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Wireless SCADA for Remote Industrial Monitoring using NI-MyRio Labview and Grafana

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Abstract

SCADA controls are limited by how much scholarship can be done with them, due to the high price and proprietary nature of these industrial monitoring systems. In this paper, we present an inexpensive wireless SCADA architecture for remotely obtaining levels within a PLC managed level station to be integrated with an NI myRIO from national instruments. The data from the process will be stored in real time using LabVIEW; this data will also be used to create a living excel dataset that can easily be moved between lab environments and into other systems for analysis and export. The final platform for this developed system is an Intel UP Squared embedded computer that runs Windows 10. Using this device we will run Grafana to create a dashboard that allows access to all historical data, as well as access to live trend information. Additionally, by using wireless communication we reduce installation complexity and provide the ability to access systems remotely in mobile devices as well using IOT. The proposed method eliminates the need for traditional SCADA control programs which allow for increased customization, scalability, and cost savings in the industrial monitoring and educational training environments. The experimental analysis shows successful transmission of data as well as the ability to obtain stable real time data with low latency and present this data in an efficient dashboard format, validating the effectiveness of the currently proposed architecture in automation/industrial settings and in academic laboratories.

Keywords: Supervisory Control And Data Acquisition (SCADA), Industrial Process Monitoring, Level Process Station, National Instruments-NI myRIO, LabVIEW, Grafana Dashboard, Programmable Logic Controller(PLC), Remote Monitoring, Industrial Automation, Embedded Systems, Liquid Level Monitoring(LLM), Open source(OS), Analog Input Module(AIM).

1. Introduction

In continuous process production, critical process variable (Liquid Level, Pressure, Temperature, etc.) must be continuously monitored to ensure operational safety, energy efficiency and quality of the product. LLM is essential in preventing overflow conditions, damage to equipment, and interruptions in production. Because they are robust, dependable, and offer deterministic performance, PLC's are used extensively in industrial applications for real time control. In most cases PLC's are supported with SCADA systems to allow for supervisory monitoring, data logging, alarm management, operator visualization, etc. However, commercial SCADA systems tend to be associated with high licensing and maintenance costs, reliance on a specific vendor for support, limited opportunity for growth/scalability and very little flexibility; therefore, commercial SCADA systems are not generally designed to be utilized by academic institutions, pilot plants and/or small industries.

The growing availability of embedded real-time controllers and wireless communications technology combined with the development of OS visualisation platforms has presented an opportunity for the creation of new alternative SCADA systems that offer flexible options at a low cost. For example, NI myRIO provides real-time data acquisition and processing, as well as wireless communications, making it an ideal controller for both industrial monitoring and educational uses. Another recent example of an OS visualisation tool is Grafana, which can be used to visualise real-time dashboard displays, analyse data historically and to provide users with a large amount of flexibility in its configuration. The purpose of this paper is to present a wireless SCADA solution that consists of a PLC-controlled level process station integrated with the NI myRIO controller and Grafana-based visualisation platform. The proposed architecture will enable users to remotely monitor the level of their process in near real-time, collect and log data from their process while also using the OS solution to provide users with options to create their own visualisations and use them as they please. The proposed architecture, through the adoption of open technologies, allows for improving the scalability of SCADA solutions, significantly reduces the costs associated with the implementation of SCADA solutions and provides users with access to SCADA for industrial automation applications and academic laboratories.

