The International Journal of Engineering and Science (IJES)
|| Volume || 6 || Issue || 12 || Pages || PP 44-51 || 2017 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Ice Water Cooling Process Research And Optimization

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ABSTRACT

The work deals with the construction of industrial cooling systems and their operation principles and an analysis of the ice cooling system the company of the system. Visualization is being developed that shows the main parameters of the cooling system and, at the end of the work, recommendations are made to improve the system performance.

***Keywords**: Automation control systems, sensor systems and applications, Modbus RTU, PLC*

Date of Submission: 09-12-2017 Date of acceptance: 22-12-2017

I. INTRODUCTION

In the modern industrial environment, cooling systems are an integral part of the production process, as they are needed in virtually all industrial sectors. Cooling is required starting with a cutter, a drill, etc. Unloading the heat generated by the machine due to the friction forces to maintain a certain temperature during the production of food products, which requires cooling to prevent damage to the product. In both cases, the reliability of the system is very important, since in the case when the temperature is not always ensured, the plant may become idle or even turn all products into a dairy factory, which is especially noticeable at the milk processing plant.

In the early days, technological complexity was the key to complexity, since it was not so much available, but at the present time special attention was paid to the efficiency of the technological solution and economic indicators, as producers want to maximize their savings. The cooling system should maintain the operating temperature and be effective enough not to overestimate the cost of the product.

II. METHODOLOGY

The compressor performs work W and compresses the refrigerant, resulting in a sharp rise in temperature. At this stage, the refrigerant reaches a pressure in which, at a slight drop in temperature, it will condense. In the next step, the refrigerant agent is cooled down the condenser by returning the heat energy Q_H to the environment or other substance, so its temperature drops slightly and condensates. Further, the refrigerant reaches the expansion valve, which regulates its supply to the heat exchanger, which in most cases is also a vaporizer. At this stage, the refrigerant pressure and temperature drops rapidly - it boils and evaporates, taking the heat from the cooling medium T_L. As a result, the temperature of the refrigerant falls, and the refrigerant gas returns to the compressor again [44].

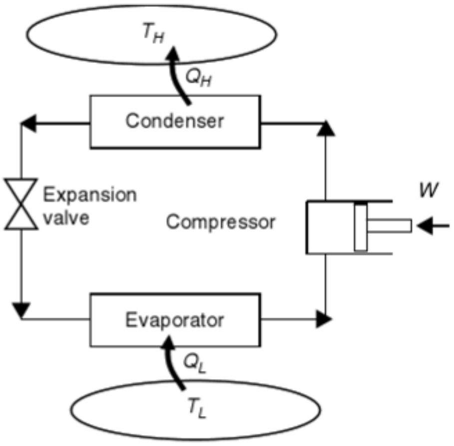


Fig.1. Gas compression type cooling circuit diagram.

Consists of 4 stages - refrigerant compression, refrigerant cooling / condensation, refrigerant expansion and refrigerant evaporation - cooling agent [**Error! Reference source not found.**].

The RS-485 interface allows you to connect up to 32 devices at a distance of up to 1.2 km and at a speed of up to 10 Mbps. Each signal has a wire pair, and the differential signal is a voltage in one conductor opposite to the polarity of the second conductor, and the receiver reads the difference between these voltages. It has good noise immunity, because noise affects both signal cables equally. In order not to reduce noise immunity, signal transmission lines should be balanced (see Figure 2). The unbalanced connection is displayed at the top of the image - the signal level is compared to the ground. With this connection, even higher voltages can occur in long lines, since the ground potential in the sender's message does not match the potential of the earth to the recipient of the message. This circuit no longer compensates for noise interference. The lower part shows a correctly balanced chain, which is partially resistant to different ground potentials [**Error! Reference source not found.**].

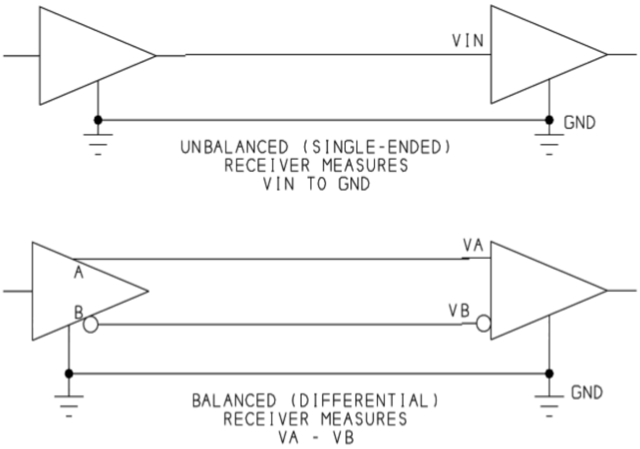


Fig. 2. Balanced and unbalanced RS-485 connector [7].

