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DESIGN AND IMPLEMENTATION OF IOT SCADA SYSTEM BASED ON OPEN CHANNEL FLOW

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Abstract- The focus of this paper is the application of a SCADA system (supervisory control and data acquisition) on water channels for use in the field of education in the water resources engineering department. In the field of distance learning, the SCADA system is regarded as a pioneering system. The proposed work focuses on using the ESP32 and a web page for communication between devices and smartphones, so that water velocity, water level, water pressure, and flow rate can be measured in an open channel. A linear actuator carrying a pitot tube is used to move it inside the channel, providing the benefit of facilitating water speed readings at different points within the water. Control the amount of water inside a tank to protect the motor pump that transports the water to the channel.
Keywords: SCADA, Channel Flow, Internet of Things, Pitot Tube.

1. INTRODUCTION

SCADA systems use a special platform to sense and monitor distant objects, collect their data, and deliver simple control commands[1]. This technology enables users to remotely check the status of equipment and their situation due to the coronavirus (COVID-19). In addition, institutions and governments start to look for alternatives to real-world education [2], [3]. To prevent the spread of COVID-19, it is important to avoid gatherings that may contribute to the transmission of the virus. [4], [5]. There are four main components of SCADA automation systems for educational platforms. The first component consists of sensing equipment that has been installed at various points throughout educational laboratories to measure the necessary variables.

Remote terminal units (RTUs) are the second section and are used to collect data remotely from sensors. SCADA Master Devices make up the third element (MTUs), which handle Human Machine Interfaces (HMI) and analyse or interpret the received data. The communication connection that links the RTUs and MTUs is the last component of SCADA [6], [7] Over the years, SCADA has evolved to allow the remote monitoring and management of processes. This study introduces an inexpensive, open-source SCADA system built on the Internet of Things (IoT) [8],[9]. The four primary functions of a SCADA system are information collecting, net data exchange, data analysis, and remote access and control systems [10]. Researchers from all over the world have already developed SCADA systems that use IoT technology. P. Rai. [11] created an IoT system to provide end-users with a portable, cost-effective monitoring system that can also remotely enable devices. However, the unreliable video camera module connected to the suggested system requires the use of an ESP32 Arducam board. The ESP32's inbuilt Wi-Fi was used to broadcast the generated video for display on the 1.8-inch SPI TFT Adafruit device. Rajalakshmi and Shahnasser [12] presented an IoT-based SCADA system that uses an Intel Edison board and Raspberry Pi 3 to collect sensor inputs. Through Node-Red MQTT brokers, the Sensor information is transmitted to Amazon Web Services (AWS). Several monitoring and control systems were implemented on the AWS IoT platform utilizing Alexa, an Amazon voice service.

A Wi-Fi-based, open-source SCADA system and a web page using JavaScript, HTML, and CSS are created in this study. The technology was created and put into use in the hydrological engineering labs of Kufa University, Najaf, Iraq. The suggested system can give an accurate measurement of water pressure, speed, and level. In addition, Protect the pump when the water goes down in the tank. Therefore, it enables students to access The SCADA on their computers or mobile devices and opens more than one student to The SCADA to view the outcomes and take notes. Students can experiment on the channel and gather the results quickly and easily.

2. METHOD

The overall proposed system is illustrated in Figure 1. The two MPX5010DP sensors, two water pressure sensors (5kPa), and two JSN-SR04 ultrasonic sensors are connected to the ESP32 devices. As well as connecting the motor to the esp32 indirectly via tb660 to facilitate control of the speed as well as the direction of rotation. As for the valve, it needs a high voltage of 12V, so it must be connected indirectly to esp32 across the relay. The esp32 receives and transmits data to the client using a web browser.

2.1. Hardware

We developed and implemented a SCADA system for use in the study of open channel flow to facilitate the investigation of hydrodynamic phenomena in open surface streams. Didacta Italy designed a 15-meter long H91.8D/15 Open Surface Tilting Flow Channel to examine the hydrodynamic properties of open surface channels [13].

