GSM BASED WATER DISTRIBUTION MONITORING AND CONTROL SYSTEM

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Declaration

I, **Gladmore Mutesva** hereby declare that I am the sole author of this thesis. I authorize the Midlands State University to lend this thesis to other institutions or individuals for the purpose of scholarly research.

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Approval

This dissertation/thesis entitled "GSM Based Water Distribution Monitoring and Control System" by Gladmore Mutesva meets the regulations governing the award of the degree of BSC TELECOMMUNICATIONS HONOURS of the Midlands State University, and is approved for its contribution to knowledge and literal presentation.

Supervisor …………………………………………………...

Date ………………………………………………………….

Dedication

The research is dedicated with love to my father, mother, sisters, brother and my fiancé, Petronella Kumire. I thank you for your love, advice, encouragement and financial support, may the dear Lord bless you

Acknowledgements

A project of this magnitude could not have been accomplished without the help and indispensable inspiration. My paramount gratitude is credited to the Almighty God who afforded me the opportunity to carry out this research. Personally I do not have the capacity of being where I am but the invisible hand of the Lord has stretched me this far.

I would like to express my sincere gratitude to my supervisors, Dr. C Nyamhere and Mr. F Mazunga for their unwavering support and guidance in this research. My special thanks also go to my family members especially my father and my mother for their support both morally and financially.

Abstract

The GSM Based Water Distribution Monitoring and Control System improves the water distribution by providing the automation of water levels in the tanks and monitoring and control of water flow in the distribution network. Water sensor detects the water level in the tanks and then sends signal to the microcontroller unit for actuation of valve and pump. The water monitoring system can detect leakages in the distribution pipeline. If a leakage occurs, an upstream solenoid valve automatically disconnects water supply in the pipeline to prevent water loss.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Technology has advanced so much in the last decade to the extent of making life more efficient and comfortable, the comfort of being able to monitor and control devices remotely [1]. With the continuous economic growth, the water demand of enterprises is also increasing. The monitoring of water resource for these enterprises can prevent the occurrence of stealing water and leaking water effectively [2]. Therefore, the monitoring system of urban water supply has aroused extensive attention in recent years. Urban water supply networks form the link between drinking water supply and drinking water consumers. These large-scale networks are vital for the survival of urban life, for maintaining a healthy level of economic development, and for the continuous operation of factories and hospitals.

1.2 Background

In the year 2000, an estimated 1.16 billion people had no access to improved water sources and double as much (2.36 billion people) had no access to adequate sanitation worldwide. Sub-Saharan Africa accounts for about 23% of the global total population without access to improved water source. The Millennium Development Goals (MDGs) recognize that access to safe water is crucial for survival and aim to halve the proportion of people without sustainable access to safe drinking water by 2015. The provision of adequate safe drinking water is only possible when the water utility is performing well. More than 90% of urban water supply and sanitation services in developing countries are provided by state-owned, monolithic water organizations also known as public water utilities.

Public water service providers, in many developing, have failed to provide consumers with adequate water supply and sanitation services. Apart from poor service coverage of less than 60%, other the problem encountered by water utilities in developing countries is non-revenue water (NRW), which often averages between 40%-60%. Water utilities in developing countries often face financial problems due to a combination of low tariffs, poor consumer records and inefficient billing and collection practices. This affects the quality of water services delivered to the consumers, if they are connected at all.

NRW results in major problems in water supply systems, and usually represents a considerable loss in revenue, creating excessive production costs and reducing the available water to customers. NRW consists of physical and commercial water losses, due to inefficient billing or illegal connections. Thus high levels of NRW indicate poor system management and poor commercial practices as well as inadequate pipeline maintenance. NRW therefore needs to be controlled in order to improve the performance of water service delivery. In developing countries, reliability of water usage measurement and distribution statistics is poor because of dependence on traditional metering techniques where a water utility employee records meter readings manually on paper.

1.3 Research Motivation

Wireless technology in recent years has become very useful in the field of automation and control especially in remote control operations. The benefits of embedded system are now being utilized into remote monitoring and control system because of lots of advantages. Remote monitoring is an effective method in order to avoid interfering with environment and improve efficiency. Remote monitoring and control will lower water expenditures by increasing the possibility of reduced consumption using analyze control devices data motivated the researcher to perform this design project. Global System for Mobile (GSM) networks can be used to transmit data for remote monitoring system and with over 90% coverage in Zimbabwe this technology can be applied in any part of the country [4]. With GSM network the system will communicate no matter the distance, provided there is network coverage. During the usage of traditional monitoring, there is involvement of manual mechanical switching. With traditional meters the consumption of water for a household is known on monthly basis, hence there is an overall demand for the local authorities to explore a new development for the benefit of consumers as well as the service provider. By using traditional billing, usages are not known as consumers are not aware of the knowledge about how much has been made in an hour or any particular interval in a day. GSM based remote monitoring will allow the water authorities to know daily usage of water bills for a particular customer and be able to monitor and control his flow rate remotely using mobile phone.

1.4 Other Authors' Works

With the rapid growth of wide urban residential areas imposes the expansion as well as modernization of water supply facilities. There are many different systems designed for efficient distribution of water, some authors used programmable logic controllers (PLC) and supervisory control and data acquisition (SCADA) systems for water distribution network. The system included remote terminal unit (RTU), specific transducers and actuators distributed on a wide geographical area and control and power panels for the pump stations. The work presented by Waterhat has developed a Prepaid Water Meter System for prepaid billing of water consumption through remote monitoring without any human intervention [5]. This system promises fast and accurate billing of water as well as preventing any misuse of it. However, Maxnest developed a water meter reading using Zigbee network that suitable for remote places to monitor the water meter reading before any billing process [6]. This could reduce the use of human resource for reading the meter and issuing a bill. Another work presented by Noxson using wireless text messaging system to send early warning short message service (SMS) messages to users advising them to proactively reduce their water consumption before system capacity is reached and systematic water shutdown takes place [6]. In smart home application, the work presented a design on a system to control home appliance remotely and provide security when the owner is away from the place. The similar work presented by Solahart which designed and developed a smart home application system. The system allows the homeowner to be able to monitor and control the house appliances via a mobile phone set by sending commands in the form of SMS messages and receiving the appliances status.

1.5 Statement of the Problem

Water service delivery in Zimbabwe is marred with problems that vary from pipe bursts which result in water leaks that may be not serviced for long periods, poor accounting of water usage and distribution, and poor revenue collection. This project seeks to alleviate such issues by monitoring water distribution pipelines for leakages, digital measuring of water flow and usage, and ensuring prepaid water supply for improved revenue realization.

1.6 Aim of the Study

To design, construct and test remote water flow monitoring and control system using GSM technology.

1.7 Objectives of the study

a) To design a prototype that monitors and control water distribution system.
b) To automatically open and close the solenoid valve and DC water pump.
c) To measure flow rate of water in the distribution pipe.
d) To detect water leakages in the water distribution pipe.
e) To receive an SMS in case of water leakage.

1.8 Project Scope

The project focuses on monitoring water distribution by measuring the flow of water at various distribution segments. It detects water leakages as a result of difference in flow rate between two successive flow sensors and allows the water utility to control water distribution using solenoid valves.

1.9 Hypothesis

Water billing is achieved efficiently when the meter read accurately water consumption and is not tampered with during its functionality. The research seeks to address the problem of estimation and false readings on the water consumption by designing a cheap and reliable prototype to monitor and control day to day usage of water in a distribution network.

1.10 Justification

Water leakages in Zimbabwe's water distribution facilities are too high, controlling water leaks by a way of minimizing these leaks saves water. Monitoring each major segment of the distribution system is essential to reduce water wastage and loss of chemicals used in treating the water. This project can be implemented in monitoring major pipelines which distribute water from the water treatment facilities to distribution tanks in order to reduce water leakages. It improves water service delivery by reducing NRW and eliminates the possibility of customers paying for water which they have not used. This system also improves revenue collection by ensuring that every connected customer's payment is monitored and water is supplied after paying. The system provides an account of the water distributed against that which would have been consumed by providing a record of the water which would have been lost or unaccounted for, which helps the water utility in evaluating its water supply process. It also avoids manual meter reading as customers will be automatically connected or disconnected from water supply by the implementation of a prepaid water supply system.

1.11 Dissertation Summary

The dissertation is organized as follows, having looked at the introduction, research motivation, background of the study and research objectives of GSM based water distribution monitoring and control system. Chapter 2 introduces on the theoretical aspects of monitoring and control of water distribution system. Chapter 3 will present methods to be used in the study, while results and analysis are presented in chapter 4. Chapter 5 concludes the dissertation and describes the future tasks needs to be considered for further developments in this design system.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter gives a detailed analysis of the literature overview of the system functionality and all the components that were used in the designing of GSM Based Water Monitoring and Control prototype. This stage is very crucial in the designing of the prototype as the designer will have a broader understanding of each and every component that was used in developing the project. This stage also gives the designer an understanding on how best to interface these components together.

2.2 Theoretical Survey on Water Distribution System

Water is one of the need of humankind and historically people were seen to establish their homes and villages close to water sources such as river and streams. These early drinking water sources were subjected to contamination, drought and ownership struggles. Early modern water distribution systems date back to 13th century; where a 5.5km lead pipeline was installed in England, which conveyed water from Tybourne Brook to London [1]. Today, large scale water distribution by water utilities is done to ensure portable water supply and centralized water treatment so that consumers may be provided with clean and safe water to drink and use close to their residential, industrial and recreational areas. Water distribution systems mainly comprise of three primary components which are; water source, water treatment and water distribution networks [2]. Water sources vary and may include reservoirs, rivers, dams and ground water wells. Water treatment facilities disinfect water from the various water sources so as to ensure its safety before delivering it to consumers via distribution networks. Water distribution networks mainly consist of piped networks which branch from a water treatment plant and are interconnected to various distribution points where the water supplied can be utilized by an end user. The distribution networks also have storage tanks, valves, pumps and nodes for branching of the distribution networks.

Water distribution systems can be designed to supply water to consumers through gravity flow, using mechanical pumping or implementing both techniques. Gravity flow is mainly implemented where the water source's altitude is high relative to the distribution points where the water is to be supplied. Gravity flow is rarely implemented since it cannot meet all the demands of urban water distribution systems and also because of its reduced flexibility. However, gravity flow can be implemented in rural areas where water supply demand may be minimal. A water distribution system therefore may use pumps to supply its customers, however, the sole use of pumps can be problematic because of variations of consumer demands, hence most urban distribution systems use pumps together with elevated storage tanks.

There are basically two pipeline networking techniques that can be employed in water distribution systems which are; loop and branched networks [3]. A branched network, shown in figure 2.1(a), has several independent links which have many terminals that prevent the circulation of water throughout the entire system. Water is therefore supplied to end users through a single pipe. The disadvantage of branched networks is that if one pipe is disconnected from water supply, in the event of a leakage or for routine maintenance, all consumers connected to that particular pipe segment would be disconnected from water supply.

Figure 2.1(b) shows a looped network which consists of multiple pipes at every single node. This ensures that water is supplied to any point through more than one pipe. The disadvantage of looped networks is the additional cost incurred in construction and maintenance of redundant pipes. Some water distribution networks may consist of the combination of these two networks.

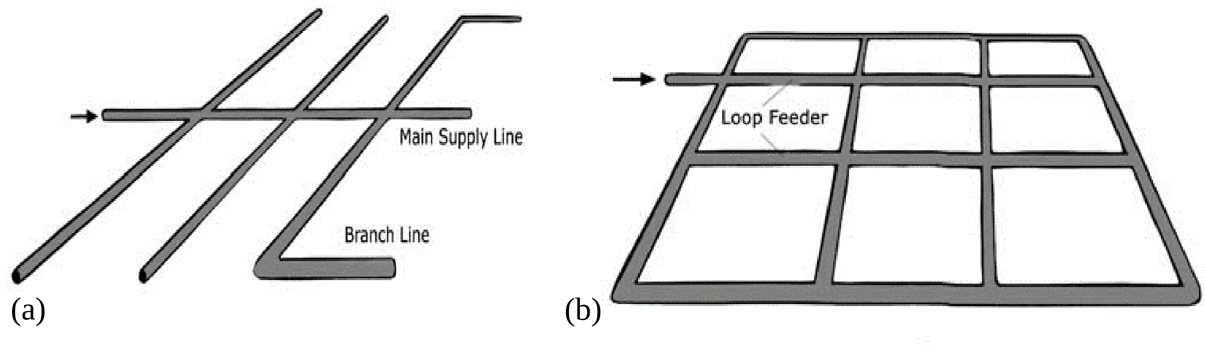


Fig 2.1: Water Distribution Network [3].

