INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH AND ANALYSIS

ISSN(print): 2643-9840, ISSN(online): 2643-9875

Volume 06 Issue 10 October 2023

DOI: 10.47191/ijmra/v6-i10-25, Impact Factor: 7.022

Page No. 4734-4740

Innovative SCADA-Based Oil Refinery Control with Arduino Integration Using Labview

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ABSTRACT: In various industrial settings, Supervisory Control and Data Acquisition (SCADA) and Programmable Logic Control (PLC) systems are commonly employed for control purposes, such as in water treatment facilities, electric power stations, and irrigation systems. However, the oil and gas refinery sector typically relies on Distributed Control Systems (DCS) to manage a wide array of process and equipment control functions.

This project departs from the conventional reliance on DCS and explores the utilization of a SCADA system, both with and without Arduino integration, to oversee and regulate oil levels within a tank that serves as a representation of a refinery. The project introduces the design and detailed implementation of a real-world SCADA system developed in LABVIEW. Effective solutions encompass automation and monitoring architectures that encompass several components, including a real-time supervision and control system, programmable logic controllers equipped with fundamental libraries, communication systems, standard or custom interfaces interfacing with sensors, electrical drive components, measuring instruments, and more. Leveraging informatics systems offers the potential to proactively prevent various phenomena through data analysis and processing, ultimately leading to optimized operations and significant cost savings. Consequently, this project introduces a SCADA system tailored for the monitoring and control of water distribution stations. This system is designed to ensure the efficient operation of pumping systems, enhance equipment and infrastructure safety and resilience, optimize energy consumption, and efficiently manage the distribution of potable water resources. The project relies on LabVIEW, a graphical programming language utilizing a dataflow model, for programming, control, and monitoring of a simulated water system. Additionally, rain sensors are employed to detect water levels within predefined minimum and maximum thresholds.

Moreover, LabVIEW is utilized for programming the Arduino UNO microcontroller board, which serves as an interface between the software and other circuit components. The results of this project demonstrate high-performance levels and the attainment of precise measurements.

KEYWORDS: SCADA system, LabVIEW, Arduino-SCADA

INTRODUCTION

A SCADA system, as described by various sources [1-3], constitutes a comprehensive system comprising multiple remote terminal units, or RTUs, responsible for the collection of field data, which is subsequently transmitted back to a central master station through a dedicated communications infrastructure. The central master station serves as the hub for displaying the acquired data and facilitating remote control operations. The real-time precision and timeliness of this data acquisition process play a pivotal role in optimizing plant and process operations, leading to heightened efficiency, reliability, and, most crucially, enhanced safety protocols. These cumulative advantages ultimately translate into cost savings when contrasted with conventional non-automated systems [4].

The successful deployment of a SCADA system hinges upon the utilization of well-established and dependable technology, accompanied by comprehensive training for all personnel involved in system operation. The history of less successful SCADA implementations often involves a multitude of factors, including suboptimal integration of system components, unwarranted complexity within the system architecture, unreliable hardware components, and unproven software solutions. While contemporary challenges have seen hardware reliability concerns diminish, the growing complexity of software applications introduces novel hurdles in SCADA system design and maintenance [5].

It's essential to note that while field devices, encompassing transducers and control devices, constitute a vital aspect of overall system functionality, they fall outside the primary scope of this SCADA manual and, therefore, will not be elaborated upon here.

Typically, a SCADA system configuration features RTUs that serve as the intermediary interface for field analog and digital signals, strategically positioned at remote sites. A robust communication system serves as the conduit for data transmission between the master station and remote sites, with communication mediums encompassing radio, telephone lines, microwave links, and possibly satellite connections. The system incorporates specific protocols and error detection mechanisms to ensure efficient and error-minimized data transmission. At the heart of the system, the master station and its sub-masters collate data from various RTUs and often furnish an operator interface for data visualization and remote control of the distributed sites. In larger telemetry systems, sub-master sites undertake the role of gathering information from remote sites and function as relays back to the central control master station, enhancing the scalability of the SCADA system [6,9].