Additionally, it is independent since it has a water storage tank. The water pump is used to move water from the collecting tank to the channel. The electric water solenoid valve, which operates at a DC voltage of 12V, a power of 8W, and a current of 0.6A, is used in conjunction with a relay as a protective measure for the water pump. The designed system prevents water from entering the tank to a depth of less than 5 cm, protecting the centrifugal pump from damage. The operation mode of Electric Water Solenoid Valve will be normally closed, Valve-type diaphragm (operated by Servo) across the relay will control the close and open the valve by esp32[14]. It is situated on the bottom of the channel, where the water pressure measurements may be recorded through a series of holes spaced 250mm apart. The pressure sensor is placed under the channel in these holes. The pressure sensor ranged from 0 to 5 KPA with an output maximum value of 4.5v and a minimum value of 0.5v will be enough to measure the pressure of water in the channel.

The water Level Measuring Apparatus allows measuring manually at the free surface level. To calculate the water level automatically instead manually, the Ultrasonic sensor JSN-SR04 was used (this sensor is water resistant) [15]. It has two main components, namely an ultrasonic transmitter and an ultrasonic receiver. The time T between the signal being transmitted and the echo being received is how the sensor determines the distance between itself and the water's surface. A pulse is quickly created and delivered to the controller when the echo is detected. By knowing the distance between the sensor and the water surface according to Equation (1), and since the height of the channel is constant HT= 50 cm, It is through Equation (2) to detect the water level in the channel. And with the ultrasonic sensor JSN-SR04, the water level can be calculated, and from the same principle, the level of the tank can be calculated, the only difference is that the height of the tank is HT= 100 cm.

$$HS = \frac{340 \times T}{2} \tag{1}$$

$$HC = HS - HT \tag{2}$$

To measure the velocity of the fluid in the channel, the Pitot tube was used. It is a tool for determining a fluid's velocity by the measurement of pressure differences. French engineer Henri Peto created it in the 1880s, while Henri Darcy improved it in the mid-1800s [16]. It consists of a tube linked to the U-manometer with an aperture that corresponds to the flow of the fluid and another opening perpendicular to it that permits measuring the static pressure [17]. To get the velocity of the fluid in the channel Equation (3) was used, where the equation is from the density and height of the water in the tube to the U-manometer, as the density of water is constant. As for the difference in the height of the water (D) and the chains, we will rely on two sensors from the MPX5010DP [18], which has an output voltage range of 0-5V, which is output linearly with pressure. where it will measure the height of the questions in units of cm, which we will convert to meters before substituting it into Equation (3).

$$V = \sqrt{2 \times G \times D} \tag{3}$$

From the datasheet can get the relation for obtaining pressure given to the sensor by Equation (4) [19].

$$P = (V_{out} - 0.04 \times V_s \pm Tol) \times 0.09 \times V_s \tag{4}$$

where V_s is the supply voltage, (V_{out}) is the voltage supplied by the sensor, and (Tol) is the tolerance, which is an adjustment that we must make with the sensor to calibrate the measurement.

Based on the differential pressure Equation related to height, from Equation (5).

$$H = \frac{R \times G}{P} \tag{5}$$

where, P is pressure, G is gravity, R is the density of water H is the level of water. After that, make calibrated the two sensors (MPX5010(A), MPX5010(B)) to match the manual calculations. Measuring the water speed at different depths depends on the movement of the pitot tube inside the water and is achieved through the use of a Linear Actuator. The linear Actuator is made up of the 2 Mounted ball bearings that were separately installed at both ends of the Lead screw.

According to the size you need to adjust the distance between the nut and the Mounted ball bearing to move a middle piece 25 cm. Two chrome-plated smooth rods and an SCS6UU linear slide block bearing with a screw nut will support the moving middle piece, which will hold the pitot tube for measuring the water flow at different points within the water. Put the shaft coupling into the Lead screw beside the Mounted ball bearing to connect the shift of the stepper motor. Steppers are therefore the ideal option for applications requiring quick positioning over a short distance since they can generate a powerful torque at a low speed while minimizing vibration [20]. After knowing the water velocity V through Equation (3) and the water level in the channel HC through Equation (2), it is possible through Equation (6) according to the flow rate (Q).

$$Q = V \times 0.4 \times HC \tag{6}$$

2.2. Software

The software program consists of two parts. One is HTML, CSS, and java code for webpage design. The second software program is the ESP32 program. The Esp32 program is designed to connect the ESP32 with sensors (ultrasonic sensor, MPX5010DP, and water pressure) to read data and send data to a web page. The web page displays the data, as well as receives data from the web page to control the stepper motor. The system includes a feature that automatically adjusts the water level in the tank using a valve and a relay.

