

**IMPLEMENTATION OF AN AUTOMATED WATER TANK LEVEL CONTROL  
SYSTEM IN THE FACULTY OF ENGINEERING.**

BY

- |                                    |            |
|------------------------------------|------------|
| ❖ AIRHIOMWANUHIMWEN OGHOSA LEONARD | ENG1805348 |
| ❖ OSAH GODWIN OMOGBEAI             | ENG1805439 |
| ❖ ODIASE SOLOMON OSASERE           | ENG1805416 |
| ❖ GOODLUCK JOSHUA ISEFIEMA         | ENG1805386 |
| ❖ GODWIN GIDEON OSAMUDIAMHEN       | ENG1905609 |

SUPERVISED BY ENGR. P. O. OLAGBEGI



A PROJECT SUBMITTED TO THE DEPARTMENT OF MECHANICAL  
ENGINEERING, FACULTY OF ENGINEERING, UNIVERSITY OF BENIN, BENIN  
CITY, EDO STATE IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE  
AWARD OF A BACHELOR OF ENGINEERING (B.ENG.), HONOURS DEGREE.

MAY 2024

# CERTIFICATION

This is to certify that this project work was carried out by AIRHIOMWAUHIMWEN OGHOSA LEONARD ENG1805348, OSAH GODWIN OMOGBEAI ENG1805439, ODIASE SOLOMON OSASERE ENG1805416, GOODLUCK JOSHUA ISEFIEMA ENG1805386 and GODWIN GIDEON OSAMUDIAMHEN ENG1905609 students of Mechanical engineering, university of Benin as a requirement to complete their bachelor's degree in mechanical engineering, under the supervision of Engr. P. O. Olagbegi.

.....  
Engr. P.O. Olagbegi  
(Project Supervisor)

.....  
DATE

.....  
Dr. I.B. Owunna  
(Project Coordinator)

.....  
DATE

.....  
Prof G. E. Sadjere  
(Head of Department)

.....  
DATE

# DEDICATION

This project is dedicated to all the members of the University of Benin Mechanical Engineering class of 2023(The Rankines), and to the mates we lost, Nosa and Chika (may their soul rest in peace), our hard work for the last 5 years has not been in vain.

To our families, their support and presence in our lives kept our academic pursuits alive.

Finally, this project is dedicated to almighty God, without him none of this would have been possible.

## ACKNOWLEDGEMENT

The successful completion of this project would not have been possible without the support of several individuals.

To our supervisor, ENGR P. O. OLAGBEGI, we say a very big thank you, for his constant, support, guidance encouragement and feedbacks throughout the project. His expertise on the area of the project set us on the right path.

We are very grateful to our family and friends for their unwavering support, encouragement and love. Their unwavering belief in us kept us going even through tough times.

We are also grateful to the staff of the department of Mechanical Engineering for the support and contributions to our academic life throughout our time in the university. Their academic and professional expertise will not be forgotten.

Finally, we thank God Almighty, for his provision over our lives and for the opportunity to be part of something this important.

# ABSTRACT

Water availability is crucial for a functional learning environment. The Faculty of Engineering has relied on manual monitoring and operation of the water tank level in the past. This project addresses this concern by implementing an automated water tank level control system.

The system utilizes sensors to continuously monitor the water level in the tank. Based on pre-defined levels, the system automatically activates the pump and solenoid valves to refill the tank when it reaches a low level and switches it off upon reaching maximum capacity. This project investigates the design, development, and implementation of this automated system. The focus is on ensuring consistent water availability, preventing overflows, and optimizing water usage within the Faculty of Engineering.

The system made use of industry manufactured solenoid valves as opposed to locally made ones previously implemented. The local solenoid valves had slower response times. The system implemented proved to be more efficient and faster than an older system.

# TABLE OF FIGURES

Figure 1 - optical level sensor(cross-section) .....	7
Figure 2- optical level sensors .....	7
Figure 3 a capacitance level sensor .....	8
Figure 4 - capacitance Level sensor working diagram .....	9
Figure 5 - a tuning fork.....	10
Figure 6 - a diaphragm level sensor.....	12
Figure 7 - a float water level sensor.....	13
Figure 8- an ultrasonic liquid level sensor .....	14
Figure 9 - a programmable logic controller .....	18
Figure 10- an arduino microcontroller.....	19
Figure 11 - a centrifugal pump .....	21
Figure 12 - a diaphragm pump .....	21
Figure 13- a positive displacement pump.....	22
Figure 14 internal view of a solenoid valve .....	23
Figure 15 - a solenoid valve .....	23
Figure 16 - a relay and relay base.....	24
Figure 17 a relay.....	24
Figure 18- tee fitting .....	36
Figure 19 - cross fitting .....	36
Figure 20 - cap fittings .....	37
Figure 21 - line diagram for the system.....	39
Figure 22 - 3d model of the tanks.....	40
Figure 23 - pictures of the pipe laying process.....	41
Figure 24 - the valves set up.....	41
Figure 25 - Image of the new central control unit. ....	48
Figure 26 - Images of the solenoid valves used.....	48

# CONTENTS

<b>CHAPTER 1</b> .....	1
<b>1.1 INTRODUCTION</b> .....	1
<b>1.2 BACKGROUND OF STUDY</b> .....	1
<b>1.3 PROBLEM STATEMENT</b> .....	2
<b>1.4 AIM AND OBJECTIVE</b> .....	3
<b>1.4.1 AIM.</b> .....	3
<b>1.4.2 OBJECTIVES</b> .....	3
<b>1.5 SIGNIFICANCE OF WORK</b> .....	3
<b>1.6 SCOPE OF PROJECT</b> .....	4
<b>CHAPTER 2</b> .....	5
<b>2.1 LITERATURE REVIEW</b> .....	5
<b>2.1.1 AUTOMATIC WATER TANK LEVEL SENSING SYSTEM:</b> .....	5
<b>2.1.2 WATER LEVEL SENSORS</b> .....	5
<b>2.1.3 CONTROL UNIT</b> .....	14
<b>2.1.4 PUMPS</b> .....	20
<b>2.2 REVIEW OF RELATED WORKS</b> .....	25
<b>CHAPTER 3</b> .....	30
<b>3.1 MATERIALS AND METHODS</b> .....	30
<b>3.2 PIPING SYSTEMS</b> .....	30
<b>3.2.1 PIPING SYSTEM CONSIDERATION</b> .....	31
<b>3.2.2 PIPING SYSTEM COMPONENTS</b> .....	35
<b>3.2.3 INTEGRATING THE PIPING WITH THE AUTOMATED CONTROL SYSTEM</b> .....	38
<b>3.2.4 BENEFITS OF PROPER PIPING IN THIS PROJECT</b> .....	42
<b>3.3 MATERIALS AND EQUIPMENT USED</b> .....	42
<b>3.3.1 MATERIALS</b> .....	42
<b>3.3.2 EQUIPMENT USED</b> .....	43
<b>3.3.3 BILL OF ENGINEERING MATERIALS</b> .....	43
<b>CHAPTER 4</b> .....	45
<b>4.1 PERFORMANCE AND EVALUATION</b> .....	45
<b>4.2 PERFORMANCE METRICS</b> .....	45
<b>4.3 EFFECTIVENESS OF SOLENOID VALVES IN CONTROLLING WATER FLOW AND PREVENTING OVERFLOWS</b> .....	46
<b>4.4 COMPARISON WITH AN OLD SYSTEM</b> .....	47

<b>CHAPTER 5</b> .....	49
<b>5.1 CONCLUSION</b> .....	49
<b>5.2 RECOMMENDATION</b> .....	50

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 BACKGROUND OF STUDY**

The availability of water is important for all forms of life, serving as a fundamental need and an indispensable element of biological processes. From consumption and hygiene to agriculture and recreation, water's applications are numerous. Its abundance in various forms - from the vast oceans to the human body itself - stresses its critical role in sustaining life. Just as oxygen is essential for life, so too is water, making it an irreplaceable foundation of our world.

It is critical to guarantee that there is always a steady supply of good and clean water available. Although water accounts for a bigger amount of the earth's mass, it is not readily available to humans for usage due to its composition and distance from the point of need. This has resulted in efforts to store and retrieve it when needed through the development of various water storage schemes or systems such as dams, reservoirs, wells, artificial lakes, and so on, which use an electric pump to aid in transportation during storage and retrieval (Okhaifoh et al., 2016). Nigerians have adopted the usage of submersible pumps and overhead or subterranean tanks for pumping and storing water.

Electrical centrifugal pumps have become one of the most common devices used in water pumping in Nigeria. This system however has significant shortcomings (Chaiko et al., 2008). The difficulties in achieving high energy efficiency and extending pump lifespan include managing pump start and stop times, as well as monitoring water levels in storage tanks. To resolve these challenges, normal human reasoning was employed, which in this context is extremely unreliable, expensive, inefficient, unproductive, and prone to error. To successfully

handle these challenges, the electric water pump must be operated more effectively, this has resulted in the design and development of several electric water pump controllers (Wara et al., 2007).

