PREPAID SMART WATER METER
UNIVERSITY OF KHARTOUM

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DECLARATION OF ORGINALITY

I declare this report entitled “PREPAID SMART WATER METER” is my own work except as cited in references. The report has been not accepted for any degree and it is not being submitted currently in candidature for any degree or other reward.

Signature: ____________________

Name: _______________________

Date: _______________________
Acknowledgment

Huge efforts were made towards achieving this project. I would like to thank first the caring Prof. Mustafa Omer Nawari for his limitless guidance and care.

Also, Special thanks and gratitude to my friends and colleagues’ who were nothing but a backbone for me. Specially my friend and partner Mohamed Osman Abdallah Saeed who showed what a true team work spirit really meant.
Abstract

Water Efficiency is considered as a major aspect for every country in the world, many studies such as integrated water management were developed to enhance the way water resources are managed. Consequently, smart water systems were developed to reach equity for water usage, economic benefits for both the consumer and the utility, improve system management and achieve maximum water efficiency.

In this project, a smart two-way communication water meter that operates in prepaid payment method was simulated using PROTEUS software on PC. The water meter communicates with the water utility company and transfer data containing the daily water usage of the user through GSM technology.

The smart water meter also contains a LCD monitor that displays the remaining balance of cubic meter of water with the aid of a PIC18F4550 Microcontroller. Therefore, the user acknowledges the consumption of water, which is a major difference between the conventional mechanical water meter and the intelligent water meter.

If fully Implemented, the smart water meter calculates the difference between the remaining balance of cubic meter of water and the input water, when the balance finishes, the valve closes the main pipe of water. The meter also sends data of consumption via SMS at known specific time intervals through the day to the utility and the utility also can monitor and the control the meter remotely.
المستخلص

تعتبر كفاءة استخدام المياه من أهم المحاور لكل دول العالم وعلى الكثير من البحوث والدراسات مثل إدارة المياه المتكاملة أجريت لزيادة وتحسين الطرق التي تدار بها موارد المياه. بناءً على ذلك، تم تطوير عداد المياه الذكي الذي يرتكز أهدافه حول تحقيق العدالة والاستخدام العادل للمياه والفوائد والمصلحة الاقتصادية لكل من مورفي المياه المستخدم، وتطوير إدارة النظام، واتخاذ تحقيق أكبر كفاءة للمياه ممكنة.

في هذا المشروع، تم المحاكاة بواسطة برنامج "PROTEUS" لعداد مياه يعمل باتجاهين للاتصال ويدار التحصيل المادي عن طريق الدفع المقدم. يقوم عداد المياه بالتواصل مع الجهة الموفرة عن طريق تكنولوجيا الـ "GSM"، وذلك بارسال رسائل "SMS" تحوي معلومات عن الاستهلاك اليومي للمياه. كما يحتوي العداد أيضاً على شريحة تحكم "PIC18F4550" وشاشة عرض "LCD" لعرض الرصيد المتبقى من المتر المكعب للمياه مما يساعد المستخدم على معرفة ما تبقى من الرصيد واستهلاك المياه. وتعد هذه الخاصية من أميز الفروقات ما بين عداد المياه التقليدي وعداد المياه الذكي.

في حالة تطبيق العداد، يقوم العداد بحساب الفرق بين الرصيد الفعلي للعداد من الامتار المكعبة والمياه المنسوبة داخل العداد. عند نفاد الرصيد يقوم بإغلاق صمام المياه الرئيسي. كما يقوم العداد بإرسال بيانات الاستهلاك اليومي خلال فترات معلومة إلى الجهة الموفرة. كما يضمن الجهة الموفرة التحكم عن بعد في العداد.
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<th>Description</th>
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<tr>
<td>AMR</td>
<td>Automated Meter Reading</td>
</tr>
<tr>
<td>MDG</td>
<td>Millennium Development Goals</td>
</tr>
<tr>
<td>SDG</td>
<td>Sustainable Development Goals</td>
</tr>
<tr>
<td>ACEEE</td>
<td>The American Council for an Energy-Efficient Economy</td>
</tr>
<tr>
<td>AMI</td>
<td>Advanced Metering Infrastructure</td>
</tr>
<tr>
<td>PLC</td>
<td>Power Line Communications</td>
</tr>
<tr>
<td>SCADA</td>
<td>Supervisory Control and Data Acquisition</td>
</tr>
<tr>
<td>MCU</td>
<td>Microcontroller Unit</td>
</tr>
<tr>
<td>RAM</td>
<td>Random Access Memory</td>
</tr>
<tr>
<td>LCD</td>
<td>liquid crystal display</td>
</tr>
<tr>
<td>GSM</td>
<td>Global System for Mobile Communication</td>
</tr>
<tr>
<td>RTC</td>
<td>real-time clock</td>
</tr>
<tr>
<td>ADC</td>
<td>Analogue-to-Digital Converters</td>
</tr>
<tr>
<td>PIT</td>
<td>Programmable Interval Timer</td>
</tr>
<tr>
<td>PWM</td>
<td>Pulse Width Modulation</td>
</tr>
<tr>
<td>SPI</td>
<td>Peripheral Interface</td>
</tr>
<tr>
<td>GPRS</td>
<td>Global Packet Radio Service</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------------------</td>
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<tr>
<td>GWP</td>
<td>Global water partnership</td>
</tr>
<tr>
<td>IWRM</td>
<td>Integrated Water Resource Management</td>
</tr>
<tr>
<td>CDMA</td>
<td>Code Division Multiple Access</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
<tr>
<td>PD</td>
<td>Positive Displacement</td>
</tr>
<tr>
<td>AFE</td>
<td>Analog Front-End</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>RAM</td>
<td>Random Access Memory</td>
</tr>
</tbody>
</table>
1 Chapter 1: Introduction

1.1 Background

Conserving water is becoming increasingly important in the world as it faces a widening gap between ever reducing water supplies due to climate change, inefficiencies in agriculture, poor water governance, industrialization, urbanization and increased demand from population growth. It results in many environmental, political, economic, and social forces. The post-2015 eight Millennium Development Goals (MDGs) and the newly adopted 17 Sustainable Development Goals (SDGs) aim at integrating social inclusion, economic development and environmental sustainability. The SDG 6.1 aims to achieve the realization of the human right to water through universal and equitable access to available, safe and affordable drinking water for all, by the year 2030 [1]. This is particularly critical for Africa which still accounts for 40 percent of the population without access to safe drinking water.

