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EDUCATIONAL STAND FOR PROGRAMMING AND CONTROL OF AN INDUSTRIAL PROCESS USING PLC AND HMI

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Abstract: This paper presents the design and implementation of an educational stand intended for programming and control of an industrial process using a Programmable Logic Controller (PLC) and a Human-Machine Interface (HMI). The proposed system aims to provide a practical learning platform for students in the field of industrial automation, enabling the development of essential skills in programming, configuration, and operation of modern control systems. The educational stand is based on an ABB AC500 PLC (PM573-ETH CPU), integrated with analog and digital input/output modules, communication modules, and an HMI panel for real-time monitoring and control. The system includes various industrial components such as actuators, control buttons, signaling devices, and measurement instruments, simulating real industrial conditions. The methodology involves the analysis of industrial automation principles, the design of the system architecture, hardware configuration, and the development of control software using the Automation Builder environment. Additionally, the HMI interface is designed to provide visualization of process parameters and user interaction capabilities. Experimental testing and validation of the system demonstrate its functionality under different operating scenarios. The results highlight the effectiveness of the proposed stand as a didactic tool for understanding PLC-based automation systems.
Key words: automation system, frequency converter, motor control, real-time monitoring, user interface

1. INTRODUCTION

Industrial automation plays a crucial role in modern production systems, ensuring increased efficiency, reliability, and safety. The use of Programmable Logic Controllers (PLC) and Human-Machine Interfaces (HMI) has become standard in industrial environments due to their flexibility and ability to control complex processes [1], [2], [6]. In technical education, it is essential to provide students with practical experience that complements theoretical knowledge [5], [7]. Educational stands that simulate real industrial processes represent an effective method for developing practical skills in automation [3], [4]. This paper presents the design and implementation of an educational stand for programming and control of an industrial process using a PLC and HMI. The main objective is to create a flexible and realistic platform for studying industrial automation systems.

2. SYSTEM ARCHITECTURE

The proposed educational stand is designed as a modular industrial automation system that integrates power supply, control, and user interface components.
The system is structured to simulate real industrial processes while providing a clear understanding of signal flow and control logic. The system includes a central PLC unit, input/output modules, and various field devices such as actuators and control elements [9].

The main components of the educational stand are illustrated in Figure 1. The power supply system (1) includes the MCB and the 12 V and 24 V DC sources. The PLC and I/O modules (2) represent the central control unit of the system. The control panel (3) includes push buttons, selector switches, potentiometers, and signalling lamps used for user interaction. The HMI interface (4) provides visualization and control of the process. Additionally, the system includes a DB connector (5) which allows external connections and integration with other systems and a serial communication interface (6).

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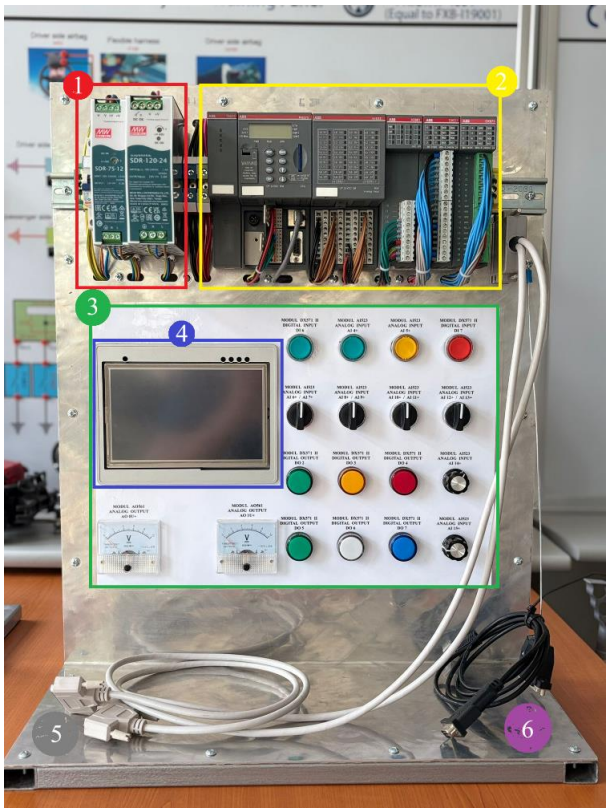


Figure 1 General view of the educational stand

3. HARDWARE IMPLEMENTATION

The hardware implementation of the educational stand is based on a modular structure that integrates power supply, control, and user interface components.

