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Smart system for controlling and monitoring water and turbidity levels in dam reservoir using arduino technology: a case study of Mudasomwa, Rwanda

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SMART SYSTEM FOR CONTROLLING AND MONITORING WATER AND TURBIDITY LEVELS IN DAM RESERVOIR USING ARDUINO TECHNOLOGY: A CASE STUDY OF MUDASOMWA, RWANDA

Marie Chantal Iribagiza

A Project Report Submitted in Partial Fulfilment of the Requirements for the Award of Degree of Master of Science in Embedded and Mobile Systems of the Nelson Mandela African Institution of Science and Technology

Arusha, Tanzania

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ABSTRACT

Energy remains an essential resource for the sustainable development of any country. Although many projects of energy production have been put in place, the hydropower type requires a dam structure for storing water to be used in water shortage times and raise it at the level it can produce substantial energy. In Africa and many other developing countries, several hydropower plants operate under manual and mechanical operations which affect the quality and speed of energy production. It becomes a problem when the water quality and quantity in the dam are manually measured. This study aims at using an Arduino-based technology for monitoring and controlling the turbidity and water levels in dam reservoirs by using different sensor types. In the case of Rwanda, there is a lack of using embedded systems in monitoring, control, and operation of hydropower plants the reason why this research is monitoring and controlling the water reservoir of the Pico hydropower plant by using Arduino. In this technological era, we are expected to diminish the time and fee charges spent on plant operational processes by using a small number of laborers. It facilitates fast information assemblage about water levels and turbidity levels which directly impact the production of electricity at the hydropower plant. In the unsafe conditions of water and turbidity, water levels less than 310 mm or greater than 330 mm and turbidity levels greater than 50 NTU, the system prototype was able to detect these unusual statuses and automatically the water valve opened or closed the incoming water according to the reservoir conditions. The developed system prototype has four main components which include the sensing component, processing component, displaying component, and alerting component. In the sensing component, the ultrasonic sensor constantly monitors the variation in water levels, and the turbidity sensor measures the turbidity of incoming water. Inside the processing component, the detected records are collected and fed to the Arduino microcontroller for more processing. The processed information can be viewed on displaying component which is Liquid Crystal Display LCD, and the alerting component generates an alarm through the buzzer and an SMS notification is sent on cellphones. The outcomes of this project research, from lab-testing, provided a smart and automatic prototype that can quickly sense the fluctuations in both turbidity and water levels, and uninterruptedly send updates to the dam workers within 3 seconds. This study was conducted in the upstream water reservoir of the Mudasomwa Pico-hydropower plant located in South Province/ Rwanda, Nyaruguru District, Ruheru sector between Remera and Uwumusebeya cells.

DECLARATION

I, Marie Chantal Iribagiza, do hereby declare to the Senate of The Nelson Mandela African Institution of Science and Technology that this project report is my original work and that it has neither been submitted nor being concurrently submitted for a degree award in any other institution.

Marie Chantal Iribagiza		09.08.2022
Name of Candidate	**Signature**	**Date**

The above declaration is confirmed by:

Prof. Kisangiri Michael		10/08/2022
Name of Supervisor 1	**Signature**	**Date**

Dr. Jema Ndibwile		11/08/2022
Name of Supervisor 2	**Signature**	**Date**

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by The Nelson Mandela African Institution of Science and Technology, a project report titled “Smart system for controlling and monitoring water and turbidity levels in dam reservoir using Arduino technology: A case study of Mudasomwa, Rwanda” in partial fulfillment of the requirements for the degree of Master of Science in Embedded and Mobile Systems of The Nelson Mandela African Institution of Science and Technology.

Prof. Kisangiri Michael		10/08/2022
Name of Supervisor 1	**Signature**	**Date**

Dr. Jema Ndibwile		11/08/2022
Name of Supervisor 2	**Signature**	**Date**

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DEDICATION

This project report is dedicated to my beloved husband Felicien Sebahire and our daughter Roxanne Iriba Sebahire for their dedicated time and encouragement that provided me with strength during my academic journey.

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%	Percent
BSS	Base Station System
CENIT@EA	Centre of Excellence for ICT in East Africa
DC	Direct current
EAC	East Africa Community
GERD	Great Ethiopian Renaissance Dam
GSM	Global System for Mobile Communication
HPP(s)	Hydropower plant(s)
ICT	Information and Communication Technology
IDE	Integrated Development Environment
IHA	International Hydropower Association
IoT	Internet of Things
JTLJ	Jackson turbidity units
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LPCs	Linear Predictive Coding
NTU	Nephelometric Turbidity Unit
OSS	Operation and Support System
PCB	Printed Circuit Board
PDA	Personal Digital Assistant
PIC	Programmable Interface Controllers
SMS	Short Message Service
USB	Universal Serial Bus

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

Hydropower is the use of dropping or fast-running water to make electrical energy from generators driven by turbines (Egré & Milewski, 2002). According to the International Hydropower Association report IHA 2021, Africa accounts for 17% of the total global population and uses only 4% of the global energy with 579 million people remaining without access to electricity in sub-Saharan Africa. In accelerating the development and improvement of both lives and livelihoods, Africa has turned to hydropower which is one of the renewable energies. Despite the low access to electricity, the African continent has over 37 gigawatts of installed hydropower capacity and has a global potential of untapped hydroelectric powers as confirmed by the 2020 IHA which is an annual hydropower status report (IHA, 2020).

In east Africa, many efforts have been put into the development of large and medium hydropower plants. Some hydropower projects have been completed while others are under construction: the 6350 MW Great Ethiopian Renaissance Dam (GERD) in Ethiopia, the 600 MW Karuma hydropower project in Uganda, the Rusumo hydropower project between Rwanda and Tanzania, and the Ruzizi hydropower projects between Rwanda, Burundi, and Democratic Republic of Congo (ANDRITZ HYDRO, 2021).

Hydropower, which is a major source of electricity in Rwanda, contributes 46.8% of the overall installed capacity from its 22 power stations all under manual and or mechanical operations. Electricity is still a scarce resource and inaccessible for 47.2% of Rwandans (Nsengiyumva, 2019). Many small and large hydropower plants (HPPs) are operated under manual and mechanical modes but few of them are under automation technology. In the case of Rwanda, there is a lack of using embedded systems in monitoring, control, and operation of HPPs the reason why this research is for monitoring and control water reservoirs of the Pico hydropower plant by using Arduino based automation system. This technology aims at decreasing the time and cost spent in plant operations by using reduced human power interactions. It would simplify fast information sharing about water levels and turbidity levels which directly impact the production of electricity at the HPP.

1.2 Statement the of Problem

One of the key factors for a country to get sustainable development is to have a stable source of energy (International Atomic Energy Agency, 2005). Like other African countries, Rwanda has the potential for untapped hydroelectric power as it has many unexploited water rivers (IHA, 2021). The available power plants and ongoing energy production projects are based on manual and or mechanical ways in their operation thus there is a high operational and maintenance costs. In addition, many studies have been done on large and medium of more than 10 MW hydropower plants (HPP) with a huge volume of water reservoir but there is a potential to exploit small HPPs of less than 10 MW which have no serious environmental problems (Geoffrey *et al.,* 2018; Gotoh *et al.,* 2011). There is insufficiency in using automation technologies in both design and operations of HPP. During their operation, the time it takes to disseminate information and to process water levels and turbidity levels are long and therefore leads to time delays.

The use of manual and mechanical technologies in hydropower production results in the creation of hard-working conditions for plant operators especially in monitoring and controlling the status of an HPP and it is clearer during the wet seasons when variations in both the water quantity and quality are significant. This study aims to produce a smart and automatic system for monitoring and controlling dam water reservoirs while answering problems of both sedimentation and inadequate water distribution by using Arduino technology. The prototype of this research project would show a way to minimize human interaction with the HPP system units of the upstream side by measuring water levels and turbidity levels which are key parameters for an efficient HPP.

1.3 Rationale of the Study

Various hydropower plants in Africa are operating under manual mode and these result in some challenges which affect both society and the community. The manual system is not easy to be controlled because it requires someone to manage water levels and turbidity levels. In addition to that, there is a problem of high cost for maintenance during its operation resulting from a long time of processing and sharing information. Therefore, it is necessary to develop an automation system for detecting the water level and turbidity level in dam water reservoirs to improve the efficiency of hydropower plants.

1.4 Research Objectives

1.4.1 General Objective

The main objective of this study is to design and provide a smart and automatic system that can control and monitor a Pico hydropower plant dam reservoir using Arduino technology.

1.4.2 Specific Objectives

(i) To identify the requirements for developing a system for detecting turbidity and water levels upstream of the dam reservoir

(ii) To develop an Arduino-based system for monitoring and controlling turbidity and water levels in a dam reservoir

(iii) To validate and implement the developed system for a selected HPP dam reservoir

1.5 Research Questions

(i) What are the key parameters to consider in improving the performance of a hydropower plant on its upstream side?

(ii) Which method can be used to decrease human interaction in detecting the levels of turbidity and water of incoming water for hydropower production?

(iii) How did the developed system detect turbidity and water levels using Arduino technology?

1.6 Significance of the Study

Manual and mechanical machinery of hydropower production creates a hard-working and less productive environment. Thus, the use of smart and automatic systems technologies in the control and monitoring of the dam's reservoirs will contribute to the reduction of maintenance and laborer costs thanks to a reduction in the times of information sharing and human intervention during operating time. In addition, information on water levels and turbidity will be provided to plant operators, thus helping to undertake long-term sustainable solutions to the problems of sedimentation and water distribution at the dam water reservoir.

1.7 Delineation of the Study

Monitoring and controlling a hydropower plant is a wide domain. This work is not focusing on electricity production in turbines. It intends to monitor and control the water level and turbidity the upstream of Mudasomwa hydropower plant. The developed system prototype will be used to produce a full-scale system.

CHAPTER TWO

LITERATURE REVIEW

2.1 Dam and Water Reservoir

A dam is an artificial structure built to contain water for hydropower generation, flood management, water supply, and or river flow diversion (Donev *et al.,* 2018). Dams and their water reservoirs have the role of regulating the water flow and storing it for numerous applications such as flooding containment, hydro energy creation, irrigation, refreshment, and fishery. Dams have been built since the beginning of human civilizations and the most famous dams of ancient times are the Jawa Dama of Mesopotamia (Jordan), Sadd el-Kafara or Dam of the Pagans in Egypt, and the Subiaco Dams of the Romans (Tata & Howard, 2022). There are sophisticated that are built based on engineering and technology. The Hoover was Dam built in the 1936 on Colorado River and Mauvoisin Dam in 1957 in Switzerland (Tata & Howard, 2022) (Fig. 1).

Figure 1: Hoover dam (Tata & Howard, 2022)

2.2 Problems with Water Reservoirs and Dams

The big and common issues of the dams and water reservoirs are mainly centered on the failure to fulfill their future objective which is the water stored for various purposes. At the first glance, the seepage and evaporation of water seem to be problematic, but sediments deposition has been testified to be a severe problem for dams and water reservoirs.

Sedimentation is the buildup of settling particles towards the water reservoir bottom and it gradually loses its water storing capacity. This may lead to clogging, sediments problems, a decrease in water storage capacity, and sometimes the reservoir may become inactive as shown in Fig 2. For hydroelectric plants, the water flowing towards the turbines can become gradually dirty and disrupted, and this results in costly maintenance and poor hydroelectricity outcomes in the generators. Apart from intensive research done before, sedimentation is still possibly the most serious technical issue faced by dam engineering (Royal IHC, 2021).

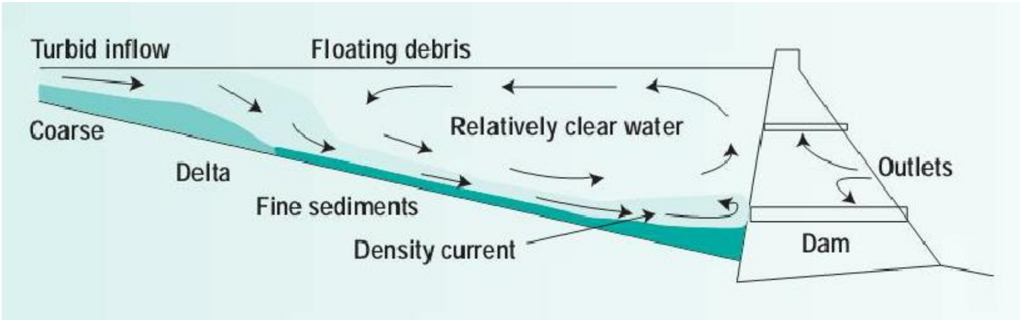

Figure 2: Sedimentation process (Palmieri *et al.*, 2003)

2.3 Related Works

Various research has been earlier done from local, regional, and global perspectives, and operational system gadgets have been deployed in monitoring and controlling the quantity and quality of water in the water dams. An automatic flooding gate control garget has been produced (Lawrance *et al.*, 2019) where the level of water was monitored but its turbidity was not considered. A water control gate that respectively utilizes 'C' and visual basic, and LPCs was designed and implemented to regulate the level of water with the highest water level, the door automatically opens but they did not arrange for the time at which this gateway would close for normal conditions and they didn't take into account of water turbidity (Iyer *et al.,* 2013). For our study, it is obvious that the levels of water and its turbidity are critically considered in taking measurements while monitoring and controlling water dams. Presently, embedded systems for monitoring and controlling water quality are made of various sensing devices that can measure different parameters such as pH, temperature, humidity, water turbidity, and water levels in the tank of water (Pasika & Gandla, 2020) but there was no combination of these factors has been used for solving the problems of water reservoirs. There is a deficiency in using technologically made systems in operational activities of water dams, at the same time answering to problems of water level and sedimentation. Technically, the time of info treatment and sharing is lengthy thus there is time delays. In addition, there would be a problem of losing the water storage capacity if turbidity levels are not well monitored in the dam reservoir and the operator couldn’t know if the water level was decreased up to the normal level. The developed system uses LPC approach which is for big dams but not suitable for the medium and small dams.

