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Design of a Control System for Self-serve Car Wash with Industrial Programmable Logic Controllers with "Internet of Things" (IoT) Capabilities

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ABSTRACT

The report is related to the improvement of the automated self-service car wash system by making better the monitoring and preventive control systems, as well as the collection and reporting of data from the operation of the system to achieve more efficient operation and optimization in customer service. For this purpose, modern industrial programmable logic controllers with "Internet of Things" (IoT) capabilities are used. The advantages are low operating costs, the long life-cycle of the equipment, maximum satisfaction of the service customers.

Keywords: *industrial programmable logic controller, self-serve car wash, IoT capabilities.*

INTRODUCTION

The "Self-Serve" services are evolving at an extraordinary quickness. There is almost no area that is not affected by the implementation of automation systems for self-service processes.

In particular, car washes and the services they offer are increasing and becoming more diverse due to the rapidly growing number of vehicles and the greater need for easy and efficient cleaning.

The trends are for even greater development, both in terms of the size of the sites and in terms of technological development in line with the latest trends in the spirit of Industry 4.0.

The growing necessity for clean vehicles and a clean environment also stimulates increased investment to provide more opportunities for easily accessible, modern, and highly functional self-service facilities with increasingly attractive digital communication systems, payment devices, and a variety of services at affordable prices.

On the other hand, this leads to high competition in the market and challenges entrepreneurs to modernize technologically their machines and equipment in order to gain

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much more added value, be highly durable, with provided fast and easy maintenance, with opportunities for technological remote monitoring, with preventive protection of the equipment, and collection of extensive data from the processes and operations.

Due to the rapidly entering industrial programmable logic controllers and Internet of Things (IoT) technologies in all spheres of life and industry, the attendance of investors in this business will become easier and that will make it more sought after and desired.

Similar developments already exist in many countries with highly developed industry, while in Bulgaria the technological management of such sites is based on microcontrollers with more limited capabilities, but there are also those that successfully apply IoT-related technologies [1].

The aim of this development is to implement modern industrial programmable controllers of the highest class in a modified system for self-service car washes, in order to apply the maximum of the capabilities of IoT for monitoring, control, and improved customer service. Subsequently, based on this model, there could be used the application of other means of automation in different technological and price ranges, depending on market preconditions [2].

The Internet of Things (IoT) is fundamental in Industry 4.0. (Fig. 1). IoT aims to unite everything in our world under a common infrastructure, giving us not only control over things around us but also informing us about the state of affairs. IoT can improve communications in an organization, innovate in business, increase customer engagement, and help evaluate workflows. IoT is used to automate the collection, processing, and analysis of data from various sources [3].

The challenges for car washes in the spirit of Industry 4.0 are related to improving the ability to prevent unforeseen downtime by accidents by means of providing early warning of occurred deviations from the normal condition of the equipment. The neural networks are used to recognize the registration numbers of cars, and their subsequently registration in a database for further processing for marketing purposes and for various smart applications which made easy customer service.

Smart self-service car washes are intelligent machines because they are equipped with digital architecture and technologies that allow two-way dialogue machine/manager, machine/user.

Some of the key features of Smart Machines are:

- they use touch-screens,
- they are integrated with telemetry systems,
- they are able to transmit official or advertising messages,

Fig. 1. Internet of Things (IoT) and Industry 4.0.

- connected to the internet,
- interactive with smartphones and other technological devices for service delivery [4].

The term SMART MACHINES identifies automated systems that meet the technical characteristics required by Industry 4.0:

- they use digital technologies,
- controlled by PLC,
- connected in a network,
- transmit fees electronically,
- use cashless payment systems,
- provide sales information,
- report products running out,
- generate statistics,
- they inform about the operating status by reporting faults, emergencies, diagnostics,
- they exchange information in a bidirectional way,
- the software can be remotely upgraded,
- they are configurable and remotely monitored,
- prepared with simple and intuitive man/machine interfaces,
- they are safe,
- provide optimization of logistics (better organization for recharging and maintenance of consumables),
- support tools (to help operators be autonomous in solving the most common problems with technical support / assistance),
- reliability (on-board real-time diagnostic / monitoring systems) [5].

METHODS

To achieve the goal of the presented project - to design a control system (and monitoring) of an automated car wash by means of industrial PLCs, a modified stationary water jet FCM918-MSE-Z is selected to be controlled and diagnosed by a Siemens S7 1200 controller; HMI KP700 and SCADA S7 WINCC display. TIA Portal V16 software was used.

