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INDUSTRIAL PROCESS MONITORING AND CONTROL SYSTEM

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The paper presents the applications designed for programmable logic controllers (PLCs) and human-machine interface (HMI), in order to monitor and automate industrial processes. Applications for PLCs are made in the EcoStructure Machine Expert Basic and SoMachine V4.3 programs, and applications for HMI in the Vijeo Designer 6.2 program. The industrial process is coordinated by the TM241CEC24R machine that monitors and controls the TM221CE16R PLCs in the liquids pumping, bottling and transport stations. The paper describes the monitoring and control system in terms of hardware and software. The achieving of an efficient monitoring and control system contributes to obtaining a predictive maintenance that leads to the proper functioning of industrial processes.

Keywords: industrial process, monitoring, control, programmable logic controller, human-machine interface, EcoStructure Machine Expert Basic, SoMachine V4.3, Vijeo Designer 6.2.

1. Introduction

A monitoring and control system has the role of constantly observing, recording and verifying, at a certain time interval of the parameters within an industrial process [1]. The monitoring and control system contributes to the maintenance and prevention of breakdowns in industrial processes [2]. For easy adaptation to process changes, we will use PLCs in pumping, bottling and transport stations for liquid substances in industrial processes [3, 4].

The PLCs in these stations receive the information from sensors, convert it into a unified current and voltage signal and transmit it to the monitoring and control system. Information transmissions are made based on certain communication protocols such as RS-232, RS-422, RS-485, Modbus-RTU, Modbus ASCI, Modbus TCP, USB, HART and ControlNet [5, 6, 7].

The stations listed above are used in the following fields: agriculture, mining, food, oil field, chemical and pharmaceutical. It is currently estimated that 20-25% of the total electricity consumption produced in the world is used to

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power various pumping stations [8]. Pumping stations are used to transport liquid from one basin to another or, to transport liquid from one industrial process to the next one. In certain pumping stations, where the liquid is transported from one high-level tank to another low-level tank or, between two tanks at different altitudes, a turbine system can be implemented to recover some of the energy consumed in the supply pumps.

Pump manufacturers have incorporated electrical devices to control and monitor pumping stations. Currently, the most widely used devices are PLCs and Remote Controlled Units (RTUs) [8]. Today main challenges of the current monitoring and control systems consist in obtaining energy-efficient industrial systems. If a problem occurs, it can be more easily identified and transmitted to the central control unit. An example consists in the Supervisory Control and Data Acquisition (SCADA) system [9]. SCADA systems using contributes to better data security in respect to industrial processes.

2. Hardware description of the monitoring and control system

The industrial process monitoring, and control system is based on four programmable controllers (one master PLC TM241CEC24R and three slave PLC TM221CE16R for hardwired architectures).

The pumping, bottling and transport stations are monitored and controlled by programmable logic controller for hardwired architectures [10]. The control of the entire industrial process is performed with the help of an master programmable controller [11]. In the simplified block diagram of the monitoring and control system of these stations (Fig. 1) is presented the Master-Slave relationship between PLCs.