1.1. Major Contributions

- The Wireless SCADA architecture is based on the integration of a PLC controlled level process station and NI's myRIO embedded real-time controller. The PLC carries out the main control functions of the SCADA System, while MyRIO is used for the acquisition of data, as well as communication. With wireless connectivity, it is possible to remotely monitor the SCADA System, greatly reduce the amount of hard-wiring required, and create greater flexibility to install the SCADA System either in an industrial environment or an academic environment.
- A standardized protocol is used to achieve consistency and reliability between the PLC and MYRIO controller when using Modbus communication. By implementing this standard, manufacturers can ensure their devices are compatible with each other regardless of manufacturer or type; thus, by using Modbus, the integration of various types of sensors and actuators will remain seamless while providing for deterministic delivery of data.
- Using LabVIEW for data handling, real-time data processing results are continuously recorded into dynamically-created Excel files as they are created. This is an effective way of storing and maintaining data that is easily accessible for performing different types of analyses, reporting on results, and combining data with other types of analytic tools from other companies. There is no need to purchase and install complex database applications.
- The Intel UP Square embedded computer platform which runs on Windows 10 is the host for a Grafana Dashboard. The dashboard allows operators to view their processes in real-time, track trends over time, and review their past data via a web-based interface that enables operators to access their process information remotely with any internet-connected device.

- The use of open-source visualization tools and embedded hardware in lieu of proprietary SCADA platforms greatly reduce the costs of both implementation and licensing. In addition to these benefits, the architecture offers a flexible, customizable, and scalable solution for small industries, research labs, and educational institutions.

2. Literature Review

PLCs are still used for industrial controllers because they offer high reliability, their performance is consistent and predictable. Clarke's research on PLC-based automation systems shows the strengths and weaknesses of traditional PLC architecture including limited flexibility and reliance on proprietary supervisory platforms when interfaced to traditional SCADA systems. As a result these limitations have stimulated the pursuit of open and interoperable industrial monitoring solutions. Communication protocols used for industrial applications are essential for enabling inter-operation between systems. Researchers Jain and others have examined the potential use of the Modbus communication protocol within industry settings and found that, as an easy-to-use communication protocol that allows for the sharing of information between PLCs and devices that monitor the condition of those PLCs, it provides an effective method for reliably transferring data from one location to the other. As such, this confirms that Modbus maintains its position among the most commonly used protocols because it is easy to use and robust, and it can be used with many different vendors; therefore it is well-suited for organizations looking to build scalable monitoring architectures.

Over time, a number of recent studies have focused on modern visualization technology as a means of monitoring industrial processes. Reports prepared by Kumar and others, using Grafana for creating dashboards to visualize industrial data, show how Grafana can be used to view both real-time data and historical data. Their work focused on the ability of Grafana to provide a dashboard for monitoring purposes in a general sense. There remains an opportunity to integrate Grafana into more robust applications within actual industrial settings and environments that utilize PLCs to control processes. Additionally, Wollschlaeger and others have discussed the trend toward using Ethernet-based communication as a method of enabling a greater number of industrial applications, as well as the increased use of IoT technology for connecting industrial automation systems within an organization. Research and reviews conducted by Xu et al. have focused on how IIoT devices and data-based approach will improve productivity in an organization through connected device technology and data accessibility for real-time monitoring of productivity. Willig has also looked at how wireless communications can be used in an organization. Willig linked wireless connectivity to industrial flexibility and also as a resource for enabling flexible, remote management of your business. The work of Ferrari et al. and Karnouskos evidence through research on the growing importance of cyber-physical systems and smart factories for obtaining and displaying realtime data to support production management activities. In conclusion, it is apparent from the findings of these studies that there is a significant gap in research regarding the creation of affordable, open and wireless SCADA solutions that will connect PLCs with modern data visualization platforms. The purpose of this paper is to create new SCADA solutions that meet this gap.

2.1. Problem Statement

The manufacturing and processing sectors of Industry are increasingly seeing the need for continuous, accurate, third-party-based measurement of liquid levels (the main critical process parameter) to increase operational safety and efficiency. Even though PLCs are typically utilized for control and automation, conventional SCADA systems (utilized for supervisory monitoring) are typically costly, highly proprietary and scale poorly, particularly with regard to smaller operations such as colleges and universities as well as small-workforce manufacturers. Conventional SCADA systems often have large licensing fees, vendor lock-in and limited flexibility for personalized use and access from remote locations. The increased demand for remote and/or wireless monitoring and the ability to view data has created a need for a very low-cost, open-source and scalable SCADA solution that could utilize existing industrial control hardware interfaced with newer contemporary visualization platform technology without using conventional (i.e., proprietary) SCADA software.

