DESIGNING VIRTUAL LEARNING ENVIRONMENT FOR PLC APPLICATIONS DEVELOPMENT

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Abstract: The current paper is the result of research program dedicated to designing new tools and instruments in designing and optimizing industrial processes control. The process is replaced by a virtual environment that reacts to the PLC commands, and answer similar with real process. For instance, to control a three phases motor, we use the real PLC, but we have neither the control equipment nor the power equipment; the simulator application will behave and replicated the missing equipment from real process. The PLC module is industry-like equipped for controlling a process. The advanced industrial processes simulator has been designed to be used for: understanding industrial processes simulation; learning PLC programming for integration in industrial processes.

1. ENGINEERING EDUCATION IS SIMPLER THAN WE BELIEVE. INTRODUCTORY APPROACH

An important research group [3] provided an excellent review report on most frequently used virtual learning methods. We will comment here only few key findings from this report. First of all they are saying that "Virtual learning programs should be student-centered and aim to improve student achievement, personalize learning, or provide students with more academic options." This strength is somehow utopic because the simplest question is related to fact that in many cases the economical, or community interest might not be overlapped with student behavior.

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In this case, the only last idea from the conclusion should be supported- more academic options.

For this important reason, another technique is implemented- blending learning. It combine face-to-face and online instruction yield the best student learning outcomes, with flexibility and self- paced instruction.

For both methods, outcome-based quality assurance metrics should be implemented.

Form the models point of views, when discussion goes over the categories, the only big underlined advantage is flexibility. This fact requires extremely big efforts to ensure logistics flexibility, especially in engineering topics.

In the same time, the main aim of the studies related to virtual learning environments is "Assessing the degree of association between the number of accesses to the VLE and the variables related to students' performance;" [1]. From them study, an excellent definition allows us to understand the importance of such education environments: "enable learning to take place according to the elements present in the learning environment, based on a continuous scale ranging from the elements specified in the environment to the elements emerging from use".

2. MODELS IN VIRTUAL LEARNING ENVIRONMENTS

A group of researchers [2] started this approach in learning techniques from different perspective- performing simulation experiments by applying lean concepts. It is difficult to provide a general definition of lean concepts, but the authors provided reference information in order to understand concept: "Some of the major factors contributing to these wastes are large setup times, long distances between machines, excess level of work-in-progress, and large batches.

The lean tools help to improve the company's operations by reducing these factors in the following way. Lean recommends the just-in-time ideology for low inventories, cellular manufacturing for less transport and motion, SMED, which is also referred to as quick setup, for less setup times and process flexibility for low batch sizes". Which is important for us is a consequence of this approach- the huge variation of knowledge base of the people who pass training system [4]. According with them research there is big advance in knowledge accumulation using model simulations when the amount of knowledge is low- see fig. 1.

In this figure three levels of knowledge bases has been used (i- high level of knowledge, ii- medium knowledge, iii- low knowledge). In the left side of upper figure (a) there are represented the percentages of correct assessment answer versus pre (p) and post evaluation test (P). In the middle and right side there are represented grades of evaluation (b) and self-evaluation (c) for the same three levels of knowledge bases. According with them metrics, the biggest advance comes from the lowest level of knowledge.
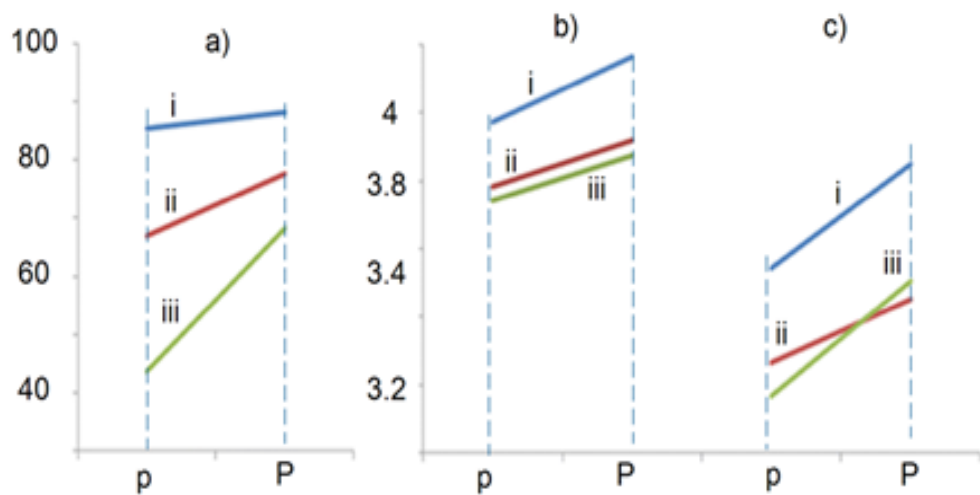
Fig. 1. Metric results for knowledge accumulation in blended virtual learning environment (figure processed following [4]).