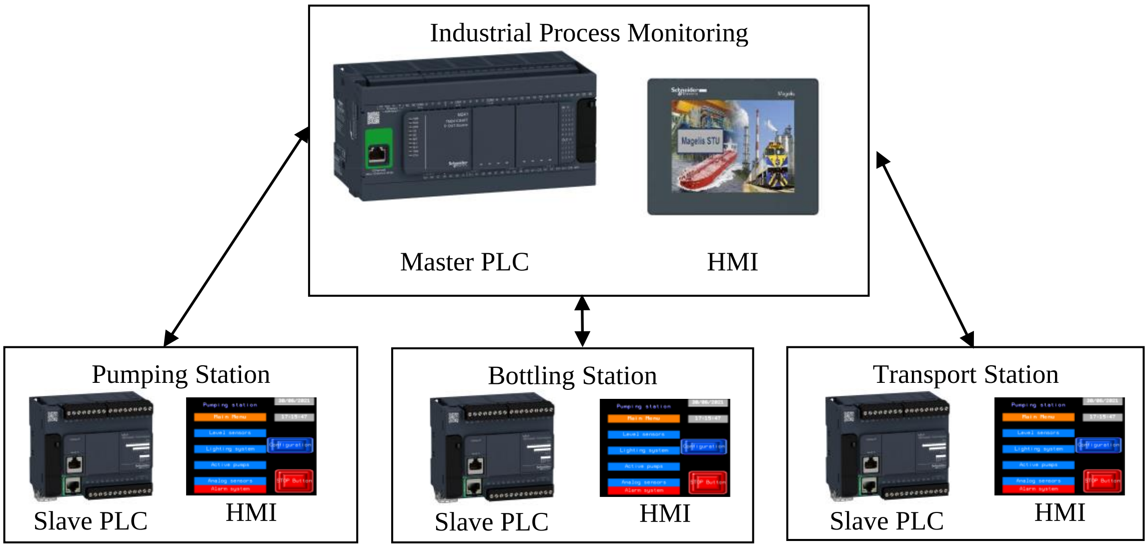

Fig. 1. Simplified block diagram of the monitoring and control system

3. Software description of the control system

Fig. 2 shows the logic diagram of the program used by to monitor and control the automatic system of the pumping station.

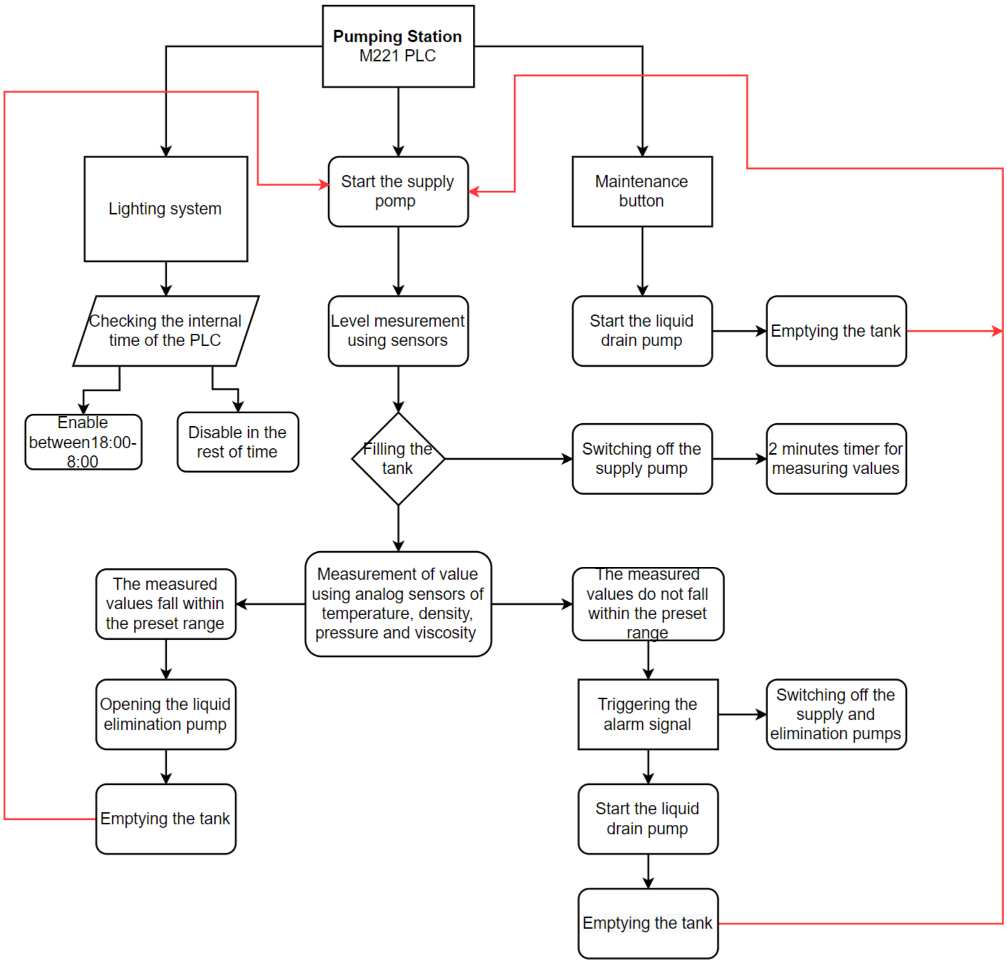

Fig. 2 Logic diagram of the pumping station

There are TM221CE16R programmable controllers in the pumping, bottling and liquid transport stations. The software used to program them is EcoStructure Machine Expert Basic [12].