SCADA technology has a rich history, with its origins tracing back to the early 1960s. Over time, it has coexisted with two competing paradigms: the Distributed Control System (DCS) and the Programmable Logic Controller (PLC). The DCS represents a variant of SCADA in which data acquisition and control functions are executed by numerous distributed microprocessor-based units situated in proximity to the devices under control or the instruments from which data is sourced[8-10]. DCS systems have evolved to offer advanced analog control capabilities, including loop control, while also featuring tightly integrated operator interfaces for effortless system configuration and operator control. The data communication infrastructure in DCS is typically designed to support high-speed data transmission [7].

On the other hand, the Programmable Logic Controller (PLC) serves as another widely adopted component within the SCADA landscape. PLCs have supplanted traditional hardwired relays with a combination of ladder logic software and solid-state electronic input and output modules. They find extensive use in implementing SCADA RTUs due to their cost-effective and standardized hardware solutions, making them a popular choice for SCADA system deployments [8-11].

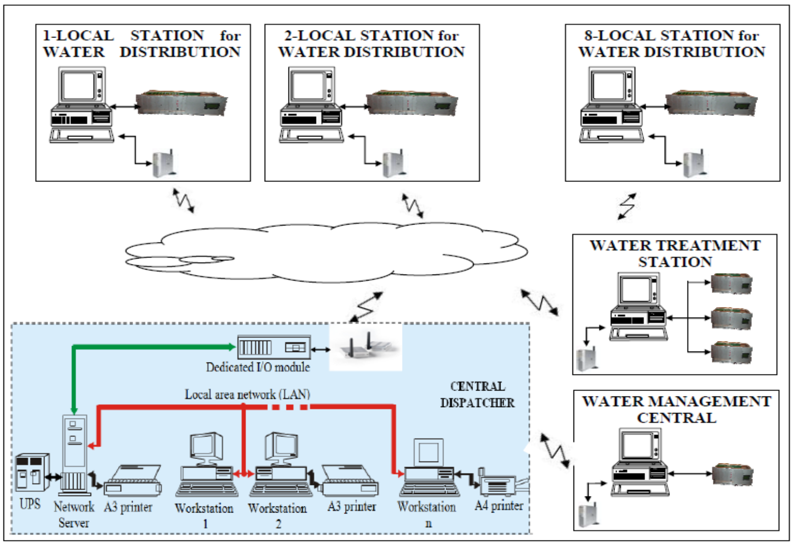

Figure 1: The Block Diagram of the SCADA System

OBJECTIVES OF THIS WORK

The important objectives of SCADA are to listed below:

1. Monitoring: Continuous monitoring of the parameters of voltage, current, etc.
2. Measurement: Measurement of variables for processing.
3. Data Communication: Transmission and receiving of large amounts of data from field to control centers.
5. Control: Online real time control for closed loop and open loop processes.

COMPONENTS OF SCADA SYSTEM

SCADA consists of hardware and software components.

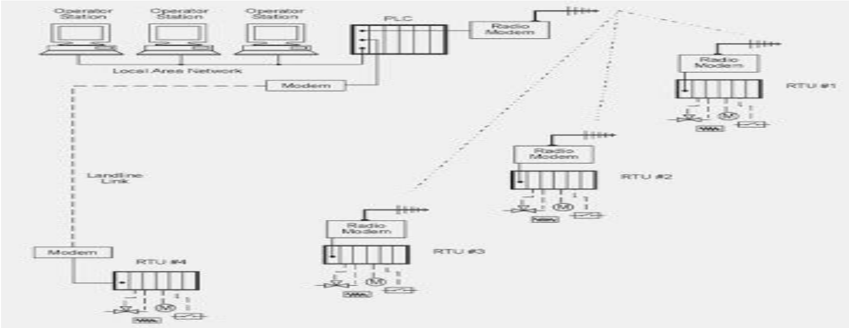

Figure 2: SCADA components

THE MAIN COMPONENTS OF HARDWARE

DAS

A data acquisition system (DAS) is an information management system responsible for gathering, storing, and disseminating data and information

