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Factorial inputs and outputs: A virtual plant for industrial control training and operations

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Abstract

The field of manufacturing and production is rapidly changing because of the fourth Industrial Revolution or Industry 4.0 and bridging theory and practice is a major requirement in industrial control and automation training, operations and virtual simulation is one such way to help bridge this kind of gap. One of such simulation program that has gained popularity among companies recently is Factory inputs and outputs (Factory I/O). This paper presents an example of a used case study of FACTORY I/O. The tank scene in the Factory I/O was used for level control and the control algorithm was implemented in the TIA portal using Siemens S7 1500 PLC integrated with the factory I/O to carry out the control of the liquid level in the tank by controlling the fill valve on the level control rig. The S7-PLCSIM TIA portal V15 communicated with the PLC in the Factory I/O drivers through an IP address. Therefore, with virtual simulation system, it is possible to test controller and control configuration before applying it to a physical system, with a methodology matching the fourth industrial revolution in a simulation environment in which theory and practice is bridged for real-time simulations.

Keywords: Virtual simulation; Factory I/O, PLC; TIA portal; Theory and practice simulation

1. Introduction

The field of manufacturing and production is rapidly changing because of the fourth Industrial Revolution also known as Industry 4.0. Improved productivity, efficiency, agility and productivity were some of the benefits of Industry 4.0. Hence, major companies have started integrating this ideology worldwide. To prepare for Industry 4.0, higher education, particularly engineering education, must adapt to these vision's requirements (Ovie and Akhil, 2022). A great tool to facilitate and enhance the knowledge of automation and control engineering is a virtual system. One of the main requirements for industrial control and automation training is bridging theory and practice, this means that learners have to master a considerable number of functional features and operating procedures of the supporting equipment using different equipment from different manufacturers. Most of the same equipment differ a lot from one manufacturer to another. Virtual systems can be a great tool to perform this task using different manufacturer equipment (Bernard and Bruno, 2017). Therefore, virtual graphics system is a veritable tool for bridging theory and practice in industrial control training environment.

A virtual system is a graphical computer simulation of a dynamic system driven by a peripheral controlling device, which can be either simulator or real-time in nature (Bernard and Bruno, 2017). Virtual systems also reduce cost, risk of injury to users and damage to machinery which makes it an attractive option for training. Factory I/O developed by Real Games is a good example of a virtual system that can be used to simulate an industrial environment. Factory I/O is a 3D factory

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simulation software that is specially designed to make virtual factories as simple and intuitive as possible and it includes a variety of scenes both for beginners and advanced users based on typical industrial applications. Furthermore, Factory I/O supports blending virtual and real time information by replacing data/control signals simulated by software with information coming from real devices; i.e, Factory I/O provides many "I/O points" to plug actual Programmable Logic Controllers (PLCs), microcontrollers, data acquisition cards, FPGAs, etc. Finally, Factory I/O allows instructors to inject failures on parts of the equipment and thus help students practice troubleshooting routines (Hector, Heradio, Donoso and Farias, 2022). The most common use of Factory I/O is as a PLC training platform since PLCs are the most common controllers found in industrial applications. However, it can also be used with microcontrollers, SoftPLC and Modbus, among many other technologies (Factory I/O, 2023). Factory I/O can also be connected with control I/O and can be useful in training Human Machine Interface (HMI) and Supervisory Control and Data Acquisition (SCADA) design. Users can interface with external applications and controllers from several manufacturers (such as Siemens and Allen-Bradley) by using the inbuilt I/O drivers, as well as with the industrial communication protocol Modbus TCP/IP and the cross-platform open-source standard OPC UA. This software uses Advanced Process Control (ACP) systems as the main control unit with a Programmable Logic Controller (PLC) being one of the most commonly used in industrial manufacturing fields. TIA Portal contains a wide range of functions and options for the Digital Enterprise, to resolve the challenges of Industry 4.0, that enables machine builders to reduce the time-to-market and for the plant operators to boost their productivity (Siemens, 2023). Training that uses virtual systems can be interesting for users as innovative thinking and logical reasoning can lead to a wide variety of customized scenarios that are both educational and could be implemented in a real factory environment. It has the benefit of allowing users to assess the impact of the developed application as they would in a similar real-time system, but at reduced costs and without the possibility of user injury or machine damage. The goal of this research is to present the use of 3D simulator, that can be considered for industrial control training. This is achieved by integrating Factory I/O and TIA portal software and training students in a basic design and implementation of PID control algorithm in a function block using the Structured Control Language (SCL). In industrial automation control systems, the PID algorithm is widely used to stabilize physical quantities (Nguyễn and Pham, 2021). This paper presents an example of a used case of FACTORY I/O to control levels in a tank system and implementing PLC algorithm in TIA portal using Siemens S7 1500 PLC integrated with the factory I/O to control the liquid level in the tank by controlling the fill valve on the level control rig.

