DESIGN AND DEVELOPMENT OF SINGLE-AXIS SOLAR TRACKING SYSTEM AND WATER LEVEL CONTROL FOR APPLICATION OF LINE FOCUS CONCENTRATOR FOR SOLAR DESALINATION PROCESS

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MUHAMMAD ADAM BIN ZAHARI

Thesis submitted in fulfilment of the requirements for the award of the degree of Bachelor of Engineering Technology in Electrical with Honours

Faculty of Engineering Technology
UNIVERSITI MALAYSIA PAHANG

DECEMBER 2017

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1. Bachelor of Engineering Technology

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ACKNOWLEDGEMENTS

I am sincerely grateful to ALLAH "S.W.T" for giving me wisdom, strength, patience and assistance to complete my project work. Had it not been due to His will and favour, the completion of this study would not have been achievable. I have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals and organizations. I would like to extend my sincere thanks to all of them.

I respect and thank to my advisor, Dr. Samson Mekbib for giving me an opportunity to do the project work in application of line focus concentrator for solar desalination process and providing us all support and guidance which made me complete the project on time. Besides that, I also thank to Assoc. Prof. Dr. Kulkarni as our co-supervisor that help us to finish our project. I am extremely grateful to him for providing such a nice support and guidance though he had busy schedule.

Next, my special thanks to Dr. Roshahliza as our co-supervisor that give me an advice and support to finish my work. She as my electrical supervisor who have helped me wherever and whenever i got stuck and for being patient with me even at the toughest hours. I would not forget all of that kindness during supervise me doing final year project. Here, I also like to convey thanks to the faculty (FTEK) for providing the laboratory facilities for doing the fabrication and give us the budget to finish the project.

Besides that, I feel a deep sense of gratitude for my parents, mother, father, who formed part of my vision and taught me good things that really matter in life. Their infallible love and support has always been my strength. Their patience and sacrifice will remain my inspiration throughout my life.I am also very much grateful to all my family members for their constant inspiration and encouragement.

Lastly, many people, especially my classmates and team members itself, have made valuable comment suggestions on this project which gave us an inspiration to improve the project. I thank all the people for their help directly and indirectly to complete this final year project.

ABSTRACT

The lack of drinking water has been a great challenge for humanity which continues to the present and will continue in the future. One of the solutions to solve this problem is solar desalination technology. The thermal conversion of solar concentrators makes it possible to reach high temperatures able to boil the salted water with pressures higher or equal to the atmospheric one. Thus, for increases the efficiency of solar desalination plant, the solar tracking system was designed to make the system more flexible to trap the sunlight. The main mechanism of the solar tracking system consists of the tracking device, tracking algorithm, control unit, positioning system, driving mechanism and sensing devices. The tracking algorithm determines the angles which are used to determine the position of solar tracker. This project discusses the design and construction of a prototype for solar tracking system that has a single axis of freedom. The control circuit is based on an ATMega328P microcontroller. It was programmed to detect sunlight via the LDRs before actuating the motor to position the parabolic frame. The parabolic frame is positioned where it is able to receive maximum light. By using this method, the application of line focus concentrator for solar desalination process will be more functional and get higher output of fresh water. Besides that, to make the system more flexible, we add the sensor which is ultrasonic sensor for measure water level. Therefore, we can make the process of desalination work automatically. The basic mechanisms of measure level sensor are controlled by using Arduino, solenoid valve, ultrasonic sensor and water pump. The control circuit is based on an Arduino microcontroller and was programmed to control the water flow into absorber tube. When the water reach at maximum point, the ultrasonic sensor will send the signal to solenoid valve to stop the water from flow into absorber tube. From the result, the highest amount of fresh water produces was 25ml when the average value of solar irradiance 318.00W/m^2. Thus, it is found that the productivity of fresh water increases as the solar irradiation increases because the rate of evaporation depends on solar intensity and the weather. Besides that, when the bad weather occur during experimental, the solar tracking system will not performed well.

ABSTRAK

Kekurangan air minuman telah menjadi satu cabaran yang besar bagi manusia pada masa kini dan akan berterusan pada masa hadapan. Salah satu cara penyelesaian untuk menyelesaikan masalah ini adalah teknologi penyahgaraman solar. Penukaran haba penumpu solar dapat mencapai suhu yang tinggi membolehkannya merebus air masin dengan tekanan yang lebih tinggi atau sama dengan tekanan atmosfera. Oleh itu, bagi meningkatkan kecekapan sistem penyahgaraman solar, sistem pengesanan solar telah direka untuk membuat sistem yang lebih fleksibel untuk memerangkap cahaya matahari. Mekanisma utama dalam sistem solar penjejakan terdiri daripada peranti penjejakan, algoritma pengesanan, unit kawalan, sistem kawasan, mekanisme pemanduan dan peranti penderiaan. Algoritma pengesanan yang menentukan sudut yang digunakan untuk menentukan kedudukan pengesan solar. Projek ini membincangkan berkenaan reka bentuk serta pembinaan sebuah prototaip bagi sistem pengesanan solar yang mempunyai kebebasan paksi tunggal. Litar kawalan adalah berdasarkan mikrokontroler ATMega328P. Ia telah diprogramkan untuk mengesan cahaya matahari melalui LDR sebelum menggerakkan motor untuk meletakkan kerangka parabola. Bingkai parabola diletakkan di mana ia dapat menerima cahaya maksimum. Dengan menggunakan kaedah ini, penggunaan penumpuan garis fokus untuk proses penyahgaraman solar akan lebih berfungsi dan mendapatkan pengeluaran air tawar yang lebih tinggi. Selain itu, untuk membuat sistem yang lebih fleksibel, kami menambah pengesan iaitu pengesan ultrasonik untuk mengukur aras air. Oleh itu, kami boleh membuat proses kerja penyahgaraman secara automatik. Mekanisme asas mengukur tahap sensor dikawal oleh Arduino, pengesan ultrasonik, injap solenoid dan pam air. Litar kawalan adalah berasaskan mikropengawal Arduino dan telah diprogramkan untuk mengawal aliran air ke dalam tiub absorber. Apabila air sampai ke titik maksimum, pengesan ultrasonik akan menghantar isyarat ke injap solenoid untuk menghalang air dari mengalir ke tiub absorber. Dari hasilnya, jumlah tertinggi air tawar ialah 25ml apabila nilai purata pancaran sinar matahari 318.00W / m^2. Oleh itu, didapati bahawa produktiviti air tawar meningkat apabila penyinaran solar meningkat kerana kadar penyejatan bergantung kepada keamatan solar dan cuaca. Selain itu, apabila cuaca buruk berlaku semasa eksperimen, sistem penjejakan solar tidak akan berfungsi dengan baik.

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LIST OF SYMBOLS

m	Meter
s	Second
h	Hour
m	Minute
ε	Angle of earth's axis of rotation
θ	Angles of Incidence
Φ	Solar Altitude
α	Solar Azimuth
Θ_z	Angle of Zenith
W	Watt
V	Voltage
A	Amphere
g	Gram
mm	Milimeter
KB	Kilobyte
KHz	Kilohertz
L	Liter
%	Percentages
°C	Degree Celsius
W/m^2	Solar Irradiance

LIST OF ABBREVIATION

DNI	Direct Normal Irradiance
HSAT	Horizontal Single Axis Trackers
LCD	Liquid Crystal Display
LDR	Light Dependent Resistor
MD	Membrane Distillation
PSAT	Polar Aligned Single Axis Trackers
RPM	Rotation Per Minute
RO	Reverse Osmosis
TSAT	Tilted Single Axis Trackers
UN	United Nations
VC	Vapor Compression
VSAT	Vertical Single Axis Trackers

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

This chapter explains the overview on solar desalination. Solar desalination is one of the methods to solve the current water crisis. This method had been employed by humankind for thousands of years. From early Greek mariners to Persian alchemists, the basic technology has been utilized to produce freshwater. Solar desalination processes the contaminated water and converts it to a potable form. It is also a process of removing salts from sea water with the help of solar energy to yield pure water. The benefits of solar desalination are it uses free solar energy for operation, inexpensive, light in weight, low maintenance costs and environment friendly. Besides that, this chapter also explains on solar tracker and the significance of solar tracker. It explains how the solar tracker works and what the significance of solar tracker for the user and why the solar tracker is invented.This project discusses the design and construction of a prototype for solar tracking system that has a single axis of freedom.The control circuit is based on an ATMega328P microcontroller. It was programmed to detect sunlight via the LDRs before actuating the motor to position the solar panel. Lastly, this chapter also cover about control the flow of salt water into absorber tube. The basic mechanisms of measure level sensor are ATMega328P microcontroller which is Arduino, solenoid valve, ultrasonic sensor and water pump. The control circuit is based on an Arduino microcontroller. It was programmed to control the water flow into absorber tube. When the water reach at maximum point, the ultrasonic sensor will send the signal to solenoid valve to stop the water from flow into absorber tube.

1.2 OVERVIEW ON ELECTRICAL SYSTEM

Due to the complex design and high costs of production, solar thermal systems have fallen behind in the world of alternative energy systems. Different mechanisms are applied to increase the efficiency of the solar collectors and to reduce the cost. Solar tracking system is the most appropriate technology to increase the efficiency of solar collectors as well as solar power plants by tracking the sun timely (akram et al., 2012). The main mechanism of the solar tracking system consists of the tracking device, tracking algorithm, control unit, positioning system, driving mechanism and sensing devices. The tracking algorithm determines the angles which are used to determine the position of solar tracker (Rajan et al., 2017). The advantage of solar tracker is can generates more electricity because the system follow the sun timely. Besides that, this system also need to control the salt water that flow in absorber tube. Due to that problem, the solenoid valve is used to control that water flow. A solenoid valve is operated using an electromagnetic solenoid coil to change the state of a valve from open to close or vice-versa (Forum, P. I., 2013). When the coil is energized the solenoid valve is ‘normally closed’ and the valve gets lifted open by the electromagnetic force produced by the coil.

1.3 PROBLEM STATEMENT

Water covers 71% of the Earth’s surface and vital for all forms of life. On Earth, 96.5% of the planet's crust water is found in seas and oceans, 1.7% in groundwater, 1.7% in glaciers and the ice caps of Antarctica and Greenland, a small fraction in other large water bodies, and 0.001% in the air as vapor, clouds (formed of ice and liquid water suspended in air), and precipitation. Only 2.5% of this water is freshwater, and 98.8% of that water is in ice (excepting ice in clouds) and groundwater. The growing scarcity of fresh water is driving the implementation of desalination on an increasingly large scale.

Around 700 million people in 43 countries suffer today from water scarcity. By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world's population could be living under water stressed conditions. With the existing climate change scenario, almost half the world's population will be living in areas of high water stress by 2030, including between 75 million and 250 million people in Africa. Thus, solar desalination technology is created to solve the water crisis. Solar desalination technology is prefer as it is cost free and clean energy, low operating cost, little maintenance, and no moving parts involved in this systems. The solar desalination uses sunlight to purify the water. The direct sunlight will help to separate the salt from water through vaporization and condensation processes using solar stills.

Thus, we designed a parabolic trough collector which can absorb and reflect the sunlight efficiently. Thus, there is maximum sunlight for the parabolic trough collectors. Besides, the designs will increase the rate of evaporation and condensation of the salt into water by using vacuum tube. In addition, we also use solar tracking to trap more sunlight. We also adding the LCDs at tracking system to display the value of light dependent resistor. The designs will be compact and lightweight so that users can carry it everywhere. We also install the solar panel at solar desalination to charge the battery in the system.

1.4 OBJECTIVES

Below are the main objectives of the projects.

1. To design and construct the circuit that can detect the water level by using ultrasonic sensor.
2. To design and construct a single axis solar tracking system for moving the parabolic trough collector.

1.5 PROJECT SCOPE

This project is focused in designing and building the prototype of solar tracking system that would be a starting point to build the realistic solar tracking system. This prototype will use the microcontroller ATmega328P and use four sensor photoresistor or other name is light dependent resistor as sensors. Besides that, this project also focuses on developing a working prototype of the parabolic trough collector type of solar desalination process. This prototype will purify the salt water contained in absorber tube using sunlight for the purpose of desalination. Lastly, this project also focuses on the installation of solenoid valve that will control the salt water flow in absorber tube.

CHAPTER 2

LITERATURE REVIEW

2.1 BACKGROUND OF SOLAR DESALINATION

Natural water resources come from the natural evaporation of earth's water surfaces (oceans and seas) .This resource is fixed as there are no other natural resources in earth. Moreover the world population is growing fast causing an increase in water demand. The lack of drinking water has been a great challenge for humanity which continues to the present and will continue in the future (Malik MAS et al., 1985). It affects every continent and around 2.8 billion people around the world at least one month out of every year. More than 1.2 billion people lack access to clean drinking water. The United Nations (UN) estimates that, of 1.4 billion cubic kilometers of water on Earth, just 200,000 cubic kilometers represent fresh water available for human consumption.

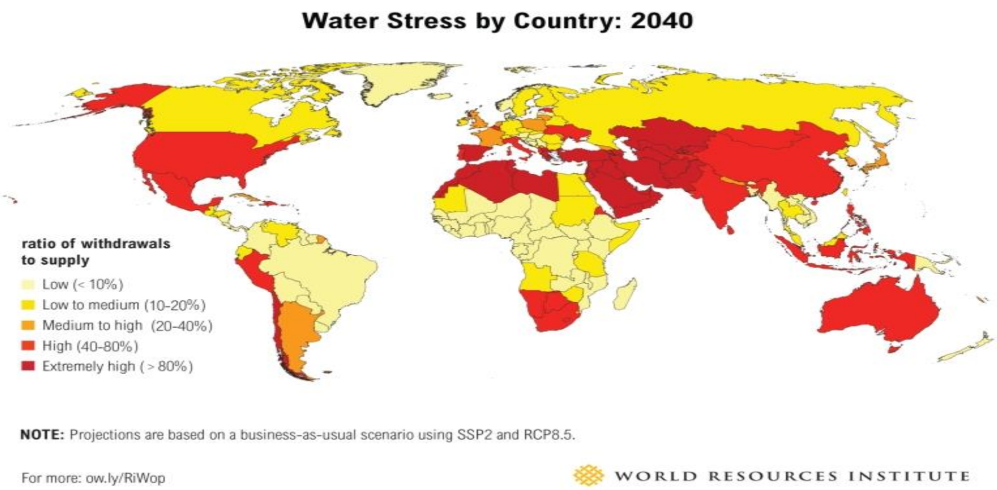

Figure 2.1: Ranking the World's Most Water-Stressed Countries in 2040 (M.Andrew et al., 2015)

More than one in every six people in the world is water stressed, meaning that they do not have access to potable water (UNDP, 2006).Those that are water stressed make up 1.1 billion people in the world and are living in developing countries.According to the Falkenmark Water Stress Indicator, a country or region is said to experience "water stress" when annual water supplies drop below 1,700 cubic meters per person per year. Based on figure 2.1, a lot of country will face the water crisis when reached 2040.

When there is not enough potable water for a given population, the threat of a water crisis is realized. The United Nations and other world organizations consider a variety of regions to have water crises of global concern. Other organizations, such as the Food and Agriculture Organization, argue that there are no water crises in such places, but steps must still be taken to avoid one. However, Ning acclaims that the fast population growth and industrialization especially in developing countries have raise the demands for both freshwater and energy (Robert Y. Ning, 2015).

The growing scarcity of fresh water is driving the implementation of desalination on an increasingly large scale. Solar desalination is a technique to desalinate water using solar energy. There are two basic methods of achieving desalination using this technique which are direct and indirect. In the direct method, a solar collector is coupled with a distilling mechanism and the process is carried out in one simple cycle (Gomez-Camacho et al., 2002). Water production by direct method solar distillation is proportional to the area of the solar surface and incidence angle and has an average estimated value of 3L/m2/day until 4L/m2/day (Codanda Devaiah Monappa, P. K., 2017). Indirect solar desalination employs two separate systems; a solar collection array, consisting of photovoltaic and/or fluid based thermal collectors, and a separate conventional desalination plant (Codanda Devaiah Monappa, P. K., 2017). Production by indirect method is dependent on the efficiency of the plant and the cost per unit produced is generally reduced by an increase in scale.