Taking into considerations upper representations (different values of slopes), another parameter could be taken into considerations- time to reach the same level of knowledge. In this case, the biggest challenge is to reduce the time for accumulating knowledge.

3. PHISYCAL MODEL AS SUBJECT OF BLENDED IN VIRTUAL LEARNING ENVIRONMENTS

3.1 Programmable Logic Circuits in industry-based applications

The industry needs PLC programming specialists (PLC = Programmable Logic Controller). To become a specialist, one must accumulate experience by practicing on PLCs connected to the plant. Obviously, a beginner should not be allowed to experiment on an actual working plant. It is required an equipment that allows making errors without causing injuries, damages or stopping the activity. Instead of the real process, a simulated plant may be used. Controlled by the PLC, a process simulator will behave just as a real plant, with sensors connected to the PLC inputs and actuators connected to the outputs.

Let's have a look at next power diagram- three phases circuit that supply a motor. Let the phase sequence of the three-phase voltage applied to the stator winding is U1-V1-W1. If this sequence is changed to W1-V1-U1, it is observed that direction of rotation of the field is reversed i.e., the field rotates counterclockwise rather than clockwise. However, the number of poles and the speed at which the magnetic field rotates remain unchanged.

Thus it is necessary only to change the phase sequence in order to change the direction of rotation of the magnetic field (fig. 2). For a three-phase supply, this can be done by interchanging any two of the three lines.
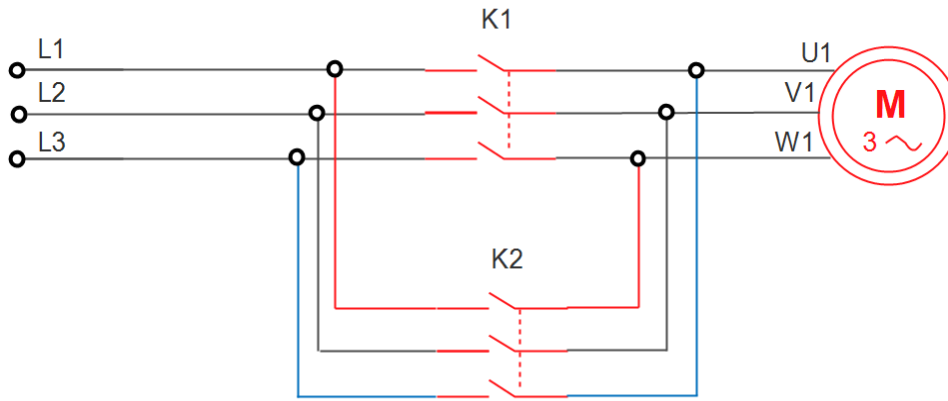
Fig. 2. The standard electric power diagram for reversing motor speed using PLC

