

A Modular Process Simulator with PLC

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Abstract: - A Modular Process Simulator can replace a vast number of expensive systems or function models used to simulate, to project and to train the programming of programmable logical controller (PLC) systems, graphically and practically. The simulation of physical processes reduces the costs and the amount of time needed for deploying the system. Different types of processes are simulated and associated with functional masks for different types of applications and with different complexity factors in order to develop algorithms for practical work in different areas and implement them onto the PLC unit. The Modular Process Simulator uses a simulation block for all the applications, having different replaceable masks according to the desired application as well as a PC program simulator.

The system's modularity allows an easy development of the system and can be used in future developments by adding FPGA (Field-Programmable Gate Array) components.

Key-Words: - process simulator, control system design, industrial processes, PLC

1 Introduction

The simulation of some industrial processes represents a modern and efficient direction for the multifunctional testing platforms designed for students training laboratories as well as for complex development of some technologic scenarios for improvement and conception of control schemes in modern technologies [8].

A large number of simulators are composed of two modules: a command segment – the PC with an interface or a PLC – and a process simulator that usually represents a micro plant or an electronic circuit.

The Modular Process Simulator presented in this paper is a hardware and software integrated system that enables training and practical work.

A programmable logic controller (PLC) or programmable controller is a control device, used for the control of applications, that employs the hardware architecture of a computer and a relay ladder diagram language. The unit has to be connected to the various process input and output devices. The controller must be programmed with the tasks that the system must perform; this is achieved by a set of software instructions [4]. The software contains program sequences that are initiated by inputs from the process, which then prompt the outputs to change the plant status [6].

The Modular Process Simulator has a hardware structure that ensures stability, accuracy and good transitions. These performances are realized by the interconnection

of PLCs and a central digital language. The PLC is used for automation of industrial processes and replaces the circuits of sequential command in cable logic.

2 Modular Process Simulator

The Modular Process Simulator is sectionalized containing two parallel panels: *the PLC* and *the demonstration panel* to hold a mask (an applied mask according to the desired application) with a large image of the process that is being simulated.

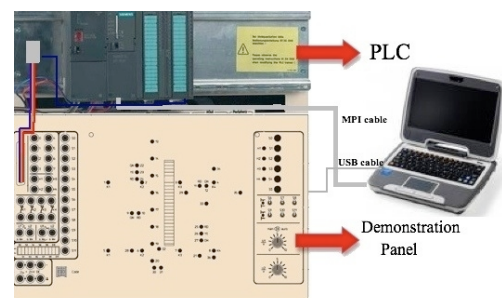


Fig. 1. The Modular Process Simulator^[7]

The connected and correspondingly programmed PLC system allows the user to study automatic functions, for which respective signals are generated automatically, while controlling the actuators. These automatic functions depend on the assigned process. The exercises

cover a wide range of gradients of complexity. They range from the simulation of elementary control processes for complete beginners with no previous knowledge of automation technology, right up to simulation of the most demanding solution strategies by applying the complete operational spectrum of large programmable memory controllers. The individual examples are obtained with masks that contain a process flow chart and are applied to the demonstration panel of the process simulator [3].

Three categories of exercises was developed:

- Simulation of simple assignments using classical contactor circuits.
- Simulation of medium difficulty assignments using industrial system models [5].
- Simulation of complex assignments using industrial system models with the incorporation of analog functions [5].

Another advantage of the Modular Process Simulator is the connectivity between the demonstration panel and the PC via a USB cable. A computer program presents the simulation of the desired application on the PC screen.

2.1 The PLC component

All the inputs and outputs of the Modular Process Simulator have been designed to meet the industrial standards for control engineering: 24 V DC for digital inputs/outputs and from 0 to 10 V DC for analog inputs and outputs.

As a result, the simulator can be operated with the programmable logical controller systems of all major manufacturers. The PLC used is a SIMATIC S7-300 series, an industrial PLC, a system which is able to withstand real industrial conditions during the entire simulations and training actions [8, 9].