With regard to the control of material flows (water and detergent), valves with an electromagnetic actuator (solenoid valves) are used, which are controlled by a discrete signal. Sensitive elements are used for the following variables:

- temperature,
- pressure,
- level,
- consumptions.

A PID controller is used to regulate the hot water temperature through a heat exchanger. The PID_Temp process object provides continuous PID control with integrated setup. PID_Temp is specially designed for temperature control and is suitable for heating or heating/cooling applications [1]. PID_Temp is cascading and can be used in manual or automatic mode [6].

Fixed pressure switches are used to regulate the pressure, which, like thermostats, are used to regulate the specific variable at only one operating point, which is pre-selected by selecting the appropriate model of sensitive element. In other words, no setpoint is present in the automatic control system [3].

To modify the machine in a self-service system will need sensors to be built in to read:

- temperature,
- fluid flow,
- level sensors.

DESIGN OF A CONTROL (AND MONITORING) SYSTEM FOR AN AUTOMATED CAR-WASH

The basic modified model FCM 918 MSE-Z of the German manufacturer FRANK was chosen to be rebuilt for control with a PLC self-service module (Fig. 2).

The parameters of the stationary water jet with two guns and three injectors for suction and injection of detergents with remote control and relay-contactor switching of solenoid valves device are presented in Table 1.

Additional equipment includes:

- Buffer tank for incoming water 1000 cubic meters,
- Particulate filters mesh type 100 µm,
- Softening system type AS-75-760 Logix,

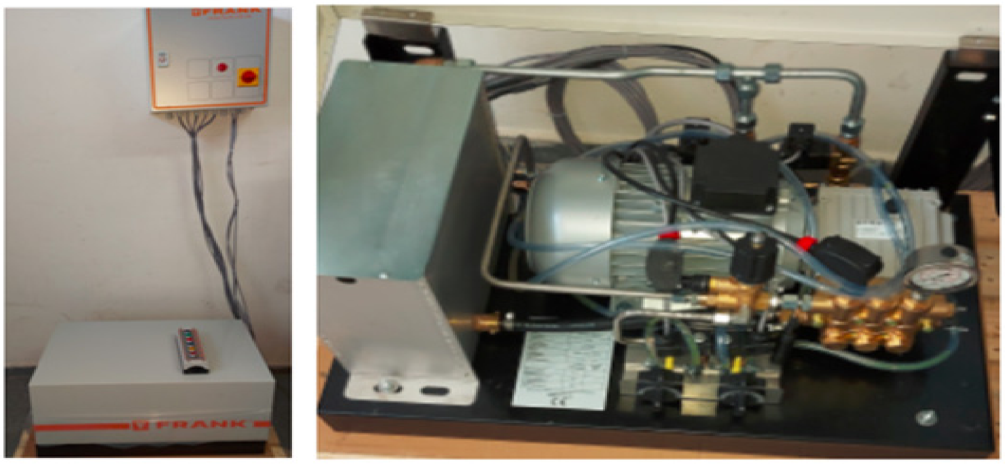

Fig. 2. Internal and external appearance of the water jet.

Table 1. Parameters of a stationary water jet [7].

Type	FCM 918 MSE-Z	
Maximum pressure	180	[bar]
Flow rate	900	[l/h]
Maximum working temperature of the water	60	[ºC]
Power supply	400/3	[VAC] 50Hz

- OSMIX reverse osmosis system,
- Hydrophore pump,
- High and low-pressure hoses,
- Coin board and control buttons,
- Heat exchanger with Mazzoni diesel burner,
- Outdoor temperature sensitive elements; pressure and flow.

The Siemens programmable logic controller is selected - model S7 1215C DC/DC/DC and one additional module SIPLUS S7-1200 SM 1223 16DE/16DA. Digital input / output 16DI/16DO, 16 DI 24 V DC, receiver/source, 16 DO, transistor 0.5A (Fig. 3).

Siemens SIMATIC HMI KTP700 Basic Panel Touch Screen 7 " and SIMATIC HMI KTP300 Basic 3 ", PROFINET interface are selected.

Configuring supervisor control via Siemens WINCC RT Advanced and OPC UA Server via Siemens PC Station.[8] PROFINET interface are illustrated on Fig. 4.

Development of a logic scheme for control and implementation of logic using Lader-diagrams. Block diagram of the ongoing processes of the self-service system with a coin device is illustrated on Fig. 5.

