also includes the protection system in case of failure, which involves stopping the rotating equipment, isolating the pipes by closing the control valve and alarming the operators (Figure 6). The programmable automation type 1214 - Siemens takes care of the operation of the installation through the functions of monitoring / technological control / emergency stop [6, 7].

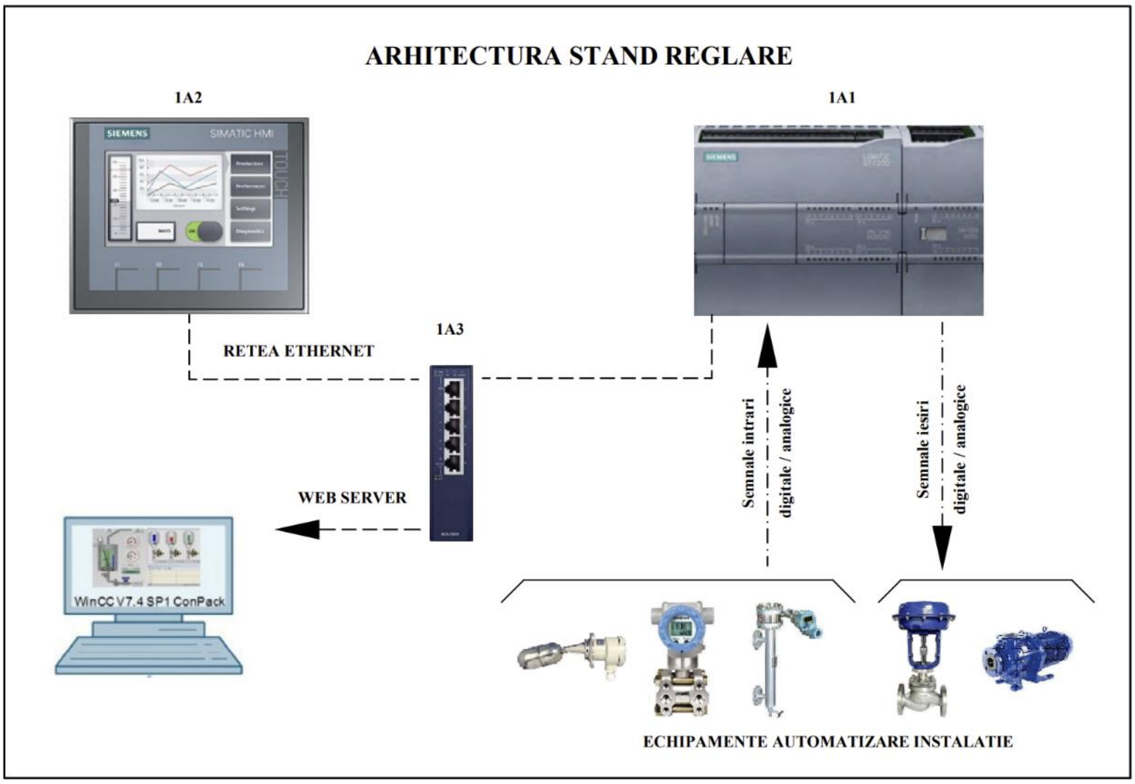

Figure 6. *TGA System Architecture*

The HMI (Human Machine Interface) interface presents 3 options on the start page, from where the operator can select which application he wants to test: flow control loop application; level adjustment loop application; cascade control loop application. In this paper we will refer only to the adjustment loop in the flow-level cascade. The HMI equipment integrates SCADA functions, database update, evolution curves of analog quantities, sound and monitor alarm system, keyboard command, periodic records, event records, alarm records and technological schemes at the human-machine interface. Figure 7 shows the main screen of the HMI in the case of cascade adjustment.

