ACCRA INSTITUTE OF TECHNOLOGY
The University of the Future

SCHOOL OF ADVANCED TECHNOLOGIES ENGINEERING AND SCIENCE

(SATES)

<u>TOPIC</u>

DESIGN AND CONSTRUCTION OF AN IOT BASED LIQUID LEVEL CONTROL SYSTEM

BY

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THESIS SUPERVISED

BY

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NOVEMBER, 2022.

DECLARATION

We hereby declare that this project work is the true result of our own original researches the under-mentioned students under the supervision of the under-mentioned supervisor. The students and supervisor certify that the work documented in this Thesis is the output of the research conducted by the students as part of final year project work in partial fulfillment of the requirements for the Bachelor of Engineering (B.ENG) in Electrical and Electronic Engineering.

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DEDICATION

It is our heartfelt desire to dedicate this work to Almighty God, our parents, all teaching staff of the electrical electronic department of Accra Institute of Technology (AIT) and friends for their prayer and support.

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Our first and foremost thanks go to the Almighty God for His perpetual love and guidance during our study.

We acknowledge with much gratitude the bits and piece on theory and design problems suggested by our supervisor, Mr. Alphonsus Bayor with his constructive supervisory work, encouragement, corrections, and recommendation given to us.

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We would also like to extend our profound gratitude to our friends and all those individuals who directly or indirectly aided us in the process and contributed towards this work.

ABSTRACT

The main purpose of this project is to design and construct an Internet of Things (IOT) Based Water Level Control and Quality Monitoring System, with Leakage Detection Abilities.

The device is used to monitor quality and control water levels in a reservoir to avoid overflow, shortage of water and the pump running dry. In this report, the chapter one describes the background of the study, statement of problem, objectives, and scope of the report. The chapter two is all about the literature review of the automatic water level's design and manufacturer of existing types. In chapter three we described the methods, designed requirement, and how the total construction was made. The chapter four will then explain the construction of the device. Finally, in chapter five, we make our summary.

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CHAPTER ONE

GENERAL INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

Liquid level refers to the position or height of a liquid surface above a line of reference. In order to ascertain the quantity of the liquid held in a container, level measurements are made. Liquid level is an important process variable in industrial plants that use large quantities of liquids such as water, chemicals, and solvents. For instance, there is need to monitor liquid level in boilers, distillation columns, underground fuel tanks, overhead tanks etc., and this necessitates the employment of liquid level instruments. Liquid level measurement techniques are grouped into two mains. Thus, direct, and indirect method (Rajput, 2009). The former is a simple, almost straightforward method that uses a direct measurement of the distance (usually height) from the reference line and the latter depends on the material (the liquid) having known physical properties that can be measured and related to level. Examples of the direct method are the use of dip stick and lead lines, sight glass and chain or float gauge. Examples of the indirect method which employs latest technology in its measurements are buoyancy, sonar or ultrasonic, resistance, capacitance, radiation, to mention a few. Level measuring instruments can be further classified based on their mode of processing and displaying readings into analogue and digital instruments. Analogue displays are in the form of calibrated printed scale on which values are indicated by a rotating pointer whose motion between the minimum and maximum readings is caused by a moveable-coil arrangement. Digital display mode on the other hand represents readings in discrete blocks or directly as numerals on a liquid crystal display (LCD).

Level reading instruments serves as replacements for tape measures which have limits on the type of measurements they can take; specifically, liquid level in large and underground tanks. They ensure safety by preventing the dangerous outcomes associated with water level in boilers varying outside certain limits. They also help in the monitoring of level in bulk storage tanks from which plant efficiency can be assessed. Liquid level measurement in the oil and natural gas industry is of much essence in helping to achieve objectives such as accurate computing of tank inventories of hydrocarbon liquid products; protection of equipment such as compressors, turbines and pumps from damage; protecting personnel against injury that may result from hydrocarbon, toxic or corrosive liquid spillage; protecting the environment from the release of objectionable liquids in rivers and the sea; and controlling phase separation processes and product loading operations

Liquid level reading instruments have been on the market for years and still considered a trusted technology in the modern electronic instrumentation industry. One is the well-known fuel gauge. The fuel gauge is an instrument used to indicate the level of fuel contained in a tank. Mostly used in cars, it may also be used for any tank including underground storage tanks

1.2 FIELD AND SUBJECT OF STUDY

The field of study with regards to this project is Electrical Engineering, whereas the subject area is Embedded Systems and Control and Instrumentation.

1.3 OBJECTIVES

1.3.1 General Objective

The main objective of this project is to design and construct an Internet of Things (IOT) Based Water Level Control and Quality Monitoring System, with Leakage Detection.

1.3.2 Specific Objectives

The specific objectives are:

- To construct a miniature pumping station for a storage tank supply destination to a reservoir.

- To design an installable water level sensing system to be mounted on a reservoir and a storage tank for level monitoring.
- To design and incorporate in-line pipeline flow monitoring system to detect leakages on the pipeline.
- To transmit real time measure liquid volume through the internet to a smart mobile device.
- To display real time measured liquid volume on both locally on a liquid crystal display and remotely on an IOT based web dash board.
- To display flow and pipeline status (leakages at precise pipeline range and pumping defects) in real-time on the app.
- To control water pumping load both locally and remote via the IOT web based dash board.
- To implement a system for monitoring water quality parameters (i.e., temperature, turbidity, and PH).

1.4 PROBLEM STATEMENT

The ordinary dipstick consists of a metal bar on which a scale is etched. The metal bar is fixed at a known position in the liquid-containing vessel. Level measurements are made by taking out the instrument and reading off how far up the scale the liquid has wetted. This technique although, in some cases, is unrivalled in accuracy, reliability and dependability, has some downsides. First, it always requires a human operator to do the removal and reading of the graduated bar. Another is that there cannot be continuous representation of the measurement and lastly the inability to measure levels conveniently and successfully in pressurized vessels. Keeping the quality of water distributed to a community is of utmost relevance to ensuring the supply of portable water to the residents. The lack of automatic detection of leakages on water supply pipelines leads to loss of volume of water in the event of a burst at a point in a water supply network.

1.5 SIGNIFICANCE OF THE STUDY

Study into the area of control and instrumentation with focus on level, temperature, pH and pressure all being measurements executed on fluids specifically liquid (water) combines to help monitor the filling of vessels and tanks as well as monitoring of quality and portability of water. The study seeks to exploit the diverse technique that involves the use of differential pressure and flow rate at various points on a water supply pipeline for detection of leakages along the pipeline. PH, temperature, and turbidity measurement procedures are also employed to determine the portability of water for safe consumption. Outcomes of the study would be a multi-functional system that monitors and control water vessel content level and detects possible leakages.

1.6 BACKGROUND AND JUSTIFICATION OF THE STUDY

1.6.1 Background

Ensuring the condition measure of process materials is executed accurately and precisely to avoid possible losses in industrial manufacturing processes necessitates the employment of various techniques depending on the parameter or specific quantity of interest. This field of science which defines as the science of automated measurement and control is referred to as instrumentation. The parameter or condition in question is a determinant of the appropriate applicable technique that best fits the measurement procedure due to the response of some physical properties of matter to the changes of these conditions. Focus area are usually level, temperature, flow, pressure, volume, mass, pH etc. In this study work, the areas of interest are temperature, flow rate, level, and PH.

Level measurement in small to medium scale commercial setups are performed usually by the direct reading methods such as the use of glass gauge method where transparent calibrated tubes are attached to the bottom (additional one attached to the top for closed tanks) of vessels being monitored with the height of liquid in the tube being equal to the height of liquid in the vessel. In industrial process control and instrumentation, level measurement is executed in various techniques that exploit the effect on behavior of propagative waves in mediums during interaction and contact with liquids. Electromagnetic waves such as infrared and radar beam and ultrasonic waves form the principle behind the operation of ultrasonic level transmitter and guide wave radar level transmitter since these waves reflects off the surface of liquids when directed to the liquid surface. The intensity of the echo received by a coupled receiver on the instrument determines the distanced travelled by the transmitted wave.

1.6.2 Justification

The main advantage of this design is the fact that level monitoring and control is undertaken on the major sump serving as the central water supply source, as well as the reservoirs which mimics receiving ends of supplied water in communities. With installation of calibrated and monitored flow meters on the pipelines at various points, differential flow rates are detected automatically to determine the state of pipelines whether there are leakages within ranges of the pipeline. In the event of a leakage, the system gives an indication of the exact region of the pipeline where the leakage has occurred and signals an alarm on the mobile application interface for quick repairs work to be performed in order to avoid loss of volume of water. This renders the system to be a fully automated design and therefore a suitable solution to the problem statements.

1.7 EXPECTED RESULTS AND POSSIBLE USAGE

The expected outcomes of this project are as follows;

- An accurate liquid level sensor for monitoring the volume of a tank's content.
- A well and vivid display of the measured liquid volume on a liquid crystal display (LCD).
- A real time volume monitoring on a mobile based android application.
- An automatic liquid pump control based on level of liquid in tank.
- A manual control of liquid pump both locally through switches and remotely using a mobile application.

1.8 LIMITATIONS OF THE STUDY

The expected final design after this research, design study would only monitor integral parameters for determining water quality but would lack a control mechanism that would introduce abnormal feedback repair for these parameters.

1.9 CHAPTER LAYOUT

This project is divided into five (5) main chapters which are Introduction, Literature Review, Methodology, System Analysis & Testing and Conclusion & Recommendation.

Chapter 1 is the General Introduction and Summary. Under this chapter is a discussed overview of trending events underlying the topic and area of study, specifically, a brief introduction to level measuring system and internet of things is given as well the problem statement, objectives, and scope of the work of the intended research and design work.

Chapter 2 provides the background information and Lliterature Rreview of the related works done by previous researches and studies related to this project.

Chapter 3 specifies the Methodology which discusses the ways or methods used to conduct this project. Also, all the procedures used to conduct the experiments will also be mentioned here. Chapter 4, the Implementation & Results and Analysis will discuss all the important requirements needed to conduct the experiments. This chapter also contains the result and the analysis of the experiments performed. Finally, Chapter 5 is the Discussion, Conclusion and Recommendations that concludes and discusses recommendations for future research

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Countless water level monitoring and control projects under electrical/electronic and computer engineering project discipline has been undertaken. All these proposed systems sought to minimize or possibly eliminate the situation of water wastage due to overflow of water on fully filled tanks as a result of pump remaining in operation during these periods. This chapter reviews some of these related works considering how reliable, effective and the novelty of the technology implemented in executing them.

2.2 PREVIOUS RELEVANT STUDIES AND RESEARCH WORK

Here we discuss relevant articles or related works

2.2.1 Remote Control of Water Pump Stations Using a Microcontroller

In a work titled "Remote Control of Water Pump Stations Using a Microcontroller ALIŞ, AKIR, ŞAHİN and DİNLER (2015)", a PIC16F84 microcontroller-based system embedded in three pump stations' control and monitoring system is controlled and monitored remotely by a stationed PC and phone line via asynchronous communication through modems. A block diagram of the connections between the various compartments of the system is shown in figure 2.1 below. On the remote side is the PIC16F84 microcontroller circuit which comprises of peripherals such as I/O ports, memory, timers, etc. which makes it very economical, simple, and easy to control through the communication protocol. It contains 35 instruction sets and a 1024 program memory.

- **The technical specifications of the data transmission are as follows:**

  In each frame of the asynchronous data transmission protocol being employed in the remote control, start bits, control characters, and stop bits are added. Though start bits are always single bit, stop bits are one or more.

  The control commands are 8-bit long data.

- Data transmission starts with the start bit, then the 8-bits which is D0 (LSB) to D7 (MSB) are sent sequentially.
- The stop bit is finally included.
- The transmission rate which usually 2400bps is set by means of software on a central PC.
- The length of data, communication speed, number of stop bits are ensured to be same on both transmitter and receiver side.
- The mode of transmission on the RS232 serial interface is the universal asynchronous receiver-transmitter (UART) protocol.

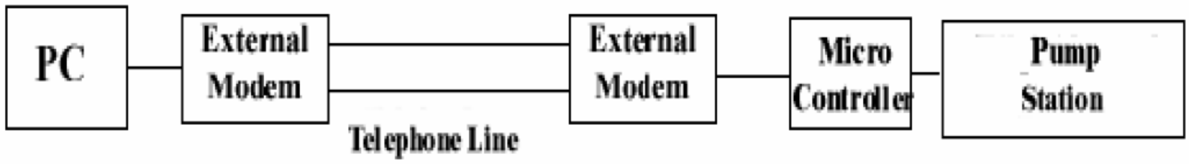

Figure 2. 1 Block Diagram of Remote Control of Pump Stations.

The system implementation technique employed in monitoring the pumps at the stations in the above paper makes it restricted to a stationary PC. This is a downside of the system since it requires constant presence of the personnel at the monitoring point (the PC station) to undertake responsive actions as per determined by the feedbacks received from the system. The quality of the water pumped at the various stations are as well not monitored to ensure distribution portable and usable water the community and it makes the proposed system applicable to only settings and setups where there is probably a separate station of water treatment and quality monitoring. The use of mobile application as proposed in this paper would ensure remote unrestricted monitoring capabilities.

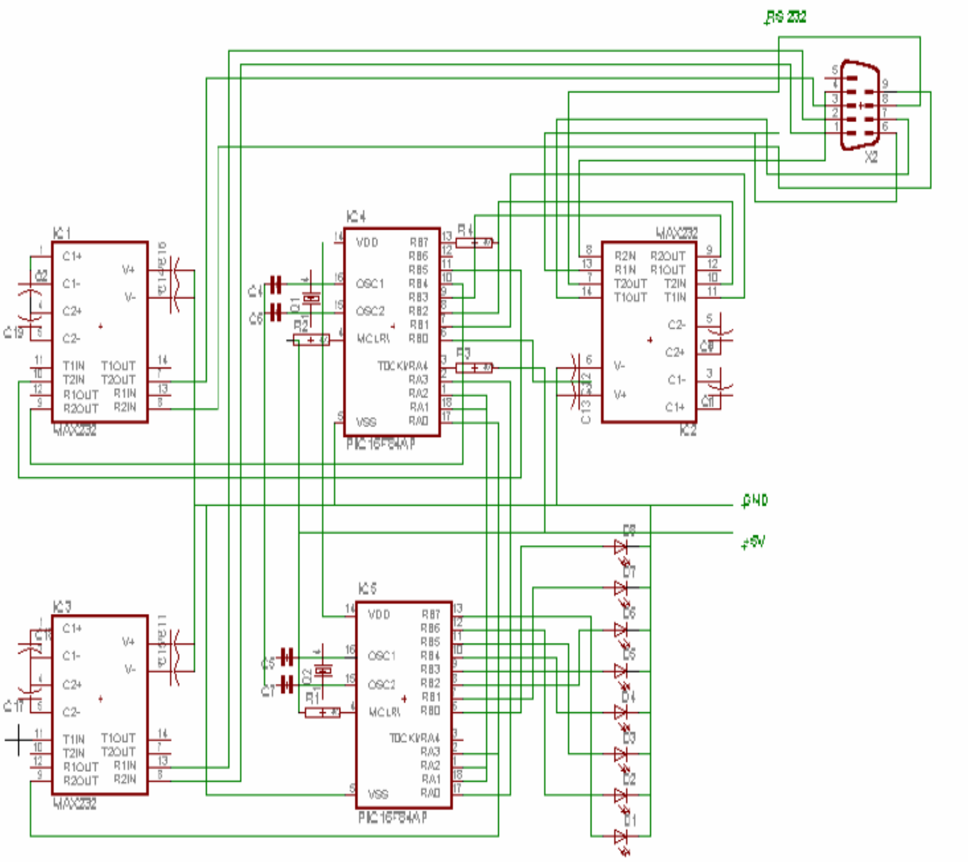

Figure 2. 2 Circuit Diagram of Pump Station Control System

The main function of the system is executed in the sequence as follows:

Data flow control between the microcontroller sides and the PC side is meant to eliminate human interaction and as well provide data sharing.

2.2.2 Internet of Things (IoT) enabled Water Monitoring System

In an International Journal of Engineering Applied Sciences and Technology paper published by Pawar, Raithatha, Patel and Belande (2021), an Internet of Things (IoT) enabled Water

Monitoring System is developed to measure water levels in vessels and tanks in real time. The designed prototype was based on the idea that water level being a crucial parameter could be measured using the ultrasonic technology and information regarding the measure levels propagated over the internet onto a cloud-based dashboard for reading and monitoring. The project presented seeks to eradicate the increasing rampant wastage of water in several uncontrollable ways and eventually to ensure efficient consumption of water by household consumers.

The integral technology employed in the paper is the Internet of Things (IoT) which is a network of interconnected physical devices, actuators, and sensors etc. that communicate and share data mutually. The term “Things” in IoT refers to the diverse devices such as cameras, biochip transponders, sensors, heart monitoring implants (collectively biomedical engineering devices) and other device in various sectors of engineering data monitoring. Data collected by these devices with the help of existing various technologies are autonomously flown between other devices. Not only do IoT enable monitoring of these devices, it as well renders the remotely controllable from around the globe in locations where internet is accessible. With the invent of IoT, great opportunities have been created for the integration of the physical world into the computerized world of smart devices for the improvement of efficiency and accuracy of these devices.

IoT has a broad range of applications which have been categorized into consumer, enterprise, and infrastructure applications. IoT for the sake of being able to network embedded devices using limited memory, power resources and processing speed (CPU), makes it applicable in almost every field. In environmental sensing fields, IoT devices are employed in the collection of information from natural ecosystems to buildings and factories. It also plays a key role in the field of environmental monitoring particularly in disaster management where it generates alerts and early warning of impending disasters.

Thingspeak: it is an open-source IoT application programming interface (API) or application (app) that stores and retrieves data from smart embedded devices using HTTP protocol over the Internet or through a Local Area Network. When a new user creates a Thingspeak account, channels are created, read API keys and write API keys are also created for reading and writing data respectively to the dashboard.

The concept of IoT is presented in figure 2.3 below.