1.1. Descriptive Analysis of the Case Study

The Tia Portal V15 software programmed for PLC S7 1500 (CPU 1511- 1PN), connected to Factory I/O water level control rig by PID algorithm was used. The CPU 1511-1 PN is the cost-effective entry-level CPU for applications with medium requirements for processing speed and speed of response in discrete production technology. The CPU 1511-1 PN can be used as a PROFINET I/O controller or as distributed intelligence (PROFINET I-Device) (Siemens, 2023). The illustration of the 3D simulation environment is shown in Figure 1a and the PLC device configuration in the TIA portal on Figure 1b.

Figure 1a 3D Simulation Environment

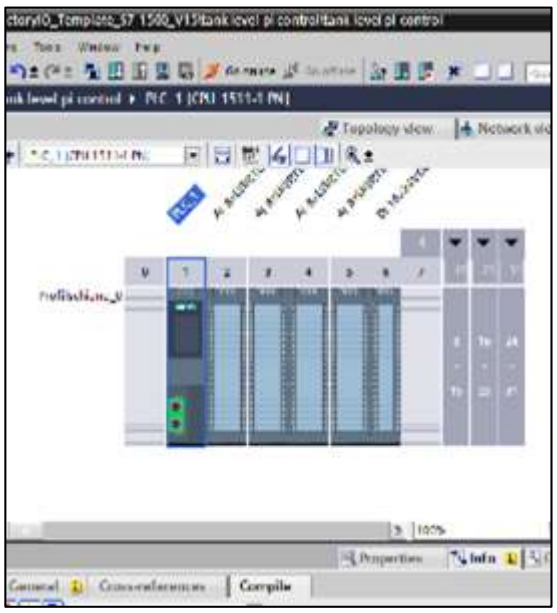

Figure 1b Device Configuration on the Tia portal

Industrial input and output devices were utilized to create a 3D simulation environment. These included sensors, actuators, and control stations. Five (5) potentiometers (analogue controlling input), Fill valve (analogue mode), discharge valve (analogue mode), Level sensor (analogue mode), Selector switch (digital mode), Digital and analogue display, etc. The control panel is shown in Figure 2.

Figure 2 Control Panel Design in Factory I/O

The aim was to control water level in the tank. The fill valve is used as the final control element in the process control. The level sensor measures the level and gives an analogue out of 0 – 10 V from empty to full tank. The setpoint is therefore set using this voltage range. The discharge valve is opened/closed manually by sending the required voltage that corresponds to the draining of choice. The process is designed to work in both manual and automatic mode. The automatic mode uses a PI algorithm coded in SCL in a function block. In the function block, there is a static variable which stores the value of the error unless it rests it. The Main Function Organization Block (main OB1) is the CPU organization block, it is executed all the time and over again. It can be interrupted by other organization blocks. The logic program in the main OB1 gives the PLC instructions which empower it. The SCL instruction in the FB is shown in Figure 3a which illustrates the logic instruction the PLC passes to the Level control tank in the Factory I/O. Figure 3b is the function block in the TIA portal in a command function.