The human reasoning or the manual method of managing the pumping system involves manually turning on or off the mains switch. This regulates the flow of fluid (in this case, water) into a storage vessel, which is then used as needed. The storage vessel is often an elevated tank. When the mains switch is turned on, the pump begins to function and water flows into the tank (energy consumption peaks). When the switch is turned off, the flow of water stops (energy consumption is zero). The manual approach is not a very effective strategy. Its usefulness arises during the low tariff time since the user can change the pumping schedule and pump water, lowering the amount spent on pumps.

This manual method of operating this system has a few drawbacks, including frequently starting and stopping the pump, which wears the motor and causes fatigue, pump fatigue caused by allowing the system to run for extended periods of time, and manually controlling valves in situations where one submersible pump supplies water to multiple tanks at the same or different levels. The downside of this technique extends to the persons in charge of the manual process, who may experience weariness due to repeated back-and-forth movements.

In order to address and correct these disadvantages, a more intelligent and automated method of monitoring and running this pumping system is employed.

## **1.2 PROBLEM STATEMENT**

In Nigeria today, many households and businesses still rely on manual method of pumping water. Some systems demand that many tanks be fed by a single pumping system (a single submersible pump). Valve operation is therefore required to reroute the flow between the tanks. Power supply instability in Nigeria contributes to this problem even more, as human interaction

is limited during idling or inactive hours. To address these concerns, this work recommends installing a water level controller to ensure that water is supplied at appropriate levels in a regulated way without the need for human effort. The initially identified problems and inadequacies can be rectified, paving the way for a more efficient and automated water distribution system.

### **1.3 AIM AND OBJECTIVE**

#### **1.3.1 AIM.**

This project aims to implement a water level control system in eight tanks in the faculty of engineering. The primary goal is to ensure the water supply to the tanks is efficient, effective and automated.

#### **1.3.2 OBJECTIVES**

The objectives of this project are as follows:

1. To design a water level controller system for 8 tanks.
2. To select the appropriate components and materials for the designed system.
3. To install the selected components for the system.
4. To test the water level controller system.

### **1.4 SIGNIFICANCE OF WORK**

One main issue that arises in households when people turn on the pumping machine is negligence i.e. they tend to forget about it (due to sleep or work) and the water overflows. While this is a very human phenomenon, it causes waste of water and electrical power. Also,

for tanks located on elevated structures -tank towers and building roofs – overflowing can lead to weakening of the structure and pollution of the environment.

Another issue is that of unstable power supply. Due to nature of power supply in Nigeria, power supply can be restored at odd hours of the day, either late at night or at midday when no one is available to turn on the mains. Continuous pumping of water without control can also cause the pumping machine to get spoilt (i.e. the components of the machine wear, and the machine become less efficient and it eventually stops working.), and as earlier stated, it can cause overflowing of water into the environment. The issues highlighted above causes the need for an automated system to arise.

The automated system can be used at any location that requires the presence and usage of water storage tanks and reservoirs.

## **1.5 SCOPE OF PROJECT**

The whole of this project includes the design and installation of a water level controller for 8(eight) tanks in the Faculty of Engineering, University of Benin. The tanks supply water to the engineering laboratory, the engineering shopping complex, ADEC, Old 1000LT, the Foundry building, and the Mechanical/Production engineering building. This involves surveying the area, designing the system, selecting the components, installing the system, testing the system and commissioning it for general usage.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1.1 AUTOMATIC WATER TANK LEVEL SENSING SYSTEM:

Automatic water tank level sensing systems play a crucial role in efficient water management (Giridhar et al., 2018). These systems consist of sensors strategically positioned within the tank to monitor water levels and transmit data to a control unit (microprocessor) (Alsultan et al., 2017). The control unit then interprets the data and initiates actions based on pre-defined parameters. For instance, the system can activate pumps to fill the tank when water levels fall below a specific threshold, or conversely, deactivate pumps to prevent overflows when the tank reaches capacity (Rahman et al., 2016).

Advanced functionalities can further enhance the capabilities of these systems. These may include alarms to notify users of abnormal water levels (Alam et al., 2014), data logging features for analyzing water usage patterns (Lee et al., 2018 [ScienceDirect]), and even remote control and monitoring capabilities via mobile phones or computers (Farooq et al., 2019). Ultimately, automatic water tank level sensing systems contribute significantly to effective water resource management by minimizing wastage and ensuring a consistent and reliable water supply (Giridhar et al., 2018).

#### 2.1.2 WATER LEVEL SENSORS

**Water level sensors**, also known as level switches, are instruments used to monitor, detect, and quantify the liquid level within a container or storage system, such as tanks, reservoirs, wells, and more (Boyle, 2020). These sensors fall into two primary categories: contact and non-contact (Alsultan et al., 2017).

Contact-based water level sensors, the more prevalent type, directly interact with the liquid to sense its level and convert this information into an electrical signal (Alsultan et al., 2017). This electrical signal is then utilized to activate alarms or shut-off valves when the liquid level reaches undesirably high or low thresholds (Alam et al., 2014).

Depending on the requirements and specific environments of use, there are various types of water level sensors. Some of which are discussed subsequently:

1. Optical level sensors represent a specific category of non-contact sensors that utilize light to detect the level of liquids or bulk solids (McKenna & Doyle, 2018). As solid-state devices, they lack moving parts, contributing to their reliability and minimal maintenance requirements (Boyle, 2020). Their operation hinges on the principle of light detection (Alsultan et al., 2017). These sensors can determine the presence or absence of liquid at a particular level by monitoring changes in light transmission or reflection (McKenna & Doyle, 2018).

Optical level sensors typically comprise an emitter and a receiver positioned at varying heights within the tank (McKenna & Doyle, 2018). When liquid covers the optical path connecting the emitter and receiver, it disrupts the light beam, prompting the sensor to detect the presence of liquid at that specific level. Subsequently, the sensor transmits a signal to a control system or display unit, indicating the current liquid level.

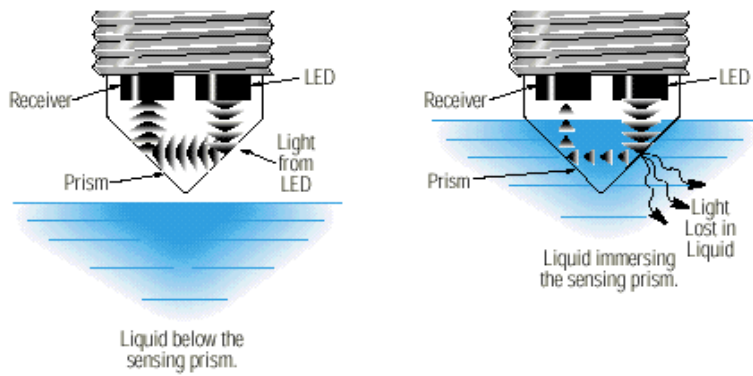


Figure 1 - optical level sensor(cross-section)



Figure 2- optical level sensors

Optical level sensors are dependent on transparency and may not be suitable for opaque liquids. They are also sensitive to ambient light and may not perform properly in the presence of external light. Optical level sensors are limited in terms of the range with which they can accurately detect liquid levels, particularly in large containers. Despite being low maintenance, they might require cleaning to remove build ups or residue that can obstruct optical part.

2. **CAPACITANCE LEVEL SENSORS:** Capacitance level sensors utilize the principle of capacitance variation between two electrodes to determine the level of a liquid, solid, or slurry within a container (Boyle, 2020). Their functionality hinges on the concept of capacitance, which refers to the ability of a conductor-insulator system to store electrical energy (McKenna & Doyle, 2018).

A typical capacitance level sensor comprises two electrodes: an active probe and a reference probe, positioned at varying heights inside the container (McKenna & Doyle, 2018). When the container is empty, or the material level rests below the probes, the capacitance between the electrodes remains relatively low. As the material level increases and engulfs the probes, the dielectric constant of the material changes, causing a rise in capacitance (Alsultan et al., 2017). This change in capacitance is then detected by the sensor and transformed into a signal reflecting the level measurement



*Figure 3 a capacitance level sensor*

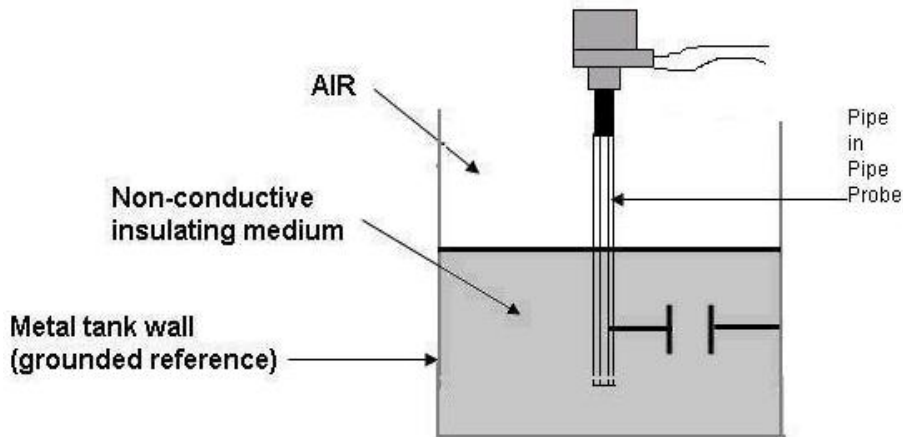


Figure 4 - capacitance Level sensor working diagram

The capacitance level sensors have limited operating range and are susceptible to electrical interference. They are also very sensitive to coating and build up. They generally have higher initial cost, compared to other level sensors.