The standard software used for configuring and programming Simatic programmable logic controllers is Step 7 [8]. The programming languages which can be used for the S7-300 are Ladder Logic, Statement List, and Function Block Diagram:

- *Statement List* (or STL) is a textual representation, similar to machine code. If a program is written in Statement List, the individual instructions correspond to the steps with which the CPU executes the program. To make programming easier, Statement List has been extended to include some high-level language constructions (such as structured data access and block parameters).
- *Ladder Logic Diagram* (or LAD) is a programming language primarily used to develop software for Programmable Logic Controllers (PLCs) used in industrial control

applications. LAD represents a program by a graphical diagram supported on the circuits diagrams of relay-based logic hardware. The name is based on the observation that the program language resembles with ladders, with two vertical rails and series of horizontal rungs between them. Ladder allows you to track the power flow between power rails as it passes through various contacts, complex elements, and output coils [2].

- *Function Block Diagram* (FBD) is a graphic representation and uses the logic boxes familiar from Boolean algebra to represent the logic. Complex functions (for example, math functions) can be represented directly in conjunction with the logic boxes. Inputs and outputs of the blocks are wired together with connection lines, or links.

The S7-300 is a modular control system for system solutions with a main emphasis on production engineering. The wide ranges of assemblies are ideally suited to cope with all required demands and a flexible application. The S7-300 contains the following types of modules [8]:

- Central processing units (CPU)
- Power supply modules (PS)
- Interface modules (IM)
- Communications processors (CP); (for connecting to PROFIBUS)
- Digital and analog modules are now called “signal modules” (SM)

As in a real application, the S7-300 modules are plugged into the profiled rail on the basic plate, fastened and connected to each other via the rear panel bus to be system compatible. The system is quickly and safely connected electrically to the inputs and outputs on the modules with the respective connector adapter. Due to its construction, the system is open to future development.

2.2 The demonstration panel

The demonstration panel is operated with a stabilized DC voltage of 24 V, e.g. supplied with the power supply unit of the PLC system. The sockets are used to connect the sensors and switches on the system simulator to the PLC system. The safety sockets on the system simulator are connected to the sensors and switches according to the assignment. Each of these switches and sensors can physically act as make or break contact depending on the setting of the respective selector with the same marking. Sockets 0 to 7 are used to connect the actuators on the applied mask, e.g. relay and contactor coils to the PLC outputs.

The operating state of an actuator is indicated with an LED assigned to the symbol. Sockets H1 to H4 are directly connected to the signal lamps or LEDs H1 to H4 on the control panel.

All the switches, signal lamps and potentiometers required for operating the control circuit illustrated on the applied mask are clearly arranged on the control panel. Only the control elements labelled on the control panel are visible, corresponding to the applied mask.

The demonstration panel contains LEDs to indicate the operating states of the actuators, such as relay and contactor coils. The LED strip, for example, clearly indicates filling levels and motions.

2.3 The PC Simulation

The PC is connected to the demonstration panel via a USB cable, which sends all the amount of information to the computer – for that a protocol of communication was developed. The PC program gives the user the opportunity to select the type of simulation he wants to perform: via the PC program or via the demonstration panel. The PC program and the demonstration panel are synchronized all the time. So, if the user chooses to perform the simulation from the PC, each state of each input and each output is sent to the other simulation – the demonstration panel – in real time and vice versa. For safety measures, if the user utilizes the PC program simulation and the USB cable is unplugged the simulation switches instantaneously to the demonstration panel.

3 Case study

From the first specified category of applications in section 2, a case study regarding the heating control in a storage room is presented. The characteristic and the operation of the process is presented and depicted in a mask as in figure 2 (the mask's view from the demonstration panel board) and figure 3 (the mask's view from the PC program).

In order to build the command procedure for this process, some steps need to be followed: drawing the PLC terminal diagram which contains pushbuttons and sensors (figure 4), drawing the process chart for the assignment (figure 5), writing the PLC program (table 1). The final step is downloading the program into the PLC and then starting the simulation.

The characteristic and the operation of the process is presented and depicted in a mask as in figure 2 and 3.

3.1 The assignment

The capacity of the heating system in a storage room is controlled by switching the radiators on and off with a PLC system.

When the heating is switched to standby mode with the pushbutton S1 “On”, the indicator H1 is lit. The radiators can be switched on and off step by step with the pushbuttons “▲” and “▼” via the valves Y1 to Y4. The heating capacity of the radiators varies. It is possible to switch different heating capacities with valves: K1: 1kW, K2: 2kW, K3: 4kW and K4: 8kW. Therefore, the heating capacity can only be switched in 1 kW steps from 0 kW to 15 kW. With the pushbutton S0 “Off” the heating system is switched off.

