Control System Simulator with PLC

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Abstract: - An Process and Control System Simulator can replace a vast number of expensive system or function models. The simulation of physical processes and their automation reduce the costs and the amount of time needed for release in function The designed system can be used to simulate, to project and to train the programming of programmable logical control (PLC) systems graphically and practically. Different electrical processes are simulated and associated with functional masks for different types of application and with different complexity factors allowing to use the system for training and for practical work in different areas. A simulation block is used for all the applications, having different replaceable masks according to the desired application.

Key-Words: - electrical processes, system simulator, control system design, PLC

1 Introduction

The simulation of the automatic control of some industrial processes represents modern and efficient direction for the multifunctional testing platforms designed for students training laboratories as well as for complex development of some technologic scenario for improvement and conception of control scheme in modern technologies.[6]

The majority of simulators are composed of the command segment – the PC with an interface or a PLC – and the process simulator that is a micro plant or an electronic circuit.

The process simulator that is presented in this paper is hardware and software intergraded system.

A programmable logic controller (PLC) or programmable controller is a digital computer used for automation of electromechanical processes[4],[5].

Process control system has a hardware structure that assures stability, accuracy and good transitions. These performances are realized by 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 Control System and Process Simulator

The Simulator is sectionalized containing three parallel panels: *the PLC*, *a demonstration panel* to hold a mask (an applied mask corresponding to different processes) with a large image of the process that is being simulated and the connection panel between the PLC connection and *the demonstration panel*.
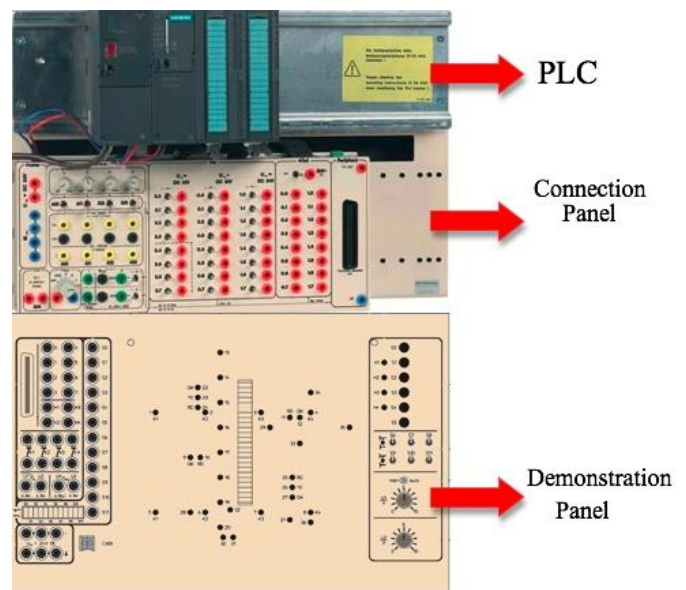

Figure 1. The Process Simulator

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

The large range of assignments allows you to study the field of automation without previous knowledge starting with small control circuits and also up market solution strategies by using the full scale of functions offered by the programmable logical control systems. The individual examples are obtained with masks that

contain a process flow chart and are applied to the demonstration panel of the process simulator.

Three categories of exercises was developped:

- Projection and testing of the simplest assignments using classical contactor circuits
- Projection and testing of the medium assignments using industrial system models [2]
- Projection and testing of the complex assignments using industrial system models with the incorporation of the analog function [3]

2.1 The PLC component

All the inputs and outputs on the Simulator have been designed to meet 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 control systems of all major manufacturers. For the PLC it is used the SIMATIC S7-300 modules, an industrial PLC, with a system which is able to offer real industrial conditions during the entire training and testing actions.[7,8]

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

- *Ladder Logic Diagram* (or LAD) is a graphic representation of the STEP 7 programming language. Its syntax for the instructions is similar to a relay ladder logic diagram: Ladder allows you to track the power flow between power rails as it passes through various contacts, complex elements, and output coils.
- *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 constructs (such as structured data access and block parameters).
- *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.

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:

- Central processing units (CPU)
- Power supply modules (PS)
- Interface modules (IM)
- Communications processors (CP); (for connecting to PROFIBUS)
- Function modules (FM); (for counting, positioning, closed-loop control)
- Digital and analog modules are now called "signal modules" (SM)

As in 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. The PLC is constructed from following modules: a power supply PS 307 2A, a CPU 313C, digital input module SM 321, digital output module SM 322, analog input/output module SM 334.

2.2 The connection panel

On the connection panel are presented 4 variable analog input voltage of 0 to 10 V DC, external analog inputs sockets to supply analog signals, e.g. from the sensors to the PLC system, two analog outputs, 20 rocker switches to simulate digital input signals, 16 outputs to access the digital output signals. All the inputs and outputs run to 2-mm or 4-mm safety sockets. It can be also seen rocker switches to either select the analog input signal via the analog simulation or via the external analog inputs or the external analog inputs via the 50-pin socket. The connection panel contains also an input to supply the external power voltage supply of 24 V to the outputs. When the selector is set to "int" position, the digital output signals are supplied with the voltage from the PS. When the selector is on "ext" position, it is possible to reach the max. switching capacity for the output stages via an externally supplied DC voltage of 24 V.

2.3 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. The PLC can only control the LEDs or the segments of the LED strip, which are assigned to the actuators on the applied mask.

3 Case study

From the first specified category of applications in section 2, a case study regarding a three-phase squirrel-cage asynchronous motor starting in star-delta connection is presented in this selection. The characteristic and the operative of the process is presented and depicted in a mask as in figure 2.

