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Design and Construction of a Global System for Mobile-Short Messaging Service (GSM-SMS) Based Remote Control System Using Android Application for Kaseba Reservoirs Discharge Valve.

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ABSTRACT

The project sought to design and construct a Global System for Mobile (GSM)-Short Messaging Service (SMS) based remote control system that will be used to remotely operate an industrial water discharge valve using an android application at Kaseba water treatment plant for Lusaka Water Supply and Sanitation Company (LWSC) in Kafue district. The project was designed and developed to pro-vide a simple and cost-effective solution for the remote control and monitoring of plant equipment and appurtenances in the water production and distribution sector.

Various technologies were used to develop and construct this project including instrumentation equipment, industrial routers and ICT. In this project, equipment such as valves and pumps can be operated remotely via mobile application. The project involved the use of GSM modules which are used for receive and send Short Message Service (SMS), a smart phone as an interface between the valve and the operator, control panel for the variable frequency Drive (VFD), programming of the GSM module using the BASIC Scripting Language. Designing and implementation of an android application using JAVA and XML programming languages on an android studio version 4.0 IDE platform. The Software Development Life Cycle (SDLC) used was agile and prototype. The system was intended to address the tedious work of the plant operators at Kaseba water treatment plant whose operation of plant equipment relied on manual operations. This system did not only automate the operations of this valve and increase efficiency in plant operation but also improve safety of opera-tors - operators need not walk to reservoir site at night to operate the valve.

Keyword: *SMS, Android mobile application, Global System Mobile, SDLC.*

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I) INTRODUCTION

Background

Industries resort to automation of plants in order to monitor, control processes and optimize production and quality. Towards this end, it is essential to make automation efficient and economical and mostly if data is required to be transferred remotely across sites. This is the case with Lusaka Water Supply and Sanitation Company (LWSC) plants, where production sites and appurtenances are not localized. The integration of Internet and wireless communication technique make many applications change from ideal into reality, such as remote monitor, diagnostic and control of different electrical equipment and installations (Pancu, 2015). One of the significant applications of the wireless automation system is to ensure the safe operation of the plant and to avert fatal possible accidents, which can also be catastrophic disaster and can have an adverse effect on the environment, (Hamed, 2018) The new age of technology has redefined communication, most people nowadays have access to mobile phones and other mobile devices such laptops, pads and so on. Thus, making our lives better and simpler. Nearly every individual has a mobile device on which he/she can be contacted on with. But application of mobile phones cannot be restricted to sending SMS to start conversation. New innovation and ideas can be generated from it that can further enhance its capabilities. Remote management of several home, offices and industrial appliances is a subject of growing interest and in recent years we have seen many systems providing such controls. There are other technologies such as SCADA, PLC and DCS systems that can be used to remotely control industrial devices but the cost of these systems limits its application to large cooperation. It is therefore, imperative that alternative means that are cost effective are found in order to improve these processes and safeguard the well-being of employees. This, therefore make GSM based systems to be the cheapest technology. Technology has advanced so much in the last three decade that it has made life more efficient and comfortable. The comfort of being able to take control of devices from one particular location has become imperative as it saves a lot of time and effort. This system will not only in-crease efficiency in plant operation but also improve safety of operators - opera-tors need not to walk to intake site at night.

Motivation and Significance of the study

Water and sanitation services are universal human rights. Therefore, countries aim at ensuring that their citizens gain access to water in sufficient quality and quantity. The states also strive to provide the best possible sanitation service. However, the access to water and sanitation service is still a challenge in most African countries. African countries have experienced rapid growth in population and increased urbanization, Zambia inclusively. These coupled with inadequate funds for expansion of water and sanitation infrastructure leave majority of African citizens unable to access improved water and sanitation services. World Health Organization (WHO) and United Nations Children's Fund (UNICEF) 2014 report indicated that 40% of people without access to improved drinking water live in Africa. Although, globally the Millennium Development Goal (MDG) of halving the number of people without access to safe drinking water was met, sub-Saharan Africa (SSA) did not meet its target. This brought about the need for Zambian water utility companies like LWSC to find alternative means that are cost effective in order to improve its production of clean water and improving service delivery. The key to achieving universal access to water and sanitation as envisaged in Vision 2030 lies with the ability of water service providers (WSP) and their partners to rehabilitate the existing water infrastructure and expand to other uncovered areas, most notably the rural poor. Thus, this project aimed at constructing

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GSM-based system to provide a simple and cost-effective solution for the remote control and monitoring of plant equipment in the water production and distribution sector.

Scope

The scope of this research work involved the design and construction of a GSM-SMS based system and development of an android application using android studio version 4.0. Programming of industrial GSM-module using the BASIC scripting language. The operator will be able to operate the valve from the comfort of their offices or anywhere else. The project is highly adaptable and can be used to remotely control and monitor various kinds of equipment such as pumps, valves and other high-power electrical appliances. This means the configuration of the system components varies depending on the equipment the system will be used on.

Project Objectives

The main objective of this project is to construct a GSM-SMS based remote control system for Kaseba Reservoir Discharge control Valve using an android application. This will enable the complete control of the water discharge control valve using the GSM-SMS based technology and android application. The project aims to improve the operation of water production and distribution systems by providing computerized monitoring and process control resulting in reduced production costs and improving delivery of water to the community.

Specific Objectives

The specific objectives of this proposal include the following:

- Solicit hardware and software requirements from user's needs. The activities under this task includes holding meetings and site visits with relevant staff of LWSC with information of existing valves and water network, proposing new technology to be used to the users and analysing how the technology can be merged with existing appurtenances.
- To develop a mobile application that will interface with electrical devices
- Developing and installing automated valve control system. The activities under this task will include the development, installation and operation of automated control valve.
- Developing relevant documentations which will support sustainability and smooth running of the system

Research Questions

The operators are required to walk long distance up the hills were the manual valve is located to regulate it to the required position. Research questions that the study sought to answer were:

1. Is it possible to automate the manual discharge control valve?
2. Is it possible to use the existing components to develop the system?
3. 3. Is it possible to develop a mobile application for interfacing with the electrical devices?

II) REVIEW OF THE LITERATURE

"Industrial automation (IA) greatly reduces the necessity for human sensory, human workforce and price. With the rapid growth in the sensors, control and automation technologies, many control systems such as Programmable Logic Controller (PLC), Distributed Control Systems, Supervisory Control and Data Acquisition (SCADA) are performing a significant role in the automation of industries by using software and hardware tools" Chattal (2019). 'To resolve the automation and control issues, industries use the ever-changing technologies for

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efficient production or manufacturing processes. These requires the top quality and reliable control systems. New trends in industrial automation deals with latest control devices and communication protocols to regulate field devices like control valves and other final control elements. Some of the smart devices or instruments utilized in automated industry has the power to regulate the processes and also communication capabilities without interfacing to other field level control devices like PLC's' (Jadhav, 2019). Satyendra (2016) Defined Automation as a set of technologies that leads to operation of machines and systems without significant human intervention and achieves performance superior to manual operation. Companies undertake projects in manufacturing automation and computer-integrated manufacturing for a spread of excellent reasons.

This section looks at similar projects that have been constructed before to resolve challenges using GSM-SMS technology and application of the android mobile application in Africa and the world at large. It also highlights the importance of incorporating such technologies in the everyday life away from just using the technology for person to person communication. A lot of projects have been constructed and implemented in different parts of African using the GSM-SMS technology for controlling and monitoring different gadgets. These projects include automation of household electrical appliances such as air conditions geysers, cooling funs automated gates etc.

In developing countries like Zambia, automation of processes and services in most parastatal companies is an expensive venture and less or little is done as the process is considered expensive. Hence alternative systems that are less costly can be used. The GSM-SMS technology that is offered by the mobile telecommunication providers is less expensive and affordable. The GSM-SMS technology is being used in different fields such as agriculture, healthy and industrial processing especially in remote areas. The implementation of mobile applications that will be acting as an interface between the user and the equipment being monitored representing the real time status of the activities, also makes life much easier.

Prakash and Sirisha (2014) designed and implemented a Vehicle Theft Control Unit using GSM and CAN Technology. This project dealt with the design & development of a theft control system, which is used to prevent/control the theft of a vehicle. The developed system made use of an embedded system based on Global System for Mobile communication (GSM) technology with CAN bus along with RFID system. The RFID reader was interfaced with the microcontroller through serial interface to detect the hospitals, hotels, petrol bunks, temples etc. The objective of the project was to build an additional feature to the present security system that would warn the owner of the vehicle by sending SMS when there was an intrusion into the vehicle. To provide a solution to avoid car stolen in the lower cost than advance security car system (GPS).

Towers (2000) Projects "Implementation of a Generalized API for Application Control by Telephony Devices" designed an API application that would use the GSM-SMS technology to addresses problems by offering an interface to telephony (DTMF, voice, SMS, WAP) services which communicates with application programs through a service daemon. Access to the applications via remote control over the Internet (WWW5, telnet, email) was also provided.

