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SCADA PROCESS VARIABLES MONITIORING INTEGRATED IN RF NETWORK

GOCE STEFANOV, MAJA KUKUSEVA PANEVA AND SARA STEFANOVA

Abstract. This paper presents the results of a developed design and practical implementation of a SCADA system. The system is designed to monitor process variables, and it is integrated with an RF IoT network. The proposed SCADA system collects, measures, stores, and displays real-time process data from an industrial plant in remote locations. The SCADA system includes RF IoT communication between MASTER and SLAVE stations. Some of the hardware sensors and components are installed in the SLAVE station, while others are in the MASTER station. A microcomputer and RF modules ensure communication between the SLAVE and MASTER stations. The system also features a data log file to store industrial data for processing.

1. Introduction

Automation has become an integral part of our daily lives, making it easier to perform various tasks. Automation, control, management, and monitoring processes are of utmost importance in industrial use [1], [2]. The aim is to ensure a simpler and more reliable work environment, especially for operators who are directly responsible for the proper functioning of the entire industrial process. The SCADA system (Supervisory Control and Data Acquisition) is used for this purpose. It is a set of system software and hardware elements that enables industrial organizations to have control over industrial processes, monitor and collect data in real-time, communicate directly with on-site devices such as motors, valves, and sensors, and collect data such as pressure, temperature, tank level, power, demand, etc. [3], [4]. Remotely based SCADA systems provide the ability to collect data and control the process remotely, create daily reports on the current and archive of previous system states, send the necessary information to operators in real-time using SMS and the IoT (Internet of Things) methodology, reduce the need for human interventions, save time, money, and energy, and enable less travel for workers.

A typical SCADA system consists of several components, such as a surveillance system that monitors and regulates physical components within a larger system, including sensors and actuators, a communication network, and remote and central monitoring stations. The RTU (Remote Terminal Unit) is an electronic device that connects objects in the physical world to a distributed control system or SCADA system by transmitting telemetry data to the main supervisory control system of the connected objects. The SCADA programming software code is programmed into the system and requires a thorough understanding of the entire process under control. To ensure that the best SCADA performance is achieved, especially when security is considered the highest priority, it is imperative that SCADA programming is performed by trained, qualified, and experienced SCADA engineers. The PLC (Programmable Logic Controller) is a small computer or microcomputer capable of managing system functions by

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Keywords. SCADA, RF Network, Internet of Things, MASTER and SLAVE stations, Data log file, Industrial Data Processing.

implementing the internal logic programmed into it. The CI (Communication Interface) refers to the interfaces and protocols that enable software installed on other computers to interact with the Microsoft platform software on a personal computer. The HMI (Human

Machine Interface) refers to a control panel or display used for machine control. Line operators, managers, and supervisors in various industries depend on HMIs to translate complex data into useful information.

In Figure 1, the SCADA system and its components are shown.