The corresponding control diagram is shown in fig. 3. At rest, the contactors K1 and K2 are open and the lamp H1 is ON. When the push-button S1 is operated, the coil of the forward rotation contactor K1 is excited, which closes both the power contacts and the retaining contacts.
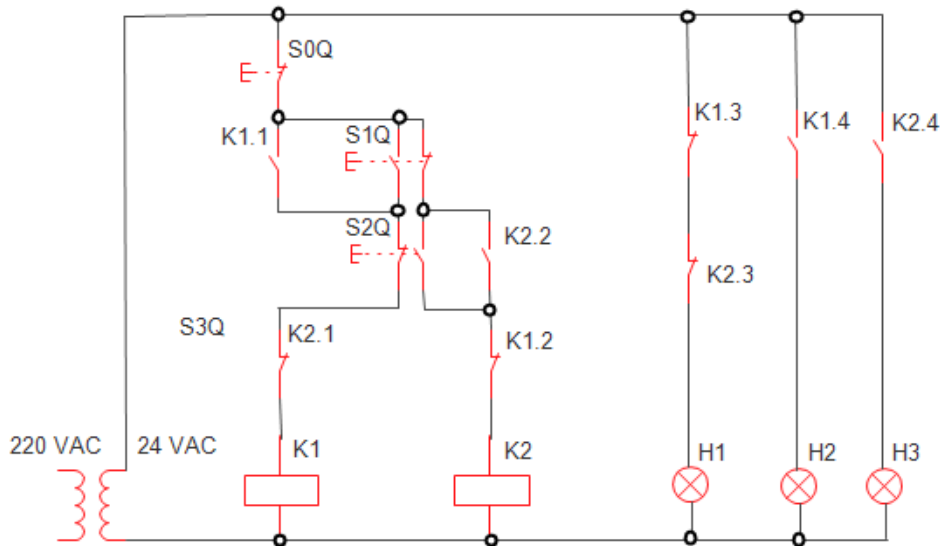
Fig.3. The control diagram, as the basic physical link between industry-based application and virtual environment.

The retaining occurs, the lamp H1 switches OFF, the red lamp H2 switches ON and the motors is started.

For the backward rotation to be obtained, the motor has to be stopped, at first,

by pushing the push- button S0Q. In fact, even when the push-button S2Q is pushed, the coil K2 can't be supplied, because the series contact K1 is open.

Operating the push-button S2Q when the system has returned to rest conditions, the backward rotation condition is obtained. In fact, it is now possible to excite the coil of contactor K2: the retaining occurs, the lamp H1 is switched OFF and the lamp H3 is switched ON. At the same time, the motor is started in the direction opposite to the previous one.

3.2 Virtualization of simple command for Programmable Logic Circuits in industry-based applications

The applications with PLC not are only are capable of performing the same tasks as hard wired control but are also capable of many more complex applications. The PLC program and electronic communication lines replace much of the interconnecting wires. The PLC discrete input/output (I/O) system provides the physical connection between the central processing unit (CPU) and real devices that transmit and accept digital signals, like is presented in fig. 4.
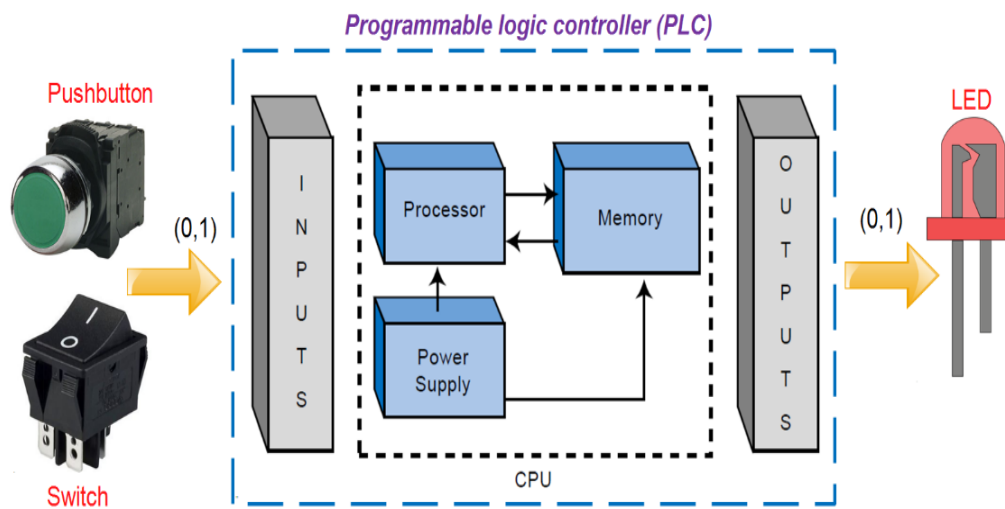
Fig.4. Input Output system design for simple command, using PLC