Pancu, (2015) Presented a paper which proposed a wireless solution, based on GSM (Global System for Mobile Communication) networks for monitoring, diagnostic and control of the medium voltage (MV) and high voltage (HV) circuit breakers. This architecture had the advantage of being used for monitoring of some electrical and

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cinematic parameters for the operating mechanism, the alarms being sent via GSM network. Also, the proposed system allows on-line monitoring and diagnostic of the equipment.

In Zimbabwe, Blessed Machengete (2017), designed and developed an android based tomato irrigation system. This project aimed at devising a simple low-cost android based tomato irrigation system based on GSM-SMS technology. The user will be able to control the Irrigation system using an android application on a smart phone. This project was developed by using Arduino Uno, SIM900 GSM module, LCD display, soil moisture sensors and water tank level sensor. The an-droid application makes use of the GSM technology to send commands to the irrigation system. This makes the Android application reliable and cheap to use.

Tun and Dr. H. Tun (2014) presented a paper entitled "Design and Construction of Condition Reporting System Based on GSM Technology for Power Station" This paper described a condition reporting system of Power plant components using GSM technology. This was to overcome the manual reporting systems commonly used in Myanmar. The objective of this paper was to transform manual system to automated reporting system with the help of GSM technology. The system comprised of GSM modem system, microcontroller system and sensing system. A dedicated microcontroller-based hardware unit (DHU) was developed to continuously measure the parameters of the viz. voltage, current and temperature of generation of the alternator to monitor the running condition of it also. Other than the generator there are subsystems which also need continuous monitoring.

Johari et al also presented the development of water level monitoring system with an integration of GSM module to alert the person-in-charge through Short Message Service (SMS), [3]. The water level is monitored and its data sent through SMS to the intended technician mobile's phone upon reaching the critical level. The prototype was tested and functioned properly as a mean to re-duce the risk of un-expected shortage of water supply.

In India, Reuters Market Light (RML) offers agricultural information to farmers since 2007. The information is sent to the farmers using SMS on their mobile phones. The information that is sent is personalized based on the stage of the crop cycle. The weather forecast and local market prices together with international commodities information is also provided by RML. One key feature of this service is that the information is personalized and can be accessed by a farmer in his own local language.

III) METHODOLOGY

A. *Baseline study*

The project site for the design and construction of a GSM-SMS based remote control system was conducted at Kaseba Water treatment plant which one of the water treatment plants for Lusaka Water Supply and Sanitation Company(LWSC) located in Kafue. The district which is roughly 50km south of Lusaka has a population of about 160, 000 people.The population mainly depend on LWSC for clean drinking water. Kaseba water treatment plant has an average daily production of 22000 cubic metre.The operation regime used thus far is manual system to distribute water to the communicate.Kaseba water treatment plant has work force of about 25 working personell who managers the affairs of the plant.

B. Data Collection

The feasibility study that was conducted at Kaseba Water Treatment plant was targeted at the plant operators and their operation supervisors who are the custodian of the plant. Interviews were conducted with the operators, supervisors and engineers on site and questionnaires were

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distributed to get more information on the challenges faced with the current manual system. The main objective of this study was to enable the operators and engineer's participation in the automation and development process of the system and acquire data on the best approach to realize the system. To achieve the objectives several activities were undertaken:

- Requirement Gathering and Analysis: Requirement Analysis is the process of defining user expectations for a new software being built or modified. Requirements analysis encompasses those tasks that go into determining the needs or conditions to meet for a new or altered product or project, taking account of the possibly conflicting requirements of the various stakeholders, analyzing, documenting, validating and managing software or system requirements. In other words, requirement is a software capability that must be met or possessed by a system or system component to satisfy a contract, standard, specification, or other formally imposed documentation

- Brainstorming: Brainstorming is a way to generate ideas within a group setting. It is usually used in the beginning stages of a project, where the possibilities for the project are not clearly understood or defined. It provides a quick means for tapping the creativity of a limited number of people for a large number of ideas. The brainstorming environment fosters an uninhibited, non-judgmental explosion of ideas, concepts, policies, decisions, and strategies. In brainstorming, all contributions are valid, and the key to a successful session is to share as many ideas as possible without evaluating them. Flowchart of activity conducting.

- Feasibility Analysis was to check how much of the idea can be put into action. A feasibility study is an analysis into the viability of an idea. Feasibility studies help answer the essential question, "Should we proceed with the proposed idea?" The objective study may be completed in conjunction with a SWOT planning process, which looks at the strengths, weaknesses, opportunities, and threats that may be present externally (the environment) or internally (resources).

- Observations (Activities, reports) the other activity that helped gather more information where observation. By definition, Observation is way of gathering data by watching behaviour, events, or noting physical characteristics in their natural setting. This included observing processes, and reports analyzing various processes of the current system.
- The sample design and actual sampling was conducted and is as presented in the Table below.

Type of Frame	Sampling Technique and Justification	Population Element
Primary frame	Judgement sampling – On consideration that being an old infrastructure, the network set would be easily be noted	Plant engineers and supervisors
Secondary frame	Convenient sampling – to manage time limitations and resources constraints, reuse of the existing components such the control panel and power.	The reuse of the industrial Routers and valves to improve on the existing system
Tertiary Frame	Probability systematic sampling – chosen to eliminate any element of bias.	25 respondents comprising were selected, on the bases of every kth respondent, where –k is a number of respondents/25

Figure 1

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C. Research Approach

Data was collected from the targeted workforce using a combination of methods, which included interviews and questionnaires. The targeted population was the plant operators, technicians and engineers at Kaseba Water treatment plant in Ka-fue. The data collection started in November 2019 and end in December 2020. The questionnaires had questions that were used to meet the Objectives of the study which were highlighted in Chapter

D. Development of the Mobile application

This section describes the system development life cycle of mobile application used to interface with the remote-control system. "Software development life cycle (SDLC) is a series of phases that provide a common understanding of the software building process. How the software will be realized and developed from the busi-ness understanding and requirements elicitation phase to convert these business ideas and requirements into functions and features until its usage and operation to achieve the business needs" [67]. A software development methodology is a framework that is used to plan, and control the entire process of constructing an application or a system. Hence, it may be required to choose the right SDLC model according to the specific concerns and requirements of the project to ensure its success. These software development systems models include the waterfall model, rapid application development model, the spiral model, the incremental model and the prototype model.

Agile methods

'Agile is a process by which a team can manage a project by breaking it up into several stages and involving constant collaboration with stakeholders and continuous improvement and iteration at every stage 9Claudius Consultancy, 2020), It is based on iterative and incremental development, where requirements and solutions evolve through collaboration between cross-functional teams. The Agile method-ology begins with clients describing how the end product will be used and what problem it will solve. This clarifies the customer's expectations to the project team. Once the project team has identified the work, prepared the schedule, and estimated the costs, the three fundamental components of the planning process are complete. This is an excellent time to identify and try to deal with anything that might pose a threat to the successful completion of the project [49]. Continuous collaboration is key, both among team members and with project stakeholders, to make fully-informed decisions' (Hannon J, 2017).

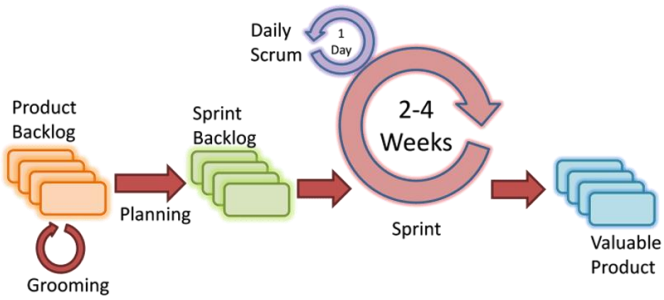

Figure 2

https://dilushasandaruwani07.medium.com/

It can be used with any type of the project, but it needs more engagement from the customer and to be interactive. Also, we can use it when the customer needs to have some functional requirement ready in less than three weeks and the requirements are not clear enough. This will enable more valuable and workable piece for software early which also increase the customer satisfaction.

Prototype Methodology

The Software Prototyping refers to building software application proto-types which displays the functionality of the product under development, but may not actually hold the exact logic of the original software. It is an activity that can occur in software development and It helps get valuable feedback from the customer and helps software designers and developers understand about what exactly is expected from the product under development

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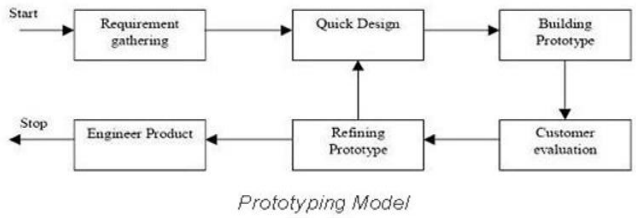
Rindani (2017). Prototyping is used to allow the users evaluate developer proposals and try them out before implementation. It also helps understand the requirements which are user specific and may not have been considered by the developer during product design Jordanhoward (2017). The diagram below show the stages involved in prototype methodology.

Figure 3

http://www.tryqa.com



Prototyping Model

The explanation of the stages involved in prototyping is well explained by (Lumauag RG, n.d) as listed below:

Requirement gathering: This step involves understanding the very basics product requirements especially in terms of user interface. The more intricate details of the interior design and external aspects like performance and security are often ignored at this stage.