Modbus RTU is a freely available protocol that communicates with the RS-232 or RS-485 interface. It uses the master / slave architecture (see Figure 3). This is a widely recognized protocol because it is easy to use and reliable. It is widely used in building management systems (BMS) and in industrial automation systems [**Error! Reference source not found.**]. Modbus RTU telegrams have a simple 16-bit self-check cycle loop (CRC), which ensures successful communication without errors. The 16-bit Modbus RTU registry structure can be used to transfer floating-point variables, table ASCII text and other data [**Error! Reference source not found.**].

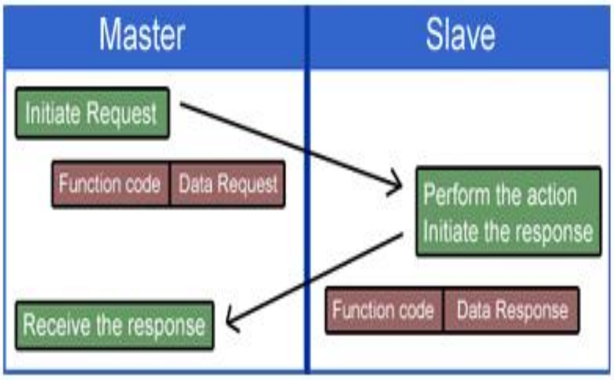


Fig. 3. Modbus RTU communication principle [**Error! Reference source not found.**].

The first stage control is provided by two controllers. The first, hereinafter referred to as Jazz 1, manages compressors 1 and 2, as well as a start signal for EVD Evolution controllers. The second controller, hereinafter referred to as Jazz 2, is controlled by a condenser fan. The third controller (Jazz 3) controls the water pump frequency converters (see Fig. 4).

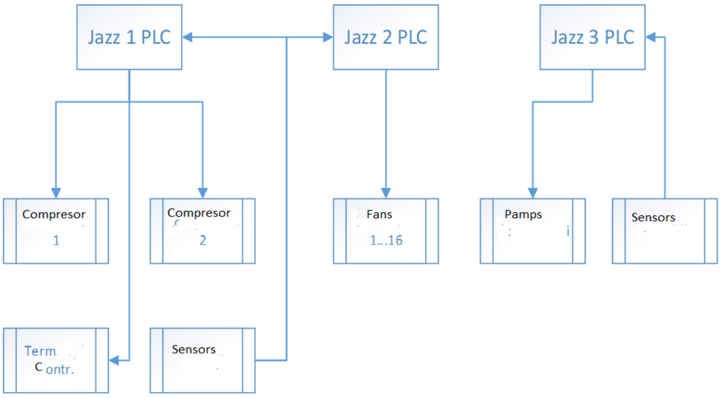


Fig. 4. Distribution of first cooling stage and water pump control.

The task of the Jazz 1 controller is to provide the flow-free cooler. Its control is based on the water inlet pipe through which the hot water flows from the factory, the water flow inlet inserted. Two temperature sensors - the water temperature before and after the flow heat exchanger, as well as the low and high pressure sensors in the collectors - before and after the compressors, are taken into account. The control algorithm is shown in Figure 5.

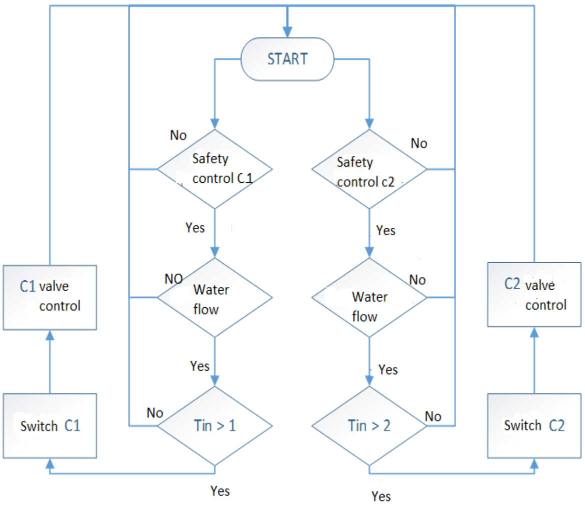


Fig. 5. Jazz 1 control algorithm.