Desalination technologies that are currently practiced have a further constraint; that it is driven almost entirely by the combustion of fuels. These fuels are still of finite supply, pollute the air, and contribute to the risk of global climate change. Because of cost free and clean energy, low operating cost, little maintenance, and no moving parts involved in these systems, solar distillation is preferred to other processes of distillation.

2.1 CLASSIFICATIONS OF SOLAR DESALINATION

Solar desalination is a technique to desalinate water using solar energy. Based on figure 2.2, there are two basic methods of achieving desalination using this technique which are direct and indirect. Direct solar desalination uses solar energy to produce distillate directly in the solar collector whereas indirect solar desalination combines conventional desalination techniques, such as multistage flash desalination (MSF), vapor compression (VC), reverse osmosis (RO), membrane distillation (MD) and electro dialysis with solar collectors for heat generation. The simple solar still of the basin type is the oldest method and improvements in its design have been made to increase its efficiency (MM. Naim, 1987). A single-effect solar still is a simple device which can be used to convert saline, brackish water into drinking water. In solar stills a transparent cover encloses a pan of saline water which traps solar energy within the enclosure. This heats up the water causing evaporation and condensation on the inner face of the sloping transparent cover. This distilled water is generally potable; the quality of the distillate is very high because all the salts, inorganic and organic components and microbes are left behind in the bath.

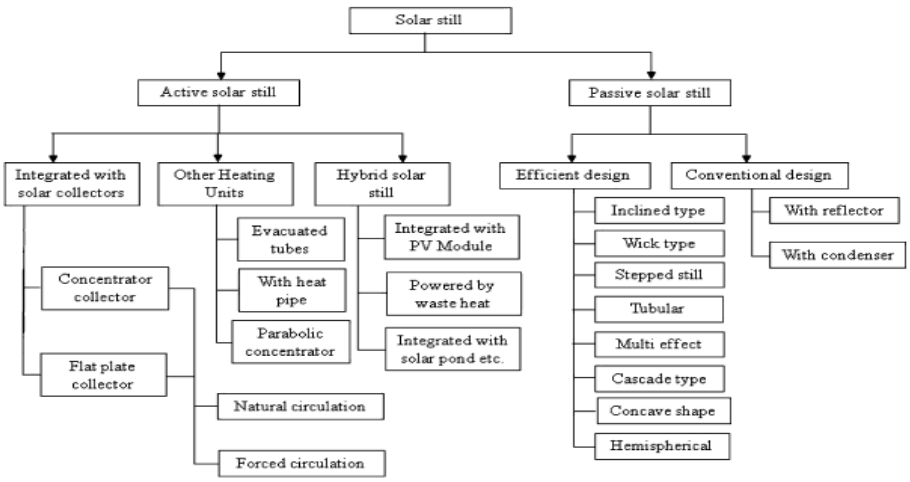

Figure 2.2: Classifications of solar still (Himanshu Manchanda et al., 2015).

2.2.1 Passive Solar Still

Passive solar stills directly use solar radiation in the distillation process. Passive solar distillation is simple in construction and operation. In the direct method, a solar collector is coupled with a distilling mechanism and the process is carried out in one simple cycle. Passive solar still usually small in sizes and requires lower costs. The efficiency and distillate output of passive solar stills is very less. There are numerous designs and operational parameters along with climatic conditions that affect the performance of a passive solar still.

2.2.1.1 Single Effect Still

Single effect passive stills are original conventional solar stills. These stills are easy to construct and have only one layer of glazing over the water surface. However, lot of heat energy is lost through the latent heat of condensation through the glazing. So, there is lot of scope to recover that heat lose in order to improve the solar still efficiency.

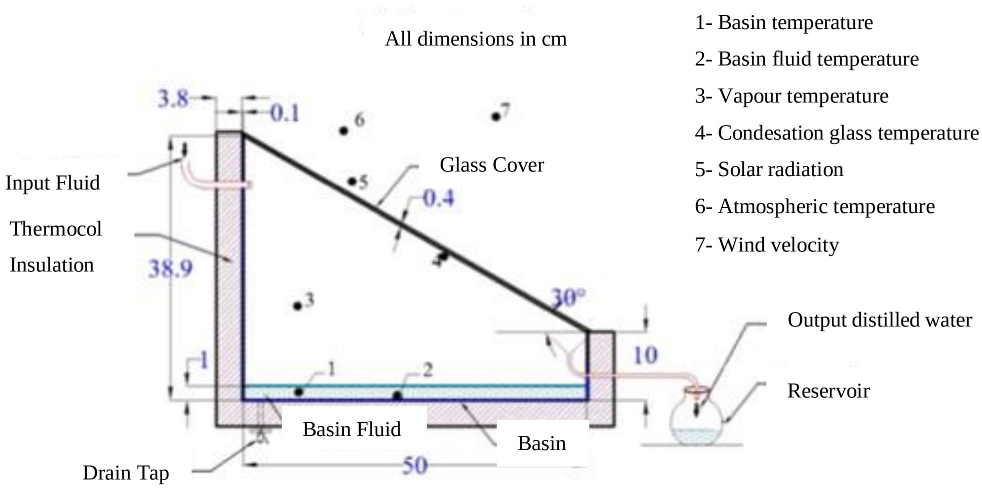

Figure 2.3: A schematic diagram of single effect passive solar still (T.Elango,A.K., 2015)

The figure 2.3 shows the schematic diagram of single effect still.The single effect still is the simplest and most common, since only one interface is necessary to convey the energy and collect the condensate. The challenge in all solar stills is keeping the distiller airtight. The efficiency will drop severely if not airtight (Gordes, J., & McCracken, H., 1985). A black and flooded shallow trough is often used. A slanted pane of glass covering, allowing condensed water vapor to slide down into an output channel. The drawback with the passive stills is solar radiation directly received by basin water is only source of energy to raise the temperature of water. The improvement is to develop the active stills. In single effect active solar stills one layer of glazing is provided as in single effect passive stills and an extra thermal energy is supplied to the basin through some external mode to raise the temperature of water. This increase in temperature results in increase of evaporation rate and in turn improves the efficiency of the still.

2.2.1.2 Multi effect

The figure 2.4 below show that the schematic diagram of multi effect solar still. Multi effect solar still is designed to improve the maximum dissipated heat. These types of stills have more than one layer of glazing cover over the water surface, thus latent heat of condensation is utilized to increase the thermal efficiency of solar still. A multi effect solar still is more productive than a single effect still. It is because the multi effect solar still uses available energy more than once.

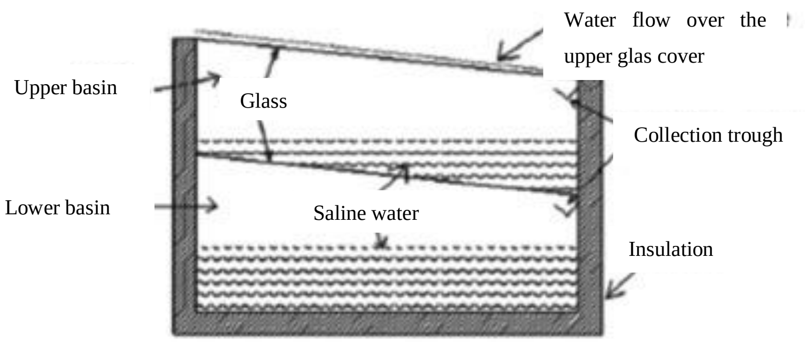

Figure 2.4: A schematic diagram of multi effect solar still (V.S.V. Bapeshwararao, 1983)

Multi-effect stills require twofold the exertion with respect to guaranteeing tight seals, and could be all the more excessively troublesome, making it impossible to clean, however they can raise the creation of freshwater altogether .The way, by which, the water is stored for its time in the liquid phase can also contrast. To achieve the better evaporation rate of water an additional thermal source is provided by an external source. This additional thermal energy source is mostly provided to the bottom most basin of the still as it receives less solar radiation than other upper basins, due to decrease in transitivity by other additional basins.

2.2.1.3 Basin Type Solar Still

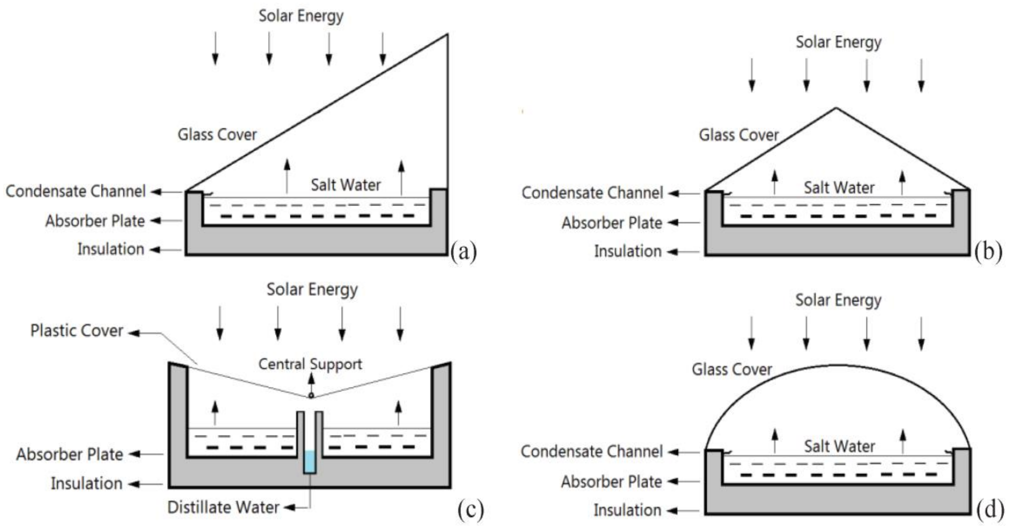

Figure 2.5: (a) single-slope basin still, (b) double-slope basin still, (c) V-type solar still, (d) Hemispherical type solar still (T. AnfasMukram, 2013)

As shown in Figure 2.5, basin type solar stills have been modified into several types according to their cover designs such as single slope, double slope, V-type and hemispherical. The raw water is taken in a basin covered with inclined transparent cover. The water in the basin evaporates due to heating by sun’s radiation. The water then condenses at the lower surface of the transparent cover. Basin and cover temperatures are the main parameters. The production increases with the difference in temperature between basin and water. The working principles of the basin type solar stills are the saline water enters the basin from feed tank. The solar radiation falls on the basin refracting from glass cover reaches the saline water which gets evaporated due to high temperature and condensation takes place at the inclined glass cover. The performance of basin stills depend on few factors such as depth of water, ambient temperature, solar radiation, glass cover inclination, wind speed and dust and cloud cover (Ali. F. Muftah et al., 2014).The productivity can be enhanced by inclining the basin at an angle depending on altitude of the place and season.

2.2.1.4 Wick Still

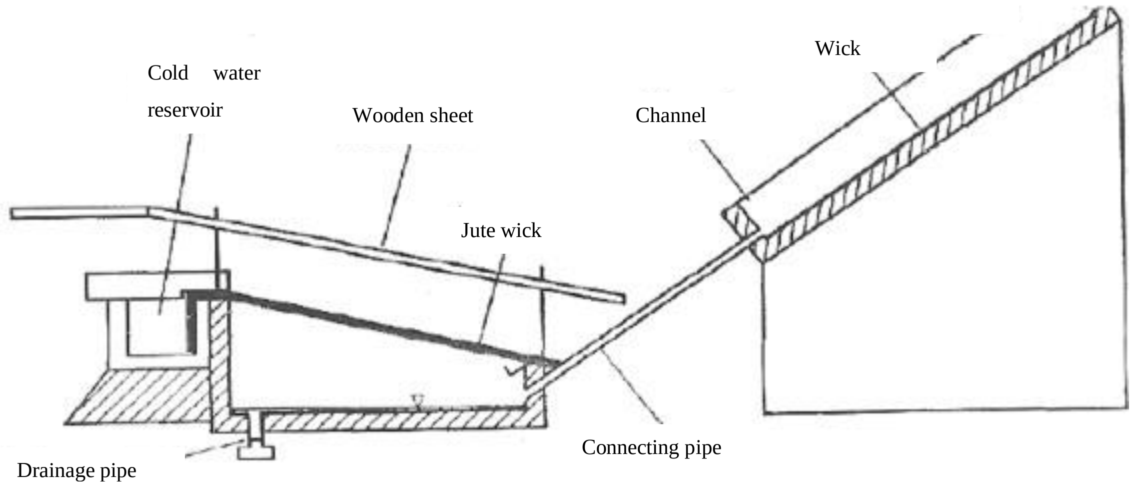

Figure 2.6: Solar distiller with wick

The wick type solar still is a glass-topped box constructed and held at angle to allow sunlight through in (V. Manikandan, 2013). The figure 2.6 was shown the schematic diagram of system. The salt water is poured in from the top. The salt water then heated by sunlight and been evaporated. The salt water condenses and drips to the bottom. There is a pool of brine attached to the wicks which separated the water into banks to increase surface area for heating. The distilled water comes out of the bottom and depending on the quality of construction most of the salt has been purged from water. Use of wick material in the solar still increases residence time of water on the absorber plate due to which the saline water attains higher temperature rapidly and hence rate of evaporation increases. The advantage of the wick is to keep the brine as shallow as possible while avoiding dry spots. Effectiveness of wick material depends on parameter like absorptivity, capillarity and thermal conductivity of wick.

2.2.1.5 Weir type cascade solar still

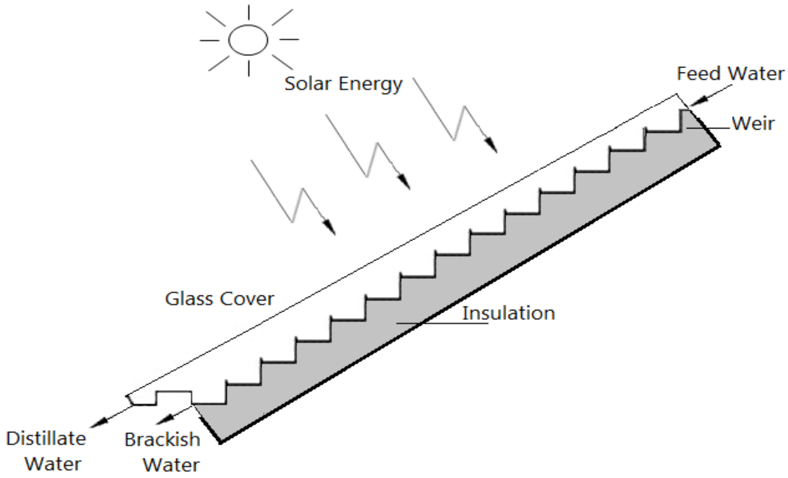

Figure 2.7: Weir type cascade solar still (Sivakumar V, 2013)

Figure 2.7 shows the weir type cascade solar still which is almost similar to the wick type where the solar still is inclined. The advantages of weir-type cascade solar stills is it do not suffer from dry spot or channelization problems since the brine is forced to flow each step one by one without leaving any dry surface on the absorber plate which increases the efficiency. Further research and modifications have been done to these weir-type cascade stills by include wick on each cascaded steps and phase change material (typically paraffin wax) beneath the absorber surface to store energy when it is abundant and give it back to the salt water when it is needed in cloudy days or evening times (Zoori HA, 2013). From Table 2.1, it shows that the productivity of the weir-type still is approximately 20% higher than conventional basin-type solar still. Besides, the average productivity of the still is approximately 5.5 L/m^2 in a day.

