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The Research Council (TRC) under FURAP Program CALL 4

Prepared by
Dr. Nizar Al Bassam
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A PROJECT REPORT
ON

Water Losses Management in Muscat, Case Study of Al Seeb Water Supply System

By:

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Guided by:

Dr. Mohammed Abushammala

MIDDLE EAST COLLEGE
Knowledge Oasis Muscat- Oman

July, 2017
A PROJECT PLANNING REPORT

ON

Water Losses Management in Muscat, Case Study of Al Seeb Water Supply System

by:

Maha Mohammed Al Sulti 15S13727
Manal Moosa Al-Bulushi 15S13737
ACKNOWLEDGEMENT

The work team acknowledge the financial support provided by The Research Council (TRC) at Muscat to conduct this research. We highly like to appreciate Dr. Mohammed Abushammala who guide and help us in preparing and progress this project. We wish also to thanks Public Authority for Electricity and Water (PAEW) to fulfill our requirement in providing us with the necessary information.

Work Team
ABSTRACT

Water supply systems in Sultanate of Oman are exposed to different stress or varied uncertain threats and hazards, among which are due to natural hazards and the others due to manmade hazards. One of the problem affecting water supply systems in Oman is the problem of water loss and Non-Revenue Water (NRW), which reflects the lost of big quantity of water through leakages.

The main aim of this project is the study in depth the problem of water losses through the water systems taking Al Seeb water system as a case study, and how the resilience to various hazards (natural and manmade) in water supply systems can be developed and improved in the Sultanate of Oman.

The work in this project is conducted by collecting and reviewing the literature and the previous studies and by fieldwork. The methodology includes documents reviews, and collecting information and data by using questionnaire and interviewing the staff. The water auditing was carried out and the performance indicators and water balance was developed to study the impact of water losses on water systems using American Water Work Association (AWWA) water auditing software. The results are discussed in the main chapters of the thesis.

The outcomes show that the values of water losses and Non-Revenue Water (NRW) in Oman are more than 30%, which is very high according to the international standards. The financial indicators show that NRW was found to be 32% of the total revenue budget. The results of the questionnaire the main factors that contribute to water losses are meters inaccuracies and water pressure it is also clear that the number of qualified staffs and tools for leak water losses program are low. The present study identified five potential method of improvement and suggested some solutions and, which should be capable of reducing the impact by 90%.
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<td>DI</td>
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<td>Desalination Plant</td>
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<td>HDPE</td>
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<td>OIFC</td>
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<td>O&amp;M</td>
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CHAPTER ONE
INTRODUCTION

1.1 General Background

Water is very vital resources for the people and animals, and all neighborhoods live in the world. The water supply systems should satisfy all the water demand for all purposes and should be of high quality. Government through Public Authority for Electricity and Water (PAEW) manages the water supply systems in Oman without private sector. Therefore, the water supply systems in Oman should be always assessed and evaluated.

The water supply systems should be always developed to meet required quality that is good for human being. The water utilities in Oman is exposed to manmade and natural threats as tropical cyclone which is common in Oman and water losses or Non-Revenue Water (NRW) through pipes leaks and other reasons. The old data show that the values of water losses in all the area of Oman is more than 40% which is very high compare to the international standard.

The high values of water losses and NRW means that large quantity of water are lost because of pipe burst, overflow of reservoirs and other reasons along with the error in read of the costumer meter and data processing. The high level of water losses impact the financial situation Public Authority for Electricity and Water through loosing a lot of money and increase the cost of operating of water systems in Oman. The high values of NRW need a well-qualified engineers and technicians to overcome this problem [1], which is so far not sufficient in PAEW. The NRW in Oman is considerable.

The project was conducted to study in general the problem of water losses and non-revenue water in Oman, and evaluate the performance of water supply systems. The project team selected water distribution system for Al Seeb Wilyat in Muscat Governorate, capital of Oman as case study for this project.
1.2 The Problem

The water supply systems in Muscat Governorate including the project area (Al Seeb Wilyat) faces many problems as it is not covered all the areas of Muscat, insufficient of trained people, and some problems in the design of water distribution networks. The major problem is water losses and nonrevenue water, which is happened due to leaks in pipelines, and the method of billing and handling the data and the problems in customer meters.

The water losses that represent one component of non-revenue water is the major problem and challenge for any water company or authority in all over the world. The problem in developing countries like Sultanate of Oman is more series. At the same time, there is less number of qualified trained people and instruments for detecting the water losses in Oman. If you count all these problems, it is necessary to have a good system for the management of water supply systems [2].

In fact, the water issues are very critical all over the world especially in this century [3]. It is more important in Oman as the water supply systems are faces a lot of problems and stresses. One of the major problems of water supply system in Oman is water losses and non-revenue water. The study of risks due to water losses in Oman is important, and this is the main purpose of the present work.

The previous studies and research in water losses and non-revenue water in Oman is lacking. Even the efforts to overcome this big problem are not clear. The data presented by Public Authority for Electricity and Water reports [4] show that the values of water losses in Oman is more than 40 percent, and the procedures and policy aiming at reducing the figures of water losses and NRW is not clear. Some studies are carried out in this subject.

The problem of water losses and NRW call for urgent emergency response plan, which should be of satisfactory level. In this case, Public Authority of Electricity and Water is concentrated currently on solving the problem of leakage as quickly as possible, without any clear pictures or strategy about the emergency response to these problems. Some work has to be done in this regards.
On summarized, the water utilities in Oman including water supply systems of Muscat are facing many problems and hazards (risks) because of natural events as tropical cyclone and manmade hazards. One of the considerable problem is the water losses or non-revenue water, which has high values as per international standards. At the same time, PAEW is responsible to provide the people in Oman with sufficient and good quality water. For this purpose, the study and evaluation the problem of water losses is very important, and in this project the trial is made to study this problem taking Al Seeb Wilayat as a case study.

1.3 Aim and Objectives

In general, the main aim of the water losses studies is to suggest some solutions and strategical points for solving this big problem in Oman. In this project, we are trying to study in depth the problem of water losses in Oman taking case study of Al Seeb Wilayat of Muscat. To achieve the above aim a number of objectives were set:

1) Carry out water auditing for Al Seeb water distribution network to estimate the values of water losses and non-revenue water in the project area.
2) To identify and evaluate the financial impact posed by Non Revenue Water (NRW) and how this impact may be reduced, thus ensuring a more cost effective delivery of the water service.
3) Proposed some points on the strategy of reducing water losses and non-revenue water in Oman.

1.4 Research Questions

The researcher formulated the following question, which is important in developing the methodology of the study:
1) Can PAEW improve the level of water losses and NRW by improving the system of repair and maintenance?
2) What are the values of water losses and NRW in the project Area?
3) What is the best strategy to overcome with water losses in Muscat?
4) To what level the problem of water losses and NRW influenced the efficiency of water supply systems in Oman?
5) How PAEW can develop the current strategy of reducing water losses?
1.5 Project Area

Al Seeb Wilayat is located within the Muscat Governorate and at present consists of a number of existing, older towns primarily located along the coastal areas and in the north east of the wilayat known as Al Khoud, Al Mawalleh and Al Hayl. Al Mabela is also an existing town that is located to the west of Seeb Wilayat. The area includes a light industrial estate occupied by small workshops and warehouses. A large percentage of the houses currently located within these towns have been provided with a fully reticulated water supply although there are still houses that are supplied from tankers and some empty pockets within the existing areas that have the potential to be developed.

The main source of water supply to the wilayat is from the Barka desalination plant. At present, water from the Barka desalination plant is pumped east through a DN1600 transmission and supplies the Seeb reservoir compound and Mawalleh reservoir. Water is then pumped further east to supply the Sultan Qaboos University, Ministry of Defense, Wave and Airport reservoirs. Water conveyed from the Barka desalination plant to the Seeb reservoir is then mixed with water from the Western Wellfields.

The water distribution system in AL Seeb area consists three type of pipes, namely, Asbestos Cement (AC), Ductile Iron (DI), and High Density Polyethylene (HDPE) pipes. Many of the pipes are very old and in bad state. The diameters of transmission pipelines range from 150- 800 mm and the total length of the pipe is 29 kilo meters, and the diameter of the distribution pipelines range from 150- 800 mm with total length of the pipe is about 740 Km.

1.6 Method And Procedure

The work in this research was is carried out by using different methods as follow:
1) Literature Review: The previous studies and data were collected.
2) Data Collection: the data necessary for the study were collected using data sheet and designed questionnaire.
3) Analysis and Discussion: The data collected were analyzed and discussed
4) Developing a strategy for reducing water losses.
5) Writing the report
1.7 Organization of the Project

This project is structured based on the problem, objectives and work proposed to be done. There are five chapters.

Chapter One outlines the problem statement, research aim and objectives, research questions, project area, method and procedures, and the structure of the project.

Chapter Two deals with the non-revenue water, causes of water losses, strategy for dealing with water losses, assessment of water losses, and the challenge of water losses in Oman.

Chapter Three entitled “Methodology” presents the research approach, research techniques, data collection, and American Water Works Association (AWWA) Auditing software.

Chapter Four displays the water losses in Al Seeb water supply system, results of questionnaire, and developing a strategy to reducing water losses.

Chapter Five present the conclusions of the study.
CHAPTER TWO
LITERATURE REVIEW

2.1 General Background

The issues of water resources management, mentoring of water losses and NRW, and evaluation the performance of water supply system is very important nowadays and need special attention as the world countries especially the developed countries like Oman are facing great problems in meeting the people demand of water. The problem of water losses and NRW in Oman and elsewhere is one of the major problems facing these countries [4]. At the same time, the evaluation of the performance of water utilities is important.

The water supply systems in Muscat Governorate and other Governorates facing the problem of pipe burst and leak, errors in reading the meters and handling of the data, and other problems that cause water losses and non-revenue water and need to take care very much in these issues. The major part of Non-Revenue Water (NRW) is the water losses, which represent one of the biggest and challenging issue in all the development countries including Oman [3], as the values of water losses are very high compare to the international standards. At the same time the equipment’s and trained people to deal with water losses problems are not sufficient in many developing countries [5; 6], and the situation is almost same in Oman.

Referring to [7] and [8], the problem of water losses is calling for serious action in developing countries as the values of water losses in many countries reach 60 percent. Therefore, this research work conducted to study the problem of water losses and non-revenue water in Oman and see if we could suggest some solution to this big problem in Oman. It should be that the study of water losses and NRW is very important in Oman, where there is the requirement of transporting water over long distances, where there is water scarcity, and where there are with customers with low financial capabilities. In this chapter, we are presenting subjected reviewed from different references.
2.2 Non-Revenue Water (NRW)

2.2.1 What is Non-Revenue Water (NRW)

As mentioned earlier, one of the major problems that affecting water supply systems in developing countries is the problem of water losses or what previously called Unaccounted for Water (UFW). These days, the term UFW is not used, instead of that they are using a term known as Non-Revenue Water (NRW).

As per the definition of International Water Association [9], non-revenue water is equal to the water system input volume minus the volume of authorized consumption. NRW is defined and expressed by different ways such as:

- The percentage of the unaccounted from the total water produces (raw water source).
- The difference between water provided to the water supply systems and water sold [9].
- As defined by [10], it is the water losses that the water supply system experienced compares the water that been consumed and sold to the people.
- Lambert [11] defined non-revenue water, as the difference between the water enter the by volume and payable authorized water consumption.

It seems that there are a difference between all the definitions given up, but all the definition consider the total volume of water that produced by the water companies or authorities and the amount of water that are commonly sold to the people which is called the billed authorized water consumption. The literatures are sometimes goes back to old term which is Uncounted For Water (UFW) which represent exactly the amount of water losses and equal to the difference between the volume of raw water produced and supplies to the people and amount volume of water provided to the people and collected its price.

The volume of unbilled authorized consumption including unbilled metered consumption and unbilled unmetered water consumption are including in the definition of non-revenue water along with the water losses from the system including real and apparent losses as will be discussed below [12].
2.2.2 Components of Water Losses and NRW

The component of water losses and non-revenue water is defined in many literature. As per the procedure of the IWA, the water produced and input to the system and the water goes out from the water system and sold the people or lost can be as what the literature call it water Balance. The form of water balance are given in many referenced as illustrated in Figure (2.1). The figure showing that that the non revenue water (NRW) have of three parts: Assists (or real) losses, marketable (or apparent) losses, and unbilled authorized consumption. The definition of these terms is given below [2].

<table>
<thead>
<tr>
<th>System Input Volume</th>
<th>Authorized Consumption</th>
<th>Billed Authorized Consumption</th>
<th>Billed Metered Consumption (including water exported)</th>
<th>Billed Non-metered Consumption</th>
<th>Revenue Water</th>
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<td>Apparent Losses</td>
<td>Unauthorized Consumption</td>
<td>Unbilled Metered Consumption</td>
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<td>Non-Revenue Water</td>
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<td></td>
<td>Real Losses</td>
<td>Leakage on Transmission and/or Distribution Mains</td>
<td>Leakage and Overflows at Utility's Storage Tanks</td>
<td>Leakage on Service Connections up to Customers' Meters</td>
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Source: [2]

**Figure (2.1): The IWA Best Practice Standard Water Balance**

- **Real (physical) losses:** As shown in the table, real losses include the water leakage from the transmission main and water distribution pipelines, the leakage because of the overflow of water from the reservoirs and water tanks, and the leakages from the house and others connections. The main reasons of real losses and leakage from different source are is the insufficient leakage control, the age of pipelines and other water infrastructure, and may be because of poor operation and maintenance. It is any leakage after the production of water and before reaching the water to the consumers [8].


• **Apparent (commercial) Losses**: As presented in the figure it consist unauthorized consumption (theft or illegal connection), and the inaccuracies in water meters;

• **Unbilled authorized consumption**: This include unbilled metered consumption and unbilled unmetered consumption as water used for firefighting, and water provided for free to certain people as construction company.

The first two items is related to water losses (real and apparent) [9]. The percentage and level of water losses gives good indicator about the performance of water supply systems [7]. The fighting and reduction of water losses can be carried out be good planning and management, money and administrative issues and by applying an effective strategy [7].

### 2.3 Causes of Water losses

The real losses are the major component of water losses in the developed and undeveloped countries, where illegal connections or theft, meter error in meters, and handling of the data is usually more significant [14]. There are numerous reasons for raising the level of water losses, which are summarized below.

#### 2.3.1 Losses in the Main Supply Lines

These losses can be defined as the amount of water lost in the main lines between water sources and even the beginning of the distribution network, and the resulting losses for leaks or damage caused to the main pipe due to high water pressure or because of the damage caused by external factors or because of erosion [15].

Moreover, the interest the plans to monitor the water pressure in the main pipeline transport by electronic control system gives the signal for the pumps to stop pumping at high pressure from the approaching alarming levels thereby preventing the occurrence of explosions and fractures in these lines as a result (WHO, 2001).
2.3.2 Losses Through Distribution Network

The amount of water lost in the distribution network between the main supply pipe and customer meters. This usually constitutes the highest proportion of water losses. This losses result from large part of the distribution network damage. In an attempt to improve this situation being the discovery of tracking losses in distribution networks of interest by a number of ways, including:

- Installation of water meters for each head of distribution area and compare the total consumption with costumer
- Conduct a comprehensive survey using electronic trace the leak in lines and / or questionable sites devices.
- The use of computer software (BABE) private trackers and leak detection for the purposes of the simulation in order to determine the priorities of renewal, rehabilitation and / or maintenance work.

2.3.3 Losses Due to Water Meters Accuracy

It can be defined as management or commercial losses counters for water consumed by the joint without being recorded. The water company is usually follow simple method to follow this loss: The key counters a standard installation on different main lines that supply water specific groups of subscribers, and then calculates the losses caused by the lack of measurement counters by comparing the total registered consumption by subscriber’s counters with a total registered consumption accuracy by main counters.

2.3.4 Illegally Water Consumption

The phenomenon of the installation of connectors and water consumption by illegal means are very limited due to the phenomenon of distinctive and mutual confidence between stakeholders and subscribers. The interest of the application of effective operation policy with respect to consumption of illegally, is asked every reader counters follow this phenomenon is explored in dubious real estate and report any questionable consumption in it. If proved the illegality of such consumption are separated link the common value of the estimated amount of water and load that period after the last screening process covering before the re-installation of the link properly.
2.4 Strategy for Dealing with Water Losses

The water companies or authorities should take water losses problem as a critical issues that to be solved in order to provide the people with sufficient quantity of water and increase the revenue. The companies should not wait until the problem increased and lead to big burst in the large pipelines, but it should solve the problem within a known strategy.

The main two components of non-revenue water is the real loss and apparent loss. The water companies should provide resources, teamwork and money to control these two losses. Unbilled authorized consumption is the third component of NRW, which does net any technical and practical action to control it. Each company needs a clear strategy to deal with the problem of water losses and NRW. According to [7] to understand and evaluate the existing water system.

Butler and Mamon [7] recommend questions like, what is quantity of water is being lost?, where is the leaking? and why the leak is happen?. Refer to Butler & Mamon [7], the first two questions, “how much” and “where from”, can be answered by carrying water balance referring to Figure (2.2), which explain and compare between different components of water losses from water systems and the difference between system input and out. The third question can be answered from the strategy and management procedures of the water supply system. The evaluation of water systems and conducted water balance will help in identifying the water losses.

After reducing the values of water losses and non-revenue water to acceptable ratio, the water companies or water authorities should continue monitoring and controlling the water losses by applying continuous assessment of the water supply systems, and fix the areas where water losses can be occur in the future. The monitoring system, which should be implemented, is of high technology and computerizes systems in order to collect, gather, and process large number of data related to the water losses issue in a very short time. The hydraulic model of the water systems will help in this regards. It will be stressed techniques and instrumentation related to the application of each phase must implement [17].
2.5 Assessment of Water Losses (Water Audit)

2.5.1 Importance of Water Audit

The water Audit is an important issue when dealing with water losses and NRW. The main purpose of water audit is determining the values of different components of water losses and NRW such as apparent and real losses, unauthorized consumption, etc. The water audit provide with a framework of water use. Water audit is most effective tool for assessing the performance of water supply systems. The International Water Association (IWA) / American Water Work Association (AWWA) have a lot of work in water auditing.

The water auditing will help the water companies and water utilities to identify and quantify all the input, output and losses from water supply, and determine exactly the amount of water losses (real and apparent) and non-revenue water, and consequently it will help in deciding about the procedures that should be taken to reduce the water losses and NRW. The water audit show how amount of water flows into and out of the water supply systems.

The water losses and NRW is due to many factors as leaks in the pipes, inaccuracy in the meters, unauthorized water consumption, etc. Water audit fixes the water input and where the water end and how much is the losses. The results of water audit depend in data and information of the system. There is no accurate information can be obtained about how much is the water losses. The water companies and utilities cannot reduce the water losses in the water system to zero, as some water loss is unavoidable. The water audit can be used as a better manage to water losses and NRW. Finally, water audit is the best tool to determine the water losses and non-revenue water [18].

2.5.2 Methodology of Water Audit

The water balance represents the framework for classifying and quantifying all water uses in the water audit. It is water balance because when you complete the auditing, the water input in the system is equal to all water uses including water losses. The standard water balance is a series of simple equations, and graphically it illustrated in Figure 1, which is common as developed by. AWWA and IWA. It
may also be presented in the form of separate equations, or in worksheet format [18].

As given in Figure (1), the water losses and non-revenue water is calculated using the following equations:

- **Water Losses** = Apparent Losses + Real Losses.
- **Apparent Losses** = Metering Inaccuracies + Unauthorized consumption
- **Real Losses** = leakage in the transmission and distribution mains + overflow from reservoirs + leakage in house connection
- **Nonrevenue Water** = Water Losses + Unbilled Authorized consumption

The equations can be calculated by following the five step [18].

- **System input:** which is the first step in completing the standard water balance? It includes water input to the system from your own resources and imported water.
- **Authorized Consumption:** the calculation of authorized consumption using billing data and records.
- **Unbilled Authorized Consumption.** Includes the public use in the area is. This type is further broken down into unbilled metered consumption and unbilled unmetered consumption.
- **Apparent Losses:** Apparent losses of water incudes unauthorized consumption as theft or illegal connection and meter.
- **Real Losses:** Real Losses include leakage and overflows prior to the point of end use.

### 2.5.3 Performance Indicators

The values of water losses and non-revenue water are important indicators for efficiency of water supply systems. If the values of water losses and NRW is very high means that the water supply system is ineffective and the activities related to planning and operation of the system is very low. The American Water Works Association (AWWA) and International Water Association (IWA) recommended some terminology related to water losses and indicators such as Infrastructure Leakage Index (ILI) for the evaluation of the performance of water systems.
(Hamilton et al, 2006). The AWWA/IWA defined three indicators for water supply systems performance, namely, Current Annual Volume of Real Losses (CARL), the Unavoidable Annual Real Losses (UARL) and the Infrastructure Leakage Index (ILI) (EPA, 2009). More detail about these indicators are explained below.

1. **Current Annual Volume of Real Losses (CARL):** is the volume of water that is lost from the system due to leakage in the transmission and distribution mains, overflow of water reservoirs and water tanks and losses from house connections [20]. The CARL is calculated using the following equation

\[
\text{CARL} = \text{Transmission mains Losses} + \text{Distribution system Losses} + \text{Storage Losses} + \text{house connections losses} \\
\text{(2.1)}
\]

2. **Annual Real Losses (UARL):** water losses cannot eliminate which is called Unavoidable losses. There will that cannot avoid which call Annual Real Losses (UARL). The UARL is a function of the length of the pipes, the number of house connections, the length of the service pipelines and the average system operating pressure [20]. The UARL calculated using the following equation:

\[
\text{UARL (liter/day)} = (18 \times Lm + 0.8 \times Nc + 25 \times Lp) \times P \\
\text{(2.2)}
\]

Where:  
Lm = Length of transmission and distribution mains in Km  
Nc = Number of house connections  
Lp = Total private connection pipes length (meter)  
P = Average operating pressure in the areae (m)

3. **Infrastructure Leakage Index (ILI):** The index, which is suggested by the IWA for water loss prevention. The ILI is defined as the percentage between the Current Volume of Real Losses and the volume of Unavoidable Losses [20].

\[
\text{ILI} = \frac{\text{CARL}}{\text{UARL}} \\
\text{(2.3)}
\]
2.6 The Challenge of Reducing NRW in Oman

2.6.1 Reducing of water losses

Protection of water by reducing wastage because the water is one of the precious resources in the Sultanate of Oman, the Public Authority for Electricity and Water is committed to reducing water losses in the water network in the Sultanate. To achieve this purpose, the discovery of leaks team is working to identify leaks and reduce differences and the difference between the amount of water produced and the amount of water used by customers.

2.6.2 Establish Zones have Counters

PAEW was created small units of water distribution system, each covering between 500 to 2500 client called zones metered where flow and pressure control and compared to the available information to ensure the measurement of the level of commercial and technical losses in the water and take the necessary action to address the difference. Analysis includes a daily estimate of the lower level of the flow in the evening, which is the process of indicators to determine the technical losses.

Yet it has been activated between 160 units are covered with counters in various parts of the Sultanate and include flow meters and rooms and data recorders and pressure points, and links touch control. This system has become a basic requirement in any new water network or a private network will you receive the body.

It was also building hydraulic models are calibrated and periodically allows the body identifying areas that suffer from low pressure areas which can be controlled by the pressure that reduces its losses in the water.

2.6.3 The strategy of reducing water losses

The strategy of reducing water losses includes:

- **Sound organization**: includes the appointment of supervisors to field customer service in order to reduce fraud and updating the customer database also includes the appointment of teams to detect leaks in various parts of the Sultanate of Oman.
- **Provide training on the job:** for example, are related to the design of training programs discovery programs through the formation of small groups of 3 to 5 employees. Through such training courses are employees define the tools and methods used to detect leaks and best practices in this area taking into account the special assets of the Authority and the operational environment on water in the Sultanate of Oman features.

- **Purchase of equipment and appropriate technology:** including leak detection equipment (by gas or audio equations).