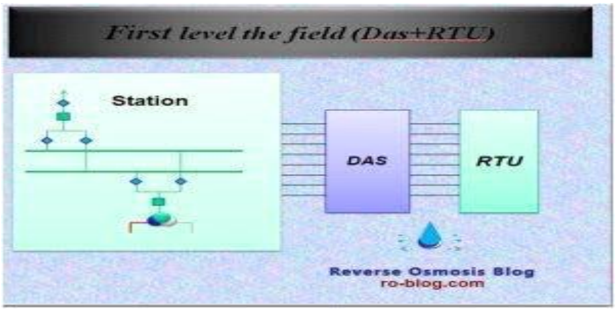

Figure 3: DAS

RTU

A remote terminal unit (RTU) is an electronically controlled microprocessor device that links physical objects to a distributed control system or SCADA (supervisory control and data acquisition) system. It achieves this by sending telemetry data to a central master system and receiving instructions from the master supervisory system to manage connected objects.

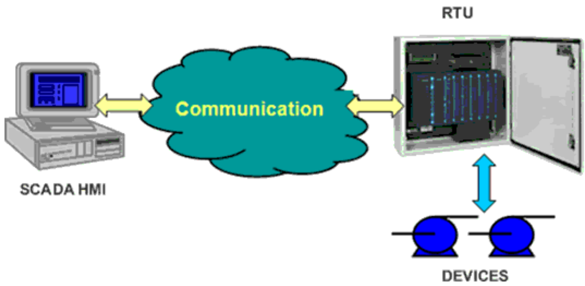

Figure 4: RTU

PLC

Programmable Logic Controller connects to I/O devices to obtain real time signals, then transfer them as digital data to supervisory system.

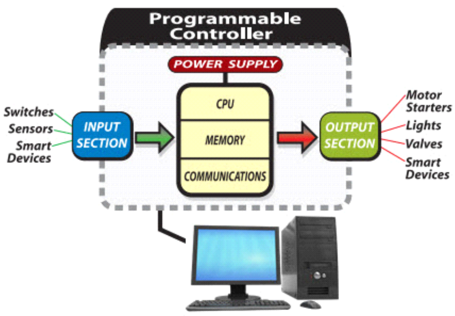

Figure 5: PLC

HMI

SCADA systems necessitate a Human-Machine Interface (HMI) that serves as a platform for displaying information gathered from Remote Telemetry Units (RTUs) and Intelligent Electronic Devices (IEDs).

SYSTEM MODELING

In this section we have to describe our system in brief to observe the system components and the way the system or systems can be monitored or controlled as well as how to monitor the system remotely to finalize a SCADA system.

The systems

1. SCADA System GUI (LabVIEW based system)
2. LabVIEW- Arduino Uno

SYSTEM MODEL AND DESCRIPTION

The project's overall scope is illustrated in Figures 2 and 3. As mentioned earlier in the introduction and abstract sections, two distinct systems are involved. The first system comprises both underground and elevated water tanks, along with a pump responsible for transferring water from the lower reservoir to the overhead tank. Utilizing an Arduino UNO board programmed through LabVIEW, this system detects water levels using a rain sensor and issues instructions to LabVIEW when predefined water level thresholds are reached. The primary objective of this study is to leverage LabVIEW for controlling an Arduino UNO board, automating water level management in an elevated tank, and providing continuous water level indication. The rain sensor serves as a non-contact sensor for measuring the distance between the liquid surface and predefined minimum and maximum levels, enabling continuous oil level monitoring. To achieve automation in an oil refinery and reduce human intervention, the development of a SCADA system is essential to oversee plant operations and minimize human-induced errors. While the SCADA system handles system monitoring, the Arduino board plays a role in internally storing instructions for executing functions such as logic, sequencing, timing, counting, and arithmetic to control various machine processes through digital and analog input/output modules. SCADA encompasses a combination of telemetry and data acquisition [1-3].

