DESIGN AND IMPLEMENTATION OF AN AUTOMATED PREPAID WATER METER: CASE STUDY: NATIONAL WATER AND SEWERAGE CORPORATION (NWSC)

BY

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FEBRUARY, 2022

DECLARATION

I, AKANKWASA JOHN BOSCO hereby declare that I am the sole author of this dissertation entitled **"The design and implementation of a prepaid water meter".** I authorize Kabale University to use this dissertation only for purposes of scholarly research.

Signature ...~ .....

Date:03/02/2022

APPROVAL

This dissertation entitled "The Design and implementation of a prepaid water meter by **AKANKW ASA JOHN BOSCO** meets the regulations governing the awarding of Bachelor of Electrical Engineering at Kabale University.

Supervisor .....

Date .....

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Contents

Abstract

The water billing systems currently available in the Ugandan market still incurs costs of reconnection in case of a disconnection, when a client clears the arrears. For example, if a client does not pay in time, a utility officer moves to the point where the water meter is located and disconnects the client to stop having access to water. The same applies to reconnection when a customer clears.

This research seeks to solve inconveniences by automating the system. If a customer uses up their credit, then water flow should be stopped instantly. Likewise, if a customer pays the bills, they should access the water instantly. In this way, costs involved in disconnection and reconnection are minimised.

Chapter

one 1.1 Introduction

A water meter measures the quantity (volume) of water that passes through a pipe or other outlet.[**I**]**.** Typically meters use a standard unit of measure of volume such as cubic feet or gallons. A prepaid water meter is where clients pay before using the water.

Therefore, an automated prepaid water meter is a system that clients can use without physical interaction with the utility officer or, the interaction can be less.

1.2 Background.

According to [2], water is vital to all known forms of life. Among the necessities of life includes food [3]. I would not hesitate to include water among the necessities of life because of the relationship it has with food. For example, in most foods, there is a certain percentage of water.

[3] Explains how water is essential is to human body. Among them include, temperature regulation, proper cellular functioning and waste removal. Reference [3] also cites that 60% of human body is water. The same reference goes ahead to tabulate the percentages of water in human body parts as shown below.

Table 1: the highest to the lowest percentages of water in human body parts

Body part	Water percentage
Brain	80 85%
Kidneys	80-85%
Heart	75-80%
Lungs	75-80%
Muscles	70-75%
Liver	70-75%
Skin	70-75%
Blood	50%
Bones	20-25%
Teeth	8-10%

Source: [3]

[4]Explains how water is essential is to human body. Among them include, temperature regulation, proper cellular functioning and waste removal.

Water can be accessed in different ways;

i) From lakes, rivers and springs.
ii) Through some foods we eat like raw sweet potatoes.

The second way is not direct and so, I focused on the direct method (i).

In the first method, different companies' tap water from the sources, process it and distribute it to its clients. Some people, however, directly go to the sources and access this free water. Tn cases where people find it tiresome moving long distances in search of water, that's when utility providers come to their rescue and access it through their channels/pipes.

It should be noted that access of piped water is not always free; it involves a cost which is incurred by final users either directly or indirectly. The payment of the bills is in different forms where the researcher sees an opportunity. It is practically impossible to satisfy all clients with one form of service. In summary, when a client pays for water bills, they should be accessing it as soon as they pay. This is where the gap is.

1.3 Problem statement.

It is inconvenient for the customer to wait for a reconnection from the company employee after they have cleared their bills. Again, it is inconvenient for the company employee who moves up and adown to bill and reconnect the customers in a location where the meter is located. It is costly in terms of facilitation which reduces company profits including other challenges like customers defaulting.

The current systems do not allow automated disconnection and reconnection when a client defaults and clears the bill respectively. This project looks forward to solving the problem of physical disconnection and reconnection.

1.4 Benefits of the study

The project's key result area was to design and implement a prepaid water meter that is cheap, more secure, less cumbersome, transparent and reliable.

Security: Any prepaid metering system must be secure as far as the consumers and stakeholders are concerned. Consumers should not sniff into the meters or tamper with them before, during and after collecting water.

Cost: The prepaid water meter system is cheap. It has lower costs due to automated means. Cost considerations are very important when coming up with choice of a meter

Reliability: the system has minimum or no errors and this enhances the quality of the system.

1.5 Objectives

1.5.1 General objective.

Design and implementation of an automated prepaid water meter.

1.5.2 Specific objectives.

I. To design the circuit for the system
2. To simulate the system prototype
3. To implement system design.

1.5.3 Expected outcomes.

The system is now ready to receive the number of units a customer pays for.