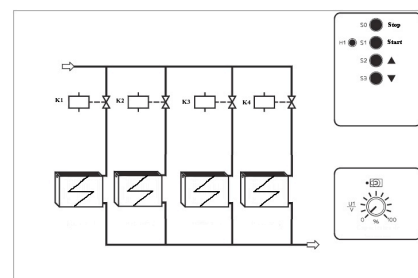


Fig. 2. The mask for the heating control view from demonstration panel board

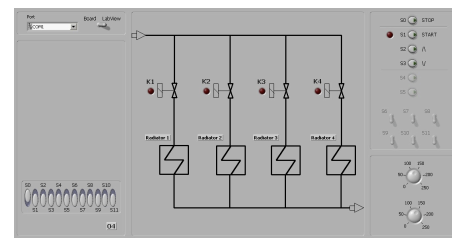


Fig. 3. The mask for the heating control view from the PC program

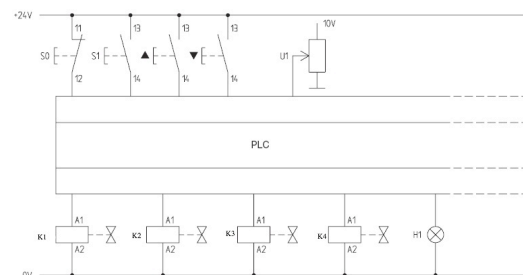


Fig. 4. The PLC terminal diagram

3.2 The solving procedure

The PLC program must be set up using the assignment list according to the functional description and the used PLC. The program will be downloaded into the PLC and then run.

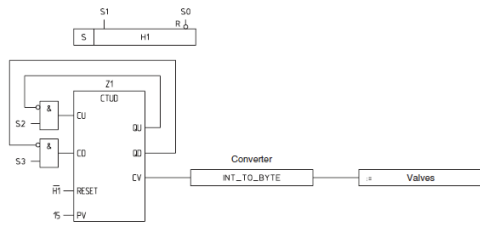


Fig. 5. The process chart for the assignment

The PLC programming software used is STEP 7 V5.2. The program written in Statement List Language is shown, in table 1:

Table 1. The Step 7 Program

<i>Network 1: Plant on/out</i>			
A	"S1"	I124.1	% On
S	"H1"	Q125.0	% Lamp plant on
AN	"S0"	I124.0	% Off
R	"H1"	Q125.0	% Lamp plant off
NOP	0		
<i>Network 2: Counter</i>			
A	"H1"	Q125.0	% Lamp plant on
A	"S2"	I124.2	% Connect
A (
A (
L	#Var2		
L	15		
==I			
)			
NOT			
)			
CU	"Counter"	C1	
A	"S3"	I124.3	% Shutdown
CD	"Counter"	C1	
NOP	0		
NOP	0		
AN	"H1"	Q125.0	% Lamp plant off
R	"Counter"	C1	
L	"Counter"	C1	
T	#Var1		
NOP	0		
NOP	0		
<i>Network 3</i>			
A (
L	#Var1		
T	#Var2		
Set	"S1"	I124.1	
SAVE	"S1"	I124.1	
CLR	"S1"	I124.1	
A	BR		
)			
JNB	_001		
L	#Var2		
T	"Ventil"	QB124	
001: NOP 0			

4 Conclusion

The System Simulator can be used for vocational training in order to practice PLC programming. It can be used for testing and analyzing command diagrams before the actual deployment. The PLC systems can simulate the real processes with several masks, as shown in the case study.

An important aspect that has to be mentioned is the system's modularity. This characteristic allows an easy development of the system and can be used in future development by adding FPGA (*Field-Programmable Gate Array*) components. In this case the commands procedure or process simulator could be implemented using FPGA technology [1]. The process simulator would be controlled via either PLC or a FPGA control board.

Another advantage of the simulator is the connectivity between the demonstrational panel and the PC, which in future development can be used as a supervisor system. The simulator is an "open" equipment as it can be developed further on future technologies.

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