Within the pumping station, the TM221CE16R PLC monitors sensors connected to the digital inputs% I0.0 ..% I0.4 for each liquid level in a tank. The sensors are located at the height of: 0%, 25%, 50%, 75% and 100% of the tank level. Input% I0.5 is used to read the status of the process stop button. This button can be used by an operator in case the maintenance operation is required or, a malfunction occurs in the industrial process. The ladder diagram (Fig. 3) explains the functioning of the pumping station based on the logic diagram (filling the tank, switching off the feed pump, a waiting time is required to perform the remaining measurements before the liquid is transported, emptying the tank).

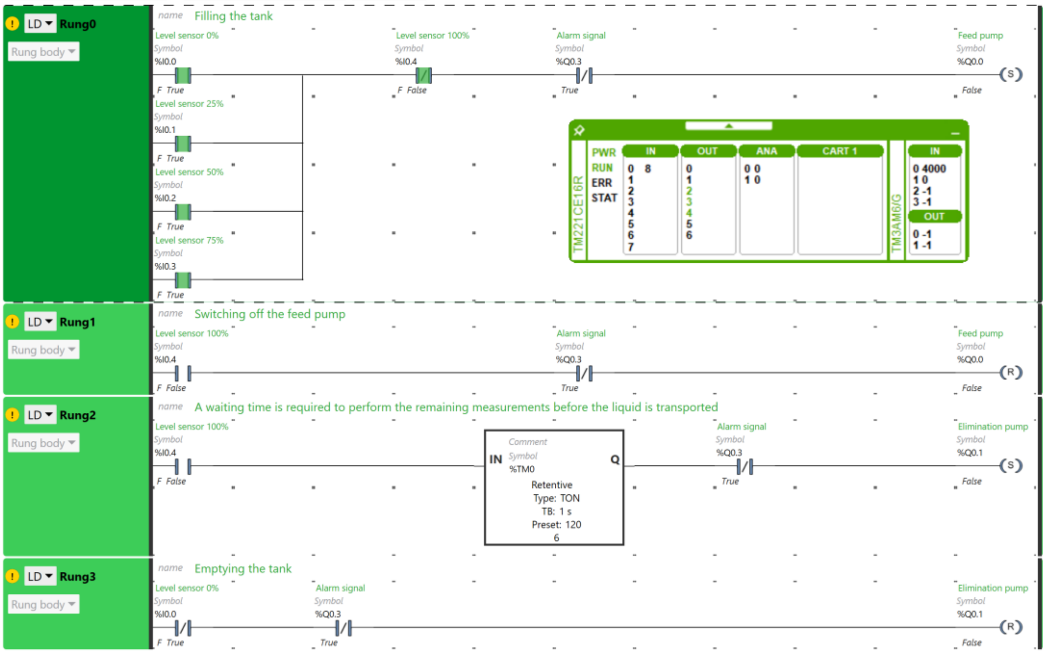

Fig. 3. Ladder diagram used by the TM221CE16R to measure the liquid level

The analog inputs associated with the temperature and density sensor are %IW0.0 and %IW0.1 and, they transmit the information in the range of 0-10V. The temperature sensor has the measuring range of 0°C - 100°C. The alarm signal is triggered when the temperature is below 20°C, or higher than 80°C. If the voltage received by the PLC is within the range of 2-8V, the system works correctly. The density sensor has the measuring range of 300kg/m^3 – 2000kg/m^3. The alarm signal is triggered if the density is less than 500kg/m^3 or, it exceeds the value of 1500kg/m^3. If the voltage received by the PLC is within the range 1,176-7V, the system works properly. The other two analogue sensors are the pressure (%IW1.0) and the viscosity (%IW1.1) of the liquid and, they transmit the information in the range of 4-20mA and 0-20mA respectively. The pressure sensor has the measuring range within 1atm - 4atm and, the alarm signal being triggered if the pressure is below 1.1atm, or higher than 2.5atm. In other words, the transmitted current is within the range of 4,533-12mA. The viscosity sensor has the measuring range between 60Pas (Pascal * second) and 150Pas, the alarm signal being triggered if the viscosity has a value lower than 60Pas, or higher than 125Pas. Under these conditions, the transmitted current is within the range of 1-15mA.

