Borneo Engineering & Advanced Multidisciplinary International Journal (BEAM)
Volume 4, Special Issue (TECHON 2025), September 2025, Pages 24-29

Design of A Remote PLC Laboratory Using WECON V-Box and Modicon M221

Full Paper
Article history
Received
15 May 2025
Received in revised form
11 July 2025
Accepted
19 August 2025
Published online
30 September 2025

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Abstract

The evolution of Industry 4.0 has emphasized the need for practical, remote learning tools in technical and vocational education training (TVET). The limitation of the availability of physical lab infrastructure, high equipment costs, geographical or scheduling constraints often affected the delivery of hands-on Programmable Logic Controller (PLC) training. This paper presents the system design and development of a SmartLab infrastructure enabling remote access to a PLC laboratory. The focus is on establishing seamless communication between the Schneider Electric Modicon M221 PLC and a cloud-based remote access system using the Wecon V-Box. The methodology involved a structured four-phase process: system specification, cloud configuration, PLC and V-Box setup, and client-server integration with remote testing. The system architecture allows a user from a remote location to securely connect to the PLC, monitor input and output (I/O) states, and perform ladder logic programming using EcoStruxure Machine Expert. Functional validation included successful registration of the V-Box, consistent Internet Protocol (IP) communication, secure Virtual Private Network (VPN) tunnelling, and physical output control through remote ladder execution. The results demonstrated stable remote access with low latency, confirming the feasibility and scalability of the SmartLab setup. This approach supports flexible TVET delivery and can be replicated across institutions aiming to modernize industrial automation training. Future enhancements will focus on expanding multi-user capabilities, improving cybersecurity, and integrating additional industrial communication standards and mobile platforms.

Keywords: - TVET, remote access, remote lab, PLC

1. Introduction

The growth of Industry 4.0 has urged and contributed to the integration of digital learning technologies into Technical and Vocational Education and Training (TVET), particularly in the field of automation and control systems. One of the fundamental components in industrial automation is Programmable Logic Controllers (PLCs), where practical understanding is critical for TVET. However, according (Parua, 2023), the limitation of the availability of physical lab infrastructure, high equipment costs, geographical or scheduling constraints often affected the delivery of hands-on PLC training.

To address the growing need for accessible practical training in industrial automation and control systems, the development of remote lab referred to in this research as SmartLab has emerged as a promising educational innovation. SmartLab enables learners to interact with real industrial equipment remotely, thus overcoming barriers related to space, time, and cost typically associated with conventional lab-based learning.

The fundamental of this solution is the integration of virtualization tools such as VirtualBox with PLC systems. This setup allows for flexible network configurations that replicate industrial environments, while also ensuring secure, remote access to control and monitoring real hardware. By utilizing this technology, students gain hands-on experience in both simulated and actual PLC environments, enhancing their practical skills and familiarity with real-world industrial systems.

The value of this approach is well-supported in literature. (Mirzoev, 2014) emphasizes that virtualization supports scalable and remote access to IT infrastructures for educational use. Similarly, (Rao et al., 2012) highlight that cloud and virtualization technologies reduce costs and improve educational reach. (Lunsford, 2009) further underscores that repeatable and individualized practice through virtualized systems enhances learning outcomes and engagement in technical education.

2. Literature Review

Remote labs have increasingly emerged as a viable and effective alternative to conventional hands-on laboratory settings. According to (Heradio et al., 2016), remote labs offer real-time interaction with physical equipment over the internet, enhancing flexibility and accessibility in engineering education. Remote labs have been shown to enhance learning efficiency, promote self-directed learning, and minimize operational costs in engineering education (Almarshoud, 2011). In the field of automation, remote laboratories have demonstrated strong potential for replicating real-world industrial scenarios, thereby enabling students to acquire essential practical skills (Gomes & Bogosyan, 2009).

The development of the remote lab relies heavily on integrating a cloud-connected platform that enables users to remotely access and control PLC systems. This integration is essential for delivering flexible, scalable, and efficient learning and monitoring environments (Armbrust et al., 2010). Equally important are remote access technologies that provide secure, seamless, and real-time connectivity to industrial devices. For instance, Virtual Private Networks (VPNs) emulate a local area network (LAN) over the internet, allowing PLCs to be accessed using their local IP addresses while ensuring secure data transmission (Tzounis et al., 2017).

This architectural approach enables remote labs to preserve the technical fidelity and interactivity of conventional hands-on labs while addressing geographic and infrastructure-related barriers. The integration of cloud-hosted environments with secure remote access technologies forms a core foundation of modern remote lab systems, supporting scalable, flexible, and inclusive engineering education (Heradio et al., 2016).