Security checks include the following signals:

- Overpressure switches on the high pressure side of both compressors and pressure switches on the low pressure side that operate when the freon pressure at the compressor inlet is less than 0.5 bar. The high pressure switch operates when the freon pressure at the compressor outlet exceeds 20 bar;
- Motor protection relays that keep up with the engine temperature;
- Outputs of soft starters that give signals of errors;
- Oil flow switches.

Jazz 2 controller drives condenser fans and its algorithm is shown in 2.8. in the picture. A soft start signal indicating that the motors are launched is placed on the discrete inputs of the Jazz 2. If one of the compressors is working, the execution of the condenser fan control algorithm begins. The first cooling stage has two parallel closed capacitors, with each of the six fans. Due to the fact that they are parallel closed and the freon flow is evenly distributed over both capacitors, the number of switched fans at any time in both capacitors is the same. This controller is connected to the pressure transducers from the compressors' low pressure and high pressure side collectors. The control of the fans follows the sensor's indication in the high-pressure collector. In the case of a single compressor and a pressure of 11 bar, the first fans are working, if 14 - then two fans and at 16 bar and more work three pairs of fans. If both compressors are working at the 11 Bar, one pair is working, at the 12 Bar there are two pairs and so on. up to 16 bar and more when all six pair of fans work.

This controller receives a 4 to 20 mA signal from soft starters and performs linearization and also switches on a discrete output if one of the compressor currents is greater than 200 A, however, this output is not used elsewhere, because nothing is connected to it.

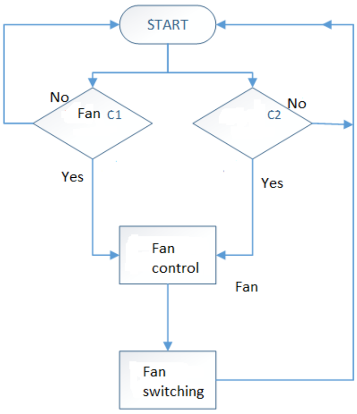


Fig. 6. Jazz 2 control algorithm.

The Jazz 3 controller controls frequency converters that are responsible for water pumps. Its control algorithm is shown in Figure 7. Pressure of 4 bar must be maintained in the water system. If this pressure falls below the 4 Bar installed, an inspection is performed or the first frequency converter works at 50 Hz. If it works at 50 Hz, then increase the second frequency converter hurts.

If the first frequency converter is not mounted on the maximum Hz, then the first converter of the hero increases. In the event of the disconnection of one of the consumers of ice water, pressure in the water system is increasing. In this case, the Hz of the second frequency converter is first reduced, and then the Hz of the first converter.

The control of the frequency converter is implemented by feeding the PLC discrete signals to the inputs of the frequency converter.

If it is necessary to increase the frequency converter levels then the signal to the third discrete input of the frequency converter is signaled.

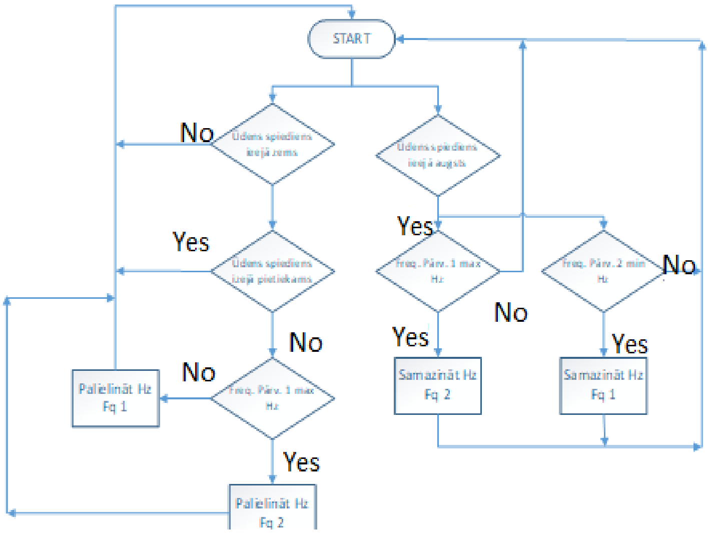


Fig.7. Jazz 3 control algorithm.