Through interface circuits (limit switches, transducers, etc.), the controller senses and measures physical quantities (e.g., proximity, position, motion, level, temperature, pressure, current, and voltage) associated with an electrical motor or industrial process. For this simple application the PLC use discrete input/output interfaces, which allowed interfacing with ON/OFF-type devices.
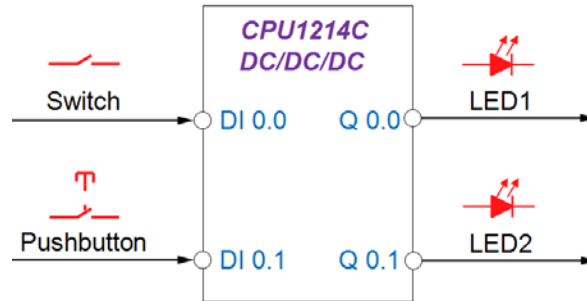
Fig.5. Systemic diagram for a simple ON/OFF process.

For upper process learning design we have designed a systemic approach (fig. 5). The systematic approach of industrial processes applications allows comparison of inputs with outputs in order to determine whether the process was run under the conditions imposed by the designer.

This application highlights the different approach of toggle switch and pushbutton. The toggle switch is connected to the digital input (DI0.0) of the PLC. When the switch is toggle ON the digital output (Q0.0) is active and the LED 1 will be ON. When the switch in toggle OFF the digital output (Q0.0) is inactive and the LED 1 will be OFF.

The pushbutton is connected to the digital input (DI0.1) of the PLC. Momentarily pressing the pushbutton completes the path for current flow and energizes the output Q0.1 (LED 2 ON). When the pushbutton is released, current continues to flow through an auxiliary contact, and the LED2 will remain ON.
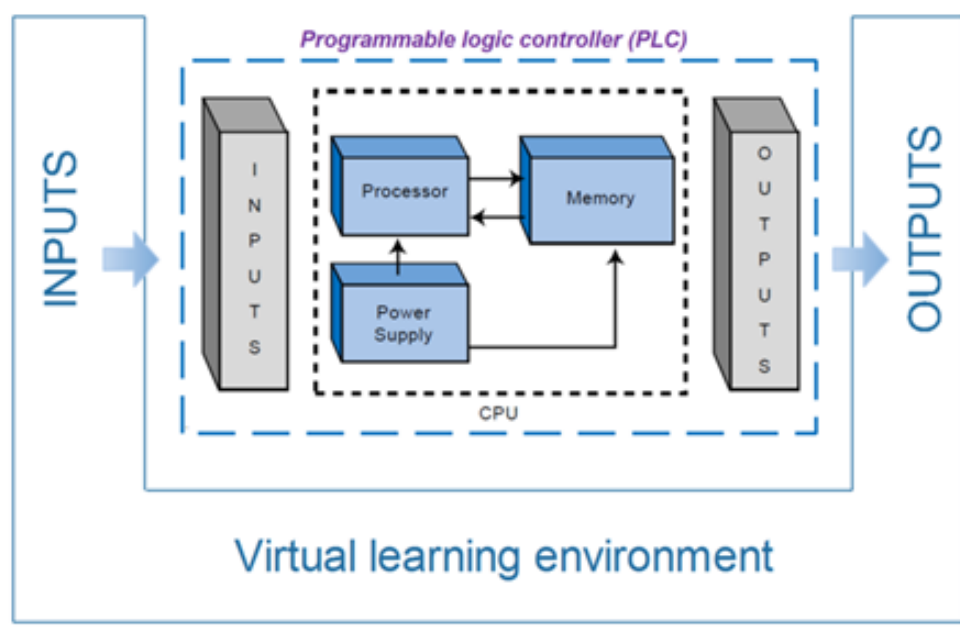
Fig. 1. Virtualization process for PLC-based industry application training

