IOP Conf. Series: Materials Science and Engineering **294** (2018) 012052 doi:10.1088/1757-899X/294/1/012052

Automation of water supply and recirculation-filtration of water at a swimming pool using Zelio PLC

C M Diniş, G N Popa and A Iagăr

Politehnica University of Timişoara, Department of Electrical Engineering and Industrial Informatics, 5 Revolution Street, Hunedoara, 331128, Romania

E-mail: corina.dinis@fih.upt.ro

Abstract. The paper proposes the use of the Zelio PLC for the automation of the water supply and recirculation-filtration system of a swimming pool. To do this, the Zelio SR3B261BD - 24V DC with 10 digital inputs (24V DC) and 10 digital outputs (relay contacts) was used. The proposed application makes the control of the water supply pumps and the water recirculation-filtration from a swimming pool. The recirculation-filtration systems for pools and swimming pools are designed to ensure water cleaning and recirculation to achieve optimum quality and lasting service life. The water filtration process is one of the important steps in water treatment in polls and swimming pools. It consists in recirculation of the entire volume of water and begins by absorbing the water in the pool by means of a pump followed by the passing of water through the filter, disinfectant and pH dosing, and reintroducing the water back into the pool or swimming pool through the discharge holes. Filters must to work 24 hours a day to remove pollutants from pools or swimming pools users. Filtration removes suspension particles with different origins. All newly built pools and swimming pools must be fitted with water recirculation systems, and existing ones will be equipped with water recirculation and water treatment systems.

1. Introduction

A new approach to automation systems is to use programmed logic of different devices (including programmable logic controllers - PLCs). This category includes all systems that operate with a code write into an implicit memory. Automated process control systems are a conglomeration of electronic devices that provides stability, accuracy, and, not least, performance [1-9].

PLCs are structures for control of industrial process, whose implementation was used to eliminate the wired logical structures and to replace them with programmable logical structures. The majority of PLCs can be programmed via PC, but it is possible to be programmed manually with the console for programming PLCs, or in case of low capacity PLCs, using the buttons and display on the front of them. The best method of reprogramming the PLCs is using the PC, thanks to the possibility of building, saving and debugging the programs. Intelligence of the PLC consists in the ability to detect different types of sensors, input and/or output devices. Usually the most used are buttons, keys, and other types of switches at the PLCs' inputs [10-16].

Zelio Logic smart relays - Schneider Electric product - are use in small automation systems comprising 10 to 40 inputs/outputs. These relays can be used both in domestic (light installations, alarm, etc.), industrial applications (small machinery, irrigation, pumping stations, etc.), and in the commercial (management of lighting, ensuring the heating, air conditioning, etc.) [17].

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Programming can be done directly using the buttons on the relays or on a PC using Zelio Soft with a programming cable, with the possibility of programming in Function Block Diagram (FBD) or in Ladder Diagram (LD) [18-21].

2. Water Supply and Recirculation-Filtration Process from a Pool

Recirculation-filtration systems for swimming pools (Figure 1) are designed to ensure water cleaning and recirculation to achieve optimal quality and lasting service life.

In addition to pipes, fittings, and valves, water recirculation and filtration systems consist of the following elements: filters, recirculation pumps and selection valves (multiport valves). When designing a swimming pool, it is necessary to consider several technological aspects that contribute to the design, such as water and hydraulic technology, civil engineering technology, electric power supply, indoor and outdoor architecture, etc.

When designing the recirculation-filtration system starts from the load capacity of a swimming pool, resulting from the number of people using the pool simultaneously and the water surface dimensions. Swimming pool load factor differs depending on the destination, for example: swimming pools, for adults, for children, etc.

Determining the filtering capacity of the plant consists of determining the amount of water recirculated per hour under the conditions of maximum use:

$$Q = N \cdot q \tag{1}$$

where:

Q = system filtering capability (m^3/h);

N = the number of people using the pool at the same time;

q = the prescribed quantity of filtered water for a person (m^3/pers. x 4).

The prescribed amount of filtered water and reintroduced into the pool for one person is: 2 m^3/ pers. x 4.

Both calculation formulas and load coefficients may differ according to the norms in force in different countries, but the final result of the calculations will differ slightly.

Figure 1. Swimming pool

The quality of the water in the pools must be closer to the drinking water qualities, that is:

- pH = 6.8 ÷ 8.5;
- transparency > 20 m;
- the iron and manganese content < 0.3 mg/l;
- acidity > 4 moll/l;
- nitrates < 40 mg/l;

• chlorinated < 100 mg/l;
• water hardness 100 ÷ 350 mg/l.