1.6 Scope

This system focused on Kabale National and Sewerage Cooperation

1. 7 Motivation

Water is a natural resource but yet scarce. Many people move long distances in search of water. There are companies that have offered to extend water to the people through pipes. In Uganda, it is National Water and Sewerage Cooperation that provides water to her citizens. In order to sustain their service, a monthly fee is paid according to the usage of water. Methods of payment for the water used have evolved over time of which they are manual. The manual payment of the fees was inconvenient to both the customers and the utility company. When a customer was to be billed, an employee from the service provider had to move to the point where the meter was located and billed the customer. It was costly especially when the company had to facilitate the employee to read and bill the customer and or, come back to reconnect if the customer did not pay instantly. On the other hand, it was inconvenient to the customer when they had to wait for the employee of the company to reconnect if they did pay instantly or in time.

It would be convenient if a customer paid and got reconnected automatically to avoid the above mentioned challenges. Fortunately it is no longer an idea, but an implementation.

Chapter two: Literature

review 2.1 Introduction

In normal situations, water is a free resource but, as the population grows, nearby water sources may not serve the available population in full capacity. Therefore, service providers find it necessary to construct water channels through pipes, from long distances, close to the population in need. That being like so, the extension of water nearer involves a cost that should be met by the final consumers, in most cases, that is in a long run.

Different payment methods are available for the clients. Among them include mobile money, airtel money, and some financial banks [5].

In this chapter, the researcher will talk about the different methods used for paying water bills in Uganda, associated with National Water and Sewerage Corporation.

2.2 Payment methods

Some companies no longer accept cash-by-hand payment in any of their offices. An example is National Water and Sewerage Corporation [5]. *"Please note that payments are no longer accepted at National Water cash offices."*

2.2.1 Telecom companies

According to [6], there are two ways to pay for water bills through telecom companies.

One is through MTN, by dialling 165#, and follow prompts. Another one is through Airtel money, by dialing 185#,and follow prompts.

There are also other options like online banking using an appropriate app to replace Unstructured Supplementary Service Data (USSD). They have similar requirements as if one was using a USSD.

2.2.2 Partnering banks

According to [5], these banks can be used to pay for water bills; Bank of Baroda, Bank of Africa, Barclays Bank, Cairo Bank, Centenary Bank, Citi-Bank, DFCU Bank, Diamond Trust, Eco Bank, Equity BankFinance Tmst Bank, KCB, Orient Bank, Post Bank, Stanbic Bank, Standard Chartered Bank, Tropical bank and UBA.

For one to pay in the bank, the requirements include customer reference number, customer name, area, telephone, amount to pay in Ugandan shillings. After payment, the customer goes to the offices for payment validation,

2.3 Analysis.

Utility providers (water) have secured convenient methods of payment to their clients as discussed before, but, an issue may arise when, a client is disconnected and needs a reconnection. In such cases, none of the payment methods provides a solution. A utility officer has to come for a disconnection and a reconnection as would be deemed.

There remains a gap, where, an automated system of disconnecting and reconnecting is vital so **that** costs associated with disconnection and reconnection minimized if not avoided.

2.4 How organisations collect bills for water.

There are different organizations that provide water, and collect money from clients so that they can stay in business. Almost all organization use some, if not all of the methods of payment mentioned above. Among the organizations in discussion include National Water and Sewerage Corporation. (NWSC).

2.4.1 Process of payment.

According to [7], NWSC bills a client, then a client goes to the bank with the bill to pay and the bank clears the client with a receipt that confirms payment of the bill the NWSC account. When the money reflects to their (NWSC) account, it recorded accordingly. If it so happened that they had disconnected the client, then the client has to approach their offices a reconnection.

2.5 Types of Metering Devices

There are two common approaches to flow measurement, **displacement** and **velocity,** each making use of a variety of technologies. Common displacement designs include oscillating piston and notating disc meters. Velocity-based designs include single- and multi-jet meters and turbine meters.

There are also (Static) non-mechanical designs, for example electromagnetic and ultrasonic meters, and meters designed for special uses. Additionally, there are electromechanical meters, like prepaid water meters and automatic meter reading meters. The latter integrates an electronic measurement component and a LCD with a mechanical water meter. Mechanical water meters normally use a reed switch, hall or photoelectric coding register as the signal output. After processing by the microcontroller unit (MCU) in the electronic module, the data are transmitted to the LCD or output to an information management system.

Water meters are generally owned, read and maintained by a public water provider such as a NWSC. In some cases, an owner of a mobile home park, apartment complex or commercial building may be billed by a utility based on the reading of one meter, with the costs shared among the tenants based on some sort of key (size of flat, number of inhabitants or by separately tracking the water consumption of each unit in what is called sub-metering).

2.5.1 Displacement water meters

This type of water meter is most often used in residential and small commercial applications and homes. Displacement meters are commonly referred to as Positive Displacement, or "PD" meters. It relies on the water to physically displace the moving measuring element in direct proportion to the amount of water that passes through the meter. The disk moves a magnet that drives the register. PD meters are generally very accurate at the low-to-moderate flow rates typical of residential and small commercial users and not practical in applications require high flow rates because displacement meters require that all water flows through the meter to "push" the measuring element. PD meters nonnally have a built-in strainer to protect the measuring element from parts that could stop or break the measuring element.[8]

Figure 1: Water meter in Belo Horizonte

2.5.2 Velocity water meters

A velocity-type meter measures the velocity of flow through a meter of a known internal capacity. The speed of the flow can then be converted into volume of flow to determine the usage. There are several types of meters that measure water flow velocity, including jet meters (single-jet and multi-jet), turbine meters, propeller meters and mag meters. Most velocity-based meters have an adjustment vane for calibrating the meter to the required accuracy.

