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Solar powered Auto irrigation system

A Project Submitted to the Department of Electrical Engineering in Partial Fulfillment for the Requirements of the Degree of B.Sc. in Electrical Engineering

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ABSTRACT

In order to reduce the consumption of electrical energy and manpower in the agricultural sector and not to waste water, an automatic irrigation system powered by solar energy was designed. The system control unit is Arduino. Moisture sensors were used to determine soil moisture. An ultrasonic sensor was used to determine the water level inside the tank. The pump that fills the tank is connected to a protection system that makes it stop working if the main source of water is empty, whether it is a well or a river.

The goal of the project is to design an automated solar powered irrigation system and use electronic sensors to determine soil moisture and a water tank filling sensor instead of having humans work on these tasks.

The battery was charged through the solar panels, the panels emit a voltage of up to 18V and a current of up to 2.8A. The battery size is 12V and 9A. Charging the battery took about 7 hours. As for the system, it can work for up to 8 and a half hours. The sensors worked on sensing the humidity as the pumps turn on when the sensor dries up and the pumps start pumping water to irrigate the area. As for the ultrasonic sensor, when it sensed the lack of water in the tank, it sent a signal to the control unit and the pump worked to fill the tank, provided that the water source (river or well) was not empty and therefore the protection system did not stop the pump.

Table of Contents

Title		Page
DECLARATION		I
APPROVAL FOR SUBMISSION		II
ACKNOWLEDGEMENTS		III
ABSTRACT		IV
Table of Contents		V
List of Symbols / Abbreviations		VIII
List of Table		VIII
List of Figure		IX
Chapter One Introduction		
1.1	Background	1
1.2	Solar Energy	5
1.2.1	Solar Panel	5
1.3	Irrigation	5
1.3.1	General Types of Irrigation	6
1.3.1.1	Surface irrigation	6
1.3.1.2	Sprinkler irrigation	7
1.3.1.3	Drip irrigation	7
1.4	Design of Solar Panel	8
1.5	Objectives and Aims	8
1.5.1	Objectives	8
1.5.2	Aim	8

1.6 Literature Review 9

1.7 Summary of Literature Review 11

Chapter Two
Methodology

2.1 Introduction 13

2 .2 Experimental setup 13

2.2.1 Solar Panel 17

2.2.2 Arduino Uno 17

2.2.3 Solar Charge Controller 18

2.2.4 Water Pump Motor 18

2.2.5 Electric Battery 19

2.2.6 Relay 19

2.2.7 Soil Moisture Sensors 20

2.2.8 Ultrasonic 21

2.2.9 Breadboard 21

2.2.10 Jump Wire 21

2.2.11 Irrigation Sprinkler 22

2.3 Test Producer 22

Chapter Three
Result and Dissection

3.1 Introduction 23

3.2 Practical Result 23

3.2.1 Case 1: Charging and Discharging Solar panel 23

3.2.2 Case 2: Moisture Sensors 26

3.2.3 Case 3: Ultrasonic Sensor 28

Chapter Four
Conclusions and Recommendations

4.1	Conclusions	29
4.2	Recommendations	29

Reference

Reference 30

List of Symbols / Abbreviations

Symbols / Abbreviations	Notations
PIC	Peripheral Interface Controller
LCD	Liquid Crystal Display
GSM	Global System for Mobile Communications
VRT	Variable Rate Treatments
PV	Photo-Voltaic
PVC	Polyvinylchloride
PN	Positive Negative
SPADIS	Solar Powered Automatic Drip Irrigation System
WSNT	Wireless Sensor Network Technology
SPV	Solar photovoltaic
PWM	Pulse Width Modulation
IDE	Integrated Development Environment
USB	Universal Serial Bus

List of Table

No. Table	Title	page
3.1	State of Charge	24
3.2	State of Discharge	25

List of Figure

Figure	Title	Page
1.1	Solar Energy	5
2.1	The photograph of Experimental Setup	14
2.2	Circuit Design	15
2.3	Block diagram of Irrigation area	16
2.4	Block diagram of Tank	16
2.5	Solar Panel	17
2.6	Arduino Uno	18
2.7	Solar Charge Controller	18
2.8	Water Pump Motor	19
2.9	Electric Battery	19
2.10	Relay	20
2.11	Soil Moisture Sensors	20
2.12	Ultrasonic	21
2.13	Breadboard	21
2.14	Jump Wire	22
2.15	Irrigation Sprinkler	22
3.1	Variation State Charge	24
3.2	Variation State Discharge	26
3.3	Moisture Sensors OFF	27
3.4	Left Moisture Sensors ON	27
3.5	Right Moisture Sensors ON	27
3.6	Ultrasonic Sensor OFF	28
3.7	Ultrasonic Sensor ON	28

CHAPTER ONE

Introduction

Chapter One
Introduction

1.1 Background:

Solar energy would be a cost-effective option for all of our power needs. Since solar energy saves electricity and resources by reducing water loss and minimizing the use of grid power, irrigation systems for agriculture is one application of this technology. A solar powered irrigation device may be a viable option for farmers. This is an environmentally friendly method of energy production which, after the initial expenditure, provides free energy.

Recently, the best method of irrigation is studied by reducing the wasted amount of water and electricity. Automated spray irrigation sort can be achieved depending on moisture sensor, this moisture sensor is connected to the controller in order to measure soil moisture content in the root zone. In order to avoid the high moisture regions, sensor must be placed at least five feet from the down pouts. This type of irrigation helps electrical power by degrading utilization from the power network and storing water by degrading the losses in water **[1].**

In some countries, agriculture is considered as one of the major source of economic progress. The income of many countries depends directly on agricultural advancement. Moreover, the continuous increase in the population of a country demands more innovations in food production technology. The factors affecting agricultural progress must be studied thoroughly to obtain maximum results. The significant building block of agriculture is the irrigation system. In other words, the efficiency of irrigation system may induce ample effects on agriculture. Irrigation process should provide water to soil consistently when it is needed and stops water flow as well, when soil has soaked enough water. The excess of water in the crops is of no good, not only water is wasted but it also destroys crops. The failures caused through manual methods of irrigation has let us to think about some advance method which can be relied upon. Anything which is cost effective, labour saving and energy saving is considered efficient. Hence in this proposed system, a method which uses very less or no labour (runs on its own) has been recommended, saves electricity and is easy to use **[2].**

An automatic irrigation system using solar power which drives water pumps to pump water from bore well to a tank and the outlet valve of tank is automatically regulated using controller and moisture sensor to control the flow rate of water from the tank to the irrigation field which optimizes the use of water **[3].**

The proper method is to be implemented for the irrigation system because of lack of rain and scarcity of water in soil. Agricultural field always needs and depends on the water level of the soil. But continuous extraction of water from soil reduces the moisture level of soil to avoid this problem planned irrigation system should be followed. And improper use of water leads to wastage of significant amount of water. For this purpose, automatic plant irrigation system is designed using moisture sensor and solar energy.

The proposed system derives power from sunlight through photo-voltaic cells. Hence, the system cannot depend on the electricity. In this proposed model by using sunlight energy, power the irrigation pump. The circuit comprises of soil moisture sensor are inserted in the soil to sense whether the soil is wet or dry.

When the moisture level of the soil is low then the sensor detects the soil condition and gives condition to the relay unit connected to the switch of the motor. It will ON in dry condition and switch off the motor when the soil is in wet condition. The moisture level of the soil is sensed by the sensor inserted into the soil which gives signal to the microcontroller

whether the land needs water or not. The signal from the sensor received through the output of the comparator and it is preceded with instruction from the program stored in the microcontroller. When the soil is dry motor ON and in wet condition motor is OFF **[4].**

agriculture plays a very important role to development of country. The most important factor for the agriculture is timely and ample supply of water. But due to uncertain rainfall and water scarcity in land reservoirs, we are not able to make proper use of agricultural resources. Also unplanned used of water results in to wasting of water on large proportion. With the increase in agricultural activity and competitive demand from different sectors, it has become important to economize on the use of water. We can optimize use of water by adopting sensor base irrigation system.

Irrigation can be described as the application of water to the soil to make available essential moisture for growth. It also serves as insurance against drought and to provide a cooling effect on the soil environment for plant growth and development. Irrigation is also aimed at improving and raising the productivity of soil resources. The drip irrigation allows water to drip slowly to the roots of plants either on the soil surface or directly onto the root zone through a network of valves, pipes etc.In the modern world of today automation is encompassing nearly every walk of life. Automation solutions are more accurate, reliable and flexible and also reduced human efforts. Now a days plant automation is the necessity of the to survive in the globally competitive markets **[7].**

Irrigation is an artificial and an essential application of water historically followed to overcome the deficiencies in rainfall for the purpose of growing crops. Irrigation is the method in which controlled amount of water is supplied to the plants at regular intervals to maintain the soil moisture which is necessary for the germination of seeds. In many countries irrigation is an old art, as much as the civilization, but for humanity it is a science, the one to survive **[8].**

Water scarcity is a critical constraint to farming in many parts of the world. As per worldometers, the world population clock shows the current world population as 7517.80 million (i.e., as on 12th July, 2017 at 03:00p.m). After 25-30 years there will be a serious problem for food. In order to meet this food problem, there is a need for producing more agriculture yields using the available limited resources and by adopting the best techniques. The available traditional irrigation techniques are: ditch irrigation; terraced irrigation; drip irrigation and sprinkler system **[9].**

Automation has changed the life of humans by several ways. In fact, it is the enlightenment of humans towards enormous opportunities to save efforts and time. Automation is growing very rapidly in the last two decades, but the concept of automation in agriculture has not developed yet as much as automation in other fields such as machineries. Automation in agriculture is very vital because of, firstly by the year 2042, the population of the whole world is anticipated to increase to 9 billion. As a result, there will be a tough challenge in giving abundant high quality, cheap, secure and nutritious foods for such population, especially in terms of the general direction to utilize arable land for bio-fuel manufacturing. The second reason is that there are some obstacles in the tradition method of agriculture. And, they are wastage of seed and incorrect spraying of pesticide on crop, so soil standard becomes deteriorated. Consequently, food or produce become harmful to human body. Another obstacle is shortage of water and it is the main problem that several countries are facing, especially countries such as India, China, Brazil, and South Asian countries. Sometimes people of these countries are incorrectly use huge amount of water, and this leads to water management deficiency. To overcome all of the above obstacles of tradition agriculture and to be in the modern agriculture field, hi-tech agricultural and entrepreneurial start-ups and existing companies are rapidly growing **[11].**

The perfection of precision-agriculture technologies in1990s revealed a new way of thinking about mechanization for crop-concern. It proposed a number of approaches that although not new, brought about a transmission in the way of thinking and management of variability. With the yield mapping, that is a process of collecting georeferenced data on crop yield and its characteristics, and VRT or Variable Rate Treatments, that are applications of materials based on the precise area or its qualities, the spatial mount of variability could be practically estimated and treated for the first time, since mechanization was first used. Preprecision agriculture's managers supposed that spatial and temporal variability occurred but did not have tools to contract with it. Since then, the rate of management and treatments of the crop decreased from farm-scale down to field-scale, or even to sub-field scale with the changing of anticipations and interests. This technology trend has carried on to the point where at this moment has several advanced controllers that let the scale of treatment to be diminish further down to each plant and even more to leaf scale. In doing so, these new techniques of implementing advanced controllers into automation field have enabled the perfection of new concepts of practical crop management that were not available before. Now, after having new levels of automation, agricultural engineers have cut the road from large-scale machineries with high costs to the small and smart scale machineries with affordable costs **[12].**

1.2 Solar Energy :

Solar Energy, radiant light and heat from the sun, Solar energy is the most abundant source of energy in the world. Solar power is not only an answer to today's energy crisis but also an environmental friendly form of energy. Photovoltaic generation is an efficient approach for using the solar energy. Solar panels (an array of photovoltaic cells) are nowadays extensively used for running street lights, for powering water heaters and to meet domestic loads. The cost of solar panels has been constantly decreasing which encourage sits usage in various sectors. One of the application of this technology is used in irrigation systems for farming. Solar powered irrigation system can be a suitable alternative for farmers in the present state of energy crisis in India. This a green way for energy production which provides free energy once an initial investment is made. Solar irrigation system is an introduction of solar system in irrigation system. These would be done for conservation of electricity & take a proper utilization of sun rays for producing energy **[14].**

Fig.1.1 Solar Energy **[14].**

1.2.1 Solar Panel :

The solar panel is also known as a PV (photo-voltaic) panel. Photo-voltaic cells use sunlight energy and generate direct current electricity. In other words. PV is used to convert sunlight energy, which is formed of energy particles known as "photons", into electricity that can be used to power electrical components. The combination of PV modules is called PV panels.

1.3 Irrigation :

Water is the most important input for plant growth in agricultural production. Irrigation is the controlled application of water for agricultural purposes through manmade systems to supply water requirements not satisfied by rainfall. Crop irrigation is vital throughout the world in order to provide the world's ever-growing population with enough food. Irrigation can be defined as replenishment of soil water storage in the plant root zone through methods other than natural precipitation. Irrigation water is brought to cultivated land through artificial means, such as pipes, hoses or ditches. The irrigated land usually contains crops, grass or vegetation which would not receive enough water from rainfall or other natural sources. Sometimes the reason to irrigate a portion of land is that it happens to be a dry season with less-than-average amounts of rainfall, or it might be necessary to do so because the land would never receive enough water on its own to be fertile. The water used for irrigation might be taken from nearby lakes, reservoirs, rivers or wells **[13].**

1.3.1 General Types of Irrigation :

1.3.1.1 Surface Irrigation:

Surface irrigation is the application of water by gravity flow to the surface of the field. Either the entire field is flooded (basin irrigation) or the water is fed into small channels (furrows) or strips of land (borders). Surface irrigation is widely utilised and therefore a well-known system which can be operated without any high-tech applications. "In general, it is more labour-intensive than other irrigation methods. Proper design of surface irrigation systems takes into account the soil type (texture and infiltration rate), slope and levelness of the field, stream size, and length of run. It is generally more difficult to obtain high uniformity of water distribution in long fields on coarse textured soils (gravel and sands) than on fine textured soils (loams to clay). Leveling the fields and building the water ditches and reservoirs might be expensive, but once this is done, costs are low and self-help capacity is very high **[13].**

Type of Surface Irrigation:

1. Basin Irrigation
2. Furrow Irrigation
3. Border Irrigation

1.3.1.2 Sprinkler Irrigation:

Sprinkler irrigation is a method of providing rainfall-like irrigation to the crops. Water is distributed through a system of pipes, usually by pumping. Spray heads at the outlets distribute the water over the entire soil surface. A typical sprinkler irrigation system consists of the following components:

1. Pump unit.
2. Mainline (and sometimes sub-mainlines).
3. Lateral lines.
4. Sprinklers.

The pump unit is usually a centrifugal pump, which takes water from the source and provides adequate pressure for delivery into the pipe system. Mainline and sub-mainline pipes deliver water from the pump to lateral pipes. In some cases these pipelines are permanent and are laid on the soil surface or buried below ground. In other cases they are temporary, and can be moved from field to field. Pipe materials used are mainly PVC- and corrugated-iron-based today, but asbestos cement or aluminum alloy materials are also in use. The laterals deliver water from mainlines or sub-mainlines to the sprinklers. They can be permanent, but more often they are portable and made of aluminum alloy or PVC in order to be moved easily **[13].**

1.3.1.3 Drip Irrigation :

Drip irrigation, also referred to as micro-irrigation, trickle irrigation or localized irrigation, involves dripping water onto the soil at very low rates (2-20 l/hour) from a system of small diameter plastic pipes fitted with outlets called emitters or drippers. Water is applied close to plants so that only the part of the soil in which the roots grow is wetted, unlike surface and sprinkler irrigation, which involves wetting the entire soil profile. With drip irrigation, applications are more frequent (usually every 1-3 days) than with other methods, thereby providing a favourable high moisture level in the soil for the plant . As long as the application rate is below the soil's infiltration capacity, the soil remains unsaturated and no free water stands or runs over the surface . A typical drip irrigation system consists of the following components:

1. Pump unit.
2. Control head.
3. Mainlines and sub-mainlines.
4. Lateral lines.
5. Emitters or drippers.

1.4 Design of Solar Panel :

Photovoltaic cell use sun light to generate electricity, the generated power is the product of voltage times the current (i.e., P = V x I). The amount of electrical power generated by an individual photovoltaic cell at its output terminals depends upon the amount of solar radiation that hits its PN junction as well as the percentage of solar radiation it actually converts into electricity, in other words its efficiency. It is known that the optimum operating voltage of a PV cell under load is about 0.46 volts, generating a 3A current in full sunlight. Hence, the power output of typical solar photovoltaic cell is 1.38W. The power generated by a single cell is not enough to do any useful work. In our case, the battery theoretical capacity is 50W, hence we need more power. **[10].**

1.5 Objectives and Aims:

1.5.1 Objectives :

design irrigation system by solar energy. To use solar energy to operate irrigation pumps, conserve water and reduce human interference in agriculture.

1.5.2 Aim :

1. To increase the use of Renewable energy sources and meet demand of electricity in rural area.
2. To save the time of farmers.
3. Reducing human intervention.
4. To reduce wastage of water.

1.6 Literature Review :

Harishankar1 et al. 2014 [3] Cost effective solar power can be the answer for all our energy needs. Solar powered smart irrigation systems are the answer to the Indian farmer. This system consists of solar powered water pump along with an automatic water flow control using a moisture sensor. It is the proposed solution for the present energy crisis for the Indian farmers. This system conserves electricity by reducing the usage of grid power and conserves water by reducing water losses.

BALAJI and SUDHA. 2016 [4] The Auto irrigation system of this system uses soil moisture sensor to detect the moisture level and 4X4 keypad for various crops control. When the moisture content of the soil is reduced then the sensor sends detected value to the microcontroller. Then the water pump is automatically ON according to the moisture level. The main aim of this paper is to reduce the human intervention for farmers and use solar energy for irrigation purpose. The entire system controlled by the PIC microcontroller.

Murtaza et al. 2017 [5] Agriculture is the source of living of majority Indians and it also has a countless influence on economy of the country. The objective of our project is to reduce this manual involvement by the farmer by using an automated irrigation system which purpose is to enhance water use for agricultural crops. The inspiration for this project came from the countries where economy is based on agriculture and the climatic conditions prime to shortage of rains & scarcity of water. The farmers working in the farm lands are only dependent on the rains and bore wells for irrigation of the land. Even if the farm land has a water-pump, manual involvement by farmers is required to turn the pump on/off when needed. The project is intended to cultivate an automatic irrigation system which controls the pump motor ON/OFF on sensing the moisture content of the soil. In the field of agriculture, use of appropriate technique of irrigation is essential. The advantage of using this technique is to reduce human intervention and still certify proper irrigation. A software application was developed by predetermining the threshold values of soil moisture, temperature and water level that was programmed into an arm controller. This paper presents the controlling and monitoring the level of water and detecting the soil moisture content.

Vaidhya et al. 2018 [6] This paper proposes a model of variable rate automatic microcontroller based irrigation system. Solar power is used as only the source of power to control the overall system. The sensor is placed on paddy field and these sensors continuously sense the water level and give the message to the farmer informing the water level without visiting the paddy fields. Thus low-cost solar power can be the answer for all our energy needs. Solar powered smart irrigation systems are the answer to the Indian farmer. This system consists of solar-powered water pump along with an automatic water flow control using a moisture sensor. It is the convenient solution for the present energy crisis for the farmers. This paper reveals a model of automatic micro controller based irrigation system. This paper proposes a model of automatic microcontroller based irrigation system. Here solar energy act as the sole supplier of energy throughout. Sensors are placed on the field and these sensors continuously sense the water level and give the message to the farmer informing the water level without visiting the paddy fields. This paper proposes a model of automatic microcontroller based irrigation system. This system reduces the cost and increases productivity. This system conserves electricity by reducing the usage of grid power and conserves water by reducing water losses.

Amol et al. 2017 [7] Now a days we know that farmers facing the problem of load shedding to their farm. It’s very difficult to those farmers who having the large areas and not having the proper utilization of water due to lack of electricity .So solar power i.e. solar panel is absolutely perfect for use irrigation systems. Using solar panel the sun energy will be converted into electrical power and saves into the batteries. The objective of irrigation system is to keep measure on food security and the aim of automatic irrigation control system is to minimize the efforts of the human operator (gardener) in irrigation activities. This control system is built around PIC microcontroller programmed using embedded C language. Also using GSM TECHNIQUE microcontroller is sending message on operator mobile about pump status.

Kumar et al. 2017 [10] : The farmers working in the farmlands are dependent on the rains, river, pond and bore wells. Even if the farm land has a water-pump, most of the time it is being kept stand-still due to non-availability of grid power in the remote areas where the potential of sun light availability is tremendous throughout the year.

Increase in agricultural production depends to a large extent on the availability of water and power. If the solar power is harnessed, an agricultural pump can run during day hours without depending on grid power. It is observed that in addition to water and power shortage, the farmers are not aware of the scientific method of irrigating the agricultural land. By adopting a proper scientific method, the farmers can save water, energy, labouring time and production cost. The main objective of this paper is to establish an automatic solar powered drip irrigation system by adopting wireless sensor network technology (WSNT) by integrating Solar Photovoltaic System (SPV), Arduino Microcontroller, Soil Moisture Sensor, Mobile Bluetooth, Water Tank, Pump etc. WSNT employed in this work contributes not only to save energy, water, fertilizers but also ensure uniform watering at right time without manual intervention leading to enhance the quality and quantity of agricultural yields.

1.7 Summary of Literature Review :

In the first research (Harishankar1 et al. 2014), propose a solution to the current energy crisis of Indian farmers by means of a system consisting of a solar powered water pump combined with automatic water flow control using a humidity sensor.In the second research (BALAJI and SUDHA. 2016), a soil moisture sensor was used to detect the soil level Humidity and 4x4 keyboard to control different crops. When the soil moisture content is reduced, the sensor sends the detected value to the microcontroller. Then it is turned on Water pump automatically according to the humidity level The whole system is controlled by a PIC microcontroller.In the third research (Murtaza et al. 2017), the use of appropriate irrigation technology is the advantage of using this technology in reducing human intervention while continuing to certify appropriate irrigation. A software application is developed by pre-determining threshold soil moisture, temperature and water level values that are programmed into a lever controller.In the fourth research (Vaidhya et al. 2018), the use of solar energy as a source of energy only to control the general system, and the sensor is placed in the fields to know the water level, and the message is given to the farmer to inform the water level without visiting the fields. Solar energy works here as the only source of energy all the time. This paper proposes a model of an automated irrigation system based on a microcontroller. This system reduces cost and increases productivity.In the fifth research (Amol and et al. 2017), this control system was built around the PIC microcontroller programmed using the C language, also using a microcontroller TECHNIQUE GSM sends a message to the operator's mobile phone about the status of the pump.

In the sixth research (Kumar and et al. 2017), an automated solar-powered drip irrigation system was created by adopting wireless sensor network technology (WSNT) by integrating the solar photovoltaic (SPV) system, Arduino controller, soil moisture sensor, portable bluetooth, storage tank . water, pump, etc. The WSNT used in this work contributes to uniform and even irrigation.

CHAPTER TWO

Methodology

Chapter Two

Methodology

2.1 Introduction:

In this chapter, an experimental part will be shows, there are two part in this project, Irrigation area and tank. **Fig.2.2** shows the circuit design. **Fig 2.3** shows block diagram of Irrigation area and **Fig 2.4** shows block diagram of Tank.

2 .2 Experimental setup :

Experimental part consist of the components as follow :

1. Solar Panel
2. Arduino Uno.
3. Solar Charge Controller
4. Water Pump Motor.
5. Electric Battery.
6. Relay.
7. Soil Moisture Sensors.
8. Ultrasonic.
9. Breadboard.
10. Jump Wire.
11. Irrigation Sprinkler.

Fig.2.1 Shows the photograph of Experimental Setup

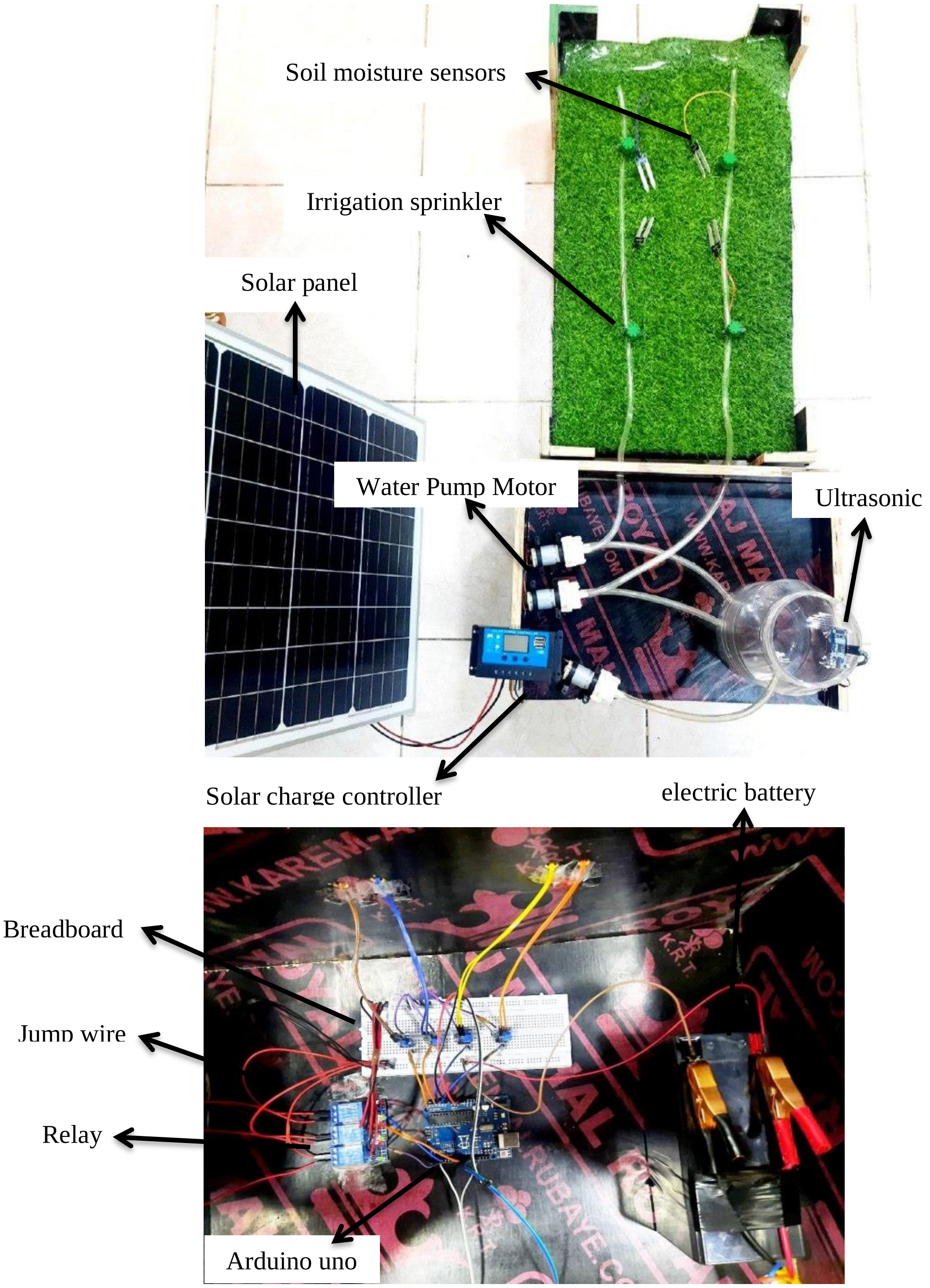

Fig.2.1 The photograph of Experimental Setup

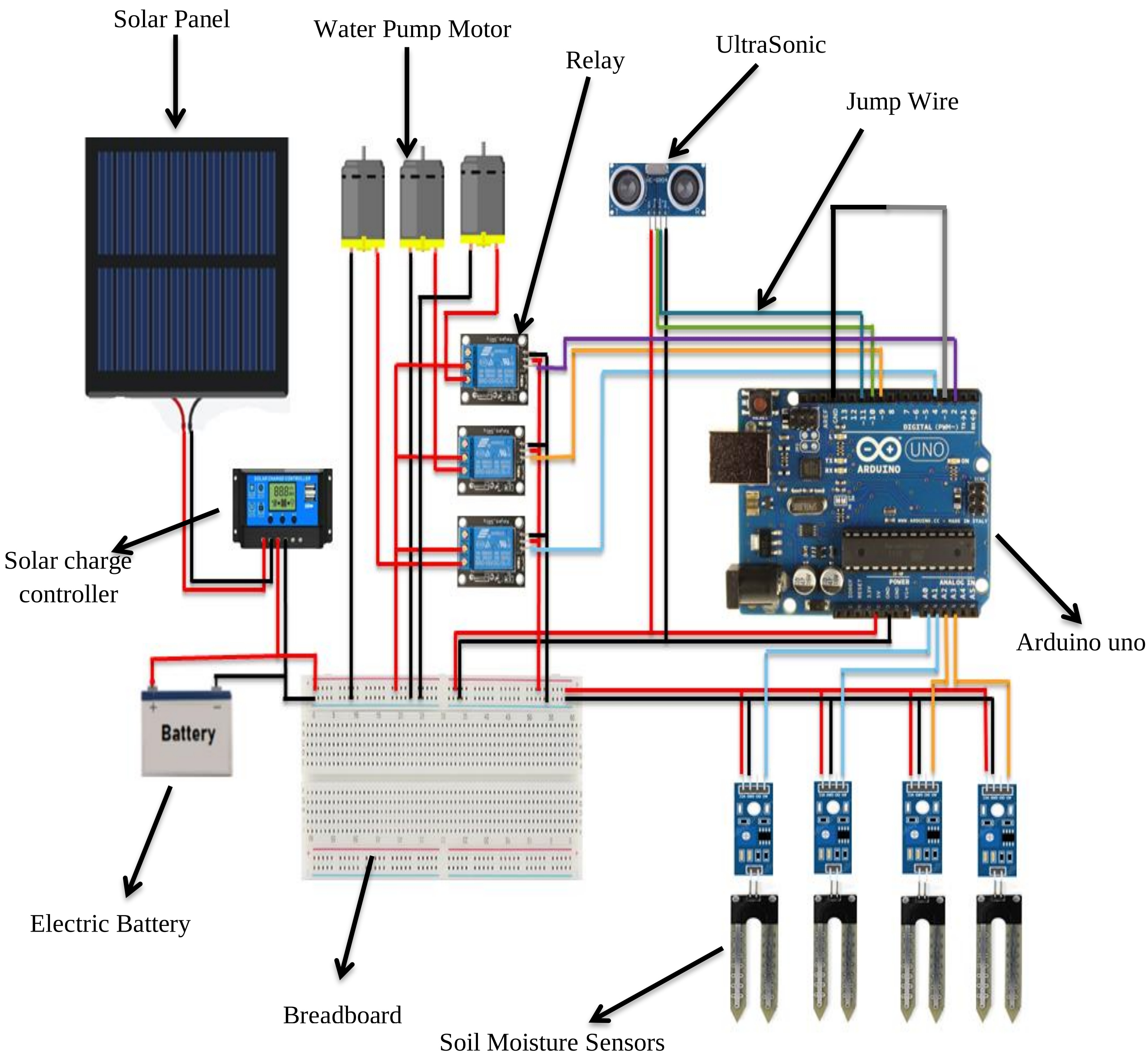

Fig.2.2 Circuit Design

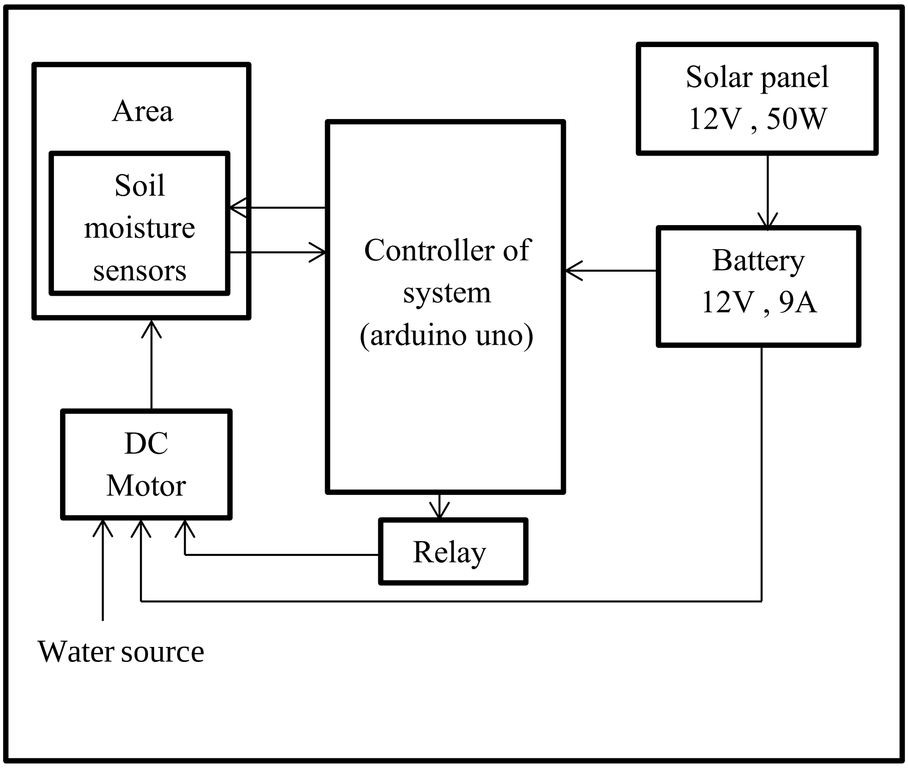

Fig.2.3 Block diagram of Irrigation area

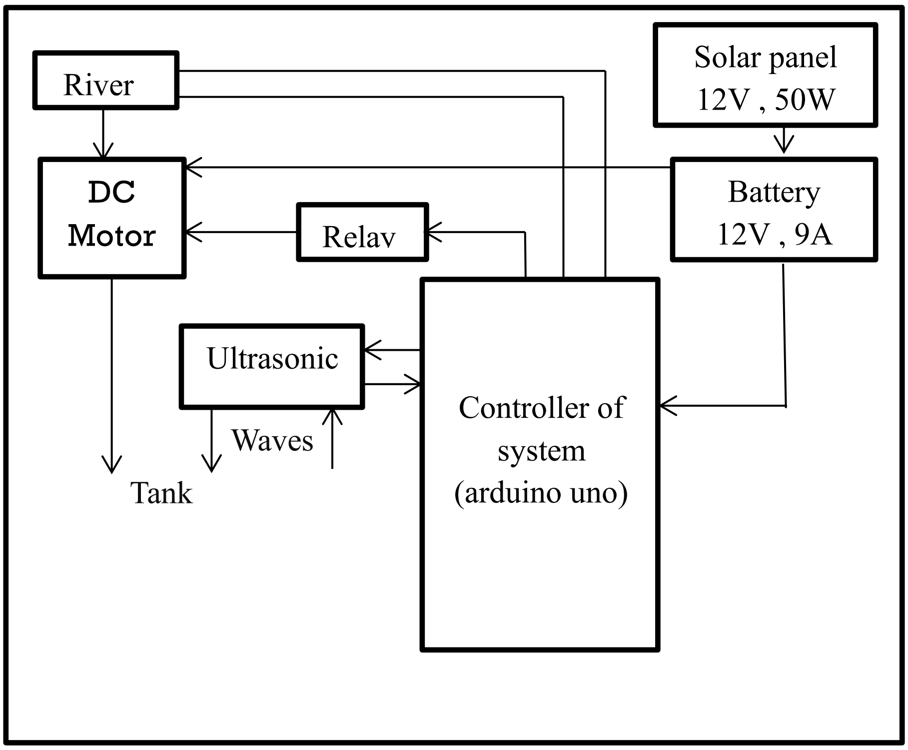

Fig.2.4 Block diagram of Tank

2.2.1 Solar Panel :

A solar cell panel, solar electric panel, photo-voltaic (PV) module, PV panel or solar panel is an assembly of photovoltaic solar cells mounted in a (usually rectangular) frame, and a neatly organized collection of PV panels is called a photovoltaic system or solar array. Solar panels capture sunlight as a source of radiant energy, which is converted into electric energy in the form of direct current (DC) electricity. Arrays of a photovoltaic system can be used to generate solar electricity that supplies electrical equipment directly, or feeds power back into an alternate current (AC) grid via an inverter system. Solar panel shown in **Fig. 2.5**.

Fig. 2.5 Solar Panel

2.2.2 Arduino Uno :

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc and initially released in 2010. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable. It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts. It is similar to the Arduino Nano and Leonardo. Arduino UNO shown in **Fig. 2.6 .**

Fig. 2.6 Arduino Uno

2.2.3 Solar Charge Controller :

Solar Charge Controller is an automatic control device used in the solar power generation system, which controls the multi-channel solar cell array to charge the battery and the battery to power the load of the solar inverter. Solar charge controller is the core control part of the whole photovoltaic power supply system. Solar charge controller shown in **Fig. 2.7.**

Fig. 2.7 Solar Charge Controller

2.2.4 Water Pump Motor :

DC-12V Pneumatic Diaphragm Water Pump Motor R365 is the perfect choice for any project that requires water to be moved from one place to another. The pump is supplied with 1M of silicon hose that you can cut to your requirements, the hose provides a good seal and will not leak. Possible uses/projects include; a small aquarium pump, automatic plant watering system, making a water feature or music activated dancing water features to name but a few. When pumping a liquid the pump runs very quietly. The pump is also capable of pumping air, though when pumping air the pump is quite noisy in comparison. The motor requires between 6 – 12V DC and between 0.5 – 0.7A and will deliver its maximum operating values when power is at the upper end of these ranges. The pump can handle pumping heated liquids up to a temperature of 80 degrees Celsius and when suitably powered can suck water through the tube from up to 2m and pump water vertically for up to 3m. This immersible pump can be used to water your plants, make a fountain or waterfall, and even change your fish tank water. It works quietly with the sound level under 30db. The pump has a filter inside as well as a suction cup which can help stick it to smooth surfaces tightly. Water Pump Motor shown in **Fig. 2.8** .