Quick Design: The initial Prototype is developed during this stage, where the very basic requirements are showcased and user interfaces are provided. These features might not exactly add an equivalent manner internally within the actual software developed. While, the workarounds are wont to give an equivalent look and feel to the customer within the prototype developed.

Building Prototype: The prototype developed is then presented to the customer and the other important stakeholders in the project. The feedback is collected in an organised manner and used for further enhancements within the product under development

Customer Evaluation: The feedback and therefore the review comments are discussed during this stage and a few negotiations happen with the customer supported factors like – time and budget constraints and technical feasibility of the particular implementation. The changes accepted are again incorporated within the new Prototype developed and therefore the cycle repeats until the customer expectations are met.

Refining Prototype: The prototype developed is then presented to the customer and therefore the other important stakeholders within the project. The feedback is collected in an organised manner and used for further enhancements within the product under development.

E. System design and implementation

A control system consists of subsystems and processes (or plants) assembled for the purpose of obtaining a desired output with desired performance, given a specified input. There are two types of control system namely; open loop control system and closed loop control system. Open loop control system involves the control of an electrical or mechanical equipment without having feedback from the equipment being controlled whereas the closed loop control system involves the use of control and having feedback from the equipment being controlled. Consider the diagram below:

Figure 4: Open Loop Control

https://www.electrical4u.com/

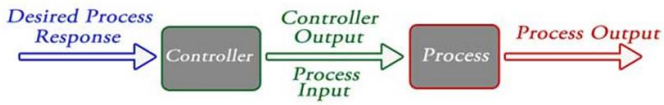
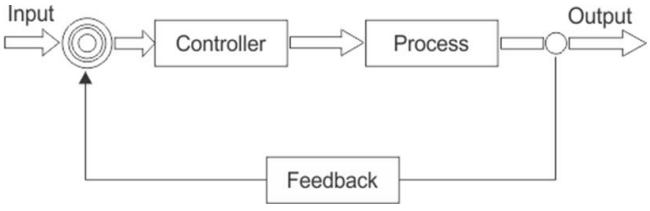


Figure 5 Closed Loop control

https://www.electrical4u.com/



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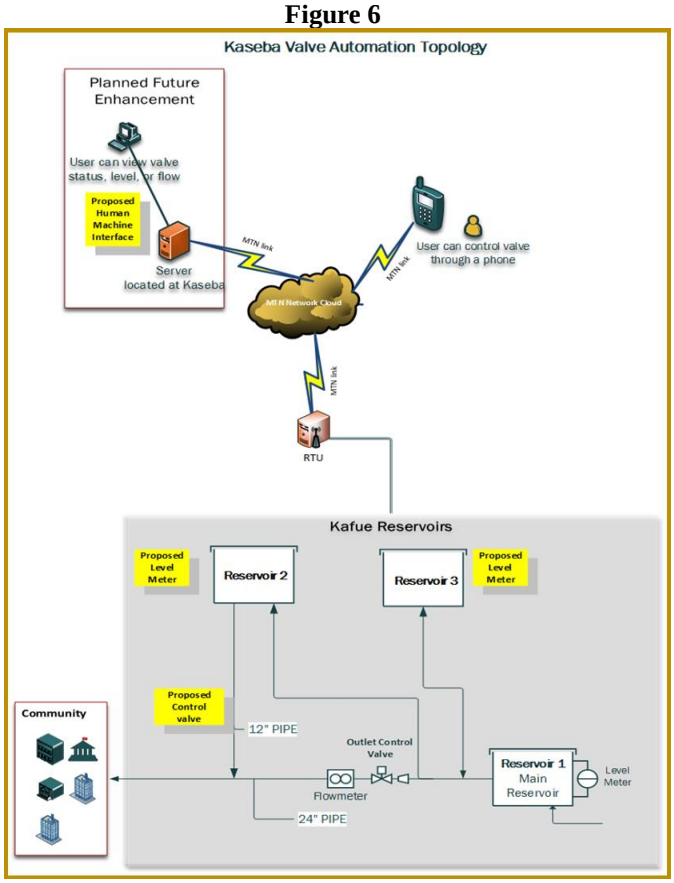
The proposed system is a closed loop control system which consists of an industrial router which acts the main controller that has GSM modem embedded in it for receiving, transmitting and switching on and off the digital input and output, 24vdc power supply, 24vdc relays for switching on and off the variable frequency drives (VFD). The motorized proportional control valve which is the final control element that needs to be controlled. The diagram below shows the layer of the system

C:\Users\client\Desktop\Final Year Project

Figure 6



Remote Terminal Unit (or RTU) is an electronic device utilizing a microprocessor, which links objects in the physical world with an automation system.

This is accomplished by transmitting telemetry data to the system and/or changing the physical state of connected objects based on control messages received from the automation system (Lea & Wells 2008). The RTU houses the following components in the project

GSM Industrial Router: This is device that was used as the main controller in this project. The industrial router has GSM module embedded in it, which is used for both sending and receiving the commands across GSM network. GSM is an open and digital cellular technology used for transmitting mobile voice and data services. A GSM modem requires a SIM card to be operated and operates over a network range subscribed by the network operator. It can be connected to a computer through serial, USB or Bluetooth connection.

It provides a two-way communication for data transmission, status and configuration setups. It is designed for wireless monitoring and control through short messaging service (SMS).

'The security strategies standardized for the GSM system make it the most secure telecommunications standard currently accessible. Although the confidentiality of a call and secrecy of the GSM subscriber is just ensured on the radio channel, this is a major step in achieving end-to- end security'. The circuit diagram is as shown in the figure below.

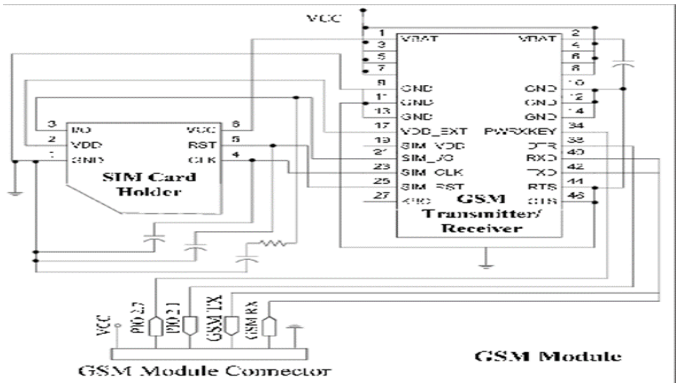


Figure 7

Power Supply is a hardware component that supplies power to an electrical device after converting it from one form to another. In this project, a 24vdc, 10A, Power supply was used. The power supply is fed with 230Vac alternating current voltage source which is converted to 24vdc voltage which is the operating voltage for GSM module and relay devices. "Switch Mode Power Supplies, or SMPS, are becoming common place and have

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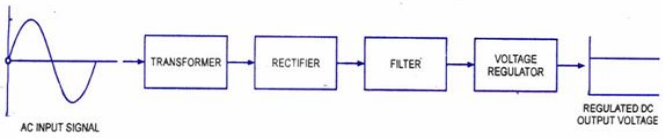
replaced in most cases the traditional linear ac-to-dc power supplies as a way to cut power consumption, reduce heat dissipation, as well as size and weight. (Saya, 2019). The diagram below illustrates power transformation in a power supply unit.

Figure 8

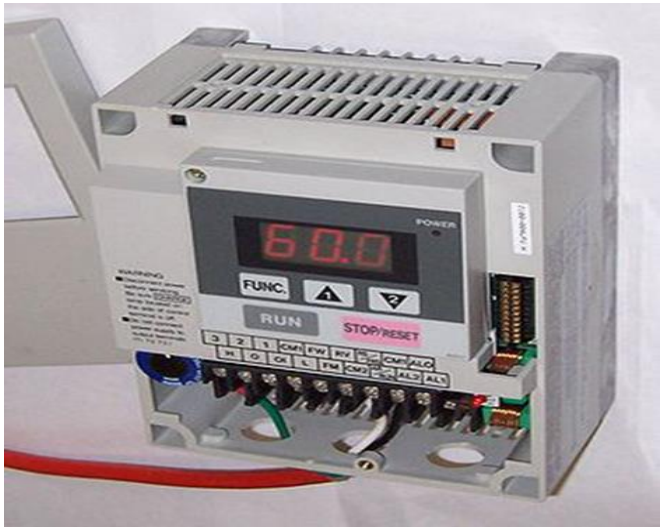
https://www.researchgate.net/



Block Diagram of a DC Power Supply

Variable Frequency Drive (VFD) is stated as a device that uses power electronics to vary the frequency of input power to the motor, thereby controlling motor speed Saya, M. (2019). It is a high-power electric device that was used to control the speed of the motor that is opens and closes the industrial valve. The function of the variable frequency drive in the project was used to convert the single phase 230Vac into three phase voltage to power the three-phase motor mounted on the control valve and to provide the forward reverse function of the control valve.