- The development of appropriate contractual instruments to manage Contractors: such as fines and frames contracts and other means. Our goal is to reduce losses of water in order to best use of assets and government funds through the support of this sector, and achieve maximum return from it and improve service to customers and Omani level, both to ensure now or in the future, and also through the preservation of the environment and available water resources in the Sultanate.
CHAPTER THREE
METHODOLOGY

3.1 General Background

For the purpose of achieving the aim and objectives of the research, a range of methods was used to collect, analyze and present the relevant data. The method of carrying a research is divided as by [21] into Qualitative or Quantitative, and Desk study or Fieldwork. The data collected by quantitative method is numeric where the data collected by qualitative is non-numeric form. Research work is usually carried out by two procedures; namely, review of literature (desk study) or by fieldwork. The desk study and fieldwork are used in this work including document reviews, interview, observation, and questionnaire.

For the purpose of this project and in order to be aware of the topic of water losses and non-revenue water and how you will study this subject, the research collected many previous studies and literature about this subject, which are reviewed and presented in chapter two. Fieldwork is used for the collection of data for water auditing and analysis. Based on the purpose of the study and the resources available, several methods are used for data collection in the area including case study, observation, questionnaire, workshops, and interviews with experts.

This chapter deals with the study methodology developed as a result of the literature review, including the research approach, research techniques, and data collection.

3.2 Research Approach

Blaxter [21] identified four basic approaches in doing research. The four approaches are:

- **Action research**: When the aim of the research is to enhance the features of its own as the people whom they are conducting research in workplace.
- **Case studies**: Is usually used to explain the problems or designate good practices about one case of study.
• **Experiment:** It used usually in scientific research and conducted to collect data by carry out experiments.

• **Surveys:** This approach is used when you want to collect data and information from a group of people by using questions.

The two approaches we are used in our project in addition to review of literature is the case study and survey.

### 3.3 Research Techniques

#### 3.3.1 Introduction

As recognized by Blaxter [21] there are four basic research techniques as the study of documents, interviews, observation and questionnaires. The nature of this study and the aims it sought to achieve required the adoption of a variety of techniques of data collection and analysis. The present study obtains research data from documents analysis, observation, questionnaires, interviews and workshops. The data obtained from those data collection techniques are further analyzed to obtain the findings of the study.

The first phase of this study was a review of relevant national and international literature in order to identify the need for such research, its context and furthermore to identify current trends and common themes. A review of relevant literature is very important in to find out the current internationally preferred or recommended methods of determining methods of risk analysis and assessments for exceptional events and manmade hazards to water supply systems and a dependable NRW number or equal performance indicators. This will displayed the advantages of the recommended process and various constituents or criteria that are essential for the computation.

#### 3.3.2 Field Work and Observation

As mentioned earlier, one of the research techniques is observation, which is usually used in both quantitative and qualitative collection of data [22]. The main aim of observation is to collect information and data about specific issues [23].
Observation can be used in any stage of the research work, at the beginning or during the work or at the end of the research for checking of data [23]. The current research work used the qualitative, observation approach where the researcher was involved with fieldwork with the host organization’s (PAEW and others) staff and fieldworkers in looking to things related to water loss. The fieldwork includes the collection of data, information and observed notes necessary for water auditing.

3.3.3 Questionnaire and Interviews

In this study, one of the sources of data was the interviews that undertook with the senior staffs and staffs of PAEW whom they are involved in water losses and non-revenue water as the respondents of the study. Interview is defined as the person-to-person encounter in which one-person gains information from another. Interviews allow the researcher to generate a rich and varied data set in a less formal setting [24]. Interviews conducted with water leakage and NRW staffs aimed at collecting information and taking their opinion related to study issues of water losses and risk assessment to water supply system.

Questionnaires generally produce quantitative data but can also capture qualitative information. Questionnaires were argued to know the respondents opinion, attitude and perception. From the answers, the researcher generally creates quantitative data that he/she analyses to address the research problem [25]. In this study one questionnaire was developed to gather information about NRW.

3.4 Data Collection

3.4.1 Data Sheet

One of the main objectives of the present study is the water losses auditing for the water distribution networks of the project area (Al Seeb Wilayat) using AWWA Audit Software. The software needs some basic input data to run it and obtained the results. These data related to water supplies, water consumption, system data, and cost data. For this purpose, we prepared the data sheet illustrated in Table (3.1). The data sheet is divided into two sections. The first section is required some basic information and the second section including data for reporting worksheet The researcher went by himself to Al Seeb Water Department at Public Authority for Electricity and Water
(PAEW) an collected all the data necessary and filled the data sheet by himself by face to face interview with the person in charge.

Table (3.1): Data Sheet for Water Loss Information

<table>
<thead>
<tr>
<th>A) Basic Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Name of City or Utility: .................................................................</td>
</tr>
<tr>
<td>2. Country: ..........................................................................................</td>
</tr>
<tr>
<td>3. Reporting Year: ................................................................................</td>
</tr>
<tr>
<td>4. Name of the Person: .........................................................................</td>
</tr>
<tr>
<td>5. E-mail: ............................................................................................</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B) Reporting Work Sheet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Water Supplies</td>
</tr>
<tr>
<td>• Volume from Own Sources: .................................................................</td>
</tr>
<tr>
<td>• Master Meter Error Adjustment: ..........................................................</td>
</tr>
<tr>
<td>• Water Imported: ..................................................................................</td>
</tr>
<tr>
<td>• Water Exported: ..................................................................................</td>
</tr>
<tr>
<td>2. Authorized Consumption</td>
</tr>
<tr>
<td>• Billed Metered: ..................................................................................</td>
</tr>
<tr>
<td>• Billed Unmetered: ..............................................................................</td>
</tr>
<tr>
<td>• Unbilled Metered: ...............................................................................</td>
</tr>
<tr>
<td>3. System Data</td>
</tr>
<tr>
<td>• Systematic Data Handling Errors: .......................................................</td>
</tr>
<tr>
<td>• Mains Length: ....................................................................................</td>
</tr>
<tr>
<td>• Number of Active and Inactive Service Connections: .........................</td>
</tr>
<tr>
<td>• Average Length of Costumer Service Line: ..........................................</td>
</tr>
<tr>
<td>• Average Operating Pressure: ...............................................................</td>
</tr>
<tr>
<td>4. Cost Data</td>
</tr>
<tr>
<td>• Total Annual Cost of Operating Water System: ..................................</td>
</tr>
<tr>
<td>• Costumer Retail Unit Cost (Applied to Apparent Losses): ...................</td>
</tr>
<tr>
<td>• Variable Production Cost (Applied to Real Losses): ...........................</td>
</tr>
</tbody>
</table>
3.4.2 Staff Questionnaire

One of our objectives is to obtain feedback from PAEW staff about the issue of water losses and non-revenue water. For this purpose, the work team developed and prepared one questionnaire for PAEW staff. The main aim of this questionnaire is to take the point of view of staff working in water losses in PAEW on the status of water loss and non-revenue in Sultanate of Oman from technical and strategic point of view. We will ask the staff in charge of water losses about their opinion about the values of water losses and NRW, the main reasons of water losses, and the proposed solution to overcome this problem.

The questionnaire was prepared according to the main aim of the study and based on similar questionnaires prepared for the same purpose [26]. After the pilot test of the questionnaire, we met twenty staff from PAEW and filled the questionnaire by face to face interview. We selected staff whom they are in charge of water losses in PAEW. The questionnaire consists of three sections, namely, basic information, water losses in Al Seeb water supply systems, and other notes. The questionnaire is given in Appendix-A.

3.4.3 Interviewing of Key Staff of PAEW

In the current research work, the main source of data for non-revenue water and water losses was the interviews based on the designed questionnaire. The interviews were conducted on the selected number of senior staffs and staffs whom are concerned with NRW program in PAEW. Interviewing staff were carried out to get out in-depth information of their knowledge, perceptions and experience with the current situation and future strategy for NRW and water losses, and their opinion of the main causes of water loss, and water losses strategy at PAEW.

These interviews were conducted personally by the researcher, in a face-to-face manner at the office of each staff. Interviews varied in length from 15 to 30 minutes. The time is fixed with the concerned staff before interviewing. If the time is not suit the staff we usually fixed another time. Twenty (20) staff from Head Offices, Operation Department and Al Seeb Water Department of PAEW was interviewed and filled the questionnaires.
Information gathered from interviews and questionnaires was verified through further interviews either with relevant persons, or through available documentation. After each interview, notes were taken, making for easier compilation of the final project. This strategy also prevented the loss of work, ideas, contacts or strategies. The data obtained from the interview was analyzed and tabulated using Microsoft Excel spreadsheet software. The results of analysis are presented in chapter 4. Some of the data collected from literature were reviewed with the concerned staff of PAEW before it used in analysis and calculation of water losses and assessment of risks.

3.5 AWWA Water Audit Software

The values of water losses and non-revenue water can be estimated by carried out water auditing. The results are usually presented in a water balance sheet with defined international terminology. The figures obtained in the water balance are usually calculated from the measurements and estimation of water input to the system, water consumption, and water losses. There are many method that developed water auditing and water balance. The most format is that which is developed by the International Water Association [2; 7). The standard water balance is illustrated in Figure (2.1).

Based on the standard water balance of IWA [27], the American Water Works Association developed Water Audit Software. The water losses including real and apparent losses, revenue water, and non-revenue water can be estimated using this software. The program was designed in excel Microsoft office with number of working sheet as presented in Appendix-B. After entering the data in the program, the program calculated the apparent and real losses, revenue and non revenue water in terms of water balance. The expression used in the program and the definition of all the expressions are listed in Appendix-C.
CHAPTER FOUR
ANALYSIS AND DISCUSSION OF RESULTS

4.1 General Background

Sultanate of Oman depends mainly in desalination as main source of water which is comparatively of high cost. At the same time, the water is transported to the people over long distance. These two factors along with the scarcity of water make the cost of water production and transport very high. Therefore, each drop of water in Oman is very important. In fact, Sultanate of Oman face a big problem of water losses and non-revenue water where the values are high compare to international figures. It is commonly stood that if we cannot avoid water losses, its values should be low and controlled. The water losses and non-revenue water in Oman is a chronic and some solution has to be done urgently. The raw data obtained from PAEW show that the water losses in Oman is more than 40% which is belong to many reasons as we study and presented in this chapter.

The best way to understand the problem of water losses and non-revenue water, and the causes of high values and the best management and solution for this problem is to study in depth this problem including understanding of the causes for NRW and the factors that affect its components. Some typical questions you have ask when we are talking about the water losses and NRW and the strategy to deal with this problem. These questions are: how much the quantity of water lost? From where the water lost? Why the values of water losses are very high? What is the proposed solution and strategy to improve the situation be reducing the losses? How can we continue mentoring and controlling this problem?

Water losses and non-revenue water represent one of the main stress factors in operating water supply systems in Sultanate of Oman. In this project, we tried to identify the problem of water losses and NRW and estimate the values of water losses and NRW for Al Seeb Wilayat water supply system in Muscat Governorate. The results obtained from this study are presented in this chapter followed by conclusions and recommendations.
4.2 Losses in Al Seeb Water Supply System

4.2.1 Results of AWWA Audit Software

The data and information that are necessary to conduct water audit were collected by the teamwork of the project using the data sheet prepared for this purpose as we explained in chapter three. The data were collected from Al Seeb Water Department of PAEW. The water auditing and water balance are conducted as mentioned earlier by using AWWA Water Audit Software version 3.0 as a first time for Al Seeb Wilayat.

The data required by the software are: (1) The basic data as the name of utility, reporting year, name of contact person, and the reporting units for water volume.; and (2) Water use and System data as water supplied, water authorized consumption, system data (length of mains, service connections, and operating pressure), and the cost data. The data collected for the last five years and from 2010 to 2014. The data obtained were fed to the software and the results of water auditing including water losses and NRW for Al Seeb water supply system were obtained. The analysis and discussion of results are presented here in this section as given below.

The reporting sheet as given by AWWA software for year 2014 is illustrated in Figure (4.1). The figure show the data obtained for the same year and how it is look when entreated to the computer software. The reporting sheets for the other years 2010, 2011, and 2013 are also prepared and it’s shown in Figures (D.1) to (D.4) of Appendix-D.

The values of water losses and non-revenue water were obtained as per volume of water. We calculated the percentage of each item. The predicted percentage values of apparent losses, real losses, total water losses, and non-revenue water for Al Seeb Wilayat water supply system are shown in Table (4.1). The same data and results are shown in Figures (4.2) and (4.3).
**Figure (4.1): Reporting Worksheet for Year 2014**

### WATER SUPPLIED

<table>
<thead>
<tr>
<th>Source</th>
<th>Volume (ML/yr)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>From own sources</td>
<td>19,452.600</td>
<td>Megalitres/yr (or ML/yr)</td>
</tr>
<tr>
<td>Master meter error adjustments</td>
<td>680.800</td>
<td>under-registered ML/yr</td>
</tr>
<tr>
<td>Water imported</td>
<td>0.000</td>
<td>ML/yr</td>
</tr>
<tr>
<td>Water exported</td>
<td>0.000</td>
<td>ML/yr</td>
</tr>
<tr>
<td><strong>Total Water Supplied:</strong></td>
<td>20,133.200</td>
<td>ML/yr</td>
</tr>
</tbody>
</table>

### AUTHORIZED CONSUMPTION

<table>
<thead>
<tr>
<th>Type</th>
<th>Volume (ML/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Billed metered</td>
<td>12,036.800</td>
</tr>
<tr>
<td>Billed unmetered</td>
<td>0.000</td>
</tr>
<tr>
<td>Unbilled metered</td>
<td>0.000</td>
</tr>
<tr>
<td>Unbilled unmetered</td>
<td>261.466</td>
</tr>
<tr>
<td><strong>Total Authorized Consumption:</strong></td>
<td>12,300.265</td>
</tr>
</tbody>
</table>

### WATER LOSSES (Water Supplied - Authorized Consumption)

<table>
<thead>
<tr>
<th>Type</th>
<th>Volume (ML/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparent Losses</td>
<td>3,092.930</td>
</tr>
<tr>
<td>Real Losses</td>
<td>3,092.930</td>
</tr>
<tr>
<td><strong>Total Water Losses:</strong></td>
<td>7,042.930</td>
</tr>
</tbody>
</table>

### NON-REVENUE WATER

<table>
<thead>
<tr>
<th>Type</th>
<th>Volume (ML/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-revenue water</td>
<td>7,298.600</td>
</tr>
</tbody>
</table>

### SYSTEM DATA

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (Kilos)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of mains</td>
<td>283.0</td>
</tr>
<tr>
<td>Number of active and inactive service connections</td>
<td>21,946</td>
</tr>
<tr>
<td>Connection density</td>
<td>42 conn./km main</td>
</tr>
<tr>
<td>Average length of customer service line</td>
<td>30.0 metres</td>
</tr>
<tr>
<td>Average operating pressure</td>
<td>30.0 metres (head)</td>
</tr>
</tbody>
</table>

### COST DATA

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost (Dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total annual cost of operating water system</td>
<td>$30,595.900</td>
</tr>
<tr>
<td>Variable production cost (applied to Apparent Losses)</td>
<td>$1.14</td>
</tr>
<tr>
<td>Variable production cost (applied to Real Losses)</td>
<td>$1,500.00</td>
</tr>
</tbody>
</table>

### DATA REVIEW

- Input values should be indicated as either measured or estimated. You have entered:
  - 3 as measured values
  - 3 as estimated values
  - 0 as default values
  - 10 without specifying measured, estimated or default
- Water Supplied Data: No problems identified
- Unbilled unmetered consumption: No problems identified
- Unauthorized consumption: No problems identified
- It is important to accurately measure the master meter - you have entered the measurement type as: measured
- Cost Data: Retail costs are less than (or equal to) production costs; please review and correct if necessary

### PERFORMANCE INDICATORS

#### Financial Indicators

- Non-revenue water as percent by volume: 36.24%
- Non-revenue water as percent by cost: 31.73%
- Annual cost of Apparent Losses: $4,502,938
- Annual cost of Real Losses: $4,784,224

#### Operational Efficiency Indicators

- Apparent Losses per service connection per day: 422.66 litres/connection/day
- Real Losses per service connection per day: 335.70 litres/connection/day
- Real Losses per length of main per day: N/A
- Real Losses per service connection per day per meter (head): 7.72 litres/connection/m
- Charitable Annual Real Losses (GAL): 725.17 cubic meters/year
- Infrastructure Leakage Index (ILI) (Real Losses/GAL): 3.90

*Only the most applicable of these two indicators will be calculated.*
Table (4.1): The Percentage Values of Water Losses and NRW for Al Seeb Water Supply System

<table>
<thead>
<tr>
<th>Year</th>
<th>Apparent Losses (%)</th>
<th>Real Losses (%)</th>
<th>Total losses (%)</th>
<th>NRW (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>20.4</td>
<td>25.0</td>
<td>45.4</td>
<td>46.7</td>
</tr>
<tr>
<td>2011</td>
<td>19.6</td>
<td>23.4</td>
<td>43.0</td>
<td>44.5</td>
</tr>
<tr>
<td>2012</td>
<td>18.3</td>
<td>22.8</td>
<td>41.1</td>
<td>42.3</td>
</tr>
<tr>
<td>2013</td>
<td>19.0</td>
<td>17.2</td>
<td>36.2</td>
<td>37.5</td>
</tr>
<tr>
<td>2014</td>
<td>19.6</td>
<td>15.4</td>
<td>35.0</td>
<td>36.2</td>
</tr>
</tbody>
</table>

Figure (4.2): The Percentage of Water Losses for Al Seeb Wilayat
As shown in Figure (4.1), the apparent losses equal to summation of unauthorized consumption (theft or illegal use), customer metering error, and systematic data handling errors. The data presented in Table (4.1) show that the percentage of apparent water losses is around 20% that is comparatively high percentage. The main reasons of high values of apparent losses are:

- The performance Oman Investment & Finance Company (OIFC) which is responsible in billing and collecting the money from the customers, as they are usually delay in reading the meters and issuing water consumption bills.
- The monthly registration for monthly readings of customers meters are not carried out periodically by the concerned people.
- The handling and processing of the collected data is not done accurately.
- The values of water pressure in many parts of the system are very high that causes water losses.
- The age of many meters is more than 15 years (are very old) and needs changing. The meters are not change periodically. There are different types of meters used in Oman.
- The shortage of integrated database software.
The percentage values of real losses are also high as apparent losses due to leaks in transmission and distribution pipelines, overflow of water from reservoirs and water tanks, and leaks in house connections. The results shown in above tables and figures show that the percentage values of real losses in the last two years are comparatively decreased. The parentage decreased from 25% in year 2010 to 15% in year 2014. The level decreased because the PAEW start three years back developing the strategy for water losses and NRW including installing District Metering Area (DMA).

As mentioned earlier, NRW equal the summation of apparent losses, real losses and unbilled authorized consumption, because of this the percentage value of NRW is high and the percentage value of apparent losses and real losses is high. The percentage of unbilled authorized consumption is less than 2%.

### 4.2.2 Performance Indicators

1) **Financial Indicator:**

The performance indicators include financial and operational indicators in which the software is calculated as results of the software. These two indicators indicated the efficiency performance of the water system. The predicted values of financial indicator of water losses and NRW for Al Seeb water supply system are listed in Table (4.2). The same data (apparent and real losses in term of cost) are plotted as illustrated in Figure (4.4).

#### Table (4.2): The Annual Cost of Water Losses and NRW as Percent of Cost

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual Cost of Water Losses</th>
<th>NRW as Percent of Cost (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Apparent Losses (USD)</td>
<td>Real Losses (USD)</td>
</tr>
<tr>
<td>2010</td>
<td>3,460,706</td>
<td>5,777,399</td>
</tr>
<tr>
<td>2011</td>
<td>3,404,691</td>
<td>5,603,662</td>
</tr>
<tr>
<td>2012</td>
<td>3,799,150</td>
<td>6,452,605</td>
</tr>
<tr>
<td>2013</td>
<td>4,078,295</td>
<td>5,020,145</td>
</tr>
<tr>
<td>2014</td>
<td>4,502,938</td>
<td>4,794,134</td>
</tr>
</tbody>
</table>
29

Figure (4.4): The Annual Cost of Water Losses for Al Seeb Water System

The total annual cost of water losses as shown in Table (4.2) and Figure (4.4) is more than 9.0 million USD because of high level of water losses. The results show also that the percentage of NRW as percent of cost is more than 30% in year 2014 and its almost as NRW as percent of volume. About one third of water supplied to Al Seeb Wilayat water supply system is considered non-revenue water.

2) Operational Indicator:

The software also predicts the operational indicators for the system. The software predicted two operational indicators, namely, the losses per service connection per day and Infrastructure Leakage Index (ILI). The data of apparent and real losses per service connection per day (liter/ connection/ day) and ILI are presented in Table (4.3).

The values of apparent losses per service connection per day are almost same as the values of apparent losses are very close (around 19%). The value of real losses per service connection per day is reduced from 568.1-liter/connection/ day in year 2010 to 492.7 liter/connection/day in year 2014 due to reduce in real losses. The value of ILI in 2014 is 3.9 in year 2014; this value is more or less satisfactory in terms of water losses where point of reference is 1.0.
### Table (4.3): The Operational Efficiency Indicators for Al Seeb Network

<table>
<thead>
<tr>
<th>Year</th>
<th>Losses per Service Connection per Day (liter/connection/day)</th>
<th>Infrastructure Leakage Index (ILI) (real losses/UARL)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Apparent losses</td>
<td>Real losses</td>
</tr>
<tr>
<td>2010</td>
<td>568.1</td>
<td>697.54</td>
</tr>
<tr>
<td>2011</td>
<td>477.9</td>
<td>578.6</td>
</tr>
<tr>
<td>2012</td>
<td>479.8</td>
<td>599.4</td>
</tr>
<tr>
<td>2013</td>
<td>490.6</td>
<td>444.1</td>
</tr>
<tr>
<td>2014</td>
<td>492.7</td>
<td>385.8</td>
</tr>
</tbody>
</table>

#### 4.2.3 System Water Balance

The water balance for Al Seeb water supply system for year 2014 is shown in Figure (4.5) and the Figures for years 2010 to 2013 are presented in Figures (D.5) to (D.8). The data presented in Table (4.4) of water balance is the same data of the reporting sheet of the software. The tables for years 2010-2013 are demonstrated in Tables (D.1) to (D.4) of Appendix D.

![AWWA WLCC Water Audit Software: Water Balance](image)

**Figure (4.5): Water Balance for Al Seeb Wilayat (Year 2014)**
Table (4.4): Water Balance for Al Seeb Water Supply System for Year 2014

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Water Exported</strong></td>
<td>Billed Water Exported</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0%)</td>
<td>Billed Authorized Consumption (63.8%)</td>
<td>Billed Metered Consumption (63.8%)</td>
<td>Revenue Water (63.8%)</td>
</tr>
<tr>
<td></td>
<td>Billed Unmetered Consumption (0%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Water Supplied</strong></td>
<td>Authorized Consumption (65.0%)</td>
<td>Unbilled Metered Consumption (0%)</td>
<td></td>
</tr>
<tr>
<td>(100%)</td>
<td>Unbilled Authorized Consumption (1.2%)</td>
<td>Unbilled Unmetered Consumption (1.2%)</td>
<td></td>
</tr>
<tr>
<td><strong>Water Imported</strong></td>
<td>Apparent Losses (19.0%)</td>
<td>Unauthorized Consumption (0.3%)</td>
<td>Non-Revenue Water (NRW) (36.2%)</td>
</tr>
<tr>
<td>(0%)</td>
<td>Systematic Data Handling Errors (18.0%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leakage on Transmission and/or Distribution mains</td>
<td>Not broken down</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leakage and Overflow at Utility’s Storage Tank</td>
<td>Not broken down</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leakage on Service Connections</td>
<td>Not broken down</td>
<td></td>
</tr>
<tr>
<td><strong>Water losses</strong></td>
<td>Real Losses (15.4%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(35.0%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

31
The water balances for Al Seeb water supply system show the percentage of all components of revenue and non-revenue water including water supplies, water losses and authorized consumption. The data presented in the table indicates that up to last year the percentage of NRW is more than 30% even the situation is improved compare to year 2010. The results show that the billed unmetered water consumption and unbilled metered water consumption is zero.