Fig. 2.8 Water Pump Motor

2.2.5 Electric Battery :

An electric battery is a source of electric power consisting of one or more electrochemical cells with external connections for powering electrical devices. Electric Battery shown in **Fig. 2.9.**

Fig. 2.9 Electric Battery

2.2.6 Relay :

A Relay is a simple electromechanical switch. While we use normal switches to close or open a circuit manually, a Relay is also a switch that connects or disconnects two circuits. But instead of a manual operation, a relay uses an electrical signal to control an electromagnet, which in turn connects or disconnects another circuit. Relay shown in **Fig. 2.10**.

Fig. 2.10 Relay

2.2.7 Soil Moisture Sensors :

Soil moisture sensors measure the volumetric water content In soil. Since the direct gravimetric measurement of free soil moisture requires removing, drying, and weighing of a sample, soil moisture sensors measure the volumetric water content indirectly by using some other property of the soil, such as electrical resistance, dielectric constant, or interaction with neutrons, as a proxy for the moisture content. The relation between the measured property and soil moisture must be calibrated and may vary depending on environmental factors such as soil type, temperature, or electric conductivity. Reflected microwave radiation is affected by the soil moisture and is used for remote sensing In hydrology and agriculture. Portable probe instruments can be used by farmers or gardeners. Soil moisture sensors typically refer to sensors that estimate volumetric water content. Another class of sensors measure another property of moisture in soils called water potential; these sensors are usually referred to as soil water potential sensors and include tensiometers and gypsum blocks. Soil Moisture Sensors shown in **Fig. 2.11** .

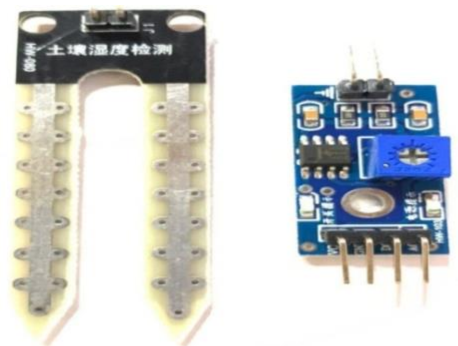

Fig. 2.11 Soil Moisture Sensors

2.2.8 Ultrasonic :

An ultrasonic sensor is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal. Ultrasonic waves travel faster than the speed of audible sound (i.e. the sound that humans can hear). Ultrasonic sensors have two main components: the transmitter (which emits the sound using piezoelectric crystals) and the receiver (which encounters the sound after it has travelled to and from the target). Ultrasonic shown in **Fig. 2.12 .**

Fig. 2.12 Ultrasonic

2.2.9 Breadboard :

An electronics breadboard, or solderless breadboard, is great for making temporary circuits and prototyping. Breadboard shown in **Fig. 2.13** .

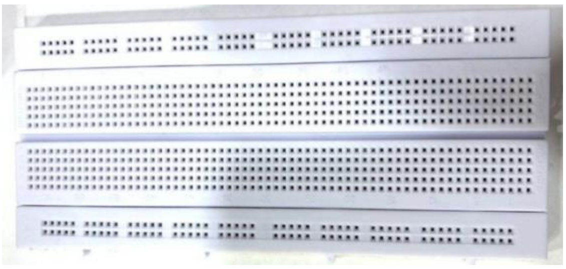

Fig. 2.13 Breadboard

2.2.10 Jump Wire :

Wires are simply wires that have connector pins at each end, allowing them to be used to connect two points to each other without soldering. Jumper wires are typically used with breadboards and other prototyping tools in order to make it easy to change a circuit as needed. Wires shown in **Fig. 2.14** .

Fig. 2.14 Jump Wire

2.2.11 Irrigation Sprinkler :

An irrigation sprinkler (also known as a water sprinkler or simply a sprinkler) is a device used to irrigate (water) agricultural crops, lawns, landscapes, golf courses, and other areas. They are also used for cooling and for the control of airborne dust.[citation needed] Sprinkler irrigation is the method of applying water in a controlled manner in way similar to rainfall. The water is distributed through a network that may consist of pumps, valves, pipes, and sprinklers. Irrigation sprinkler shown in **Fig. 2.15.**

Fig. 2.15 Irrigation Sprinkler

2.3 Test Producer :

1. Connecting power sources.
2. The sensors start working to give the results to the controller.
3. Humidity sensors give a signal to the control unit. If the area is not wet, the water pumps are working, if it is wet, the pumps remain idle.
4. Ultrasonic measures the water level in the tank to give a signal to the pump. If the water level is low, the pump works, if it is full, it stops.

CHAPTER THREE

Result and Discussion

Chapter Three
Result and Discussion

3.1 Introduction:

Nowadays the irrigation system have been most important for human to control the irrigation in dry area. the solar PV in this project used to power the system to reduce energy consumption and for friendly environment system .the Arduino used to control this system.

Two types of results was found by this system, first one for solar charging and discharge, the second one sensor will be used in this project.(Soil moisture sensors, Ultrasonic Sensor)

3.2 Practical Result:

3.2.1 Case 1: Charging and Discharging Solar panel:

In this part, the batteries are charged through solar panels. The capacity of the acid battery voltage used is 12V and 9A. The maximum voltage of solar panels was 18V.

Table 3.1 shows the state of charge with the time taken to charge the battery from its lowest state after being discharged to 10% of the full charge level, where it was fully charged within a period of 6 hours.

Through the ratio, it is clear that discharging the batteries took 8 hours and 20 minutes, while charging the batteries took 6 hours and 10 minutes from 7 am to 1:10 pm, The variation the battery voltage increases with time illustrator **Fig 3.1**.

Table 3.1 : State of Charge

percentage of charge%	Time in (min)	Time o'clock	Voltage (V)
10	60	7:00 AM	11.6
20	60	8:00 AM	11.7
30	50	9:00 AM	11.8
40	50	9:50 AM	11.9
50	35	10:40 AM	12
60	35	11:15 AM	12.1
70	30	11:50 AM	12.2
80	25	12:20 PM	12.4
90	25	12:45 PM	12.5
100	----	1:10 PM	12.7

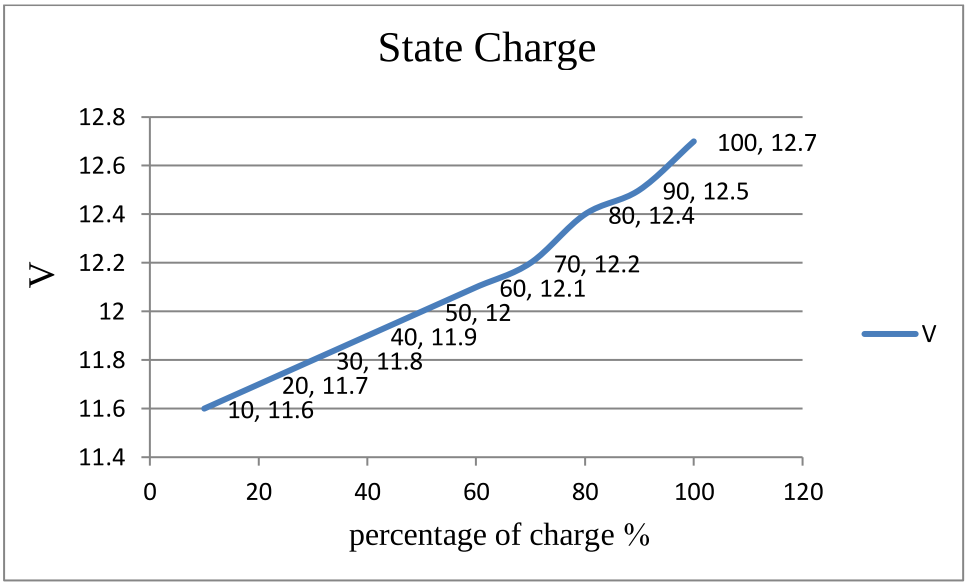

Fig 3.1 Variation State Charge

At hours from 10:30 AM to 01:00 PM, notice that during these hours the solar panels give the highest voltage output values as shown in **Fig 3.1**.

In **Table 3.2** shows the state of discharge and the period of time the batteries last, with 12.7V being the highest value when the charge rate is 100% and it starts to decrease gradually until it reaches its lowest value of 11.5V when it is 10% of the charge rate. The time for the discharge process begins after sunset, when energy begins to be drawn from the batteries. the battery voltage decrease with time illustrator **Fig 3.2.**

Table 3.2 : State of Discharge

percentage of charge%	Time in (min)	Voltage (V)
100	50	12.7
90	100	12.6
80	150	12.4
70	200	12.3
60	250	12.2
50	300	12.1
40	350	12
30	400	11.9
20	450	11.8
10	500	11.5

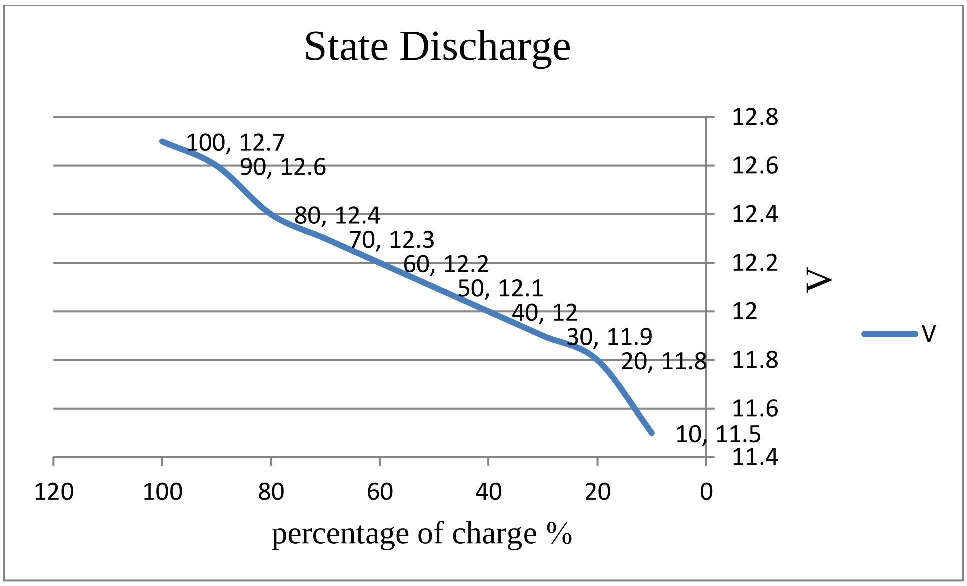

Fig 3.2 Variation State Discharge

3.2.2 Case 2: Moisture Sensors :

In this part there are four moisture sensors, every two humidity sensors are connected to each other and close to each other. When one or both of the sensors sense low moisture in the area they are in, they send the result to the controller. Therefore, the pump will irrigate the area.

In **Fig 3.3**. the sensors are located inside a wet area. Therefore, the pumps were turned off. In **Fig 3.4.** when we remove one of the sensors of the left zone, the removed sensor will sense the dryness of the zone and send a signal to the controller so that the pump irrigate the zone, and when the sensor gets wet and becomes wet again, it will send a signal to the controller to turn off the pump.

In **Fig 3.5.** repeat the same process, but on the sensors on the right, we notice that the second pump will work when we remove one of the sensors because the sensor sensed the dryness of the soil and its need for irrigation, so the sensor sends the signal to the control unit so that the pump works to spray water in the area, and when Sensor returns to wet, pump stops working.

Fig 3.3. Moisture Sensors OFF

Fig 3.4. Left Moisture Sensors ON

Fig 3.3. Moisture Sensors OFF

Fig 3.5. Right Moisture Sensors ON

3.2.3 Case 3: Ultrasonic Sensor :

The ultrasonic sensor senses the water level in the tank by sending waves and picking up the result. If the water level is low, it sends a command to the control unit to turn on the pump to fill the tank. When the water rises to the required level, it sends a command to the control unit to stop the pump.

In **Fig 3.3** , when the water level is too low in the tank, the ultrasonic sensor picks up the reflected waves, senses the low water level and gives the pumps a command to work and fill the tank. In **Fig 3.4** , the water level is close to the end of the tank, so it is pretty much full, and within walking distance of the ultrasonic sensor to stop, giving the stop command to the pumps to stop working.

A protection system is also built in for the pump that fills the tank through the control unit. It consists of two protection wires attached to the end of the pump pipe that fills the reservoir and its pipe either in the river or in the well. When there is water, the two wires will be connected, but if there is no water in the well or river, the two wires will be separated, and even if there is no water in the tank, the pump will not work. The benefit of this system is to protect the pump from continuous work in the absence of water, which leads to damage to the pump, and these two wires were made to work in this way through the code that was programmed in the control unit

Fig 3.6: Ultrasonic Sensor OFF

Fig 3.7: Ultrasonic Sensor ON

CHAPTER FOUR

Conclusions and Recommendations

CHAPTER FOUR

Conclusions and Recommendations

4.1 Conclusions :

1. The use of solar energy for agricultural projects to reduce costs resulting from the provision of electricity needed to operate the pumps, and because these areas are far from energy sources.
2. Automated irrigation using moisture sensors is better for reducing human effort costs, giving more accurate results, and conserving water.
3. An ultrasonic sensor was used instead of a float because it is more accurate in determining the water level and can be programmed to choose the desired level.

4.2 Recommendations :

1. Connect the system to the user via WiFi by sending moisture sensor ratios and results to the farmer.
2. Connect the ultrasonic sensor to Wi-Fi as well, so the user can know the water level in the tank and send an alarm if the water exceeds the desired level.

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شكر واهداء

أشكر الله تعالى على فضله حيث أتاح لي إنجاز هذا العمل بفضله، فله الحمد أولاً وآخرًا.

نتقدم بجزيل الشكر والتقدير الى الاستاذة المشرفة "هبه هادي كردي" على كل ما قدمته لنا من توجيهات ومعلومات كما نقدم جزيل الشكر الى أعضاء لجنه المناقشة الموقرة.

وأيضا أتقدم بالشكر إلى أبي وأمي، إلى من يجري حبهما جري في عروق دمي، كلمات الحبّ عجزت عن وصف حبّي الكبير لعظمتكم، فحروف العشق عجزت عن نظم أجمل القصائد والألحان فيكم.

أسم الطالب
اطياف مثنى راضي
اية ابا بكر سعدي
سجاد مسلم كاظم
احمد سلمان عزيز

خلاصة

من أجل تقليل استهلاك الطاقة الكهربائية والأيدي العاملة في القطاع الزراعي وعدم إهدار المياه ، تم تصميم نظام ري آلي يعمل بالطاقة الشمسية. وحدة التحكم في النظام هي Arduino. تم استخدام مستشعرات الرطوبة لتحديد رطوبة التربة. تم استخدام جهاز استشعار بالموجات فوق الصوتية لتحديد مستوى الماء داخل الخزان. المضخة التي تملأ الخزان متصلة بنظام حماية يجعله يتوقف عن العمل إذا كان المصدر الرئيسي للمياه فارغًا ، سواء كان بئرًا أو نهرًا.

الهدف من المشروع هو تصميم نظام ري آلي يعمل بالطاقة الشمسية واستخدام مستشعرات إلكترونية لتحديد رطوبة التربة وجهاز استشعار لتعبئة خزان المياه بدلاً من جعل البشر يعملون في هذه المهام.

تم شحن البطارية من خلال الألواح الشمسية ، وتصدر الألواح جهدًا يصل إلى 18 فولت وتيار يصل إلى 2.8 أمبير. حجم البطارية 12 فولت و 9 أمبير. استغرق شحن البطارية حوالي 7 ساعات. أما بالنسبة للنظام فيمكن أن يعمل لمدة تصل إلى 8 ساعات ونصف. عملت المستشعرات على استشعار الرطوبة حيث تعمل المضخات عندما يجف المستشعر وتبدأ المضخات في ضخ المياه لري المنطقة. أما بالنسبة للحساس بالموجات فوق الصوتية ، فعندما استشعر نقص الماء في الخزان أرسل إشارة إلى وحدة التحكم وعملت المضخة لملء الخزان بشرط أن يكون مصدر المياه (نهر أو بئر) غير فارغ وبالتالي فإن نظام الحماية لم يوقف المضخة.

وزارة التعليم العالي والبحث العلمي
الجامعة العراقية

كلية الهندسة

قسم هندسة الكهرباء

نظام ري آلي يعمل بالطاقة الشمسية

مشروع مقدم إلى قسم هندسة الكهرباء هي جزء من متطلبات نيل درجة البكالوريوس. في هندسة الكهرباء

من قبل

اطياف مثنى راضي

اية ابا بكر سعدي

سجاد مسلم كاظم

احمد سلمان عزيز

بأشراف

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Ministry of Higher Education and Scientific Research
Al-Iraqia University
Collage of Engineering
Electrical Engineering Department

Solar Energy Based Water Purification System

A Project Submitted to the Department of Electrical Engineering in Partial Fulfillment for the Requirements of the Degree of B.Sc. in Electrical Engineering

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2022-2023

DECLARATION

We hereby declare that this project report is based on our original work except for citations and quotations, which have been duly acknowledged.

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Signature

Name: حسين احمد محسن

Date:

APPROVAL FOR SUBMISSION

We certify that this project report entitled “Solar energy based water purification system” was prepared by Doha Ammar, Saif AL-dein Zuhair, and Ahmed Abd-Alnabi has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Electrical Engineering at Al-Iraqia University.

Approved by :

Signature :

Supervisor : Asst. Lec. Hiba H. Kurdi

Date :

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First and forement, prises and thanks to ALLAH who helped us to complete this research

We would like to thank the project supervisor (Lec. Hiba H. Kurdi), who each provided advice and Guidance throughout the search process and assist us in completing this work.

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ABSTRACT

Nowadays, pure water for drinking is a global problem, and water is the basis of life, getting pure water in faraway areas is a major problem of this project.

The aim is to design a water purification system using clean energy by solar panels and using (reverse osmosis) by purifying water and reading the water quality and sending it to the mobile.

The project was run and implemented using Solar panel, reverse osmosis system, controller (esp8266), Battery (Lead acid), pH sensor and TDs sensor, and dc-dc converter. The reverse osmosis system is turned on, which starts by purifying the water and sending it to the purified water tank. Sensors placed inside the purified water tank begin to read the data and send it to the controller which in turn will send the data to a program on the phone, the data is read from the phone and make sure that the water is clean and safe to drink.

The result showed that the system by using the sensors could produce pure water, and the remaining dirty water can be revised and entre in to system to reused it and all this work has done by renewable energy system.

Table of Contents

Title	Page
DECLARATION	**I**
APPROVAL FOR SUBMISSION	II
ACKNOWLEDGEMENTS	III
ABSTRACT	IV
Table of Contents	V
List of Table	VII
List of Figures	VIII

Chapter One

Introduction

Title	Page
1.1 Background	1
1.2 Solar Energy	2
1.3 Solar Panel	3
1.4 Water Purification Systems	3
1.5 Types of Water Purification Systems	3
1.5.1 Reverse osmosis (RO)	3
1.5.2 Ultrafiltration and microporous filtration	4
1.5.3 Ultraviolet (UV) radiation	4
1.6 Aim and Objective	5
1.6.1 Objective	5
1.6.2 Aim of Project	5
1.7 Literature Review	6
1.8 Summery	7

CHAPTER TWO

Methodology

2.1 Introduction……………………………………………………………………8

2.2 Experimental Setup……………………………………………………………9

2.2.1 Solar System Circuit…………………………………………………… 9

2.2.2 Purification System Circuit………………………………………………9

2.3 Solar Charging Circuit………………………………………………………12

2.3.1 Solar Panel……………………………………………………………12

2.3.2 Solar Charger Controller……………………………………………13

2.3.3 Battery…………………………………………………………………14

2.4 Purification System Circuit…………………………………………………15

2.4.1 NodeMCU ESP8266…………………………………………………15

2.4.2 Reverse Osmosis (RO)………………………………………………16

2.4.3 Ultrasonic sensors……………………………………………………16

2.4.4 DC-DC Converter……………………………………………………17

2.4.5 Ph Sensor………………………………………………………………17

2.4.6 Tds sensor………………………………………………………………18

2.4.7 Breadboard……………………………………………………………19

2.4.8 Wire……………………………………………………………………20

2.5 System Design…………………………………………………………………21

2.5.1 Part 1: Solar Charge Circuit…………………………………………21

2.5.2 Part 2: Arduino Circuit Connection…………………………………22

2.5.3 Part 3: Ro Connection…………………………………………………23

2.6 Test Producer……………………………………………………………………23

CHAPTER THREE

Result & Dissection

3.1 Introduction………………………………………………………………………….24

3.2 Practical Result………………………..…………………………………………….24

3.2.1 Case 1: Charging and Discharging Solar Bank……………………………..…….24

3.2.2 Case 2: Discharging Solar Bank Battery…………………………………….…..26

3.2.3 Case 3: Measurement of PH and TDS in water……………………………………….29

CHAPTER FOUR

Conclusion & Recommendation

4.1 Conclusion…………………………………………………………………………..31

4.2 Recommendation……………………………………………………………………31

References

References……………………………………………………………………………..32

List of Table:

Table Title **Page**

3.1 State of Charge……………………………………………………………….….25

3.2 State of Discharge…………………………………………………………….….27

3.3 Parameter of Solar Output…………………………………………………..…....28

3.4 Acidity and basicity of some substances……………………………………….…...29

List of Figures:

Figure Title **Page**

1.1 Solar panel system…………………………………………………………………2
1.2 Basic principle of Reverse osmosis……………………………………………..…4
1.3 Basic principle of UV water purification……………………………………………..5
2.1 [A] the Block Diagram of Circuit……………...……………………………………9
2.2 [B] the Block Diagram of Circuit……………………………………………………..11
2.3 The contents of the project practically……………………,………………………12
2.4 Solar Panel ……………………………………………………………………13
2.5 Solar Charger Controller ……………………………………………………..14
2.6 Battery (lead acid)……………………………………………………………….15
2.7 NodeMCU ESP8266 ……………………………………………………………….16
2.8 Reverse Osmosis (RO) ………………………………………………………….17
2.9 Ultrasonic sensors……………………………………………………………………..17
2.10 DC-DC Converter from 12 v to 24 v ……………………………………………....18
2.11 ph sensor ……………………………………………………………………………19
2.12 Tds sensor ……………………………………………………………………………..20
2.13 Breadboard……………………………………………………………………….20
2.14 wire ……………………………………………………………………………...21
2.15 Solar Charge Circuit……………………………………………………………...22
2.16 Arduino circuit Connection ……………………………………………….….23
2.17 Ro Connection……………………………………………………………………24
3.1 Variation State Charge………………………………………………………………25
3.2 Variation State Discharge……………………………………………………...26
3.3 [A] Variation Solar voltage Output………………………………………………….27

3.3 [B] Variation Solar current Output…………………………………………………….27

3.4 Acidity and basicity of water in the project……………………………………………..29

3.5 Readings sensors on blynk…………………………..…………………………...30

3.6 Readings sensors on phone..…………………………….…………………….....……..30

CHAPTER ONE
Introduction

CHAPTER ONE
Introduction

1.1 Background:

Water is the most important substance on earth Humans are fully dependent on water to survive and to live healthily. This makes water a very scarce resource since it is used daily, Water purification is the process of removing undesirable chemicals, biological contaminants, suspended solids as well as gases from water.

Research shows that to maintain a healthy lifestyle, an average male/female consumes approximately 3.7 liters/2.7 liters of water per day with many areas not connected to the electricity grid, particularly in developing countries, access to clean, decontaminated water is a critical problem.

Therefore, it is necessary to develop a water purification system that disinfects and cleans biologically contaminated water through the utilization of a readily available energy source, the sun.

The development of a sustainable water purification system which is relatively easy to manufacture and maintain, while relying on a readily available power source (like solar energy) is necessary and important. Although it is not a permanent solution, such a system can assist in improving the quality of human life.

Solar energy poses no polluting effect and may be used as a dependable energy source. A solar water purification system consists of a solar collector that absorbs sunlight to ensure boiling which is the first stage of purification; and a filter that removes contaminants **[1].**

The Solar-Powered Water Purification System functions to remove chemical and microbial impurities from salt water through the use of solar energy. The use of sustainable energy sources creates an environmentally friendly and self-contained system that can be used in a wide range of locations **[2].**

1.2 Solar Energy:

Solar power is simply usable energy generated from the sun in the form of either electric or thermal energy. Solar energy is captured in a variety of ways, with the most common being a solar photovoltaic system, or PV system, that converts the sun's rays into usable electricity and Low-carbon energy does not cause global warming or environmental problems, but is clean energy that depends on renewable sources

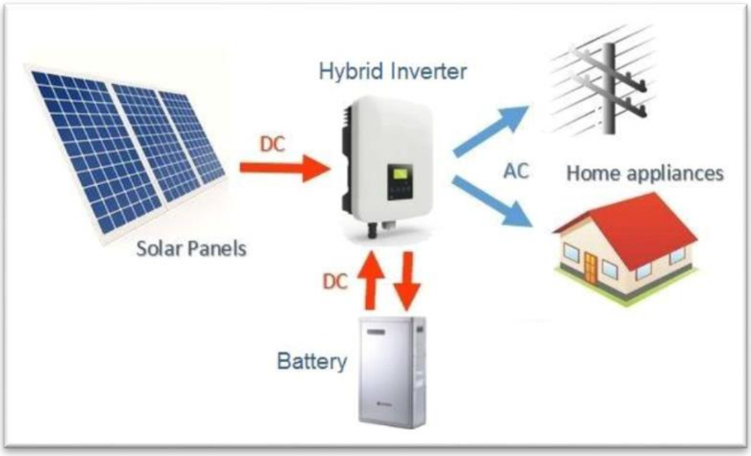

Fig. 1.1 Solar Panel System

Photovoltaics were initially solely used as a source of electricity for small and medium-sized applications, from the calculator powered by a single solar cell to remote homes powered by an off-grid rooftop PV systems in the Fig. 1.1 , as the cost of solar electricity has fallen, grid-connected solar PV systems have grown more or less exponentially. Millions of installations and gigawatt-scale photovoltaic power stations continue to be built. As of 2021, solar generates 4% of the world's electricity, compared to 1% in 2015 the cheapest liveliest cost of electricity is utility-scale solar **[3].**

.

1.3 Solar Panel:

Solar energy begins with the sun. Solar panels (also known as "PV panels") are used to convert light from the sun, which is composed of particles of energy called "photons", into electricity that can be used to power electrical loads. Solar panels can be used for a wide variety of applications including remote power systems for cabins, telecommunications equipment, remote sensing, and of course for the production of electricity by residential and commercial solar electric systems **[3].**

1.4 Water Purification Systems:

Water purification is the process of removing unwanted chemicals, biological contaminants and floating solids from water. The goal is to produce pure healthy water suitable for human consumption or for specific purposes. Most of the water that is purified is water for human consumption (drinking water) Water can be purified for other purposes, including this includes medical, pharmaceutical, agricultural, chemical and industrial applications through many Methods that we will mention later.

The goal is to produce pure healthy water suitable for human consumption or for specific purposes. Most of the water that is purified is water for human consumption (drinking water). Water can be purified for other purposes, including this includes medical, pharmaceutical, agricultural, chemical and industrial applications through many methods that we will mention later **[4].**

1.5 Types of Water Purification Systems:

There are many types of water purification, but we will mention the most important ones.

1.5.1 Reverse Osmosis (RO):

Reverse osmosis (RO) is a water purification process that uses a partially permeable membrane to separate ions, unwanted molecules and larger particles from drinking water. In reverse osmosis, an applied pressure is used to overcome osmotic pressure, a colligative property that is driven by chemical potential differences of the solvent, a thermodynamic parameter **[5].**

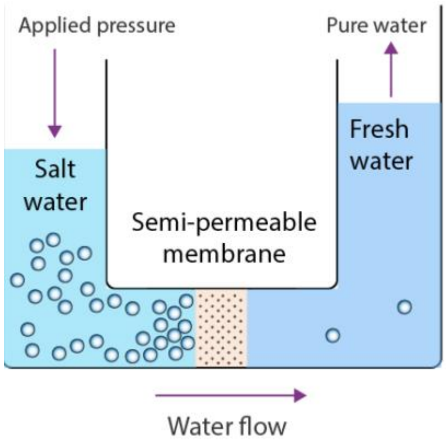

Fig 1.2 Basic Principle of Reverse Osmosis

The result is that the solute is retained on the pressurized side of the membrane and the pure solvent is allowed to pass to the other side. To be "selective", this membrane should not allow large molecules or ions through the pores (holes), but should allow smaller components of the solution (such as solvent molecules, e.g., water, H2O) to pass freely as in the Fig1.2 **[5].**

1.5.2 Ultrafiltration And Microporous Filtration:

Microfiltration (MF) and ultrafiltration (UF) solve a variety of process liquid treatment and purification needs, generally with low operational costs and a small footprint. MF and UF are typically incorporated within a larger treatment process, and, when used to pretreat process streams, MF/UF systems are particularly effective at preventing costly fouling of downstream equipment, such as RO units or removing bacteria and virus from drinking water **[6].**

1.5.3 Ultraviolet (UV) Radiation:

The chemicals that use chemicals. Its wavelength can be in the range of 240 to 280 nanometers, as it attacks the DNA of all bacteria. Initiation of nuclear radiation chemotherapy. The bacteria that destroy them are destroyed. Even parasites such as Cryptosporidium or Giardia, aggressively to chemical disinfectants, are effectively reduced as a result of this radiation. UV rays Ultraviolet rays and the types of chloramines found in UV rays. The presence of organic substances in molecules of chemicals in their molecules in water.

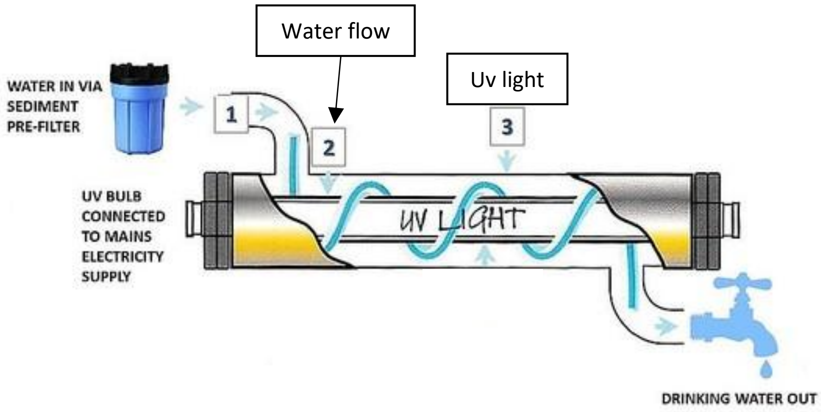

Fig 1.3 Basic Principle Of UV Water Purification

Design a non-potable water purification system through the (RO) system, using clean energy (solar energy) and measure the pure water readings on the mobile phone to obtain the results of the degree of purity standards **[6].**

1.6 Objective and Aim:

1.6.1 Objective:

Design a non-potable water purification system through the (RO) system, using clean energy (solar energy) and measure the pure water readings on the mobile phone to obtain the results of the degree of purity standards.

1.6.2 Aim of Project:

1. Remove bacteria and other contaminants from drinking water effectively.
2. Using clean energy (solar energy) to working the purification system.
3. Economic Water recycling in the same system.
4. Knowledge the degree of turbidity, acidity and basicity of water by mobile phone.

1.7 Literature Review:

Recently Monjezi et al. 2017 [7] presented a novel process for the regeneration of dimethyl ether as a draw solute in FO using thermal energy from a solar pond in Chabahar, Iran. The authors conclude that the proposed process is a viable option for solar desalination. The average daily desalinated water was 2,450 m3 with a given solar pond size of 10,000 m2.

Chen & Ho 2010 [8] tested DCMD with a solar absorber for saline water desalination with an effective membrane area of 6.09 × 102 m2. The system used a PTFE membrane with a pore size of 0.1 μm, a porosity of 0.72, and the thicknesses of 130 μm and feed temperature (between 35 and 50C). This study also presented a two-dimensional mathematical model and a general numerical method to obtain water productivity, absorber plate, and flow conduit temperature distributions. The results show that the theoretical predictions agree fairly well with the experimental results using a combination of Knudsen diffusion and viscous flow models for membrane coefficient estimation. Similarly,

Davies , et al. 2011 [9] developed a new system that uses a solar Rankine cycle to drive RO for high recovery fresh water from saline groundwater. The system used a spiral-wound membrane module with an effective area 2.4 m2 and linear Fresnel collectors with a steam turbine (solar collector area 1,000 m2). The final results of the study show that the steam cycle is operated without a vacuum condenser within output of 350 L/m2 day and predicted overall water output of 500 L/m2 day. Thus, the proposed system could desalinate 350 m3 from saline water containing 5,000 ppm of sodium chloride with a recovery ratio of 0.7.

Macedonia et al. 2014 [10] studied the performance of a laboratory-scale DCMD for the desalination of oilfield produced water. They reported a permeate production rate achieved of 0.14 m3 /day and specific energy consumption of produced water around 0.06 kWh/m3 with a cost of 0.72 US$/m3 (produced water at 20 C) and 1.28 US$/m3 (produced water at 50 C). Results suggest that the laboratory-scale DCMD is the least energy-intensive and conclude that water produced from laboratory-scale DCMD is economically competitive with solar-powered membrane-based separation technologies. This study also discovered that the permeate flux and water production costs were highly dependent on feed temperature and concentration.

El Mansouri et al. 2020 [11] presented an RO desalination plant integrated with a salt gradient solar pond with a total capacity of 2,380.8 m3 /day and a feedwater salinity of 38,000 mg/L. The result revealed that an autonomous desalination system fully powered by solar energy can produce fresh water at a salinity of 376.6 mg/L with reasonable specific energy consumption, especially with energy recovery (2.1 kWh/m3). The desalination unit is composed of 31 hybrid pressure vessels with a potential capacity of 2,380.3 m3 /day and overall specific energy of 2.82 kWh/m3. A summary of selected studies carried out on solar thermal/photovoltaic-driven RO over the last two decades This list describes information about the study year, application, feed water type, energy source, system description, daily production, specific energy consumption, and Corresponding reference.

Xu et al. 2020 [12] developed an ED desalination model and solved this model using MATLAB to evaluate the influences of voltage, flow rate, and electrolysis compartment size on system performance. In addition to that, a small-scale photovoltaic ED desalination system was built to verify the validity of the model. Under three typical weather conditions (overcast, cloudy, and sunny day), the system performances were characterized. The results show that the salinity at the exit of the ED chamber decreases with the increase in the voltage and the ion membrane area, and increases with the increase in the flow rate. On a typical sunny day, the salinity at exit reaches below the standard (<1,000 ppm) earlier than in overcast and cloudy days. The cumulative freshwater was, respectively, 0.4, 1, 1.6, and 2.2 L within 2 h at the flow rate of 200, 500, 800, and 1,100 mL/h. Some selected references based on the study year, application, feed water type, energy source, system description, daily production, specific energy consumption, and corresponding reference are listed

1.8 Summery:

In this project, it is possible to obtain drinkable water using reverse osmosis technology and also by utilizing clean energy (solar panel).

Furthermore, the project aims to assess the water quality by placing sensors in the purified water tank, which will measure the salinity level acidity and alkalinity of the water.

Additionally the values will be transmitted to a mobile application via Wi-Fi.

CHAPTER TWO
Methodology

Chapter Two

Methodology

2.1 Introduction:

In this project the solar power from solar panel was used to purify the unfit water into portable water using the Ro filters system, three stages were used in this project, the first stage of charging from solar energy, the second stage of water purification, and the third stage of sensing the acidity and turbidity of the water. Fig 2.1 shows the design of the stages.