3. **TUNING FORK LEVEL SENSORS:** Tuning fork level sensors function based on the principle of mechanical resonance, making them particularly adept for applications demanding reliable level detection in harsh or challenging environments (Giridhar et al., 2018). These sensors leverage a piezoelectric crystal's resonant frequency to induce vibration in the switch (Alsultan et al., 2017).

A typical tuning fork level sensor consists of two prongs crafted from metal or another appropriate material (McKenna & Doyle, 2018). These prongs are designed to vibrate at a specific, inherent frequency when stimulated by an external force, such as an electric current. When the tuning fork is submerged in a liquid, the surrounding medium's density differs from air, causing a shift in the vibration frequency (Rahman et al., 2016). The

sensor's electronics then detect this change in frequency and translate it into a liquid level measurement based on the established frequency correlation.



*Figure 5 - a tuning fork*

The tuning fork level sensors have no moving parts and are less affected by coating, build-up, or turbulence compared to some other level sensing technologies. Making them useful in very challenging environments.

It is worthy to note that they are limited by range, i.e. the range within which they can accurately detect liquid levels. They also have high initial cost.

4. **DIAPHRAGM LIQUID LEVEL SENSORS:** Diaphragm liquid level sensors, also known as diaphragm pressure sensors or pneumatic level switches, function based on the principle of hydrostatic pressure (McKenna & Doyle, 2018). This principle states that the pressure exerted by a liquid column is directly proportional to the height of the liquid above the sensor (Alsultan et al., 2017 [ScienceDirect]). As the liquid level rises, the internal pressure within the detection tube increases correspondingly, eventually

triggering the activation of a microswitch (Rahman et al., 2016). Conversely, when the liquid level falls, the air pressure also decreases, causing the switch to open.

Diaphragm liquid level sensors can be configured to provide two functionalities depending on the specific application requirements:

- **Point Level Detection:** In this mode, the sensor identifies whether the liquid level has reached a predetermined threshold, offering a binary on/off signal (Giridhar et al., 2018).
- **Continuous Level Measurement:** The sensor provides a continuous output signal that corresponds to the liquid level within the container (Boyle, 2020).

These sensors are particularly advantageous in applications where direct contact with the liquid is undesirable, such as those involving corrosive or hazardous substances (Alsultan et al., 2017). However, they may have limitations in terms of:

- **Maximum Pressure Tolerance:** They might not be suitable for high-pressure applications due to limitations in the maximum pressure they can withstand (McKenna & Doyle, 2018).
- **Operational Temperature Range:** The sensor's reliable operation may be restricted by the specific temperature range it's designed for (Boyle, 2020).



## 5. FLOAT WATER LEVEL SENSOR:

Float level sensors, also known as float switches, represent the most established type of liquid level sensor technology (Alsultan et al., 2017 [ScienceDirect]). Their operation hinges on the buoyancy principle, where a buoyant float rises or falls in accordance with the liquid level, triggering the activation or deactivation of a switch mechanism (McKenna & Doyle, 2018). As the liquid level fluctuates, the float moves up and down, exerting a pushing force on an attached arm (Giridhar et al., 2018). The arm can be connected to two primary types of switches:

- **Magnetic Switch:** The movement of the arm can be translated into an on/off signal through a magnetic switch (Boyle, 2020).
- **Mechanical Switch:** Alternatively, the arm can be linked to a mechanical switch that operates in a similar on/off manner (Rahman et al., 2016).

In some instances, the arm might be connected to a level gauge instead of a switch. This level gauge visually indicates the liquid level, typically displaying a range from "full" to "empty" as the liquid level changes (Boyle, 2020). The float itself is crafted from a buoyant material, such as plastic, ensuring it stays afloat on the liquid's surface whose level is being monitored (Alsultan et al., 2017 [ScienceDirect]).

### **Advantages of Float Level Sensors:**

- It has simple and reliable operation (McKenna & Doyle, 2018)
- It is cost-effective (Giridhar et al., 2018)
- It is easy to install and maintain (Boyle, 2020)

### **Limitations of Float Level Sensors:**

It may not be suitable for turbulent liquids or applications with a lot of splashing (Alsultan et al., 2017). It can also be limited in accuracy, particularly in large tanks (Rahman et al., 2016). The moving parts can be susceptible to wear and tear over time (McKenna & Doyle, 2018)



*Figure 7 - a float water level sensor*

They are commonly used in automotive applications, such as fuel tanks and coolant systems, to monitor fluid levels and trigger warning indicators or control actions. They are simple devices and hence easy to install. They possess a wide operating range and can operate in diverse environments. Unlike other level sensors, they are very affordable.

6. **ULTRASONIC LIQUID LEVEL SENSOR:** Ultrasonic level sensors function based on the well-established principle of ultrasonic sound waves (McKenna & Doyle, 2018). These sensors emit high-frequency sound pulses that travel towards the liquid surface and then reflect back (Alsultan et al., 2017). By measuring the time it takes for the sound waves to

complete this round-trip journey, the sensor can determine the distance to the liquid level (Boyle, 2020). This information is then translated into a real-time measurement of the liquid level.



*Figure 8- an ultrasonic liquid level sensor*

Ultrasonic liquid level sensors are utilized in marine vessels, ships, and offshore platforms for monitoring fuel levels, ballast tanks, and cargo hold levels. They can measure liquid levels over a wide range of distances, from a few centimetres to several meters, depending on the sensor's design and specifications.

Ultrasonic sensors may be affected by obstructions such as foam, vapor, or suspended solids in the liquid, which can interfere with the accuracy of level measurements. Changes in temperature, humidity, and air density can affect the speed of sound in air, potentially influencing the accuracy of level measurements.

### **2.1.3 CONTROL UNIT**

Control units, also known as control systems or controllers, are essential components in various automated systems. They act as the brains of these systems, responsible for regulating and

managing their overall operation (Boyle, 2020). Control units function by receiving input signals from sensors or human operators. This information is then processed, and output signals are generated to control actuators, valves, motors, and other devices connected to the system (McKenna & Doyle, 2018). There are two types of control systems, including:

1. **Open-loop control systems:** These systems do not have feedback, meaning that the output is not influenced by the actual performance of the system. Instead, the input to the system is predetermined based on a set of predetermined rules or instructions. This makes open-loop control systems less precise and less responsive to changes in the system or the environment.
2. **Closed-loop control systems:** Closed-loop control systems, compared to open-loop systems, incorporate a feedback mechanism to ensure accuracy and adaptability (McKenna & Doyle, 2018). These systems continuously monitor the system's output and compare it to a predetermined desired output, also known as the setpoint (Boyle, 2020). The difference between these two values, termed the error signal, serves as the basis for adjusting the system's input signal.

In water tank level control systems, control units play a critical role in monitoring and managing the water level effectively. They are the processing unit; basically, acting as the brain of the system. The following are ways control units' function in such systems.

1. **Sensor Integration:** Control units integrate with various sensors to measure water level. These can be ultrasonic sensors, pressure sensors, float switches, or others depending on tank requirements (Yoon et al., 2018). The choice of sensor type is crucial for accuracy and reliability in diverse environments (Muthukumar et al., 2014).

2. **Data Processing:** The control unit processes sensor readings to determine the current water level. This processing may involve noise filtering, environmental factor compensation, and converting raw readings into usable water level data (Olsson et al., 2009).
3. **Setpoint Adjustment:** Users can define desired water level parameters (setpoints) through the control unit. The unit compares the current level with the setpoints to determine if adjustments are necessary (Guohua et al., 2010).
4. **Decision Making:** Based on the comparison with setpoints, the control unit decides to activate or deactivate pumps, valves, or other mechanisms to maintain the desired water level (Wang et al., 2018).
5. **Feedback Loop:** Control units continuously monitor the water level and adjust operations as needed. This creates a closed-loop feedback system where the unit constantly evaluates the system and takes corrective actions to maintain the setpoint (Åström & Hägglund, 2006).
6. **Alarm and Alerting:** Control units often include features to alert operators of abnormal conditions. These can be high or low water levels, sensor failures, or system malfunctions. Alerts can be visual, audible, or transmitted remotely to a monitoring system (Muthukumar et al., 2014).
7. **Remote Monitoring and Control:** Modern control units offer remote monitoring and control capabilities. Operators can access system status and make adjustments from a central location via computer, smartphone, or other connected devices (Yoon et al., 2018).