The% M0 memory bit is used to operate the lighting system. It changes its status according to the scheduled calendar (logical value 1, if we are in the time interval 6pm-8am). Memory words (%MW0) are used to retrieve information from analogue sensors. The information is transmitted to the PLC in the form of unified current or voltage signals, their values being stored at the central system level.

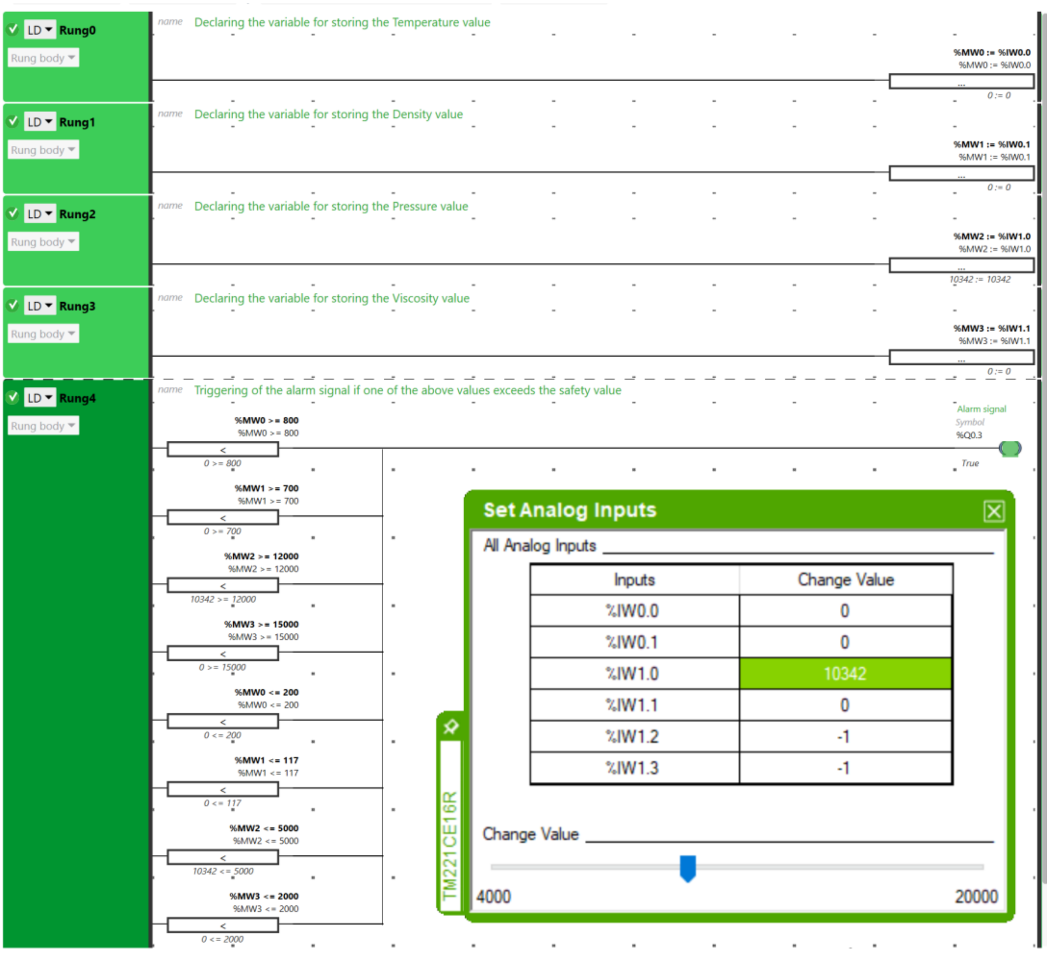

Fig. 4. Ladder diagram used by TM221CE16R for analogue sensors

The ladder diagram (Fig. 4) explains the functioning of the pumping station based on the logic diagram (triggering of the alarm signal if one of the temperature, density, pressure, viscosity values exceed the safety value).