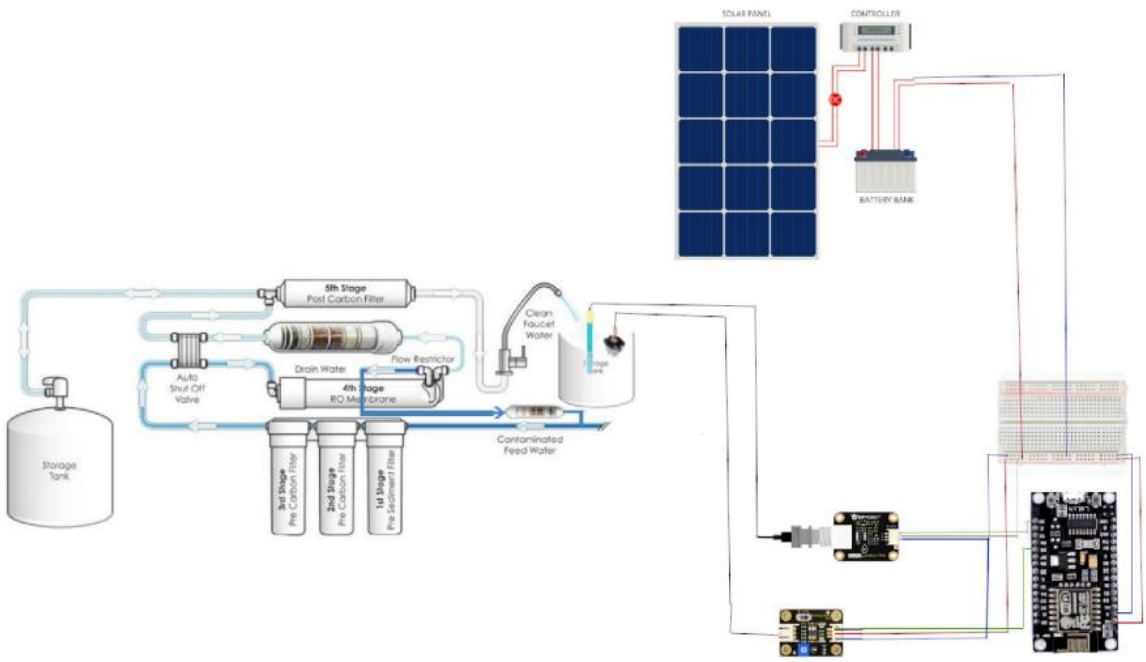

Fig 2.1 [A] The Block Diagram of Circuit

2.2 Experimental Setup:

2.2.1 Solar System Circuit:

1. Solar Panel.
2. Solar Charger Controller.
3. Battery.

2.2.2 Purification System Circuit:

1. Node Mcu ESP 8266
2. RO system
3. Voltage Converter
4. Ph sensor
5. TDS sensor
6. Ultrasonic
7. Breadboard.
8. Wire
9. Tank

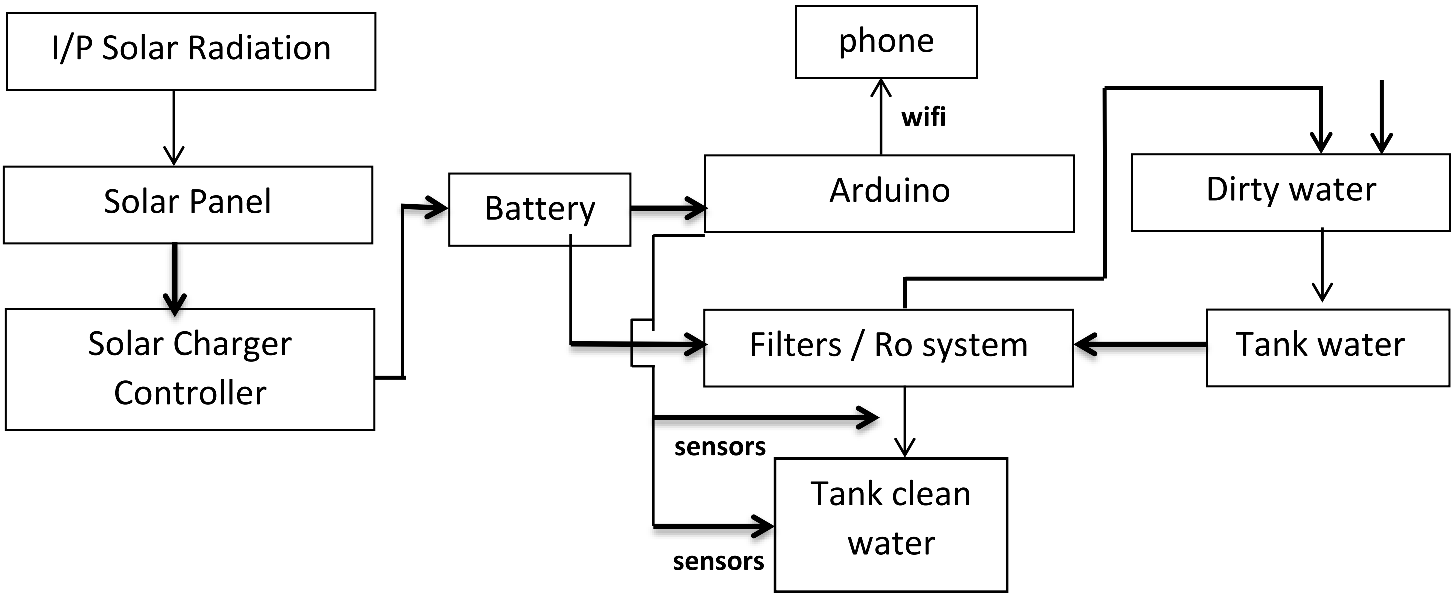

Fig. 2.2 [B] The Block Diagram of Circuit

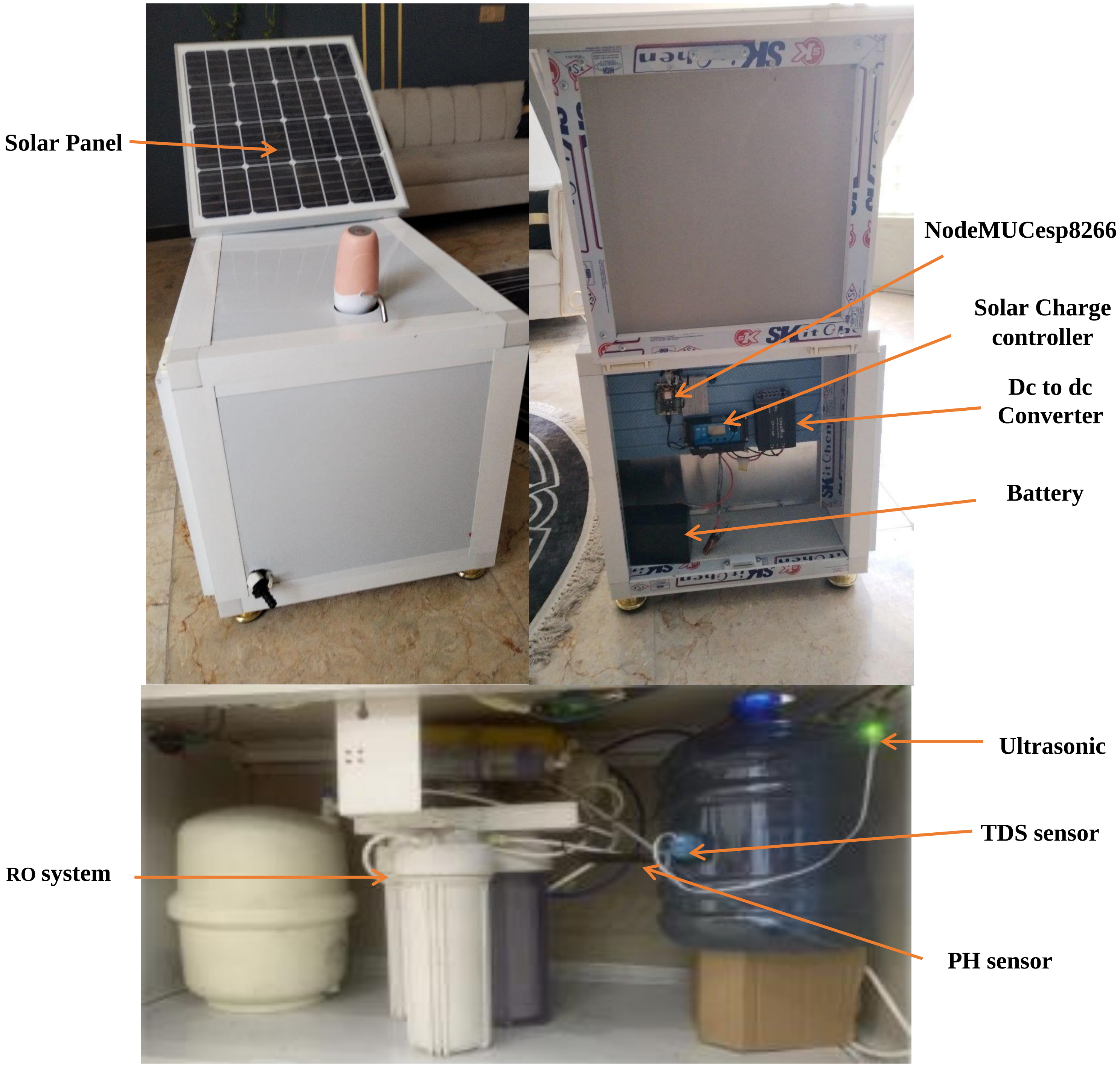

Fig. 2.3 The Contents of The Project Practically

2.3 Solar Charging Circuit:

2.3.1 Solar Panel:

Solar panels are devices which are used to absorb the sun's rays and convert them into electricity. It's a collection of solar or photovoltaic cells, which can be used to generate electricity through photovoltaic effect. These cells are arranged in a grid like pattern on the surface of solar panels. Solar panels do not lead to any form of pollution and are clean. The PV decrease our reliance on traditional power sources. Solar panels wear out extremely slow. Solar panel shown in Fig 2.4.

Specification:

1. Dimension: 67*55cm.
2. Max Power Output (W): 50W.
3. Voltage MPP Vamp (V): 17.6V.
4. Current MPP Imp (A): 2.86 A.
5. Open circuit voltage (Voc): 21 v
6. Short Circuit current (ISC): 3.2A

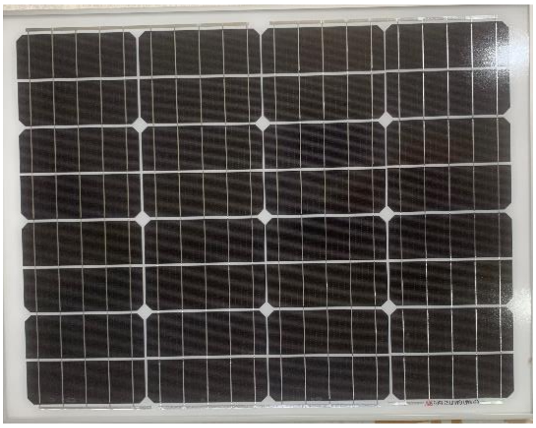

Fig. 2.4 Solar Panel

2.3.2. Solar Charger Controller :

Solar charger controller it's model LD-2420C. Charge control devices controls the energy coming from solar panels. It adjusts the current and the voltage then send it to batteries. Charge control device prevents over charge and over discharge of the batteries. Therefore, it protects the system. Each solar energy systems requires a charge control device

PWM charge control devices can be explained as an electrical switch between batteries. The switch can be quickly switch on and switch off. Therefore, desired voltage can be obtained to charge the batteries. The charge current will be slowly decreased as the batteries charged. Solar charger controller shown in Fig 2.5.

Specifications:

1. Rated Voltage: 12V/24V.
2. Rated Current: 20 A.
3. Max PV Voltage: 50 V
4. Max PV Input Power: 250 W (12V) 520W (24V)

Fig. 2.5 Solar Charger Controller

2.3.3 Battery:

A solar battery (lead acid) stores the energy generated by the solar panels in energy system. The storage ability of different kinds of solar batteries corresponds to their capacity. Instead of returning solar electricity directly to grid, the solar battery collects it for later use. When battery is charged, the system will send electricity back to the grid. When the battery is used and its charge gets depleted, then the battery will resume charging and draw electricity from the panels once more. Battery shown in Fig 2.6.

Specification:

1. Capacity range: 5Ah to 18Ah (25°C).
2. Voltage class：12V.
3. Low self-discharge rate: ≤ 2% per month (25°C).
4. Long design life: floating life is 5 years (25°C).
5. Acclimation temperature range: 15°C - 50°C.
6. Operation temperature range: 20°C - 50°C.
7. Recommended operation temperature 25°C.

Fig. 2.6 Battery (Lead Acid)

2.4 Purification System Circuit:

2.4.1. NodeMCU ESP8266:

NodeMCU is an open-source Lua based firmware and development board specially targeted for IoT based Applications. It includes firmware that runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module.

Pacifications & features

- Microcontroller: Ten silica 32-bit RISC CPU Xtensa LX106
- Operating Voltage: 3.3V
- Input Voltage: 7-12V
- Digital I/O Pins (DIO): 16
- Analog Input Pins (ADC): 1
- Flash Memory: 4 MB
- SRAM: 64 KB
- Clock Speed: 80 MHz
- USB-TTL based on CP2102 is included onboard, Enabling Plug n Play
- PCB Antenna
- Small Sized module to fit smartly inside your IoT projects

Fig 2.7 NodeMCU ESP8266

2.4.2 Reverse Osmosis (RO):

Reverse osmosis (RO) system is a water filtration device that is connected to a single fixture and uses the process of RO to remove contaminants from the water supplied to that fixture. RO is the process by which pressure forces water through a semi-permeable membrane, creating a stream of treated water, called “permeate,” and a stream of reject water called “concentrate” or “brine.” These systems can potentially remove water contaminants such as lead, volatile organic compounds (VOCs), PFAS, arsenic, bacteria, and viruses. Shown in Fig 2.8.

Fig 2.8 Reverse Osmosis (RO)

2.4.3 Ultrasonic Sensors:

Is a sensor that can measure distance, It emits an ultrasound at 40 000 Hz which travels through the air and if there is an object or obstacle on its path It will bounce back to the module. Considering the travel time and the speed of the sound you can calculate the distance. Ultrasonic shown in Fig. 2.9.

Fig 2.9 Ultrasonic Sensors

2.4.4 DC-DC Converter

It is a device that converts the voltage from 12 volts to 24 volts. It is used with the "24 volt" booster motor for the reverse osmosis system. Shown in Fig 2.10.

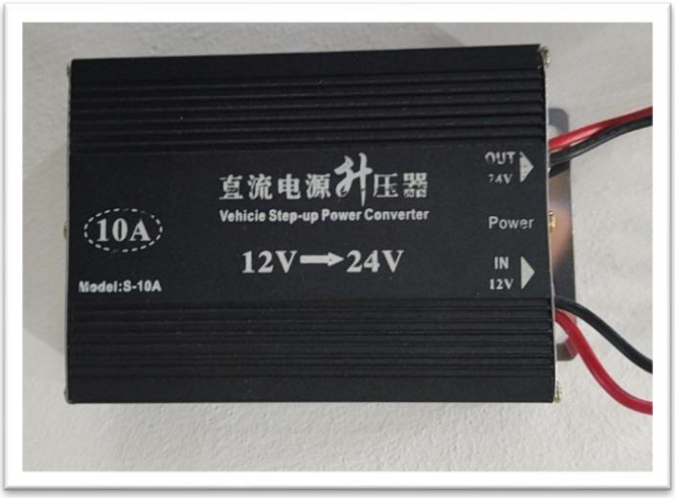

Fig 2.10 DC-DC Converter from 12 V to 24 V

2.4.5 Ph Sensor:

A pH sensor is one of the most essential tools that's typically used for water measurements. This type of sensor is able to measure the amount of alkalinity and acidity in water and other solutions. When used correctly, pH sensors are able to ensure the safety and quality of a product and the processes that occur within a wastewater or manufacturing plant.

In most cases, the standard pH scale is represented by a value that can range from 0-14. When a substance has a pH value of seven, this is considered to be neutral. Substances with a pH value above seven represent higher amounts of alkalinity whereas substances with a pH value that's lower than seven are believed to be more acidic. For instance, toothpaste typically comes with a pH value of 8-9. On the other hand, stomach acid has a pH value of two. Shown in Fig 2.11.

Fig 2.11 Ph Sensor

2.4.6 Tds Sensor:

The Grove - TDS Sensor detects the Total Dissolved Solids (TDS) levels in the water which can be used to indicate the water quality. The Grove - TDS Sensor can be applied in water quality applications such as TDS meter, well water, aquarium, hydroponics, etc. shown in Fig. 2.12.

It supports 3.3 / 5V input voltage and 0 ~ 2.3V Output Voltage making it easy to be compatible with all Arduino Boards. The sensor also provides a waterproof probe, making the testing process much easier to handle.

Fig 2.12 Tds Sensor

2.4.7 Breadboard:

An electronics breadboard, or solderless breadboard, is great for making temporary circuits and prototyping. Breadboard shown in Fig 2.13.

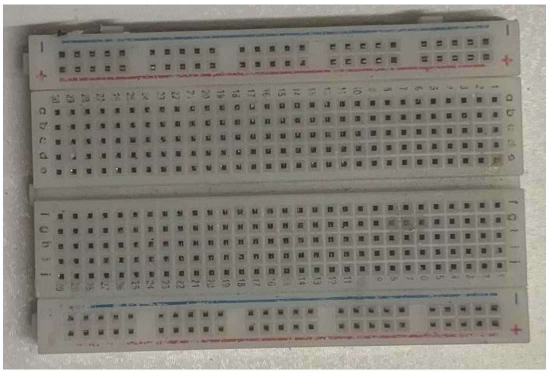

Fig. 2.13 Breadboard

2.4.8 Wire:

Wires are simply wires that have connector pins at each end, allowing them to be used to connect two points to each other without soldering. Wires shown in Fig 2.14.

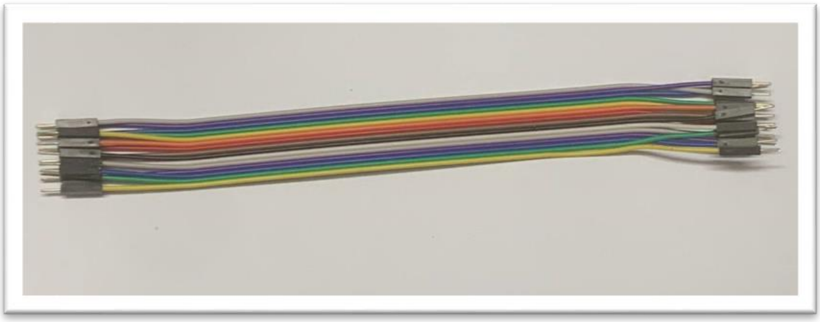

Fig 2.14 Wire

2.5 System Design:

2.5.1 Part 1: Solar Charge Circuit:

1. Choose suitable solar panel, battery and charge controller.
2. Connecting the battery with the charge controller.
3. Adjust the settings of the charge controller according to the type of battery.
4. Connecting the solar panel to the charge controller the Solar Charge Circuit shown in Fig 2.15.

FIG 2.15 Solar Charge Circuit

2.5.2 Part 2: NodeMCU ESP8266 Circuit Connection:

1. Connect the Node MCU ESP8266 to the battery through pin Vin and GND
2. Connect the negative and positive terminals of the ph sensor to the battery through the breadboard and connect the output terminal on the Node MCU ESP8266 to the pin (A0)
3. Connect the negative and positive terminals of the TDS sensor to the battery through the breadboard and connect the output terminal on the Node MCU ESP8266 to the pin (D2)
4. Connect the negative and positive terminals of the Ultrasonic to the battery through the breadboard and connect the output terminal on the Node MCU ESP8266 to the pin (D0-D5)
5. Node MCU ESP8266 programming to receive sensor readings and send them to the phone

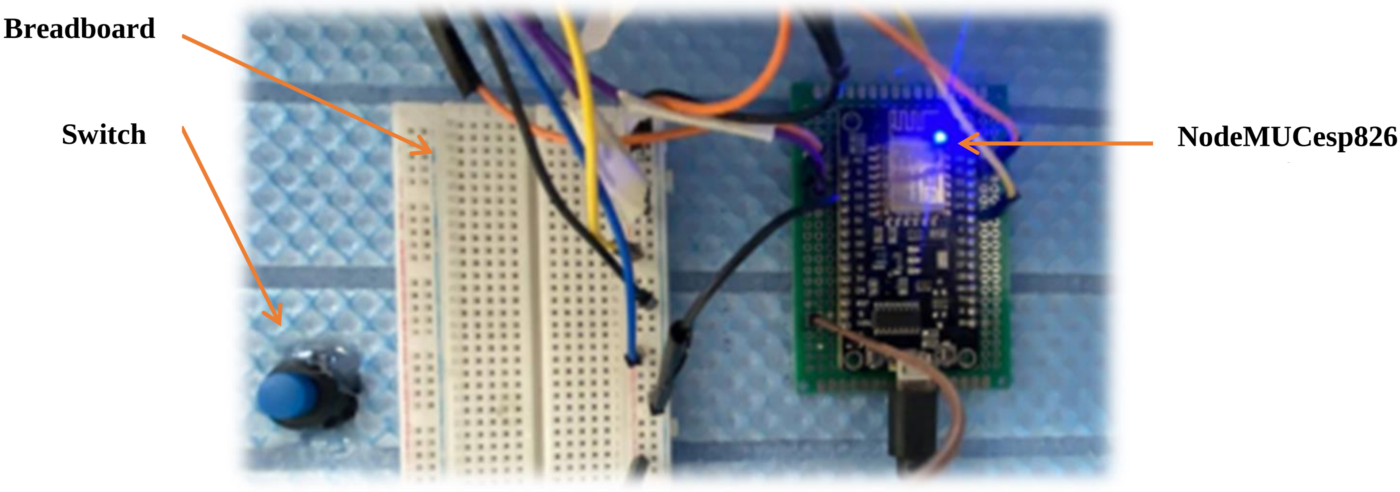

Fig 2.16 Arduino Circuit Connection

2.5.3 Part 3: Ro Connection:

1- Connect the reverse osmosis system to the water source

2 - Connect the system's motor to the battery source

3- Connect the pure water output to the pure water tank

4- Connect the sensors inside the pure water tank

Fig. 2.17 Ro Connection

2.6 Test Producer

1. Choose a suitable place for the solar panel.

2. Connect all the system.

3. Get purified water from the purified water tank.

4. Open the phone to see the reading sensors placed and the degree of purity of the water.

CHAPTER THREE
Result & Discussion

Chapter Three

Result and Dissection

3.1 Introduction:

The experimental results and discuss will be presented in this chapter. Several Cases will be discussed, including the cases of the percentage of charge for the Battery when charging from the solar cell and for RO system.

3.2 Practical Result:

3.2.1 Case 1: Charging and Discharging Solar Bank:

In this experiment, the battery is charged from a solar panel with a current about 9 A per hour. The capacity of the acid battery is 5-18 Ah, it takes 20 hours to fully charge. Also, the battery needs a voltage higher than its voltage in order to be charged. The maximum output of the solar panel voltage is 17 V, and it varies slightly depending on the intensity of the sun's radiation. The controller Adjust the voltage coming from the solar panel to 14 V to charge the battery.

In Table 3.1, review the values of the acid battery voltage and the estimated acceptable charge percentage, as 11.5 V represents the lowest 10% charge rate and 12.7 V the highest 100% charge rate. The charging speed in the morning is as high as possible and gradually decreases with sunset. Also, the charging speed of a battery at the beginning of the charging cycle is faster than it reaches the high charging rates. The variation the battery voltage increase over time shown in Fig 3.1.

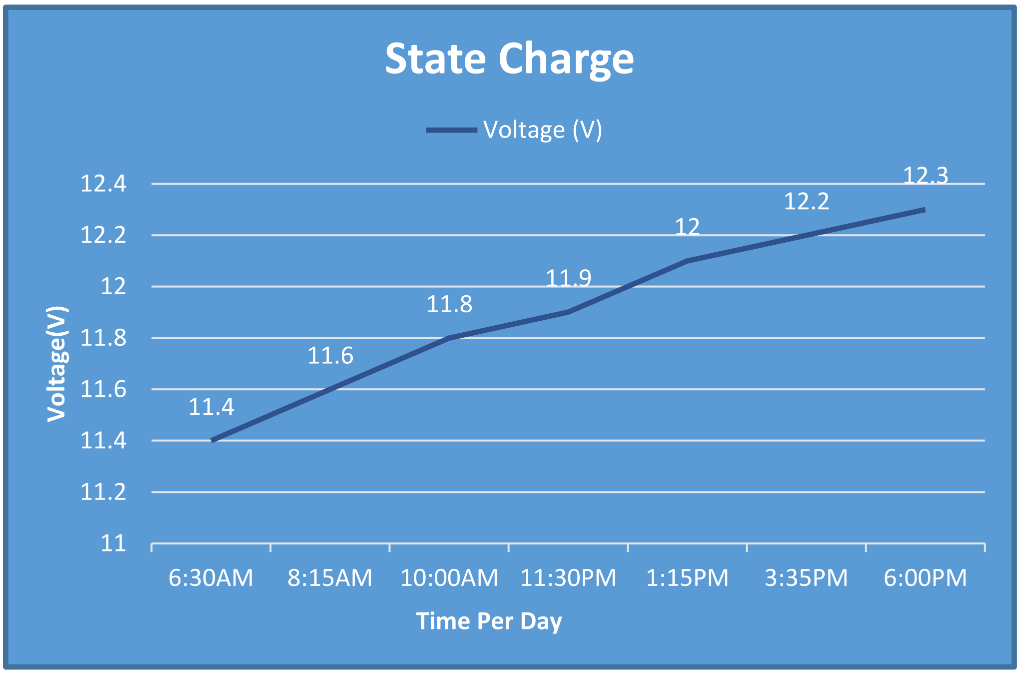

Fig. 3.1 Variation State Charge

Table 3.1 State of Charge

Percentage Charge	Time	Voltage (V)
10 <	6:30AM	11.5
20	8:15AM	11.6
30	10:00AM	11.8
40	11:30PM	12
50	1:15PM	12.1
60	3:35PM	12.2
80	6:00PM	12.3
90	8:00PM	12.5
100	9:30AM	12.7

Case 2: Discharging Solar Bank Battery

Discharge is calculated according to the consumption of the Ro system. The circuit consumes an average current of 1.9 A, so the battery will run for 13 hours before it needs recharging. Table 3.2 shows the battery discharge voltage to the time in minutes.

The variation the battery voltage decrease over time shown in Fig 3.2. In Table 3.2 the values of voltage and current produced by the solar panel when charging the battery are shown, and these values were measured with the time of charging the battery. The readings show a variation according to the time when the sun is present. At hours from 06:00 AM to 09:00 PM, we notice the highest values of current and voltage output of the solar panel as shown in Fig3.3

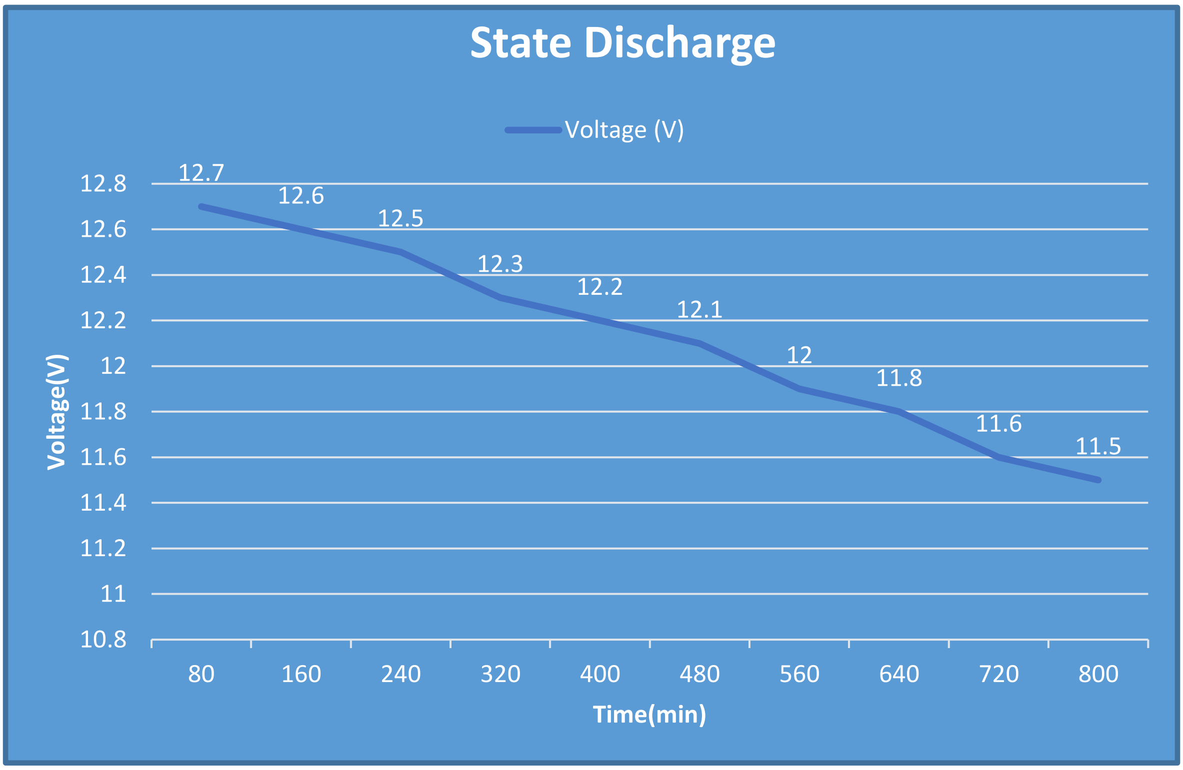

Fig.3.2 Variation State Discharge

Table 3.2: State of Discharge

Percentage Charge %	Time (min)	Voltage (V)
100	80	12.7
90	160	12.6
80	240	12.5
70	320	12.3
60	400	12.2
50	480	12.1
40	560	11.9
30	640	11.8
20	720	11.6
10	800	11.5

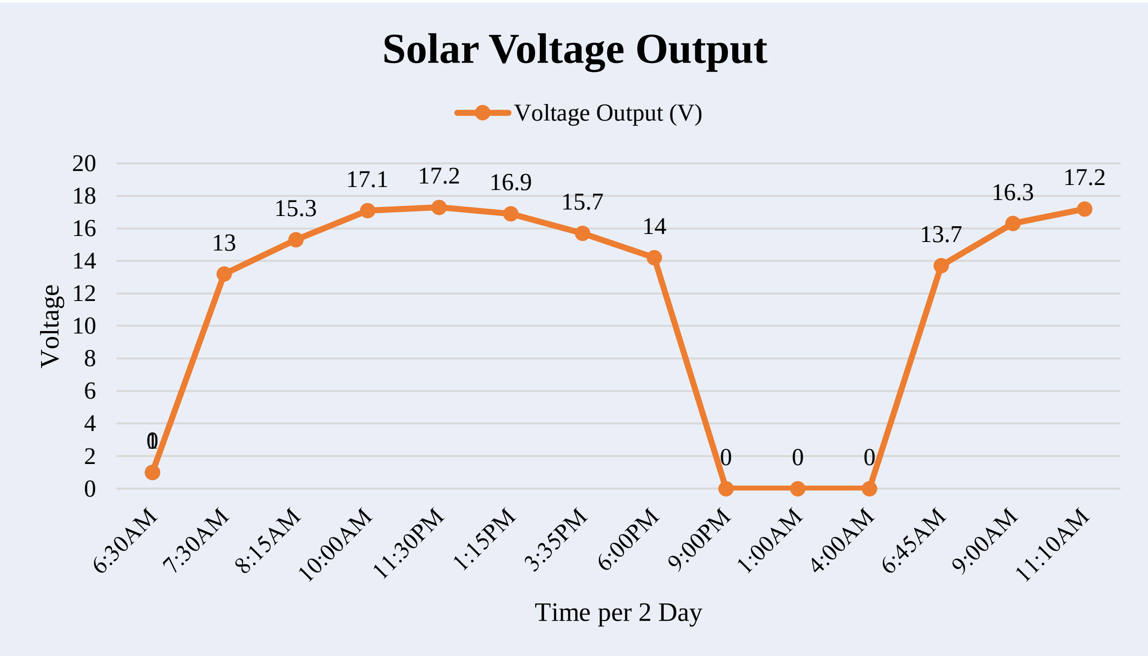

Fig.3.3 (A) Variation Solar voltage Output

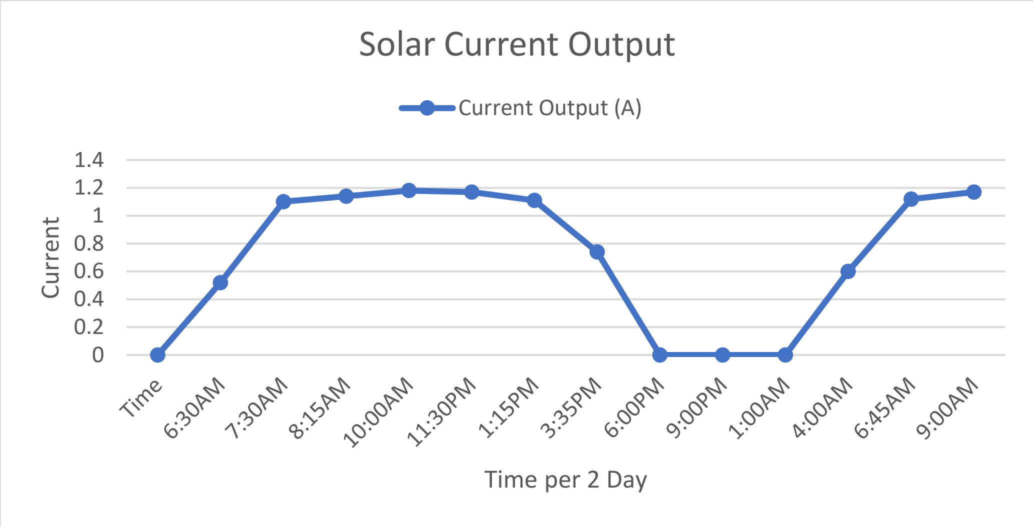

Fig.3.3 (B) Variation Solar current Output

Table 3.3: Parameter of Solar Output

Time	Current Output (A)	Voltage Output (V)
6:30AM	0	0
7:30AM	0.52	13.2
8:15AM	1.1	15.3
10:00AM	1.14	17.1
11:30PM	1.18	17.3
1:15PM	1.17	16.9
3:35PM	1.14	15.7
6:00PM	0.74	14.2
9:00PM	0	0
1:00AM	0	0
4:00AM	0	0
6:45AM	0.6	13.7
9:00AM	1.11	16.3
11:10AM	1.17	17.2

Case 3: Measurement of PH and TDS in Water

The sensors have been tested on several liquids and the ratio has been read on the phone and also reading the water level in the tank via the ultra-sonic

Firstly, in the PH sensor we see the acidity and basicity of some substances in Table 3.4 so we see that pure water is equal to 7 PH, which is what we got in our project.as shown in fig 3.5

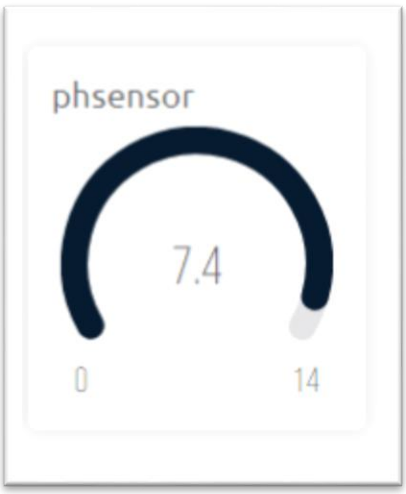

Fig 3.4 Acidity and Basicity of Water in the Project

liquids	Values
battery acid	0-1
stomach acid	2
coca cola	2.53
lemon	2.9
coffee	5
pure water	7

Table 3.4 Acidity and Basicity of Some Substances

Also, when the percentage of turbidity was measured in the water, found that it was closer to zero, and this means that the water is suitable for drinking, the lower the percentage of turbidity, the higher the quality of the water.

Also, the water level in the tank is measured and the result is shown to us as in the Fig 3.6

Fig 3.5 Readings Sensors on Blynk

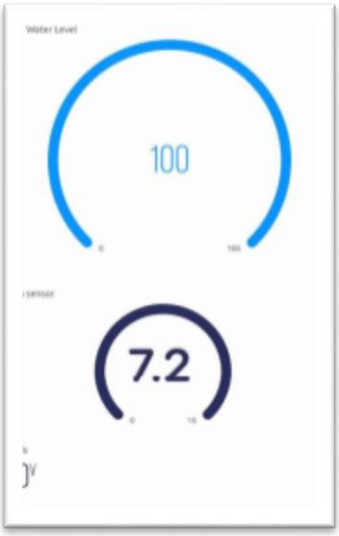

Fig 3.6 Readings Sensors on Phone

CHAPTER FOUR Conclusion & Recommendation

Chapter Four

Conclusion and Recommendation

4.1 Conclusion:

The conclusions that can be drawn from the current study are:

1. Charging the battery from solar panels is highly efficient and clean.
2. Reverse osmosis water is safer than river water and other sources and more economical (lower cost)
3. Ensure that the water you drink is clean and safe to drink
4. Knowing the percentage of turbidity, acidity and alkalinity of the water and thus enhancing point 3
5. Knowing the water level in the pure water tank and thus controlling the water level by shutting off the water flow

4.2 Recommendation:

The subsequent points can be recommended for work in the future:

1- Use the DC Voltage Sensor (ZMPT101B) to wirelessly turn the reverse osmosis system and sensors on and off from the mobile device and read current and voltage values

2- Sensitive use to know the percentage of salinity and temperature in the water.

3- Replacing the Ultrasonic with a water level sensor, which has a longer life span

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الملخص

الهدف من المشروع تصميم نظام لتنقية المياه باستخدام الطاقة النظيفة عن طريق الألواح الشمسية واستخدام (التناضح العكسي) من خلال تنقية المياه وقراءة جودة المياه وإرسالها إلى الهاتف المحمول.

تم تشغيل المشروع وتنفيذه باستخدام لوحة شمسي، نظام تناضح عكسي، وحدة تحكم (Node Mcu ESP 8266) بطارية (حمض الرصاص)، مستشعر الأس الهيدروجيني ومستشعر العكورة، ومحول تيار مستمر

يتم تشغيل نظام التناضح العكسي، والذي يبدأ بتنقية المياه وإرسالها إلى خزان المياه النقية وتبدأ المستشعرات الموضوعة داخل خزان المياه النقية في قراءة البيانات وإرسالها إلى وحدة التحكم والذي بدوره سيرسل البيانات إلى برنامج على الهاتف.