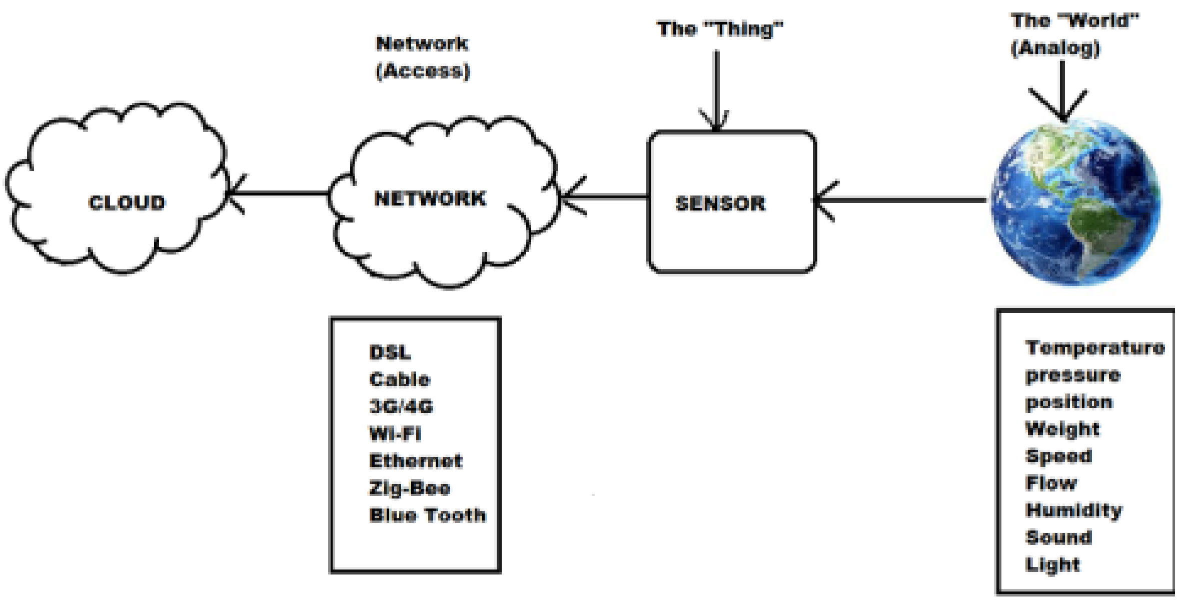

Figure 2. 3 IoT Network Architecture.

- ✓ **Prototype Implementation**:

The system is deployed with water level monitoring implemented using an HC-SR04 ultrasonic sensor and data transmission from the sensor done through the wireless gateway of the consumer's network.

HC-SR04 Ultrasonic Sensor: Ultrasonic transceiver module also known as a proximity sensor is applied in distance measurement between two bodies i.e., the body carrying the sensor and a reference body. It's made up of an ultrasonic transmitter, ultrasonic wave receiver and a control circuit. Distance measurement is executed by first reflecting transmitted ultrasonic waves at the target object which gets picked up by the receiver. Computation of the time difference between transmission and reception of wave goes further to give the distance travelled. It is very effective in computing distances in a range of 2 to 400 centimeters or 1 inch to 13 feet.

✓ **Raspberry Pi 3**:

This is the 3rd generation model of a credit card sized board microcomputer with built-in Quad core 64bit CPU, Wi-Fi, bluetooth, wired and wireless LAN; and a Broadcom BCM 2837 processor. It is used for multiple applications that require any of it featured wireless connectivity.

System diagram of the proposed setup is shown in figure 2.4 below.

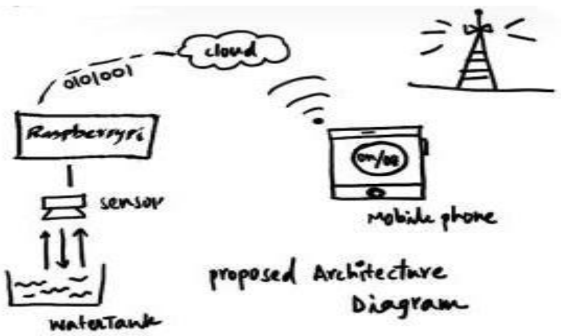

Figure 2. 4 System Diagram of IoT Based Water Monitoring System.

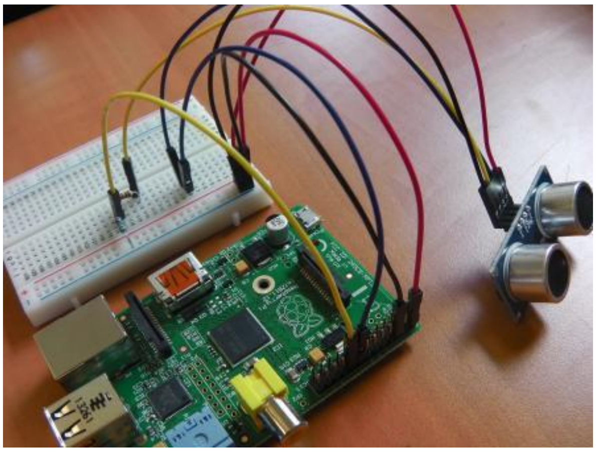

Figure 2. 5 Circuit Diagram for Prototype of IoT Water Monitoring System

Water level related data collected by the sensor and sends it via the on-board Wi-Fi to the cloud. The water level is then displayed on the remote Thingspeak dashboard which can be viewed on the user's mobile device. Data regarding water level on the dashboard is retrieved in real-time (i.e. every 20 seconds) and displayed in centimeters on the y-axis of a level-time graphical representation of the data. Figure 2.6 shows a view of the dashboard.

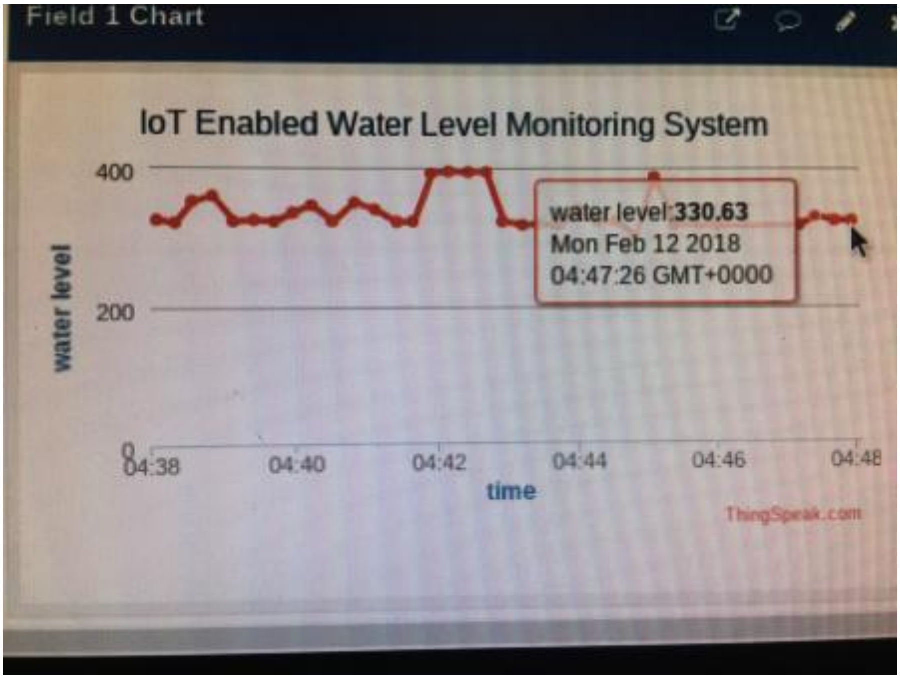

Figure 2. 6 Thingspeak dashboard for IOT water level monitoring.

The above discussed project does not implement water quality monitoring but only monitors water level in a tank. Its application is limited to liquids whose quality level in terms of durability and usability is not of essence.

2.2.3 Smart Water Pump

In an International Journal of Engineering Applied Sciences and Technology paper published by Pawar, Raithatha, Patel and Belande (2021), a "Smart Water Pump" was designed and constructed. The rampant wastage of water due to overflow on the storing tanks in factories caused by continuous running water pumps leads to frequent shortage of water available for usage in the factories. Overhead tanks used in households for protecting the water from pest infestation and growth of algae have pumps that are often left unattended to and remained in ON state since the level of water in the tank is not visible due to the color and height of the tank. This necessitates the monitoring of the water flowing in and flowing out of the storage tank by a system that focuses on water level and water quality (by Sivaiah, Purna, Sownya, Susmitha, Sai and Suma, ‘’Internet of Things (IoT) Enabled Water, 2018).

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- ✓ **The electronic circuitry comprised of the following:**

Arduino Uno: A microcontroller board based mainly on the AVR microcontroller Atmega328 and developed by open-source electronics platform Arduino.cc. The Atmega328 is a unique microcontroller which acts as an 8-bit microcontroller**.** The Uno comes with 6 analog input pins, a USB interface, 14 digital I/O ports that are used to interface to external electronic devices and circuits. Of the 14 I/O ports, 6 can be used for PWM output. These I/Os allows circuit designers to sense and control external electronic devices in the real world. It is an open-source platform, meaning the software: Integrated Development Environment (IDE) for programming the board is readily available and can be modified and optimized by anyone for better functionality. It only requires some basic skills to study it. It's being programmed using C and C++ language (Sivaiah, et al., 2018).

Ultrasonic Proximity Sensor: Ultrasonic transceiver module also known as a proximity sensor is applied in distance measurement between two bodies i.e., the body carrying the sensor and a reference body. It is very effective in computing distances in a range of 2 to 400 centimeters or 1 inch to 13 feet. Unlike sharp rangefinders such as the DJI LiDAR module which get impaired by black content and sunlight, the ultrasonic since it transmits and receives back ultrasound waves, is barely impaired and distracted within its range of operation. In this application, it serves the water level monitoring sensor to determine the state of the motor depending on the water level computed as per the echoed ultrasound signals given by the sensor. At minimum level of water, the motor starts to fill the tank whilst at predetermined maximum level, the pump motor is stopped to halt the filling process.

- ✓ **DC Motor**

An electromechanical device that converts electrical energy into mechanical energy. A direct current (DC) motor operates on direct current other than alternating current (AC). DC motors consist of an armature, a stator, and a commutator with brushes (unlike AC motors). Opposite polarity between the magnetic fields generated in the stator and rotor causes a turn of the rotor seen as a rotation of the motor’s shaft. Categories of DC motors are series-wound, shunt-wound, permanent magnet, and compound-wound. In this application it serves as the pump motor which turns at the minimum water level detection.

- ✓ **Turbidity Sensor**

A measure of the number of impurities in water, also termed as the total suspended is a determinant of quality of the water. This measure is termed as turbidity and its measured using a turbidity sensor. When the solid in the water increases, the sensor detects the impurities and alerts the user. The sensor’s range can be adjusted to generate trigger signals at specific limits. The flow chart and circuit diagram for the smart water pump are shown in figure 2.7 and figure 2.8 respectively.

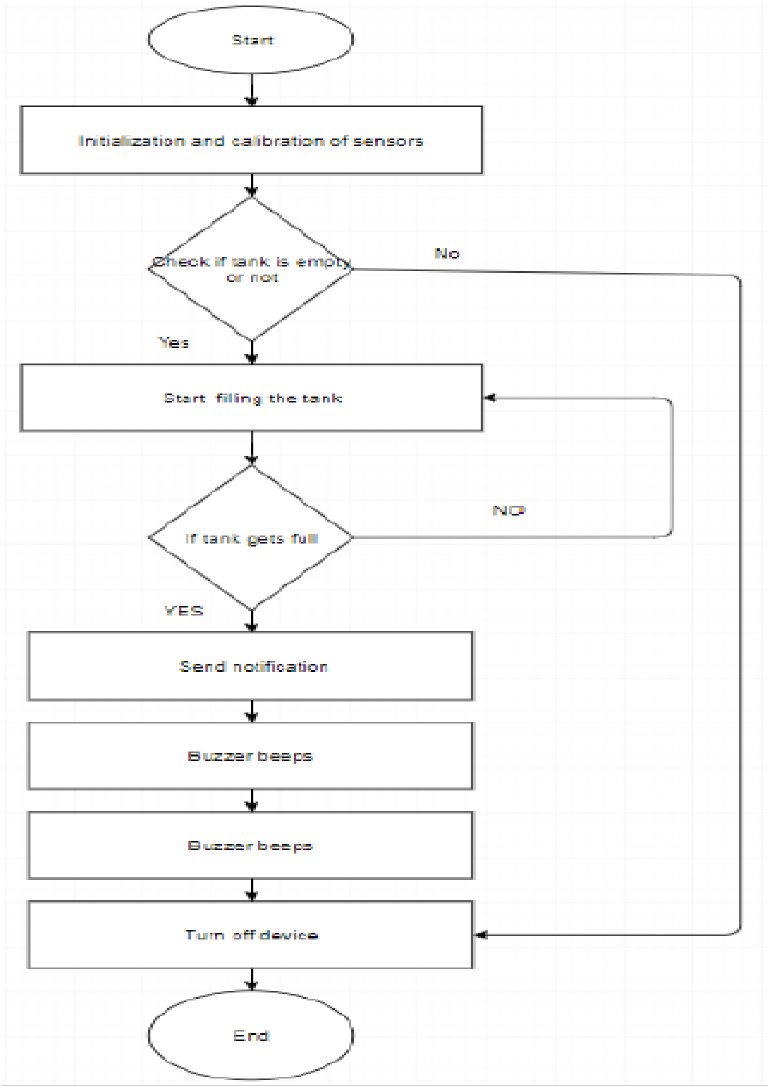

Figure 2. 7 Flow Chart of Smart Water Pump.

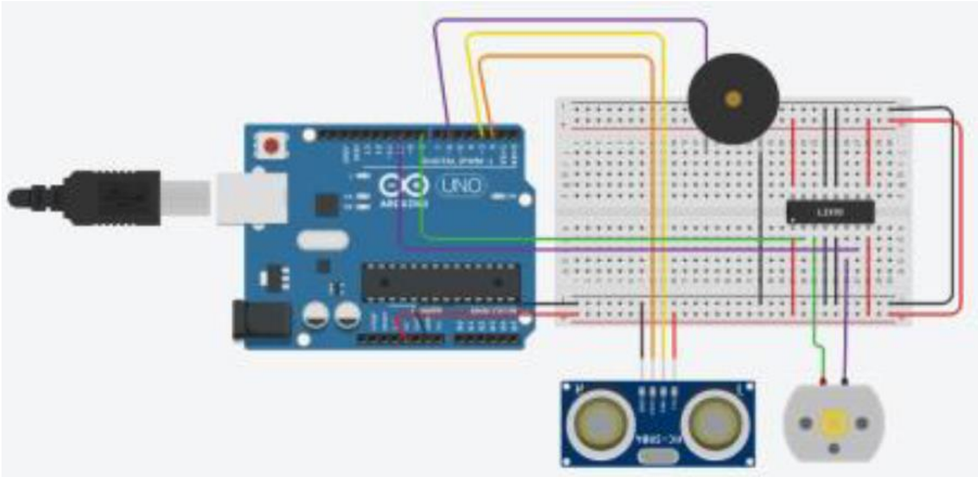

Figure 2. 8 Circuit Diagram of Smart Water Pump.

It was concluded that the project succeeded in reducing incessant wastage of water on a large scale. Also, the displayed results were correct and unique. With the system being automatic, control of the pump motor did not require human intervention which leads to the reduction of error and human discrepancies to a minimum. With the implementation of diverse sensing devices for monitoring of essential parameters in the system, the water that reach out to consumer is very clear and portable and not wasted.

The above discussed project implements water quality monitoring but only on turbidity. However, acidic, and alkaline concentrated water could be high clarity in terms of its solid particles content. In this situation, water that has been polluted with acidic industrial waste could be pumped to consumers without noticing it acidic nature since a pH test was not performed on it.

2.2.4 Smart Water Level and Leakage Detection” system prototype

In an international journal of engineering and technology paper published by Kadar, Sameon and Rusli, (2018) “SMART2L: Smart Water Level and Leakage Detection” system prototype was proposed and designed to minimize Non-revenue Water (NWR): best defined as the difference between the measure volume of water pumped into a water distribution system and the consumer-billable volume. NWR in-effect amounts to an unaccountable volume of water that gashes out of the distribution system mainly through leakages that are likely to be caused by pipe bursting. The proposed prototype, SMART2L, is a system that uses Wi-Fi to establish direct sensor-to-sensor communication. The tank water level and leakage detection are implemented using sensors integrated into the system.

2.2.5 The Proposed System.

The task of SMART2L system is to aid in the monitoring and managing of water level and leakage within a water distribution system by integrating very few sensors to guarantee the security and efficiency of the system operation. The sensors interfaced to an Arduino microcontroller, are programmed to calculate the flowrate and volume of water with outputs displayed through a mobile app. The system also aims at avoiding tank drying or overflow during the process. Its automated technique seeks to reduce manpower and power consumption and most importantly, to alert the users using e-mail notification system (Kadar, Sameon and Rusli, 2018).

SMART2L employs an e-tape water level sensor to determine water level in the tank depending on the position of the water surface inside the tank. Leakage sensor is used to detect any leaks, small seeps or ruptures in the flow or on the storage tank. The SMART2L automatically sends an e-mail to notify the user of any changes in the storage level and controls the pump automatically. The flowrate sensor is also used to calculate the flowrate of the water and the volume of water output. Figure 2.11 highlights the flowchart of the steps taken in implementing SMART2L system.