Water conservation means using less water as well as using alternate sources of water. Today’s integrated programs embrace the use of water efficient appliances and technologies. Through the use of control systems, a far better water utilization is achieved. Automatic leak detection and monitoring systems permit to identify and then fix leaks, and even cut off the flow. Incentives and tighter regulation are yet another component.

Smart Water meter is a device that measures water consumption at specific time intervals and the volume of water consumed at that time and communicate this data with the utility company.

In this paper, a better, fair and more convenient solution for water conservation and usage was attempted through using a smart two ways communication water meter.

1.2 Problem Statement

They say: “if you can’t measure, you can’t manage”. Although Sudan has one of the biggest water resources in the world, we still tackle the water service economically inefficiently by paying depending on your demographic location in the country, for example if you live in a first-degree neighborhood you pay a more fixed charge and if you live in a second-degree neighborhood you pay a less fixed charge and so on. Therefore, it doesn’t depend on the consumption/conservation of the water.
Also, the waste and loss of water is a major concern, thereby a way to reach maximum water efficiency is a must by determining the present and future leakage through embracing the feature of feedback and communication. Another important part for the utility is to be ready for future warnings such as high demands and loads for different areas and this can be achieved by analyzing big data through using forecasting and prediction techniques.

1.3 Motivation

A smart water meter provides an interface between the utility and the customer. Successfully implemented, this meter will benefit the customer as well as the water utility in the following ways:

- The device will show the remaining balance so that the consumer knows how much he has consumed and when he needs to refill the account.
- The utility companies will have a better idea of water demand. This will help them to plan ahead.
- The utility companies would be able to collect the expenses from customers in advance, so they will no longer have to deal with late payments.
- Since the meter will send daily consumption data to the utility company; it will help reduce water bypass and determine water leakage.

1.4 Objectives

The smart water must be able to do the following:

1. Measure water consumption accurately.
2. Display real time account balance.
3. Communicate with the utility company to:
   - Perform a daily verification of water consumption.
   - Give signals from the utility company to the client such as closing the valve and sending consumption data.
4. Cut water off when there is zero credit on the account.
1.5 Thesis Layout

Chapter 2: This chapter gives an introduction to smart water meter generally, the development of it through history, the evolution of smart water meters and its benefits and problems as presented in different papers.

Chapter 3: This chapter shows the design methodology by giving a detailed description of the meter components and introducing the entire system scheme.

Chapter 4: This chapter carries out the results from the Simulation in Chapter 3.

Chapter 5: This chapter discuss the results obtained in the previous chapters. Along with conclusion, limitation and future work.
Chapter 2: Literature Review

2.1 Introduction:

Water meters are used to measure the volume of water used by residential or commercial buildings that are supplied with water by a public water supply utility. It is also, very useful in finding water leaks. It operates by continuously measuring the incoming water volume subtracts it from the available gallons or cubic meters and then displays the remaining volume.

The difference between a conventional water meter and a smart (intelligent) water meter is that in smart water meter there is an on-going monitoring an evaluation of the use of water by the utility company. We can bound the system with four key processes:

- The measurement.
- Data transfer.
- Processing and analysis.
- Feedback of water use data.

as described in Table 2-1.
Table 2-1 Processes of an intelligent metering system.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Data transfer</th>
<th>Processing and Analysis</th>
<th>Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water meter used to capture information about water consumption. Residential intelligent metering typically uses displacement meters which generate a pulse signal after a set volume passes through the meter.</td>
<td>Means by which data is transferred from meters to utilities, customers and back. Data is transferred from the water meter via broadband, cable or wireless (e.g., radio, GSM, CDMA *). May be fully remote or require near range collection.</td>
<td>Means by which a utility/third party stores (e.g., data servers) and manipulates (e.g., end-use analysis software package) water use data. Implications for third party access.</td>
<td>Method by which data is provided to customers for interpretation, e.g., postal bill, email, web interface, smart phone application. Behavior change may/may not ensue.</td>
</tr>
</tbody>
</table>

2.2 Study and analysis

The American Council for an Energy-Efficient Economy (ACEEE) reviewed more than 36 different residential smart metering and feedback programs internationally. This is the most extensive study of its kind. Their conclusion was: “To realize potential feedback-induced savings, advanced meters [smart meters] must be used in conjunction with in-home (or on-line) displays and well-designed programs that successfully inform, engage, empower and motivate people." [2]

2.2.1 Integrated Water Resources Management as a possible solution to access to water

The Global Water Partnership (GWP) defines water governance as the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and the delivery of water services at different levels of society. Thus, Integrated Water Resource Management (IWRM) is aimed: at promoting more equitable access to water resources and the benefits that are derived from water in order to tackle poverty; to ensure that scarce water is used
efficiently and for the benefit of the greatest number of people; and to achieve more sustainable utilization of water, including for a better environment. [3]

Treating water as an economic good entail allocating water to its highest value and moving towards full cost pricing to encourage rational use and recover the cost. Economic tools ought to determine how limited water resources are to be distributed efficiently and equitably. In addition, managing water as an economic good is essential to achieving financial sustainability of water service provision by pricing water at levels that guarantee full cost recovery [4].

Most countries within southern African regions have adopted IWRM plans to try to improve the management of water resources by adopting the concept of promoting efficiency, equity and sustainability of water resources. However, the adoption of IWRM has not been totally beneficial to the management of water in urban areas as many residents still do not have access to drinking water.

2.2.2 Growing Global Demand for Smart Water Meter

The global demand for smart water meter is growing. As the demand for water rises, water utilities around the globe will be facing pressure to manage water resources as efficiently as possible, and this smart water meter is a key element in smart water management, providing information that helps utilities to control cost and achieve efficient use of resources. Moreover, there are projects demonstrating the growing demand for smart water meter in Europe and North America.

Smart meters and associated smart grid technology currently represent a $3 billion annual industry, projected to rise to $15 billion annually by 2015. According to some forecasts, there will be close to one billion smart meters in the world by 2020, with 65 million in the US alone. The figure 2-1 below gives a glance of revenues of smart water meter around the world since 2010. [5]
2.2.3 Evolution of Smart Meters

In the 1990s, automated meter reading (AMR), the technology of automatically collecting data from energy metering devices and transferring that data to a central database for billing, troubleshooting and analyzing, took to the scene. This technology saved utility providers the expense of periodic trips to each physical location to read a meter. Additionally, billing became based on real-time consumption rather than on estimates based on past consumption. This timely information coupled with analysis helped both utility providers and customers better control the use and production of electric energy, gas usage or water consumption.