By virtualization of the real application, we obtain an implementation like in fig. 6. The virtual support is replacing the real buttons and lamps. Through this approach, the intention is to create flexible applications.

4. VIRTUAL SUPPORT IMPLEMENTATION

4.1 Touch-app multi-applications implementation

The virtual training support is based on an all-in-one PC with standard computational facilities. It has been designed as a panel that allows PLC connectivity-see fig. 7. Where: 1 is display with touch screen facility for interaction with user; 2 is Ethernet port for TCP/IP based network connection; 3 is USB 2.0 port for external storage of the applications; 4 is VGA port for second display connection; 5 is power switch; 6 is a pair of 24VDC- GND power supplying; 7 represents the group of 8 female analog outputs electrical connection; 8 represents the group of 8 female analog inputs electrical connection; 9 represents the group of 16 female digital outputs electrical connection; 10 represents the group of 16 female digital input electrical connection.
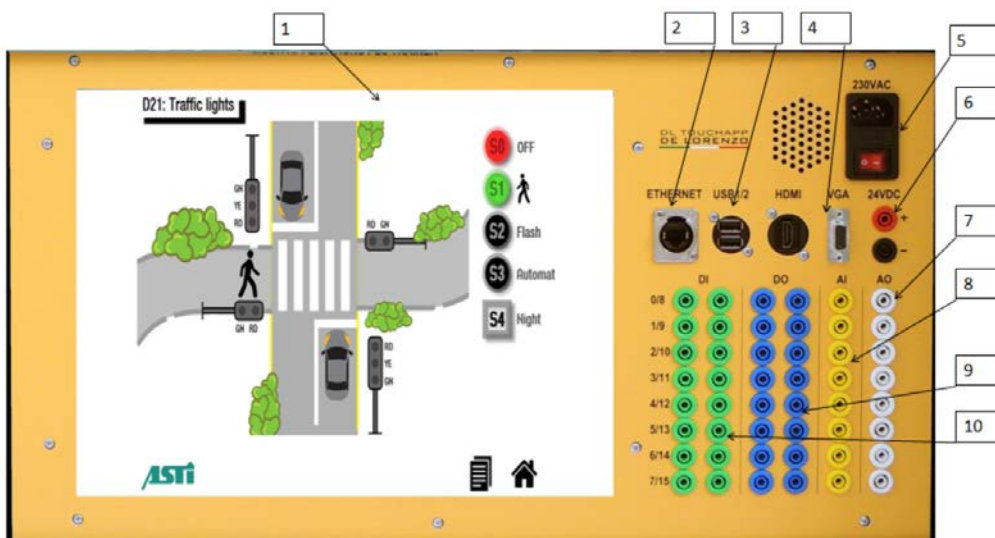

Fig. 2. All-in-one PC- based process virtual training system

In this way, we can replicate most of interfaces with practical applications. It is an industrial process simulator for technical training with a virtual learning environment that offers a complete software package for discrete and continuous automation processes in various fields of industry. It offers robust hardware architecture with rugged and safe enclosure for demanding training applications. The trainer, in complete configuration is shown in next figure and will be described in details during this paragraph.

4.2 Touch-app and PLC connected together for multi-applications implementation

Next figure (fig. 8) shows our implementation support. Where: 1 is Touch- based multi- application simulator; 2 represents the branch of wires for interconnection between Multi Application simulator an PLC module; 3 is the PLC module; 4 is the router that establish the local network for programming; 5 is a multi power plug. As you observe in upper figure, we didn't add the PC which can be used for programming PLC. It should be part of your lab facilities. On this table you can add your PC, and eventually a video projector for sharing the way to make experiments.