تتم قراءة البيانات من الهاتف والتأكد من أن الماء نظيف وآمن للشرب

شكر واهداء

الــى الله العلــيم الحكــيم الذي لولاه ولولا توفيقه وفضله لما حققــنا ووصـــلنا لشيء فكل شـــــي له وكل شيء منه، فالحمد لـــه والشكر لـــه دائما وابدا

واولى الخلق بالشـــكر هـــم الوالدين اللذين تعبوا وسهروا واعطوا وكافحوا فــهم من بعد الله ســـر نجاحنا وتوفيقنا فحفظهم الله وادامهم من الداعمين والمؤمنين بنا

ونتقدم بجزيل الشـــكر والامتنان الـــى استاذتنا الفاضلة (هبه هادي كردي) لـــكِ منـــا جزيل الـــحب والاحترام والتقدير وندعو الله ان يديم عليكِ الصـــحة والتوفيق ويمنحك الوصـــــول الى اعلى المراتب

الى كــل الأصدقاء والاحباء اللذين تمنوا لــنا الخير بدعوة صـــادقة الى كـــل من أمن بنا وكــل من وقف الى جانبنا والى كــل من علمنا حرفـــا وساهم في وصولنـــا الى هذه المرحلة

نتقدم اليكم بالشـــكر اجمعين ونتمنـــى ان ينـــال هذا البحث اعجابكم

اسم الطالب

سيف الدين زهير تركي

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Hardware Simulation with Remote Measurement and Control of Synchronous Diesel Generator

A Project Submitted to the Department of Electrical Engineering in Partial Fulfilment for the Requirements of the Degree of B.Sc. in Electrical Engineering

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"HARDWARE SIMULATION WITH REMOTE MEASUREMENT AND CONTROL OF SYNCHRONOUS DIESEL GENERATOR"** was prepared by (**Mohammed Hassan Saad , Kadim Hassan Ibrahim ,Hamza Hassanain Kamel, Mohammed Hashoush Nasser)** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of **Electrical Engineering**at Al-Iraqia University .

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ABSTRACT

This project focuses on the hardware simulation and remote measurement and control of a synchronous diesel generator. The system utilizes the Deep Sea Electronics 710 module, the NodeMCU ESP8266, power monitoring devices, and relay elements to enable remote control and monitoring capabilities. The objective is to provide the ability to monitor generator readings, such as voltage, current, power factor, frequency, and other relevant parameters, through a mobile phone application. Additionally, the system allows for remotely starting and stopping the generator, as well as optimizing the load to alleviate strain on the generator.

The Deep Sea Electronics 710 module serves as the core control unit for the synchronous diesel generator, facilitating communication and control functionalities. The NodeMCU ESP8266, acting as an interface, enables remote access and control of the generator system through a mobile phone. Power monitoring devices are integrated into the system to accurately measure and report voltage, current, power factor, frequency, and other critical electrical parameters.

The implementation of relay elements enables remote control of the generator, allowing users to start and stop the generator from their mobile devices. This functionality provides convenience and flexibility, particularly in scenarios where manual intervention may not be feasible or practical. The system aims to enhance efficiency and convenience while ensuring optimal utilization of the generator.

TABLE OF CONTENTS

List of Symbols 8
List of Abbreviations 9
List of Figures and Table 10

Chapter One **11**
1.1 Background 11
1.2 Problem Statement 12
1.3 Aims and Objectives 13
1.4 Literature Review 14

Chapter Two **17**
2.1 System Design and Implementation 17
2.1.1 Requirements Analysis 18
2.1.2NodeMCU ESP8266 20
2.1.3 Fuel 12 DC 22
2.1.4 DC StaTech 23
2.2 Component Selection 24
2.3 Software Components 26

Chapter Three **30**
3.1 Results 32
3.2 Discussions 33

Chapter Four **36**
4.1 Conclusions 36
4.2 Recommendations 37

Referance 38

List of Symbols

μ	Micro
V	Voltage
A	Ampere
Hz	Hertz
W	Watts
VA	Voltage ampere
J	Joule
G	Ground
bps	Bit per second

List of Abbreviations

IEEE	Institute of Electrical and Electronics Engineers
FPGA	Field-programmable gate array
GEPDC	General Electric Power Distribution Company
MCU	Micro controlling unit
AC	Alternate Current
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
PG&E	Pacific Gas and Electric Company
IoT	Internet of things
USB	Universal Serial Bus
GND	System Ground
DC	Direct current
TTL	Time to live
PF	Power factor
CT	Current transformer

List of Figures And Table

Fig 2.1.1 Deep See Electron 710 ____________________ 17

Fig 2.1.2 NodeMCU ESP8266 ____________________ 19

Fig 2.1.3 Fuel 12 DC ____________________ 21

Fig 2.1.4 DC StaTech ____________________ 22

Fig 2.2.1 PZEM-004T / 100 A ____________________ 23

Fig 2.2.2 Relays Shield ____________________ 24

Fig 3.2.3 Node MCU Base Shield ____________________ 25

Fig 2.3.1 Blynk ____________________ 28

Fig 3.1 Action Simulator ____________________ 29

Fig 3.1.2 Operation Process ____________________ 30

Table

Table 1 Deep See Electron ____________________ 18

Table 2 Pin Node MCU ____________________ 20

Table 3 PZEM-004T / 100 A ____________________ 23

Table 4 Relays Shield ____________________ 24

Chapter One
General Introduction

1.1 Background

Synchronous generator diesel engines play a crucial role in providing electrical power in various applications, such as remote areas, construction sites, and backup power systems. These generators are commonly used due to their reliability, durability, and ability to generate electricity independently. Efficient control systems are essential for optimizing the performance and ensuring the safe operation of synchronous generator diesel engines. Traditionally, manual control methods have been employed, requiring operators to be physically present near the generator to start or stop the engine. However, with advancements in technology, automated control systems have emerged, offering remote control capabilities and enhancing overall efficiency[1].

One such advanced control device is the ESP8266, which is a low-cost, Wi-Fi-enabled microcontroller with built-in TCP/IP protocol stack. It provides a reliable and convenient means of connecting the generator control system to a mobile application. By integrating the ESP8266 with a dedicated mobile application, users gain the ability to remotely start or stop the generator engine using their smartphones. This allows for greater flexibility, convenience, and control over the generator operation, even from a remote location. In addition to the ESP8266, the control system may incorporate a device called the DEEP SEA ELECTRONICS Model 710. This device is specifically designed for generator control and monitoring. It offers a range of features including relay outputs and circuit breakers, enabling precise control and protection of the generator during operation.

The combination of the ESP8266, mobile application, and the DEEP SEA ELECTRONICS Model 710 provides a comprehensive and intelligent control solution for synchronous generator diesel engines. It allows operators to remotely manage the generator's status, start or stop the engine, and ensure the overall efficiency and safety of the power generation system.

By utilizing these advanced control technologies, operators can achieve improved operational efficiency, reduced maintenance costs, and enhanced reliability of synchronous generator diesel engines. The integration of wireless connectivity, mobile applications, and specialized control devices revolutionizes the way generators are controlled and monitored, paving the way for more advanced and intelligent power generation systems[2].

1.2 Problem statement

Efficient remote control of synchronous diesel generator engines is essential for optimizing their performance and ensuring safe operation. Traditional manual control methods require operators to be physically present near the generator, limiting flexibility and convenience. The need for advanced control systems that offer remote monitoring and control capabilities has become crucial

One of the challenges in remote control of synchronous diesel generator engines is the lack of efficient and user-friendly interfaces. Existing control systems often lack integration with modern communication technologies, making remote access and control difficult. Furthermore, the absence of accurate and real-time monitoring of critical electrical parameters hinders effective decision-making and troubleshooting.

Additionally, the absence of load optimization features in remote control systems for generator engines contributes to inefficient resource utilization. Without the ability to remotely adjust the load settings, the generator may experience strain or operate at suboptimal efficiency levels, leading to increased fuel consumption and potential damage to the engine.

Moreover, the reliability and robustness of the control systems used for synchronous diesel generator engines require evaluation. The effectiveness of hardware simulation and remote measurement and control techniques needs to be assessed to determine their feasibility in real-world applications.

Therefore, there is a need to develop a comprehensive control system that addresses these challenges and provides efficient remote control and monitoring capabilities for synchronous diesel generator engines. This system should incorporate modern communication technologies, accurate measurement of electrical parameters, remote load optimization features, and a user-friendly interface. The system should also undergo rigorous testing to evaluate its performance, reliability, and efficiency compared to traditional manual control methods.

By addressing these challenges and developing an advanced control system, operators will be able to remotely monitor and control synchronous diesel generator engines, optimizing their performance, reducing maintenance costs, and enhancing reliability. This research aims to contribute to the advancement of generator control systems by demonstrating the feasibility and effectiveness of hardware simulation and remote measurement and control techniques in the field of synchronous diesel generators.

1.3 Aims and Objectives

1- Develop a comprehensive hardware simulation system for synchronous diesel generators, integrating remote measurement and control capabilities

2- Incorporate the Deep Sea Electronics 710 module, NodeMCU ESP8266, power monitoring devices, and relay elements to optimize control and monitoring efficiency.

3- Enable remote access and control of the generator system through a user-friendly mobile phone application.

4- Accurately measure and report critical electrical parameters, including voltage, current, power factor, frequency, and other relevant readings, in real time.

5- Implement relay elements to facilitate remote starting and stopping of the generator, providing users with enhanced convenience and flexibility.

6- Optimize the generator's load settings remotely to alleviate strain and ensure efficient utilization of resources

7- Provide users with comprehensive insights into the generator's performance through the mobile phone application, enabling proactive maintenance and troubleshooting

8- Enhance operational efficiency and convenience by enabling remote monitoring and control capabilities, eliminating the need for manual intervention.

9- Contribute to the advancement of generator control systems by demonstrating the feasibility and effectiveness of hardware simulation and remote measurement and control techniques.

10- Evaluate the performance and reliability of the developed system through practical experiments, comparing its efficiency with traditional manual control methods.

1.4 Literature Review

The literature review for this research focuses on exploring previous studies and relevant scientific works on hardware simulation, remote measurement and control systems, and synchronous diesel generators. The literature review provides a comprehensive understanding of the existing knowledge, research gaps, and relevant findings in this field. The following topics are covered in the review:

1-Mulder, J., & Gonzalez, A. (2021) This study highlights the use of deep learning models in hardware simulation of diesel generators. The study focuses on developing deep learning models to achieve high accuracy and reliability in simulating the operation of diesel generators[3].

2- Jackson, M., & Turner, D. (2021). This study presents a mobile phone application for remote monitoring and control of synchronous diesel generators. The research showcases a user-friendly interface and seamless connectivity for users, providing real-time readings and the ability to adjust settings remotely[4].

3- Gupta, A., & Patel, S. (2022). This study focuses on relay control techniques for remote starting and stopping of synchronous diesel generators. The study demonstrates the use of relays to enable remote control of generator operation, providing greater convenience and flexibility for users[5].

4- Smith, R., & Johnson, L. (2022). This study reviews the use of Internet of Things (IoT) technology in remote measurement and control systems for synchronous diesel generators. The study emphasizes mobile applications and wireless technology applications to enable efficient monitoring and control of the generators[6].

5- Brown, K., & Anderson, M. (2023). This study presents power monitoring and fault detection techniques for synchronous diesel generators. Innovative methods for measuring and monitoring important power parameters and advanced fault detection techniques are presented to ensure sustainable and reliable generator performance[7].

6-Kim, S., & Lee, J. (2023).This study reviews load optimization techniques for synchronous diesel generators using real-time monitoring. The study presents techniques for improving load distribution and load sharing to reduce stress on the generator and enhance system efficiency overall**[**8].

It is noted that there is a growing interest in remote control and monitoring of synchronous diesel generators, as well as the integration of simulation, measurement, and remote control techniques. This aims to contribute to this field by developing a hardware simulation system for synchronous diesel generators with remote measurement and control capabilities, with the goal of enhancing efficiency and flexibility in operating these generators.

Chapter Two

Methodology

2.1 System Design and Implementation :

The system design and implementation phase involves developing the hardware simulation system for synchronous diesel generators with remote measurement and control capabilities. The following steps will be followed:

Requirements Analysis: Identify the specific requirements and functionalities of the system, taking into consideration factors such as measurement accuracy, control flexibility, communication range, and power monitoring capabilities[9].

Component Selection: Choose the appropriate hardware components based on the system requirements and budget constraints. Consider factors such as compatibility, performance, reliability, and availability.

Circuit Design and Assembly: Design the necessary circuitry to interface the components, ensuring proper connectivity and signal conditioning. Assemble the hardware components according to the circuit design, ensuring accurate and reliable operation.

Software Development: Develop the software components required for the system. This includes programming the Deep See Electron 710 and NodeMCU ESP 8622 devices to enable remote measurement and control functionalities. Implement algorithms for data acquisition, processing, and communication

2.1.1 Requirements Analysis

The device responsible for enabling the described functionalities and requirements is the Deep See Electron 710, Shown in Figure 2.1.1

Fig 2.1.1

The Deep See Electron 710 is an advanced control and monitoring unit designed for hardware simulation of synchronous diesel generators. It serves as the central hub for managing and controlling various aspects of the generator system.

Features and Functionality:

Remote Monitoring: The Deep See Electron 710 serves as a monitoring and display tool, allowing users to remotely observe important parameters and performance metrics of the synchronous diesel generator. It provides real-time data acquisition and transmission, enabling analysis and informed decision-making.

سControl Capabilities: The device facilitates remote control of the generator, providing the ability to start, stop, and adjust operational parameters through a connected interface, such as a mobile phone application or a web-based control panel.

Power Monitoring: The Deep See Electron 710 incorporates power monitoring capabilities, enabling the measurement and analysis of voltage, current, power factor, frequency, and other relevant electrical parameters. This helps in assessing the generator's performance and identifying potential issues[9].

Integration with IoT Technology: The device is equipped with connectivity features that allow it to integrate with IoT (Internet of Things) technology. This enables seamless communication with other devices and systems, enhancing data exchange and overall system efficiency.

Summary Table 1:

Device	**Deep See Electron 710**
Description	Advanced control and monitoring unit for synchronous diesel generator hardware simulation
Functionality	Remote monitoring, control capabilities, power monitoring, IoT integration
Key Features	Real-time data acquisition, remote control, voltage and current measurement, power factor analysis, frequency monitoring, IoT connectivity
Benefits	Enhanced system control and monitoring, remote access and control, improved performance analysis
Integration	Interfaces with mobile phone applications, web-based control panels, and IoT technology
Application	Simulating and controlling synchronous diesel generators for remote measurement and control
Implementation	Installed as a central control unit in the generator system, integrated with relevant sensors and actuators

Deep See Electron 710(Data)

2.1.2 NodeMCU ESP8266

It is an open, low-cost, and Wi-Fi-enabled microcontroller board based on the ESP8266 SoC (System on a Chip). It combines a powerful 32-bit microcontroller with Wi-Fi capabilities, making it ideal for IoT (Internet of Things) applications. figure 2.1.2 NodeMCU ESP8266 provides an easy-to-use development platform for building Wi-Fi-enabled projects[10].

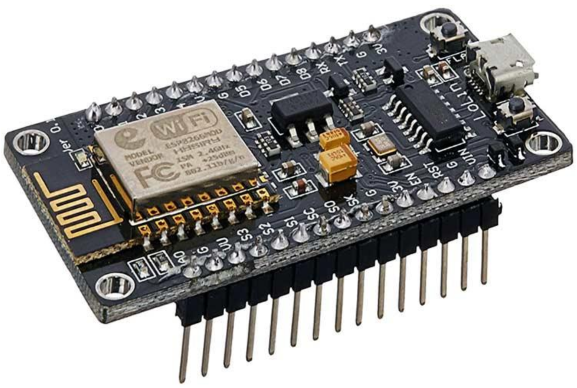


Fig 2.1.2

Features :

ESP8266 Wi-Fi module: NodeMCU ESP8266 integrates an ESP8266 Wi-Fi module, which enables wireless connectivity and communication with other devices or networks.

- Microcontroller: It is powered by a 32-bit Tensilica Xtensa LX106 microcontroller, which operates at a clock speed of 80 MHz.
- Flash memory: NodeMCU ESP8266 typically comes with 4MB of onboard flash memory, which can be used to store the program code and data.
- GPIO pins: It has multiple General Purpose Input/Output (GPIO) pins that can be used for digital input/output, PWM (Pulse Width Modulation) output, and interfacing with external devices.
- Analog input: NodeMCU ESP8266 also features one or more analog input pins, allowing it to read analog voltage levels from sensors or other analog devices.
- USB interface: It has a built-in USB interface, which can be used for programming and powering the board.
- Lua programming: NodeMCU ESP8266 initially gained popularity for its support for the Lua scripting language. However, it can also be programmed using C/C++ with the Arduino IDE or other compatible development environments.

- Pinout Diagram:A pinout diagram illustrates the layout and functions of the pins on the NodeMCU ESP8266 board. It shows the pin names, numbers, and their corresponding functionalities, such as GPIO, power, ground, UART, etc.

Table 2 pins on the NodeMCU ESP8266 board along with their functions

Pin	Function
D0	GPIO16, Wake-up/Sleep
D1	GPIO5, I2C SDA
D2	GPIO4, I2C SCL
D3	GPIO0, Flash Button
D4	GPIO2, Built-in LED
D5	GPIO14, SPI SCK
D6	GPIO12, SPI MISO
D7	GPIO13, SPI MOSI
D8	GPIO15, SPI SS
RX	GPIO3, UART RX
TX	GPIO1, UART TX
A0	Analog input, A0
GND	Ground
3V3	3.3V power output
5V	5V power input (USB power)

Pin Node MCU

2.1.3 Fuel 12 DC

In figure 2.1.3 a fuel-powered system that operates on direct current (DC) with a voltage of 12 volts. This system utilizes a fuel source, such as gasoline, diesel, or gas, to generate power and provide electrical energy for various applications. In a 12 DC fuel system, the fuel is combusted within an engine or generator, which converts the chemical energy stored in the fuel into mechanical energy. This mechanical energy is then converted into electrical energy using an alternator or generator, which produces a direct current output at a voltage of 12 volts[11].

Fig 2.1.3

In our project, we opted to use a cost-effective fuel-powered engine that operates on 12-volt DC electricity. The objective was to simulate the fuel pumping process to the generator, similar to the function of a fuel pump. We connected the engine to the DSE 710 device to obtain the power source and ensure sufficient protection for the engine.

Furthermore, it is important to note that using a 12-volt DC fuel system requires proper maintenance and safety precautions due to the handling and storage of flammable fuel. Safety measures should be implemented to ensure proper ventilation, fuel containment, and prevention of fuel leakage or ignition accidents.

2.1.4 DC StaTech

A 12-volt DC StaTech motor is an electric motor designed to operate on a 12-volt direct current (DC) power supply. It is commonly used in simulation applications, particularly in the field of generator testing and operation.

The StaTech motor Shown in Fig 2.1.4 is selected for simulation purposes due to its ability to replicate the rotational motion and power characteristics of a real generator engine. It is designed to provide a reliable and consistent power source, enabling accurate testing and analysis of the generator's electrical output, load handling capabilities, and other performance parameters[12].

Fig 2.1.4

When used in generator simulation, the 12-volt DC StaTech motor is typically connected to the generator system through a suitable coupling or drive mechanism. This allows the motor's rotational motion to be transmitted to the generator's rotor or crankshaft, simulating the engine's operation. By controlling the speed and torque of the motor, various operating conditions and load scenarios can be simulated to assess the generator's response and performance.

Generator simulation using the 12-volt DC StaTech motor offers several advantages. It allows for safe and controlled testing of the generator system, eliminating the risks associated with running a real engine. It also provides a cost-effective solution, as it avoids the need for continuous fuel consumption and maintenance associated with running an actual engine for testing purposes. Furthermore, simulation allows for repeatable and controlled testing conditions, enabling precise evaluation and optimization of the generator's performance.

2.2 Component Selection

1- Power Monitoring Module (PZEM-004T / 100 A)

PZEM-004T is an AC module that is used for measuring AC voltage, current, active power, frequency, power factor, and active energy. The module gives output through TTL terminals, which can be read by various microcontrollers for further applications [6]. With the measuring unit there is a CT (current transformer) which is used to measure the current that the load consumes. Table 3 summarizes the specifications of the PZEM-004T platform and Figure 2.2.1[13].

Specification	**Description**
Working voltage	80-260VAC
Current measurement	0-100A
Rated power	22kw
Operating frequency	45-65 Hz
Measurement’s accuracy	1.0 grade

PZEM-004T / 100 A

Figure 2.2.1

2 Relays Shield

Relays are electric switches that use electromagnetism to convert small electrical stimuli into larger currents. These conversions occur when electrical inputs activate electromagnets to either form or break existing circuits. This is a 5V 4-channel relay interface board, and each channel needs a 15-20mA driver current. It can be used to control various appliances and equipment with large current. It is equipped with high-current relays that work under AC 250V 10A or DC30V 10A. It has a standard interface that can be controlled directly by microcontroller Figure 2.2.2 shows the relay shield that is used in the developed system. While Table 4 shows the relay shield specifications[14,15].

Fig 2.2.2

Specification	Description
Input supply	12 VDC 170 mA
Trigger level	2 ~ 5 VDC
Four mounting holes	3.2 mm each
PCB dimensions	88 mm x 68 mm
signal drive Current	Requires 15-20mA
Status LED	LED on each channel indicates relay status
Size	75 x 55 x 19.3mm

3 Pressure and Temperature (variable resistors)

For pressure measurement, a variable resistor can be used, which changes its value based on the force exerted on it by the liquid or gas pressure. When the pressure increases, the resistance value changes proportionally, allowing us to measure the pressure based on the reading of the resistance value. Shown in Figure 2.3.4 [16].

Regarding temperature, a variable resistor can be used, which changes its value based on changes in temperature.

Fig 2.3.4

Regarding temperature, a variable resistor can be used, which changes its value based on changes in temperature. The resistance value becomes variable when exposed to temperature changes, as the flow of electric current in the resistor increases with temperature rise, enabling us to measure the temperature based on the change in resistance value.

By using variable resistors for pressure and temperature measurement, the electrical readings resulting from the change in resistance value can be converted into specific values for pressure or temperature using appropriate equations and calibration.

4. Node MCU Base Shield

Node MCU Base / IO board, built-in power supply and male header. This base board is designed to ease the prototyping using Node MCU V3 board (Lolin). It extends the GPIO of Node MCU to header pins, which also includes the Vin, VUSB, 5V, 3.3V and GND. The product features are ease the access of GPIO pins on Node MCU Plug ad use prototyping board for Node MCU LUA V3 board Eliminates the need of breadboard Extends the 5V, 3.3V, GND pins. Ease the interface between Node MCU to various sensor and actuator module Contains 5V Voltage regulator that is capable of output maximum 1A DC Barrel Jack for power input 6V to 24V DC. Figure 2.2.4 shows the node MCU shield[17].

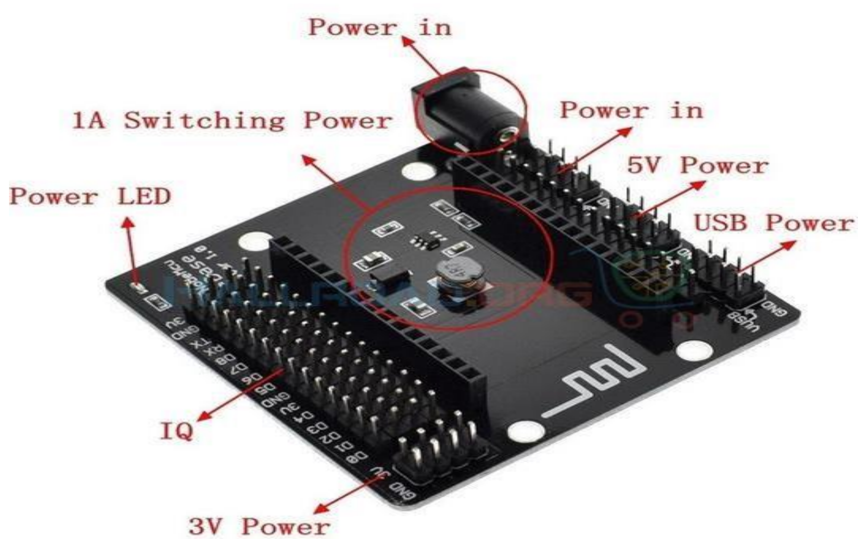


Fig 2.2.4

2.3 Software Components

Arduino (IDE)

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and Genuino hardware to upload programs and communicate with them [18]. That is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards, but also, with the help of third-party cores, other vendor development .

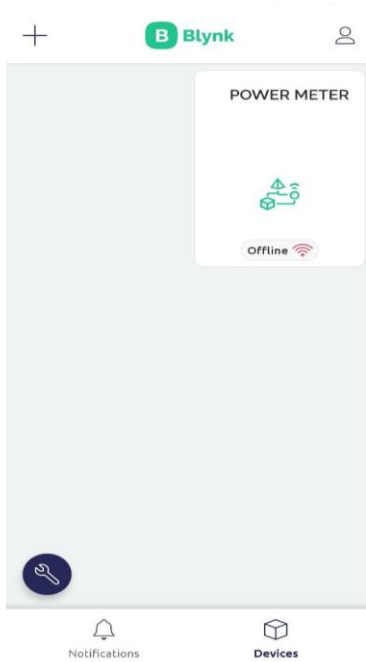
libraries

- #include<WiFiClient.h> Creates a client that can connect to a specified internet IP address and port as defined in client.connect()
- #include <ESP8266WiFi. h> This library provides ESP8266 specific Wi-Fi routines that we are calling to connect to the network. The actual connection to Wi-Fi is initialized by calling: begin("network-name", "pass-to-network"
- #include<liquidcrystal_i2c H> Display. A library for I2C LCD displays. The library allows to control I2C displays with functions extremely similar to LiquidCrystal library
- #include <wire.h> The Wire library allows you to communicate with I2C devices, often also called "2 wire" or "TWI" (Two Wire Interface)
- #include<ESP8266WebServer.h> Dead simple web-server. Supports only one simultaneous client, knows how to handle GET and POST
- #include <BlynkSimpleEsp8266.h> With Blynk apps for iOS and Android apps you can easily drag-n-drop graphic interfaces for any DIY or commercial

✦ project. It's a pure WYSIWG experience: no coding on iOS or Android required[18].

Blynk (iOS and Android interface developer)

Blynk is an iOS and Android-based application interface developer, ensuring the controlling of many controllers like Arduino, Raspberry Pi and ESP8266 via Internet. This program, a graphics interface can be developed for projects within the shortest period of time possible by simply using Widgets, without the need to write any code. Blynk is not dependent on a certain controller, but rather, it has the ability to operate in compatible with the controllers of various companies. It offers affordable solutions for project developers, while providing these users with the opportunity to benefit from the cloud service of Blynk, as well[19].

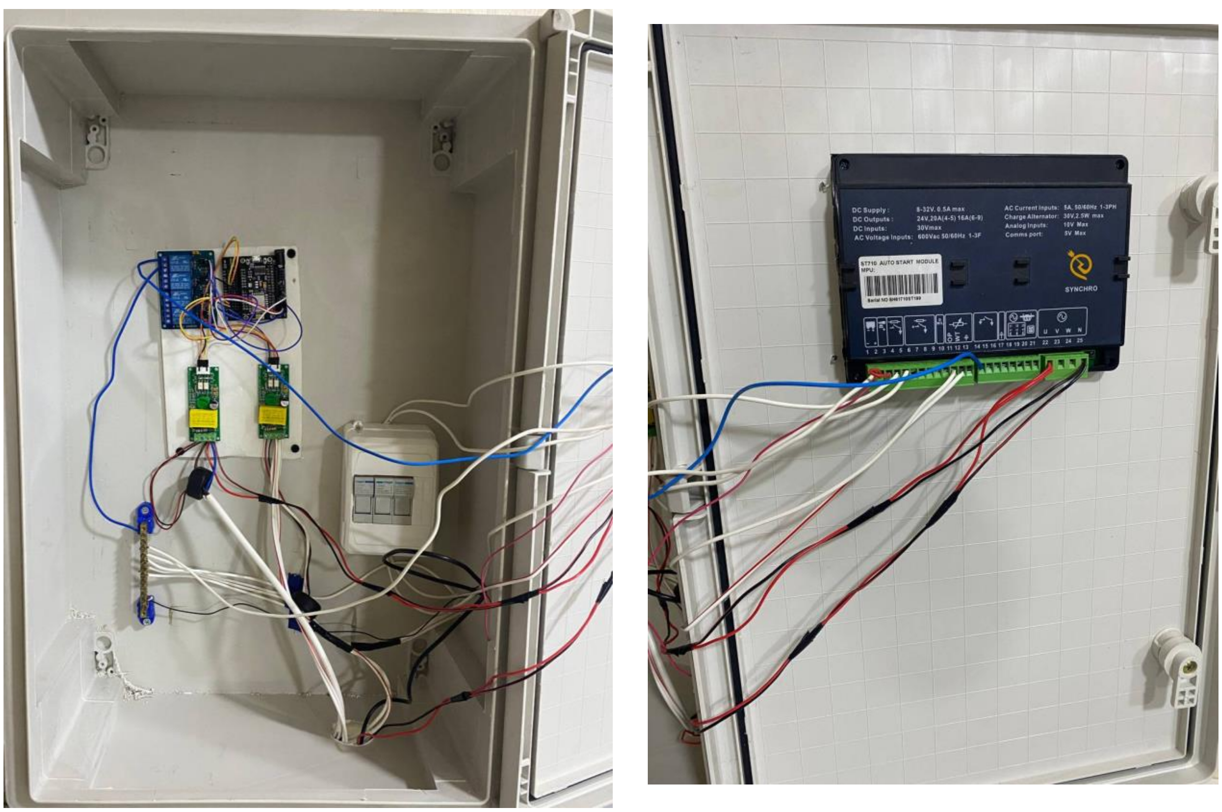


Chapter Three

Results and Discussions

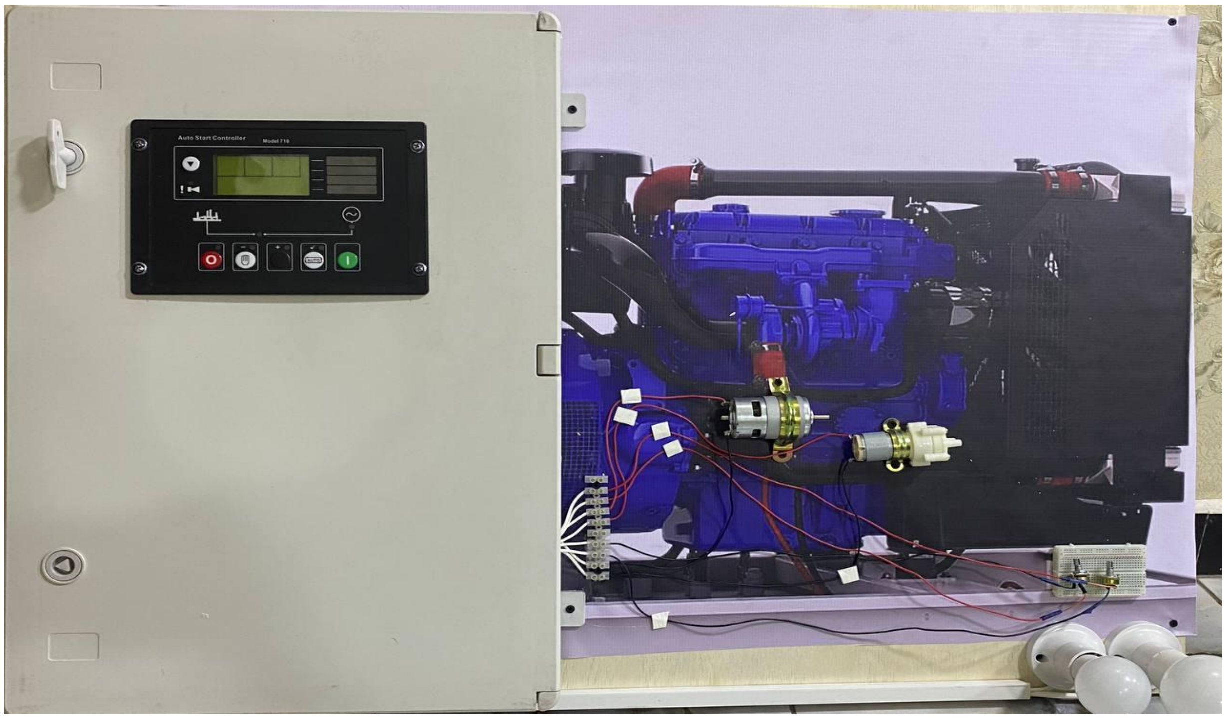
3.1 working

The DSE device was connected to the starter motor shown in Figure 3.1, also known as the crank, and the fuel motor in the generator. A variable resistor was used to measure the generator's pressure and temperature, as it was being simulated. We utilized a variable resistor in conjunction with the generator, and then connected it to a NodeMCU. Two power monitors from Power Montoring were employed, one for the generator's load, and the other for the national electricity. Afterwards, we connected the NodeMCU to a relay for controlling the input signal.



Figer 3.1

The operation process as Figure3.1.2 is as follows: after supplying 12V to the DSE device, a signal is sent to the starter motor and the fuel motor. They are activated by increasing the value of the variable resistor, which is simulated as pressure or temperature. As the pressure or temperature increases, the motor disconnects and stops. Consequently, the generator produces electricity, the load is activated, and readings are taken from the program.



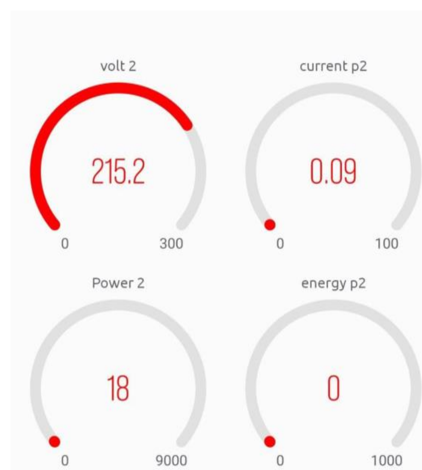
Figer 3.1.2

In the event of any issues with the starter motor or the fuel motor, the DSE device does not read the measurements and gives a warning signal, indicating that something is not functioning or there is a specific fault. Regarding the work program, it is called "Crank." There is an "Off" position and an "On" button for turning off and turning on, respectively.

3.2 Results

After completing the connection of all the components and preparing the software, connected the system to the mobile phone via Wi-Fi network. We will also read the current values of electric current, voltage, power factor, and other information related to electrical power. Using the software (Blynk),

we will display these values on the screen of the mobile phone or computer, allowing us to determine the amount of current consumed by the system and the amount of current generated.

Generator	National Electricity
	

3.3 Discussions

In this project, a system for remote measurement and control of a synchronous diesel generator using various hardware and software components. The system utilized the Deep Sea Electronics 710 module, NodeMCU ESP8266, power monitoring devices, and relay elements. The software components included the Arduino IDE and libraries such as WiFiClient, ESP8266WiFi, liquidcrystal_i2c, wire, ESP8266WebServer, and Blynk.

During the working phase, the DSE device to the starter motor and fuel motor of the generator. A variable resistor was used to simulate the generator's pressure or temperature. By adjusting the value of the variable resistor, the motors were activated or stopped accordingly. This allowed the generator to produce electricity, activate the load, and obtain readings from the program.

If any issues occurred with the starter motor or fuel motor, the DSE device would not read the measurements and provide a warning signal. This ensured the detection of faults or malfunctions in the motors. The software program, named "Crank," included an "Off" position and an "On" button for turning off and on the system, respectively.

after connecting all the components and setting up the software, the system was connected to a mobile phone via a Wi-Fi network. The software (Blynk) enabled the display of real-time values of electric current, voltage, power factor, and other electrical power-related information on the mobile phone or computer screen. This allowed for monitoring the current consumption and generation of the system.

After analyzing the results in the Blynk program, the voltage reading 215.2 volts and the current value 0.009 amps. The power value is calculated to be 18 watts, and the energy consumption is currently at 0. These readings are obtained when the load is a small electric lamp.

These measurements provide valuable information about the load, as well as the input and output voltage and current. By monitoring these values, we can gain insights into the efficiency and performance of the system. Furthermore, with further development, we can enhance the capabilities of the system by incorporating additional features.

For instance, we can implement a monthly billing calculation feature to track and manage the energy consumption and expenditure. This would enable users to better manage their electrical usage and budgeting. Additionally, we can incorporate pressure monitoring capabilities to ensure optimal performance and safety of the generator.

Furthermore, an annual and daily load calculation feature can be introduced to provide users with comprehensive insights into their power consumption patterns over time. This would enable better planning and resource allocation. The possibilities for further enhancements are vast, and the system can be customized to meet specific requirements and industry demands.

By continuously improving and expanding the system's functionalities, we can create a comprehensive and efficient solution for remote monitoring and control of synchronous diesel generators. This would provide users with greater convenience, cost-effectiveness, and sustainability in their power management practice

Chapter Four
Conclusions and Recommendations

4.1 Conclusions

the project focused on the hardware simulation and remote measurement and control of a synchronous diesel generator in a smart meter project. The objective was to develop a system that enables remote monitoring and control of the generator through a mobile phone application.

Through the implementation of the Deep Sea Electronics 710 module, NodeMCU ESP8266, power monitoring devices, and relay elements, the system successfully achieved its goals. The Deep Sea Electronics 710 module served as the core control unit, facilitating communication and control functionalities. The NodeMCU ESP8266 acted as an interface, enabling remote access and control of the generator system.

Power monitoring devices were integrated into the system to accurately measure and report important parameters such as voltage, current, power factor, and frequency. This allowed for real-time monitoring and analysis of the generator's performance.

The inclusion of relay elements enabled remote control of the generator, providing users with the ability to start and stop the generator from their mobile devices. This added convenience and flexibility to the system, especially in situations where manual intervention may not be feasible.

The system's ability to optimize the load on the generator was another significant achievement. By remotely adjusting the load, the system alleviated strain on the generator, ensuring efficient utilization and reducing the risk of overload.

Overall, the implementation of the smart meter project with remote measurement and control capabilities showcased the potential for improved efficiency, convenience, and optimal utilization of the synchronous diesel generator. The system provided users with remote access to monitor and control the generator, enhancing control capabilities and enabling real-time decision-making.