Figure 9



Source: *https://www.elprocus.com/*

Relays**:** 'A relay is a switching device as it works to isolate or change the state of an electric circuit from one state to another. Relays are the primary protection as well as switching devices in most of the control processes or equipment' (Bansod et al, 2018). All the relays respond to one or more electrical quantities like voltage or current such that they open or close the contacts or circuits as stated by Krishna et al (2019). There is no electrical connection inside the relay between the two circuits – the link is magnetic and mechanical only.

The picture below depicts different types of relays that be used in different circuits.

Types of Relays are available with several different operation types depending on your application:

Normally-Open (NO): This simply means that the two power contacts of the relay are connected when the relay coil is turned on and disconnected when the relay coil is turned off.

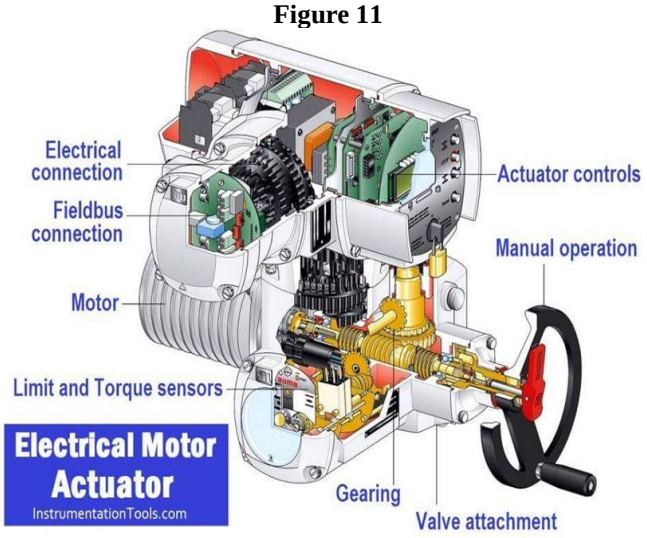
1. Normally-Closed (NC): This is the opposite of Normally-Open; the power contacts are connected when the relay is off and disconnected when the relay is on.
2. Latching: This means that the contactor switch in the relay is not spring-loaded, and it stays in whatever position it is placed into until the polarity is reversed to the coil, which returns the contactor switch to its original position. This is like a typical home light switch—it stays on until you switch it off.
3. Non-latching: This is the "normal" type of relay that we use for failsafe switches. The relay contactor switch is spring-loaded and returns to the preset position unless power is applied to the coil. This is comparable to a momentary button switch—it stays on only while you press the button; otherwise, it springs back to the off position.

Figure 10

Source: *www.elprocus.com*

Control Valve; Control valves are valves used to control conditions such as flow, pressure, temperature, and liquid level by fully or partially opening or closing in response to signals received from controllers that compare a "set point" to a "process variable" whose value is provided by sensors that monitor changes in such conditions Control Valve is also termed as the Final Control Element (Hussein et al 2015).'The opening or closing of control valves is usually done automatically by electrical, hydraulic or pneumatic actuators. Positioners are used to control the opening or closing of the actuator based on electric, or pneumatic signals. These control signals, traditionally based on 3-15psi (0.2 to 1.0 bar), more common now are 4-20mA signals for industry' (Som, 2013). Consider the diagram below:

Figure 11



Android mobile application, Android applications are developed using Java which can be ex-ported rather easily to the new platform. Android is an open-source platform for mobile, embedded and wearable devices (Android Developer Blog, 2016). "Mobile application development is the process by which application software is developed for low power handheld devices, such as personal digital assistants, enterprise digital assistants or mobile phones. These applications can be pre-installed on phones during manufacturing, downloaded by customers from various mobile software distribution platforms, or delivered as web applications using server-side or client-side processing (e.g. JavaScript) to provide an "application-like" experience within a Web browser".

Database Servers: A database is an organized collection of data, generally stored and accessed electronically from a computer system. A database management system (DBMS) is a software tool that makes it possible to organize data in a database. The ten functions in the DBMS are: data dictionary management, data storage management, data transformation and presentation, security management, multiuser access control, backup and recovery management, data integrity management, database access languages and application programming interfaces, database communication interfaces, and transaction management.

F. System Design

Systems design is the process of defining, developing and designing systems which satisfies the specific needs and requirements of a business or organisation. A systemic approach is required for a coherent and well-running system. Bottom-Up or Top-Down approach is required to take into account all related variables of the system. A designer uses the modelling languages to express the information and knowledge in a structure of system that is defined by a consistent set of rules and definitions. The designs can be defined in graphical or textual

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modelling languages. Some of the examples of graphical modelling languages are

1. Unified Modelling Language (UML): To describe software both structurally and behaviorally with graphical notation.
2. Flowchart: A schematic or stepwise representation of an algorithm.
3. Business Process Modelling Notation (BPMN): Used for Process Modelling language.
4. Systems Modelling Language (SysML): Used for systems engineering.

Design methods:

G. Context diagram

The following diagram shows how the mobile application interacts with its environment.

C:\Users\client\Desktop\Final Year Project Figure 12

Figure 1

The context diagram of the GSM-SMS based system is as shown in Figure 9. The GSM-SMS based system offers operators the opportunity to control the valve remotely without physically being present on site. The system can be operated from any location assuring the smooth operation. The system is able to give the real time status of the valve with feedback indicating the status on site.

A. System Software Level architectural design

A system analysis was done in order to determine the requirements of the system. The android mobile application and system requirements documents were generated. Functional and non-functional requirements were developed. In order to develop the requirements, the use case diagram and use case text were developed.

The mobile application which was developed is based on the short message service (SMS) platform. The android application has three main functions; to send a start and stop command in form of SMS text, receive the feedback status and indicate whether the valve has opened or closed to the required position or not. The operators will act accordingly if the feedback is not as requested.

B. Functional Requirements

A functional requirement describes a functional behavior that a system or system component should be able to perform. Functional requirements are the properties or function of the System. Mobile application supports three users, namely; Administrator, User and Valve. User has limited administrative tasks. The following are the functional requirements of Android application:

1. Operator must be able to open and close Valve Using SMS.
2. Indicate Status: The android application must be able to indicate the current valve position
3. The valve must stop the VFD upon closing or opening the Valve 100%
4. The shift engineer must be able to check the log events in case of failure

C. Non-Functional Requirements

Non-Functional requirements can be defined as global constraints on the software system and they include development costs, operational costs, performance, reliability, maintainability, portability, robustness etc. They usually cannot be implemented in a single module of a program (Sami, 2012). The mobile application which was developed has the following non-functional requirements.

1. The System must be user friendly. The operators must be able close and open the control without difficult.
2. The system must be to execute commands within a prescribed minimum time of 60s.
3. The System must be operated on the local panel parallel to the GSM-SMS system.

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D. Use case diagrams

Use Case Diagram captures the system's functionality and requirements by using actors and use cases. Use Cases model the services, tasks, function that a system must perform. Use cases represent high-level functionalities and the way a user will handle the system. Use-cases are the core concepts of Unified Modelling language modelling.

Figure 13: Use Case diagram for GMS-SMS Android Application

The case diagram, shown in Figure 13. Shows how the operator interacts with the system. The operator is able to interact with the system through an SMS enabled GMS mobile phone via an android application.

Figure 13:
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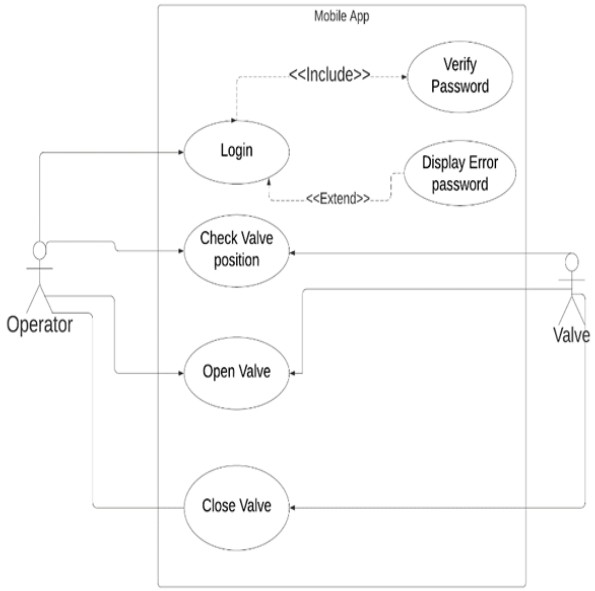