This study aimed to provide a smart and automatic system for monitoring and controlling the quality and quantity of water in the water dam by utilizing Arduino. Research on a system which is “water level monitoring and dam gate control over IoT” has been done (Krishna *et al.*, 2018; Santosh, 2018) with the main objective of opening and closing the gate to sense the water levels in the water dam. For our study, the levels of water were measured at various stages. From the system settings, the gate was able to open and close, the buzzer produced alarms and through the BLYNK Application, operators were able to receive SMSs via their phones, email accounts, and Twitter at the same time (Krishna *et al.*, 2018). This BLYNK Application requires strong internet and in places where the internet problems reside, no notifications would be received about the change of water levels in the dam. For the proposed system, the GSM module SM900A provides options to send notifications without an internet connection.

Another study that utilizes the GSM tool to monitor, control, and alert the levels of water in a dam structure with a microcontroller, was used to make the comparison of the water levels in the dam using the set sensor optimum preset values. The GSM device was employed to communicate all information to the dam control room (Yuvarani & Archana, 2016). In the project research work of (Al-hadhrami & Shaikh, 2017), a system for distant monitoring of a dam has been done where LED and buzzer are used to inform the authority if the predefined level has reached its maximum, and a DC motor for programmed process opens and then closes the gate based on set water level values. The problem comes when the operator is so far from the dam and it is not possible to know any information regarding the status of the dam.

In our system, turbidity and water levels were censored, and at the preset optimum stages, automated feedback that opens/ closes the valves of the barrage structure (dam) and the SMS is transferred to the operator by using GSM techniques, and the buzzer produces alarming sounds. Intentionally, our study aims at assisting the dam operators to get the capacities of distantly monitoring and controlling the dam component units without no much human interaction. This system offers a simple way of checking the status of a functional valve; by opening or closing the water flow. The dam user has capabilities of controlling the dam units remotely and the buzzer gives an alarming sound when the levels of water go high up. In this system, the turbidity and ultrasonic sensors detect turbidity and water levels separately in the reservoir, and then the measured values are shown on the LCD.

In India, researchers designed the automated dam system by the use of IoT technology with Raspberry Pi and Python programming languages are very important. The automatic gates utilize a DC motor to regulate themselves. In their project, sensing devices of water levels were also utilized in information gathering to regulate the gates, and turbidity measuring tools have been utilized. This system requires the android application that provides to display the collected information for further decision-making by the person in charge. The proposed system should have a monitoring screen computer and LCD to permit the operator to monitor the turbidity and water levels in a real-time manner. Again the system can show the dam conditions and can check for dam wall cracks, so the principal aim of that project was to automate and monitor a dam gate and to sense if dam wall corrosion has been developed (Rao *et al.,* 2020).

In Indonesia, people have developed intelligent and automated systems for monitoring and controlling power plants. Their project aimed to control environmental factors using some sensing tools. They used a PIC microcontroller to collect and display data from various sensor components. The GSM module was also used to notify the user of the condition of the boiler, such as when the boiler became too hot or cold. All values are displayed on the LCD component. Their system used various parameters such as water volume, gas, temperature, and pressure level. The main goal was to monitor and control these important parameters of the power plant to avoid power plant wastage that could affect the population around the power plant (Ashwin & Manoharan, 2018). In a study conducted in India, IoT dam automation and applications use sensors to measure the dam's three water levels, detect water levels, and automatically open the dam gate when the highest level of the reservoir is reached. The relay module controlled the opening and closing of the gate by sensing the water level in the reservoir. So they considered only one parameter, the water level (RaviKumar *et al.,* 2020). An automated system with microcontroller-based tools can control the dam system, which is designed to sense changes in water level and inflow and control the actual moment of the gate in real-time. The time when the stepping motor was used (Kumara *et al.,* 2016).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Agile-Based Development

This study used an agile-based methodology. It is a non-stop process of developing and testing a viable system prototype as summarized in Fig. 3. This method seems to be flexible. This means you have the opportunity to change your requirements even afte the development and testing process has begun. Completeness and improvements were made at each complete phase of the system prototype, which proved to be important

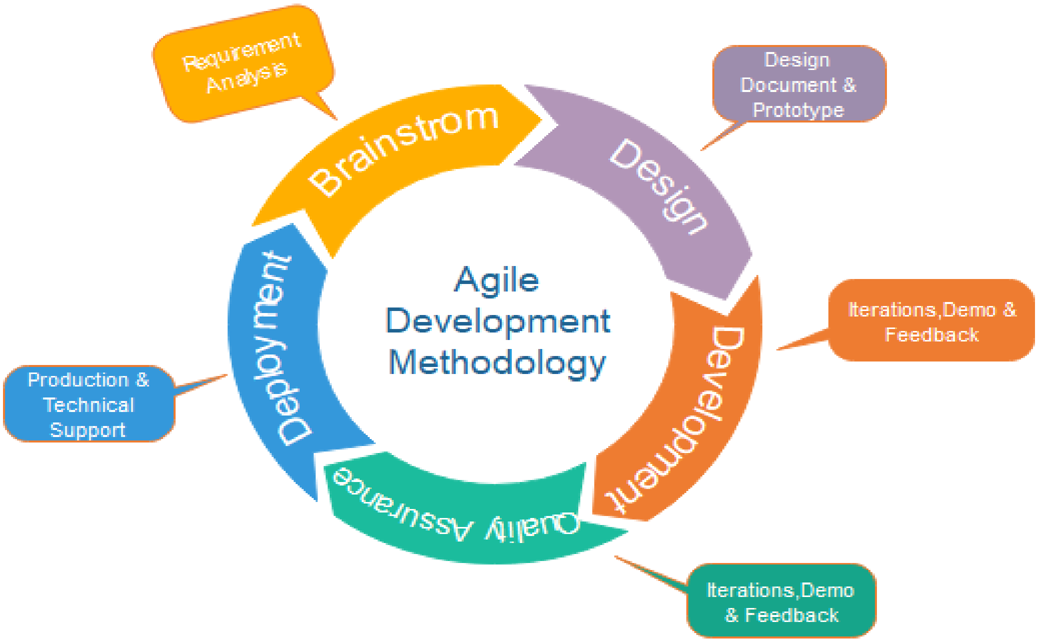

Figure 3: Agile methodology

3.2 Study Area

The proposed system was developed and implemented as a pilot project in one of the sub-Saharan countries, which is Rwanda. A study was conducted in the upstream water reservoir of Mudasomwa Pico-Hydropower Plant located in South Province/ Rwanda, Nyaruguru District, Ruheru Sector between Remera and Uwumusebeya Cells (Fig. 4). The site is around 20 km from the nearest national grid and 1 km from the nearest road, the target village to power has a total of 625 households and the total population is estimated to be around 2500 people. Successful implementation of the developed system would be implemented in HPP water reservoirs within the country and outside the country.

Figure 4: Intake of Mudasomwa pico-hydropower plant (Hobuka Company, 2021)

3.3 System Working Principle

Information about turbidity and water levels is taken by respective sensors (water sensor and turbidity sensor) and the collected measurements are read by an Arduino microcontroller and displayed through LCD. At thresholds which are corresponding to maximum and minimum water levels, and maximum turbidity levels, the buzzer alarms the operator, and an immediate SMS is sent to the corresponding authorities for further proper decisions. If the maximum set water level is attained in one water reservoir, an SMS is immediately sent to the person in charge, and the valve gate automatically allows the water to bypass or be stored in another reservoir depending on water quality and available water quantity in the such reservoir. Again, if the maximum turbidity level is reached at the inflow structure, an SMS is also sent to the person in charge and the specific valve gate (Fig. 5) allows the water to bypass and avoid sediments deposition in water reservoirs.

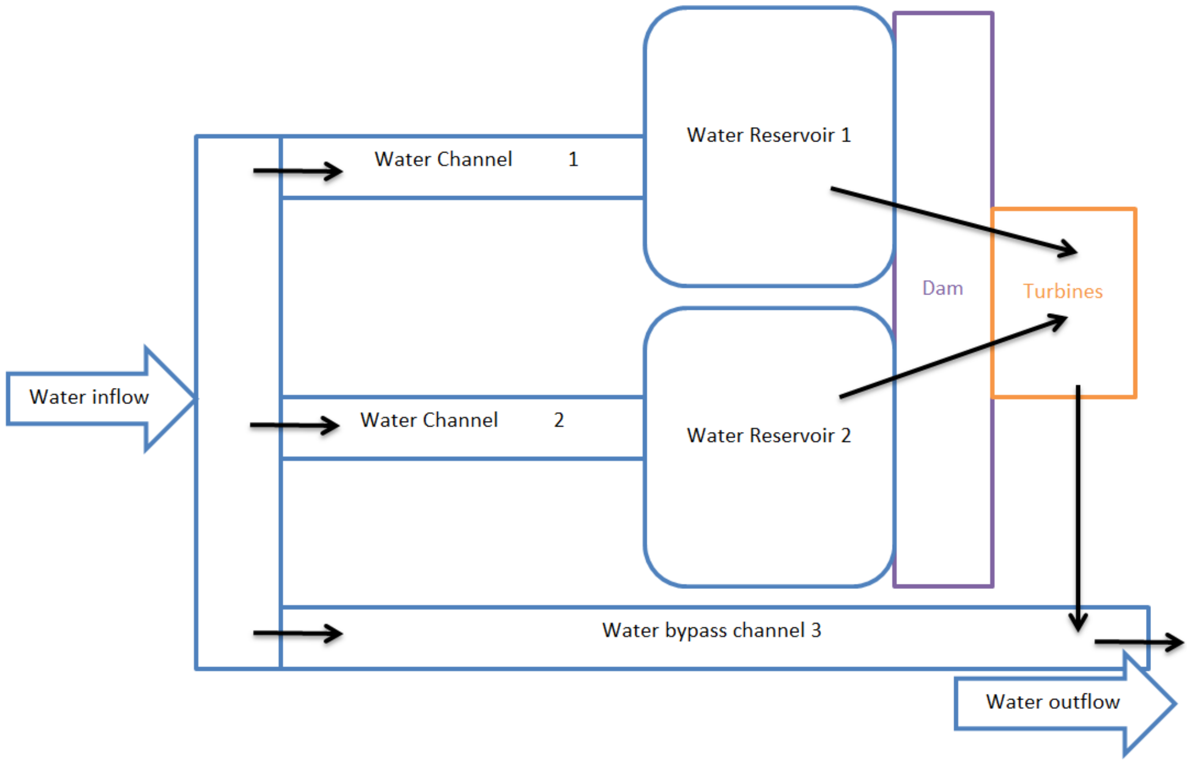

Figure 5: View of an existing HPP water reservoir layout with proposed points of measuring

3.4 Requirement Identification and Data Collection

In this project, a document review and research desk served in identifying the problems and possible solutions of HPPs at both local and global levels. This would also help to identify and examine the limitations and gaps in different existing methodologies. The data would be collected by measuring the levels of water and turbidity in the dam structure on the upstream side. Thus, giving a clear understanding of how and at which water level and turbidity values would affect the state of a water reservoir and the whole HPP, it also gives a clear picture and some insights into how the system installation was done for an HPP dam reservoir.

3.5 System Design

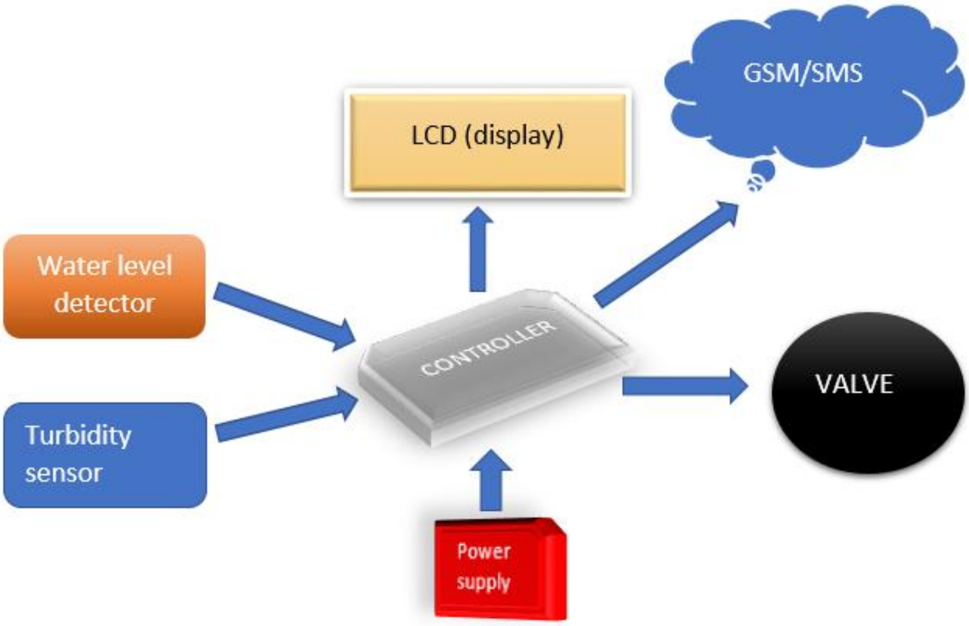

Figure 6: Block diagram of the developed system

The developed system prototype has four main components which include the sensing component, processing component, displaying component, and alerting component. In the sensing component, the ultrasonic sensor constantly monitors the variation in water levels, and the turbidity sensor measures the turbidity of incoming water. Inside the processing component, the detected records are collected and fed to the Arduino microcontroller for more processing. The processed information can be displayed on the LCD and the alarm component will generate an alarm via buzzer and send an SMS notification.