The results of apparent and real losses are the same as explained above. The results of water balances are also show that the percentage value of authorized consumption is less than 2%. It includes things such as firefighting and training, flushing of water pipes sewers, road cleaning, watering of gardens water for building, etc.

### 4.3 Results of the Questionnaire

#### 4.3.1 Introduction

As the levels of water losses and NRW in Oman is very high (greater than 40%), it is necessary to check the main causes of water losses, solution to reduce water losses, and the existing strategy and practice program for NRW and water losses reduction. For this purpose, the teamwork prepared one questionnaire as explained in chapter 3. The teamwork seek to discover from PAEW staff working in water losses their insights about the status of NRW values, their opinion of the affect and main causes of water loss, and their the PAEW’s procedures and policy related to water loss reduction.

The output of the questionnaire help the teamwork to recognize the existing situation and management program related to NRW and water losses in project area and how the situation can be improved. The data and results obtained from the questionnaire are presented in this section.

The first question to PAEW staff is (what do think the percentage of water losses in Al Seeb water supply system?). Most of the staff answers is between 20-40%, where it seems some staff do not know the estimated value of water losses. The answers of the staff were consistent with the estimated percentage as illustrated in Figure (4.6).
The answers of the staff to the question (In which system the PAEW strategy concentrates of obtaining water loss figure) as presented in Figure (4.7) are confirmed that PAEW strategy focuses mainly on UFW.
4.3.2 Causes, Impacts and Solutions
In order to study the causes, impacts and solutions, we asked the staff (What do you think the main causes of water losses?). The staff answers are given in Figure. The results show that the main factor that contributes to water losses is first the meters inaccuracies, then the water pressure. The other factors contribute in water losses by less degree as presented in the figure.

![Figure (4.8): The Main Causes of Water Losses](image)

The teamwork study the effect of water losses values on system operation and cost. The responses to the question (What do you think the possible effects of high water losses figures?) are listed in Figure (4.9). The data confirm that the high values of water loss associated with high cost of operation and maintenance, short lifetime of existing resources and increase spending on development. Most probably, the high water losses did not affect water properties.
Figure (4.9): The Possible Affect to High Water Losses Figures

Figure (4.10) summary the response of the PAEW staff to the question (What is the best solution to reduce water losses in Al Seeb water system?) about of the best solutions and strategy that could be followed to overcome the problem of water losses and NRW, and the best method to reduce them. Each staff has six priorities to answer from 1 to 6. The active leakage detection programme is the first priority as 60% of the staff think that an active leak detection programme will help much in reducing water losses and NRW.

The second priority is the improving metering is 40% of the staff think that the improving metering is the first thing that should be done to reduce water losses and NRW. The improvement of pipe maintenance and replacement of old pipes should be also considered. But it seem, fighting the illegal connection not necessary.
4.3.3 Procedures and Policy

The second set of the questions about the procedures and policy that should be developed as per opinion of PAEW staff regarding the water losses and NRW, as clear policy and procedures are very important in any leakage reduction program. The question in procedures and policy have five option (strongly agree, agree, neutral, disagree, and strongly disagree). The answers of the staff are given in Figure (4.11).

Most of the staff agree that there is procedures and policy inside PAEW that are followed and for this purpose of reducing water losses and NRW. This means there is a continuous effort for this issue. Reduction program is almost implemented beside pressure management and network maintenance and rehabilitation program that certainly allow for reducing water losses and NRW in Oman. We noticed the effect of these procedures and policy when we carried out the water auditing for the project area as values of water losses and NRW are decreased in the last two years.
Obstacles for Fighting Water losses

The last part of including seven questions is about the obstacles for fighting water losses. The answers to the set of questions are shown in Figure (4.13). It seems the number of trained staff that should be assigned to leak reduction at PAEW is very less, and may me the equipment’s and tools are also less. At the same the staff that have working in water, losses are not well trained and no refreshing training programme for them, it is clear that training is given a very low priority.

The other important factor that considered as obstacles for fighting water losses is the lack of appropriate technologies for water loss reduction. The financial situation of the PAEW is comparatively strong and no problem in this regards that prevent the application of any strong program for fighting water losses. It seems maintenance system should be improved for better performance of the water supply system through reducing water losses. The other factors such as public and personnel awareness and acceptance have not big obstacles for fighting water losses.
4.4 Developing a Strategy to Reduce Water Losses

Based on the results of this project, the teamwork suggested the following most important actions:

1. **Integrated Management:** The issue of water losses is responsibility off different department at PAEW as Water Operations, Customer Services, Asset and Planning and Project Departments

2. **Data reporting:** The data reporting improvement will be addressed through a two pronged approach:
   - Installing and maintaining a network of devices to measure all inputs to and outputs from all part of the water system.
• Implementing a reporting methodology based on hydraulic systems and using physical measurement devices as well as closely monitoring the performance of Billing and Collection Contractors.

3. Flow Monitoring and Implementation of District Metered Areas (DMA): Monitoring the volume of water produced by the different sources and the water supplied throughout the country by installing DMA’s in all the area. DMA’s installation programme is ongoing in Muscat and Several DMA’s will also be implemented on distribution networks in the regions.

4. Leak Repair and Meter accuracy checking and replacement: At the current time, all leak repairs are out-sourced in all regions. The recommendation here is to develop limited in-house capability but continue to utilize external companies to provide most efficient form of leak repair (cost and speed).

5. Leakage teams: It is essential that sufficient leakage team are to be created and providing them with the necessary training and equipment to enable them to carry out their allotted tasks efficiently and to raise leak detection practices in Oman.
CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The current study investigated the problem of water losses and non-revenue water in Sultanate of Oman taking Al Seeb Wilayat water supply system as a case study for this project. In order to contribute to this goal, the figures of NRW and the size of water losses problem in Oman were obtained for the project area and discussed in the chapter four. The conclusions were developed by reviews the project objectives and questions and how this study addressed and answered these questions. The main conclusions drawn from the present study are:

1) The results reveal that the values of water losses and Non-Revenue Water (NRW) in Oman are more than 30%, which is very high according to the international standards.

2) The results show that the main factors that contribute to water losses is the method of estimating water consumptions due to meters inaccuracies, and the water pressure in some part of the network, that calls for improvement in meter reading accuracy and timely identification of meters that require maintenance.

3) The financial impact posed by Non-Revenue Water (NRW) was found to be 32% of the total revenue budget. This is high in comparison with international norms.

4) The results reveal that the best solutions to water losses problem are active leak detection program, improve metering, improvement of pipe maintenance and replacement of old pipes.

5) The five most important actions of improvement were identified which should be contribute in reducing the water losses.

6) It is concluded that there is requirement of strong established water management systems, which would be able to provide all the citizens in Oman with sufficient quantity and good quality of water.
5.2 Recommendations

The current study should open the door for more research particularly the study of stress factors in operating water systems in Oman, the resilience of water systems, and hydraulic performance of water systems.
REFERENCES


## Appendix- A

### Questionnaire for PAEW Staff

#### A) Basic Information

1. Name of Person:  
2. Position:  
3. Department:  
4. Mobile:  
5. E-mail:  

#### B) Water Loss in Al Seeb Water Supply System

1. **Basic Data of Water losses**

   Q.1 What do think the percentage of water losses in Al Seeb Water Supply System? 
   - 10-20%
   - 20-30%
   - 30-40%
   - More than 40%
   - Don't know

   Q.2 What do you think the main causes of water losses? Please prioritize the causes according to their contribution (1 = very high, 6 = very low) 
   - Meter Inaccuracies
   - Losses during repair
   - Age of pipes
   - Illegal Connection
   - Service reservoir overflow
   - Water pressure

   Q.3 What is the best solution to reduce water losses in Al Seeb water system? Please prioritize the actions according to their efficiency(1 = very high, 6 = very low) 
   - Improve pipe maintenance
   - Clampdown on illegal connection
   - Pipe replacement
   - Active leak detection
   - Increase public Awareness
   - Improve metering
Q.4 In which system the PAEW strategy concentrates of obtaining water loss figure?:
- Leakage Level (%)
- Leakage level (%) and UFW
- UFW
- Non-Revenue Water
- UFW and NRW

Q.5 What do you think the possible effects of high water losses figures? Please prioritize the factors according to their effect (1 = very high, 6 = very low)
- Pressure reduction
- Increase expenditure on development
- Water contamination
- High cost of Operation and Maintenance
- Short lifespan of existing resources
- Property damage

### 2. Procedures and Policy

| Q.6 | The National water policy exists which aims at reducing water losses. |
| Q.7 | The program for water loss reduction is applied. |
| Q.8 | Management of Pressure is used to reduce water losses |
| Q.9 | Network Maintenance/ Rehabilitation Program is applied |
| Q.10 | Procedures to fight illegal connections are implemented |

### 3. Obstacles for Fighting Water Losses

<p>| Q.11 | The situation of PAEW |
| Q.12 | The financial situation of PAEW |
| Q.13 | Lack of appropriate technologies for water loss reduction |
| Q.14 | Repairing and Maintenance system |
| Q.15 | Lack of trained technicians |
| Q.16 | Personnel awareness |
| Q.17 | Public approval / awareness |</p>
<table>
<thead>
<tr>
<th>C) Other Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Please state your view on the subject of water losses and NRW in Oman:</td>
</tr>
</tbody>
</table>

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Appendix- B

AWWA Water Audit Software Worksheets

Figure (B.1): Instruction Worksheet
Figure (B.2): Reporting Worksheet
### SYSTEM DATA

- **Length of mains:**
- **Number of active and inactive service connections:**
- **Connection density:**
  - **Average length of customer service line:** (pipe length between midstop and customer meter or property boundary)
- **Average operating pressure:**

### COST DATA

- **Total annual cost of operating water system:**
- **Customer retail unit cost (applied to apparent losses):**
- **Variable production cost (applied to real losses):**

### PERFORMANCE INDICATORS

#### Financial Indicators
- Non-revenue water as percent by volume of water supplied:
- Non-revenue water as percent by cost of operating system:
- Annual cost of apparent losses:
- Annual cost of real losses:

#### Operational Efficiency Indicators
- Apparent losses per service connection per day:
- Real losses per service connection per day:
- Real losses per length of main per day:
- Real losses per service connection per day per meter (head) pressure:
- **Unavoidable annual real losses (UARL):**

From Above, Real losses = Current Annual Real Losses (CARL):
- **Infrastructure Leakage Index (ILI) (GAL/L/UrL):**

* only the most applicable of these two indicators will be calculated

---

**Figure (B.2): Reporting Worksheet-Cont.**
Figure (B.3): Water Balance Worksheet
# Appendix- C

## AWWA Water Audit Software - Definition of terms

<table>
<thead>
<tr>
<th>Item Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume from own sources</td>
<td>The volume of treated water input to system from own production facilities</td>
</tr>
<tr>
<td>Master meter error</td>
<td>An estimate or measure of the degree of any inaccuracy that exists in the master meters measuring the Volume from own sources. Please also indicate if this adjustment is because the master meters under-registered (did not capture all the flow) or over-registered (overstated the actual flow)</td>
</tr>
<tr>
<td>adjustment</td>
<td></td>
</tr>
<tr>
<td>Water imported</td>
<td>Bulk water purchased to become part of the water supplied. Typically this is water purchased from a neighboring water utility or regional water authority. Be sure to account for any import meter inaccuracy in reporting this volume</td>
</tr>
<tr>
<td>Water exported</td>
<td>Bulk water sold and conveyed out of the water distribution system. Typically this is water sold to a neighboring water utility. Be sure to account for any export meter inaccuracy in reporting this volume</td>
</tr>
<tr>
<td>AUTHORIZED CONSUMPTION</td>
<td>$=\ \text{billed metered} + \ \text{billed unmetered} + \ \text{unbilled metered} + \ \text{unbilled unmetered}$</td>
</tr>
<tr>
<td></td>
<td>The volume of metered and/or unmetered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorized to do so by the water supplier, for residential, commercial and industrial purposes. This does NOT include water sold to neighboring utilities (water exported). Authorized consumption may include items such as fire fighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, frost protection, building water, etc. These may be billed or unbilled, metered or unmetered.</td>
</tr>
<tr>
<td>Billed Authorized</td>
<td>All consumption that is billed and authorized by the utility. This may include both metered and unmetered consumption. See &quot;Authorized Consumption&quot; for more information.</td>
</tr>
<tr>
<td>Consumption</td>
<td></td>
</tr>
<tr>
<td>Unbilled Authorized Consumption</td>
<td>All consumption that is unbilled, but still authorized by the utility. See &quot;Authorized Consumption&quot; for more information.</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Billed metered consumption</td>
<td>All metered consumption which is billed. This includes all groups of customers such as domestic, commercial, industrial or institutional. It does NOT include water sold to neighboring utilities (water exported) which is metered and billed. The metered consumption data can be taken directly from billing records for the water audit period. The accuracy of yearly metered consumption data can be refined by including an adjustment to account for customer meter reading lagtime, however additional analysis is necessary to determine the adjustment value, which may or may not be significant.</td>
</tr>
<tr>
<td>Billed unmetered consumption</td>
<td>All billed consumption which is calculated based on estimates or norms but is not metered. This might be a very small component in fully metered systems (for example billing based on estimates for the period a customer meter is out of order) but can be the key consumption component in systems without universal metering. It does NOT include water sold to neighboring utilities (water exported) which is unmetered but billed.</td>
</tr>
<tr>
<td>Unbilled metered consumption</td>
<td>Metered Consumption which is for any reason unbilled. This might for example include metered consumption of the utility itself or water provided to institutions free of charge. It does NOT include water sold to neighboring utilities (water exported) which is metered but unbilled.</td>
</tr>
<tr>
<td>Unbilled unmetered consumption</td>
<td>Any kind of Authorized Consumption which is neither billed nor metered. This component typically includes items such as fire fighting, flushing of mains and sewers, street cleaning, frost protection, etc. In most water utilities it is a small component which is very often substantially overestimated. It does NOT include water sold to neighboring utilities (water exported) which is unmetered and unbilled - an unlikely case. This component has many sub-components of water use which are often tedious to identify and quantify. Because of this, and the fact that it is usually a small portion of the water supplied, it is recommended that the auditor apply the default value of 1.25% of the volume from own sources. Select the default percentage to enter this value. If the water utility already has well validated data that gives a value substantially higher or lower than the default volume, then the auditor should enter their own volume. However the default</td>
</tr>
</tbody>
</table>
| WATER LOSSES | \( = \) apparent losses + real losses  
The difference between System Input and Authorized Consumption. Water losses can be considered as a total volume for the whole system, or for partial systems such as transmission or distribution systems, or individual zones. Water Losses consist of Real Losses and Apparent Losses. |
|---|---|
| Apparent Losses | \( = \) unauthorized consumption + meter under-registration + data handling errors  
Includes all types of inaccuracies associated with customer metering as well as data handling errors (meter reading and billing), plus unauthorized consumption (theft or illegal use). NOTE: Over-registration of customer meters, leads to under-estimation of Real Losses. Under-registration of customer meters, leads to over-estimation of Real Losses. |
| Unauthorized consumption | Includes water illegally withdrawn from hydrants, illegal connections, bypasses to consumption meter or meter reading equipment tampering. While this component has a direct impact on revenue, in most water utilities the volume is low and it is recommended that the auditor apply a default value of 0.02% of the volume from own sources. If the auditor has well validated data that indicates the volume from unauthorized consumption is substantially higher or lower than that generated by the default value then this value can be entered. However, for most water utilities it is recommended to apply the default value. Note that a value of zero will not be accepted since all water utilities have some volume of unauthorized consumption occurring in their system. |
| Customer metering inaccuracies | Apparent water losses caused by the collective under-registration of customer water meters. Many customer water meters will wear as large cumulative volumes of water are passed through them over time. This causes the meters to under-register. The auditor has two options for entering data for this component of the audit. The auditor can enter a percentage under-registration (typically an estimated value), this will apply the selected percentage to the two categories of metered consumption to determine the volume of water not recorded due to customer meter inaccuracy. Alternatively, if the auditor has substantial data from meter testing to arrive at their own volumes of such losses, this volume may be entered directly. Note that a value of zero will be accepted but an alert will appear asking if the customer population is unmetered. Since all metered systems have some degree of inaccuracy, then a positive value should be entered. A value of zero in this component is valid only if the water utility does not meter its customer population. |
| Systematic data handling errors | Apparent water losses caused by systematic data handling errors in the meter reading and billing system. |
| Real Losses | Physical water losses from the pressurized system and the utility’s storage tanks, up to the point of customer consumption. In metered systems this is the customer meter, in unmetered situations this is the first point of consumption (stop tap/tap) within the property. The annual volume lost through all types of leaks, breaks and overflows depends on frequencies, flow rates, and average duration of individual leaks, breaks and overflows. |
| NON-REVENUE WATER | = Apparent Losses + Real Losses + Unbilled Metered + Unbilled Unmetered Water which does not provide any revenue to the utility |
| Revenue Water | Water which is charged to customers to provide revenue to the utility. |
| **Length of mains** | Length of all pipelines (except service connections) in the system starting from the point of system input metering (for example at the outlet of the treatment plant). It is also recommended to include in this measure the total length of fire hydrant lead pipe. Hydrant lead pipe is the pipe branching from the water main to the fire hydrant. Fire hydrant leads are typically of a sufficiently large size that is more representative of a pipeline than a service connection. The average length of hydrant leads across the entire system can be assumed if not known, and multiplied by the number of fire hydrants in the system, which can also be assumed if not known. This value can then be added to the total pipeline length. Total length of mains can therefore be calculated as:

\[
\text{Length of Mains, miles} = (\text{total pipeline length, miles}) + \left[ \frac{(\text{average fire hydrant lead length, ft}) \times (\text{number of fire hydrants})}{5,280 \text{ ft/mile}} \right]
\]

or

\[
\text{Length of Mains, kilometres} = (\text{total pipeline length, kilometres}) + \left[ \frac{(\text{average fire hydrant lead length, metres}) \times (\text{number of fire hydrants})}{1,000 \text{ metres/kilometre}} \right]
\] |
| **Number of active AND inactive service connections** | Number of service connections, main to curb stop. Please note that this includes the actual number of distinct piping connections whether active or inactive. This may differ substantially from the number of Customers (or number of accounts) |
| **Connection density** | =number of connections / length of mains |
| **Average length of customer service line** | This is entered for unmetered services and in cold or other areas where meters are installed inside homes and buildings. It is the length of customer service line either between the utility's service connection (often at the curbstop) and the meter, or to the building line (first point of customer consumption) if customers are unmetered. Note that the length of service connection between the main and customer service line is owned by the utility and its length and potential leakage is accounted for in the UABL formula by the number of service connections. |
| **Average operating pressure** | The average pressure may be approximated when compiling the preliminary water audit. Once routine water auditing has been established, a more accurate assessment of average pressure should be pursued. If the water utility infrastructure is recorded in a Geographical Information System (GIS) the average pressure at many locations in the distribution system can be readily obtained. If a GIS does not exist, a weighted average of pressure data can be calculated from water pressure measured at various fire hydrants scattered across the water distribution system. |
| **Total annual cost of operating the water system** | These costs include those for operations, maintenance and any annually incurred costs for long-term upkeep of the system, such as repayment of capital bonds for infrastructure expansion or improvement. Typical costs include employee salaries and benefits, materials, equipment, insurance, fees, administrative costs and all other costs that exist to sustain the drinking water supply. These costs should not include any costs to operate wastewater, biosolids or other systems outside of drinking water. |
| **Customer retail unit cost** | The Customer Retail Unit Cost represents the charge that customers pay for water service. This unit cost is applied to the components of apparent loss, since these losses represent water reaching customers but not (fully) paid for. It is important to compile these costs per the same unit cost basis as the volume measured included in the water audit. For example, if all water volumes are measured in million gallons, then the unit cost should be dollars per million gallon ($/mil gal). The software allows the user to select the units that are charged to customers (either $/1,000 gallons, $/hundred cubic feet or $/1,000 litres) and automatically converts these units to the units that appear in the "WATER SUPPLIED" box. Since most water utilities have a rate structure that includes a variety of different costs based upon class of customer, a weighted average of individual costs and number of customer accounts in each class can be calculated to determine a single composite cost that should be entered into this cell. |
| **Variable production cost (applied to Real Losses)** | The cost to produce and supply the next unit of water. (E.g., $/million gallons) This cost is determined by calculating the summed unit costs for ground and surface water treatment and all power used for pumping from the source to the customer. It should also include the unit cost of bulk water purchased as an import if applicable. |
**Unavoidable Annual Real Losses (UARL)**

\[
\text{UARL (gallons/day)} = (5.41 \text{Im} + 0.15 \text{Nc} + 7.51 \text{Ip}) \times P,
\]

\[
\text{or}
\]

\[
\text{UARL (litres/day)} = (18.01 \text{Im} + 0.8 \text{Nc} + 25.01 \text{Ip}) \times P
\]

where:
- \( \text{Im} \) = length of mains, (miles or kilometres)
- \( \text{Nc} \) = number of service connections
- \( \text{Ip} \) = total length of private pipe, (miles or km)
  
  \[= \text{Nc} \times \text{average distance of private pipe} \]

The UARL is a theoretical reference value representing the technical low limit of leakage that could be achieved if all of today's best technology could be successfully applied. It is a key variable in the calculation of the Infrastructure Leakage Index (ILI). It is not necessary that water utilities set this level as the target level of leakage, unless water is unusually expensive, scarce or both. **NOTE:** The UARL calculation has not yet been fully proven as effective for very small water distribution systems. If,

\[
(\text{Im} \times 32) + \text{Nc} < 3000 \text{ (gallons per day)} \text{ or}
\]

\[
(\text{Im} \times 20) + \text{Nc} < 3000 \text{ (litres per day)}
\]

then the calculated UARL value may not be valid. The software does not display a value of UARL or ILI if either of these conditions is true.

**Infrastructure Leakage Index (ILI)**

The ratio of the Current Annual Real Losses (Real Losses) to the Unavoidable Annual Real Losses (UARL). The ILI is a highly effective performance indicator for comparing (benchmarking) the performance of utilities in operational management of real losses.
Use of Equiiz Buttons

NOTE: For unbilled unmetered consumption and unauthorized consumption, a recommended default value can be applied by selecting the Percent option. The default values are based on fixed percentages of water supplied and are recommended for use in this audit unless the auditor has well validated data for their system. Default values are shown by purple cells, as shown in the example above.

If a default value is selected, the user does not need to identify if an estimated or measured value has been used, the user should leave the drop-down box empty.