3. System Model and Architure

The five-layer architecture as shown in Figure 1 of the proposed monitoring and control system allows for real-time observation of operations at the manufacturing level through the reliable and interoperable relationship of these five layers. The modularity of this architecture significantly increases the capacity to expand the system and allows it to be easily integrated into existing processes or systems within both the industrial and academic sectors. The Process Layer, which is the basic layer of the entire monitoring and control system, consists of a Level Sensor and a Tank for collecting and storing the tank contents. The Level Sensor produces a continuous electrical output signal indicating the height of the liquid within the tank, which represents the primary process variable of this monitoring and control system to provide input to the Control Layer. The Control Layer is made up of the Delta PLC, which is responsible for controlling and processing the signals in real-time. The Control Layer receives an input signal from the Level Sensor in either an analog or digital format, applies the necessary scaling, filtering, and control algorithms to the incoming signal and keeps the process operating in a stable state.

The Control Layer also serves as a communication link between the field devices and the upper-level monitoring systems. The Data Acquisition Layer implements an NI myRIO embedded real-time controller that consumes PLC process data through Modbus RTU over an RS-485 bus. This standardized industrial protocol allows for reliable, repeatable, and guaranteed transmission of data between different kinds of equipment. The Data Management Layer functions primarily in the area of data storage and organization. LabVIEW logs the processed information supplied by myRIO into a continually live Excel file. This allows for well-structured, reproducible, and compatible data storage options when interfaced with third-party analytic and visualization products. The Visualization Layer consists of an Intel UP Squared embedded system with the Windows 10 operating system, running Grafana as the dashboard system as shown in Figure 1. The Intel UP Squared reads the live data from the Excel document and displays the live data in real time on dashboards, as well as rendering graphical representations of trends and historical activity via a web-based interface. As a result, the layered architecture ensures complete transparency and integrity throughout the entire process of transferring raw data from the sensor through to the dashboard and has the potential to grow into a scalable remote monitoring system over time.

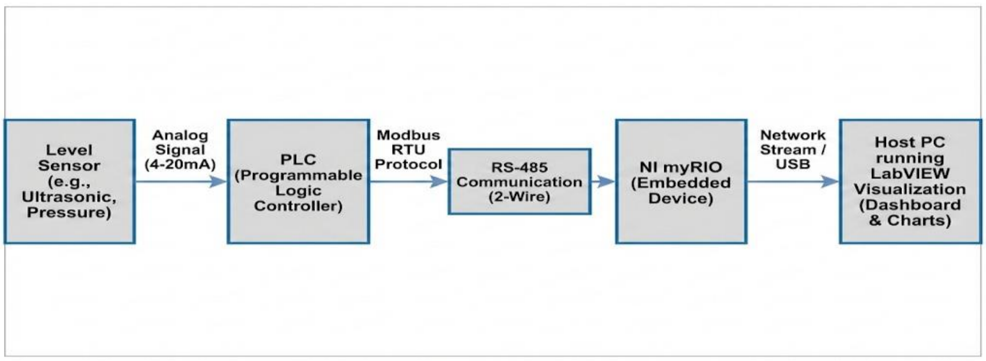

Figure. 1. System Architecture for Wireless SCADA-PLC-MyRio

4. Proposed Methodology

Initial step is to set up the PLC to receive data from the level sensors and save it to its internal memory. The analog output signal from the level sensor is inputted into the AIM of the PLC, where it is converted from an analog to a digital value. The raw measurement from the AIM is then scaled within the PLC program based on engineering units (such as percentages or the actual liquid height). To keep the data continuously updated, the PLC program will map the scaled measurement to designated holding registers that function as an interface for communicating with any external devices monitoring the liquid levels. Therefore, the proper mapping of the registers helps provide consistent data to support communication protocols (e.g., Modbus). Furthermore, the PLC refreshes the holding register values in a cyclic manner so that it can provide real-time and deterministic data access and reliable process control.