The second stage management is realized by two controllers. The first controller (Jazz 4) controls the operation of compressors and the activation of EVD Evolution, the second controller controls the fans for two capacitors that are identical to the capacitors used in the first cooling step (is shown) in Figure 8.

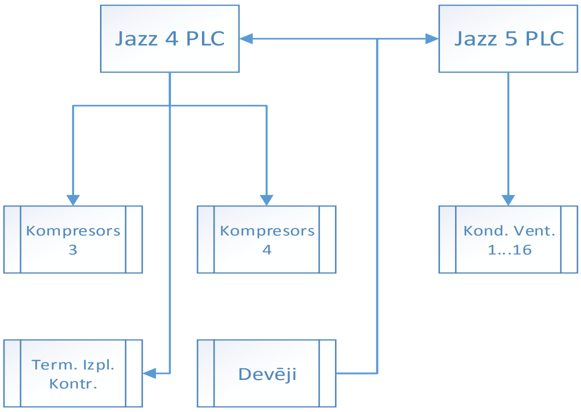


Fig.8. Second cooling stage control.

Jazz 4 controller control algorithm has common elements with Jazz 1 controller control algorithm, but with each difference. In the first stage there is one Freon circulation circuit with parallel closed compressors and capacitors, with a common receiver, economizer and oil separator. In the second cooling stage there are two independent Freon circuits with separate receivers, capacitors, oil separators and economizers. Jazz 4 management algorithm is shown in Figure 9.

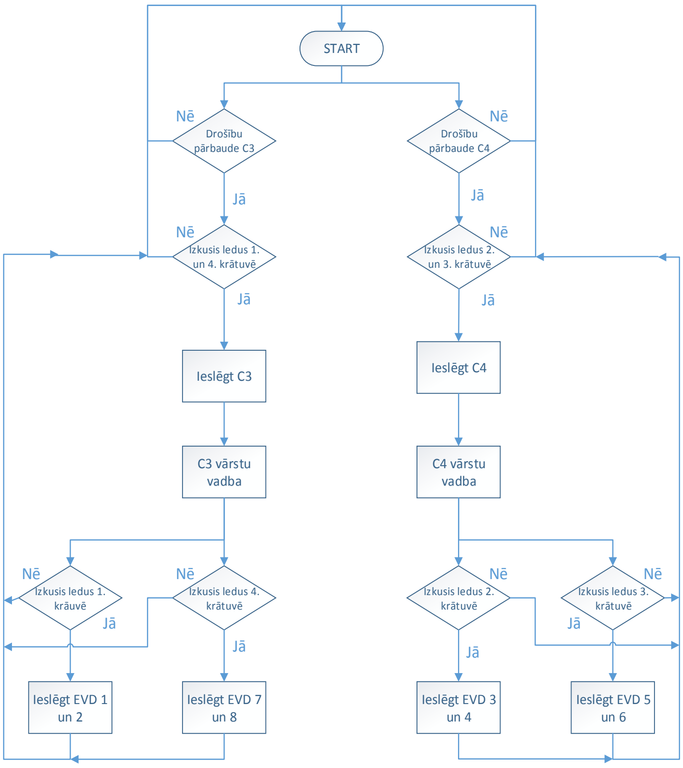


Fig.9. Jazz 4 control algorithm.

Jazz 5 controller controls two capacitors responsible for freon liquefaction in the 2nd cooling stage. Its operation algorithm is equal to the Jazz 3 controller algorithm, with the correction to two independent contours. The controller receives a signal from the pressure transmitters on the high pressure side for both compressors and a 4 to 20 mA signal for the current size from both soft starters and a signal that one of the compressors is working. The control algorithm for both capacitors is the same.At a working compressor with a pressure on the high pressure side above 11 Bar, there is a single fan, at 12 Bar two fans, etc. At 16 Bar and more, all six fans work.Similar to the Jazz 3 controller, the current is compared with a constant 200 A, and if the compressor current exceeds this value, the discrete output is turned on. Analogically with the Jazz 3 controller, it is not connected.