Units and Conversions

The user may develop an audit based on one of three unit selections:
1) Million Gallons (US)
2) Megalitres (Thousand Cubic Metres)
3) Acre-feet

Once this selection has been made in the instructions sheet, all calculations are made on the basis of the chosen units. Should the user wish to make additional conversions, a unit converter is provided below (use drop down menus to select units from the yellow unit boxes):

<table>
<thead>
<tr>
<th>Enter Units:</th>
<th>Convert From...</th>
<th>Converts to...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Million Gallons (US)</td>
<td>1 Million Gallons (US)</td>
</tr>
</tbody>
</table>

(conversion factor = 1)
Appendix - D

Water Audit Reporting Worksheets and Water Balances

Figure (D.1): Water Audit Reporting Worksheet for Year 2010
Figure (D.2): Water Audit Reporting Worksheet for Year 2011
Figure (D.3): Water Audit Reporting Worksheet for Year 2010
Figure (D.4): Water Audit Reporting Worksheet for Year 2011
### Figure (D.5): Water Balance for Al Seeb Wilayat (Year 2010)

<table>
<thead>
<tr>
<th>Category</th>
<th>Quantity</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Exported</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>Own Sources</td>
<td>14,891.100</td>
<td>Authorized Consumption 8,128.039</td>
</tr>
<tr>
<td>Water Supplied</td>
<td>14,891.100</td>
<td>Unauthorized Consumption 7,941.900</td>
</tr>
<tr>
<td>Water Imported</td>
<td>0.000</td>
<td>Real losses 3,727.354</td>
</tr>
<tr>
<td>Water Losses</td>
<td>6,783.061</td>
<td>Unauthorized Consumption 3,035.707</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Customer Metering Inaccuracies 162.080</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Systematic Data Handling Errors 2,856.400</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leakage on Transmission and/or Distribution Mains Not broken down</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leakage and Overflows at Utility’s Storage Tanks Not broken down</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leakage on Service Connections Not broken down</td>
</tr>
<tr>
<td>Billed Water Exported</td>
<td>7,941.900</td>
<td>Revenue Water 7,941.900</td>
</tr>
<tr>
<td>Billed Authorized Consumption</td>
<td>8,128.039</td>
<td>Billed Unmetered Consumption 0.000</td>
</tr>
<tr>
<td>Billed Unauthorized Consumption</td>
<td>7,941.900</td>
<td>Billed Unmetered Consumption 0.000</td>
</tr>
<tr>
<td>Unbilled Authorized Consumption</td>
<td>186.139</td>
<td>Unbilled Unauthorized Consumption 0.000</td>
</tr>
<tr>
<td>Unbilled Unauthorized Consumption</td>
<td>186.139</td>
<td>Unbilled Unauthorized Consumption 0.000</td>
</tr>
</tbody>
</table>

### Figure (D.6): Water Balance for Al Seeb Wilayat (Year 2011)

<table>
<thead>
<tr>
<th>Category</th>
<th>Quantity</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Exported</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>Own Sources</td>
<td>15,265.151</td>
<td>Authorized Consumption 8,663.314</td>
</tr>
<tr>
<td>Water Supplied</td>
<td>15,265.151</td>
<td>Unauthorized Consumption 8,472.500</td>
</tr>
<tr>
<td>Water Imported</td>
<td>0.000</td>
<td>Real losses 3,615.266</td>
</tr>
<tr>
<td>Water Losses</td>
<td>6,601.837</td>
<td>Apparent Losses 2,986.571</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Customer Metering Inaccuracies 172.908</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Systematic Data Handling Errors 2,775.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leakage on Transmission and/or Distribution Mains Not broken down</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leakage and Overflows at Utility’s Storage Tanks Not broken down</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leakage on Service Connections Not broken down</td>
</tr>
<tr>
<td>Billed Water Exported</td>
<td>8,472.500</td>
<td>Revenue Water 8,472.500</td>
</tr>
<tr>
<td>Billed Authorized Consumption</td>
<td>8,663.314</td>
<td>Billed Unmetered Consumption 0.000</td>
</tr>
<tr>
<td>Billed Unauthorized Consumption</td>
<td>8,472.500</td>
<td>Billed Unmetered Consumption 0.000</td>
</tr>
<tr>
<td>Unbilled Authorized Consumption</td>
<td>190.814</td>
<td>Unbilled Unauthorized Consumption 0.000</td>
</tr>
<tr>
<td>Unbilled Unauthorized Consumption</td>
<td>190.814</td>
<td>Unbilled Unauthorized Consumption 0.000</td>
</tr>
</tbody>
</table>
**Figure (D.7): Water Balance for Al Seeb Wilayat (Year 2012)**

<table>
<thead>
<tr>
<th>Water Exported</th>
<th>Billed Water Exported</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>Billed Authorized Consumption 10,532.400</td>
</tr>
<tr>
<td></td>
<td>Billed Metersed Consumption (incl. water exported) 10,532.400</td>
</tr>
<tr>
<td></td>
<td>Billed Unmetered Consumption 0.000</td>
</tr>
<tr>
<td></td>
<td>Unbilled Authorized Consumption 0.000</td>
</tr>
<tr>
<td></td>
<td>Unbilled Metersed Consumption 0.000</td>
</tr>
<tr>
<td></td>
<td>Unbilled Unmetered Consumption 228.202</td>
</tr>
<tr>
<td></td>
<td>Revenue Water 10,532.400</td>
</tr>
<tr>
<td></td>
<td>Non-Revenue Water (xSW) 0.000</td>
</tr>
</tbody>
</table>

- **Own Sources** (Adjusted for known errors): 18,256.160
- **Water Supplied**: 18,256.160
- **Water Losses**: 7,495.588
- **Real losses**: 4,162.271
- **Apparent losses**: 3,332.587
- **Leakage on Transmission and/or Distribution Mains**: Not broken down
- **Leakage and Overflows at Utility’s Storage Tanks**: Not broken down
- **Leakage on Service Connections**: Not broken down

**Figure (D.8): Water Balance for Al Seeb Wilayat (Year 2013)**

<table>
<thead>
<tr>
<th>Water Exported</th>
<th>Billed Water Exported</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>Billed Authorized Consumption 11,752.300</td>
</tr>
<tr>
<td></td>
<td>Billed Metersed Consumption (incl. water exported) 11,752.300</td>
</tr>
<tr>
<td></td>
<td>Billed Unmetered Consumption 0.000</td>
</tr>
<tr>
<td></td>
<td>Unbilled Authorized Consumption 0.000</td>
</tr>
<tr>
<td></td>
<td>Unbilled Metersed Consumption 0.000</td>
</tr>
<tr>
<td></td>
<td>Unbilled Unmetered Consumption 235.045</td>
</tr>
<tr>
<td></td>
<td>Revenue Water 11,752.300</td>
</tr>
<tr>
<td></td>
<td>Non-Revenue Water (xSW) 7,051.300</td>
</tr>
</tbody>
</table>

- **Own Sources** (Adjusted for known errors): 18,803.600
- **Water Supplied**: 18,803.600
- **Water Losses**: 6,816.255
- **Real losses**: 3,238.803
- **Apparent losses**: 3,577.452
- **Leakage on Transmission and/or Distribution Mains**: Not broken down
- **Leakage and Overflows at Utility’s Storage Tanks**: Not broken down
- **Leakage on Service Connections**: Not broken down
Table (D.1): Water Balance for Al Seeb Water Supply System for Year 2010

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water Exported</strong></td>
<td>Billed Water Exported</td>
<td>Revenue Water</td>
</tr>
<tr>
<td>0.00</td>
<td>(0%)</td>
<td>(53.3%)</td>
</tr>
<tr>
<td><strong>Own Sources</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Adjusted for known errors)</td>
<td>Billed Authorized Consumption</td>
<td>(53.3%)</td>
</tr>
<tr>
<td>93.7%</td>
<td>Billed Unmetered Consumption</td>
<td>(0%)</td>
</tr>
<tr>
<td><strong>Water Supplied</strong></td>
<td>Unbilled Authorized Consumption</td>
<td>(1.3%)</td>
</tr>
<tr>
<td>100%</td>
<td>Unbilled Metered Consumption</td>
<td>(0%)</td>
</tr>
<tr>
<td><strong>Water Losses</strong></td>
<td>Unbilled Unmetered Consumption</td>
<td>(1.3%)</td>
</tr>
<tr>
<td>(45.4%)</td>
<td></td>
<td>Non-Revenue Water (NRW)</td>
</tr>
<tr>
<td><strong>Water Imported</strong></td>
<td>Apparent Losses</td>
<td>(20.4%)</td>
</tr>
<tr>
<td>8.3%</td>
<td>Unauthorized Consumption</td>
<td>(0.3%)</td>
</tr>
<tr>
<td></td>
<td>Customer Metering Inaccuracies</td>
<td>(1.1%)</td>
</tr>
<tr>
<td></td>
<td>Systematic Data Handling Errors</td>
<td>(10.0%)</td>
</tr>
<tr>
<td></td>
<td>Real Losses</td>
<td>(25.0%)</td>
</tr>
<tr>
<td></td>
<td>Leakage on Transmission and/or Distribution mains</td>
<td>Not broken down</td>
</tr>
<tr>
<td></td>
<td>Leakage and Overflow at Utility’s Storage Tank</td>
<td>Not broken down</td>
</tr>
<tr>
<td></td>
<td>Leakage on Service Connections</td>
<td>Not broken down</td>
</tr>
<tr>
<td>Own Sources (Adjusted for known errors)</td>
<td>87.9%</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>Water Supplied</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Water Exported</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Billed Water Exported</td>
<td>(0%)</td>
<td></td>
</tr>
</tbody>
</table>

| Authorized Consumption                  | (58.8%) |

| Billed Authorized Consumption           | (55.5%) |
| Billed Unmetered Consumption            | (5%)    |
| Unauthorized Consumption                | (13%)   |
| Unbilled Metered Consumption            | (0%)    |
| Unbilled Unmetered Consumption          | (1.3%)  |
| Unauthorized Consumption                | (0.3%)  |
| Apparent Losses                        | (19.6%) |
| Non-Revenue Water (NRW)                 | (44.5%) |
| Customer Metering Inaccuracies          | (1.1%)  |
| Systematic Data Handling Errors         | (10.2%) |

| Real Losses                             | (23.8%) |

Leakage on Transmission and/or Distribution mains: Not broken down
Leakage and Overflow at Utility’s Storage Tank: Not broken down
Leakage on Service Connections: Not broken down
Table (D.3): Water Balance for Al Seeb Water Supply System for Year 2012

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Exported</td>
<td>Billed Water Exported</td>
<td></td>
</tr>
<tr>
<td>0.00</td>
<td>(0%)</td>
<td></td>
</tr>
<tr>
<td>Own Sources</td>
<td>Billed Authorized Consumption</td>
<td>Billed Metered Consumption</td>
</tr>
<tr>
<td>(Adjusted for known errors)</td>
<td>(57.7%)</td>
<td>(57.7%)</td>
</tr>
<tr>
<td>(100%)</td>
<td>Billed Unmetered Consumption</td>
<td></td>
</tr>
<tr>
<td>Water Supplied</td>
<td>(0%)</td>
<td></td>
</tr>
<tr>
<td>(100%)</td>
<td>Unbilled Metered Consumption</td>
<td></td>
</tr>
<tr>
<td>(1.2%)</td>
<td>Unbilled Unmetered Consumption</td>
<td></td>
</tr>
<tr>
<td>Water Losses</td>
<td>Apparent Losses</td>
<td></td>
</tr>
<tr>
<td>(18.2%)</td>
<td>Unauthorized Consumption</td>
<td></td>
</tr>
<tr>
<td>(41.1%)</td>
<td>(0.2%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Customer Metering Inaccuracies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.2%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Systematic Data Handling Errors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(16.8%)</td>
<td></td>
</tr>
<tr>
<td>Real Losses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(22.9%)</td>
<td>Leakage on Transmission and/or Distribution mains</td>
<td>Not broken down</td>
</tr>
<tr>
<td></td>
<td>Leakage and Overflow at Utility’s Storage Tank</td>
<td>Not broken down</td>
</tr>
<tr>
<td></td>
<td>Leakage on Service Connections</td>
<td>Not broken down</td>
</tr>
<tr>
<td>Non-Revenue Water (NRW)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(42.3%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Water Supplied (100%)
### Table (D.4): Water Balance for Al Seeb Water Supply System for Year 2013

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
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</thead>
<tbody>
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<td>Own Sources</td>
<td>Water Exported: 0.00</td>
<td>Billed Water Exported: 0%</td>
<td></td>
</tr>
<tr>
<td>(Adjusted for known errors)</td>
<td>Authorized Consumption: (03.6%)</td>
<td>Billed Authorized Consumption: (82.5%)</td>
<td>Billed Metered Consumption: (82.5%)</td>
</tr>
<tr>
<td></td>
<td>(100%)</td>
<td>Unbilled Authorized Consumption: (1.3%)</td>
<td>Billed Unmetered Consumption: (0%)</td>
</tr>
<tr>
<td></td>
<td>Water Supplied: (100%)</td>
<td>Unbilled Metered Consumption: (0%)</td>
<td>Revenue Water: (02.6%)</td>
</tr>
<tr>
<td></td>
<td>Water Losses: (30.2%)</td>
<td>Unbilled Unmetered Consumption: (1.3%)</td>
<td>Non-Revenue Water (NRW): (37.5%)</td>
</tr>
<tr>
<td></td>
<td>Water Imports: (3%)</td>
<td>Unauthorized Consumption: (0.2%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Customer Metering Inaccuracies: (1.3%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Systematic Data Handling Errors: (17.5%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Real Losses: (17.2%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leakage on Transmission and/or Distribution mains: Not broken down</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leakage and Overflow at Utility’s Storage Tank: Not broken down</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leakage on Service Connections: Not broken down</td>
<td></td>
</tr>
</tbody>
</table>
TRC-FURAP

Faculty Mentored Undergraduate Research Award Program

A PROJECT REPORT ON

Automatic daily activity management system for the elderly

By

Abeer Nasser Hamood AL-Siyabi, 11f7792

Team member - Al-anood Abdullah Ahmed Al-alawi, 12f9636

Mentored by

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Knowledge Oasis Muscat, Muscat, Oman

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ABSTRACT

At present, the percentage of the old person who are no longer able to do the work has increased. They are unable to serve themselves, and need someone to help them and be next to them always. There are around 700 elderly people in Muscat who need care. This project is one to address this problem is Automatic daily activity management system for the elderly. The aim of this project is to provide a solution to the inconvenience faced by elderly people when they are sick and physically not strong enough to walk by themselves to carry out some of the daily activities. It provides convenience for the near and dear ones of the elderly, and at the same time it makes the life of elderly less miserable. There by reducing the number of the elderly in nursing home.

In this system, there is a remote control to select things which are in need. This remote has two switches. When the elderly person press 1, the stepper motor corresponding to tray 1 (the tooth brush and cup of water) is activated. The corresponding arm containing the materials, load sensors move to its position near the elderly person. This sensor is used to measure weight of material. If weight is less than a threshold, the sensor will be send SMS to the person responsible for the elderly person and to keep the thing back if same button is pressed. Similar steps are followed for thing other things. By just pressing the remote control, the material automatically comes and goes back. When the elderly have to take medicine at a certain time, for medicine tray – the timings for taking medicine can be programmed in the unit. When the programmed time is reached the tray moves by itself. No user intervention is required for this action. If medicine were not taken before a specified time, an alarm is generated. Again if medicine is not taken after second phase of time, SMS is sent to the concerned phone number.
1. INTRODUCTION

The purpose of this project is to care for a large number of elderly people in homes or hospitals every day and not to have a caregiver present all the time. In this chapter the background of the project, project goals, project limitations and overview of the project report are discussed.

1.1 Background of the Project

At present, the percentage of seniors who are no longer able to do the work has increased. They are unable to serve themselves, and need someone to help them and be next to them always. They become more sensitive and do not feel happy without someone around them. They need help from another person for their daily activities. Some of the common activities everyone needs in such situations are: brushing of teeth, going to wash room, taking medicines at the correct time as instructed by doctors and taking food. It may be difficult to find someone always near to the elder people.

Many institutions have started looking into this problem to help the elderly to do their activities daily; this project is one to address this problem.

This project aims to create a system to care for a large number of elderly people in homes or hospitals every day so that they do not need to have a caregiver present with them all the time. The project has the following goals.

1- The project provides a solution to the inconvenience faced by elderly people when they are sick and physically not strong enough to walk by themselves to carry out some of the daily activities.

2- It provides convenience for the near and dear ones of the elderly, and at the same time it makes the life of elderly less miserable.

3- Reducing the number of the elderly in nursing home.

4- Easy to use and inexpensive.
1.2 Project Objectives

1- A remote control for the elderly person to reach their things easily.

2- The system will automatically send a short message to the person responsible when the elderly need assistance for a particular purpose.

3- A timer for the things that have to be taken at a certain time.

4- Stepper motor controlled arm for foods, medicine with water and toothbrush to move this thing near the elderly.

1.3 Project Limitations

Load sensor measures the different weight (200g 1k 2k 5k) of the materials which are used so they should have a specific weight. If the material in the cans is more than (200g 1k 2k 5k) the sensor cannot work. In addition, the stepper motor for medicine when is working automatically is occurring to hamper other motor to rotation. Firstly wait the motor medicine to finish the operation then other motors can work.
2. SYSTEM TESTING

After the completion of the simulation of the project in ISIS program, the electronic tools are connected in the breadboard. The outputs are successfully obtained as shown in figure 2.1.

![Final connection in breadboard](image)

**Case 1:** Using Arduino uno, four switches (ON1, OFF1, ON1, OFF1) are used to control two stepper motors in two directions at 90° angle and NRF401 is used to transfer the signal. This part is for transmitter which is called remote control. First the circuit is connected in the breadboard, then the code is checked in Arduino programs to see if it is working or not, by pressing serial monitor in the program. When the button is pressed, the screen for the serial monitor shows the name of the switches 1, 2, 3 or 4 whichever is pressed. This mean the codes are correct as shown in figure 2.3.

![Check the code from serial monitor (remote control)](image)
Case 2: The two motors are connected with the help of the driver which has 12 voltages in Arduino MEGA component. When button ON1 is pressed, the signal will transfer from a transmitter to a receiver is pressed by using NRF401. As a result the motor will rotate around $90^\circ$ angle and when OFF1 is pressed, the motor will return back. The two stepper motors with load sensors are connected to measure the weight of the material. If the material is less than half a kilo the load sensor will send SMS for the person responsible for the elderly person, to mobilize the material again as shown in figure 2.4.

![Figure 2.4: Two motors with two load sensors](image)

Case 3: One motor is connected with RTC, IR sensor, GSM, and LCD. The LCD shows to shown the day and data. In this part the stepper motor moves automatically by setting the timer for code as shown in figure 2.5.

![Figure 2.5: Motor which is rotate automatically](image)
When the stepper motor is rotated around 90° angle, it waits 3 minutes, and then returns back. The sensor checks if the elderly person has taken the medicine or not. If not taken after 8 seconds, the buzzer will be ON to alarm the elderly person to take the medicine. After that when time for taking the medicine is over, the stepper motor returns back and sends an SMS to the person responsible for the elderly person, as shown in figure 2.6.

![Figure 2.6: Rotate the stepper motor and sensor check if elderly take drag or not](image)

However, if the sensor has checked, that the elderly person has taken the medicine in time or not, the motor will return back as shown in figure 2.7.

![Figure 2.7: The sensor check if there medicine or not](image)

After finishing the connection in the breadboard, the remote control in PCB is soldered and designed as shown in figure 2.8. Then, the Arduino MEGA is designed with two motors and two load sensors as shown in figure 2.9. In addition, the motor which is moving automatically
with IR sensor is designed to detect if the elderly person has taken medicine or not as shown in figure 2.10.

Figure 2.8: Solder the remote control in PCB

Figure 2.9: Design Arduino MEGA

Figure 2.10: Design motor which is rotate automatically
A PROJECT REPORT
ON
POWER MANAGEMENT SYSTEM BASED ON
PREDEFINED SCHEDULE USING CONTROL APP.

By
Ghadeer Saif Saaiyad AL-Rahbi, 11f7600

Guided by
Dr. Anilloy Frank

Knowledge Oasis Muscat, Muscat, Oman

The Research Council, Oman

August, 2017
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My appreciation to the head and faculty members of the department of Electronics & Communication Engineering for supplying different workshops to develop our work.

The warmest thank for my project supervisor Dr. Anilloy Frank, who guidance my work from the beginning to the final step of the project.

Also my thanks go to academic writing unit for providing various workshops that contain different parts to improve ways of writing the report.

The sense of gratitude to my family for help over doing this project.
ABSTRACT

In large organizations devices operating on electrical energy are manually switched and remain ON throughout the day. Most venues are seldom used or used according to predefined schedule. When the energy devices remain ON, even when the venue is not being used, a lot of energy is wasted. The proposed approach suggests development of automatic ON or OFF switching devices to avoid wasting energy for each venue depending on the time table.

The proposed project intends to conserve energy consumption by optimizing scheduling of load to optimize utilization. Considering the importance given to energy conservation by the Sultanate of Oman, to save energy, a study on the present prevailing system has been carried out. The results of this study provide an insight to the energy consumed in a sample venue. The project approach has significant improvement to save energy.

In order to overcome the energy wasted over manually switching, this project is designed to load devices according to using time by android application. The android application has been designed to gather all essential timetable details of each room. Which connected directly with microcontroller through Wi-Fi communication. According to received data, the signal which received by microcontroller may include either high voltage or low voltage. The microcontroller detects the voltage and based on the data which received from android application, its activates the relay driver to switch particular relay.
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CHAPTER 1

INTRODUCTION

This chapter describes the background of the project, project objectives, project limitations and overview of the project report. The proposed idea intends to conserve energy at consumption by optimizing scheduling of load to optimize utilization.

1.1 Background of the Project

Theme of energy conservation is an important part in the plans and strategies of any country. In the Sultanate of Oman, demand for electric power has been fast rising due to rapid economic and population growth as we observe in recent times. Rationalization of energy use and work on energy conservation projects is itself a way to a reduction of the consumed energy. In most of the organizations where the normal switching is used, the electrical energy remains ON throughout the day, therefore there is a high possibility of energy being wasted. Energy conservation is directly linked with growth of communities. It is necessary for the economic development of the country. There are many functions totally dependent on energy, and they directly stop when the supply of energy stops. Therefore, it is our responsibility to create a system to save energy.

The idea of this project comes from the rising of using electric power. In large organizations devices operating on electric energy are switch on manual, which is does not has the ability to manage work of the energy devices. Nowadays the mobile applications designed to run on smartphones. As we know smartphones is the useful technique, which will change radically of how provide the services. This project use a mobile application to control the energy devices of each venue based on predefined time table. It is a useful technique for all organizations to energy conservation.

Under above conditions to avoid wastage of energy due to manually switching, this project reduce wastage by scheduling energy devices for each venue depending on the time table. Power management system based on predefined schedule using control
The app aims to cut the electrical consumption and to improving organizations efficiency in the using of electric power. As shown in Figure 1.1, to optimize consumption of energy, control app is developed which will read the time table of each venue. It provides signals to control devices for turning the devices ON or OFF. The control device receives the signals from the control app and appropriately switches ON or OFF through relay, thereby optimizing energy usage. Wi-Fi communication is used to communicate between control device and control app.

![Figure 1.1 Block diagram of proposed idea.](image-url)

### 1.1.1 Sample energy consumption and saving of a venue at MEC.

The sample consumption for venue at MEC is summarized in Table 1.1 and Table 1.2. The energy requirement of the venue is tabulated in Table 1.1. In normal conditions the total consumption is tabulated in Table 1.2. Using the project approach the saving of energy is tabulated in Table 1.3.
Table 1.1 Energy requirement for a venue.

<table>
<thead>
<tr>
<th>Electrical Appliance</th>
<th>Power per unit</th>
<th>Quantity</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamps</td>
<td>26W/1000</td>
<td>9 x 4</td>
<td>0.936 kW</td>
</tr>
<tr>
<td>AC</td>
<td>1000W/1000</td>
<td>2</td>
<td>2 kW</td>
</tr>
<tr>
<td>Projector</td>
<td>225W/1000</td>
<td>1</td>
<td>0.225 kW</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>3.161 kW/h</strong></td>
</tr>
</tbody>
</table>

Table 1.2 Normal energy consumption without scheduling from 7am to 9pm.

<table>
<thead>
<tr>
<th></th>
<th>Hours/day</th>
<th>Hours/year</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working days (5day)</td>
<td>14 h</td>
<td>3640 h</td>
<td>11506.04 kW</td>
</tr>
<tr>
<td>Nonworking days (2 day)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 1.3 Energy consumption with scheduling.

<table>
<thead>
<tr>
<th>Working Days</th>
<th>Hours/Day</th>
<th>Hours/Year</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunday</td>
<td>14 h</td>
<td>728 h</td>
<td>2301.208 kW</td>
</tr>
<tr>
<td>Monday</td>
<td>5 h</td>
<td>260 h</td>
<td>821.86 kW</td>
</tr>
<tr>
<td>Tuesday</td>
<td>9 h</td>
<td>468 h</td>
<td>1479.348 kW</td>
</tr>
<tr>
<td>Wednesday</td>
<td>8 h</td>
<td>416 h</td>
<td>1314.976 kW</td>
</tr>
<tr>
<td>Thursday</td>
<td>8 h</td>
<td>416 h</td>
<td>1314.976 kW</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>7232.368 kW</strong></td>
</tr>
</tbody>
</table>
The total consumption without scheduling is 11506.04 kW

The total consumption with scheduling is 7232.368 kW

The net energy saving is 11506.04 - 7232.368 = 4273.672 kW

The consumption is reduced by 42.7% resulting in energy saved.