Figure 2: velocity meter

2.5.2.1 Multi-jet meters

Multi-jet meters are very accurate in small sizes and are commonly used in " to 2" sizes for residential and small commercial users. Multi-jet meters use multiple ports surrounding an internal chamber to create multiple jets of water against an impeller, whose rotation speed depends on the velocity of water flow. Multi-jets are very accurate at low flow rates, but there are no large size meters since they do not have the straight-through flow path needed for the high flow rates used in large pipe diameters. Multi-jet meters generally have an internal strainer element that can protect the jet ports from getting clogged [7]

2.5.2.2 Turbine meters

Turbine meters are less accurate than displacement and jet meters at low flow rates, but the measuring element does not occupy or severely restrict the entire path of flow. The flow direction is generally straight through the meter, allowing for higher flow rates and less pressure loss than displacement-type meters. They are the meter of choice for large commercial users, fire

protection and as master meters for the water distribution system. Turbine meter bodies are commonly made of bronze, cast iron or ductile iron. [7]

Figure 3: Turbine Meter

2.5.3 Compound meters

A compound meter is used where high flow rates are necessary, but where at times there are also smaller rates of flow that need to be accurately measured. Compound meters have two measuring elements and a check valve to regulate flow between them. At high flow rates, water is nonnally diverted primarily or completely to the high flow element. The high flow element is typically a turbine meter. When flow rates drop to where the high flow element cannot measure accurately, a check valve closes to divert water to a smaller element that can measure the lower flow rates accurately. The low flow element is typically a multi-jet or PD meter. By adding the values registered by the high and low elements, the utility has a record of the total consumption of water flowing through the meter.[8]

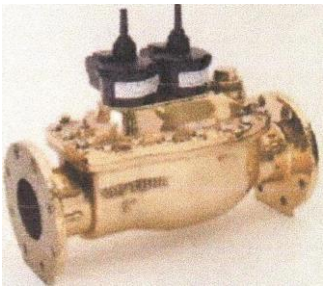


Figure 4: Compound meter

2.5.4 Static Meter

A static meter, which is any metrology device with no moving parts, has significant advantages over traditional mechanical meters. Static meters have already been used for years in the commercial and industrial markets. Static meters are classified as **electromagnetic and ultrasonic time-of-flight.**

Static meters have significantly better accuracy, especially at low flow rates. Furthermore, due to their lack of moving parts, they are more reliable and their performance does not degrade over time. With less leakage, there is less waste and loss. Consequently, the service provider is not billing the cost of lost revenue back to the consumer.

In this meter, a piezo transducer is pulsed. The resultant acoustic wave travels through the media (water in our discussion) and is picked up at a second piezo transducer downstream. After this path is completed, the piezo transducer signals are reversed; the downstream piezo is pulsed and the upstream piezo picks up the signal. The difference in the time of flight for the two pulses enables the measurement of the flow, since the acoustic wave's speed is proportional to flow

2.5.4.1 Electromagnetic meters

Magnetic flow meters are technically a velocity-type water meter, except that they use electromagnetic properties to determine the water flow velocity, rather than the mechanical means used by jet and turbine meters. In an electromagnetic meter, a magnetic field is applied to the pipe and a voltage is generated perpendicular to the flux lines. This voltage is proportional to the flow rate. While this type of meter provides excellent accuracy, it tends to have fairly highpower consumption.[8]

Figure 5: Electromagnetic flow meter

2.5.4.2 Ultrasonic meters

The dominant type of static meter technology today is ultrasonic time-of-flight. Ultrasonic water meters use one or more ultrasonic transducer to send ultrasonic sound waves through the fluid to determine the velocity of the water. Since the cross-sectional area of the meter body is a fixed and known value, when the velocity of water is detected, the volume of water passing through the meter can be calculated with very high accuracy. Because water density changes with temperature, most ultrasonic water meters also measure the water temperature as a component of the volume calculation. The Figure 2-10 below shows of a Water meter ultrasonic time-of-flight solution features the MAX35101 time-to-digital converter with analog front-end (AFE).