The goal of water recirculation and filtration:

• ensuring the quality of the pool water without brutal intervention and without changing the chemical properties;
• removing impurities and micro-organisms from pool water while preserving water quality;
• by filtering and disinfecting, preventing water quality changes;
• ensuring an economical and environmentally friendly process;
• permanent assurance of water quality, regardless of the weather conditions, the number of people in the pool and the amount of impurities.

The filtering process consists in recirculation of the entire volume of water and begins by absorbing the water in the pool by means of a pump followed by the passage of water through the filter, disinfect dosing and the pH, and reintroducing the water back into the pool through the discharge holes.

All newly built pools and swimming pools must be fitted with water recirculation systems, and existing ones will be equipped with water recirculation and water treatment systems. The circulation of water in the pool must be ensured so that there are no dead spaces where the water stagnates. In these spaces the water is not disinfected and is not filtered properly.

Water filtration has the purpose of removing suspensions from the water to obtain transparent and clear water (Figure 2). At the same time, the amount of disinfectants used is reduced by filtration.

Filters must to work 24 hours a day to remove pollutants from pools or swimming pools users. Filtration removes suspension particles with different origins. There are a number of types of filters available, the choice of filters will be based on certain factors, including: filtration rate, water quality, efficiency, maintenance mode, washing method. Cycle is the filter capacity typically expressed in hours and represents the length of time that all water in the swimming pool is filtered. At least one complete cycle per day is recommended.

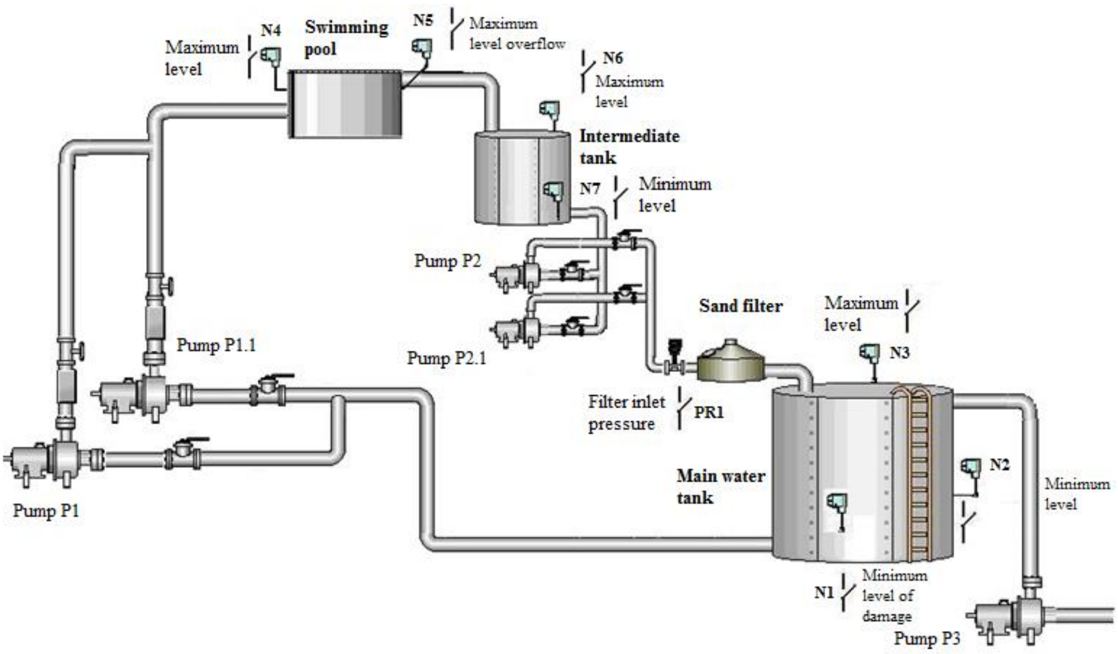

Figure 2. Schematic representation of the water supply and filtration system

Pumps P1 and P2 are working pumps, and P1.1 and P2.1 are back-up pumps. Each pump in the circuit has a normally open auxiliary contact of the contactor, which will signal to the PLC the state of the contactor (1 or 0 logic). If during main-pump operation there are faults that lead to their being switched off (disconnected of contactors), the back-up pumps will operate automatically after a period of time.

The level in the main tank during filtration cycles will remain within the maximum and minimum limits with N2 and N3 level sensors.