3.1 Power Supply System

The system is powered from a 230 V AC mains source, which is protected by a miniature circuit breaker (MCB). The power is then distributed to two stabilized power supplies manufactured by Mean Well, namely SDR-120-24 and SDR-75-12, which provide 24 V DC and 12 V DC, respectively. The 24 V DC source is used to supply the PLC, input/output modules, and control elements, while the 12 V DC source is dedicated to potentiometers and analogue adjustment components.

3.2 PLC and I/O Modules

The control system is built around an ABB AC500 programmable logic controller, specifically the PM573-ETH CPU, which acts as the central processing unit of the system.

To extend its functionality, the PLC is equipped with several input/output modules, including DX571 digital input/output modules, AI523 analogue input modules, and AO561 analogue output modules. These modules allow the system to interface with both digital and analogue signals, enabling the implementation of various industrial control scenarios [10], [11].

3.3 Control Panel and HMI

The educational stand includes a control panel equipped with push buttons, selector switches, signalling lamps, voltmeters, and potentiometers, allowing direct interaction with the system. Additionally, the system is equipped with an ABB CP635 B0 HMI panel, which provides real-time visualization and control of the process [13], [14].

3.4 Communication Interfaces

The system is equipped with communication interfaces that allow connection to external devices and systems. The PLC supports both serial and Ethernet communication [12]; however, the Ethernet interface is used in the current implementation for data exchange with the HMI and PC. Additionally, a DB connector is included to provide access to multiple input and output signals, enabling interconnection with other educational stands or external equipment.

4. EXPERIMENTAL SETUP

The experimental setup consists of the developed educational stand interconnected with an external training system and a frequency-controlled motor, as shown in Figure 2.

The experimental setup presented in Figure 2 consists of the developed educational stand interconnected with an external training system. The developed stand (1) represents the main control unit based on the ABB AC500 PLC and associated input/output modules, responsible for processing signals and executing the control logic. The connection between the two systems is achieved through a DB connector (2), which enables signal exchange between the developed stand and the external system. The external system (3) integrates a Siemens SINAMICS G110 frequency converter. Additionally, a three-phase motor (4) simulates the main load of the industrial process.

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Figure 2 Experimental setup including the developed stand, frequency converter and motor

5. PLC PROGRAMMING AND HMI

The control logic of the system was developed in the ABB Automation Builder environment using the Structured Text (ST) language [2], [8]. The main program, PLC_PRG, manages both the operating modes of the stand and the interaction with the external training system and the frequency converter. The software structure is based on two main operating modes, namely HMI mode and stand mode. The selection between these modes is performed through dedicated switches. In HMI mode, the process is controlled through parameters introduced from the operator interface, while in stand mode the operation is performed directly from the physical control elements mounted on the stand, such as push buttons, switches, and potentiometers. In HMI mode, the program executes a predefined speed profile for the controlled motor. The sequence is divided into several time intervals corresponding to acceleration, steady operation, deceleration, and direction change. The frequency reference is calculated step by step according to the selected values for positive and negative speed, cycle number, and segment duration. This operating principle allows the implementation of a bidirectional motion profile, displayed graphically on the HMI interface.

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Figure 3 HMI screen with motion profile

The motion profile shown on the HMI is defined through parameters such as tp1, ta1, ts1, td1, tp2, ta2, ts2, and td2, which represent the timing of each operating segment. Based on these values, the PLC calculates the output frequency and transmits the corresponding analog command to the frequency converter. The output signal is generated through the analog output channel AO_CH1, scaled according to the selected maximum frequency.

In stand mode, the motor can be controlled directly from the panel elements. The start and stop commands are received either from push buttons or from selector switches, depending on the selected operating configuration. The direction of rotation can be set to direct or reverse, while the frequency reference can be selected either from fixed levels or through potentiometer adjustment. The ramp time is also configurable using analog input signals, allowing a gradual variation of the output frequency.