The first-generation of smart meters, which appeared in 2005, transmitted information back to the utility company monthly. The second-generation of smart meters could transmit daily and some even hourly. The third-generation of smart meters now allows two-way communication, on-demand. As a result, utility providers can now extract detailed information on power usage of individual homes.
2.3 Brief History

The smart water metering market emerged in the 2000s as water utilities responded to global trends of using detailed and near real time data and analytics to deliver more predictive and proactive services. The backbone of this effort is advanced metering infrastructure (AMI) technology. AMI can provide a remote and constant two-way data link between utilities, meters and consumers. Communications are delivered through various technologies including power line communications (PLC), telephony, broadband, fiber optic cable, wireless radio frequency and cellular transmissions.

A communications infrastructure of concentrators, repeaters and gateways, data is passed between meter and utility and funneled into analytical software that can immediately set off predetermined alerts. This is as well as produce accurate billings and consumption patterns at neighborhood and area levels, inform other utility software such as GIS (Geographic Information Systems) and SCADA (Supervisory Control and Data Acquisition) and departments including customer services, pumping stations and reservoirs. Apart from monitoring the current status of water consumption, data can contribute towards hydraulic modelling to help predict outcomes and changes in water distribution.

Hydraulic modelling and network monitoring can be used by utilities to make evidence-based network investments and upgrades. Utilities can also send information back to the meter to perform remote upgrades and fixes, reset alert parameters, shut off water supply during change of tenancy or reduce water flow for unpaid accounts.

2.3.1 AMR

Automatic meter reading, or AMR, is the technology of automatically collecting consumption, diagnostic, and status data from water meter or energy metering devices (gas, electric) and transferring that data to a central database for billing, troubleshooting, and analyzing. This technology mainly saves utility providers the expense of periodic trips to each physical location to read a meter. Another advantage is that billing can be based on near real-time consumption rather than on estimates based on past or predicted consumption. This timely information coupled with analysis can help both utility providers and customers better control the use and production of electric energy, gas usage, or water consumption.
AMR technologies include handheld, mobile and network technologies based on telephony platforms (wired and wireless), radio frequency (RF), or powerline transmission.

2.3.2 AMI

Advanced Metering Infrastructure (AMI) refers to systems that measure, collect, and analyze energy usage, and communicate with metering devices such as electricity meters, gas meters, heat meters, and water meters, either on request or on a schedule. These systems include hardware, software, communications, consumer energy displays and controllers, customer associated systems, meter data management software, and supplier business systems. AMI extends automatic meter reading (AMR) technology by providing two-way meter communications, allowing commands to be sent toward the home for multiple purposes, including time-based pricing information, demand-response actions, or remote service disconnects.

2.3.3 AMI vs. AMR

Water utilities often debate whether to fully convert to AMI or run an AMR water grid instead. The truest of smart water grid definitions requires AMI technology and its enabling two-way communications. Many water utilities, however, do not see a clear advantage to AMI and feel the uni-directional communications from meter to utility offered by AMR is fit for purpose. Receiving one-way information for accurate billing, leakage and NRW detection and GIS and SCADA is viewed as solving the bulk of water utility needs. Many water utilities feel the financial cost to roll out and operate an AMI grid will not justify the benefits of two-way communications. It is felt that remote upgrades rather than replacements will be infrequent, centralized alarms will be sufficient and utilities will rarely restrict water flows into homes, even if this is legally permitted. [6]
This issue needs to be addressed on a case by case basis, but water utilities, widely known to be risk-averse, will find the most "future-proofed" investment in AMI deployments. An example of which is the UK's most advanced project currently being deployed by Thames Water in London. AMI offers the most advanced capabilities and as this technology evolves and utilities grow more sophisticated in their data analysis and operations, AMR deployments may prove limiting; water utilities stand to gain the most through AMI.

Smart water metering differs from smart energy metering in that smart water meters are rarely in convenient reach of mains power supply. As a result, smart water meters are dependent on a reliable and long-lasting battery to power data transmission. Ensuring a 15-year battery life, which matches the lifespan of most meters, is essential for investments. Because of the proximity to water and possible submersion of meters, batteries are sealed water-tight and are not meant to be replaced.

Operating an AMR deployment with scheduled data transmissions does not impinge on this 15-year battery life. Deploying an AMI system, however, where meters must be constantly ready to receive incoming transmissions can drain battery life significantly, down to eight years or less.
This has a large impact on the business case for investment. The market is seeing solutions to this challenge where meters will power up to potentially receive transmissions on scheduled intervals rather than a constant state of readiness. This ensures maximized battery life and offers the benefits of a two-way AMR-like communications system. The figure 2-3 below demonstrate the growth of all three types of water meter: Basic Meter, One-Way Meter and Two-way Meter.

![The NAM Market for Water Meters](image)

**Figure 2-3 Market for Water Meters**

### 2.4 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 noting 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 city, rural water association or private water company. 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).

2.4.1 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 normally have a built-in strainer to protect the measuring element from parts that could stop or break the measuring element. [7]
2.4.2 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.

![Velocity meter](image)

*Figure 2.5 velocity meter*

2.4.2.1 Multi-jet meters

Multi-jet meters are very accurate in small sizes and are commonly used in ½" 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]

2.4.2.2 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]

2.4.3 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 normally 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. [7]
2.4.4 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.

2.4.4.1 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 high-power consumption. [7]
2.4.4.2 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).
2.5 Implementing Static Meters

Until now the technology for static meters was not practical for residential water use. However, recent evolutionary changes in service delivery are creating opportunities.

The greatest challenge for residential use of static meters is straightforward: power. It takes power to operate an electronic device. Because most water meters are not wired for power, static meters traditionally were not a practical option. With the onset of AMR (advanced meter reading) and AMI (advance meter infrastructure), this is changing. AMI and AMR enable remote meter reading and/or control, typically with wireless communications technologies.

When a service provider decides that they need the capabilities of AMI/AMR, they now need to power the meter, either through a line voltage or from a battery. Since power has to be provided to the meter anyway, this opens the door to static metering. The power required for static metering adds to the power requirements to be sure, but it does not create a new challenge. Concurrent improvements in battery technology are helping drive the change in meter technology. Because
power densities are improving, the life of the meters is also increasing. It is not uncommon to see static meters with a battery life of 15 or more years.