2.2.1 Non Revenue Water

Non-Revenue Water (NRW) is the difference between the amount of water put into the water distribution system and the amount of water that is billed to customers [4].

NRW = (Total Volume of Water Distributed) – (Total Volume of Water Billed to Customers)

NRW consists of three components which are:

- Physical (or real) losses
- Commercial (or apparent) losses
- Unbilled authorized consumption

Real losses are due to water leakages which occur in the distribution system. Apparent losses are caused by data handling errors in meter reading and water theft. NRW in Zimbabwe is 35-40% on average [5]. Although the evidence of NRW is overwhelmingly high, the actual figures are unknown largely because of lack of equipment required in adequate monitoring systems to assess water losses and record water utility performance. It is standard practice to split water losses as real and apparent losses when assessing losses in a water distribution system. Real losses are valued at marginal production cost of water whilst apparent losses are valued at the retail rate since its loss is after the customer's water meter.

2.2 Water Pipeline Infrastructure

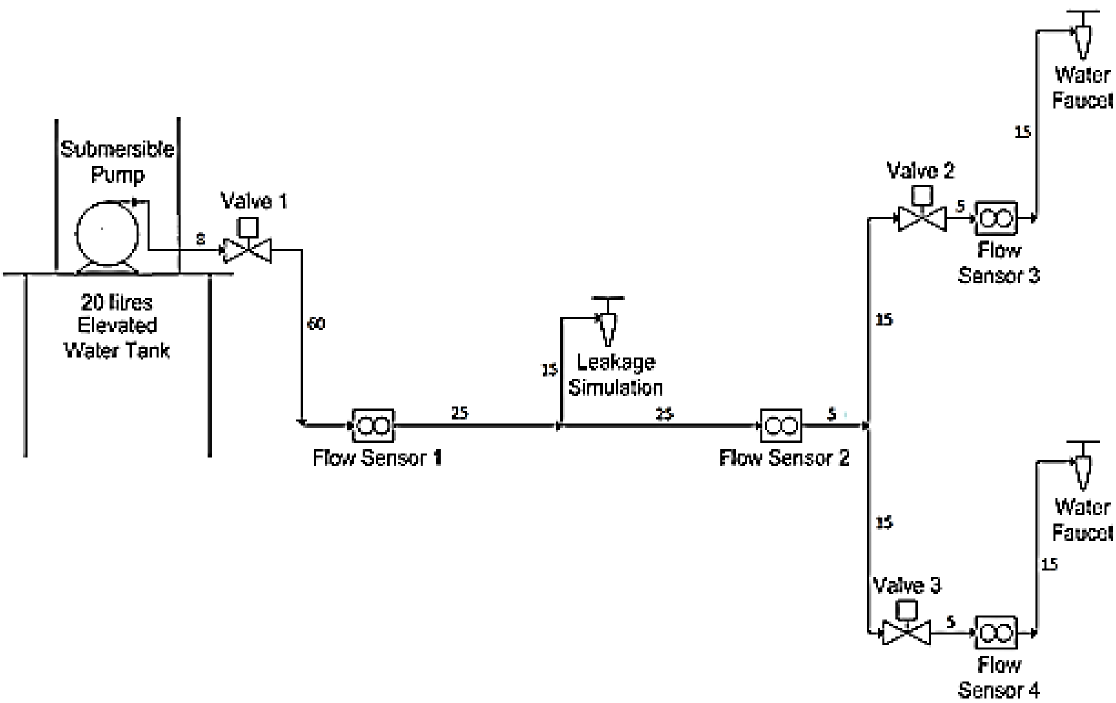


Fig 2.2: Water Distribution System [6].

The components which are used for the design of the prototype are:

- Water flow Sensor
- GSM modem
- Solenoid valve
- Water level indicator
- Water level sensor
- Water pump controlling system
- Programmable Logic Controller
- Arduino Uno

2.3 Solenoid valve

A solenoid valve is a combination of two basic functional units which are a solenoid (electromagnet) with its core and a valve body containing an orifice [7]. Liquid flow through the orifice is permitted or prevented by the motion of the core when the solenoid is energized or de-energized. Solenoid valves are normally closed, such that the orifice is shut (closed) when the solenoid is not energized and opens when the solenoid gets energized [8].

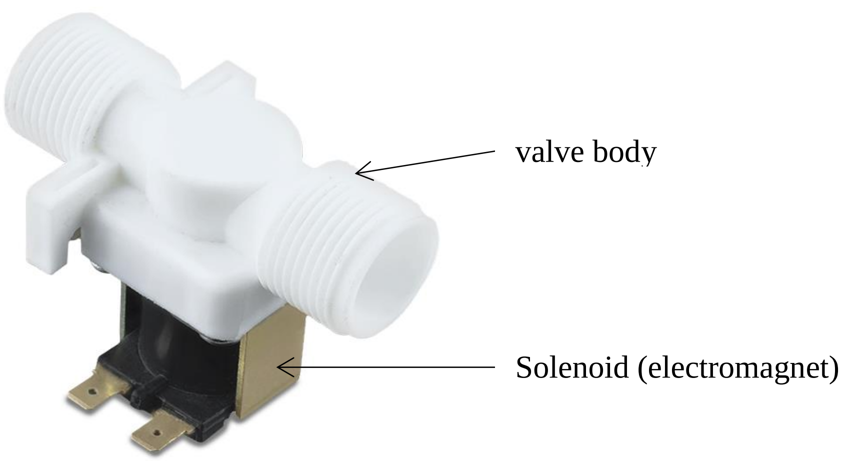


Fig 2.3: Solenoid valve [8].

The solenoid valve shown in figure 2.2 is electrically operated and can be used to control water supplies with pressure from 0.2 to 10 bars [9]. It can be operated at 12V or 24V DC voltage. When power is supplied, the valve will be opened and it is closed by removing power from its terminals. This solenoid valve was used in the project to open or terminate supply of water from the distribution tank, and also control the distribution of water to customer 1 and customer 2. A 12VDC supply was to be used to energize the coil of the valve.

2.4 Water flow sensor

The water flow sensor is a Hall Effect water flow sensor which consists of a plastic valve body, a water rotor, and a hall-effect sensor [10]. When water flows through the rotor, it rolls and its speed changes with different rate of flow. The hall-effect sensor outputs the corresponding pulse signal. The output high signal level is above 4.5V and the output low signal level is less than 0.5V.

Fig 2.4: Water flow sensor [10].

The flow sensor comes with three wires: red (5-24VDC power), black (ground) and yellow (Hall Effect pulse output). The motion of the liquid flow through the sensor can be determined by counting the pulses from the output of the sensor, each pulse is approximately 2.25 millilitres [11]. The flow sensor generates 450 pulses per litre. The main reasons for choosing the YF-S201 Hall Effect flow sensor is because of its ability to generate pulses that correspond to the water flow at different water flow velocities. It has an accuracy of +/-10% and can operate to a maximum water pressure of 2.0MPa.

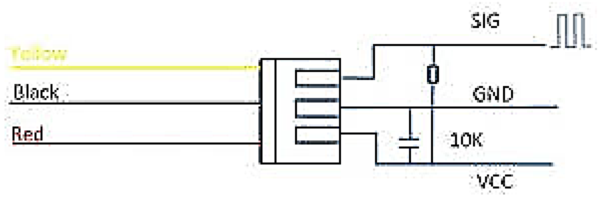


Fig 2.5: Flow sensor wiring [11].

Figure 2.5 shows the connections which are made to the flow sensor. The red wire is connected to +5VDC whilst the black wire is connected to the ground terminal of the power supply. A 10kΩ pull up resistor is connected between the red wire and the signal (yellow) wire in order to saturate the pulse signal between 5V and 0V.

The following equation was used in order to determine the volume of water which was passing through each flow sensor:

Volume through flow sensor = $\frac{\text{number of pulses produced by flow sensor}}{450}$ (litres) ………..(2.1)

2.5 Water level Sensor

To make special water level sensor we would like to introduce some convenient materials such as Iron rod, nozzles, resistance, rubber etc. A connecting rod made by iron and steel which should be connected with ground and we need at least four nozzles which should be connected with +5V via a 1kΩ resistance. We need to bind them together and put a rubber at their joint point which will act as an insulator for every nozzle. When the sensor touches water, nozzles and connecting rod get electric connection using water conductivity.

2.5.1 Water level Indicator

For water level indication unit we can use some LED light which will work for water level indication. By touching different water levels through water level sensor, LED should be indicated as on/off (i.e. on: yes sensor senses water).

2.5.2 Water pump controlling system

We can control the water pump by connecting it with an output pin of microcontroller via a motor driver circuit. When microcontroller sends a positive signal (+5v) or a ground signal

(0v) to the motor driver circuit, then the water pump become on or off respectively. We also would like to use a manual switch on the motor driver circuit which is supposed to use for controlling it manually. It makes this system more users friendly.

2.6 GSM Sim900 Module

To communicate to the system, for remote control, the user sends a short message service (SMS) to the GSM module which is part of the central system [12]. Figure 2.6 below shows a labelled picture of the GSM module used. This GSM Shield is compatible with all boards which have the same form factor (and pinout) as a standard Arduino Board. GSM module delivers GSM/GPRS 850/900/1800/1900MHz performance for voice, SMS, Data, and Fax in a small form factor.

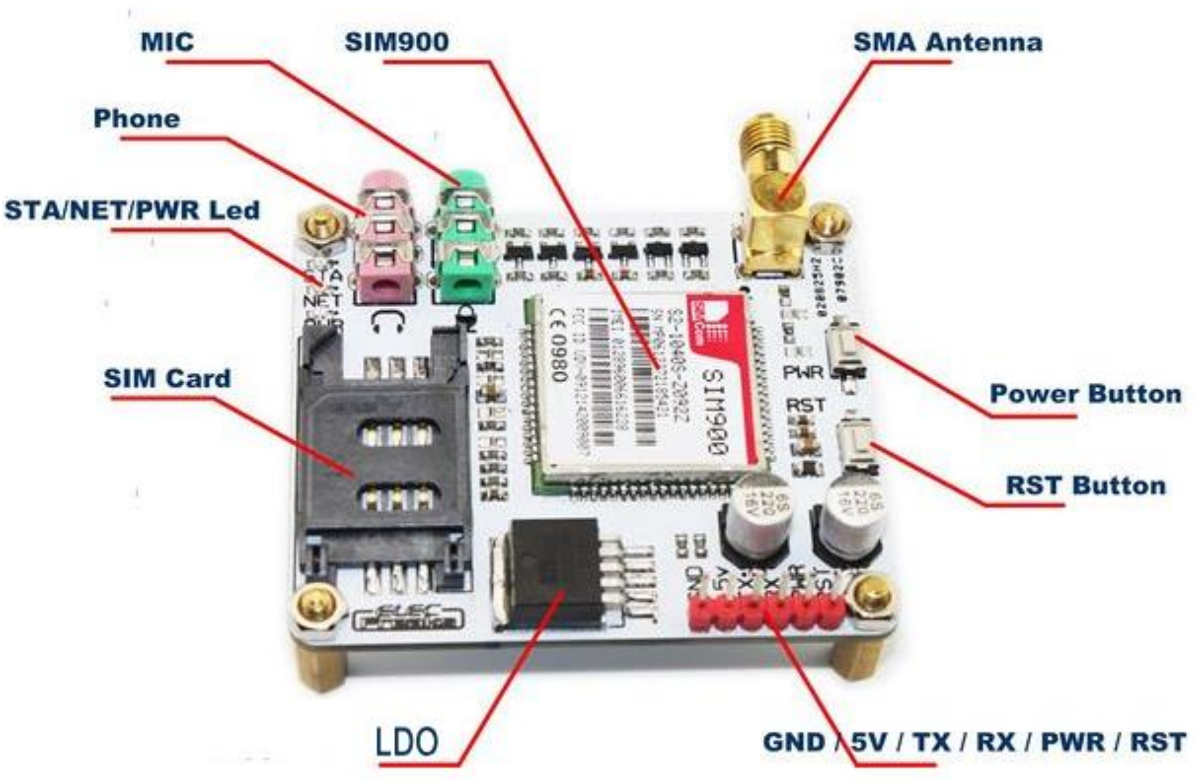


Fig 2.6: GSM Module [12]

As shown above, the module will hold a SIM card to which text messages are sent. It is also used by the system to send texts as feedback to the user.