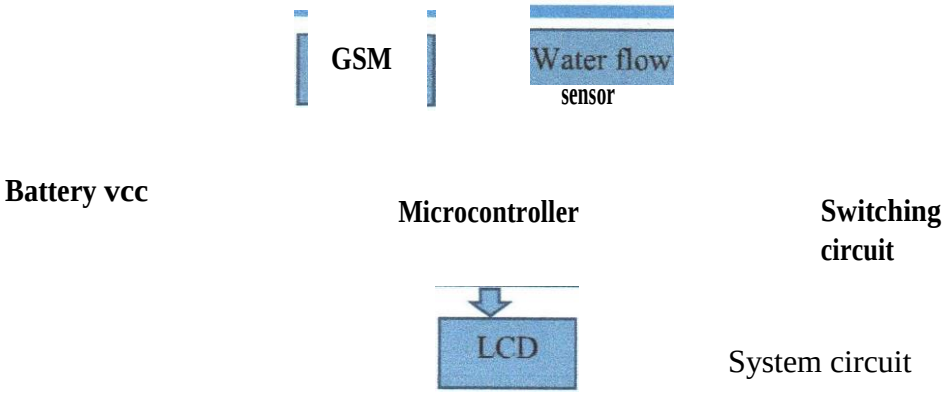
Figure 6: Ultrasonic meter

Chapter three:

Methodology 3.1 Introduction

In this chapter, the researcher seeks to discuss methods that were used to achieve the specific objectives in line with the general objective.

3.2 block diagram for the proposed system.



According to the block diagram above, the battery was used to power on the system circuit. Within the system circuit, there are different components. Their functions are explained as below;

Microcontroller (Arduino Uno)

A microcontroller is an electronic circuit that can be programmed to perform specific task as instructed [7]. It controls electronic devices connected to its PINs as expected.

A microcontroller was used to store a program/instructions to control the switching circuit, receive and send signals to and fro GSM, water flow sensor and LCD, for display. In my project, I used an Arduino Uno microcontroller because, it consumes less power and is easy to program.

i)

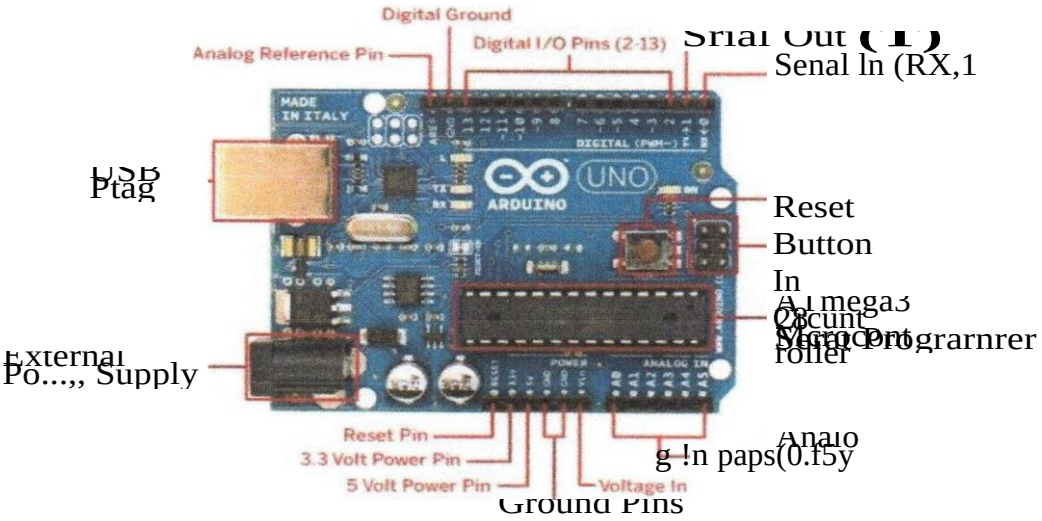


Figure 7 Arduino Uno microcontroller board

GSM (SIM800L): sends and receives messages of the current balance on the user's cell phone. The GSM was connected to the Arduino uno microcontroller through one of the pins that was programmed to send a 0(off) or l(on) to the circuit. The reason for why I used a GSM is because it does not have any deterioration (8]. In addition, the GSM in discussion has features that are compatible with mobile phones such as, sms, calls, input/out pins and audio interface that gives a user options of whether to receive both calls and sms[9].

Water flow sensor

I used YF-S201 water flow sensor. It works on the Hall-effect principle and with a flow rate range of 1~30L/min. The module has three pins: Power, Ground, and the analog output. YF-S201 consumes very little current and can work with an allowing pressure of<1.75 MPa[9].

Measurement of the amount of water that passes through the sensor is easy, that is, for the sensor to make one pulse, approximately 2.25 millilitres should have passed [11]. Mathematically, there are 1000 millilitres in a 1 litre; therefore, billing a client is easy, that is, set the price of one litre

of water, then the cost of 1 millilitre is $\frac{1}{cost\ of\ 1\ ltr}$, but in this case, water is prepaid and a client has to first pay for the system to open for them.