Other factors are driving the residential adoption of static meters, notably improved leak detection and the ability to act on that information. A meter that can detect a leak and then react, such as through an automatic valve shutoff, adds significant safety to the home. While not necessarily an immediate safety hazard, water leak detection could spare the homeowner unnecessarily high-water bills and prevent water damage.

2.6 Payment Methods

There are two General Approaches for payment or refilling the account of the water meter. These approaches or methods are Prepaid or Postpaid. Thus, Electronic meters can be either postpaid meters or prepaid meters. A brief discussion about both meters is discussed as follows. But the Prepaid Meter is discussed intensively regarding the project’s scope.

2.6.1 Postpaid Meters

In the case of postpaid meters, consumers receive bills based on regular meter readings—monthly, or even more often. This will have a positive impact on the accuracy of the bills.

2.6.2 Prepaid Meters

In the case of prepaid meters, consumers pay prior to actual consumption. Traditionally, prepaid meters have been targeted at low-income segments. The overall uptake of prepaid meters is low, principally because the service is seen as inconvenient.

In general, prepaid consumers had to approach payment points to “re-charge” their meters. The payment points are usually managed by the utility company or a third party and tend to be scarce. Payment methods for prepaid smart meters are expected to be more diverse than for regular prepaid meters. Smart prepaid meters are likely to leverage the proliferation of other technologies, such as the Internet and smart phones. New solutions will enable consumers to “re-charge” their meters through a wider range of electronic or online payments (instead of “recharging” through the scarce payment points). Contactless payment is seen as a user-friendly payment method for
consumers. A number of form factors can be used to enable contactless payments, but smart cards and mobile phones are at the forefront of industry advancements. However, as the utilities’ smart grids visions become a reality, we expect to see a greater number of prepaid smart meters. The Figure 2-11 below shows the block for a Prepaid Smart Water Meter.

2.7 Payment Solutions

There are several ways used globally to pay for the water consumption, the following are the most common of them:

2.7.1 RF ID Credit Cards

Contactless credit cards are cards that use radio-frequency identification (RFID) for making secure payments. It allows cardholders to wave their cards in front of contactless Meter payment terminals to complete transactions. Unlike a barcode, the tag need not be within the line of sight of the reader, so it may be embedded in the tracked object.

2.7.2 Barcode

With the deployment of Pay point payment solutions, barcodes could be used. The customer would pay with a bank card or cash, with the generated barcode allowing the user to reload energy levels.

2.7.3 Coins

This is the simplest and the most widely established way to pay via a prepaid meter. The main disadvantage of this system is the vulnerability of the meter itself. Indeed, there is a risk of
theft of the cash, while fraud is not rare. The other negative impact is on the energy supplier or subcontractor companies that need to collect the cash on a regular basis.

2.7.4 Pin/Tokens

This is one of the most important payment solutions used in the metering ecosystem. This payment concept offers simplicity and flexibility. There are different form factors to store the token or PIN. For example, the consumer could buy a ticket, including a token number, from dedicated shops and supermarkets. Alternatively, some solutions allow customers to reload a plastic key or a magnetic strip card via a dedicated vendor machine.

2.8 Benefits of Smart Water Metering

Advanced metering systems can provide benefits for utilities, retail providers and customers. Benefits will be recognized by the utilities with increased efficiencies, outage detection, tamper notification and reduced labor cost as a result of automating reads, connections and disconnects. Retail providers will be able to offer new innovative products in addition to customizing packages for their customers. In addition, with the meter data being readily available, more flexible billing cycles would be available to their customers instead of following the standard utility read cycles. With timely usage information available to the customer, benefits will be seen through opportunities to manage their energy consumption. Because of these benefits, many utilities are moving towards implementing some types of AMI solutions.

The benefits of smart metering for the utility: [8]

- Accurate meter reading, no more estimates
- Improved billing
- Accurate profile classes and measurement classes, true costs applied
- Improved security and tamper detection for equipment
- Energy management through profile data graphs
- Less financial burden correcting mistakes
- Less accrued expenditure
- Transparency of “cost to read” metering
- Improved procurement power though more accurate data - “de-risking” price
- In cases of shortages, utility will be able to manage/allocate supply.
• The benefits of smart metering for the customer.
• Improved billing and tracking of usage.
• in conjunction with volumetric pricing it provides an incentive for water conservation.

2.9 Problems of water metering

• Studies indicate that the implementation of PPWMs entrenches social inequality and poverty in society; as the rich use more water as there are able to pay for it. The two biggest barriers to prepaid metering in the North America market have been the high cost of meter as customers have to pay between US$225 - US$400 per installation. In addition, it is viewed as economic discrimination in terms of racial, social or cultural profiling. The poor have to consider their consumptions, hindering their water requirements and productive water use for improving their livelihood strategies. Productive use of water includes uses such as brewing, animal watering, construction and small-scale. An aspect of good neighborliness is lost in cases where PPWMs are introduced this is because water is likely to be treated as an individualized market commodity thereby largely excluding the poor from accessing it. Since the development in the United Kingdom, the use of these meters have spread through countries like Brazil, Egypt, Uganda, Curacao, Nigeria, Tanzania, Swaziland, Sudan, Malawi, Namibia and South Africa. Where the common evidence found, that the prepaid system of water supply being enforced on the poor is dangerous environmentally, socially, politically and questionable morally. The UKs 1998 Water Act declared prepayment meters to represents a threat to public health and water cutoffs to be an unacceptable method of recovering outstanding debt [9]

• Sudden changes in pressure can damage meters to the extent that many meters in cities in developing countries are not functional. Also, some types of meters become less accurate as they age, and under-registering consumption leads to lower revenues if defective meters are not regularly replaced. Many types of meters also register air flows, which can lead to over-registration of consumption, especially in systems with intermittent supply, when water supply is re-established and the incoming water pushes air through the meters. In addition, the real working life of prepaid meters is only about five to seven years, compared to the estimated 15 to 20 years for conventional meters.
From a cost perspective for the utility company, the operational cost, maintenance and installation cost and the price of the meter can be expensive.

- Utility can possibly control amount allocated to users. [10]
- Risk of loss of privacy - details of use reveal information about user activities.
- Greater potential for monitoring by other/unauthorized third parties.
- Potentially reduced reliability (more complicated meters, more potential for interference by third parties).
- Increased security risks from network or remote access [11]
3 Chapter 3: Design and Methodology

3.1 Introduction

This chapter shows the design methodology by giving a detailed description of the meter components and introducing the entire system scheme.

