DEVELOPMENT OF SOLAR WATER PUMP FOR AQUACULTURE

WILSON SHUM KENG HANG

Bachelor of Engineering Technology (Energy & Environmental) with Honours

UNIVERSITI MALAYSIA PAHANG

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ABSTRAK

Pada masa kini, masyarakat dan saintis telah digesa untuk beralih kepada sumber tenaga boleh diperbaharui seperti solar, angin dan biogas untuk menggerakkan sistem pengepaman air. Matahari telah terbukti sebagai sumber pengeluar kuasa yang paling menggalakkan kerana ketersediaannya kerana kebanyakan Semenanjung Malaysia mempunyai enam jam siang setiap hari dan ia memberi manfaat kepada alam sekitar. Industri akuakultur, yang bermula pada tahun 1920-an dan berkembang pesat tetapi dikaitkan dengan kebimbangan alam sekitar. Pam air solar untuk akuakultur adalah terutamanya untuk pemilik kolam ikan yang sukar mengeluarkan air tercemar. Jarak kolam ikan jauh dari kawasan yang dibangunkan, justeru kurang atau tiada sambungan grid. Reka bentuk pam air tidak dapat memberikan kuasa yang mencukupi dan tidak mudah untuk bergerak apabila ia digunakan untuk menarik air dari kolam yang jauh dan dalam. Projek ini bertujuan untuk membina pam air suria yang digerakkan untuk akuakultur dan menilai watt sistem suria. Pam air direka bentuk dengan perisian Siemens NX ke dalam pam emparan dan dibina untuk berfungsi bersama stesen pengecas solar. Arah kardinal iaitu Utara, Selatan, Barat, Timur dan sudut panel suria iaitu 0° dan 45° ditetapkan sewajarnya untuk mengukur voltan, arus dan faktor-faktor yang akan mempengaruhi bacaan seperti ketumpatan fluks sinaran suria, modul dan suhu persekitaran, kelembapan dan keadaan cuaca. Ini bertujuan untuk memilih pengeluaran watt tertinggi kerana orientasi panel solar terbaik adalah pada 0-15° dan semasa arah selatan. Purata kadar alir pam air seperti yang direkodkan pada 0.0787 l/s dengan menggunakan pengiraan kadar aliran manual. Pengecasan akan mengambil masa kira-kira 4 jam untuk mengecas 55% daripada bateri SLA. Dengan kadar alir purata di atas, pam air memerlukan kira-kira 8 minit dan 20 saat untuk menyelesaikan mengeluarkan air dari akuarium 10 gelen. Pam air suria untuk akuakultur mungkin direka bentuk dan dibina dalam saiz yang lebih besar untuk kegunaan yang lebih meluas dalam sektor akuakultur.

ABSTRACT

Nowadays, the community and scientists have been urged to switch to renewable energy sources like as solar, wind, and biogas to power the water pumping system. Sun has shown to be the most encouraging power producing resources due to their availability as most of Peninsular Malaysia has six hours of daylight each day and it is environmentally beneficial. The aquaculture industry, which began in the 1920s and is rapidly increasing but associated with environmental concerns. The solar water pump for aquaculture is mainly for the fishpond owners who are hard to remove out the polluted water. The distance of fishpond far from the developed area, hence less or no grid connection. The design of the water pump is unable to provide sufficient power and not easy to move around when it is used to withdraw the water from a far and deep-water pond. This project aims to build a mobilized solar water pump for aquaculture and evaluate the wattage of the solar system. A water pump was designed with Siemens NX software into centrifugal pump and built to work together with solar charging station. The cardinal directions which were North, South, West, East and angle of the solar panel which were 0° and 45° were set accordingly to measure voltage, current and the factors which will affect the readings such as solar radiation flux density, module and ambient temperature, humidity and weather condition. This was aimed to select the highest wattage production as the best solar panel orientation is at 0-15° and during south direction. The average flowrate of the water pump as recorded at 0.0787 l/s by using the manual flow rate calculation. The charging will take about 4 hours to charge 55% of the SLA battery. With the average flowrate above, the water pump will require around 8 minutes and 20 seconds to finish remove the water from a 10-gallon aquarium. The solar water pump for aquaculture may be design and built in a larger size for a wider use in the aquaculture sector.

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LIST OF SYMBOLS

cm	Centimeter
E_2	Counter Electro-Motive Force (EMF) generated by the air gap flux
°	Degree (angle)
I_x	Excitation current
Z_1	Impedance of the stator
"	Inches
l	Litre
m	Meter
mm	Milimeter
π	Pi = 3.14159265359
r	Radius
s	Second
I_1	Stator current
R_1	Stator effective resistance
X_1	Stator leakage reactance
V_1	Terminal voltage of the stator
V	Volt
W	Watt

LIST OF ABBREVIATIONS

AC	Alternating current
Ah	Ampere-hours
BLDC	Brushless DC electric motor
DC	Direct current
hp	Horsepower
IoT	Internet of things
Pb	Lead
Li	Lithium
Ni-Cd	Nickel cadmium
NiMH	Nickel metal hydride
PV	Photovoltaic
SLA	Sealed lead acid
SBPWM	Simple Boost Pulse Width Modulation
SPVWPS	Solar photovoltaic water pumping system
SE	Southeast
SW	Southwest
V	Volts
ZSI	Z source inverter

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

According to the World Energy Outlook 2004, worldwide primary energy consumption would increase by roughly 60% from 2002 to 2030, with an average annual growth rate of 1.7 percent. Demand will increase to 16.5 billion tonnes of oil equivalents (toe) from 10.3 billion toe in 2002 (Bilen et al., 2008). Nonetheless, the rate of rise is expected to be slower than in the previous three decades, when demand grew at a rate of 2% per year. Global energy demand will continue to rely heavily on fossil fuels, notwithstanding the rise of renewables. A significant portion of Malaysia's daily energy needs are still met by a mix of fossil fuels such as oil, natural gas and coal.

The community and scientists have been urged to switch to renewable energy sources like as solar, wind, and biogas to function the water pumping system because of the continuous usage of fossil fuels and their destructive effect on the ecosystem. Sun and wind have shown to be the most encouraging power producing resources in domestic power generation due to their availability and ability to be employed instantly without requiring government approval due to their topological benefits. They are also environmentally beneficial because they do not generate any garbage or wastes. Most of Peninsular Malaysia has six hours of daylight each day. The amount of solar radiation is directly proportional to the amount of time spent in direct sunlight. The daily average solar radiation in Malaysia is roughly 5.5 kWh/m^2 (15MJ/m^2) (Oh et al., 2010). Malaysia's solar power potential is estimated to be four times that of the world's fossil fuel reserves, as assessed by photovoltaic (PV) systems. In a year, most locations in Malaysia experience sun irradiation intensities ranging from 13.67MJ.$m^{-2}.\ day^{-1}$ to 17.18MJ.$m^{-2}.\ day^{-1}$. Apart from that, the predicted lowest solar irradiation intensity was 10.53 MJ.$m^{-2}.\ day^{-1}$ in November, compared to a maximum intensity of 19.28

MJ.m^{-2}. day^{-1} in January (Shavalipour et al., 2013). The northern portion of Peninsular Malaysia is thought to have advanced solar energy system development, with medium to extremely high average intensities occurring throughout the year in certain of these areas.

The aquaculture industry, which began in the 1920s and is rapidly increasing, has become a critical pillar in Malaysia's national food security (Samah & Kamaruddin, 2015). The aquaculture sector has grown at a 10% annual pace on average during the last 5 years (FAO, 2021). Malaysian aquaculture has improved substantially in terms of methods, farmed species, and contribution to national economy during the previous 15 decades. Despite its many benefits, including as contributing to the national economy, aquaculture in Malaysia is nonetheless associated with environmental concerns. Converting agricultural land to aquaculture areas is required for large-scale fish production (Polpanich et al., 2018). The majority of aquaculture sites are located in open spaces in rural areas with no shelter is built to cover the fishpond. Aquaculture consumes a lot of water, which results in a lot of effluent (Ghaly et al., 2005). Artificial fishponds in brackish water and freshwater cultures create the majority of wastewater. Because it includes a wide range of pollutants, such as high quantities of organic matter, minerals, proteins, hormones, and biomasses, the effluent that is produced by aquaculture is considered to be harmful to the environment (Dauda et al., 2019; Zhang et al., 2014).

The solar water pump for aquaculture is mainly for the fishpond owners that doing fish culture to be sell. Some of the issues that we know for the owners are hard to clean the ponds and remove out the polluted water especially when eutrophication occurs. Since ponds are an open environment, the owners may find that pollutants enter the water which will affect water quality and can have an impact on the health of the pond. The water in the fishponds is also polluted due to flood, other wildlife, fish provender, pesticides, chemical and heavy rain which may contain acidity composition and to raise the acidity of the water or lower the pH value. Rain normally is having the pH of 5.2 to 5.6 which is acidic, however industrial pollution may bring it down to 2.5. If the pH is less than 4 or more than 11, most aquaculture species will perish fast. Most species can withstand a pH range of 6 to 9, but pH levels outside of this range resulting in reduced growth and increased disease susceptibility. Most species thrive in a pH range of 7 to 8.5. For example, from January 1, 2010, to December 31, 2015, the pH values of 402 precipitation samples in the Yangtze River's source region were analysed, with a focus on the 14 regions which acid rain occurred. Acid rain's characteristics in the Yangtze River's source area included a pH range of 4.0 to 8.57, with a mean of 6.37 (Zong-Jie et al., 2017).

For the aquaculture activities, the fishpond owners are using the water pump in which the sources for driving the pump are mainly diesel and grid electricity. Unstable sources of electricity that faced by the owners is due to the lack of grid connection at the non-urban areas. This caused a challenge when it came to distributing water to isolated regions that are unable to be linked directly to a national grid station (Meah et al., 2008). Hence, it will cause the owners to have trouble with the electric supply for their routine at the fishpond area. Pumping water may be accomplished with the help of a variety of non-traditional forms of energy. In spite of this, the solar photovoltaic (PV) system emerged as the most viable option. It has been shown that the availability of solar energy has a direct correlation with the need for water, despite the fact that solar energy is both clean and naturally abundant (Meah et al., 2008). In many areas where there is a significant demand for water and the electric grid does not reach, the sun intensity is great. This presents an opportunity for solar power generation. Electric supply is very important for the usage of the water pump which used to remove and drawing out the water from the pond, without the stable electric supply, the water pump will be not able to function properly whenever it is needed to use. However, there are a few of renewable energy sources may be utilised for water pumping, solar is gaining popularity since it is accessible almost everywhere, even in distant locations, reducing reliance on the grid and diesel for pump drive.

1.2 Problem Statement

Engine-driven pumps, grid-powered pumps, manual-powered pumps, and generator-driven pumps are among the contemporary water pumping methods in use. Due to the distance of fishpond from the developed area, there will be less or no grid connection to such area. Hence, when the owners carry out their aquaculture activities at such area, they will be facing the problem of short of electricity supply. The electric current supply at such areas will be unstable compared to the supply at rural area. This is due to the aging of the electrical grid connection at such area as this area is far, hence less maintenance will be carried out frequently because the cost to maintain is high which including the transportation fees. Hence, the grid connection will be aged easily compared to the rural area at which much potential power is wasted during the process of transmitting the electricity. Moreover, the majority of these systems have grown more costly to operate as a direct result of the continuous rise in the price of fuel that has occurred over the course of the last few years. As a result, the pump which uses diesel or grid connected electricity as main sources of energy is causing difficulties to the owners and needed to be replaced.

Normally, the size of a fishpond is not small at all because if the pond is small, it will waste a lot of time and energy of the workers to take care of the pond and feed the fishes. Furthermore, if the fishpond is small in area, the owners will not be able to feed a large number of fishes, resulting in lower profits and high energy wastage. Moreover, when the fishpond design is small, it will cause the owners to spend more money to construct more ponds to cover up the volume of ponds in order to feed the aquaculture species. Hence, the area of the fishpond normally is large and deep. Then, the design of the water pump normally is not easy to move around the pond to withdraw the water from a far and deep area. Majority of the water pump which has sufficient power is large in size and heavy hence it will cause the users to have a difficult time to carry it around to pump out the water.

1.3 Objectives

i. To design and fabricate a mobilized solar water pump for aquaculture.
ii. To evaluate the solar energy power supply in terms of wattage.

1.4 Scope of the Study

In order to achieve the objectives, the following scopes of works are proposed.

i. Designing of solar photovoltaic panels and the solar charging battery which provide energy to operate the water pump. The designation will include some criteria which are the angle of the solar panel to be located.

ii. Designing the holder of the solar panel which can be easily rotated and move at which roller is required by using Siemens Nx.

iii. Fabricating the designation of the holder of solar panel by welding and other manufacturing process.

iv. Monitoring and measuring which cardinal direction and tilt angle of solar panel under the sun provide the most solar power and data is collected for continual usage whenever wants to recharge the water pump battery.

v. Installing temperature sensor at the solar panel to observe to take the data when and at which temperature the solar panel operate well.

vi. Fabricating a suitable water pump to the solar systems that is in a portable mode which the specifications of water pump such as motor voltage, load current, overall power consumption, motor rpm, pipe size and flow rate are required to do early research.

CHAPTER 2

LITERATURE REVIEW

2.1 Aquaculture in Malaysia

Malaysia has one of the world's highest fish consumption rates, with 59 kg per capita consumed in 2016 (Waiho et al., 2020). Malaysia's primary source of protein is now mostly dependent on its marine farming sector. The Malaysian coastal settlements are largely made up of the Bottom 40% (B40) of the population, and aquaculture is their principal source of income (Waiho et al., 2020). A growing number of Malaysians are turning to aquaculture as an important source of income. Although it only provides 0.2% of the country's gross domestic product, this sector has been successful in developing and exporting high-value items to fulfil domestic demand (FAO, 2016). The aquaculture industry now employs around 49,989 fish farmers and culturists (Kurniawan et al., 2021).

2.1.1 Type and Species of Aquaculture in Malaysia

The most common type of aquaculture is brackish water aquaculture, although there is also freshwater pond aquaculture and marine aquaculture. Food such as brackish water fish, freshwater fish, and seaweed while for non-food such as ornamental fish and aquatic plant commodities are all part of Malaysian aquaculture. Brackish water aquaculture produced 224.171 tonnes of fish worth more than RM 2.3 billion in 2019. Anadara granosa (54%) is the most often grown species, followed by shrimp (22.4%), Panaeus monodon (17.3%), and other marine fish species (6.3%). The black tiger shrimp has the greatest value among the most precious items, followed by white leg shrimp (Kurniawan et al., 2021). In 2019, freshwater pond aquaculture produced 105,101 tonnes of fish worth more than RM 711 million. Oreochromis niloticus (44.7%), catfish (36.7%), carps (10.08%), and other species (8.52%) are the most cultivated freshwater fish (FAO, 2021). Red tilapia is the most valued commodity produced in Malaysian freshwater aquaculture, followed by catfish (FAO, 2021). Seaweed aquaculture generated 174,083 tonnes of wet weight production worth RM 52 million. In 2019, ornamental fish production totalled 325,328,503 pieces, valued at RM 350,326, while aquatic plant output was 117,006 bundles, valued at RM 19,924 (Kurniawan et al., 2021).

2.2 Water Pump

There are literally thousands of different designs of the water pump, making it one of the oldest and most widely used equipment in the world. Water pumps utilise electricity to raise the pressure of fluids and transport them from one location to another, such as water. Supplying municipal, industrial, and agricultural water is a common goal for water pump manufacturers across the globe today. Animal strength, electric motors use the electrical power, human muscular power, such as hand cranking, foot pedalling, and reciprocating pistons, may be used to power pumps. Besides, a water pump can be powered by a battery, solar energy, on-site fuel-powered engines which the fuels are the diesel, gasoline, or steam generated by coal, charcoal or wood engines. In modern water pumps, electricity is the most common power source, although diesel and gasoline engines are also employed (Aliyu et al., 2018). It is possible to power tiny pumps using solar panels in places where there's no other power source, like the desert. An efficient water pump makes a significant contribution to the pumping system's overall performance.

2.2.1 Types of Water Pump

A broad range of pump sizes are available to suit a wide range of needs. The pumps may be categorised as either dynamic or displacement pumps based on their primary working mechanism. Centrifugal and special-effect pumps are subclassifications of dynamic pumps. Rotary pumps and reciprocating pumps are two subcategories of displacement pumps. Submersible, centrifugal, and positive displacement pumps are the most common pump types in solar photovoltaic water pumping system (SPVWPS). All pump designs can theoretically handle any liquid. Centrifugal pumps, followed by rotary and reciprocating pumps, are the most cost-effective when compared to other pump types. As a result of the improved or better efficiency of a positive displacement pumps, the benefits of enhanced efficiency are sometimes outweighed by higher maintenance costs (Hamidat

& Benyoucef, 2008). Literature about the comparison between centrifugal pump and positive displacement pump is shown in Table 2.1.