As long as the sensor contact N1 (fault minimum level) in the main tank is closed, the pump P1 will not have a starting condition because it would start without water on the suction line and would destroy it. From this reason, during operation of the system, the level in the main tank reaches the fault minimum level of damage, pump P1 will stop and will no longer have the starting condition until after the water supply of the basin, after opening the sensor N1 contact.

3. Automating Process of Water Supply and Recirculation-Filtration of Water from a Pool with Zelio PLC

The present application requires a large number of digital inputs and outputs, so it was chose a Zelio PLC SR3B261BD, 24V DC type with 10 digital inputs (1 logic, 24V DC) and 10 digital relay outputs.

Using PLC type it will use hardware configuration from the software (Zelio Soft 2) – Figure 3. In application it was use Zelio PLC SR3B261BD - 24V DC (Figure 3) and FBD the programming language (Figure 4).

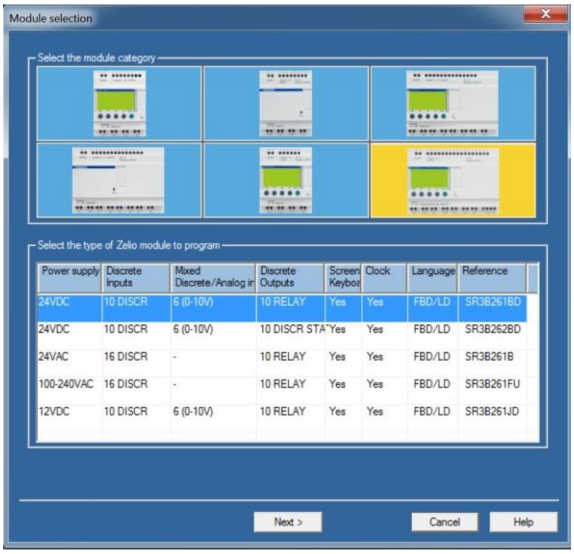

Figure 3. Configuring PLC in the software

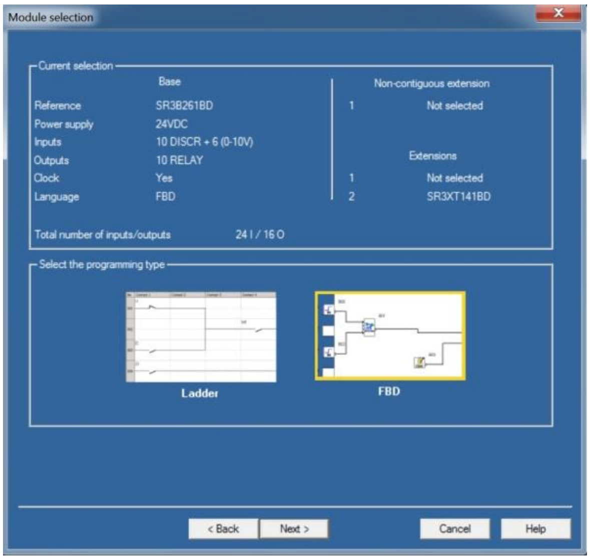

Figure 4. Information regarding final hardware configuration PLC

Table 1. The digital inputs of the PLC

Input	No	Symbol	Function	Comment
I1	B00		Pushbutton	Automatic start-up button
I2	B01		Pushbutton	Stop button in automatic mode
I3	B02		Illuminated pushbutton	Emergency stop button
I4	B03	IN	Discrete input	Minimum damage level sensor N1 in the tank
I5	B04	IN	Discrete input	Minimum level sensor N2 in the tank
I6	B05	IN	Discrete input	Maximum level sensor N3 in the tank

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I7	B06		Discrete input	Maximum level sensor N4 in a swimming pool
I8	B07		Discrete input	Maximum overflow sensor N5 in the swimming pool
I9	B08		Discrete input	Maximum level sensor N6 in the intermediate tank
IA	B09		Discrete input	Minimum level sensor N7 in the intermediate tank
IB	B10		Discrete input	Maximum pressure sensor PR1
IC	B11		Discrete input	Contact NO contactor P1
ID	B12		Discrete input	Contact NO contactor P1.1
IE	B13		Discrete input	Contact NO contactor P2
IF	B14		Discrete input	Contact NO contactor P2.1

In the Tables 1, 2 and 3 are shown input and output variables of the PLC, and configurable functions used in the program. In the Table 4 is shown programming functions displayed information on the PLC.