Table 2.1: Distillate productivity from the conventional basin- and weir-type (single-pane) stills (S.B. Sadineni et al., 2008)

Day	Distillate productivity (1/m^2/day)	
	Conventional basin-type still	Weir-type still (single-pane)
8 September	4.6	5.5
9 September	5.1	6.3

10 September	4.3	5.2
11 September	4.8	5.6
12 September	4.9	5.8
13 September	4.2	5.0
14 September	3.4	4.1

2.2.1.6 Spherical Solar Still

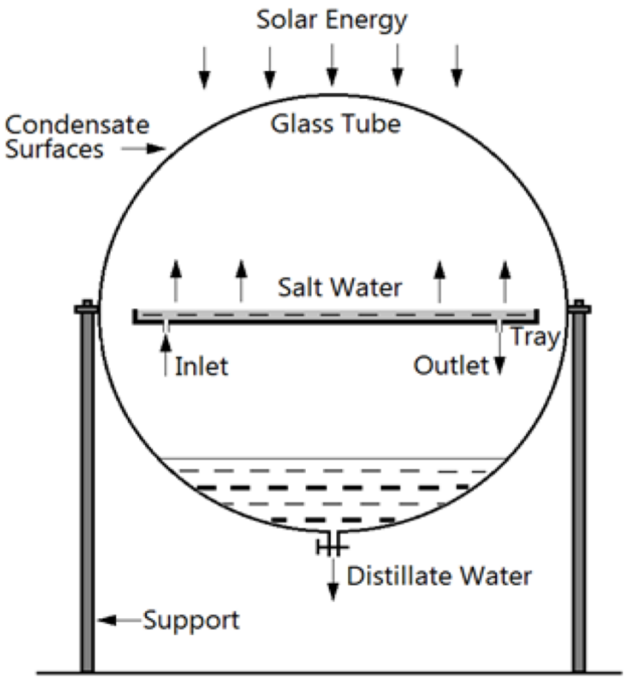

Figure 2.8: Spherical Solar Still (Robert Y. Ning, 2015)

Figure 2.8 represents the simple spherical solar stills which are about 30% more efficient than an equivalent conventional solar still. They have even more condensation area per evaporation surface compared to cylindrical solar stills but it is not scalable as easy as cylindrical ones (Arjunan TV et al., 2009). As an improvement for the productivity, the circular absorber basin can be coated with black paint for maximum absorption of incident solar radiation (T. Arunkumar, K. V., 2012). Moreover, a wiper can be installed to wipe out the water frequently to the distillation container and thus increases the yield. However, this spherical solar still have not been used widely as other solar stills due to the difficulty in fabrication process.

2.2.2 Active Solar Still

Active solar still can increase the productivity of output. Besides that, active solar still also can control the electrical to maximize the effectiveness. But some of the performance of the solar stills cannot be predict such as intensity of solar radiation, ambient temperature and wind velocity. After that, they also have parameters that can be predicted such as depth of water, glass cover angle, fabrication materials, temperature of water in the basin and insulation thickness. Those parameters can be modified to improve the performance of the desalination process (Sampathkumar K. et al., 2010).

2.2.2.1 Double Basin Active Solar Still Coupled with Evacuated Glass Tubes

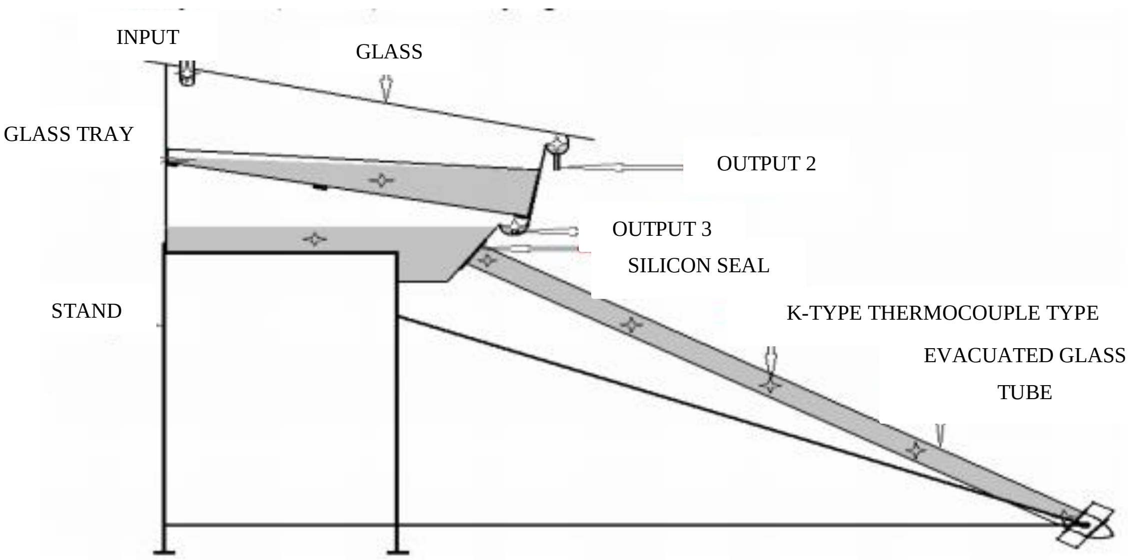

Figure 2.9: Sychmetric diagram of Double basin Solar still coupled with Evacuated glass Tubes (Kolhe, R. D., 2016)

Figure 2.9 shows the solar radiation is transmitted through toughened glass cover to the saline water in the basin. After that, the saline water in basin get heated by sunlight and evaporation occur. Thus, Evaporated water particles condense on the inner side of the glass cover. Then, the condensed water flows down the cover due to slope and reaches the distillate channel, where it collected by the storage. Lastly, to increase distillate output of a solar still, black granite gravel is used inside the inner and outer basins of a solar still to reduce the quantity of water. The black granite gravel functions as energy storage medium and also as an insulation layer to reduce the bottom and side loss coefficients and the black gravel also used for absorbing the excess heat energy from solar radiation during the noon hours (M. Sakthivel, S. S., 2008).

2.2.2.2 Parabolic Trough Collector

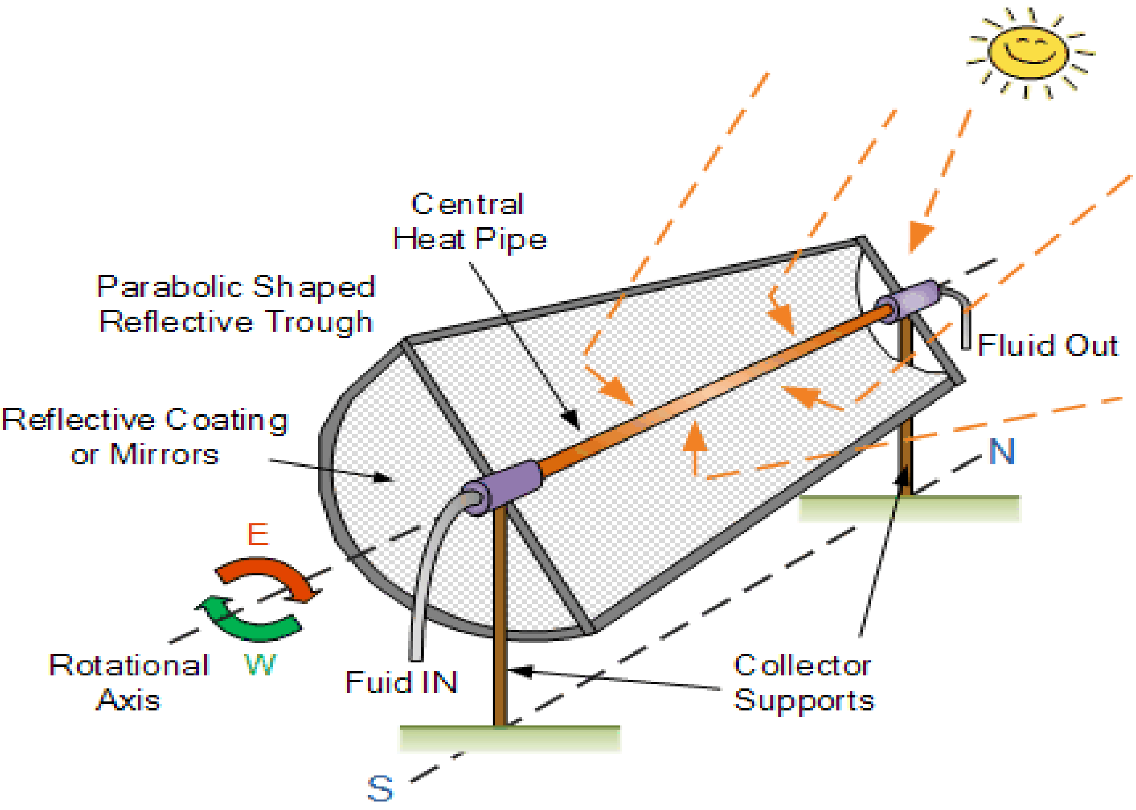

Figure 2.10: Diagram Parabolic Trough Collector (Parabolic Trough Reflector, April 2017)

Figure 2.10 shows the parabolic trough collector operation begins with filling the saline water in tank. After that, the saline water will flowing down into the level control box. Then, the water flow to the absorber until it reaches the desired level of water. The glass cover permits solar radiation to pass through and totally reflected to the absorber. So, the absorber which is contained saline water being heated by the direct sunlight and reflected rays. Besides that, to get a reflected sunray, we can use the solar tracking system to detect the position of sunlight such as shown in figure 2.11 above. The glass cover traps the solar energy inside it and reduces the convective heat losses. Lastly, the glass cover is inclined to facilitate water vapour which condenses on interior surface to flow into the water storage.

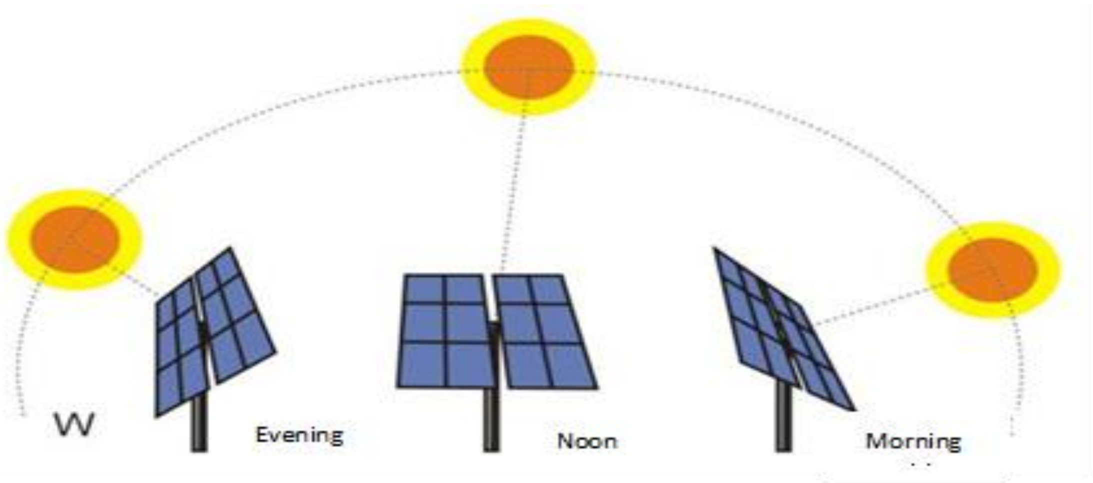

Figure 2.11: Diagram show the Solar Tracking (Loeffler, M., 2016)

2.2.2.3 Point-Focus Parabolic Solar Still

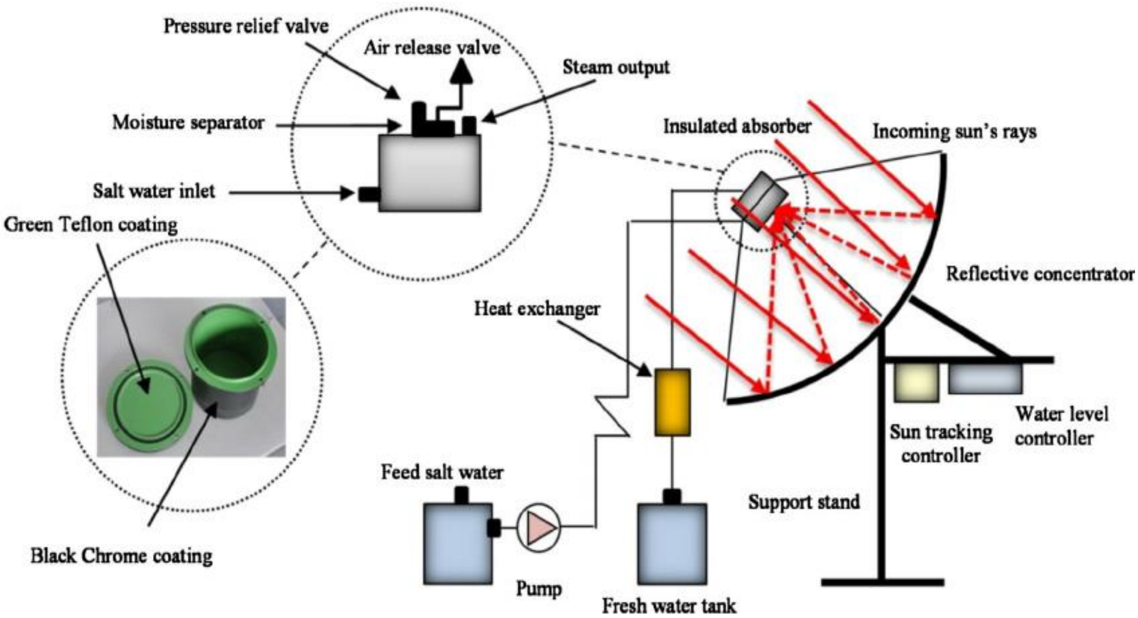

Figure 2.12: Diagram Point-Focus Parabolic Solar Still (Shiva Gorjian, B. G., 2014)

The figure 2.12 shows that how to design and construct the point-focus parabolic solar still. The development of point-focus parabolic solar still consists of parabolic dish concentrator, two axis solar tracking, absorber, two plate heat exchange. In the first operation cycle of the developed solar still, the parabolic dish will follow the incoming solar insolation to the bottom side of the absorber which is locate at the focal point. The saline water is vaporized inside the absorber because get heated by directed sunlight and reflection rays. The generated steam flows up and condenses in the plate heat exchanger, where it gives out the evaporation latent heat to the working fluid. Then the cold water would give the heat gained from the steam to the saline water in the other plate heat exchanger to increase its temperature before entering the absorber. This process will continues until the level of saline water in the absorber reaches the determined minimum level. Thereby, the brine in the absorber is discharged by opening an electric drain valve attached to the exit vent of the absorber. It takes about 20 s to completely drain the brine and pump the brackish water again into the absorber (Shiva Gorjian, B. G., 2014).

2.3 COMPARISON OF PRODUCTIVITY FOR DIFFERENT TYPES OF SOLAR STILLS

Table 2.2 shows the comparison of productivity for different types of solar still which are single effect, multi effect, basin type solar still, wick still, weir type cascade solar still, spherical solar still, double basin still coupled with evacuated glass tubes, parabolic through collector and point-focus parabolic solar still.

Table 2.2: Comparison of productivity for solar still

Type of Solar Still	**Capacity (L/m²/day)**	**Reference**
Single Effect Still	NA	Al-Hayeka 2014
Multi Effect	NA	T Blanco, J., &Alarcon, D., 2007
Basin Type Solar Still	2.00	Zaki et al., 1993
Wick Still	4.2	Kassem, 2016
Weir Type Cascade Solar Still	3.85	Sadineni et al., 2006
Spherical Solar Still	2.3	Arunkumar et al., 2012

Double Basin Still Coupled with Evacuated Glass Tubes	5.181	Tiris, 1998
Parabolic Trough Collector	NA	Harlima Derbal, 2011
Point-focus Parabolic Solar Still	3.56	Arunkumar et al., 2013

2.4 LIMITATIONS OF SOLAR DESALINATION

Desalination facilities may curtail the dependence of local water agencies on climate sensitive sources of supply. However, desalination proposals should evaluate the long-term climatic risks and benefits. A major concern that should be considered while increasing productivity is to maintain economic feasibility and simplicity. The system components and hardware used to enhance productivity are still expensive often impeding commercialization. Even though solar energy is free, the equipment required for capturing, converting it to useful forms and storing it can be expensive. Another limitation of desalination is that it may introduce biological or chemical contaminants into water supply (Heather Cooley et al., 2016). Hence, initiatives should be implement to filter and separate chemical containments such as oil from the saline water in order to produce quality potable water.

