Using Remote Laboratories for Education in Industrial Processes and Automation

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Abstract

The use of remote labs in education as a complement to traditional laboratories allows a better grasp of knowledge. This article discusses the advantages of using remote laboratories over traditional teaching practices to optimize the use of space and staff. It presents a case study of a PLC that can be accessed remotely via an Internet connection, solving problems of robustness, security of connection, and interactive presentation easily understood by the user with the integration of streaming video and virtual simulations.

Introduction

Distance education has evolved with the use of information and communications technologies, improving e-learning by implementing remote laboratories, which provide access to physical equipment for learning and experimentation. Such laboratories have a positive reception in teaching automation and industrial processes.

Using traditional hands-on laboratories in education allows students to have contact with real equipment, allowing better knowledge through interactivity achieved in these practical environments [1]. This shows it is easier for students to understand basic concepts by direct interaction than purely theoretical classes. However, space limitations, staff, and the amount of equipment in traditional laboratories prevent proper learning by students [2]. On the other hand, virtual laboratories and graphic simulations that do not require a physical space allow students to understand theoretical concepts of hard visualization or arduous implementation by complexity or size [3, 4]. However, virtual laboratories limit contact with the equipment, reducing the experimental component [5].

Remote laboratories complement distance education since they integrate the management and control of the physical equipment with the versatility and remote access of virtual laboratories [6], resolving the lack of studio equipment, time limitations, and the obligation to make unnecessary travel, promoting active learning [7]. From the academic point of view, the implementation of remote laboratories allows the students to devise their own questions and answer them through experimentation. Safety standards are presented by the platform to avoid dangerous mistakes or affect the equipment [8].

ISBN 978-1-60643-379-9

Remote laboratories have a common structure, consisting of a user interface to manage and visualize the physical environment, a server where the website and the database are stored, a laboratory server that is responsible for receiving and processing data from the equipment and run user actions, and the equipment to be controlled [9]. The implementation of these laboratories is a challenge in the design of the network architecture, due to the need for a robust platform that ensures remote access for students and integrates control and data acquisition [10].

Remote Laboratory Structure

The remote laboratory is composed of a system of production scale, controlled by a Siemens programmable logic controller (PLC) S7 300, an IP camera that focuses the system, a computer that works as a server and manages the access to the network, and a router to provide access from the Internet.