Below is the image a water flow sensor and how it works. [11].

j)

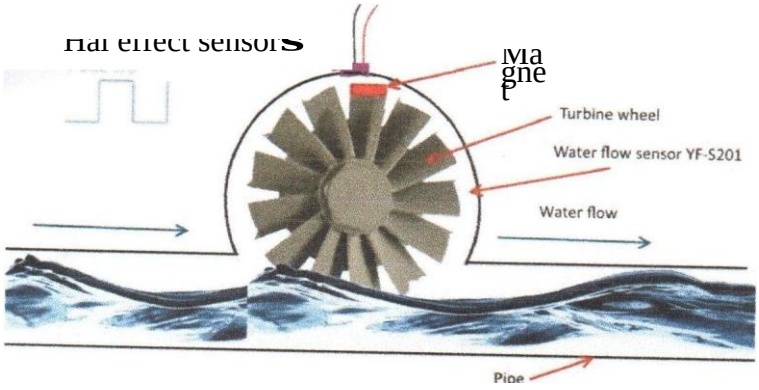


Figure 8: water flow sensor working.

"When the water flows through the pipeline, it makes the turbine wheel to rotate and hence the magnet flux interferes the hall sensor, the rate of interference is depends on the speed of water flow, so the hall effect sensor produce pulse signal output, this pulse output can be calculated as water volume."

Water flow direction

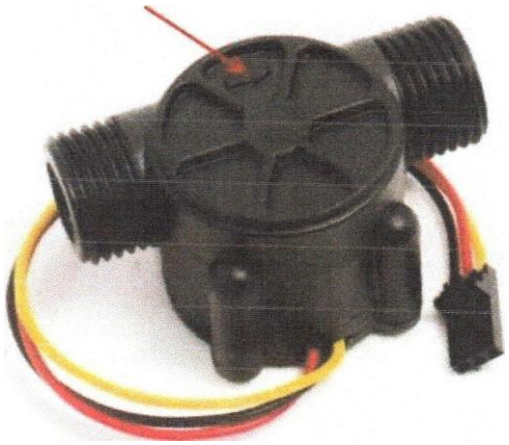


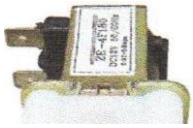
Figure 9: water flow sensor **SOLENOID VALVE.**

The 12V DC solenoid valve is of the 2-way switch type used for the simple on/off control of water, air, when fitted into a pipe work system it controls the flow or no flow of water.

How a solenoid valve works.

The working of a solenoid valve is not complicated, when powered on, the valve opens, and when not powered, the valve remains closed.

Below is how the solenoid valve I used in the system looks like.



k)

Figure 10: solenoid valve

Switching circuit: contains a tap emulator controlled by the microcontroller.

. **The relay.** The relay does the switching by the control of the Arduino, and the solenoid valve.

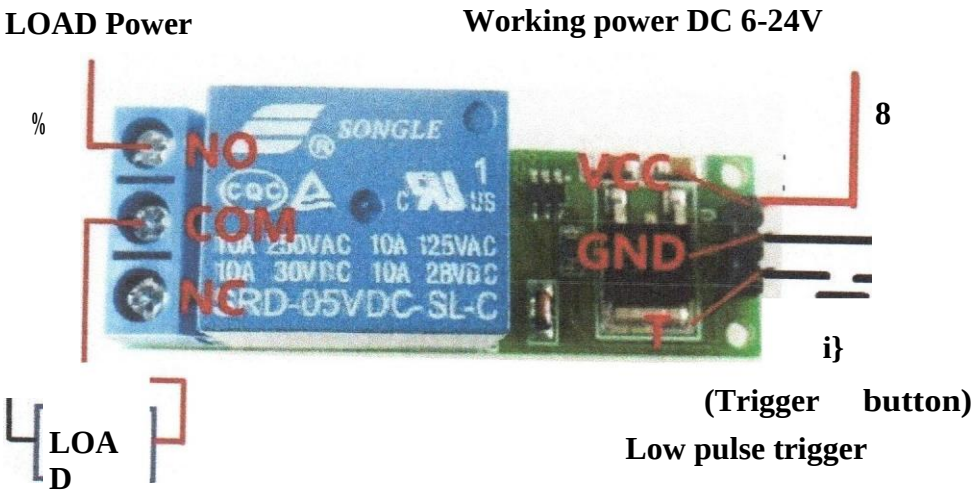


Figure 11: Relay switch

When a customer clears the bill, a switch (tap emulator) should close to allow flow of water. Likewise, when the balance runs to 0, the switch should be opened to stop flow of water. For purposes of the project, I used a relay switch to control the valve.

LCD: Used to display current balance. It uses less power which was cost effective. Specifically, I used **LM016L.**

How the LCD looks like.