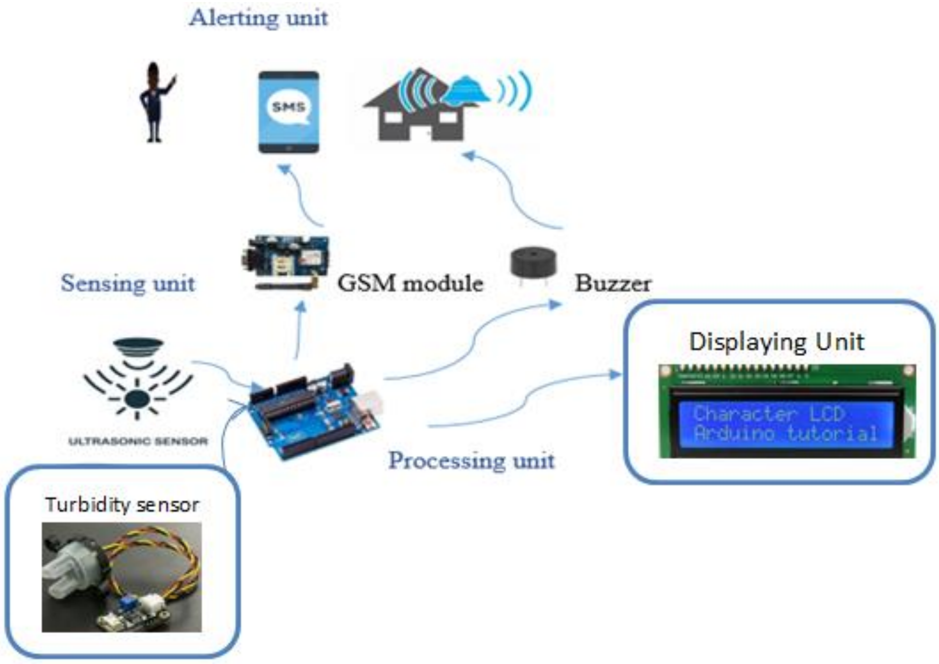

Figure 7: System architecture

(i) Sensing component

In the sensing component, there are turbidity and ultrasonic sensors for measuring turbidity and water levels respectively in the water reservoir. Normally, the ultrasonic sensing component popularly determines the distance between the sensor and the physical body. For this research, both the turbidity and ultrasonic sensors have been used to sense the change of turbidity and turbidity levels by taking all measurements of incoming water in the dam water reservoir.

(ii) Processing component

In the processing and monitoring part, an Arduino-Nano was used as an open-source microcontroller board. Its operating voltage varies from 5 V to 12 V with a frequency of 16 MHz. This microcontroller type obtains input data from ultrasonic and turbidity sensing chips (sensors) for additional processing and analysis. The GSM module SIM900A which remains the smallest and cheapest hardware device for communication allows mobile SIM users to send or receive SMS and can make calls. The operation temperature of this device is - 20^0 C to 55^0 C and it uses a 900 and 1800 MHz frequency with an operating voltage of 3.5 V-4.5 V.

(iii) Alerting component

This alerting part consists of a buzzer that produces an alarm and GSM module and a GSM that sends SMS notifications. The alarm produced is used to alert the person in charge to control the dam water reservoir, this device has a frequency of 2300 Hz and power consumption of 4V to 8V. A GSM module was used to send SMS to the cellphone of the dam user near the water reservoir**.**

(iv) Display unit

The display unit is a sort of flat panel display, consisting of an LCD. This component is of low electric consumption and low cost as its operational voltage ranges from 4.7 V to 5.5 V and its frequency is less than 500 Hz.

3.6 Description of Electronics Devices Used

This part consists of the various hardware requirements in detail such as a microcontroller (Arduino-Nano), sensors, GSM module, buzzer, valve relay, and LCD, and it shows which kind of requirements to be used and describes how these electronic devices operate in this research project.

(i) Arduino

Arduino-Nano R3 is the smallest board and breadboard-friendly board based on the ATmega328 and has more or less functionality of Arduino due milanove, with min USB as shown in Fig. 8, its clock speed is 16 MHz, 7-12 V input voltage and power consumption is 19 Ma (Arduino.cc, 2021). By using a sensor and actuator, Arduino receives the data from the environment it is not expensive, and very easy for designing different devices.

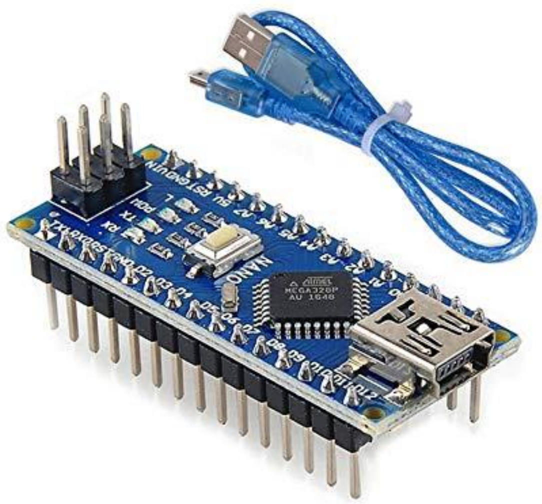

Figure 8: Arduino Nano

(ii) Ultrasonic sensor

This HC-SR04 ultrasonic sensor in Fig. 9 has pins that are labeled with VCC, echo trigger, and ground. The ultrasonic sensor trigger pin is coupled to PIN 7 of the Arduino board. While the ultrasonic sensor's echo pin is connected to PIN 6 of the same board. The VCC and GND pins of the ultrasonic sensor are linked to the 5 V and ground pins of the Arduino. Here are the 5 LEDs that are used to show the percentage of water availability in the water tank. The first LED indicates 20%, the second indicates 40%, and so on. And the last one shows 100% (Fahad, 2019).

Figure 9: Ultrasonic Sensor

(iii) Turbidity sensor

Turbidity is the large quantity of very small particles suspended in water reservoirs that are unseen by the human naked eye. It is made of two parts; transmitter and receiver. An analog turbidity sensor is used to detect the water quality by measuring the quantity of turbidity and it is capable of measuring the particles suspended in water. The analog turbidity sensor consists of analog and digital signal output modes. It operates at 5V DC voltage with the time of 500ms and its temperature operation is 5 ^{0}C~90 ^{0}C. A turbidity sensor is a piece of technology that is capable to measure the clarity of the water, it is used for measuring turbidity level in water; its unit is Nephelometric Turbidity Units (NTU) or Jackson turbidity units (JTLJ) and these two units are roughly equal, they indicated in several variations, low turbidity measurement provide high water quality. The turbidity values were displayed in the LCD16X2 display (Admin, 2020). The turbidity sensor was connected to the Arduino board through an analog to digital converter and it is exemplified by the voltage of the output pin where the larger turbidity is the smaller output voltage (Fahad, 2019). This analog turbidity sensor has both digital and analog signal output ways. You can choose the way (mode) according to the MCU as the threshold is adaptable in digital signal mode. The turbidity sensor comes in three parts as shown in Fig. 10.

Figure 10: Turbidity sensor

(iv) GSM Module

GSM module is a kind of wireless modem that receives a SIM card on it to provide cellular communication. This module network has three main classification systems which are the base station system (BSS), switching system (SS), and operation and support system (OSS) (Lawrance *et al.*, 2019). GSM SIM900A modem is complete with GSM/GPRS module, operated in many kinds of cellphones (simple ones and smart and automatic phones) and PDA. SIM900A is used in IoT development and embedded applications that are 68-terminal devices (Components101, 2021). The reason for using the GSM module SIM900A in this project is to provide communication by sending an SMS notification to the person in charge about the status of turbidity and water levels in the water reservoir but this SMS was sent to the subscribed mobile phone number (Components101, 2021).

Figure 11: GSM Module

(v) Buzzer

A buzzer is among the warning devices which is an electrical device that makes signaling and alarm sounds. It is also used to alert people to know some changes in the event. A buzzer device, its operating voltage is 4V to 8V, the resonant frequency is 2300 Hz and its sound type is a continuous beep. It is connected to a microcontroller to produce the sound when the water level is over the threshold. A buzzer (Fig. 12) was used in this research to alert people when the water level increases to the highest level in the water reservoir. This helps the person in charge to know that the valve of the dam was off and no incoming water in the dam because it is full. Furthermore, it provides the people to monitor and control the dam water reservoir away from the dam.

Figure 12: Warning device (buzzer)

(vi) Liquid Crystal Display (LCD)

LCD is among the electronic devices which are used to display information (digital/analog) by the use of a liquid crystal display. In this research, we used 16X2 LCD instead of using 16x4LCD or 16x2 LCD has two lines and each line displays 16 characters. In our system, the display was connected to a microcontroller for the purpose to display the measurement values of turbidity and water levels in the dam reservoir.

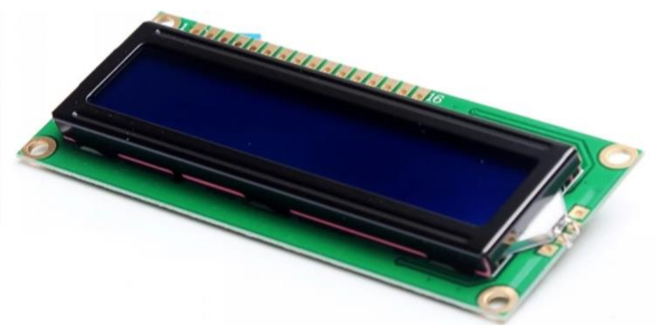

Figure 13: Liquid crystal display (LCD)

(vii) Relay module

In this research, a 12V 2-channel Relay board was used. A relay is a programmable electrical switch that can be turned on or off by controlling the devices. It is like a bridge between Arduino and the low voltage devices pinned to Arduino. This relay can allow the current to pass through or not and it is powered with 5V from Arduino which is low voltage (arduinogetstarted.com, 2021). A relay has three pins: a normally open pin, a common pin, and a normally closed pin all requiring low voltage. In this project, a relay was used to switch the valve off or on by using 12V when a relay receives a signal from an Arduino pin (arduinogetstarted.com, 2021).

Figure 14: Relay module

(viii) Valve

A valve is used to control water flow in one direction, normally a valve allows water to flow in or to stop the flow. It works due to the relay module; it operates at 12V when the relay receives the Arduino signals that provide the valve to use 12V to allow water to flow in or not. Monitoring and controlling reservoir turbidity and water level in this study, when the water level rises to the maximum level of the dam, the valve closes and when it drops to the minimum level of the dam, the valve allows water to pass.

Figure 15: Valve 12V

3.7 System Implementation

3.7.1 Configuration and Integration of the System Constituents

A schematic diagram was created and designed using Proteus software. This diagram realistically illustrates how the system components are electrically connected and work on the Arduino Nano board (Fig. 16). The Arduino is equipped with a micro-controller that collects input data from a variety of devices and sensors and converts that data into valuable output. The Arduino Nano consists of 14 output pins and 22 input pins. Pin 14 is digital and pin 8 is analog. The data pin of the turbidity sensor was attached to the analog Arduino pin A0. Both the ultrasonic sensor's trigger and echo pins are connected to Arduino pins. So, the trigger pin is connected to pin 5 and the echo pin is connected to pin 6. The trigger pin is for output and the echo pin is for input. The pins of LCD RS; EN; D4; D5; D6 & D7 are joined to digital pins of Arduino 3; 4; 9; 10; 11 & 12.

The transmitter and receiver GSM module pins are connected to Arduino pins 7 and 8, respectively. A cable with a 2-pin valve connected to the Arduino and a 13-pin buzzer connected to the Arduino. Arduino supplied 5V voltage power to all these device components. During system integration, all units were connected. Their interaction proved effective system function and compliance with requirements.