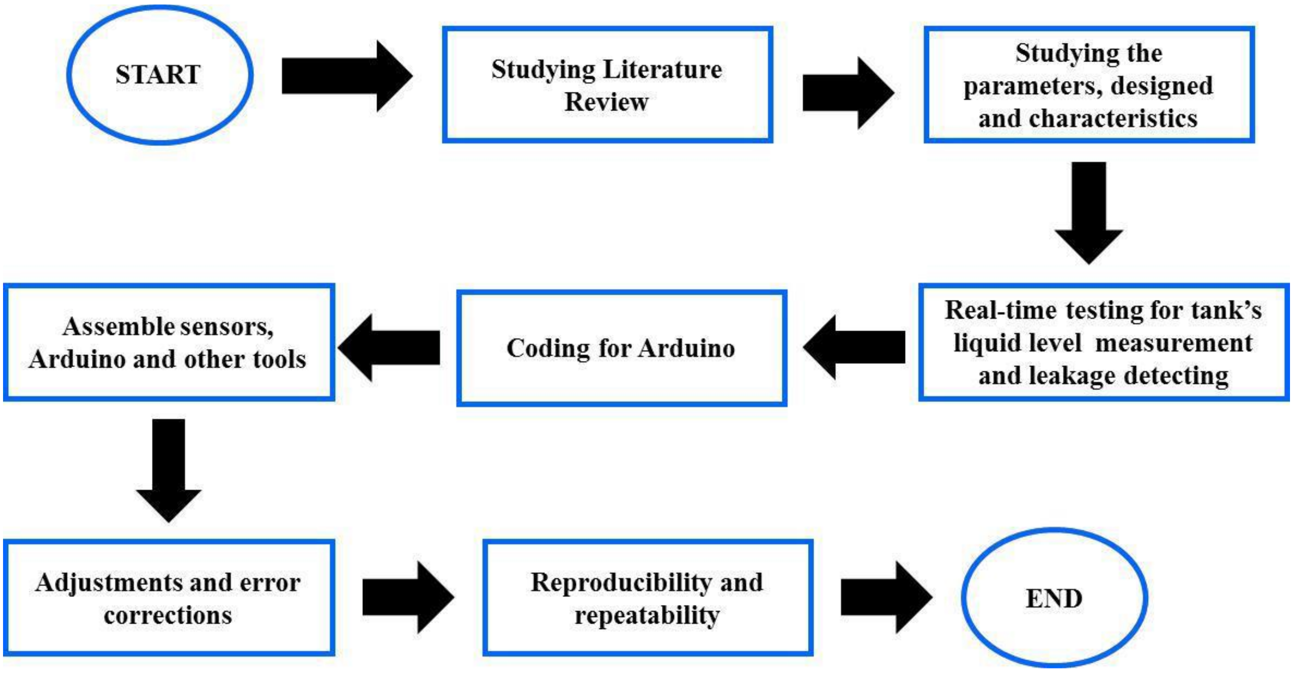

Figure 2. 9 Overview of SMART2L Implementation Phases

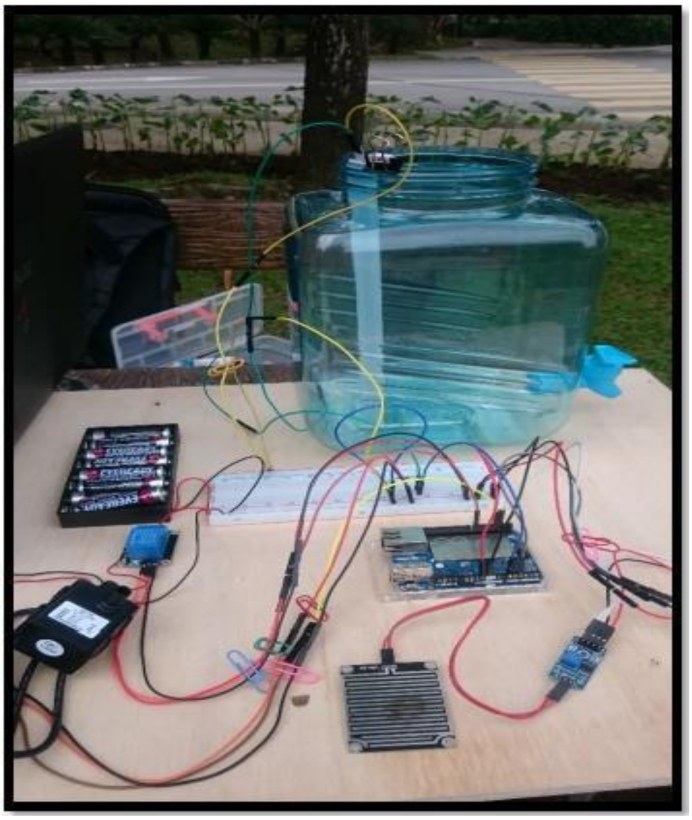

Figure 2. 10 Sensors connected to Arduino Yun

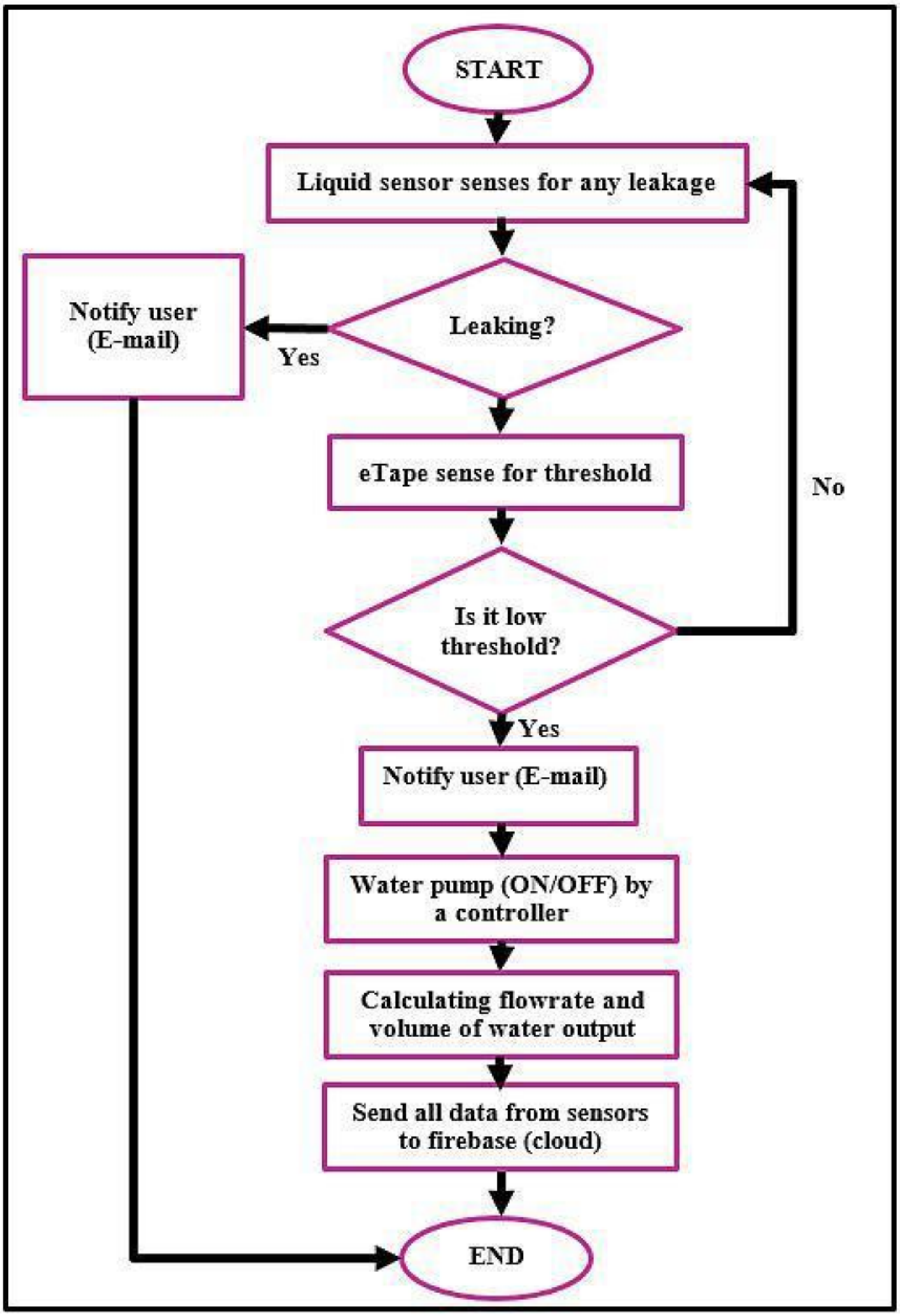

Figure 2. 11 Flowchart of SMART2L

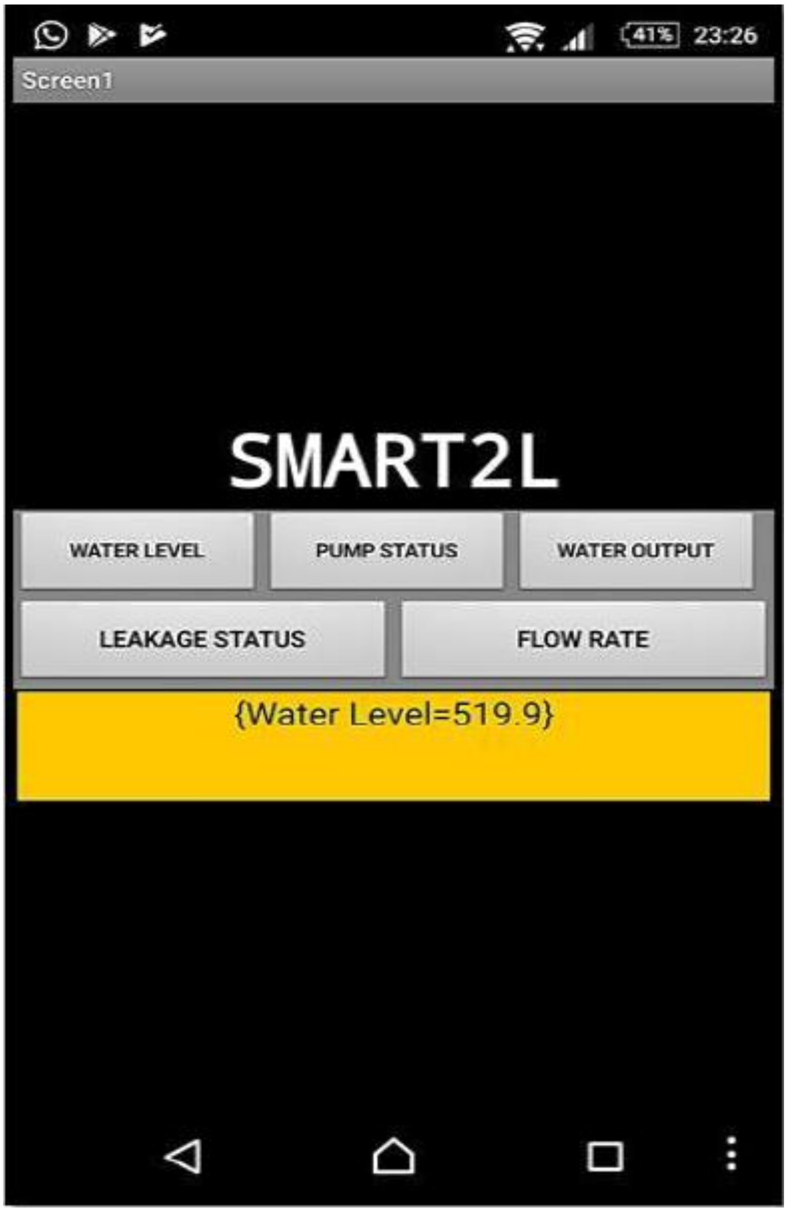

Figure 2. 12 The interface of mobile SMART2L application

The system developed in the above paper despite having monitoring features for keeping track of the pump status, flow rates which transforms to leakage detection and notifications, it does not implement water quality monitoring which is of essence for application on the consumer level. That renders the system applicable only in environments where water quality in terms of its turbidity level, pH and temperature does not factor into it use.

2.2.6 Detection of Water Level, Quality and Leakage using Raspberry Pi with Internet of Things

In an international journal of engineering and technology paper, published by Arjun, Dr. Latha and Prithviraj (2017) "Detection of Water Level, Quality and Leakage using Raspberry Pi with Internet of Things" was proposed for a water quality monitoring system based on wireless sensor network was presented. The system was constituted by a base station and several sensor nodes. In the node side, water quality data was collected by sensors such as pH and Temperature. Here they made use of ARDUINO UNO 3 as hardware component to interface between sensors and GSM module (Arjun, et al., 2017).

A tank containing water is immersed with pH and turbidity sensors for water quality measurement, FSR sensor for water pressure detection and LED lights and ultrasonic sensors for determining the water level. These sensors measure the corresponding values in the water. Outputs of the pH sensors are converted from analog to digital by Raspberry pi using ADC. System uses LAN for communication with the control center. It's a real time system and it doesn't need any man machine interaction for activity in the water quality measuring system. This requires a LAN or internet connection for communication. The systematic arrangements of the components are shown in the Fig 2.13.

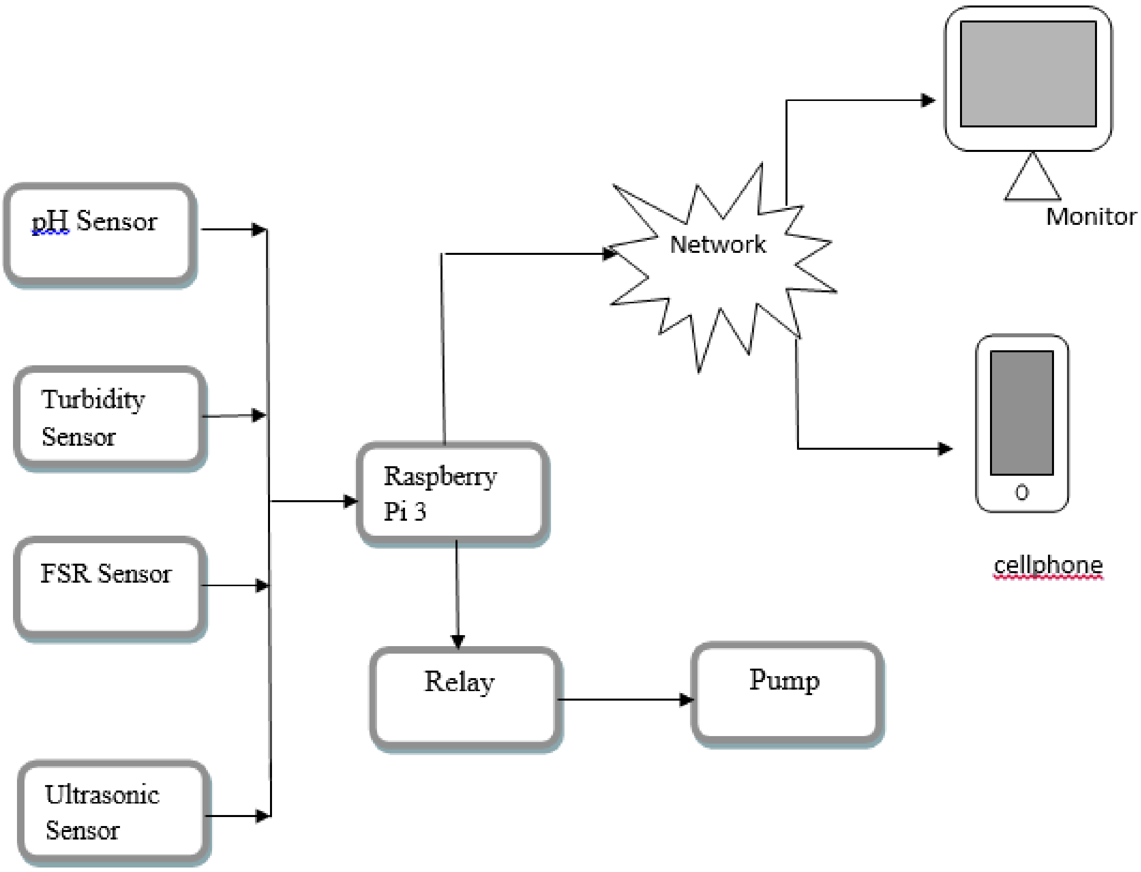

Figure 2. 13 Architecture of working model.

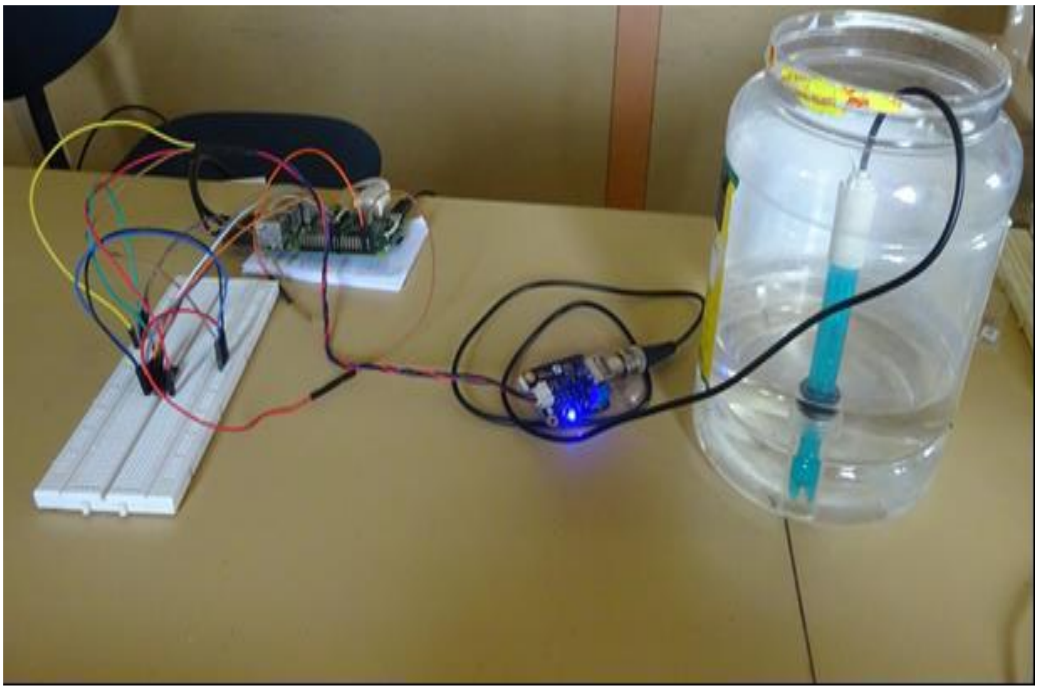

Figure 2. 14 Connection of pH Sensor to Raspberry Pi.