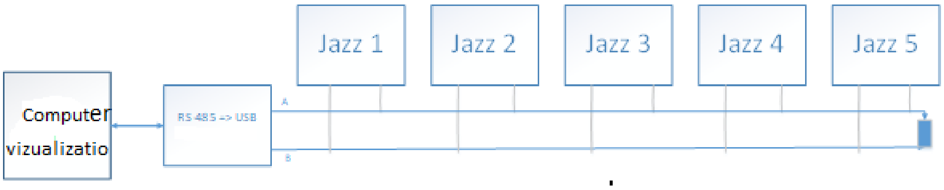


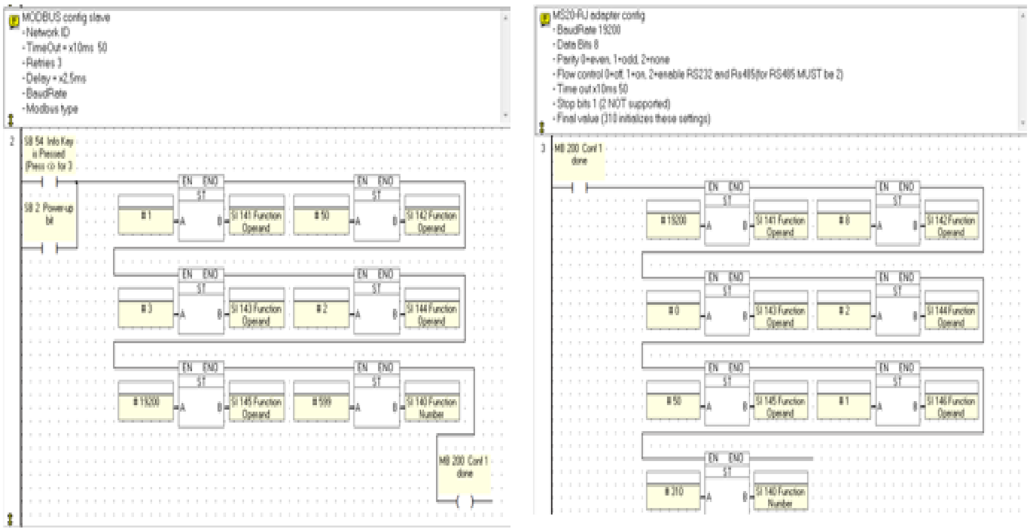
Fig.10. Created Network

To provide data exchange for the visualization of a PC with a PLC, it is necessary to create a network that connects the controllers to the computer. A CAT 5 Internet cable is installed, one end of the twisted pair is connected to the Jazz 1 controller MJ-20RS communication module and the other end to the RS-485 to the USB converter, which in turn is connected to the computer's USB port. The exported network is shown in Figure 10. The Jazz 1 walks through the other Jazz controllers, with a terminal impedance of 120 ohms. These impedances are embedded in all MJ-20RS communication adapters and connected or unlocked using DIP switches.

III. COMMUNICATION NETWORK CHANGES WITH PLC

All Jazz controllers are connected to the wires with each other. At Jazz 4, which is the last device on the network, the IDEC controller port 3 is connected in parallel. For communication to occur, reprogramming all Jazz controllers is required. For these controllers, the parameterization of communications takes place without the intermediation of the menus; their network parameters can be configured only by typing the constants into the specified registers of the system.

In Fig.11 show corrected parts of the program with comments that are responsible for communication. In the first part, entering the Service Register (SI) 140 value of 599 allows the RS-485 interface to be used for programming without switching between different communications modes. If it has a value of 600, then the RS-485 port will be closed for programming and will need to use a programming adapter to connect to the controller via the RS-232 port.


MODBUS config slave
-Network ID
-TimeOut = x10ms 50
-Retries 3
-Delay = x2.5ms
-BaudRate
-Modbus type

MS20-RJ adapter config
- BaudRate 19200
- Data Bits 8
- Parity 0=even, 1=odd, 2=none
- Flow control 0=off, 1=on, 2=enable RS232 and Rs485(for RS485 MUST be 2)
- Time out x10ms 50
- Stop bits 1 (2 NOT supported)
- Final value (310 initializes these settings)