The module's features include,

- Power Supply: +5V
- Fully compatible with Arduino
- Free serial port connecting, allows user to select Hardware/Software Serial port control
- EFCom not only can use the button for power on, but also can use the digital pin of Arduino to power on and reset the SIM900 module.
- Quad-Band 850/ 900/ 1800/ 1900 MHz
- Low power consumption: 1.5mA(sleep mode)
- Operation temperature: -40°C to +85 °C
- Dimension: 60mm x 53mm

2.6.1: Configuring GSM Module

The GSM is configured and controlled via its UART using simple AT commands. AT Commands are simple textual commands sent to the GSM modem over its serial interface (UART) [13]. The following steps were taken in the initial configuration of the module:

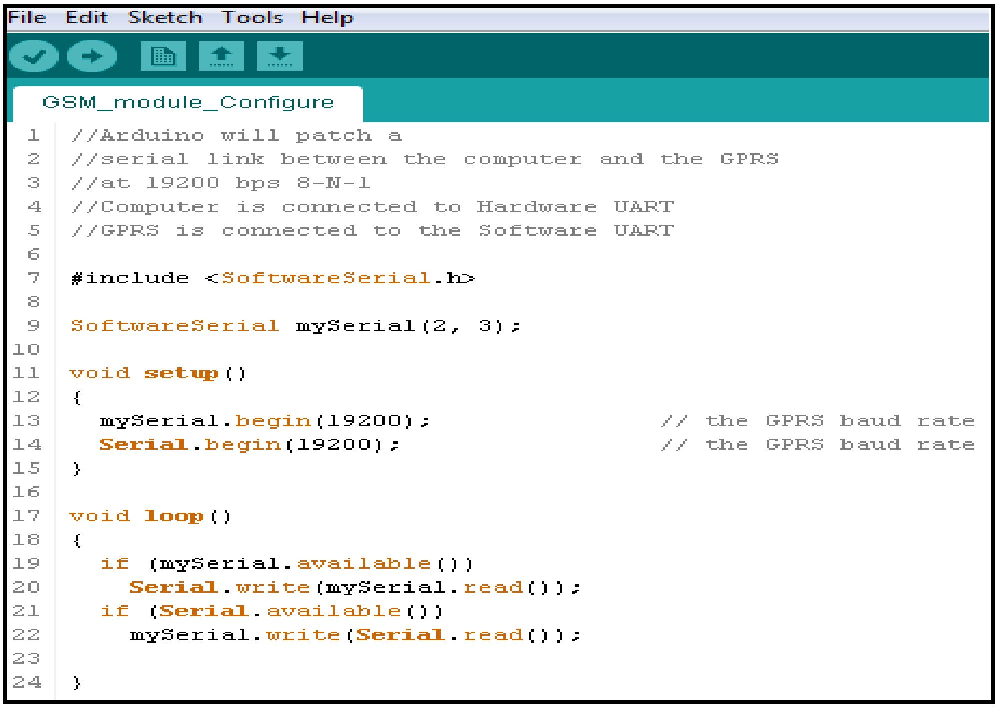
1. Installed the SIM card in the GSM module.

2. Connected the antenna to the module.

3. Connected the module to the Arduino board. Mounted the GSM_TX & GSM_RX jumpers on the module in SW Serial position - that is connected the GSM_TX to D2 (RX) and GSM_RX to D3 (TX) [13].

4. Connected the Arduino to the computer using a USB cable.

The ATmega328P microcontroller on Arduino Uno board has only one UART which is used for communicating with the personal computer (PC). An Arduino Sketch (software written using Arduino are called sketches) running inside the ATmega328P is required to emulate a second serial port (UART) using software on the digital pins D2 and D3 of the Arduino board and patch through all the communication between this second software serial port and the actual hardware serial port. An on-chip TIMER of ATmega328P in interrupt mode is used to emulate the second serial port. By doing this, all the data coming from the computer (connected to the actual hardware UART) would be relayed as is to the GPRS (connected to software UART) and we would be able to issue AT commands to control the GPRS.




```
//Arduino will patch a
//serial link between the computer and the GPRS
//at 19200 bps 8-N-1
//Computer is connected to Hardware UART
//GPRS is connected to the Software UART

#include <SoftwareSerial.h>

SoftwareSerial mySerial(2, 3);

void setup()
{
  mySerial.begin(19200);               // the GPRS baud rate
  Serial.begin(19200);                 // the GPRS baud rate
}

void loop()
{
  if (mySerial.available())
    Serial.write(mySerial.read());
  if (Serial.available())
    mySerial.write(Serial.read());

}
```

Fig 2.7: Arduino sketch for serial port emulation

To finish off the configuration, the final step was to change the factory setting for baud rate for the GSM module by sending the command, "AT+IPR=9600" in the Arduino serial monitor. This command sets the baud rate to 9600, the baud rate chosen for this project.

Lastly the command "AT" was sent. The GPRS responded by sending back an "OK". This meant that the GPRS/GSM module had been successfully configured.

The EFcom GSM module only support VCC/+5V Power supply. Because of the power supply range of SIM900 transmitting burst will cause voltage drop and the power supply must be able to provide sufficient current up to 2A.

2.7 Arduino Uno Board

The Arduino Uno is a microcontroller board based on the ATmega328 [14]. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button [14]. It contains everything needed to support the microcontroller, all that is needed is simply to connect it to a computer with a USB cable or power it with an A.C-to-D.C adapter or battery.

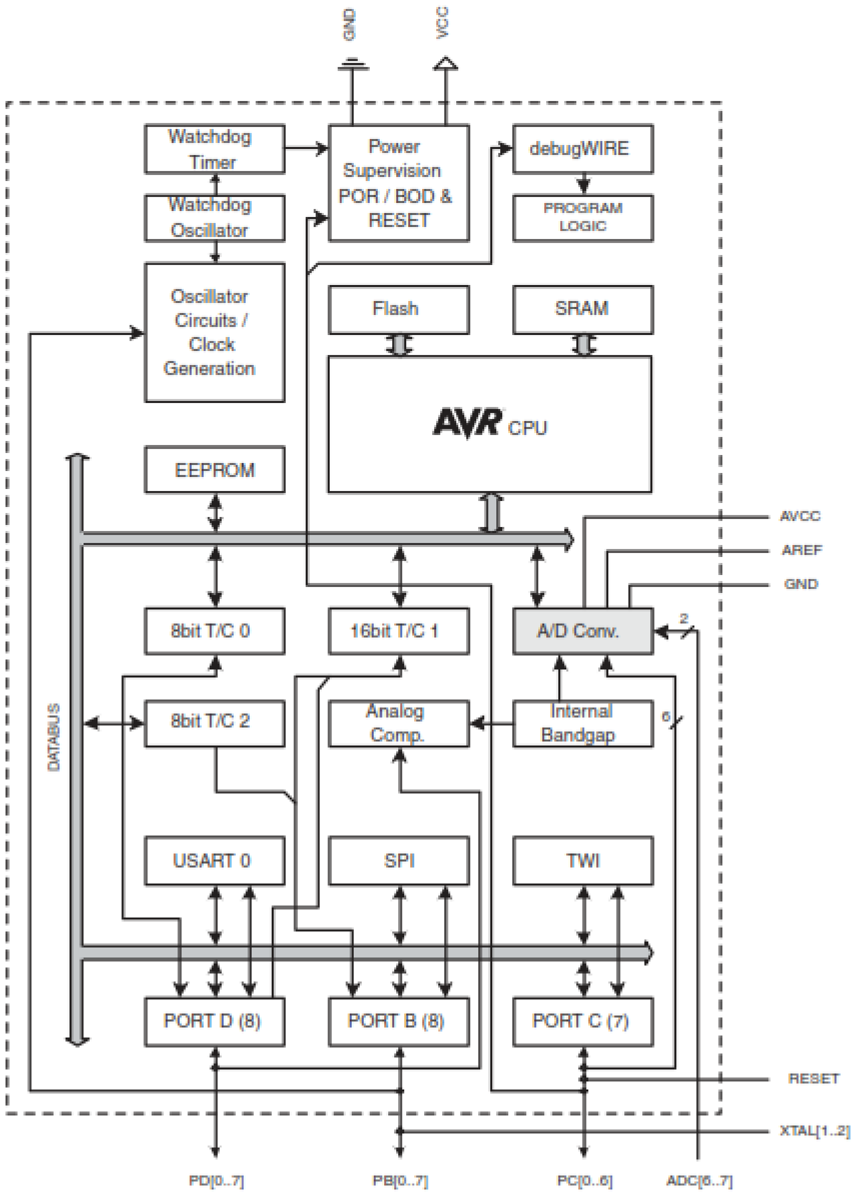


Fig 2.8: Block diagram of the Atmega 328 Microcontroller [15].

This configuration is quite ideal for prototyping as there is no tiresome wiring needed to power the ATMEGA 328 and hook up external resonators. Another added advantage is that there is no need for an external programmer as is in the case of other micro-controllers of the PIC16FXXXX type. With the ARDUINO a program can simply be uploaded from the development environment via a provided USB cable.

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

Fig 2.9: Arduino bottom and top view [15].

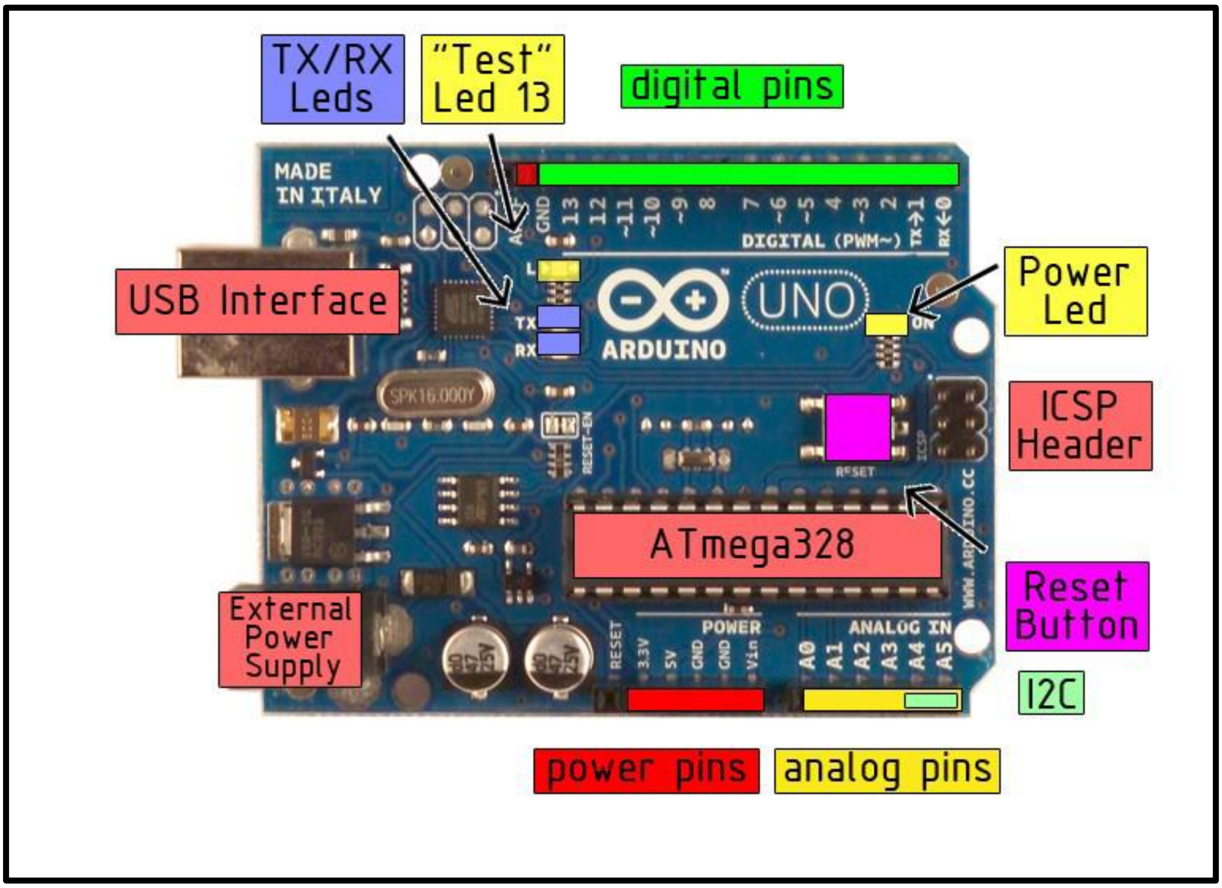


Fig 2.10: Arduino Board Pin Layout [15].