Examples of control units employed in water tank level sensing systems are:

1. Programmable Logic Controllers (PLCs)
2. Microcontroller-based Systems
3. SCADA (Supervisory Control and Data Acquisition) Systems

**1. PROGRAMMABLE LOGIC CONTROLLERS:** Programmable Logic Controllers (PLCs) are specialized industrial computers designed for real-time control of machinery and processes in harsh environments. Unlike general-purpose computers, PLCs prioritize reliability and robustness. They are built to withstand extreme temperatures, humidity, and electrical noise often encountered in industrial settings (Whitson et al., 2006).

#### **Components of a PLC:**

- **CPU (Central Processing Unit):** The CPU is the brain of the PLC, responsible for executing control logic, processing inputs, and generating outputs.
- **Input Modules:** Input modules interface with sensors and other devices to provide the PLC with information about the system's state, such as water level measurements.
- **Output Modules:** Output modules drive actuators, such as pumps or valves, to control the system based on the PLC's instructions.
- **Programming Interface:** PLCs are programmed using specialized software, typically ladder logic, function block diagrams, or structured text. These programming languages allow engineers to create control algorithms and logic to manage the water tank level effectively.



Figure 9- a programmable logic controller

**2. MICRO CONTROLLER BASED SYSTEMS:** Microcontroller-based systems have become a prevalent choice for various applications, including water tank level control. These systems harness the power of microcontrollers, tiny integrated circuits that pack a punch. Microcontrollers integrate a processor core, memory, and essential peripherals onto a single chip, enabling them to execute control logic and seamlessly interface with sensors and actuators (Matin et al., 2010). This compact and versatile design makes them ideal for implementing automated control systems like water tank level management.

#### **Components of Microcontroller-based Systems:**

1. **Microcontroller:** The heart of the system, the microcontroller executes the control algorithms, processes input data from sensors, and generates output signals to control actuators.
2. **Sensors:** These devices measure parameters such as water level in the tank and provide analog or digital signals to the microcontroller.

3. **Actuators:** Actuators, such as pumps or valves, are controlled by the microcontroller to adjust the water level based on the system's requirements.
4. **Power Supply:** Microcontroller-based systems require a stable power supply to operate reliably.
5. **Communication Interfaces:** Optional interfaces allow the system to communicate with other devices, such as a computer or smartphone, for monitoring and control purposes

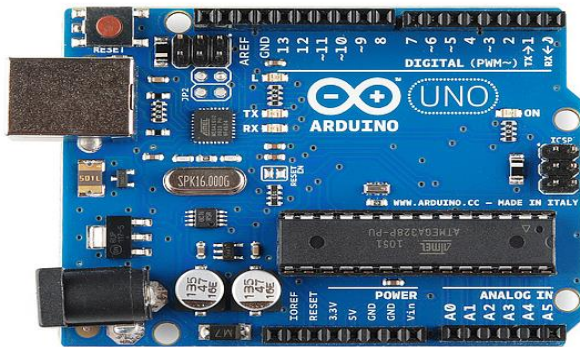


Figure 10- an arduino microcontroller

3. **SCADA SYSTEMS:** Supervisory Control and Data Acquisition (SCADA) systems are integral to managing and controlling complex industrial processes, including water tank level control in various sectors such as manufacturing, utilities, and infrastructure. The system consists of both software and hardware components and enables remote and on-site gathering of data from the industrial equipment.

#### **Components of SCADA Systems:**

1. **Human-Machine Interface (HMI):** This component provides a graphical interface for operators to monitor the system in real-time, view data trends, and interact with controls.

2. **Remote Terminal Units (RTUs) or Programmable Logic Controllers (PLCs):** RTUs or PLCs are deployed at the water tank site to gather data from sensors, control actuators, and communicate with the SCADA system.
3. **Communication Infrastructure:** SCADA systems rely on communication networks, such as Ethernet, serial connections, or wireless technologies, to exchange data between the central server and remote sites.
4. **Centralized Server:** The central server hosts the SCADA software applications responsible for data processing, control logic execution, alarming, and historical data storage.
5. **Data Acquisition System:** This system collects data from sensors installed at the water tank site, including water level sensors, temperature sensors, flow meters, and pressure transducers

#### **2.1.4 PUMPS**

A pump is an electromechanical device that plays a vital role in moving fluids. It utilizes mechanical action to transfer these liquids, typically converting electrical energy into hydraulic energy (McKenna & Doyle, 2018). There are many different types of pumps, including:

##### **Centrifugal pumps**

They make use of centrifugal force to move fluids through a piping system. They are often used in industrial, agricultural, and domestic applications to pump water, solvents, oils, acids, and other thin liquids.



*Figure 11 - a centrifugal pump*

### **Diaphragm pumps:**

Also known as membrane pumps, these pumps use a flexible membrane, usually made of rubber, to move and pressurize fluids. They are used for low pressure, low flow applications, and can pump many types of gases, liquids, and slurries.



*Figure 12 - a diaphragm pump*

### **Positive displacement pumps:**

These move fluids by repeatedly enclosing a fixed volume and moving it mechanically through the system. They are often used as metering pumps because they accurately control flow rates by changing the speed at which the pump is driven.



*Figure 13- a positive displacement pump*

## **VALVES**

Valves are fundamental components in any fluid flow system, playing a critical role in regulating and directing the movement of fluids (Sarrazin et al., 2004). They achieve this by opening, closing, or partially obstructing passageways within the system.

One prominent type of valve is the solenoid valve, an electromechanical device specifically designed to control the flow of fluids, including water (Van de Steen et al., 2006). The operation of a solenoid valve relies on an electric current to manipulate the movement of a plunger or piston within the valve body. When the solenoid coil is energized, it generates a magnetic field. This magnetic field, in turn, attracts the plunger or piston, creating an opening that allows fluid to flow through the valve (Van de Steen et al., 2006). Conversely, when the coil is de-energized, the magnetic field dissipates. This loss of magnetic force allows a spring to return the plunger or piston to its original position, effectively shutting off the flow of fluid.

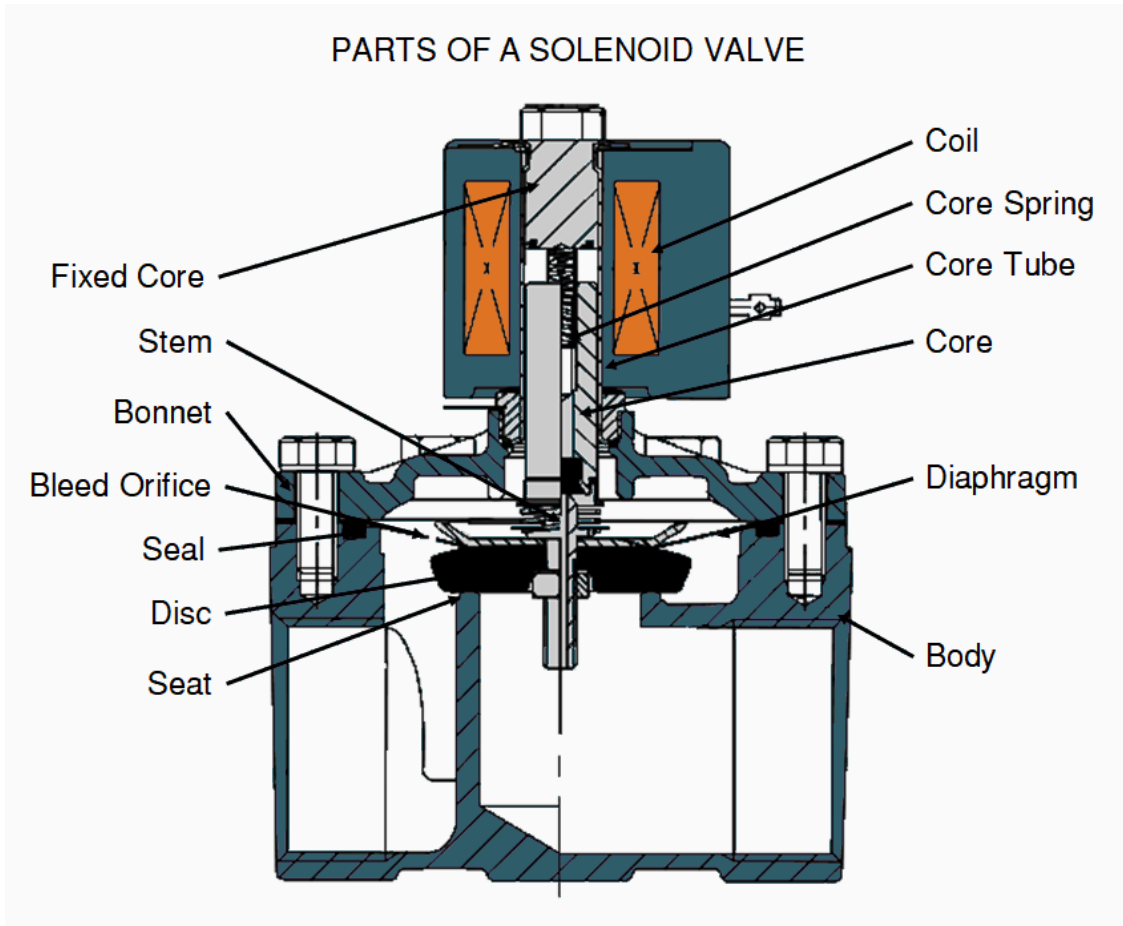


Figure 14 internal view of a solenoid valve



Figure 15 - a solenoid valve

## RELAYS

A relay is an electrically operated switch that functions by opening and closing electrical contacts within a circuit. This action can also indirectly activate or deactivate other devices connected to the circuit (wang et al., 2007). Relays are comprised of two key terminal sets: input terminals for receiving control signals and operating contact terminals for managing the flow of current. Notably, these operating contacts can come in various configurations, including make contacts (designed to establish a connection when activated), break contacts (intended to interrupt a connection), or even a combination of both (Van de Steen et al., 2001).