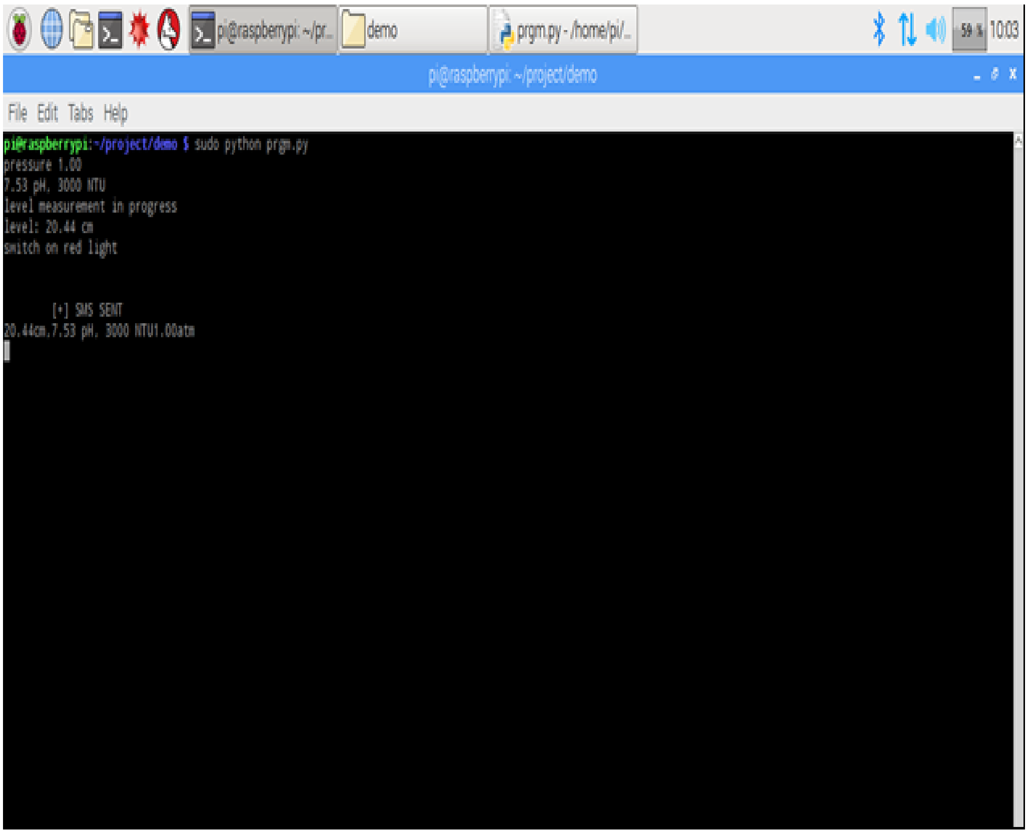

Figure 2. 15 Output of all sensors.

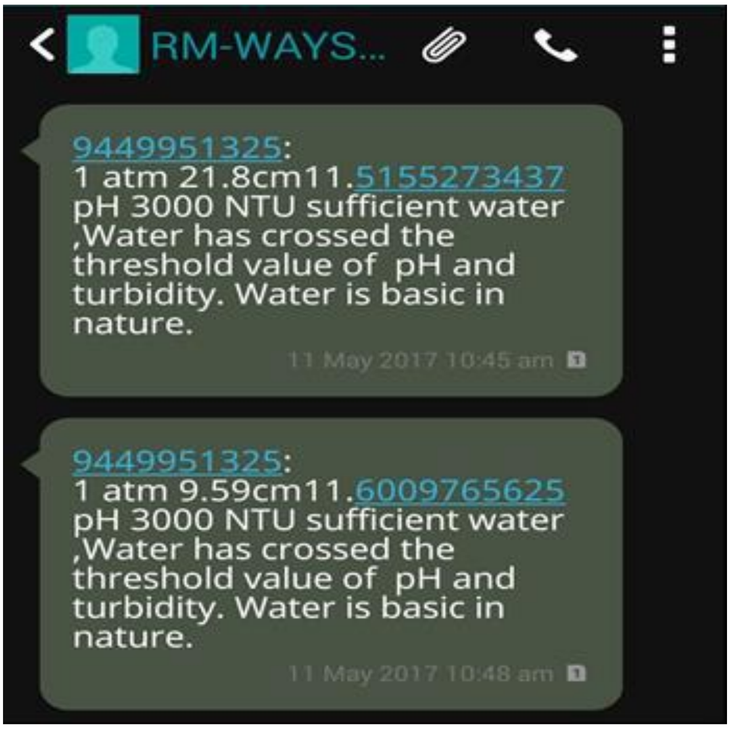

Figure 2. 16 SMS Notification.

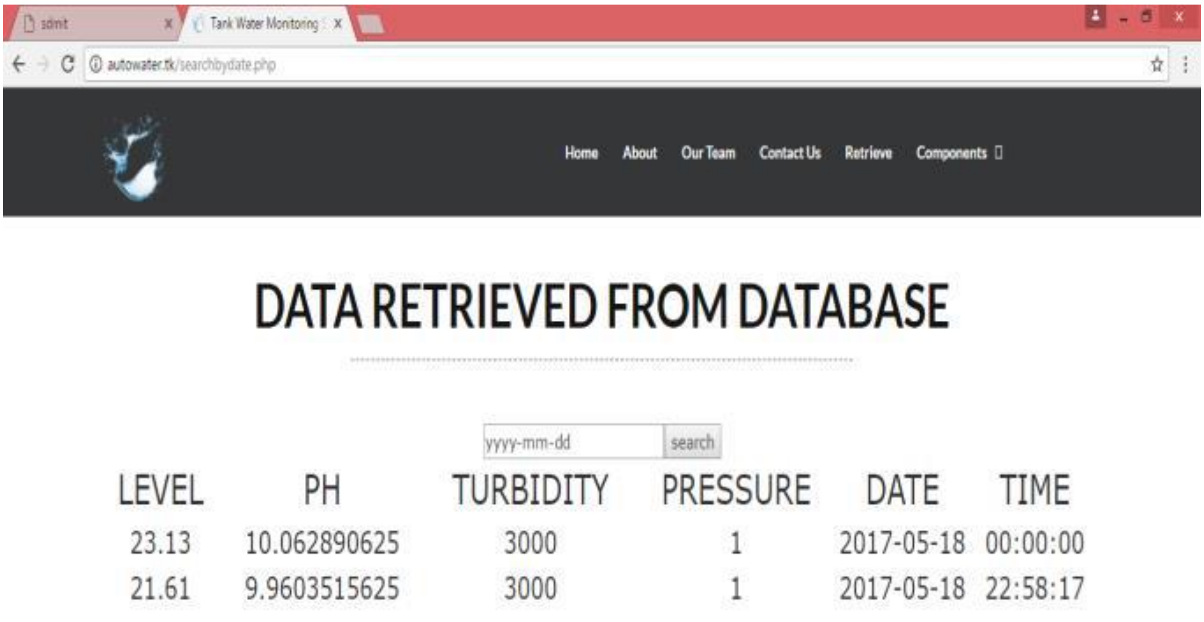

Figure 2. 17 Website data.

The implemented technique in the above paper rightly displays information in real time vividly on a dashboard as well as in a tabular form. However, the system lacks remote control capability for updating the state of the water pump in the event of a notification regarding an overflow (filling beyond maximum level) which could prompt for manual turning off the pump. This is an assumed incident of an automatic turning off failure. This feature is proposed in this paper to be implemented under the system development stage.

2.3 LITERATURE GAP AND CONCLUSION

The existing technology lacks at least one of the features implemented in this project. Either monitoring the pumps at the stations requires constant presence of a personnel at the monitoring point to undertake responsive actions as per determined by the feedbacks received from the system, the quality of the water pumped at the various stations not being monitored, hence, a separate station of water treatment and quality monitoring required which makes it expensive, lack of water leakage monitoring device and lacks remote control capability for updating the state of the water pump in the event of a notification regarding an overflow.

The use of mobile application would ensure remote unrestricted monitoring capacities in this paper. Data flow control between the microcontroller sides and the PC side is meant to eliminate human interaction and as well provide data sharing.

The tank water level and leakage detection are implemented using sensors integrated into the system. This feature is proposed in this paper to be implemented under the system development stage.

In order to improve on the deficiencies indicated above in the existing systems reviewed, our project integrated all the eliminated features to produce a complete system to monitor, control and ensure quality of water supply via IOT.

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

This chapter will cover the details explanations of the various methods, systematic procedures, components or materials, tools and equipment that are used to achieve the objectives of design and construction of an IOT based liquid level control system

Also, this chapter details the various component specification and system requirements and software used to construct an IOT based liquid level control system

3.2 PROJECT APPROACH

The main objective of this research and design process that is., designing and constructing a system with constituent components and devices such as liquid level sensor (ultrasonic transceiver), 12VDC pump, flow sensors, turbidity sensor, pH sensor, temperature probe, Wi-Fi module, electromechanical relay, transistors, liquid crystal display (LCD) with main function of operating a water level monitoring and pump control as well as water quality check system. The system's full functioning operation would be met by undergoing the following predefined sequence of operation procedure (SOP):

- The system when operating in manual mode, the 12VDC submersible pump continuously pumps water after manually switch locally from a button. Switching OFF pump would also be done manually irrespective of water level in tanks.
- In automatic mode of operation, ultrasonic water level sensor interfaced to microcontroller sends transduced echoed ultrasound signals for computation of water level in tank as a determinant of the pump state. i.e., pump stops when water level is at maximum and starts when water is drained to the minimum level.

- Flow rate of water pumped from reservoir is measured using flow sensors at the installed at entry point of pipes as well as exit point of pipe into consumer storage tanks.
- Drastic reduction in flow rate at exit point flow sensor for a consumer line gives an indication of a possible pipe burst. Notification to this effect is given both on local LCD and remotely on app.
- Before water in reservoir is pumped to consumer storage tanks, its quality in terms of turbidity level, pH and temperature level is assessed. These parameters are monitored in real-time displaying their current readings locally and on app.

The system's operational sequence as stated above would be achieved by an electronic circuit represented by the block diagram in figure 3.1 below which depicts the architecture of the system with indication of the individual peripherals interfaced to the microcontroller which acts as the central processing unit of the entire system.

In the subsequent sections and subsections are brief discussions of the various hardware and software tools, equipment, and circuit components.

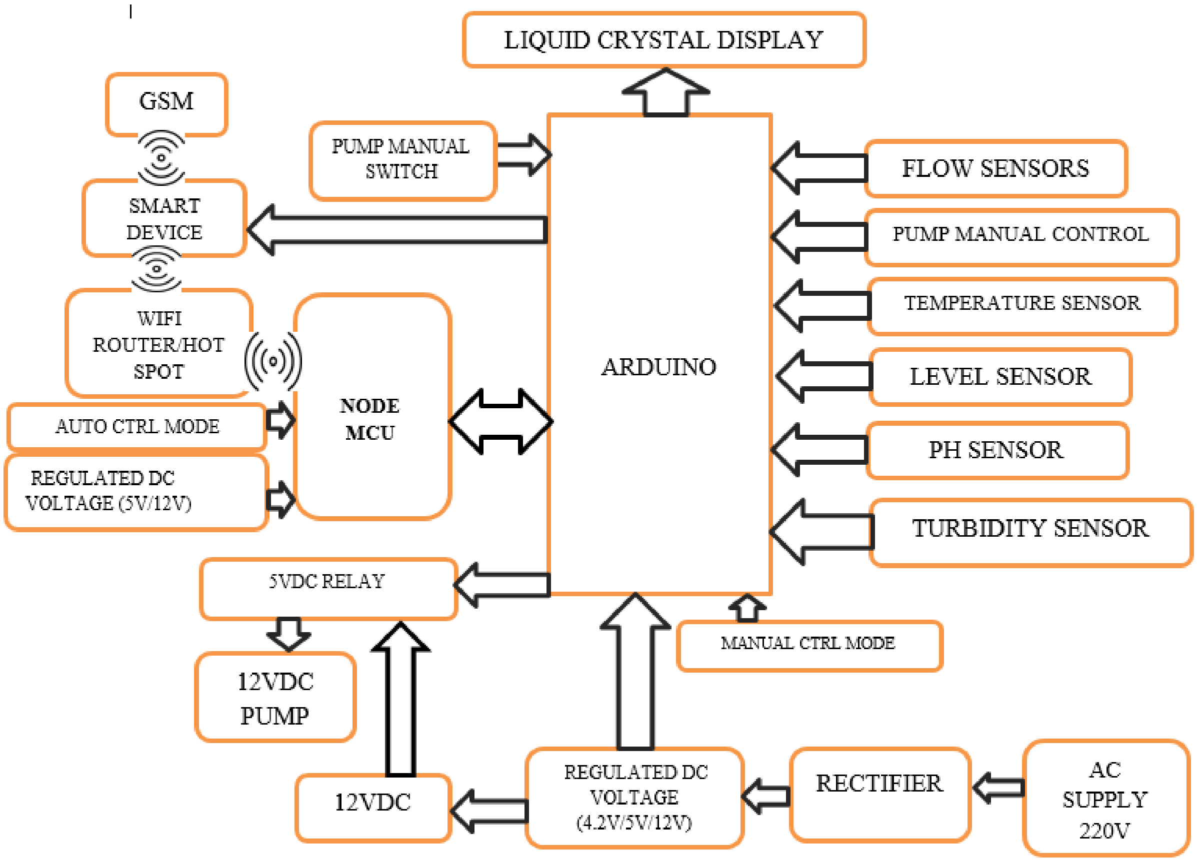

Figure 3. 1 System Block Diagram

3.2.1 System Organization or build up

The system when operating in manual mode, the 12VDC pump continuously pumps water after manually switch locally from a button or remotely from mobile app via the internet. Switching OFF pump would also be done manually irrespective of water level in tanks. In automatic mode of operation, ultrasonic water level sensor interfaced to microcontroller sends transduced echoed ultrasound signals for computation of water level in tank as a determinant of the pump state. i.e., pump stops when water level is at maximum and starts when water is drained to the minimum level. Flow rate of water pumped from reservoir is measured using flow sensors at the installed at entry point of pipes as well as exit point of pipe into consumer storage tanks. Drastic reduction in flow rate at exit point flow sensor for a consumer line gives an indication of a possible pipe burst. Notification to this effect is given both on local LCD and remotely on app. Before water in reservoir is pumped to consumer storage tanks, its quality in terms of turbidity level, pH and temperature level is assessed. These parameters are monitored in real-time displaying their current readings locally and on app.

3.3 REQUIREMENT ANALYSES

This includes;

- ✓ **Tools**
- ✓ **Software Requirement**
- ✓ **Hardware Requirement**

3.3.1 Tools

A tool is any physical item that can be used to achieve a goal. In every project development, there are various tools that are needed to achieve accurate results. In this project however, the various tools used in the design and construction are listed in table

- ✓ **Tools and functions used for the construction of IOT based liquid level control**

Table 3. 1 Tools used for the construction of IOT based liquid level control

TOOLS	FUNCTIONS
Soldering Iron	It supplies heat to melt the solder so that it can flow into the joint between two workpieces.
Soldering lead	Fusible metal alloy used to join metal workpieces and having a melting point below that of the workpiece(s)
Multimeter	Used to troubleshoot electrical problems and testing electrical and electronic
Set of Screwdrivers	Used for fastening screws
Pliers	Used to grip objects
Cutters	For cutting of wires
Breadboard	A construction base for building the prototype.

3.3.2 Software requirement

Software is the set of instructions in the form of programs to govern the computer system and to process the hardware components. Examples are; Proteus, Arduino Integrated Development Environment (IDE), Raspbian OS, Python Ide, Fritzing etc.

3.3.2.1 Proteus software

Proteus software is a simulating platform for simulating an electronic circuit of a wider range (from oscilloscope analyzable circuits to embedded system programmable circuits with sensors and actuators) for experimentation, observation, data collection and analysis of even complex circuits.

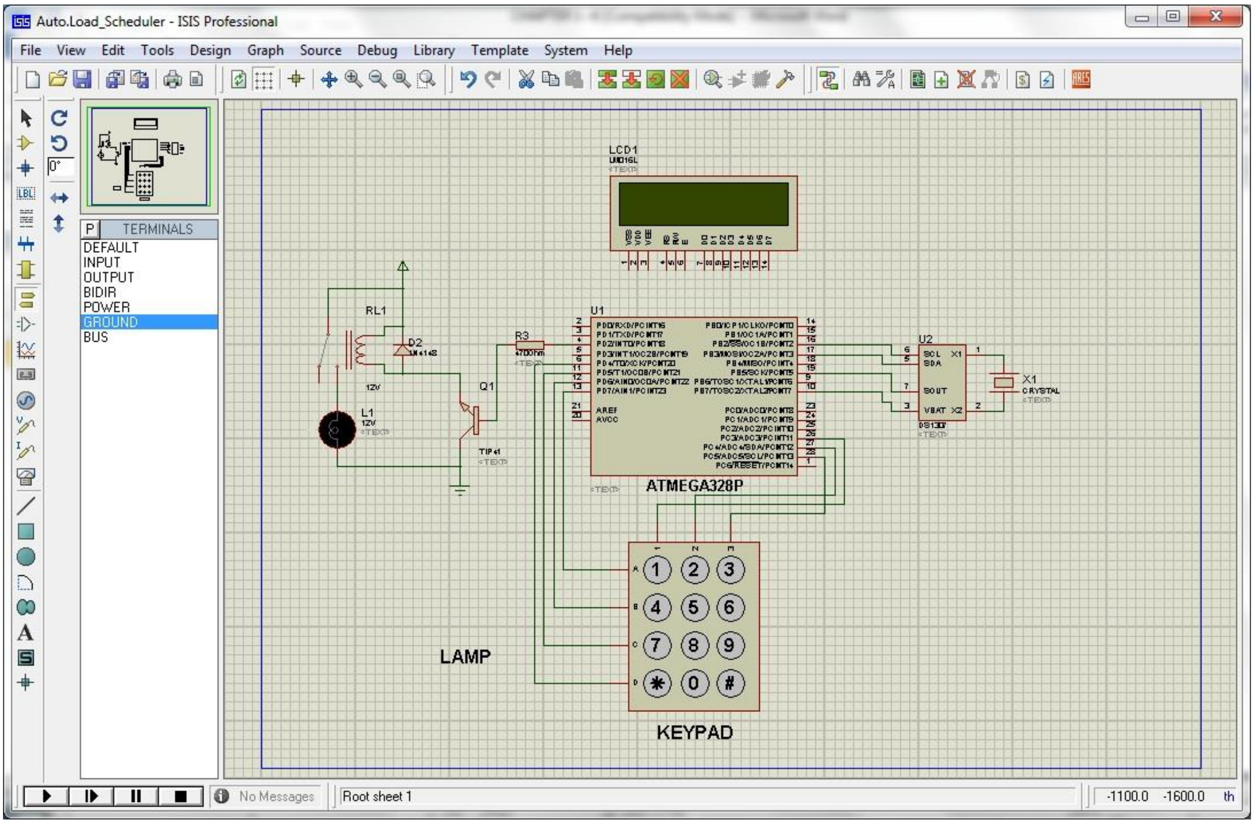

Figure 3. 2 Proteus simulating software.