Table 2.1 Features of the Arduino Uno

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by boot loader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

2.7.1 Power

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the GND and VIN pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

2.7.2 Memory

The ATmega328 has 32 KB (with 0.5 KB used for the boot loader). It also has 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).

2.7.3 Input and output

Each of the 14 digital pins on the Uno can be used as an input or output, using pin Mode(),digital Write(), and digital Read() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kilo Ohms.

2.7.4 Communication

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer.

The '16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, an .inf file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A Software Serial library allows for serial communication on any of the Uno's digital pins.
The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus.
Reasons for selecting the Arduino.

- The Arduino can be powered by USB or an external power supply.
- The ATMEGA has 32KB of memory, 2KB SRAM and 1KB EEPROM.

- The ATMEGA328 provides UART TTL (5V) serial communication.
- The serial communication over USB appears as a virtual com port to software on the PC.
- The Arduino development is based on C programming making it easy to work with.
- Features automatic software reset capabilities.
- Incorporates USB overcurrent protection.
- Each of the 14 digital pins can be used for input and output.
- The development environment is derived from processing developed by CASEY REAS and BEN FRY, this makes it easy when working with graphic user interfaces.

2.8 Relay

A relay is an electromagnetic switch operated by a relatively small electric current that can turn on or off a much larger electric current [16]. The heart of a relay is an electromagnet (a coil of wire that becomes a temporary magnet when electricity flows through it).

Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal [17]. Many sensors or microcontrollers are incredibly sensitive pieces of electronic equipment and produce only small electric currents. They are often required to drive bigger pieces of apparatus that use bigger currents. Thus relays bridge the gap, making it possible for small currents to activate larger ones.

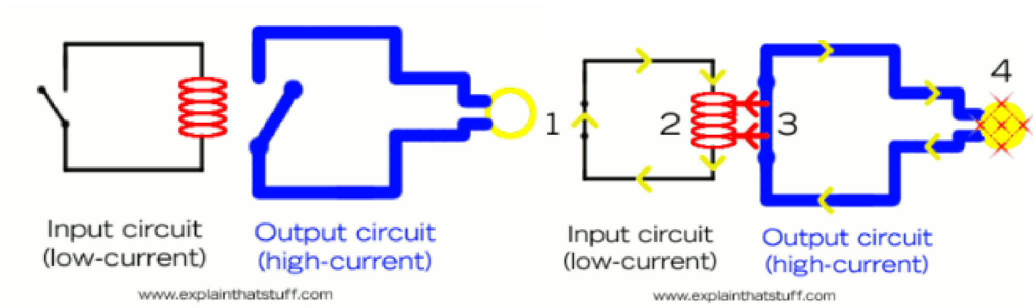


Fig 2.11: Operation of a relay [17].

Figure 2.11 shows a relay acting as an open switch and acting as a closed switch. When the switch is closed a light is switched on at point 4. The end part of the Remote Control System is the interface between relays.

For easy handling, a 5V 4-Channel Relay module, shown below, was used in this project. It is controlled directly the Arduino. Each 5V Relay needs 20mA driving current. It has LED indication for each Relay's Status.

Fig 2.12: 5V 4-Channel Relay Module [17].

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CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will give a detailed analysis of each of the subsystem that leads to the proper functioning of the prototype. It gives an account on the design of all the subsystems and how these components are interfaced with each other that are the central processing unit, the software that was used in the project and how the system was properly implemented, a flow chart showing the execution of the program and also the block diagram of the overall system.

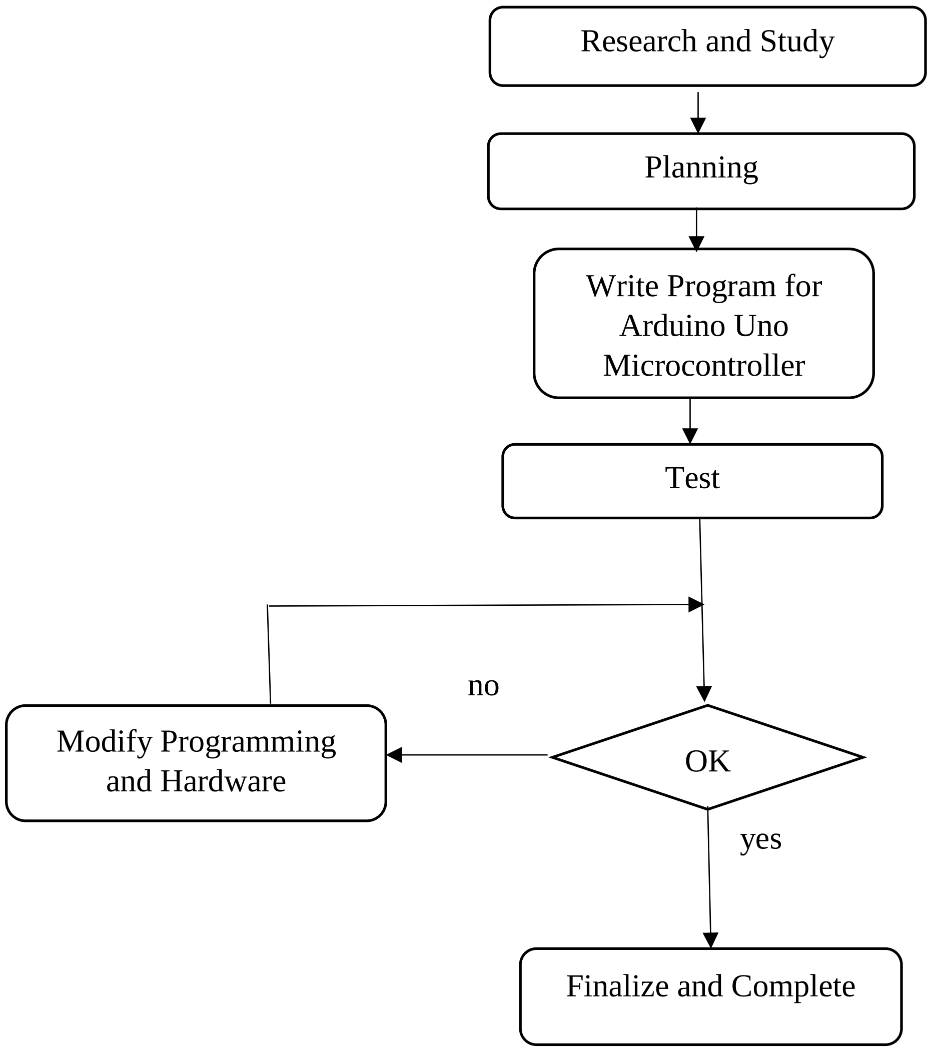

Fig 3.1: Diagram showing project flow chart.

3.2 Structure of the overall system

The overall system consists of the following hardware components

i. GSM Modem
ii. Water flow sensor
iii. Solenoid valve
iv. Water level sensor
v. Arduino Uno Board
vi. Water pump

The Arduino Uno Microcontroller is the central processing unit which is responsible for controlling all the processes and is interfaced with three main subsystems which include:

- **The Sensing Unit**- consist of the YF-S210 water flow sensor which monitors the water flow rate and provides output in the form of pulses. The Arduino Uno Microcontroller has an inbuilt analogue to digital convertor which does the signal conditioning of electric signals received before they are processed by the controller.
- **Communication and Data Display Unit**- consists of the GSM/GPRS modem which accepts data from the microcontroller and send it to a specified number on the GSM network.
- **Control Unit**- consists of a DC water pump motor which drives the flow of water and a solenoid valve which controls the flow of water.

These sensors systems are all interfaced with the microcontroller which acts as the central processing unit. The microcontroller is then interfaced with the controlling devices which perform the intended actuation. The structure of the system is as shown below.

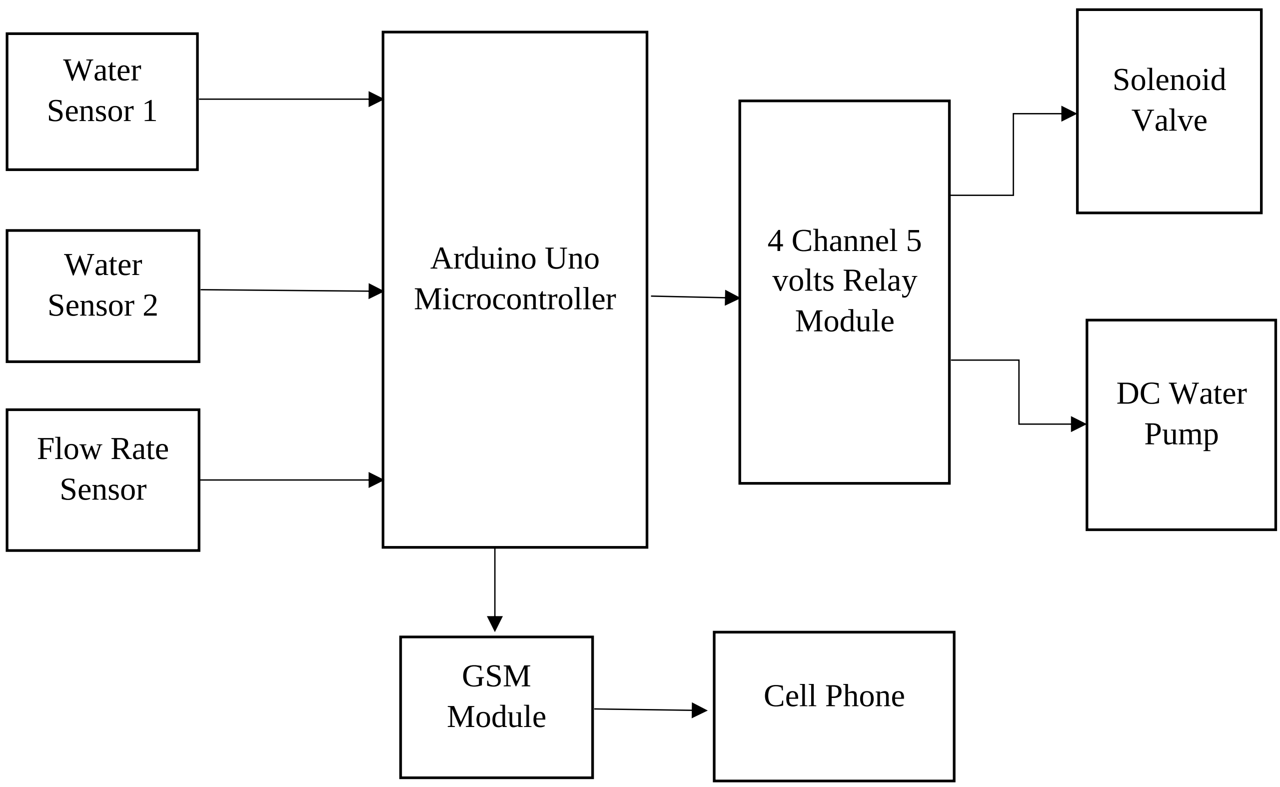

Fig 3.2: Block Diagram of Water Monitoring and Control System

Figure 3.2 shows the control system block diagram responsible for controlling the process. All field sensors and actuators (flow sensors and solenoid valves) are interfaced to a central processing unit (Arduino Uno). Flow Sensor 1 is used to determine the volume of water supplied into the water distribution network from the distribution tank. Flow Sensor 2 is used to determine pipe flow volume in order to determine the differential volume flow from Flow Sensor 1, so as to calculate water loss via leakages.

3.3 System Operation

The project works in a condition of low water level and water level sensor detect the amount of water and then sends a signal to microcontroller unit. The microcontroller circuit send a signal to the DC pump and solenoid valve for driving the flow of water as well as opening and closing of the valve.

3.4 Hardware Implementation

A breadboard is used to make up temporary circuits for testing in the hardware implantation part [1]. No soldering is required, so it easy to change connections and replace components. The breadboard is made up of many strips of metal (copper usually) which run underneath the board, which also connect the holes on top of the board.