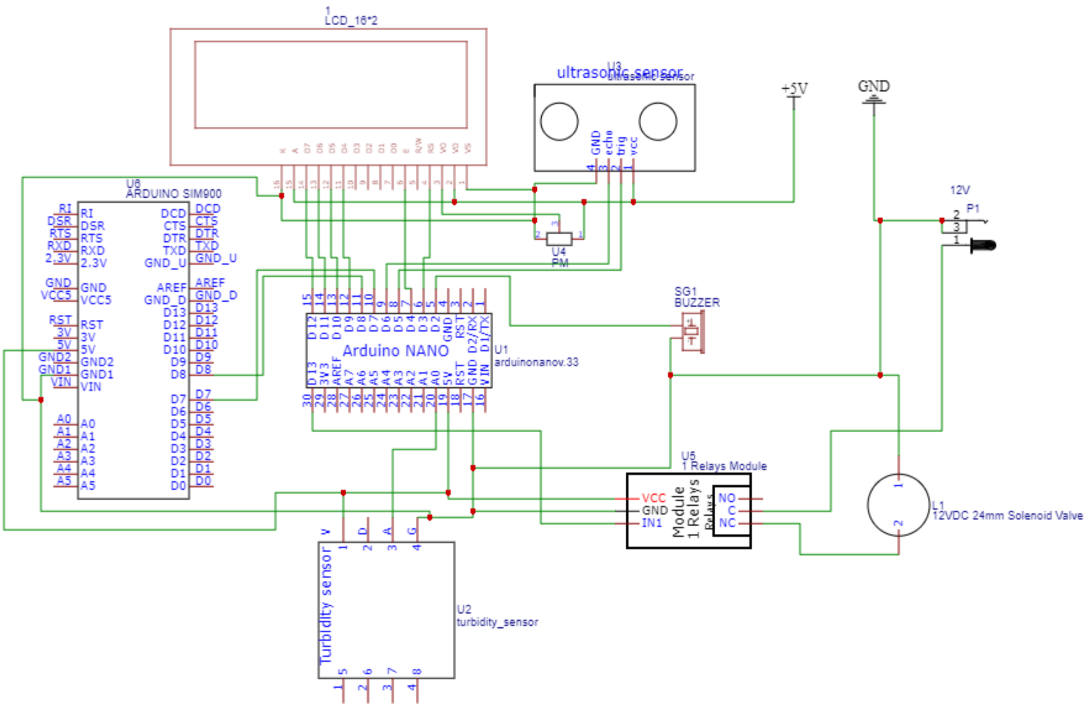

Figure 16: Circuit diagram

3.7.2 Programming Languages and Software Used

This prototype was created using C programming in the Arduino Integrated Development Environment (Arduino IDE). C programming is an advanced programming language, a universal method that facilitates software development, and is a popular programming language because of its faster execution time compared to other advanced languages. This is why many systems and many other languages fall into language C (Agnihotri, 2021).

Arduino IDE is open-source and the Arduino software is transcribed into functions after C++ and C programming languages. This tool offers the capability to write and upload the code to the Arduino IDE is open source and Arduino software translates into functions based on the C ++ and C programming languages. This tool provides the ability to write code and upload it to your Arduino board. When using the Arduino IDE, customers use different libraries depending on the type of sensor or component required by the system, and the output is displayed in the Arduino IDE's serial monitor window. Like other types of microcontrollers, the ATMEGA 238 microcontroller is housed on an Arduino board and programmed using the C computer programming language.

The study also used EasyEAD software, an online schematic application. EastEDA is easy to get started and understand when drawing software that consists of many complex software libraries and links. Its functions are easy to work with and easy to handle. It was used in this research project because it is a kind of PCB design scheme and electronic circuit diagram simulation.

3.7.3 The functionality of the Developed System

Figure 17 shows a flowchart of the designed system prototype. This flowchart illustrates the algorithms used to symbolize information processes for both system activity and connectivity (Prasad, 2014). Activity and connection order is indicated by boxes of various types or rows. The flowchart (Fig. 17) shows the step-by-step system operation from simple switch on to switch off.

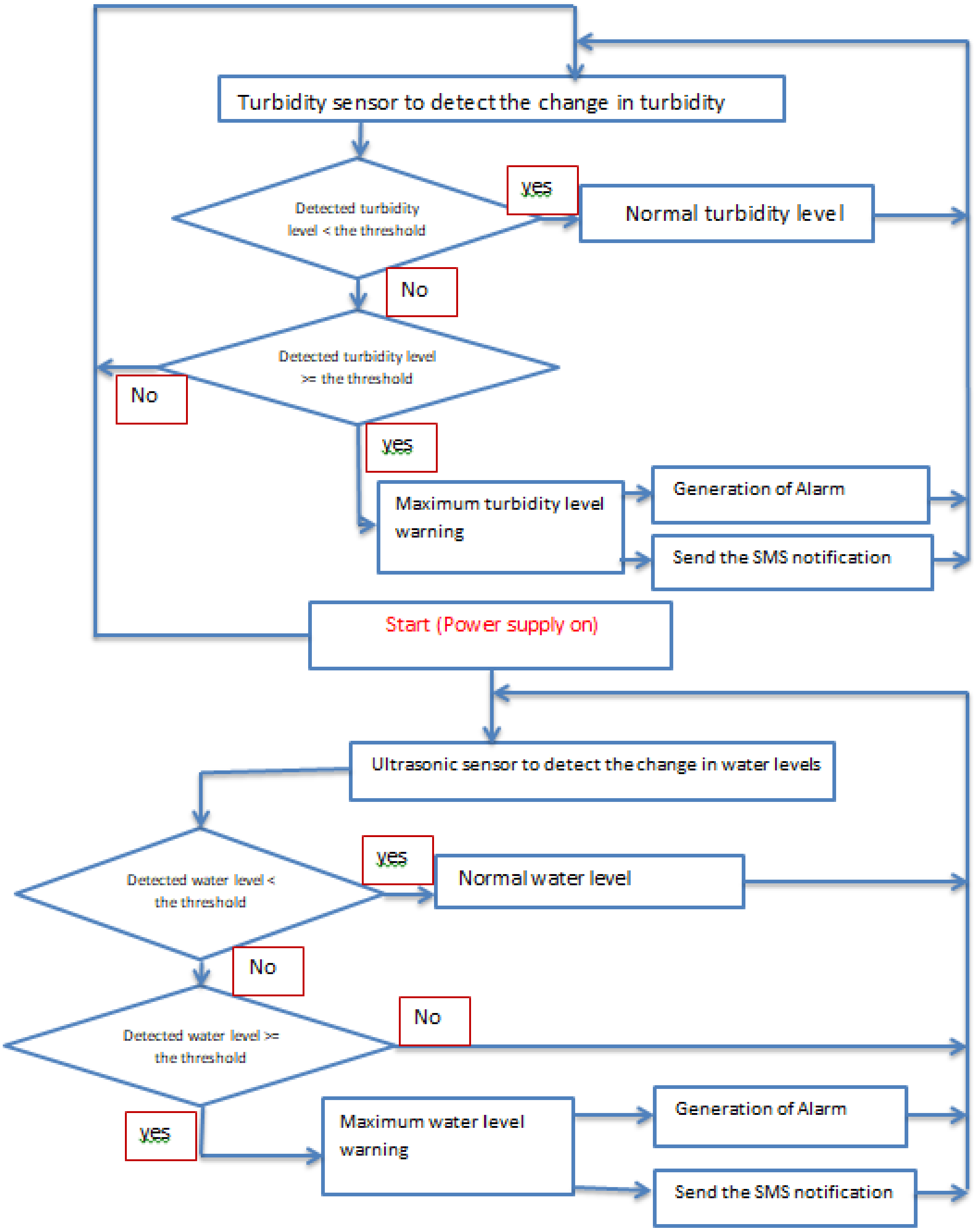

Figure 17: Flowchart of the developed prototype

When powered on, the system prototype ran several iterations for all operating system components and started initializing the default parameters. In this study, turbidity and ultrasonic sensors were utilized to detect and measure turbidity and water level in the reservoir, respectively. These sensors continuously monitored turbidity and water level fluctuations, and the information obtained was sent to the Arduino board for processing and analysis. We then collated each piece of analysis with the best data we needed. When the value exceeds a predefined threshold, an anomalous condition is detected, an alarm is generated as a warning using a buzzer connected to the Arduino board, and the generated SMS is sent, via the GSM module to the operator.

3.8 System Prototype Testing

System prototype testing is a process that runs throughout the integrated system and ensures that it meets the specified requirements. Before testing the entire system prototype, we performed a test activity in combination with the previous component unit for all components and their functionality. System testing was performed using an approach called lab testing.

3.8.1 Laboratory Testing Approach

For laboratory tests, two water containers were used. One is the water source and the other is the dam reservoir. Water from the first container flowed into the reservoir through a pipe with a water valve. Two sensors were attached to the reservoir and pipes to continuously record changes in turbidity and water level.

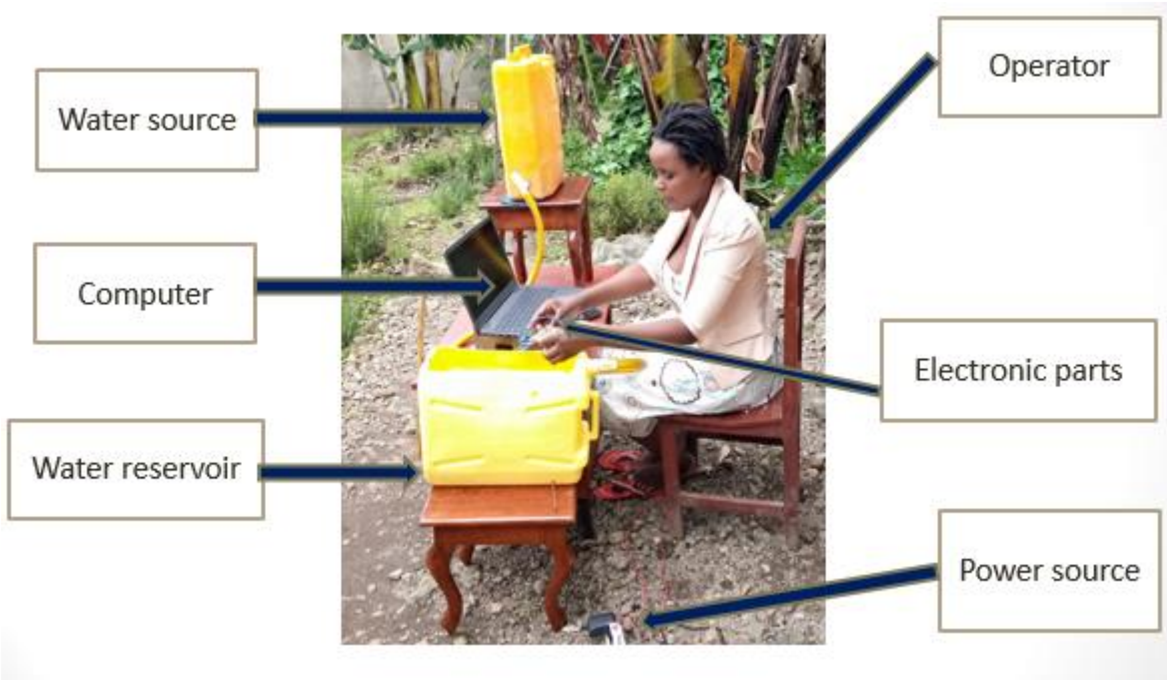

Figure 18: Prototype development

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

This part shows and describes the working principles of the prototype and the results of lab tests. During prototype development and laboratory testing, measured turbidity and water level values were obtained using a variety of software and hardware modules. Two water vessels were used. The first is the water source and the second is the prototyping system reservoir. This means that water moves from the primary container to the secondary container through a pipe with a regulating valve. Ultrasonic sensors are commonly used to measure the distance between a sensor and a tangible material and were utilized in this research to monitor the water level in a reservoir by detecting the distance in mm. Therefore, water from the "first vessel" source flows toward the reservoir, and the water level in the reservoir is also monitored. When the distance between the ultrasonic sensor and the water surface equals the maximum water level of 310 mm, the reservoir fills up and the valve shuts off immediately. At this time, there is no water flow from the 1st tank to the 2nd tank, and an SMS notification is immediately sent to the operator's phone, and at the same time, a buzzer sounds an alarm to warn the surrounding area. SMS notifications, buzzer alarms, and valves are activated as soon as the water level reaches the maximum set level of the water tank and exceeds it. If the water level of the dam rises to the normal water level, no alarm or SMS notification is issued, the water level must return to the maximum set value of 310 mm, and the valve is turned on until the water level drops to the minimum set value. If the reservoir water level is 330 mm, the valve will open directly to allow water to flow from the first vessel to the second vessel, which is the dam reservoir. Generally, the closer the ultrasonic sensor is to the water surface, the higher the water level. While measuring the turbidity level of the reservoir, a turbidity sensor was used to detect and record the turbidity value of the water in the NTU. Turbidity is the degree of turbidity or dispersed small particles in a particular liquid, and drinking water turbidity levels are less than 4 NTU.

Turbidity sensors measure changes in the turbidity values of various types of water flowing into a reservoir. In our study, normal water turbidity was assumed to be less than 50 NTU. If it exceeds 50 NTU, it will exceed the maximum turbidity, sound an alarm, sound a buzzer, and immediately send an SMS notification to the person in charge's mobile phone. Together the water level and turbidity measured by the corresponding sensing devices changed a lot simultaneously on the serial monitor and LCD screen. The following tabulated texts provide various measurements of turbidity and water level in the water dam and a description of the corresponding reservoir condition.

Table 1: Comparison of output measurements of water level obtained in lab-testing

Water level	Measurements of water level	Status description in a water dam
Minimum	The measured distance, between the sensor and the surface of water >= 330 mm.	**Bad condition**: the water level was low in the dam reservoir and the valve was switched on.
Normal	The measured distance, between the sensor and the surface of the water, is any value falling between 330 mm and 310 mm.	**Normal condition**: this water level was controlled. And the valve is switched on and the water is allowed to enter the water reservoir.
Maximum	The measured distance, between the sensor and the surface of water <=330 mm.	**Bad condition:** The dam is full which means that the water level in the dam reservoir is at or exceeds its highest level, the water is still controlled and no water is coming in.