3.2 Design Approach

The smart water metering system consists of Water Flow Sensor, Batteries, microcontroller, Liquid Crystal Display (LCD), Keypad, GSM Module and Real Time Clock.

- Water Flow Sensor generally produces electrical pulses proportional to the amount of water consumed by the consumer, and these pulses go to the microcontroller.
- The microcontroller continuously subtracts the consumed water from the available credit and display the result on the LCD.
- When the result of the subtraction is zero, the microcontroller sends a signal to close the valve.
- Batteries are used to supply the system with the appropriate voltage levels to the different electronic components of the meter.
- RTC is used to supply the system with the real time and date.
- The GSM Module is used to communicate with the utility company providing it with the updates of the consumption rate.

3.3 System Design

3.3.1 Power Supply

Any invention of latest technology cannot be activated without source of power so in this fast-moving world we deliberately need a proper power source which will be apt for particular requirement. The power supply section is the most important one for circuit operation. It provides requirement power supply for every one blocks and it produce constant 5 volts DC voltage.
3.3.2 Microcontroller

A microcontroller is a compact integrated circuit designed to govern a specific operation in an embedded system. A typical microcontroller includes a processor, memory and input/output (I/O) peripherals on a single chip.

A microcontroller's processor will vary by application. Options range from the simple 4-bit, 8-bit or 16-bit processors to more complex 32-bit or 64-bit processors. Generally, microcontrollers are designed to be readily usable without additional computing components because they are designed with sufficient onboard memory as well as offering pins for general I/O operations, so they can directly interface with sensors and other components.

Microcontroller processors can be based on complex instruction set computing (CISC) or reduced instruction set computing (RISC). CISC generally has around 80 instructions while RISC has about 30, as well as more addressing modes, 12-24 compared to RISC's 3-5. While CISC can be easier to implement and has more efficient memory use, it can have performance degradation due to the higher number of clock cycles needed to execute instructions. RISC, which places more emphasis on software, often provides better performance than CISC processors, which place more emphasis on hardware, due to its simplified instruction set and, therefore, increased design simplicity, but because of the emphasis it places on software, software can be more complex. Which ISC is used varies depending on application.[13]

3.3.3 Liquid Crystal Display (LCD) display

The LCD (liquid crystal display) is based upon the liquid crystal technology. By applying Voltage to the LCD, it becomes opaque, but before that it was a transparent material. The above property is main operating principle of LCD. The LCD display is used for displaying account balance and power usage; It also acts as an interface between user and power meter.[13]

3.3.4 GSM (Global System for Mobile Communication) Modem

A GSM Modem is a specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, just like a mobile phone. From the mobile operator perspective,
a GSM modem looks just like a mobile phone. When a GSM modem is connected to a computer, this allows the computer to use the GSM modem to communicate over the mobile network. While these GSM modems are most frequently used to provide mobile internet connectivity, many of them can also be used for sending and receiving SMS and MMS messages. A GSM modem can be a dedicated modem device with a serial, USB or Bluetooth connection, or it can be a mobile phone that provides GSM modem capabilities. Communication with the GSM is done using a series of machine instructions used to activate features on an intelligent modem known as AT commands set. The AT command set is the standard set of instructions for configuring and controlling modems. The commands are short sequences of ASCII characters. All command strings (i.e., sequences of characters) must be prefaced by the letters AT, an abbreviation for attention, thereby accounting for the name of the set.[14]

3.3.5 Real Time Clock (RTC)

A real-time clock (RTC) is a computer clock that keeps track of the current time. RTCs are present in almost any electronic device which needs to keep accurate time.

Although keeping time can be done without an RTC, using one has benefits:

- Low power consumption (important when running from alternate power).
- Frees the main system for time-critical tasks.
- Sometimes more accurate than other methods[15]

3.4 The Water Meter Components

3.4.1 Batteries

An electric battery is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices.

Broadly there is two types of batteries:

- **Primary** (single-use or "disposable") batteries are used once and discarded
- **Secondary** batteries, also known as secondary cells, or rechargeable batteries.
3.4.1.1 **Advantages of Primary Battery**

- High energy density since no design compromises necessary to accommodate recharging.
- Best alternative for low cost, low drain applications such as watches or hearing aids.
- The obvious choice for single use applications such as guided missiles and military ordnance.
- Low initial cost
- Convenient.
- Wide availability of standard products

In this project 5V single-use battery was used.[16]

![Figure 3-1 batteries](image)

3.4.2 **PIC18F4550**

A PIC microcontroller is a small computer in a single integrated circuit containing a processor core, memory and programmable I/O peripherals. Program memory in the form of NOR flash is also often included on chip, as well as a typical small amount of RAM.

PIC Microcontrollers are designed for embedded applications in contrast to the microprocessors used in personal computers or other general purposes applications.

3.4.2.1 **Features:**

- **General Purpose I/O (GPIO):** Microcontrollers usually contain from several to dozens of general purpose input/output pins (GPIO). GPIO pins are software configurable to either an input or an output state. When GPIO pins are configured to an input state, they
are often used to read sensors or external signals. Configured to the output state, GPIO pins can drive external devices such as LEDs or motors.

- **Analogue-to-Digital Converters (ADC):** Many embedded systems need to read sensors that produce analog signals. This is the purpose of the analog-to-digital converter (ADC). Since processors are built to interpret and process digital data, i.e. 1s and 0s, they are not able to do anything with the analog signals that may be sent to it by a device. So the analog to digital converter is used to convert the incoming data into a form that the processor can recognize. A less common feature on some microcontrollers is a digital-to-analog converter (DAC) that allows the processor to output analog signals or voltage levels.

- **Timers:** In PIC microcontrollers programming timers are very useful. In addition to the converters, many embedded microprocessors include a variety of timers as well. One of the most common types of timers is the Programmable Interval Timer (PIT). A PIT may either count down from some value to zero, or up to the capacity of the count register, overflowing to zero. Once it reaches zero, it sends an interrupt to the processor indicating that it has finished counting. This is useful for devices such as thermostats, which periodically test the temperature around them to see if they need to turn the air conditioner on, the heater on, etc. Timers are a very important part of Microcontrollers that would be focused on in later labs.