3.4.1 Interfacing GSM/GPRS with Arduino

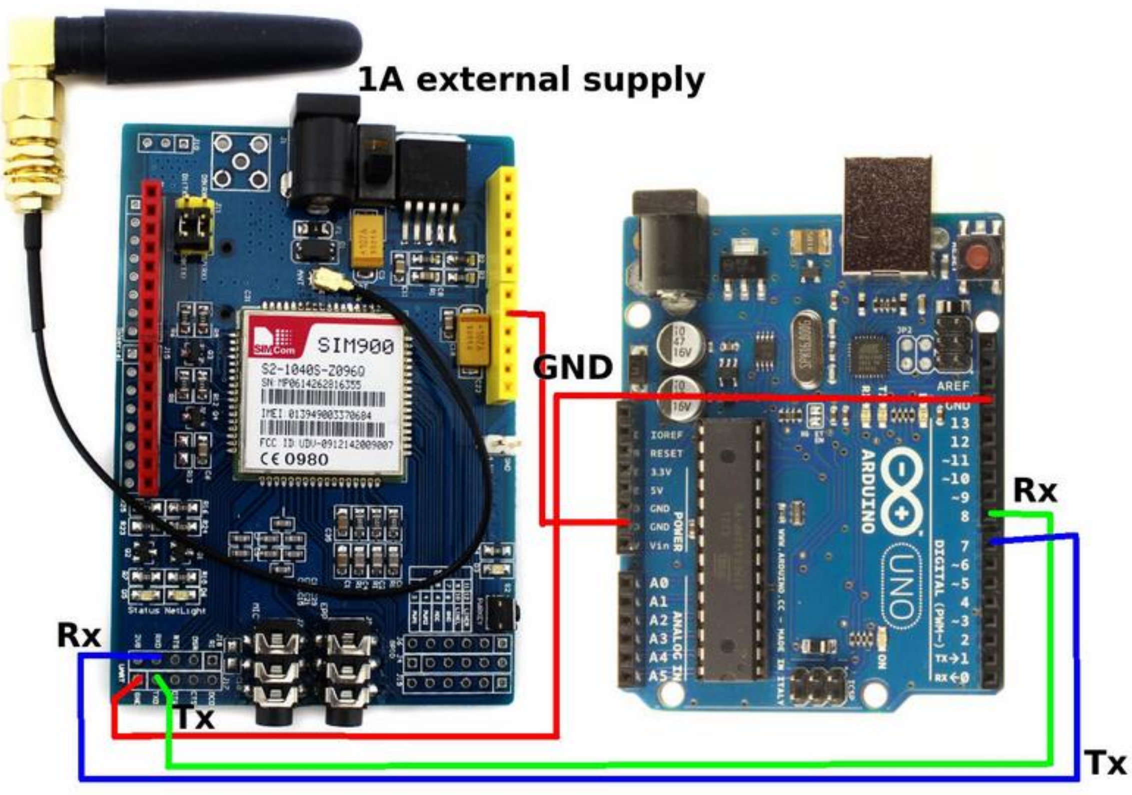

Fig 3.3: Arduino and GSM modem connections [2].

The GSM modem is used in the data communication unit in this prototype to send notifications in form of SMS to the specific numbers using GSM network. The GSM is used to monitor flow rate of water wireless. The following steps are used to connect GSM and Arduino:

- Insert the SIM in the plastic holder so that the metal contacts are facing the shield, with the notch of the card at the top of the bracket.
- Slide the SIM all the way into the bracket
- Push the SIM to the board and slide the metal bracket towards the edge of the shield to lock it in place.
- Once the SIM is inserted, mount it on top of an Arduino board.
- To upload sketches to the board, connect it to your computer with a USB cable and upload your sketch with the Arduino IDE. Once the sketch has been uploaded, you can disconnect the board from your computer and power it with an external power supply
- Digital pins 2, 3 and 7 are reserved for communication between the Arduino and modem and cannot be used for sketches. Communication between the modem and Arduino is handled by the Software Serial library on pins 2 and 3. Pin 7 is used for the modem reset.
- Developer versions of the GSM shield required you to press the Power button on the shield for a few moments to turn the modem on.

3.4.2 How to interface water flow sensor with Arduino Uno

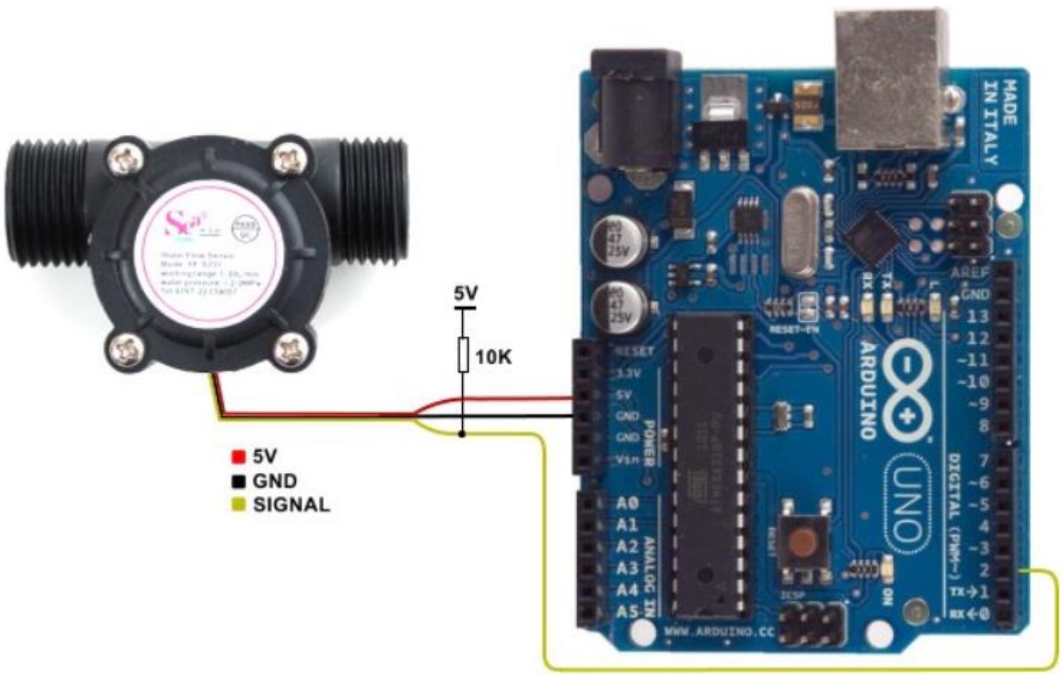

Fig 3.4: Connection of flow sensor and Arduino [3].

The flow rate sensor have three wires connected to the Arduino Uno which are the 5V Vcc (Red Wire), the Gnd (Black Wire) and the signal/pulse (Yellow Wire). Black wire of the flow rate sensor is connected to Arduino’s ground pin and red to the Arduino’s 5V pin. The yellow wire will need to be connected to a 10k pull up resistor and then to Arduino digital pin 2.

3.4.3 Theoretical aspects behind the water flow sensor

The YF-S210 water flow sensor is a Hall Effect water flow sensor which consists of a plastic valve body, a water rotor, and a hall-effect sensor. When water flows through the rotor, it rolls and its speed changes with different rate of flow [4]. The hall-effect sensor outputs the corresponding pulse signal. The output high signal level is above 4.5V and the output low signal level is less than 0.5V. The motion of the liquid flow through the sensor can be determined by counting the pulses from the output of the sensor: each pulse is approximately 2.25 milliliters.

3.4.4 How to interface a LED with Arduino Uno

In order to connect a light emitting diode (led) to an arduino board the components required are resistor, led, connecting wires and an arduino board. A resistor is used to limit the amount of current that passes through the led. A button can be used to turn on and off the led.

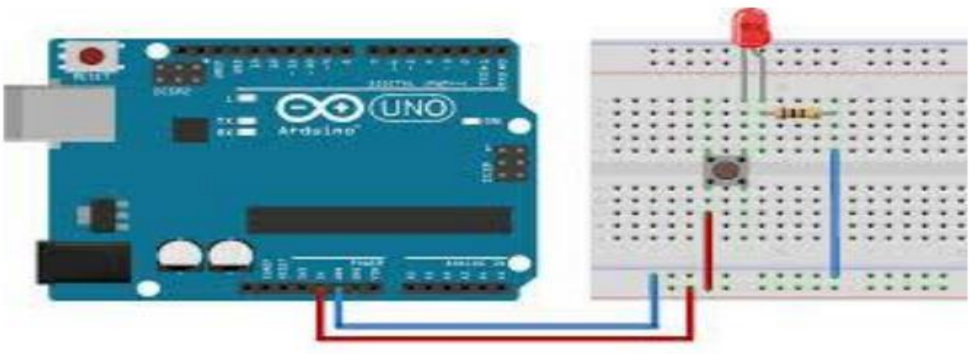

Fig 3.5: Connections between Arduino and LED [5].

3.4.5 Interfacing Water Sensor with Arduino

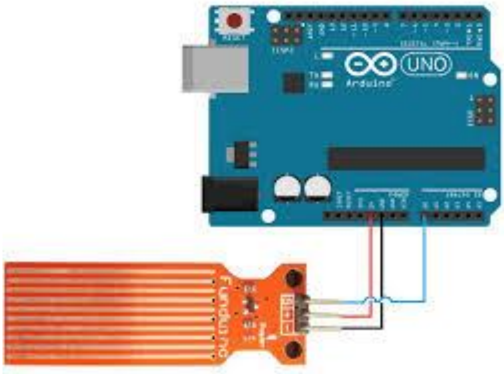

Fig 3.6: Water Sensor and Arduino Uno connection.

The Funduino water sensor is interfaced with the Arduino Uno microcontroller using the following steps:

- The signal pin of the sensor is connected Analog 0 or A0 of the Arduino Board.
- The Vcc (+) pin of the of the water sensor is connected to +5v of the breadboard.
- The GND (-) pin of the water sensor is connected to GND of the breadboard.

The Arduino board is connected to the computer using a USB cable and a programme code is uploaded on the Arduino board and water level is displayed on the serial monitor.

3.4.6 Interfacing Relay Module with Arduino Board

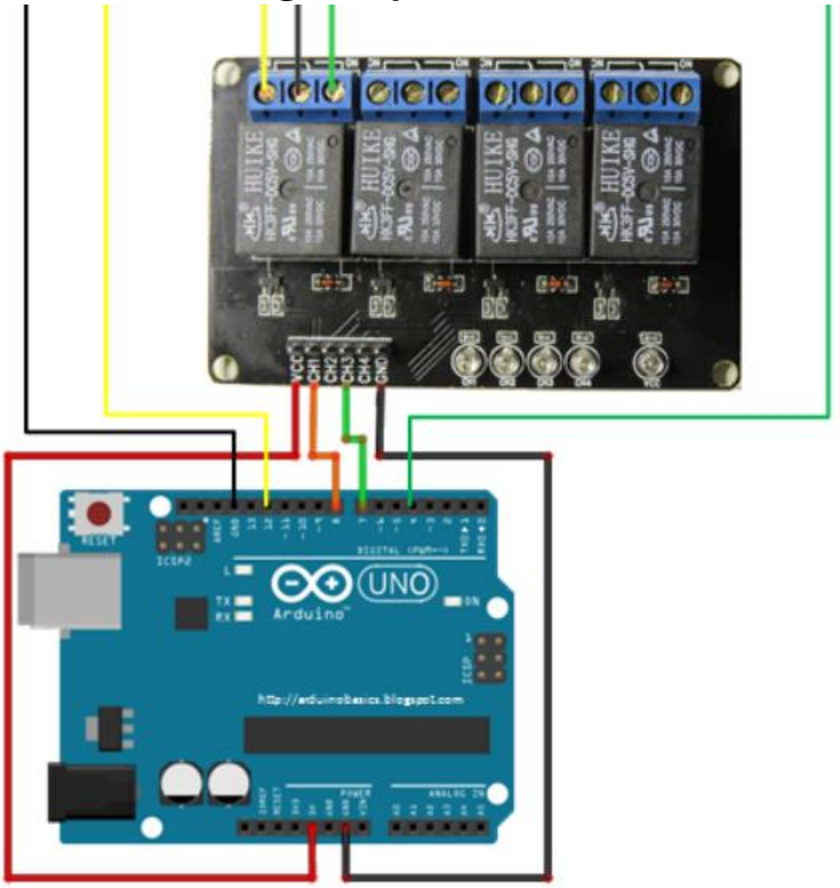

Fig 3.7: Relay and Arduino connections.