Future work could involve further refinement and enhancement of the system, such as integrating additional features like predictive maintenance or integrating renewable energy sources for a more sustainable power generation system.

4.2 Recommendations

Monitoring and protection: Utilize advanced control technologies like the ESP8266 and DEEP SEA ELECTRONICS Model 710 to enable remote monitoring and control of synchronous generator diesel engines. This enhances convenience, flexibility, and efficiency.

Enhance Mobile Application: Improve the user interface and user experience of the mobile application to ensure ease of use and provide real-time access to generator status and control functionalities.

Integrate Safety Features: Incorporate safety features, such as circuit breakers and protection mechanisms, into the control system to ensure the safe operation of the generator.

Conduct Regular Maintenance: Establish a routine maintenance plan to ensure the long-term reliability of the generator. This includes monitoring critical parameters, performing inspections, and addressing any issues promptly.

Implement Security Measures: Implement robust security measures to protect the control system from unauthorized access or tampering. This can involve encryption, authentication protocols, and regular security updates.

Explore Energy Efficiency: Consider implementing energy efficiency measures in the control system, such as load optimization and power factor monitoring, to optimize fuel consumption and reduce operational costs.

Provide Training and Support: Offer comprehensive training and ongoing support to operators and users of the control system to ensure proper understanding and utilization of its features.

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شكر و تقدير

شكرا لله اولا

اما بعد....

لابد لنا ونحن نخطو خطواتنا الأخيرة في الحياة الجامعية من وقفة نعود إلى أعوام قضيناها في رحاب الجامعة مع أساتذتنا الكرام الذين قدموا لنا الكثير باذلين بذلك جهودا كبيرة في بناء جيل الغد لتبعث الأمة من جديد. ..

وقبل أن نمضي تقدم أسمى آيات الشكر والامتنان والتقدير
والمحبة إلى الذين حملوا أقدس رسالة في الحياة. ..
إلى الذين مهدوا لنا طريق العلم والمعرفة...
إلى جميع أساتذتنا الأفاضل. ......
ونخص بالذكر اساتذتنا
(دكتور اياد تحسين)
(استاذ سعد عودة)

"كن عالما .. فإن لم تستطع فكن متعلما ، فإن لم تستطع فأحب العلماء ،فإن لم تستطع فلا تبغضهم"

محمد حسن سعد

كاظم حسن ابراهيم

محمد حاشوش ناصر

حمزة حسنين كامل

2022/2023

Ministry of Higher Education and scientific research

Al – Iraqia University

College of Engineering

Electrical Engineering Department

Design and Implementation of Smart Library

A Project

Submitted to the College of Engineering of Al-Iraqia University in Partial Fulfillment of the Requirements for the Degree of Bachelorof Science In Electrical Engineering

Presented By

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بسم الله الرحمن الرحيم

{وَقَضَى رَبُّكَ أَلاَّ تَعْبُدُواْ إِلاَّ إِيَّاهُ وَبِالْوَالِدَيْنِ احسانا}

صدق الله العلي العظيم

الاسراء آية : (23)

Certificate

I certify that this project entitled **"Design and Implementation of Smart Library"**was prepared by**AHMAD MOHSEN AWWAD**, **SARAH HABIB KHUDAIR**, **RANDA RAAD MOHI** and **MARYAM SAMIR ABDEL HADI**fadelunder my supervision at Al-Iraqia University / College of Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical Engineering.

Signature:

Name: **Asst. Lect. RaghdaAbdUlRab**

(Supervisor)

Date: 26/ 6 /2022

Signature:

Name: Asst. Prof. Dr. **BaraaMunqith**

(Head of Department)

Date: / /

Certificate

We certify, as an examining committee, that we have read this project entitled **"Design and Implementation of Smart Library"**, examined student**AHMAD MOHSEN AWWAD**, **SARAH HABIB KHUDAIR**, **RANDA RAAD MOHI** and **MARYAM SAMIR ABDEL HADI**in its content and found it meets the standard of thesis for the degree of Bachelor of Science in Electrical Engineering.

Signature:		Signature:	
Name:	(Member)	Name:	(Member)
Date:	/ /	Date:	/ /

Signature:

Name: (Chairman)

Date: / /

Approval of the College of Engineering

Signature:

Name: **Asst. Prof. Dr. MowafaqShyaaAlwan**

(Dean)

Date: / /

Dedication

Whoever taught us How do I start the journey of a thousand miles step by step to my dear father …….

To the nostalgic heart that was beside us in all past stages

For those who taught me that great deeds are not completed without patience, determination and perseverance to my dear mother….

My teachers who have guided usIt leads us to the path of knowledge ….

My brothers and friends who were a canle on my way.

Acknowledgements

In the name of God, the Most Gracious, the Most Merciful, and prayers to the most honorable of the prophets and messengers. I thank God Almighty for granting us health, patience and perseverance in work, and making the effort to follow up and complete this study.

We extend our sincere thanks and respect to the distinguished professor, Dean of the College of Engineering, Assistant Professor Dr. Mowafaq the Respected and Head of the Electricity Department, Assistant Professor,Dr. BaraaMunqith

the respected and Asst. Lect. RaghdaAbdUlRab ,for the great support you gave us and for the sincere effort and follow-up that you showed us that led us to complete our project

Abstract

Library members can have their library card activated for use when the library is in self-access (Smart Library) mode. A short induction will be required before your library card is activated. This induction will provide all the details you need on how the system works and how to use the Smart Library safely and responsibly. The induction will be available in a number of ways – in person at the library whilst the library is staffed, or as part of a dedicated induction session in the evening. We are also intending to introduce an online induction in the near future. To access a Smart Library, you scan your library card at the door and enter your PIN. The door will then open and you can use the library in the normal way. 15 minutes before closure audio loud speaker announcements will begin warning that the library is due to close and the public computers will switch off 10 minutes before closure. Lights will go out once the library is closed.The smart library project was designed and implemented, where we can search for the name of a specific book, and if the book exists, it will be indicated through headphones with its location specified, and in the case of the book that does not exist, we will be notified.

List of Content

Chapter One

1.1 Introduction ………………… 1

1.2 Research Problem…………… 3

1.3 Research Aims.................... 2

1.4 A Literature Review................. 4

Chapter Two

2.1 Introduction 5

2.2 Electronic Circuit Components 5

2.2.1 Arduino Uno SMD …………5

2.2.2 Micro SD Card (64GB) 7

2.2.3 Computer Speakers……8

Chapter Three

3-1 introduction 9

3-2 Hardware.....................10

3-4 General Research Flowchart.....................11

3-5 The method of work.....................12

3-6 Project photos....................13

3-7 Programming....................14

Chapter Four

4.1 Conclusions And Recommendations..................... 18

4.1.1.Conclusions..................... 18

4.1.2. Recommendations............ 18

References

List of Figures

Figure	No. of Page
2-1	6
2-2	7
2-3	8
3-1	11
3-2	12

1.1
Introduction

A library fitted with ‘Smart Library’ technology is able to be open to library users without being staffed. The technology enables remote control of library buildings, including automatic doors, lighting, self-service kiosks and public computers. This allows us to significantly extend library opening hours, so more people can use the library at times that is convenient for them.

Library members can have their library card activated for use when the library is in self-access (Smart Library) mode. A short induction will be required before your library card is activated. This induction will provide all the details you need on how the system works and how to use the Smart Library safely and responsibly. The induction will be available in a number of ways – in person at the library whilst the library is staffed, or as part of a dedicated induction session in the evening. We are also intending to introduce an online induction in the near future. To access a Smart Library, you scan your library card at the door and enter your PIN. The door will then open and you can use the library in the normal way. 15 minutes before closure audio loud speaker announcements will begin warning that the library is due to close and the public computers will switch off 10 minutes before closure. Lights will go out once the library is closed.

The smart library project was designed and implemented, where we can search for the name of a specific book, and if the book exists, it will be indicated through headphones with its location specified, and in the case of the book that does not exist, we will be notified.

1.2 Research Problem

There are several problems present in The system that have become an essential part of our research, including:

1. Difficulty accessing the book in a short time
2. Not knowing the books available in the library
3. It takes a lot of time searching

1.3 Research Aims

A smart library's objective is **to provide smarter services**. The key to success is innovation. As a result, big data technology may be used to provide smart services. In addition, big data may be used to create improvements, Our system provides the following services:

1. Access to the book in a short time
2. knowing the books available in the library
3. Reducing the time spent searching for a specific book

1.4 A Literature Review

Libraries can be described as social and technological-intellectual infrastructures, as essentialelements in a "larger network of public services and knowledge institutions of which each library isa part" [1]. Their traditional function is to buy, preserve, and make available books, journals, and othermediatoagivenlocal,academic,orothercommunity.But,asaninformationservice,theyalsoallowconnections between people, and they have the potential to become de facto community centers.They are a physical space, a good place to go and have a good time, welcoming and comfortable,highlyaccessible,inexpensiveorfree,withregulars,suchasstaff[2].Howcantheycontributetothesmartcity?

Libraries are cultural and scientific institutions, with holdings, book stacks, reading rooms,physicallearningspaces,aswellasvirtualhubsofknowledgeconsumptionandproduction.Theyplayaroleineducationandinformationliteracy.Theyareculturalassets,oneofthoserareplaceswheretechnology and even productivity meet communal and human values. How does the smart city impacttheseassets?

Libraries have a problem with advocacy and marketing.For nearly forty years now, peoplequestion the future of the library. Some of them even predict the end of the library, unable to copewith the digital age and social change, unsustainable, some kind of vintage of the Gutenberg era;having reached an impasse, they "may disappear like the dinosaurs" [3]. Can the smart city providea newperspective?Canitaddtothelibrary valueandits“returnoninvestment”?

Will the technological development contribute to the decline or “significant alteration” of thetraditionallibrary?Isthisthe“endofwisdom”[4]?Onethingissure:theemergingurbanenvironment

of information technologies and connectivity, mobility, digital nomads, and local community, is highlyrelevant for the future development of libraries, and libraries must propose innovative solutions iftheyaretostayinthegame.Inotherwords,librariesshouldinterpretthechallengeofthesmartcityasanopportunity,notasathreat.

2.1 Introduction

Smart libraries are aligned with the developmental trends and innovations in education delivery. Virtual classrooms, distance education, online classes and similar trends are synonymous to education in this age. Smart libraries are changing the landscape of information service delivery in today's world. As users get more sophisticated in their information seeking endeavours, libraries must respond positively by adopting methods and innovations to meet the needs of their users. Failure to meet up to users expectations would see them being by-passed for other information providers.

2.2 Electronic Circuit Components

An electronic circuit consists of several components:

2.2.1 Arduino Uno SMD

The Arduino Uno SMD is a version of the Arduino Uno, but uses an surface mount version of the Atmega328P instead of the through-hole version. This version was made in response to a shortage in supply of the through-hole Atmega328P. The board is based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.
The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter[5].as shown in the figure (2-2) below:

Advantages

a completely solve the traditional UNO board is not compatible with win7,

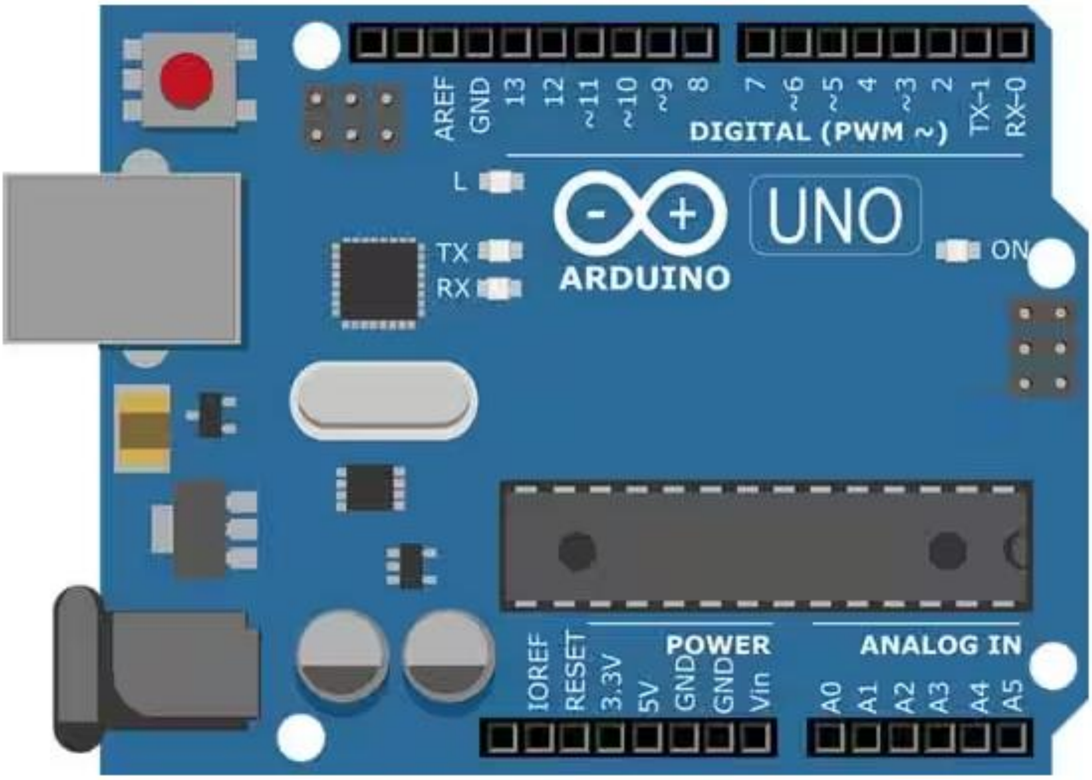


Figure (2-1) Arduino Uno SMD[7]

win8 and win10 system instability above. Increased pin socket , to facilitate the use of DuPont line. Replaces the 16u2, so the cost is reduced by half, consumers get the maximum benefit[5] .

2.2.2 Micro SD Card (64GB)

- Capacity: 64GB
- Speed: Class 10
- For use with Cello and Ferguson Android TVs
- Other applications: Mobile Phones, Laptops, Tablets, Music Players, Digital Camera, Digital Photo Frame
- One year warranty

Figure (2-2) Micro SD Card (64GB)

2.2.3 Computer Speakers

Computer speakers, or multimedia speakers, are speakers sold for use with computers, although usually capable of other audio uses, e.g. for an MP3 player. Most such speakers have an internal amplifier and consequently require a power source, which may be by a mains power supply often via an AC adapter, batteries, or a USB port. The signal input connector is often a 3.5 mm jack plug (usually color-coded lime green per the PC 99 standard); RCA connectors are sometimes used, and a USB port may supply both signal and power (requiring additional circuitry, and only suitable for use with a computer). Battery-powered wireless Bluetooth speakers require no connections at all. Most computers have speakers of low power and quality built in; when external speakers are connected they disable the built-in speakers.

Figure (2-3)Computer speakers,

2.2.4 HC-06 Bluetooth

The HC-06 is a class 2 slave Bluetooth module designed for transparent wireless serial communication. Once it is paired to a master Bluetooth device such as a PC, smartphone, and tablet, its operation becomes transparent to the user. All data received through the serial input is immediately transmitted over the air

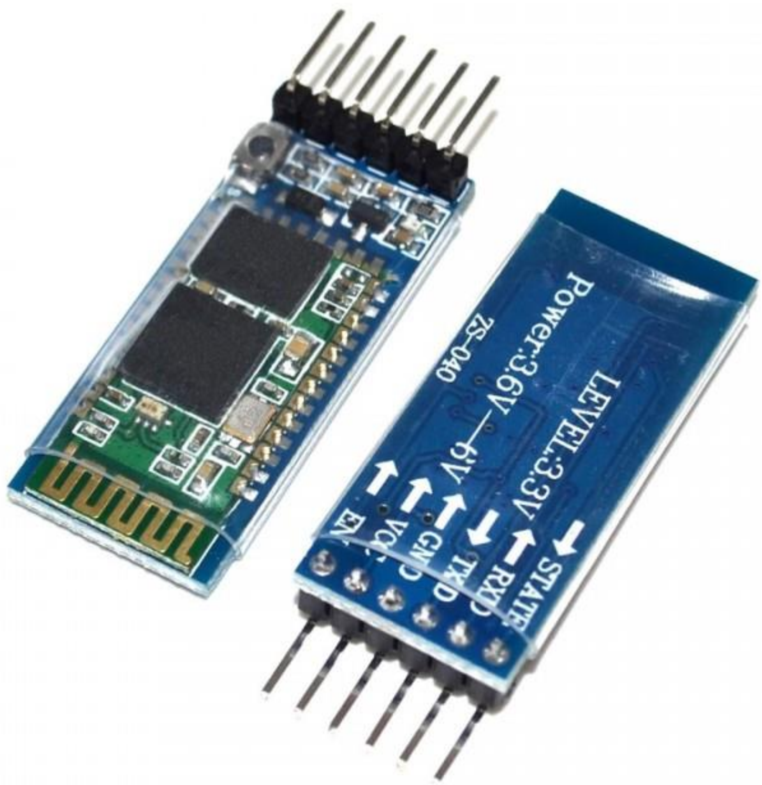


Figure (2-4) HC-06 Bluetooth,

2.2.5 connect to phone

tap the HC06 in the list, and you will then be asked for the PIN - it is 1234. Finally, open your terminal app on the smartphone, and select "Connect a device" from the app menu. Select the HC-06 option and then wait a moment. The LED on the Bluetooth module should stay on and the app will show "connected: HC-06

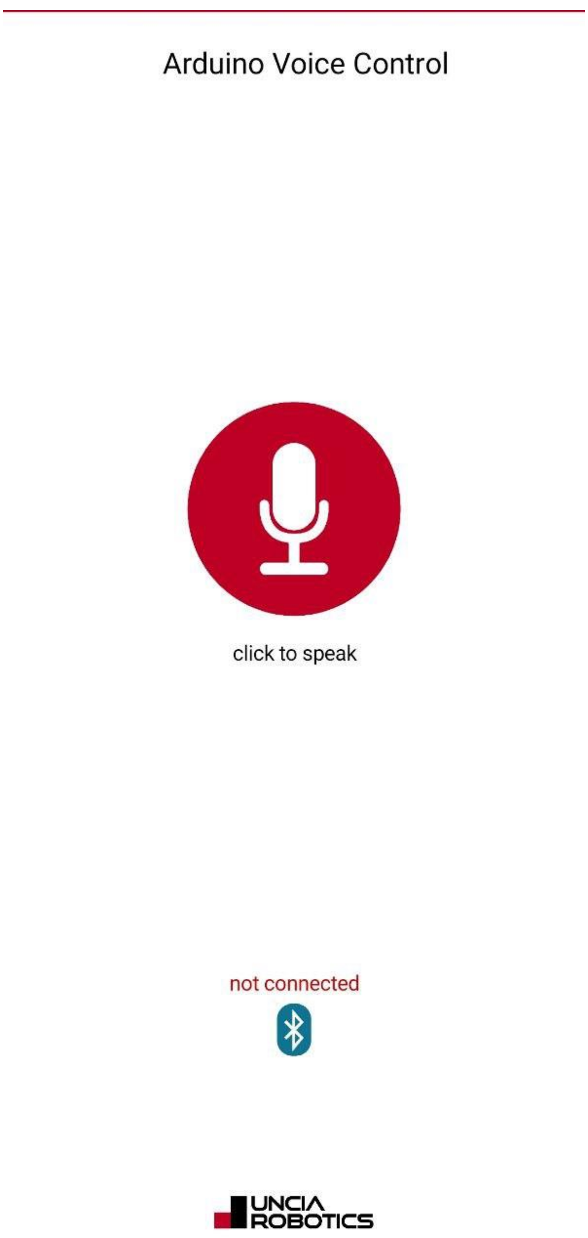


Figure (2-5) apliction,

2.2.6 . Micro Sd Card Module

The micro- SD Card Module is a simple solution for transferring data to and from a standard SD card. The pin out is directly compatible with Arduino, but can also be used with other microcontrollers. It allows you to add mass storage and data logging to your project

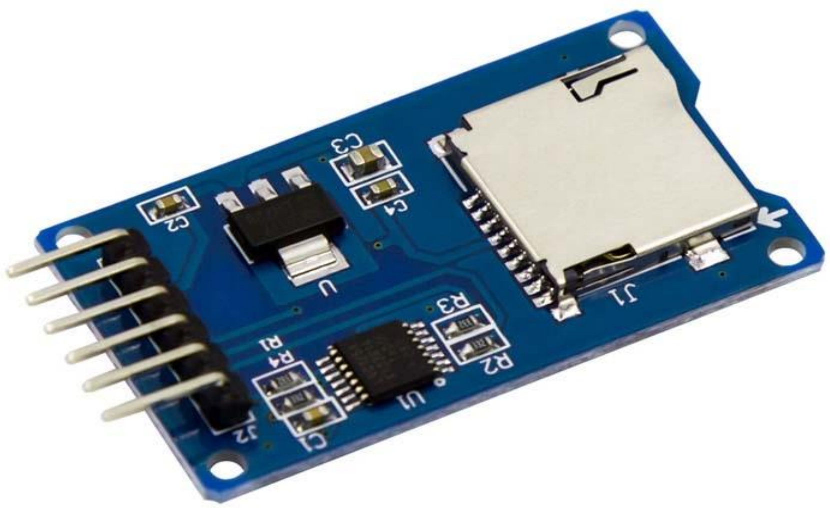


Figure (2-6) Micro Sd Card Module

3-1 introduction.

During Smart library hours you can :

•Borrow, return and renew library items and pay charges using the self-service kiosks.

• Collect reserved items that are awaiting collection at the reservation collection point and borrow them using the self-service kiosks .

•Use the public PCs and free library WiFi.

• Print from the public PCs, photocopy and scan documents .

•Access and browse the public library catalogue on public PCs.

•Meet as a group free of charge in the open library space.

• Hire a meeting room (pre booking required).

3-2 Hardware

In order to complete the work requirements, a computer with the simple specifications below was used

- CPU: Intel® core ™ i3 CPU M380 @ 2.53GHz 2.53.
- Memory: 400 GB (2.93 GB usable).
- Hard drive: 465.76 GB.

The proposed system can be applied with any hardware specification.

3-2 Hardware

In order to complete the work requirements, a computer with the simple specifications below was used

- CPU: Intel® core ™ i3 CPU M380 @ 2.53GHz 2.53.
- Memory: 400 GB (2.93 GB usable).
- Hard drive: 465.76 GB.

The proposed system can be applied with any hardware specification.

3-3 Software

The software used during the work to complete the requirements of our project is as follows

- Operating system: windows 7 (32-bit).
- Compiler: Arduino

3-4General Research Flowchart

The work was divided into three stages, and each stage fulfills part of the work requirements as follows:

- Input
    - Detectors
- Control
    - Arduino Uno SMD
- Output
    - Sound &Lighting

The diagram(3.1) below shows the stages of work:

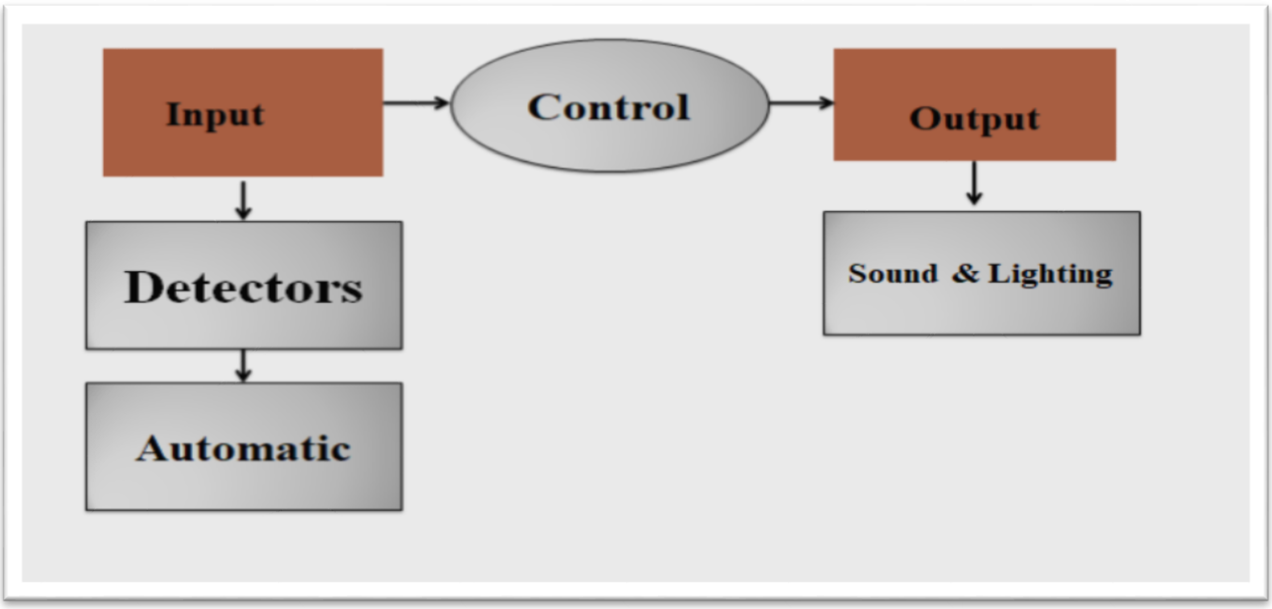


Figure (3.1) Research Flowchart

3-5The method of work

The smart library project was designed and implemented, where we can search for the name of a specific book, and if the book exists, it will be indicated through headphones with its location specified, and in the case of the book that does not exist, we will be notified

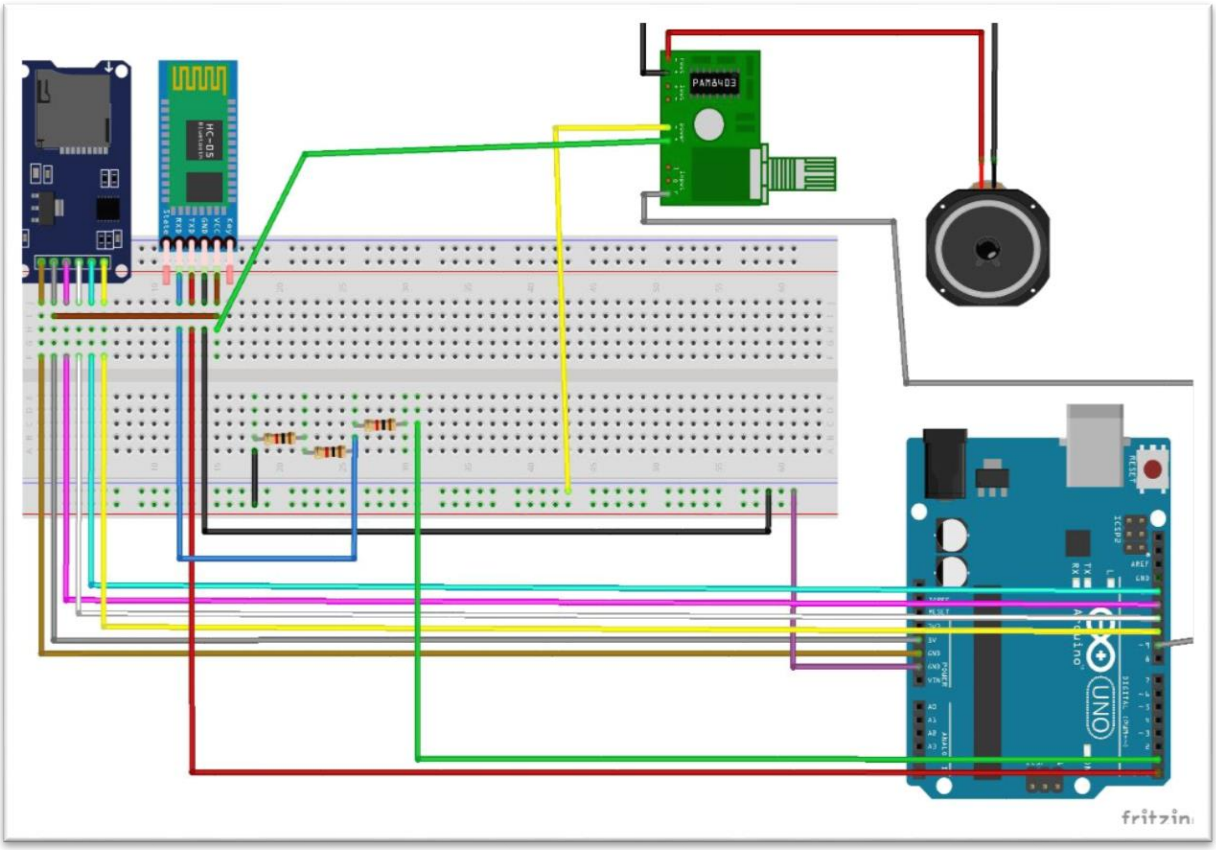
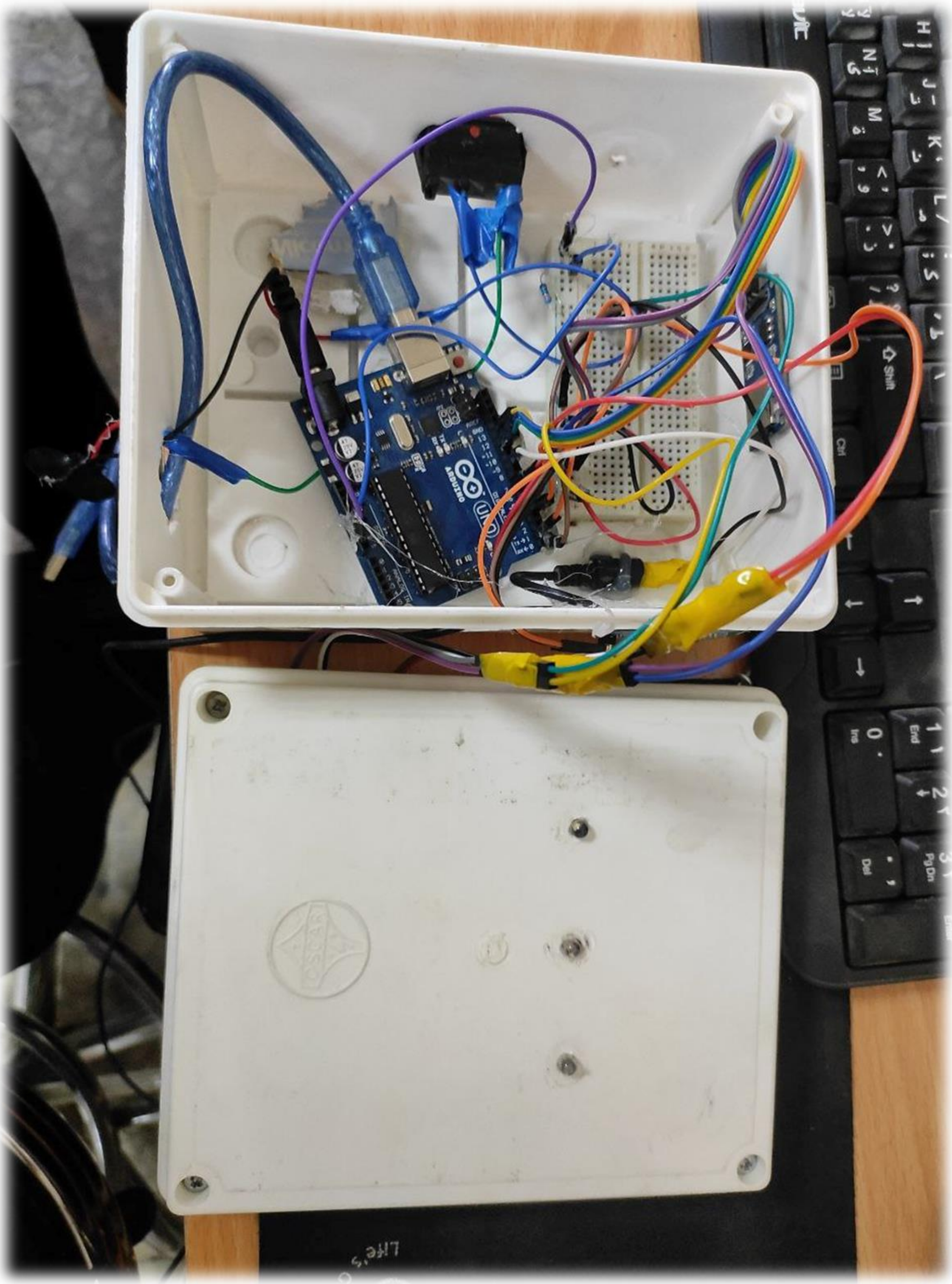


Figure (3.2) the electronic circuit

3-6 Project photos

Below is a collection of project photos:



3-7Programming

```
#include "SD.h" //Lib to read SD card

#include "TMRpcm.h" //Lib to play audio

#include "SPI.h" //SPI lib for SD card

#defineSD_ChipSelectPin 4 //Chip select is pin number 4 TMRpcm music; //Lib object is named "music" String voice ;

void setup()

{

 pinMode(5,OUTPUT);

   pinMode(6,OUTPUT);

 pinMode(7,OUTPUT);

 music.speakerPin = 9;

 //Auido out on pin 9 Serial.begin(9600);

//Serial Com for debugging if (!SD.begin(SD_ChipSelectPin)) { Serial.println("SD fail"); return;

}

digitalWrite(5,HIGH);

delay(200);

digitalWrite(6,HIGH);delay(300);

digitalWrite(7,HIGH);delay(300);

digitalWrite(5,LOW);

delay(300);

digitalWrite(6,LOW);delay(300);

digitalWrite(7,LOW);delay(300);

music.setVolume(6);

 //   0 to 7. Set volume level 5&1 or 6&0 music.quality(0);

 //  Set 1 for 2x oversampling Set 0 for normal //music.volume(0);
```

```
  //   1(up) or 0(down) to control volume music.play("a11.wav");
//plays a file starting at 30 seconds into the track    }
void loop()
 {
while (Serial.available())
{ /*check for serial or signal*/   char c = Serial.read () ;
/*define a variable that read that signal*/
if (c == '#')
{ /*when # is detected...*/     break ; /*exit the loop*/   }
voice += c ;   }     if (voice.length() > 0)
{ /*if you receive any data...*/     Serial.println(voice) ;
      if (voice == "electrical machine")
{       digitalWrite(5,HIGH);
delay(200);
digitalWrite(6,HIGH);delay(300);
digitalWrite(7,HIGH);delay(300);
digitalWrite(5,LOW);
delay(300);
digitalWrite(6,LOW);delay(300);
digitalWrite(7,LOW);delay(300);
music.setVolume(6);
 //   0 to 7. Set volume level 5&1 or 6&0 music.quality(0);
  music.play("b1.wav");
delay(100);
  }
if (voice == "electrical power")
{
```

```
digitalWrite(5,HIGH);
delay(200);
digitalWrite(6,HIGH);delay(300);
digitalWrite(7,HIGH);delay(300);
digitalWrite(5,LOW);
delay(300);
digitalWrite(6,LOW);delay(300);
digitalWrite(7,LOW);delay(300);
       music.setVolume(6);
 //   0 to 7. Set volume level 5&1 or 6&0 music.quality(0);
     music.play("c1.wav");
     }
if (voice == "engineering analysis")
{     digitalWrite(5,HIGH);
delay(200);
digitalWrite(6,HIGH);delay(300);
digitalWrite(7,HIGH);delay(300);
digitalWrite(5,LOW);
delay(300);
digitalWrite(6,LOW);delay(300);
digitalWrite(7,LOW);delay(300);
  music.setVolume(6);
 //   0 to 7. Set volume level 5&1 or 6&0 music.quality(0);
    music.play("d1.wav");
   }
if (voice == "electrical circuit")
{ digitalWrite(5,HIGH);
```

```
delay(200);
digitalWrite(6,HIGH);delay(300);
digitalWrite(7,HIGH);delay(300);
digitalWrite(5,LOW);
delay(300);
digitalWrite(6,LOW);delay(300);
digitalWrite(7,LOW);delay(300);
   music.setVolume(6);
 //   0 to 7. Set volume level 5&1 or 6&0 music.quality(0);
      music.play("e1.wav");
   }
voice="" ; }
delay(100);
 }
```

4.1 Conclusions And Recommendations

After applying and operating the system, we present a number of conclusions and recommendations as follows:

4.1.1.Conclusions

A smart library's objective is to provide smarter services. The key to success is innovation. As a result, big data technology may be used to provide smart services. In addition, big data may be used to create improvements, Our system provides the following services:

1. Access to the book in a short time
2. knowing the books available in the library
3. Reducing the time spent searching for a specific book

4.1.2. Recommendations

Practical application of this project in large and central libraries with some updates

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الخلاصة

يمكن لأعضاء المكتبة تنشيط بطاقة المكتبة الخاصة بهم للاستخدام عندما تكون المكتبة في وضع الوصول الذاتي (المكتبة الذكية). ستكون هناك حاجة إلى تعريف قصير قبل تنشيط بطاقة المكتبة الخاصة بك. سيوفر هذا التعريفي جميع التفاصيل التي تحتاجها حول كيفية عمل النظام وكيفية استخدام المكتبة الذكية بأمان ومسؤولية. سيكون التعريفي متاحًا بعدة طرق - شخصيًا في المكتبة أثناء وجود موظفين في المكتبة ، أو كجزء من جلسة تعريفية مخصصة في المساء. نعتزم أيضًا تقديم تعريف عبر الإنترنت في المستقبل القريب. للوصول إلى مكتبة ذكية ، تقوم بمسح بطاقة المكتبة الخاصة بك عند الباب وإدخال رقم التعريف الشخصي الخاص بك. سيفتح الباب بعد ذلك ويمكنك استخدام المكتبة بالطريقة العادية. قبل 15 دقيقة من الإغلاق ، ستبدأ الإعلانات الصوتية بصوت عالٍ في التحذير من أن المكتبة على وشك الإغلاق وسيتم إيقاف تشغيل أجهزة الكمبيوتر العامة قبل 10 دقائق من الإغلاق. تنطفئ الأضواء بمجرد إغلاق المكتبة ، وقد تم تصميم مشروع المكتبة الذكية وتنفيذه ، حيث يمكننا البحث عن اسم كتاب معين ، وإذا كان الكتاب موجودًا ، فسيتم الإشارة إليه من خلال سماعات الرأس مع تحديد موقعه ، وفي حالة الكتاب غير موجود ، سيتم إعلامنا.