Figure 14
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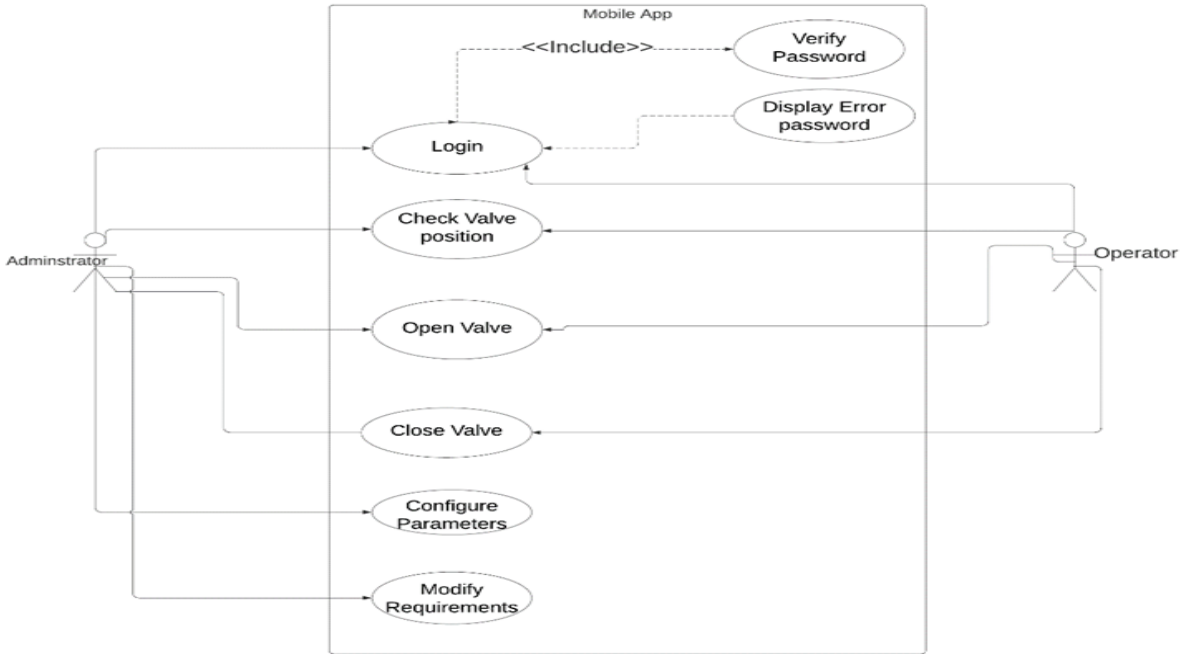

The use case shown in Figure 14, Shows how the administrator and the user of the system interact with the system. Both the administrator and the user can check valve position, close valve, and open valve. As shown in Figure 14, the administrator is able to edit, modify or reconfigure the system to improve the performance where possible.

Modular design of the system function

Consider the diagram below of the GSM-SMS based system.

Figure 15

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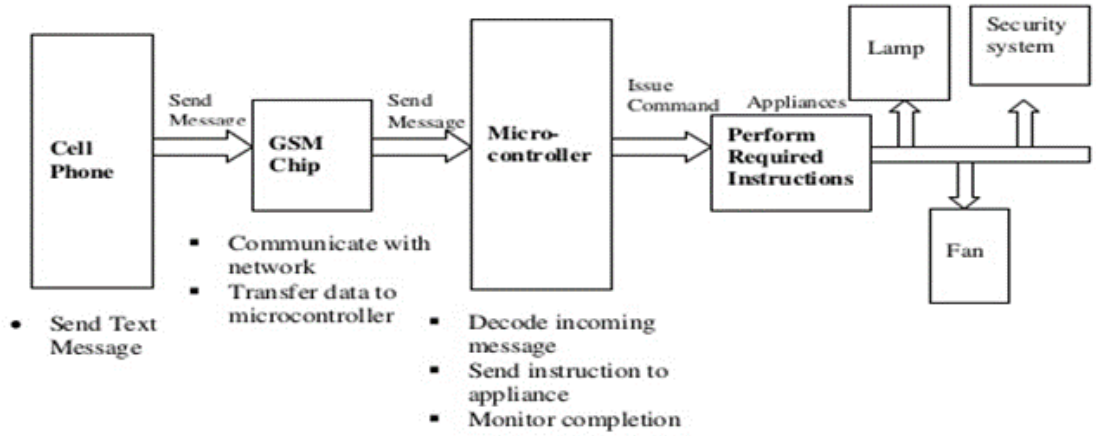

Considering that the system is fully functional, the process of controlling the de-vice (Valve) which is connected to the GSM-SMS industrial module will proceed through the following steps:

- The operator sends text message containing command to the GSM module via android application installed on smartphone.
- GSM module receives the message from the smart phone decodes it and sends commands to the microcontroller
- Microcontroller issues commands to the Variable frequency drive
- VFD commands the final controller to open/close to the required position
- VFD give a feedback command to the microcontroller upon attaining the valve position
- Microcontroller commands the GSM module to send a feedback text to the android application on the smart
- Android application indicates status until changes are made to the system.

E. System Class Diagram

The system class diagram of the GSM-SMS System is presented as shown in Figure 12. The diagram is an illustration of the classes and their associations represented by the Unified Modeling Language (UML).

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Figure 16

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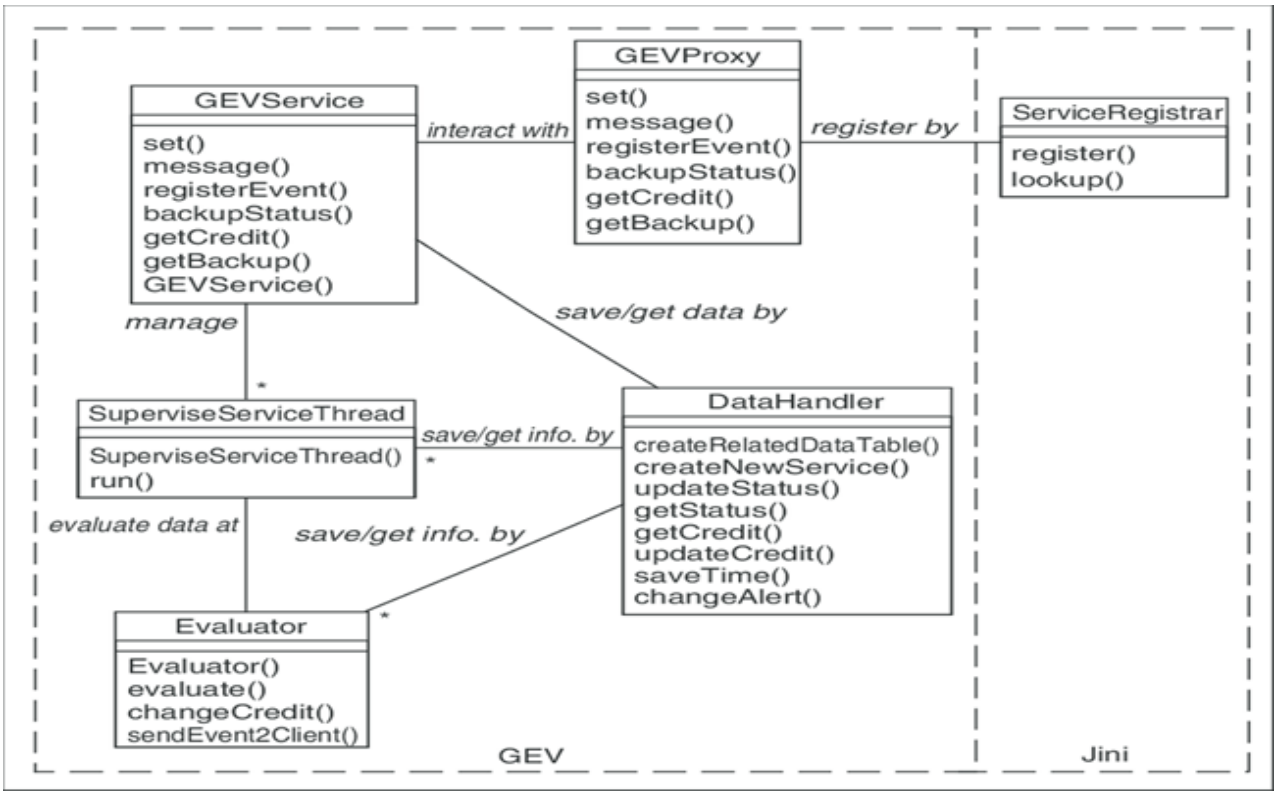

The class diagram is the main building block of object-oriented modeling. It is used both for general conceptual modeling of the system, and for detailed modeling translating the models into programming code

F. System Data Model Design

Figure 17

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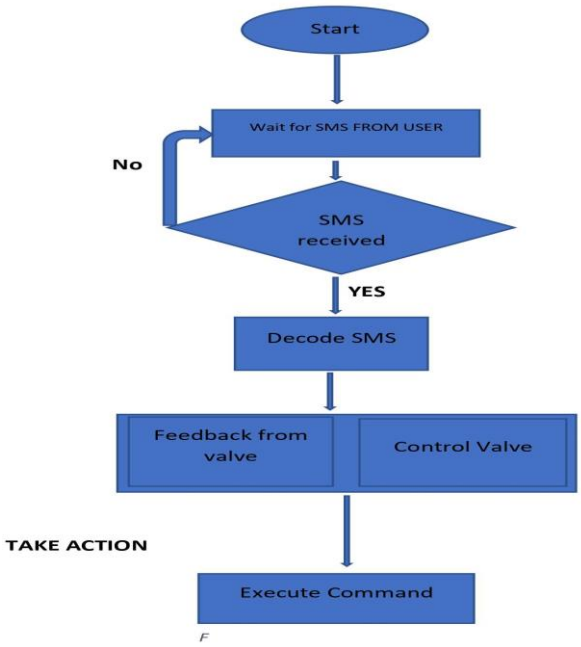

F

This section gives the design of the flowchart diagram conceptual level. The GSM-SMS module use the basic scripting for decoding text messages received from a smart phone. "BASIC is the name of a high-level programming language developed at Dartmouth College, New Hampshire USA under the auspices of professors Kemeny and Kutz during their academic years- 1963-64. The language was developed. To teach beginners the basic constructs of programming theory and as much, one of the easiest programming languages to learn" [67]. The acrimony, BASIC stands for Beginner's All-Purpose Simplified Instruction Code which began as an interactive computer programming language especially easy to learn, Usman (2017).