Table 3.2: Connection between Arduino and Relay

Arduino Uno	Breadboard	Relay Module
5V		Vcc
GND		GND
Digital Pin 6		CH1
Digital Pin 7		CH2
GND		Common Terminal

3.5 Software development

3.5.1 Arduino Integrated Development Environment (IDE)

For programming, the Arduino integrated development environment (IDE) platform was used. The application was written in Java. It supports C and C++ programming languages. The Arduino IDE includes a code editor with features such as syntax highlighting, brace matching, and automatic indentation, and is also capable of compiling and uploading programs to the microcontroller with a single click. By using the Arduino Integrated Development Environment (IDE) software, the instructions of how water monitoring and control system should be run were coded before it can be can be loaded into the microcontroller. As an open source, the software is easily available for the system development purpose. The figure 3.9 below showed the interface of the Arduino IDE and it is able to highlight the syntax, compiling and loading the program into the Arduino Uno easily.

The Arduino Uno was programmed by setting up the all the pins needed to be read and to be controlled. Three digital pins are set as the outputs for controlling the DC pump, solenoid valve and GSM module. The sensors are connected to the two analog pins that are available.

Once all the pins are set, the Arduino Uno will be coded to run the algorithm. Firstly, the microcontroller will read the analog input from the sensors. All the sensors are representing the water level and the result will be analysed. The pump execution times were calculated based on the water level on the tank.

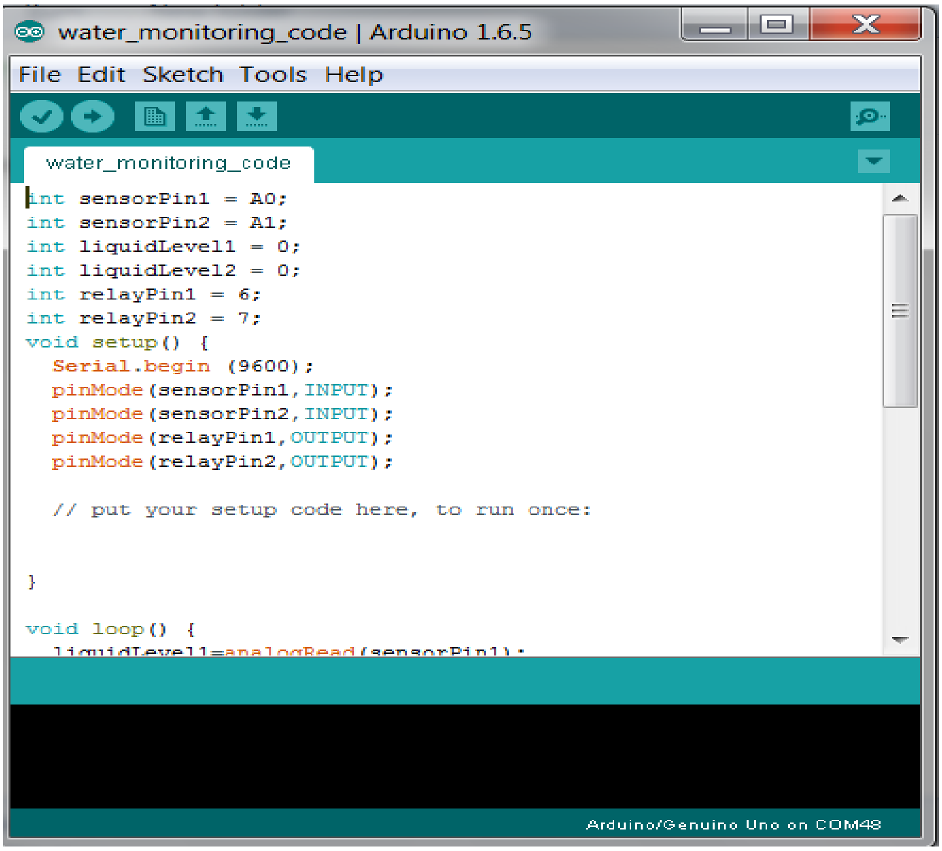

Fig 3.8: Arduino IDE

3.6 System flow chart

The system flow chart shows how the prototype will work with other systems joined together. It also shows how the execution of the code or instructions and flow of data is going to be done in connecting the sub systems and how they work together as one complete system. The data flow of the system is shown on the flow chart below:

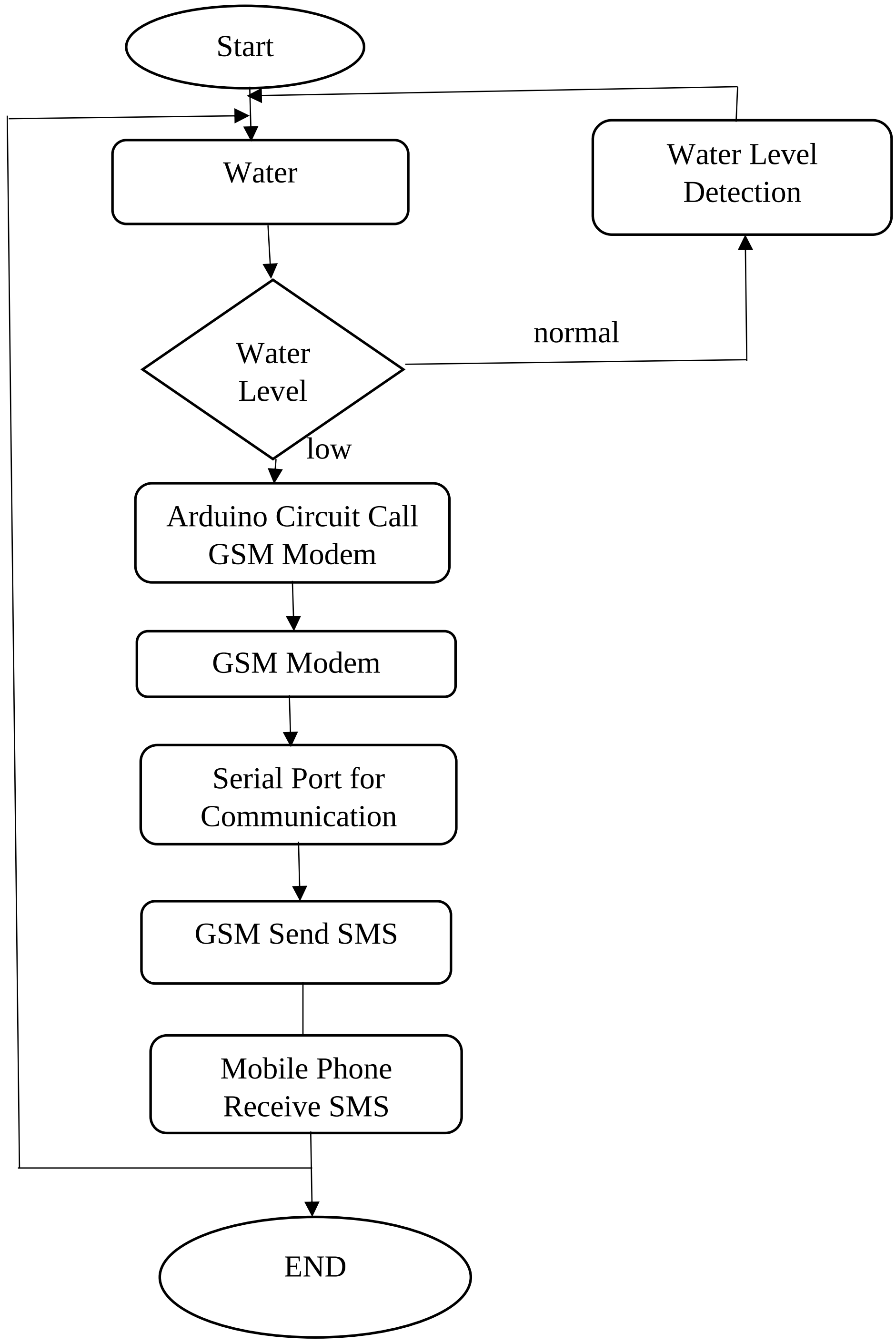

Fig 3.9: System Flow Chart.

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CHAPTER 4

RESULTS AND ANALYSIS

4.1 Introduction

The prototype was successfully designed and build as per initial work plan and this chapter gives presentation and real analysis of the results obtained from the designing of the prototype. An experiment was carried out to practically investigate the behaviour of water flow rate as a function of pressure and water flow rate as a function of length of water pipe / tube. The results of water level sensor output voltage in variation with water level changes was also noted down.

4.2 Presentations of Results

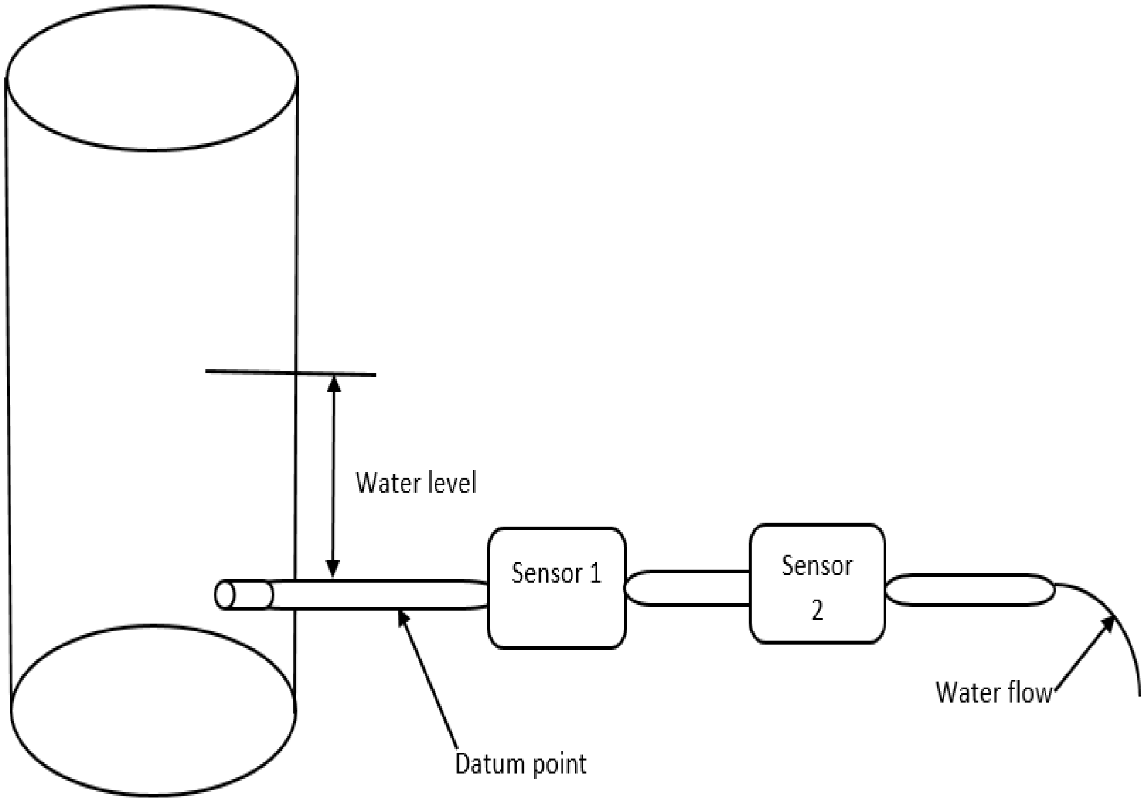

Fig 4.1: Water measurement diagram.

Table 4.1: Table of results showing the water level sensor output voltage and the corresponding water level in the in the tank.