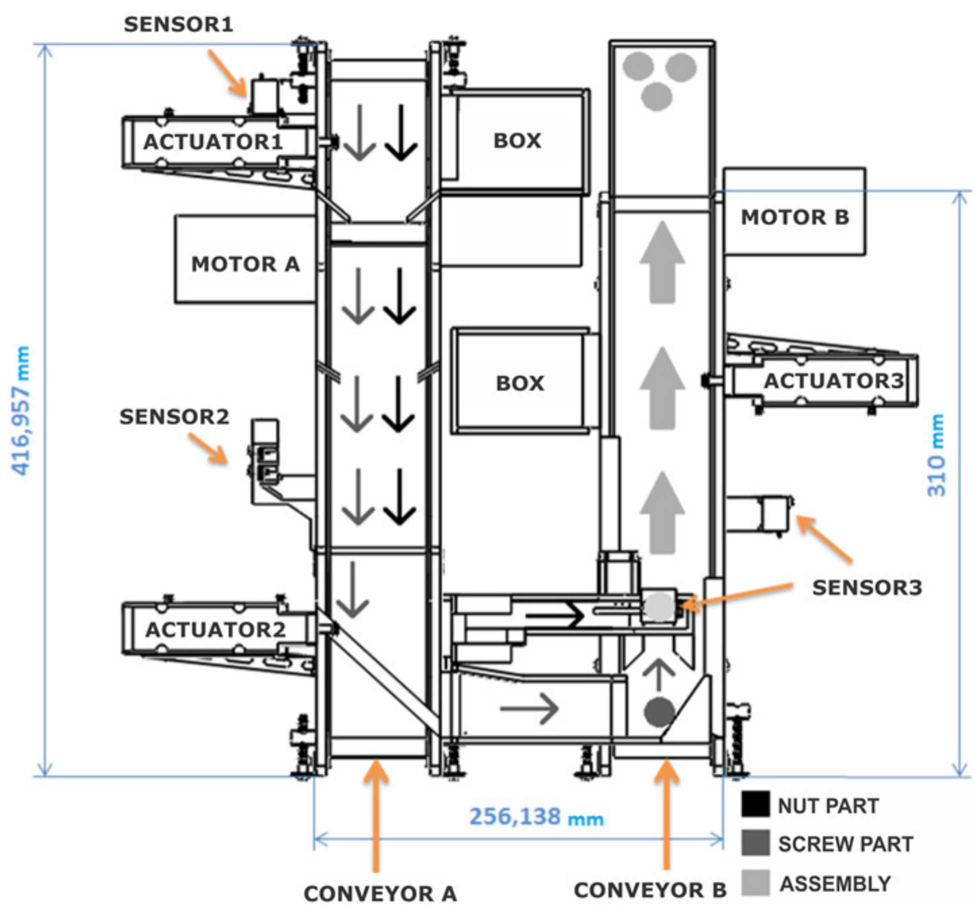

Figure 1. Assembly plant

The assembly plant scale is a teaching system consisting of conveyor belts driven by gearmotors, linear actuators, and proximity sensors that simulate an industrial assembly line.

Figure 1 shows a diagram of the system operation. Sensor 1 identifies the presence of material, actuator 1 places it in the beginning of the conveyor belts, conveyor A carries the individual parts of the assembly from the start line to the top, sensor 2 identifies the type of component, and actuator 2 guides it to the jointer section. Conveyor B carries the assembly to the end point, sensor 3 verifies that the assembly is correct, and the actuator 3 separates defective assemblies.

The system is controlled by a Siemens PLC S7 315F-2PN/DP with a digital input/output module 16DI/16DO, an analog input/output module 4AI/2AO, and an industrial Ethernet connection port that allows the PLC programming from Siemens TIA Portal software. The PLC is located in a frame, as shown in Figure 2, designed for easy transport and wiring. It has a SysLink connection that provides access to the input/output digital and analog modules in the PL. This bus is connected to the actuators and sensors of the assembly plant through a conditioning circuit, allowing a safe and fast connection.

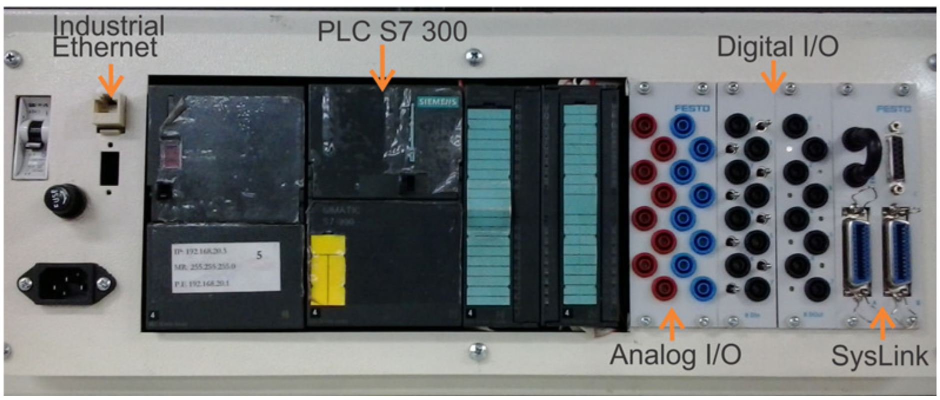

Figure 2. PLC s7 300 frame

The PC server is a bastion-host in dual-homed architecture, running Apache server, PHP interpreter, MySQL database engine, and OpenVPN server. It stores the website stored and is connected to a database to manage users, activities, and a reservation system. Students access the website through VPN to program the PLC from their own computers and see IP Camera images like they were in the same network.

The system of production scale is connected to the PLC via SysLink connection. The IP camera and the PLC are connected to the PC server through an access point, and the PC server is connected to the Internet through the router. Student access from the Internet to the website is stored in the PC server, which validates the username and password in the database. If this is correct, it modifies IPtables to redirect the user IP to the internal lab network and allows access to other network services (PLC and IP camera). Once finished, the session is closed, and the IP is removed from the list of allowed clients and waits for a new connection. Figure 3 shows the network for the remote laboratory.