This serves as a feedback mechanism to protect the pump motor from damage when the water level in the tank falls below 5 cm. Figure 3 depicts a flowchart of the stages that make up the system's operation. We can create a webpage.h header file that contains the code for a web page (HTML, CSS, JavaScript) and saves it near the form code of ESP32. To draw graphs for the water's delta of height (*D*), velocity, and flow rate, and barographs for the water level in the tank and the water level in the open channel, use the chart.js library [21]. Create a graphical depiction of a water pressure gauge with a range of 0 to 5 using the animated.js library. Figure 2 illustrates the web page. Create custom range sliders with a range of 0 to 30 cm to control the stepper motor that linear ball screw moves the pitot tube. The ESP32 simultaneously functions as an access point (AP) and a station mode (STA).

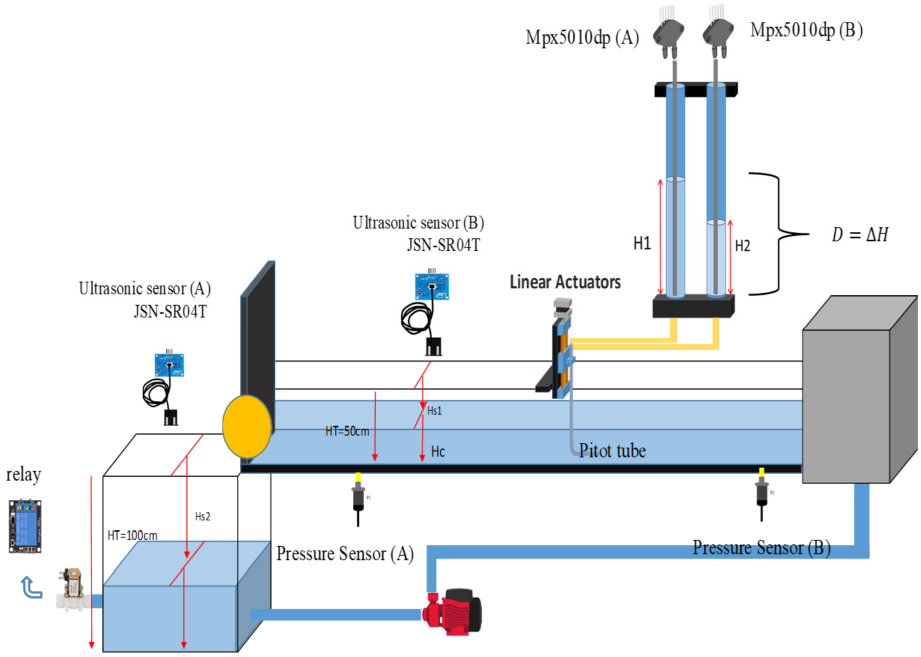

Figure 1. The system's structural elements

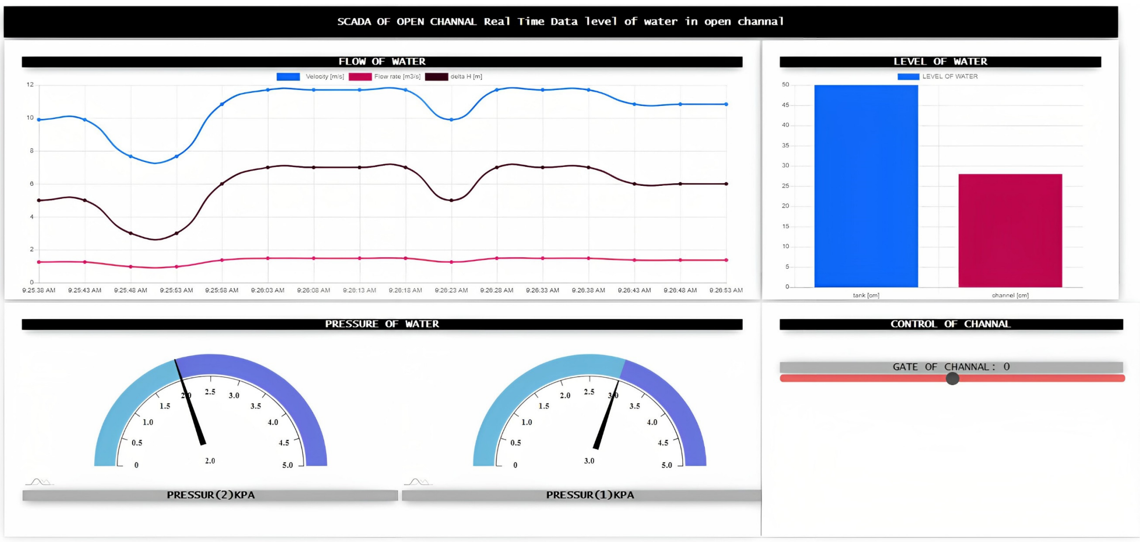

Figure 2. The web page of the system

r3. RESULTS AND DISCUSSION