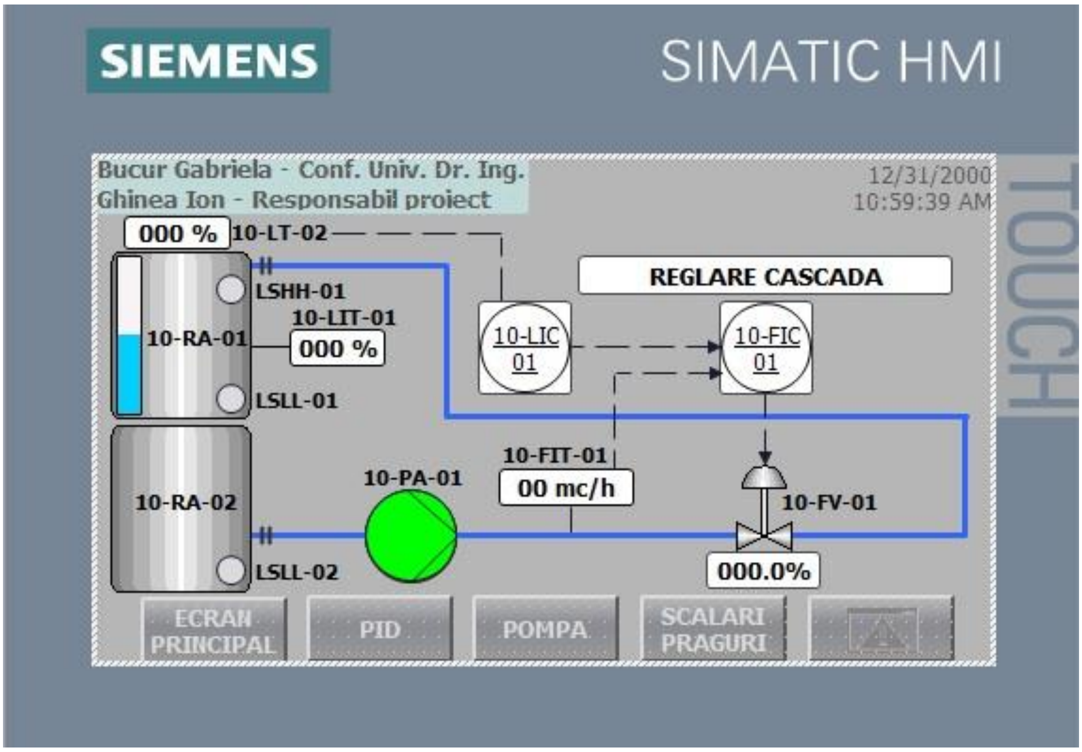

Figure 7. *Main screen of the level-flow cascade system adjustment application*

In the PID sub-screen of the application it will be possible to change the PID parameters and to control the adjustment valve both manually and automatically (Figure 8).