If a failure occurs in the system or, the operator has to perform the maintenance operation, the system will be shut down according to the ladder diagram presented in Fig. 5.

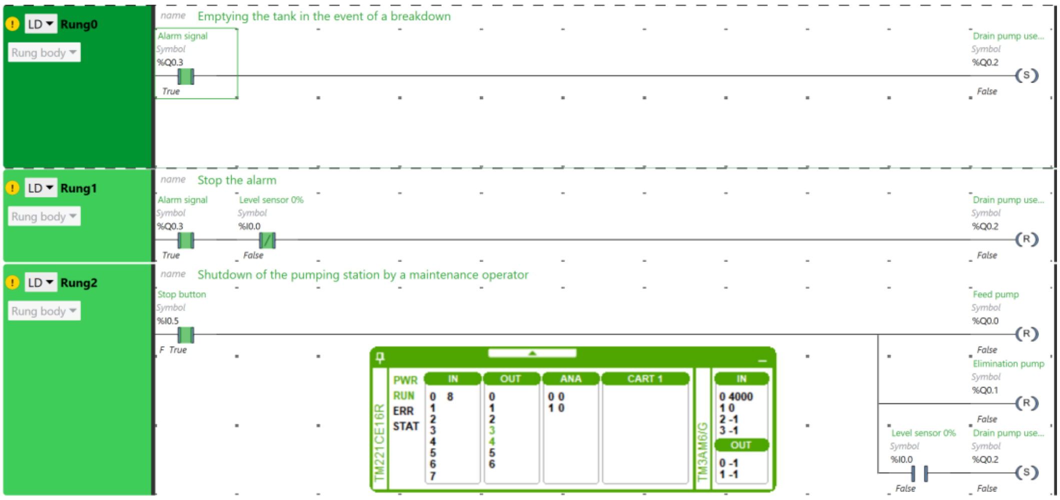

Fig. 5. Ladder diagram implemented on the TM221 PLC of the alarm system

The monitoring and control of the entire industrial process is performed using the TM241CEC24R [13] programmable controller. The program developed in SoMachine V4.3 coordinates the activity within the three stations, pumping, bottling and transport. Fig. 6 shows the configuration of the PLC used as Master. It addresses slave devices using the protocol of the remote terminal unit (RTU).

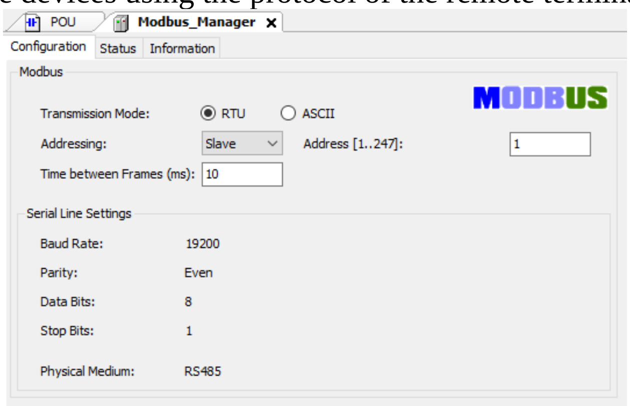

Fig. 6. The setting parameters used for TM241CEC24R PLC

The maintenance operation of all three stations is performed using the program shown in Fig. 7.