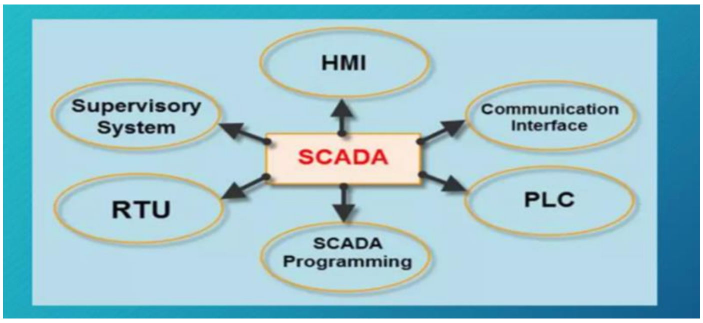
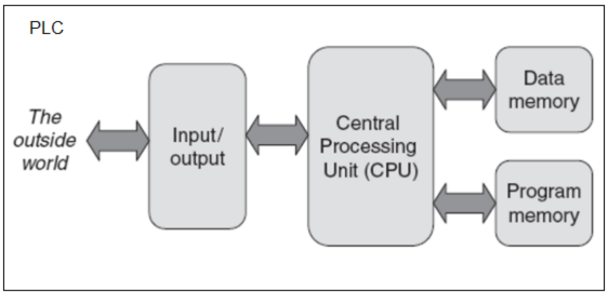
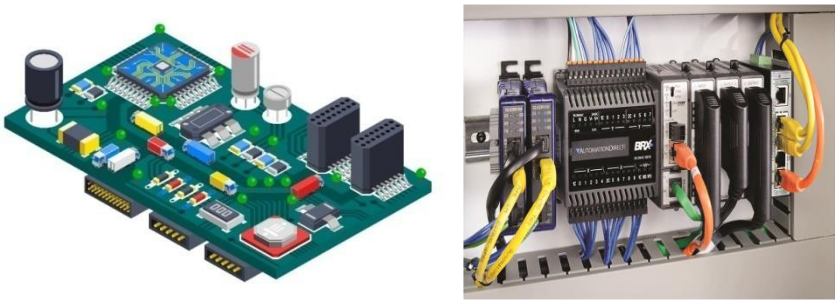


Figure 1: *SCADA systems and their components.*

In typical SCADA systems, the Programmable Logic Controller (PLC) plays a key role. The term "PLC" has historical roots in the early days of industrial process control, and its meaning has evolved with technological advancements. Initially, it referred to an electromechanical assembly responsible for overseeing a specific industrial process device. With the progression of electronics, the term "PLC" became associated with an electronic device implemented in discrete techniques. The core of a PLC is a microcomputer as shown in Figure 2. Additionally, an industrial PLC is equipped with a sufficient number of input and output units along with memory units.



a)



b) c)

Figure 2: *(a) Block diagram of PLC, (b) Electronic board on PLC (only microcomputer architecture), and (c) Industrial PLC.*

Programmable Logic Controllers can be programmed using five methods as follows:

- LD (Ladder Diagram)
- SFC (Sequential Function Charts)
- FBD (Function Block Diagram)
- ST (Structured Text)
- IL (Instruction List)

This paper aims to design a SCADA system for temperature and humidity control in an industrial process. The primary objective is to achieve the specified task using minimal hardware components and user software.

2. Design of a SCADA System for Monitoring of Temperature and Humidity in RF Network

The SCADA system has the task of collecting temperature and humidity data, as well as data for analog signals and signals from a gas sensor, from two measuring points, and displaying them on a computer terminal. Additionally, the solution should enable data logging of measurement data. Figure 3 illustrates the block diagram of this SCADA system.