Table 2. Digital outputs of the PLC

Input	No	Symbol	Function	Comment
Q1	B16		Motor	K1 – ON P3 functioning
Q2	B17		Motor	K2 – ON P2 functioning
Q3	B18		Motor	K3 – ON P1.1 functioning
Q4	B19		Motor	K4 – ON P2 functioning
Q5	B20		Motor	K5 – ON P2.1 functioning
Q6	B21		Green indicator light	Functioning plant
Q7	B22		Red indicator light	Filter damage

Table 3. Configurable functions from the program

No	Symbol	Function	Parameters	Comment
B23		RS switching	Priority: RESET has priority	
B25		LCD display	See details below	Started
B29		LCD display	See details below	Emergency stop
B30		RS switching	Priority: RESET has priority	S/R pump P3
B34		LCD display	See details below	P3 - ON
B36		RS switching	Priority: RESET has priority	S/R pump P1

B38	Cycling timing	On time: 0H 2M 0S Off time: 0H 2M 1S Function Li Continuous flashing	
B43	RS switching	Priority: RESET has priority	
B45	LCD display	See details below	Filter damage
B46	Cycling timing	On time: 0H 0M 1S Off time: 0H 0M 1S Function Li Continuous flashing	
B49	Timer	On time: 0H 0M 2S Off time: 0H 0M 0S	
B50	LCD display	See details below	P1 - ON
B51	LCD display	See details below	P1.1 - ON
B53	Timer	On time: 0H 0M 2S Off time: 0H 0M 0S	
B55	LCD display	See details below	P2 - ON
B56	LCD display	See details below	P2.1 - ON

Table 4. Programming functions displayed information on the PLC

B25	LCD display	STARTED															
S	T	A	R	T													

B50	LCD display	P1 - ON															
						P	1	-	O	N							

B51	LCD display	P1.1 - ON															
P	1	.	1	-	O	N											

B55	LCD display	P2 - ON															
												P	2	-	O	N	

B56	LCD display	P2.1 - ON															
									P	2	.	1	-	O	N		

B34	LCD display	P3 - ON															
P	3	-	O	N													

B29			LCD display				Emergency STOP										
E	M	E	R	G	E	N	C	Y		S	T	O	P				

B45			LCD display				Filter Damage										
					F	I	L	T	E	R		D	A	M	A	G	E

4. Description of the program implemented in the Zelio PLC

In view of the above requirements, it has been done using programming software program Zelio Soft 2 shown in Figure 5 and PLC implementation is shown in Figure 6.

Initially the pool and the two containers from the filtration plant are empty. The pump no. 3 is for filling the main water tank.

When the water tank is empty or has a very low level, the N2 level sensor has the "low level" contact (closed) and also the minimum level sensor N1, has the closed contact, which means that the level in the tank is at the fault minimum limit.

Pump no. 3, it will automatically stop when the level in this tank reaches the maximum level, signaled by closing the maximum N3 sensor.

Once the main water tank has been filled, the N1 low level sensor and then the N2 high level sensor will open the contacts. If this condition is achieved and the water tank is not filled with water, than the N4 peak level sensor contact is not closed, it automatically switches on the P1 water pump by transporting water from the main tank in the basin.

Because the P1 pump will consume water from the main tank, which has a much smaller volume than the basin, during the water supply of the basin, pump P3 will start several times in automatic mode, commanded by the low level sensor contact N2 and high level sensor contact N3 to resupply this tank with water. The flow rate of P3 pump is higher than the flow rates of other pumps in the plant, so the main tank will never run out of water.

After the tank has been filled, which is signaled in the PLC by the contact of the maximum level sensor N5 from swimming pool, at this moment the PLC will interrupt the basin's water supply sequence and start the water recirculation and filtration sequence from the inside of the basin, as long as the N4 sensor is on. The water recirculation and filtration sequence will be done by the on-delay time starting of the P1 pump to add water to the basin, causing the pool to overflow with water, the surplus water flowing through its overflow holes, the water being collected and transferred by falling into the intermediate tank. After a series of consecutive starts of P1 pump, the excess water stored in the intermediate tank will reach the maximum level, signaled to the PLC by closing the normally open contact of the N6 level sensor of the intermediate tank.

At this point, the water pump P2 will automatically start, which will drain the water from the intermediate tank, through the sand filter, transferring it back to the main tank.