Table 2.1 Comparison of Pumps

Types of Pumps	**Features**	**References**
Centrifugal	Because of their dependability, simplicity, adaptability, and affordability, centrifugal pumps are often employed to pressurise liquids. Centrifugal pumps, despite their basic design, provide several benefits, including little maintenance, smooth operation, and low vibration. However, centrifugal pumps have several drawbacks, including cavitation, pressure head limitations, and poor hydraulic efficiency owing to performance degradation.	(Bozorgasareh et al., 2021) (Bill Forsthoffer, 2005)
Positive displacement	This pump is more efficient than the centrifugal with fewer average energy losses and the flow rate is nearly the same regardless the pressure. Moreover, it will not significantly be affected by the viscosity of the fluid. However, it does not discharge the fluid continuously.	(Li et al., 2017)
Centrifugal and positive displacement pump	The pump with more energy-efficient than centrifugal pumps are positive displacement ones because they have less losses and deliver more water. Experimental data from an Algerian pumping test facility validates the mathematical model.	(Hamidat & Benyoucef, 2008)

2.2.1.1 Special-effect pumps

There is another name for the kinetic pumps, and that is the special effects pump. This particular kind of pump is one in which adding energy still increases kinetic and velocity, but it makes use of effects different than those generated by centrifugal pumps. These pumps may further be broken down into two distinct categories, which are the electromagnetic pump and the jet pump. The fluid is pushed into the drive nozzle of the jet pump, which turns the pressure of the fluid into a high-velocity jet. Jet pumps are employed. A regular jet pump has to have all of its internal space filled with water in order to function properly. After the system has been primed, a centrifugal pump will be used to expel the water from the system. By using the energy of electromagnetism, a pump that can move electrically conductive liquids such as brine, molten salts, and liquid metals may be constructed. This kind of pump is called an electromagnetic pump. In this method, a magnetic field is arranged such that it is perpendicular to the path that the liquid takes and the path that the current takes. This causes an electromagnetic force to be generated, which in turn causes the liquid to flow ahead.

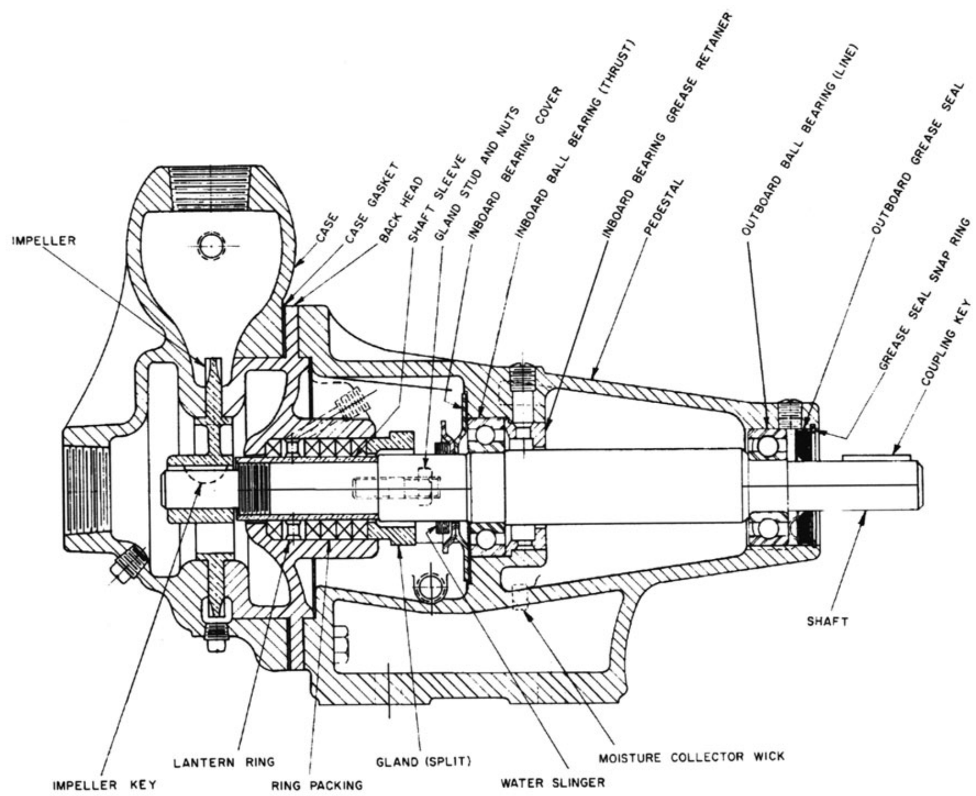


Figure 2.1 Regenerative special effect pumps

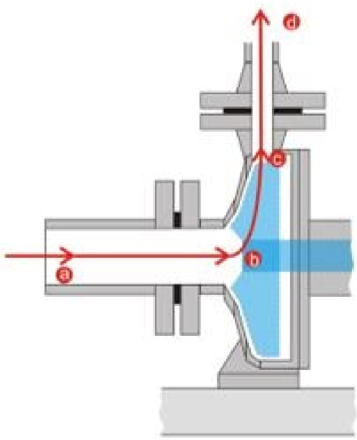


Figure 2.2.2 Mechanism process of special effect pump

2.2.1.2 Rotary pump

A rotary pump is another kind of positive displacement pump in which the movement of a predetermined quantity of fluid occurs with each rotation of the pump. The capacity that can be provided by these pumps remains constant no matter what the pressure is. The fluid is moved with the help of spinning gears in rotary pumps. This rotating gear creates a liquid seal with the pump casing, which allows for suction to be made at the pump intake. The liquid that is being sucked into the pump at this time is then transported to the discharge after being caught in the gears that are turning within the pump. The fact that there is absolutely no oil used in the procedure is unquestionably a distinct benefit.

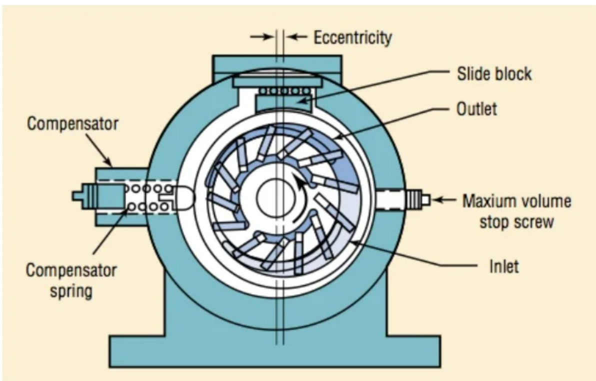


Figure 2.3 Rotary pump

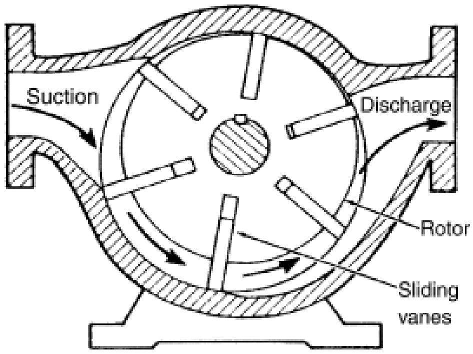


Figure 2.4 Mechanism process of rotary pump

2.2.1.3 Reciprocating pump

Pumps that employ recirculation transfer the volume of water that has been accumulated in a contained area to the discharge area under the influence of applied pressure. When the flow rate is low, but the pressure is high, reciprocating pumps are used. This pump operates by having a piston travel back and forth inside a cylinder that remains stationary. A connecting rod is what secures the piston to the crankshaft in an internal combustion engine. This piston moves because the crankshaft is moving, which in turn causes the connecting rod to move, which in turn causes the piston to move. The fact that this crankshaft is connected to a motor enables it to rotate.

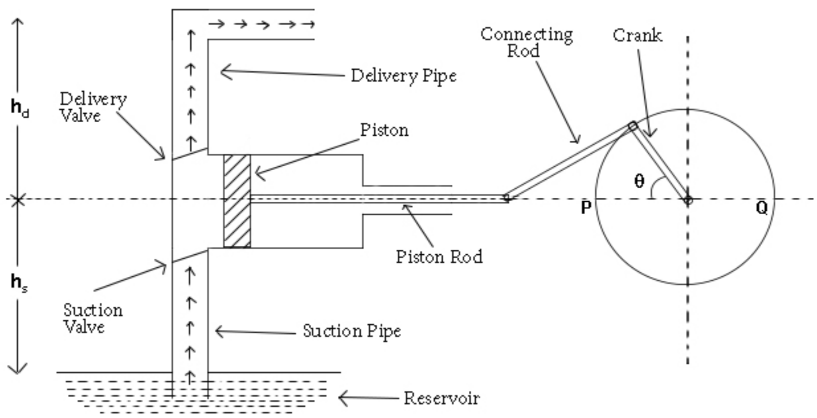


Figure 2.5 Reciprocating pump and its mechanism process

2.2.1.4 Centrifugal pump

A centrifugal pump has a very simple construction. The impeller and the diffuser are the two primary components that make up the pump. Bernoulli's principle, which asserts that an increase in fluid velocity is followed by a drop in pressure or potential energy (and vice versa), is necessary for the operation of pump impellers. This concept allows pump impellers to function properly. The only portion that rotates is the impeller, and it is connected to a shaft so that it may be propelled by a motor. Impellers are often crafted from a variety of materials, including bronze, polycarbonate, cast iron, stainless steel, and other metals and alloys. The impeller is contained inside the diffuser, which is also known as a volute. The diffuser catches and directs the water that is expelled from the impeller. Centrifugal force helps move water out of the impeller after it has been drawn into the impeller's centre, also known as the "eye." As water is drawn from the eye of the impeller, a region of low pressure is generated, which results in the introduction of more water into the eye. This is brought about by the combination of atmospheric pressure and centrifugal force. As the water passes past the impeller while it is spinning at a very high speed, the water picks up speed and 'throws' water out at the edge (Short & Thompson, 2003).

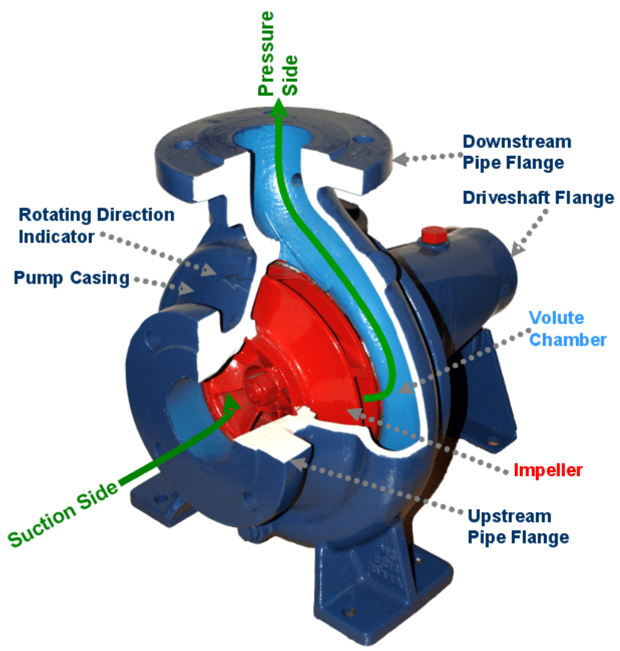


Figure 2.6 Centrifugal pump

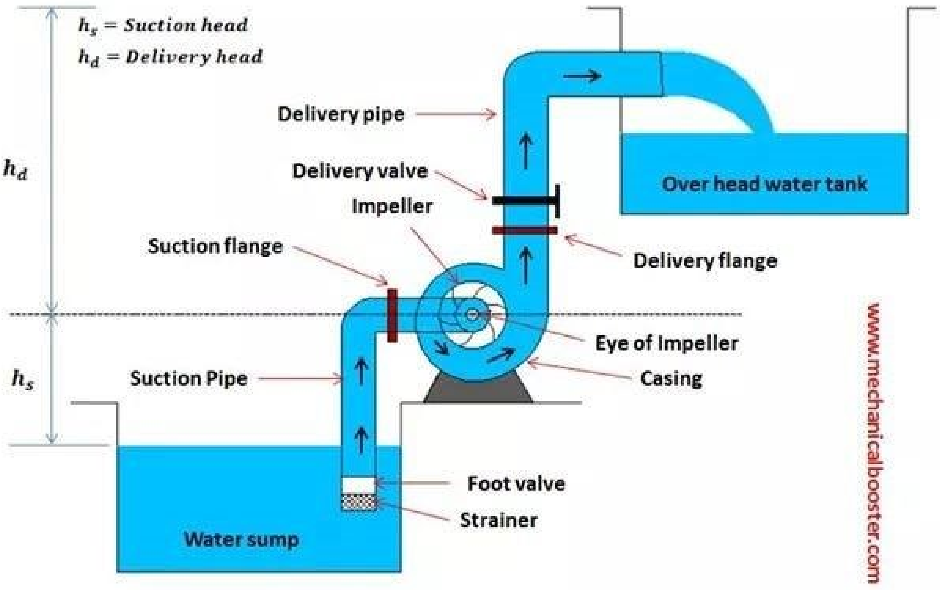


Figure 2.7 Mechanism process of centrifugal pump

2.2.2 Electricity operated water pump

Electricity-operated water pumps are those that require an electrical input to function. This category includes most commercially available water pumps. Most commercially available water pumps are powered by either electricity or diesel oil. The national systems have traditionally delivered power produced mostly by burning fossil fuels. For isolated places that unable to directly linked to a national grid station, this posed a challenge (Meah, Ula, et al., 2008). Therefore, solar energy is chosen to replace such dependants as it can produce electricity as the source for the water pump to operate. Such pumps give a natural practicability for solar PV powered water pumping due to the fact that the output of PV panels may be utilised as input to the pumps in a more straightforward manner through a DC/AC converter (Mankbadi I & Ayad, 1988).

2.2.3 Motor

There are many different types of motors on the market today, including AC, DC, permanent magnet, brushed, brushless, synchronous and asynchronous, variable reluctance, and many others. The size, efficiency, price, power input, system availability, and maintenance condition all play a role in selecting the right motor. DC motors are popular because they do not require an inverter or controller to transform the DC output of a PV array and may be used directly by the motor. For big applications which are above 9 hp, DC motors are more efficient than AC motors, which require the inverter to transform the PV array output from direct current to alternating current. The usage of an inverter results in more energy and costs, as well as a reduction in system efficiency (Verma et al., 2020).

2.2.4 AC motor

Motors using alternating current induction are the most common kind to be found in industrial motion control systems as well as in mains-powered home appliances. The most important dominant point of AC induction motors are their straightforward and long-lasting design, their ability to connect directly to an AC power source, and their low start-up and operating expenses (Sado & Hassan, 2018). Figure 2.8 depicts the induction AC motor's comparable circuit.

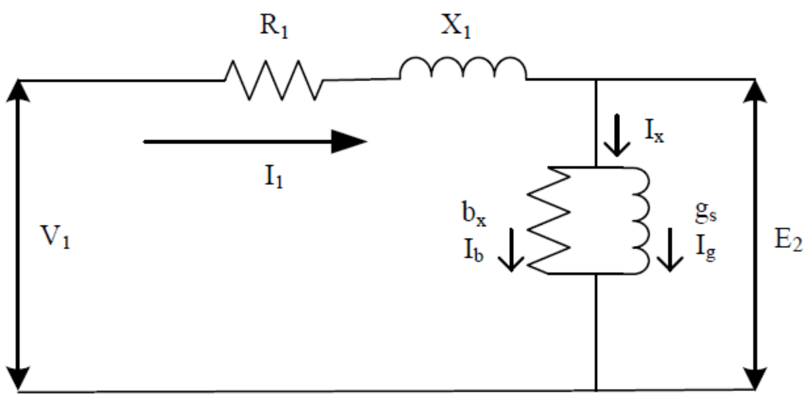


Figure 2.8 AC induction motor

In Figure 2.8, V_1 is the terminal voltage of the stator, I_1 is the stator current, X_1 is the stator leakage reactance, R_1 is the stator effective resistance, E_2 is the counter Electro-Motive Force (EMF) generated by the air gap flux, I_x is the excitation current and Z_1 is the impedance of the stator.

2.2.5 DC motor

PV-based water pumping relies heavily on motors, which play a significant role in the design of electric drives. When DC motors were first introduced, they were primarily employed for water pumping. Due to the existence of brushes and a commutator, the low efficiency and frequent maintenance of DC motors lead to the usage of AC induction motors for water pumping (Nisha & Gnana Sheela, 2020a). As a result of this, synchronous motors for water pumping were developed as an alternative to DC motors and induction motors. These motors include a rotor that is constructed of permanent magnets that have a high-power density. These motors are further divided into Sinusoidal and Trapezoidal wave Permanent Magnet Motors (Brushless DC or BLDC motors), which are the most common kind of synchronous motors. A few advantages of BLDC motors include their high efficiency, low maintenance requirements, and good dynamic performance when used in solar water pumping systems powered by photovoltaics (PV) (Singh et al., 1998). Research had been done by Verma et al., 2020 regarding the types of motor used. Table 2.2 describes the DC motors which were broadly used in Solar Powered Water Pumping System (SPWPS).