*Figure 16 - a relay and relay base*



*Figure 17 a relay*

## 2.2 REVIEW OF RELATED WORKS

Water and its supply are an essential and non-negotiable aspect of life on earth. It has a myriad of applications, from the day to day running of our homes (washing clothes and dishes, cooking, cleaning, drinking, watering plants, etc.) to usage in production/manufacturing industries. It occurs naturally as rivers, waterfalls, oceans/seas, springs, and even rainfall.

Naturally occurring water was the main source of water for day to day usage in the pre-historic times. Fetching water from rivers and streams and subsequent storage in clay pots, locally known as “calabash” was the order of the day. Other materials used to store water are bamboo, stone pots, etc. Across different generations and civilizations, water storage has developed; from the Indus valley civilization (3000 – 1500BC) making use of granaries, to Johannes Joubert, a Lucerne farmer, developing a better system for storing and using rainwater(1970s). Today, there are different type of tanks for water storage, including overhead tanks, ground water tanks, etc.

Alongside the advancement of water storage, water sourcing became more advanced too. From fetching water from natural water bodies using clay pots to the “Shardoof” of the Egyptians in 200BC to the centrifugal and positive displacements pumps of today’s world.

This section aims to explore different ways water tanks making use of submersible centrifugal pumps are optimized with the use of different water tank level sensing and pumping techniques. It is worthy to note that the most common method of sensing and monitoring water tank levels, especially in Nigeria, is manually. Manual method involves being physically present to turn on or off the mains when the tank gets full and overflows.

In a 2012 research by Saraswati et al., an automatic water level monitoring system was designed to eliminate the hassle of manual measurements. The system uses an AT89S51 microcontroller for overall control, an ultrasonic sensor for accurate water level readings, and

a SIM300C GSM modem for SMS communication. Upon receiving a request SMS, the system measures the water level and sends a report back via SMS. This system's versatility allows for placement in various locations, requiring only a simple initial setup via SMS based on its specific installation conditions. The system boasts a relatively low average measurement error of 3.74%, with a maximum measurable water depth of 432 cm and an operational voltage range of 4 to 4.5 volts.

In a 2017 research, Khadim et al. explored a cost-effective system for controlling liquid levels in a tank. It uses an Arduino Uno microcontroller to collect data from an ultrasonic sensor for accurate and reliable level measurement under various conditions. A LabVIEW software displays the liquid level and motor status (on or off) based on the measured level. The system offers flexibility and simplifies liquid tank level control.

In another research, Salam et al., 2017, designed an automatic water tank filling system. It uses several components to manage the filling process without human intervention. These include an ultrasonic sensor, a control unit, a water flow sensor, a small computer (Arduino), and a pump. The ultrasonic sensor acts like a fancy echolocation tool. It sends out a sound wave and measures how long it takes to bounce back from the water surface. Based on this time, the system can figure out how full the tank is. The computer then uses this information to turn the pump on and off automatically, keeping the tank filled to the desired level.

In 2016, Okhaifoh et al, conducted a research similar to Salam et al., 2017. The study describes the design, building, and testing of a Microcontroller Based Automatic Control for Water Pumping Machine and Level Indicator (MBACWPMLI). The system uses ultrasonic sensors, similar to bat echolocation, to measure water depth in a tank. It sends sound waves and measures the time it takes for them to bounce back. A microcontroller uses this time to calculate the distance to the water surface and controls both indicator lights and the pump itself. The

MBACWPMLI has pre-set minimum and maximum water levels. When the water level falls below the minimum (0.27 meters), the microcontroller turns on the pump. Conversely, when the water level reaches the maximum (0.05 meters), the pump is switched off. During testing, the MBACWPMLI successfully turned the pump on and off at the correct levels, and the corresponding indicator lights functioned properly.

A research carried out by Ejiofor et al, (2013), focused on upgrading a standard water pump controller by incorporating a control system with advanced features. It used a microcontroller to automate the pump operation for an overhead tank. This system can not only sense the water level but also turn the pump on or off based on that level. Additionally, it displays the water level status on a convenient LCD screen. This research offers a significant improvement over existing controllers by using a precisely calibrated circuit to show the water level and opting for safer DC power instead of potentially risky AC power.

Shah et al., (2017), proposed a new system to address the growing concern of water waste caused by overflowing tanks. Traditional water tanks lack the ability to monitor or control water levels, leading to significant water loss. Existing solutions may have limitations. The project aimed to develop a cost-effective and efficient way to monitor and control water levels using IoT technology and an Android application.

In 2016, Wadekar, et al., researched a helpful Internet of Things (IoT) device for managing and planning water use in residential areas. The system is easy to install and consists of sensors placed inside the water tank. These sensors constantly monitor and transmit real-time water level data to the cloud. Users can then access this information through a convenient Android app on their smartphones, visualizing the water level from anywhere with an internet connection. Additionally, the system automates pump operation based on the water level. When

the level gets low, the pump automatically turns on, and it shuts off as the tank approaches full capacity.

Natividad and Palaoag, (2019), explored using Internet of Things (IoT) technology to improve water distribution in communities. They described a system built with various sensors (water pressure, ultrasonic), switches, valves, and a mini-computer (Raspberry Pi) to monitor and control water flow. The project aimed to create a cost-effective and reliable method for better water distribution. The researchers developed a prototype system that simulates real-world water distribution operations. They also built a web application as a user interface for monitoring pumping station status and controlling the system remotely. To make more informed decisions, the system incorporated a fuzzy logic algorithm. Overall, the experiment was successful, demonstrating the effectiveness of the IoT-based model for water distribution monitoring and control.

In 2015, Verma et al. carried out a research that explores the design and initial findings of an IoT system for managing water distribution on a large campus. The system focuses on two key elements:

1. **Low-cost ultrasonic water level sensors:** These sensors are designed to be affordable and suitable for installation in both overhead tanks and ground-level reservoirs. Special techniques are used to ensure these sensors can accurately measure water levels across large distances.
2. **Sub-GHz wireless network:** This network uses low-frequency radio waves to connect the sensors to a central hub. The hub then uploads the collected data to the internet for visualization and analysis, allowing for better monitoring and management of the campus's water distribution system.

Water is a vital resource, and traditional methods of managing water tank levels can be wasteful and inconvenient. The preceding review explored various research efforts aimed at optimizing water tank systems through automation and improved monitoring.

Alsultan et al., (2017) described the development of a low-cost wireless sensor network system for monitoring water level in irrigation canals. While the application focuses on open water channels, the concept of using ultrasonic sensors for remote level monitoring can be adapted to water tank control systems, especially for large tanks.

Sarrazin et al. (2004) discussed the use of valves for flow control in microfluidic devices. While the research focused on passive valves inapplicable to water tank systems, it highlights the concept of using control mechanisms to regulate fluid flow. This aligns with the core function of a water tank level control system, where valves are employed to manage water inflow based on tank level.

The researches presented demonstrates a clear shift towards more sophisticated water tank level sensing and pumping techniques. These advancements utilize technologies like ultrasonic sensors, microcontrollers, and the Internet of Things (IoT) to automate pump operation, prevent overflows, and even enable remote monitoring.

As these technologies continue to develop, we can expect even more efficient and user-friendly water management systems to emerge in the future. This will not only conserve water but also provide greater convenience and control for users.

## **CHAPTER 3**

### **MATERIALS AND METHODS**

This chapter discusses piping and its components. It discusses how piping was implemented in this project. This chapter also highlights the materials and equipment used for and during the course of the project.

#### **3.1 PIPING SYSTEMS**

This project involves the design and installation of an automated water tank level controller. One of the main considerations of this project is water availability. The project intends to provide water for various locations in the faculty of engineering. In order to achieve this, piping is required.