Output Voltage (V)	Water Level (ml)
0.64	131
0.93	203
1.43	295
2.01	417
2.29	463
2.67	543
2.87	587

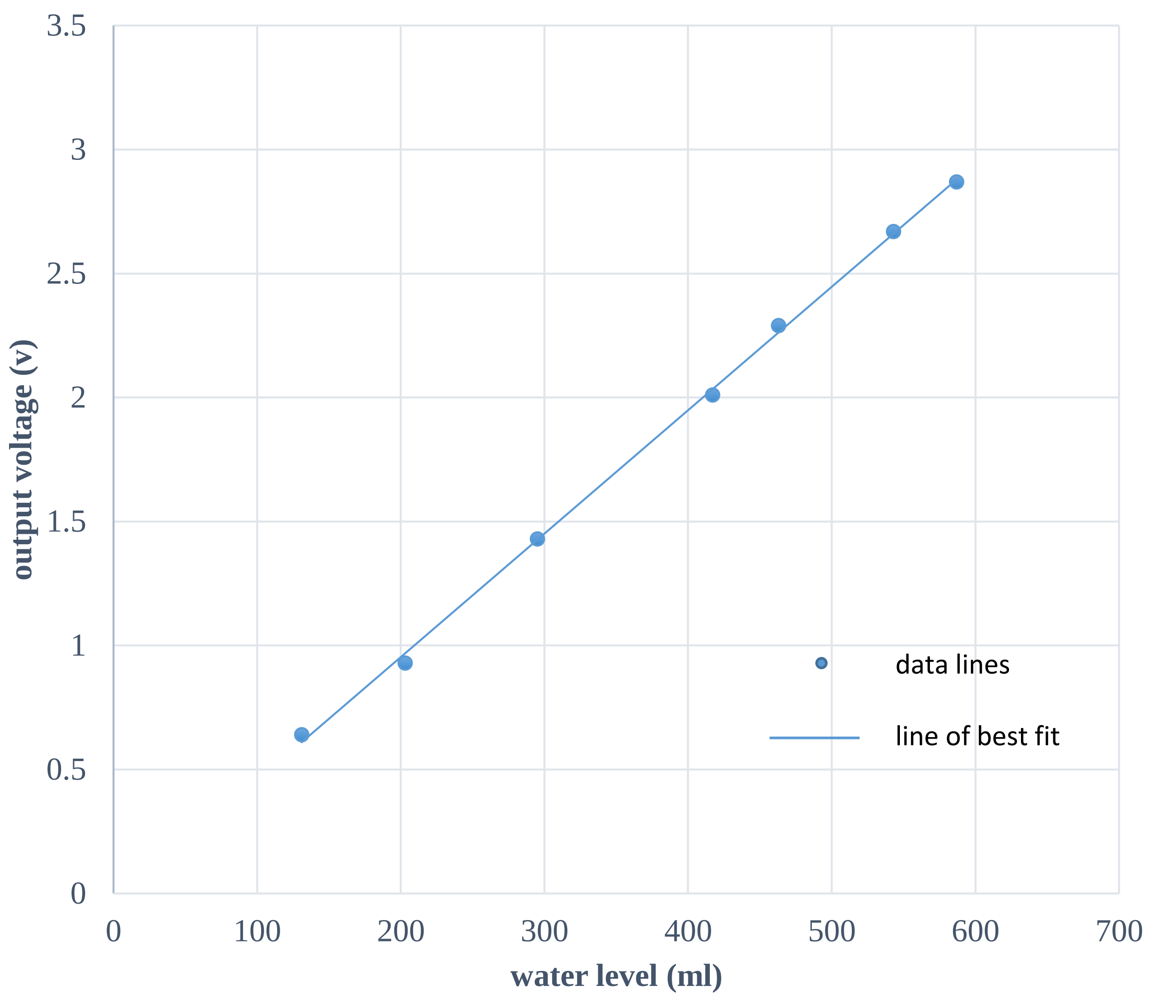

Fig 4.2: Diagram showing a graph of output voltage against the corresponding water level showing the variation of output voltage with increasing water level.

Table 4.2: Table of results showing the water flow rate and the corresponding pressure.

Flow rate (L/min)	Pressure (Pa)
35	25
83	50
100	75
150	100
175	125
210	150
256	175
280	200

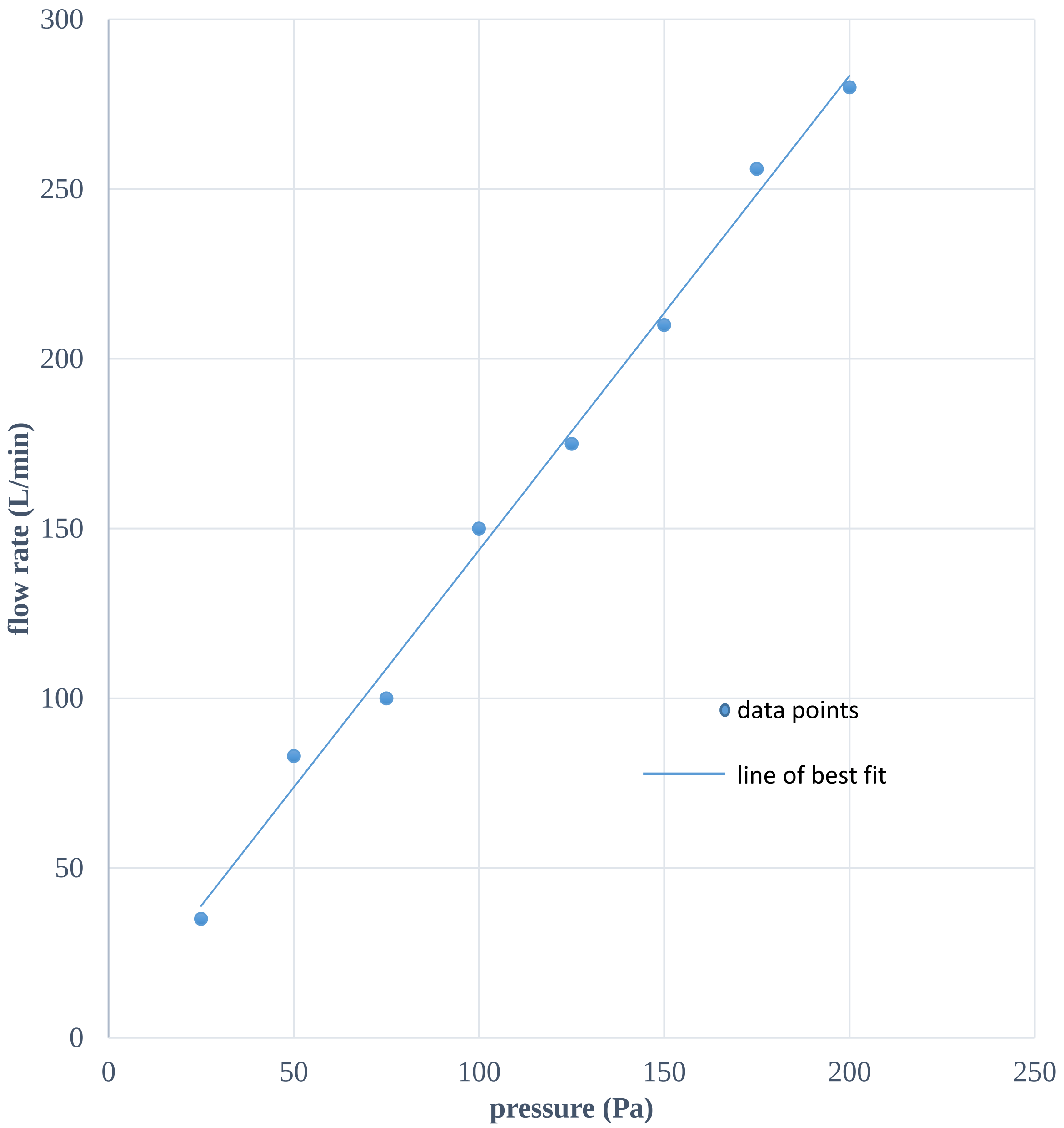

Fig 4.2: Diagram showing a graph of water flow rate and the corresponding water pressure in the tank.

Table 4.3: Table of results showing the water flow rate and the corresponding pressure.

Flow rate (L/min)	Tube length (cm)
320	10
263	18
189	25
140	40
110	50
80	60
67	70
40	80
27	90
24	100
20	120

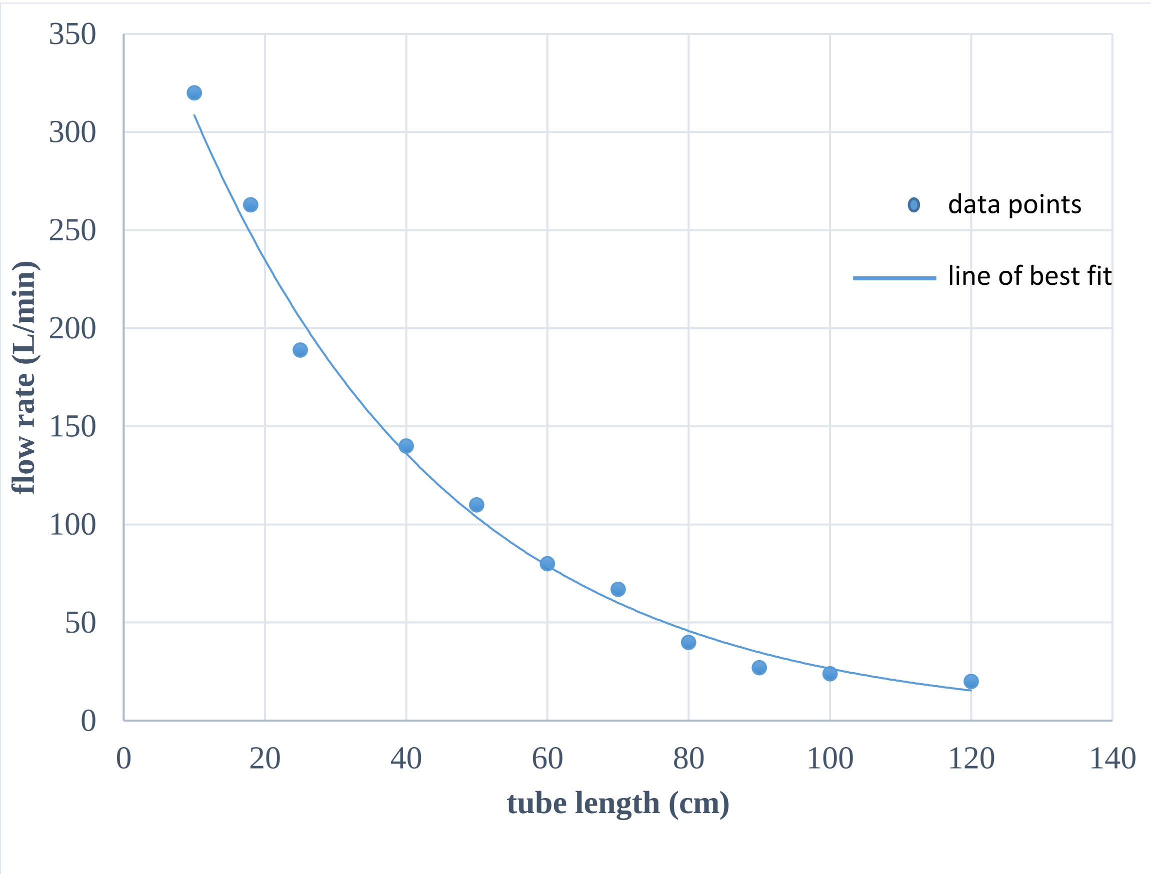

Fig 4.3: Diagram showing a graph of water flow rate and the corresponding tube length.

4.3 Results, Analysis and Interpretation

Fig 4.1 shows the variation of output voltage of the water sensor with increasing water level in the tank. The output voltage of the Integrated Circuit varies linearly with increasing water level. The maximum output voltage of the water level sensor is 3.5V and the minimum output is 0.0V.

Fig 4.2 shows the relationship between water flow rate and the corresponding pressure inside the tank. As the pressure increases output flow rate also increases linearly. The linear relationship is an indication that the designed sensor is reliable.

Graph 4.3 shows the relationship between the flow rate and the corresponding length of the tube or pipe. As the length of the pipe increases the flow rate decreases.

4.4 Software Development

The software of the prototype Arduino C was successfully implemented and was uploaded on Arduino Uno microcontroller. The hardware components responded well with code snippets and statements. The digital pin 13 of the Arduino board was set to be LOW when the flow rate reaches a value of less than 80 L/hr and turn the solenoid valve OFF. The pin was also set to be HIGH when the flow rate was above 280 L/hr and turn the solenoid valve ON. The figure below shows serial monitor displaying the rate of flow using the Arduino Uno Integrated Development Environment (IDE) when the code was uploaded.

4.5 Prototype Overview

The prototype was successfully designed and built within the planned time frame. The hardware components were successfully integrated into one complete working system and responded well to programming codes from the Arduino Uno software. The developed system has four inputs and four outputs. The inputs are analog while the outputs are digital. At the input side there are sensors these are connected to input of the analog pins of the Arduino Uno board which has fixed memory address, and it reads the status of respective sensor by reading input memory bit during every scan cycle. At the output side there are four outputs. All the outputs are connected to digital pins of the Arduino Uno board and assigned to fixed memory address. Output status is displayed on the GSM at these address points.