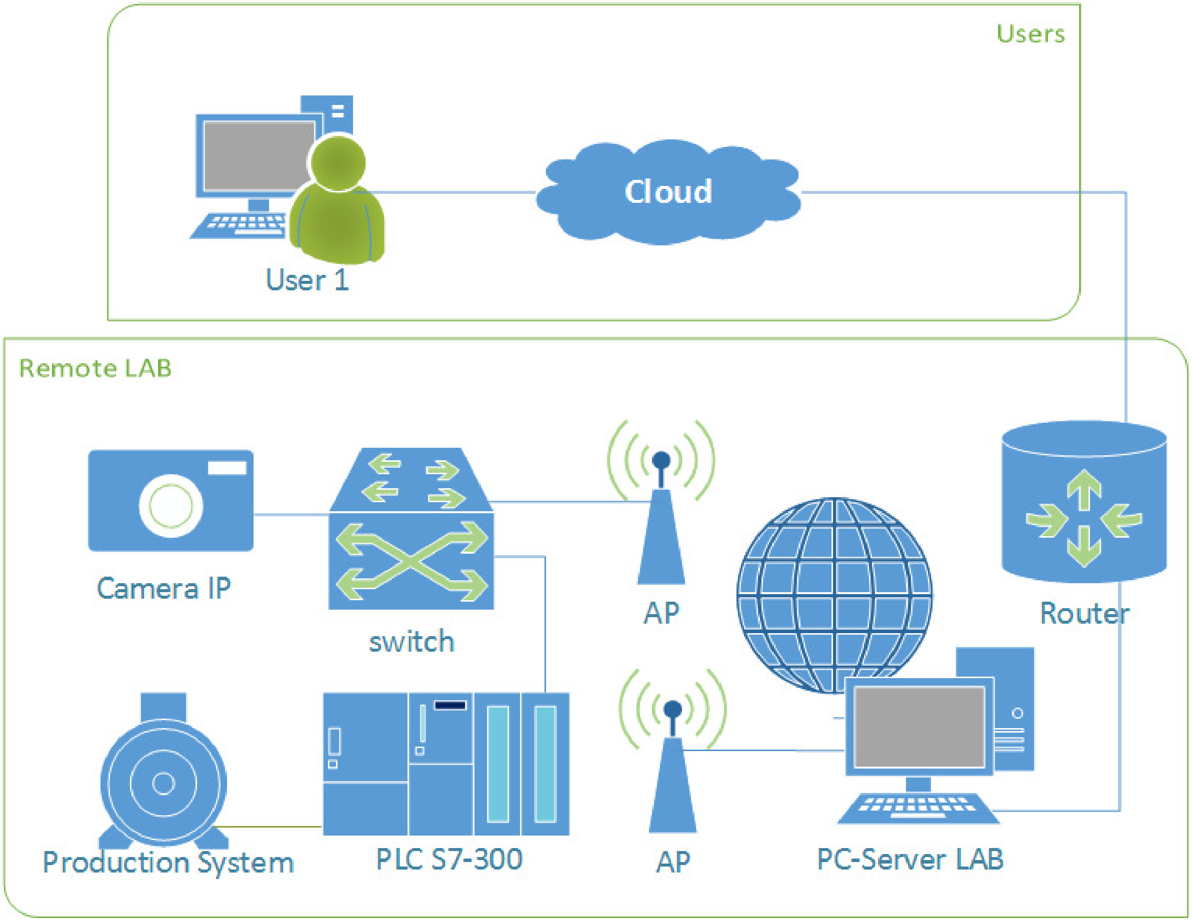

Figure 3. Network diagram

User Interface

Users only need a standard Web browser to access the lab because the GUI is a website developed with HTML5, CSS3, and JavaScript technologies. The website is designed to be intuitive and easy to understand. It has three pages with different functions: login, scheduling, video streaming, and learning. The login function allows students access by a user name and password, with a secure HTTP POST method over SSL protocol. The information is compared to the database; if it is correct, the student can access the contents of the pages. The home page has a scheduling function, a virtual calendar to check availability and to make system reservations. The laboratory page has the video streaming function from the IP camera (Figure 4). The UMNG page has the learning function. It shows a brief statement of the basic laboratory use and a table with the PLC inputs and outputs assignment. Along with the plant's actuators and sensors, it guides the student in basic subjects such as the connection to the TIA Portal and the creation of a new project.