In conclusion, solar desalination is already a vitally important option as it is renewable source and eco-friendly. The current project is intended to design and fabricate a line focus concentrator for solar desalination of brackish water and purification of non-potable water. The reason for choosing line focus concentrator among others is because it can produce higher yield with lower cost of installation. Even though passive solar stills are cheaper and have lower cost, the productivity is no very significant compare to line focus concentrator. However, to have a better productivity, the need for strong and direct sunlight is essential and it is fragile in nature. Improvements can be done in the material selection by selecting non-fragile and long-lasting material.

2.5 SOLAR GEOMETRY

Solar Geometry describes the relationship between the sun and earth. Besides that, the earth orbits the sun in an approximate circle which is radius 150 000 000 km with the sun at its center. The orbit of earth about the sun is almost circular at an average distance of 149.6 million km. The earth's axis of rotation is tilted by an angle ε = 23.441° with respect to the normal to the plane of the earths orbit (Mitton, S., 1977)

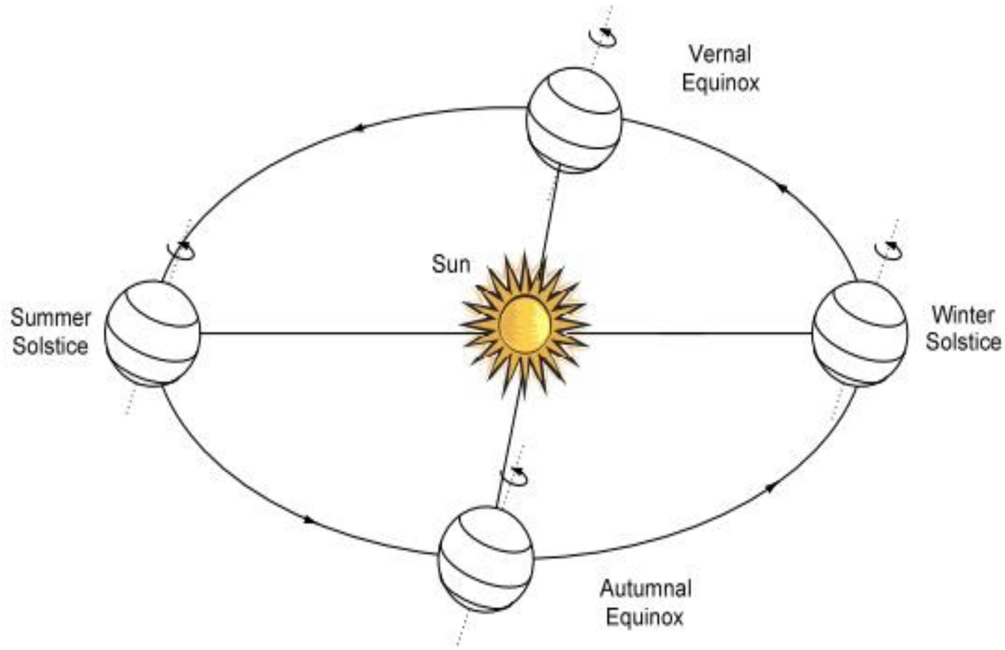

Figure 2.13: Rotation of the earth around its axis and its elliptical orbit around the sun

The figure 2.13 shows that the rotation of the earth around its axis and its elliptical orbit around the sun.The plane of the earth's revolution is called the ecliptic and includes the sun. Besides, ecliptic can be defined as the apparent path of the sun's motion on the celestial sphere as seen from earth. The full revolution takes 365.24 days which is 365 days 5 h 48m 46s to be precise and as the calendar year is 365 days. An adjustment is necessary that one extra day every four years and it called the 'leap year'. This would mean 0.25 days per year, which is too much. The excess 0.01 day a year is compensated by a one day adjustment per century (Szokolay, S. V., 2007).

2.6 SOLAR ANGLES

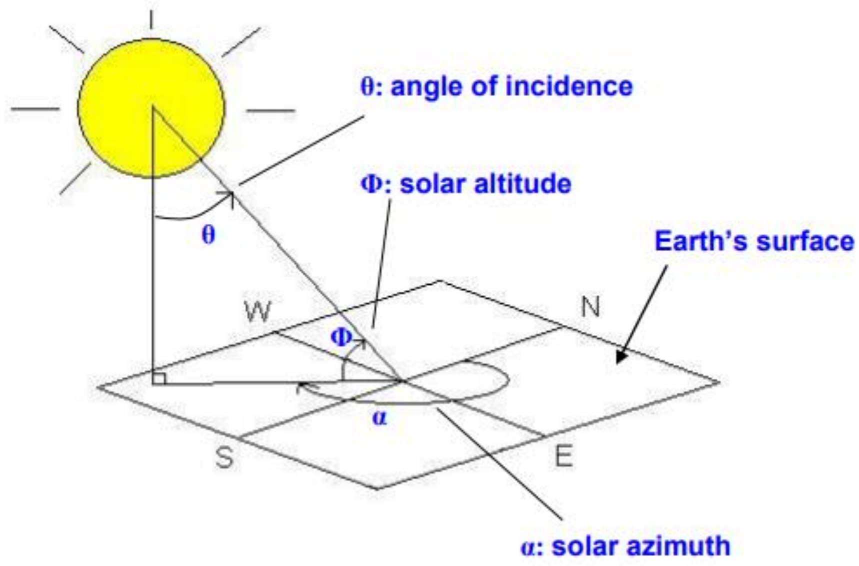

Figure 2.14: Solar geometry diagram

Based on figure 2.14, the angles of solar divide by three angle which are angle of incidence, solar altitude and solar azimuth and zenith.

2.6.1 Angles of Incidence, θ

The declination point, indicated by δ, changes regularly because of the tilt of the Earth on its axis of rotation and the turn of the Earth around the sun. In the event that the Earth were not tilted on its axis of rotation, the declination would dependably be 0°. Be that as it may, the Earth is tilted by 23.45° and the declination edge differs give or take this sum. Just at the spring and fall equinoxes is the declination edge equivalent to 0°. Declination is calculated with the following formula:

$$d = 23.45 * \sin[\frac{360}{365*(284+N)}] \quad [2.1]$$

From the formula above, d is declination and N is the number of day. For example, 1 January is one day.

The figure 2.15 below show the tilt angle changes and the rotation of the Earth around the sun and the change in the declination angle.

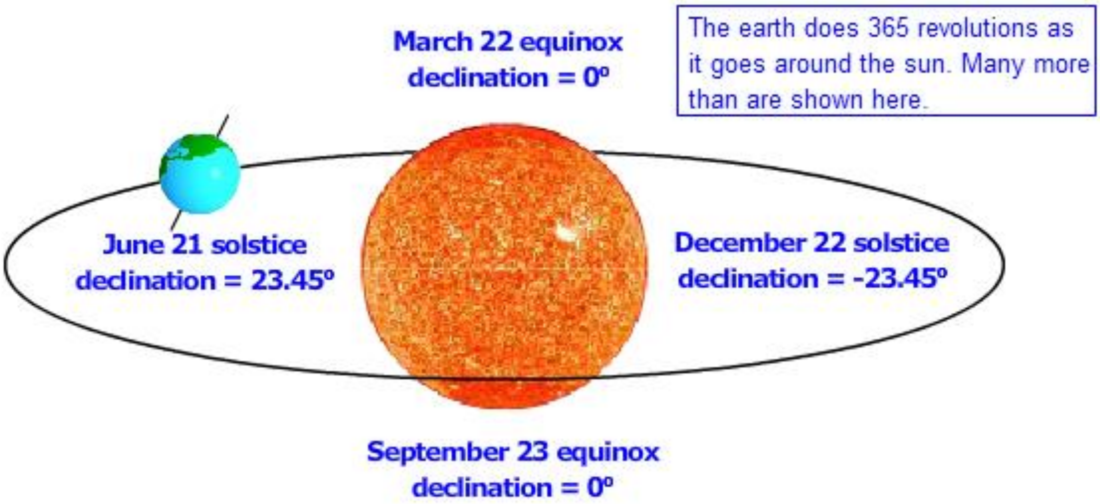

Figure 2.15: Figure show that how the tilt angle changes from the summer solstice in the northern hemisphere (or winter in the southern hemisphere) to the northern hemisphere winter solstice (summer in the south) (P. I. Cooper, 1969).

2.6.2 Solar Altitude, Φ

Solar altitude refers to the angle of the sun in respect to the Earth's horizon. Solar altitude is measured in degrees. The value of the solar altitude varies based on the time of day, the time of year and the latitude on Earth. Regions close to the equator have a higher solar altitude than regions close to the Earth's poles (Murmson, S., 2017). The altitude angle is calculated as follows:

$$\sin(Al) = [\cos(L) * \cos(D) * \cos(H)] + [\sin(L) * \sin(D)] \qquad [2.2]$$

From the formula 2.2, Al means the solar altitude angle and L represent the Latitude (negative for Southern Hemisphere). Next, D is for declination (negative for Southern Hemisphere) while H represent the Hour angle.

2.6.3 Solar Azimuth, α and Zenith, θz

The figure 2.16 show the measurements of zenith and azimuth are firmly identified to the measurement of solar altitude. The solar zenith angle of the sun is in respect to the zenith, or straightforwardly overhead. This is the complement to solar altitude. Thus, if the solar altitude is 46 degrees, the solar zenith angle will be 44 degrees. Besides that, Azimuth measures the sun's angle with respect to north, in the eastward direction. On the off chance that the sun is expected north in the sky, the azimuth will be zero. In the event that the sun is expected east in the sky, the azimuth edge will be 90 degrees. Solar altitude, zenith and azimuth all change for the duration of the day and year (Murmson, S., 2017).

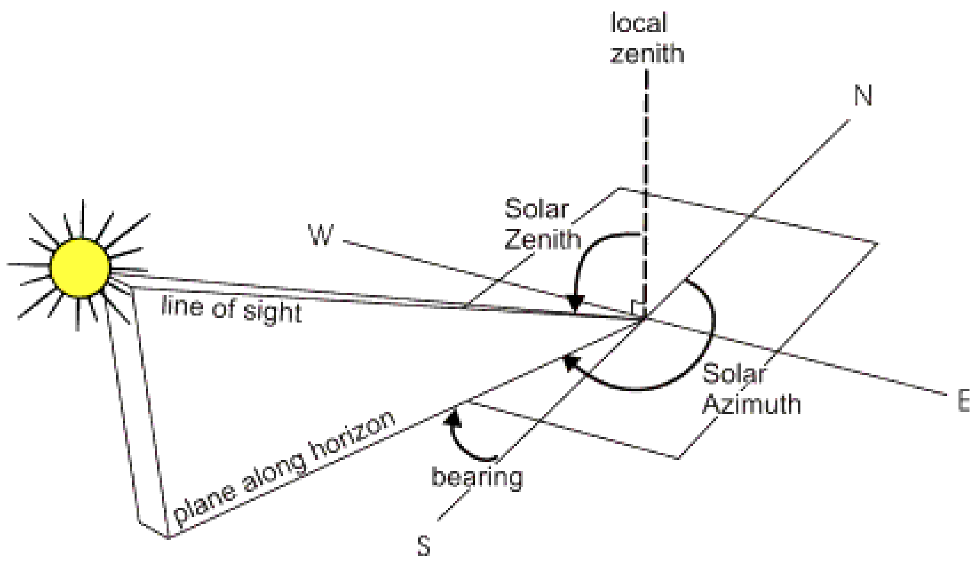

Figure 2.16: Figure show that the angle between Solar Zenith and Solar Azimuth.

2.7 TYPES OF SOLAR TRACKER

There are many types of solar tracker which are passive solar tracker, active solar tracker. Besides that, the active solar tracker divide by two types which are single-axis solar tracker and dual-axis solar tracker. The function of solar tracker is to change their orientation throughout the day to follow the sun’s path to maximize energy capture.

2.7.1 Passive Solar Tracker

Passive trackers utilize a low breaking point packed gas liquid that is headed to the other side or the other the other (by sun powered warmth making gas weight) to make the tracker move in response to an imbalance. As this is a non-precision orientation it is unsuitable for certain types of concentrating photovoltaic collectors, yet works fine for regular PV panel types (Shah, A., 2011).

2.7.2 Active Solar Tracker

Active trackers use motors and rigging trains to coordinate the tracker as instructed by a controller, reacting to the sunlight based heading. Since the motor expend vitality, one needs to utilize them just as vital.

2.7.2.1 Single-Axis Solar Tracker

Single axis trackers have one degree of freedom that acts as an axis of rotation. The axis of rotation of single axis trackers is regularly adjusted along a true North meridian. It is conceivable to adjust them in any cardinal direction with advanced tracking algorithms. There are several common implementations of single axis trackers. These include horizontal single axis trackers (HSAT), vertical single axis trackers (VSAT), tilted single axis trackers (TSAT) and polar aligned single axis trackers (PSAT) (Shah, A., 2011). The figure 2.17, show the movement of single axis solar tracker.

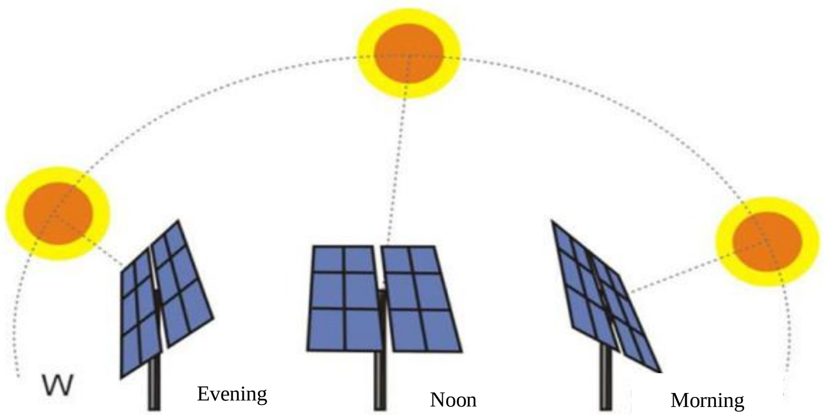

Figure 2.17: Diagram show the Single-Axis Solar Tracking (Loeffler, M., 2016)

2.7.2.2 Dual-Axis Solar Tracker

The second type of active solar tracker is dual-axis solar tracking. By using this method will gain greater power output than a single-axis solar tracker. Besides that, dual-axis solar tracker have their own disadvantages which are more costly and most complicated to design. Dual axis solar trackers have both a horizontal and a vertical axis. Hence, they can track the sun's apparent motion virtually anywhere in the sky no matter where it is positioned on earth as shown in figure 2.18.