1.2 Project Objectives

The specific objectives of this project are:

• Developing energy devices scheduling control based on predefined time table.

In organizations, usually each venue has a time table. The switching of devices in a venue can be optimized based on the time table.

• Configuring the schedules.

Developing an automatic mechanism that configures device switching ON or OFF based on schedules.

• Controlling includes switching ON or OFF.

Programming the control device to turn devices ON or OFF.

• Communication between microcontroller and app using Wi-Fi.
• Developing a control app for scheduling.
1.3 Project Limitations

Limitations of this project are mentioned below:

- Range of Wi-Fi connectivity.
- System behavior can be abnormal due to de-sync between control app and control devices.
- This project control only specific venues which are mentioned in control app.
- The pic microcontroller which is used is 8bit which cannot open operating system.

1.4 Overview of the Project Report

This project consists of six chapters. Each chapter explain in details the requirements of the project. Chapter one (Introduction) describes the Background, Objectives and Limitations of this project. Chapter two (Methodology) discusses the methodical of designed the project. Chapter three (Literature review) reviews some projects which cover similar problems. Chapter four (The budgeting and project management) describes the Estimation the project budget, Project schedule and Risk management.

Chapter five (Design and analysis) contains the System block diagram, System flowchart and Technical Requirements (Hardware components and software) used in this project. Chapter six consist of Simulation, Testing and Implementation of all unit in this project.

Chapter seven about Critical Evaluation. Chapter eight consist of (Legal, Social and Ethical aspects related to the project). Chapter nine discuses conclusion and recommendation.
CHAPTER 2

METHODOLOGY

This chapter discusses methodology of the project. There are various methodologies available such as the Waterfall model, V-model, Incremental model, RAD model, Agile model, Iterative model and Spiral model. The methodology followed for the development of this project is the V-model methodology as shown in Figure 2.1 (Software Testing Class 2016).

![Figure 2.1 The V-model methodology (Software Testing Class 2016)]
In the project requirement, the requirements of the proposed idea for this project are determined. Finding features, objectives and block diagram of this project. Collecting data sheet of components. Both software and hardware requirements are formulated including for microcontroller, relay, RTC, Wi-Fi module and software design for microcontroller and for control app.

In the system design, from the uses of the project requirements the block diagram, functional details and all experts of the system are considered. Focuses on design and analyze of the system.

In the module design, the system is subdivided into functional modules, each of them is designed separately. It includes the design of power supply, ESP8266 Wi-Fi module and software design for microcontroller and control app.

The implementation includes development of the prototype of the system.

In the unit testing, each module is tested and verified.

In the integration testing, the modules are connected together and tested for compatibility.

In the validation, the system is tested for meeting the objectives.
CHAPTER 3

LITERATURE REVIEW/THEORY

This chapter discusses past papers and projects that cover similar solutions.

3.1 Scheduled Virtual Machine Shutdown/Startup - Microsoft Azure.

(Stahl 2016) in his project proposes to configure automated power schedule for shutting down and starting the VMs as shown in Figure 3.1. The automation scheduled startup and shutdown of Azure virtual machines allows to implement multiple granular power schedules for virtual machines, by using simple tag metadata in the Azure. This tag is used to define shutdown schedules (Stahl 2016).

The time range is a two times of the day or absolute dates, that define a period of time when VMs should be shut down. In (Stahl 2016) project, external devices are not controlled. The schedule is not flexible and does not handle variable time schedule during the day or different days of the week. It does not also have an option to control the schedule through control app. In (Stahl 2016) project, there is no possibility to run the shutdown and startup for several VMs at the same time.
3.2 Controlling Appliances using Bluetooth from Mobile Phones

(Bhonwal 2012) in his project proposes to control any home appliance from the PC or a mobile using Bluetooth. As shown in Figure 3.2, the application will connect to a device. The Bluetooth module in the device will receive and send the data received to an AVR microcontroller which controls a relay (Bhonwal 2012).

This project only control the devices which are in the room. It does not communicate with Wi-Fi. As (Bhonwal 2012) project uses Bluetooth, the range of controlling devices is limited.
3.3 Power management for shopping mall with bidirectional visitors counting.

(Pulakala 2016) in his paper project, refers to provide a method for automatic control of devices such as lights, fans, AC and other device in a shopping mall. As shown in Figure 3.3, by using a microcontroller which used to carry out the task of controlling the room lights as well as for counting the number of visitors in the room. When somebody enters into the room then the counter is incremented by one and the light in the room will be switched ON and when any one leaves the room then the counter is decremented by one. The light will switch OFF only after all the persons in the leave (Pulakala 2016).
(Pulakala 2016) project, is based on power management by switching the devices ON and OFF. Therefore, it saves power consumption. It does not work for wireless. The sensors used also increase the cost of the project.

![Block diagram of power management for shopping mall with bidirectional visitors counting](image)

**Figure 5.3** Block diagram of power management for shopping mall with bidirectional visitors counting (Pulakala 2016)
CHAPTER 4

BUDGETING AND PROJECT MANAGEMENT

This chapter describes the project budget, project schedule, and risk management.

4.1 Project Budget

The below Table 4.1, clarify the cost of project. That to control project costs within the approved budget and meeting the project objective.

Table 4.1 Summary of project budget.

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Item Description</th>
<th>Category</th>
<th>Justification</th>
<th>Estimated Cost (In OMR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Microcontroller, Programmer, Components</td>
<td>Equipment</td>
<td>Components required to develop the prototype</td>
<td>342</td>
</tr>
<tr>
<td>2</td>
<td>Microcontroller, Programming, Simulation, App development software</td>
<td>Software</td>
<td>Software licenses for development of Micro-controller Program, simulation, and app development</td>
<td>370</td>
</tr>
<tr>
<td>3</td>
<td>IEEE access subscription</td>
<td>Purchasing of Literature</td>
<td>For literature review</td>
<td>100</td>
</tr>
</tbody>
</table>

Total Budget : 812 OMR
4.2 Project Schedule

The below Table 4.2 provide information on how the distribution of the project management plan was controlled and followed.

Table 5.2 Project Schedule.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Sep-16</th>
<th>Oct-16</th>
<th>Nov-16</th>
<th>Jan-17</th>
<th>Feb-17</th>
<th>Mar-17</th>
<th>Apr-17</th>
<th>May-17</th>
<th>Jun-17</th>
<th>Jul-17</th>
<th>Aug-17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part-1: Project Planning and System Design</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Searching for title</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deciding of the objectives</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description and block diagram</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methodology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Literature review</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Theoretical (designing &amp; analysis)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulation hardware</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepare planning report and presentation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Submit planning report and presentation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part-2: System Implementation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Software development</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Co-Simulation (hardware &amp; Software)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prototype implementation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Testing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Validation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final report</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.3 Risk Management

Table 4.3 show the risks that are faced in the project and that have an impact on project objectives. The risk categories are Management Risks, Technology Risks, Resource Risks, Timing Risks and External Risks (John 2015).
Table 6.3 Identification of risks.

<table>
<thead>
<tr>
<th>Risk Identification</th>
<th>Define the risk</th>
<th>Mitigation</th>
</tr>
</thead>
</table>
| **Timing Risks**    | - Take more time to finish some work. | To avoid this risk,  
- Setting a clear timetable of the work according to plan.  
- Giving enough time for each work. |
| **External Risks**  | - Events and holidays retard the achievement of the work on time. | To avoid this risk,  
- Compensation for the day’s work on holidays. |
| **Resource Risks**  | - Lack of skill, software licenses and non-availability of components are effect on the working of the project and it loses time. | To avoid this risk,  
- Search for people who have more knowledge on software design and for alternative components. |
CHAPTER 5

DESIGN AND ANALYSIS

This chapter provide system initial design, technical requirements, schematic diagram and system design & analysis.

5.1 System Initial Design

This part consist of system block diagram and system flow chart.

5.1.1 System Block Diagram

The representation of all major functionality system components and interfaces between subsystems is shown in Figure 5.1.
5.1.2 System Flow chart

The system flow chart is shown in Figure 5.2, which represent the flow of data through an information processing systems, the operations performed within the system and the sequence in which they are performed to get the solution of a problem.

![Diagram of System Flow Chart](https://via.placeholder.com/150)
5.2 Technical Requirements

This part includes a description of hardware and software components.

5.2.1 Hardware Components

This part discusses in detail the major components used in this project with their technical hardware components.

1. Microcontroller PIC16F887

PIC16F887 is basically a small chip that works as a computer. It is designed to provide high or low signals to relay driver and control the switching devices. The pin diagram of PIC16F887 microcontroller is shown in Figure 5.3. The maximum voltage of this chip is 5.5 V and more details are shown in Table 5.1.

![Figure 5.8 Pin diagram of PIC16F887 (Technology 2016)](image-url)
2. Relay Driver

ULN2003A is one of popular really driver circuits used to provide isolation between high voltage and low voltage circuit. ULN2003 can derive up to seven relay at same time. Relays are mostly used for interfacing with microcontroller and digital system (Malik 2015). In this project ULN2003A relay driver interfaced with microcontroller to derive relays according to signal which microcontroller is received form control app. Figure 5.4 show the pin diagram of ULN2003A relay driver. This IC can used up to 5V for high voltage application.
Referring to the datasheet, the details of relay driver ULN2003A is shown in Table 5.2.

Figure 5.9 Pin diagram of relay driver ULN2003A (CircuitsToday 2015)

Table 5.8 Details of ULN2003A relay driver (Alldatasheet 2016)

<table>
<thead>
<tr>
<th>Pin Count</th>
<th>16 Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Voltage</td>
<td>50 V</td>
</tr>
<tr>
<td>Input Voltage</td>
<td>30 V</td>
</tr>
<tr>
<td>Continuous Collector Current</td>
<td>500 mA</td>
</tr>
<tr>
<td>Continuous Base Current</td>
<td>25 mA</td>
</tr>
<tr>
<td>Operating Ambient Temperature Range</td>
<td>−20 to 85 °C</td>
</tr>
<tr>
<td>Type Of Transistor</td>
<td>NPN Type</td>
</tr>
<tr>
<td>No. Elements of each chip</td>
<td>7 Element</td>
</tr>
</tbody>
</table>
3. Relay

As shown in Figure 5.5, a solid state relay is used in this project. It is an electric switching device which switches either ON or OFF depending on the applied voltage across its control terminals. This type of relay can switch current loads up to 40 A with input voltage 3 – 32 V DC. Table 5.3 indicates the datasheet of solid state relay.

Figure 10.5 Solid State Relay (Electronics n.d.)
Table 5.9 Specification of solid state relay (Electronics n.d.)

<table>
<thead>
<tr>
<th>Type</th>
<th>Terminal Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SSR-50DA</td>
</tr>
<tr>
<td>Model</td>
<td></td>
</tr>
<tr>
<td>Rated Load Current</td>
<td>50A</td>
</tr>
</tbody>
</table>

Input Data

<table>
<thead>
<tr>
<th></th>
<th>SSR-50DA</th>
<th>SSR-75DA</th>
<th>SSR-50DA-H</th>
<th>SSR-75DA-H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Voltage</td>
<td>3~32VDC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min. ON / OFF Voltage</td>
<td>ON&gt;2.4V, OFF&lt;1.0V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trigger Current</td>
<td>7.5mA / 12V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Method</td>
<td>Zero Cross Trigger</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Operating Data

<table>
<thead>
<tr>
<th></th>
<th>SSR-50DA</th>
<th>SSR-75DA</th>
<th>SSR-50DA-H</th>
<th>SSR-75DA-H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Voltage</td>
<td>24~380VAC</td>
<td>90~480VAC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min. Blocking Voltage</td>
<td>600 VAC&lt;Repetitive&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage Drop</td>
<td>1.6V / 25°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. Duration Current</td>
<td>650A</td>
<td>920A</td>
<td>650A</td>
<td>920A</td>
</tr>
<tr>
<td>Leakage Current Max.</td>
<td>6.0mA</td>
<td>6.0mA</td>
<td>6.0mA</td>
<td>6.0mA</td>
</tr>
<tr>
<td>Response Time</td>
<td>ON&lt;10ms, OFF&lt;10ms</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

General Data

<table>
<thead>
<tr>
<th></th>
<th>SSR-50DA</th>
<th>SSR-75DA</th>
<th>SSR-50DA-H</th>
<th>SSR-75DA-H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric Strength</td>
<td>Over 2.5KVAC/1min.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isolation Strength</td>
<td>Over 50M Ω / 500VDC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>-20°C ~ +80°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Housing Material</td>
<td>Intensive ABS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>Appr. 125g</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4. ESP8266

Espressif Systems Smart Connectivity Platform (ESCP) is a small amazing module easy to learn and use too. It is self-contained system on chip SOC and it support UART communication. The block diagram of this module is shown in Figure 5.6. ESP8266 is powered up with 3.3V. The current consumption of this module is 80mA at idle stat and it can draw as much as 300mA during operation. The details of ESP8266 is shown in Table 5.4.

![ESP8266 Wi-Fi module](image)

Figure 11.6 ESP8266 Wi-Fi module (Team 2015)
Table 5.10 details of esp8266 Wi-Fi module (Team 2015)

<table>
<thead>
<tr>
<th>Categories</th>
<th>Items</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wi-Fi Parameter</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Certificates</td>
<td></td>
<td>FCC/CE/TELEC/SRRC</td>
</tr>
<tr>
<td>Wi-Fi Protocols</td>
<td></td>
<td>802.11 b/g/n</td>
</tr>
<tr>
<td>Frequency Range</td>
<td></td>
<td>2.4G-5.5G (2400M-2483.5M)</td>
</tr>
<tr>
<td>Tx Power</td>
<td></td>
<td>802.11 b: +20 dBm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>802.11 g: +17 dBm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>802.11 n: +14 dBm</td>
</tr>
<tr>
<td>Rx Sensitivity</td>
<td></td>
<td>802.11 b: -91 dBm (11Mbps)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>802.11 g: -75 dBm (54 Mbps)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>802.11 n: -72 dBm (MCS7)</td>
</tr>
<tr>
<td>Types of Antenna</td>
<td></td>
<td>PCB Trace, External, IPEX</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Connector, Ceramic Chip</td>
</tr>
<tr>
<td>Peripheral Bus</td>
<td></td>
<td>UART/SDIO/SP1/2C/2S/IR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remote Control</td>
</tr>
<tr>
<td>Hardware Parameters</td>
<td></td>
<td>GPIO/PWM</td>
</tr>
<tr>
<td>Operating Voltage</td>
<td></td>
<td>3.0-3.6V</td>
</tr>
<tr>
<td>Operating Current</td>
<td></td>
<td>Average value: 80mA</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td></td>
<td>-40°C~125°C</td>
</tr>
<tr>
<td>Ambient Temperature Range</td>
<td></td>
<td>Normal temperature</td>
</tr>
<tr>
<td>Package Size</td>
<td></td>
<td>5x5mm</td>
</tr>
<tr>
<td>External Interface</td>
<td></td>
<td>N/A</td>
</tr>
</tbody>
</table>
5. Real time clock DS3231

It is a computer clock which keeps track of the current time. In this project RTC used to keep accurate time in schedule. RTC provides information of year, month, day, hours, minutes, and seconds. Referring to Table 5.5 clock operating voltage is 3.3V. Figure 5.7 shows pin configuration of DS3231.

![Figure 12.7 pin configuration of DS3231 (Maxim Integrated 2015)](image)

Table 5.5 details of DS3231 (Maxim Integrated 2015)

<table>
<thead>
<tr>
<th>Operating voltage 3.3 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Pins 16 Pin</td>
</tr>
<tr>
<td>Compensation Valid Up to 2100</td>
</tr>
<tr>
<td>8-Pin DIP and 8-Pin SO Minimizes Required Space</td>
</tr>
<tr>
<td>I2C Serial Interface</td>
</tr>
<tr>
<td>Optional Industrial Temperature Range: -40°C to +85°C</td>
</tr>
</tbody>
</table>
6. LCD

As shown in Figure 5.8 Liquid Crystal Display (LCD) used to display the state of the system. Referring to the Table 5.6 the operating voltage of LCD is 5V.

Figure 13.8 LCD display (Kushagra 2012)

Table 5.6  pin description of LCD 2x16 (Kushagra 2012)
7. Regulator

Regulator is an electronic device that maintains the voltage of a power source within acceptable limits. As shown in Figure 5.9, the LM7805 voltage regulator is used with external components to obtain adjustable voltage and currents. This type of regulator is a 5V voltage regulator referring the details shown in Table 5.7.

![LM7805 PINOUT DIAGRAM](image)

Figure 14.9  LM7805 Voltage Regulator (Ltd 2015)

Table 5.7  details of LM7805 voltage regulator (Ltd 2015)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output voltage</td>
<td>5 V</td>
</tr>
<tr>
<td>Max output current</td>
<td>1 A</td>
</tr>
<tr>
<td>Output type</td>
<td>Fixed</td>
</tr>
<tr>
<td>Minimum input voltage</td>
<td>7.5 V</td>
</tr>
<tr>
<td>Maximum input voltage</td>
<td>25 V</td>
</tr>
<tr>
<td>No. of pins</td>
<td>3</td>
</tr>
<tr>
<td>Power rating</td>
<td>2 W</td>
</tr>
<tr>
<td>Minimum operating temperature</td>
<td>-40 °C</td>
</tr>
<tr>
<td>Maximum operation temperature</td>
<td>+85 °C</td>
</tr>
<tr>
<td>Number of outputs</td>
<td>1</td>
</tr>
<tr>
<td>Polarity</td>
<td>Positive</td>
</tr>
<tr>
<td>Load regulation</td>
<td>100 mV</td>
</tr>
</tbody>
</table>
5.2.2 Software tools

This part describe the required software that used for simulate and for implement this project. The software program which used to complete this project is a MPLABX for programming microcontroller. Android studio for developing control app. Arduino program for programming ESP8266 Wi-Fi module. And for simulation Proteus ISIS program is used.
5.3 Schematic Diagram

Figure 15.10 circuit diagram
5.3.1 Operation of the system:

The android application has been designed to gather all essential timetable details of each room. Which connected directly with microcontroller pic16f887 through Wi-Fi communication. Different relays which operate with 230V are connect with delay driver. The delay driver is connect with pic16f887 which operate with 5V, the purpose of relay driver is to provide isolation between high voltage and low voltage circuit. In addition microcontroller don’t have enough current to drive the relays there for relay driver is used to derive relays properly.

When the android application is connected with accesses point of ESP8266 it allows the user to enter the room details and send those details to the microcontroller. According to received data, the signal which received by microcontroller may include ether high voltage or low voltage. The microcontroller detects the voltage and based on the data which received from android application, its activates the relay driver to switch particular relay.
5.4 System Design & Analysis

5.4.1 ESP8266 Wi-Fi module

The operation voltage of ESP8266 is 3.3V, therefore in this project ESP8266 connected with device of 5V. As shown below by building voltage divider the tow device can communicate. Since output voltage is going to 3.3V and input voltage is 5V and the value of $R_2$ choose to be 2 kΩ, we can calculate the value of $R_1$.

$$V_{out} = V_{in} \cdot \frac{R_2}{R_1 + R_2}$$

$$V_{out} = \frac{V_{in} \cdot R_2}{R_1 + R_2}$$

$$V_{out} \cdot R_1 + V_{out} \cdot R_2 = V_{in} \cdot R_2$$

$$R_1 = \frac{V_{in} \cdot R_2}{V_{out}} - R_2$$

∴ $R_1 = 1\text{kΩ}$
5.4.2 Power supply

The microcontroller require a 5V DC supply, so the AC 230V needs to be converted into 5V DC. By using the step-down converter in the power supply circuit, the rectifier designed for 5V DC. Since the 7805 is rated at a maximum current of 1A, the value of capacitor depends on the output voltage and output current. By using capacitance formula we can calculate value of capacitor.

\[ Q = C \times V \quad \rightarrow \quad 1 \]

\[ Q = C \times IR \]

\[ Q = I \times RC \]

\[ Q = I \times T \quad \rightarrow \quad 2 \]

Subsisted equation 2 in 1

\[ IT = CV \]

\[ \therefore C = \frac{IT}{V} \]

The input voltage is 230V AC 50Hz, the output voltage of the transformer 5V AC 50Hz. The transformer frequency remain constant.

\[ T = \frac{1}{2\pi f} \]

\[ T = \frac{1}{2\pi \times 50} = 3.1847 \times 10^{-3} \text{ Second} \]

The output voltage is 5V and output current is 1A.

\[ \therefore C = \frac{IT}{V} \]

\[ C = \frac{1}{5 \times 0.0031847} = 636.74 \mu F \] for this project 680\mu F is used
CHAPTER 6

SIMULATION, TESTING AND IMPLEMENTATION

6.1 System Simulation

Various units which simulated are described and compared with design value.

6.1.1 Power supply

As the operating system design the DC voltage must be +5V which be checked from the output pin of regulator to confirm it is in the correct voltage range. Figure 6.1 show the output voltage from the regulator.

Figure 6.16 output voltage from the regulator
Table 6.1 include summary of the design and the simulation for each part of power supply unit as shown in Figure 6.1.

Table 6.11 output voltage value of each part of power supply unit.

<table>
<thead>
<tr>
<th>Testing point</th>
<th>Design value</th>
<th>Simulation value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_1$</td>
<td>12 V AC</td>
<td>12 V AC</td>
</tr>
<tr>
<td>$V_2$</td>
<td>9 V DC</td>
<td>9 V DC</td>
</tr>
<tr>
<td>$V_3$</td>
<td>5 V DC</td>
<td>5 V DC</td>
</tr>
</tbody>
</table>
6.1.2 Microcontroller

The simulation of programming pic microcontroller is shown in Figure 6.2.

Figure 6.17 simulation of pic microcontroller
6.1.3 Android Application

The android application has been designed to gather all essential timetable details of each room. That happen only When the android application is connected with accesses point of ESP8266. Then the user can enter the room details and send them to the microcontroller. Figure 6.3 Show the layout of android application.

![Figure 6.3 layout of android application](image)

- To enter IP Address of ESP8266
- Button to access with network
- Edit text to enter room number
- Edit text to enter date
- Edit text to enter start time
- Edit text to enter end time
- Button to send data to PIC microcontroller

Figure 6.18 layout of android application
6.2 System Testing

This part consist the description of the unit step testing.

6.2.1 Power supply

The power supply unit is designed to get an output from each part of power supply circuit as shown in Figure 6.4, 6.5 and 6.6. Table 6.2 Testing point for each part of power supply.

Figure 6.19 output voltage across transformer
Figure 6.20 output voltage across bridge rectifier

Figure 6.6 output voltage across regulator 7805
Table 6.12 Testing point for each part of power supply

<table>
<thead>
<tr>
<th>Testing point</th>
<th>Design value</th>
<th>Simulation value</th>
<th>Testing value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_1$</td>
<td>12 V AC</td>
<td>12 V AC</td>
<td>11.10 V AC</td>
</tr>
<tr>
<td>$V_2$</td>
<td>9 V DC</td>
<td>9 V DC</td>
<td>9.67 V DC</td>
</tr>
<tr>
<td>$V_3$</td>
<td>5 V DC</td>
<td>5 V DC</td>
<td>4.97 V DC</td>
</tr>
</tbody>
</table>

6.2. 2 ESP8266

The voltage of ESP8266 is designed to be 3.3V across $R_X$ and Vcc of this Wi-Fi module. The first part is to get the output from $R_X$ as shown in Figure 6.7. The second part is to get the output from Vcc as shown in Figure 6.8. The circuit is tested at each part which match the result at the designing and simulation as shown on Table 6.3.

Figure 6.7 output voltage across $R_X$
Figure 6.8 output voltage across $V_{cc}$

Table 6.13 Testing of ESP8266 Wi-Fi module unit.