Piping refers to a network of interconnected pipes, fittings, valves, and other components used for transporting liquids or gases between locations. It also involves the physical layout of pipes and other components within a building. Plumbing, which is a more familiar piping system, involves the network of pipes that provide potable water to residential and non-residential areas. The roles piping plays in this project are as follows;

1. The piping system forms the network that carries water from the single pump to each of the 8 (eight) individual tanks.
2. A well-designed piping system minimizes resistance to water flow. This is achieved by using pipes with the appropriate diameter and strategically placing them with minimal bends and fittings. By reducing resistance, the system ensures that sufficient water pressure and flow reach even the furthest tank, guaranteeing that all tanks receive their fair share of water.

### 3.1.1 PIPING SYSTEM CONSIDERATION

The delivery of water efficiently to 8(eight) tanks from a single pump requires careful piping system design. The factors considered in the system design/selection are as follows;

#### 1. Water Demand:

Water demand is the total amount of water used in a given area over a specific period of time. The first step involves determining the total daily or hourly water demand for all eight tanks combined. This will dictate the overall capacity the piping system needs to handle.

Water demand = Average daily water demand per person × Population

#### 2. Pipe Size (Diameter):

**Flow Rate Calculations:** Based on the total water demand, the required flow rate through the pipes is calculated. The Probable Simultaneous Demand (PSD) which considers the maximum number of fixtures likely to be used at once, is calculated. The PSD obtained will be a value in litres per second or gallons per minute. This is the desired pipe flow rate.

**Diameter Selection:** Using the calculated flow rate and considering the chosen pipe material's friction characteristics, the appropriate pipe diameter is selected. Larger diameters allow higher flow rates but come at a cost increase. Conversely, smaller diameters may lead to excessive pressure drops and restrict flow.

$$D = \sqrt{\frac{4Q}{\pi v}}$$

Where

D= diameter of pipe

Q = Volumetric flow rate (volume of fluid flowing per unit time)

$v$  = Flow velocity (speed of the fluid in the pipe)

It is also possible to find pipe size/diameter with pipe size charts, given flow rate.

### 3. **Pressure Drop:**

**Friction Loss:** Water flowing through pipes experiences friction, causing a pressure drop along the pipe length. This pressure drop is considered during design to ensure sufficient pressure reaches all eight tanks.

**Pressure Rating:** Pipes are rated for a maximum pressure they can handle. The design ensures the operating pressure within the pipes stays below the chosen pipe's pressure rating.

### 4. **Material Used:**

Selecting the appropriate material to use, is an important aspect of any project that requires piping. Factors like durability, corrosion resistance, cost, pressure rating, and suitability for the fluid being transported are considered when selecting materials for piping.

A breakdown of important considerations when carrying out material selection for piping is given below:

#### **Fluid Properties:**

- **Chemical composition:** The type of fluid being transported is the primary factor. For instance, corrosive fluids like acids or alkalis might require special materials like stainless steel or lined pipes to prevent deterioration.
- **Temperature:** Fluids can have varying temperature ranges. Some materials like PVC might not be suitable for high-temperature applications where they could melt or deform. Some metals also become brittle at very low temperatures.

#### **Pressure Requirements:**

- **Operating pressure:** The pipes need to withstand the pressure of the flowing fluid. Higher pressure systems require the use of thicker pipes or stronger materials like steel.

#### **Application and Environment:**

- **Purpose:** The application of the piping system plays a role. For potable water lines, copper or PEX might be suitable choices, while fire sprinkler systems might use steel pipes for their strength.
- **Environment:** Consider the surrounding environment. If the pipes will be exposed to sunlight, PVC will not be a great choice, because it degrades over time. For underground piping, the material needs to be resistant to corrosion from soil conditions.

#### **Cost and Installation:**

- **Material cost:** Different materials have varying costs per unit length. Factors like metal prices can affect the price of steel pipes.
- **Installation considerations:** Some materials like copper might require specialized skills or tools for joining, thereby impacting installation costs.

#### **Common Pipe Materials:**

- **Steel:** Steel pipes are expensive compared to other pipes, but they are the strongest and offer the most durability of all kinds of water supply pipes. They can withstand very high-water pressure, come in more convenient (longer) lengths than most other pipes and thus cost less to transport and install. They are also easier to weld. Galvanized steel offers improved corrosion resistance. Stainless steel provides excellent corrosion resistance but comes at a higher cost.

- **Copper:** Copper pipes are quite popular for piping systems due to their durability, corrosion resistance, and their ability to handle hot water. They are also easy to bend and install, fire-resistant, and recyclable. They are however more expensive than some alternatives and require soldering expertise for installation.
- **PVC (Polyvinyl Chloride):** PVC pipes are non-corrosive, extremely light and thus easy to handle and transport. They are also strong and come in long lengths that lower installation/transportation costs. They however are susceptible to physical damage when laid above ground and can become brittle when exposed to ultraviolet light (sun light). They are great for cold water applications, unsuitable for high temperatures or pressures and will soften when exposed to temperatures above 65°C.
- **PEX (Cross-linked Polyethylene):** It is a flexible plastic pipe used for piping in residential and commercial buildings. It's made by chemically or physically modifying the molecular structure of polyethylene to permanently link its polymer chains. PEX is a popular alternative to copper and galvanized steel pipes,
- **HDPE (High-Density Polyethylene):** HDPE pipes are made from a thermoplastic derived from natural gas and are known for their tensile strength, corrosion resistance, and impact resistance. They are flexible plastic pipes that are used to transport liquids and gases. They are often used to replace aging concrete or steel main pipelines.

For this project, 1-inch Polyvinyl Chloride (PVC) pipes were used. The decision to use them came as result of their cost, durability and resistance to corrosion and chemical damage. Majority of the piping was done underground and PVC offers one of the best corrosion

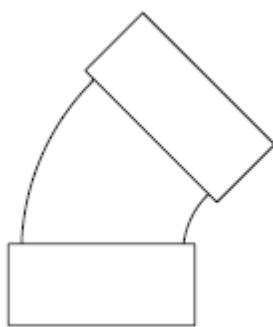
resistances for underground piping as it is plastic and not easily affected by the components of soil. It is also lightweight, easy to install, and has a long lifespan, making it a popular choice for various plumbing and drainage systems. Additionally, PVC pipes are also known for their smooth interior surface, which allows for efficient water flow and reduces the likelihood of clogs or blockages.

### 3.1.2 PIPING SYSTEM COMPONENTS

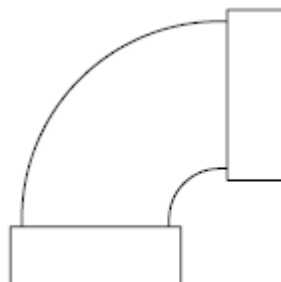
The preceding sections have discussed pipes and their selection criteria for this project. In order to efficiently deliver water from the pump to each tank, a network of pipes and essential components need to work together seamlessly. In this section, the components which were used alongside the pipes in this project will be discussed.

**PIPE FITTINGS:** Pipe fittings are connectors, adapters, and control devices that are used to terminate, join, regulate flow or change direction within a pipe network. Fittings for pipe are most often made from the same base material as the pipe being connected, e.g., stainless steel, steel, copper or plastic. In this project the pipe material is PVC, therefore the fitting material is also PVC. The common types of pipe fittings are listed below;

1. Elbow: This is installed between two pipes allowing a change of direction, usually 90° or 45°.



45° elbow



90° elbow

2. Tee: This is used to either combine or split a fluid flow. It is a pipe that has adjacent outlets and used to connect pipes at 90° angle.



*Figure 18- tee fitting*

3. Cross: This has one inlet and three outlets, or vice versa. Just like the Tee, it also combines or split flow.



*Figure 19 - cross fitting*

4. Cap/Plug: This is a pipe fitting that creates a watertight seal, and is used to seal/block an open-ended pipe. The cap has female threads while the plug has male threads.



Figure 20 - cap fittings

**VALVES:** A valve is used to regulate or stop the flow of a fluid by partially or completely closing/opening of a passageway. There are different kinds of valves used in piping; some common examples are:

1. Ball valve
2. Butterfly valve
3. Globe valve
4. Check valves
5. Diaphragm valve

Valves are either manually operated – by a lever or hand wheel, or they are operated automatically - by a pneumatic actuator or electrical motor. In this project, both manually and automatically operated valves were used.

### **The Solenoid Valve**

To ensure that the water tanks received the right amount of water (and at the right time), to maximize water availability within the system, Solenoid Valve was used. A solenoid is an electrically operated valve. A typical solenoid valve consists of the following:

1. Solenoid Coil – This is an electromagnet

2. Plunger
3. Spring
4. Valve Body – This houses the components of the valve.
5. Flow Path – These are openings in the valve body that permit fluid flow.

When an electric current energizes a coil, it generates a magnetic field that pulls a metal plunger within the valve body. This plunger movement opens or closes a flow path, allowing or stopping the flow of fluids or gases depending on the valve's design and initial state. A spring usually counteracts the magnetic pull, so when the current ceases, the spring returns the plunger to its original position, controlling the flow once again.

### **3.1.3 INTEGRATING THE PIPING WITH THE AUTOMATED CONTROL SYSTEM**

As earlier stated in this report, the main consideration of this project is to use an automated pumping system to aid the availability of water in the faculty of Engineering. This section aims to explain how the automated system and the piping system are integrated.