Table 2.2 Types of motors used in SPWPS

Type of Motor Used	Type of Pump Used	Features	References
DC shunt motor	Centrifugal pump	Steady state dynamics analysis is performed on a mathematical model. Over the course of the day, the motor's speed remains constant, and its efficiency exceeds 75%. Voltage and current overshoots only last for a short time.	(Metwally & Anis, 1996)
Switched reluctance motor	Centrifugal pump	When compared to DC or induction motors, SRM are more efficient and cost-effective. Up to 85% motor efficiency and up to 95% system efficiency are possible. The pump and the pipe system accounted for three-quarters of the total possible energy losses.	(Metwally & Anis, 1994)

Table 2.2 Continued

Type of Motor Used	Type of Pump Used	Features	References
Brushless DC motor	Helical rotor pump	Minimal weight/torque ratio, great efficiency (80–90%), and low maintenance are all hallmarks of the BDCM design. In order to model the whole system, PSI/e was used. Achieved in the range of 30 to 50% efficiency, which excludes the array system.	(Langridge et al., 1996)
Induction motor	Centrifugal pump	The higher the frequency, the better the IM's system efficiency, although it is best to keep it minimal for best results. Experimental data from a system deployed in Jordan's desert area was used to verify the simulation findings, and they were found to be quite close.	(Daud & Mahmoud, 2005)

2.2.6 Advantages and disadvantages of solar water pump

After scientists became aware of the detrimental effects that the combustion of fossil fuels had on the environment, their research efforts shifted toward the development of self-contained water pumping systems that are capable of being run by energy derived from renewable sources. With the rise in PV panel prices owing to advances in PV technology, employing solar-powered water pumping systems becomes more viable economically because of the difficulties connected with fossil fuels, such as their availability, shipping costs, price, and environmental impact (Foster & Cota, 2014). Pumping water may be accomplished with the help of a variety of non-traditional forms of energy. In spite of this, the solar photovoltaic (PV) system emerged as the most viable option. It has been shown that the availability of solar energy has a direct correlation with the need for water, despite the fact that solar energy is both clean and naturally abundant (Ula, et al., 2008). In many areas where there is a significant demand for water and the electric grid does not reach, the sun intensity is great. This presents an opportunity for solar power generation. In order to directly create electricity, photovoltaic panels take use of the sun's rays. This electricity may then be utilised to power electrically driven water pumps. Table 2.3 is showing the comparison of the previous study about the current solar water pumps with the pump type and motor type. It can be concluded that most of the solar water pump nowadays are focusing on agriculture, irrigation or domestic usage.

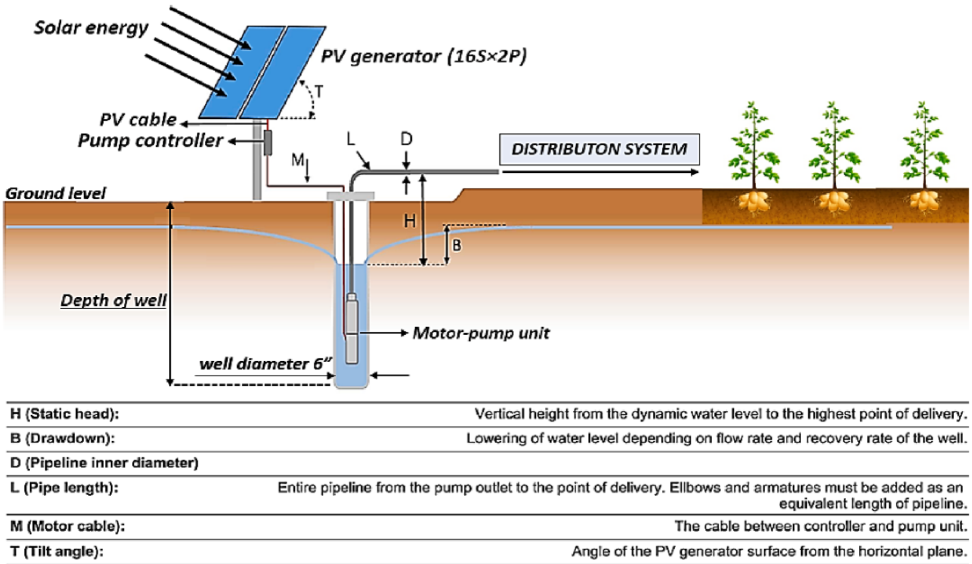


Figure 2.9 Design of solar water pump for agricultural

Source: Chahartaghi & Nikzad (2021)

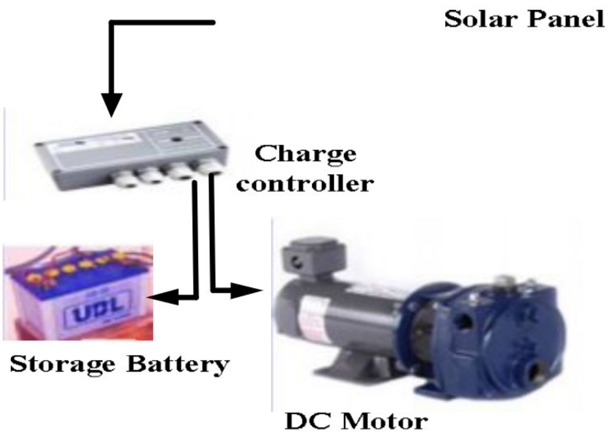


Figure 2.10 Design of solar water pump for rural

Source: (Yin Min Nyein & Aung Ze Ya 2011)

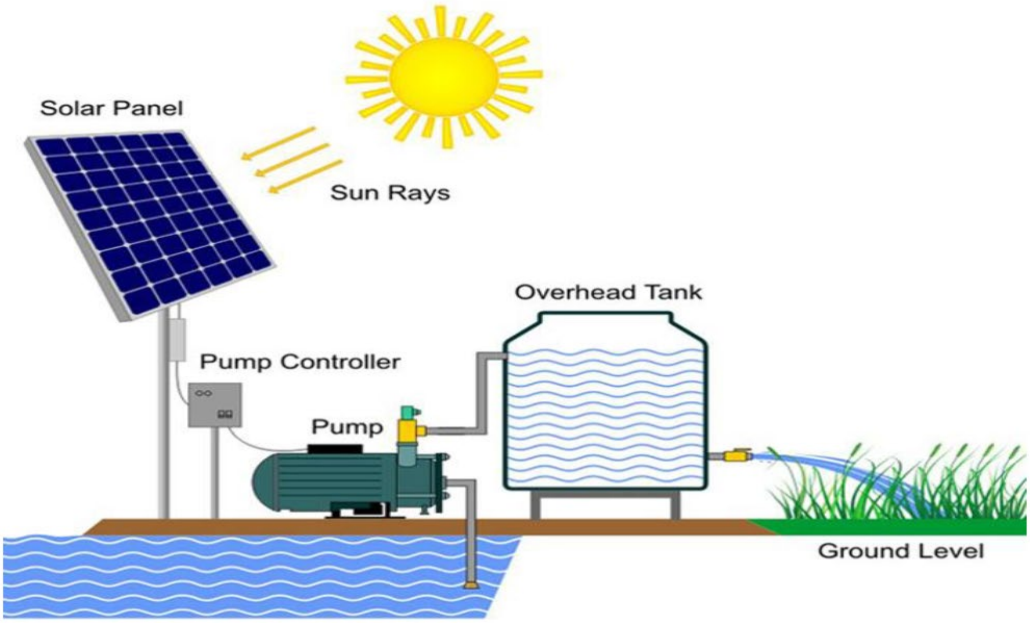


Figure 2.11 Design of solar water pump for irrigation

Source: Izzat Malak (2016)

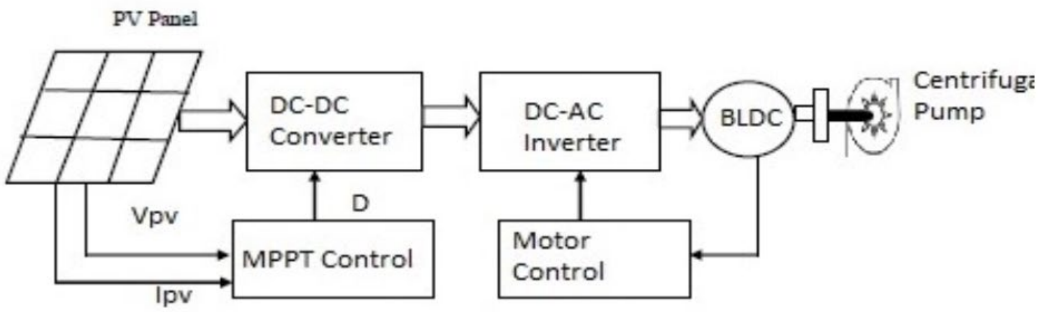


Figure 2.12 Design of solar water pump for domestic water pumping

Source: Nisha & Gnana Sheela (2020b)

Table 2.3 Study of solar water pump

Case location	Study Purpose	Pump type	Motor type	How it works & remarks	References
Isfahan	Agriculture	Multistage centrifugal	AC	The electrical need to start the motor-pump unit which is connected to a distribution system to irrigate the crop is given by irradiating the solar array with sunlight at an ideal angle of inclination. The motor-power pumps and efficiency, as well as its speed and discharge characteristics, are unaffected by changes in the outside temperature.	(Chahartaghi & Nikzad, 2021)
Myanmar	Rural	Single-state centrifugal pump	DC permanent magnet motor	The working flow is simple where the energy is collected by solar panel then transfer to charge controller and then to storage battery or directly to the DC motor to operate the pump. DC motor is a pleasant preference because photovoltaic modules only procedure direct current, and less specialized power conditioning equipment is needed.	(Yin Min Nyein & Aung Ze Ya, 2011)
Ifrane, Morocco	Irrigation	Surface, submersible pump (centrifugal pump)	DC	The photovoltaic (PV) array powers the water pumps. The pump, controller, and array are three components. If there is sunshine and water to pump, the system is supposed to work. It is a good to have either water storage or to have the array 'oversized' to pump water in low light circumstances. Solar water pumps may work with changing voltages and currents since DC technology is applied in them.	(Izzat Malak, 2016)

Table 2.3 Continued

Case location	Study Purpose	Pump type	Motor type	How it works & remarks	References
India	Domestic water pumping	Centrifugal pump	BLDC motor	The water is held in tanks and works as a storage system, removing the need for a battery. PV arrays are made up of a series-parallel mix of PV modules that are connected in series to meet the voltage requirements, and the PV output power fluctuates with the fluctuation in solar insolation. To run at a voltage that provides the most power, several MPPT Algorithms are employed in conjunction with DC-DC converters or inverters. The DC-DC converter output is fed into a three-phase VSI, which powers the synchronous motor. The total efficiency of the solar water pumping system was found to have been increased by better system design and load matching employing BLDC Motor.	(Nisha & Gnana Sheela, 2020b)

2.2.7 Pump head

The accuracy of the pump head selection is critical in determining total efficiency. The pump head, often known as the discharge head, is a measurement of the pump's power. The greater the pump head, the more pressure the pump can create. Benghanem et al. investigated the performance of several pump heads which are 50 m, 60 m, 70 m and 80 m in 2014 (Benghanem et al., 2014). The experiment takes place in a genuine well on the farm near Madinah, in bright sunlight. With a SQF submersible pump, it was found that the highest efficiency at 80 m head. The results of the experiment showed that the flow rate is dependent on the pumping head and solar irradiance level, with system efficiency increasing when the pumping head is reduced under low solar irradiance. When the insolation level rises, the system efficiency rises along with the input power to the subsystem, and the system reaches its rated state at a greater efficiency (Odeh et al., 2006). As the rated pump speed is attained, the insolation level becomes less essential, and the pump head becomes the most critical element in determining subsystem efficiency.

2.3 Solar energy

Renewable energies are increasingly broadly employed as choices to traditional fossil fuels, which have caused significant air pollution and global warming, to build ecologically sustainable cities and societies (Javed et al., 2021; Ma et al., 2015). Solar energy which is one of the renewable energies is the radiant energy that the sun produces, and the sun radiates or sends out a vast quantity of energy every day. Solar energy has been used in a variety of applications as a vital renewable energy source (Ma et al., 2014). Solar thermal energy, ocean thermal energy conversion, solar ponds, solar towers, and photovoltaic systems are just some of the technologies that are presently being utilised to collect the sun's energy.

2.3.1 Solar radiation

The energy generated by the sun that shines on the earth is known as solar radiation. Kilowatts per square metre (kW/m^2) is a standard unit of measurement. At its outer atmosphere, the planet gets a relatively constant 1.36 kW/m^2 of solar energy. By the time this energy reaches the earth's surface, however, the entire quantity of solar radiation has been decreased to around 1 kW/m^2. The strength of sunlight or solar radiation changes according to the location. The north and south sides of a mountain serve as a good analogy for illustrating this disparity. Because the sun's energy must pass through varying amounts of the earth's atmosphere as the incidence angle of the sun changes, the intensity of sunlight fluctuates depending on the time of day. During solar noon, when the sun is directly above and light is passing through the least amount of atmosphere, solar intensity is at its highest. Early in the morning and late in the afternoon are the times of day when the sun is at its weakest since it has passed through the maximum amount of atmosphere. The most productive hour of sunshine is when solar radiation levels reach 1 kW/m^2 are between 9:00 a.m. and 3:00 p.m. in most places. Solar electricity may still be produced outside of this time frame, although at considerably lower levels.

When solar radiation enters the atmosphere, it takes a new direction. It is broken down into three distinct pathways. For starters, when dust, gas, ice, and water vapour are present in the atmosphere, scattering occurs. It dispersed more with shorter wavelength energy than with longer wavelength energy. Scattering and how it reacts with different wavelength sizes are demonstrated through the atmosphere, which features a blue sky and white clouds. Second, when solar radiation is absorbed by water, its energy is transferred to the water, raising its temperature. This is true of all absorbent surfaces, from the leaf of a tree to asphalt. A material absorbs solar light and converts it to heat energy. Finally, albedo is reflection. The proportion of total reflection is expressed by albedo, which is a reflecting characteristic of a surface. The visible and deeper colours indicate that it has a low albedo, whilst the lighter colours indicate a greater albedo. The angle of the sun affects the value of albedo because the energy is not as powerful at a lower angle as it is at a higher angle. Furthermore, smooth surfaces have a greater albedo, whereas rough surfaces have a lower albedo.

Peninsular Malaysia naturally has high levels of solar radiation due to its location near the equator and the fact that it is a tropical nation with year-round daylight. However, even during the most severe droughts, it is highly unusual to have a whole day with the sky being fully clear. Peninsular Malaysia has around six hours of sunlight each and every day on average. The amount of time spent in the sun has a significant impact on solar radiation. As a result, its seasonal and geographical changes are quite comparable to those of sunlight (Shavalipour et al., 2013).

2.3.2 Solar irradiance

Solar irradiance refers to the amount of solar energy received by or projected onto a certain surface. Also, the material's surface is used to measure solar irradiation, which is expressed in kW/m^2. The solar panel serves as this surface in a PV-powered system. Solar irradiance is an essential component in the study of meteorology, hydrology, and climate change, as well as the use of renewable energy (Nourani et al., 2022). Solar irradiance is seldom measured because of the constraints imposed by both technology and expense, despite the fact that it is very important (Nourani et al., 2019).

2.3.3 Solar insolation

The quantity of solar irradiance measured over a certain duration is known as solar insolation. Typically, solar irradiation is measured using peak sun hours, which are the same number of hours per day when solar irradiation is 1 kW/m^2. As a reminder, although though the sun is visible for 14 hours of the day, it only produces enough energy for six peak sunlight hours.

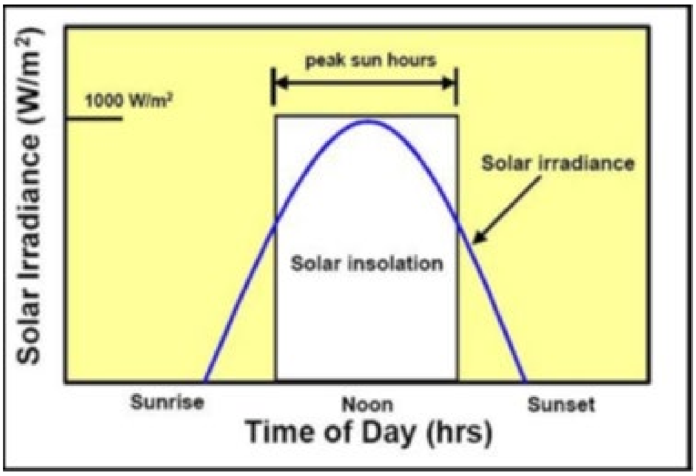


Figure 2.13 Solar irraidance and peak sun hours

Source: Morales (2010)

Figure 2.13 shows how to calculate the peak solar hours for any given day. In order to calculate the number of peak sun hours for a given day, solar irradiance which is represented by the blue arc is divided by 1 kW/$m^2$is indicated by the white rectangle. Peak sun hours and equivalent full sun hours are synonyms for the term "peak sun hours" (solar insolation). It is common to use the term "solar radiation" to refer to hours of uninterrupted sunlight.

2.3.4 Solar angle

The solar angles may be used to determine the location of the sun in the sky from any point on the globe (Tilt and Azimuth angles). The tilt angle has a important impact on the PV (photovoltaic) panels' capability which is the performance of the solar PV array. This is as a result of the fact that the amount of solar radiation that is allowed to reach the surface of the photovoltaic panel varies depending on the tilt angle (Sado & Hassan, 2018). To get optimal power production, it is critical to position the PV panels at a tilt angle for any site. When solar panels are perpendicular to the sun's beams, they are most effective. The Azimuth and Tilt angles are shown in Figure 2.14 (Twidell & Weir, 2006). However, the sun's course and height change throughout the year. On June 21st, the highest point in the sun path will have the highest height angle value, and on December 21st, the lowest. From dawn to mid-day, the tilt angle lowers until it reaches its lowest point, then climbs until it reaches 90° at sunset. Table 2.4 has shown the previous study done by researchers about the optimum fixed tilt angle of solar panel at different places in Malaysia. It can be concluded that the best angle is at the range of 0° to 30° at different location in Malaysia.