<table>
<thead>
<tr>
<th>Testing point</th>
<th>Design value</th>
<th>Simulation value</th>
<th>Testing value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage across $R_X$</td>
<td>3.3V</td>
<td>3.3V</td>
<td>3.32V</td>
</tr>
<tr>
<td>Voltage across $V_{cc}$</td>
<td>3.3V</td>
<td>3.3V</td>
<td>3.30V</td>
</tr>
</tbody>
</table>
6.3 System Implementation/Prototyping

This part consist the connection of all the units and each point for each unit are checked to set the performance of the project. The implementation of this project into tow section.

6.3.1. Control Unit Section

As explained in previous chapter of control unit design, the control unit circuit design into six units. The units are as following:

1. Microcontroller Unit: Figure 6.9 is clarify all unit that connect with pic16f887 unit.

![Figure 6.9 Microcontroller Unit](image-url)
2. ESP8266 Wi-Fi Module Unit: Figure 6.10 Show connection of ESP8266 pins.

Figure 6.10 ESP8266 Wi-Fi Module Unit
3. **RTC Unit**: Figure 6.11 shows the pins connection of RTC unit.

![RTC Unit](image)

4. **LCD Unit**: Figure 6.12 shows the connection of LCD Unit pins.

![LCD Unit](image)
5. Relay Unit: Figure 6.13 show the circuit connection of relay unit.

![Figure 6.13 Relay Unit](image)

6. Power Supply Unit: Figure 6.14 Show the unit which connect with power supply of 5V.

![Figure 6.14 Power Supply Unit](image)
The final assembly of control unit section is shown below in figure 6.15. The value of control unit section at all steps is defined in Table 6.4.

Table 6.14 value of control unit section at all step

<table>
<thead>
<tr>
<th>Unit Testing</th>
<th>Testing point</th>
<th>Design value</th>
<th>Simulation value</th>
<th>Testing value</th>
<th>Integration test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Supply Unit</td>
<td>$V_1$</td>
<td>12 V AC</td>
<td>12 V AC</td>
<td>11.10 V AC</td>
<td>11.2 AC</td>
</tr>
<tr>
<td></td>
<td>$V_2$</td>
<td>9 V DC</td>
<td>9 V DC</td>
<td>9.67 V DC</td>
<td>9.52 DC</td>
</tr>
<tr>
<td></td>
<td>$V_3$</td>
<td>5 V DC</td>
<td>5 V DC</td>
<td>4.97 V DC</td>
<td>4.98 DC</td>
</tr>
<tr>
<td>ESP8266 Unit</td>
<td>V across $R_X$</td>
<td>3.3V</td>
<td>3.3V</td>
<td>3.32V</td>
<td>3.3V</td>
</tr>
<tr>
<td></td>
<td>V</td>
<td>3.3V</td>
<td>3.3V</td>
<td>3.30V</td>
<td>3.31 V</td>
</tr>
</tbody>
</table>

6.3.2. Android Application Unit Section

This unit section has been implemented and tested with control unit section as shown in Figure 6.15.
Figure 6.15 implementation circuit
CHAPTER 7

CRITICAL EVALUATION

The project objectives has been achieved after all steps of implementation which is in summary “to control the electrical appliances according to the details of the schedule which received by android application”. The evaluation during system implementation are mentioned below:

- During unit test of power supply, it was work sometime and sometime not. That case of the AC power supply was not connect between L and N. then it is fixed and it work perfect.
- Pic 11f887 is a precision internal oscillator, but in this project external oscillator is connected with pic to make the error of UART protocol is equal to zero. The error percentage is calculated by formula from datasheet.
- The pic18f45k22 microcontroller has been changed to pic16f887 because this project consist only one Rx and Tx.
- For proper functioning of relay unit, the relay driver has to be properly powered.
CHAPTER 8

LEGAL, SOCIAL AND ETHICAL ASPECTS RELATED TO THE PROJECT

The idea of this project comes from the rising of using electric power which effect the social environment. In large organizations devices operating on electric energy are switch on manual, which is does not has the ability to manage work of the energy devices. Nowadays the mobile applications designed to run on smartphones. As we know smartphones is the useful technique, which will change radically of how provide the services. This project use a mobile application to control the energy devices of each venue based on predefined time table. It is a useful technique for all organizations to energy conservation.

There is no legal and aspects related to this project.
CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

The project develop an automatic mechanism that configures device switching ON or OFF based on schedules. That by programming the control app and the control device to turn devices ON or OFF. Feature of this project it use Wi-Fi communication between microcontroller and app. The benefit of this project is reduce wastages of energy and cut the electrical consumption due to manually switching. In addition this project will improving organizations efficiency in the using of electric power.

In future this project can include option of gradient which will also work for reducing energy consumption. Also the android application to be designed to read the x-mal file.
REFERENCES


APPENDIX A

Android application code

package mec11f7600.com.control_app;

import android.content.Context;
import android.os.AsyncTask;
import android.os.Bundle;
import android.util.Log;
import android.support.v7.app.AppCompatActivity;
import android.view.MotionEvent;
import android.view.View;
import android.view.inputmethod.InputMethodManager;
import android.widget.Button;
import android.widget.EditText;
import android.widget.Toast;
import java.io.IOException;
import java.io.InputStream;
import java.net.HttpURLConnection;
import java.net.URL;

public class MainActivity extends AppCompatActivity implements
View.OnClickListener {
    private static final String DEBUG_TAG = "HttpExample";
    Button btnConnect, btnSend;
EditText txtIP, txtRoomNum, txtDate, txtStart, txtEnd;

@Override
protected void onCreate(Bundle savedInstanceState) {
    super.onCreate(savedInstanceState);
    setContentView(R.layout.activity_main);
    btnConnect = (Button) findViewById(R.id.btnConnect);
    btnSend = (Button) findViewById(R.id.btnSend);
    btnConnect.setOnClickListener(this);
    btnSend.setOnClickListener(this);
    txtIP = (EditText) findViewById(R.id.txtIP);
    txtRoomNum = (EditText) findViewById(R.id.txtRoomNum);
    txtDate = (EditText) findViewById(R.id.txtDate);
    txtEnd = (EditText) findViewById(R.id.txtEnd);
    txtStart = (EditText) findViewById(R.id.txtStart);
    btnSend.setEnabled(false);
}

@Override
public boolean onTouchEvent(MotionEvent event) {
    InputMethodManager imm = (InputMethodManager)getSystemService(Context.INPUT_METHOD_SERVICE);
    imm.hideSoftInputFromWindow(getCurrentFocus().getWindowToken(), 0);
    return true;
}
@Override

public void onClick(View v) {
    String stringUrl = txtIP.getText().toString();
    if(v == btnConnect){
        new DownloadWebpageTask().execute("http://" + stringUrl);
    } else if(v == btnSend) {
        new DownloadWebpageTask().execute("http://" + stringUrl +
            "?RoomNum=\" + txtRoomNum.getText().toString() + "&Date=\" +
            txtDate.getText().toString() + "&StartTime=\" +
            txtStart.getText().toString() + "&EndTime=\" +
            txtEnd.getText().toString() + "\$\");
    }
}

private class DownloadWebpageTask extends AsyncTask<String, Void,
    Integer> {
    @Override

    protected Integer doInBackground(String... urls) {
        try {
            return downloadUrl(urls[0]);
        } catch (IOException e) {
            return 404;
        }
    }
}
@Override

protected void onPostExecute(Integer result) {
    if (result == 200){
        if (txtIP.isEnabled()) {
            btnConnect.setText("Connected");
            txtIP.setEnabled(false);
            btnConnect.setEnabled(false);
            btnSend.setEnabled(true);
            Toast.makeText(getApplicationContext(),"Connected ^_^" , Toast.LENGTH_SHORT).show();
        }
    }else{
        btnConnect.setText("Connect");
        txtIP.setEnabled(true);
        btnConnect.setEnabled(true);
        btnSend.setEnabled(false);
        Toast.makeText(getApplicationContext(),"Error *_*" , Toast.LENGTH_SHORT).show();
    }
}

private int downloadUrl(String myurl) throws IOException {
    InputStream is = null;
    int len = 500;
try {
    URL url = new URL(myurl);
    HttpURLConnection conn = (HttpURLConnection) url.openConnection();
    conn.setReadTimeout(10000 /* milliseconds */);
    conn.setConnectTimeout(15000 /* milliseconds */);
    conn.setRequestMethod("GET");
    conn.setDoInput(true);
    conn.connect();
    int response = conn.getResponseCode();
    Log.d(DEBUG_TAG, "The response is: " + response);
    // is = conn.getInputStream();
    // Convert the InputStream into a string
    // String contentAsString = readIt(is, len);
    // Log.d(DEBUG_TAG, "The contentAsString: " + contentAsString);
    return response;
}

// Makes sure that the InputStream is closed after the app is
// finished using it.

} finally {
    if (is != null) {
        is.close();
    }
}
Pic microcontroller code

#define _XTAL_FREQ 7372800
// PIC16F877A Configuration Bit Settings
// 'C' source line config statements

#define RS PORTBbits.RB2
#define EN PORTBbits.RB3
#define D4 PORTBbits.RB4
#define D5 PORTBbits.RB5
#define D6 PORTBbits.RB6
#define D7 PORTBbits.RB7
#define Relay_0 PORTDbits.RD0
#define Relay_1 PORTDbits.RD1
#define Relay_2 PORTDbits.RD2
#define Relay_3 PORTDbits.RD3
#define Relay_4 PORTDbits.RD4

#include <xc.h>
#include <pic16f887.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include "lcd.h"
#include "uart.h"

// CONFIG1
#pragma config FOSC = HS    // Oscillator Selection bits (HS oscillator: High-speed crystal/resonator on RA6/OSC2/CLKOUT and RA7/OSC1/CLKIN)
#pragma config WDTE = OFF   // Watchdog Timer Enable bit (WDT disabled and can be enabled by SWDTEN bit of the WDTCON register)
#pragma config PWRTE = OFF  // Power-up Timer Enable bit (PWRT disabled)
#pragma config MCLRE = OFF  // RE3/MCLR pin function select bit (RE3/MCLR pin function is digital input, MCLR internally tied to VDD)
#pragma config CP = OFF     // Code Protection bit (Program memory code protection is disabled)
#pragma config CPD = OFF    // Data Code Protection bit (Data memory code protection is disabled)
#pragma config BOREN = OFF      // Brown Out Reset Selection bits (BOR disabled)
#pragma config IESO = OFF       // Internal External Switchover bit (Internal/External Switchover mode is disabled)
#pragma config FCMEN = OFF      // Fail-Safe Clock Monitor Enabled bit (Fail-Safe Clock Monitor is disabled)
#pragma config LVP = OFF        // Low Voltage Programming Enable bit (RB3 pin has digital I/O, HV on MCLR must be used for programming)

// CONFIG2
#pragma config BOR4V = BOR40V   // Brown-out Reset Selection bit (Brown-out Reset set to 4.0V)
#pragma config WRT = OFF        // Flash Program Memory Self Write Enable bits (Write protection off)

#define MSB(x) ((x>>4)+ '0')          //Display Most Significant Bit of BCD number
#define LSB(x) ((x & 0x0F) + '0')    //Display Least Significant Bit of BCD number

char rxchar, i = 0, flag = 0;
//unsigned char rxarray[20];
unsigned char msg[6];

unsigned char temp[10];
unsigned char roomNum[10] = "0";
unsigned char roomDate[10];
unsigned char roomStart[10];
unsigned char roomEnd[10];

int second;
int minute;
int hour;
int hr;
int day;
int dday;
int month;
int year;
int ap;

unsigned short set_count = 0;
short set;

char time[] = "00:00:00 PM";
char date[] = "00-00-00";

void I2C_Master_Init(const unsigned long c) {

}
SSPCON = 0b00101000;
SSPCON2 = 0;
SSPADD = (_XTAL_FREQ / (4 * c)) - 1;
SSPSTAT = 0;
TRISC3 = 1; //Setting as input as given in datasheet
TRISC4 = 1; //Setting as input as given in datasheet
}

void I2C_Master_Wait() {
    while ((SSPSTAT & 0x04) || (SSPCON2 & 0x1F));
}

void I2C_MASTER_START() {
    I2C_Master_Wait();
    SEN = 1;
}

void I2C_MASTER_REPEATEDSTART() {
    I2C_Master_Wait();
    RSEN = 1;
}

void I2C_MASTER_STOP() {
    I2C_Master_Wait();
    PEN = 1;
}

void I2C_MASTER_WRITE(unsigned d) {
    I2C_Master_Wait();
    SSPBUF = d;
}

unsigned short I2C_MASTER_READ(unsigned short a) {
    unsigned short temp;
    I2C_Master_Wait();
    RCEN = 1;
    I2C_Master_Wait();
    temp = SSPBUF;
    I2C_Master_Wait();
    ACKDT = (a) ? 0 : 1;
    ACKEN = 1;
    return temp;
}
int BCD2Binary(int a) //Convert BCD to Binary so we can do some basic calculations
{
    int r, t;
    t = a & 0x0F;
    r = t;
    a = 0xF0 & a;
    t = a >> 4;
    t = 0x0F & t;
    r = t * 10 + r;
    return r;
}

int Binary2BCD(int a) //Convert Binary to BCD so we can write to the DS1307 Register in BCD
{
    int t1, t2;
    t1 = a % 10;
    t1 = t1 & 0x0F;
    a = a / 10;
    t2 = a % 10;
    t2 = 0x0F & t2;
    t2 = t2 << 4;
    t2 = 0xF0 & t2;
    t1 = t1 | t2;
    return t1;
}

unsigned short read_ds1307(unsigned short address) {
    unsigned short r_data;
    I2C_Master_Start();
    I2C_Master_Write(0xD0); //address 0x68 followed by direction bit (0 for write, 1 for read) 0x68 followed by 0 --> 0xD0
    I2C_Master_Write(address);
    I2C_Master_RepeatedStart();
    I2C_Master_Write(0xD1); //0x68 followed by 1 --> 0xD1
    r_data = I2C_Master_Read(0);
    I2C_Master_Stop();
    return (r_data);
}

void write_ds1307(unsigned short address, unsigned short w_data) {
    I2C_Master_Start(); // issue I2C start signal
//address 0x68 followed by direction bit (0 for write, 1 for read) 0x68 followed by 0 --> 0xD0
I2C_Master_Write(0xD0); // send byte via I2C (device address + W)
I2C_Master_Write(address); // send byte (address of DS1307 location)
I2C_Master_Write(w_data); // send data (data to be written)
I2C_Master_Stop(); // issue I2C stop signal

unsigned char BCD2UpperCh(unsigned char bcd) {
    return ((bcd >> 4) + '0');
}

unsigned char BCD2LowerCh(unsigned char bcd) {
    return ((bcd & 0x0F) + '0');
}

void interrupt serialESP() {
    if (PIR1bits.RCIF) { // test the interrupt for uart rx
        PIR1bits.RCIF = 0;
        rxchar = UART_Read(); //
        if (rxchar == '?') {
            UART_Read_Text(temp, "=", 10);
            UART_Read_Text(roomNum, ",", 10);
            UART_Read_Text(temp, "&", 10);
            UART_Read_Text(roomDate, "&", 10);
            UART_Read_Text(temp, "=", 10);
            UART_Read_Text(roomStart, "&", 10);
            UART_Read_Text(temp, "=", 10);
            UART_Read_Text(roomEnd, "$", 10);
            flag = 1;
        }
    } // end if (PIR1.RCIF)
} // end interrupt

void main() {
    ADCON1 = 0x0F;
    ANSEL = 0;
    ANSELH = 0;
    I2C_Master_Init(100000);

    PIE1bits.RCIE = 1;
    INTCONbits.PEIE = 1;
    INTCONbits.GIE = 1; //
nRBPU = 0;
PORTB = 0;
PORTC = 0;
PORTD = 0;
TRISA = 0xFF;
TRISB = 0;
TRISD = 0;

Lcd_Init();
Lcd_Clear();
Lcd_Out(1, 1, "WELCOME TO");
Lcd_Out(2, 1, "Android Control");
__delay_ms(2000);
UART_Init(9600);
Lcd_Clear();
Lcd_Out(1, 1, "Time:");
Lcd_Out(2, 1, "Date:");

while (1) {

    if (flag == 1) {
        flag = 0;
        Lcd_Clear();
        Lcd_Out(1, 1, "Room Num:");
        Lcd_Out(1, 14, roomNum);
        Lcd_Out(2, 1, "Date:");
        Lcd_Out(2, 7, roomDate);
        switch (atoi(roomNum)) {
        case 1:
            Relay_0 = 1;
            Relay_1 = 0;
            Relay_2 = 0;
            Relay_3 = 0;
            Relay_4 = 0;
            break;
        case 2:
            Relay_0 = 0;
            Relay_1 = 1;
            Relay_2 = 0;
            Relay_3 = 0;
            Relay_4 = 0;
            break;
        case 3:
            Relay_0 = 0;
            Relay_1 = 0;
            break;
        }
    }
}
Relay_2 = 1;
Relay_3 = 0;
Relay_4 = 0;
break;
case 4:
    Relay_0 = 0;
    Relay_1 = 0;
    Relay_2 = 0;
    Relay_3 = 1;
    Relay_4 = 0;
    break;
case 5:
    Relay_0 = 0;
    Relay_1 = 0;
    Relay_2 = 0;
    Relay_3 = 0;
    Relay_4 = 1;
    break;
default:
    Relay_0 = 0;
    Relay_1 = 0;
    Relay_2 = 0;
    Relay_3 = 0;
    Relay_4 = 0;
}
__delay_ms(5000);
Lcd_Clear();
Lcd_Out(1, 1, "Start:");
Lcd_Out(2, 1, "End: ");
Lcd_Out(1, 7, roomStart);
Lcd_Out(2, 7, roomEnd);
__delay_ms(5000);
Lcd_Clear();
Lcd_Out(1, 1, "Time:" );
Lcd_Out(2, 1, "Date:" );
}
__delay_ms(20);
set = 0;
if (PORTAbits.RA0 == 1) {
    __delay_ms(100);
    if (PORTAbits.RA0 == 1) {
        set_count++;
        if (set_count >= 7) {
            set_count = 0;
        }
    }
}
if (set_count) {
    if (PORTAbits.RA1 == 1) {
        __delay_ms(100);
        if (PORTAbits.RA1 == 1)
            set = 1;
    }
    if (PORTAbits.RA2 == 1) {
        __delay_ms(100);
        if (PORTAbits.RA2 == 1)
            set = -1;
    }
    if (set_count && set) {
        switch (set_count) {
            case 1:
                hour = BCD2Binary(hour);
                hour = hour + set;
                hour = Binary2BCD(hour);
                if ((hour & 0x1F) >= 0x13) {
                    hour = hour & 0b11100001;
                    hour = hour ^ 0x20;
                } else if ((hour & 0x1F) <= 0x00) {
                    hour = hour | 0b00010010;
                    hour = hour ^ 0x20;
                }
            write_ds1307(2, hour); //write hour
            break;
            case 2:
                minute = BCD2Binary(minute);
                minute = minute + set;
                if (minute >= 60)
                    minute = 0;
                if (minute < 0)
                    minute = 59;
                minute = Binary2BCD(minute);
            write_ds1307(1, minute); //write min
            break;
            case 3:
                if (abs(set))
                    write_ds1307(0, 0x00); //Reset second to 0 sec. and start Oscillator
                break;
            case 4:
                day = BCD2Binary(day);
day = day + set;
day = Binary2BCD(day);
if (day >= 0x32)
    day = 1;
if (day <= 0)
    day = 0x31;
write_ds1307(4, day); // write date 17
break;
case 5:
    month = BCD2Binary(month);
    month = month + set;
    month = Binary2BCD(month);
    if (month > 0x12)
        month = 1;
    if (month <= 0)
        month = 0x12;
    write_ds1307(5, month); // write month 6 June
    break;
case 6:
    year = BCD2Binary(year);
    year = year + set;
    year = Binary2BCD(year);
    if (year <= -1)
        year = 0x99;
    if (year >= 0x50)
        year = 0;
    write_ds1307(6, year); // write year
    break;
}
second = read_ds1307(0);
minute = read_ds1307(1);
hour = read_ds1307(2);
hr = hour & 0b00011111;
ap = hour & 0b00100000;
dday = read_ds1307(3);
day = read_ds1307(4);
month = read_ds1307(5);
year = read_ds1307(6);

time[0] = BCD2UpperCh(hr);
time[1] = BCD2LowerCh(hr);
time[3] = BCD2UpperCh(minute);
time[4] = BCD2LowerCh(minute);
time[6] = BCD2UpperCh(second);
time[7] = BCD2LowerCh(second);

date[0] = BCD2UpperCh(day);
date[1] = BCD2LowerCh(day);
date[3] = BCD2UpperCh(month);
date[4] = BCD2LowerCh(month);
date[6] = BCD2UpperCh(year);
date[7] = BCD2LowerCh(year);

if (ap) {
    time[9] = 'P';
    time[10] = 'M';
} else {
    time[9] = 'A';
    time[10] = 'M';
}
Lcd_Out(1, 6, time);
Lcd_Out(2, 6, date);
__delay_ms(1000);
TRC – FURAP
Faculty Mentored Undergraduate Research Award Program

A PROJECT REPORT

ON

A hovercraft controlled by Android Application
and by Gesture

By

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AUGUST, 2017
ACKNOWLEDGEMENT

I want to say thanks to God for made the hard simple and for giving me the capacity to finish the report and much obliged for everybody who helped me in finishing the project. Likewise I thank my advisor Mr. MadhavPrabhu for his helping and guiding when I need it. Also I gratitude the Department of Electronics and Telecommunication to provide everything I need to complete the project successfully.

And I need to express especially gratitude for my Colleagues and everybody helping me through the planning project to complete the report successfully and give me a motivation in these months, especially my Colleagues.
A hovercraft is a non-wheeled vehicle that can hover over land as well as water easily using high powered fans and aerodynamic design. Propose an advanced hovercraft that uses high rpm motors interfaced with an AVR family Microcontroller to achieve desired functionality. The motor hovercraft rotates at a very high RPM that allows it to generate a force enough to make it hover on the surface thus reducing the friction it to minimum. Then use the motor propeller mounted behind it to push the hovercraft in forward direction. Also need to use a servo motor attached to the hovercraft rudder that helps the hovercraft to move in desired directions by bending the air at accurate angles.

The system works collectively to hover while continuously managing servo as well as propeller motor to drive the hovercraft as desired. Now to control the hovercraft, use an android application. The android application sends movement commands to the hovercraft circuit. The circuit consists of a Bluetooth receiver to receive and process these commands. The commands received by receiver are now processed by the microcontroller and it then operates all three motors accordingly as desired by the user.
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1. INTRODUCTION

Hovercraft is a vehicle that glides over a smooth surface by hovering upon an air cushion. Because of this, a hovercraft is also called an Air-Cushion Vehicle. The hovercraft creates vents or currents of slow-moving, low-pressure air that are pushed downward against the surface below the hovercraft. The common

Nowadays, with high development in the world “A hovercraft controlled by Android Application and by Gesture” is design for water competitions and adventures with Matlab are used to control the hand gesture. Also with high performance motors to more efficient that with more power turns. The aerodynamic hovercraft design and with high power motors it can hover on water and on land.

So, this chapter gives overview of using Android Application with high power motors and Matlab to move the hovercraft by hand gesture, background of the project, objectives and limitations.

1.1 Background of the Project

Hovercrafts are manually controlled by the motors, but with great development in the world, people want a different and new life system, especially in water sports competitions and adventures. Also with the efficient turning with full power and high performance. That's why the idea of the project was formed.

A hovercraft microcontroller consist of motor below hovercraft(hovering motor) rotates at a very high RPM that allows to generate a force enough to make it hover on the surface thus reducing the friction below it to minimum. Then the rudder motor(propeller motor) mounted behind it to push the hovercraft in forward direction with servo motor attached to the hovercraft rudder that helps the hovercraft to move in desired directions by bending the air at accurate angles. An electronic speed control(ESC) to vary the motor speed to its direction. The fan rotates in any direction to move the hovercraft by rotating the propeller opposite.
However, the system works collectively to hover while continuously managing servo as well as propeller motor to drive the hovercraft as desired. And it controlled by Matlab and Android application that send movement commands to the hovercraft circuit. The circuit consists of Bluetooth receiver to receive and process these commands. The commands received by receiver are processed by microcontroller, then operates all three motors accordingly as desired by the user. (Kumar, Jain and Jaipurkar 2014)

### 1.2 Project Objectives

This hovercraft is a new device that used in aquatic recreation and adventure races. The basic aim is to use both hardware and software design and implementation of hovercraft controlled by Android and Matlab.