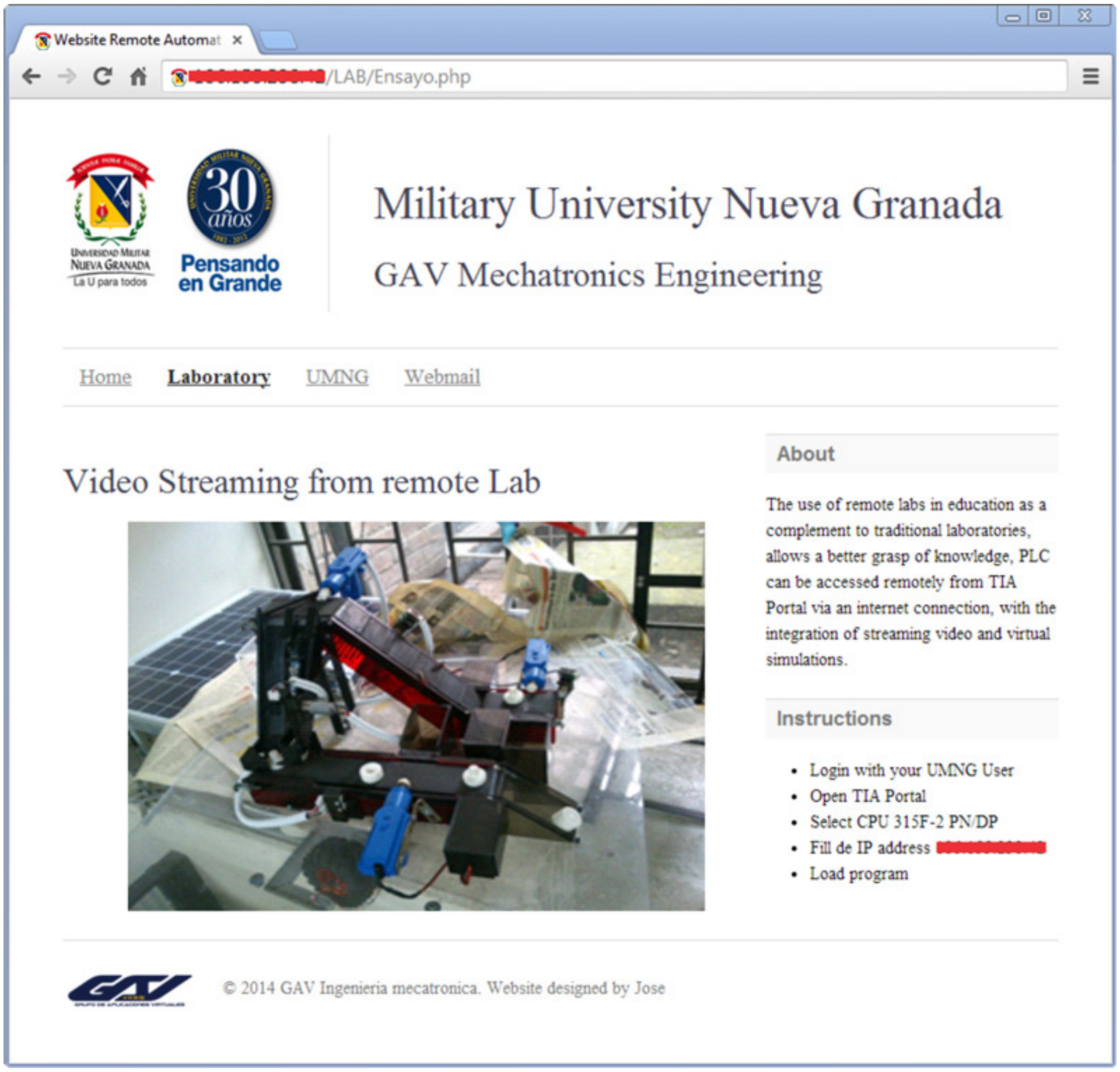

Figure 4. Website screen capture

To program the PLC, it is necessary install and connect to VPN client in the user's computer, create a new project in the TIA Portal, define the correct hardware to the specifications shown on the website, and set the PLC IP in the hardware manager, as shown in Figure 5. Once students have established the correct connection to the program and loaded the PLC configuration, they can develop their own programs, either by experimentation and validation of knowledge or as part of a practical exercise to perform outside the classroom.