On the right side, there is a PLC "packed" into a training panel, built around a S7-1200 controller module.
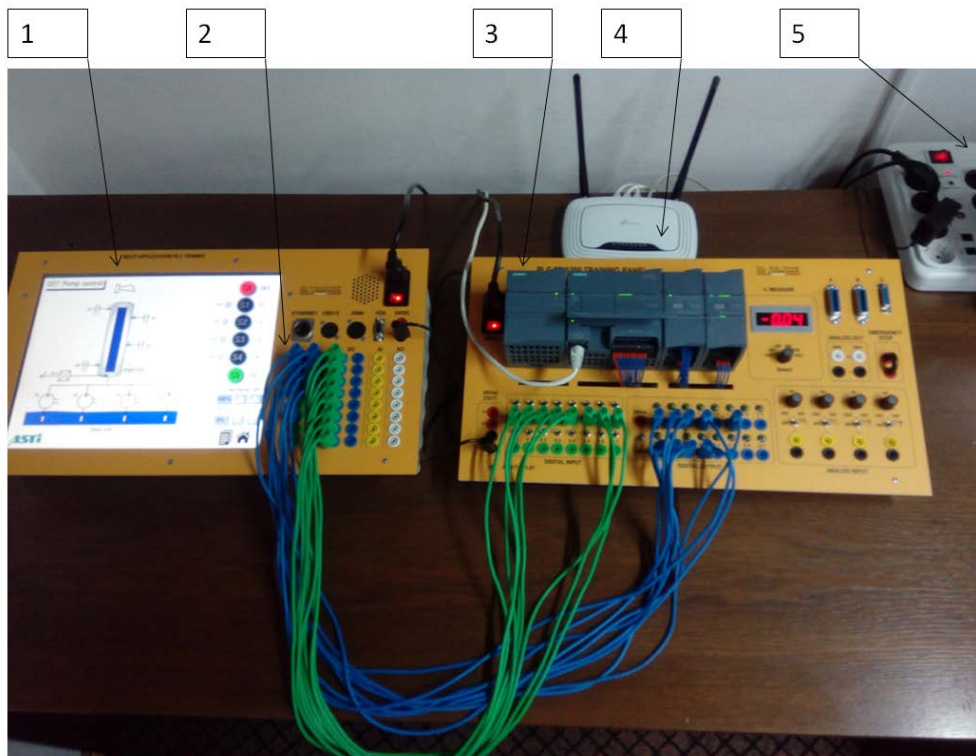

Fig. 3. Multi-apps and PLC connected together for flexible applications implementations.

4.3 Programming PLC for multi-applications implementation

Even it is not the subject of current paper we are informing you here that for PLC programming we used TIA Portal STEP 7 Basic. The well know and typical interface is shown in fig. 9.