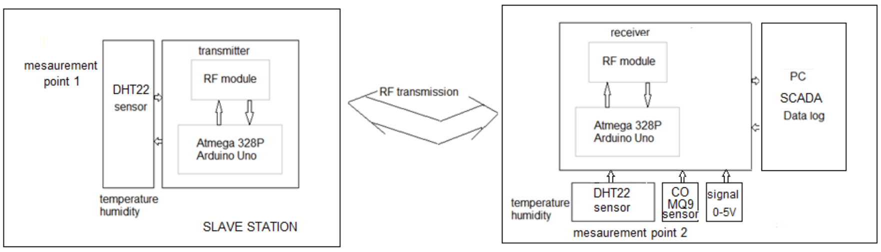


Figure 3: *Block diagram of the proposed SCADA system using RF transmission.*

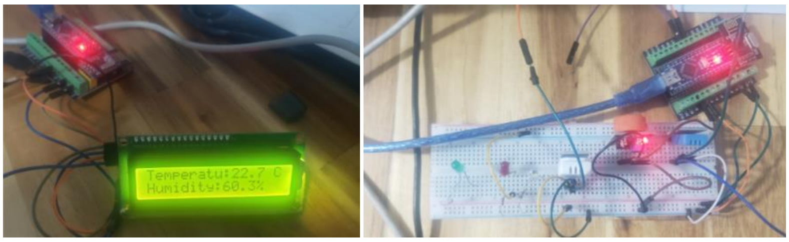
The SCADA system consists of a MASTER and a SLAVE station. The MASTER station incorporates one measuring point for measuring process variables temperature and humidity, along with a microcomputer responsible for receiving signals from the two measuring points and creating the SCADA system. The SLAVE station consists of the second measuring point for temperature and humidity measurements and an associated microcomputer. The measuring point at the SLAVE station is positioned remotely, and RF IoT communication is used for transmitting data from it to the MASTER station. To implement such a concept, RF modules NRF24L01 are installed in the SLAVE and MASTER stations. DHT22 sensors are used at both measurement points to measure temperature and humidity. Additionally, the MASTER station features measurements of an analog signal ranging from 0-5V and a signal from a CO gas sensor, implemented with an MQ9 board sensor.

Based on the information stated above, the SCADA system will receive, display, and store the following measured values:

- Humidity from the DHT22 sensor in the SLAVE station,
- Temperature from the DHT22 sensor in the SLAVE station,
- Humidity1 from the DHT22 sensor in the MASTER station,
- Temperature1 from the DHT22 sensor in the MASTER station,
- Voltage signal in the MASTER station, and
- CO gas concentration signal in the MASTER station

2.1 Design of RF Communication between the SLAVE and MASTER Station

The electronic system solution that provides RF communication for measuring a signal from a DHT22 sensor originally presented in [5], was used in the proposed application. For the design of the SCADA system, only a prototype of the RF receiver that receives the signal from the RF transmitter is presented here, as shown in Figure 4a.



a) b)

Figure 4: a) *Prototype of the RF receiver that receives the signal from the RF transmitter*, b) *The hardware of the MASTER station.*

This prototype is used to control whether the signal from the RF SLAVE station is received at the MASTER station. The prototype is expected to display the same measured values of temperature and humidity as those shown on the SCADA screen.

2.2. Design of the MASTER station

The main part of the MASTER station is an ATMEAG 328P microcomputer implemented on an Arduino nanoboard. The hardware of the MASTER station is shown in Figure 4b. The microcomputer 328P on the Arduino nano board, the RF module NRF24l01, and the CO sensor MQ9 are described in more detail in [6] – [9]. However, this paper focuses on the design of the SCADA system.

2.3 Design of the SCADA system

The SCADA system is based on Omron CX-Supervisor software. CX-Supervisor is dedicated to the design and operation of PC-based visualization and machine control. It is simple to use for small supervisory and control tasks and offers a wealth of power for the design of the most sophisticated applications. CX-Supervisor boasts powerful functions for a wide range of PC-based HMI requirements. Simple applications can be created rapidly with the aid of many predefined functions and libraries, and even very complex applications can be generated with a powerful programming language or a

VBScript.

CX-Supervisor has an extremely simple, intuitive handling, high user-friendliness, and it allows the developer to rapidly configure, test, and debug a project. It runs on standard PC desktop computers running Microsoft Windows. CX-Supervisor comprises two separate executable Windows programs, the CX-Supervisor Development environment, and the CX-Supervisor Runtime environment. Applications are created and tested using the development environment and then delivered as a final customer application with the runtime environment. The runtime-only environment may only be used for executing an application previously generated using the development environment. It is not possible to generate a new runtime application using the runtime environment. The connection between sensor hardware, microcontroller, and CX-Supervisor SCADA system is shown in Figure 5.