3.3.2.2 Arduino Integrated Development Environment (IDE)

The Arduino IDE is an open-source coding platform that comes with a Microsoft Windows, Linux and Macintosh versions downloaded from the Arduino website for developing instruction set in the C/C++ programming language to be uploaded onto the ATMEGA328P uC via the Arduino UNO boards USB communication port. It was developed using the java programming language by the Arduino team. Below is a screenshot of the Arduino IDE

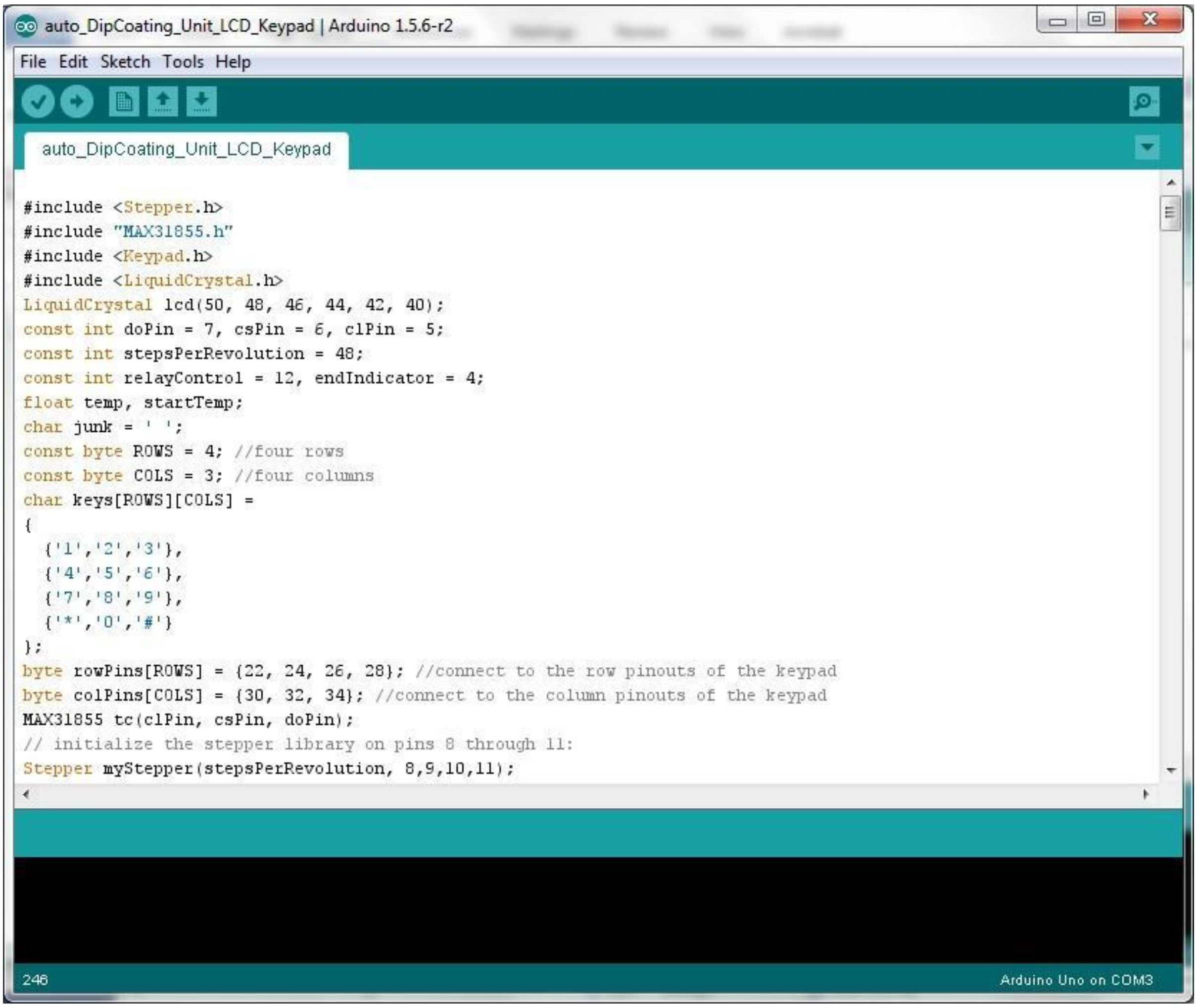

Figure 3. 3 Arduino IDE.

3.3.3 Hardware Requirements

They enable software programs to be installed and run on them. Examples of hardware components include: resistors, transistors, transformer, relay etc.

- **Main Hardware requirement for the construction of IOT based liquid level control**

Table 3. 2 Hardware requirement for the construction of automatic water level controller

NUMBER	**COMPONENT**
1	Flow Sensor
2	Turbidity Sensor
3	Temperature Sensor XH-W1209
4	NodeMCU ESP8266
5	12VDC Pump
6	Ultrasonic Sensor HC-SR04
7	LM016L 12V LCD
8	5V Relay
9	DC-DC Boost Adjustable Buck Converter (×2)
10	Perforated Circuit Board

3.3.3.1 Flow Sensor

The sensor has a standard 1/2″ coupling (21 mm) on both sides and is therefore easy to connect to, for example, a garden system. The output of the sensor gives 5 pulses per second with a duty cycle of approximately 50% for each litre of fluid passing through per minute: Q [L/min] = f_{pulse} [Hz]/5.

Specifications:

- Voltage range: 5-15VDC
- Pulse frequency per L/min: 5Hz
- Measuring range: 1-30L/min (with an accuracy of +-10%)
- Maximum water pressure: 1.75MPa
- Working temperature: -25-80^{o}C

- Duty cycle pulse: 50% +-10%
- Voltage pulse (with 5V as input voltage): 4.7V

Pinout:

- Red: Vcc/plus (5-15V)
- Black: GND/min
- Yellow: Signal

Figure 3. 4 Flow Sensor

3.3.3.2 Turbidity Sensor

Turbidity sensor is the use of optical principles, through the transmission and scattering in liquid solution rate comprehensive judge turbidity conditions. Because the turbidity value is gradual change amount, usually detected in the dynamic environment, the turbidity value of turbidity sensor needs external control to AD converter to convert the turbidity situation of the corresponding environment.

Figure 3. 5 Turbidity Sensor

3.3.3.3 pH Sensor

pH stands for potential Hydrogen, and it tells us whether a solution or substance is BASIC (pH above 7.0), ACIDIC (pH below 7.0) or NEUTRAL (pH of 7.0). Analog pH sensor, specially designed for Arduino controllers is easy to use and can be used as a plug and play solution to measure pH value of a solution without any additional circuit required. It has an LED which works as the Power Indicator, a BNC connector and PH2.0 sensor interface.

To use it, just connect the pH sensor with BNC connector, and plug the PH2.0 interface into the analog input port of any Arduino controller. With a simple program to read analog voltage, you will get the pH value easily.

Edulfitr

✓ **Specification:**

- Power: 5.00V
- Module Size: 43 x 32mm (1.69×1.26″)

• Measuring Range :0 – 14PH

• Measuring Temperature: 0 – 60 deg c

• Accuracy: ± 0.1pH

• Response Time: < 1min

• pH Sensor with BNC Connector

• Gain Adjustment Potentiometer

• Power Indicator LED

Figure 3. 6 pH Sensor.

3.3.3.4 Temperature Sensor

XH-W1209

Specification

- Control range: minus 50 to 110 degrees Celsius
- Lamp colour: Red lamp
- Temperature measurement accuracy: 0.1 degrees Celsius
- Control precision: 0.1 degrees Celsius
- Hysteresis accuracy: 0.1 degrees Celsius
- Refresh rate: 0.55
- High-temperature protection: 0 to 110 degrees Celsius

- Input Power: DC12V
- Measurement input: NTC (10K 0.5%) waterproof sensor
- Output Range: All Relays 10A
- Environmental requirements: minus 10 degrees Celsius to 60 degrees Celsius humidity 20% to 85%
- Specification size: 48 * 40mm
- Power consumption: Quiet current: less than or equal to 35mA
- Current: less than 65mA
- Display Type: 0.28-inch, three digital tubes
- Line length: 50cm

Figure 3. 7 Temperature Measurement Module.

3.3.3.5 NodeMCU ESP8266

The NodeMCU ESP8266 Devkit is based on widely explored esp8266 System on Chip from Expressif. **NodeMCU** is an open source IoT platform, firmware and development kit which makes it easy to prototype your IoT project with a few lines of Lua Script code.

It integrates GPIO, PWM, IIC, 1-Wire and ADC all in one board. Power your development in the fastest way combining with NodeMCU Firmware. It also combines features of a WIFI access-point, station, and microcontroller so you can use it directly without a separate microcontroller. It uses simple LUA based programming language.

✓ **Features**

- Arduino-like IO which allows you to code as if you were using an Arduino, but interactively in Lua script.
- Event-driven Nodejs style network API for network applications, which facilitates developers writing code running on a 5mm*5mm sized MCU in Nodejs style to greatly speed up your development time.
- Low cost

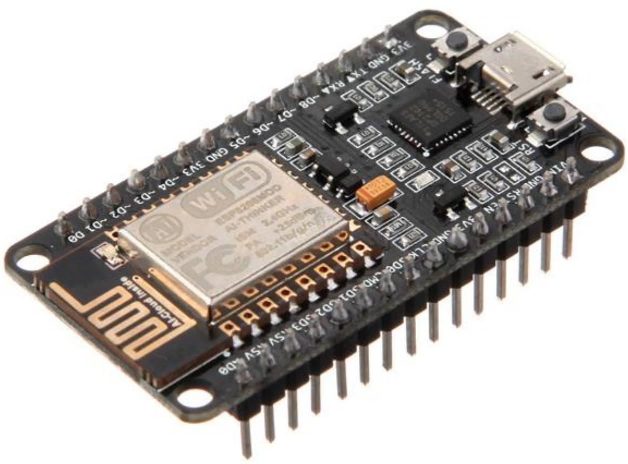

Figure 3. 8 NodeMCU ESP8266

3.3.3.6 12VDC Pump

This water pump is a high-performance brushless DC pump with long-life, small size, high efficiency, low noise, and low power consumption and uses a high-performance stainless-steel shaft.

It is waterproof (IP68) with flow rate of 4L/MIN. The axis is enclosed with static sealing, not dynamic, which can avoid leaking problems.

The 12VDC pump can be used in many fields, such as cooling system, Garden fountain, Aquarium, car cooling system, humidifier, air conditioner, and many other cooling and circulation systems.

Very easy to use, just connect the red wire to 12V and black wire to ground.

✓ **Specifications**

- Water pump housing material: PA66 +30% GF
- Pump material: ABS
- Condition of use: Continuously
- Pump outlet diameter: 8mm
- Power consumption: 4.2W
- Rated voltage: 12V DC
- Maximum load current: 350mA
- Max flow rate: 4L/MIN (1.06G/MIN)
- Max Static Head: 3m(9.7ft)
- Water proof class: IP68(can be submersible installed)
- Life span: More than 30000hrs
- Power supply: DC power modules, solar panels battery
- Sizes: 51x34x42.7
- Weight: 50g

- Fluids: Water, acid, and alkali solution

  This pump however is not suitable for pumping oil or highly viscous liquids.

Figure 3. 912VDC Pump.

3.3.3.7 Ultrasonic Sensor

The HC – SR04 Ultrasonic sensor module provides 2cm – 400cm non-contact measurement, with an accuracy of up to 3mm.

The module includes an ultrasonic transmitter, receiver, and control circuit.

The basic working principle is shown below:

- A short ultrasonic pulse is transmitted at the time 0, reflected by an object.
- The sensor receives this signal and converts it to an electric signal.
- The next pulse can be transmitted when the echo is faded away.
- This time period is called cycle period.
- The recommend cycle period should be not less than 50ms.
- If a 10μs width trigger pulse is sent to the signal pin, the Ultrasonic module will output eight 40kHz ultrasonic signal and detect the echo back. The measured distance is proportional to the echo pulse width and can be calculated by the formula below.

- If no obstacle is detected, the output pin will give a 38ms high level signal. Test distance = (high level time × velocity of sound (340M/S) / 2.

  Applications include distance measurement, level detection, mapping, obstacle detection, etc.

  Interfaces well with Arduino

✓ **Specifications**

- **Working Voltage**: DC 5V
- **Working Current**: 15mA
- **Working Frequency**: 40Hz
- **Max Range**: 4m
- **Min Range**: 2cm
- **Measuring Angle**: 15 degrees
- **Trigger Input Signal**: 10µS TTL pulse
- **Dimension**: 45 * 20 * 15mm

Figure 3. 10 Ultrasonic Sensor.

3.3.3.8 LM016L I2C LCD

This 20 x 4 Parallel LCD comes with an I2C backpack attached which means you use only 2 pins, SDA and SCL of your microcontroller to control your LCD saving you lots of I/O pins.

Here are all the features the I2C Backpack adds. It is very easy to use. You can control the contrast of the LCD from the LCD backpack or disable it altogether.

✓ **Specifications**

- **Power supply:** 5V
- **Power supply range for LCD:** 0-13.5V
- **Backlight:** Yes
- **Display size:** 2.4″W x 0.62″H
- 20 characters x 4 lines
- 5×7 dots with cursor

Figure 3. 11 20x4 I2C LCD.

3.3.3.9 5v Relay

General purpose relays to control a high power or high voltage circuit with a low power circuit.

Specifications

- **Mounting Style**: Through Hole
- **Package:** 5-pin package
- **Coil Voltage**: 5V, 6V, 9V
- **Contact Current**: 40mA, 33.3mA, 16.7mA

• **Coil Resistance:** 125Ω, 180Ω, 720Ω, (±10%)

• **Dimensions:** 0.95 (L) x 0.276 (W) x 0.291 (H) in

Figure 3. 12 5V Relay

3.3.3.10 DC-DC Boost Adjustable Buck Converter

Buck converter accepts a DC input voltage and produces a DC output voltage. In the case of a DC–DC converter, input and output voltages are both DC. A power semiconductor device is used as a switch to turn on and off the DC supply to the load. The switching action can be executed by a BJT, a MOSFET, or IGBT. A diode together with an external inductor as well as an output capacitor, produces the regulated dc output. A variable resister is manually regulated to attain the required voltage with in the rated range of the buck converter. Three of these back converters were implemented, i.e. 4.2V, 5V and 12V regulated.

Specifications

- LM2577 module
- Input range: 3V ~ 32V
- Output range: 5V ~ 35V
- Input Current: 3A , no load 18mA

Figure 3. 13 DC-DC Buck Converter

3.3.3. GSM GPRS Shield Development Board

- GPRS mobile station class B
- Compliant to GSM phase 2/2+
- Class 4 (2 W @ 850 / 900 MHz)
- Class 1 (1 W @ 1800 / 1900MHz)
- Low power consumption – 1.5mA(sleep mode)
- Industrial Temperature Range – -40°C to +85 °C

Figure 3. 14 SIM900 Quad Band GSM GPRS Shield Development Board

CHAPTER FOUR

SYSTEM DESIGN, IMPLEMENTATION, TESTING, RESULTS AND ANALYSIS

4.1 INTRODUCTION

In this chapter is presented the procedures, techniques employed, detailed implementation approach of the various required software and hardware tools for the execution of the prototype to meet the system's SOP as follow:

- The system when operating in manual mode, the 12VDC pump continuously pumps water after manually switch locally from a button or remotely from mobile app via the internet. Switching OFF pump would also be done manually irrespective of water level in tanks.
- In automatic mode of operation, ultrasonic water level sensor interfaced to microcontroller sends transduced echoed ultrasound signals for computation of water level in tank as a determinant of the pump state. i.e., pump stops when water level is at maximum and starts when water is drained to the minimum level.
- Flowrate of water pumped from reservoir is measured using flow sensors at the installed entry point of pipes as well as exit point of pipe into consumer storage tanks.
- Drastic reduction in flow rate at exit point flow sensor for a consumer line gives an indication of a possible pipe burst. Notification to this effect is given both on local LCD and remotely on app.
- Before water in reservoir is pumped to consumer storage tanks, its quality in terms of turbidity level, pH and temperature level is assessed. These parameters are monitored in real-time displaying their current readings locally and on app.

4.2 IMPLEMENTATION

Achieving all specific objectives outlined in chapter 1 of this research thesis is by undertaking the system design work which involves fabricating, assembling, programming, and installing various diverse working system components to arrive at the complete setup which would operate as per the SOP stated above in section 4.1.

4.2.1 External Reset Circuit for Arduino Board

To ensure the possibility of resetting the Arduino board during operations in the event of unexpected interruptions, a push button connection between the Arduino's RESET pin and ground (GND) pin. The circuit is shown in figure 4.2 below.