Table 2: Comparison of output measurement of turbidity level in the dam water reservoir

Turbidity measurements in a water dam	Status description in a water dam
The measured turbidity level is less or equal to 4 NTU	**Good and safe condition**: this turbidity is low and the water is safe for drinking purposes.
The measured turbidity level is between 4 NTU and 50 NTU	**Good condition**: this turbidity is increasing to a high level but it is not causing any serious problems in the dam.
The measured turbidity level is strictly greater than 50 NTU	**Bad condition:** this turbidity level increases up to the maximum level and beyond that, it can create sediments deposition at the bottom of the dam reservoir.

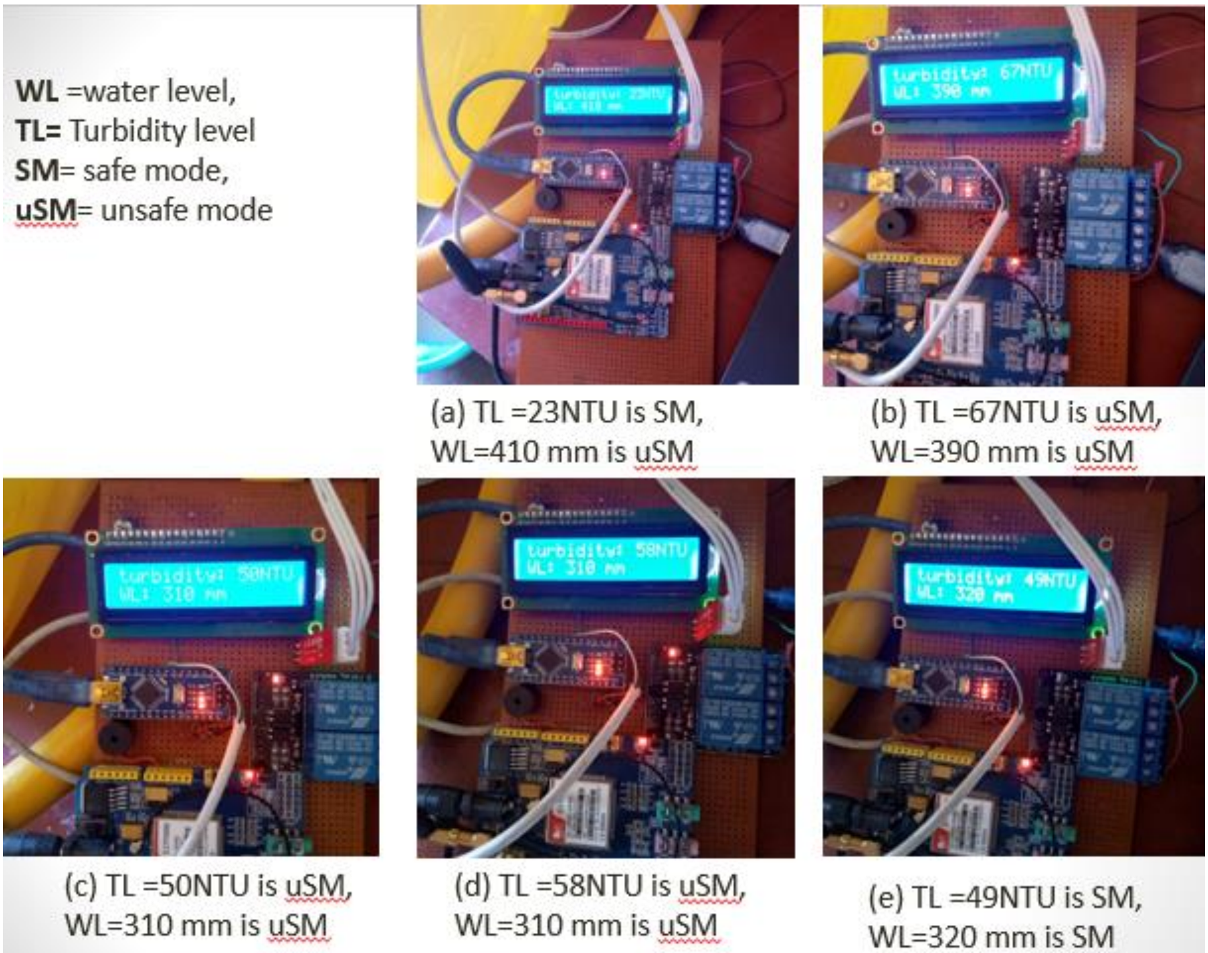

Figure 19: Results from system lab-testing

4.2 Discussion

Various lab-testing trials have shown that both turbidity and water level can be quickly recorded and measured, and information can be sent directly to the dam operator. The values given in Fig. 19 were the instantaneous turbidity and water level obtained from laboratory experiments. Different water quantity and turbidity measurements have been censored by the turbidity and ultrasonic sensing tools accordingly. New information from the two sensing devices is delivered by the serial monitor and can be seen on the PC screen.

If both the water level and turbidity fluctuate above the threshold values, a warning message and alarm will sound via the cellphone and buzzer, respectively. Figure 20 shows various short messages sent to the dam operators' phones to inform them that they have reached a critical state. Figure 18 displays a laboratory prototype designed at the time of installation. The information in Table 3 on the design and implementation of laboratory-scale prototypes allows you to set up an automated field system at an affordable cost, ensuring accuracy, efficiency, and effectiveness.

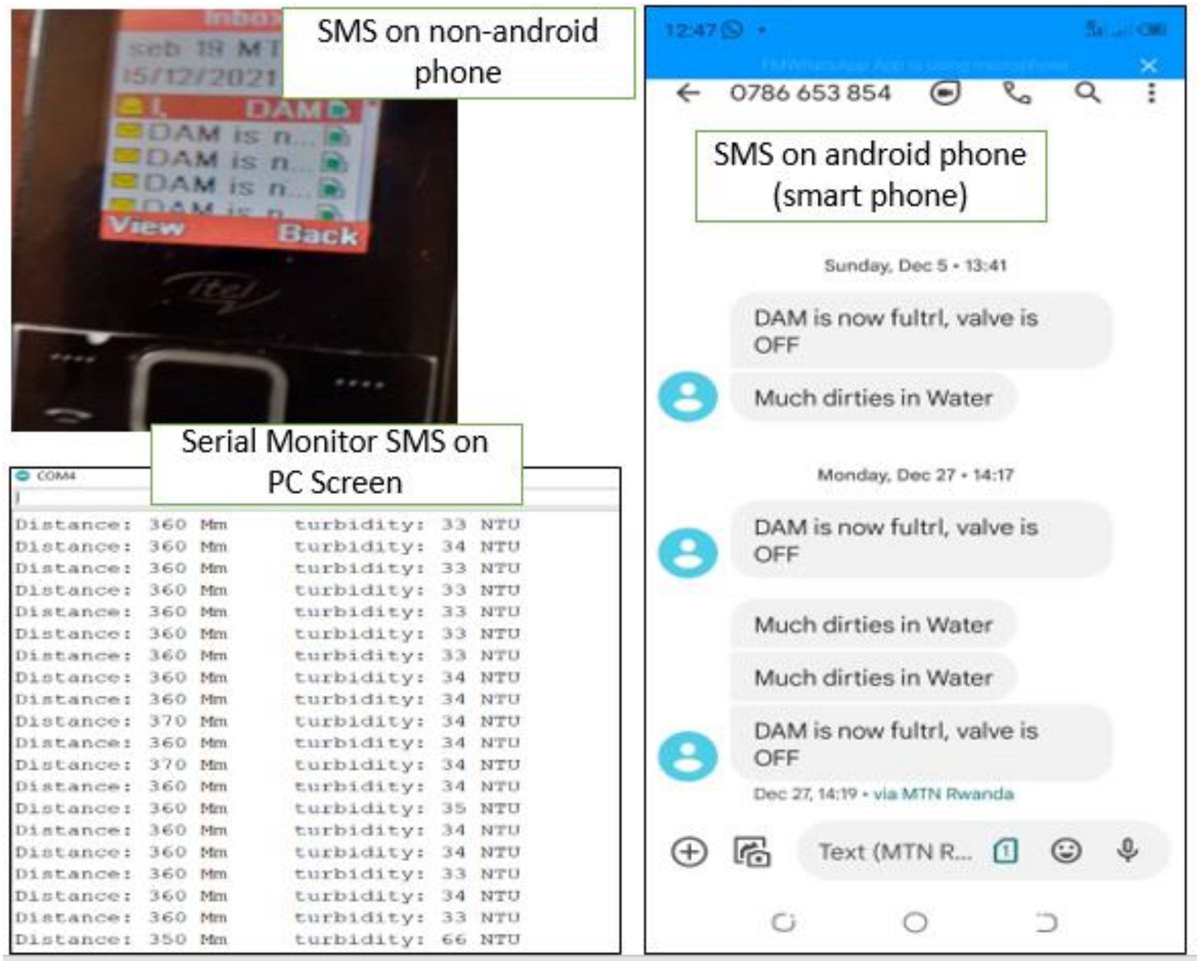

Figure 20: Short Message Service (SMS) notification to both computers and cellphones

Table 3: Attributes of the developed prototype

Attribute	Description
System Working	The developed prototype works under automation.
Affordability	The developed prototype is cost-effective and it can be scaled up.
System Flexibility	The prototype shows flexibility with the users.
Parameter Detection and Real-Time Updating	The updates on water and turbidity status were timely provided and the operators were alerted by SMS and sound.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

It is necessary to control changes in the water level and turbidity of specific reservoirs. If the amount of water is small, the amount of hydroelectric power generated will be small also, and if the amount of water is too large, it will cause floods, which may lead to property damage and death. When the turbidity increases, sediments settle at the bottom of the reservoir. These sediments reduce the storage volume of the reservoir as the available water space is replaced by the sediments, thereby affecting hydropower production. During this investigation, prototype requirements were identified and system development was carried out. This study aims to contribute to reducing and possibly alleviating the problems of both variations in water level and changes in turbidity for any water dam. This can be achieved by monitoring and controlling the turbidity and water levels, informing the in-charge persons about the unusual, detected statuses in the water dam. The designed prototype distributes information about the water level and turbidity conditions within 3 seconds, permitting the responsible person to act accordingly. Due to its functionality, this prototype has proven to be easy to use, economical to use, and low maintenance. The results of our research project from the lab testing have created a prototyping model that can quickly measure fluctuations in turbidity levels and water levels, and keep dam operators up-to-date. Some of the limitations of this study are due to time and financial constraints: (a) The field test was not executed, and (b) The data could not be saved on the cloud server.

5.2 Recommendations

The use of automated technology has proven to be efficient and effective in many areas. Using an Arduino-based system would be a great addition to the existing almost manual system for monitoring and controlling the water level and turbidity level of the reservoir. The following recommendations apply to both the public and private sectors, and to anyone interested in hydropower:

(i) The use of the developed prototype system and upscaling of it will promote automatic systems operation of the current hydropower plant in Rwanda, EAC, and other developing country.

(ii) Governments and their authorities through the concerned ministries should assist and encourage the water dam owner to shift from manual-based systems to smart and automatic controlled ones as it requires small financial funding.

(iii) The academic and research institutions should contribute to the advancement of the designed prototype, assessing its operational capabilities for fruitful field implementation.

(iv) The funding organizations like World Bank, African Development Bank, and many others should not only put efforts into big hydropower plant projects but also the small plants should be taken into consideration.

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APPENDICES

Appendix 1: Sample of Code Used for Designing Smart and Automatic Dam Water Reservoir

HOME PAGE CODES

```
#include <SoftwareSerial.h>

#include <LiquidCrystal.h>

int sensorPin = A3;

const int rs = 3, en = 4, d4 = 12, d5 = 11, d6 = 10, d7 = 9;

LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

SoftwareSerial mySerial(7, 8);

#define echoPin 6

#define trigPin 5

int valve = 2;

int buzzer = 13;

long duration;

int distance;

int distance1;

void setup()

{

  lcd.begin(16, 2);

  Serial.begin(9600);

  lcd.print("DAM CONTROLLER");

  delay(4000);

  pinMode(valve, OUTPUT);

  pinMode(buzzer, OUTPUT);

  pinMode(trigPin, OUTPUT);

  pinMode(echoPin, INPUT);
```

```
  mySerial.begin(9600);

  digitalWrite(valve, HIGH);
  Serial.println("Initializing...");
  delay(1000);



}

void loop()
{
  int sensorValue = analogRead(sensorPin);
  int turbidity = (map(sensorValue, 0, 750, 100, 0) +5
   );

  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
  duration = pulseIn(echoPin, HIGH);

  distance1 = duration * 0.034 / 2;
  distance = (distance1 * 10);
    Serial.print("Distance: ");
  Serial.print(distance);
  Serial.print(" Mm"); Serial.print("     ");
```

```
 Serial.print("turbidity: ");
Serial.print(turbidity);
Serial.println(" NTU");
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("turbidity:");
lcd.print("  ");
lcd.setCursor(11, 0);
lcd.print(turbidity);
lcd.print("NTU");
lcd.setCursor(0, 1);
lcd.print("WL: ");
lcd.print(distance);lcd.print(" mm");
if (distance <=310) {
  digitalWrite(valve, LOW);
  digitalWrite(buzzer, HIGH);
  delay(3000);
  digitalWrite(buzzer, LOW);
  water_level();
}
else if (distance > 330)
{
  digitalWrite(valve, HIGH);
  //    digitalWrite(buzzer, HIGH);
  //    delay(3000);
  //    digitalWrite(buzzer, LOW);
}
```

```
  if (turbidity > 50) {
    durty();
    digitalWrite(buzzer, HIGH);
    delay(3000);
    digitalWrite(buzzer, LOW);
  }



  delay(800);
}
void durty()
{

  mySerial.println("AT");
  updateSerial();

  mySerial.println("AT+CMGF=1");
  updateSerial();
  mySerial.println("AT+CMGS=\"+250786653854\"");
  updateSerial();
  mySerial.print("Much dirties in Water");
  updateSerial();
  mySerial.write(26);
  //  delay(60000);
}
void water_level()
{
```

```
  mySerial.println("AT");
  updateSerial();

  mySerial.println("AT+CMGF=1");
  updateSerial();
  mySerial.println("AT+CMGS=\"+250786653854\"");
  updateSerial();
  mySerial.print("DAM is now fultrl, valve is OFF");
  updateSerial();
  mySerial.write(26);
}

void updateSerial()
{
  delay(500);
  while (Serial.available())
  {
    mySerial.write(Serial.read());
  }
  while (mySerial.available())
  {
    Serial.write(mySerial.read());
  }
}
```