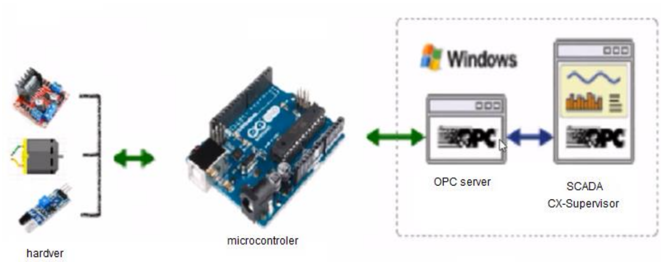
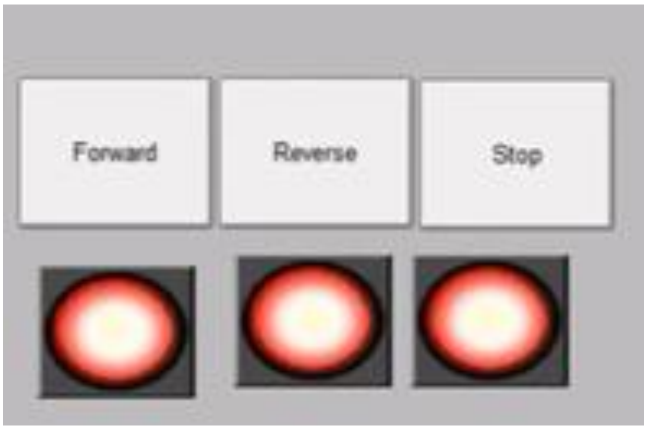


Figure 5: *Connection between sensor hardware, microcontroller, and CX-Supervisor SCADA system.*

a) Setting up Graphic Symbols

The first step is to set up graphic symbols, which can be done once the project page is created. Figure 6a shows how graphic objects can be constructed and added to the page. The graphics editor uses a Graphic Object toolbar, and a floating window called the Palette to control objects.



a.)

b)

Figure 6: *a) Setting graphical symbols, b) Setting variables for graphical symbols.*

These tools allow users to construct and control graphical objects on the page with ease. The toolbar consists of several small icons, each one representing a graphical object that can be used to create an application. Some of the objects are simple graphical primitives like straight lines, ellipses, and rectangles. Others are more advanced such as the gauge object, which has built-in functionality. Overall, the graphics editor provides an intuitive interface for creating and manipulating graphical objects.

b) Setting up Variables for Graphical Symbols

To set up graphical symbols, a point variable is created for each symbol with the appropriate size and unit, as demonstrated in Figure 6b. These variables correspond to the variables in the Arduino code provided in Figure 7.