The objectives are as follows:

1. Using Microcontroller (AT Mega 328p) to control the hovering motors and rudder motor.
2. Using Bluetooth encoder Model (HC-05) to receive instructions from Android or Matlab.
3. Programming the Microcontroller to turning of hovercraft as per the commands send by Android or Matlab.
4. Using Matlab to control the hand gesture.
5. Using a servo motor to rotates hovercraft by particular angle and hovering motors to drive hovercraft.
6. Using electronic speed control (ESC) to vary the speed motors.

### 1.3 Project Limitations

A hovercraft which controlled by Android and by Gesture is a new idea that used Microcontroller (AT Mega 328p) to control the motors, but there are some limitations in this project.

The limitations are as follows:
1. The speed of the hovercraft in km per hours will depend on the motors, which is limited speed in the hovercraft.

2. The distance of the Bluetooth encoder that receive the instructions is not up to the far distance, which is the Bluetooth will be up to 100 meters.

3. The device does not bear heavy weights and does not return back (pull only).

4. For simulation, most components used at this project at the circuit diagram doesn't simulate.

5. The Hovercraft might stop working after one hour of operation as the LiPO batteries get drained off due to the heavy duty motors so recharge the batteries.

### 1.4 Overview of the Project Report

The report is containing six chapters as follows:

Chapter 1: Introduction that give reader general information about the idea in background, objectives, limitations and overview of the report.

Chapter 2: discuss the methodology with description that used in the report and implementation.

Chapter 3: present the literature review, where the past related projects are discussed in third chapter.

Chapter 4: show the costing plan, scheduling plan, Gantt chart and identify the risk managements.

Chapter 5: illustrates system initial design for “A hovercraft controlled by Android Application and by Gesture”. It show the block diagram, flow chart and system schematic diagram.

Chapter 6: present the conclusion as summary of the project and suggestions for future work.
2. METHODOLOGY

This chapter complete and covers methodology and its details description to achieve the aims successfully from initial to final stage of planning and implementation.

Here in this project a V-Model methodology and steps are explained as shown in figure 2.1:

Figure 2.1: VModel Methodology(SEI Insights 2016)

**Requirement Analysis:** this stage determined the requirements of a hovercraft controlled by Android Application and by Gesture in both software and hardware components. And it shows the scheduling plan and design of the system.

**System Design:** it is the second stage in the methodology which completes the details of the components. System design is develop and improve the specification of the project than implemented.
**Functional design:** this stage shows the software components that used in this project to design and to prototype the idea. When the objectives are finalizing, then the system of the project is become ready to doing the test before the implementation.

**Implementation:** The most important stage in the project. And it is necessary to operate the development of the system prototype properly without errors in the implementation.

**Unit testing:** verified and testing each part in the functional design.

**Integration Testing:** this stage become after unit testing that integrates all the requirements that used in the system together to check the compatibility.

**Acceptance Testing:** the aims of the system are to ease the way of billing and to avoid the queues in the counter, and the system is tested to get the successful outcomes.
3. LITERATURE REVIEW/THEORY

This chapter presents previous research projects that related to the project. Past related project shows the drawback of it and how the system is improved.

3.1 Past related projects:

In this stage, four past related project are discussed in details.

3.1.1 Efficient Wireless Motor Controller:

In this project, authors have designed system that control motors in long distance and combining wireless communications with power. The core idea is to build car moved in reverse, avoid crashes and controlled by remote. The “Efficient Wireless Motor Controller” by using infrared technology is to control two motors. Figure 3.1 is shows the block diagram of “Efficient Wireless MotorController”

In this project, the motors have ability to stop, start, reverse, decelerate and accelerate. Also it’s able to move right and left with detector sensors to stop the motors immediately to avoid car crash. (Lucas 2009)

However, the idea is control the motors from long distance but, it’s more complex and more expensive.

![Block diagram of “Efficient Wireless MotorController”](image)

Figure 3.1: Block diagram of “Efficient Wireless MotorController” (Lucas 2009)
3.1.2 A Gesture Based Interface For Remote Robot Control:

In this paper, the authors have designed system work by hand gestures for controlling a remote robot. The device have sequences of gesture that interpreted by using HMM based recognition engine. The sequences of interpreted gesture have translated into commands to control the remote robot. Figure 3.2 shows the software environment of this paper. Here, “a remotely placed mobile robot is controlled by using the gesture based interface. The robot is connected to a serial port to a Pentium system. Each gesture is mapped to a sequence of commands which transmitted in serial ports to the robot. The robot is expected to move around under the control for providing him visual feedback about the remote environment”. (Ashutosh 1998)

Although the robot moves appropriately with attached camera and it controlled by software system, but it limited to simple hand gestures and weak software program. Therefore, it is useful project.

![Figure 3.2: Software Environment. (Ashutosh 1998)](image)

3.1.3 System to control a television set using hand gestures:
In this paper, author has designed system that recognizes the gestures like circles, squares and lines. The project is works for at least six feet distances and unable to running on low-power CPUs like netbooks or an FPGA. The system is powerful for small movements and also people can walk in front of the device. Figure 3.3 is shows the block diagram of “System to control a television set using hand gestures.” System that control a television by using hand gestures is control the basic functions like power ON/OFF, Volume UP/DOWN and Channel UP/DOWN. It works with television and computer and recognizes gestures from right and left hands (IEEE xplore 2016). However, the idea is control the television to the masses but, it’s more complex and more expensive.

Figure 3.3: Block diagram of “System to control a television set using hand gestures”. (IEEE xplore 2016)

3.1.4 Gesture Controlled robot
In this project, authors have built and designed an accelerometer (ADXL335) robot controlled by using hand gestures with (ATmega16) Microcontroller. Sensor of ADXL335 accelerometer used as input device placed on the hand. Microcontroller (ATmega16) used to control the robot as processing unit and read the values of the accelerometer (x, y and z-axis values). To drive the motors that connected to the robot, authors have used the DC Motor Driver. And radio frequency link (RF) used as channel for wireless communication. However, the idea is used hand gesture to control the robot, but it’s more complex and more expensive.

Figure 3.4: Block diagram of “Gesture Controlled robot” (Mohd Aftab Usmani 2014)
4. BUDGETING AND PROJECT MANAGEMENT

This chapter shows the costing plan which presents the hardware requirements of the project, scheduling plan, Gantt chart and identify the risk managements.

4.1 Project Budget

Table 4.1 is shows the components that used in the project the approximate cost and some item description.

<table>
<thead>
<tr>
<th>Sr.No</th>
<th>Description</th>
<th>Qty.</th>
<th>Amount In OMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bluetooth Encoder HC05</td>
<td>1</td>
<td>4.37</td>
</tr>
<tr>
<td>2</td>
<td>Arduino UNO R3 board with DIP ATmega328P</td>
<td>1</td>
<td>11.78</td>
</tr>
<tr>
<td>3</td>
<td>High Quality LiPo 3S 2200mAh 25C Battery 11.1V</td>
<td>2</td>
<td>117.04</td>
</tr>
<tr>
<td>4</td>
<td>Planetary DC Geared Motor 1400 RPM</td>
<td>2</td>
<td>77.52</td>
</tr>
<tr>
<td>5</td>
<td>HS-7950TH Ultra Torque HV Coreless Titanium Gear Servo</td>
<td>1</td>
<td>47.88</td>
</tr>
<tr>
<td>6</td>
<td>PIC microcontroller Unviersal Target Board</td>
<td>1</td>
<td>1.33</td>
</tr>
<tr>
<td>7</td>
<td>Gemfan 1045 Propeller fan</td>
<td>2</td>
<td>8.36</td>
</tr>
<tr>
<td>8</td>
<td>Ormino iMax B3 imaxRC Pro Compact Charger</td>
<td>1</td>
<td>13.3</td>
</tr>
<tr>
<td>9</td>
<td>Ormino obby wing Platinum Brushless ESC 30A</td>
<td>1</td>
<td>4.37</td>
</tr>
<tr>
<td>10</td>
<td>Resistors (330Ohms and 10Kohms)</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>LEDs Red 5V</td>
<td>2</td>
<td>0.5</td>
</tr>
<tr>
<td>12</td>
<td>Capacitors (1microF, 22picoF, 10microF)</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>Transistor BC47</td>
<td>2</td>
<td>0.5</td>
</tr>
<tr>
<td>14</td>
<td>Lot 5 Large 40mm DC Buzzer</td>
<td>1</td>
<td>4.94</td>
</tr>
<tr>
<td>15</td>
<td>Momentary Push Button Horn Switch</td>
<td>1</td>
<td>3.23</td>
</tr>
<tr>
<td>16</td>
<td>Crystal 16Mhz</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>17</td>
<td>New DIYmall ESP8266 ESP-01S WiFi Module</td>
<td>1</td>
<td>17.86</td>
</tr>
<tr>
<td>18</td>
<td>Wires and connectors</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>22</td>
<td>Parallax Ping Ultrasonic Range Sensor 28015</td>
<td>1</td>
<td>34.77</td>
</tr>
<tr>
<td>23</td>
<td>Generic HC-SR505 Mini Pyroelectric PIR Sensor</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>24</td>
<td>ELECTROPRIME ENC-03MB Gyroscope Sensor</td>
<td>1</td>
<td>31.92</td>
</tr>
<tr>
<td>25</td>
<td>ELECTROPRIME a12100500ux0333 mmA7361 Accelerometer</td>
<td>1</td>
<td>28.88</td>
</tr>
<tr>
<td>26</td>
<td>SainSmart Digital Capacitive Switch Touch Sensor</td>
<td>1</td>
<td>28.5</td>
</tr>
</tbody>
</table>
4.2 Project Schedule

![Figure 4.1: Project Schedule](image)

4.3 Risk Management

Table 4.3 is describing the risk management in management risks, timing risks and technical risk.

![Table 4.2: Risk Management](image)
<table>
<thead>
<tr>
<th>Risk Type</th>
<th>Description</th>
<th>Possible Impact</th>
<th>Mitigation Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timing risk</td>
<td>Accruing, so it will change.</td>
<td>Late of finishing the planning report on time could be a big risk.</td>
<td>Must follow the scheduling plan to complete the report on time and to avoid the risk.</td>
</tr>
<tr>
<td>Technical risk</td>
<td>Complete the project on time.</td>
<td>Lead to the delay or failure in the implementation of the project.</td>
<td>Attend workshop and search for more information from the internet.</td>
</tr>
<tr>
<td></td>
<td>Using complex and new technologies in the project.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Correction of the objectives or analyzing data.</td>
<td>It leads to a risk if the objectives or data analysis are not clear.</td>
<td>Develop appropriate and a good plan to avoid a future problems that affecting the project.</td>
</tr>
</tbody>
</table>
5. DESIGN AND ANALYSIS

This chapter is discussed the system block diagram, system flow chart, technical requirements, schematic diagram, system design and analysis.

5.1 System Initial Design

This part shows system block diagram and system flow chart with the descriptions.

5.1.1 System Block Diagram

Microcontroller Atmega 328p is control the hovering motor, Ruddar motor and the turning of hovercraft as per the commands sent using either Android App or by using Matlab. Hovering motor and ruddar motor are the high speed coreless brushless outrunner motors. Turning motor is a servo motor which rotates by particular angle given by the controller. An electronic speed control (ESC) to vary an electronic speed motors. And a Bluetooth Module (HC-05) is used to receive instructions from the Android phone or Laptop with Matlab.
5.1.2 System Flow chart

System flow chart of “A hovercraft controlled by Android Application and by Gesture” as shows in figure 5.2. The system initializing when the application starts and Bluetooth received then select the buttons. If the system is selects the buttons, then “Blue control” is select the buttons (A,B,C,D,E,F,G,H) to control the directions of the hovercraft. If there is no buttons select then the system start again.

On the other hand, the hovercraft is also controlled by Gestures at Matlab. When the bluetooth receive of the laptop the program at matlab is processing the image, the hand gestures will controlled the hovercraft and it move right, left, straight and stop. And if there is no hand gestures the system will return back to process the image.
5.2 Technical Requirements

5.2.1 Hardware components

In this part hardware components will discussed in details.

5.2.1.1 ATMEGA 328:

The Atmel ATMEGA 328 is a low power CMOS 8-bit microcontroller taking into account the AVR improved RISC design. By executing capable guidelines in a solitary clock cycle, the ATMEGA 328 accomplishes throughputs drawing nearer 1 MIPS for each MHz permitting the designer of the system to streamline power utilization versus handling speed.
It gives the accompanying components: 4K/8K/16K bytes of In-System Programmable Flash with Read-While-Write capacities, 256/512/512 bytes EEPROM, 512/1K/1K bytes SRAM, 23 universally useful I/O lines, 32 broadly useful working registers, three adaptable Timer/Counters with analyze modes, interior and outside interrupts, a serial-programmable USART, a byte-arranged 2-wire Serial Interface, a SPI serial port, a 6 channel 10 bit ADC (8-channels in TQFP and QFN/MLF bundles), a programmable Watchdog Timer with inward Oscillator, and five programming selectable power-saving modes. Figure 5.3 shows pin mapping circuit of ATMEGA 328.(Datasheet 2016).

Features of ATMEGA 328: RISC Architecture with CISC Instruction set, Powerful C and get together programming, Scalable, Same intense AVR microcontroller center, Low power utilization and both digital and analog input and output interfaces.
5.2.1.2 Bluetooth Module (HC-05):

The Android stage consist support for the Bluetooth system stack, which permits a system to wirelessly exchange information with other Bluetooth device. The application structure gives access to the Bluetooth usefulness through the Android Bluetooth APIs. These APIs let applications wirelessly interface with other Bluetooth devices, enabling point to point and multi point wireless features.(Ali express 2015)

Using the Bluetooth APIs, an Android application can perform the following:
Scan for other Bluetooth devices, query the local Bluetooth connector for matched Bluetooth devices, Establish RFCOMM channels, associate with different devices through services discovery, exchange information to and from different devices and deal with multiple connections.
5.2.1.3 Servo Motor (V3006):

A servo motor is a special geared DC motor equipped with an electronic circuit for controlling the direction of rotation, as well as the position, of the motor shaft. Because a servo motor allows precise angular positioning of their output shaft, they are used extensively in robotics and radio-controlled cars, airplanes, and boats to control the motion of their various parts. In this lab session, we will first explore what a servo motor consists of and how it works and then illustrate how to interface it with a PIC microcontroller.

A servo motor (or servo) is a little box that contains a DC motor, an output shaft (servo arm) which is connected to the motor through a series of gears, and an electronic circuit to control the position of the shaft. The objective of using a servo is to achieve precise angular positioning of an object. (Embedded-Lab 2016)

Figure 5.5: Servo Motor. (Embedded-Lab 2016).
5.2.1.4 Brushless DC Motor (A2212/13T 1000KV):

These kinds of motors are high power motors used to allow the rotation of the wheels and make them move forward direction, backward or turning left. These motors have a RPM per volt. These motors will require 11.1 volts to work. The maximum efficiency is 80% and maximum efficiency current is 75%. The working principle of the motors could be achieved if the current conveying conductor is set in an attractive field, it acquire a mechanical force. These motors need LiPo battery to work and ESC to control the motor speed. These kinds of motors have internal mechanism, either electronic or electromechanical, in order to change the direction of the current that flows in a particular part of the motor. So, the motors speed could be controlled by making some changes to the strength of the current in its field rolling or using a variable supply voltage. Only small motors are used in toys.(IEEE Globalspec 2016)

Figure 5.6: Brushless Outrunner Motor (A2212/13T 1000KV) (IEEE Globalspec 2016)
5.2.1.5 Electronic Speed Control (ESC) 30A :

An electronic speed control (ESC) is used to vary and control the brushless DC motor speed. Its drive the motor with 30Amp current. Also to control the motor direction. ESC used to generate or regulate low voltage and limit current for brushless motor and microcontroller. Generally ECS accepted 50HZ PWM. ESC is connected between the LiPo battery and the brushless motor. ESC used two cells or three cells. The input 30A, 35Amp and the output 20A, 25Amp. (IEEE Globalspec 2016)

![Electronic Speed Control (ESC) 30A](image)

Figure 5.7: electronic speed control(ESC) 30A  (IEEE Globalspec 2016)

5.2.1.6 Lithium Polymer Battery (LiPo Battery) Discharge Battery:

LiPo Battery is high power battery and its safety. LiPo has three cells in series and in parallel is one cell. The voltage at single cell is 3.7V. The three cells at series is 11.1V. Also the maximum storage capacity is 2.2Ah. LiPo used at high motor power as brushless motor. LiPo battery can work for one hour and can recharge LiPo by used compact charger B3. (IEEEGlobalspec 2016).
5.2.2 Software components

5.2.2.1 Matlab:

A Matlab program is used simulate and design equations in the mathematical form. (B.Moler 2004)

Hand movements recognized by the program and what the meaning of each movement will be present here:

Step 1: Loaded the image of the hand gesture

Figure 5.8: Lithium Polymer Battery (LiPo Battery) (IEEE Globalspec 2016)

Figure 5.7: Left.jpg
Step 2: Skin -colors segmentation

The white and black colors, the hand is white (1) and the background is black (0)

This depend on skin color, scaling factor (Red, Green, Black) $\frac{R}{G} = 0$ to $1$

Threshold value $\frac{R}{G} > Th = 1(skin), \frac{R}{G} < Th = 0(background)$, is to remove the gap and noise that filter it.
Step 3: Located the COG (central of gravity), the midpoint at the hand, to detect the COG that take main of location of all the point which are white that one.

Step 4: Draw the circuit cutting, the circuit cut both the finger and wrist that interested in finger.

I interested in finger

\[ x(\text{raw}) = \text{center} + \text{radius} \cdot \cos \theta \]

\[ y(\text{colum}) = \text{center} + \text{radius} \cdot \sin \theta \]

Step 5:

Count the transition from black to white

The black is zero and white is one

The number of transition (the finger) – 1 (the wrist)

5.2.2.2 Android:

Android is an open-source operating system which means that any manufacturer can use it in their phones free of charge.

It was built to be truly open. For example, an application can call upon any of the phone’s core functionality such as making calls, sending text messages, or using the camera.

In this project, two Applications in Android are used:
1. Control Joys Tick. Figure 5.3 shows Control Joys Tick Application.

![Control Joystick](image1)

Figure 5.11: Control Joys Tick in Android

2. Bluetooth Control Figure 5.4 shows Bluetooth Control Application.

![Blue Control V2.0](image2)
5.3 Schematic Diagram

Figure 5.12: Bluetooth Control Android

Figure 5.13: Schematic Diagram
This is the reset and crystal circuit diagram. The RES SW is the reset switch and the C5 capacitor and R2 resistor helps in the reset of the microcontroller when the reset switch is pressed. On the right side is the crystal X1 with its supporting capacitors C3 and C4. Together they work to generate clock pulse for the microcontroller, which in this case is 16 MHz. These components get connected in this diagram virtually through labels. The reset label means that connection gets virtually connected to any other label on the circuit diagram having a label reset. Similarly the labels XTAL1 and XTAL2 get connected to the controller pins having the same labels respectively.

In this the circuit diagram of the power supply laid out. The connector J1 is the input connector where the battery gets connected. BR1 is the bridge rectifier to rectify the input for any disturbance in the input voltage. C1 capacitor is used as filter to smoothen the input supply. The U2 IC is a voltage regulator and is used to regulate the voltage to 5VDC. C2 is again used to filter out spikes and give a clean 5VDC output. LED D5 is used as power indicator LED and R1 is used to limit the current to the LED.
This is the microcontroller part of the circuit diagram. Here, all the pins have their respective labels to where they will get connected in the actual layout in the PCB.

There are a reset pin label on pin 1 which gets connected to the same label of reset from the reset circuitry part. For the motor connections, oc1a, oc1b and oc2a labels are getting connected to their respective labels on the motor connector labels. Oc2b is a redundant connection label which is not getting used. EN1 and EN2 are also redundant connections labels and not used. XTAL1 and XTAL2 connections go to the crystal circuitry. VCC and GND connections are power connection labels. Rest of the pin of the microcontroller are not getting used in the project.

This is the concluding part of the circuit consisting of motor connectors and Bluetooth module connector. J3, J4 & J5 are motor connectors each representing where the connections of the forward thrust motor, the hover motor and the rudder motor get connected. The VCC and GND labels give them the power supply needed to run and the oc1a, oc2a and oc1b are the connections from the controller to the motors which tell it when to run and when not to. The J2 connector is the Bluetooth connector which has rx and tx pins connecting with the controller. It acts as the interface between the controller and the android device for communication purpose.
That at this figure the hovercraft schematic diagram Figure 5.13. This consists of three motors. That two high power RPM motors (1000kv brushless motors) to drive the hovercraft, one below hovercraft (hovering motor) that to reduce friction on surface to make it hover at high performance power. The hovering motor is attached to a propeller which propels air into the hovercraft body so that it will hover over a surface its high speed motor and other motor (rudder motor) behind hovercraft to push or make it at forward direction with high RPM(high speed motor). On the other hand the servo motor is fixed at hovercraft rudder to control the movement of hovercraft to desired direction by curvature air at desired angle. Also two ESC (electronic speed control) to control the speed of motors and controlling the power(charge controlling), its connected between the motors and the batteries. The hovering motor, rudder motor and servo motor are controlled by using Microcontroller (AT Mega 328p) to success the desired output. The reset button that pressing will initiate the system and put the rudder motor in normal position. Also using Bluetooth encoder Model (HC-05) at the hovercraft to receive instructions and controlling by Android application (Bluetooth control) or by Matlab (hand gesture). The android application send the moves command to hovercraft, at the hovercraft Bluetooth(HC-05) received that and processes this command then this command receive is process by micro atmega328 at finally the motors are working. All this project is operating by high power batteries. There are two batteries (LiPo batteries), it has 11.1V and 2.2A and this type of battery is recharging battery.
5.4 System Design & Analysis

Servo motor:

The frequency 50 Hz (period of 20 ms)

It operates at 5 V and the angular rotation through 180°.

The range of PWM between 1.0 to 2.0 (ms).

<table>
<thead>
<tr>
<th>PWM (ms)</th>
<th>Angular position (ccw)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7</td>
<td>0</td>
</tr>
<tr>
<td>1.1</td>
<td>45</td>
</tr>
<tr>
<td>1.5</td>
<td>90</td>
</tr>
<tr>
<td>1.9</td>
<td>135</td>
</tr>
<tr>
<td>2.3</td>
<td>180</td>
</tr>
</tbody>
</table>

Delay clock cycle = i * 10

When (i) = 7

Pulse width = 7 * 10 * 10 = 0.7ms

When (i) = 23

Pulse width = 23 * 10 * 10 = 2.3ms
**Brushless Motor:**

That speed control using PWM and it will be 2 signal (high and low) between 0 and period T.

Time ($t_1$)

$V_{input}$ that ON state

Time ($t_2$)

$V_{input}$ that zero state

The total time period = $t_1 + t_2$

$V_{output}$ that

$V_a = V_{max}$

$T_{ON}$ = time period pulse on

$T_{OFF}$ = time period pulse off

The $V_{output}$ = varied form 0V to 5V

1) For the high speed signal (90%): That means ON time the green part of the signal and the white part that mean not receiving any voltage.

2) For the half voltage signal (50%):
3) For the low voltage signal (10%):

Than mean the average value of voltage is varied so used the PWM to control the speed of motor.

**LiPo Battery:**

The voltage:

There are 3 cells

Cell 1 = 3.70V

Cell 2 = 3.70V

Cell 3 = 3.70 V
\[ V = 3 \times 3.70V = 11.1 \, V \]

The current:

\[ 1C \times C = \text{Capacity of battery} \]

\[ 1C = 1 \times 2200\text{mAh} = 2.2\text{Ah} \]

### 6. SIMULATION, TESTING AND IMPLEMENTATION

At this chapter shows the system simulation and the system testing of this project. That includes the discuss of the circuit and application. Also that shows the result of the input/output and description of this project implementation. There are screenshots that contains the description of this final project testing, simulation, prototyping and implementation.