In order to build the command procedure for this process, some steps need to be followed: drawing of the pushbuttons and the sensor into the PLC terminal diagram (figure 3), drawing of the current flow chart for the control unit according to the assignment (figure 4), the process chart for the assignment (figure 5), the PLC program designed according to the current flow (table 1). The final step is downloading the program into the PLC and then starting the simulation.

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

3.1 The assignment

A three-phase squirrel-cage asynchronous motor starts in star connection in order to avoid high starting currents and then automatically changes over to delta connection after the running up period.

The motor starts running in star connection when the start button S1 is activated. After a running period of

aprox. 10 s, the circuit is automatically changed over to delta connection.

The pilot lamp H1 indicates the operating state of the asynchronous motor. The activation of the motor protective relay is simulated by pressing pushbutton S5.
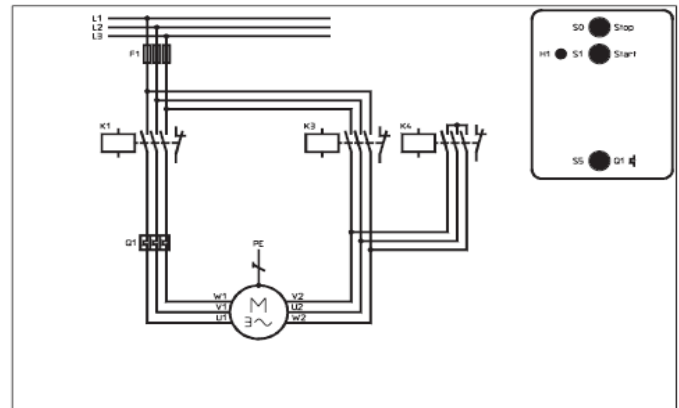

Fig. 2. The mask for the assignment automatic star-delta connection
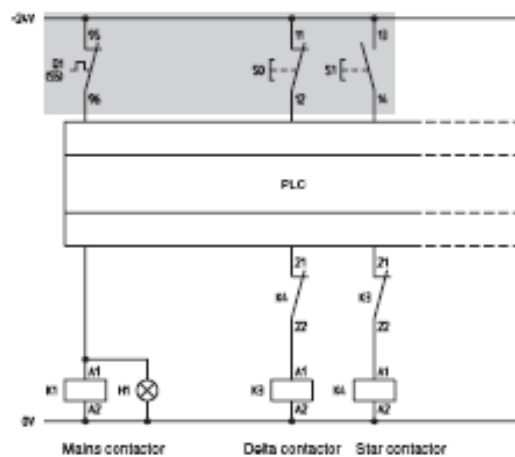

Fig. 3. The PLC terminal diagram

3.2 The solving procedure

The first step is to draw the contacts into the PLC terminal diagram considering the requirements for fail-safe circuits. The drawing of the current and the process flow chart is the next step, followed by the setting up of the assignment list according to the functional description and the used PLC. Next, the PLC program must be set up using the current or the process flow chart according to the functional description. The program will be downloaded into the PLC and then simulated.
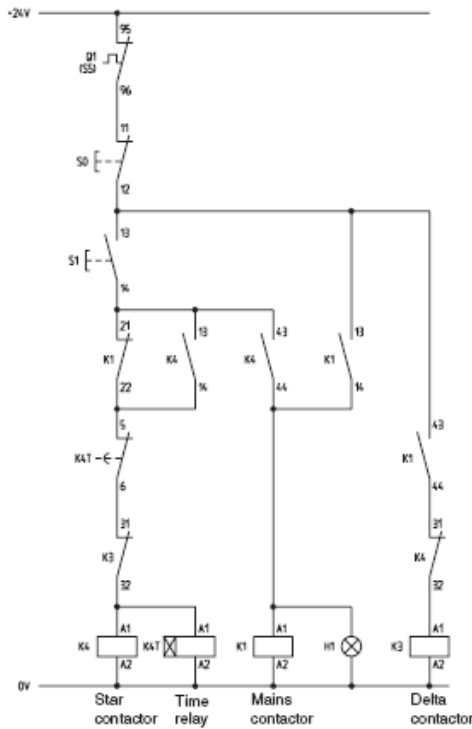
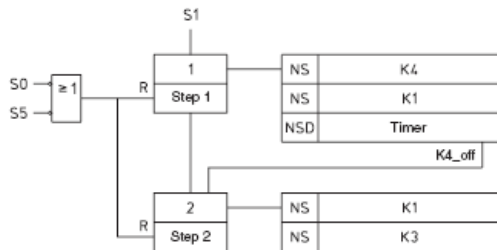Figure 4. The current flow chart for the control unit

Figure5. The process chart for the assignment

The used PLC program is STEP 7. In table 1, the program using the Statement List Language is shown:

Table 1. The Step 7 Program

```
PROGRAM funct1
VAR
S0 AT %I0.0.0.0.0 : BOOL ; (*Stop*)
S1 AT %I0.0.0.0.1 : BOOL ; (*Start*)
S5 AT %I0.0.0.0.5 : BOOL ; (*Motor protection*)
K1 AT %Q0.0.0.0.0 : BOOL ; (*Mains contactor*)
K3 AT %Q0.0.0.0.2 : BOOL ; (*Delta contactor*)
K4 AT %Q0.0.0.0.3 : BOOL ; (*Star contactor*)
H1 AT %Q0.0.0.0.0 : BOOL ; (*Pilot lamp*)
K2T : TON ; (*Time relay*)
K4_off : BOOL ; (*Delta on*)
END_VAR
```

4 Conclusion

The System Simulator can be used for vocational training in order to practice programming of PLCs. 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 use 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] and the system will be used for training and testing using both technologies PLC and FPGA.

The simulator is an "open" equipment as it can be developed further on future tehnologies.

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