Design and Implementation

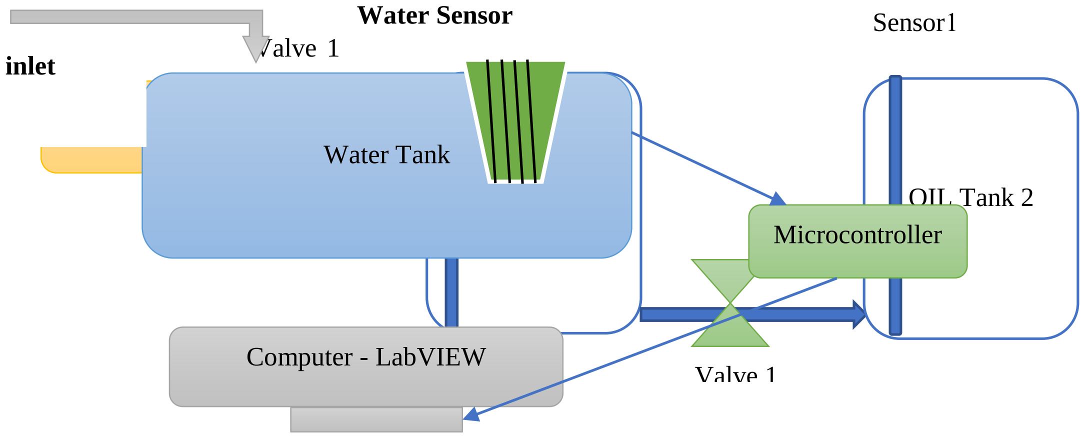

Figure7: A diagram of SCADA system to control and monitor the water tank

In this section of the paper, we will explore several significant subjects that have strong connections to the project covered in previous chapters. As mentioned in Chapter Two, we mentioned that the project was approached in two distinct ways to showcase LabVIEW's capability in designing a SCADA system. Each of these approaches will be examined separately, as detailed below:

SCADA System Design

The initial phase of the project relied entirely on the LabVIEW software. We constructed the project within this software platform and integrated various distinct components.

Tank: The primary component utilized in this phase is a tank, represented as a numerical component within the software. This tank can be filled with various substances such as oil or water.

Water In: The Water In icon is employed to input water or oil into the tank, allowing us to compute the quantity of fluid introduced.

Water Out: Similar to the Water In icon, this component serves to measure the fluid output from the tank in our project.

LED Indicator Buttons: These icons functioned as indicators or alarms, signaling when the tank was either full or empty

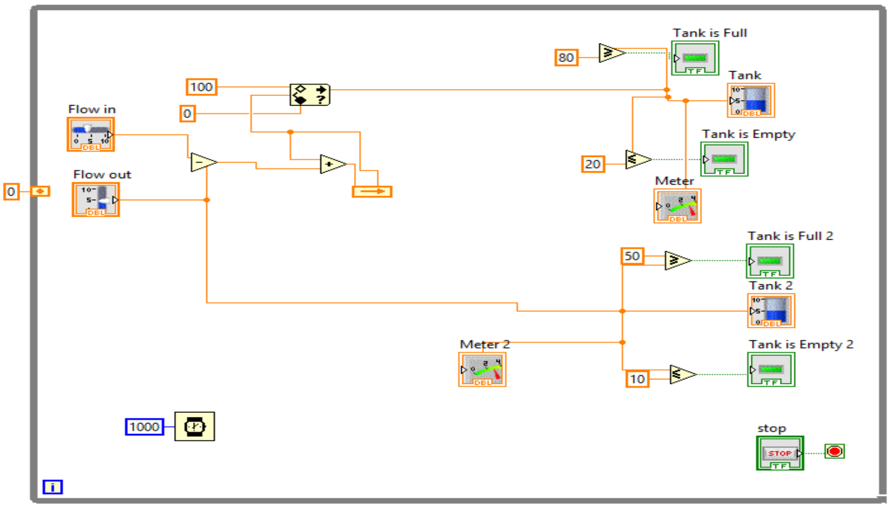

Figure 8: Schematic of the LabVIEW

As depicted in Figure 4, all the project components and the employed comparators are visible. The illustration clearly demonstrates the tank's connections to two distinct measurement components, representing the inflow and outflow. Furthermore, the figure illustrates the mathematical operations we implemented to convey the flow path and the specific functionality required for the project to the software.