The results and discussion section of a paper present the findings of an experiment and discusses their significance. In this case, the experiment involved using two MPX5010DP sensors to determine the velocity of water across a pitot tube. The water pressure was 5kPa and two ultrasonic sensors (JSN-SR04) were used to determine the water level.

The ESP32 was used to control the flow of water in the channel through a web page. The results showed that the MPX5010DP sensors were able to accurately measure the water level in the tubes of U manometer through pipes connected to the Pitot tube, as shown in figure 4. and figure 5. The use of two sensors allowed for more precise measurements and better accuracy in the velocity of water across the pitot tube.

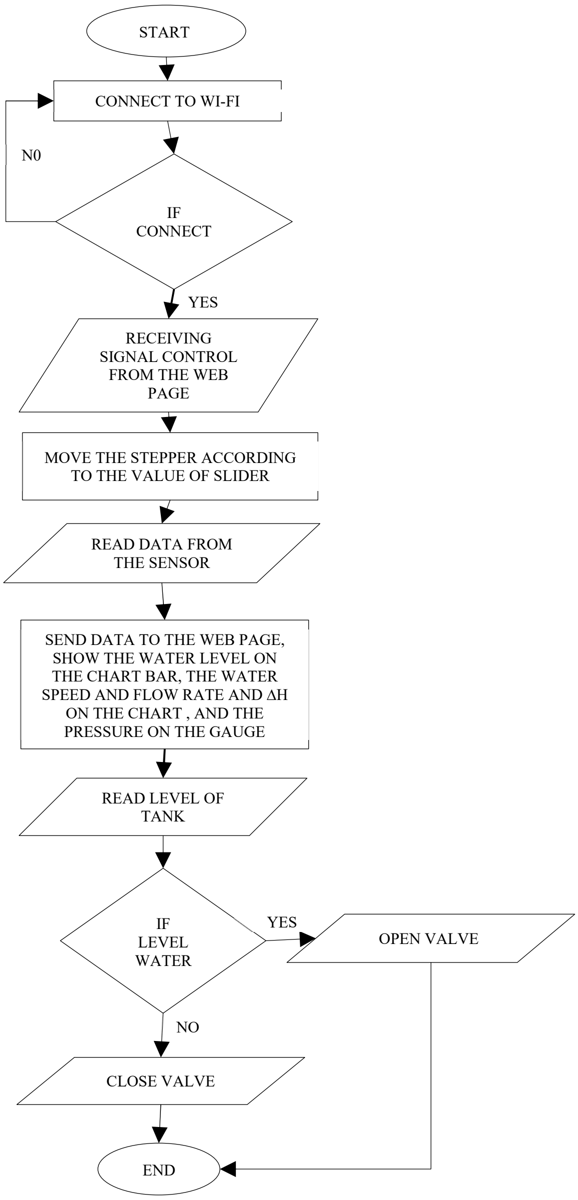

Figure 3. The system's flowchart

Figure 6 show the comparison between the readings taken by the SCADA system and manual readings demonstrate the consistency and accuracy of the system When calculating the velocity of water at different depths, thus affirming its effectiveness.