The prototype automation system started working by immersing the water level sensors in water. The DC pump is always ON pumping water into the tank, when the water level is below a critical point the distribution valve is closed and is open when the water rises to a certain water level point. If the water level is normal the distribution valve is opened automatically and the water is supplied to the end users. To identify the excess flow of water and any leakages in the pipes we used a flow rate meter.

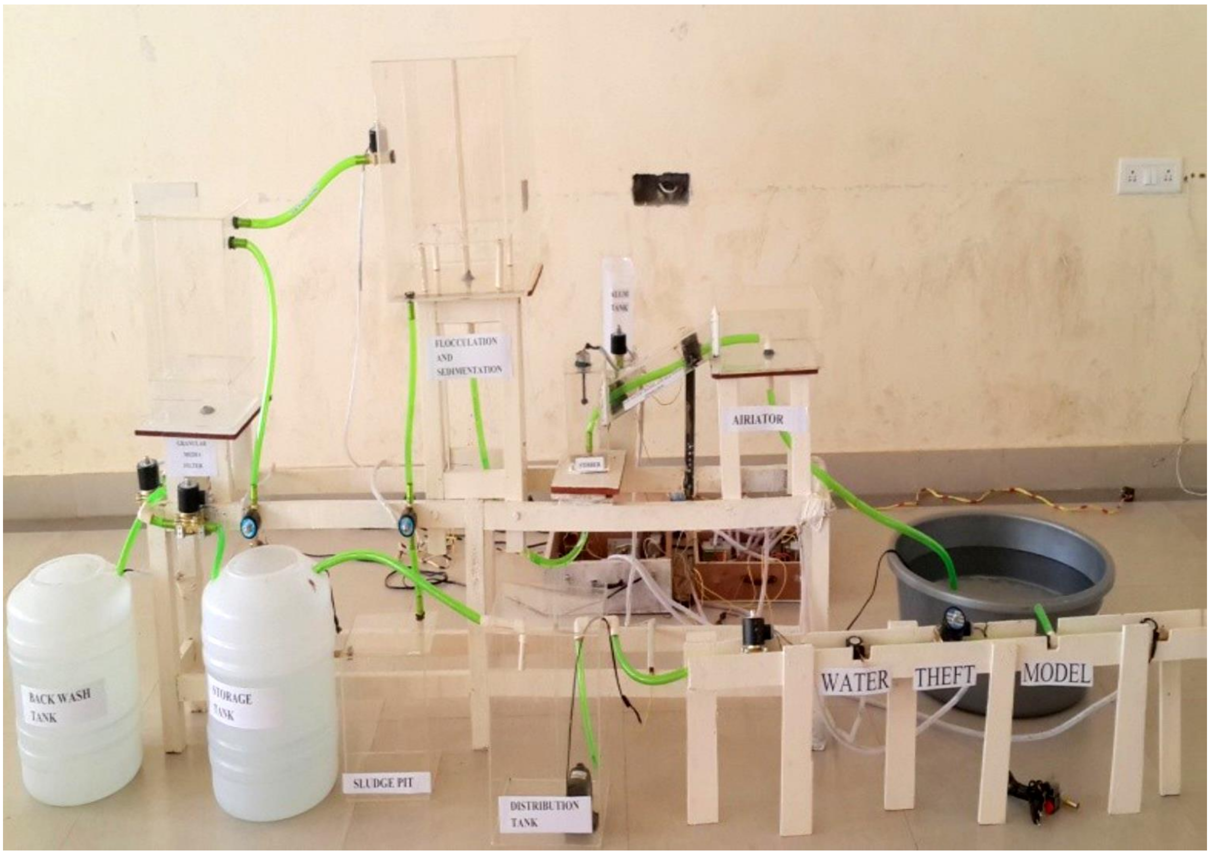

Fig 4.4: Shows the prototype overview

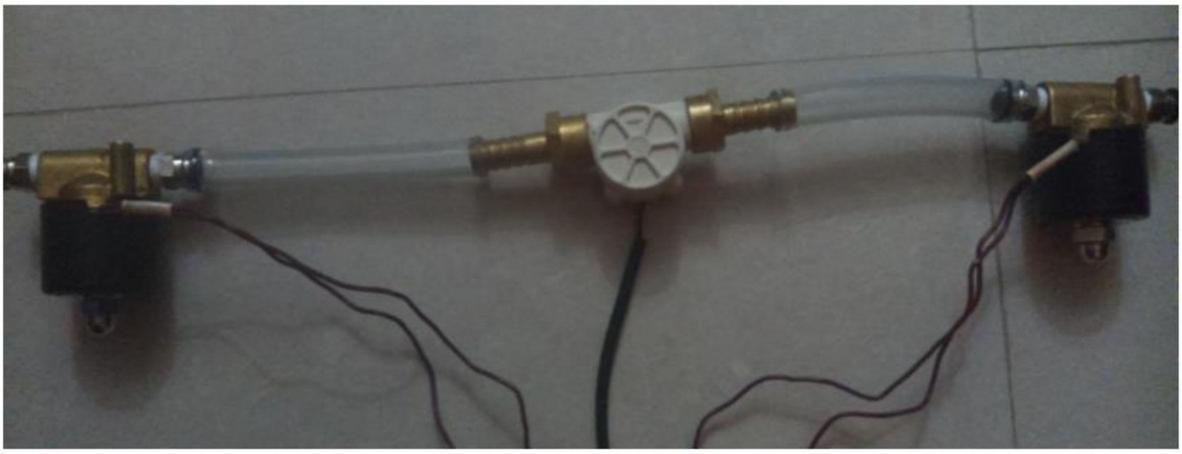

Fig 4.5: Shows water distribution pipe with valves and flow rate sensor.

CHAPTER 5

CONCLUSION

5.1 Introduction

The prototype which monitors and controls the water level in a distribution tank and flow rate in the transmission pipe using GSM network was successfully built. The hardware components were successfully integrated into a complete working system and operated well with the software.

5.2 Discussion

Water distribution monitoring and control system will help in reducing the water wastage as well as overflow. Furthermore it can indicate the amount of water in the storage tank, give information about the distribution process, display data about the process and also transmit alarm and warning remotely using communication device. Whereby using the current system at water authority, all the processes are done manually and need human assistance. The prototype also measures the flow rates at the distribution pipes. On the other hand the end users are using suction pumps to suck the water directly from the home street pipelining which results in decrease in water pressure. This almost amounts to the water theft and this can be monitored through the variations in the flow given by the sensors mounted on the distribution channels.

5.3 Recommendations

- The system can be improved by using acoustic waves in order to pin point the exact location of a leak and they produce a distinct sound at the point of the leak.
- In order to ensure adequate pressure in the distribution network, a demand driven distribution system where the pumping rate is regulated by water demand using a VSD is recommended.
- Monitoring of the water distribution system via a SCADA application will be advantageous since the status of various control equipment and the conditions of the distribution network can be easily view from a centralized location.

5.4 Conclusion

The results obtained during testing and implementing of the project were as expected and fulfilled the objectives of the project. However, the behavior of the flow sensors was not consistent. This would have been due to their large tolerance of +/-10%.

APPENDIX A

Software algorithm

```
#include <GSM.h>

volatile int NbTopsFan; //measuring the rising edges of the signal

volatile int NbTopsFan2; //measuring the rising edges of the signal

int Calc;

int Calc2;

int hallsensor = 2 ;    //The pin location of the sensor

int hallsensor2 = 3 ;    //The pin location of the sensor

 int sensorPin1 = A0;

int sensorPin2 = A1;

int liquidLevel1 = 0;

int liquidLevel2 = 0;

int relayPin1 = 6;//Solenoid valve

int relayPin2 = 7;//Pump

int ledPin10 =10;//redled pin number 10

void rpm ()     //This is the function that the interupt calls

{

 NbTopsFan++;  //This function measures the rising and falling edge of the signal

 NbTopsFan2++;  //This function measures the rising and falling edge of the signal

//hall effect sensors signal

}

// The setup() method runs once, when the sketch starts

void setup() //
```

```
{
  digitalWrite(ledPin10,LOW);//should be off initially
digitalWrite(relayPin1, LOW);//activate solenoid valve
  digitalWrite(relayPin2, LOW);//activate pump
 pinMode(hallsensor, INPUT); //initializes digital pin 2 as an input
 //pinMode(hallsensor2, INPUT); //initializes digital pin 3 as an input
 Serial.begin(9600); //This is the setup function where the serial port is
//Serial.begin(9600);  //Baud rate of the GSM/GPRS Module
  Serial.print("\r");
  delay(1000);
  Serial.print("AT+CMGF=1\r\n");
  Serial.print("");
   //digitalWrite(relayPin2, LOW);//activate pump
   delay(3000);
   digitalWrite(relayPin1, LOW);//activate solenoid valve

  //delay(3000);
//initialised,
 attachInterrupt(0, rpm, RISING); //and the interrupt is attached

Serial.begin (9600);
  pinMode(sensorPin1,INPUT);
  pinMode(sensorPin2,INPUT);
  pinMode(relayPin1,OUTPUT);
```

```
  pinMode(relayPin2,OUTPUT);
  pinMode(ledPin10,OUTPUT);
}
// the loop() method runs over and over again,
// as long as the Arduino has power
void loop ()
{
  liquidLevel1=analogRead(sensorPin1);
liquidLevel2=analogRead(sensorPin2);
//Serial.println("sensor1 reading\r\t\t");
Serial.println (liquidLevel1);
Serial.println (liquidLevel2);
NbTopsFan = 0;      //Set NbTops to 0 ready for calculations
 NbTopsFan2 = 0;      //Set NbTops2 to 0 ready for calculations
 sei();            //Enables interrupts
 delay (5000);      //Wait 1 second
 cli();            //Disable interrupts
 Calc = (NbTopsFan * 60 / 7.5); //(Pulse frequency x 60) / 7.5Q, = flow rate1
 cli();            //Disable interrupts
 Calc2 = (NbTopsFan2 * 60 / 7.5); //(Pulse frequency x 60) / 7.5Q, = flow rate2
//in L/hour
 Serial.print ("L/hour 1       \r "); //Prints "L/hour" and returns a  new line
 Serial.println (Calc, DEC); //Prints the number calculated above
  //Serial.println("");
```

```
//Serial.println("sensor2 reading\r\t\t");

//Serial.println (liquidLevel2);

 Serial.print ("L/hour 2\r        "); //Prints "L/hour" and returns a  new line

  Serial.println (Calc2, DEC); //Prints the number calculated above

  Serial.println("");

  delay(5000);

 //------------------------------------------------------------------------------------------

 if (Calc <300)

 {

digitalWrite(10,HIGH);//red led should go high when flowrate is below threshold

  delay(3000);

  Serial.print("AT+CMGS=\"+263775188958\"\r");      //Number to which you want to send the sms

  delay(3000);

  Serial.println("burst pipe\r");   //The text of the message to be sent

  delay(3000);
Serial.println("****************************************************************************************************");

Serial.println("****************************************************************************************************");


  Serial.write(0x1A);

    digitalWrite(relayPin2, HIGH);//deactivate pump

    delay(3000);

 }   else
```

```
 {
  digitalWrite(10,LOW);//switchoff red led
  delay(2000);
  }
 if(liquidLevel2>300)
 {
digitalWrite(relayPin2, HIGH);//deactivate pump
}
else {
  digitalWrite(relayPin2, LOW);//activate pump
  delay(20000);
}
  }
```

APPENDIX B

List of components

Component	**Voltage value**	**Quantity**
GSM Module	5V	1
Arduino Uno	5V-12V	1
Water Level Sensors	5V	2
Flow Rate Sensors	5V	2
DC pump	12V	1
Solenoid Valves	12V	2
LED(green and red)	**…………..**	2
Connecting wires	**…………..**	1
Buckets	**…………...**	2

APPENDIX C

List of Abbreviations

MDG – Millennium Development Goals.

NRW – Non Revenue Water.

DC - Direct Current.

IC -Integrated Circuit.

IDE - Integrated development Environment.

GSM – Global System for Mobile Communications.

LED - Light Emitting Diode.

SCADA –Supervisory Control and Data Acquisition.

RTU – Remote Terminal Unit.

SMS – Short Messaging Service.

TX -Transmit.

RX – Receive.

USB –Universal Serial Bus.

GND – Ground.

GPRS – General Packet for Radio Services.