#### 6.1 System Simulation

The function for the hardware and software simulation, To get the desired input and output of project and make sure this result as the project working before the final implementation step. At this project is used continuity checking for hardware simulation to test the circuit components in the breadboard. That checking the current flowing at the electronic circuit, if there are short or open circuit or any connected is broken. By using the ISIS Proteus 7 for hardware simulation as that components available there, code simulation for ATMEGA328 using Arduino1.6.8 software and using the matlab for simulation the hand gesture part. As result, For all simulation get and show the desired input and output.

#### 6.1.1 Hardware Simulation on ISIS Proteus 7.0

As show at the hardware simulation circuit at figure 6.1.1 that some different when compare at project circuit diagram because at the ISIS Proteus 7 not available all the components but there are replace to others components do same function as simulation. At the lift side of figure 6.1.1 There are five push button switch as control the motors
direction and switch on the power as mentioned (start button, lift button, right button, forward button, stop button) and all those push button connected to RN(10k). There is L293D drive that provide bi-directional drive to the DC motors and there is a servo motor. All that control by atmega328p at the middle of the figure 6.1.1. On the right side is the crystal X1 with its supporting capacitors C3 and C4 which in this case is 15 MHz.

Figure 6.1.1 Hardware simulation circuit diagram

6.1.2 Hardware simulation system operation

As shown in figure 6.1.1 that the power on (Vcc) at the simulation circuit and there are switch on all components. So the main components the Atmega328p to controlling all system. Here, all the pins have their respective labels to where they will get connected in the system.
For the motors, the servo motor gets connected from pin 15. The DC motors get connected from pins 23, 24 for IN1, IN2 respectively and pins 25, 26 for IN3, IN4 respectively. Also connected pins 5, 6, 11, 12, and 13 to the push button switches. The XTAL1 and XTAL2 crystal X1 get connected to pins 9 and 10 together they work to generate clock pulse for the Atmega328p.

Figure 6.1.2.1 hardware simulation system operate
Figure 6.1.2.2 hardware simulation system (start)
Figure 6.1.2.3 hardware simulation system (forward)

Figure 6.1.2.4 hardware simulation system (left)
Figure 6.1.2.5 hardware simulation system (right)
6.1.3 C Code Simulation for ATMEGA 328 on Arduino1.6.8

At this part using C Code on Arduino1.6.8 for simulated atmega328
Figure 6.1.3.2 C Code Simulation for ATMEGA 328 on Arduino1.6.8
Figure 6.1.3.3 C Code Simulation for ATMEGA 328 on Arduino 1.6.8
6.1.4 System simulation matlab

At this part using MATLAB Code and simulated to control the system

Figure 6.1.4.1 MATLAB Code and simulation
Figure 6.1.4.2 MATLAB Code and simulation

Figure 6.1.4.3 MATLAB Code and simulation
6.2 system testing

When finish simulation and get the desired result, did testing for hardware components on the breadboard. Also the other components that not implement in the breadboard but including the system. At the continuity test that test or check the electronic circuit by visual check first that checking the components of all system if any components are damage or burnt. Then checking the current flowing at the electronic circuit, if there are short or open circuit or any connected is broken. That did after soldering the hardware components and modify. At this project did the continuity tests after soldering for each components at the electronic circuit both the main and others components to prevent and protect the electronic circuit form any fault. On the other hand, test the power by measuring the power supply output when apply voltage to the electronic circuit. That to make sure the micro atmega328 and system work probably and get the desired output. Because the atmega328 controlling all the system. So the testing for this system it will that testing implementation at PCB and testing at when add others components at final design.

Figure 6.2.1 The system implement in board with circuit connection

At figure 6.2.1 the all system implemented at the board for testing and get the output without control by android application, so all system control by atemag328. Testing the all motors (hover motor, rudder motor and servo motor) and testing the Bluetooth (HC-05).
At figure 6. implement the circuit and soldered on circuit board printed. Testing all connection and all components and get result. Other components connect to board as M1(hover motor), M2(rudder motor) and M3(servo motor).

6.2.1 Testing hardware part

At figure 6. show the testing board and show the LED red on and the buzzer on. Also the atmega328 control the motors.
figure.6.2.1.2 testing the Bluetooth(HC-05) and rudder motor

6.2.2 Testing matlab part
Figure 6.2.2.1 connect matlab and connect with the system

Figure 6.2.2.2 enter the image (straight) and connect with the system
Figure 6.2.2.3 enter image (left) and connect with the system.
6.3 System Implementation/Prototyping

After testing all system and get the desired output. At this part, design the project. Also show prototype of the all system project to see every part working and get every things clear.

Figure.6.2.2.4 enter image (right) and connect with the system

Figure.6.3.1 implement the motors in the system

Figure.6.3.2 that fitted the three motors in the design the hover motor under the design, servo motor at the front and fitted rudder motor in the servo motor.
Figure 6.3.2 implement PCB in the design

Figure 6. show that fitted the PCB in the design and put all the connection

Figure 6.3.3 implement the LiPo batteries

Figure 6. show that connect the LiPo batteries and ESC to the system.
Figure 6.3.4 The system power on

Figure 6. show the hover craft power on and control by android application (blue control).
7. CRITICAL EVALUATION

This chapter shows and describes technical problems that encountered while developing this project and the way to solves those problems. Those problems that show before at limitations which can solve and others cannot solve. While the planning and implementation of this project learnt valuable to develop and make this better project.

The objectives of this project as at chapter one are give the system performance result. The output of the objectives got as desired and successful.

The objectives are as follows:

- Using Microcontroller (ATMega328p) to control the hovering motors and rudder motor.
- Using Bluetooth encoder Model (HC-05) to receive instructions from Android or Matlab.
- Programming the Microcontroller to turning of hovercraft as per the commands send by Android or Matlab.
- Using Matlab to control the hovercraft by hand gesture.
- Using a servo motor to rotates hovercraft by particular angle and hovering motors to drive hovercraft.
- Using electronic speed control (ESC) to vary the speed motors.

On the other hand, when finishing the project there are some problems are faced as that hardware or software problems:

- At simulation ISIS software: there are some components not available at this project such as HC-05 bluetooth, servo motor, ESC and brushless motor. So
replaced by some components work correctly and give desired output. So it replaced by DC motor and by press button.

- At matlab software: the matlab program that include the image codes and Bluetooth codes and other codes that for motors are not give the desired output to control the hovercraft, so search for others codes and checking, change some codes to got desired output.

- At connection between hardware and software: that connection between the matlab program and hovercraft specially the HC-05 Bluetooth of hovercraft and matlab Bluetooth. So checking the distance to receive instructions and the codes.

- At hardware tested: when implement and tests some components at breadboard there are operated as desired but when implement and tests at stripboard are not operated as desired. So checking the connection and components and changing some connection and changing some burnt components because some connection wrong.

- At arduino software and C++ program: that the way to use the arduino to program some components as the atmega328 to control the motores and the codes that write at the program. So enter a course to learn how to program the atmega328 at arduino and put the codes at the program C++. also the others codes used to others components to got the desired output.

At both planning and implantation of this project, there are many lessons learned to got better project and a desired result. So that improved many things:

- Testing the components before implement at the system and operating.
- Using arduino to programming the components and improved skills.
- Using software program ISIS Proteus 8 to simulation and matlab program that its more familiar.
- Schedule of work to help and finishing the work on time and avoid any risks.
- Searching of components datasheets to avoid any risks during implement at project and operating.
8. LEGAL, SOCIAL AND ETHICAL ASPECTS RELATED TO THE PROJECT

At this chapter shows and discuss the social, ethical aspects, legal and the actions acceptable this project at society. on the other hand, ethical aspects actions from the engineering organization. On this project implementation should satisfying for the society and public. Also must provide and meet legal requirements.

This project likes others projects that development the our life to the best and comfortable using. From one idea to improve the life and safe using at the society. At this project provide and effects for the society without any problems or difficulty at human.

There are many useful from this project. The main useful or benefit that use new technology or development for technology. That using the high power performance with that aerodynamic design. Also that using high RPM motors with AVR microcontroller to be the high performance and got the best desired output. As result to be safety using this project at competition at the sea or at any smooth surface or as the toy for children that the aerodynamic design and covering. An android application that controlling all this project for safety and very easy way. That will be affects and acceptable at socially. Also by using the software that Matlab to simulate and control the the project. So can using this project technology at our life.

There are advantages and limitations at the final user at this project are matching with the IEEE Code of Ethics:

1) The responsibility is accept to making decision with the safety and healthy for the public and environment;

At this project the circuit use custom design to reducing costs. After review the past projects close to this projects, the tests results and the simulation and all this output matching with second code of IEEE.

2) To be correct and estimates on the obtainable data, this device maybe related to people. To make this system more perfect, add more characteristic. This matching with eighth code of IEEE.
3) To try and accept of the work technical and to correct the errors.

4) An understanding the system and technology its by documenting the way as matching fifth code of IEEE.

Most the components using at this project ether hardware or software are not available at the market and there are available at online.
9. CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

This project that about the hovercraft with high power performance with un wheel and the device is used at this system both hardware and software components in water races or at any smooth surface that can hover both at land or water with some develop technology. A hovercraft is controlled by Matlab through hand gestures and by two applications in the Android. This project is connected between hardware and software components to did same functionally that controlling the hovercraft. Also that connection it happened by the Bluetooth encoder (HC-05), that between hovercraft and android application and on the other hand between hovercraft and matlap program.

Additionally, the schematic diagram has two high power motors to drive the hovercraft, one below hovercraft that to reduce friction on surface to make it hover at high performance power and other motor behind hovercraft to push or make it at forward direction with high RPM. On the other hand the serve motor is fixed at hovercraft rudder to control the movement of hovercraft to desired direction. Also the ESC to control the speed of motors. The hovering motor and radar motor that controlled by using Microcontroller (AT Mega 328p). Also using Bluetooth encoder Model (HC-05) to receive instructions and controlling by Android application or Matlab. In addition this project operating by two high power batteries. https://hobbyking.con

Finally, the stage of project planning and implementation is a good experience for all software programming or hardware and it’s completed on time that by following the scheduling plan. The planning schedule help to complete the implementation stage and make every things going easy at time and completed all project.
9.2 RECOMMENDATIONS

- The project need more power to be more performance if make more weight on.
- The project need to recharge the batteries after one hour from switch on to remind the speed same as before.
- The project need to configure with WiFi to cover more distance when receive the instruction, Bluetooth encoder only cover 15 meter to receive the instruction.
- The project need to be close when controlling by the matlap by hand gesture.
REFERENCES

1. Ali express (2015) Bluetooth Module Breakout (HC-05), [Online], Available: 


3. Datasheet (2016) ATmega328, [Online], Available: 


6. SEI Insights (2016) SEI Insights, [Online], Available: 
https://insights.sei.cmu.edu/sei_blog/2013/11/using-v-models-for-testing.html [1 May 2016].


APPENDIX A

Features

- High Performance, Low Power AVR® 8-Bit Microcontroller
- Advanced RISC Architecture
  - 131 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 20 MIPS Throughput at 20 MHz
  - On-chip 2-cycle Multiplier
- High Endurance Non-volatile Memory Segments
  - 4/8/16/32K Bytes of In-System Self-Programmable Flash program memory
  (ATmega48PA/88PA/168PA/328P)
  - 256/512/1K1K Bytes EEPROM (ATmega48PA/88PA/168PA/328P)
  - 512/1K/1K2K Bytes Internal SRAM (ATmega48PA/88PA/168PA/328P)
  - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
  - Data retention: 20 years at 85°C/100 years at 25°C
  - Optional Boot Code Section with Independent Lock Bits
  - In-System Programming by On-chip Boot Program
  - True Read-While-Write Operation
  - Programming Lock for Software Security
- Peripheral Features
  - Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
  - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
  - Real Time Counter with Separate Oscillator
  - Six PWM Channels
  - 8-channel 10-bit ADC in TQFP and QFN/MLF package
    - Temperature Measurement
  - 6-channel 10-bit ADC in PDIP Package
    - Temperature Measurement
  - Programmable Serial USART
  - Master/Slave SPI Serial Interface
  - Byte-oriented 2-wire Serial Interface (Philips I²C compatible)
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - On-chip Analog Comparator
  - Interrupt and Wake-up on Pin Change
- Special Microcontroller Features
  - Power-on Reset and Programmable Brown-out Detection
  - Internal Calibrated Oscillator
  - External and Internal Interrupt Sources
  - Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended Standby
- I/O and Packages
  - 23 Programmable I/O Lines
  - 28-pin PDIP, 32-lead TQFP, 28-pad QFN/MLF and 32-pad QFN/MLF
- Operating Voltage:
  - 1.8 - 5.5V for ATmega48PA/88PA/168PA/328P
- Temperature Range:
  - -40°C to 85°C
- Speed Grade:
  - 0 - 20 MHz @ 1.8 - 5.5V
- Low Power Consumption at 1 MHz, 1.8V, 25°C for ATmega48PA/88PA/168PA/328P:
  - Active Mode: 0.2 mA
  - Power-down Mode: 0.1 µA
  - Power-save Mode: 0.75 mA (excluding 32 kHz RTC)
APPENDIX B

43R Servo (360° Rotation) Specification

Thank you for choosing Spring Model’s product.

<table>
<thead>
<tr>
<th>MODEL</th>
<th>TYPE</th>
<th>WEIGHT</th>
<th>4.8V SPEED</th>
<th>4.8V TORQUE</th>
<th>4.8V DESCRIPTION</th>
<th>GEAR BEARING</th>
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</thead>
<tbody>
<tr>
<td>SM-S4303R</td>
<td>Analog</td>
<td>44</td>
<td>80</td>
<td>3.3</td>
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<tr>
<td>SM-S4308R</td>
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<td>SM-S4315R</td>
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<td>62</td>
<td>14.5</td>
<td>201.4</td>
<td></td>
</tr>
</tbody>
</table>

▲ 43R Robot series servo controled via analog signal (PWM), stopped via middle point positioner.
▲ Standard interface (like JR) with 30cm wire.
▲ Rotation and Rest Point Adjustment: when analog signal inputs, servo chooses orientation according to impulse width. When impulse value of impulse width is above 1.5ms, servo is clockwise rotation, conversely, counterclockwise. Rest point need use slotted screwdriver to adjust the positioner carefully. Servo stops rotation when the input signal is equivalent to impulse width.
▲ Please choose correct model for your application.
Caution: Torque over-loaded will damage the servo’s mechanism.
▲ Keep the servo clean and away from dust, corrosive gas and humid air.
▲ Without further notification when some parameters slightly amend for improving quality.

Dimension (Unit: mm)
APPENDIX C

HC Serial Bluetooth Products
User Instructional Manual

1 Introduction

HC serial Bluetooth products consist of Bluetooth serial interface module and Bluetooth adapter, such as:

(1) Bluetooth serial interface module:
   Industrial level:   HC-03, HC-04(HC-04-M, HC-04-S)
   Civil level:       HC-05, HC-06(HC-06-M, HC-06-S)
                      HC-05-D, HC-06-D (with baseboard, for test and evaluation)

(2) Bluetooth adapter:
   HC-M4
   HC-M6

This document mainly introduces Bluetooth serial module. Bluetooth serial module is used for converting serial port to Bluetooth. These modules have two modes: master and slaver device. The device named after even number is defined to be master or slaver when out of factory and can’t be changed to the other mode. But for the device named after odd number, users can set the work mode (master or slaver) of the device by AT commands.

HC-04 specifically includes:

Master device:     HC-04-M, M=master
Slave device:      HC-04-S, S=slaver

The default situation of HC-04 is slave mode. If you need master mode, please state it clearly or place an order for HC-04-M directly. The naming rule of HC-06 is same.

When HC-03 and HC-05 are out of factory, one part of parameters are set for activating the device. The work mode is not set, since user can set the mode of HC-03, HC-05 as they want.

The main function of Bluetooth serial module is replacing the serial port line, such as:

1. There are two MCUs want to communicate with each other. One connects to Bluetooth master device while the other one connects to slave device. Their connection can be built once the pair is made. This Bluetooth connection is equivalently liked to a serial port line connection including RXD, TXD
### APPENDIX D

**Motor: MS2212-13 KV: 980**

<table>
<thead>
<tr>
<th>Technical Datas</th>
<th>Recommended Prop (inch)</th>
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<td><strong>KV</strong></td>
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<tr>
<td>Configuration</td>
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<td>Stator Length</td>
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<tr>
<td>Shaft Diameter</td>
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<tr>
<td>Motor Dimension (Dia. * Len)</td>
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<tr>
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<td>No. of Cells (Lipo)</td>
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<td>Max Continuous current (A) 180S</td>
<td>15A</td>
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<tr>
<td>Max Continuous Power (W) 180S</td>
<td>160</td>
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<tr>
<td>Max. efficiency current</td>
<td>(6-11A)&gt;78%</td>
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<tr>
<td>Internal resistance</td>
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<td><strong>Tested with T-motor 18A ESC</strong></td>
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<td>860</td>
<td>30.34</td>
<td>5.97</td>
<td>0.21</td>
</tr>
</tbody>
</table>
APPENDIX E

Lithium Polymer

Charge Characteristics

Discharge Rate Characteristics

Discharge Temperature Characteristics

Cycle Characteristics

**Table:**

<table>
<thead>
<tr>
<th>Model</th>
<th>Nominal Voltage (V)</th>
<th>Capacity (mWh/pcs)</th>
<th>Standard Charge System</th>
<th>External Dimensions (mm$^3$)</th>
<th>Weight (Max.g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPF3865269</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UPF404261</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>UPF406371</td>
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<tr>
<td>UPF417656</td>
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<tr>
<td>UPF574159</td>
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<tr>
<td>UPF606168</td>
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<tr>
<td>UPF644406</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

- **T1:** Discharge 2.0A (V ≤ 3.00V)
- **T2:** Discharge 0.5A (V ≤ 3.0A)
- **T3:** Discharge 0.2A (V ≤ 3.00V)

**Applications:**
- Notebook computer
- Cellular phone
- PDA
- Personal transceivers
- Handy terminal
- Cancorder
- Digital camera
- DVD player
- Digital audio player
- etc.

*1: Discharge 0.2A (V ≤ 3.00V) *2: Maximum without tab. *3: The maximum thickness of the standard shipment charging condition.
APPENDIX F

Waypoint brushless motor controllers use higher quality and more LEDs than is typical—for lowest internal resistance and are an optimized controller chip and firmware. As such, they outperform many ESCs which may cost two or even three times as much...

**Programmable Features**

<table>
<thead>
<tr>
<th>Battery Type</th>
<th>Lithium Polymer*</th>
<th>NiCD/NiMH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Break Strength</td>
<td>No Brake, Soft, Medium, Hard Brake</td>
<td>Soft, Medium, Hard Brake</td>
</tr>
<tr>
<td>Startup Speed</td>
<td>Very Slow, Slow, Medium, Fast</td>
<td>Very Slow, Slow, Medium, Fast</td>
</tr>
<tr>
<td>Frequency</td>
<td>60* to 30kHz</td>
<td>60* to 30kHz</td>
</tr>
<tr>
<td>Timing</td>
<td>Auto, 5, 12, 18, 25 degrees</td>
<td>Auto, 5, 12, 18, 25 degrees</td>
</tr>
</tbody>
</table>

The 10A to 20A Waypoint ESCs have a built-in speed limiter that will limit the maximum speed to 200km/h for both LiPo and nicad batteries. All ESCs are updated with firmware 2.0 to 4.82. After 4.82, the ESC must be re-calibrated to ensure proper performance.

**Waypoint Electronic Speed Controller (ESC) Setup**

1. **Initial Throttle Range Setup (you MUST complete this step!)**
   - Turn on transmitter and set throttle to maximum position (zero all trim)
   - Connect ESC to Receiver via a common channel with correct polarity
   - Connect Main Battery Pack to the ESC

   **After approximately 2 seconds,** the LED flashes rapidly, then 1 second later you will hear 2 beeps confirming the maximum throttle position has been set.

   **Within 16 seconds,** move throttle to minimum position, the LED flashes slowly for 1 second, then you will hear 2 beeps indicating minimum throttle position is set and confirmed. Disconnect the main battery pack from the ESC.

   You only need to do this once for your transmitter, as throttle range will be stored in the memory of the speed controller. If changing transmitter, reset the throttle range by performing again steps (a), (b), and (c) above.

Using your Waypoint Brushless ESC:

1. **Turn on transmitter with the throttle stick at minimum position.
2. Connect battery to the ESC. The LED flashes rapidly for 1 second, and then you will hear 2 beeps confirming minimum throttle range detected. Then you will hear one beep confirming the ESC is armed and ready. You're ready to fly.

   If you cannot arm properly, hear a pulsed warning tone, see continuous flashing LED

   **Check your transmitter. Is it on? (for Futaba TRANSMITTER, set Throttle to 100%)
   **Check the ESC Connectors to receiver. Proper Channel to polarity
   **Check Motor Connectors to ESC, reverse them if necessary.
   **Check your battery. Fully charged? Good condition? Replace battery?
   **Fly one receiver.

   Disconnect battery and then reconnect battery and listen again for warning signals.

   **Through Initial Throttle Range Setup again, careful to move stick to minimum throttle (50%) within 10 seconds after setting maximum throttle range.**

   **WARNING:** Do not fly your model with an ESC attached to the ESC, but your motor will not hear the confirmation tones.

**General Setup Instructions for Motor and ESC**

- Combined length of wires between Controller and Battery must NEVER exceed 20cm (8”)
- Use only quality Gold connectors of 20A + rating
- Insure proper solder joints
- Do NOT shorten Motor wires! (choose ESC size if needed)
- NEVER connect Battery—ESC reverse polarity
- Firmly mount the motor in model before running
- Test system first without propeller attached
- To reverse motor direction, switch connection of any two wires between Motor and Controller
- Do NOT exceed max suggested prop size, unless you confirm current is within spec with accurate ammeter.

**COOLING AIRFLOW MUST BE PROVIDED TO MOTOR AND ESC TO OVERTEMP. DAMAGE IS NOT COVERED BY WAYPOINT WARRANTY**

**Programming Waypoint ESC**

If you are using lithium polymer battery packs, in many cases you will not need to program the ESC at all. For many models, the default settings are already ideal. However, if you are using NiCd or NiMH batteries, or need to adjust brake setting for your glide, for example, then you will need the programming card #W-BLESC-PRG, your ESC connected to a Motor, a Battery Pack, and the instructions below.

Remove propeller from motor during programming!

(a) Consult the list below, and set Programming Dip Switch Bank (#1) to match your preferred ESC Settings
   (Switch 1 must be in the Zero (off) position)

(b) Connect your ESC to Program Card ESC Connector (#2)
   (Red=(+)-, Brown= (-), Orange-Signal)

(c) Connect your Battery Pack to the ESC

(d) Push Program Button (#3) and hold it until you hear 3 tones, each one second apart.

   Release the program button, detach battery, disconnect ESC from Programmer card.
   You are done!

**#3 Program Button**

**#2 ESC Connector**

**#1 Programming Switch Bank**

**SWITCHES 2 and 3: BATTERY TYPE**

001 = NiCd or NiMH
111 = Lithium Polymer

**SWITCHES 4 and 5: BRAKE STRENGTH**

001 = M3 Brake
111 = M5 Brake

**SWITCHES 6 and 7: STARTUP SPEED**

001 = Fast Start (0.15 seconds)
111 = Slow Start (0.70 seconds)

111 = Very Slow (1.0 second)

**SWITCHES 8 and 9: FREQUENCY**

001 = 450Hz
111 = 32kHz

**SWITCHES 10, 11, 12: TIMING**

001 = AUTO
111 = 10 degrees
011 = 12 degrees
101 = 15 degrees
001 = 20 degrees

NOTE: You can program without a MOTOR attached to the ESC, but you will not hear the confirmation tones.