Fig. 6 presents Ladder Diagram for controller programming [8], input of the coin device and permission of Buttons from 1-5, PAUSE and STOP at the entrance.

On Fig. 7 is given Automatic temperature control of the heat exchanger with PID controller [9], Emergency STOP of the high-pressure pump

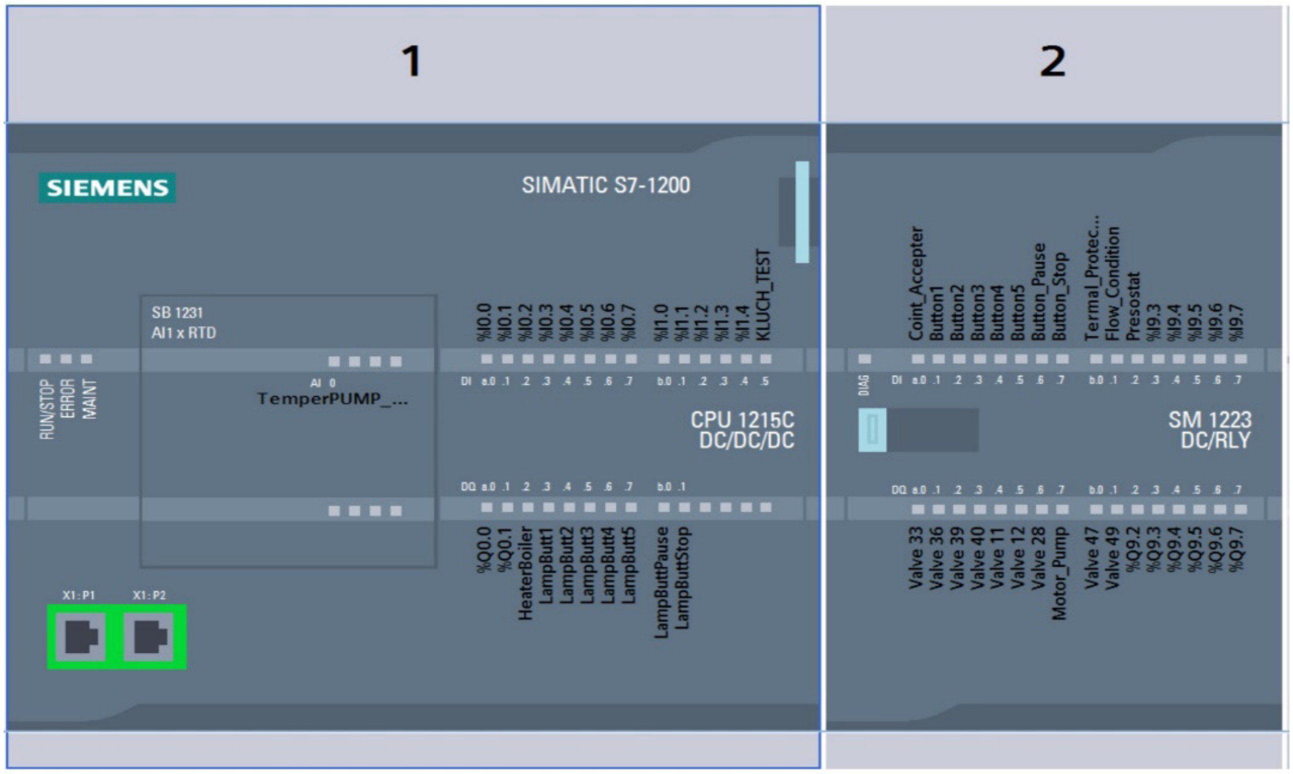

Fig. 3. Controller selection and configuration in Siemens TIA Portal V16.