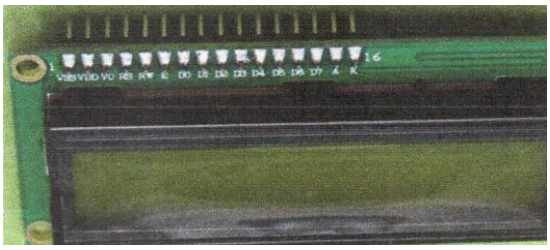
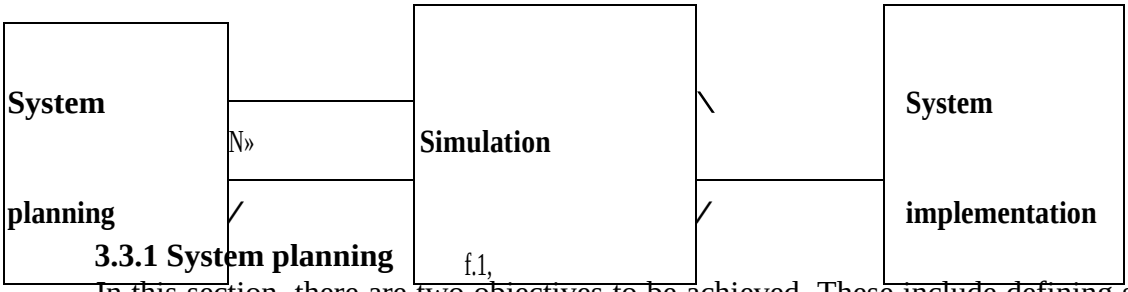


Figure 12: LMO 16x2 LCD

3.3 system planning



3.3.1 System planning

In this section, there are two objectives to be achieved. These include defining system requirements and designing the circuit for the system.

System requirements.

For the case of system requirements, the researcher searched the internet for appropriate hardware and software components that the system required. In addition, the researcher visited the offices of national water and Sewerage Corporation to find out more requirements that wou1d use.

Designing the system.

The circuit was designed using circuit maker software. The software contains a platfonn under which various electronic devices were connected virtually together and modeled to test their functionality.

3.3.2 Simulation

Simulation was done using proteus software. The software helped the researcher to detect en-ors within the connection of the circuit before it is implemented on the breadboard.

3.3.3 System implementation

The system was implemented in two ways;

l) Writing a code to load onto the microcontroller and

ii) Connecting components of the system in the breadboard.

The researcher used arduino for writing system code that was loaded onto the microcontroller, to control other system hardware.

On the other hand, system components were connected on the breadboard so that a fully functioning system was produced.

Chapter four

This chapter seeks to present the evaluation for the research. **4.1 System description.**

The system is powered using Alternating current that passes through a power supply that converts it to direct current (12V).The 12V is passed through the buck-to-buck converter to convert it to a suitable voltage for the sim800L and the Arduino microcontroller.

When a client needs to pay for water, a short message is sent to the SIM card that is in gsm module. Specifically, a number should be sent to the SIM card, which is processed into an integer as units paid for water access. When the balance comes to zero, the solenoid valve closes and water stops flowing until a client pays.

Below is the circuit diagram for the system.