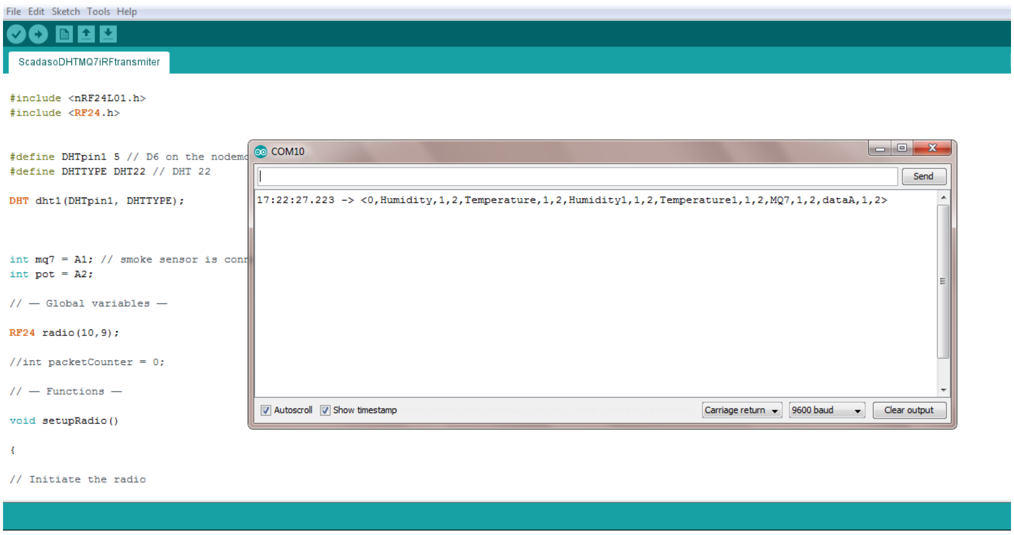


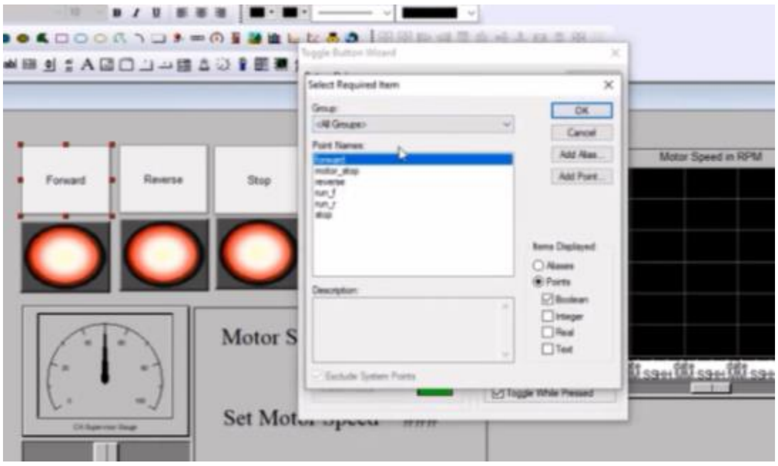
Figure 7: *Variables in Arduino codes.*

c) Setting Graphical Symbols with Variables

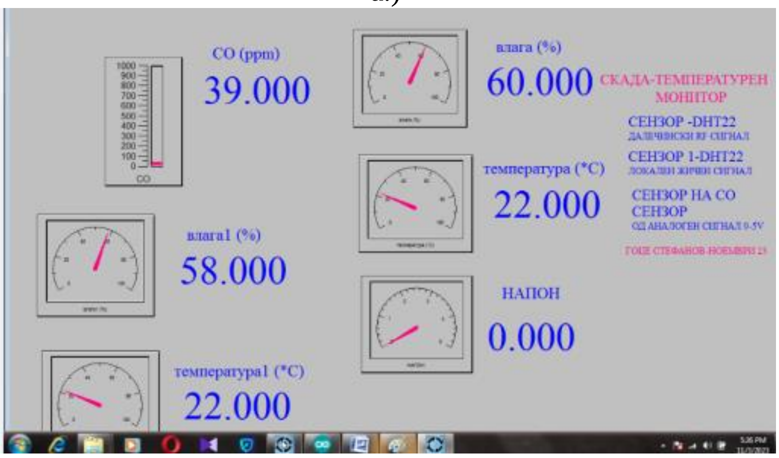
Finally, each graphical symbol is associated with a corresponding variable, as presented in Figure 8a.

2.4 Design of Prototype on SCADA system

The SCADA screen with defined variables is shown in Figures 8a and 8b.



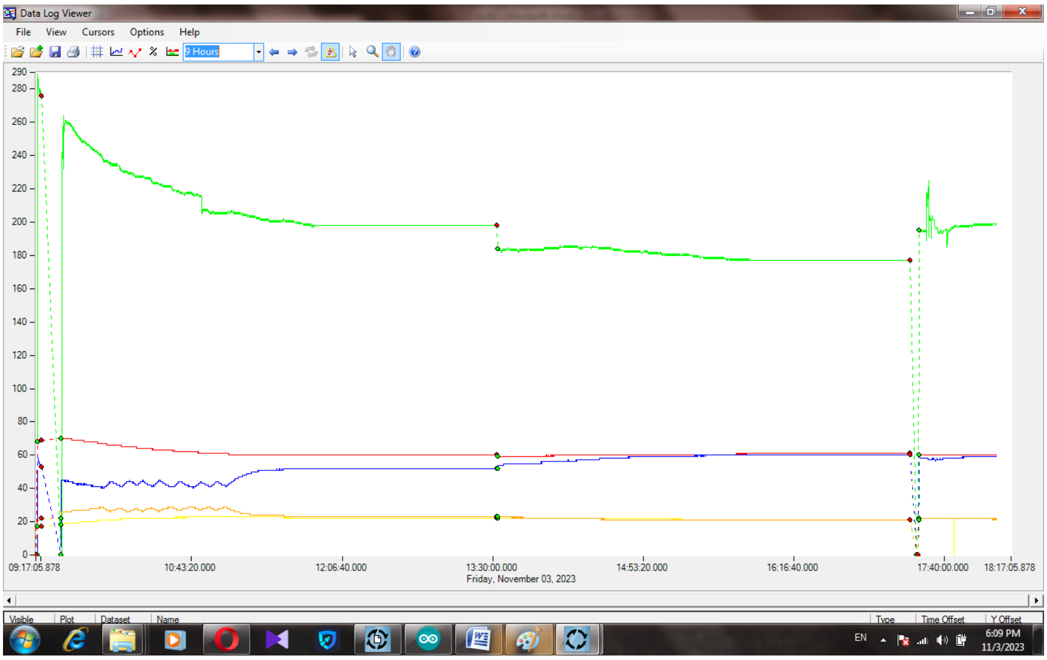
a.)