M. User Interface Design

This section outlines how the user interface design was done. Android Mobile application was developed using Android studio which uses JAVA

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WHILE THE GSM module will use BASIC scripting language for interpretation of SMS. Colors white, blue and grey are adopted for all the GUIs in order to keep the interface simple and easy to use. The GUI interface is made up of a main JFrame window which contains all the menus.

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Figure 18

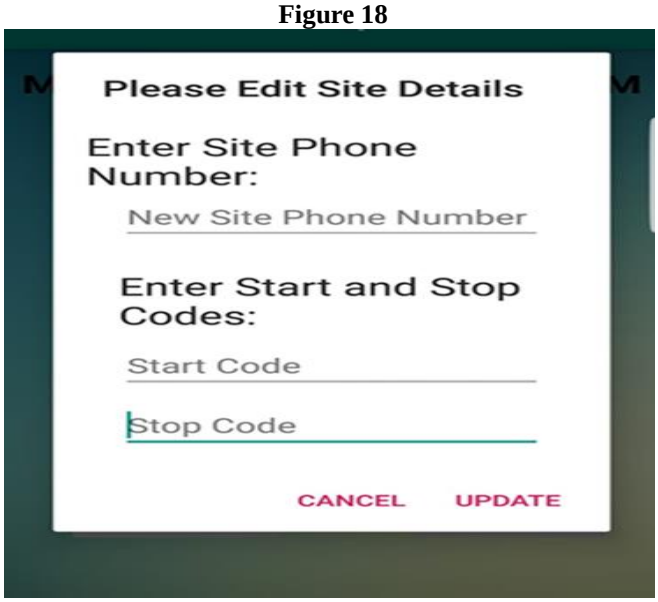

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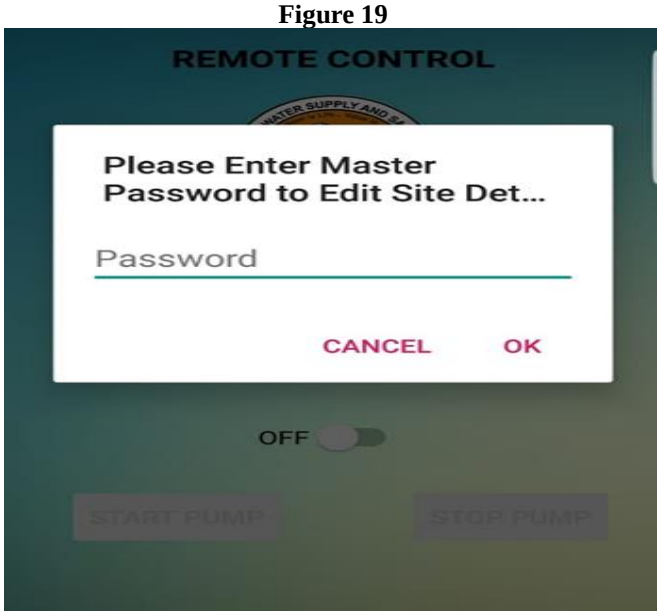
Figure 19



The screen shot shown in Figure 14, is the manage Product frame that is used to enter SIM card numbers for the GSM-SMS modules and other information such as valve status, pump status etc.

IV)RESULTS

Introduction

This chapter looks at the results of the research that was conducted at Kaseba Water Treatment Plant in Kafue with regard to the construction of a GSM-SMS based control system and an android application to remotely open and close the valve. The survey revealed that the respondents (operators) were exposed to risks of body pains and early death. The results also showed the need of automating the valve as every employee had the knowledge and appreciation on the use of SMS technology, among the respondents.

Finally, we look at the results of the survey that enabled us to determine the development of the mobile application. We also look at the results of the implementation of the control system called GSM based Industrial control System using the information fusion developed in Chapter 3. An android application is developed using Android studio IDE, Java as the programming language. The system uses SMS for the actors to interact with it. The prototype is tested using an SMS server (Diafaan SMS gateway) that interacts with MySQL database.

Baseline Study Results

In this section, we look at the results of the survey which was conducted as part of this research, on which the justification for construction of a GSM-SMS sys-tem and the mobile application is based. In the next section, we look at the results of the construction of GSM-SMS system and implementation of the mobile application.

i. Results and Discussion

In this section, we look at the results of the prototype which was constructed to demonstrate the operation of the GSM-SMS based remote control system. In this prototype model, Ewon industrial router was as a GSM module and control to regulate the switch on and off for a prescribed number of seconds representing the valve opening on site. The

complete assembly of the prototype realized on panel as it will be seen in the diagrams below.

System Implementation Results

In this section, the results of the GSM-SMS based automation prototype system connected to the MySQL database via a Diafaan gateway, are covered. MySQL database was incorporated in the prototype to enhance the storage and monitoring purpose in the real set up of the system. The interaction of the operator with the GSM-SMS based automation system using an android application was also demonstrated.

i. The Operator

The android smart mobile phone is used by the operator to send the command signals using SMS to a GSM module number that is embedded in the GSM mobile application as discussed in previous chapter. When the operator wants to send command signals from smart phone, he/she opens the application and select the per-cent opening on the mobile application and activates the control in order to send the SMS. The SMS is transmitted as number to the GSM module. Upon receiving the SMS, GSM module decrypt the text message using the BASIC scripting language and activates the digital outputs equivalent to the number of seconds which to an operator represents the percentage valve opening on site. The GSM module will wait until the valve has opened to the required percentage to send the feedback to the mobile application which inform the operator that the valve is truly open on site. In the prototype demonstration the feedback from the Led was sent back to the MySQL database. The picture below depicts the mobile application before the LED is operated. Consider the diagrams showing how the system was being tested.

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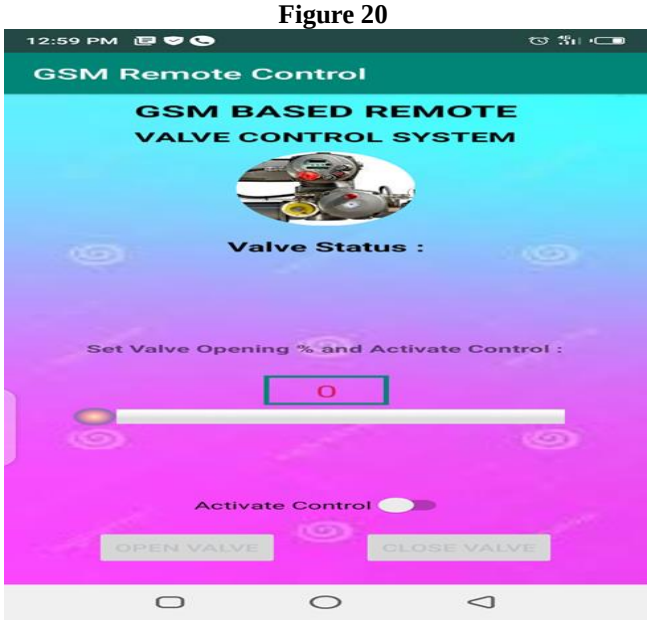
Figure 20



Using a mobile application to select the percent valve opening or closing, a number is sent is sent to a module. The module interprets the number of seconds to close the digital output which in turns opens the vale to the required position. These seconds represents the number of turns on the actual valve hence the percentages. The module will respond to commands upon confirmation from the valve.

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Figure 21

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ii. The Owner of the GSM-SMS based automation system

The owner of the System can be either a firm, farmers or a household. The owner assumes the role of the administrator or user of the GSM-SMS based automation system. The Diafaan SMS gateway system has a login screen for the system administrator to access in order to gain entry into MySQL database. The access to the database has been restricted to the administrator for easy monitoring of the system. The other category of the system user is the standard User who is restricted to managing the mobile application to interact with the valve. The figure 22 below shows the login screen for the Administrator.

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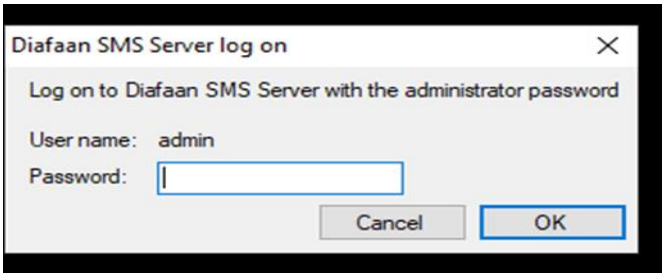
Figure 22



As can be seen in Figure 22, the system administrator logs into the Diafaan SMS Server system using a username and password. The system administrator then creates the users on the system according to the standard and operating procedure that the owner of the system will have set in place.