شكر وتقدير

بسم الله الرحمن الرحيم

والصلاة إلى أشرف الأنبياء والمرسلين. أشكر الله عز وجل أن منحنا الصحة والصبر والمثابرة في العمل ، وبذل الجهد لمتابعة وإنجاز هذه الدراسة.

نتقدم بخالص الشكر والاحترام للأستاذ المتميز ، عميد كلية الهندسة ، الأستاذ المساعد الدكتور موفق المحترم ورئيس قسم الكهرباء الدكتور براء المحترم والمدرس المساعد الست رغدة عبد الرب على الدعم الكبير الذي قدمتموه لنا وعلى الجهد الصادق والمتابعة التي أظهرتموها لنا والتي دفعتنا لإتمام مشروعنا.

وزارة التعليم العالي والبحث العلمي
الجامعة العراقية
كلية الهندسة
قسم الهندسة الكهربائية

تصميم و تنفيذ المكتبة الذكية

مشروع

مقدمة إلى كلية الهندسة في الجامعة العراقية وهي جزء من متطلبات نيل درجة بكالوريوس علومفي الهندسة الكهربائية

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م.م رغده عبد الرب

Ministry of Higher Education and Scientific research
Al-Iraqia University
Engineering College
Electrical Engineering Department

An Approach for the Estimation of the Signal-To-Noise Ratio in Surface Myoelectric Signals

A Project Submitted to the Department of Electrical Engineering in Partial Fulfilment for the Requirements of the Degree of B.Sc. in Electrical Engineering

BY
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Moamel salem Hammed
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SUPERVISOR

Assist Prof : Anas Fouad Ahmed

2022-2023

يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ

المجادلة11

DECLARATION

We hereby declare that this project report is based on our original work except for citations and quotations, which have been duly acknowledged.

Signature : ___________________________

Name : **Sajjad Haithem Qassim**

Date : ___________________________

Signature : ___________________________

Name : **Moamel salem Hammed**

Date : ___________________________

Signature : ___________________________

Name : **Hassan Youssef Ktaeif**

Date : ___________________________

APPROVAL FOR SUBMISSION

I certify that this project report entitled **"An Approach for the Estimation of the Signal-To-Noise Ratio in Surface Myoelectric Signals"** was prepared by **Sajjad Haithem Qassim , Moamel salem Hammed Hassan Youssef Ktaeif** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of **Electrical Engineering** at Al-Iraqia University .

Approved by,

Signature : ___________________________

Supervisor : **Assist Prof. Anas Fouad Ahmed**

Date : ___________________________

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All others who have indirectly supported this research: I would like to acknowledge all those who have indirectly influenced and contributed to this research project.

ABSTRACT

The estimation of the signal-to-noise ratio (SNR) in surface myoelectric signals plays a critical role in the analysis and interpretation of these signals. Accurate estimation of SNR provides valuable insights into the quality and reliability of the recorded myoelectric signals, which is essential for applications such as prosthetics control, rehabilitation, and human-computer interaction. In this paper, we present an approach for the estimation of SNR in surface myoelectric signals. The approach involves a combination of signal processing techniques and statistical analysis. First, the raw myoelectric signals are acquired from the surface electrodes using appropriate sensors. Then, preprocessing techniques are applied to remove noise, artifacts, and interference from the signals. This is followed by the estimation of the power spectrum of the signals using methods such as Fourier analysis or wavelet transform. The developed approach has potential implications in various applications, including prosthetics control, rehabilitation therapy, and human-machine interfaces. Accurate estimation of SNR can improve the performance and reliability of these applications by enabling better signal interpretation and control. Future work may involve exploring advanced signal processing techniques, real-time estimation algorithms, and the integration of SNR estimation in practical systems.

TABLE OF CONTENTS

DECLARATION **ii**

APPROVAL FOR SUBMISSION **iii**

ACKNOWLEDGEMENTS **iv**

ABSTRACT **v**

TABLE OF CONTENTS **vi**

Chapter one 1

1.1 Introduction **1**

1.2 Structure of Muscle and Motor Unit **4**

1.2.1 Muscle Electrical Activity **5**

1.2.2 EMG Recording **5**

1.2.3 EMG properties **6**

1.2.4 NOISES IN EMG SIGNAL **7**

1.3 Problem Statement: **9**

1.4 Motivation **9**

1.5 Aims of the project **10**

1.6 Outline **11**

Chapter Tow **12**

Literary survey **12**

Chapter Three 16

3.1 MATLAB 16

3.2Materials and methods: 17

3.2.2 Separating Signal From Noise 19

3.2.3 Description of the Algorithm **21**

Chapter Four 25

4.1 Validation of the Algorithm 25

Chapter Five **29**

5.1Conclusion 29

5.2Future work 30

References 31

APPENDICES **33**

List of figures

Figure1-1	Skeletal muscle structure	3
Figure 1-2	Skeletal muscles provide force to move levers in human body	4
Figure 1-3a	concentric (single-channel) needle	6
Figure 1-3 b	quadrifilar (multiple channel) needle.	6
Figure (3-1)	Cyclostationary processes	17
Figure (3-2)	Histograms of the series of the normalized sum of squares Cr (in logarithmic scale)	19
Figure (3-3a)	Histogram of Log10 C relative to a cyclic signal	22
Figure (3-3b)	Histogram of Log10 C relative to a cyclic signal	23
Figure (3-4)	Representation of 1 cycle of the synthetic SMES obtained	24
Figure (4-1)	Apply code	26
Figure (4-2a)	The result	27
Figure (4-2b)	The result	28

Chapter one

General introduction

1.1 Introduction

Surface electromyography (sEMG) is a non-invasive technique that measures the electrical activity of muscles by placing electrodes on the skin surface. The signal-to-noise ratio (SNR) is an important parameter to evaluate the quality of sEMG recordings, as it determines the ability to extract useful information from the signals. There are several methods to estimate the SNR in sEMG signals, but one common approach is to use the ratio between the mean amplitude of the signal and the standard deviation of the noise. However, this approach can be affected by various factors, such as muscle fatigue, electrode placement, and motion artifacts [1]. The analysis of the myoelectric signal allows us to determine if a specific muscle is active or silent . In particular, myoelectric control is an advanced technique concerned with the detection, processing, classification, and application of SMES to the active control of prosthetic limbs, human-assisting robots, or rehabilitation devices. The movements of the corresponding body segments imply cyclic contractions of muscles. As a consequence, an SMES detected from a specific muscle results in a sequence of pseudo periodical activation bursts . However, the probe detects a background noise that is unavoidable in any dynamic test. The relevance of considering the muscle activation timing is supported by several studies demonstrating its usefulness in orthopaedics, treatment of cerebral palsy, and a number of other clinical applications .Well established techniques to determine the activation pattern of a muscle are based on single- or double-threshold statistical detectors . These detectors require, as a necessary input parameter to set the (first) threshold, the background noise level. Furthermore, double-threshold detectors require additional parameters in order to fine tune the second threshold. In particular, it is important to estimate the SNR and, to a minor extent, the duty cycle (DC) of the detected signal. The method we present in this contribution allows us to estimate the root-mean-square value of the background noise (enoise) , the SNR, and the DC of an SMES generated during cyclic movements. This is done following a statistical approach that does not require any a priori knowledge on the signal [2].

1.1.1 Skeletal muscle structure

To understand how muscles contract, we must first know about their structure Skeletal muscles are composed of multiple fascicles, which are bundles are many smaller muscle fibers surrounded by a layer of connective tissue (the perimysium) . In many skeletal muscles, the fascicles are aligned parallel to one another, running along the length of the muscle . Some muscles have fascicles which meet at one attachment point (convergent), while others feather out from a central tendon (pennate). The arrangement of the fascicles affects the direction and angle at which the fibers can pull, and also affects force generation in the muscle .Each muscle fiber is itself composed of many smaller myofibrils, containing the molecular machinery for contraction . Positioned right next to the T-tubules is the sarcoplasmic reticulum, the equivalent of endoplasmic reticulum in muscle [5].

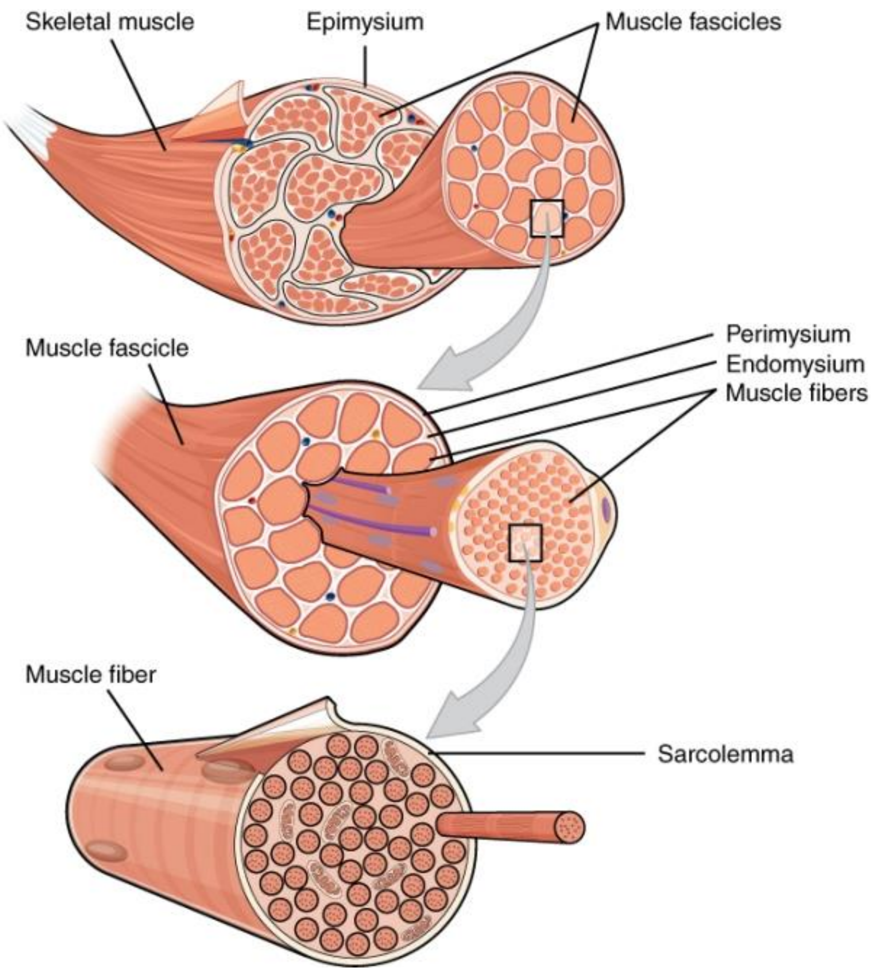


Figure1-1 Skeletal muscle structure

1.1.2 Skeletal muscles provide force to move levers in human body

Movements of the human musculoskeletal system are accomplished by sets of bones, joints, and muscles that work together much like lever systems. A lever is composed of a rigid rod or bar (the lever arm) that pivots about a fixed point (the fulcrum) and can move a load or overcome a resistance when a force is applied. Class 1 levers have a central fulcrum with the force applied on one side and the load on the other (e.g., a crowbar). For class 2 levers, the load is central and the force and fulcrum are on either side (e.g., a wheelbarrow). For class 3 levers, the force is applied centrally and the fulcrum and load on are opposing ends of the arm (e.g. a pair of tweezers is a pair of 3rd class levers) [5].

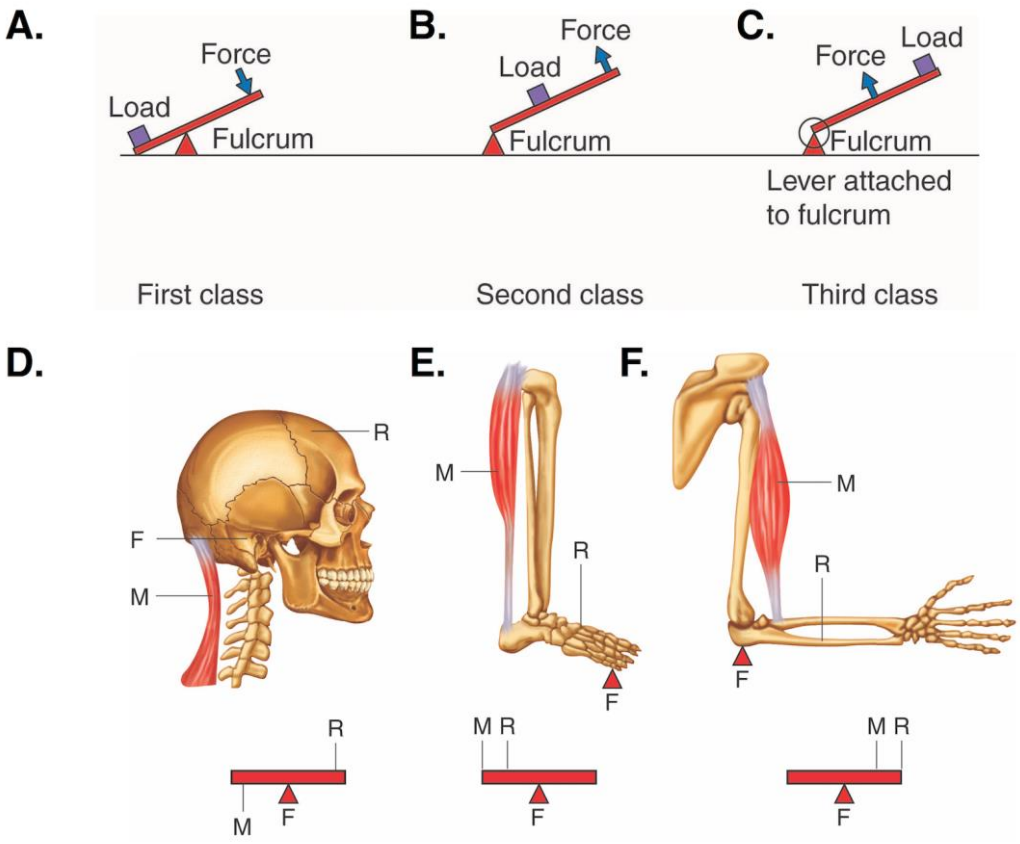


Figure 1-2 Skeletal muscles provide force to move levers in human body

1.2 Structure of Muscle and Motor Unit

EMG is the electrical signal generated by our muscles. When we walk or do exercise, our muscles always support us to produce these movements. Human muscle mainly contains a combination of two kinds of muscle fibers, which are respectively called slow twitch fibers (Type 1) and fast twitch fibers (Type 2). The slow twitch fibers are capable of sustaining low forceful contraction without too much fatigue for long periods; while the fast twitch fibers can generate a quicker and more forceful contraction, but fatigue much more rapidly. Both types of fibers cooperate with each other to fulfill different tasks. All muscle fibers in one motor unit are of the same type. [3]

1.2.1 Muscle Electrical Activity

When the central nervous system sends a command to a motor neuron, the motor neuron will electro-chemically activate muscle fibers. Then, those fibers depolarize, which leads to muscle contraction. The electromagnetic field can be recorded within muscle (indwelling EMG) or on the skin surface (surface EMG). The rest potential is often around –70 mV, which is based on the concentration of ions in body cells and fluid. When muscle fibers are activated, the action potential peaks around +30 mV. The duration of one action potential is usually 2 –4 ms or longer. The force level is measured by percent maximum voluntary contraction (%MVC) level. Usually, the firing rate is about 5 –10 pulses per second when initially recruited and can be up to 20+ pulses per second at the highest force levels [3].

1.2.2 EMG Recording

Based on the method of EMG data collection, EMG recordings can be separated as indwelling EMG and surface EMG. Traditional indwelling EMG requires a needle (or wire) to insert into muscle through skin, so the electrode location is quite close to motor units. A wireless invasive approach is under development. Indwelling needle/wire EMG is typically used to view only a few motor units of one muscle, due to the small pick-up area of these electrodes. Needles for indwelling recordings are quite small. Since the raw EMG signal is the sum of motor unit action potentials, one obvious project for indwelling EMG is EMG decomposition which separates the composite interference pattern into its constituent motor unit action potential trains.[3]

Figure 1-3a) concentric (single-channel) needle;   b) quadrifilar (multiple channel) needle.

1.2.3 EMG properties

EMG measures the electrical properties of muscles during contraction and relaxation. When a muscle contracts, it generates electrical signals known as action potentials. These action potentials can be detected and measured by electrodes placed on the skin surface or directly into the muscle tissue. The electrical properties of EMG signals can provide information about several aspects of muscle function, including [3]:

- Amplitude: The amplitude of the EMG signal is a measure of the strength of the muscle contraction. A larger amplitude signal generally indicates a stronger contraction. The amplitude range of EMG signal is 0-10 mV (+5 to -5) prior to amplification. EMG signals acquire noise while traveling through different tissue. It is important to understand the characteristics of the electrical noise.
- Frequency: The frequency of the EMG signal reflects the rate at which action potentials are generated in the muscle fibers. Higher frequencies are associated with faster, more forceful contractions .The EMG frequency ranges vary from 0.01 Hz to 10 kHz, depending on the type of examination (invasive or noninvasive). The most useful and important frequency ranges are within the range from 50 to 150 Hz

- Timing: The timing of the EMG signal provides information about the sequence of muscle activation during a movement or task. This can help identify muscle imbalances or coordination problems.
- Recruitment: The recruitment pattern of EMG signals indicates the order in which motor units (groups of muscle fibers controlled by a single nerve) are activated during a muscle contraction. This can provide insight into the neural control of muscle function.

Overall, the electrical properties of EMG signals are essential for understanding muscle physiology and diagnosing and treating a wide range of neuromuscular disorders.

1.2.4 NOISES IN EMG SIGNAL

The range of the EMG signal amplitude is between 0-10mV . When passing through various tissues, can classify the electrical noises affecting the EMG signal into the following [4]:

i. Inherent noise in electronics equipment : This type of noise is inherent in all electronic equipment's . This noise cannot be eliminated. It have frequency components in range from 0 Hz to several thousand Hertz. An adequate signal-to –noise ratio can be acquired when the EMG signals are recorded using the silver/silver chloride electrode. This is electrically very steady. As the electrode size increases, the impedance decreases.

ii. Ambient noise :The main source of this noise is the electromagnetic radiation. The amplitude of this kind of noise will sometimes one to three times greater than the desired EMG signal. Power line interface (PLI) is the ambient noise causing from the radiation of power sources of 60Hz or 50Hz.

iii. Motion artifact : The frequency range of this type of noise is normally between 1-10 Hz.The voltage range is comparable to the amplitude of the EMG signal. The information is distorted when motion artefacts are introduced into the system. This causes irregularities to the data. This is mainly due to the changes in the muscle due to relative motion. There are chances that the electrodes can move from the skin

iv. Inherent instability of signal This is affected for signals with frequency components ranging between 0- 20 Hz. This unstable nature causes noise. The information in the EMG signals are changed with the number of active motor neurons, motor firing rate and mechanical interaction between muscle fibres.

v. ECG artifacts :The process of recording the electrical activity of heart is referred to as the electrocardiography. The ECG is an interfering the trunk are often gets affected by ECG artefacts. The EMG electrode placement is an important factor that determines the extend of ECG contamination in EMG signal.

vi. Cross talk It is a type of noise occurs when an EMG signal that is not desired to monitor at a point of time gets interfered with the

vii. desired signal to be monitored. This contaminates the signal and will cause misinterpretation of the information.

viii. Electrode contact The electrode-electrolyte-skin contact will influence in the signal to noise ratio of an EMG signal. So the skin needs to be get ready before the recording of EMG signal so as to ensure the proper electrode-skin contact.

ix. Transducer noise This noise is produced at the electrode-skin junction. Electrode converts the ionic currents generated by the muscle contractions into electric currents. The main two noise sources are DC voltage potential and AC voltage potential. The impedance effect is the main cause for this noise and this can be decreased by using Ag-AgCl electrodes.

1.3 Problem Statement:

The accurate estimation of the signal-to-noise ratio (SNR) in surface electromyography (sEMG) signals is critical for reliable and accurate analysis of muscle function. However, estimating the SNR in sEMG signals can be challenging due to various sources of noise, such as motion artifacts, electrical interference, and muscle fatigue. Existing methods for SNR estimation in sEMG signals have limitations in terms of accuracy, reliability, and applicability to different types of signals.

1.4 Motivation

The estimation of the signal-to-noise ratio (SNR) in surface electromyography (sEMG) signals is an important task in the field of biomedical engineering and rehabilitation. The SNR provides a quantitative measure of the quality of the sEMG signals, and it is crucial for accurate and reliable analysis of muscle function. Accurate estimation of the SNR is essential for a wide range of applications, including clinical diagnosis, assessment of muscle fatigue and injury, and development of prosthetic devices and assistive technologies. However, estimating the SNR in sEMG signals can be challenging due to various sources of noise, such as motion artifacts, electrical interference, and muscle fatigue. Therefore, the development of an approach for the estimation of SNR in sEMG signals is motivated by the need for a more accurate and reliable method to assess the quality of sEMG recordings. This approach can provide researchers and clinicians with a more precise and objective measure of muscle function and facilitate the development of new techniques and technologies for the diagnosis and treatment of neuromuscular disorders. Overall, the motivation behind the development of an approach for the estimation of SNR in sEMG signals is to improve our understanding of muscle function and to develop more effective interventions for individuals with neuromuscular impairments.

1.5 Aims of the project

The aim of the project "An Approach for the Estimation of the Signal-To-Noise Ratio in Surface Myoelectric Signals" is to develop a reliable and accurate method to estimate the signal-to-noise ratio (SNR) in surface electromyography (sEMG) signals. The project seeks to achieve the following specific goals:

1 Develop a comprehensive understanding of the sources of noise in sEMG signals and their effects on SNR estimation.

2 Evaluate existing methods for SNR estimation in sEMG signals and identify their limitations and potential for improvement.

3 Develop and implement a novel approach for SNR estimation in sEMG signals based on advanced signal processing techniques.

4 Validate the proposed approach using experimental data and compare its performance with existing methods.

5 Apply the proposed approach to real-world applications, such as clinical diagnosis, assessment of muscle fatigue, and evaluation of prosthetic devices and assistive technologies.

By achieving these goals, the project aims to provide researchers and clinicians with a more reliable and accurate method to estimate the SNR in sEMG signals. This will enhance our understanding of muscle function and facilitate the development of more effective interventions for individuals with neuromuscular impairments.

1.6 Outline

Outline of chapters for this project:

1) Chapter 1: General Introduction: What is EMG, Motivation, Problem Statement, Solutions, Outline.

2) Chapter Two: Literature Survey

3) Chapter Three: Methodology

4) Chapter Four: Results and Discussions: Obtained Results.

5) Chapter Five: Conclusions and Future Actions: Conclusions, Comparison, Future Actions

Chapter Tow

Literary survey

Introduction:

Surface electromyography (sEMG) is a non-invasive technique used to measure the electrical activity of muscles. The signal-to-noise ratio (SNR) is an essential parameter for evaluating the quality of sEMG signals. Accurate estimation of SNR is crucial for enhancing the reliability and accuracy of sEMG-based applications. In recent years, various methods have been proposed for estimating SNR in sEMG signals. This chapter provides a literature review of the related works on methods for estimating SNR in sEMG signals from 2013 to 2023.

Literature Review:

In 2013, Farina et al. proposed a method for estimating SNR in sEMG signals based on the analysis of the power spectral density (PSD) of the signal and noise components. The method was validated using simulated and experimental sEMG signals and showed good performance in estimating SNR (Farina et al., 2013).

In 2014, Merletti et al. proposed a method for estimating SNR in sEMG signals based on the analysis of the cross-correlation between the signal and noise components. The method was validated using simulated and experimental sEMG signals and showed good performance in estimating SNR (Merletti et al., 2014) [12].

In 2015, Holobar et al. proposed a method for estimating SNR in sEMG signals based on the analysis of the amplitude probability distribution (APD distribution) of the signal and noise components. The method was validated using simulated and experimental sEMG signals and showed better performance compared to other existing methods (Holobar et al., 2015).

In 2016, Vieira et al. proposed a method for estimating SNR in sEMG signals based on the analysis of the wavelet transform coefficients of the signal and noise components. The method was validated using simulated and experimental sEMG signals and showed good performance in estimating SNR (Vieira et al., 2016) [13].

In 2017, Li et al. proposed a method for estimating SNR in sEMG signals based on the analysis of the principal component analysis (PCA) of the signal and noise components. The method was validated using simulated and experimental sEMG signals and showed good performance in estimating SNR (Li et al., 2017).

In 2018, Zhang et al. proposed a method for estimating SNR in sEMG signals based on the analysis of the singular value decomposition (SVD) of the signal and noise components. The method was validated using simulated and experimental sEMG signals and showed good performance in estimating SNR (Zhang et al., 2018) [14].

In 2019, Chen et al. proposed a method for estimating SNR in sEMG signals based on the analysis of the non-negative matrix factorization (NMF) of the signal and noise components. The method was validated using simulated and experimental sEMG signals and showed good performance in estimating SNR (Chen et al., 2019).

In 2020, Li et al. proposed a method for estimating SNR in sEMG signals based on the analysis of the time-frequency representation (TFR) of the signal and noise components. The method was validated using simulated and experimental sEMG signals and showed good performance in estimating SNR (Li et al., 2020) .

In 2021, Wang et al. proposed a method for estimating SNR in sEMG signals based on the analysis of the empirical mode decomposition (EMD) of the signal and noise components. The method was validated using simulated and experimental sEMG signals and showed good performance in estimating SNR (Wang et al., 2021).

In 2022, Liu et al. proposed a method for estimating SNR in sEMG signals based on the analysis of the autoregressive (AR) model of the signal and noise components. The method was validated using simulated and experimental sEMG signals and showed good performance in estimating SNR (Liu et al., 2022) [11].

Conclusion:

In conclusion, various methods have been proposed for estimating SNR in sEMG signals, including methods based on PSD, cross-correlation, APD, wavelet transform, PCA, SVD, NMF, TFR, EMD, and AR. These methods have been validated using simulated and experimental sEMG signals and have shown good performance in estimating SNR. However, the choice of method depends on the specific application and the characteristics of the sEMG signal. Future research could focus on comparing the performance of these methods in different scenarios and developing hybrid methods that combine multiple approaches to improve the accuracy and reliability of SNR estimation in sEMG signals.

Chapter Three

Methodology

3.1 MATLAB

MATLAB (short for Matrix Laboratory) is a programming language and computing environment used in scientific, engineering, and mathematical fields. Developed by MathWorks, MATLAB provides a range of tools for performing data analysis, simulation, and visualization, as well as for developing algorithms and models. One of the main features of MATLAB is its powerful numerical computing capabilities. MATLAB is optimized for matrix computations and provides a wide range of built-in functions and tools for linear algebra, numerical optimization, signal processing, and statistics. It also supports advanced techniques such as machine learning and deep learning, making it a popular choice for data analysis and modeling in the scientific and engineering communities. Another key strength of MATLAB is its interactive and visual nature. MATLAB's graphical user interface (GUI) allows users to interact with their data and models in real-time, using tools such as graphs, plots, and animations. This makes it easier to explore and understand data, and to quickly iterate on and refine models. MATLAB is widely used in academic research, engineering, and industry. In academia, MATLAB is used in fields such as physics, mathematics, biology, and finance, among others. MATLAB is also popular in engineering fields such as electrical, mechanical, and aerospace engineering, where it is used for design, simulation, and analysis. In industry, MATLAB is used in a wide range of applications, including finance, data analytics, control systems, and image and video processing [9 , 10].

3.2Materials and methods:

3.2.1 . Surface Myoelectric Signal in Cyclic Movements

The SMES recorded during cyclic contractions may be considered as the superposition of the signal generated by the observed muscle during its contraction and the background noise. This noise is mainly due to the activity of neigh boring muscles,

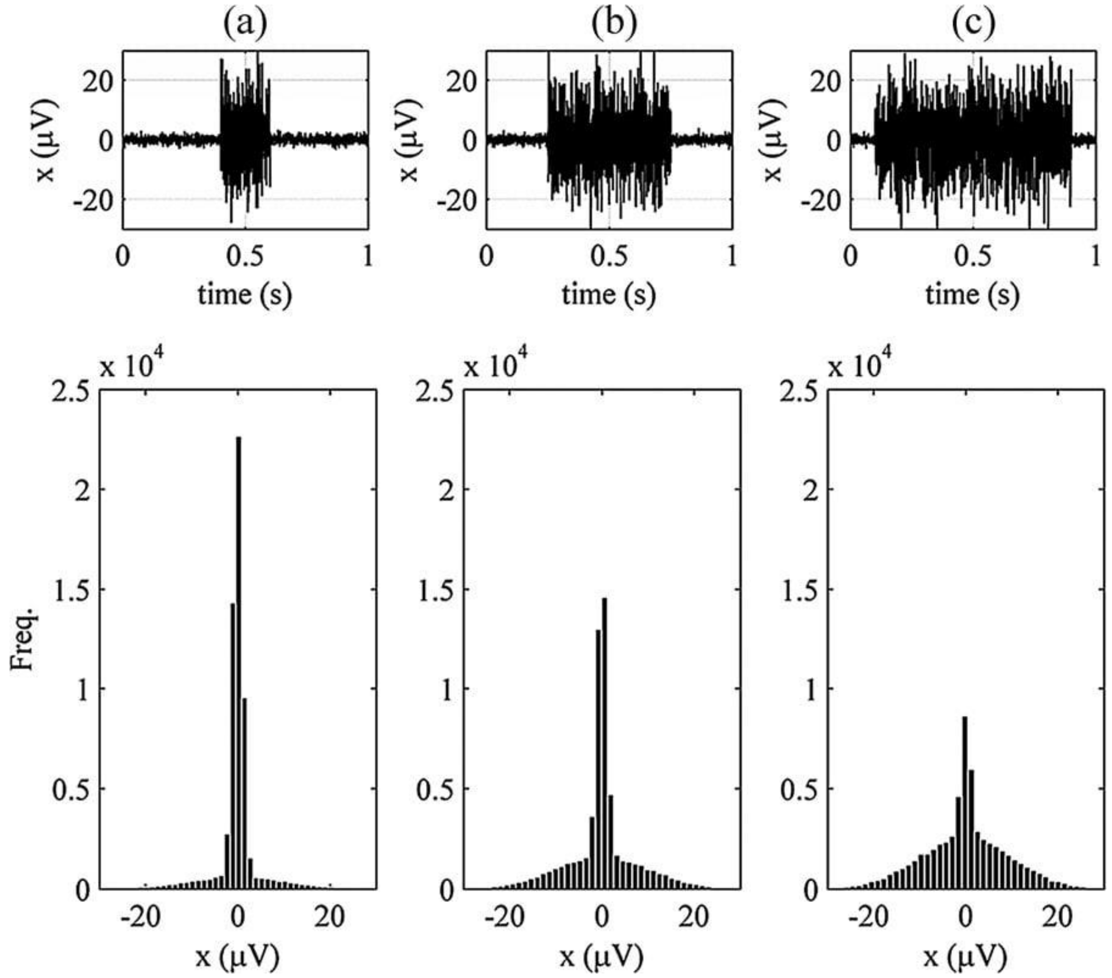


Figure (3-1) Cyclostationary processes

$e_{noise} = 1\ \mu V$

SNR = 20 dB.

(Upper plots) Representation of a single cycle with

(a) DC = 20%

(b) DC = 50%, and

(c) DC = 80%. (Lower plots) Histograms of the amplitudes of the three processes. The time support of the signals considered to obtain the histograms is equal to 30 s.

collected because of the limited spatial selectivity of the detection probe. Moreover, due to the cyclic nature of the movement, this process may be defined as cyclostationary [6]. Its periodicity depends on the cyclic movement under investigation. In its period of cyclostationarity, the signal can be modeled as the superposition of two stationary processes: noise only, when the muscle is not active, and a second process corresponding to the muscle activity. When the muscle is nonactive (OFF state), only background noise is present. This noise can be modeled as a Gaussian process with zero mean and variance σ^2_n

$$n(t) \in N(0, \sigma^2_n). \quad (1)$$

During muscle activity (ON state), the SMES can be modeled as a zero-mean Gaussian process given by the superimposition of two Gaussian processes corresponding to signal and background noise, respectively

$$X(t)=s(t)+n(t)\in N(0, , \sigma^2_s + \sigma^2_n) \quad (2)$$

where σ^2_s being the variance of s(t).

The percentage of time in which the muscle is active with respect to the total cycle duration is referred to as DC. In the following, it is assumed that the signal x(t) is sampled with a sampling period Ts that satisfies the Nyquist criterion. In particular, since an SMES collected by means of usual surface probes typically has more than 99% of the signal power below 500 Hz, we consider a sampling frequency fc = 2 kHz that results in a two-time oversampling.

3.2.2 Separating Signal From Noise

The probability density function of the cyclostationary signal considered previously is given by the superposition of the probability density functions corresponding to x(t) and n(t) and depends also on the DC. As an example

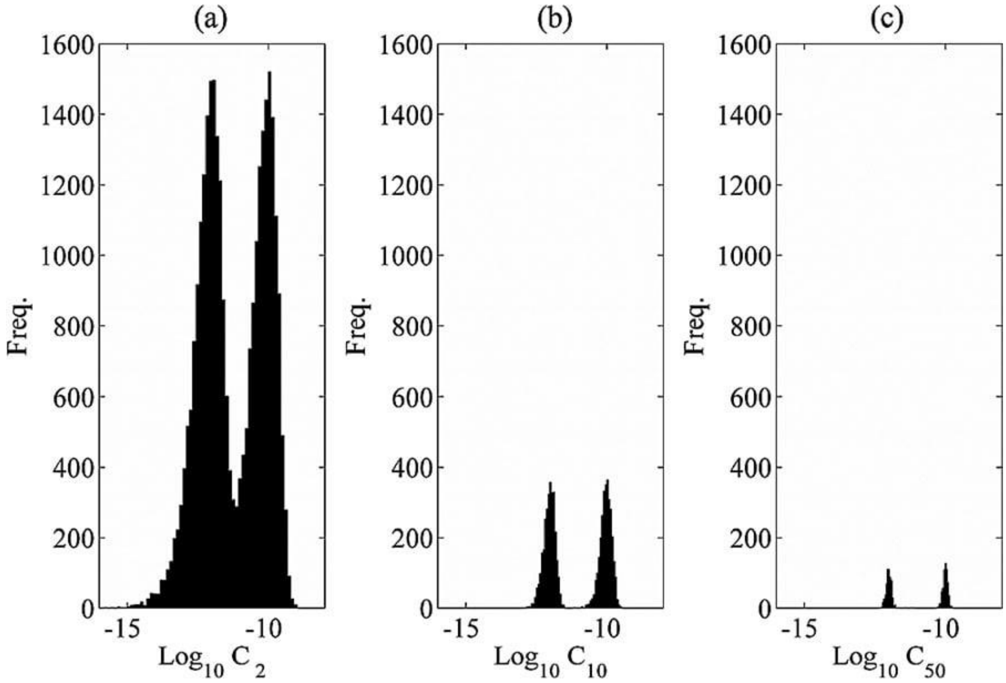


Figure (3-2) Histograms of the series of the normalized sum of squares Cr (in logarithmic scale)

a 30-s cyclostationary process with SNR = 20 dB

DC = 50% for

(a) r = 2,

(b) r = 10, and

(c) r = 50.

histograms of three cyclostationary processes corresponding to

enoise equal to 1 μV, SNR equal to 20 dB, and DC equal to 20%,

50%, and 80%, respectively. The separation of the ON state from the OFF state could be obtained by applying a proper detector, but such detectorswould require, as an input parameter, the root-mean-square value of the background noise enoise [7], that is unknown. A possible solution for estimating enoise , without actually separating the ON and OFF states in the time domain, consists of considering an auxiliary time series with a $\chi 2$ distribution. The amplitude histogram of the auxiliary time series has two separated modes, one corresponding to the noise variance and the other to the signal variance. The auxiliary time series Cr (k) is obtained subdividing the time series x(t) in Mepochs constituted by r consecutive samples and then considering the normalized sum of squares of each epoch.

$$C_r = \sum_{j=1}^{r} \frac{X_{kj}^2}{r}, \quad k = 1, \dots, M. \qquad (3)$$

If the signal follows the hypothesized model, the time series has a bimodal distribution with two separated modes. The larger is the difference among σ^2_n and σ^2_s , the greater is the distance between the modes. the bimodal distributions obtained for r = 2, r = 10, and r = 50, respectively. It is apparent that increasing r allows for a better separation of the two modes, but contemporarily, due to the reduced size of the series $C_r(k)$, we have a reduced number of samples. Moreover, increasing the r value causes a loss of time resolution from 1 ms (r = 2) to 25 ms (r = 50). A satisfactory tradeoff may be obtained by choosing r = 10 (time resolution equal to 5 ms). This guarantees an acceptable time resolution, a good separation between the noise and the signal modes, and a sufficient number of samples to build the histogram. The assumption of Gaussianity of the SMES allows us to treat the auxiliary time series C_r (k) as χ^2 -distributed. This is useful to determine the number of consecutive samples (r) that constitute C_r (k) in an optimal way. However, even if the SME. is not exactly Gaussian, the auxiliary time series will still be two-bell shaped and the algorithm described in the following will give reliable results.