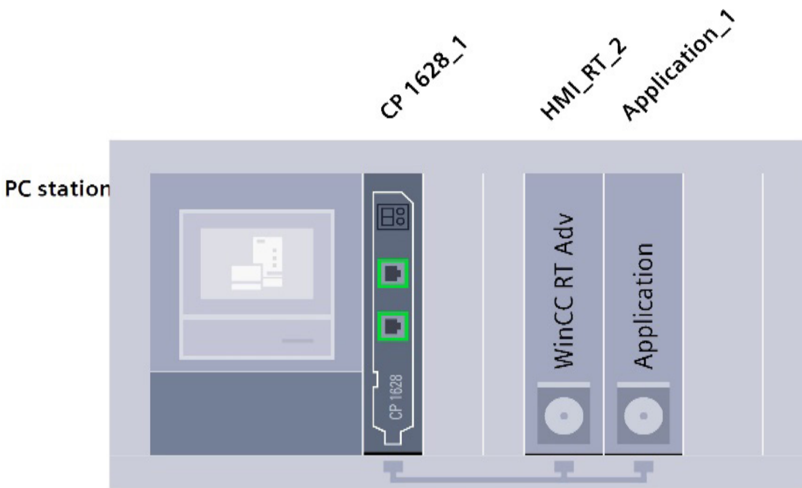

Fig. 4. Configure supervisory control.

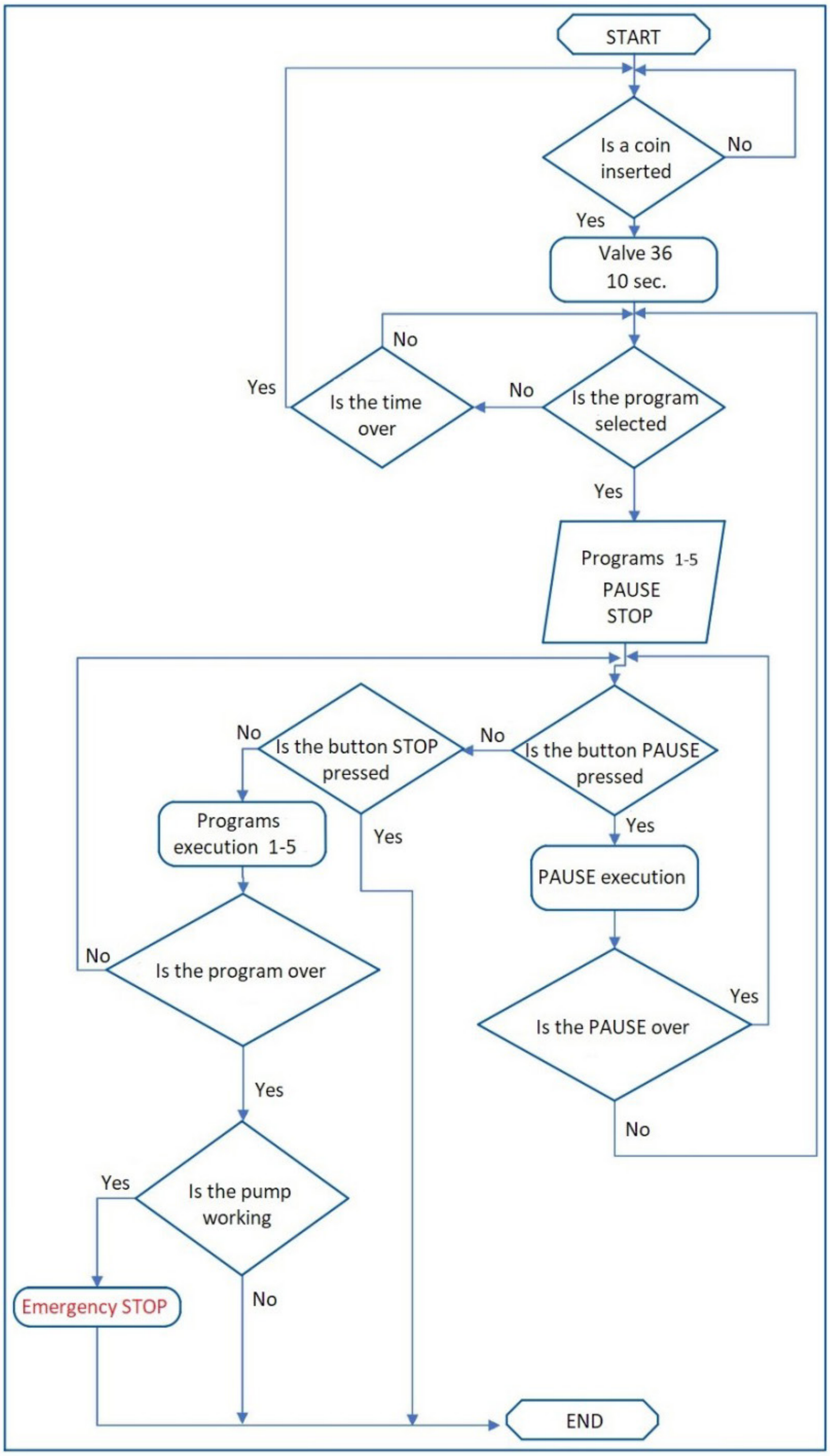

Fig. 5. Development of a logical control scheme.