In summary, this paper proposes a phased implementation that integrates cloud infrastructure and secure remote access technologies as essential components for establishing a functional and scalable remote lab system, referred to as SmartLab.

3. Methodology

The architecture of the proposed SmartLab remote access system is shown in Fig. 1. The methodology consisted of four key phases: (1) System Specification, (2) Cloud Configuration via Wecon V-NET Access Platform, (3) PLC and V-Box Configuration and (4) Client-Server Integration and Remote Testing. Each phase involved critical interactions between devices and software systems to ensure reliable SmartLab functionality.

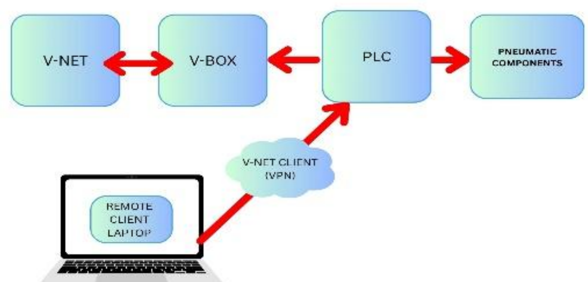

Fig. 1: Architecture of the SmartLab remote access system

3.1 System Specification

The main hardware and software components required for this paper include PLC, remote access gateway, EcoStruxure Machine Expert as a programming platform and cloud client. The PLC used in this design is Schneider Electric Modicon M221 (TM221CE24R), with 14 inputs and 10 relay outputs. Wecon V-Box, as a remote access gateway, is used to simulate complete laboratory setups—such as PLC programming environments, SCADA systems, or HMI applications—without the need for physical hardware and Wecon VPN (WVPN) serves as a cloud client to host lab environments and manage device connectivity. Table 1 summarizes the functional differences among three key software tools used in the configuration and operation of the SmartLab remote access system: V-NET Access and WVPN.

Table 1: Differences between two software tools used in the SmartLab remote access system

Tool	Main Role	Installed on	Usage stage	Key features
V-NET Access	V-Box setup and registration	Local PC (LAN to V-Box)	During initial setup	Device binding and static IP config
WVPN	Advanced/alternative VPN access	Remote PC/Laptop	During remote access	Manual VPN tunnel management

3.2 Cloud Configuration via Wecon V-NET Access Platform

To start V-Box a microUSB cable, 24 VDC power supply unit and an internet connection and a web browser are required. First, V-Box is powered up with a 24 VDC power supply unit and installed with an antenna. For 4G models, sim card is installed prior to performing the earlier steps. After a Wecon account is registered, the latest version of V-NET Access PC software is downloaded and installed. Network configuration is performed after the V-Box successfully detected in the V-NET Access platform as shown in Fig. 2. The V-Box was first registered under a V-NET account and initialized using the V-NET Access application on a local PC.

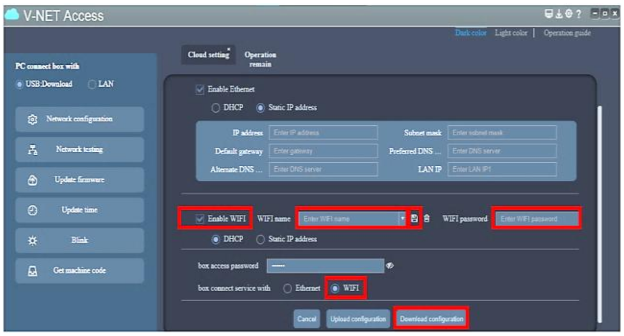

Fig. 2: V-Box network configuration via V-NET Access

3.3 PLC and V-Box Configuration

A structured configuration process is carried out between PLC and V-Box remote gateway to enable remote interaction within the SmartLab setup. On the V-NET Access platform, communication port for PLC, COM1, type of PLC which is Modicon and communication protocol are selected as shown in Fig. 3. The configuration between PLC and V-Box is shown in the Communication tab as depicted in Fig. 4. The PLC's local IP address was configured to match the subnet used by the V-Box, allowing consistent connectivity to be achieved. Real-time data points were defined by assigning internal word or bit addresses for monitoring and control of digital I/O states. Features such as alarm setup, group-based data organization, and historical data logging can be utilized to enhance feedback and ensure data integrity.