Arduino –SCADA System design

Arduino UNO microcontroller

The Arduino Uno is a "microcontroller board centered around the ATmega328P. It features 14 digital input/output pins (with 6 offering PWM functionality), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header, and a reset button. Technical specifications for the board, as extracted from its datasheet

Water sensor module

This sensor operates by employing an arrangement of exposed traces linked to the ground, with sense traces woven among them. The sensor traces include a gentle pull-up resistor rated at 1 MΩ, which elevates the sensor trace value to a high state until a water get changed.

Arduino and Water sensor connection

Here we connect the signal pin (S) to analog pin A0. This allows the Arduino board to be able to read the analog voltage value.

Arduino, Water sensor connection with LabVIEW

In figure below, we will have the connection of the Arduino and the water sensor with the LabVIEW. As once can see that the LabVIEW should recognize the Arduino board and the sensor before starting using the or running the project.

In this way the user should install some of the well-known libraries and files through the LabVIEW manager to let the LabVIEW recognize the development board of the microcontroller. As anybody can see, that we chose the Arduino library through the LabVIEW and we chose analog device to recognize the analog input from the sensor.

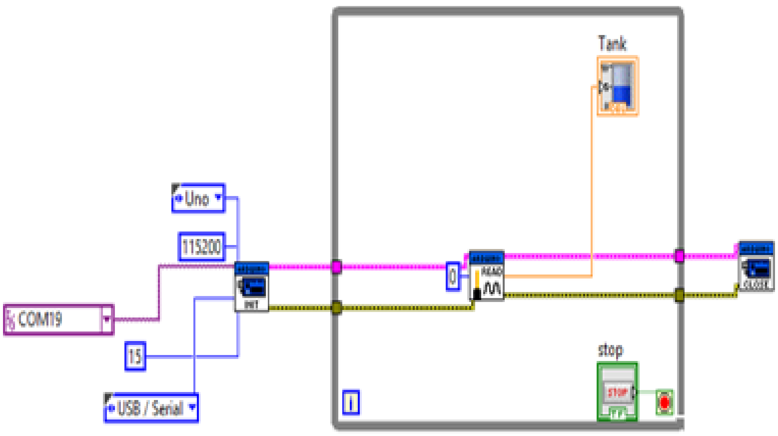

Figure 9: Arduino - LabVIEW

Implementation

In this section, we implemented the design and the wiring of the LabVIEW to achieve the goal that we already discussed. From the figure below we can notice that we have two tanks each one relies on the other.

The inlet of the fluid to the first tank can be controlled and monitored through the computer directly and that is the main reason that SCADA represent the important tool to the plants or the factories because the monitoring and controlling will be very easy and close to the person in charge of the duty.

From the figure, we can see that if the first tank is empty a green light will be lid but does not mean that the tank is fully empty it might have a percentage of filling. The red bottom will be lid if the tank is full or approach 80 percent of its height.

We can control the inlet flow and the outlet flow through the sliding bar that are appeared next to the tank. Also, we can see that the second tank is fully rely on the first tank.