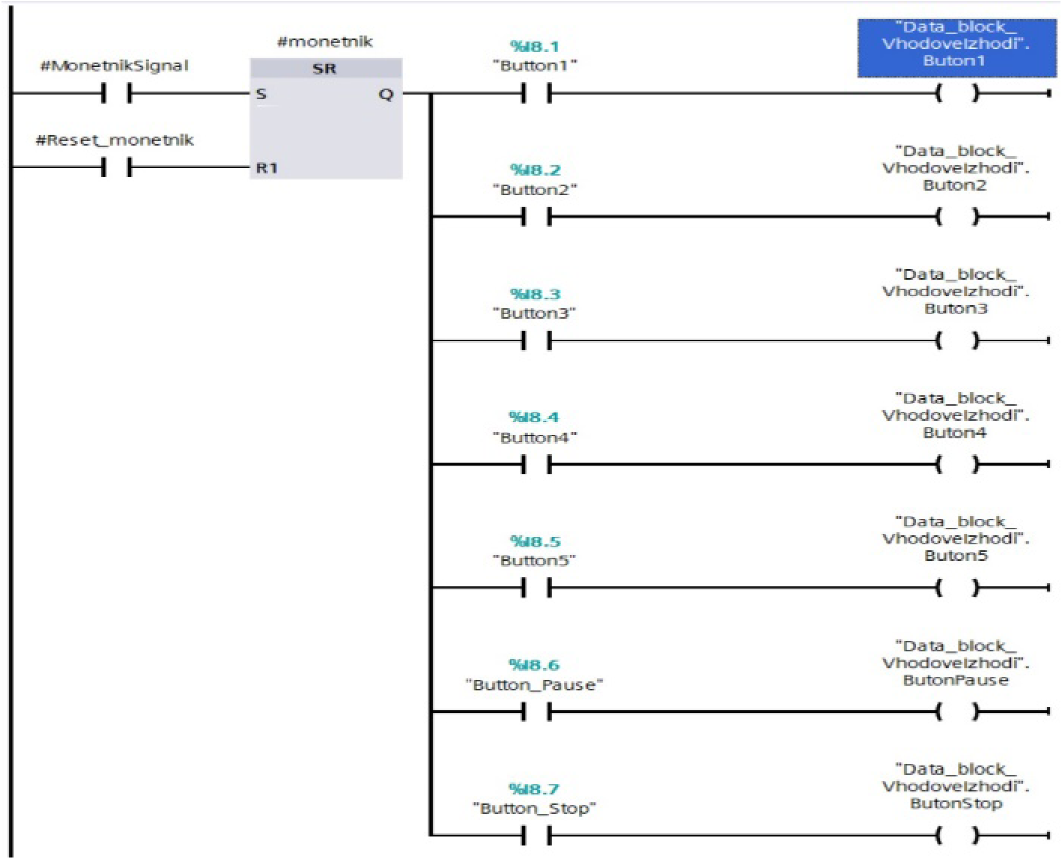

Fig. 6. Ladder Diagram.