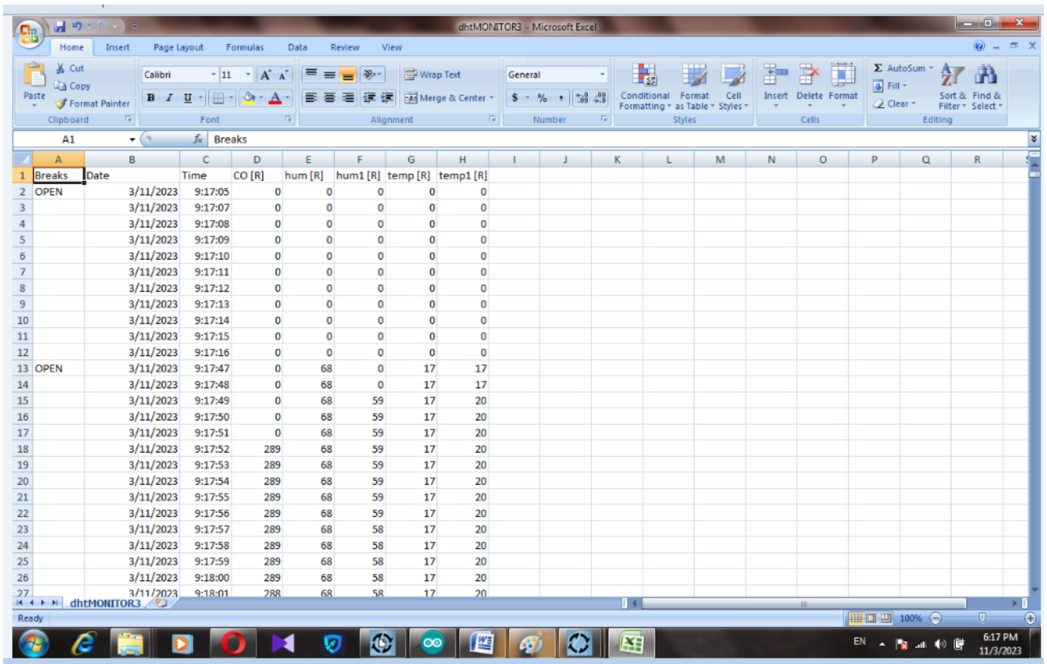
b)

Figure 8: *a) Graphical symbol associated with a corresponding variable*, *b) SCADA screen with defined variables.*

The figures for the observed variables CO, Humidity, Temperature, Humidity1, and Temperature1 are presented in Figures 9a and 9b, along with the real-time data log file.



a.)