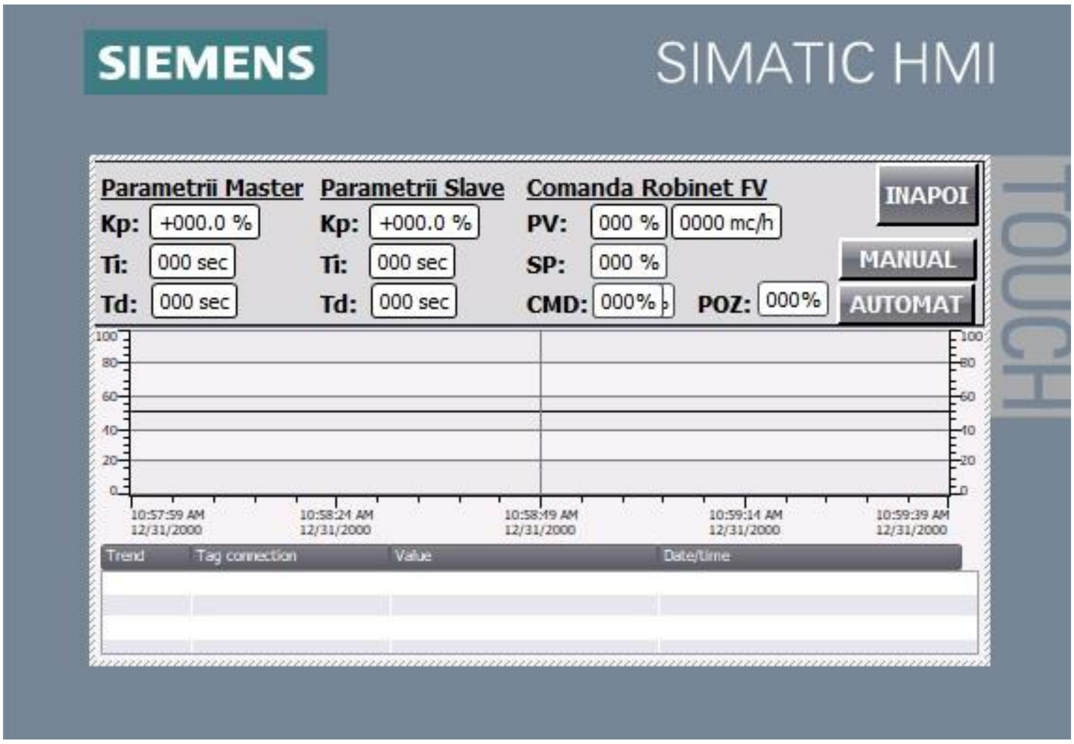

Figure 8. *Sub-screen "PID" level-flow cascade control application*

In the PUMP sub-screen of the application, the pump will be commanded and its states will be monitored (Figure 9).

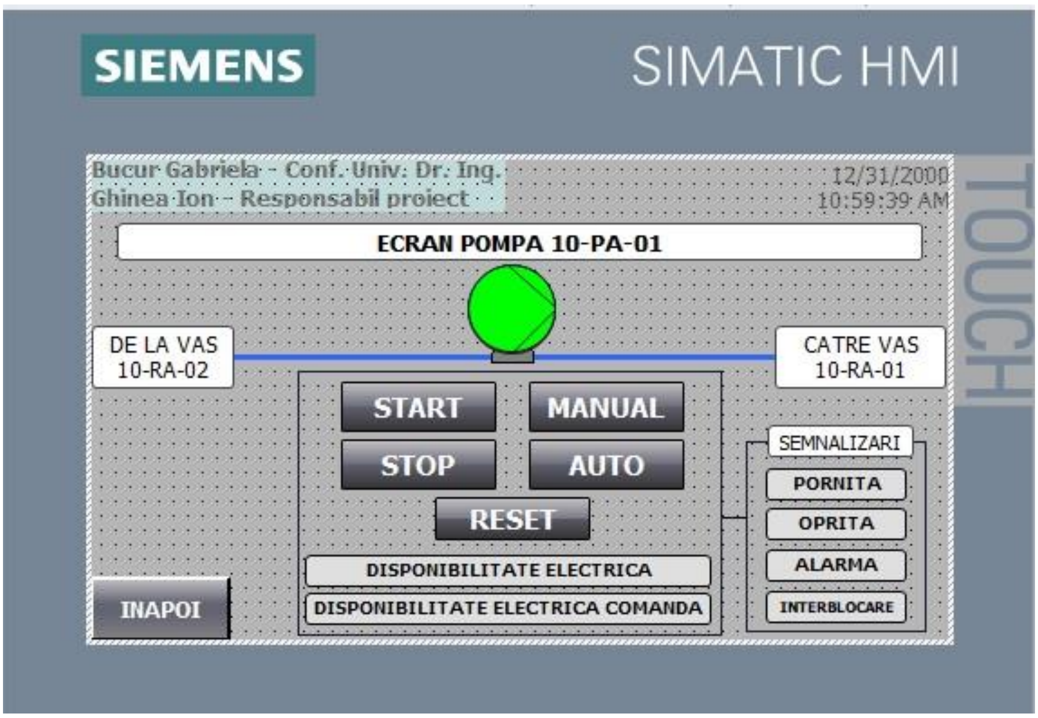

Figure 9. *Sub-screen "PUMP" level-flow adjustment cascade application*

In the SCALE THRESHOLDS subscreen of the application, the scaled and scaled values of the transducers in the application will be monitored (Figure 10).