The PLC and myRIO are both equipped with RS-485 communication that uses Modbus RTU protocol to communicate, which is a common protocol used in industrial facilities as a result of being simple to use and highly reliable. In this case, the myRIO acts as a Modbus Master and the PLC acts as a Modbus Slave. In addition, the holding registers on the PLC hold Predefined data associated with the level of material within the tank (level data). To ensure that both the myRIO and PLC can communicate effectively and without error, we set the same communication parameters on both devices: These parameters included baud rate; parity; stop bits, and slave identification number. As a result, the myRIO is able to communicate with the PLC effectively due to the benefits of noise immunity and long distances provided by RS-485 communications as shown in Figure 1. The myRIO is able to periodically poll the holding registers of the PLC for the updated process variables. Also, the use of Modbus RTU ensures interoperability with future expansions of the system with additional industrial devices.

An application based on LabVIEW was designed for the myRIO development platform that allows for managing real-time collection of data from an industrial programmable controller (PLC). The LabVIEW application uses Modbus protocol communication blocks to read the registers of the PLC's holding register every fixed period of time. Real-time data collection is accomplished using a deterministic loop structure to minimize latency and provide stable, consistent collection times. Collected level data have been validated, scaled, and formatted for future usage using LabVIEW. Communication error detection and invalid data detection within the LabVIEW application were included. LabVIEW's Graphical Programming Environment facilitates system integration and provides ease of change to the acquisition logic. The layer of real-time data collection will facilitate the interface between industrial control hardware and the levels of data aggregation and visualization.

Using the file management and reporting features of LabVIEW, the collected performance measure data is stored in an ever-increasing Excel spreadsheet. Each individual piece of collected data includes a date/time stamp and can be continually added to the existing Excel spreadsheet as it is collected. Thus, a structured set of data is created that can be used for analysis, data visualization, and further analysis. This allows data to be readily available for analysis without the requirement for complicated database management systems while still being compatible with various commonly used data analysis tools. The live Excel spreadsheet serves as a lightweight data repository that can be easily accessed by both locally and remotely operated computer applications. Access to the Excel file is controlled to ensure that data is not lost as new data is continually added. This simple yet efficacious means of recording real-time data logging is especially advantageous for use in either a training environment or a small-scale industrial setting.

The Intel UP Squared platform has Grafana configured in such a way as to pull data from either an active Excel file or an intermediary converted data source. The proper methods of data parsing have been implemented to ensure that level and timestamp values are extracted using the best means possible. In addition, custom panels within Grafana's dashboard have been created that show the current level of trends and data from a historical perspective, as well as system status. The way that Grafana allows users to customize the configuration of their panels also makes it easy for operators to see alerts, graphs, and gauges at a glance. Refresh rates on each panel have also been adjusted to allow users to get visual data in almost real time but will not put too much pressure on the overall system. This provides an easy-to-use and interactive dashboard that will allow users to monitor and analyze the status of their current process, thereby improving overall efficiency by quickly detecting abnormalities and trends associated with their processes.

A combination of an Intel UP Squared embedded system (that is connected to a network) and the hosting of the Grafana dashboard over the same network allows users to gain wireless remote access to their dashboards. Users can access their dashboard through a standard web browser using the public IP address of the UP Squared system and can view their dashboard on many different types of devices including laptops, tablets and smartphones. To protect against unauthorized access to the dashboard, network security measures (such as firewall rules, etc.)

and user authentication has been implemented. One of the benefits of utilizing a wireless connection is that it decreases the need for cumbersome wiring and increases the overall flexibility of the system, particularly in a distributed environment. This wireless capability provides operators and instructors with the ability to monitor the system from anywhere in real-time, thereby providing increased usability of the system and enabling remote supervision, training, and diagnostics.