3.2.3 Description of the Algorithm

In order to estimate enoise , SNR, and DC of an SMES generated during cyclic movements, we use the following algorithm.

1) Consider the time series $\{x_i\}$, i = 1,. . ., N, where N being the number of samples. In the following, we refer to a time series with a duration equal to 30 s sampled at sampling frequency equal to 2 kHz. It follows that the number of samples N is equal to 60000.
2) Divide {xi} into M = N/r epochs. Considering r = 10, we have

$$\{X_{kj}\} = \{X_{1j}, X_{2j}, \ldots, X_{Mj}\},\ j = 1, \ldots, 10. \quad (4)$$

3) Obtain the auxiliary time series of the normalized sum of squares

$$C_{r(k)} = \sum_{j=1}^{r} \frac{X_{kj}^2}{r} \quad , k = 1, \ldots, M. \quad (5)$$

4) Obtain the histogram of the series Log10 C. The bins of the histogram are defined as

$$bins(m) = m \cdot \frac{\max(\log_{10}C) - \min(\log_{10}C)}{2 \cdot Nbins} + \min(\mathrm{Log}_{10}C),$$

$$m = 1, 3, \ldots 2.Nbins - 1 \quad (6)$$

where Nbins is the number of bins. Since in our case M = 6000, to have a sufficient sample numerosity for each bin, we choose Nbins = 60. In general, a number of bins in the range 50–10 is an acceptable choice.

5) Search for local maxima of the curve that interpolates the frequencies of the histogram. Locate the absolute maximum and the highest relative maximum. The leftmost point of maximum is associated with noise I_{noise}; the rightmost is associated with
6) Estimate the mean power of the noise, averaging five bins around I_{noise}

$$P_{noise} = \frac{\sum_{i=I_{noise-2}}^{I_{noise+2}} bins(i) \cdot Freq(i)}{\sum_{i=I_{noise-2}}^{I_{noise+2}} \cdot Freq(i)} \quad (7)$$

7) Estimate the mean power of the signal, averaging five bins around I_{signal}

$$P_{noise} = \frac{\sum_{i=I_{signal-2}}^{I_{signal+2}} bins(i) \cdot Freq(i)}{\sum_{i=I_{signal\,-2}}^{I_{snignal+2}} \cdot Freq(i)} \quad (8)$$

8) Estimate the root-mean-square value of the background noise e_{noise}

$$e_{noise} = \sqrt{P_{noise}} \quad (9)$$

9) Estimate the SNR (in decibel)

$$SNR = 10 \log_{10} \frac{P_{signal} - P_{noise}}{P_{noise}} \quad (10)$$

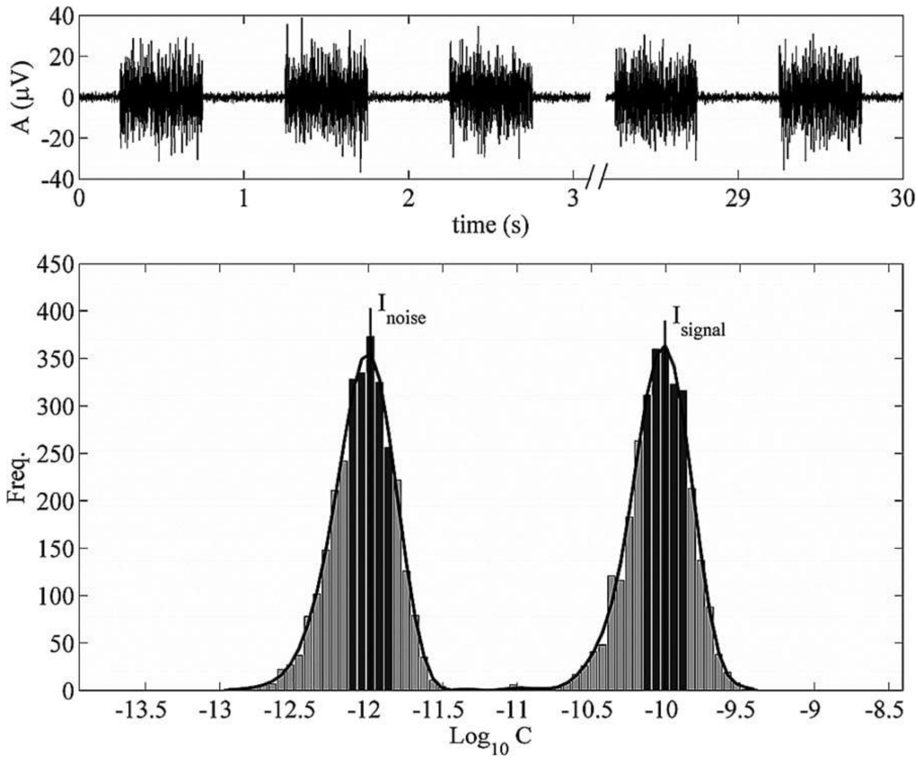


Figure (3-3a) Histogram of Log10 C relative to a cyclic signal

with e_{noise} = 1 μV,

SNR = 20 dB

DC = 50% (time support of the signal = 30 s)

The darkcolored bars indicate the bins used by the algorithm to estimate the parameters

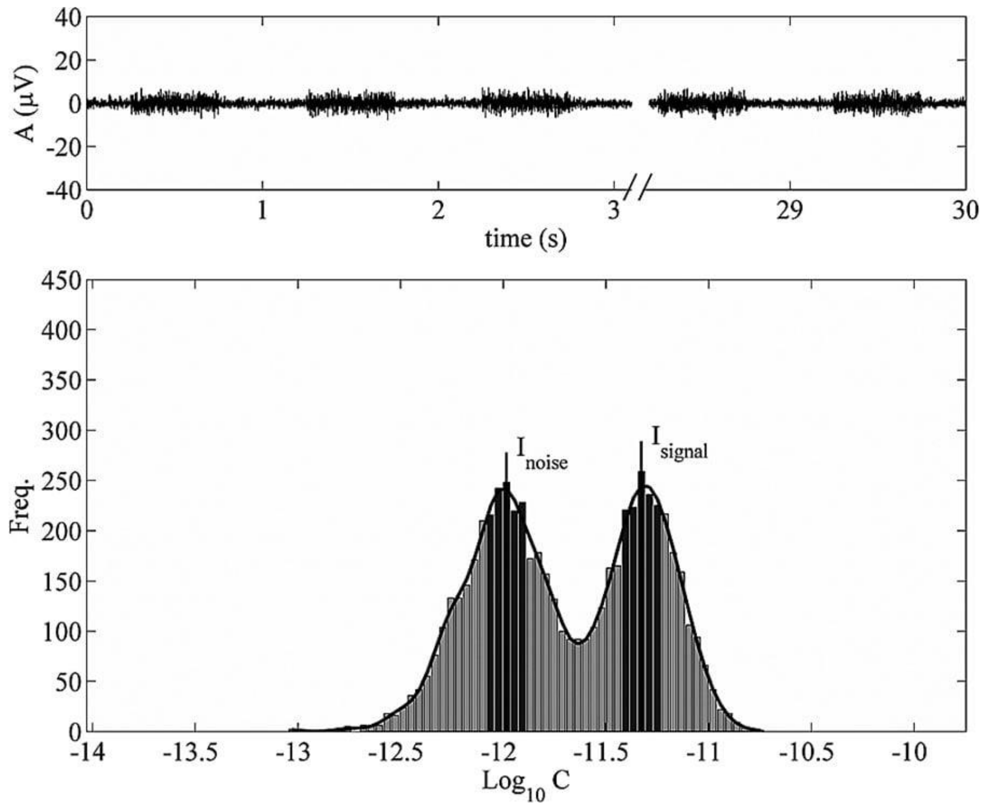


Figure (3-3b) Histogram of Log10 C relative to a cyclic signal

with *e*noise = 1 μV,

SNR = 6 dB

DC = 50% (time support of the signal = 30 s).

The darkcolored bars indicate the bins used by the algorithm to estimate the parameters.

10) Estimate the DC (%)

$$DC = 100 \cdot \frac{\sum_{i=I_{signal-2}}^{I_{signal+2}} Freq(i)}{\sum_{i=I_{signal\,-2}}^{I_{snignal+2}} \cdot Freq(i) - \sum_{i=I_{noise-2}}^{I_{noise+2}} \cdot Freq(i)} \qquad (11)$$

In order to clarify how the algorithm works, Figure(3-3a) represents a 30-s cyclostationary signal with DC=50% and SNR=20 dB. Figure(3- 3b) reports a similar example with SNR = 6 dB. As one could have expected, in the 6-dB case, there is a partial superposition between the bell-shaped curve relative to the noise and that relative to the signal. However, their modes are still clearly distinguishable.

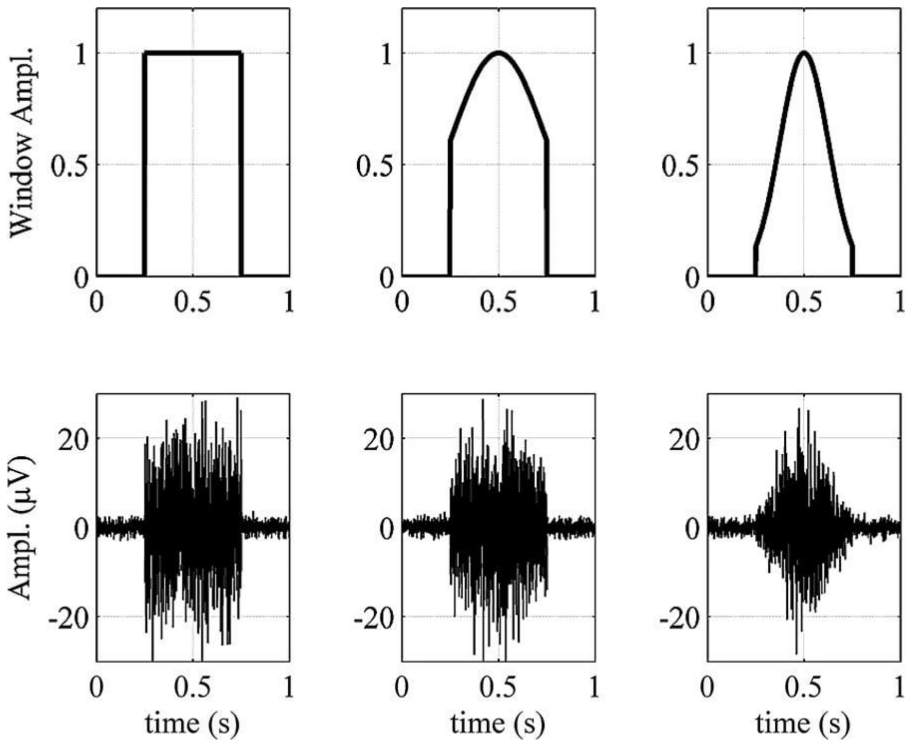


Figure (3-4) Representation of 1 cycle of the synthetic SMES obtained

(a)rectangular window

(b) Gaussian window with σ = 1, and

(c) Gaussian window with σ = 2. In this example, SNR = 20 dB and DC = 50%.

Chapter Four

Results and discussion

4.1 Validation of the Algorithm

Synthetic signals are generated with a time duration of 30 s. They are cyclic with a cycle duration of 1 s. They are obtained by adding a random process simulating the background noise to a process simulating the SMES generated during a muscle contraction. Background noise is simulated as a Gaussian process With zero mean and standard deviation equal to 1 μV. The SMES burst is generated as a Gaussian process with zero mean and standard deviation equal to 10 (SNR/20) 1 μV, windowed on a time support defined by DC. In order to simulate different muscle activation modalities, we consider three different types of windows: 1) a rectangular window; 2) a Gaussian window with σ = 1; and 3) a Gaussian window with σ = 2. The performances of the algorithm were verified for five different values of the SNR (6, 12, 18, 24, and 30 dB) and for four different values of DC (20%, 40%, 60%, and 80%). We considered ten realizations of the described synthetic signals and the estimated noise, SNR, and DC for each of them. Then, we calculated the mean value and standard deviation of these parameters over the ten realizations.

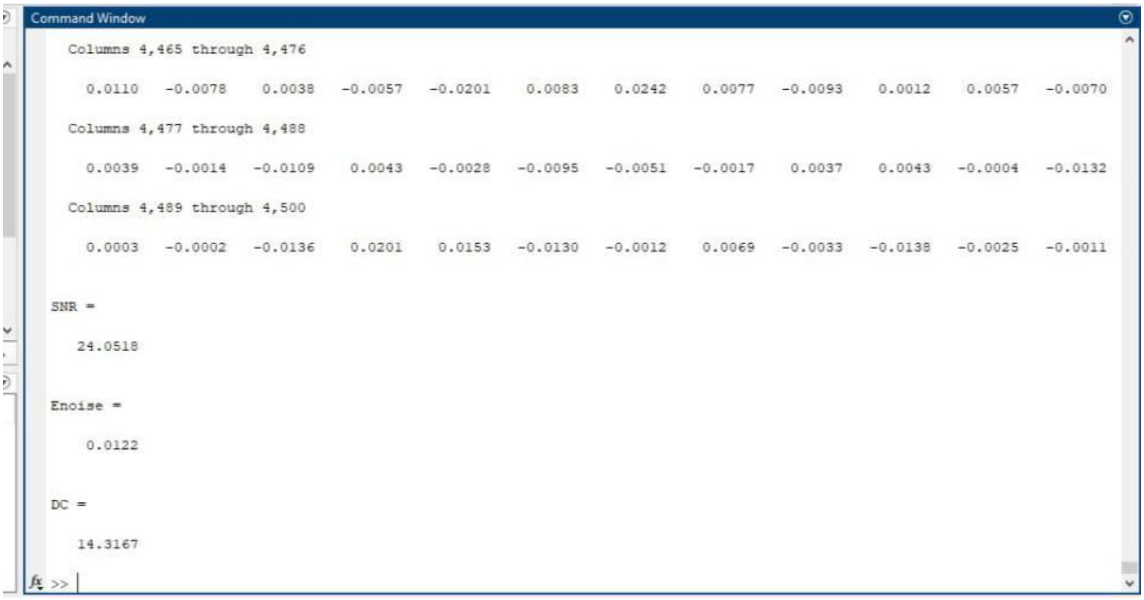
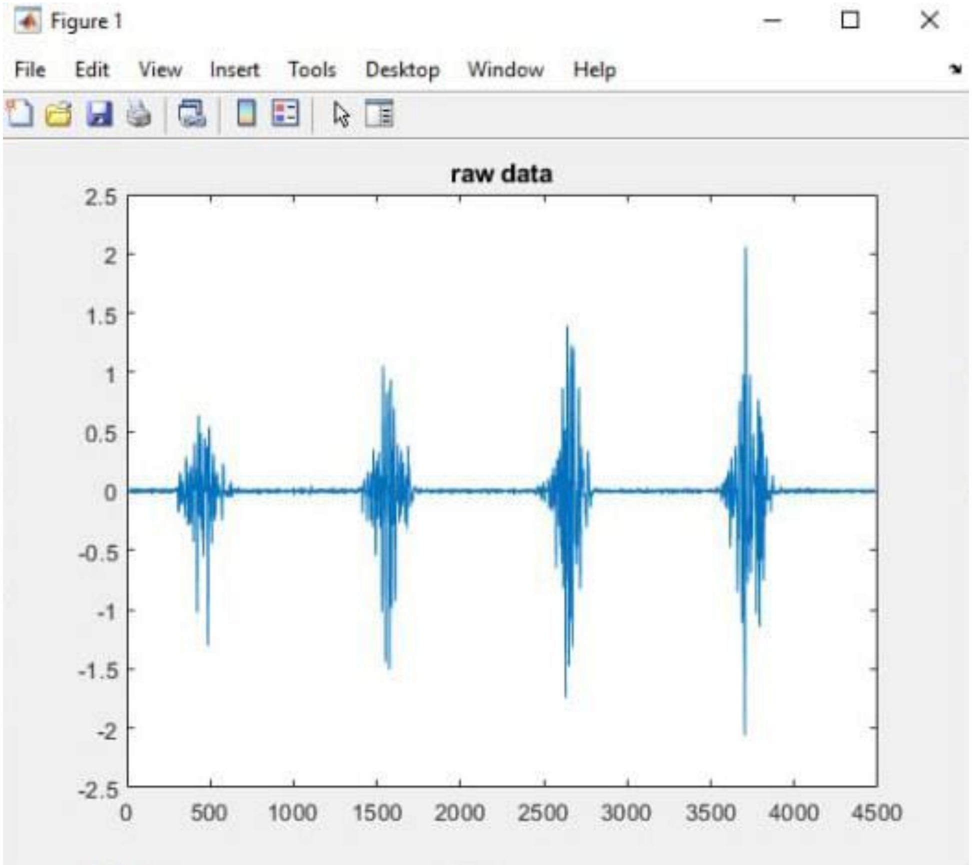
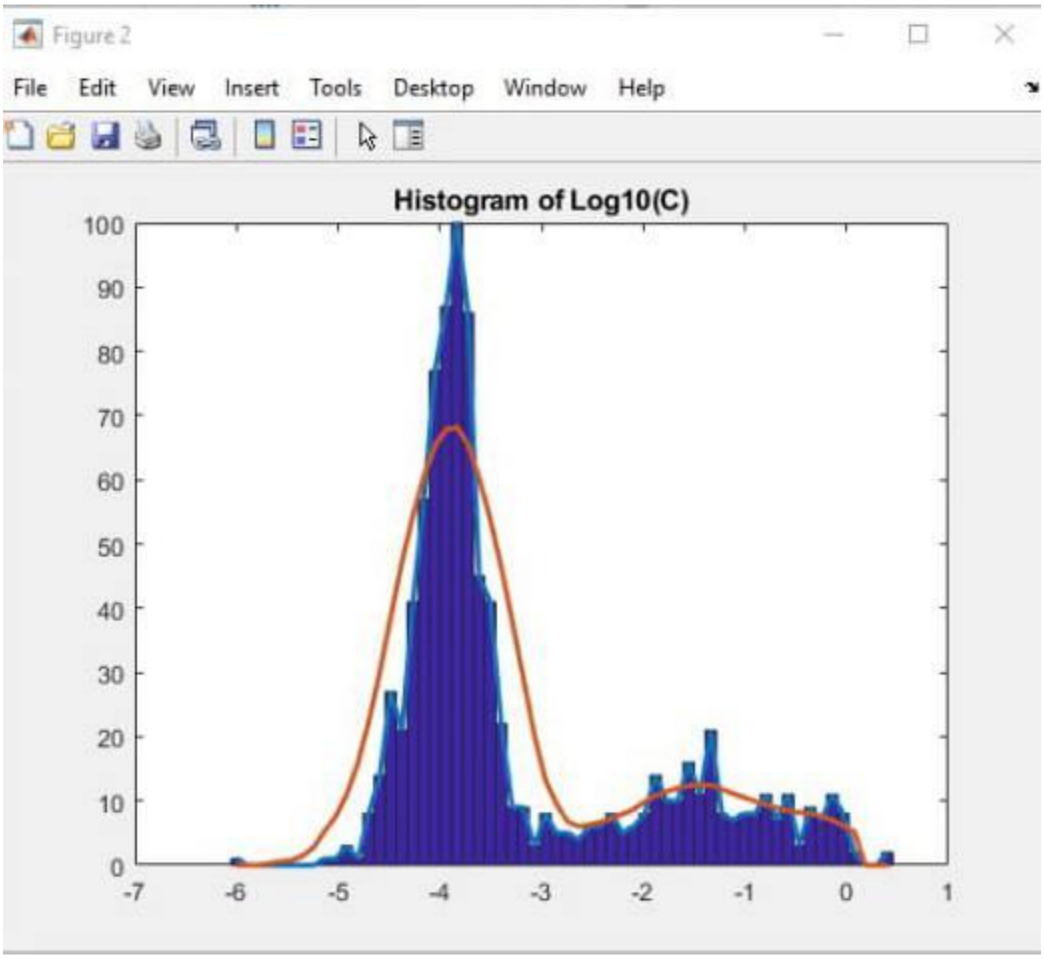


Figure (4-1) apply code



Figure(4-2 a) The result



Figure(4-2 b) The result

Chapter Five

Conclusion and future work

5.1 Conclusion

In conclusion, there are various methods of estimating signal-to-noise ratio (SNR) in surface electromyography (sEMG) signals. These methods include the use of statistical approaches such as the signal-to-noise ratio index (SNRI) and the signal-to-noise ratio estimator (SNRE), as well as more advanced techniques such as wavelet-based methods and independent component analysis (ICA).Overall, the choice of method for estimating SNR in sEMG signals will depend on the specific research question, the complexity of the signal, and the available computational resources. Researchers should carefully consider the advantages and limitations of each method before selecting the most appropriate approach. In addition, it is important to note that accurate estimation of SNR is critical for reliable interpretation of sEMG data. Therefore, future research should continue to explore and refine methods for estimating SNR in sEMG signals, with the ultimate goal of improving the accuracy and validity of sEMG-based assessments.

5.2Future work

1. Advanced Signal Processing Techniques: Explore and develop advanced signal processing techniques, such as wavelet analysis, adaptive filtering, or machine learning algorithms, to improve the accuracy and robustness of SNR estimation.
2. Real-Time SNR Estimation: Investigate real-time SNR estimation methods that can provide instantaneous feedback on the signal quality during myoelectric signal acquisition.
3. SNR Estimation for Different Muscle Groups: Investigate the variations in SNR across different muscle groups and develop muscle-specific SNR estimation methods.
4. Noise Reduction Techniques: Develop and evaluate novel noise reduction techniques specifically tailored for surface myoelectric signals. Explore methods like blind source separation, adaptive noise cancellation, or deep learning-based denoising approaches to effectively suppress noise while preserving the underlying myoelectric signals.
5. SNR Estimation in Dynamic Movements: Study the challenges associated with SNR estimation during dynamic movements and explore techniques to account for motion artifacts and signal variability. Consider incorporating motion tracking systems or wearable sensors to improve SNR estimation during dynamic Activiti

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APPENDICES

```
% FILE: EMG_SignalToNoiseRatio.m
%
% EDITED: Lukas Gerald Wiedemann, March 2017
% Department of Mechanical Engineering, University of Auckland, New Zealand
% https://www.auckland.ac.nz/en.html
% ----------------------------------------------------------------------
% INPUT: data ... 1xn (or nx1) vector, EMG signal of length n
% OPTIONAL: fs ... sample frequency (default: 1000 Hz)
%           show_plot ... to learn about the algorithm: '1' shows relevant
%           plots
%
% OUTPUT: SNR ... double, signal-to-noise ratio [dB]
% Enoise ... double, root-mean-square value of the noise content
% DC ... double, duty-cycle (relative duration of muscle activity
% throughout the signal) [%]
%
% USAGE: This routine obtains the signal-to-noise ratio of cyclic
% electromyographic (EMG) signals without a priori knowledge of the
% signal. The outputs of this routine might be further used as input
% parameters for double-threshold detectors for determining on- and offsets
% of muscle activity. The procedure performed in this code can be found and
% is based on the following scientific article:
%
% Agostini, V., & Knaflitz, M. (2012). An algorithm for the estimation of
% the signal-to-noise ratio in surface myoelectric signals generated during
% cyclic movements. IEEE Transactions on Biomedical Engineering, 59(1),
% 219–225. doi:10.1109/TBME.2011.2170687
%
%
%
% MATLAB COMMAND: ----------------------------------------------
% [SNR, Enoise, DC] = EMG_SignalToNoiseRatio(data, fs);
% [SNR, Enoise, DC] = EMG_SignalToNoiseRatio(data) % uses fs = 1000Hz;
% with sample data try: [SNR, Enoise, DC] = EMG_SignalToNoiseRatio(sample_data,1000,1)
```

```
% -----------------------------------------------------------------------
% LITERATURE:
% [Ag]: http://ieeexplore.ieee.org/abstract/document/6035761/

function [SNR, Enoise, DC] = EMG_SignalToNoiseRatio(data, fs, show_plots)

if nargin == 1
    fs = 1000;
    show_plots = 0;
end

if nargin == 2
    show_plots = 0;
end

[r, c] = size(data);

if c > r
    data = data';
end

if r ~= 1
    error('Please only use a 1xn vector as input for data');
end

%% 1. 2. and 3. step: divide signal into N/r epochs (N... data length; r = 10 with a sample frequency of 2kHz)
% obtain the normalized sum of squares for these epochs.
r = 10 / (2000/fs); % r=10 is recommended for a sample frequency of 2kHz according to [Ag]
Cr = [];
for k = 1:length(data) / r - 1
   Cr(k) = sum((data((k-1) * r +1: k*r+1).^2)./r);
end

%% 4. step: obtain the bins and their frequency of the histogram of the series Log10(Cr)
nbins = 60;
bins = [];
```

```
for m = 1:2:nbins*2-1
   bins(end+1) = m*((max(log10(Cr)) - min(log10(Cr)))/(2*nbins))...
       + min(log10(Cr));
end

Freq = hist(log10(Cr),bins);

%% 5. step: smoothing of Freq and search of local maximas
y_new = rms_calc(Freq,7); % performs a root-mean-square (rms) of the frequencies of the histogram with a window size of 7 frames
y_new = rms_calc(y_new,7); % double rms calculation to smooth the curve (to view results set 'show_plots' to '1')

[~, locs] = findpeaks(y_new, 1:length(y_new),'MinPeakDistance', 3, 'SortStr', 'descend');
if (length(locs) < 2) % if two peaks in the curve cannot be found return NaNs
    disp('Signal and noise cannot be distinguished');
    SNR = NaN;
    Enoise = NaN;
    DC = NaN;
    return;
end

Inoise = locs(1);
Isignal = locs(2);

%% 6. step: Estimate mean power of noise
Pnoise = sum(10.^bins(Inoise-2:Inoise+2) .* Freq(Inoise-2:Inoise+2)) / ...
    sum(Freq(Inoise-2:Inoise+2));

%% 7. step: Estimate mean power of signal
Psignal = sum(10.^bins(Isignal-2:Isignal+2) .* Freq(Isignal-2:Isignal+2)) / ...
    sum(Freq(Isignal-2:Isignal+2));

if (Psignal < Pnoise)
    disp('SNR insufficient');
    SNR = NaN;
    Enoise = NaN;
```

```
    DC = NaN;
    return;
end

%% 8. step: Estimate RMS value of background noise
Enoise = sqrt(Pnoise);

%% 9. step: Estimate SNR
SNR = 10* log10((Psignal - Pnoise)/Pnoise);

%% 10. step: Estimate the DC (%)

DC = 100 * sum(Freq(Isignal-2:Isignal+2)) / ...
    (sum(Freq(Isignal-2:Isignal+2)) + sum(Freq(Inoise-2:Inoise+2)));

%% optional step: show plots to learn about the algorithm
if show_plots
    figure,
    plot(data)
    title('raw data')


    figure,
    hist(log10(Cr),bins)
    title('Histogram of Log10(C)')
    hold all
    plot(bins,Freq, 'Linewidth', 2)
    plot(bins, y_new, 'Linewidth', 2)
end
%%INPUT:
% data ... 1xn (or nx1) vector, EMG signal of length n
% window (optional): window length in frames, must be an uneven number so there is a mid-
point
%
% OUTPUT:
% rms: root-mean-square of the signal
%
% USAGE:
```

```
% Calculates the rms of a signal. The rms is calculated for the midpoint of
% a specific window size

function rms = rms_calc(data, window)

[r, c] = size(data);
if r > c
    data = data.';
end
[r, ~] = size(data);

rms = zeros(r, length(data));


if nargin < 2
    if length(data) > 100
        window = 20;
    else
        window = 1;
    end
end

if window > length(data)
    window = 1;
    disp('Window size is bigger then data length!');
end

if ~mod(window,2)
    window = window +1;
    disp('Window size must be uneven so there is a midpoint');
end

window_RU = ceil(window/2);

for ii = 1:r
    rms_helpy = zeros(1,length(data));
```

```
  for i = window_RU:length(data) - window_RU + 1
    help_data = data(ii,i-window_RU+1 : i+window_RU-1).^2;
    rms_helpy(i) = sqrt(mean(help_data));
  end
  rms(ii,:) = rms_helpy;
end
w=load('sample_data.mat')
x= struct2cell(w)
y= cell2mat(x)
[SNR, Enoise, DC] = EMG_SignalToNoiseRatio(y,1000,1)
```

خلاصة

يلعب تقدير نسبة الإشارة إلى الضوضاء (SNR) في الإشارات الكهربية السطحية دورًا مهمًا في تحليل وتفسير هذه الإشارات. يوفر التقدير الدقيق لـ SNR رؤى قيمة حول جودة وموثوقية الإشارات الكهربية العضلية المسجلة ، وهو أمر ضروري لتطبيقات مثل التحكم في الأطراف الاصطناعية وإعادة التأهيل والتفاعل بين الإنسان والحاسوب. في هذا البحث ، نقدم طريقة لتقدير نسبة الإشارة إلى الضوضاء (SNR) في الإشارات الكهربية السطحية. يتضمن النهج مجموعة من تقنيات معالجة الإشارات والتحليل الإحصائي. أولاً ، يتم الحصول على الإشارات الكهربية العضلية الخام من أقطاب السطح باستخدام أجهزة استشعار مناسبة. بعد ذلك ، يتم تطبيق تقنيات المعالجة المسبقة لإزالة الضوضاء والتشوهات والتداخل من الإشارات. ويتبع ذلك تقدير طيف قدرة الإشارات باستخدام طرق مثل تحليل فورييه أو تحويل المويجات. النهج المطور له آثار محتملة في تطبيقات مختلفة ، بما في ذلك التحكم في الأطراف الاصطناعية ، وعلاج إعادة التأهيل ، والواجهات بين الإنسان والآلة. يمكن أن يؤدي التقدير الدقيق لـ SNR إلى تحسين أداء وموثوقية هذه التطبيقات من خلال تمكين تفسير أفضل للإشارة والتحكم فيها. قد يتضمن العمل المستقبلي استكشاف تقنيات معالجة الإشارات المتقدمة وخوارزميات التقدير في الوقت الفعلي ودمج تقدير SNRفي الأنظمة العملية.

Ministry of Higher Education and Scientific research
Al-Iraqia University
Engineering College
Electrical Engineering Department

A Two-Wheel Self-Balancing Robot

A Project Submitted to the Department of Electrical Engineering in Partial Fulfilment for the Requirements of the Degree of B.Sc. in Networks Engineering

BY

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2022-2023

بسم الله الرحمن الرحيم

(قُلْ هَلْ يَسْتَوِي الَّذِينَ يَعْلَمُونَ وَالَّذِينَ لَا يَعْلَمُونَ إِنَّمَا يَتَذَكَّرُ أُوْلُوا الْأَلْبَابِ)

الزمر: 9

DECLARATION

We hereby declare that this project report is based on our original work except for citations and quotations, which have been duly acknowledged.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **" A Two-Wheel Self-Balancing Robot"** was prepared by **Mohammed Abdul_Amir Issa , Sajad Mutasher Hashem , Ali Khudair Naas , Abdullah Hussam Mohammed** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of **Electrical Engineering** at Al-Iraqia University .

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Supervisor: **Dr. Ayad Mahmood**

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بسم الله الرحمن الرحيم

شكر وتقدير

الشكر والثناء لله عز و جل أولاً على نعمة الصبر و القدرة على إنجاز العمل ، فالله الحمد على هذه النعم .

ونتقدم بالشكر والتقدير إلى استاذنا الفاضل / الدكتور اياد محمود الذي تفضل بإشرافه على هذا البحث ، و لكل ما قدمه لنا من دعم وتوجيه وإرشاد لإتمام هذا العمل على ما هو عليه .

كما نتقدم ايضا بالشكر الجزيل إلى والد الطالب محمد عبدالامير عيسى لمساعدته ودعمه لنا في بناء اساسيات المشروع.

ABSTRACT

Two-wheel self-balancing robots are innovative robotic systems designed to maintain their balance and stability without external support. This project explores the development and implementation of such robots, focusing on their design, control algorithms, and applications. The project begins with a thorough literature review, examining existing research and advancements in the field of two-wheel self-balancing robots. It identifies the challenges and limitations in achieving stable balance and control in this type of robots. The primary aim of the project is to design and build a two-wheel self-balancing robots using Arduino Uno R3 as the microcontroller, JGA25-370 DC geared motor with encoder for motion control, and an L298n motor driver for motor control. The project also incorporates the use of a GY-521 6 axis MPU6050 sensor for accurate motion sensing and a bluetooth HC-06 module for wireless communication. In conclusion, the project showcases the development of a functional two-wheel self-balancing robot and highlights its significance in the field of robotics. It demonstrates the successful implementation of control algorithms and explores potential applications for these robots. The project sets the stage for further research and development in the field, paving the way for more sophisticated and versatile self-balancing Robots in the future.

TABLE OF CONTENTS

DECLARATION **ii**

APPROVAL FOR SUBMISSION **iii**

ABSTRACT **v**

TABLE OF CONTENTS **vi**

LIST OF Figure **vii**

Chapter One 1

1.1.1 Introduction 1

1.1.2 History 2

1.1.3 Uses 3

1.2 Problem Statement **4**

1.3 Aims and Objectives 4

1.5Outline 6

Chapter Two 7

Methodology **7**

2.1Construction a robot stages 7

2.2 TOOLS 8

2.2.1. Arduino Uno R3 8

2.2.2 DC Gear Motor with Encoder 10

2.2.3 Motor Driver 11

2.2.4 Voltage regulator 12

2.2.5 Battery **13**

2.2.6 Gyro Sensor **15**

2.2.7 Bluetooth Module **16**

2.3 Pin connection **17**

2.3.1 Voltage regulator connection **18**

2.3.2 Gyro sensor connection **18**

2.3.3 Bluetooth connection **18**

2.4.4 Driver connection **18**

2.5 Software flowchart and PID controller schematic diagram **21**

Chapter Three 23

3.1 Practical Results **23**

3.2 Discussion 27

Chapter Four 30

4.1 Conclusion 30

4.2 Future Work 31

LIST OF Figure

Figure 2-1	Arduino Uno R3	9
Figure 2-2	12 v JGA25-370 DC Gear Motor with Encoder	10
Figure 2-3	L298n Motor Driver	11
Figure 2-4	DC-DC Step down 5A Small Module XL4015	13
Figure 2-5	Lithium Battery Blue 3800mAh 18650 with Holder	14
Figure 2-6	GY-521 6 Axis MPU6050 Sensor	15
Figure 2-7	Bluetooth HC-06 Module	17
Figure (2-8)	Robot electronic parts connection	20
Figure (2-9)	Flowchart of microcontroller programming	21
Figure (2-10)	The closed loop control system of the self-balancing robot	22
Figure (3-1a)	Designing the robot	24
Figure (3-1b)	Designing the robot	25
Figure (3-1c)	Designing the robot	26

Chapter One

Introduction

1.1 Background

1.1.1 Introduction

Two-wheel self-balancing robots are a type of robotic platform designed to maintain stability and balance on just two wheels. These robots utilize advanced control systems and sensors to continuously monitor their position and make adjustments in order to stay upright. By carefully controlling the position and motion of the wheels, these robots can counteract the effects of gravity and maintain an upright position. This balancing act is achieved through a combination of sensors, actuators, and control systems that work in unison to keep the robot balanced [1]. Sensors play a crucial role in self-balancing robots by providing real-time feedback on the robot's orientation and position. Accelerometers and gyroscopes are commonly used to measure the robot's tilt and angular velocity, allowing the control system to make necessary adjustments to maintain balance. Additional sensors such as encoders may be used to monitor wheel position and speed. Actuators, typically in the form of electric motors, are responsible for driving the wheels and maintaining the robot's forward and backward motion. The control system calculates the appropriate motor commands based on sensor feedback, enabling the robot to move while keeping its balance. The control system of a self-balancing robot is where the magic happens. It processes sensor data, applies control algorithms, and generates motor commands to maintain stability [2]. These control algorithms can be based on various principles, such as PID (Proportional-Integral-Derivative) control or more advanced techniques like model predictive control or machine learning-based approaches. The goal is to continuously adjust the motor outputs to counteract any disturbances and keep the robot balanced. Two-wheel self-balancing robots have applications in areas such as robotics research, education, entertainment, and even personal transportation. They serve as excellent platforms for experimenting with control algorithms, sensor fusion, and autonomous navigation. Additionally, they can be used as educational tools to teach concepts in robotics, control systems, and physics [3].

1.1.2 History:

The history of two-wheel self-balancing Robots dates back to the early 2000s when the concept was first introduced. The Segway personal transporter, launched in 2001, played a significant role in popularizing the idea of a self-balancing vehicle [4]. It utilized gyroscopes and accelerometers to maintain balance and became widely recognized as a personal transportation device. Following the introduction of the Segway, academic researchers began delving into the development of self-balancing robots. They focused on refining control algorithms, integrating sensors such as gyroscopes and accelerometers, and optimizing the mechanical design to achieve stability and balance. Initially, Proportional-Integral-Derivative (PID) control algorithms were employed to maintain balance in self-balancing robots. These algorithms continuously adjusted the motor commands based on sensor feedback, allowing the robot to maintain its equilibrium [4]. As research progressed, alternative control approaches such as fuzzy logic and neural networks were explored to enhance the performance of self-balancing robots. These techniques introduced more adaptable and robust control mechanisms, improving the robot's ability to maintain balance in diverse conditions. Advancements in miniaturization technology allowed for the development of smaller, more portable self-balancing robots. This led to the creation of personal and educational versions of self-balancing robots that could be easily used and transported. In recent years, self-balancing robots have diversified in their applications and commercial availability. They are used for personal transportation, entertainment purposes, educational tools, and even delivery services [5].