The water tank control system's piping network isn't physically linked to the automated control system. Instead, they communicate through a network of sensors, valves, and electrical controls within a relay base. This relay base serves as an intermediary between the physical pipe components and the control system's electrical signals.

Float less relays, situated in each tank, serve as water level sensors. They measure water levels without relying on physical floats that may degrade over time. When a tank reaches a predetermined water level threshold, i.e. full or empty, the float less relay sends a signal through wires to the relay base.

The control system receives this signal and interprets it according to its programmed instructions. For instance, if the signal indicates a low water level in a specific tank, the system initiates a refill process. The control system then activates the relevant magnetic contactor within the relay base. This contactor functions as an electronic switch, delivering a specific electrical current to the pump motor as well as designated solenoid valve for that tank. Consequently, not only does the solenoid valve open to allow water flow, but the pump motor also activates to ensure adequate water supply to the tank.

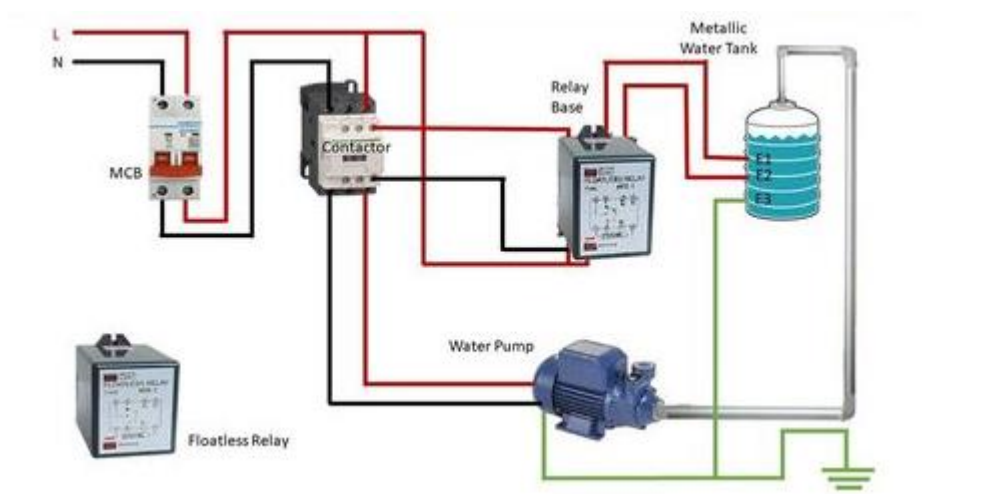


Figure 21 - line diagram for the system

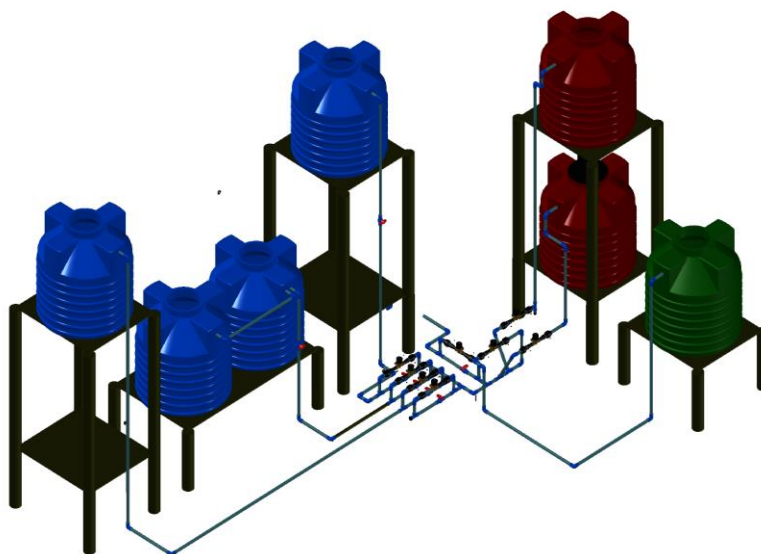


Figure 22 - 3d model of the tanks





*Figure 23 - pictures of the pipe laying process*



*Figure 24 - the valves set up*

### **3.1.4 BENEFITS OF PROPER PIPING IN THIS PROJECT**

In the water tank control system, proper piping is critical for maximizing the availability of water. It ensures efficient flow of, minimizes pressure losses, and contributes to a reliable system operation, ultimately leading to better water management for all tanks. Some specific benefits are listed below:

- With efficient flow and minimized pressure loss, each tank fills up quicker, maximizing the overall refill capacity of the system.
- Reduced pressure loss ensures consistent water pressure across all tanks, leading to more uniform filling and minimizing the risk of some tanks being underfilled.
- Efficient flow and minimized pressure loss require the pump to work less to deliver the same amount of water. This translates to lower energy consumption and operational costs.

## **3.2 MATERIALS AND EQUIPMENT USED**

### **3.2.1 MATERIALS**

1. PVC Pipes
2. Limit switches
3. Relays
4. Wires
5. Solenoid valves
6. Ball valves
7. Contactor

8. Tee fittings
9. Float less switches
10. 90° Elbow fittings
11. Union Couplings
12. Nuts and bolts
13. Screws

### **3.2.2 EQUIPMENT USED**

1. Drilling machine
2. Measuring tape
3. Screwdriver
4. Pliers
5. Pipe wrench
6. Cutter
7. Spanner

### **3.2.3 BILL OF ENGINEERING MATERIALS**

S/N	Components	Units	Material	Unit cost	Total cost
1	Wires				
2	Ball valves				
3	Solenoid valves				

4	Utility box				
5	Float less switch				
6	90° elbow fitting				
7	Union couplings				
8	Angle bar				
9	Relays				
11	Tee fittings				
12	Contactors				
13	Key switch				

## CHAPTER 4

### RESULTS AND PERFORMANCE DISCUSSION

#### 4.1 PERFORMANCE AND EVALUATION

In this chapter, the performance of the implemented control system shall be discussed and also compared to a previously implemented system.

In testing the system, the speed and efficiency of turning on/off the pump and solenoid valves whenever the tanks were full or below the threshold, were observed.

#### 4.2 PERFORMANCE METRICS

1. **Average Refill Time per Tank:** This metric measures the average time it takes for an individual tank to get filled after a refill cycle is initiated. It helps to know the overall efficiency of the system in delivering water.
2. **Consistency of Water Levels Across Tanks:** Ideally, all tanks should reach a similar water level, indicating even distribution throughout the system. This metric measure how each tank level varies from each other after a refill cycle. This can be expressed as a standard deviation of water levels or a percentage difference from the target level.
3. **Solenoid Valve Response Time:** This metric measures the time it takes for a solenoid valve to open or close upon receiving a signal from the control system. A fast response time ensures there is a proper control of water flow.
4. **Number of Overflow Events:** Monitoring the occurrence of overflows in any tank helps evaluate how effective the system is in preventing overfilling. A well-functioning system with properly calibrated sensors and responsive solenoid valves should experience little to no overflow.
5. **Energy Consumption:** Over time, monitoring the amount of energy consumed by the system helps to be able to give proper assessment of the system in terms of power usage.

### **4.3 EFFECTIVENESS OF SOLENOID VALVES IN CONTROLLING WATER FLOW AND PREVENTING OVERFLOWS**

The solenoid valves in the water tank control system played a vital role in precisely controlling water flow and preventing overflows. A breakdown of the effectiveness based on observed data is given below:

1. **Rapid Response Times:** The solenoid valves demonstrated fast response times, opening and closing within 0.1 seconds upon receiving a signal from the control system. This rapid response ensures precise control over the starting and stopping of water flow for each tank refill cycle.
2. **Minimal Overflows:** Throughout the testing and operation period, the system experienced zero (0) overflows. This very low number indicates the effectiveness of the solenoid valves in stopping water flow once the designated water level was reached in each tank.

#### **Factors Contributing to Effectiveness:**

The following are factors that contribute to the effectiveness of the solenoid valves:

- **Reliable Control System:** The accurate and timely signals sent by the control system based on float less relay readings ensure the solenoid valves receive the correct commands to open and close at the appropriate time.
- **Proper Valve Selection:** Selecting the proper solenoid valves for the system ensures sufficient capacity to handle the required water flow without compromising on response time.

Overall, the solenoid valves functions very well in controlling water flow and preventing overflows. The rapid response times and reliable operation, coupled with a proper control

system, contributes significantly to the overall success of the automated water tank control system.

#### **4.4 COMPARISON WITH AN OLD SYSTEM**

An earlier implementation of an automated water tank level control system in the faculty of engineering served only 3 water tanks. It also incorporated the use of locally fabricated solenoid valves. The system not only served a limited area, the solenoid valve did not perform as well as an efficient system requires. The response time of the solenoid valve was slow, an average of 0.65 seconds. Also, the solenoid valve dropped in overall efficiency after a couple of months.