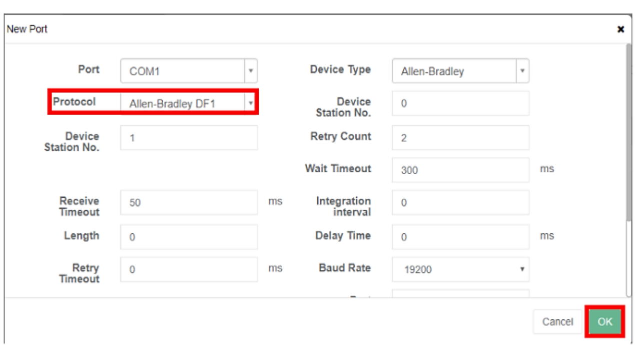

Fig. 3: PLC communication configuration

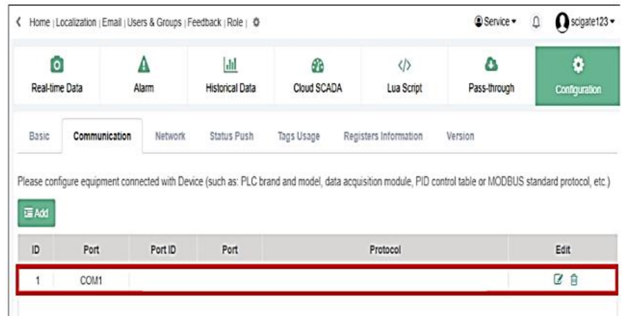

Fig. 4: Configuration between PLC and V-Box

3.3 Client-Server Integration and Remote Testing

PLC is connected to V-Box prior in performing client-server integration. The latest version of WVPN tool is downloaded and installed to a client-server PC. WVPN tool is logged in using the username and password of the registered V-Box as shown in Fig. 5. Once logged in, all the devices that were registered to this account appear on the interface as shown in Fig. 6. At this stage, the V-Box device is selected, and the advanced settings menu is accessed. Within this configuration, a static IP address is assigned to the PC to ensure consistent network identification. It is essential that both the PC and the V-Box are configured within the same subnet to facilitate proper communication. Finally, a VPN connection is established by right-clicking on the V-Box icon and selecting the "Connect" option.

When a VPN connection is established, the Status tab will show "VPN connected" as shown in Fig. 7. The connection between client-server PC and V-Box is tested by pinging the static IP address. The remote connection is tested by using EcoStruxure software where a simple ladder diagram is constructed to turn on a green indicator lamp (output) which is connected to one of the PLC outputs. Fig. 8 displays the physical setup, where a PLC is connected to a V-Box and a laptop running EcoStruxure Machine Expert – Basic.