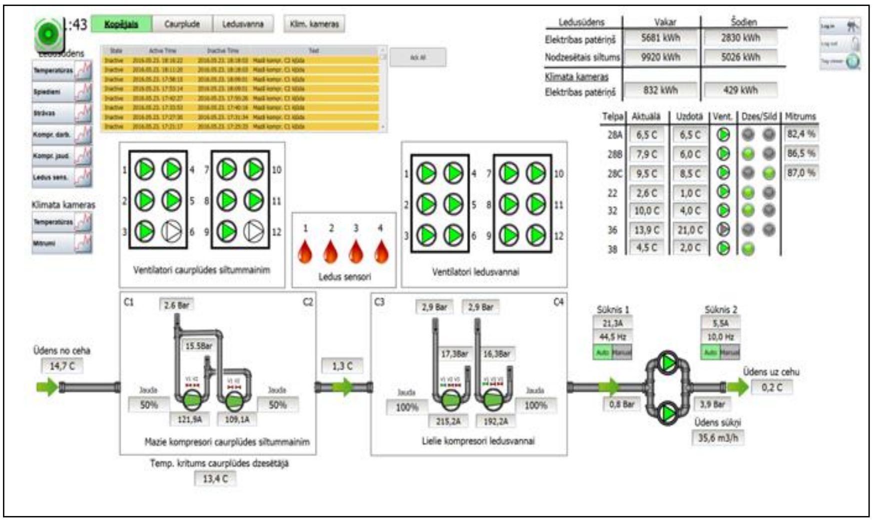
a b

Fig. 11. Jazz PLC Communications cconfigurations Part 1(a) and Part 2(b)

IV. WATER COOLING PROCESS RESEARCH AND OPTIMIZATION VISUALIZATIONS DEVELOPMENT

In order to increase the frequency of data retrieval from Jazz controllers, the Modbus RTU protocol must be used as it allows to read multiple registers simultaneously in one communication cycle, for example, all controller inputs and outputs can be read out with only two communication cycles. In order to more fully visualize the process, both water pump frequency converters are also integrated in the communication network to solve the problem when the frequency converters stop working and water supply to the plant is not provided.

They already have an integrated option to communicate using the Modbus RTU protocol and do not require additional costs.



Ledusūdens	Vakar	Šodien
Elektrības patēriņš	5681 kWh	2830 kWh
Nodzesētais siltums	9920 kWh	5026 kWh
Klimata kameras		
Elektrības patēriņš	832 kWh	429 kWh

Telpa	Aktuālā	Uzdotā	Mitrums
28A	6,5 C	6,5 C	82,4 %
28B	7,9 C	6,0 C	86,5 %
28C	9,5 C	8,5 C	87,0 %
22	2,6 C	1,0 C	
32	10,0 C	4,0 C	
36	13,9 C	21,0 C	
38	4,5 C	2,0 C	

Fig.12 . Visualization main window

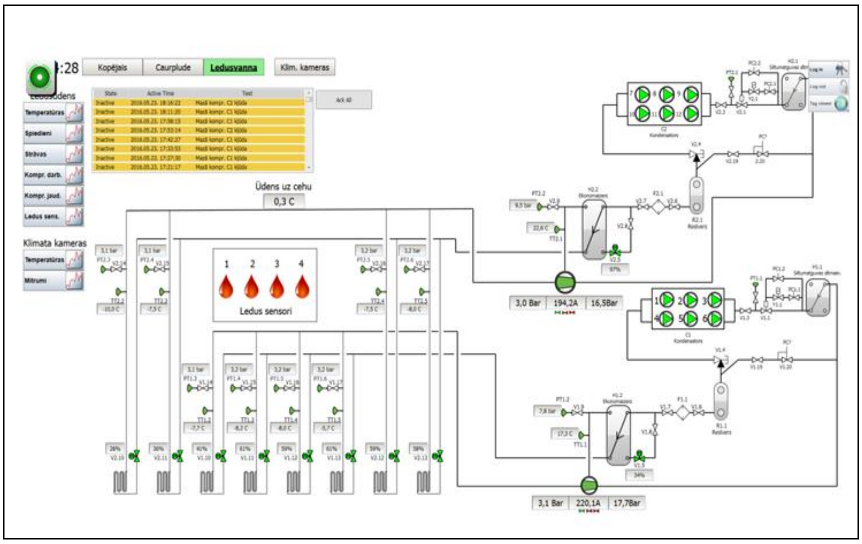


Fig. 13. Cooling stage visualization

a **b**

Temperature curves (a) and pressure curves (b)

V. CONCLUSION

1. Without the elements considered, maintenance and preventive maintenance are complex, since most problems become apparent only when their removal becomes long and costly. In situations where it is necessary to establish communication between several identical devices with an RS-485 interface, the protocol should be preferred. Using the protocol, you can achieve better results at the frequency of data recovery, thanks to the ability to reduce the number of sessions by reading several registers in one session.

2. The created visualization system significantly improved the stability of the ice water system, resulting in a reaction to errors almost instantly.

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Vitaly Savicky. “Ice Water Cooling Process Research And Optimization.” The International Journal of Engineering and Science (IJES), vol. 06, no. 12, 2017, pp. 44-51.