Overall, the new automated water tank control implemented offers several advantages over the old system. The current system serves water to 8 water tanks situated in about 5 locations in the faculty of engineering. The use of industry manufactured solenoid valves led to a faster average refill time and improved water level consistency.



Figure 25 - Image of the new central control unit.



Figure 26 - Images of the solenoid valves used

## CHAPTER 5

### CONCLUSION AND RECOMMENDATIONS

#### 5.1 CONCLUSION

The water tank level control system was successfully implemented in the faculty of engineering. It serves 8(eight) tanks in various locations in the faculty; the engineering laboratory, the foundry building, ADEC, the engineering shopping complex, Old 1000LT, and the Mechanical/Production engineering building. The system solves a problem of ensuring water is constantly available in these locations, as long as there is power supply.

The implementation of the system also means that the people in charge of turning on the pump and monitoring the tanks have been relieved of their duty and can spend their time on more productive activities.

The results of the tests carried out on the system, to check refill times, overflow, and valve response times were very encouraging. Comparing the implemented system with a system that was implemented earlier, the new system has a faster average valve response time. It also serves more locations unlike the old system and is more efficient.

With the increase in the appeal towards automated systems/ devices in today's world, it is expected that there will be widespread adoption of this system especially among Nigerians. It is quite affordable and the improved life quality it offers justifies the cost.

Research in the area of water level control remains ongoing and in the foreseeable future, significant advancement will be seen. Emerging fields like Machine learning and deep learning will be used for water level control to track patterns in power supply, water demand, etc., and make intelligent control decisions based on them.

## **5.2 RECOMMENDATION**

Technology has gotten to where it is today because of the constant need to improve on existing technologies.

1. In the future, more efficient water level sensors can be used replace the float less relay.
2. A human machine interface can be used in future iterations of the system.
3. The system and its benefits should be extended to the whole campus to solve the issue of water availability in hostels, residential areas and other faculties.

## REFERENCES

1. Ejiofor Virginia Ebere (PhD), Oladipo Onaolapo Francisca (PhD), 2013. Microcontroller based Automatic Water level Control System.  
<https://www.rroj.com/open-access/microcontroller-based-automatic-water-levelcontrol-system.pdf>
2. Eka Cahya Prima, Siti Sarah Munifahab, Robby Salamb, Muhamad Haidzar Azizb, Agustin Tia Suryanic, 2016. Automatic Water Tank Filling System Controlled using Arduino based Sensor for Home Application.  
[https://www.sciencedirect.com/science/article/pii/S1877705817311761?ref=pdf\\_download&fr=RR-2&rr=87449beeff0a527e](https://www.sciencedirect.com/science/article/pii/S1877705817311761?ref=pdf_download&fr=RR-2&rr=87449beeff0a527e)
3. Riadh Adnan Kadhim, Abdul Kareem Kasim Abdul Raheem and Sabah Abdul Hassan Gitaffa, 2016. Implementing of liquid tank level control using Arduino LabVIEW interfacing with ultrasonic sensor.  
<https://journal.uokufa.edu.iq/index.php/kje/article/view/1172/1100>
4. Savali Wadeker, Vinayak Vakare, Ramratan Prajapati, Shivam Yadav, Vijaypal Yadav, 2016. Smart water management using IOT  
<https://ieeexplore.ieee.org/document/7993425>
5. JE Okhaifoh, CK Igbinoba, KO Eriaganoma, 2016. Automatic control for water pumping machine with water level indicators using ultrasonic sensor  
<https://www.ajol.info/index.php/njt/article/view/140655>
6. J G Natividad and T D Palaoag 2019. IoT based model for monitoring and controlling water distribution  
<https://iopscience.iop.org/article/10.1088/1757-899X/482/1/012045/pdf>

7. P. P. Shah, A. A. Patil and S. S. Ingleshwar, "IoT based smart water tank with Android application," *2017 International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC)*, Palladam, India, 2017, pp. 600-603, doi: 10.1109/I-SMAC.2017.8058250.  
<https://ieeexplore.ieee.org/document/8058250>
8. M. Saraswati, E. Kuantama and P. Mardjoko, "Design and Construction of Water Level Measurement System Accessible through SMS," *2012 Sixth UKSim/AMSS European Symposium on Computer Modeling and Simulation*, Malta, Malta, 2012, pp. 48-53, doi: 10.1109/EMS.2012.60.  
<https://ieeexplore.ieee.org/document/6410127>
9. P. Verma *et al.*, "Towards an IoT based water management system for a campus," *2015 IEEE First International Smart Cities Conference (ISC2)*, Guadalajara, Mexico, 2015, pp. 1-6, doi: 10.1109/ISC2.2015.7366152.  
<https://ieeexplore.ieee.org/document/7366152>
10. Alam, M. J., Rahman, M. S., & Ali, M. S. (2014). Design and development of a microcontroller based automatic water level controller using GSM modem.  
<https://ieeexplore.ieee.org/abstract/document/8815027>
11. Alsultan, A. I., Muthucumaran, K., & Abdullah, M. N. (2017). Development of a low-cost wireless sensor network system for monitoring water level in irrigation canals.  
<https://www.sciencedirect.com/science/article/abs/pii/S0378377414003424>
12. Farooq, M. U., Islam, N., & Kim, S. W. (2019). IoT-based smart water management system using machine learning for real-time monitoring and leakage detection.  
<https://ieeexplore.ieee.org/document/9752141>

13. Giridhar, M., Mahesh, S., & Jagadeesh, P. S. (2018). Design and development of automatic water level controller using internet of things. [https://www.researchgate.net/publication/377182713\\_Automatic\\_Water\\_level\\_Controller\\_using\\_IOT](https://www.researchgate.net/publication/377182713_Automatic_Water_level_Controller_using_IOT)
14. Lee, J. H., Kim, J. H., & Kim, D. H. (2018). A water level management system based on IoT and machine learning for agricultural greenhouse. <https://www.sciencedirect.com/science/article/pii/S1877050920322808/pdf?md5=388ce1402961122319525a2df2c1a687&pid=1-s2.0-S1877050920322808-main.pdf>
15. Rahman, M. S., Alam, M. J., & Ali, M. S. (2016). Design and development of a smart irrigation system using IOT. <https://ieeexplore.ieee.org/document/10176528>
16. Boyle, D. (2020, September 21). Level sensors: An essential part of process control. Control Engineering [https://www.wika.com/en-gb/lp\\_tc\\_fluid\\_control.WIKA](https://www.wika.com/en-gb/lp_tc_fluid_control.WIKA)
17. McKenna, B., & Doyle, L. (2018). Level measurement and control techniques. In Instrumentation and process control (pp. 221-258). Springer, Cham.
18. Whitson, W. L., & Moore, B. R. (2006). The technician's guide to programmable controllers. Cengage Learning.
19. Matin, M. A., Islam, M. R., & Rana, S. K. A. (2010). Microcontroller Based Low Cost Automatic Water Level Controller. 2010 International Conference on Electrical and Computer Engineering, 232-235.
20. Sarrazin, H., Saury, D., & Pouffary, Y. (2004). Flow control by passive valves for microfluidic devices. <https://iopscience.iop.org/article/10.1088/1742-6596/2230/1/012013/meta>
21. Van de Steen, D., De Schutter, B., & De Moor, B. (2006). Design and validation of a micro solenoid valve for fast fluid switching. <https://www.sciencedirect.com/topics/engineering/solenoid-valve>

22. Åström, K. J., & Hägglund, T. (2006). Control system design. Studentlitteratur.
23. Guohua, L., Xiaohong, L., & Yuhua, L. (2010). Design of a Water Level Control System Based on Fuzzy Logic Control. 2010 3rd International Conference on Measuring Technology and Mechatronics Automation (ICMMMA), 1, 642-645.  
<https://ieeexplore.ieee.org/document/7503395>
24. Muthukumar, K., Jothi, L., & Priyadharshini, S. (2014). Intelligent Water Level Monitoring System Using Wireless Sensor Networks. 2014 International Conference on Circuit, Power and Computing Technologies (ICCPCT), 1444-1448.
25. Olsson, J., Nielsen, P. H., & Jørgensen, O. (2009). Real-time correction of ultrasonic water level measurements for improved accuracy. Measurement, 42(7), 964-971.  
<https://iopscience.iop.org/article/10.1088/1757-899X/518/4/042025>
26. Wang, Q., Liu, Y., & Liu, Z. (2018). Design and Implementation of a Water Level Control System Based on PLC. 2018 International Conference on Computer Science and Mechatronics Automation (CSMA), 237-240.  
<https://ieeexplore.ieee.org/document/9422619>
27. Yoon, S., Park, J., & Ryu, J. (2018). Design and Implementation of a Smart Water Level Monitoring System using LoRa. 2018 International Conference on Information and Communication Technology Convergence (ICTC), 1143-1145.  
<https://ieeexplore.ieee.org/document/9489082>
28. Whitson, W. L., & Moore, B. R. (2006). The technician's guide to programmable controllers. Cengage Learning.