The volume of the intermediate tank is smaller than that of the primary tank. The P2 pump will automatically switch on depending on the maximum level sensor contact N6 from the intermediate tank and will switch off depending on the level sensor contact N7 of the intermediate tank.

If the filter is partially or totally clogged, the water pressure at its inlet will increase, the pressure sensor PR1 will close the normally open contact, causing the plant to shut down and display a fault message on the PLC screen.

Also, an PLC output will be activated to supply a siren for acoustic warning about the occurrence of the fault. If the emergency stop button is pressed, all components of the system will shut down and the "Disconnect" message will be displayed on the PLC screen.

Some pictures regarding PLC operation are shown in Figures 7-10.

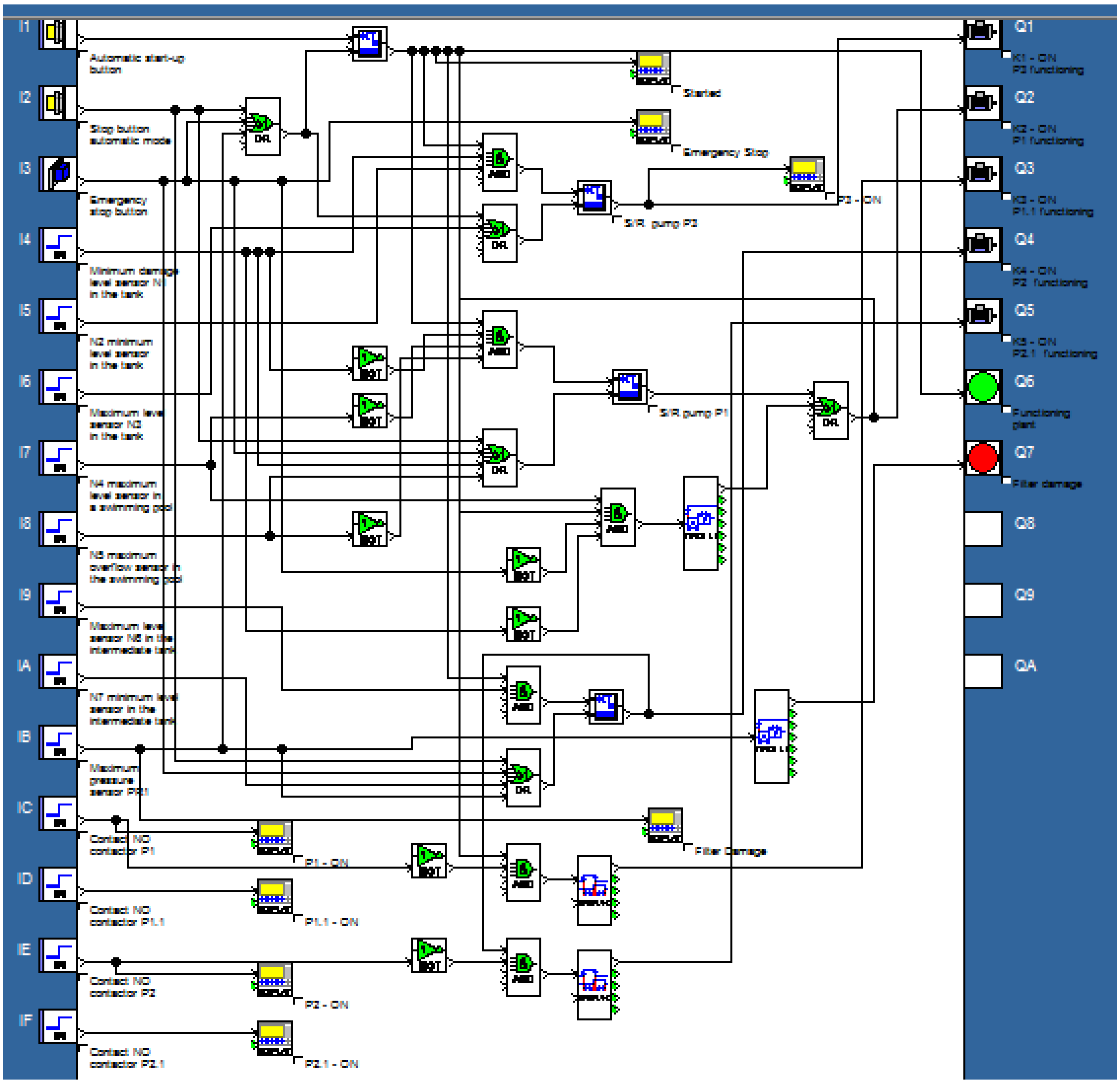

Figure 5. Program made on the PLC for swimming pool

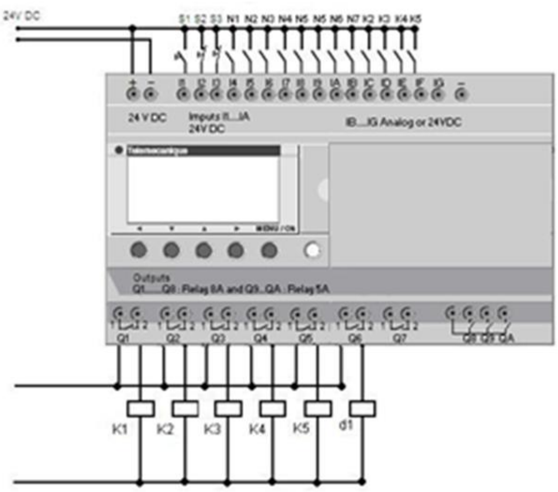

Figure 6. PLC implementation

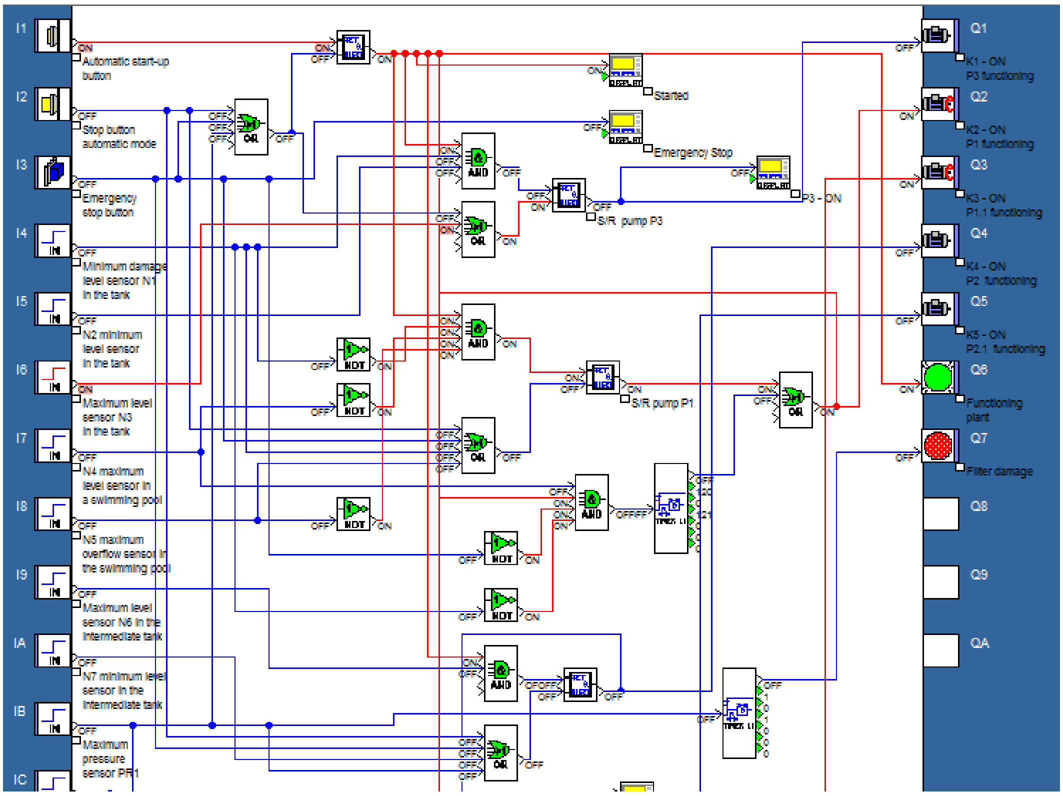

Figure 7. Sequence of PLC program - 1

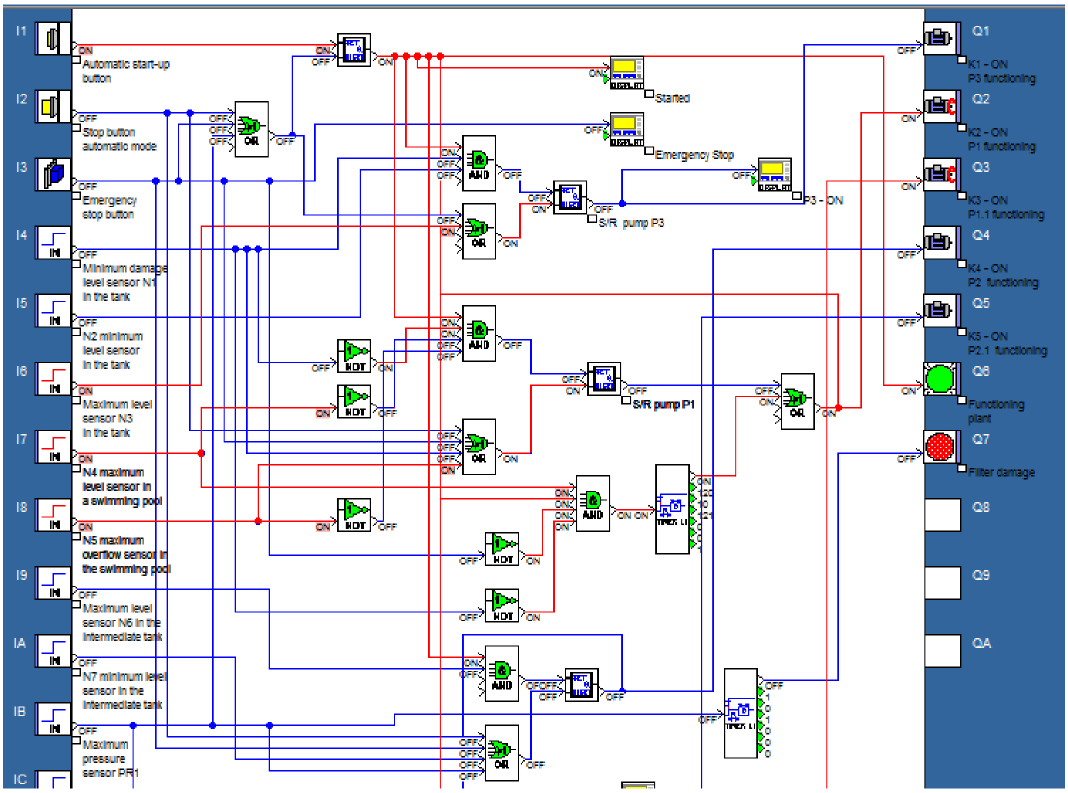

Figure 8. Sequence of PLC program - 2

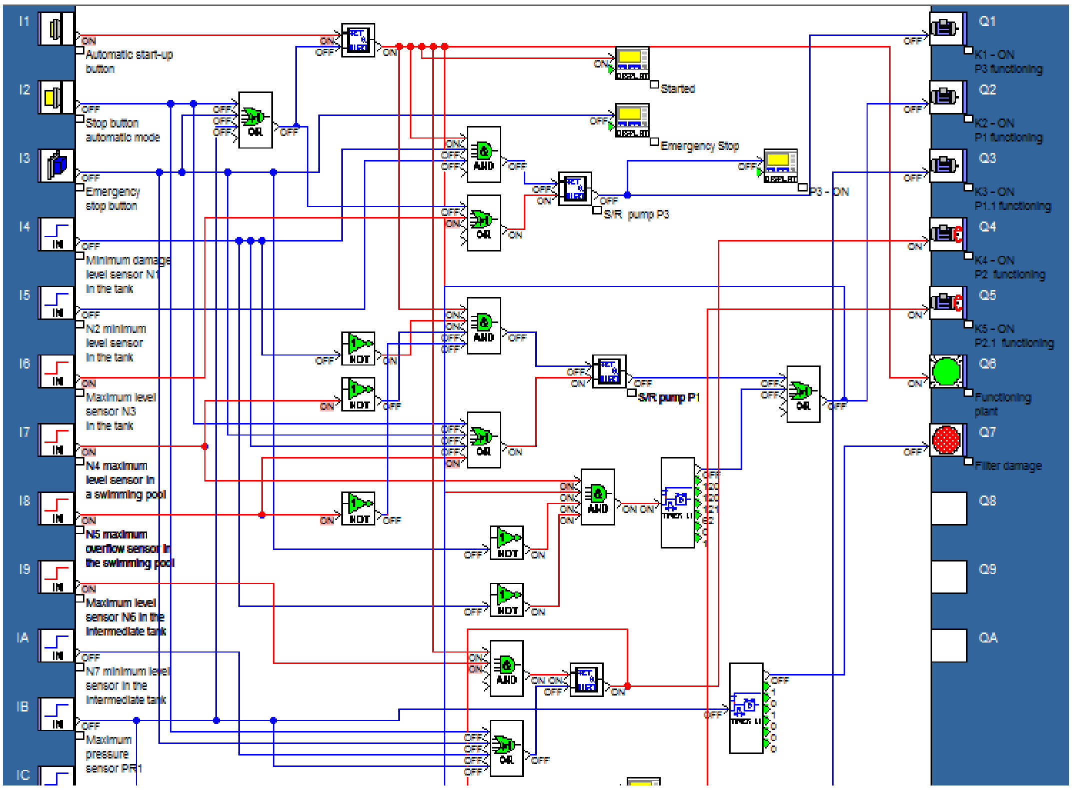

Figure 9. Sequence of PLC program - 3