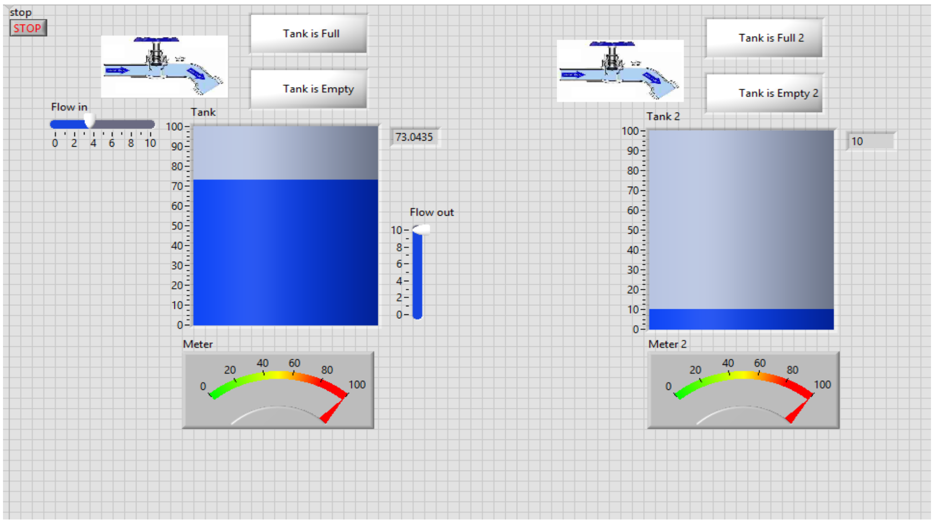

Figure 2: LabVIEW Based SCADA System

Arduino - LabVIEW

we will explain how to use a water sensor to detect the amount of water we have in a tank. We will use the S pin as **analog input** connecting *Arduino*, the value read will be higher depending on the sensor surface is covered with water. This is because the water acts as a conductor, given that the water we use in our deposits not be pure water (*H2O*), since if water is nonconductive. But rarely we will use this type of sensors to measure the water level in a tank of pure water.

We will control and monitor the system (the tank and the amount of water in and out from the tank) through LabView by using the components we mentioned earlier.

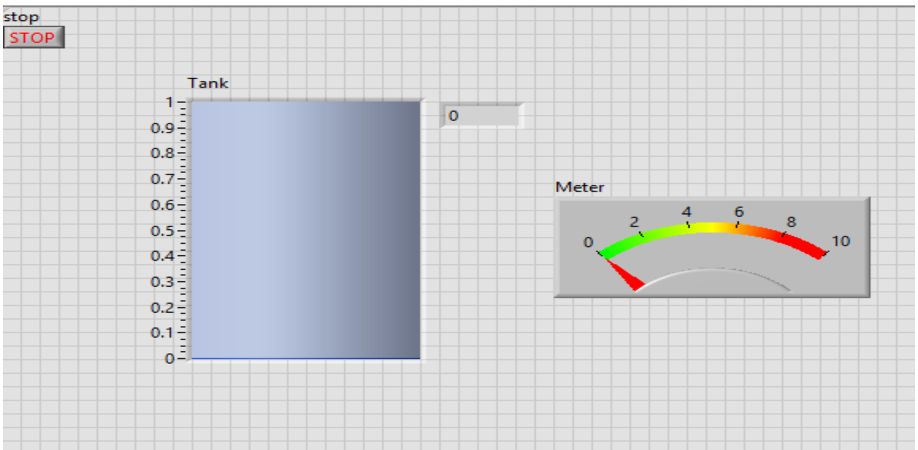

Figure 11: LabVIEW based Arduino

RESULTS

From the discussion and figures above, we can say that both systems apply important achievements by controlling the equipment whether in the real or in the imaginary word. In the first method, our system succeeded very much by applying SCADA system fundamentals and principals where we used LabVIEW software to control and monitor the system and give observations and judgments about the system behavior. In the other side, our system showed the same observation when we used the second method which we used an experimental setup to control and monitor the system behavior.

CONCLUSION AND FUTURE WORKS

Conclusions

In this project, we designed and implement SCADA system for oil refinery. In this project, we designed two methods to achieved this task. The first design by using the LabVIEW only to serve as the inlet and outlet source of the fluid and at the same time the LabVIEW was used to monitor the system. This design was succeeded to achieve the duty.
The second design was by using an experimental setup. In the setup, we utilized Arduino Uno as a microcontroller and distance sensor to measure the water level. This is also won our satisfactions.

Future Works

In future work, we will design three sections of SCADA for oil refinery to satisfy all the requirements of the oil refinery.

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