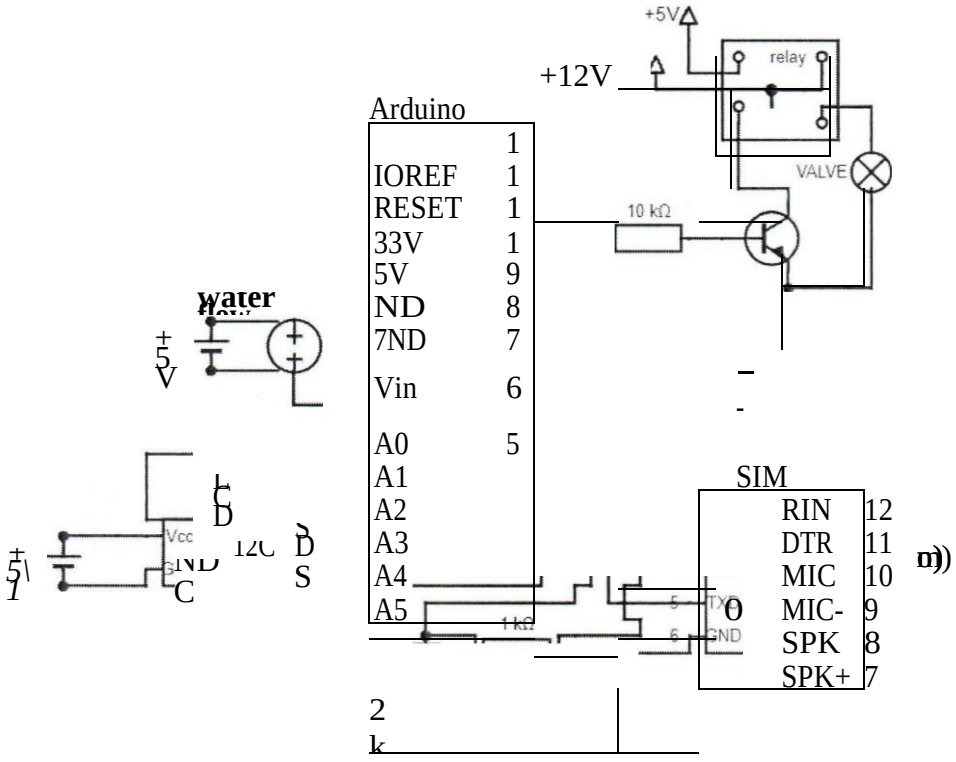


Figure 3: Circuit diagram for the system

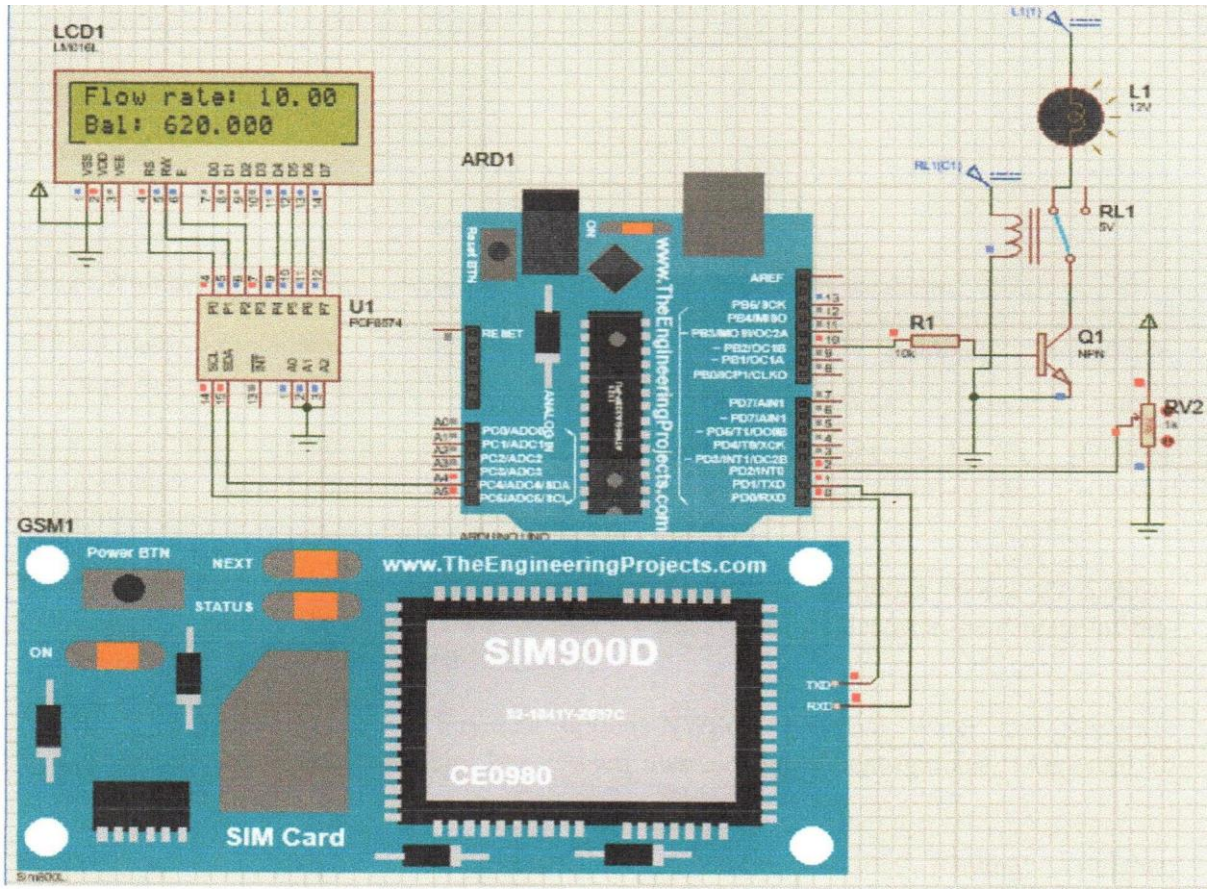


Figure ***14:*** *Simulated diagram for the system* **4.2 Limitations**

Much as a solution has been provided, the system does not guarantee efficiency of upto I 00%. Some of the limitations of the system that limit its efficiency include the following,

i) The system does not have a database where to store variables. Whenever the system restarts, all variables are initialised, which makes the system inefficient.
ii) In case of no network coverage, the system will not work because it depends on the sms received.
iii) There is a threshold of water that is supposed to be in the sensor so that the fan can be spilled on water movement. This means that the way the sensor should be positioned matters.
iv) For some customers who are not connected to the grid, this system may not be of great benefit to them since it uses electricity (AC) as a source of power.

4.3 Recommendations.

For improved efficiency and how to make the system flexible, the researcher recommends that

i) Software developers can develop a database in which the system should be reading state variables.
ii) Developing standalone power supply for the system. For example solar or batteries.

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at-acoptexcom/. [Accessed l 7 11 2021].