- **Pulse-Width Modulation (PWM):** A dedicated Pulse Width Modulation (PWM) block makes it possible for the CPU to control power converters, resistive loads, motors, etc., without using lots of CPU resources in tight timer loops. The PWM generation hardware remains busy in generating a clock signal of your desired frequency and duty cycle whilst the processor can execute regular programs.

- **Universal Synchronous Asynchronous Receiver/Transmitter (USART):** This block makes it possible to receive and transmit data over a serial line with very little load on the CPU. Dedicated on-chip hardware also often includes capabilities to communicate with other devices (chips) in digital formats such as I²C and Serial Peripheral Interface (SPI).[17]

- **MULTIPLE IDLE MODES:** It has the advantage of working even when its CPU disabled but peripherals being active. The power can be reduced up to 4% in these states.
- **NANO WATT GENERATION**: PIC18F4550 is an 8-bit microcontroller. PIC18F4550 has been applied with NANO WATT technology, therefore, it requires very low strength for its operation.[18]
3.4.3 16x2 LCD

A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. The reasons being: LCDs are economical, easily programmable, have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on.

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD, and the data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD.

![Figure 3-4 LCD](image)

**Table 2 LCD Pin Description**

<table>
<thead>
<tr>
<th>Pin no.</th>
<th>Symbol</th>
<th>External connection</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vss</td>
<td>Power supply</td>
<td>Signal ground for LCM</td>
</tr>
<tr>
<td>2</td>
<td>VDD</td>
<td>Power supply</td>
<td>Power supply for logic for LCM</td>
</tr>
<tr>
<td>3</td>
<td>V0</td>
<td>Contrast adjust</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>RS</td>
<td>MPU</td>
<td>Register select signal</td>
</tr>
<tr>
<td>5</td>
<td>R/W</td>
<td>MPU</td>
<td>Read/write select signal</td>
</tr>
<tr>
<td>6</td>
<td>E</td>
<td>MPU</td>
<td>Operation (data read/write) enable signal</td>
</tr>
<tr>
<td>7~10</td>
<td>DB0~DB3</td>
<td>MPU</td>
<td>Four low order bi-directional three-state data bus lines. Used for data transfer between the MPU and the LCM. These four are not used during 4-bit operation.</td>
</tr>
<tr>
<td>11~14</td>
<td>DB4~DB7</td>
<td>MPU</td>
<td>Four high order bi-directional three-state data bus lines. Used for data transfer between the MPU</td>
</tr>
<tr>
<td>15</td>
<td>LED+</td>
<td>LED BKL power supply</td>
<td>Power supply for BKL</td>
</tr>
<tr>
<td>16</td>
<td>LED-</td>
<td>Power supply</td>
<td>Power supply for BKL</td>
</tr>
</tbody>
</table>
3.4.4 4x3 Keypad

The Keypad is used as an interface between the user and the meter, it’s used as one of the payment solution mentioned in chapter two to recharge the account by entering a PIN code which is generated from the utility water company or the vending machine from the sale point.

While entering the PIN code using the keypad, the LCD displays the numbers typed on the keypad. The keypad used in this project is 4x3 Keypad.

![Figure 3-5 Keypad](image)

3.4.5 Water Flow Sensor

Water flow sensor consists of a plastic valve body, a water rotor, and a hall-effect sensor. When water flows through the rotor, rotor rolls. Its speed changes with different rate of flow. The hall-effect sensor outputs the corresponding pulse signal. This one is suitable to detect flow in water dispenser or coffee machine. We have a comprehensive line of water flow sensors in different diameters. Check them out to find the one that meets your need most.
3.4.5.1 Features

- Compact, Easy to Install.
- High Sealing Performance.
- High Quality Hall Effect Sensor.[19]

Figure 3-6 Water Flow Sensor

3.4.6 GSM

GSM/GPRS module is used to establish communication between a computer and a GSM-GPRS system. Global System for Mobile communication (GSM) is an architecture used for mobile communication in most of the countries. Global Packet Radio Service (GPRS) is an extension of GSM that enables higher data transmission rate. GSM/GPRS module consists of a GSM/GPRS modem assembled together with power supply circuit and communication interfaces (like RS-232, USB, etc) for computer. GSM/GPRS MODEM is a class of wireless MODEM devices that are designed for communication of a computer with the GSM and GPRS network. It requires aSIM (Subscriber Identity Module) card just like mobile phones to activate communication with
the network. Also, they have IMEI (International Mobile Equipment Identity) number similar to mobile phones for their identification.

A GSM/GPRS MODEM can perform the following operations:

1. Receive, send or delete SMS messages in a SIM.
2. Read, add, search phonebook entries of the SIM.
3. Make, Receive, or reject a voice call.

The MODEM needs AT commands, for interacting with processor or controller, which are communicated through serial communication. These commands are sent by the controller/processor. The MODEM sends back a result after it receives a command. Different AT commands supported by the MODEM can be sent by the processor/controller/computer to interact with the GSM and GPRS cellular network.

![Figure 3-7 GSM & PIC18F4550 Block Diagram](image-url)
3.4.6.1 AT Commands

AT command set is the fundamental interface with the modem. An AT command is simply a string of characters preceded by the AT prefix that is sent to the modem. The commands typically instruct the modem to perform some action or set some characteristic within the modem. The modem has two states: command state and on-line state. In command state, the modem will accept and respond to AT commands. In the on-line state, the modem will transmit data, but ignore AT commands.

AT commands has the following format:

- The command is prefixed with AT (Attention).
- The command is terminated by a carriage return <CR> (except the A/ command and escape sequence).
- The commands can be entered in upper case or lower case.
- The AT prefix can be in upper case or lower case, but both the A and the T must be the same case.
- Multiple commands can be strung together on a single line and spaces may be included between commands but are not necessary.[20]
3.4.7 Real Time Clock (RTC – PCF8583)

The PCF8583 is a clock and calendar chip, based on a 2048 bit static CMOS1 RAM organized as 256 words by 8 bits. Addresses and data are transferred serially via the two-line bidirectional PC-bus. The built-in word address register is incremented automatically after each written or read data byte. Address pin A0 is used for programming the hardware address, allowing the connection of two devices to the bus without additional hardware.