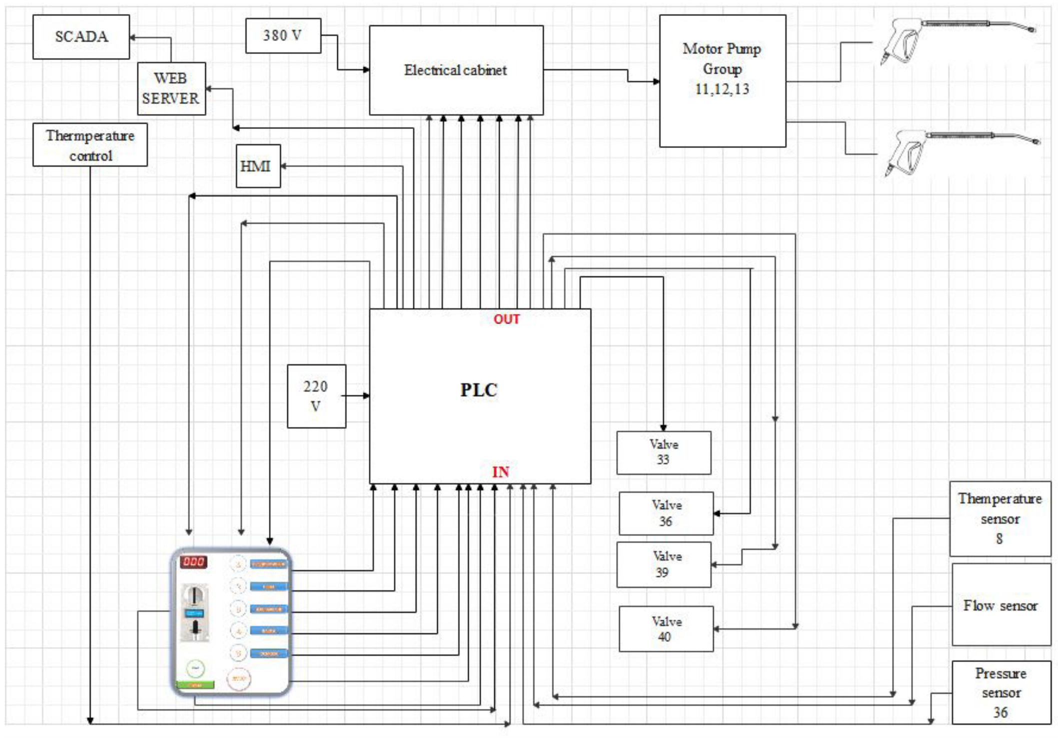

Fig. 7. Block diagram for automatic temperature control of the heat exchanger with PID controller [10].

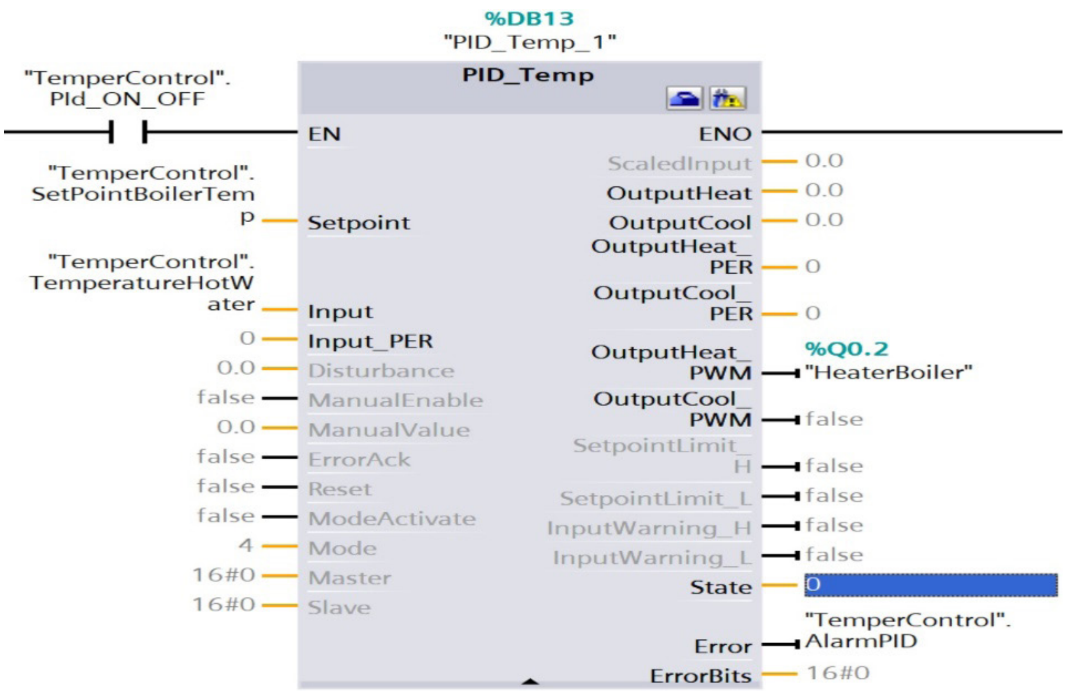

Fig. 8. HMI operator panel.