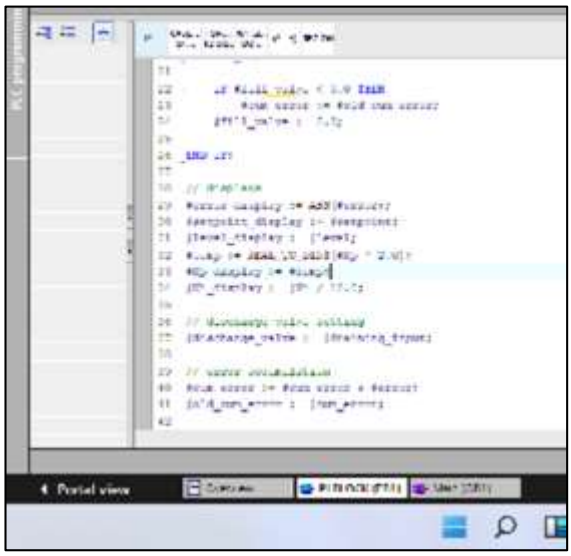

Figure 3a SCL Instruction

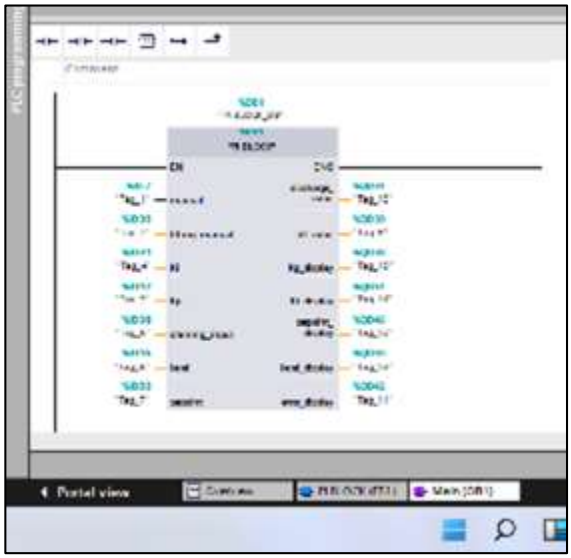

Figure 3b Function Block

An I/O Driver is a built-in feature of Factory I/O responsible for "talking" an instruction to an external controller. Factory I/O includes many I/O Drivers, each one for a specific technology. It selects a driver in the Factory I/O based on the controller to use. Next, to configure this driver, so it can know how to "talk" or give instruction to the controller and how to read and write I/O from it. In this case, the driver of interest is Siemens S7 -PLCSIM and the model is S7-1500. The S7-PLCSIM TIA portal V15 communicate with the PLC in the Factory I/O drivers through the IP address shown in Figure 4 and it is supported by TCP/IP and PROFINET connection.