3.4.7.1 Features of PCF8583

- PC-bus interface operating supply voltage: 2.5 V to 6 V
- Clock operating supply voltage 1.0 V to 6.0 V at 0 °C to +70 °C
- 240 × 8-bit low-voltage RAM
- Data retention voltage: 1.0 V to 6.0 V
- Operating current (at fSCL = 0 Hz): max 50 μA
- Clock function with four year calendar
- Universal timer with alarm and overflow indication
- 24 hour or 12 hour format
- 32.768 kHz or 50 Hz time base
- Serial input and output bus (PC-bus)
- Automatic word address incrementing
- Programmable alarm, timer, and interrupt function.[21]

Figure 3-9 RTC
3.5 Software Development

The system software is implemented by C language and the developed code is edited, compiled and debugged by mikroC PRO 6.6.3 software.

- For the developed code refer to appendix A.

3.6 Complete System Design

Putting all the mentioned components together gives the complete Energy Meter design shown in Figure 3-9

Figure 3-10 Complete System Design
4 Chapter 4: Results and Discussion

4.1 Introduction

This chapter is about Simulation and Discussion. Simulation was done with the use of software simulating program “Proteus 7.1 Professional”, along with C language Compiler “mikroC PRO 6.6.3” for the code written to the MCU.

Several separate code blocks were written for different blocks of the meter in order to simulate and test them separately before integration and system simulation and testing.

Some of the hardware components of the meter could not be simulated due to their unavailability on simulation programs, such as the Water flow sensor.

4.2 Block Simulation

4.2.1 LCD Simulation

A code was written to the MCU to continually output “Smart Water Meter” on the LCD. The LCD was connected to PORT D of the MCU.

![LCD Simulation](image)

Figure 4.1 LCD Simulation
4.2.2 RTC Simulation

The RTC was connected to the MCU at PORT D to pin6 (SCL) and pin7 (SDA), with pull-up resistors connected to pin5 (SDA) and pin6 (SCL) of the RTC as shown in the Figure below.

The operation of the RTC requires to have those pull up resistors, along with a crystal oscillator of 32.786kHz for the internal clocking circuit.

It is recommended to connect a battery to pin7 (3 volts VBAT) of the RTC because in case of power disconnection, the date and time obtained by the RTC will be lost and reset to the default values on repowering in the absence of the battery.

An LCD was connected to the same PORT to display the Time & Date, and a code was written into the MCU to carry this operation.

![Figure 4-2 RTC Simulation](image-url)
4.2.3 Keypad Simulation

The Keypad was connected to the Microcontroller at PORTA (from pin0 – pin6). And it worked perfectly as excepted by entering random numbers as shown in the figure below.

![Keypad Simulation Figure](image)

Figure 4-3 Keypad Simulation

4.3 System Simulation

Here the system was simulated using signal generator instead of the Water Flow Sensor with the exception of Input Batteries and the GSM modem. The complete code was written into the microcontroller and the output from the signal generator was connected to pin0 of PORT C. The input of the signal is subtracted from the previous remaining balance to obtain the new remaining balance which was successfully displayed on the LCD.

- The entire circuit could not be simulated on software due to unavailability of some of the hardware components of the meter such as the Water flow sensor and the GSM module.
• The Water Flow Sensor was replaced with a signal generator to simulate the output from the IC to the MCU at pin0 of PORT C.

• Moreover, the system simulation excluded the GSM part because it can only be tested by physically connecting the Modem to the circuit, and the Batteries was also removed from system simulation for its insignificance to software simulation.

• A LED was connected to pin7 of PORT D to indicate the statue of the Water Main Valve.

The Simulation starts with initial 150 gallons as shown in the figure below. And as there is a remaining balance, the Main valve –which is indicated by the yellow led- is open.

*Figure 4-4 System Simulation with the valve highlighted*
The process continues with the signal coming from the signal generator decrease the reaming balance. And the valve still opened as in the figures 4-5 below.

*Figure 4-5 System Simulation with the valve open*
As Shown Below, The remaining Balance is decreasing.

Figure 4-6 System Simulation Subtracting
When the result of the subtraction is zero, the supply of the water is stopped as shown in the figure below.

![Figure 4-7 System Simulation with balance zero and a closed valve](image)

At 12 am the GSM should send the daily water consumption, the C code for this process is:

```c
if(seconds==0 && minutes==0 && hours==0){
    SendDailyConsmpt();
    delay_ms(60000);
}
```
5 Chapter 5: Conclusion

5.1 Conclusion

This paper presented a prepaid smart water meter using two-way communication. It was an effort towards upgrading existing water meters; thus, improving the revenue collection for the scheduled supply.

The main achievement was that a water measurement system was successfully simulated. An LCD display was interfaced as well as a GSM modem with the proposed system and also a user-friendly interface program was successfully implemented. This user interface notifies the user of his current account balance after measuring the input accurately and assists him in recharging his account. A signal Generator was used as an input because it’s similarity with the Flow Measurement Sensor in the Smart Water Meter. The Sensor generates pulses an input to the Microcontroller with certain frequency. These analogue signals converted to digital signals with an internal ADC (analog to digital converter) in the Microcontroller. The GSM module was also successfully tested using the Hyper-Terminal program available on a PC.

The proposed prepaid meter was successfully implemented on a software model which was simulated with the help of Proteus 7.1 Professional and MikroC 6.6.3. For hardware implementation, the PIC18F4550 is categorized as a commercial microcontroller because of its low cost. Thus, this water meter is cost effective.

5.2 Limitation

However, the project still suffers from some limitation:

- The disability of the Proteus 7.1 Professional software to produce a power graph of the circuit in the simulation. And some components could not be found in the library of the Proteus 7.1 Professional such as the Meter flow sensor. So we used Pulse Generator because it mimics the use of Meter Flow Sensor.
- If the project is implemented, the power supply could be a problem because the batteries suggested for this project is finite and it has an estimated life time. And it’s also irreplaceable due to the sensitivity of the water meter internal components with
electricity. So, when the battery dies, the whole meter has to be replaced with a new unopened one.

- The Security introduced in this project which is the PIN code as a payment solution is vulnerable and not secure enough.