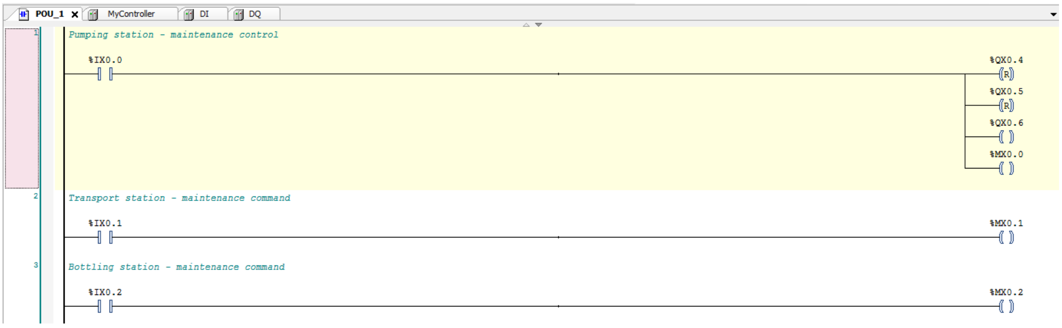

Fig. 7. Ladder diagram used for TM241CEC24R

4. Software description of the monitoring system

Vijeo Designer 6.2 software was used to create the human-machine interface [14]. The main menu of the pumping station is shown in fig. 8 and it contains information from digital sensors, analogue sensors, lighting system status, pumps status and alarm system.

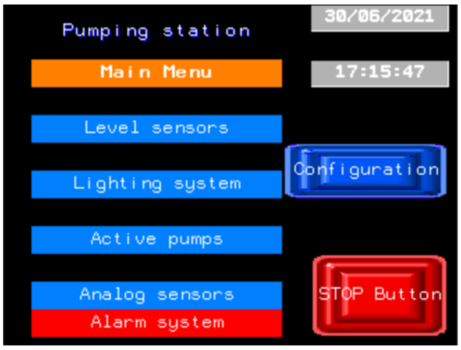

Fig. 8. The main menu of the human-machine interface designed to control the pumping station

The human-machine interface panels that display the status of the level sensors are shown in Fig. 9. In the case presented in Fig. 9, it can be seen that the level of liquid in the tank is 50%.

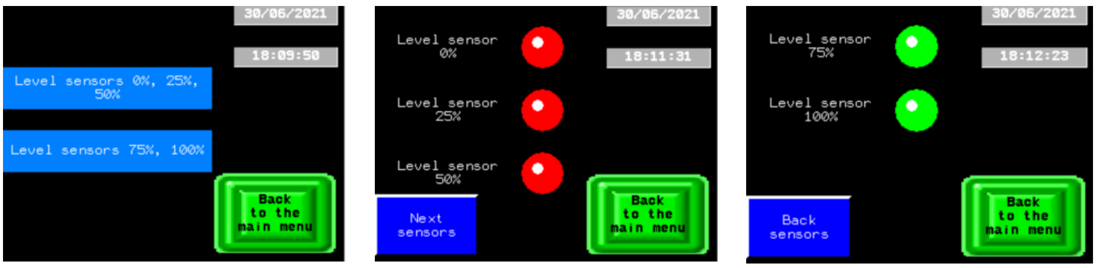

Fig. 9. The human-machine interface that presents the level of digital sensors

Other submenus that can be accessed from the main menu are: the status of the lighting system, the pumps and the analogue sensors. In the case shown in

Fig. 10, the time interval is active, the lighting system is turned on and the drain pump is not activated because the level of the liquid in the tank is 50%. If the temperature sensor is selected, the temperature level is exceeded, and the alarm system is activated.