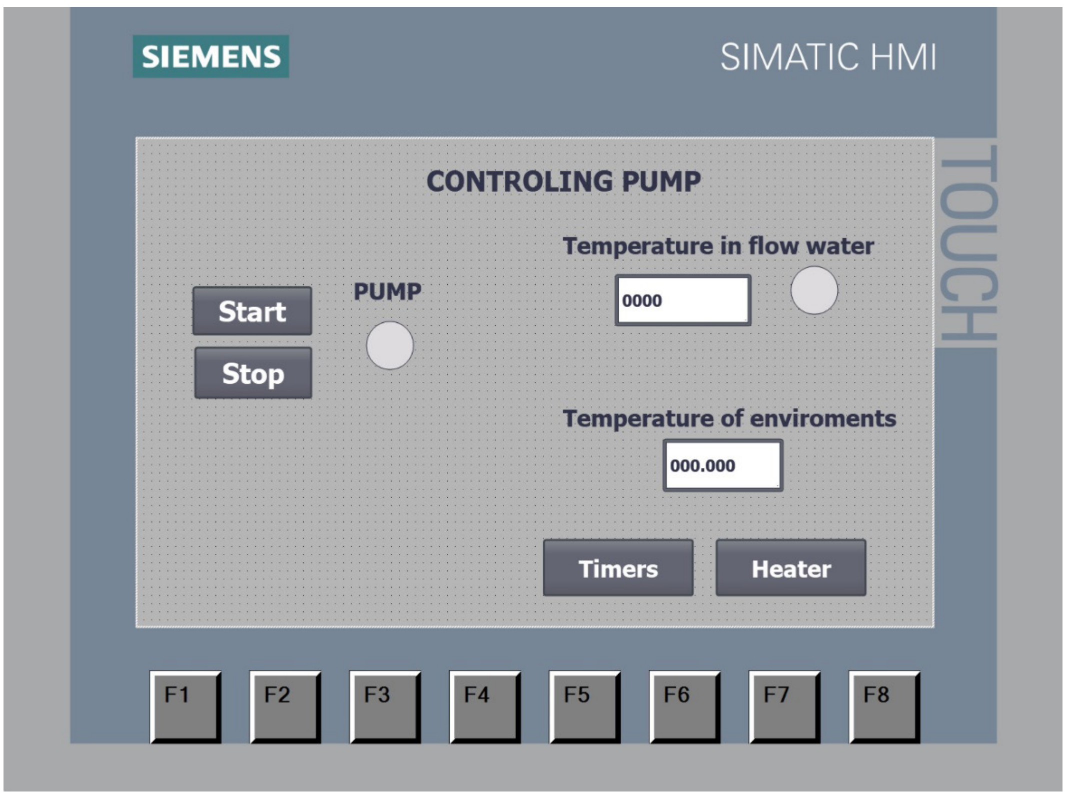

Fig. 9. Configuration scheme.

Table 2. Controller configuration.

Inputs: 12	Outputs: 16
Program buttons from 1-5 – 24V	Start-Stop of High pressure pump
Button - Pause – 24V	Valves for injectors - 11, 12, 28
Button - Stop – 24V	Actuators – 33, 36, 39, 40
Coin acceptor – impulse signal - 5V	HMI
Thermostat – 24V	OPC UA Server
Temperature sensor 8 - 24V	WINCC RT Advanced Scada
Flow sensor 35 - 24V	Program display and duration
Pressure switch 36 - 24V	

and program interruption. Activation of a signal lamp when the permissible temperature of 60 degrees is exceeded.

HMI operator panel - control and setting the times of each program; high pressure pump control; control of the hot water heat exchanger is shown on Fig. 8, [11].

A configuration diagram in the controller development environment is shown in Fig. 12, and the description of its configuration is presented in Table 2.

Implementation programs are as follows (Fig. 9):

- First program – Prewash with high pressure and detergent,
- Second program – Active foam,
- Third program – Rinse with high pressure,
- Forth program – Wax with high pressure,
- Fifth program – Polish with osmotic water,
- Pause – Interrupt the program for 2 min,
- Stop – Cancel the program.

CONCLUSIONS

The technological processes and the devices of an automated self-service car wash are described. The tendencies in the development and application of the modern systems for management and monitoring of the self-service car washes with smart devices and the Internet of Things are presented.

Logic block diagrams and Lader diagrams for programmable logic controllers have been developed, as well as the related HMI panel and WINCC SCADA for control and monitoring of basic system parameters, thus realizing the main goal of the thesis, namely - improving the management system of self-service car wash with IoT capabilities.

The next goal of this development is to create a web server for remote access to the SCADA system and to collect statistical information about the entire car wash process. Internet applications are used to improve communication and customer service, such as cashless payments; promotional campaigns, including individual promotional messages.

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