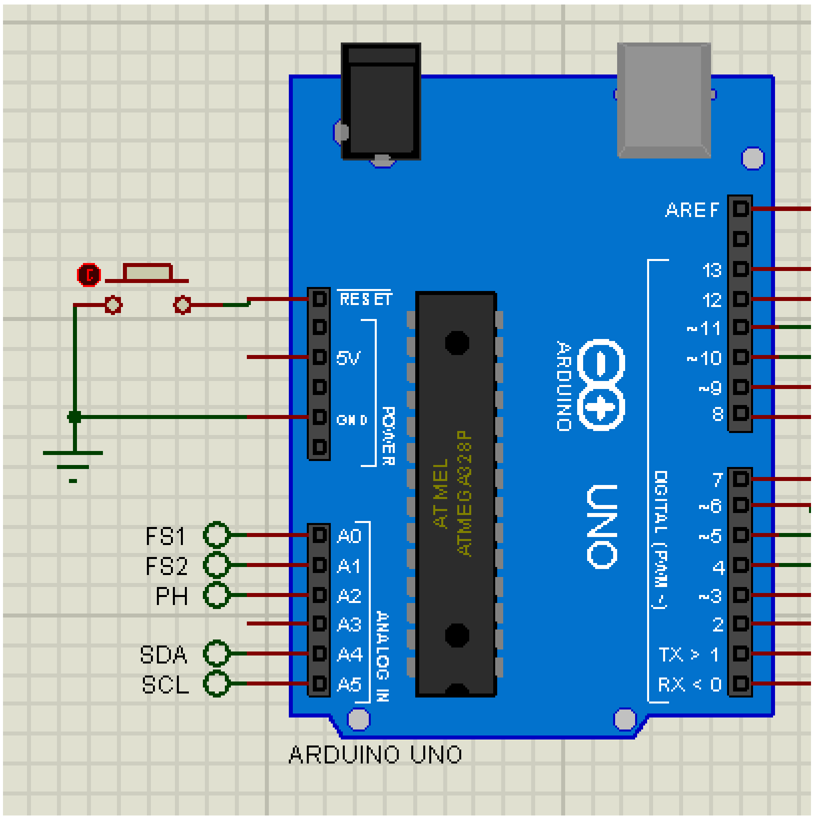

Figure 4. 1:Arduino Reset Connections.

4.2.2 12V, 5V Power Supply Circuit.

This was built using a 12V, 3000mA transformer rectified by S4VB20 bridge rectifier and filtered using a 100uF, 25V capacitor. The rectified output of the bridge rectifier was regulated using a buck converter for a stable 12V output. For the supply of 5V, another buck converter was used to regulate the rectified output to obtain a constant 5V output. To power the Arduino board, 12V from the power supply circuit is connected to the Vin and GND on the Arduino board.

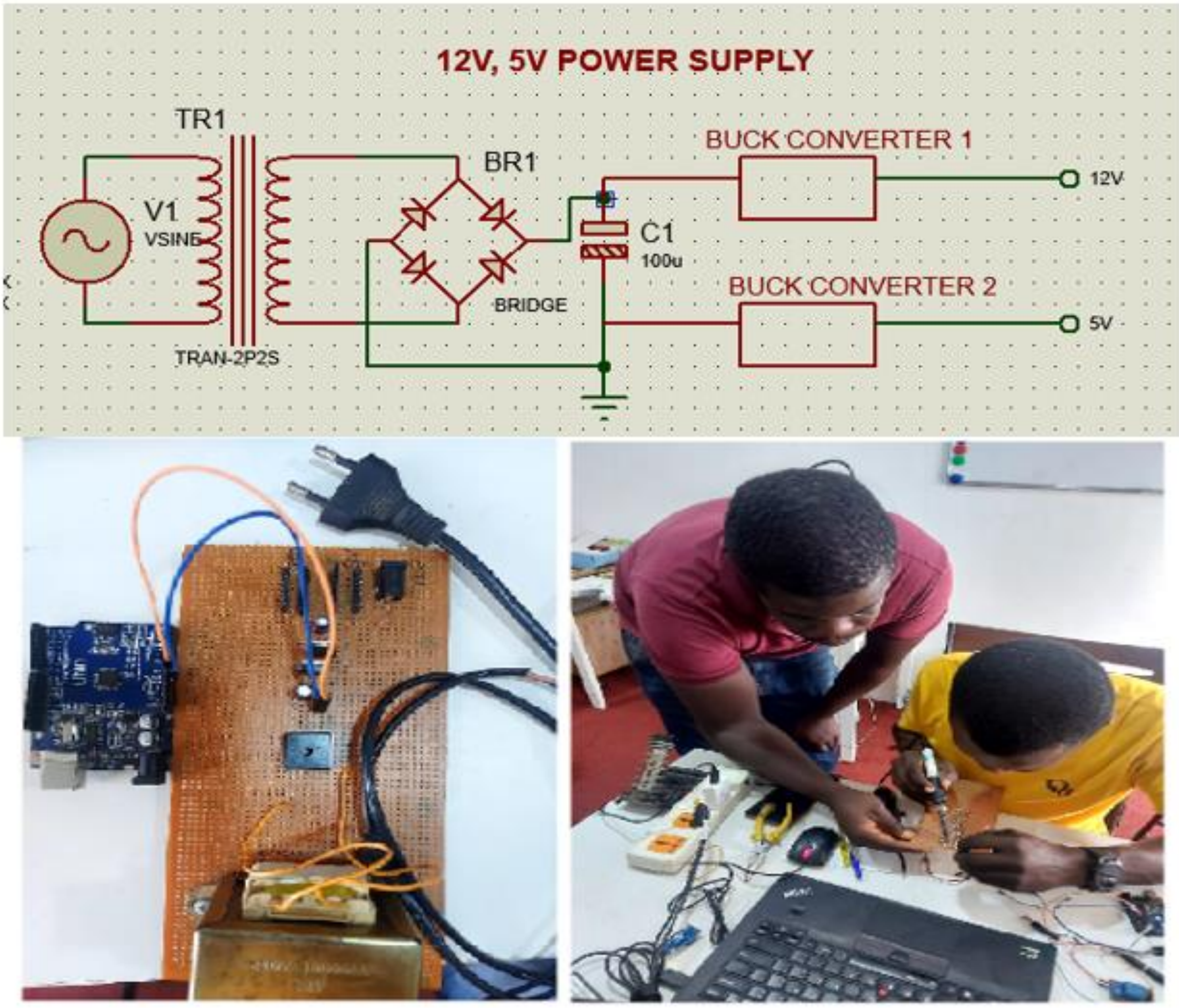

Figure 4. 2: 12V-5V Power Supply Circuit Board.

4.2.3 1602L display Interface

For text-based information and prompt display an I2C 20x4 liquid crystal display which connects also to I2C interface is added. The I2C connection is made to the SDA (A4) and SCL (A5) pins on the Arduino board. The connections are shown figure 4.4 below.

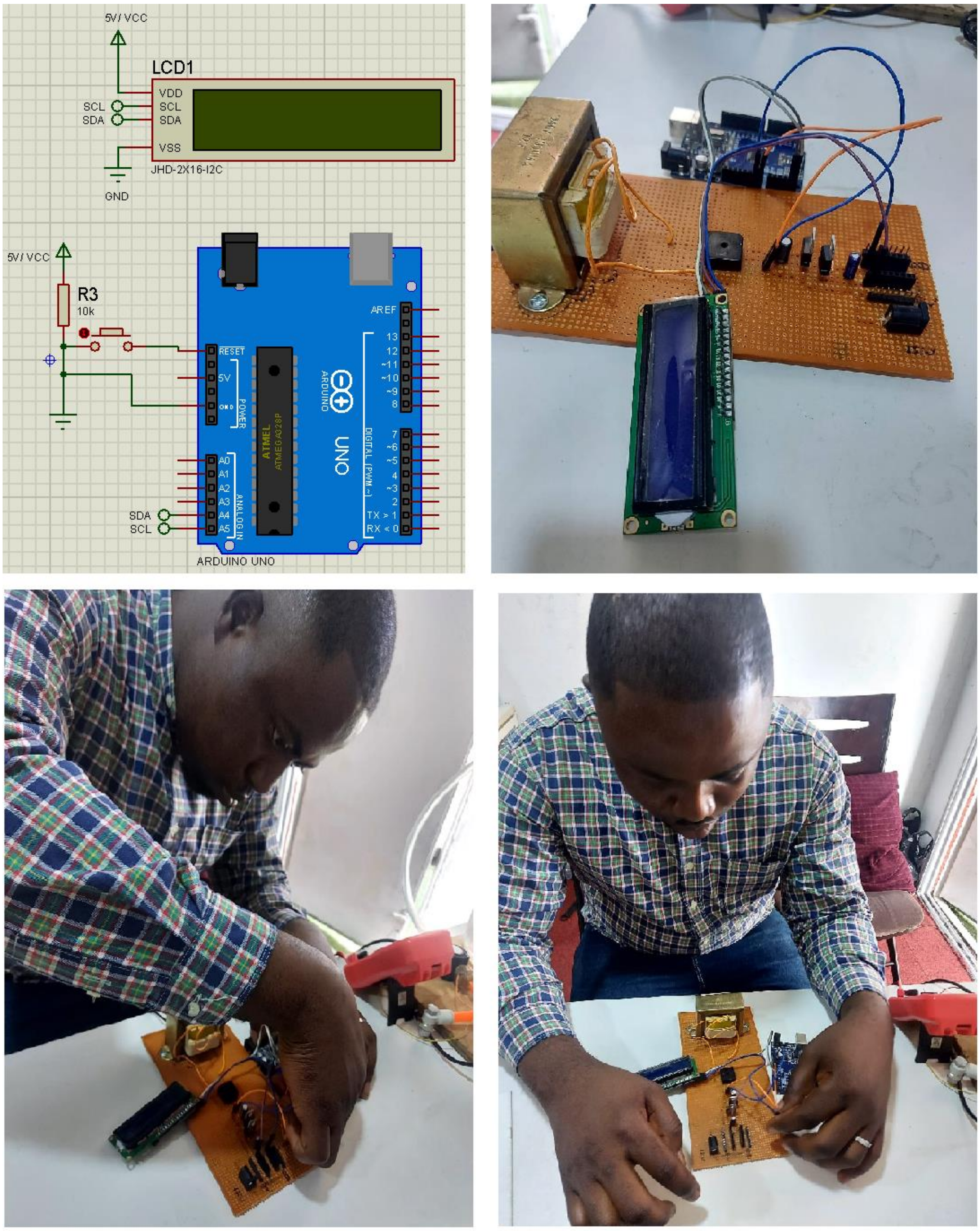

Figure 4. 3: I2C LCD connection to Arduino.

4.2.4 Water Level Monitoring System.

The water level monitoring system measures the volume of water in the reservoir from which water is pumped to storage tank. This is implemented using an ultrasonic transceiver to convert measured distance between the sensor and the water surface to volume readings. The Vcc and GND pins connect to 5V and GND (Ground) power rails respectively on the power supply board. The ultrasonic sensor's trigger and echo terminals connects to Arduino pins 2, 3 respectively for reservoir and 4, 5 respectively for the storage tank. The circuit connection is shown in figure 4.4 below

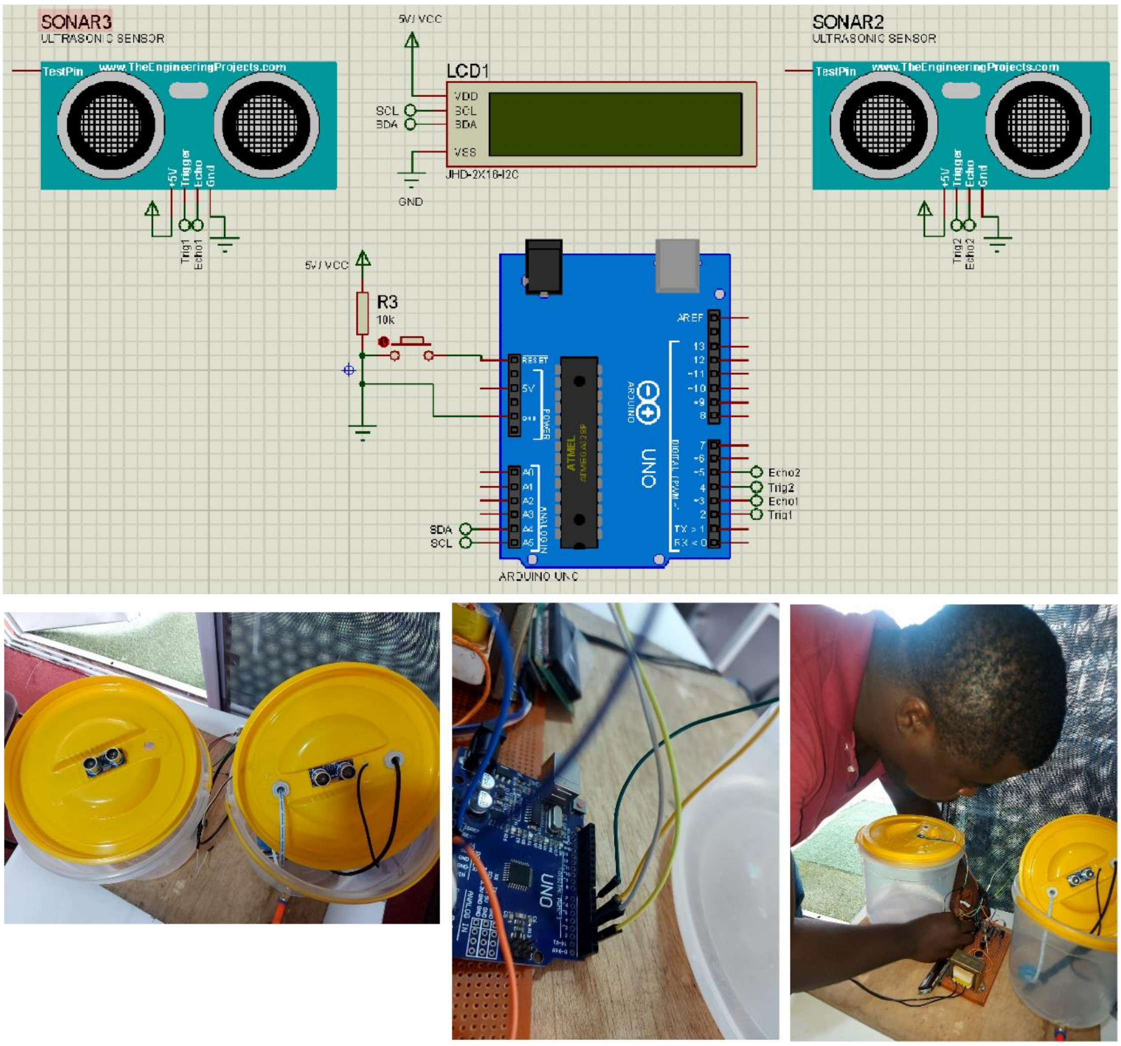

Figure 4. 4: Ultrasonic Sensor Circuit Connection.

4.2.5 Pump Power and Control Circuit.

The 12VDC pump connected to the bottom of the reservoir by a 10mm water hose serves as the means of supplying water storage tank. The pump requires a supply DC voltage 12V to operate and to connect it to a supply a momentary switch that connects to pin 6 of the Arduino acts as its switching button. A relay energizing signal connection is made to pin 7 of the Arduino energize the 5V relay to connect 12V from its common terminal to the normally open (NO) terminal. In figure 4.5 is the circuit connection diagram for the push button and the 5V relay switching circuit.

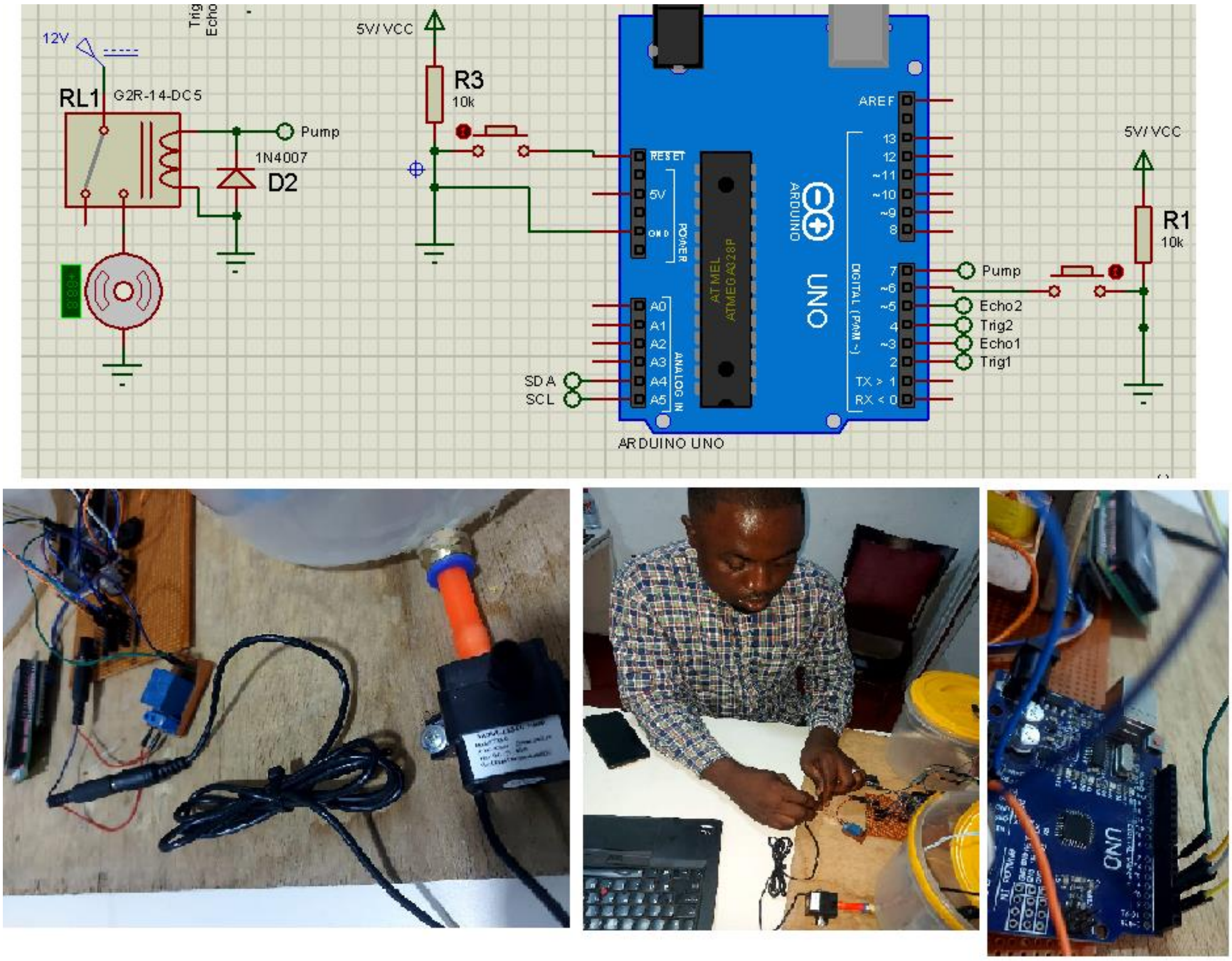

Figure 4. 5: 12VDC Pump Switch and Relay Circuit.