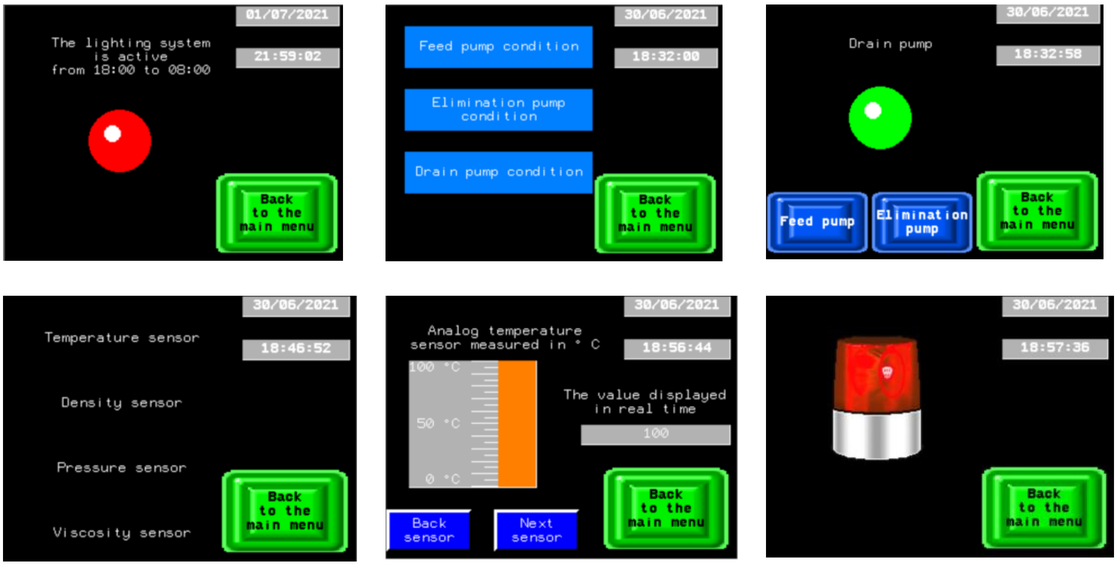

Fig. 10. The human-machine interface that shows the status of the lighting system, the pumps and the level of the analogue sensors

The last presented interface is regarding the M241 PLC. The main menu in Fig. 11 allows the selection of stations and the monitoring of their parameters. The stop button will shut down the industrial process in case of system maintenance or malfunction.

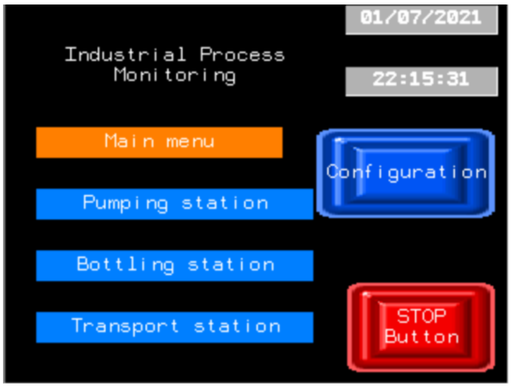

Fig. 11. The main menu of the human-machine interface made for the monitoring process

If the pumping station button is selected, the condition of the pumps and the activated maintenance operation can be observed in Fig. 12.

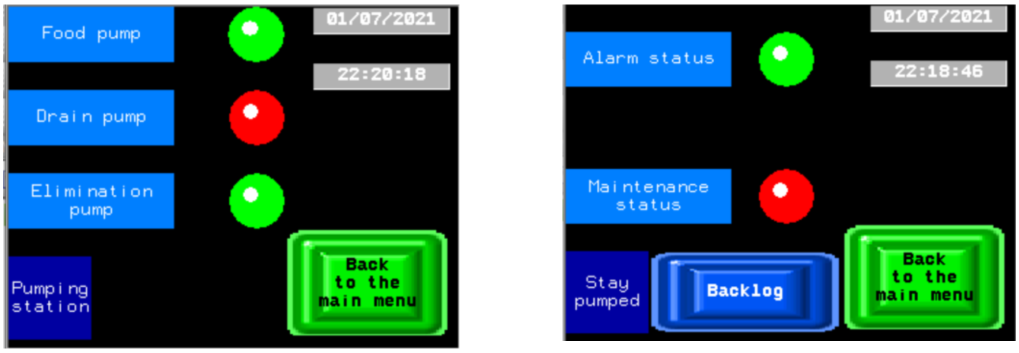

Fig. 12. The human-machine interface displays the status of the pumps in the pumping station and the activation of the maintenance process

5. Conclusion

The monitoring and control of industrial processes is presented in the paper on two levels:

- level one is the station level;
- level two is the level of process management.

Data processing allows the user to perform statistical analyses, parameters identification, alarms type and to interpret this information for the purpose of operational management of industrial processes. The achieved surveillance applications allow the monitoring of the industrial process through the programmable logic controllers and the communication with the users through the human-machine interface.

In conclusion, the authors' contribution consists in performing the communication interface at all levels of the industrial process. The proposed monitoring and control system can be used successfully in a wide range of domains such as: oil field, agriculture, mining, chemical, pharmaceutical and food industry. In the industries presented above, there are processes similar to those presented in the paper. In this sense, software applications made for the PLC as well as those for the human-rail interface can be easily adapted to new areas.

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