Appendix 2: Results of Water and Turbidity Values

Display of water and turbidity changes by serial monitor on PC screen _1

COM4

SI

```
Distance: 330 Mm     turbidity: 41 NTU
Distance: 320 Mm     turbidity: 41 NTU
Distance: 320 Mm     turbidity: 41 NTU
Distance: 320 Mm     turbidity: 41 NTU
Distance: 320 Mm     turbidity: 41 NTU
Distance: 320 Mm     turbidity: 41 NTU
Distance: 320 Mm     turbidity: 41 NTU
Distance: 320 Mm     turbidity: 41 NTU
Distance: 320 Mm     turbidity: 42 NTU
Distance: 320 Mm     turbidity: 41 NTU
Distance: 310 Mm     turbidity: 41 NTU
Distance: 310 Mm     turbidity: 51 NTU
Distance: 310 Mm     turbidity: 50 NTU
Distance: 310 Mm     turbidity: 54 NTU
Distance: 320 Mm     turbidity: 43 NTU
Distance: 320 Mm     turbidity: 43 NTU
Distance: 310 Mm     turbidity: 43 NTU
Distance: 310 Mm     turbidity: 43 NTU
Distance: 310 Mm     turbidity: 43 NTU
Distance: 310 Mm     turbidity: 44 NTU
Distance: 310 Mm     turbidity: 53 NTU
Distance: 310 Mm     turbidity: 54 NTU
Distance: 320 Mm     turbidity: 58 NTU
Distance: 320 Mm     turbidity: 58 NTU
Distance: 310 Mm     turbidity: 42 NTU
Distance: 310 Mm     turbidity: 43 NTU
Distance: 310 Mm     turbidity: 42 NTU
Distance: 310 Mm     turbidity: 50 NTU
Distance: 310 Mm     turbidity: 48 NTU
```

Display of water and turbidity changes by serial monitor on PC screen _2

COM4

```
Distance: 360 Mm     turbidity: 33 NTU
Distance: 360 Mm     turbidity: 34 NTU
Distance: 360 Mm     turbidity: 33 NTU
Distance: 360 Mm     turbidity: 33 NTU
Distance: 360 Mm     turbidity: 33 NTU
Distance: 360 Mm     turbidity: 33 NTU
Distance: 360 Mm     turbidity: 33 NTU
Distance: 360 Mm     turbidity: 34 NTU
Distance: 360 Mm     turbidity: 34 NTU
Distance: 370 Mm     turbidity: 34 NTU
Distance: 360 Mm     turbidity: 34 NTU
Distance: 370 Mm     turbidity: 34 NTU
Distance: 360 Mm     turbidity: 34 NTU
Distance: 360 Mm     turbidity: 35 NTU
Distance: 360 Mm     turbidity: 34 NTU
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Distance: 360 Mm     turbidity: 33 NTU
Distance: 360 Mm     turbidity: 34 NTU
Distance: 360 Mm     turbidity: 33 NTU
Distance: 350 Mm     turbidity: 66 NTU
Distance: 360 Mm     turbidity: 39 NTU
Distance: 340 Mm     turbidity: 36 NTU
Distance: 350 Mm     turbidity: 35 NTU
Distance: 350 Mm     turbidity: 83 NTU
Distance: 340 Mm     turbidity: 50 NTU
Distance: 340 Mm     turbidity: 51 NTU
Distance: 320 Mm     turbidity: 57 NTU
Distance: 330 Mm     turbidity: 60 NTU
Distance: 340 Mm     turbidity: 61 NTU
```

Display of water and turbidity changes by serial monitor on PC screen _3

COM4

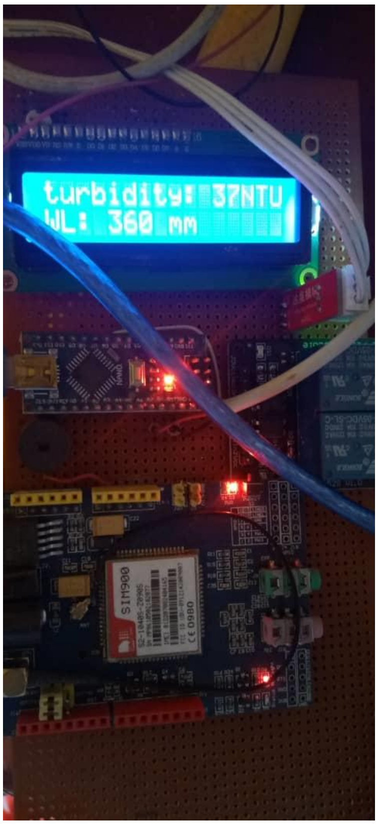
```
Distance: 350 Mm     turbidity: 49 NTU
Distance: 350 Mm     turbidity: 49 NTU
Distance: 360 Mm     turbidity: 50 NTU
Distance: 360 Mm     turbidity: 51 NTU
Distance: 370 Mm     turbidity: 49 NTU
Distance: 350 Mm     turbidity: 50 NTU
Distance: 350 Mm     turbidity: 49 NTU
Distance: 350 Mm     turbidity: 50 NTU
Distance: 360 Mm     turbidity: 49 NTU
Distance: 360 Mm     turbidity: 50 NTU
Distance: 360 Mm     turbidity: 49 NTU
Distance: 360 Mm     turbidity: 50 NTU
Distance: 370 Mm     turbidity: 49 NTU
Distance: 360 Mm     turbidity: 52 NTU
Distance: 360 Mm     turbidity: 51 NTU
Distance: 370 Mm     turbidity: 51 NTU
Distance: 370 Mm     turbidity: 54 NTU
Distance: 360 Mm     turbidity: 52 NTU
Distance: 370 Mm     turbidity: 54 NTU
Distance: 370 Mm     turbidity: 55 NTU
Distance: 370 Mm     turbidity: 57 NTU
Distance: 380 Mm     turbidity: 56 NTU
Distance: 370 Mm     turbidity: 56 NTU
Distance: 390 Mm     turbidity: 58 NTU
Distance: 380 Mm     turbidity: 58 NTU
Distance: 380 Mm     turbidity: 50 NTU
Distance: 390 Mm     turbidity: 49 NTU
Distance: 370 Mm     turbidity: 51 NTU
Distance: 380 Mm     turbidity: 51 NTU
```

Appendix 3: Display of Water and Turbidity Values on LCD

(a)

(b)

(c)



(d)

(a) The system is safe for both water and turbidity conditions.
(b) The system is safe for water level but insure for turbidity conditions
(c) The system is safe for turbidity but unsafe for water level conditions.
(d) The system is not safe for both water and turbidity conditions

Appendix 4: Certificate of Academic Internship

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Kigali, on 28th December, 2019

To whom it may concern

I, PASIKA Peace for Glee,the Managing Director of HOBUKA Ltd hereby confirm that Mrs. MARIE CHANTAL IRIBAGIZA a Student at the NELSON MANDELA AFRICAN INSTITUTION OF SCIENCE AND TECHNOLOGY (NM-AIST) has been at HOBUKA Ltd for an academic Internship of (6) months.

In the Period of Internship, Mrs. MARIE CHANTAL worked on the project entitled "Smart system for controlling and monitoring water and turbidity levels in Dam Reservoir using microcontroller technology; Embedded and Mobile Systems". She demonstrates the Professional skills, problem analysis, and development of solution.

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Appendix 5:   Research Outputs

Research publication certificate (DOI: 10.31695/IJASRE.2022.8.1.11)

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Smart System for Controlling and Monitoring Water and Turbidity Levels in Dam Reservoir using Micro-Controller Technology

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ABSTRACT

A micro-controller-based technology has been developed for monitoring and controlling the water quality and quantity in dam reservoirs by using various sensors. This system is able to automatically detect and measure the changes in water and turbidity levels of incoming water for hydropower production. In this project, an Arduino UNO micro-controller and GSM Technology control the operations of the system through sending messages and regulating automatic water valves according to the instant status of the dam water. The developed prototype has four units: sensing unit, processing unit, displaying unit, and alerting unit. In the sensing unit, the ultrasonic sensor continuously monitors the change in water levels and the turbidity sensor takes turbidity measurements of incoming water. In the processing unit, the detected data are collected and fed to the microcontroller for further processing. This technology is expected to reduce the time and cost incurred during the hydropower plant operations by using a small amount of manpower and will facilitate fast information collection.

Keywords: Automation, Arduino Uno, Micro-controller, Sensors, Serial monitor.

1. INTRODUCTION

Dam is a man-made structure designed to hold back water for generating electricity, water supply, flood management or river flow diversion [1]. Dam and water reservoir are both built to regulate the flowing water and to store this latter for various purposes such as flood reduction, hydroelectric production, recreation, fisheries and irrigation. The most common problems encountered by the water reservoir and dams are mainly based on failure to fulfil the intended purpose which is to store water. Apart from water evaporation and water seepage, sedimentation and flooding have been reported to be serious problems for water reservoirs and dams. In hydropower production, the quantity and quality of water are monitored and controlled time to time but the use of manual and mechanical technologies result in the creation of hard-working conditions and it becomes more obvious during the rainy seasons where changes in both water quantity and quality are very important. The purpose of this research is to design a smart system for controlling and monitoring dam water reservoirs while alleviating both sedimentation and improper water allocation problems by using an Automated Microcontroller Technology.

2. LITERATURE REVIEW

Information of water quantity and quality is important in life-cycle of any dam reservoir in hydroelectric production. This smart system detects and takes the quick measurements of water and turbidity levels. It controls, monitors, and warns about any critical change in water level and turbidity of incoming water. This technological system reduces the time and cost incurred during the hydropower plant operations by using small amount of manpower, and facilitates fast information collection and process.

2.1. Previous Studies

Studies have been previously conducted at both global and regional scales and working systems have been developed to monitor and control water level and or water quality in dam reservoirs. An automated flood gate control system has been developed [2] where water level was monitored but water turbidity was not taken into consideration. Embedded water gate control systems using respectively C and Visual Basic, and Linear Predictive Coding (LPCs) were developed to control the water level where at the highest water level the gate is allowed to open automatically but they do not provide the time at which the gate would close if the water level is at normal condition and they didn't consider water quality [3] [4]. It is clear that water level and water quality under turbidity in our case are crucial parameters to be considered while monitoring and controlling dam water reservoirs. Currently, smart systems for controlling and monitoring water quality consist of many sensors that measure various parameters such as temperature and humidity, pH levels, the turbidity in the water, and water level in the storage tank [5] but no combination of these parameters has been used for reducing sediments deposition in dam water reservoir. There is a lack of using smart technology in design and operations of dam water reservoirs while alleviating both sedimentation and improper water allocation problems. And the time of information dissemination and processing is very long which consequently leads to time delays. The purpose of this research is to design a Smart System for Control and Monitoring water levels and turbidity levels in the dam reservoir of a Pico Hydropower Plant by using Microcontroller Technology. A study of a system which is Water Level Monitoring and Dam Gate Control over Internet of Things (IoT), was developed [6]. The main objective of this IoT based methodology system was to control (open and close of gate) by detecting water level in the dam. In this system, water level values were detected at different level changes. Depending on the set water level values, the dam gate might close or open, the buzzer alarmed and using the Blynk application, the people in charge were receiving through phone SMS, Email and Twitter at the same moment [6].

In 2016, T.T.Yuvarani and R.Archana developed a system that uses GSM technology for monitoring, controlling and warning of dam water level, where they used microcontroller to compare the level in the dam using the water level sensor's threshold value.

The Global System for Mobile Communication (GSM) module is utilized to relay dam level status to the control room [7]. In the project research work of [8], a system for remote monitoring of a dam was developed. In India, people developed the system of dam automation using IoT, where they used python to program Raspberry pi. The gates are under automation that uses a direct current (DC) motor to control them. In this system, water level sensors are also used to collect data in order to control the gates and they use turbidity sensors to measure the turbidity of water. It also displays the status of the dam and checks the cracks of walls, so the main purposes of the system were automatic dam gate control and corrosion detection [9].