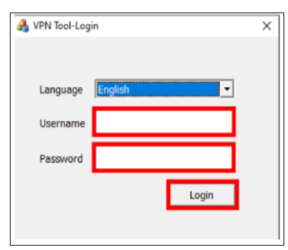

Fig. 5: VPN login

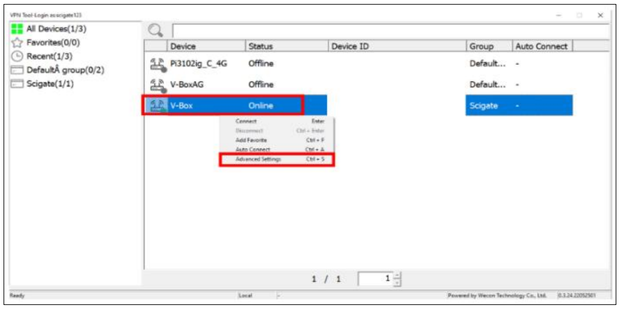

Fig. 6: Interface shows devices registered to the account

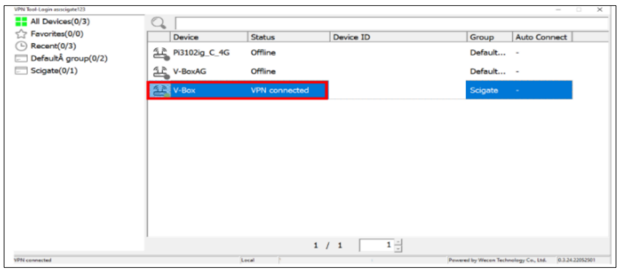

Fig. 7: Interface shows VPN is connected

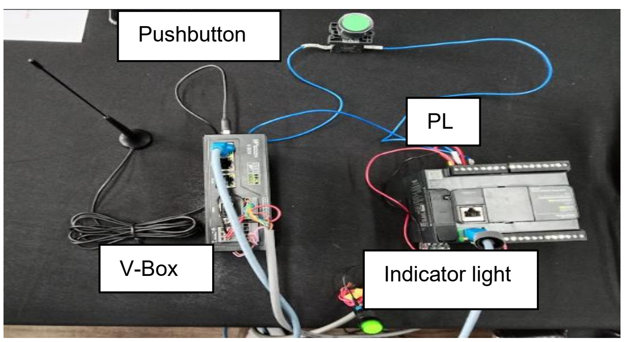

Fig. 8: V-Box and PLC connection

4. Result and Discussion

This study successfully established a functional remote lab environment through the integration of a Schneider Electric Modicon M221 programmable logic controller (PLC) with a V-Box device using the V-NET platform. The system was evaluated based on connectivity and the stability of remote access via virtual private network (VPN). Table 2 outlines the step-by-step process undertaken to establish a functional remote lab system for remote PLC access. Each row in the table represents a crucial development phase involving interactions between hardware devices, cloud platforms and software tools.

The configuration process was implemented using V-NET Access platform to register and initialize the V-Box, assign a static IP to the Modicon M221 PLC, and define appropriate communication protocols. IP address consistency between the PLC and V-Box ensured that they operated within the same subnet, which was critical for maintaining stable communication. Real-time data points were successfully mapped to PLC inputs and outputs, providing the foundation for remote monitoring and control. The WVPN enabled secure VPN connections from remote computers.

Table 2: Interaction flow

Interaction Step	Devices/Tools Involved	Action
Device Wiring and IP Setup	Modicon M221, V-Box	Connect devices, assign IP addresses
Cloud Registration	Wecon V-NET Web Portal	Register V-Box, link PLC via IP, configure protocols
Remote Access Simulation	V-NET Access, EcoStruxure, VirtualBox	Connect from remote environment, program PLC remotely
VPN Tunneling and Security Testing	Wecon VPN (WVPN)	Configure secure tunnels and test data integrity

Fig. 9 shows an outcome in the V-NET Access platform, confirming that a V-Box device has been properly added and registered to a user account. On the left panel, under the "Default group," the green icon next to V-BoxAIG indicates that the device is online and actively connected to the cloud server. This status confirms that the V-Box has been correctly configured, assigned to a group, and is ready for remote communication with the connected PLC.

Fig. 9: Confirmation of V-Box device registration in V-NET access dashboard

The successful configuration of the PLC with the V-Box demonstrates the feasibility of enabling secure remote interaction within the SmartLab environment. As shown in Fig. 10, the communication port COM1 was correctly identified and assigned for PLC communication, with the appropriate protocol and device type (Modicon) configured through the V-NET Access platform.

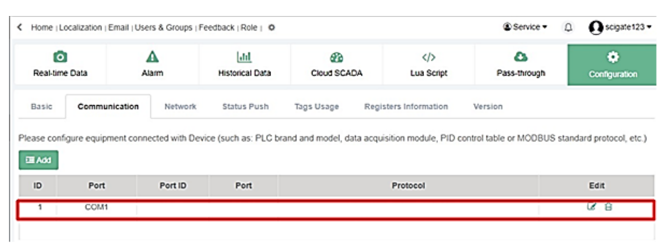

Fig. 10: Interface of successful communication configuration between PLC and V-Box

These connections successfully established virtual local area networks (LANs), allowing Schneider's EcoStruxure

Machine Expert – Basic to interface with the PLC as though it were on the same physical network. Latency measurements averaged below 475 milliseconds during multiple remote programming sessions as shown on Fig. 11.

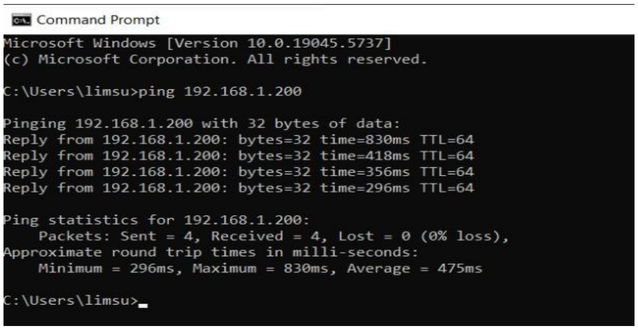

Fig. 11: Result of ping test

The devices will now be accessible, allowing the EcoStruxure software on the client laptop to perform remote programming and real-time monitoring. Fig. 12 and Fig. 13 demonstrate that software logic successfully controls physical output.