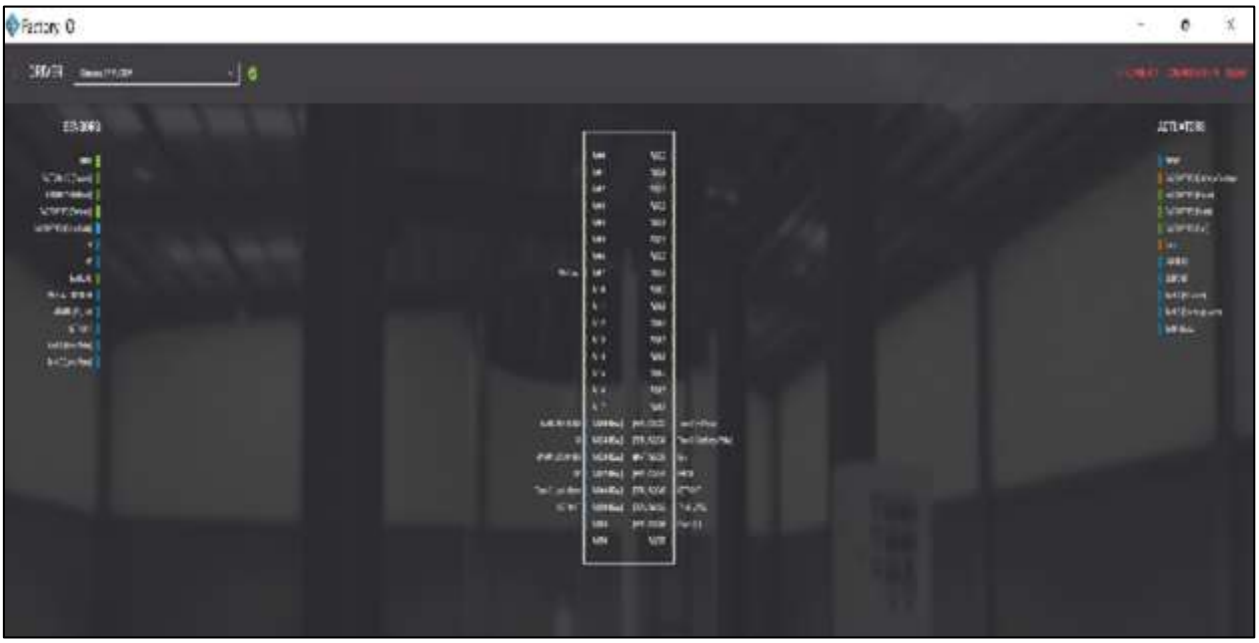

Figure 4 Factory IO Connection with PLCSIM

In the factory I/O simulation environment, the program written on the PLC was tested. The Figure 5 shows the simulation result on the factory I/O.

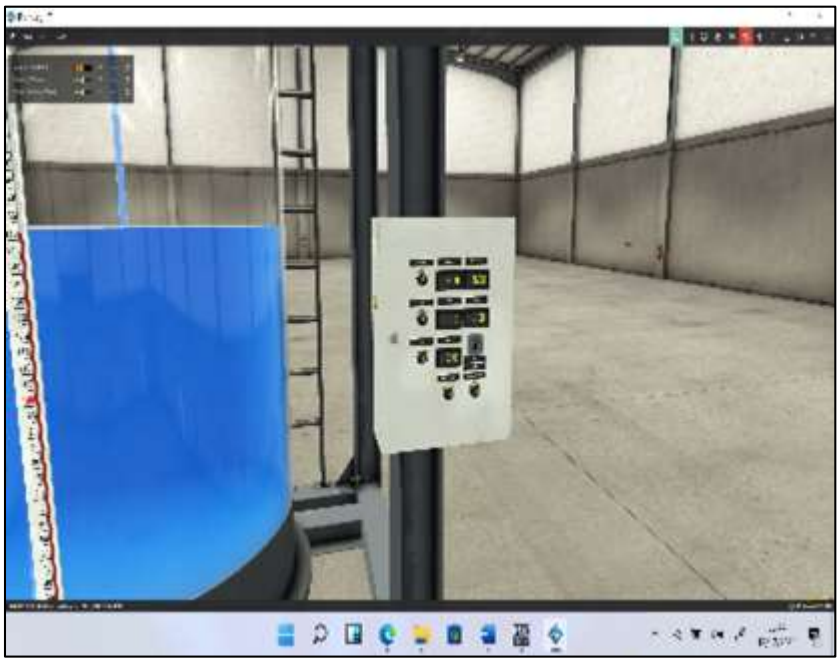

Figure 5 Level Process Simulation in Factory I/O

2. Discussion

Factory I/O is a virtual reality training simulator that can be used in almost and any industry to help train users in an immersive virtual environment. Students as well as professionals can use virtual simulation to Improve the learning experience and this is because the virtual reality simulator produces a near real-life situation, making the experience more engaging. The potential benefits of making available a whole factory I/O to engineering students from their first class is tremendous. Students can easily understand the motivations of the course contents, appreciate the limitations of simplistic solutions, and develop an interest in more sophisticated approaches. Students are able to acquire abilities in factory I/O that are difficult to practice in academic settings, like identifying or troubleshooting faults or recognizing the importance of having operational protocols that are well specified. Another benefit was that accidents and loss can be avoided with virtual graphics training compared to real time.

3. Conclusion

Due to technological advancement and industry 4.0; professional workers now require the ability to work with virtual graphic systems. Hence, the educational environment must adopt new teaching strategies. The use of simulation software in the classroom has the significant benefit of improving student learning through active participation. Factory I/O is one of the best virtual simulation software available for both training purposes and as a tool to asses various factory environments before implementing them in the real world. Factory I/O is user-friendly and appropriate for the PLC training field because it can be operated with only fundamental programming expertise. TIA Portal also has inbuilt control boxes and analog and digital inputs and outputs functions which offer better control over PLC functions.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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