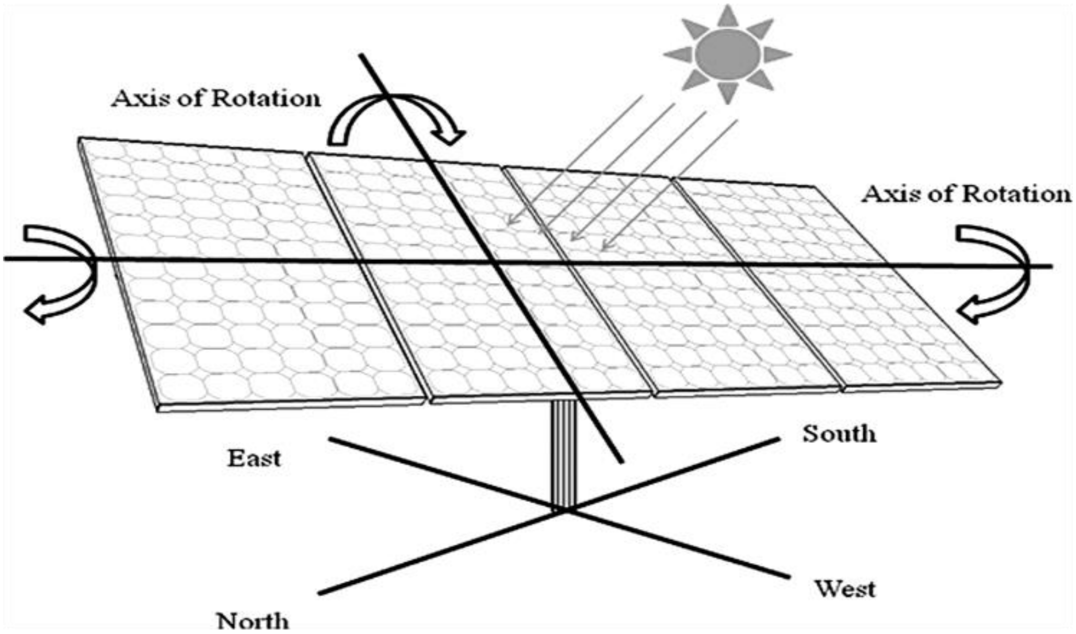

Figure 2.18: Diagram show the Dual-Axis Solar Tracking

CHAPTER 3

METHODOLOGY

3.1 PROTOTYPE DESIGN

The design of the parabolic solar trough collector was shown in Figure 3.1 with labels for every part of the parabolic solar trough collector and the dimensions for every material were shown in Table 3.1.

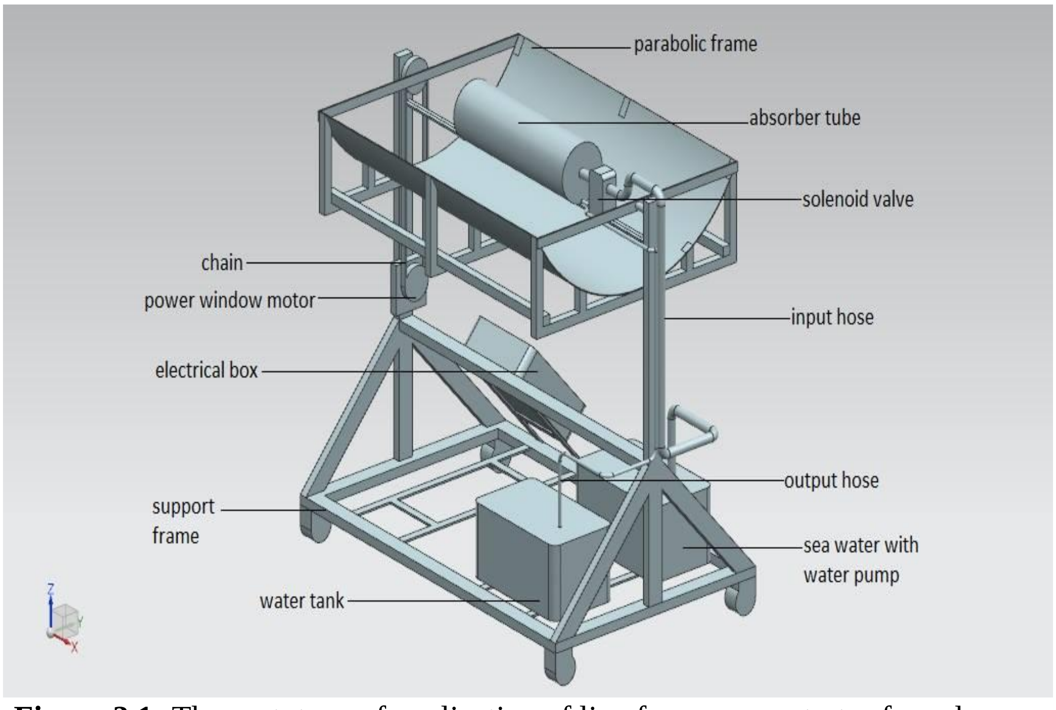

Figure 3.1: The prototype of application of line focus concentrator for solar desalination process

Table 3.1: The dimensions of the materials for application of line focus concentrator for solar desalination process

Parameter	Value
Height of the support stand due	1.0m
Distance between the two stands	1.0m
Width of the stand	0.6m
Thickness of the stand	0.02m
Length of the support frame	0.9m
Breadth of the support frame	0.9mx1.0m = 0.9m
Thickness of the support frame	0.02m
Inner diameter of the pipe	0.21m
Outer diameter of the pipe	0.25m
Length of the pipe	0.8m
Length of the parabolic solar trough collector	0.4m
Breadth of the parabolic solar trough collector	17.34m
Thickness of the parabolic solar trough collector	0.05m
Water pump power	30W
Power Window Motor	12V
Water tank capacity	10L

3.2 SET UP THE APPLICATION

The setup of the application of line focus concentrator for solar desalination process was shown in the figure 3.2 through 3.11 as following.

The figure 3.2 show the condition of parabolic. The aluminium is attached on zink plate to make the reflection more efficient.

Figure 3.2: The parabolic solar trough collector which covered with the aluminum sheet

The figure 3.3 show the support frame of the application of line focus concentrator for solar desalination process. We used rectangular hole steel to make the support frame to reduce the weight of system.

Figure 3.3: The frame support of the application of line focus concentrator for solar desalination process

The figure 3.4 show the installation of light dependent resistor on the corner of parabolic trough collector.

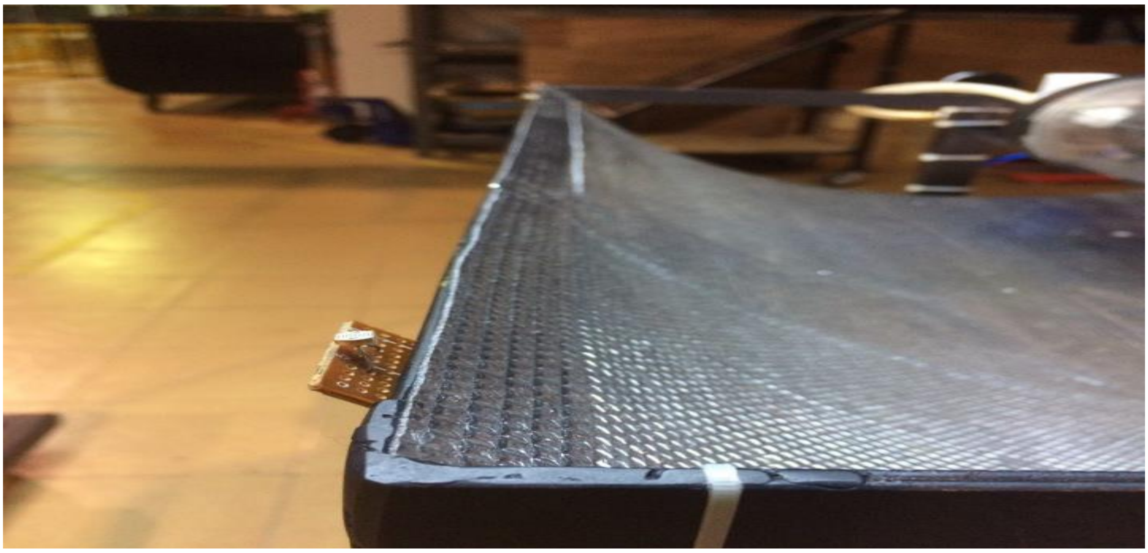

Figure 3.4: The light dependent resistors were installed on the surface of the application of line focus concentrator for solar desalination process

The figure 3.5 show the fabrication of absorber tube. The black steel in the glass is the bottle flask. Besides that, the ultrasonic sensor also install in the glass for detect the water level flow in absorber tube.

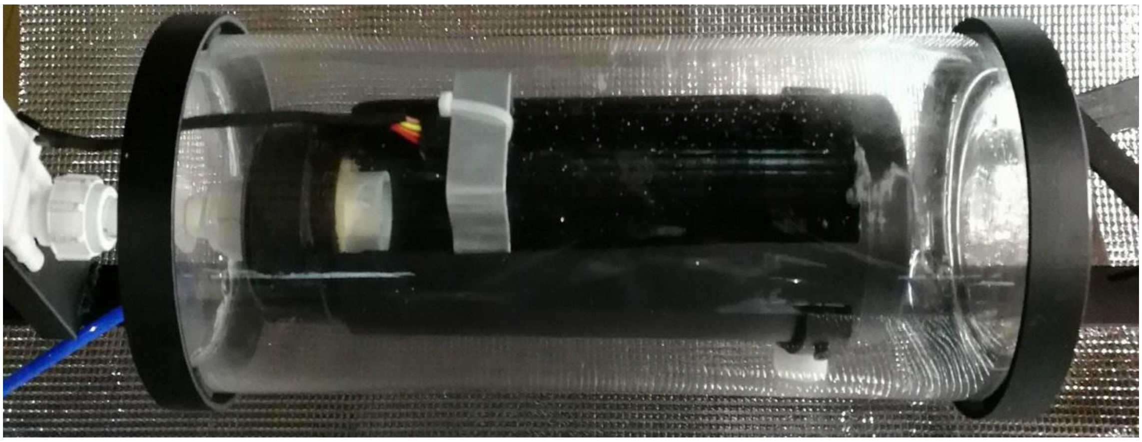

Figure 3.5: The absorber tube of the application of line focus concentrator for solar desalination process

The figure 3.6 is show the water pump immersed inside the seawater tank and connected to the inlet of the stainless steel.

Figure 3.6: Water pump was immersed inside the seawater tank and connected to the inlet of the stainless steel

The figure 3.7 show the motor chain of the application of line focus concentrator for solar desalination process. In this system, we used power window motor to drive the parabolic trough collector.

Figure 3.7: The motor chain of the application of line focus concentrator for solar desalination process

The figure 3.8 below show that how the ultrasonic sensor was installed in the absorber tube.

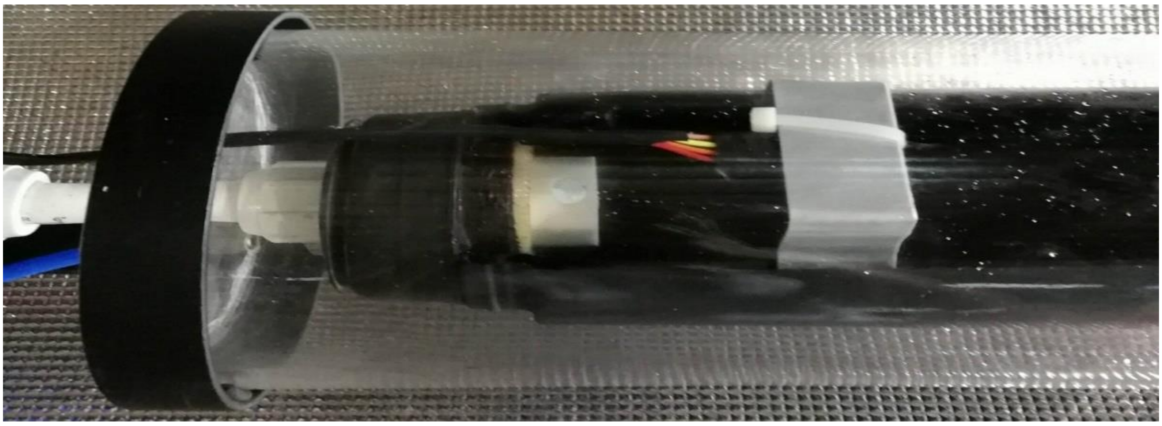

Figure 3.8: The sensor to estimate the seawater level in the absorber tube

The figure 3.9 show the solenoid was installed beside the glass to cut the water from flow into absorber when the water reached at the maximum point.

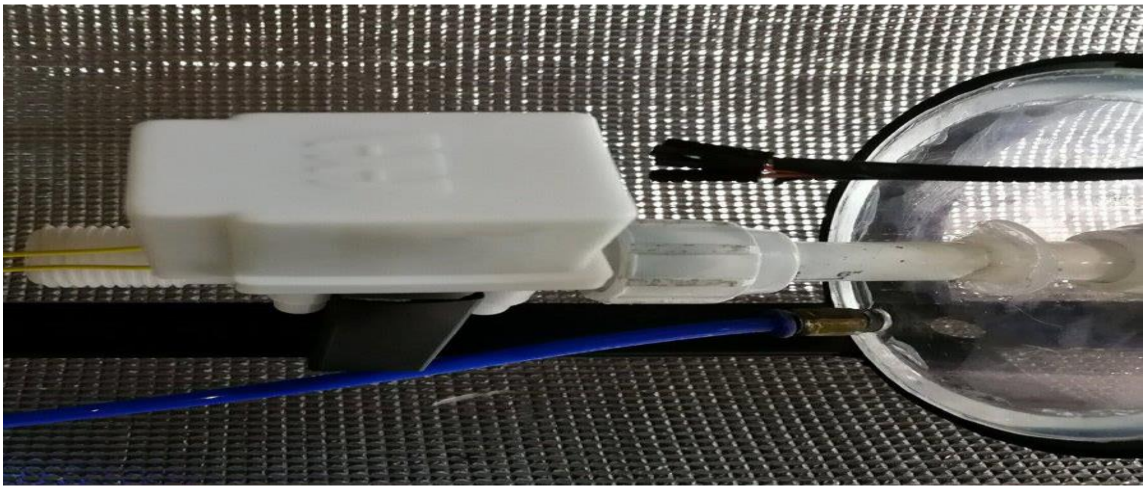

Figure 3.9: The solenoid valve to control the flow of water into absorber tube

The figure 3.10 show the installation of limit switch. The function of limit switch is to stop the parabolic frame from rotating. When the parabolic frame touched the limit swtich the motor will automatically stop.

Figure 3.10: The limit switch apply at the system to stop the rotation of motor from moving

The figure 3.11 show the complete fabrication of solar desalination process and their support system which are solar tracking system anf measuring level water from flow into absorber tube.

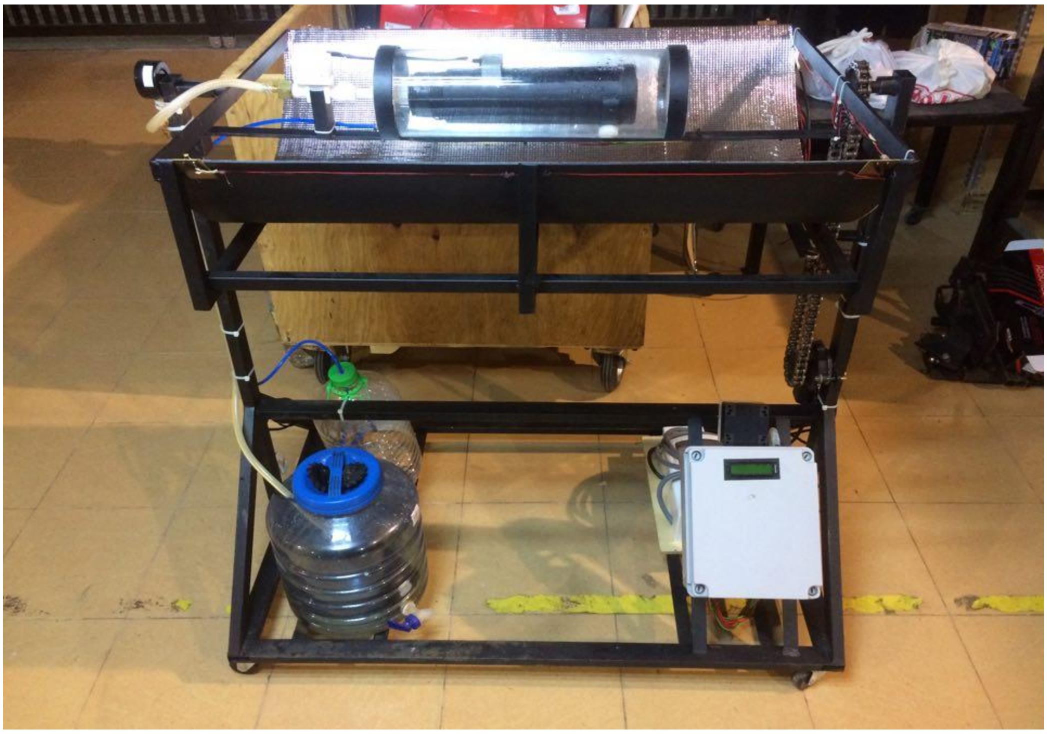

Figure 3.11: Final application of line focus concentrator for solar desalination process assembly

3.3 MODIFICATION OF THE APPLICATION OF LINE FOCUS CONCENTRATOR FOR SOLAR DESALINATION PROCESS

We had modified the design of the parabolic solar trough collector before we entered the workshop to do the fabrication of the prototype. Previously, the length of the supporting system is estimated to be 1m. However, we planned and changed the length of the supporting system to 0.5m as it seems more convenient and easier to modify. Besides, the modification of the length was for the purpose of easier installation of other materials and components such as absorber tube.