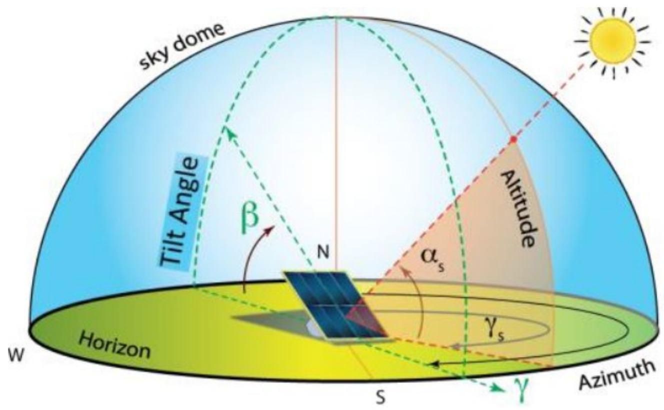


Figure 2.14 Solar tilt and azimuth angle

Source: (Sarkar, 2017)

Table 2.4 Study of Optimum fixed tilt angle of Solar Panel.

Case Study	**Optimum-fixed tilt angle**	**Applied tool**	**Method**	**References**
Ipoh, Perak	0° or tilt angle = latitude of location	-	Collares-Pereira and Rabl	(Sunderan et al., 2011)
Kuala Lumpur	15° to 30°	PVSYS-50, Excel, Matlab	-	(Elhassan et al., 2011)
Perlis	-17.16° to 29.74°	-	-	(Daut et al., 2011)
Kuala Terengganu	0° to 23°	Matlab	Liu and Jordan	(Khatib et al., 2012)
Kuala Lumpur	10°	Excel	Cooper's equation	(Omidreza et al., 2012)

2.3.5 Photovoltaic (PV) panels

A photovoltaic array is made up of one or more PV modules, which are collections of PV cells that are connected electrically in series and parallel in order to generate a certain current and voltage, when subjected to a specified amount of irradiance (Hamidat & Benyoucef, 2009). The PV solar cells are the primary element of the PV module. These cells are responsible for the immediate conversion of the solar radiation that is received on their surfaces into electric energy (Benyoucef et al., 2007). PV panels, as seen in Figure 2.15, comprises a sequence of solar cells.

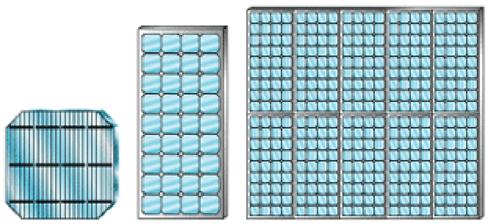


Figure 2.15 Solar cell, PV solar panel, and PV panel array

Source: Morales (2010).

Solar cells generate direct current (DC) energy when exposed to sunlight and include two or more layers of specially prepared semiconductor material. These layers are composed of either crystalline material or thin film material (Morales, 2010). The amount of power that is generated by the PV cell array is equal to the product of its voltage and current (Helikson et al., 1991). A common solar cell able to produce around 3 watts of power in direct sunlight. A thin film or crystalline semiconductor layer may be employed. The efficiency of silicon-based crystalline solar cells is about 15%. Efficiency ranges from 8% to 11% for thin-film solar cells, which may be built of any number of different metals. Silicon solar cells are significantly more durable, but they are also heavier and more expensive. There are several elements that affect the effectiveness of solar PV panels, including the material used to produce electricity, the quality of workmanship in solar PV panel installation, environmental conditions, dirt on the PV panel and design. The solar PV panels are covered with dust and debris that prevents the sun's rays from accessing the surface. As a result, it is necessary to clean the solar PV panels (Ekinci et al., 2022).

2.3.6 Solar photovoltaic energy conversion

Both the solar thermal and solar photovoltaic methods are the two approaches that can be used to transform the solar energy from the sun. PV modules and arrays are only one component of a PV system. This system consists of a variety of mounting structures that face south towards the sun, as well as components that convert DC to alternating current (AC) power that may be used for devices or machines in the house. The solar photovoltaic technique is employed in the experiment, and the solar photovoltaic panel is based on the conversion concept that when light strikes a semiconductor, energy is produced, and it causes the flow of electrons, which is converted into electrical energy.

2.3.7 The photoelectric effect

PV systems use the photoelectric effect to turn the sun's energy into electricity. As depicted in Figure 2.16, Electrons in a material are stimulated and jump from one layer of conductivity to the next when incoming photons make contact with a conductive surface, such as a silicon cell or metal sheet. The excitation of electrons and their transfer from the p-layer to the n-layer causes a voltage difference across the electrical circuit in this illustration, prompting electrons to flow through the remainder of the circuit to maintain charge balance. The system is set up so that the external circuit has an electrical load, allowing the current flow to execute a beneficial purpose. In other words, the behaviour of electrons in a solar cell produces a voltage that may be used to power a water pump system.

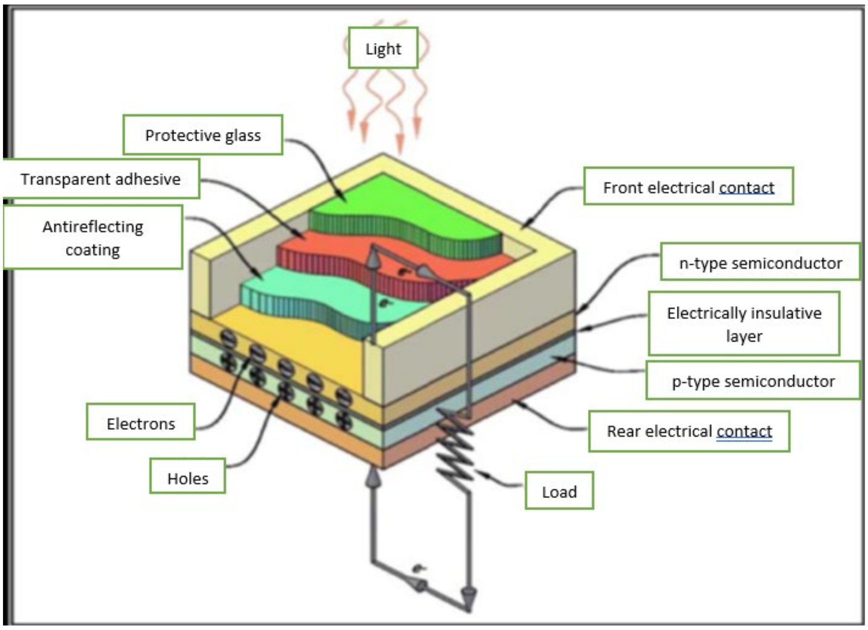


Figure 2.16 The photoelectric effect and subsequent electron motion

Source: Morales (2010).

2.3.8 Battery types

For the purpose of storing chemical energy in the form of electrical energy, a battery is an essential component of stand-alone solar PV systems. When using a battery, the chemical energy it contains is transformed into electrical energy. A battery's voltage is measured in volts (V), its capacity is measured in Ampere-hours (Ah), and it has a maximum current, which is significant for starting an engine. When it is required, the energy that has been stored in the batteries may be drawn out to power electronic devices. Batteries are available in a variety of sizes, forms, voltages, and storage capacities, allowing for the selection of batteries to be dependent on their intended use and purpose. These batteries include single-use (non-rechargeable) batteries as well as multiple-use (rechargeable) batteries. There are four basic varieties of batteries, depending on the technology: lead (Pb), nickel cadmium (Ni-Cd), nickel metal hydride (NiMH), and lithium (Li) (Kamouny et al., 2017). Table 2.5 shows a comparison of the various types of batteries available on the market today.

Table 2.5 Four major types of batteries

Specifications	Lead (Pb)	Nickel-Cadmium (Ni-cd)	Nickel Metal Hydride (Nimh)	Lithium (Li): Li-ion et Lipo
Energy/weight	20-40Wh/kg	20-40Wh/kg	30-80Wh/kg	100-250Wh/kg
Energy/volume	40-100Wh/l	20-150Wh/l	140-300Wh/l	200-620Wh/l
Life duration	4-5 years	2-3 years	2-4 years	7 years
Number of charge cycles	400-1200 cycles	1500 cycles	500-1200 cycles	1200 cycles
Voltage/item	2.1V	1.2V	1.2V	3.6V or 3.7V

Source: Kamouny (2017).

2.3.9 Solar charge controller

A charge controller is a device that regulates the pace at which electricity is transferred to or from a battery. It keeps the battery from overcharging in order to keep the amount of energy given to the battery by the PV array from increasing when the battery is completely charged, and it may keep the battery from overvolting, which would degrade its performance. Solar panel voltages are often greater than battery voltages, which is advantageous if the battery requires extensive recharging but disadvantageous if it is nearing full charge. The solar charge controller checks the voltage of the battery and determines how much current may be safely sent into it. The voltage is then chopped up into pulses of the same voltage by the circuit. When the pulses are longer, the average voltage and charge current increase. The voltage and charge current are lower when the pulses are shorter. The pulses are longer at the start of a charge cycle when more charge current is needed for quicker charging and shorter at the finish. The act of disconnecting the battery from electrical loads when the battery has very little charge is considered over discharging (Khera et al., 2016).

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter is focusing on the methods and procedures that need to be carried out to achieve the objectives of this project. The selected methods have been taking every aspect into consideration to assure that the solar water pump for aquaculture is performing well. The methodology including material selection, methodology flowchart, designing and technical analysis planning. Moreover, the process flow of the project which are design and fabrication process of the solar charging system and the modification of the purchased water pump will be presented.

3.2 Flow process for solar water pump for aquaculture

Figure 3.1 shows the overall fabrication process of the solar water pump for aquaculture. Firstly, the project is started by identifying the component that need to be used to make the solar water pump. The design of the water pump is using a Siemens NX software. After that, process of material selection is done by literature review. The fabrication of the water pump was completed after the type of material used was decided. When the fabrication is done, the solar charging station was tested by checking the battery can be charged by the solar charging station. If it cannot be used, the solar charging station will be modified. After that, the water pump was fabricated and modified. Testing and analysis will be conducted to the water pump to evaluate the performance of the water pump.

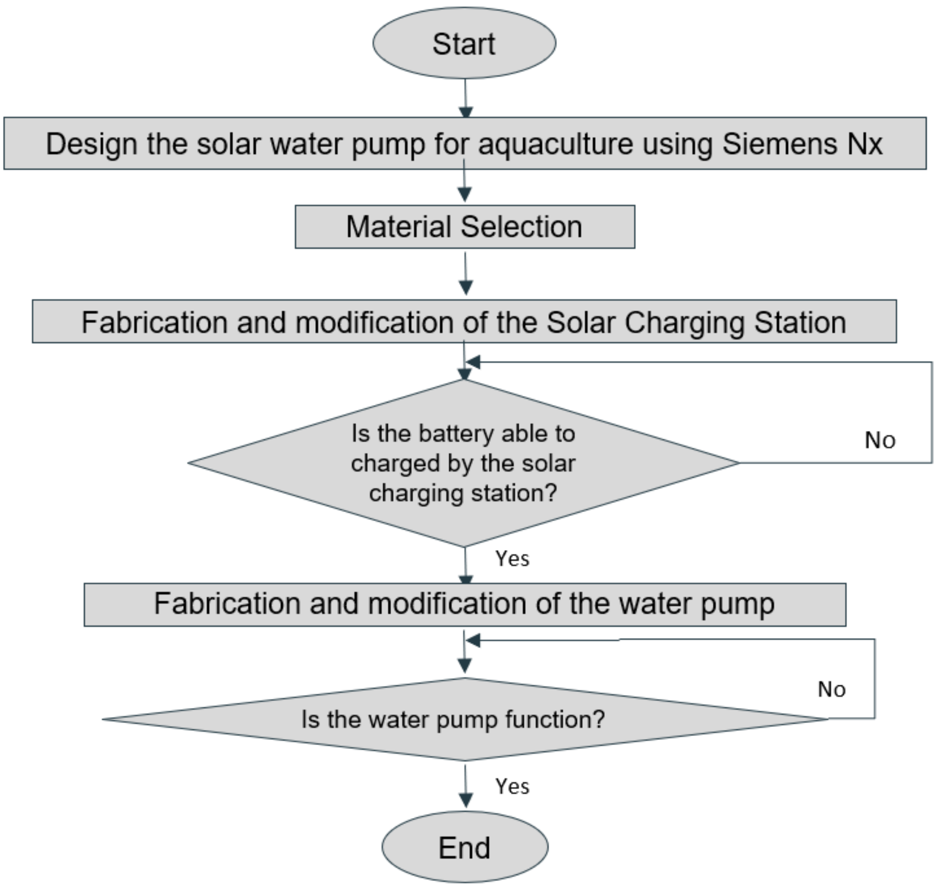


Figure 3.1 Flowchart of overall fabrication process

3.3 Evaluation of solar energy power supply

Figure 3.2 shows the flowchart of evaluation of solar energy power supply. Firstly, the weather will be observed. If it is rainy or cloudy, the evaluation will be delayed until the weather is sunny. The starting time to take the reading is 9 a.m. The solar charging station was tested outdoor, and the solar panel was opened 45° and facing North. A thermometer was used to measure the ambient temperature around the solar charging station. Solar power meter was used to measure the solar radiation flux density. Then a clamp meter was connected to the solar panel and measure the voltage. The reading was recorded, and the steps were repeated at different time, angle and direction such as South, East and West.

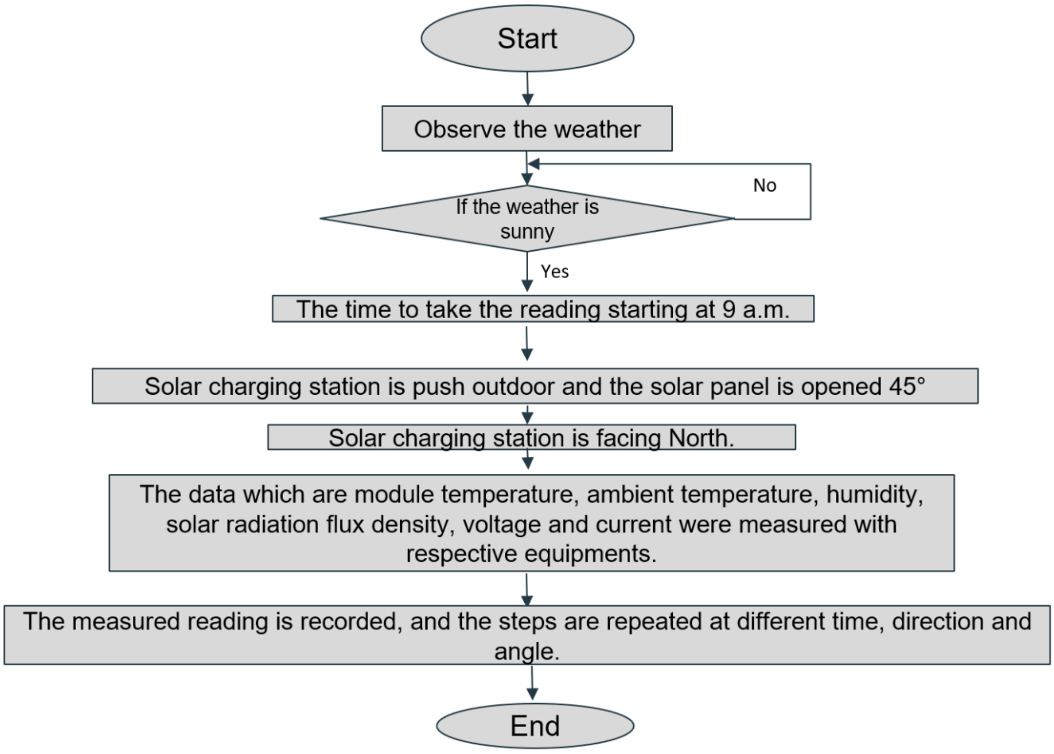


Figure 3.2 Flowchart of evaluation of solar energy power supply

3.4 Flow process of operating the solar water pump for aquaculture

Figure 3.3 shows the flowchart of operation process of solar water pump for aquaculture. Firstly, the solar charging station is set up outside under the sun during daytime. The solar charging station is adjusted to the best angle and face to the suitable direction which had been evaluated during section 3.3. Then the battery will be charged using the solar charging station. Then, the battery will be connected to the motor of the water pump. When the arrangement and connection are done, the rocker switch can be switched on. After that, the motor will be rotating, and the water pump will draw out the water from the pump. The drawn water is then release out from the pump. The switch is turned off when the water drawing process is stopped, or the battery usage is finished. Finally, the battery is taken off and charge for the next usage.