4.2.6 Flow Meter Leakage Detection Circuit.

To detect the flow rate of the water being pumped by the 12V pump a YF-S201 flow sensor connected in between water hose as in-line instruments. There are two flow sensors connecting the analog pins A0 and A1 of the Arduino. The connections are shown figure 4.6 below.

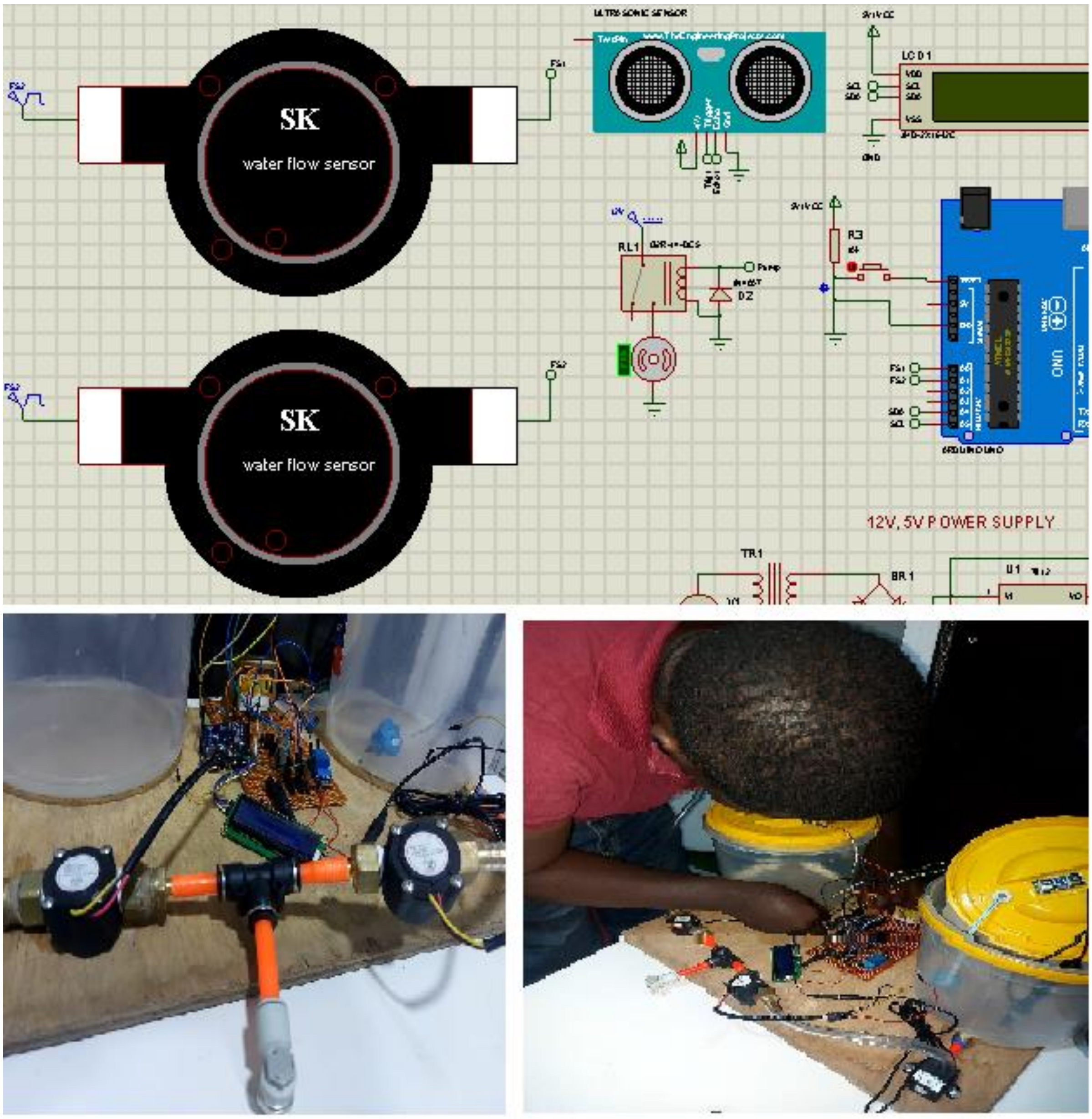

Figure 4. 6: Flow Sensors Connection Diagram.

4.2.7 pH Sensor

Connection of the pH sensor for measuring the pH level of the water in the main tank is to pin A2 of the arduino. This is shown in figure 4.7.

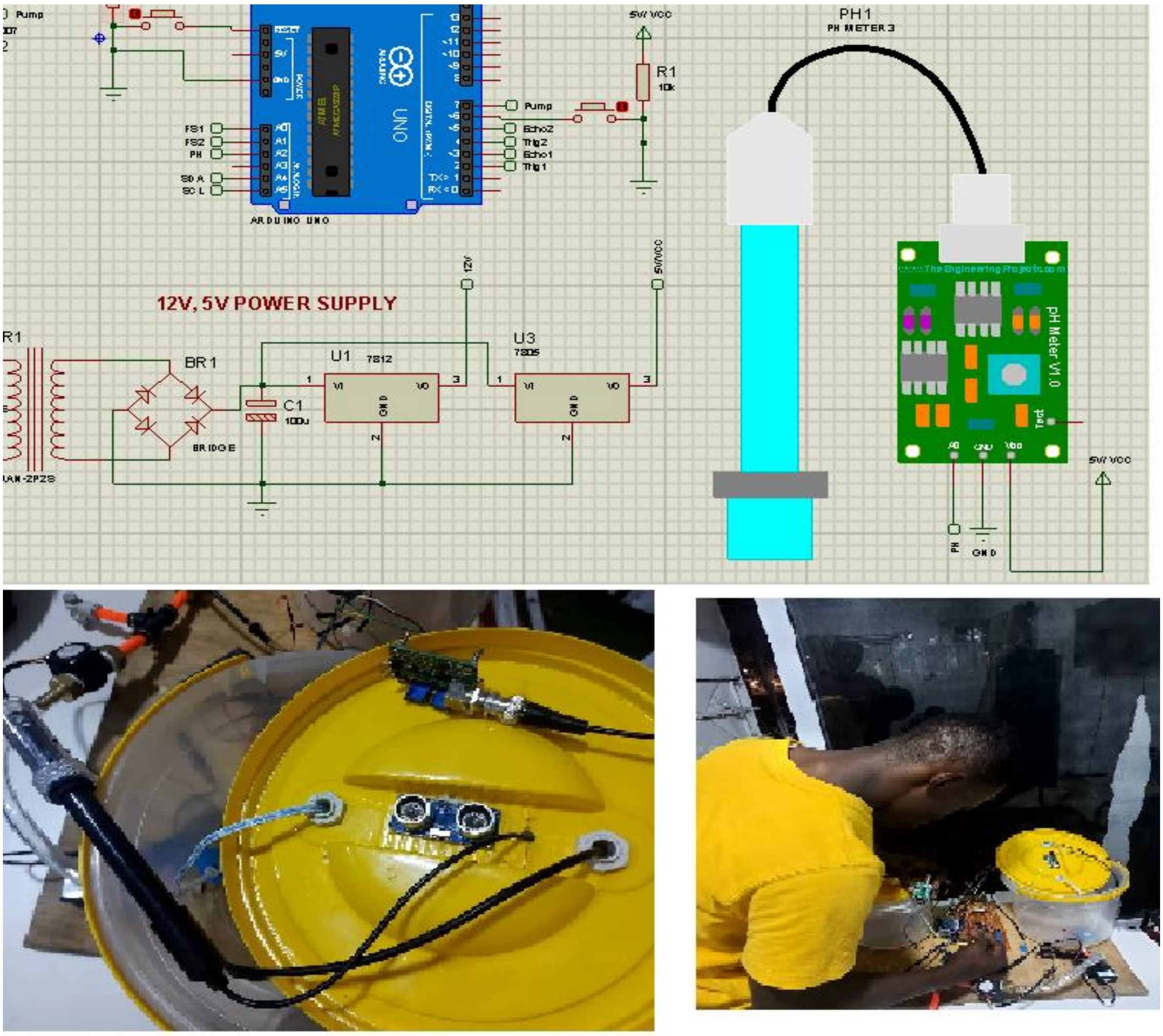

Figure 4. 7: PH Meter Connection Diagram.

4.2.8 DS18B20 Temperature Probe Circuit.

To measure the temperature of the water in the reservoir a DS18B20 temperature probe is connected to pin 8 on the Arduino. A 4.7kΩ pullup resistor is connected between the supply 5V and the data terminal of the probe.

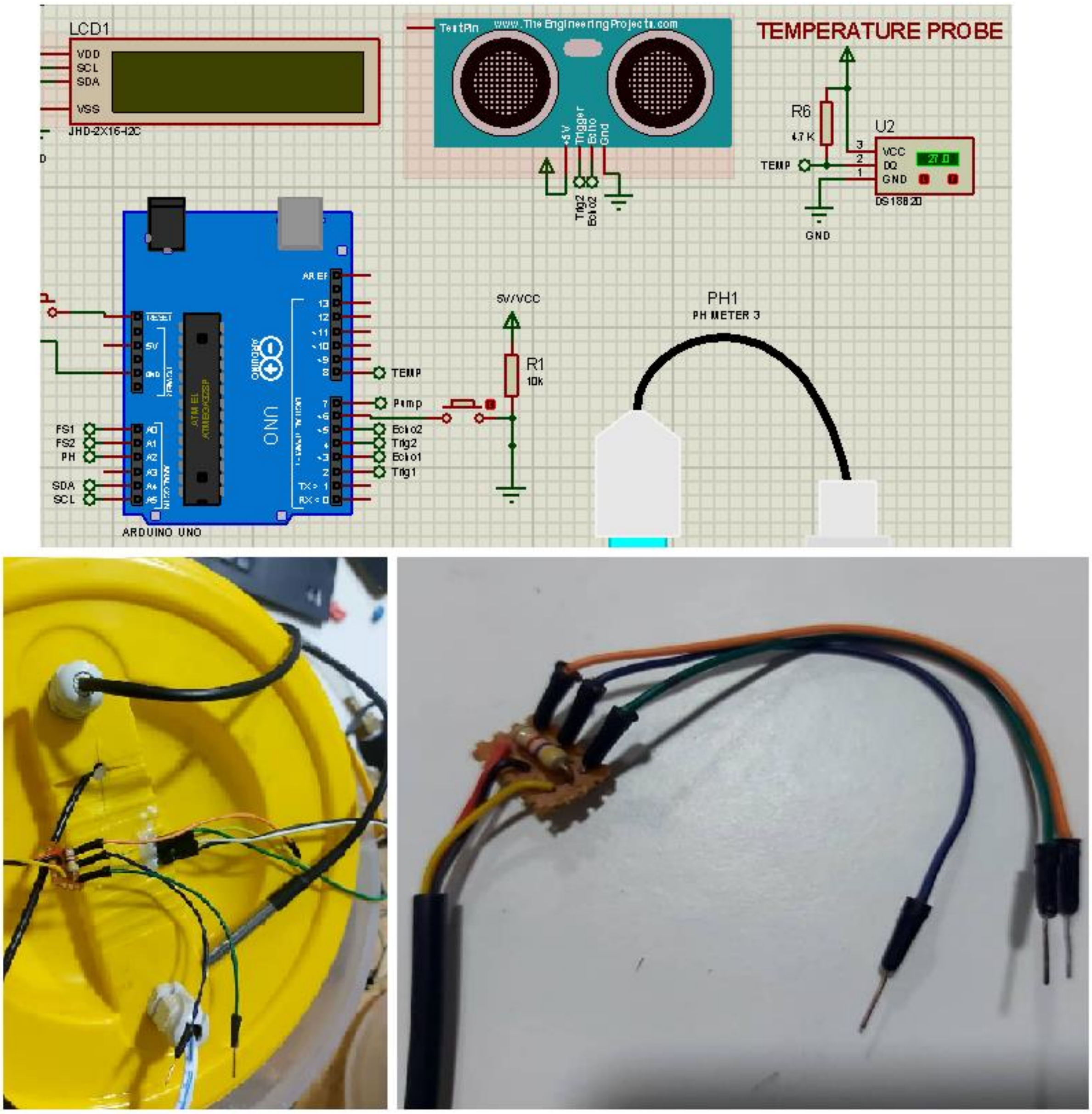

Figure 4. 8: DS18B20 Temperature Probe Connection.

4.2.9 Turbidity Sensor

The turbidity sensor connects to the Arduino on pin 9 as shown in figure 4.9 below.

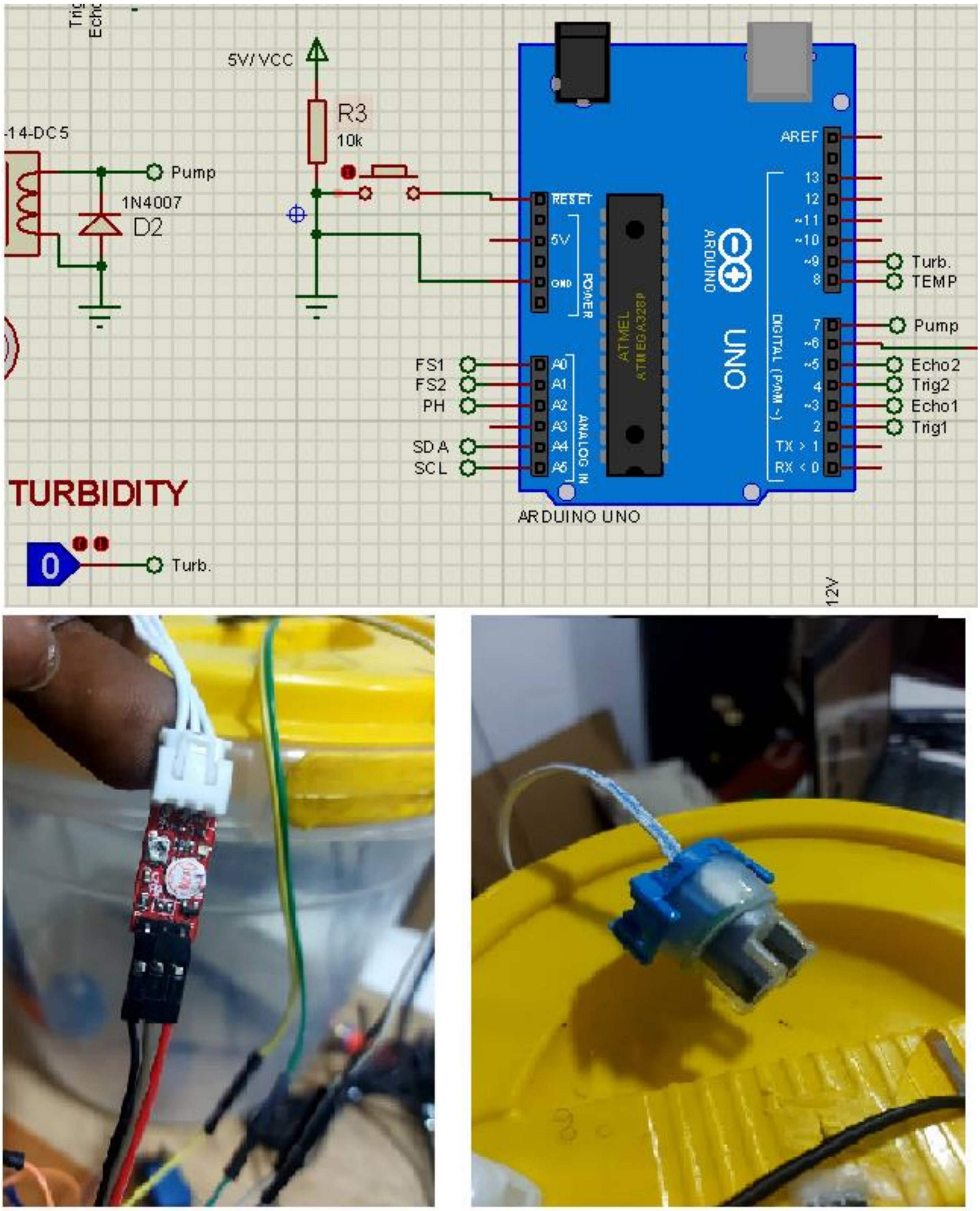

Figure 4. 9: Turbidity Sensor Connection.

4.2.10 NodeMCU ESP8266 Controller

The NodeMCU connects to the Arduino on pins D1(RX) & D2(TX) and 10(RX) & 11(TX) respectively in order to establish a serial communication between the two controllers. Serial data received from the Arduino is broadcasted on the internet to be accessed through a web-based application. The connection is shown in figure 4.10 as follows.