Of course, programming PLC for virtual environment support must be according

with electrical wiring shown in fig. 8. The PLC program can be further expanded to accommodate a wide variety of commercial and industrial applications. Start/Stop pushbuttons, selector switches, indicator lights, and signaling columns can be added. Motor starters can be added for control of additional motors. Over-travel limit switches can be added along with proximity switches for sensing object position. Various types of relays can be added to expand the variety of devices being controlled.
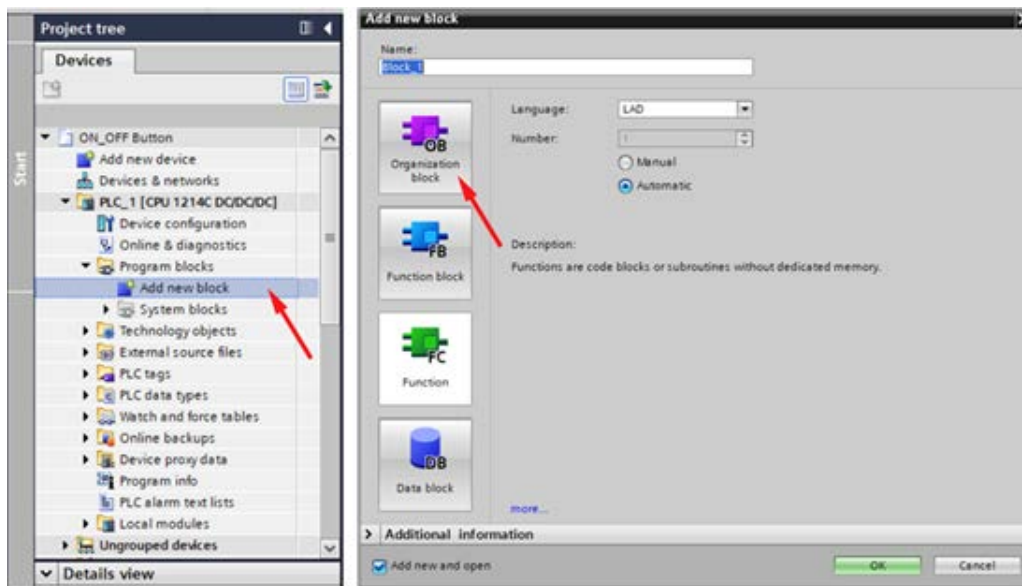

Fig. 9. The typical interface for PLC programming using TIA portal.

5. TRANSPORTATION SYSTEM IMPLEMENTATION AS VIRTUAL TRAINING SUPPORT

5.1 Problem implementation

A system of three conveyor belts in series is used for transporting materials over a long distance. Operator commands are fulfilled only if allowed by the PLC. It is not allowed to start a conveyor while the next one is stopped (because the transported material would overflow).Also, it is not allowed to stop a conveyor while the previous one is still running (because the transported material would overflow). For this process, the systemic diagram is shown in fig. 10.

The control sequences must have the below described functionality:

The system begins to operate after the main start button S4 was pressed; the lamp H4 shows that the system is working.

Conveyor motors are controlled by contactors Q1, Q2, Q3 and can be individually switched on by pressing the corresponding buttons S1, S2, S3. Lamps H1, H2, H3 show the operating status of each belt. It is not allowed to start a conveyor while the next one is stopped (because the transported material would overflow). The belts can

be stopped by pressing button S0, which causes the whole system to stop. Overloading any motor (simulated by pressing button S5) also results in stopping all the motors (equivalent to 3 NC protection relays connected in series).
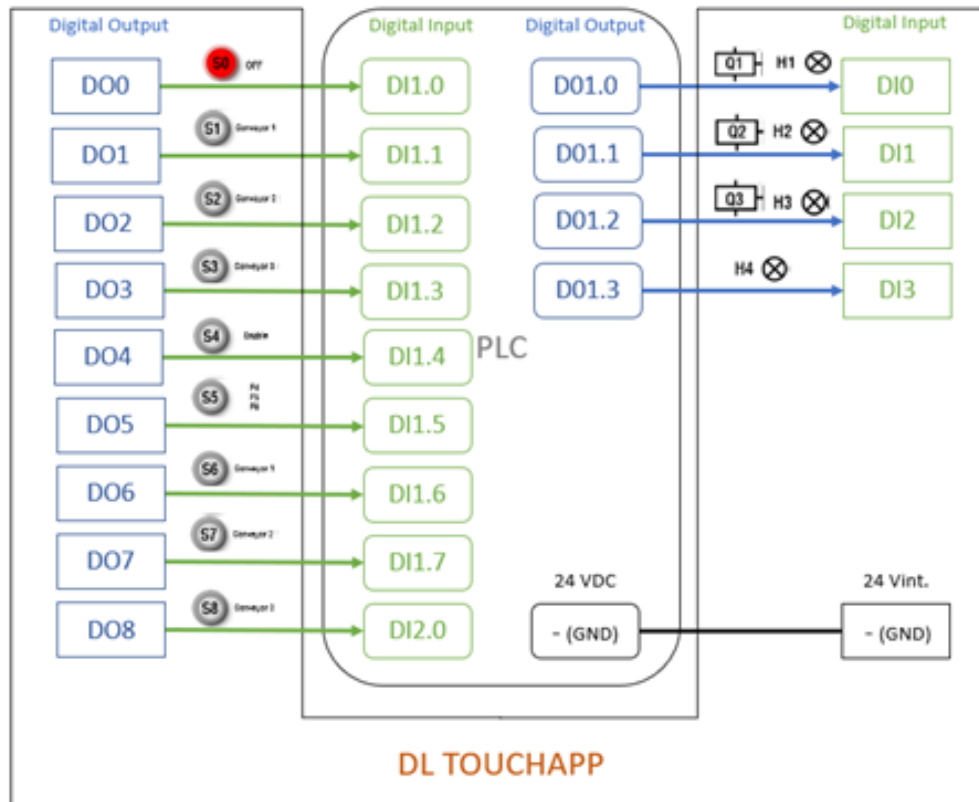