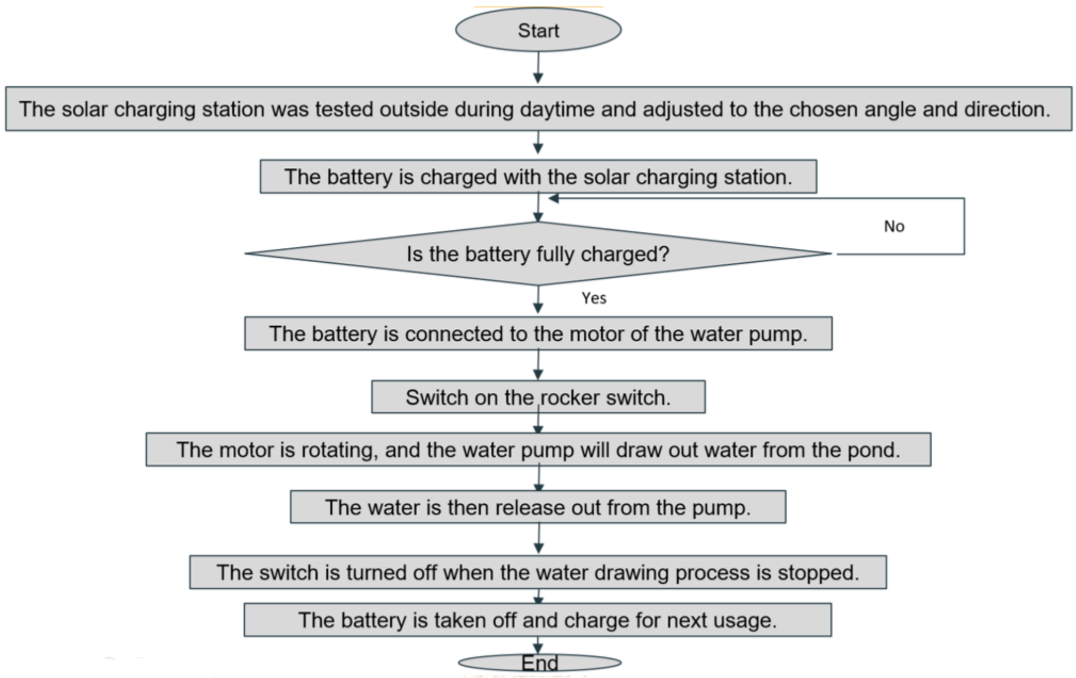


Figure 3.3 Flowchart of operation process of solar water pump for aquaculture

3.5 Designing process

The mechanism for the solar charging station was developed independently since it may operate as a portable storage to store the water pump. The charging station can accommodate a water pump, hoses, an auxiliary battery, a motor, and a toolbox for assembling the solar water pump. The solar panel on the charging station is movable which can be moved left and right to increase power while also serving as a storage cover. The solar panel may also be lifted to have an angle of 180°. The goal of the design is to increase the surface area of the solar panel's exposure to the sun. More exposure to the sunlight implies that more voltage may be generated.

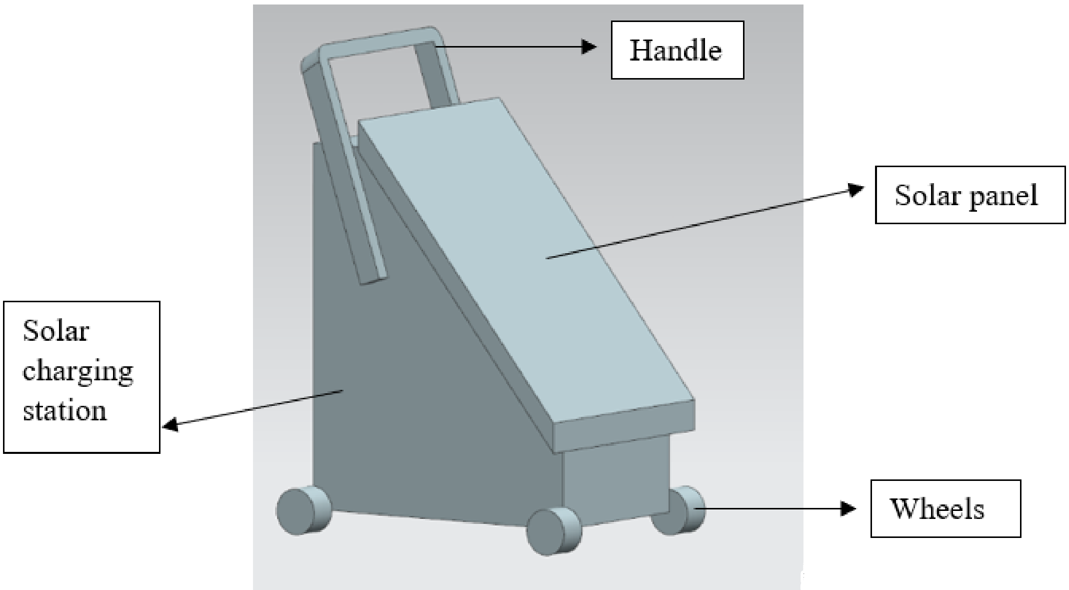


Figure 3.4 Solar charging system model

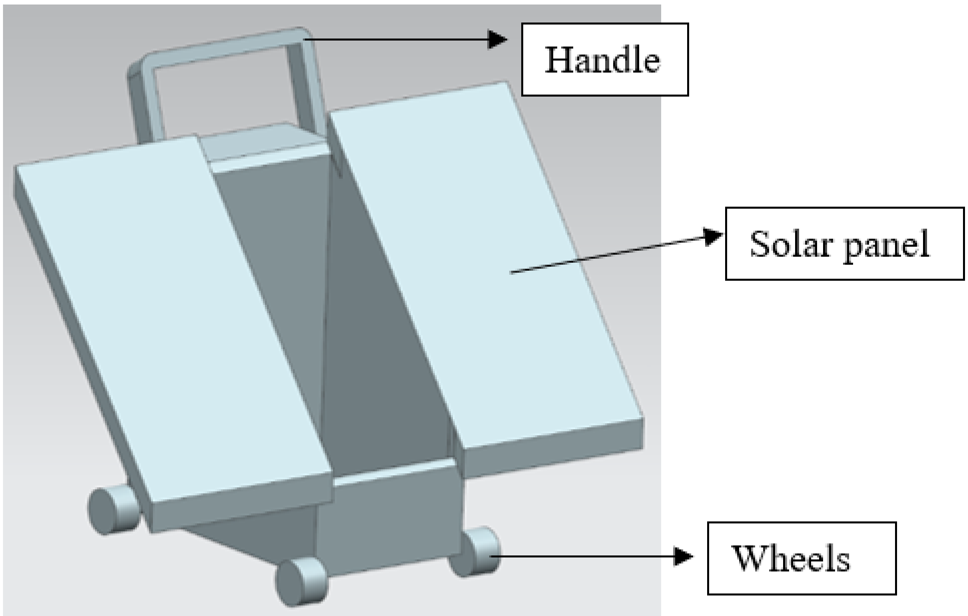


Figure 3.5 Opening of the solar charging station

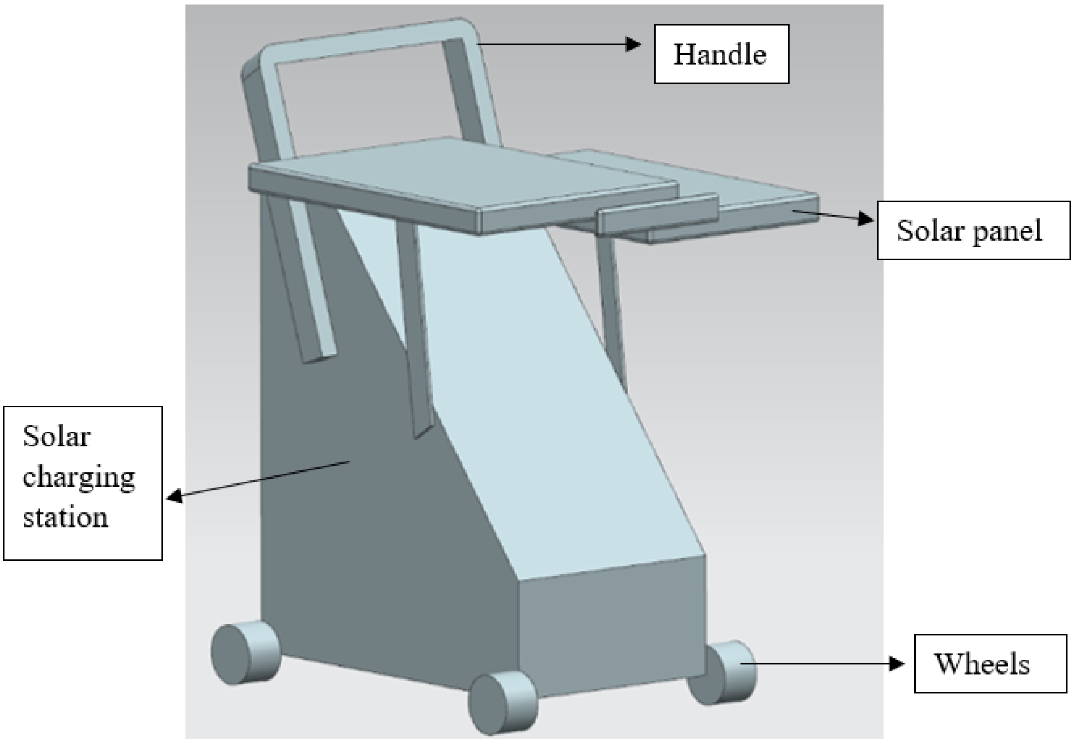


Figure 3.6 180° Opening of the solar charging station

The water pump is designed as in the Figure 3.7. The overall water pump basically shall include a battery, a DC motor, a pump and two hoses. One end of the motor will connect to the pump while the other end will connect to the water with the aid of wires. Switch is designed to set up after the motor to control the on and off the water pump. Moreover, the water pump is designed in a bigger and suitable size in order to transfer more amount of water. One of the hoses will connect to the straight side of the motor which act as the inlet and the other end is act as the outlet of water. Figure 3.8 to Figure 3.12 showed the dimensions design of the centrifugal water pump.

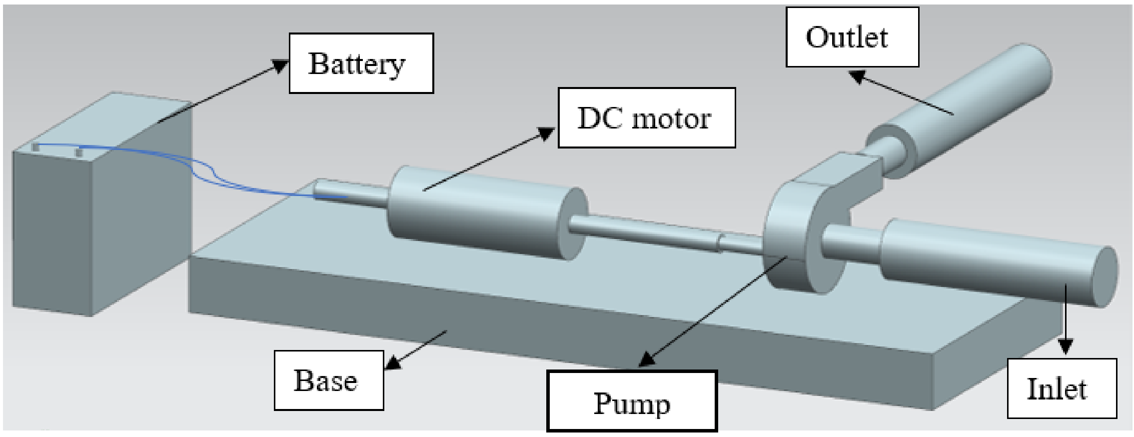


Figure 3.7 Water pump with battery

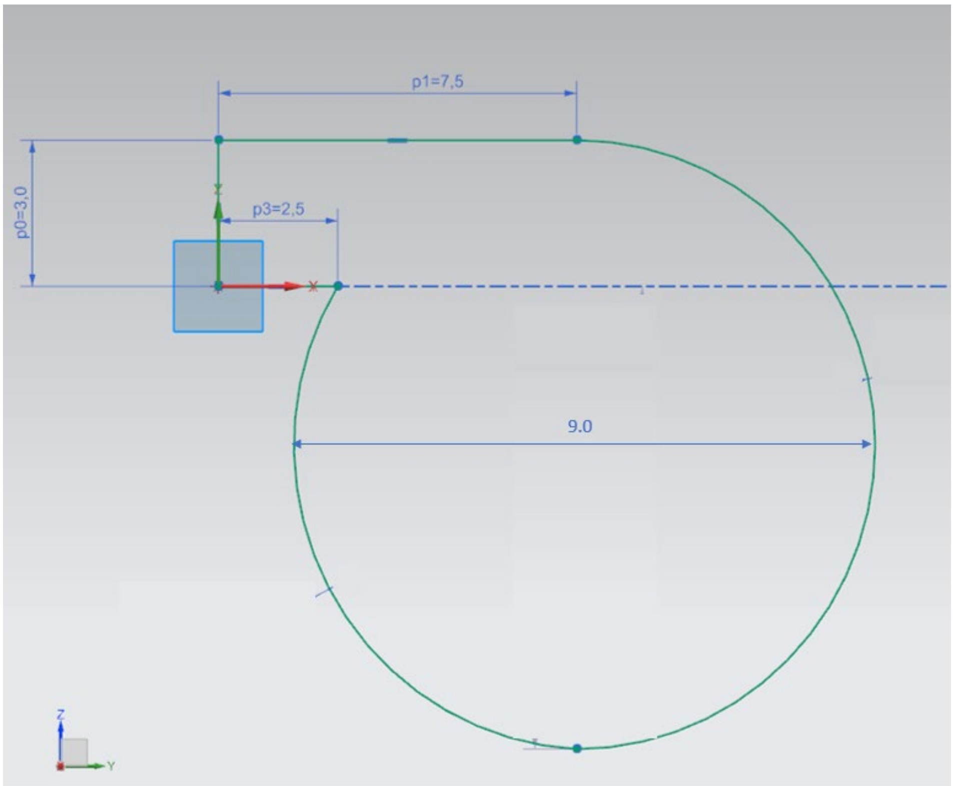


Figure 3.8 Dimension of the water pump

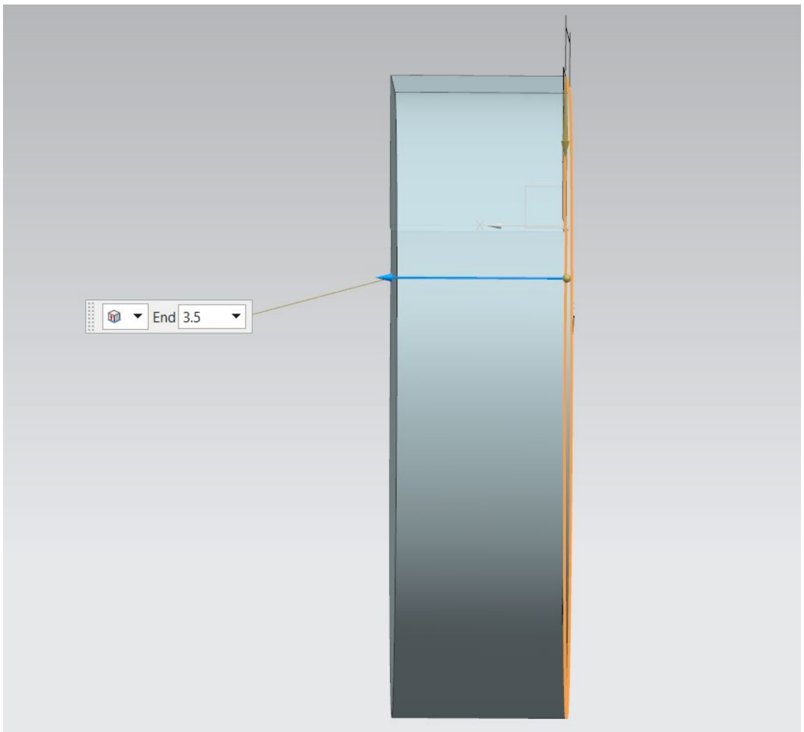


Figure 3.9 The width dimension of the water pump

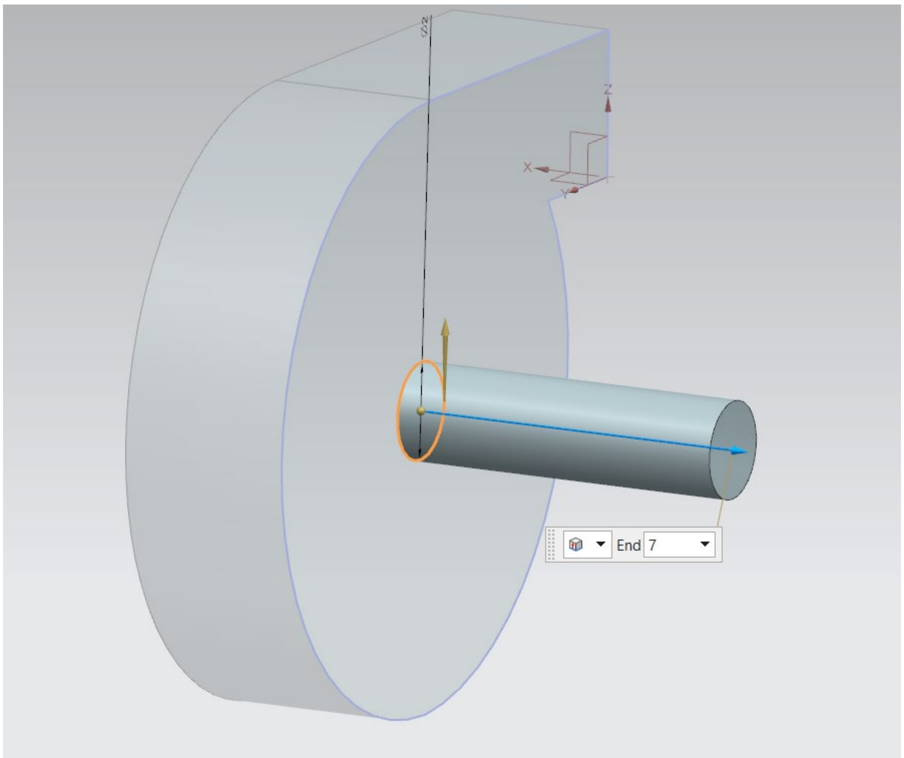


Figure 3.10 3D dimension of the inlet of the water pump

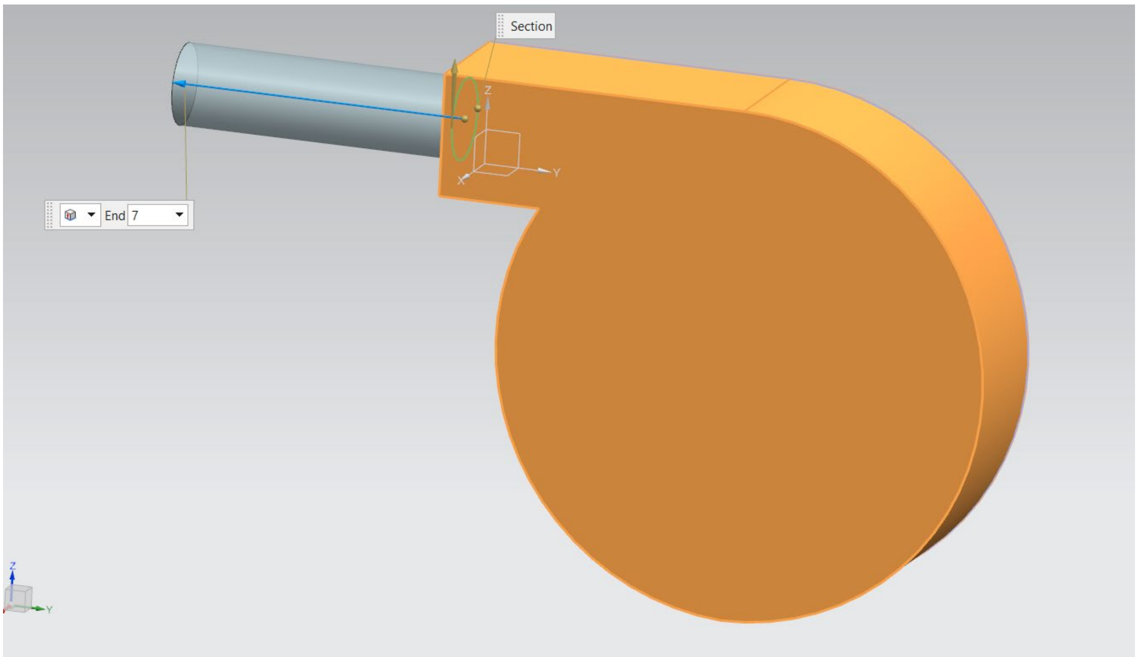


Figure 3.11 3D dimension of the outlet of the water pump

3.6 Material

While designing the Solar Water Pump for Aquaculture, the materials needed are very important in order to make the project successful. After the designing stage of Solar Water Pump for Aquaculture was completed, material selection was carried out to identify the ideal and proper equipment and materials. If one of the materials or equipment is missing, then it will cause the project to not function as desired. The materials needed are listed by part below.