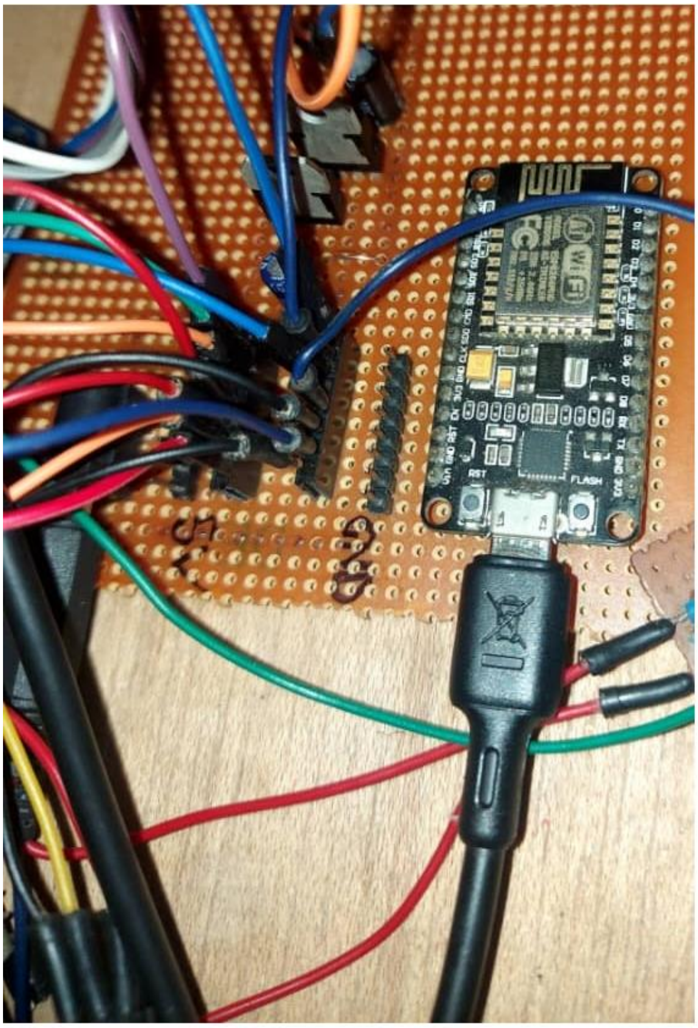

Figure 4. 10: NodeMCU-Arduino Serial Connection.

4.2.11 Web-Based Remote Pump Control and Sensor Monitoring.

To monitor the sensor readings remotely either on a PC or a mobile smart device with internet browsing functionality, a web-based application is developed using HTML, CSS, JavaScript and Knockout.js.

To access the web-based application, the user must type an IP address received from the system via SMS whenever stared into a browser's address bar. This IP address is dynamic since it changes with change in location of the system, particularly the NodeMCU.

For authentication purposes, the user must enter some credentials to access the web-based dashboard. i.e., name, cell phone number and access code.

The web interface presents a switch button for turning ON the pump manually and monitoring its operating state as well. On the interface is also found readings for the various sensors indicating the volume of water in the tank, the pH value, temperature, turbidity, and flowrate of the pumped water.

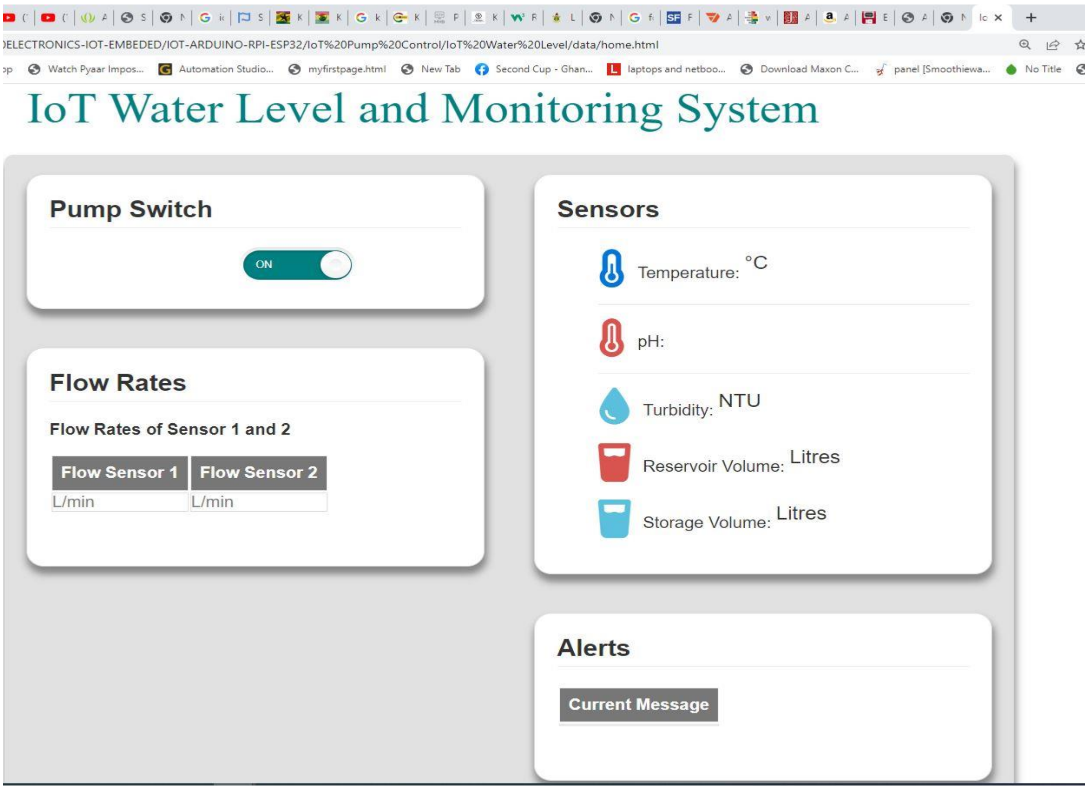

Figure 4. 11: Web-Based Dashboard

- **Pump switch:** manual remote switch for the pump.
- **Flow rates:** displays flow rates of flow sensors 1 and 2.
- **Sensors:** displays other sensors, i.e., temperature (°C), pH, turbidity (HTU) reservoir and storage tanks volume (Litres)
- **Alerts:** current alert information on the system which requires attention.

4.2.12 Complete Circuit Diagram

Shown in figure 4.12 is the complete circuit diagram of the project design.

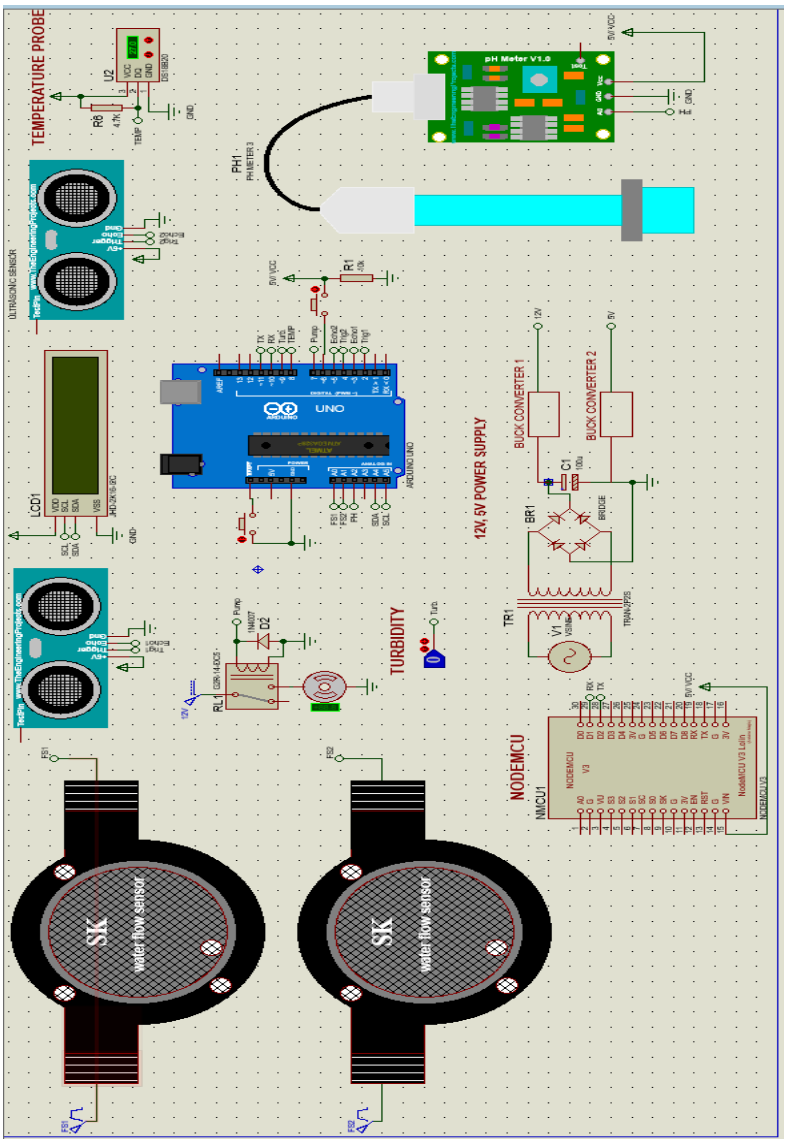

Figure 4. 12: Complete Circuit Diagram.

4.2.13 Complete System Setup.

Figure 4. 13: Full System Setup.

4.3 TESTING, RESULTS AND ANALYSES

In this section is presented the testing stages the final system is taken through and the associated results obtained as well as observations made. The tests were performed in accordance to the system's SOP whilst respective observations and results were recorded. Presented in the subsequent subsections are various stages of test scenarios and results obtained for each as well as the relevant discussed observations made.

4.3.1 System Testing and result

The testing stages and scenarios are as follows;

- Starting of the system by powering it with a 12V DC supply unit. When switched on, 'WELCOME! IOT PUMP CONTROL & WATER QUALITY MONITORING SYSTEM!' is displayed on the LCD after initializing.

Figure 4. 14: System Started.

- Pump can be started manually as indicated below using the push button ensuring all tube connections and tanks in place. PUMP ON, RESERVOIR VOL: STORAGE VOL: and TEMPERATURE are displayed. Pump starts running hence flow detected by the flow sensors.

Figure 4. 15: Pump State, Volumes and Temperature Displayed.

- FLOWRATES 1 and 2 in L/MIN, PH, and TURBIDITY in NTU are displayed locally on the LCD and remotely on web dashboard.

Figure 4. 16: Flowrates, Turbidity and PH Displayed.

Figure 4. 17: Flow Rates Displayed.

- Leakage is created using regulating valve in-between flow sensors by opening to allow drain of water as demonstrated in figure 4.19. Flowrate between sensors drops significantly. ALERT!

LEAKAGE DETECTED! is displayed on the LCD as shown in figure 4.19 and on the web dashboard.

Figure 4. 18: FS2 Flow Rate Reduced.

Figure 4. 19: Leakage Alert Message Displayed.

- Pump is turned OFF using same button. Zero flowrate is registered on the LCD.

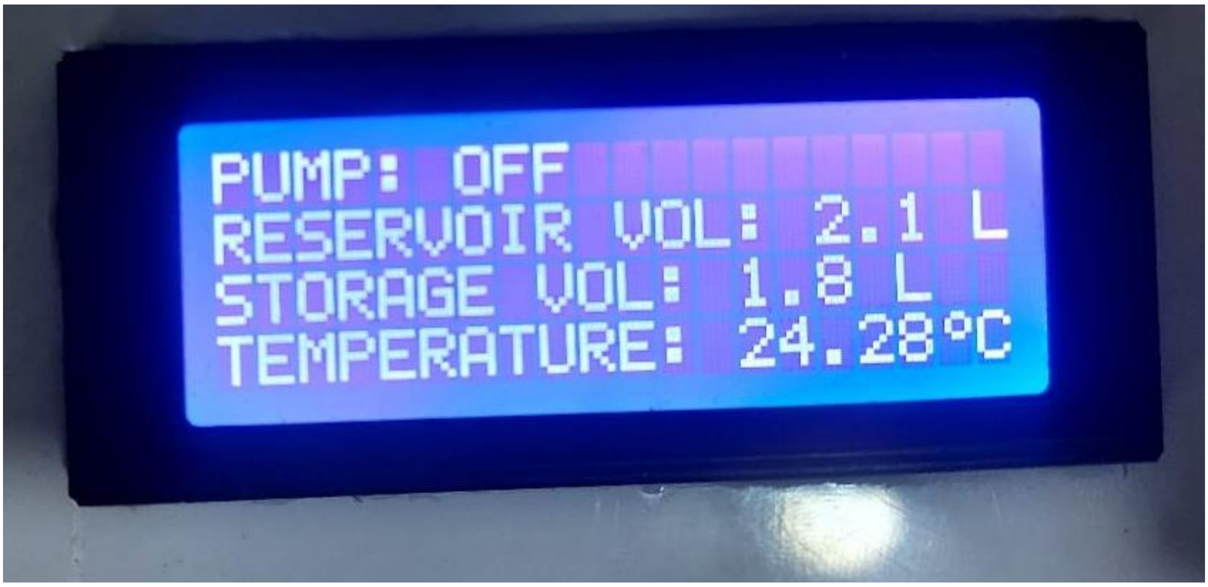

Figure 4. 19: Pump Turned OFF.

Figure 4. 20: Zero Flow Rates Displayed.

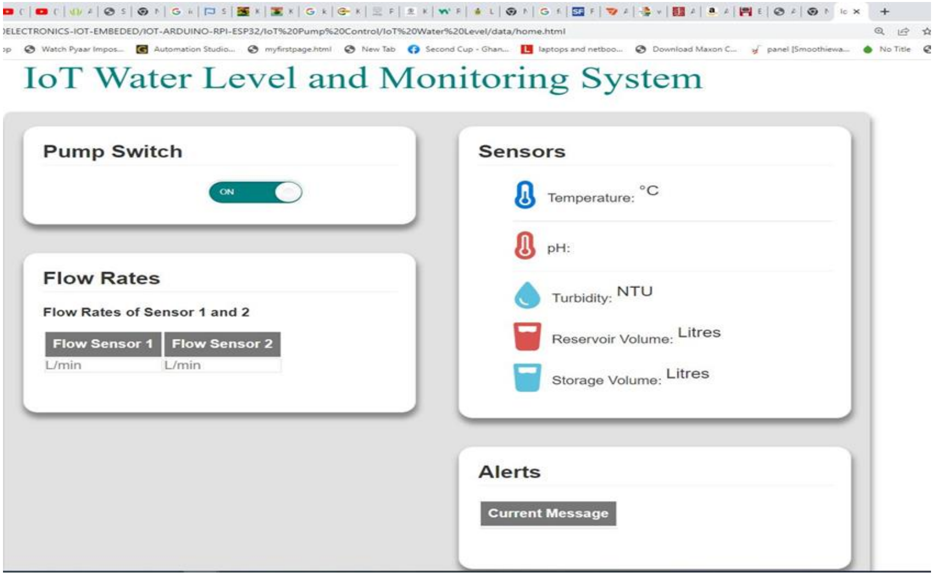

Figure 4. 21: Web Dashboard Displaying Leakage Alert.

4.3.2 Analyses of the result

A successful start and initiation of the system is indicated by the "IOT PUMP CONTROL & MONITORING SYSTEM" displayed on the LCD as shown in figure 4.14.

The after initialization retrieves all sensor and actuator status values and displays them on the LCD as evident from the results in figure 4.15 to figure 4.17.

From figure 4.18, a clue of an introduction of leakage into the water flow pipes is given by the reduced flow rate of flow sensor 2 (FS2). FS2's flow rate is affected by the leakage created since the valve drains down a portion of the water supposed to run through the exiting end of the tube to fill tank 2. This however does not affect the other parameter readings with exception of the volume of water in the tank which is due to the pumping action that took place. A leakage alert is then given for immediate action to be taken.

From figure 4.20 and figure 4.21, turning OFF the pump maintains various sensor reading such PH, turbidity and temperature but affects flow rate since there is no water flowing through the flow sensors as shown in figure 4.21. The web dashboard is updated with the leakage condition as shown in figure 4.22.

CHAPTER FIVE

DISCUSSION OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

The system when started indicates the “IOT PUMP CONTROL & MONITORING SYSTEM” display on the LCD as shown in figure 4.14.

Initialization retrieves all sensor and actuator status values and displays them on the LCD as evident from the results in figure 4.15 to figure 4.17.

From figure 4.18, a clue of an introduction of leakage into the water flow pipes is given by the reduced flow rate of flow sensor 2 (FS2). FS2’s flow rate is affected by the leakage created since the valve drains down a portion of the water supposed to run through the exiting end of the tube to fill tank 2. This however does not affect the other parameter readings with exception of the volume of water in the tank which is due to the pumping action that took place. A leakage alert is then given for immediate action to be taken.

From figure 4.20 and figure 4.21, turning OFF the pump maintains various sensor reading such PH, turbidity and temperature but affects flow rate since there is no water flowing through the flow sensors as shown in figure 4.21. The web dashboard is updated with the leakage condition as shown in figure 4.22.

We encountered some few challenges during the design and construction stages. The most difficult one was during the programming and simulation process, which led to several coding and troubleshooting until we got it right. Unavailability of major components on the Ghanaian market meant we had to import them at high cost and delay in arrival. The sensors employed were very sensitive.

5.2 SUMMARY OF FINDINGS

The findings from the project are outlined as follows:

- LEAKAGE ALERT was displayed on the LCD when leakage was stimulated by opening the drain valve as indicated in figure 4.19.
- A deference in flowrate between the flow sensors indicated feedback of leakage.
- The system automatically turned off pump when reservoir level dropped.

5.3 CONCLUSION

This prototype is designed to monitor water quality and control levels in a reservoir to avoid overflow, shortage of water and the pump running dry. To solve the problem of water wastage due to leakages, it is equipped with functionality of leakage detection on the water lines and automatic stop and start of the pump.

Results obtained from testing undertaken on the system prototype proved the concept of practically monitoring water supply pipelines for leakages using flow sensors/gauges in real time. It is a feasible innovative approach to the eradication of incidents of long-term water leakages due to pipe bursts that leads to wastage of portable water and spillage of sewerage water which is a threat to human health. The implementation of this project idea by the Ghana Water Company Limited (GWCL) will lead to the avoidance of further future water leakages.

This project enables the flexibility of monitoring and controlling working parameters constituting the successful delivery of quality water through IoT based system on smart devices using the web base remote. This design is environmentally friendly.

5.4 RECOMMENDATIONS

This project recommends that the subsequent IoT based water level monitoring system should make use of the next generation technology components for future improvements. These involves,

- Precise point of leakage Technology
- Data Logging
- Industrialization *(Ghana Water Company Limited)*

A precise point of leakage identification technology will enable maintenance team to accurately locate the leaking part of the discharge or return line in the shortest possible time to promote efficiency.

When equipped with a data logging function, the IoT based water level monitoring system can store information which could be retrieved for analysis and troubleshooting purposes.

This prototype is a perfect solution to water wastage in distribution by the Ghana Water Company Limited (GWCL) if appropriately and specifically developed to suite the system of the company. We therefore recommend the next development be focused on industrialization, specifically GWCL.

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