The program also includes signal processing for status indication through signaling lamps. Depending on the operating condition, the system activates different lamps to indicate forward operation, reverse operation, stop condition, speed range, or ramp selection. This improves the visibility of the process state during laboratory operation.

The HMI interface was configured to provide real-time monitoring and intuitive control of the system. It allows the user to set the operating parameters, visualize the motion diagram, and start or stop the controlled sequence. The integration between the PLC program and the HMI interface ensures efficient supervision of the process and improves the educational value of the stand.

6. RESULTS AND TESTING

The developed system was tested under real operating conditions in order to validate its functionality. The experimental setup consists of the developed educational stand interconnected with an external training system and a frequency-controlled motor. As shown in Figure 4, the motion profile displayed on the HMI corresponds accurately to the motor behavior.

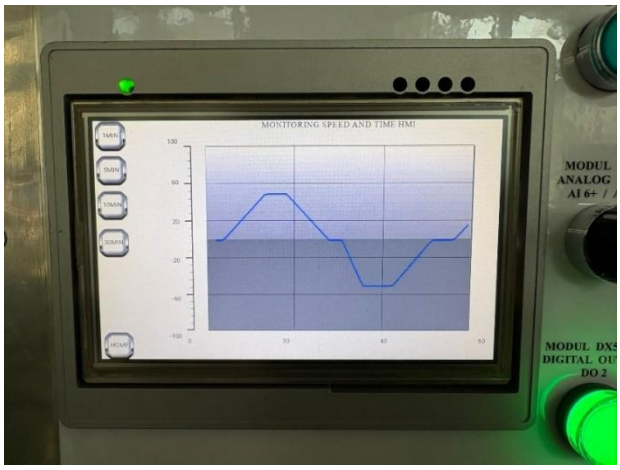


Figure 4 HMI visualization of the motor speed profile during operation

The experimental results confirmed the correct operation of the control system. The PLC successfully

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processed input signals and generated appropriate output commands, ensuring proper control of the frequency converter and motor operation. The implemented motion profile was accurately executed, with smooth transitions between speed levels and correct switching between forward and reverse directions.

The HMI interface provided real-time monitoring of the system parameters and allowed intuitive user interaction. The displayed motion diagram corresponded to the actual behavior of the motor, confirming the correct implementation of the control algorithm. The system demonstrated stable operation, reliable communication between components, and consistent response to control commands, proving its suitability for educational and training purposes in the field of industrial automation.

7. CONCLUSIONS

This paper presented the design and implementation of an educational stand for programming and controlling an industrial process, built around an ABB AC500 PLC (PM573-ETH CPU), digital and analog input/output modules and an ABB CP635 HMI panel. The stand reproduces the main elements of a real automation system, namely power distribution, control logic, field devices, operator interface and communication with external equipment, in a compact and modular structure suitable for laboratory use.

The tests carried out with the external training system, the SINAMICS G110 frequency converter and the three-phase motor confirmed the correct operation of both operating modes: in HMI mode, the predefined speed profile was executed with smooth transitions between segments, while in stand mode the motor was controlled directly from the panel elements, including the direction of rotation, the frequency reference and the ramp time. The correspondence between the motion diagram displayed on the HMI and the actual behaviour of the motor shows that the stand can be used to teach PLC programming in Structured Text, analog signal scaling and frequency converter control. Future developments may include the use of the serial and DB interfaces for interconnection with other educational stands, the integration of additional industrial communication protocols and the development of a set of laboratory exercises with progressive difficulty.

8. CREdit authors statement

Conceptualization: I.L., A.C.; Data curation: I.L.; Formal analysis: I.L.; Funding acquisition: not applicable; Investigation: I.L.; Methodology: I.L., A.C.; Project administration: A.C.; Resources: I.L., A.C.; Software: I.L.; Supervision: A.C.; Validation: I.L., A.C.; Visualization: I.L.; Writing – original draft: I.L.; Writing – review & editing: I.L., A.C..

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