Table 3.1 Description of the material selected.

Material	Description
12V Battery	In order to run the water pump, a 12V, 7.0Ah SLA battery is needed. In addition, the battery is rechargeable, and it operates on the power gathered from the solar panel and stored inside.
Solar panel	A 30-watt solar panel is used in conjunction with a battery to give power to the battery. It was designed to be adjustable in order for the user to get as much as possible of the available sunlight.

Table 3.1 Continued

Material	Description
Charge controller	Using a charge controller, it can prevent the battery from overcharging by limiting the voltage and current that is sent from the solar panel to the battery cell.
Temperature sensor	The solar panel's performance data is collected by using a temperature sensor, which allows researchers to investigate the correlation between temperature and voltage. For example, the higher the temperature, the lower the voltage or vice versa.
Aluminium zinc sheet	The cover for the body structure of the solar charging station is made of aluminium zinc sheet. The aluminium zinc sheet is a low-weight material with exceptional corrosion resistance for example, aluminium is widely used in aerospace applications.
Hollow bar	For the frame of the solar charging station, hollow bar steel is utilised as a reinforcement. It was chosen for this project because of its minimal weight. Dimension for the body frame is 36 cm x 70 cm x 64 cm.
Wheels	The solar charging station is equipped with wheels measuring 4 inches in diameter. It is utilised to make the charging station portable, which makes it more convenient to use.
Plastic hose	Two plastic hoses are required to put at the outlet and inlet of the water pump for the flowing in and out of the water.
DC motor	DC (direct current) motors are handier and more portable since they can get their power straight from a battery. They are simpler to use and control than other options. DC motors are often more energy efficient than their AC counterparts.
2’’ flat head tapping screw	The screws are used to screw up the DC motor with the wooden based.

Table 3.1 Continued

Material	Description
3/4'' flat head tapping screw	The screws are used to screw up the water pump with the wooden based.
Impeller	The energy that is generated by the motor that is driving the pump is transferred to the fluid that is being pumped by the impellers, which cause the fluid to accelerate radially outward from the centre of rotation.
Rocker switch	Connection and disconnection of the circuit are accomplished by using a rocker switch. In electrical devices, it is utilised as an ON/OFF switch on the primary power sources for the devices.
Wire	The wire is having the diameter of 12 gauge or around 2mm. The wire is chosen in a thicker size because it can reduce the surface temperature and this help to reduce the dangerous heat of it through its ability to withstand high amount of heat, hence increasing its durability. Moreover, the thicker wire can be bent or twisted almost to any form or shape without breaking.
Insulated electrical wire terminals crimp connector	The connectors are prepared with 2 different sizes which are 0.7cm and 0.5cm to connect to the end of the motor and the rocker switch without soldering the wire to the end.
Iron cylinder	The iron was made into a cylinder shape with the diameter of 0.669 inch (1.7cm). The cylinder will be use as the inlet and outlet of the water.
Petronas green 62 spray paint	The spray paint is used to colour up the water pump to prevent rusting and make the wooden based to be look nicer as the wooden based are the raw wood.
L-shaped bracket	The brackets were made by welding process, and they will be used as the support of the water pump to allow it to stand and also connect to the wooden based.

Table 3.1 Continued

Material	Description
U-shaped bracket	The brackets were made by welding process, and they will be used as the support of the DC motor to allow it to stay stationary while operating and also connect to the wooden based.
Wood	The wood are cut into desired shapes to make as the based for the water pump and the DC motor.
Shaft and bush	The shaft is a rotating machine element, that is circular in cross section. It is used to transmit power from one part to another. The bush is a mechanical element used to reduce friction between rotating shafts and stationary support member.

3.7 Fabrication and modification phase for solar charging station

Fabrication is the process of manufacturing goods by integrating usually standardised elements using one or more independent processes. Fabrication may include more than one process at a time. Fabrication may result in the production of finished goods, or it can result in the production of components that are subsequently used in the production of those goods. To shape, cut, or mould raw material into a finished product, popular fabrication methods include cutting, punching, forming, shearing, stamping, and welding. As soon as the design and the selection of the materials have been finalised, the fabrication process may begin. This process started out with the fabrication of the solar charging station system.

Hollow bar steel was decided as a chosen material to construct the charging station's body structure for the body of the solar charging station. Each piece of hollow steel was welding together to produce a strong body structure. The body frame's dimensions were 36 cm x 70 cm x 64 cm. The holder for the solar panels must be designed and were constructed. The holder was slid in between the two solar panels to function as a storage door which cause the solar panels are adjustable and doing so will maximise the sunshine exposure that the surface of the solar panel receives when it is opened horizontally either in 180° or 45°. This was the primary motivation for the design of the product.

Solar panel holders were then weld to the body frame and charging station wheels where the diameter of the wheel is four inches may be attached to the body frame if desired. An aluminium zinc sheet was used to cover the frame. Then, wire preparation and clamping was required in order to connect the two solar panels in a parallel configuration. Following completion of all other tasks, the solar panel may then be attached to the solar panel holder.

3.8 Fabrication and modification phase of water pump

The fabrication of the solar water pump will be continued after the solar charging station was completed. The water pump will be designed using closed impeller design with four vanes and as substitute to the centrifugal pump. The materials chosen such as iron pieces, shaft connector, shaft and bush are mostly unusable hence the design can reduce solid waste and the cost of the product.

Firstly, a hole of the screw was made according to the size of shaft. Two circular plates will be made from iron sheet. The modified screw will be inserted in one plate and welded, and the shaft will be inserted to it. Then, the iron sheet fins that had been cut out were welded on the plate and the other plate which a larger hole that had been cut off was placed on it and welded. After that, two more iron sheets were cut out roughly in the shape of six. The bush was put on one of the sheets and it was used as the outside cover where it later connected with the motor. A shaft connector was used to connect the different size shaft of motor and the pump.

One hole was cut out from the other sheet and the hole was connected using an iron sheet cylinder by welding which make it as the inlet. Two parts of 6 shape iron sheets were connected to each other when the impeller had put between the two sheets and welded properly to ensure no leakage of the water from interior. The iron cylinder made by the iron sheets was connected as the outlet of the impeller. The whole product was sprayed with paint to prevent rusting.

Lastly, the motor which had done wiring process was connected to the pump. The wiring was able to connect the motor to the 3 legs rocker switch and the battery which as the on and off controller and the power supply of the water pump. Then, the motor and the water pump were put on a piece of wood and fixed it on it by screw up the bracket that made by the welding process. This can prevent the water pump and motor do not move around during the operation which can affect its' efficiency. Testing and analysis were conducted to the solar water pump for aquaculture to evaluate the performance of the water pump and does it function properly by drawing out water from the pond and release it through the use of the pump.

3.9 Testing and analysis of the solar charging station and water pump

The solar charging station was tested through checking its production output which is voltage and current based on different orientation and angles. From 9:00 a.m. until 4:00 p.m. local time in Kolej Kediaman 2, Universiti Malaysia Pahang, Gambang, Kuantan, Malaysia with the longitude of 103°07'27.18'' E and latitude of 3°43'48.96'' N, PV output voltage, current, ambient temperature, module temperature, humidity, and solar radiation flux were measured by using digital multimeter, thermometer, humidity meter and (TES 1333) solar power meter. Each data parameter was gathered every hour at the empty space where no blockage of sunlight toward the solar panels to determine the wattage efficiency of the PV panel. Figure 3.12 are showing the environment of the reading taken according to different cardinal direction starting from North to South. Appendix I to Appendix M are showing the measurement reading taken process.

Figure 3.12 Solar panels faced four different orientations which are East, North, West and South according to the sequence.

Figure 3.13 is showing the full connection of the water pump to the motor shaft then how the motor is connected to the rocker switch and battery. The motor used there is the 775 DC motor. The 775 motor is a common choice for projects and applications requiring a lot of power. Mainly steel with certain protective coatings, and a few plastic pieces, make up its rustproof housing. This high-torque, high-power device is ideal for use in robots, quadcopters, and other high-power industrial and other applications. The typical dimensions of 775 DC motors are 66.7 mm by 42.0 mm. The motor has a cylindrical shape, thus the 42.0 mm outside diameter, and a height of 66.7 mm. This typical measurement is 775. It has brushless commutation with the voltage range between 12 V to 24 V.

Once the shaft of motor and water pump are locked together and ensure it is tight, then the three wires were used to connect the SPDT rocker switch. The blue wire indicated the negative pole while the red colour indicate the positive pole.

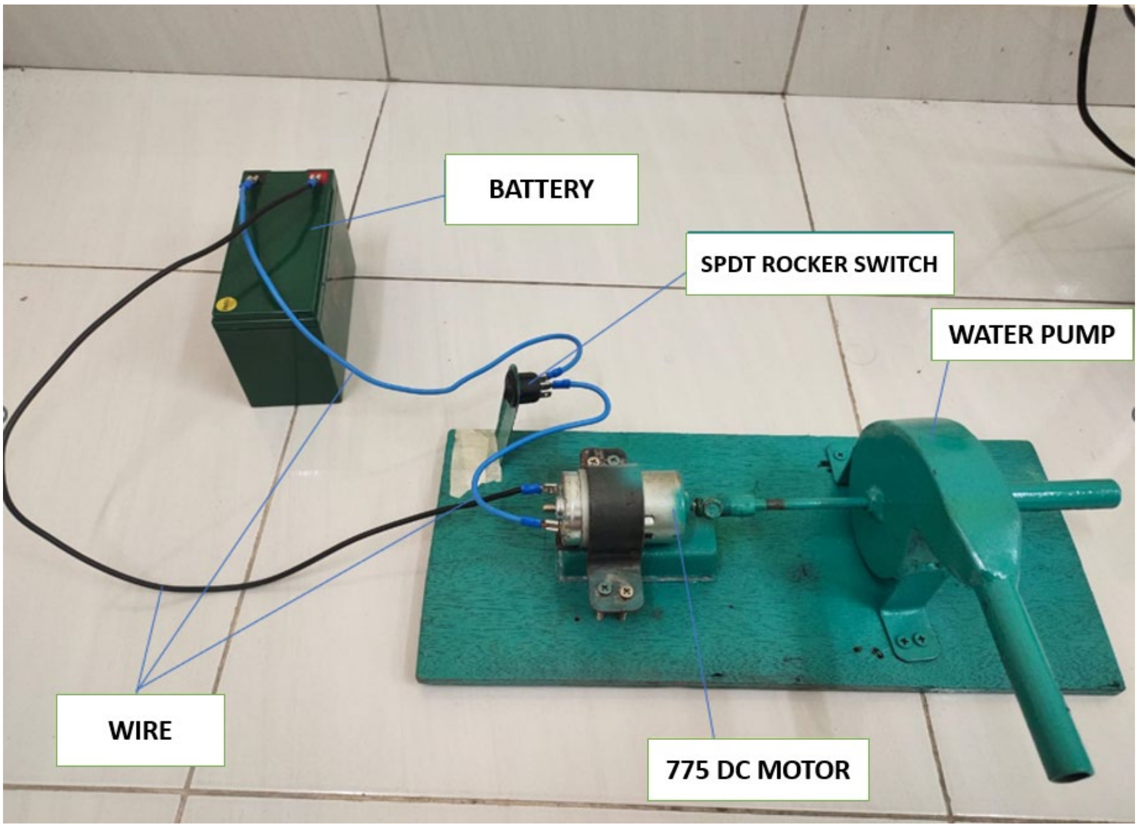


Figure 3.13 Overview of the full connection of water pump, motor with battery

How much liquid the pump can move in a particular length of time is known as its flow rate. The water pump's output volume may be determined using one of two techniques: make use of a flow metre, a simple instrument that, as its name implies, measures the volume of fluid moving through a certain conduit. Fasten the flow meter's output to the pipe leading out of the system. The meter's readout will tell us how fast the system is moving. The second method is collecting liquid at the pump system's discharge point. This is a manual flow rate calculation. This fluid may be collected in a container such as a bucket or vat. The flow rate then may be calculated by timing how long it takes to gather a certain volume of fluid. The flow rate is determined using Equation 3.1.

$$Flow\ rate = \frac{Volume\ of\ Liquid\ Collected}{Time\ Taken} \qquad \text{(Eq. 3.1)}$$

Velocity of the water is calculated by first finding the diameter of the outlet and inlet which are the same that is 1.2 cm or 0.012 m. Then calculate the area using the formula of πr^2. Equation 3.2 shows the formula of velocity.

$$Velocity = \frac{Flowrate\ (\frac{m^3}{s})}{Area\ (m^2)} \qquad \text{(Eq. 3.2)}$$

3.10 Cost analysis

Cost analysis is based on the designation of the project. The average construction cost for the water pump is with the range of RM 300 to RM 400. The material to construct the water pump without the motor is basically reuse the component of the recycle materials. Hence, this can reduce the cost of the construction without buying new materials. The detail breakdown of the material and costing for the development of the water pump prototype is tabulated in Table 3.1. In overall, the total cost estimation is RM 393.40.

Table 3.2 Cost for project

NO	ITEM PURCHASED	COST (RM)	PER UNIT	TOTAL COST(RM)
1	DC Motor	25.00	1	25.00
2	Hose	30.00	2	60.00
3	Wire	5.00	2	10.00
4	Rocker Switch	3.00	1	3.00
5	Hose Lock	5.00	2	10.00
6	Solar Panel	100.00	2	200.00
7	Battery	40.40	1	40.40
8	2’’ Flat head tapping screw	3.00	1	2.00
9	3.6.16 3 / 4’’ Flat head tapping screw	3.00	1	3.00
10	0.7cm Insulated electrical wire terminals crimp connector	10.00	1	10.00
11	0.5cm Insulated electrical wire terminals crimp connector	10.00	1	10.00
12	Spray Paint	10.00	2	20.00

3.11 Gantt chart

Activity	Week													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Group member separation	■													
Supervisor separation	■													
Discussion on the project		■	■											
Literature survey				■	■	■	■	■						
Generate and analyse designs					■	■	■	■	■					
Select and finalize the practical design							■	■	■					
Material listing									■					
Proposal's first draft preparation									■	■				
Submission of the proposal first draft										■				
Project advisor's approval of first draft											■	■		
Prepare the presentation slides												■		
Present the proposal													■	
Finalize of the proposal													■	
Submission of the final proposal														■

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Figure 4.1 showing the completed product of the Solar Charging Station. Figure 4.2 and Figure 4.3 showing product of water pump. The connection of the two solar panels together is in parallel. A parallel connection is created when the positives of two solar panels are joined together, as well as when the negatives of each solar panel are joined together. Increasing the amps while maintaining the same voltage may be accomplished by connecting solar panels in parallel. There are a several methods for doing this, the most common of which is the use of a branch connection, particularly for more compact systems. The branch connection is in the form of a Y, and it features two inputs for positive energy that combine into one, as well as two inputs for negative energy that combine into one. In order to guarantee the user's safety while using the system, the electrical wiring system has also been examined and evaluated.