	A	B	C	D	E	F	G	H
1	Breaks	Date	Time	CO [R]	hum [R]	hum1 [R]	temp [R]	temp1 [R]
2	OPEN	3/11/2023	9:17:05	0	0	0	0	0
3		3/11/2023	9:17:07	0	0	0	0	0
4		3/11/2023	9:17:08	0	0	0	0	0
5		3/11/2023	9:17:09	0	0	0	0	0
6		3/11/2023	9:17:10	0	0	0	0	0
7		3/11/2023	9:17:11	0	0	0	0	0
8		3/11/2023	9:17:12	0	0	0	0	0
9		3/11/2023	9:17:13	0	0	0	0	0
10		3/11/2023	9:17:14	0	0	0	0	0
11		3/11/2023	9:17:15	0	0	0	0	0
12		3/11/2023	9:17:16	0	0	0	0	0
13	OPEN	3/11/2023	9:17:47	0	68	0	17	17
14		3/11/2023	9:17:48	0	68	0	17	17
15		3/11/2023	9:17:49	0	68	59	17	20
16		3/11/2023	9:17:50	0	68	59	17	20
17		3/11/2023	9:17:51	0	68	59	17	20
18		3/11/2023	9:17:52	289	68	59	17	20
19		3/11/2023	9:17:53	289	68	59	17	20
20		3/11/2023	9:17:54	289	68	59	17	20
21		3/11/2023	9:17:55	289	68	59	17	20
22		3/11/2023	9:17:56	289	68	59	17	20
23		3/11/2023	9:17:57	289	68	58	17	20
24		3/11/2023	9:17:58	289	68	58	17	20
25		3/11/2023	9:17:59	289	68	58	17	20
26		3/11/2023	9:18:00	289	68	58	17	20
27		3/11/2023	9:18:01	288	68	58	17	20

b)

Figure 9: a) *Real-time waveform for variables CO, Humidity, Temperature, Humidity1, and Temperature1, b) Data log file for the same variables.*

In Figure 10, the RF receiver receives the signal from the DHT22 in Figure 4a, and the SCADA screen displays it.

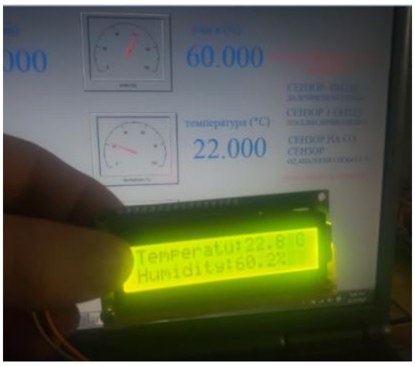


Figure 10: *Compared data between the RF receiver of the DHT22 signal and SCADA screen.*

3. Analysis of the results

Based on the results presented, it can be concluded that it is possible to design a functional SCADA system using a microcomputer and appropriate hardware components with Omron software. The proposed solution meets all the requirements of a SCADA system, including the collection and measurement of process data from various hardware components with different signal ranges (analog or digital), direct and remote connection of hardware components (using RF IoT, as in our proposal), integration of multiple microcomputers (SLAVE and MASTER), visualization of the measurement data on a computer screen (SCADA screen), creation of waveforms for the measurement signals, and generation of an Excel data log file for measured values.

For the development of this SCADA system, we used a previously designed RF IoT device in this paper, as shown in Figure 4a. The reliability of the measured values is confirmed by the results presented in Figure 10, which show that both the RF receiver (on its LCD) and the SCADA display depict identical temperature and humidity values (22°C and 60% humidity). One of the advantages of this proposed system is that it enables real-time monitoring of the measured quantities, as shown in Figure 9a. Additionally, the data log file (Figure 9b) provides the possibility for further analysis and investigation of the obtained process values for industrial process improvement or operator training.

4. Conclusion

In conclusion, the methodology outlined in this paper demonstrates the capability for remote and real-time monitoring of process variables in an industrial plant. Its implementation involves using hardware and software tools based on a microcomputer, IoT RF communications, and SCADA user software. The implemented SCADA system fulfils all the tasks set out at the beginning of the paper, including collecting, measuring, and visualizing various process data on the SCADA screen, creating waveforms of the measured values in real time, and storing them in a data log file for further use.

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