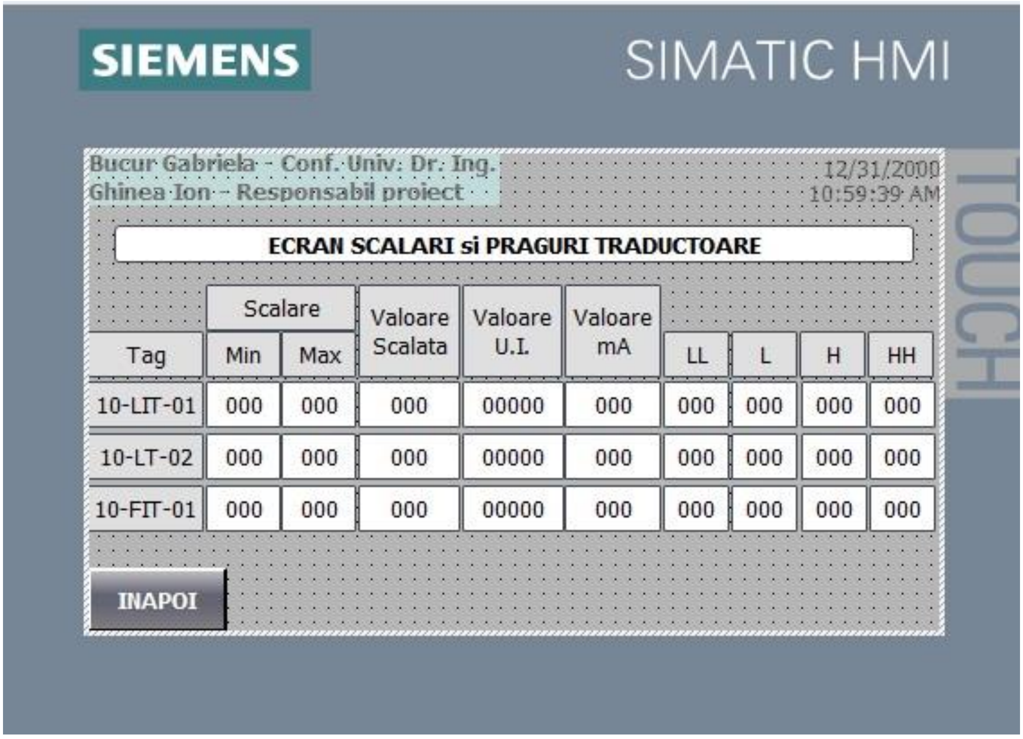

Figure 10. *"SCALAR THRESHOLDS" sub-screen, level-flow cascade regulation application*

The entire software is made in an open architecture, recommended by ISO norms. The PLC communicates in the network by adopting the protocol TCP/IP. An executable program used for the real-time application program was made.

The supervision and command functions will include close/open and increase/decrease operations in accordance with the analog position indicator. The equipment will check the interlock conditions before actually giving the commands to the operator. When the command is logically prohibited, the error will be displayed on the monitor.

The analog quantity evolution analysis program displays the quantity evolution on the monitor in the form of a graph. The operator will be able to choose different time intervals for which the keyboard evolution analysis is done. There is also the function of online tracking of the evolution of sizes.

Self-diagnosis software was developed, which can locate the position of the defects, correct the defects, etcito ensure soft/hard maintenance. The self-diagnosis software shows exactly where the fault occurred, estimates the downtime of the entire system, including the communication line, process controllers, process interfaces and all peripherals. All soft/hard faults in the system are forwarded to remote monitoring.

Figure 11 shows the logical operation diagram of the control loop in the level-flow cascade.

CONCLUSIONS

Cascade control is a control strategy used in engineering and process control systems to improve the overall performance of a control loop. It involves using multiple control loops in a hierarchical arrangement, where the output of an inner loop is used as the setpoint or reference for an outer loop. In a cascade control system, there are typically two control loops: the primary or outer loop and the secondary or inner loop. The inner loop controls a fast-responding process variable, while the outer loop controls a slower-responding process variable. The basic point behind cascade control is to improve the mitigation of the disturbance and setpoint tracking of the overall system by providing faster and more accurate control. By using the output of the inner loop as the setpoint for the outer loop, the outer loop can respond more quickly to changes in the process and reduce the effects of disturbances. Advanced control techniques, such as proportional-integral-derivative (PID) control, adaptive control may be used to design and implement cascade control systems.