Appendices

System code

```
#include "SoftwareSerial.h"
#include <LiquidCrystal_
I2C.h> #include <Wire.h>

SoftwareSerial mySerial(ll, 12);
LiquidCrystal_I2C lcd(0x27,
16,2);
const byte sensorPin=2; //pin for interrupt
const byte solenoidPin=l0; //pin to control the tap through the
relay
float pulses=0.0; // balance of water for use
float volume= 0.0; // volume of water used since the reset of the
system
String numbers[]={"+2567853003 l 7","+256771643270",
"+256776705292"}; String message;

void setup()
{
/ /Serial.
begin(9600);
mySerial.begin(960
0); lcd.init();
Jed.clear();
lcd.backlight(
);
```

```
    pinMode(sensorPin, INPUT);      II sensor pin always low
    pinMode(solenoidPin, OUTPUT);   II make solenoid pin output to switch solenoid
off
    //Serial.println("lnitializing
    Sim800L..."); led.setCursor(0,0);
    lcd.print("Sim    initializing
    ... "); delay(3000);
    led.clear();
    led_ display();

    initialize sim();

    attach Interrupt( digitalPinTolnterrupt(sensorPin), pin_ ISR,
    RISING);
}
I/ I IIII/II///I/ Il\/I/II/LOOP Il\// llll/l\/l\//!I//II//I/
int count_low_ balance= 1;
int count_zero_balance = 1;
void loop()

 read_ sms();
 led_
 display();
 if(pulses>0)
 {digitalWrite(solenoidPin,
  HIGH); if(pulses=50)
  {
   if( count_low_balance>0)
   {
    delay( 100);

    message = "Your balance is running low, please pay to avoid disconnection! Water
management.";
```

```
        send                loop();
        count_low_balance
      }
        -= I;

    }
   }
  else


    digitalWrite(solenoidPin,
    LOW);   if(   count_   zero_
    balance>0)
    {message = "You have been disconnected for water access due to insufficient balance!
Please pay to have access to water again. Thank you.";
     send_loop):
     count_zero_balance -= I;
   }


}


I I I////// I I! I I// II// II I I/ I ITNTERR UPTS/ I// I I/////////// II /I// I I II
I I void pin JSR()
{
 if(pulses>
 0) {
  pulses-=   l;
  volume+=
  I;
  //Serial.println("Pulses:   "+(String)pulses
  );          //Serial          .println("Volume:
 }"+(String)volume ); / /Serial.println();

}                                                    2
                                                     1
```

p)

I I I// II I II I I/// I I/ II/// I!! I!/// I I II// I/ II I/// I I II/ I! I I I/// I// I I!. I IS END SMS/ *///I// I I II I/// I II I I II I I I I I I! I I I/// I I I II I I I I I I I II I I I I I I/ I II I I I I I I/// II I I I II I*

```
void send _loop()
{
 delay(! 0);
 for(int i=0; i<sizeof(numbers)/sizeof(String);i++)
 {
  send_sms(numbers[i], message);
 }
+ }
void send_sms(String number, String message)

 mySerial.println("              AT
 +CMGF= I"); delay(] 0);
 mySerial.println("A                          T
 +CMGS=\""+number+"\""); delay(10);
 mySerial          .println(
 message); delay(l 0);
 mySerial.
 write(26);
 delay(10);
}
```

I I I I llllll!llllllll ll//!l!.II Ill ll!IIIIIII//III//I! / I//II Ill// II!.!/ I I I/READ SMS/ *////I/ I I// II I/ I I II I I/// I II I// I I I// I I I I I I I/ I I I/ I/ I I/////* I I I II I I I I /I I I *I I I I I I I I I*

```
void read_sms()
{
 delay(100);
```

I I I//III/II /I I! Ill! Ill!.!/ II/ Ill/Ill/I/II/Ill/II/ I I I II/II/use the water/ *I/ I// II I/II/I I// I/ /Ill I I I/II/II /Ill/ II// I I/ I !Ill/ Ill// ll/!.I/ I/! II*

p c t o pa y fo r

```
 String message _read;
 /
```

```
    if(Serial.available())
    {
     while(Serial.available
     ()) {
      II serial received some
      data char inchar =
      Serial.read();
      message_read.concat(inch
      ar);
     }
    receive_message =message_ read;
    Serial.println("Message from pc:
    "+receive_message); pulses += receive_message.
    tofloat(); Serial.println("Pulses(PC):
    "+(String)pulses);
 *I
I I II I// I I I I I I I I/////// II I I I III// I I II I// I// I I I/// I I II I I I II I I/use
                                                th gs m t o pa y fo r
e
water//////////////////////////////////////////////////////////
///
   while(mySerial.available())
   char inchar =
   {
   mySerial.read();
   message_read.concat(incha
message = message_read;
   r);
String body= message.substring(message.lastIndexOf("")+ I
,message.length()); pulses+= body.tofloat();
//Serial.print("Units bought: ");
//Serial.println(body);
}


void
led_display) {
```

```
  lcd.setCursor(0,0);
  lcd.print("Bal:
  "+(String)pulses                );
  lcd.setCursor(0, I);
}
  lcd.print("Vol:
  "+(String)volume );
//Ill/II     I/     ll/llll//l//l/!I
l//l!!l//l!I!!     II     void
initialize_ sim()
{
mySerial.println("AT    +CMGF=    I");
mySerial.println("AT          +CNMI=l
,2,0,0,0"); }
```