Besides, we also not decided to order the handmade absorber tube online as the price of one unit of absorber tube ordered online from Alibaba cost RM 1000. The price is too expensive and we lack of budget. We planned not to order online as the inner and outer diameter of the absorber tube online did not meet the prototype's specifications. If we bought the absorber tube, we need to change all the prototype dimensions and the calculation of the focal point. Thus, we discussed and chose to do a handmade absorber tube.

The vacuum flask and the tempered glass were important materials to fabricate into the absorber tube. The two tempered glass we bought from Giant Supermarket as outer of the absorber tube. The length of the tempered glass was 0.4m. The thickness of the tempered glass is 0.01m, 0.10m of inner diameter and 0.12m of outer diameter. The vacuum flask we got from senior's last time prototype as this could reduce the overall budget. The length of the absorber tube previously is 1.1m but we changed the length into 0.3m. The main reasons we changed the length of the absorber tube was for easy fabrication and welding. It would not take much of the time and make sure we could finish the prototype in time.

The pulley of the parabolic solar trough collector was been changed into the motor chain. The motor chain was from the motorcycle of one of our team members. Our team member used the recycled motor chain as the motor chain will not produce unnecessary noises. Besides, the motor chain reduced the friction losses as the motor chain had more contact area. The motor chain decreased energy loss through vibration. The motor chain can be changed easier and the structure was simpler.

3.4 DIFFICULTIES THAT FACED DURING THE PROTOTYPE FABRICATION AND TESTING PROCESS

Project management involves coordinating various aspects of a project in order to bring forth a positive result. This coordination can include elements such as personnel, materials, procedures and facilities. During fabrication of the parabolic solar trough collector, we faced some problem on materials. The main problem that we faced is how to design the homemade absorber tube which is 1m long. Previously, we discussed among us to buy the readymade absorber tube but we did not get it because it was expensive which cost RM1000. So, we agreed to make the absorber tube. The problem that we faced was we cannot cut the glass into the dimension that we want. After that, we tried to solve this problem by asking the mirror shop to cut the glass but they also cannot cut the cylinder glass according to the dimensions stated. Lastly, we make the brainstorming how to solve the problem and we agreed to modify the size of the support system. By changing the size of the support system, we did not need to cut the glass.

Besides that, we also faced the problem of the time management. During the fabrication we got a problem to meet up among us because our schedule not same. So, there is difficulty for us to meet up together to do the fabrication of prototype together. This is a great challenge for us since time management is quite precious. To overcome this problem, we asked the permission from the lab instructor to enter the lab at night to finish our prototype. With this solution, we can finish our prototype on time. After that, the problem we face is the component and the material that we ordered did not arrive in time which were important in the fabrication. So, to counter this problem, we buy the two tempered glasses by our own at the shop. However, the materials will be more expensive because we bought in small quantity.

Next, the problem that we facing during fabrication is we do not know how to operate the certain machine and equipment. But, we are lucky because the instructor gave us assistance and watched us when we used certain machine and equipment. After that, the problem that we faced during the fabrication was handling the material. During the fabrication, the main part of the prototype, absorber tube was broken down. This is because the tempered glass that we bought was fragile. We did not know that the middle diameter of the glass very thin because the front of the glass seems very thick. So, we assumed the thickness of the glass same but vice versa. When we wanted to make a hole at glass, the middle of the glass was broken down. Then, to solve the problem we make the hole at the lit of the glass because we use acrylic glass for the lit. Thus, this can prevent the glass from broken.

Lastly, the electrical part also got the problem during construct the circuit. During the fabrication the circuit, there was shock circuit and two of Arduino got burn. So, we need to troubleshoot the circuit to indentify the problem that we face. Besides that, the LCD that we used to display the analog value of LDR also got problem. The Value of LCD will disturb when the motor running. This is because the motor that we used was consumed a lot of current that can disturb the current flow into LCD. So, to overcome the problem, we separate the source of LCD and Motor.

3.5 MATERIALS

3.5.1 Light Dependent Resistor

Light dependent resistor is a light-controlled variable resistor. It also called photoresistor or photocell. A light dependent resistor is made of a high resistance semiconductor. It also a component that has a variable resistance that can changes according the light intensity that falls upon it. So, it can be used in light sensing circuits. Because of that, we can use LDR or photocell in our project to trek the sunlight. This LDR will be fixed on the parabolic through collector in order to detect where the sunlight will fall on. This will make the parabolic through collector moves according to the position of sunlight and increases the efficiency of the parabolic through collector. The figure 3.12 show the graph of light intensity versus resistance while figure 3.13 show the symbol of LDR.

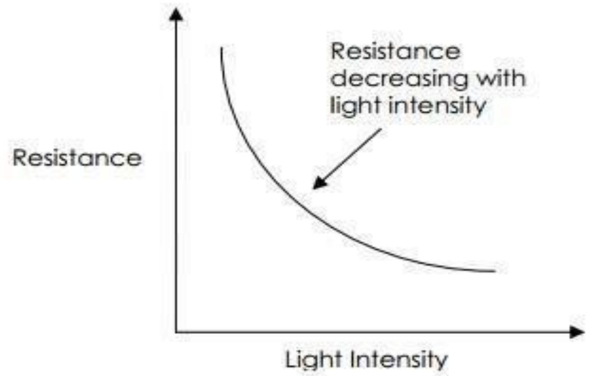

Figure 3.12: Resistance vs light intensity graph

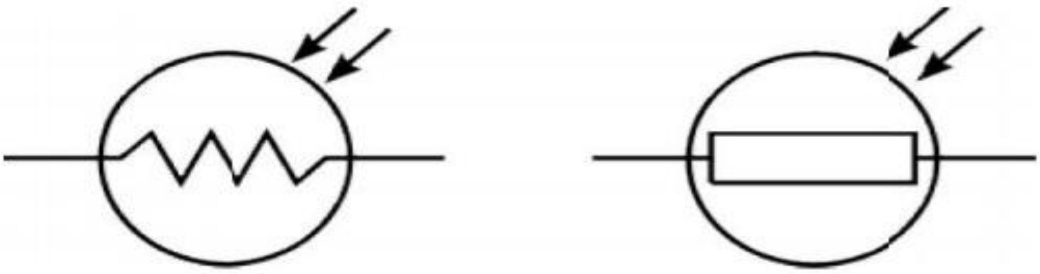

Figure 3.13: Symbol of Photoresistor

3.5.2 Power Window Motor

Stepper motors are DC motors that move in discrete steps. Besides that, they also have multiple coils that can organize in a groups and called as phases. Then, the motor will rotate one step at a time because of energizing each phase in sequence. Stepper motors also electromagnetic device that converts digital pulses into mechanical shaft rotation. With a computer controlled stepping, we can achieve very precise positioning and speed control. For this reason, we will fixed the stepper motor to rotate the shaft. So, the parabolic through collector can move according the movement of sunlight. The figure 3.14 show the picture of power window motor while the table 3.2 show the specifications of power window motor.

Figure 3.14: Picture of Power Window Motor

Table 3.2: The specifications of the power window motor

Specification	Details
Voltage Rating	12VDC
Speed (No Load)	~ 85RPM
Current (No Load)	<3A
Current (Load)	<7A
Current (Lock)	~20A at 12V
Torque	30Kg.cm

3.5.3 Absorber tube

The absorber tube was located and mounted at the focal point of the application of line focus concentrator for solar desalination process with the support of two holders from the base frame. The absorber tube was made up from high grade vacuum flask with length of 0.4m. The high grade vacuum flask is selected as the inner tube while the tempered glass is selected as the outer tube. The high grade vacuum flask is been selected as it is an insulating storage vessel that greatly lengthens the time over which its contents remain hotter or cooler than the flask's surrounding. The vacuum flask consists of two flasks, placed one within the other and joined at the neck. The gap between the two flasks is partially evacuated of air, creating a near vacuum with significantly reduces heat transfer by conduction or convection.

The upper surface of the vacuum flask with 0.22m in long and 0.45m in diameter was cut off horizontally as shown in the Figure to allow the solar radiation exposure into the vacuum flask and increase the area of the vacuum flask in absorption of the sunlight. The higher the absorption of the sunlight, the faster the heating process of the seawater. The vacuum flask is painted black as black is the colour that absorbs the most heat among all the colors in the spectrum. The black colour absorbs all wavelengths of light and reflects none of them. Thus, the black vacuum flask will get hotter faster and cause the seawater easily heated up. The easily heated up seawater will increase the rate of evaporation and increase the yield of the desalinated water.

The tempered glass is selected as the outer diameter of the receiver tube as it is physically and thermally stronger than normal glass. The measurements of the tempered glass are given: 0.01 m of thickness, 0.10 m of inner diameter and 0.12 m of outer diameter of tempered glass, 0.4 m in length. The tempered glass is situated at the focal point of the parabolic solar trough collector. The parabolic trough solar collector uses aluminum sheet in the shape of a parabolic cylinder to reflect and concentrate sun radiations towards the receiver tube located at the focus line of the parabolic cylinder. The tempered glass will receive the sun radiations will reflect the sun radiation to the vacuum flask. Thus, high reflectivity of the tempered glass will increase the high efficiency of the application of line focus concentrator for solar desalination process and decrease the time taken that required by seawater in undergoing heat and evaporation process. The figure 3.15 show the installation of absorber tube.

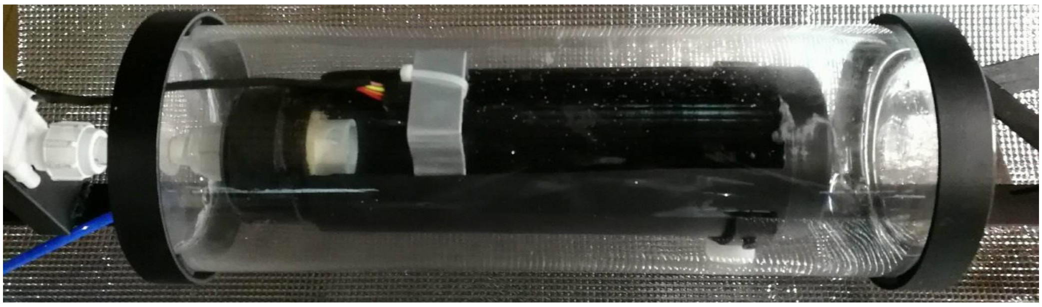

Figure 3.15: The Absorber Tube

3.5.4 Steam Hose Pipe

Steam hose pipe can be used for piping system. It is used for inlet and outlet flow of water. Steam hose pipe can reduce corrosion of pipe as it is resistant of salt water. The price of steam hose pipe is cheaper than aluminum pipe. It also will be used to flow the freshwater into fresh water tank. Steam hose pipe is selected as it is high resistant of steam.

3.5.5 Aluminum Sheet

The figure 3.16 show the how the aluminium sheet was installed on zink of parabolic frame. Aluminum sheet is selected as the reflector of the solar trough collector. The reflector is very important as it decides the fraction of the solar irradiance to be collector by the absorber tube. A parabolic reflector reflects and concentrates all the sun ray on the absorber tube. The reflector is a parabolic shaped galvanized aluminium sheet with a reflectivity of 86% at clean surface (Avadhesh Yadav, 2013)

The aluminium sheet is been selected as reflector because it has the highest reflectivity if compared with other materials. For aluminium sheet maximum temperature is 52.3 ^{o}C is 24.22% more than steel sheet as the reflector and 8.5% more than aluminium foil as reflector (Avadhesh Yadav, 2013). The efficiency by using the aluminium sheet as reflector compared to steel sheet is 61.18% more. Efficiency by using aluminium sheet as reflector compared to aluminium foil as reflector is 18.98% more.

Figure 3.16: The aluminium sheet of parabolic solar trough collector

3.5.6 Water Pump

The figure 3.17 show the picture of water pump that used in prototype for pump the water into absorber tube. A 30 W of the Aquarium Submersible Water pump is used in the application of line focus concentrator for solar desalination process as illustrated in the Figure 3.6. The aquarium submersible water pump is a pump that can be fully submerged in the water. The motor is hermitically sealed and close-coupled to the body of the pump.

The function of the aquarium submersible water pump is to push water to the surface by converting rotary energy into kinetic energy into pressure energy. (How Submersible Pumps Work: Advantages and Disadvantages of Submersible Pump, n.d.). Firstly, the water is been pulled into the pump. First in the intake, where the rotation of the impeller pushes the water through the diffuser .From there, it goes to the surface.

The advantage of the aquarium submersible water pump is the pump does not spend a lot of energy to move water into the pump. Water pressure pushes the water into the submersible pump, thus saving a lot of energy of the pump. Besides, the submersible pump does not produce noise as there is no ‘spike’ in pressure as the water flows through the pump.

Figure 3.17: The Aquarium Submersible Water Pump JIX- 850

3.5.7 Supporting system

The supporting system is made from stainless steel as stainless steel got corrosion resistance. The stainless steel can resist corrosion in atmospheric conditions and can resist corrosions in most acids, alkalis solutions, and chloride bearing solutions at elevated temperatures and pressures (Benefits of Stainless Steel, n.d.) .

The stainless steel been selected as ease of fabrication. The stainless steels can be cut, welded, formed, machined and fabricated easily. Besides, the stainless steel provides the aesthetic appeal. The stainless steels are available in many surface finishes. It is easily and simply maintained resulting in a high quality and pleasing appearance. The stainless steel been chosen if compared to other materials because of life cycle comparison. It is a durable and low maintenance material and least expensive if compared to other materials. The figure 3.18 show the support frame of application of line focus concentrator for solar desalination process.

Figure 3.18: The support frame of application of line focus concentrator for solar desalination process.

3.5.8 Single axis sun tracking system

Single axis solar trackers can either have a horizontal or a vertical axis. The horizontal type is used in tropical regions where the sun gets very high at noon, but the days are short. The vertical type is used in high latitudes such as United Kingdom where the sun does not get very high, but summer days can be very long (harshi1990, 2013). The device is used to orient the solar trough collector to the sun. The single axis sun tracking system is used to move the solar trough collector towards the direction of the sun. The sun trackers can increase the amount of irradiation received by the solar trough collector. The more sunlight been absorbed, the more the output of heat produced. However, the sun tracker can only move either vertically or horizontally. Thus the primary benefit of a tracking system is to collect solar energy for the longest period of the day, and with the most accurate alignment as the Sun's position shifts with the seasons. The figure 3.19 show the example of solar tracking system.