The ultrasonic sensors were also able to accurately determine the water level in the open channel and tank with comparative media using a Water Level Measuring Apparatus with a capacity of up to 50 cm. Figure 7. shows the results of two JSN-SR04 ultrasonic sensors. Five points of data are obtained from the sensor readout for each fixed point of measurement. The following are the results of tests from the ultrasonic sensor. Based on the data from the ultrasonic sensor comparison, it can be seen that the JSN-SR04 type of ultrasonic sensor generates about the same correction value from each set point.

The correction value produced by the ultrasonic sensor increases as the distance from the fixed point of measurement increases.

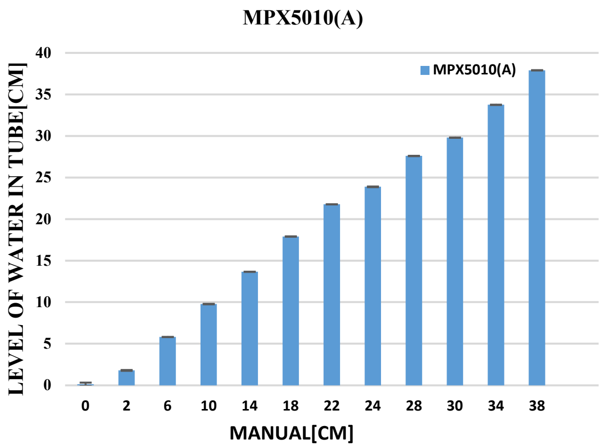

Figure 4. Accuracy Comparison Manual versus mpx5010(A)

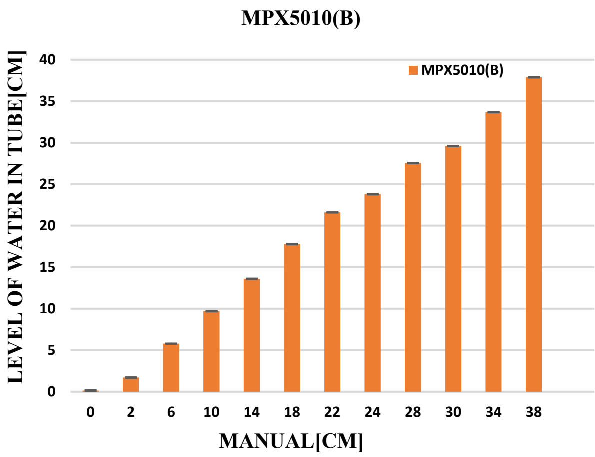

Figure 5. Accuracy Comparison Manual versus mpx5010(B)

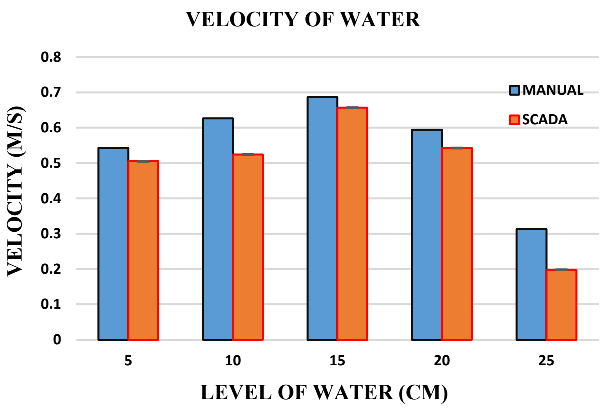

Figure 6. Difference in water speed readings between the SCADA system and manual measurements

Two sensors were used to measure the water pressure, one of which is used in the upstream of channel , which is characterized by high pressure, because the incoming water pours into the open channel in this area in the form of a waterfall, and the other is in the downstream of channel , so collecting five samples of the water level in the channel set at various levels when the water is static, and comparing it with the manual results that you get from the manometer. Figures 8 and 9 shows a comparison of results with standard deviation. The results have explained the convergence of the values between two sensor readings and the manual readings, And the efficiencies of this sensor in sensing water pressure.