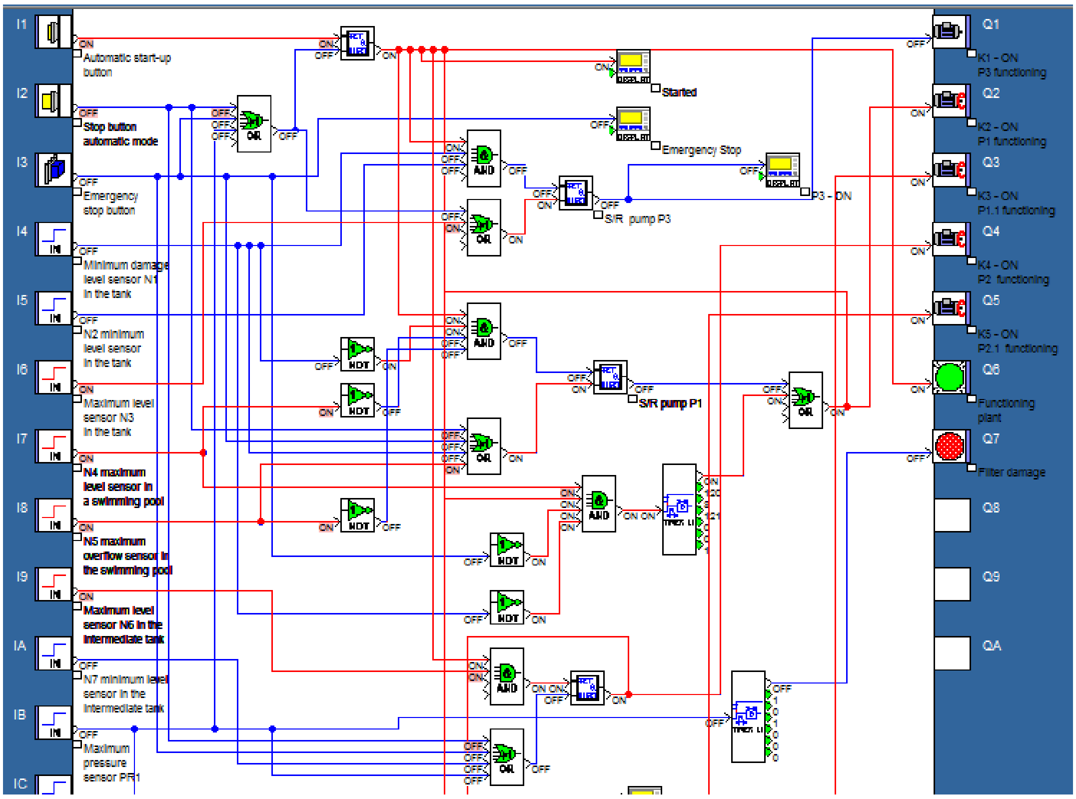

Figure 10. Sequence of PLC program - 4

5. Conclusions

Currently, many of the industrial and household applications are controlled by PLCs. There are PLCs built for easier or more complicated applications, and there are many companies that build them. Low capacity PLCs have the most common applications, both in industrial and household applications.

Compared with classical installation, by using PLC, the number of conductors used in installation are considerably reduced, and, also, the control installation simplifying. During development and debugging the PLC program, it is much easier to find a fault in the conductors, because the state of inputs and outputs of the PLC are signal on its display, and it is easily finding the fault occurred in the control installation with PLC.

Low capacity PLC can be successfully used for monitoring and control of small processes, and they have the advantages to connect of various sensors. Changing the operation mode of the electrical installation is done, in some cases, only by modifying the PLC program, and in some cases by changes, both, the program and the connections of the conductors from control installation.

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