A remote controlled system system refers to a system or device that can be monitored, operated or controlled from a distance. It involves the use of communication technologies to transmit commands or instructions from a remote location to the system being controlled. Remotely controlled systems rely on communication mediums to transmit control signals between the user and the controlled device. These mediums can include wired connections (such as Ethernet or serial communication) or wireless technologies (such as Wi-Fi, Bluetooth, or cellular networks).

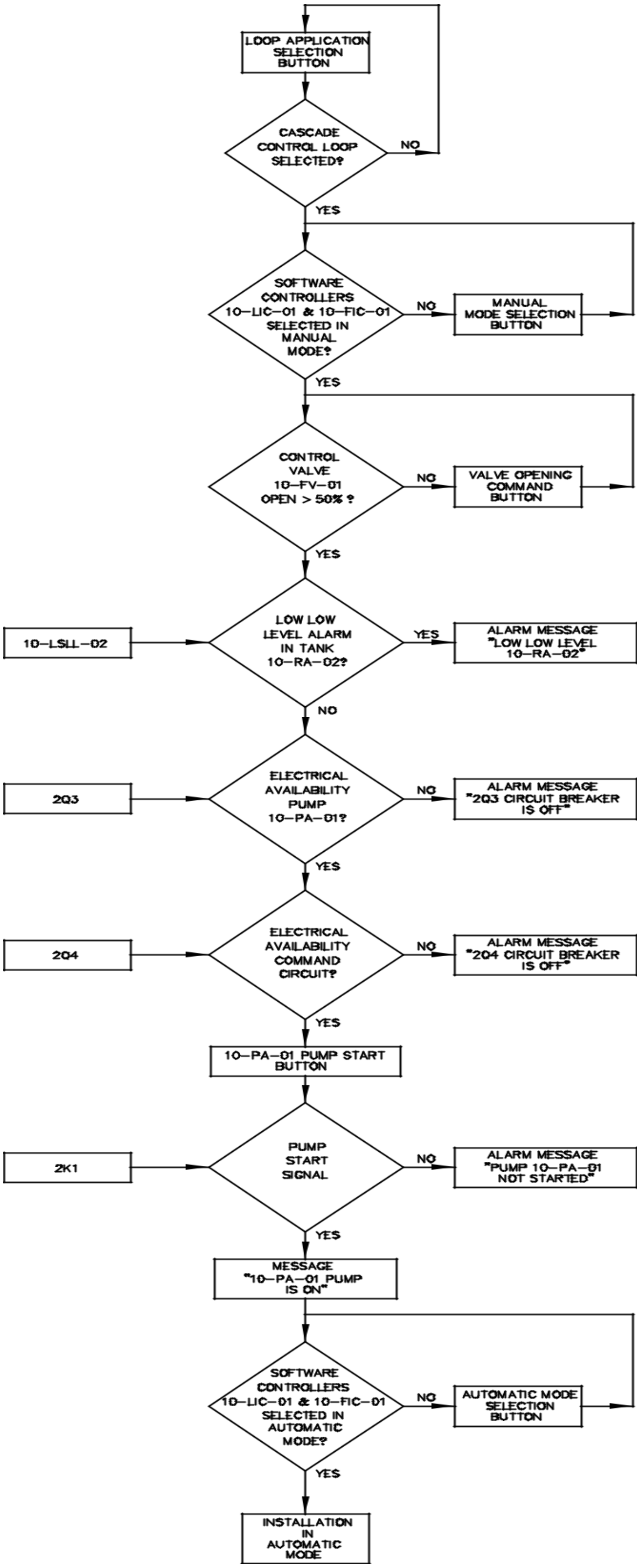

Figure 11. *The logic diagram of the control loop in the level-flow cascade*

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