In Indonesia, researchers developed an embedded system based for power plant monitoring and controlling. This system had the importance of monitoring the environmental conditions by using various sensors, PIC microcontroller was used to read data from the different sensors, GSM was used to send the status of the boiler to the user whether for instance the temperature inside the boiler increases to the threshold value. All values were displayed on the Liquid Crystal Display (LCD) display. In this system, they considered many parameters like water, temperature, gas, and pressure levels. The main purpose of this system was to monitor and control these parameters for power plants in order to prevent the power plant wastage which affects the persons who surround the power plant [10]. In the research of dam automation and application using IoT in India, the main aim was to measure three levels of water in dam where the sensor was used to sensor the water level and when it reaches the full level reservoir the dam gate opens automatically. A relay module was used to control the opening and closing of the gate by detecting water level in the dam. The only one parameter considered was a water level [11]. An embedded system with microcontroller based can control dam system and this has been done by developing a system for detecting the level of water and the inflow water change that provide the moment of gates to be controlled in real-time by using stepper motor [12].

3. MATERIALS AND METHODS

In this project, the agile development methodology is used for a continuous iteration of development and testing of the viable prototype. An improvement is done for each complete stage of the system if it is found to be necessary. In our proposed system, both water level and turbidity level are monitored and when they reach to maximum levels, there is an automatic action to open or close the valve on the dam and the message is sent to the person in-charge by using GSM Module at the same time the buzzer alarms. The purpose of this project is to help the users to have the ability of remotely controlling and monitoring their dams without human interaction with the dam units. This system provides an easy way to check the information of valve function; in closing and opening. The user can control the dam from far or around and the buzzer provides an alarm when the water level goes high up. From the proposed system, the ultrasonic sensor and turbidity sensor detect water level and turbidity level respectively in the dam and then the sensed data is displayed through LCD.

3.1. Block Diagram and System Architecture

The proposed system has four units including sensing unit, processing unit, displaying unit and alerting unit. In the sensing unit, the ultrasonic sensor continuously monitors the change in water levels and the turbidity sensor takes turbidity measurements of incoming water (Figure 1 (b)). In the processing unit, the detected data are collected and fed to the microcontroller for further processing. The processed data is viewed on a display unit which is LCD, and the alerting unit consists of the alarm to be generated and an SMS notification to be sent (Figure 1 (a)).

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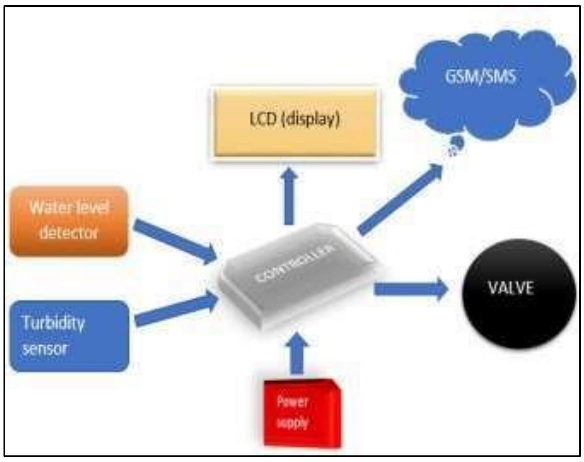

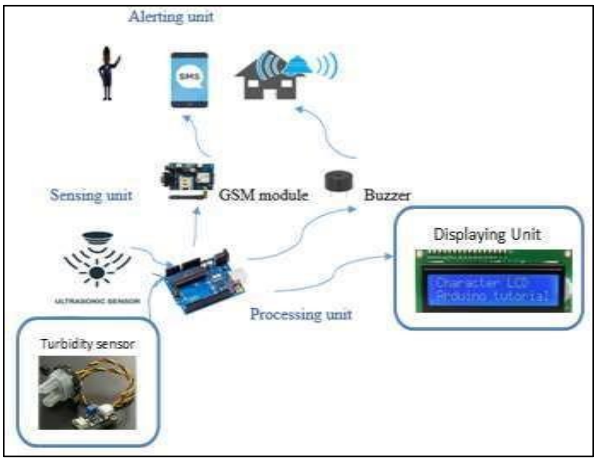

Figure 1.a. Block Diagram

Figure 1.b. System Architecture

3.2. Flowchart

In the flowchart Figure 2, there is a pictorial diagram representation of an algorithm used to represent information processes for both system activity and connectivity. The activities and the connection order are shown by boxes of different kind and rows respectively. The flowchart diagram on figure below shows a by-step system operation from the start to the end.

The system was turned on and continued to run many iterations for all system components in operation and starting the initialization of set parameters. In this project study, the ultrasonic sensor and turbidity sensor were used to detect respectively water level and turbidity level in the dam water reservoir. These sensors continuously monitored the changes in water level and turbidity level and the data obtained from the sensors were sent to the micro-controller for processing and analysing. Afterward, each analysed data was compared to the required optimum. If water and turbidity levels exceed their respective thresholds, the abnormal conditions were detected, and a buzzer connected to the microcontroller was used to output an alarm for warning and notifying through Short Message Service (SMS) using the GSM module the responsible personnel to act accordingly.

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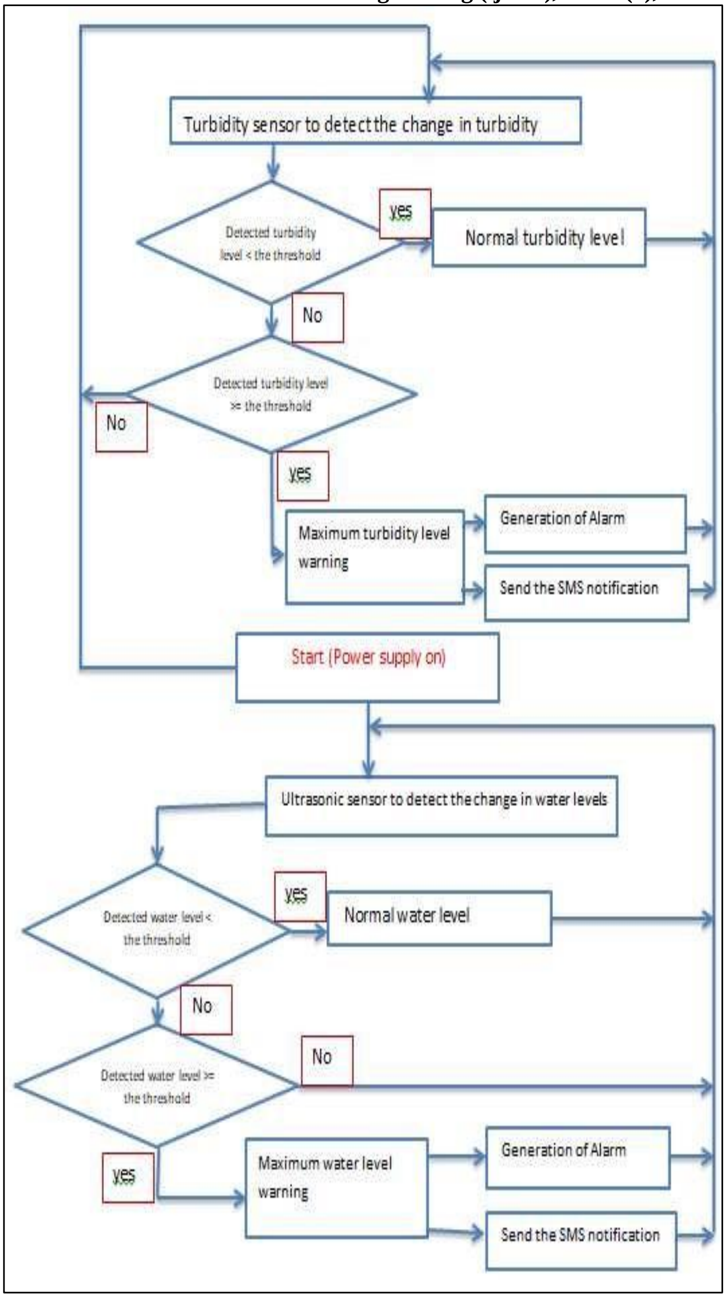

Figure 2: Flowchart of the system

3.3. Circuit Diagram

The system circuit diagram graphically represents how the system components are electrically connected on Arduino Nano board (microcontroller board) in order to operate and it is represented in Figure 3. Arduino Nano has one board microcontroller that collects input information from various sensors and devices, and transforms this information into useful outputs. This Arduino Nano consists of 22 input and output pin; 14 pins are digital pins, and 8 pins are analogue pins, the turbidity sensor data pin was attached to an analog Arduino pin, which is A0. The ultrasonic sensor trig and echo pins are both connected to Arduino pins that means trig pin connected to 5 pin and echo pin connected to 6 pins. The trig pin is designed for output and the echo pin is designed for input. The pins of LCD RS, EN, D4, D5, D6 and D7 are connected to digital pins of Arduino 3, 4, 9, 10, 11 and 12. The pins of the GSM module which are transmitter and receiver are connected to 7 and 8 pins of Arduino. A wire of valve is connected to Arduino on pin 2 and a wire of buzzer is connected to Arduino on pin 13. Arduino was supplied by energy of 5V to

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all these components. During the system integration process, all units were linked together. Their interaction proved the effective system functionality and its compliance with the requirements.

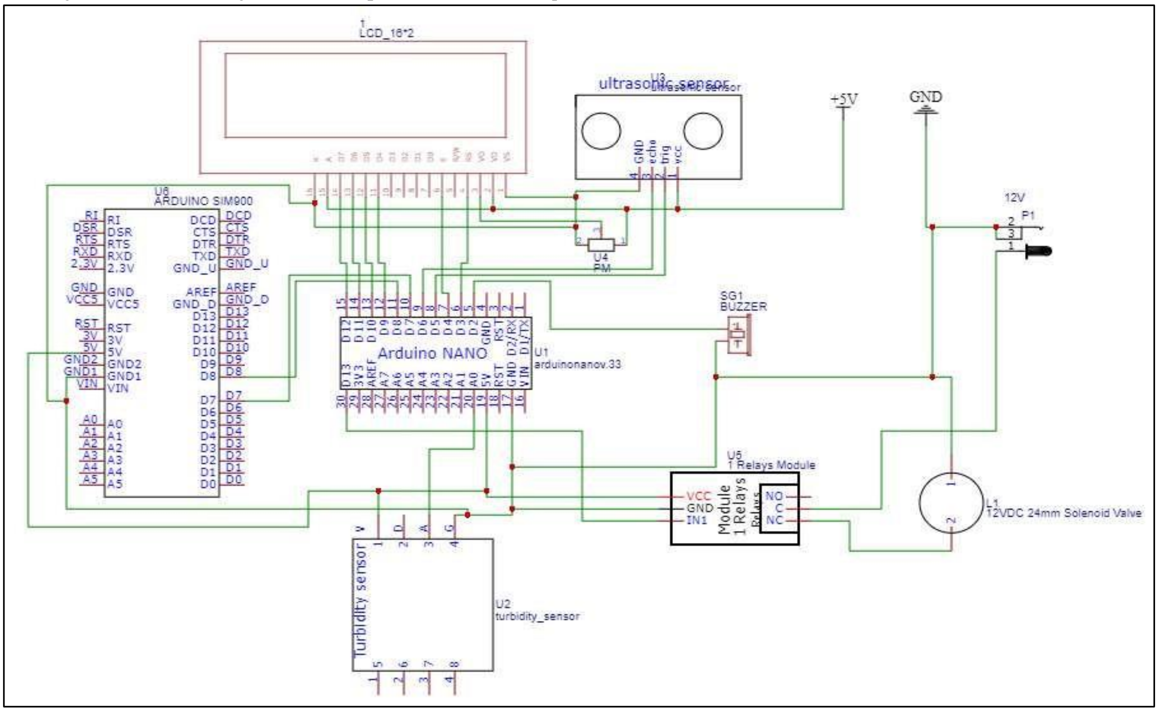

Figure 3: system circuit

3.4. Programming Languages and Software Used

This system was built using C programming under the Arduino IDE (Integrated Development Environment). C programming is a high-level programming language and general-purpose procedure which plays important role for developing software to this language is popular programming language and it minimizes the time of execution comparatively to other high-level languages the reason why many systems and other many languages are built under C language [13]. Arduino IDE is an open-source Arduino software which is transcribed in functions after C++ and C programming languages. This tool provides the ability to write and to upload the code to the Arduino board. By using this Arduino IDE, the user imports various libraries depending on the sensors or component required by the system then the output is displayed on the serial monitor window in Arduino IDE. Like other microcontrollers, ATMEGA 238 microcontroller was housed in an Arduino board and was programmed under C computer programming language. In this study, the EasyEAD software was also used. EastEDA is an online circuit drawing application which is very easy to start and understand drawing software that consists of many complex software libraries and links. Its function is simple and is easy to use. It is the type of Printed Circuit Board (PCB) design schematics and simulation for electronic circuit diagrams, the reason why it was used in this project.