5. Result and Discussion

The wireless supervisory control and data acquisition system (SCADA) that the authors developed was able to acquire, transmit, and provide instantaneous (near real-time) level readings from a process station while demonstrating how effectively the system architecture was constructed as shown in Figure 2. By incorporating a programmable logic controller (PLC), a National Instruments (NI) myRIO, and Grafana, the data was able to flow smoothly from the field level to the visualization layer. While the SCADA system operated continuously, the communication via the RS-485 Modbus link remained stable, with no loss of data and no interruptions to communication observed throughout the testing, illustrating that the SCADA framework is easily integrated into many different types of applications. The real-time acquisition of level data via the myRIO and LabVIEW environment provided for deterministic and repeatable sampling of the level signal. All data collected was automatically entered to an Excel file with date and time stamps, so that the level data could be continuously updated while maintaining structure, which allowed both real-time visualization and historical analysis using Excel, thereby eliminating the need for complex database management. Furthermore, wireless communication enabled the SCADA system to be easily deployed in locations remote from the user while maintaining system reliability and performance. The dashboard created with Grafana for this SCADA project provides greatly improved visibility into level trends with interactive graphical displays and gauges as shown in Figure 2. The Grafana-based visualization provided a much more intuitive way for the user to analyze real-time information and understand the system's performance in comparison to traditional human-machine interface (HMI) panels where users typically are unable to analyze dynamic trends, zoom in or out on the data, or obtain historical context. Operators were able to quickly assess both the varying levels of the equipment as well as any abnormalities, and trends over time collected through the systems were available through remote access via both web and mobile device as shown in Figure 4 formats which demonstrates that this application has the ability to facilitate distributed supervision. All evidence indicates that the developed wireless SCADA solution provides an accurate, dependable, and economical means of performing real-time monitoring of industries and educational applications as shown in Figure 3.

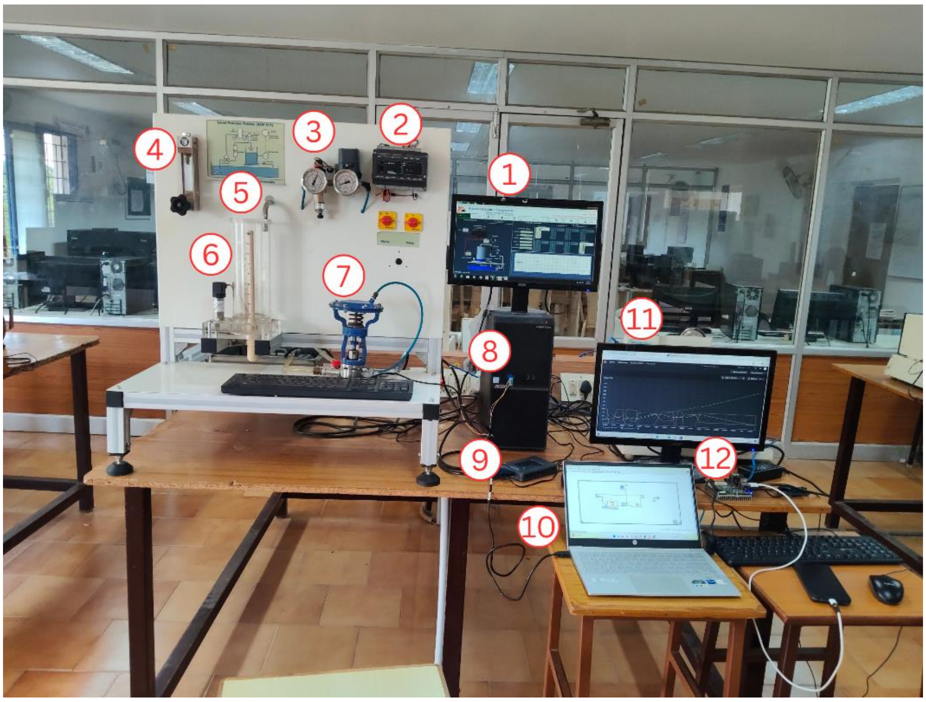

Figure.2. Connection diagram

1- PC for PLC(ACE), 2 - Delta PLC, 3 - Air regulator, 4 - Rotameter, 5 - Tank, 6 - Ultra sonic transmitter, 7 - Pneumatic actuator, 8 - RS485 to USB convertor, 9 - NI-MyRio kit, 10 - MyRio coding, 11 - Intel Upsquared display, 12 - Intel Upsquared kit.