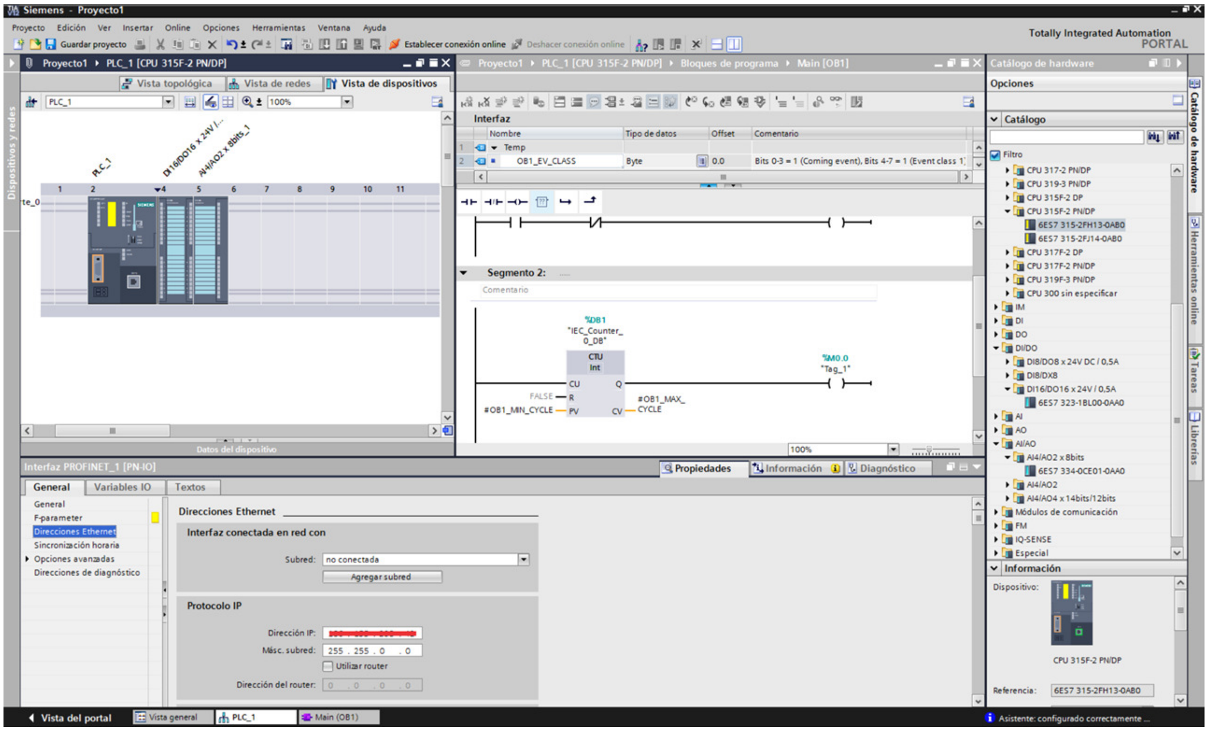

Figure 5. TIA Portal Project

Conclusion

The remote lab allows students to program the PLC from the comfort of any place they choose, in contrast to the physical laboratory, where they will be busy using different teaching materials. The video integration allows students to see their programs running, improving their motivation by avoiding the limitation that produces programmed actions in a virtual environment. With the use of a virtual tutor, the need of having a person to explain the system connections and its performance disappears.

With the use of the tools in the TIA Portal, students can remotely monitor the system with the creation of SCADA systems, allowing contact to real industrial environment and with it, increase the students' motivation and experience, providing tools that will be used in an industry working environment.

In future work, a 3-D vision system can be included to provide a more immersive experience for students. Also, the integration of other PLC models and other systems to control can be implemented, expanding the remote working network and distance-learning.

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