5.3 Future work

- Furthermore, some enhancements and improvements could be done, such as:
- This project was simulated on Proteus 7.1 Professional, with more time and researches a hardware model can be implemented.
- The finite irreplaceable power supply could be improved because of the advancement of technology. For example, a renewable source of energy such as Solar energy can be used, if the sufficient knowledge found.
- Because of the advancement of technology in fields such as IOT (Internet of Things) and AI (Artificial Intelligence), smartphones and Internet can be used to access the Smart Water Meter Remotely to monitor the consumption and control the valve. Furthermore, recharging the account balance. Also from the AI perspective, charging the user could be more specific, for example, a maximum limit could be set according to the user consumption and hence charging less or more for the user consumption.
- The Security introduced in this project which is the PIN code as a payment solution is vulnerable and not secure enough. A more secure approach could be implanted.
- The Tariff cost doesn’t depend on the season of the year or the time of the day. In developed countries which use the smart water meter, the tariff cost varies regarding the time of consumption.
References


Appendix A

The Complete Code

// Keypad module connections
char keypadPort at PORTB;

// End Keypad module connections

// LCD module connections
sbit LCD_RS at RD0_bit;
sbit LCD_EN at RD1_bit;
sbit LCD_D4 at RD2_bit;
sbit LCD_D5 at RD3_bit;
sbit LCD_D6 at RD4_bit;
sbit LCD_D7 at RD5_bit;

sbit LCD_RS_Direction at TRISD0_bit;
sbit LCD_EN_Direction at TRISD1_bit;
sbit LCD_D4_Direction at TRISD2_bit;
sbit LCD_D5_Direction at TRISD3_bit;
sbit LCD_D6_Direction at TRISD4_bit;
sbit LCD_D7_Direction at TRISD5_bit;

// End LCD module connections

// RTC module connections
sbit Soft_I2C_Scl at RD6_bit;
sbit Soft_I2C_Sda at RD7_bit;
sbit Soft_I2C_Scl_Direction at TRISD6_bit;
sbit Soft_I2C_Sda_Direction at TRISD7_bit;
// End Software I2C connections

// Global variables
unsigned short kp = 0; // For Keypad
char txt[6];
char seconds, minutes, hours, day, month, year; // For RTC
char number[] = "+249927767818"; // For GSM
int daily_cons = 0;
int sensor;
int Balance;

// --------------GSM Module Initialization
void GSM_init()
{
    UART1_Init(9600);
    delay_ms(1000);
}

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

void SendDailyConsmp()
{
    UART1_Write_Text("AT");
    Delay_ms(1000);
    UART_Write(0x0D);
    Delay_ms(1000);
    UART1_Write_Text("AT0");
    Delay_ms(1000);
    UART_Write(0x0D);
    Delay_ms(1000);
    UART1_Write_Text("AT+CMGF=1");
    Delay_ms(1000);
    UART_Write(0x0D);
    Delay_ms(1000);
    UART1_Write_Text("AT+CMGS=");
    Delay_ms(200);
    UART1_Write(0x22);  // "
    Delay_ms(200);
    UART1_Write_Text(number);
    Delay_ms(200);
    UART1_Write(0x22);  // "
    Delay_ms(1000);
UART_Write(0x0D);
Delay_ms(1000);
UART1_Write_Text(daily_cons);
Delay_ms(2000);
UART_Write(26);
Delay_ms(1000);
UART_Write(0x0D);
Delay_ms(1000);

} //--------------------- Reads time and date information from RTC (PCF8583)

void Read_Time() {

Soft_I2C_Start(); // Issue start signal
Soft_I2C_Write(0xA0); // Address PCF8583, see PCF8583 datasheet
Soft_I2C_Write(2); // Start from address 2
Soft_I2C_Start(); // Issue repeated start signal
Soft_I2C_Write(0xA1); // Address PCF8583 for reading R/W=1

seconds = Soft_I2C_Read(1); // Read seconds byte
minutes = Soft_I2C_Read(1); // Read minutes byte
hours = Soft_I2C_Read(1);       // Read hours byte
day = Soft_I2C_Read(1);         // Read year/day byte
month = Soft_I2C_Read(0);       // Read weekday/month byte
Soft_I2C_Stop();                // Issue stop signal

} //-------------------- Formats date and time

void Transform_Time() {

seconds  =  ((seconds & 0xF0) >> 4)*10 + (seconds & 0x0F);  // Transform seconds
minutes  =  ((minutes & 0xF0) >> 4)*10 + (minutes & 0x0F);  // Transform months
hours    =  ((hours & 0xF0)  >> 4)*10  + (hours & 0x0F);    // Transform hours
year     =   (day & 0xC0) >> 6;                             // Transform year
day      =  ((day & 0x30) >> 4)*10    + (day & 0x0F);       // Transform day
month    =  ((month & 0x10)  >> 4)*10 + (month & 0x0F);     // Transform month
}

void Display_Bal(){

Lcd_Cmd(_LCD_CLEAR);               // Clear display
Lcd_Cmd(_LCD_CURSOR_OFF);          // Cursor off
Lcd_Out(1,3,Balance);
Lcd_Out(2,9,"Galloons");
}

}
void main() {
    Keypad_Init();  // Initialize Keypad
    Lcd_Init();    // Initialize LCD
    Delay_ms(500);
    GSM_init();    // Initialize GSM
    Soft_I2C_Init(); // Initialize RTC

    OSCCON = 0X70;
    ADCON1 = 0x0F;
    TrisD.f7 = 0; // The Main Valve
    TrisC.f0 = 0; // The Water flow Sensor

    while (1) { // Endless loop
        Read_Time(); // Read time from RTC(PCF8583)
        Transform_Time(); // Format date and time

// entering data from keypad
    kp = 0; // Reset key code variable
// Wait for key to be pressed and released
do
 // kp = Keypad_Key_Press(); // Store key code in kp variable
 kp = Keypad_Key_Click(); // Store key code in kp variable
while (!kp);

// Prepare value for output, transform key to its ASCII value
switch (kp) {

case  1: kp = 49; break; // 1

case  2: kp = 50; break; // 2

case  3: kp = 51; break; // 3

case  4: kp = 52; break; // 4

case  5: kp = 53; break; // 5

case  6: kp = 54; break; // 6

case  7: kp = 55; break; // 7

case  8: kp = 56; break; // 8

case  9: kp = 57; break; // 9

case 10: kp = 42; break; // *

case 11: kp = 48; break; // 0

case 12: kp = 35; break; // #
}

Lcd_Chr(1, 10, kp); // Print key ASCII value on LCD
}
Calculate Daily consumption

daily_cons = daily_cons+sensor;

//Calculate the Remaining Balance
Balance = Balance-sensor;
if(Balance==0)
{
    PORTD.f7 = 0;
}
else
{
    PORTD.f7 = 1;
}

//Display the Remaining Balance
Display_Bal();

//send the daily consumpution at 12am
if(seconds==0 && minutes==0 && hours==0){
    SendDailyConsmpl();
    delay_ms(60000);  
}