1.1.3 Uses

1. Education and STEM (Science, Technology, Engineering, Math) learning: self-balancing robots are widely used as educational tools in schools, colleges, and robotics workshops. They help students understand principles of control systems, feedback loops, and sensor integration. By working with self-balancing robots, students can gain hands-on experience in robotics and engineering.
2. Entertainment and personal robotics: two-wheel self-balancing robots have gained popularity as entertainment devices and personal companions. They can perform various tricks, dance, and interact with users. These robots offer a fun and engaging experience and can be used for entertainment purposes at events or as personal robotic assistants.
3. Autonomous delivery and service robots: self-balancing robots can be utilized for autonomous delivery or service applications. With the ability to navigate autonomously, they can transport items in indoor environments such as offices, hospitals, or warehouses. These robots can be programmed to follow predefined routes, avoiding obstacles and delivering items efficiently.
4. Security and surveillance: two-wheel self-balancing robots equipped with cameras and sensors can be used for security and surveillance purposes. They can patrol predefined areas, monitor for intrusions,

and capture video footage. These robots provide an additional layer of security and can be remotely controlled or operate autonomously.

5. Rehabilitation and healthcare: self-balancing robots are utilized in rehabilitation and healthcare settings to assist individuals with balance and mobility training. These robots can provide support and stability to patients during therapy sessions, helping them regain strength and improve their motor skills [6].

1.2 Problem Statement:

Inverted suspended body manifesto faces stability issues since it is a volatile control machine. The cost of sampling data and the amount of computing time required for a microcontroller to execute a set of instructions. An excessive processing delay gives more time to correct the inverted suspended body's lean perspective and exit the system's vertical symmetry duty.

When compared to classical robotics, it was shown that self-balancing robotics may require significantly more power to operate DC motors in order to maintain symmetry. Motors should keep the robot from falling over in order to preserve its stability. Remarks and corrective measures were required for this act. The mpu6050 gyro + accelerometer, which provides each velocity and rotation in response, is the response component in each 3-axes **[7]**.

1.3 Aims and Objectives

The aim of the project is to design, build, and program a two-wheel self-balancing robot that can maintain stability and navigate its environment autonomously or under user control The objectives of the project are:

1. To design and mechanical construction and sensor integration: research and select appropriate components for the robot, including motors, wheels, chassis, and sensors such as accelerometers, gyroscopes, and encoders to measure the robot's orientation, angular velocity, and wheel position. Calibrate and test the sensors to ensure accurate and reliable data acquisition.
2. To control system development: design and implement a control system that uses sensor feedback to maintain balance and stability.

1.4 Literature Review

- M. A. Hannan, et al. (2017) study present the development of a two-wheel self-balancing robot using fuzzy logic control. They describe the mechanical design, sensor integration, and control system implementation. They evaluate the performance of the robot in terms of stability and response to disturbances, demonstrating the effectiveness of the fuzzy logic control approach [8].
  - K. Gupta, et al. (2018) focus on the design and implementation of a two-wheel self-balancing robot using PID control. They discuss the selection of appropriate sensors, motor control, and PID tuning parameters. They present experimental results showing the robot's ability to maintain balance on different terrains and under various conditions [9].
  - A .L Sarip, et al. (2019) present the design and control of a two-wheel self-balancing robot specifically developed for educational purposes. They emphasize the simplicity of the mechanical design, sensor integration, and control system implementation to facilitate understanding and learning. They evaluate the robot's performance in terms of stability, control response, and user-friendliness [10].
  - Jamuar, et al. (2020) compare different control algorithms, including PID, fuzzy logic, and model predictive control, for a

two-wheel self-balancing robot. They discuss the advantages and limitations of each approach and present experimental results to evaluate the performance of the robot under different control strategies [11].

- S. R. Patel, et al. (2021) focus on the design and development of an autonomous two-wheel self-balancing robot capable of navigation in dynamic environments. They discuss the integration of additional sensors, such as distance sensors and cameras, for environment perception and mapping. They present experimental results demonstrating the robot's autonomous navigation capabilities [12].

1.5 Outline

- Chapter two will deal with Methodology, equipment, connectivity and the way it works
- Chapter three will deal with the results and discussions
- Chapter four will be a conclusion for the entire project in addition to the future work of the project

Chapter Two

Methodology

2.1 Construction a robot stages:

1-The design stage of the robot structure: simple material that is available in the market and is cheap and at the same time strong enough to make the special structure of a robot was chosen.

2-The second stage is to search and gather all the needed components for the robot:

▪Arduino Uno R3

▪12 v JGA25-370 DC Gear Motor with Encoder

▪L298n Motor Driver

▪DC-DC Step down 5A

▪Small Module XL4015

▪Lithium Battery Blue 3800mAh 18650 with Holder

▪GY-521 6 Axis MPU6050 Sensor

▪Bluetooth HC-06 Module

3- The third stage is the stage of connecting the electronic components: {Two developers were used and connected with a motor driver, then the motor driver was connected with the Arduino, and the MPU6050 sensor was used and connected with the Arduino, then Bluetooth was connected with the Arduino and with the electronic breadboard, and then the circuit was fed with a voltage source through four lithium batteries}.

4-The fourth stage is the stage of final assembly of the three main components of the robot (electronic components, electric motors and wheels), and their installation on the chassis.

5- The fifth stage is programming the robot using the program (Arduino Uno R3), and PID algorithms, where we were able to achieve balance in the robot through the code of the PID algorithm. The reason behind using the PID controller and algorithms is that their main purpose is to reduce the error rate between input and output values are minimized through continuous adjustment of the outputs.

6- The last stage is to test the robot to ensure that the system works, anticipate and solve any problems encountered in the behavior of the robot.

2.2 TOOLS

1. Arduino Uno R3
2. 12 v JGA25-370 DC Gear Motor with Encoder
3. L298n Motor Driver
4. DC-DC Step down 5A Small Module XL4015
5. Lithium Battery Blue 3800mAh 18650 with Holder
6. GY-521 6 Axis MPU6050 Sensor
7. Bluetooth HC-06 Module

2.2.1. Arduino Uno R3

The Arduino Uno R3 show in figure (2-1). is a popular microcontroller board used in many robotics projects, including Two-Wheel Self-Balancing Robots. It is based on the ATmega328P microcontroller and provides a versatile platform for prototyping and developing various electronic projects.

The Arduino UNO R3 is frequently used microcontroller board in the family of an Arduino. This is the latest third version of an Arduino board and released in the year 2011. The main advantage of this board is if we make a mistake we can change the microcontroller on the board. The main features of this board mainly include, it is available in DIP (dualinline-package), detachable and ATmega328 microcontroller. The programming of this board can easily be loaded by using an Arduino computer program. This board has huge support from the Arduino community, which will make a very simple way to start working in embedded electronics, and many more applications. Arduino Uno R3 is one kind of ATmega328P based microcontroller board. It includes the whole thing required to hold up the microcontroller; just attach it to a PC with the help of a USB cable, and give the supply using AC-DC adapter or a battery to get started [13] Arduino Uno specifications are following:

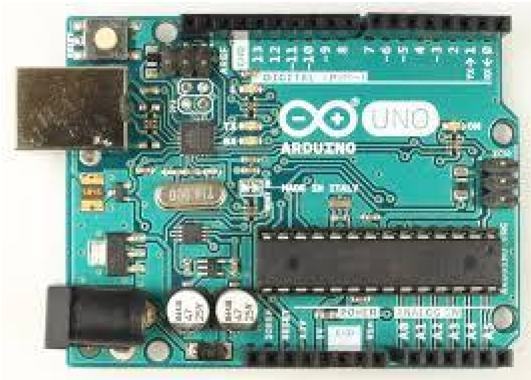

Figure 2-1 Arduino Uno R3 [13]

1. It is an ATmega328P based Microcontroller
2. The Operating Voltage of the Arduino is 5V
3. The recommended input voltage ranges from 7V to 12V
4. The i/p voltage (limit) is 6V to 20V
5. Digital input & output pins (PWM)-6
6. DC Current for each I/O Pin is 20 mA
7. DC Current used for 3.3V Pin is 50 mA
8. SRAM is 2 KB
9. EEPROM is 1 KB
10. The speed of the CLK is 16 MHz
11. In Built LED
12. The weight of the Arduino board is 25 g

2.2.2 DC Gear Motor with Encoder

The 12V JGA25-370 DC show in figure (2-2).geared motor with encoder is a versatile motor commonly used in robotics and automation. It offers high torque, precise control, and on-site feedback through its built-in encoder. This compact and robust motor is ideal for integration into small robots, vehicles, or mechanical systems. Operating at 12V, it ensures compatibility and ease of use in various robotics projects. With a gear reduction gearbox, it provides increased torque output while reducing revolutions, making it suitable for applications requiring forceful object manipulation. The motor's gear ratio of approximately 25:1 strikes a balance between speed and torque, making it versatile for a wide range of robotic tasks. The built-in encoder provides real-time feedback on position and speed, enabling precise control and motion monitoring. This is beneficial for applications such as autonomous navigation, robotic arm control, or stabilization systems [14].

Figure 2-2 JGA25-370 DC Gear Motor with Encoder [14]

2.2.3 Motor Driver

The L298N motor show in figure (2-3).driver is an integrated circuit (IC) commonly used for controlling and driving DC motors or stepper motors in robotics and automation projects. It provides a convenient and efficient solution for controlling the speed and direction of motors using microcontrollers or other control systems. The L298N Motor Driver is designed as a dual H-bridge driver, which means it can control two DC motors or one stepper motor simultaneously. Each H-bridge within the IC consists of four transistors that allow bidirectional control of the motor's rotation. The main features and functionality of the L298N Motor Driver include [15]:

1. Motor Compatibility: The L298N can effectively drive DC motors within a voltage range of 5V to 35V and a maximum current of up to 2A per channel.
2. Control Signals: The L298N Motor Driver requires control signals from a microcontroller or other control system to determine the speed and direction of the motors. It utilizes two digital input
3. signals per motor channel: one for speed control using pulse width modulation (PWM) and another for direction control.
4. H-Bridge Configuration: The H-bridge configuration of the L298N allows for the control of the motor's polarity and direction.
5. Built-in Protection: The L298N Motor Driver incorporates built-in protection features such as thermal shutdown and overcurrent protection. These features help safeguard the motor driver and connected motors from damage caused by excessive heat or current spikes.

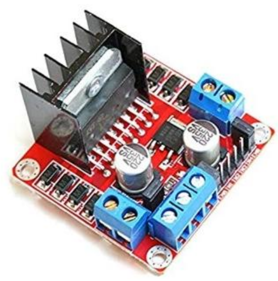

Figure 2-3 L298n Motor Driver [15]

2.2.4 Voltage regulator

The DC-DC Step-down 5A Small Module XL4015 show in figure (2-4). is a popular voltage regulator module used to step down higher input voltages to lower output voltages. It is commonly utilized in various electronic projects to power low-voltage components or systems efficiently. Here is an overview of the module: The XL4015 module is specifically designed for step-down voltage regulation and offers the following features and specifications [16]:

1. Input Voltage: The module can handle input voltages ranging from 4V to 38V DC. It is important to ensure that the input voltage does not exceed the module's specified maximum voltage.
2. Output Voltage: The XL4015 module allows for adjustable output voltages within a range of 1.25V to 36V DC. The output voltage can be set by adjusting the onboard potentiometer or through an external voltage control.
3. Maximum Output Current: The module is capable of delivering a maximum output current of up to 5A. It is essential to ensure that the connected load does not exceed this maximum current to avoid overloading the module.
4. Efficiency: The XL4015 module is known for its high efficiency, often achieving conversion efficiencies above 90%. This

efficiency is beneficial for reducing power dissipation and maximizing power utilization.

5. Protection Features: The module incorporates several protection mechanisms, including over-temperature protection, short circuit protection, and overcurrent protection.
6. Compact Design: The XL4015 module has a small form factor, making it easy to integrate into various electronic projects. Its compact size allows for flexibility in installation and usage.

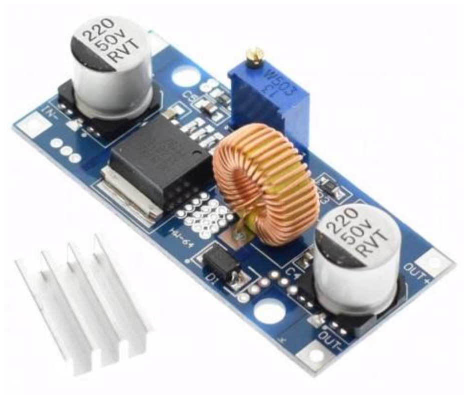

Figure 2-4 DC-DC Step down 5A Small Module XL4015 [16]

2.2.5 Battery

The Lithium Battery Blue 3800mAh 18650 with Holder show in figure (2-5) is a rechargeable lithium-ion battery commonly used in various electronic devices, including portable electronics, power banks, flashlights, and other applications that require a high-capacity and reliable power source.

The Lithium Battery Blue 3800mAh 18650 with Holder offers the following features and specification [17]:

1. Battery Type: The battery is an 18650 lithium-ion cell, which is a cylindrical-shaped battery with a diameter of 18mm and a height of 65mm.

2. Capacity: The battery has a rated capacity of 3800mAh, which indicates the amount of charge it can store.
3. Voltage: The battery has a nominal voltage of 3.7 volts. However, it is important to note that the actual voltage may vary depending on the charge level of the battery.
4. Rechargeable: The Lithium Battery Blue 3800mAh 18650 is a rechargeable battery, allowing it to be charged and used multiple times.
5. Battery Holder: The battery is equipped with a holder, which provides a convenient way to securely hold and connect the battery in electronic projects.
6. Protection Circuitry: Some versions of the Lithium Battery Blue 3800mAh 18650 may include built-in protection circuitry, such as overcharge protection, over-discharge protection, and short-circuit protection.

Figure 2-5 The Lithium Battery Blue 3800mAh 18650 with Holder [17]

2.2.6 Gyro Sensor

The GY-521 6 Axis MPU6050 Sensor show in figure (2-6). is a popular module used for motion sensing and orientation tracking in various electronic applications, including robotics, drones, and motion-controlled devices. It combines a 3-axis accelerometer and a 3-axis gyroscope in a single integrated circuit, providing accurate motion detection and measurement capabilities. The GY-521 6 Axis MPU6050 Sensor offers the following features and specifications [18]:

1. Accelerometer: The module includes a 3-axis accelerometer, which measures linear acceleration along three orthogonal axes (X, Y, and Z).
2. Gyroscope: The module also incorporates a 3-axis gyroscope, which measures angular velocity or rotational motion along the X, Y, and Z axes.
3. Integrated Sensor Fusion: The MPU6050 sensor combines the data from the accelerometer and gyroscope to perform sensor fusion and provide accurate measurements of motion and orientation.
4. Digital Interface: The GY-521 module communicates with a microcontroller or other devices through a digital interface, typically using I2C (Inter-Integrated Circuit) protocol.
5. Programmable Features: The MPU6050 sensor offers various programmable features, including sensitivity ranges for the accelerometer and gyroscope, digital low-pass filters, and interrupt functionality.
6. Motion Detection and Gesture Recognition: The sensor can be used to detect motion, gestures, and changes in orientation.

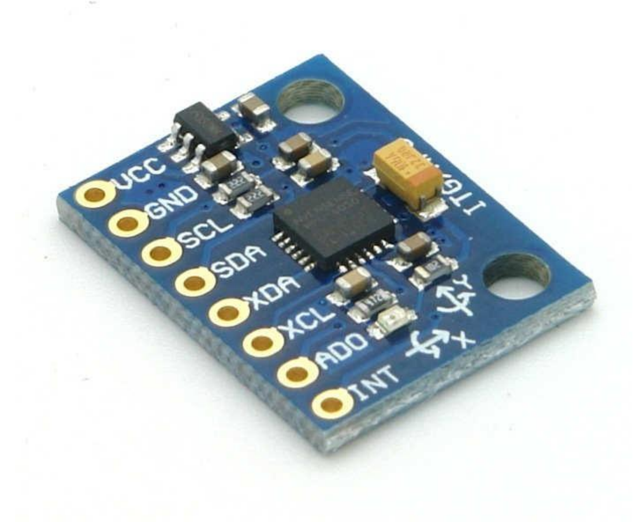

Figure 2-6 GY-521 6 Axis MPU6050 Sensor [18]

2.2.7 Bluetooth Module

The Bluetooth HC-06 module show in figure (2-7). is a popular Bluetooth communication module that allows wireless communication between electronic devices. It is commonly used in various projects where wireless connectivity is required, such as home automation systems, robotics, and IoT applications. The Bluetooth HC-06 module offers the following features and specifications [19]:

1. Bluetooth Version: The HC-06 module is based on Bluetooth version 2.0, which is an older version of the Bluetooth protocol.
2. Communication Range: The module has a communication range of approximately 10 meters (33 feet) in an open space.
3. Serial Communication: The HC-06 module is designed for serial communication and uses a simple and straightforward AT command set.
4. Operating Voltage: The module typically operates at a voltage of 3.3V, making it compatible with most microcontrollers and digital circuits.

5. Data Rate: The HC-06 module supports a maximum data rate of 2.1 Mbps. The actual data rate may vary depending on factors such as the distance between devices, signal quality, and other interference.
6. Communication Modes: The module supports both Master and Slave modes of operation. In the Slave mode, the HC-06 module can be connected to a Master device such as a smartphone or a computer.
7. Easy Pairing: The HC-06 module has a simple pairing process that allows it to connect and communicate with other Bluetooth-enabled devices seamlessly.

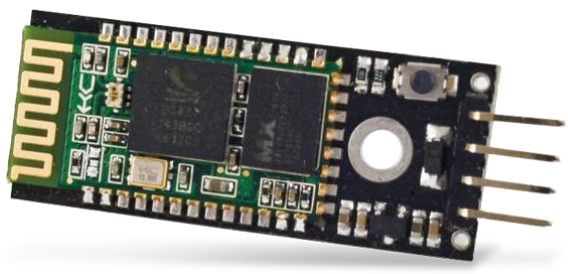

Figure 2-7 Bluetooth HC-06 Module [19]

2.3 Pin connection

- Motor wires each one 6
- We only used 2
- The first motor is connected to the A side with the L298n driver
- red and white
- The second motor is connected to the B side with the L298n driver
- red and white

2.3.1 Voltage regulator connection

- From the source 14.8v four lithium batteries with reduction becomes 12v
- Log into the Breadboard to positive port (+) and negative port (-)

2.3.2 Gyro sensor connection

- Connect Vcc to the 3.3v port on the Arduino
- Connect Gnd to the Gnd port on the Arduino
- Connect Scl to A5 port on Arduino
- Connect Sda with A4 port on Arduino
- Connect Int to pin 2 of the Arduino

2.3.3 Bluetooth connection

- Connect the Vcc with the 5v port on the breadboard
- Connect Gnd with the Gnd line in the mailboard
- Connect Tx to Rx in Arduino
- Connect Rx to Tx in Arduino

2.4.4 Driver connection

- Each side A, B is a motor
- The first port is for the 12V input voltage from the bridge
- The second/terrestrial port is the entry from the mailboard
- The third port/ was used as a 5v output to feed the Arduino into the (Vin) port
- And take Gnd from the post to feed the Arduino
- Connect Ena with pin 5 on the Arduino
- Connect In1 with pin 6 on the Arduino
- Connect In2 with port No. 7
- Connect In3 with port No. 8

- Connect In4 with port No. 9
- Connect Enb with port No. 10

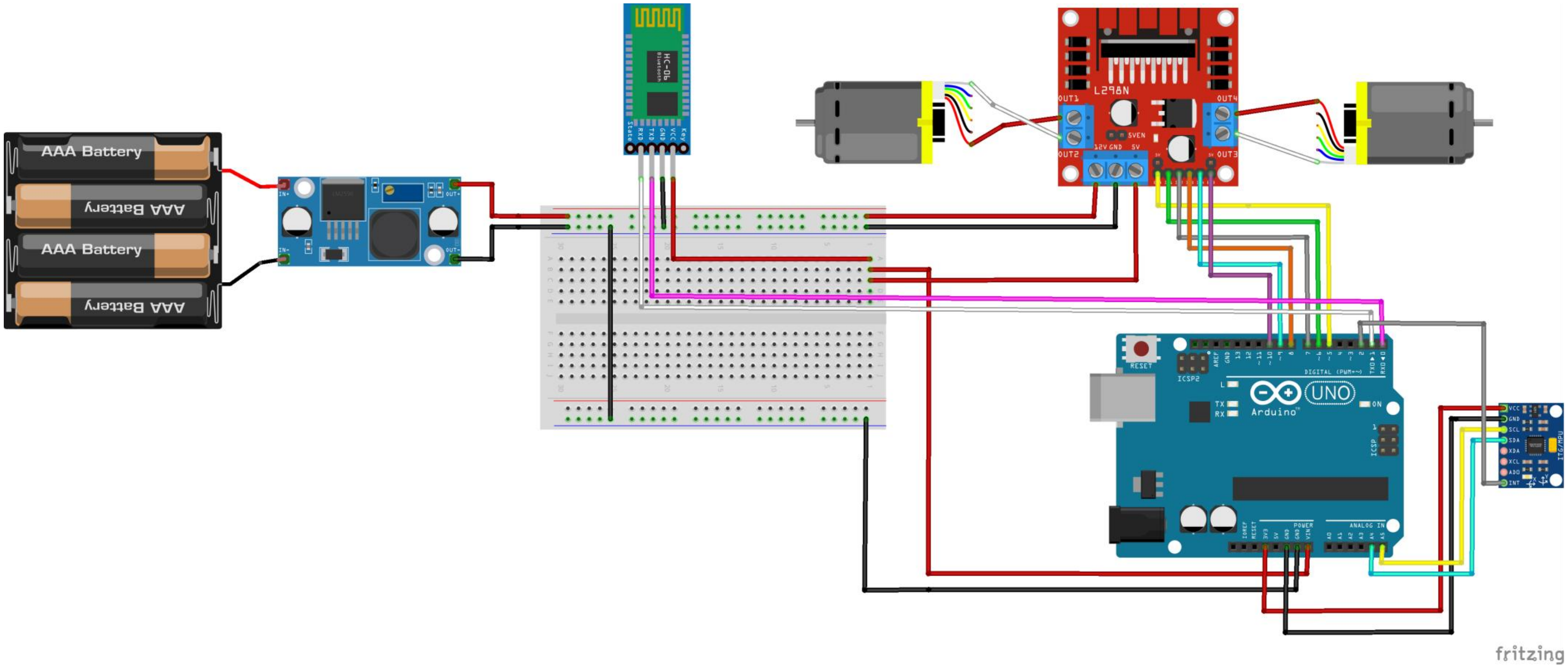

Figure 2-8 Robot electronic parts connection

2.5 Software flowchart and PID controller schematic diagram

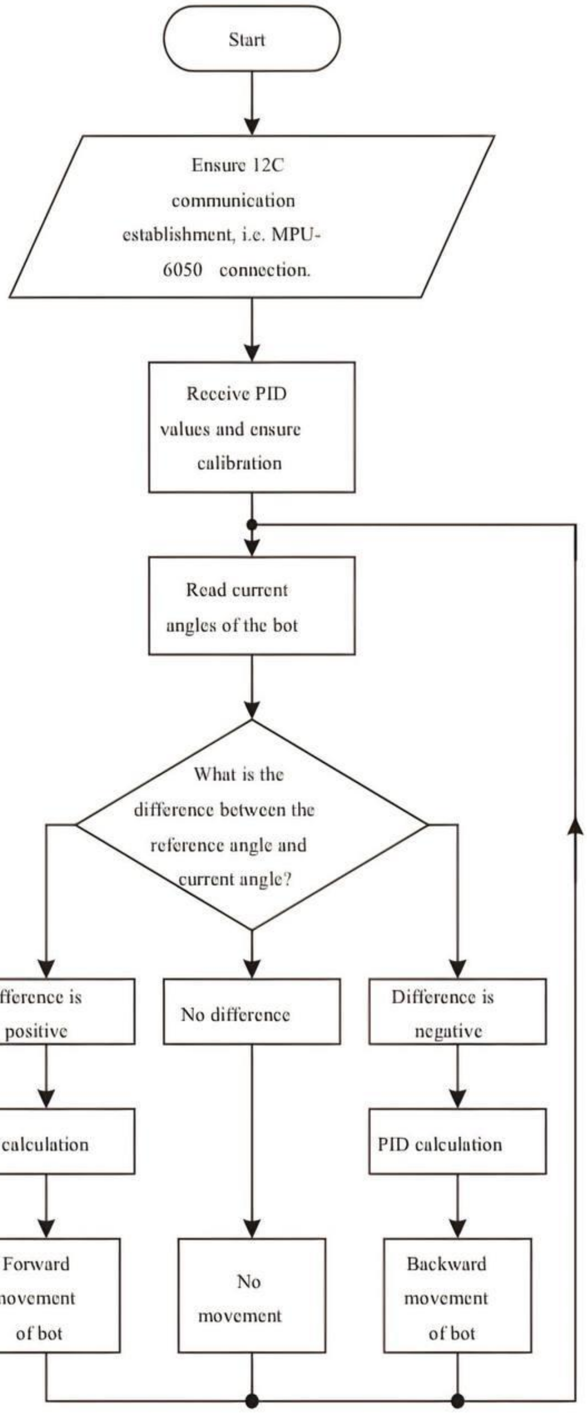

Figure 2-9 Flowchart of microcontroller programming.

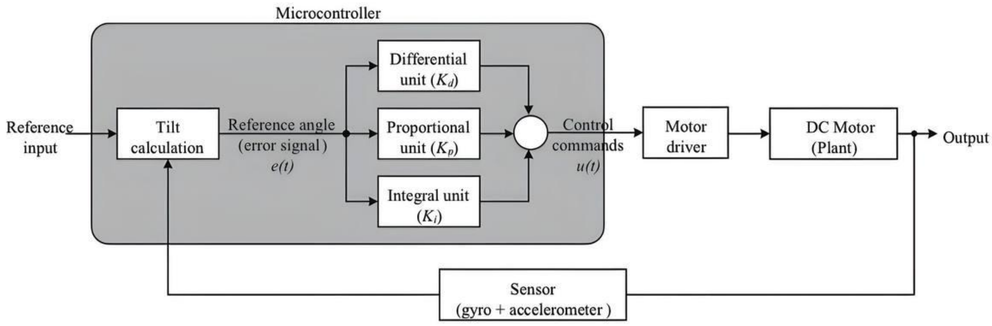

Figure 2-10 . The closed loop control system of the self-balancing rob

Chapter Three

Results and Discussions

3.1 Practical Results:

After the designing the robot shown in figure (3-1a) and testing all the stages, the robot has the capability of balancing the load of the robot chassis, i.e., the body of the robot (load) through its wheels instead of dragging the weight around like a regular robot after the body falls. This robot is programmed in such a way that the wheels ensure self-balancing by moving in the direction of the robot's tilt. For example, if the body of the robot is tilting forward, then the wheels move forward to balance it. If the body of the robot tilts backward, then the wheels move backward to ensure that the robot self-balances. It is essential to point out the fact that the wheels of this robot only move in two directions, i.e., backward and forward. After the design and assembly phases of the robot, it was tested multiple times across various terrains and obstacles to check whether it has the capability of not only moving from one place to another and self-balance while moving. The first goal of this project of making the robot balanced using the PID algorithm was achieved after the PID algorithms for the APM controller was developed using Arduino Uno R3as this algorithm was based on the inverted pendulum theory that was previously designed

using Matlab/Simulink simulation.This algorithm has programmed the robot to move in the direction of tilt. With the help of the MPU6050 sensors, the APM detects the movement of the robot body or tilt in the forward or backward directions. After detecting the motion of the tilt, the

APM is programmed by the PID algorithm, to autonomously move the motor and the robot's wheels in the tilt's direction. This PID algorithm ensures the achievement of the first goal of this project of a self-balancing robot by automatically moving the robot in the direction of the tilt to ensure the maintenance of the robot's balance in motion. The second and

third goals of this project were to make the robot move while self-balancing by using the RC transmitter and receiver and making it navigate using GPS,

Figure (3-1a) Designing the robot

Figure (3-1b) Designing the robot

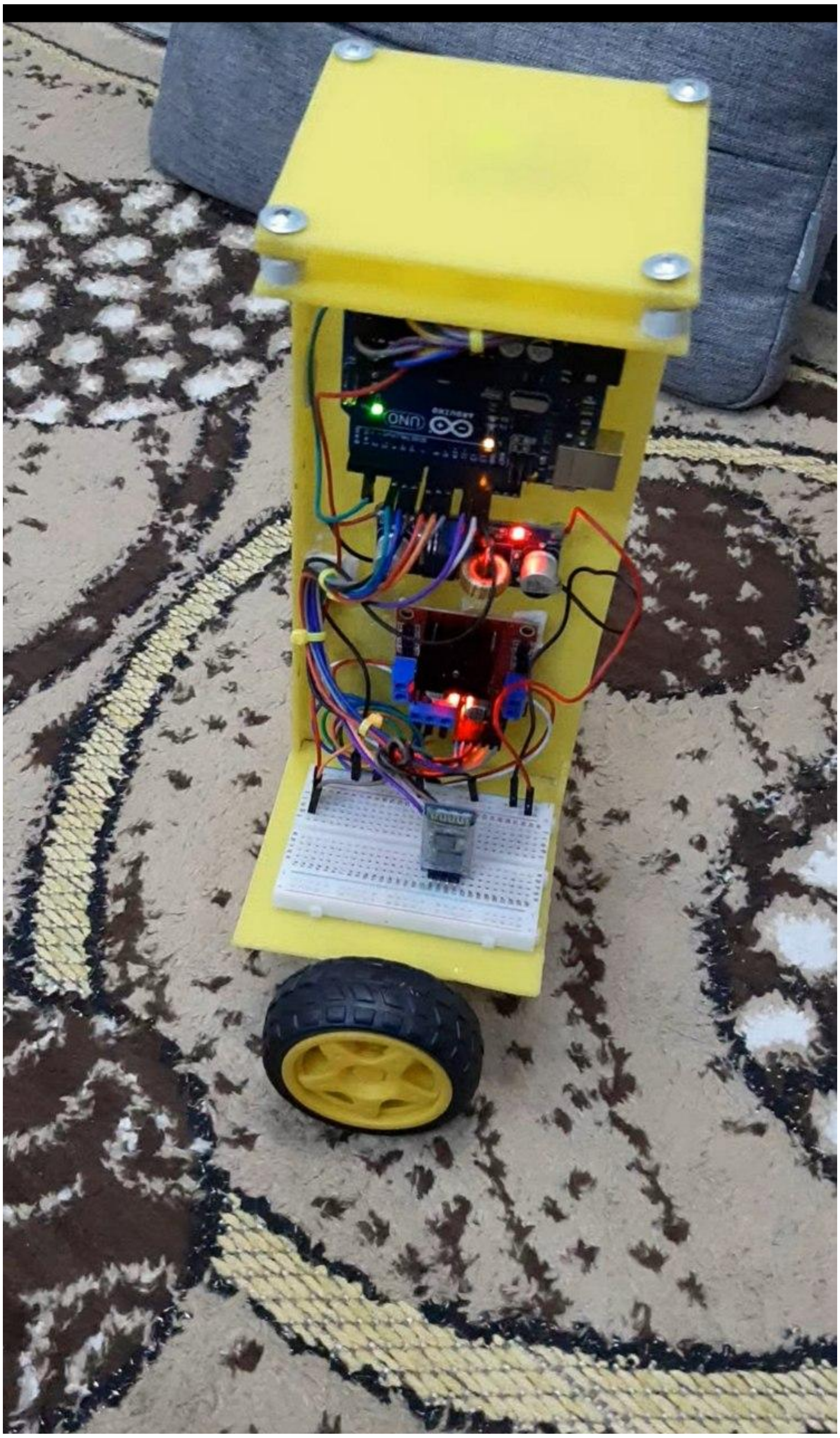

Figure (3-1b) Designing the robot

3.2 Discussion

The smart two wheels balancing robot, as mentioned earlier in this report, is following the inverted pendulum theory. Control theory requires keeping some of the variables steady, including the robot's position in this case, for which a special type of controller known as PID is required. The parameters particularly have gains known as Kp, Kd, and Ki The requirement of the PID was essential as it gives correction among the desired values (input) and actual values (output). The difference between the output and input values is known as error. The reason as to why the PID controller and algorithms are used is that their main purpose is to reduce the error between input and output values to the minimum by the continual adjustment of the output In the self-balancing robot, the input (desired tilt in terms of degrees) is settled by the software. The APM reads the robot's current tilt and gives it to the PID algorithm that performs the required calculations for controlling the motor of the robot and ensuring that through continued movement, the robot maintains its upright position. However, it is necessary for the PID that the gains in Kp, Ki, and Kd are tuned to the optimal values. Most engineers use software like Matlab for computing values automatically. However, the autonomous capabilities of APM allow us to develop a PID algorithm that ensures the robot motor rotates in the direction of the tilt after detection and stabilises the robot in the upright position after the tilt is corrected. The concept of this system is of balancing the robot by ensuring that the motors of the robot counteract the fall in either forward or backward direction. This action mainly requires the robot to perform feedback and correct actions at the same time. That is why the APM system was used with this robot system so that through the PID algorithm, the robot is programmed to move in the direction of the tilt for maintaining its balance and preventing the robot from falling The

Arduino board is also used in this system, which was also programmed for the wheel encoders. The Arduino Uno R3 Mini board uses the information provided by the APM to understand the latest orientation of the robot. Corrective action is performed by the combined action of the motor and wheels. The APM controller is used for this robot system mainly because this type of system is easy to use and provides GPS with a compass that helps in the navigation of a robot system

Furthermore, APM can be programmed through the PID algorithm, which allows us to ensure that the robot not only has the capability of moving from one point to another but is also capable of maintaining its balance or upright position. The brushed DC motors and with CPR 48 encoders are the best choice of motor for this project because it gives the lower power 6V that is combined with the 34.104:1 super metal gearbox to ensure good integration with the board. After all the components were selected, the final design of the robot was prepared, after which the assembly phase began in which all these components were joined to resemble the robot's final design. and robot wheels rotate in the direction of the tilt to ensure that the robot maintains its balance and prevents the body from falling to the ground. All the components of the system were connected, Next, the two main programs for the Arduino Uno R3 Mini and the APM were written. The code for APM is for controlling movement and balancing the robot while the code for Arduino Uno R3 Mini is for acquiring the wheel velocity from the encoders. It was ensured before testing the robot that there is a good connection between the board and the controller. The concept of the inverted pendulum is essential for understanding the working of this robot system. According to this concept, the robot can be balanced much more adequately if the centre of mass is greater than that of the wheel axles. A higher centre of mass means a greater moment of inertia that corresponds to the lowered angular acceleration, i.e., a slower fall.

Chapter Four

Conclusion and Recommendations for Future Work

4.1 Conclusions

In conclusion, Two-Wheel Self-Balancing Robots are innovative and fascinating creations that showcase the principles of balance and control in robotics. These robots are designed to maintain their stability and remain upright without external support, mimicking the way humans maintain their balance.While they offer exciting possibilities, the development of Two-Wheel Self-Balancing Robots is not without its challenges. Issues such as stability control, power management, and mechanical design require careful consideration and ongoing improvements.The future of Two-Wheel Self-Balancing Robots holds great promise. Advancements in sensors, artificial intelligence, and machine learning can enhance their capabilities and enable them to navigate complex environments autonomously. They can also find applications in fields such as healthcare, logistics, and entertainment.By continuously pushing the boundaries of technology and refining the design and control of Two-Wheel Self-Balancing Robots, we can unlock their full potential and revolutionize various industries. The field of robotics is ever-evolving, and these robots serve as a testament to the ingenuity and creativity of researchers, engineers, and robotics enthusiasts.In conclusion, Two-Wheel Self-Balancing Robots offer an exciting avenue for exploration, innovation, and practical applications. With continued research and development, these robots have the potential to make a significant impact in various domains, contributing to advancements in technology and improving our daily lives.

4.2 Future Work

1. Advanced Control Algorithms: Research and develop more sophisticated control algorithms for enhanced stability and maneuverability of the robot.
2. Obstacle Detection and Navigation: Integrate sensors, such as LiDAR (Light Detection and Ranging) or depth cameras, to enable the robot to detect and navigate around obstacles autonomously.
3. Gesture and Voice Recognition: Incorporate gesture and voice recognition technologies to enable intuitive human-robot interaction.
4. Energy Efficiency and Battery Life: Optimize power management techniques to improve the robot's energy efficiency and extend its battery life. This can involve developing intelligent power-saving algorithms, incorporating energy harvesting mechanisms, or exploring alternative power sources such as solar panels.
5. Robust Mechanical Design: Enhance the mechanical design of the robot to improve its durability and ruggedness. This can include the use of high-quality materials, reinforcement of critical components, and incorporating shock-absorbing mechanisms to withstand impacts and vibrations.
6. Real-World Applications: Explore practical applications for Two-Wheel Self-Balancing Robots in various industries. This can include areas such as delivery services, surveillance and security, personal mobility assistance, or even entertainment and exhibitions.
7. Human-Robot Collaboration: Develop algorithms and mechanisms that enable safe and efficient collaboration between humans and Two-Wheel Self-Balancing Robots. This can involve integrating sensors for detecting and responding to human

presence, ensuring smooth interaction and cooperation in shared spaces.

8. Miniaturization and Portability: Work towards miniaturizing the robot's components and making it more compact and portable. This would enable its use in a wider range of environments and applications, including areas with limited space or remote locations.
9. User Interface and Visualization: Design user-friendly interfaces and visualization tools to monitor and control the robot's behavior. This can include mobile apps, web interfaces, or augmented reality (AR) systems that provide real-time feedback and data visualization.
10. With the integration of additional sensors and advancements in mapping and navigation algorithms, self-balancing robots gained the capability of autonomous navigation. They could detect obstacles, plan paths, and create maps of their environment.

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