Figure 4.1 Solar charging station

Figure 4.2 Left and right view of the water pump

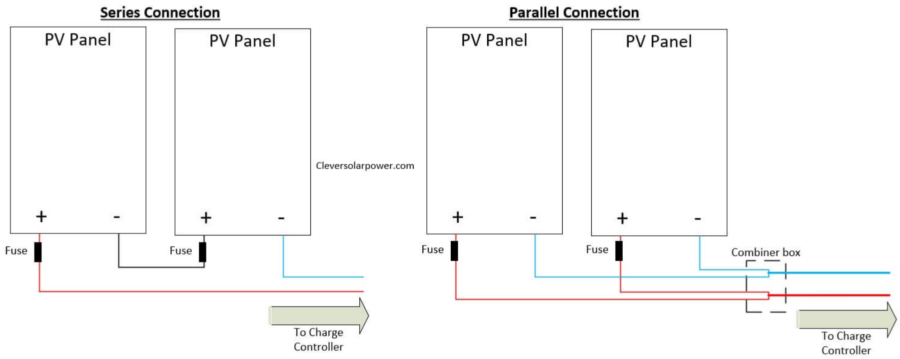


Figure 4.3 Parallel connection between two solar panels

(Source: https://cleversolarpower.com/two-solar-panels-one-controller-one-battery/)

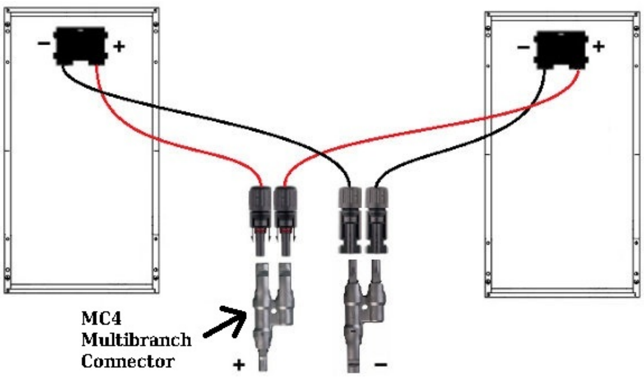


Figure 4.4 Connection of the solar panels

(Source: https://www.solar-electric.com/learning-center/how-to-use-mc4-connectors-cables.html/)

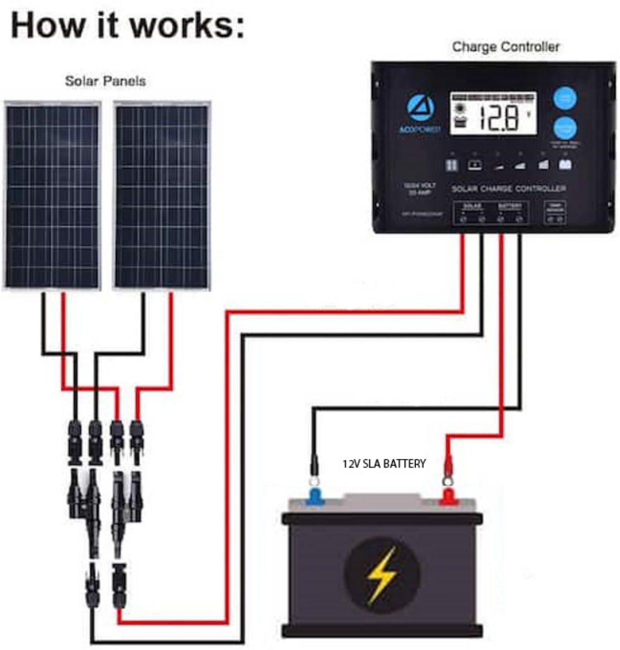


Figure 4.5 The overall connection of solar panel to charge controller and battery.

Figure 4.6 The real parallel connection of solar panels to solar charge controller.

4.2 Performance analysis

4.2.1 Effect of orientation and angle of solar panel to the module temperature

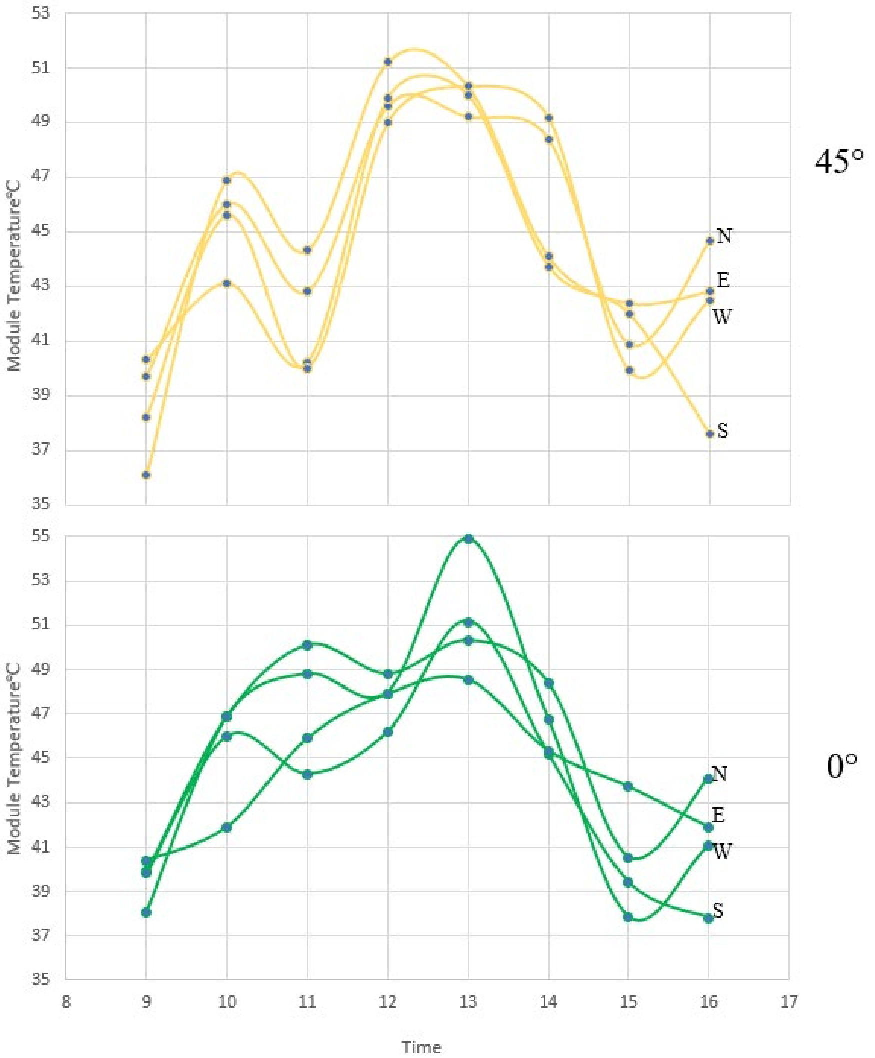


Figure 4.7 Module temperature against the time of different angles and orientation of solar panels.

As in Figure 4.8, it shows that the module temperature at each time according to different angle and orientation. At different orientation and angles, the module temperatures were varied. The temperature of the panel at various locations under intense sun irradiation may vary dramatically as a result of varying heat transfer from different parts of the photovoltaic module (Jaszczur et al., 2018). It can be concluded that when the solar panel is facing West and South and at 0°, the module temperature is the highest.

This is due to at 1 p.m., the sun is located at West and near to South. Hence, the solar panels were able to receive as much solar radiation as possible. When the sun is directly shine on the solar panels, this will cause the module temperature of the solar panels to increase. Moreover, when at 0°, the solar panels can get as much exposure as possible to sunlight as at this angle, the sun is directly perpendicular to the solar panels. Hence, more heat and higher module temperature will occur. In contrast, during morning 9 a.m., the sunlight is not as strong as during the peak sun hour and the result was showing at both angles at West had the average lowest reading due to the solar panels were facing behind the sun. Therefore, there are less penetration of solar radiation towards the solar panels and causing the module temperature to be low. To conclude, the result shown a increase in module temperature started from the beginning till 2 p.m. and a drop in the module temperature starting from 2 p.m. to 4 p.m due to the solar radiation decreases. The PV temperature increased from 7 a.m. to 2 p.m. due to an increase in solar radiation as well as an increase in ambient air temperature, after 2 p.m., the sun radiation decreased rapidly, as did the ambient air temperature which cause the drop in the PV temperature. (Jenan Basher et al., 2018).

4.2.2 Effect of orientation and angle of solar panel to the current

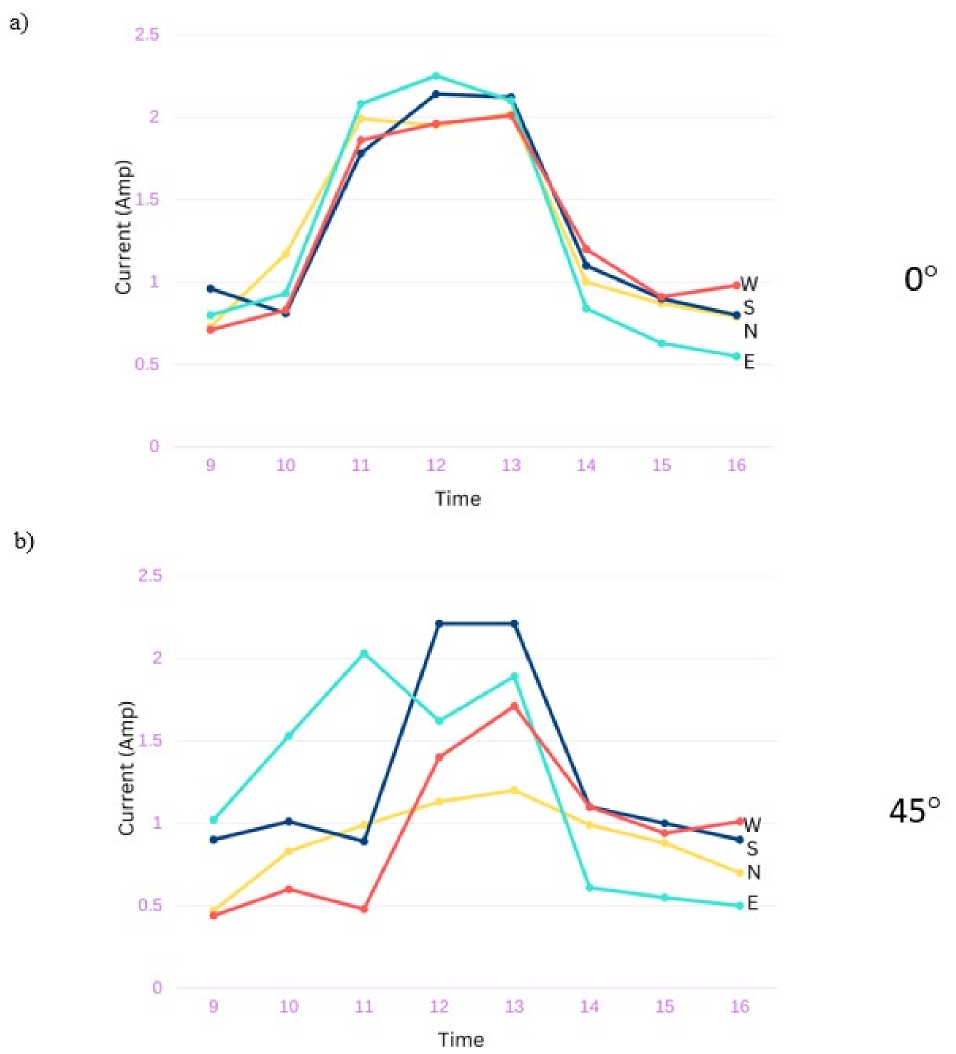


Figure 4.8 Current against the time of different angles and orientation of solar panels of a) 0° and b) 45°.

As in Figure 4.9, at 0°, for all orientation the average current output is higher than 45°. As discussed in 4.2.1, the current output is highly affected by the solar radiation coverage on the solar panels. The higher the solar radiation coverage, the higher the current production (Jenan Basher et al., 2018). At 0°, the sunlight is perpendicular to the solar panels while at 45° it is not perpendicular. Therefore, the result of 0° produce higher current compared to 45° will get. Solar radiation has a significant impact on photovoltaic cells. The resultant current is proportional to the flux of photons, whereas the open-circuit voltage differential grows logarithmically with increasing light intensity (Ibrahim Abass et al., 2019). For both angles, the solar panels' current output were increasing till the peak sun hours unless the weather condition is not good when results were taking, and the current will start to drop once the time reached after 2 p.m.

4.2.3 Effect of orientation and angle of solar panel to the voltage

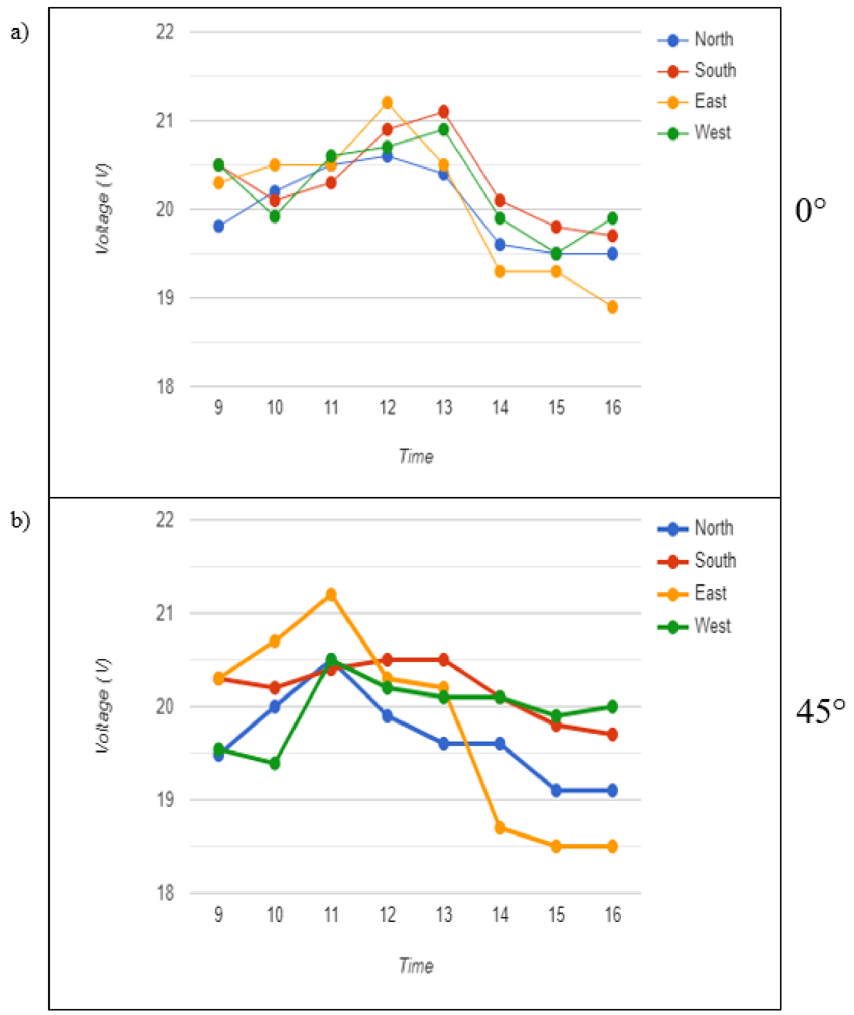


Figure 4.9 Graph of voltage against the time of different angles and orientation of solar panels.

Figure 4.10 shows the comparison of output voltage of the solar panels from two different angles. For both angles, the output voltage was increasing by time till 1 p.m., then the output will decrease unless there are unpredictable changing to weather condition. For example, a sudden increase in solar radiation flux due to less cloud covered or the sky is becoming cloudy that block the sunlight. In a normal day, the solar radiation flux density theoretically will increase as the time reaches noon. Hence causing the output voltage to be increased till the time. However, at 0°, the voltage production was higher for all orientation compared to 45°. The reason will be the same as the current output production due to the perpendicular of contact sunlight with solar panels. It was the solar panel's capacity to generate voltage over an external load that allowed electricity to be generated under continuous sun irradiation. Different solar panel tilt angles were shown to have a significant effect on power production (Khyber, 2012).

4.2.4 Effect of orientation and angle of solar panel to the solar radiation flux and wattage according to different time

The sun appears to be always in motion, rising on one side of the sky, travelling across it, and setting on the other. The apparent motion across the sky is caused by Earth's rotation. The Earth rotates from West to East on its own axis. Hence, the sun at different time will be located at different orientation. Moreover, the intensity of sunlight is different as well hence contributed to different weather condition, ambient temperature, module temperature and humidity. This will directly influence the production of the solar panels.

4.2.4.1 Effect of orientation and angle of solar panel to the solar radiation flux and wattage at 9 a.m.

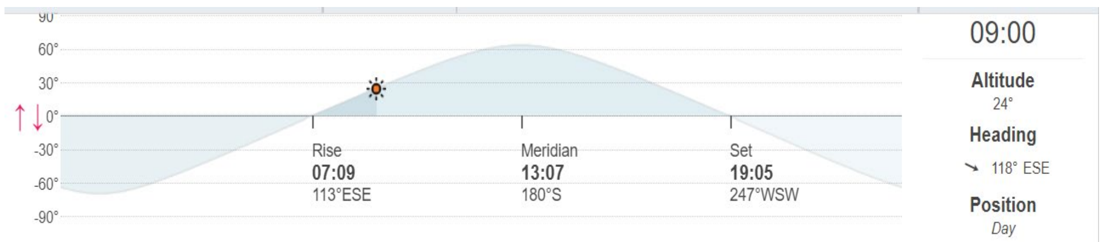


Figure 4.10 The sun direction at 9.00 a.m.