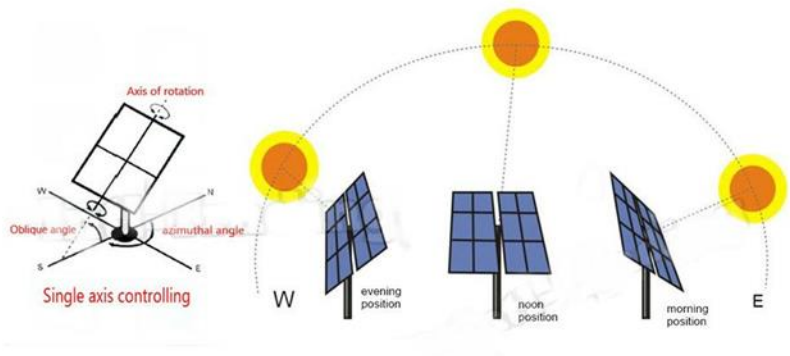

Figure 3.19: Example of solar trackers system

3.5.9 Analog to Digital Conversion

Digital controllers have many advantages which are increased flexibility and ease of change to the control program. Besides that, the logic capabilities of digital systems that allow the implementation of complex algorithm and the immunity to drift faced by electronic components in analog control. Most of the signals that appear in the industry are analog for temperature and pressure. Hence, these signals need to be converted to digital signals to be used by the digital controller feedback loop. The control signal produced by the digital controller needs also to be converted back to analog to drive the plant being controlled (NME ICT initiative of MHRD, 2017). The figure 3.20 below show the block diagram of analog to digital conversion.

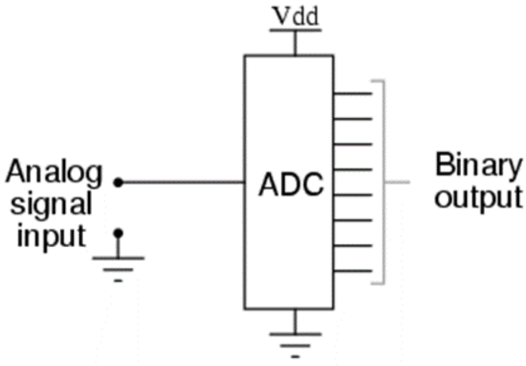

Figure 3.20: Block diagram for Analog to Digital Conversion

3.5.10 Arduino UNO

Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board, often referred to as a microcontroller and a piece of software, or IDE which is Integrated Development Environment that runs on your computer. Besides that, it also used to write and upload computer code to the physical board (ARDUINO AG, 2017). The figure of 3.21 show the picture of Arduino UNO while the table of 3.3 show the specifications of Arduino UNO.

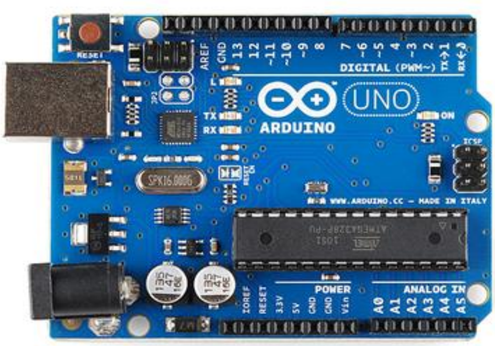

Figure 3.21: Arduino Uno

Table 3.3: The specifications of Arduino UNO

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
LED_BUILTIN	13
Length	68.6 mm
Width	53.4 mm
Weight	25 g

3.5.11 LCD

The LCDs have a parallel interface, meaning that the microcontroller has to manipulate several interface pins at once to control the display. The process of controlling the display involves putting the data that form the image of what you want to display into the data registers, then putting instructions in the instruction register. The Hitachi-compatible LCDs can be controlled in two modes which are 4-bit or 8-bit. The 4-bit mode requires seven I/O pins from the Arduino, while the 8-bit mode requires 11 pins. For displaying text on the screen, you can do most everything in 4-bit mode, so example shows how to control a 2x16 LCD in 4-bit mode.

3.5.12 Motor Chain

The figure 3.22 below show the motor chain of application of line focus concentrator for solar desalination process. A motor chain is connected to a worm geared stepped motor to control the movement of the parabolic solar trough collector towards the sun direction. The length of the motor chain is 0.5m. The motor chain is been selected as it is quiet and will not cause unnecessary noises. Besides, the motor chain reduces the friction losses as the motor chain has more contact area. The motor chain decrease energy loss through vibration. The motor chain can be changed easier and the structure is simpler.

Figure 3.22: The motor chain of application of line focus concentrator for solar desalination process

3.5.13 Ultrasonic Sensor

An Ultrasonic sensor is a device that can measure the distance to an object by using sound waves. Its sends out a high-frequency sound pulse and then times how long it takes for the echo of the sound to reflect back. Ultrasonic sensor consists transmitter and receiver. The ultrasonic sensor uses this information along with the time difference between sending and receiving the sound pulse to determine the distance to an object. Next, 8 cycles of 40KHz audio are sent out of the transmitter and it starts counting how long it takes for the echo to arrive. Besides that, the speed of sound is approximately 341 meters (1100 feet) per second in air. The picture of ultrasonic sensor was shown in figure 3.23 while the specifications of ultrasonic sensor shown in table 3.4. The mathematical formula for calculate distance shown below:

$$\text{Distance} = \frac{\text{Speed Of Sound} * \text{Time Taken}}{2} \quad [3.1]$$

Figure 3.23: The picture of Ultrasonic Sensor

Table 3.4: The specifications of Ultrasonic Sensor

SPECIFICATIONS	**DETAILS**
Supply voltage	+5V DC
Operating current	15mA
Detection range	2cm – 4m
Dimensions	45mm x 20mm x 15mm

3.5.14 Solenoid Valve

Initially the sensor senses the process towards the outlet side of the solenoid valve. When it senses that certain quantity of the flow of the fluid is required, it allows the current to pass through the solenoid valve. Due to this the valve gets energized and the magnetic field is generated which triggers the movement of the plunger against the action of the spring. Due to this the plunger moves in upwards direction, which allows the opening of the orifice. At this instant the flow of the fluid is allowed from the inlet port to the outlet port. If the current passing through the solenoid valve is constant, the position of the plunger and hence opening of the orifice remains constant.

If the sensor senses that more flow of the fluid is required, it allows the increase in current passing through the solenoid valve, which creates more magnetic field and more upwards motion of the plunger. This leads to further opening of the orifice and more flow of the fluid from the inlet port to the outlet. If the required flow of fluid is less, the sensor allows passage of the lesser current to the solenoid valve. When the sensor senses that the fluid is no more required in the process, it stops the flow of the current to the solenoid valve completely. Due to this the solenoid valve gets de-energized and the plunger reaches the bottom most position and closes the orifice completely thus stopping the flow of fluid from the inlet port to the outlet port. In this way the solenoid coil operates the valve as if it is being operated by the human being. When the flow of certain quantity of fluid is required it opens the valve to required extent and when the flow is not required it shuts the valve entirely. The picture of solenoid valve was shown in figure 3.24.

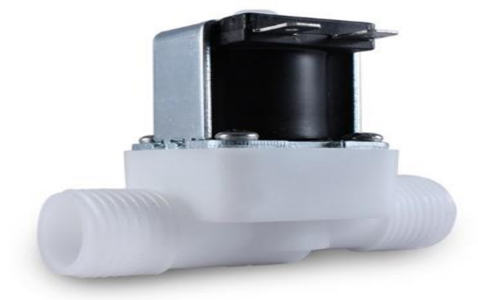

Figure 3.24: The picture of Solenoid Valve

3.6 WORKING PRINCIPLE OF APPLICATION OF LINE FOCUS CONCENTRATOR FOR SOLAR DESALINATION PROCESS

Solar radiation is converted into thermal energy in the focus of solar thermal concentrating system. The parabolic solar trough collector is line focus concentrators. The parabolic trough solar collector uses aluminum sheet in the shape of a parabolic cylinder to reflect and concentrate sun radiations towards a receiver tube located at the focus line of the parabolic cylinder. The receiver absorbs the incoming radiations and transforms them into thermal energy, the latter being transported and collected by a fluid medium (seawater) circulating within the absorber tube. The receiver tube is made of vacuum flask which is tube is surrounded by a tempered glass. The space between the vacuum flask and the tempered glass is evacuated, a vacuum can be applied in the space between the glass and the metal pipe to further minimize heat loss.

The parabolic solar trough collector is provided with single-axis solar tracker to ensure the solar beam falls parallel to its axis. The parabolic solar trough collector can only use direct solar radiation, called beam radiation or Direct Normal Irradiance (DNI).

The light dependent resistor is used to detect the focus, sun cloud and day and night condition and give instruction to the stepped motor through a control system to focus the collector, to follow approximately the sun path when cloudy conditions exist and return the collector to the east during night.

The generated steam form at the absorber tube will flow up and condenses in the helical of the aluminum pipe. The condensed steam will turn into the fresh water droplet and flow into storage tank. The heat from the steam will be released and transferred back the evaporation latent heat to the cold salt water through heat exchanger. The evaporation latent heat absorbed by the cold salt water will increase the temperature of the saltwater that flowing into the absorber pipe. The excess salt will be pumped out from the absorber pipe to avoid the sedimentation in the absorber pipe. It is because the sedimentation will affect the output of fresh water produced. After the excess salt been pumped out, the salt water will be pumped into the absorber pipe and the process repeat as follow.

CHAPTER 4

RESULT AND DISCUSSION

4.1 PERFORMANCE OF PARABOLIC SOLAR TROUGH COLLECTOR USING SINGLE-AXIS SOLAR TRACKING SYSTEM

For this thesis, we compare the amount of fresh water produced by two system which are the parabolic trough collector and point focus solar still. Both of this system use the support system which is solar tracking system to make the system more efficient working under sunlight. Next, we also compare the solar irradiance during doing the experiment. This is because, the solar irradiance can effect the amount of fresh water produced. Solar irradiance is the power per unit area received from the Sun in the form of electromagnetic radiation. It varies with the geographical location. Besides that, it is measured perpendicular to the incoming sunlight. In the case of solar irradiance, it is usually measure the power per unit area, so irradiance is typically quoted as W/m^2 that is Watts per square meter.

Table 4.1: The Amount of fresh water produced (ml) For Three Consecutive days for the parabolic solar trough collector

Amount of fresh water produced, ml	Day 1 (27/11/2017)	Day 2 (28/11/2017)	Day 3 (29/11/2017)	Average
	18.0	20.0	25.0	21.0

The finished prototype is undergone the three days experiment to study the capacity and performance of the parabolic solar trough collector. The prototype of the parabolic solar trough collector was tested from 10:00am till 5:00pm in front of Block T of University Malaysia Pahang. The experiment had been carried three day starting from 27 November 2017 till 29 November 2017. Based the table 4.1, the amount of fresh water produced, ml for day 1 is 18.0ml while in day 2 20.0ml. For the day 3 the amount of fresh water produced, ml is 25.0ml. The amount of the fresh water produced on Day 1 is the lowest as the weather on that day is very cloudy. The solar radiation on that day is low as the solar radiation is shrouded by the clouds. The amount of fresh water produced on day 3 is highest as the weather is finer than day 1. The solar radiation on day 3 is higher than day 1. The results of the solar irradiance and the graph of time against solar irradiance for three consecutive days are recorded in table 4.2 below:

Table 4.2: The average solar irradiance (W/m^2) measured for three consecutive days

Time	**Solar Irradiance (W/m^2)**		
	Day 1	**Day 2**	**Day 3**
10.00 a.m.	110.7	120.4	119.8
11.00 a.m.	113.8	122.5	154.8
12.00 a.m.	96.9	240.8	270.8
1.00 p.m.	90.6	222.5	460.8
2.00 p.m.	71.5	240.5	420.7
3.00 p.m.	99.8	220.5	425.8
4.00 p.m.	422.5	427.8	430.5
5.00 p.m.	250.7	250.8	260.8
Average	**157.06**	**230.73**	**318.00**

Based the table 4.2, the average value of solar irradiance, W/m^2 in day 1 is the lowest based on three consecutive days which is $157.06W/m^2$ while for day 2 is $230.73W/m^2$. Next, the average value of solar irradiance, W/m^2 in day 3 is $318.00W/m^2$ which is the higher value that we get during doing experiment. The value of solar irradiance can effect the amount of fresh water produced, ml. Here we can conclude that, when the value of solar irradiance increase, the higher amount of fresh water produced, ml.

Table 4.3: The amount of fresh water produced by Point Focus Solar still (Marimuthu, 2006).

Amount of fresh water (ml)	**Day 1**	**Day 2**	**Day 3**	**Average**
	155	170	120	148.3

Table 4.4: The average solar irradiance (W/m^2) measured for three consecutive days when testing the Point focus solar still (Marimuthu, 2006).

Time	**Solar Irradiance (W/m^2)**		
	Day 1	**Day 2**	**Day 3**
10.00 a.m.	575.7	470.7	350.7
11.00 a.m.	821.5	891.5	413.5
12.00 a.m.	845.7	940.7	448.7
1.00 p.m.	895.5	975.5	690.5
2.00 p.m.	910.5	1012.9	710.5
3.00 p.m.	917.7	995.7	717.7
4.00 p.m.	895.2	870.2	595.4
5.00 p.m.	307.2	507.2	307.2
Average	**655.35**	**735.69**	**461.24**

Based on the Table 4.3 and table 4.4, the amount of fresh water increases when the solar irradiance increases. As the evaporation takes place using solar energy it is a given fact that the amount of fresh water produced increase with solar intensity. The more intense the solar radiation, the faster the rate of evaporation takes place which results in higher productivity. Besides that, it is found that for an increase in solar irradiance for day 2 from 655.35 W/m^2 to 735.69 W/m^2, the production of fresh water also increased from a value of 155 ml to 170 ml. Meanwhile, for a decrease in solar irradiance from 735.69 W/m^2 to 461.24 W/m^2, the fresh water production decreased sharply from a value of 170 ml to 120 ml. Thus, it is proven that the solar irradiance received influence the volume of fresh water.

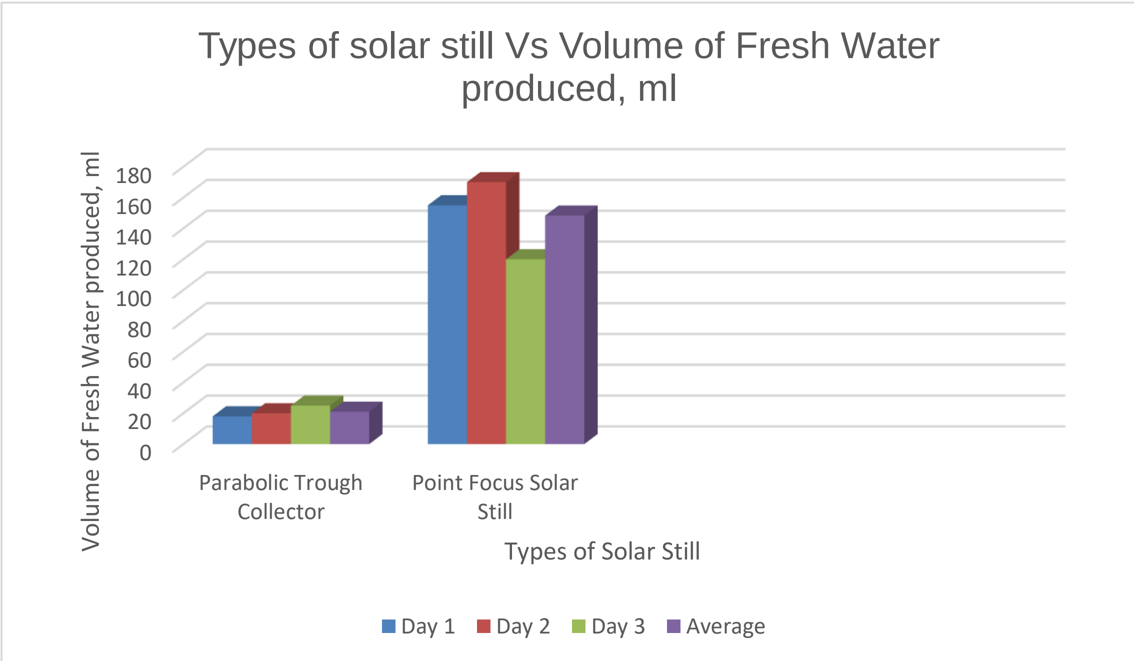

Figure 4.1: Types of solar still versus Volume of fresh water produced, ml

Figure 4.1 shows that the comparison of output for fresh water produced, ml versus types of solar stills. The purple colour of bar above represent the average of fresh water produced, ml. The average volume of fresh water produced for point focus solar still is 148.3ml which is higher than parabolic trough collector, 21.0ml. This is because of several factors that effect the volume of fresh water produced. One of the factors is weather. During our experimental, the weather very cloudy that effect the volume of fresh water produced. This reasons can be prove by looking the table 4.2 which is show the value of solar irradiance. The solar irradiance is the one important aspects that can effect the producing of fresh water using solar still. Besides that, based on the table 4.2 and table 4.4 we can see that the difference of value of solar irradiance. The value of solar irradiance during testing the point focus solar still higher than the value of solar irradiance when testing the parabolic trough collector. So, this result will effect the volume of fresh water produced.