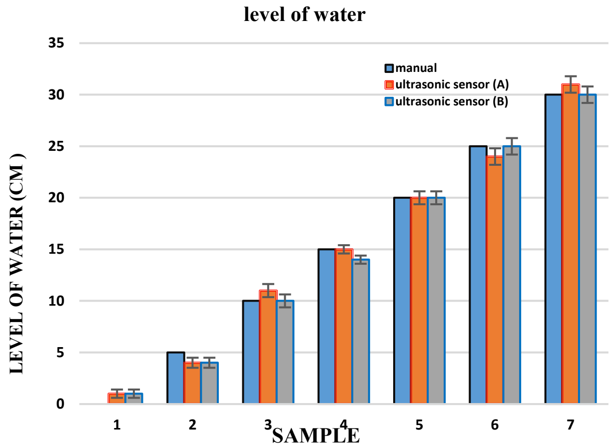

Figure 7. Accuracy comparison of the JSN-SR04 ultrasonic sensor with the manual

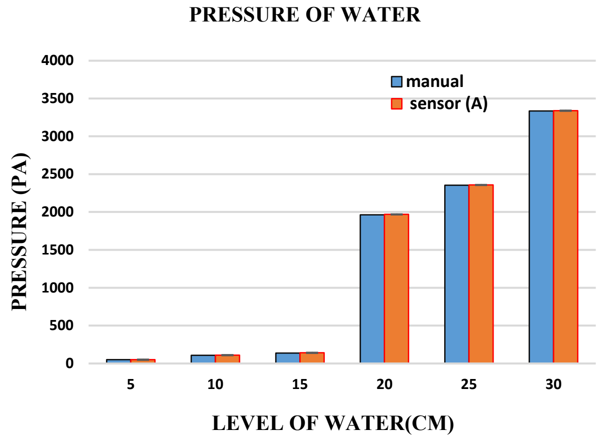

Figure 8. Comparing the Reliability of Manual and Digital Water Pressure Sensors (A)

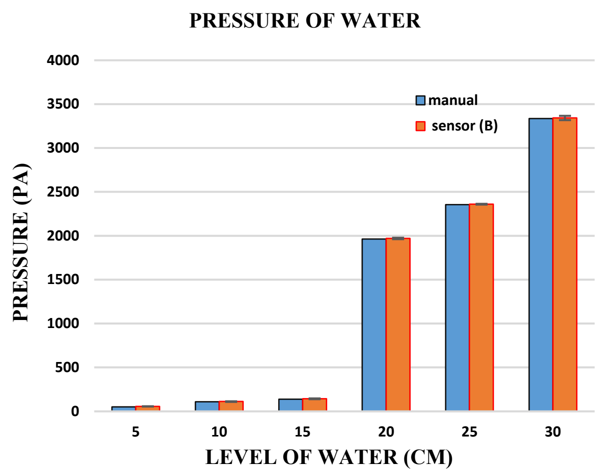

Figure 9. Comparing the Reliability of Manual and Digital Water Pressure Sensors (B)

Overall, using the ESP32 in combination with the MPX5010DP sensors, water pressure sensors, and ultrasonic sensors allowed for precise and accurate measurements of the water velocity, water pressure, and level in the flow channel. This information is valuable for understanding the dynamics of water flow and can be used to improve the design and operation of flow channels in a variety of applications. Regarding restrictions, it's critical to keep in mind that elements like water viscosity and temperature may have an impact on how accurate the readings are. In order to increase the precision of the measurements, future study may concentrate on investigating these elements and creating techniques to take them into consideration.

4. CONCLUSION

This paper proposed the development of an effective SCADA system for controlling the open water channel. It consisted of an ESP32, MPX5010DP, the pitot tube, an Ultrasonic sensor, a (TB6600) stepper driver, linear Actuators with Lead Screws and stepper motor, and water pressure. This server gives the system a secure, comprehensive monitoring and controlling water channel across a web page hub where a user can connect from anywhere and monitor and manage an open water channel to make it easier to take measurements. where this system adds flexibility to the water channel in controlling it and taking readings by students.

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