Fig. 10. The link between virtual process and PLC.

In addition to the behavior of the functional description 1, the belts can be individually switched off by using the switches S6, S7, S8 (which work as buttons because they return to middle after being pressed down). It is not allowed to stop a conveyor while the previous one is still running (because the transported material would overflow).

5.2 Interaction. Results.

In first functional description, the system is started by pressing S4 Enable button. The operating status of entire system is signaled by H4 lamp. First, the third conveyor belt should be started by pressing the S3 (Conveyor 3) start button. The contacts of the simulated contactor relay Q3 (conveyor 3 motor) are closing and the belt motor is powered up. The arrows on the third motor diagram should circle around showing the operating status while H3 lamp is green lighted.

Next, the second conveyor belt should be started by pressing the S2 (Conveyor 2) start button. The contacts of the simulated contactor relay Q2 (conveyor 2 motor) are closing. The arrows on the second motor diagram should move clockwise while the H2 lamp is green lighted.

Last, the first conveyor belt should be started by pressing the S1 (Conveyor 1) start button. The contacts of the simulated contactor relay Q1 (conveyor 1 motor) are closing. The arrows on the first motor diagram are moving showing the operating status, while the H1 lamp is green lighted. When the S0OFF button is pressed the contacts Q1, Q2 and Q3are turned off, shutting down all three conveyors simultaneous and turning off the H4 lamp. In case of an overload on one of the conveyor belts, simulated by pressing the S5 button, the F4, F5 and F6 protection relays connected in series decuples the mains and stops all three motors simultaneous.

The control circuit is a low voltage/ current circuit that "control" larger voltages and currents that supply power to equipment. It is well known that contactors relays are switching devices providing electrical isolation between the control signals and the commanded electrical circuits. Different combinations of normally open (NO) and normally closed (NC) contacts should be used to open and to close the command circuits.

6. CONCLUSIONS

A system of three conveyor belts in series is used for transporting materials over a long distance. For avoiding the overflow of transported material, operator commands should simultaneous obeys 2 rules: it is not allowed to start a conveyor while the next one is stopped; it is not allowed to stop a conveyor while the previous one is still running.

This process was simulated using contactor relays and buttons from the DL TOUCHAPP interface. The control function was implemented with the SIEMENS PLC model S7-1200. It is a typical training "chain" where we can "add" a virtualized environment to our training lab.

The functionality of the system, in terms of power and control electric scheme must be discussed by students before writing the PLC program. Performing the experiment, the students can observe that materials can be transported over a long distance by correct operated conveyor belts.

The operator commands can be made with push buttons, by correctly programming the SIEMENS SIMANTIC S7-1200 PLC unit. Through this kind of implementation we are adding knowledge base to the people that have not access to them of them level of preliminary skill is very low. During training process, them understanding of the process information and systemic architecture has been easy fitted.

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