4.2 PERFORMANCE OF WATER LEVEL CONTROL USING ULTRASONIC SENSOR

For this thesis also, we test the performance of water level control by using ultrasonic sensor. This sensor will work when it detect the distance 3cm from sensor itself with the water. The salt water will flow into the absorber. Then, when salt water increase until 3cm from the sensor, it will send the signal to solenoid valve to stop the salt water flow into absorber tube. Besides that, for testing the system work or not, we add the light as indicator. So, when water reached 3cm from distance of sensor, the indicator light will turn on.

Table 4.5: The result of measuring water level control

Distance, cm	Indicator light “On” or “Off”
3 cm	On
4 cm	Off
5 cm	Off
6 cm	Off

Based on table 4.5, the indicator light will turn on when water reached 3cm from the sensor. This distance can be changed by changing the coding that we created to control the water level.

4.3 COST ANALYSIS

Table 4.6: Cost analysis that used to create the parabolic trough collector

ITEM		COST(RM)
1.	Water proofing box	16.00
2.	5x TIP120 power Darlington transistor	39.00
3.	DC 12V Solenoid Valve	22.10
4.	5x Light intensity Photosensitive sensor	13.77
5.	I2C/IIC LCD 1602 Display Module	25.00
6.	2x Cushion Kitchen Sheet	10.60
7.	AC-to DC Converter	50.00
8.	2xArduino UNO	70.00
9.	12x PCB stand	9.60
10.	40P Male to Male Jumper Wire 20cm	3.90
11.	6x Spray Paint Flat Black	35.40
12.	WTC Hose Connect PVC	4.10
13.	Wheel Set FLB50-4S	8.50
14.	Glue Gun 20W	8.90
15.	Glue Stick	2.70
16.	6x Micro Limit Switch	10.80
17.	2x Glass Vase	37.80
18.	6 × CABLE LUGS RNB5 5-6	3.00
19.	2 × Fuse box	5.70
20.	Rectangular hole steel	150.00
TOTAL		**526.87**

The table 4.6 shows the amount that we need to create the parabolic trough collector. The economic analysis is a systematic approach to determine the optimum use of scarce resources, including comparison of two or more alternatives in achieving a specific objective under the given assumptions and constraints. Economic analysis takes into account the opportunity cost of resources employed and attempts to measure in monetary terms the private and social costs and benefits of a project to the community and society. The overall cost to fabricate the prototype of parabolic solar trough collector is RM 526.87.

4.4 DISCUSSION

The objective of the project was to design a system that tracks the sun for a parabolic trough collector. This was achieved using a system with three stages or subsystems. Each stage has its own role. For the first stage, an input stage that was responsible for converting sunlight to a voltage. We used four LDRs in every corner of parabolic Trough Collector. Then, the values obtained by the LDRs are compared and if there is a significant difference. The input stage is planned with a voltage divider circuit so it gives wanted scope of brightening for splendid enlightenment conditions or when there is diminish lighting. This made it conceivable to get readings when there was cloudy weather. Potentiometer is aligned to meet those changes.This LDRs are suitable for this project because their resistance varies with light. Besides that, their also low cost and and are practical.

Next, the stage two is the control stage which is performed by microcontroller Atmega328P. The microcontroller will receives the value voltage of LDR. Then, the microcontroller will determines the action that need to perform. Besides that, it also was programmed to ensure it sends a signal to the DC motor that moves in accordance with the generated error. After that, the final stage was performed by DC power window motor. The DC power window motor had enough torque to drive the parabolic frame. Based on the table 3.2, the torque of power window motor is 30kg.cm. So, the DC power window motor was suitable used in parabolic trough collector to move the parabolic frame. But during the experiment, the solar tracking system not doing well. This is because, we faced obstacles when carrying out the test during December month because it was raining season in Gambang and most of the time the sky will be cloudy. So, it is difficult to obtain accurate reading. This can be refered to Table 4.2 which is shown that the low values of solar irradiance.

The second objective of this project is to design and construct the circuit that can detect the water level. This was achieved by using ultrasonic sensor thatcan detect the distance of water level from the sensor itself. An Ultrasonic sensor is a device that can measure the distance to an object by using sound waves. Its sends out a high-frequency sound pulse and then times how long it takes for the echo of the sound to reflect back. The speed of sound is approximately 341 meters per second in air. Lastly, the mathematical formula for calculate distance shown in Equation [3.1].

The speed of sound is the constant value which is 341 meters per second in air. Besides that, time taken is the time that take by sound to travel from sensor to obstacle and back to sensor.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

In a nutshell, a cost-effective, simple and low cost prototype of parabolic solar trough collector been designed and fabricated. The prototype parabolic solar trough collector is to provide the clean useful water. The average output of fresh water for three consecutive days is 21 ml/day. The average solar radiation for three consecutive days is 234.85 W/m². The low productivity of the freshwater is mainly due to cloudy weather with average temperature of 28ºC. Besides that, it has been decided to make a solar tracker with active tracking mechanism.The parabolic trough collector with a single axis solar tracking system was designed. The solar tracking system was designed to track the sunlight. To drive the parabolic frame, we will be using DC power window motor with high reduction ratio so that we can achieve high driving torque and a very low rpm. Tracking will be achieved by the help of circuit made by the help of relay and four LDRs. Next, we able to design and construct the circuit that can detect the water level by using ultrasonic sensor. This system work to detect the water level that flow in absorber tube. As a result, two of the objectives were achieved.

5.2 RECOMMENDATIONS FOR FURTHER WORK

With the available time and resources, the objective of the project was met. The project is able to be implemented on a much larger scale. For future projects, the sensing element for water level sensor can be improved by replacing with a high quality sensor that can withstand with seawater. This is because, the ultrasonic sensor that we used in project was rusting due to the reaction with seawater vapor. In addition, the relay module that we used in the project can replaced by using motor driver L293N which can control the speed of motor. Lastly, the implementation of solar panel can be done to improve the power circuit of this project. The solar panel can reduce the usage of electricity.

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APPENDICES

APPENDIX A: Code for solar tracking system

```
#include<LiquidCrystal.h>
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);
int LDR1 = A0; //Analog input 1
int LDR2 = A1; //Analog input 2
int LDR3 = A2; //Analog input 3
int LDR4 = A3; //Analog input 4
int MTRFWD = 7; // Digital 7
int MTRREV = 6; // Digital 6
int sensorValue1, sensorValue2, sensorValue3,
sensorValue4,switchValue1,switchValue2;
int sw1=8;
int sw2=9;


void setup()
{
  Serial.begin(9600);
  pinMode(LDR1, INPUT);
  pinMode(LDR2, INPUT);
  pinMode(LDR3, INPUT);
  pinMode(LDR4, INPUT);
  pinMode(sw1,INPUT);
  pinMode(sw2,INPUT);
  pinMode(MTRFWD, OUTPUT);
  pinMode(MTRREV, OUTPUT);
  Serial.begin(9600);
  lcd.begin(16, 2);
  delay(100);
}
```

```
void loop()
{
  sensorValue1 = analogRead(LDR1);
  sensorValue2 = analogRead(LDR2);
  sensorValue3 = analogRead(LDR3);
  sensorValue4 = analogRead(LDR4);
  switchValue1 = digitalRead(sw1);
  switchValue2 = digitalRead(sw2);
  Serial.print("sensor1 = ");
  Serial.println(sensorValue1);
  Serial.print("sensor2 = ");
  Serial.println(sensorValue2);
  Serial.print("sensor3 = ");
  Serial.println(sensorValue3);
  Serial.print("sensor4 = ");
  Serial.println(sensorValue4);
  Serial.print("sw1 = ");
  Serial.println(switchValue1);
  Serial.print("sw2 = ");
  Serial.println(switchValue2);

  delay(50);
  lcd.setCursor(0, 0);
  lcd.print("S1=");
  lcd.print(sensorValue1);
  delay(100); //Delay of 1 second for ease of viewing in serial monitor
  lcd.setCursor(8, 0);
  lcd.print("S2=");
  lcd.print(sensorValue2);
  delay(100); //Delay of 1 second for ease of viewing in serial monitor
  lcd.setCursor(0, 1);
  lcd.print("S3=");
```

```
  lcd.print(sensorValue3);
  delay(100); //Delay of 1 second for ease of viewing in serial monitor
  lcd.setCursor(8, 1);
  lcd.print("S4=");
  lcd.print(sensorValue4);
  delay(100); //Delay of 1 second for ease of viewing in serial monitor

  if((sensorValue1 < 700) && (sensorValue2 < 700) && (sensorValue3 > 700) &&
(sensorValue4 > 700))
   {
    if((switchValue1==LOW))
    {
    digitalWrite(MTRFWD, LOW);
    digitalWrite(MTRREV, HIGH);
    }
    else
    {
    digitalWrite(MTRFWD, HIGH);
    digitalWrite(MTRREV, HIGH);
    }
   }
  else if ((sensorValue1 > 700) && (sensorValue2 > 700) && (sensorValue3 < 700)
&& (sensorValue4 < 700))
    {
     if((switchValue2==LOW))
    {
     delay(1000);
    digitalWrite(MTRFWD, HIGH);
    digitalWrite(MTRREV, LOW);
    }
     else
    {
    digitalWrite(MTRFWD, HIGH);
```

```
    digitalWrite(MTRREV, HIGH);
    }
    }
  else
  {
    digitalWrite(MTRFWD, HIGH);
    digitalWrite(MTRREV, HIGH);
  }

  delay(1000);
}
```

APPENDIX B:Code for measuring water level control

```
#define trigPin 6
#define echoPin 7
#define ledPin 2
int solenoidPin = 4;
void setup() {

Serial.begin (9600);

pinMode(trigPin, OUTPUT);
pinMode(echoPin, INPUT);
pinMode(ledPin,OUTPUT);
pinMode(solenoidPin, OUTPUT);
}

void loop() {



long duration, distance;
digitalWrite(trigPin, LOW); // Added this line
delayMicroseconds(2); // Added this line

digitalWrite(trigPin, HIGH);
// delayMicroseconds(1000); - Removed this line
delayMicroseconds(10); // Added this line
digitalWrite(trigPin, LOW);

duration = pulseIn(echoPin, HIGH);
distance = (duration/2) / 29.1;
if (distance >= 20 || distance <= 0){
Serial.println("Out of range");
```

```
}

else {

Serial.print(distance);
Serial.println(" cm");

}

if (distance <=3 && distance >= 0){
  digitalWrite(ledPin,HIGH);
  digitalWrite(solenoidPin, LOW);
  delay(1000);
 }
 else{
  digitalWrite(ledPin,LOW);
  digitalWrite(solenoidPin, HIGH);
  delay(1000);
 }

 delay(500);
}
```

APPENDIX C: Picture of circuit project

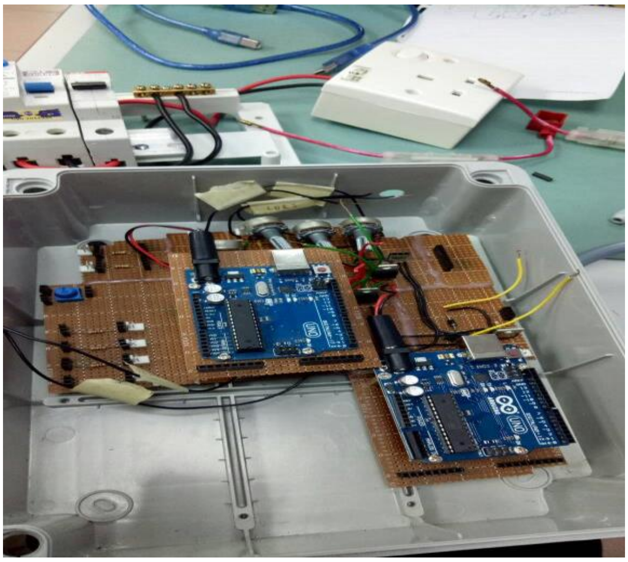

Figure C1: Design of circuit

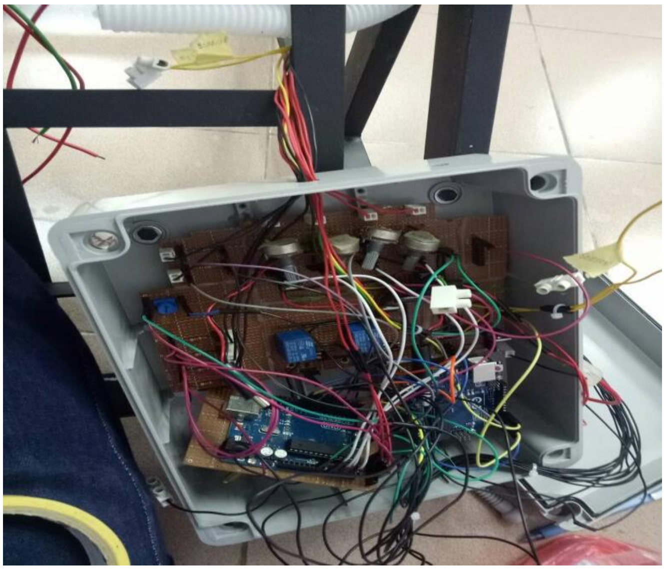

Figure C2: Design of circuit with wiring

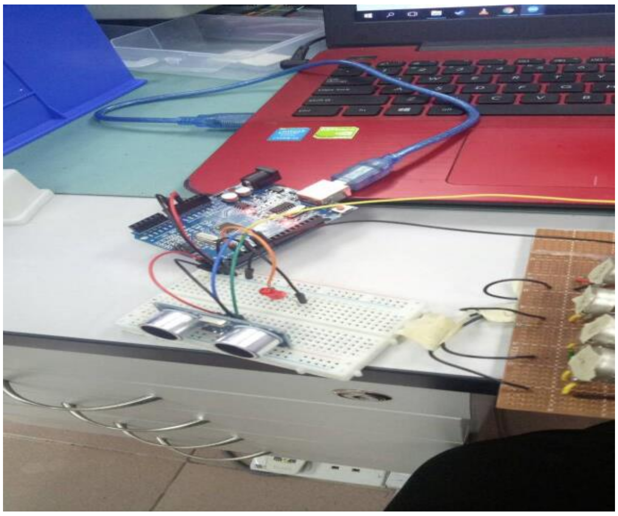

Figure C3: Design of ultrasonic sensor

Figure C4: Distribution Fuse Box

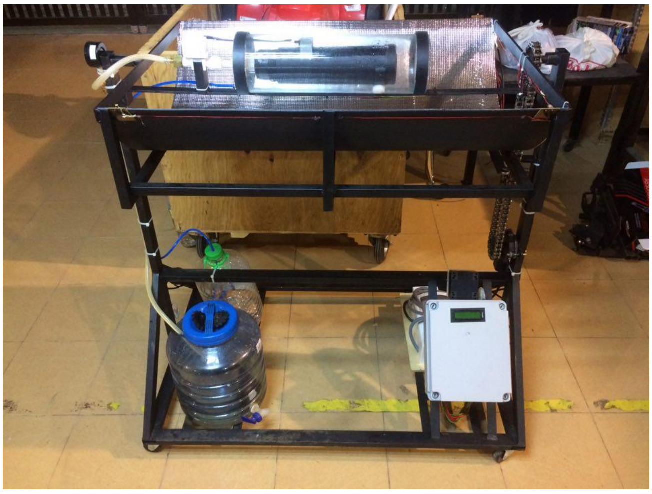

Figure C5: Complete design of Solar Desalination Process