6. Conclusion

The proposed wireless SCADA system provides an economical and efficient alternative to traditional proprietary SCADA solutions typically used in industrial settings. By combining a PLC-based control system with NI myRIO embedded controllers along with using the open-source Grafana platform for data visualization, this system is capable of providing reliable real-time monitoring and visualizing data without requiring expensive proprietary SCADA software licensing. By having a layered architecture, the system provides an uninterrupted flow of data from the process level through to the supervisory level while providing deterministic performance and stable communication. Modbus RTU communications allows for interoperability between various industrial devices, whereas LabVIEW-based data acquisition systems and logging to Microsoft Excel provide a simple and efficient means of managing collected data. Enhancing situational awareness is possible via Grafana dashboards as shown in

Figure 3, which enable both dynamically visualising current trends and analysing historical data, in addition to adding web/ mobile-based as shown in Figure 4 access points to the installations, thereby enhancing their flexibility and usability in distributed and educational environments. In conclusion, the proposed SCADA system offers an ideal solution for integrating with industrial training laboratories, as well as research facilities and small-scale industrial applications due to the importance of cost-effectiveness, scalability, and customisation. Therefore, as demonstrated in this study, there is sufficient evidence to support that open and embedded technologies are likely to serve effectively as replacements for conventional SCADA systems while maintaining equivalent or superior monitoring capabilities with enhanced visualisation.

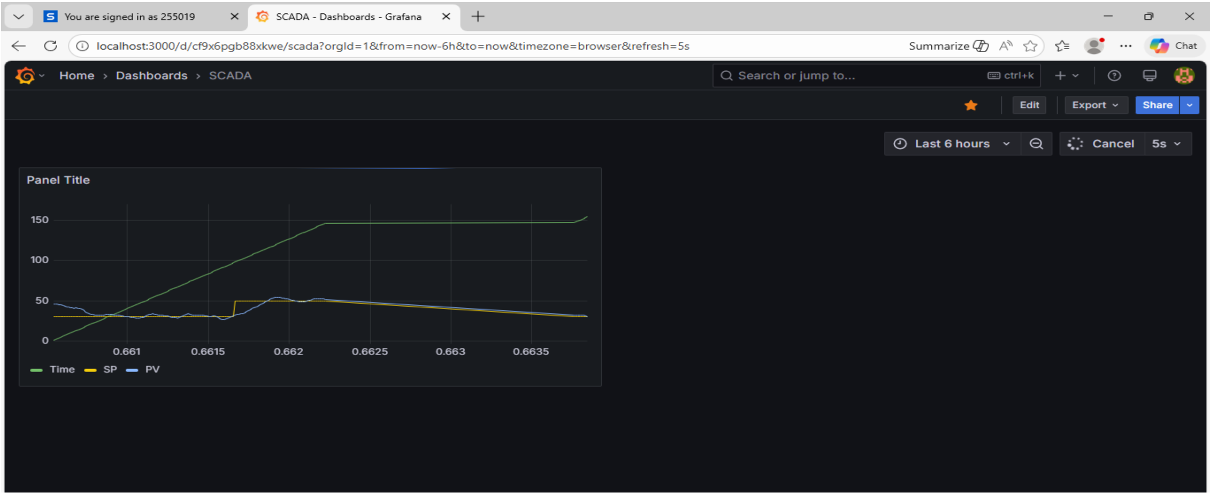

Figure.3. Output Grafana from Intel Upsquared

Figure.4. Grafana output from mobile

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Conflict of Interest/Competing Interests
No conflict of interest.

Data Availability
The raw data supporting the findings of this research paper will be made available by the authors upon a reasonable request.

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