Once the administrator login, they will be able to view how the operation of the valve was being conducted. Information such as the running hours for a particular position of the valve can be traced. This can be seen in the database screen shoot below:

Figure 23

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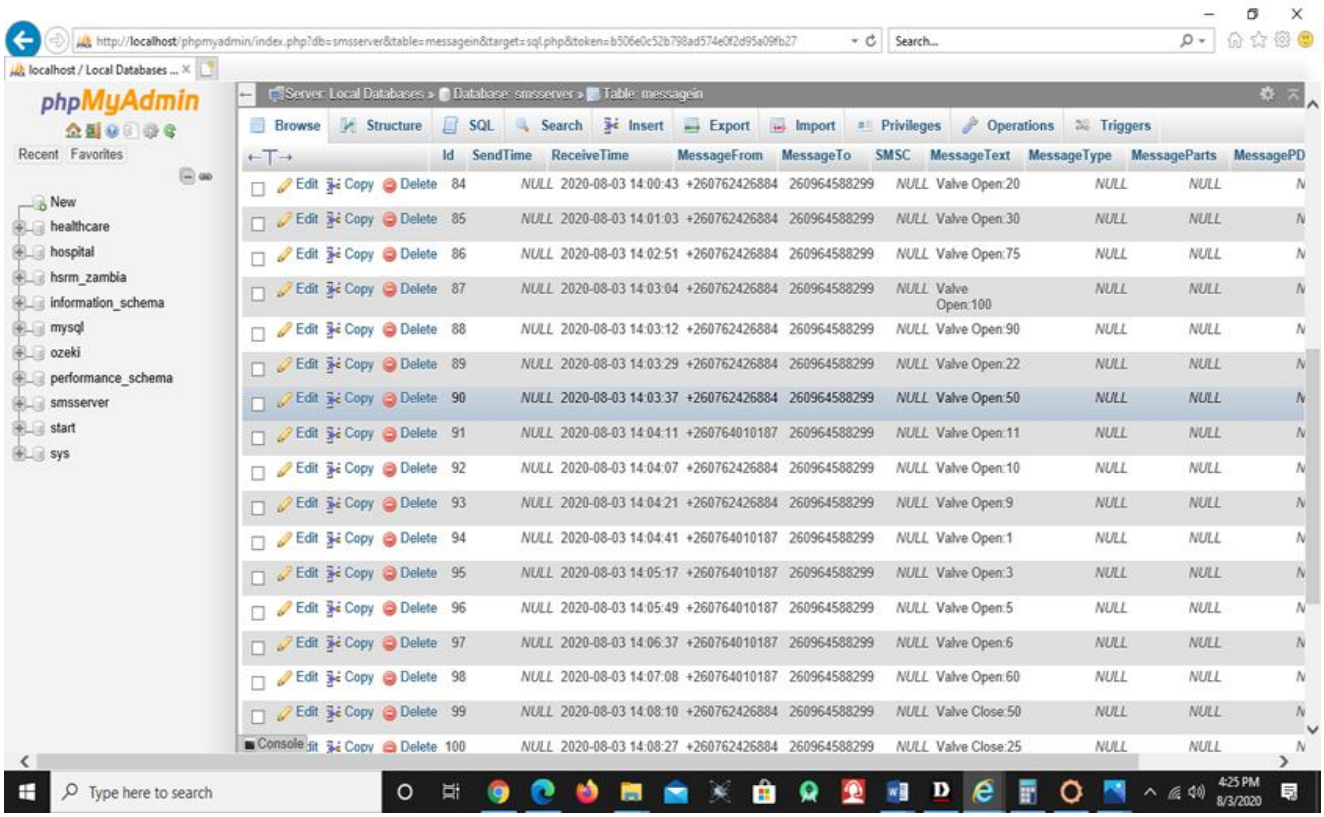

The MySQL database is used to the indicated position and what time the valve was opened to the prescribed position.

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Figure 24

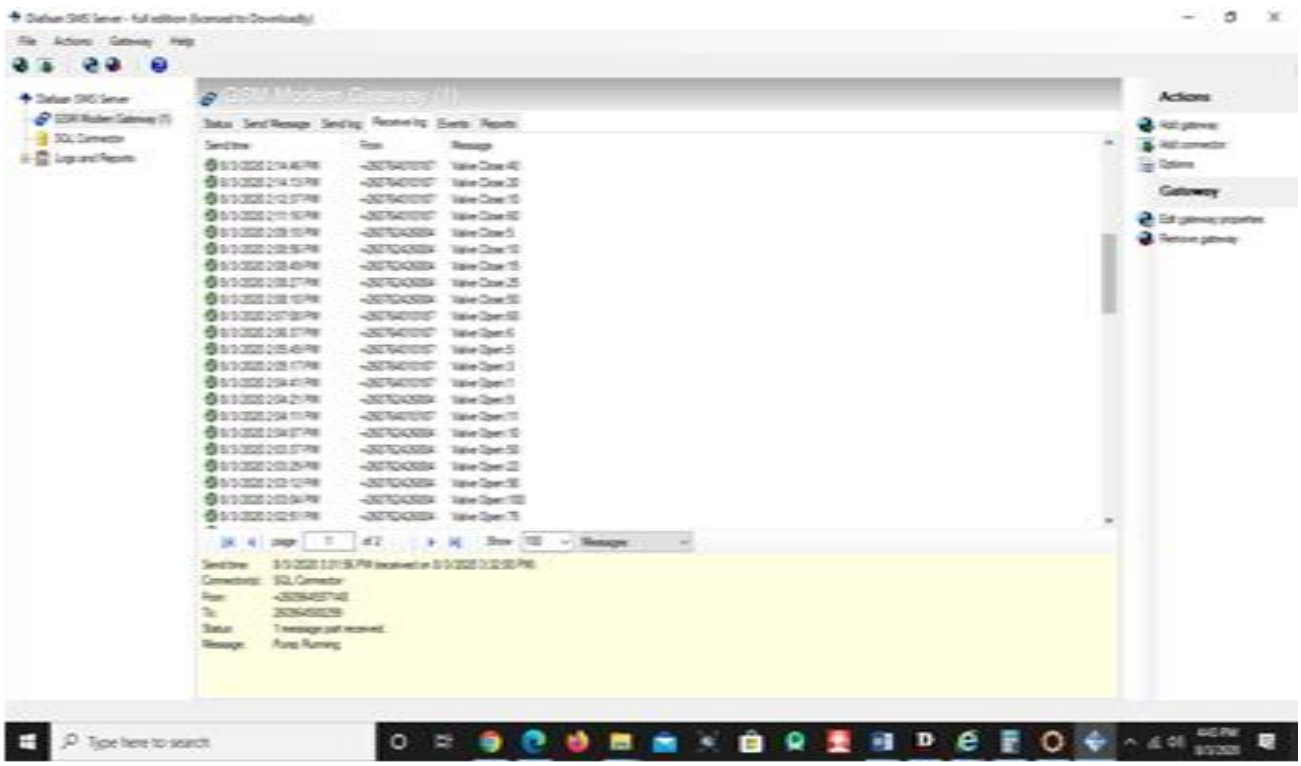

Figure 18 above shows the SMS text messages that were received as feedback from the valve upon opening to the required position.

The modem which is the gateway between the server and the GPRS/GSM net-work is monitored using the window shown in figure 18. This window can be used to control the modem by way of starting it or stopping it. The window can be used to view or delete the sent and received messages. The system has a number of functionalities which include the generation of reports among other things.

The diagram below shows the assembly of the prototype in pictures.

Figure 25
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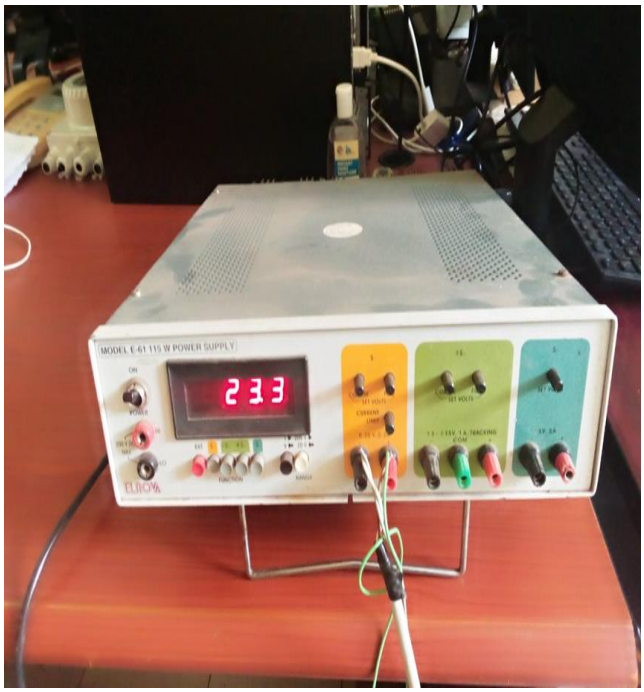
iii. GSM-SMS Based Automation system Evaluation

The post implementation evaluation was done where 15 participants from the Kaseba Water



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Treatment tested the application. These included plant operators, supervisors and artisans from production, maintenance and commercial departments. The results are as shown in

Item	Attribute	Participants Agreeing	Participants disagreeing	Total Participants
	Ease of use	11	4	15
	Network connectivity	13	2	15
	Fit for purpose	15	0	15

As it can be deduced from the commissioning stage, it was found that 11 participants were satisfied with the attribute of ease of use while 4 did not agree. The network connectivity attribute was said to be acceptable while 2 did not agree because they experienced a delayed response from the valves after sending the open and close command. As for the Fit for purpose attribute, everyone agreed that the system met the needs of the users.