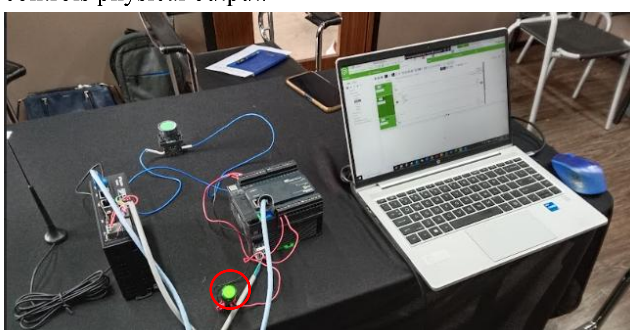

Fig. 12: Green indicator light is turned ON

Fig. 13: Simulation shows green indicator light is turned ON

The role of differentiation among the Wecon tools was instrumental in streamlining the SmartLab deployment. V-NET Access served as a setup and device binding utility, and the WVPN provided remote access through VPN support. The successful integration of these tools not only supported seamless connectivity for the remote lab but also reduced the technical learning curve for TVET facilitators.

Overall, the integration of the PLC with the V-Box and V-NET system provides a secure, flexible, and scalable infrastructure for remote lab applications. The configuration enables remote access to industrial hardware, supporting digital transformation in TVET. These results suggest strong potential for widespread adoption in TVET environments, particularly where remote access and cloud-based control of automation systems are necessary.

Recent studies have explored various remote PLC lab configurations, but few have achieved the level of integration and ease-of-use demonstrated in this study. A technical article by (Wilcher, 2024) demonstrated how Raspberry Pi could be used as a PLC using OpenPLC. Although it enabled ladder logic programming and remote access, the system lacked industrial-grade robustness and required manual configuration of runtime parameters and GPIO libraries, making it less user-friendly and secure for educational or industrial deployment. A 2021 survey discussed using Raspberry Pi as a soft PLC in SCADA systems. It emphasized the limitations in processing power, industrial compatibility, and long-term reliability compared to commercial PLCs (Bidyanath, 2021). These studies contrast with your system's use of Schneider Electric's Modicon M221 PLC and EcoStruxure software, which offer industrial-grade reliability, built-in support for standard protocols, secure VPN access via WVPN, simplified configuration through V-NET Access, direct PLC programming and control, which is more aligned with hands-on automation training.

4. Conclusion and Recommendations

The remote lab setup with PLC and V-Box offers a scalable and secure platform for remote PLC access and TVET education. The combination of cloud-based V-Box services and VPN technology enables students to interact with real hardware from anywhere, promoting flexibility in technical training. This setup can be replicated across TVET institutions to modernize PLC education. This study has successfully demonstrated the integration of a PLC with a V-Box gateway as part of a remote-accessible SmartLab system. By utilizing the V-NET Access and WVPN, the PLC was securely connected to a cloud-based infrastructure, enabling remote programming, monitoring, and control. The configuration process, which included static IP assignment, ladder logic development in EcoStruxure Machine Expert – Basic, and VPN connectivity via WVPN, was effectively executed and validated. The system functioned reliably, with successful communication between the V-Box and the PLC, and physical outputs accurately reflecting control logic in real time. The SmartLab setup was further tested in a virtualized environment using V-Box, confirming its scalability and compatibility with remote learning platforms. The interface of V-NET Access also provided clear status monitoring, confirming the successful registration and connectivity of the V-Box device. Together, these findings indicate that the proposed system is not only technically feasible but also educationally relevant for TVET institutions. Based on the outcomes of this research, it is recommended that SmartLab systems be adopted to support flexible, remote-access PLC training. SmartLab enables students and instructors to interact with real industrial hardware regardless of physical location, which is especially beneficial in hybrid or distance learning environments. Future work should explore multi-user access management, cybersecurity protocols, and the integration of additional industrial communication standards to enhance robustness and scalability. Expanding the system to accommodate mobile applications or IoT-based dashboards could further enrich the user experience and align with emerging Industry 4.0 practices.

Acknowledgement: This research is fully supported by Dana Trans-Tech 4 TVET for TVET Applied Research Grant Scheme. The authors fully acknowledged Ministry of Higher Education (MOHE) and Pusat Penyelidikan dan Inovasi, Jabatan Pendidikan Politeknik dan Kolej Komuniti for the approved fund which makes this important research viable and effective.

Author Contributions: The research study was carried out successfully with contributions from all authors.

Conflicts of Interest: The authors declare no conflict of interest.

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