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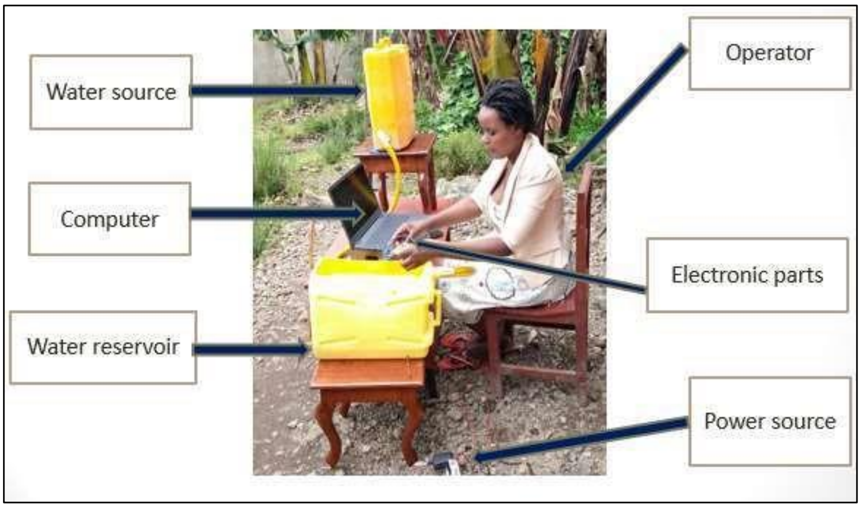

Figure 4: Prototype development

4. RESULTS AND DISCUSSION

4.1. Results

During the development and lab testing of our prototype, the measurements of the water and turbidity levels were obtained by using various hardware and software components. Two containers have been used from which the first container was considered as a source of water and the second container is a dam water reservoir. This means that the water flows from the first container to the second container through pipes with valves. The ultrasonic sensor is popular for measuring the distance in mm between sensing unit and the physical object and in this project, it starts to monitor water level in the water reservoir. Therefore, the water from the source flows into the dam water reservoir and water level in the dam is monitored. If the measured distance between ultrasonic sensor and water surface is equal to 310 mm which is maximum level, the dam reservoir is full, and the valve is switched off. At this time there is no water flow from the water source to the dam and the SMS notification is immediately sent to the mobile phone of the person in charge at the same time the buzzer produces an alarming sound. The SMS notification, the sound of buzzer and the low of valve are activated at the time when water level reaches its maximum level in the dam water reservoir. When the water level rises to normal state in dam, there is not alarm, no SMS notification and the valve is on until the water level reach to maximum level which is 310mm and when the water level decreases to its minimum level of 330 mm in dam, the valve is switch on directly in order to allow water to flow from the water source to the dam water reservoir. Generally, the water level is increased when the distance between sensor and water surface is decreased. On the side of measuring turbidity level in dam water reservoirs, a turbidity sensor was used to measure the turbidity values of water in Nephelometric Turbidity Units (NTU). Turbidity is the level of cloudiness in a liquid and drinkable water has a turbidity level which is less than 4 NTU. The turbidity sensor detects and measures the variation of turbidity levels of incoming water in the dam. The normal turbidity level in water was set to be less than 50 NTU in this project. And if it is over than this value (50 NTU), in this case the maximum turbidity level is exceeded, and the buzzer warns by producing the alarms and SMS notification is sent to the mobile phone of the person in charge. Both the turbidity level and the distance detected by the respective sensors changed more time on the LCD screen and serial monitor at the same time. The tables below display the different measurements of water level and turbidity level in dam water reservoir and their status description of dam.

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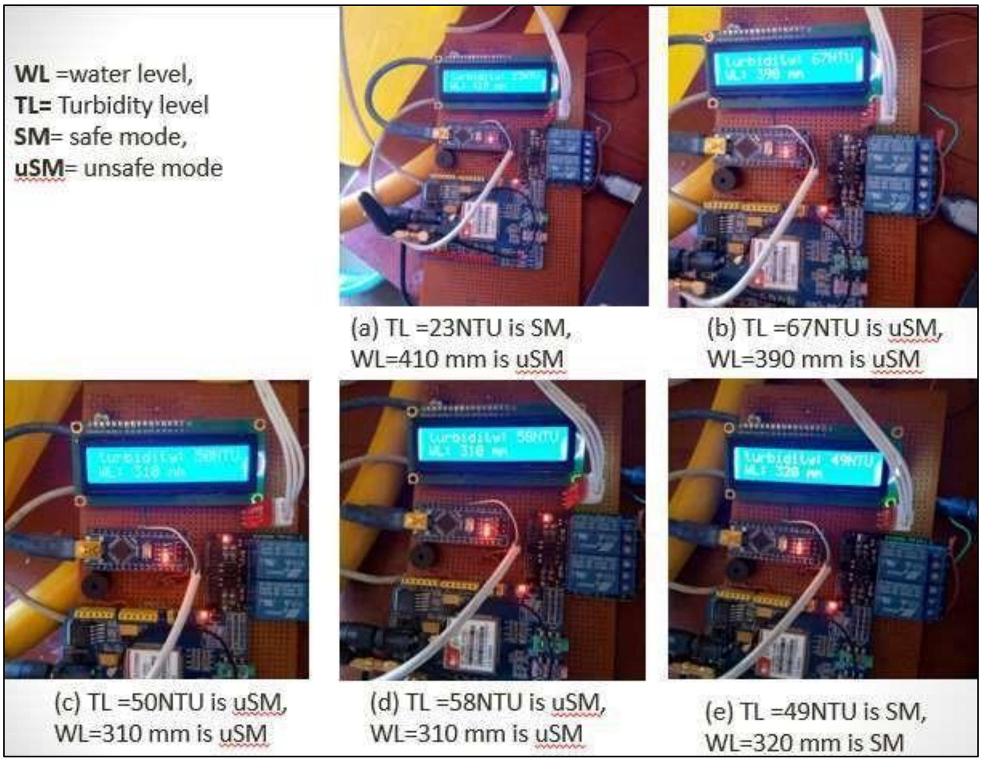
Table 1: Comparison of output measurements of water level obtained in lab testing

N0	Water level	Measurement of water level	Status in dam reservoir
1	Maximum	The measured distance between sensor and water surface in dam is less or equal to 310 mm	Bad condition, dam is full: water level in dam is at its highest, but water is still controlled and no incoming water.
2	Normal	The distance measured between sensor and water surface is any value between 330 mm and 310 mm	Normal condition: Water level is controlled, and valve is switched on and the water can enter in the dam reservoir.
3	Minimum	The distance measured between sensor and water surface greater or equal to 330 mm	Bad condition: water level was low in dam, valve was ON

Table 2: Comparison of output measurement of turbidity level in the dam water reservoir

N0	Turbidity level measurements in water dam	Status description in water dam
1	The turbidity level measured </=4NTU	Good condition: this turbidity is low and safe for drinking
2	The turbidity level measured >/=50NTU	Bad condition: Turbidity level increases up to maximum level and beyond that, it can create sediments.
3	The turbidity level measured <50NTU	Good and safe condition: Turbidity level is increasing to a high level but not cause any problem in the water dam.



(a) TL =23NTU is SM, WL=410 mm is uSM
(b) TL =67NTU is uSM, WL=390 mm is uSM
(c) TL =50NTU is uSM, WL=310 mm is uSM
(d) TL =58NTU is uSM, WL=310 mm is uSM
(e) TL =49NTU is SM, WL=320 mm is SM

Figure 5: Results from lab system

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4.2. Discussion

The lab experiments conducted showed that both water level and turbidity levels can be automatically detected, measured and the information can be immediately shared to the dam operators. In Figure 5 and 6, the shown values were the instant water and turbidity levels from the lab experimentation. The water level distance and turbidity parameters were monitored by ultrasonic and turbidity sensors respectively. Updates of data from the sensors were provided by a serial monitor on the computer screen. The changes in both water and turbidity levels which exceed the optimum creates the generation of an alerting SMS and sound through the mobile phone and the buzzer respectively. Figure 6 shows the short messages that were sent to the phones of the dam operators to let them know that a danger state was attained. Figure 4 shows the developed lab prototype as installed. Based on the gained information about the design and implementation of a lab scale system, an automated field system can be implemented at affordable cost, accuracy, efficiency and effectiveness are assurances.

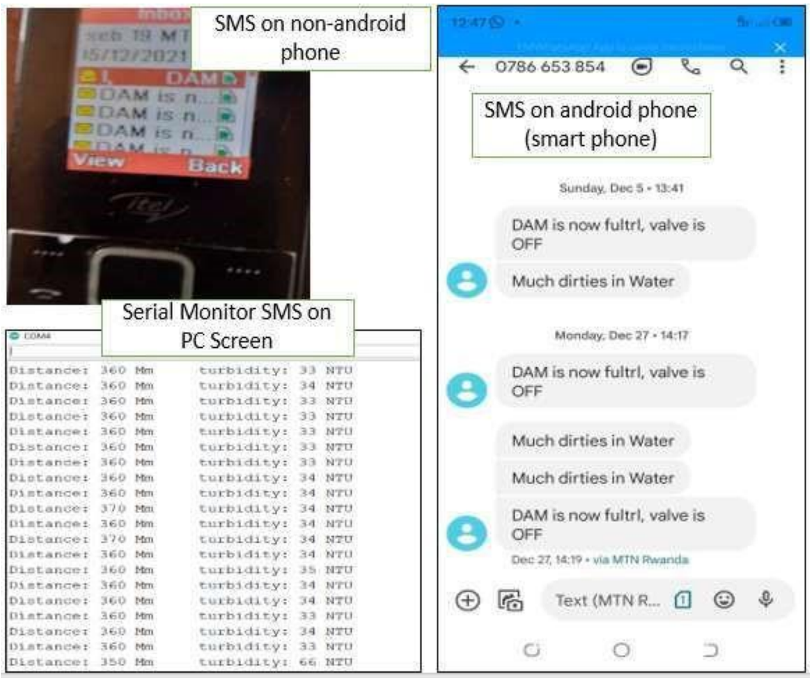

Figure 6: SMS notification to both computer and mobile phones

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Water level variations and changes of turbidity in any water reservoir should be controlled. If the quantity of water becomes too small, the hydropower production is negatively affected and if it turns too high, it causes inundation which creates a loss of properties and human deaths. When turbidity increases to a high level, it creates a sedimentation phenomenon which is the accumulation of sediments in the bottom of the water reservoir. Sediments tend to reduce the capacity of a water reservoir as the usable volume of water is occupied by this settled matter thus affecting hydropower production. The developed prototype system has proved that the information on water level and turbidity status can be disseminated within 3 seconds thus allowing the authorities to act accordingly. Through its functionality, this system proved to be user friendly, economically applicable and does not require rigorous maintenance. The results of this conducted study, from lab testing, have provided a smart prototype which can quickly detect the changes in both water and turbidity levels, and continuously send updates to the dam operators.

5.2. Recommendation and future work

The application of smart technologies in various fields has proven to be effective and efficient. The use of Arduino microcontroller centred system would effectively improve the current systems, which are mainly manual, in control and monitoring water and turbidity levels in dam water reservoirs. The academic and research institutions, funding organizations and governments should be involved in upgrading the developed prototype, evaluating its operation for successful field implementation at large scale.

Acknowledgment

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Appendix 6: Poster Presentation

Smart System for Controlling and Monitoring Water and Turbidity Levels in Dam Reservoir using Arduino Technology

Marie C. Iribagiza[1], Prof. Kisangiri Michael [2], Dr. Jema D. Ndibwile [2], and Eng. Felicien Sebahire[3]

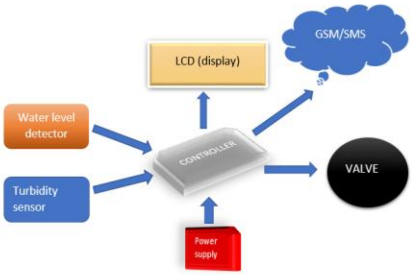
1. Introduction

The most common problems encountered by the water reservoir and dams are mainly based on failure to fulfil the intended purpose which is to store water. Apart from water evaporation and water seepage, sedimentation and flooding have been reported to be serious problems for water reservoirs and dams. In hydropower production, the quantity and quality of water are monitored and controlled time to time but the use of manual and mechanical technologies result in the creation of hard-working conditions and it becomes more obvious during the rainy seasons where changes in both water quantity and quality are very important. The purpose of this research is to design a smart system for controlling and monitoring dam water reservoirs while alleviating both sedimentation and improper water allocation problems by using an Aduino Technology.

2. Problem statement

There is insufficiency in using automation technologies in both design and operations of hydropower plant (HPP). During their operation, the time it takes to disseminate information and to process water levels and turbidity levels is long and therefore leads to time delays. The aim of this study is to produce a smart and automatic system for monitoring and controlling dam water reservoirs while answering to problems of both sedimentation and inadequate water distribution by using Arduino technology. The prototype of this research project would show a way to minimize human interaction with the HPP system units of the upstream side by measuring water levels and turbidity levels which are key parameters for an efficient HPP.

3. Tools



4. Results

The water from the source flows into the dam water reservoir and water level in the dam is monitored. For the water levels (WL) and turbidity status (TS) which are unsafe, the SMS notification is immediately sent to the mobile phone of the person in charge at the same time the buzzer produces an alarming sound. The unsafe water levels are when WL less than 310 mm or greater than 330 mm. And the unsafe water turbidity is when TS is greater than 4 NTU.

5. Conclusion

During this investigation, prototype requirements were identified and system development was carried out. This study aims to contribute to reducing and possibly alleviating the problems of both variations in water level and changes in turbidity for any water dam. This can be achieved by monitoring and controlling the turbidity and water levels, informing the in-charge persons about the unusual, detected statuses in the water dam. The designed prototype distributes information about water level and turbidity conditions within 3 seconds, permitting the responsible person to act accordingly. Due to its functionality, this prototype has proven to be easy to use, economical to use, and low maintenance. The results of our research project from the lab-testing have created a prototyping model that can quickly measure fluctuations of turbidity level and water levels, and keep dam operators up-to-date.