C. Summery

This Chapter presented the results of the baseline study and the development of the GSM-SMS Based Automation system. It covers the successful implementation of a MySQL database prototype that is able to successfully register feed-back status of the valve and perform successful operation sessions with remote valve sending and receiving open and close commands on the GSM-SMS based automation system on which it was implemented. The operators interrogated the GSM-SMS based automation system using SMS android application on smart mobile phone.

V) DISCUSSION AND CONCLUSION

Introduction

From the discussion in Chapter 4, the following are some of the recommendations that were deduced from the data that was gathered. The chapter begins with the discussion then conclude with recommendation based on the results of the research. It then looks at the possible future works pertaining to this research.

Discussion

This section discusses the implementation and results that were outlined in the previous chapter and how they relate to the objectives of this study.

As a way to justify the development of a GSM-SMS based system and mobile application that will mitigate the risks associated with manual operation of the control valve, the questions were asked and the corresponding responses from the respondents were as shown in the table below. It shows the main findings of this research with respect to the objectives of the research.

The baseline studies

The first objective sought to establish the possibility of automating the industrial manual valve using the cheapest means in order to reduce on manual labour. The study revealed that the manual operation of the valve has a negative effect on the operators in terms of their physical healthy. The research, showed that the automation of the industrial manual valve will play a major role in safe guarding the operators and help the company operate the equipment safely. This also applies to other areas that were still using the manual operation of industrial equipment. Lusaka water Supply and Sanitation Company (LWSC) has allotted of water sources that remotely located and are still manually operated.

Use of Technology

The second objective was to determine the level of utilization of ICTs among operators in the industrial automation. This objective was based on assessing the usage and appreciation of technology as a way

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of mitigation the risks associated with manual operation of equipment.

Firstly, the survey revealed that 90% of the respondents at Kaseba Water Treatment complained of the manual work involved in the operation of the equipment at this water treatment plant and the distance they had to walk from the treatment plant to the reservoirs to adjust the valves. Further, the operators had a risk of being bitten by sneaks as the reservoirs were sneak infested areas.

Use of Mobile phone

The survey revealed that 80% of the operators at treatment plant were very much conversant with use of mobile smart phones and about 95% were conversant with the usage of GSM technology.

Development of the mobile application as a solution

The project was designed and developed to provide a simple and cost-effective solution for the remote control and monitoring of plant equipment and appurtenances in the water production and distribution sector. Various technologies used to develop and implement this project including instrumentation equipment, industrial routers and ICT. GSM technology was used as a transmission medium for control signals between remote sites in the form of Short Message Services (SMS). In this project, equipment such as valves and pumps can be operated in fully automated mode or operator controlled via mobile app.

Currently the majority of water production and distribution systems used in Zambia are operated manually or rely on inefficient electrical/ mechanical automation techniques. Said operating methods may lead to damage to equipment, poor service delivery, excessive use of electricity and generation of non-revenue water due to factors such as operator error.

The project therefore aims to improve the operation of water production and distribution systems by providing computerized monitoring and process control resulting in reduced production costs and improving delivery of water to the community.

The survey revealed that there was a considerable appreciation in the use of mobile phones among the operators. The mobile smart phone is a tool with which the operators could use to open and close the automated valve remotely. The phone will also be used to check the position of the valve without physically going on site. Doing so would reduce the need to walk to the reservoirs and hence reduce the exposure to risks that are associated with the manual operation. The survey also shows an appreciation in the use of mobile money by the operators, and it would not be a challenge to reorient the operators to use mobile applications on phone.

The discussion above, motivated the development of a mobile application that would be used by operators to remotely control the valve in cost effective way. The mobile application was built using the agile software development method, using Android IDE and MySQL as explained in Chapter 3 and 4.

The Prototype was developed with some few components just to demonstrate the principal operation of the project on site. The prototype used an industrial router with a GSM module controller embedded inside which has one digital input and one digital output. The GSM modem was used to link the GSM module to Diafaan SMS Server which in turn interacts with MySQL database. The other equipment used on the prototype is the solenoid valve which will act as the industrial control valve, and an external relay that will switch on and off the solenoid valve.

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Figure 26
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S/N	Research Question	Objective	Methodology	Result
1	Is it possible to automate the manual discharge control valve?	To establish the current status of the operation regime	Questionnaire Oral interview	The research, showed that a automation of the valve was possible as the material for reuse were compatible with the requirement
2.	How can we determine the levels of water without physically present on site?	To determine the level the method of sending notification to the central place	Questionnaire Oral interview	80% of the total number of respondents appreciated the need to know the reservoir via mobile phone
3	Is it possible to develop a mobile application for interfacing with the electrical devices	To develop a mobile application that would interact with the high-power devices	-Agile method -Protyping Method -Android studio IDE -Java Programming -BASIC -Apache server -MySQL	The mobile application prototype was implemented and tested

The system also, required the operator to observe the level of water in the reservoir as they operate the Valve using the GSM-SMS based Automation System. On the other hand, the system is also required to keep track of the system operation by use of MySQL database.

Comparison with Other Similar Works

Significant works have been made in the area of innovative use of GSM-SMS technology in various fields, such as health, education, commerce and banking as discussed in chapter 2 of this research. This research acknowledges the work that was done by Johari (2017) where an SMS based water level monitoring system was used to monitor the level of water in a tank with an integration of GSM module to alert the person-in-charge through Short Message Service (SMS). This system only alerts the person in charge through normal messages. The GSM-SMS based remote control system has gone further to incorporate a mobile application for controls, feedback and reservoir monitoring to enhance the operation of the control valve.

Possible Application

The work in this study is an attempt to reduce the cost of automating small and medium systems that are manually operated by reducing the manual labour and move to smart systems. The targeted market is the water sector i.e., water utility companies, commercial farmers and domestic users. The majority of the aforementioned target market has plants and equipment in remote geographical locations. These sites require monitoring and control. Currently, Personnel have to physically visit sites to perform water operations. The project will improve these operations by enabling client's control and monitor the status of single or multiple plants and equipment from a remote location. This will result in more efficient operation of water systems as processes would be controlled remote systems. This will further result in reduced production and maintenance costs, less generation of waste water, better usage of equipment, improved water distribution and more efficient energy usage.

This system can also be applied to farmers who can

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control their irrigation system using this application by reducing the need of walking long distances to operate their irrigation systems. This system can further be extended to any institution or domestic users who want to remotely control their electrical equipment.

Summary

This study proposed the development of a remote-control system that would improve the efficient operation of equipment and safety of employees. Water utility companies, farmers as well as domestic users will experience reduced operating and maintenance costs i.e reduced maintenance costs due to correct usage of equipment, reduced electricity usage due to automated operation of equipment resulting in energy saving, reduction in operating costs since operators may no longer have to travel long distances to operate equipment.

This system can be used by other players in the water utility company. Further GSM-SMS based automation system addresses the problem of manual operation and improve the production of in an organization that cannot afford the expensive control systems. With the integration of the database a lot of data can be captured from site for analysis, comparison and fine tuning of the system to suite the production requirements.

Conclusion

GSM-SMS technology can be used to improve production, safety of employees and quality of products for individuals, small and medium organization by automating their systems. A GSM-SMS system such as the GSM-SMS BASED Automation system can help individuals, small and medium organisation to save on their resources that include time, money and quality of product they trade in. Application of ICTs in this manner will stimulate good organisation management in production industry.

The GSM-SMS based System was implemented to work on the SMS platform because the SMS technology is cheaper compared to the SCADA and DCS systems which require a lot of investment. The prototype was implemented and demonstrated.

Future works

The automation of the control valve implemented a number of functionalities in the application but the following were not implemented:

1. Integration of the mobile application to the SCADA/DCS system.
2. Development of a desktop GSM based remote which will provide centralised operation of a process
3. Development of web-based system that can use internet as the transmission medium.

These functionalities were not implemented due to limited financial resources and time which was allocated to this study.

VI. ACKNOWLEDGMENT

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Many thanks to the Information and Communications University and Engineering students. I am also thankful to my coworkers and management at Lusaka Water Supply and Sanitation Company for allowing me to do my research at one of the water treatment plant in Kafue Finally, my thanks go to all the people who have supported me to complete the research work directly or indirectly.

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