(Source: https://www.timeanddate.com/sun/@1735254?month=12&year=2022)

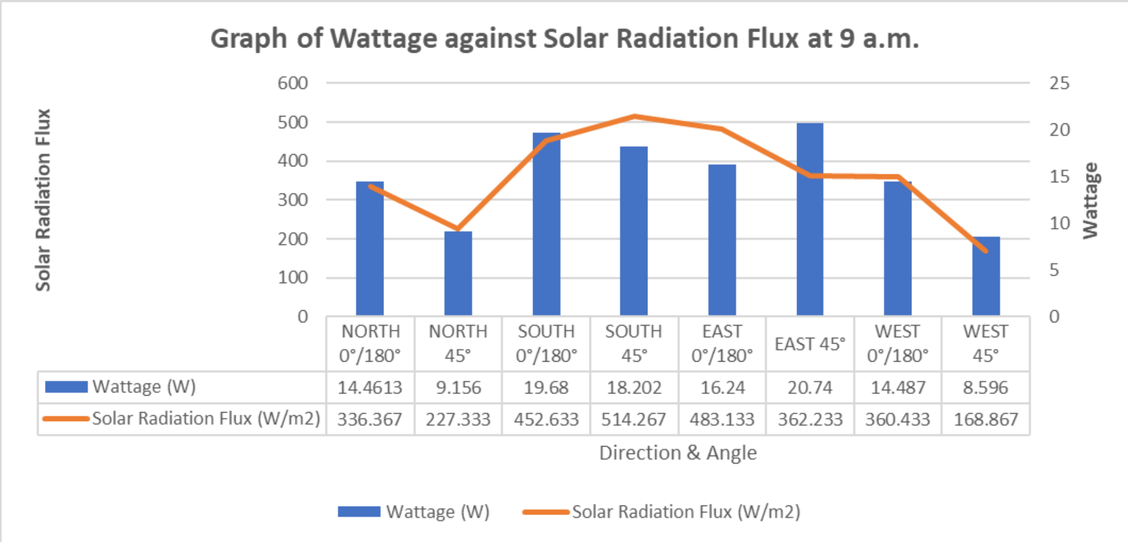


Figure 4.11 Wattage against Solar Radiation Flux at 9 a.m.

Table 4.1 The surrounding condition at 9 a.m.

Time	**Direction & Angle**	**Ambient Temperature (℃)**	**Module Temperature (℃)**	**Humidity (%)**	**Weather Condition**
9.00 a.m.	NORTH 0°/180°	29.5	39.9	68	Cloudy
	NORTH 45°	29.6	39.7	67	Cloudy
	SOUTH 0°/180°	33.3	39.8	63	Cloudy
	SOUTH 45°	34.1	40.3	63	Cloudy
	EAST 0°/180°	31.533	40.4	70	Cloudy
	EAST 45°	27.767	36.1	73	Cloudy
	WEST 0°/180°	30.3	38.1	66	Cloudy
	WEST 45°	30	38.2	68	Cloudy

According to the sun direction, at 9 a.m., it will be at the East-southeast. Hence, when the solar panel was facing both South and East direction, the amount of solar radiation flux received are higher than facing North and West as they are facing backward of the sun. East 45° was having the most wattage production although it had a lower solar radiation flux was because its module temperature was the lowest as solar panel is most efficient at 25℃ (Irwanto et al., 2014). Therefore, this direction's temperature is nearest to the optimum operating temperature of solar panel. However, all results of wattage and solar radiation flux for all direction and angle were not that high as the weather condition was cloudy, ambient temperature was low and humidity wads very high as well. When cloud cover is dense, solar power generation drops. Light cloud cover on photovoltaic modules is predicted to account for a 23.80% drop in output power within the region. As an additional note, it is anticipated that a thick cloud cover on a solar module would result in a loss in output power of 66.75% (Amusan & Otokunefor, 2019).

4.2.4.2 Effect of orientation and angle of solar panel to the solar radiation flux and wattage at 10 a.m.

Figure 4.12 The sun direction at 10.00 a.m.

(Source: https://www.timeanddate.com/sun/@1735254?month=12&year=2022)

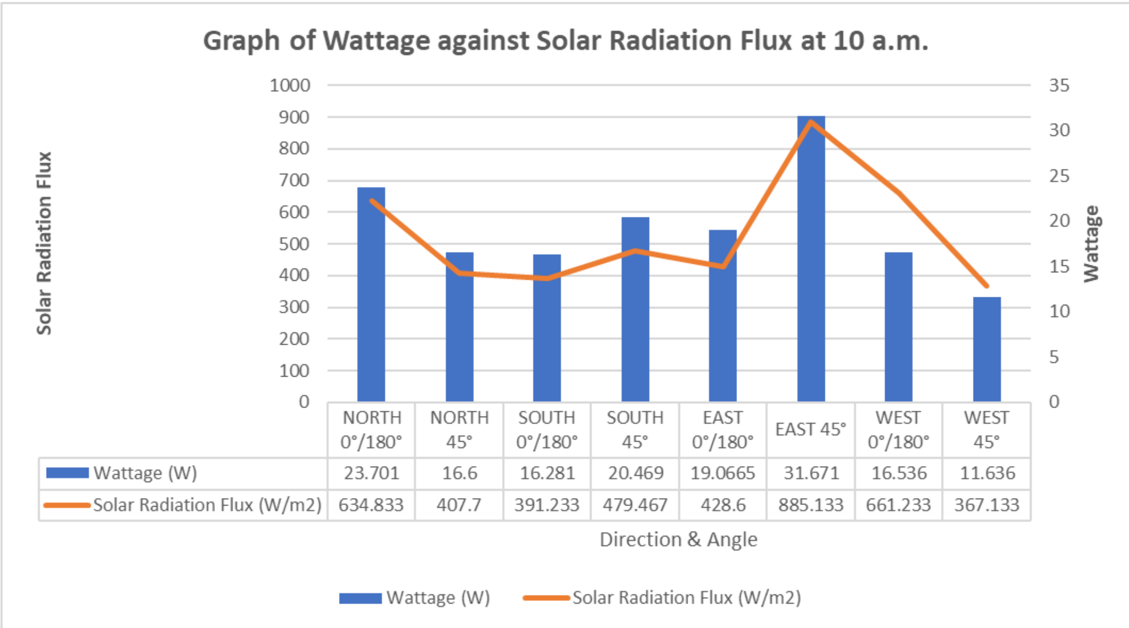


Figure 4.13 Wattage against Solar Radiation Flux at 10 a.m.

Table 4.2 The surrounding condition at 10 a.m.

Time	Direction & Angle	Ambient Temperature (°C)	Module Temperature (°C)	Humidity (%)	Weather Condition
10.00 a.m.	NORTH 0°/180°	32.9	46.9	45	Sunny
	NORTH 45°	36.5	46	55	Cloudy
	SOUTH 0°/180°	34.9	44.1	53	Cloudy
	SOUTH 45°	32.7	43.1	53	Cloudy
	EAST 0°/180°	30.833	41.9	54	Cloudy
	EAST 45°	33.3	46.9	48	Sunny
	WEST 0°/180°	32.6	46.9	54	Sunny
	WEST 45°	34.1	45.6	49	Sunny

The wattage of solar panel abled to produce at 10 a.m. was highest at East 45° again. One of the factors was it received the highest solar radiation flux and then the weather condition is sunny. Both west 0° and 45° were still having the lowest wattage production because they were facing backward of the sun. Hence causing sunlight unable to penetrate to the solar panels. North 0° was having the second highest was because the weather condition at the moment was sunny while South direction was cloudy and having a high humidity during measurement was taken hence causing the reading to be lower than North 0°. A cloudy sky severely reduces the amount of direct sunlight that reaches the module's surface, resulting in negligible energy production. This results in reduced daily energy production by the module compared to clear skies (Bonkaney et al., 2017). When the humidity is high, just a thin film of water forms on the surface of the solar panel, reducing its effectiveness. Refraction occurs when energy or photon-containing light contacts the denser water layer, resulting in a reduction in the light's intensity, which seems to be the root cause of the efficiency drop. (Kumar Panjwani & Bukshsh Narejo, 2014).

4.2.4.3 Effect of orientation and angle of solar panel to the solar radiation flux and wattage at 11 a.m.

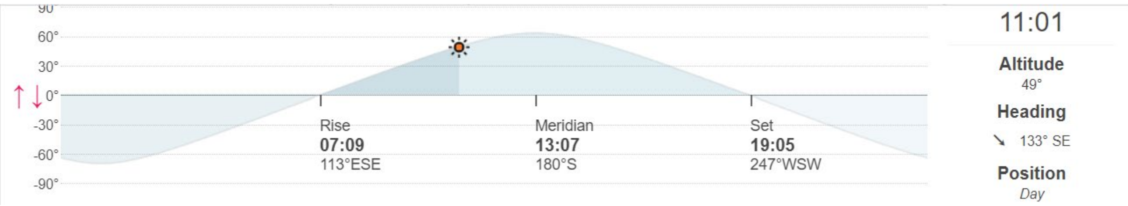


Figure 4.14 The sun direction at 11.00 a.m.

(Source: https://www.timeanddate.com/sun/@1735254?month=12&year=2022)

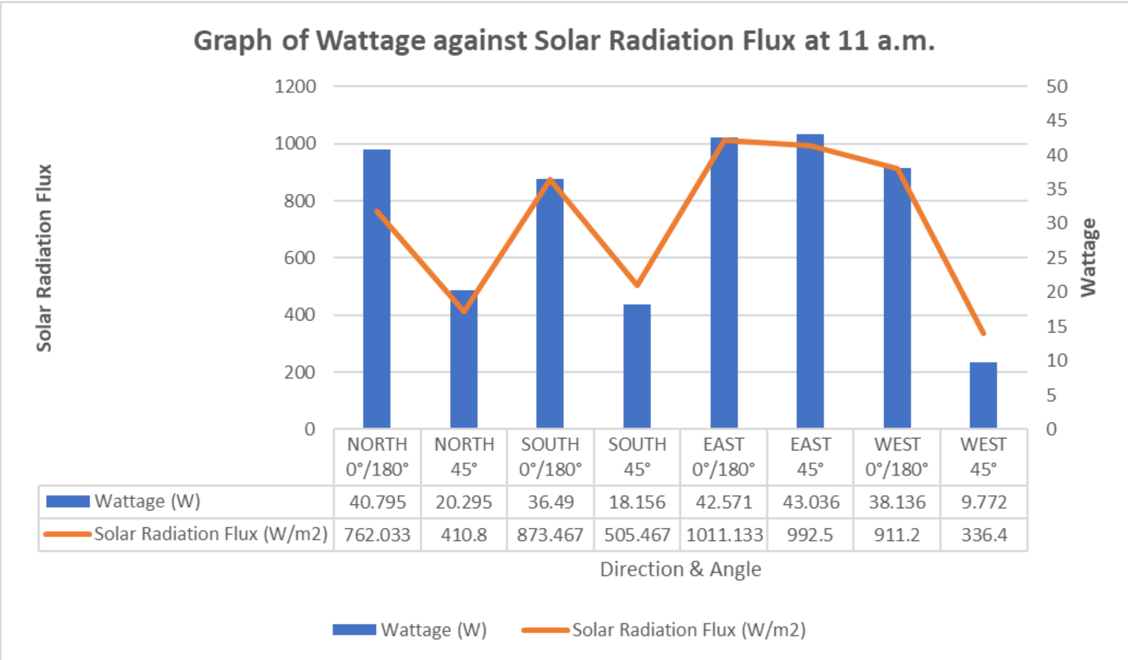


Figure 4.15 Wattage against Solar Radiation Flux at 11 a.m.

Table 4.3 The surrounding condition at 11 a.m.

Time	Direction & Angle	Ambient Temperature (°C)	Module Temperature (°C)	Humidity (%)	Weather Condition
11.00 a.m.	NORTH 0°/180°	35.9	50.1	46	Sunny
	NORTH 45°	31.3	42.8	47	Sunny
	SOUTH 0°/180°	33.5	44.3	44	Sunny
	SOUTH 45°	33.1	40.233	54	Cloudy
	EAST 0°/180°	36.9	45.9	41	Sunny
	EAST 45°	34.6	44.3	45	Sunny
	WEST 0°/180°	36.3	48.8	46	Sunny
	WEST 45°	34.3	40	57	Cloudy

The sun direction at 11 a.m. is at Southeast (SE), halfway between south and east. However, the time is nearly to peak hour, hence the solar radiation flux is very high at almost all direction. We can observe that almost all 0° at all orientations were having high wattage production because this angle allowed to receive more sunlight compared to 45°. South 45° was having unexpectedly low reading because it was cloudy although the sun direction was nearly to South which causing the solar radiation to drop and affect the production of the solar panels. West 45° was still having the lowest reading not only because the solar panels were facing back to sun and also it was cloudy contributed to low wattage.

4.2.4.4 Effect of orientation and angle of solar panel to the solar radiation flux and wattage at 12 p.m.

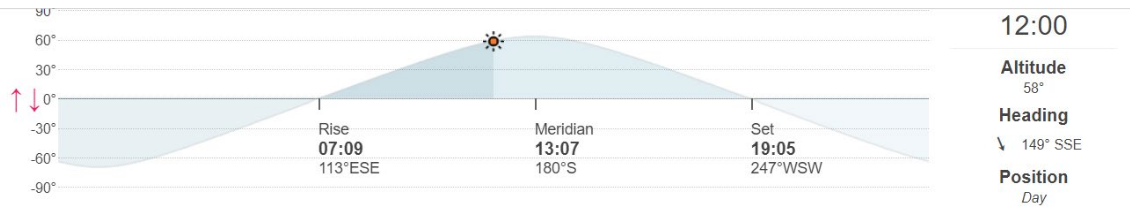


Figure 4.16 The sun direction at 12.00 p.m.

(Source: https://www.timeanddate.com/sun/@1735254?month=12&year=2022)

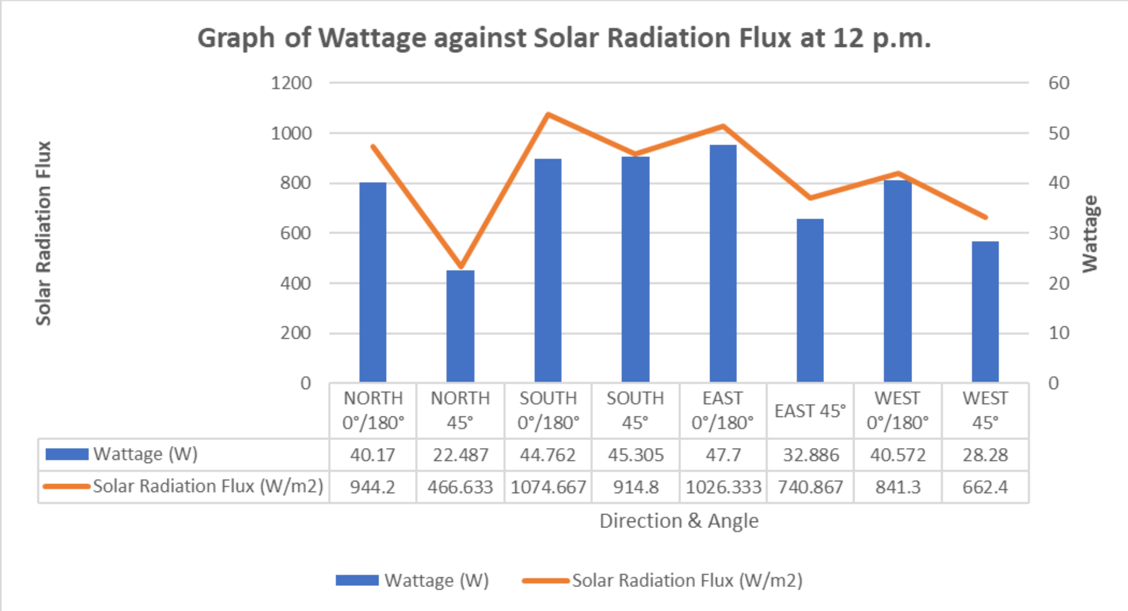


Figure 4.17 Wattage against Solar Radiation Flux at 12 p.m.

Table 4.4 The surrounding condition at 12 p.m.

Time	Direction & Angle	Ambient Temperature (℃)	Module Temperature (℃)	Humidity (%)	Weather Condition
12.00 p.m.	NORTH 0°/180°	36.1	48.8	38	Sunny
	NORTH 45°	35.8	49.6	38	Sunny
	SOUTH 0°/180°	34	46.2	36	Sunny
	SOUTH 45°	34.767	49.9	39	Sunny
	EAST 0°/180°	36.2	47.9	35	Sunny
	EAST 45°	35.8	51.2	33	Sunny
	WEST 0°/180°	35.7	48	39	Sunny
	WEST 45°	36.2	49	40	Sunny

12.00 p.m. was the peak sun hours. The weather condition was also sunny during the measurement taken. Hence, the wattage production by the solar panel was generally higher than any other time. East 0° was having the highest wattage reading with 47.7 W. In Figure 4.18, the result showed all directions with 0° produced more than 40 W where 45° produced only average between 20 to 30 W except South 45° which was able to produce second highest wattage because the sun direction was toward South-southeast. South 0° was the third highest with 44.762 W. Hence, we can find out that South direction no matter which angles will be contribute to a very high and stable electricity production compared to other direction at 12.00 p.m. This is due to the sun's orientation was towards South near to 1 p.m. Numerous research had been done prove that in all over the world, the orientation of solar modules should be positioned with a flatter tilt angle towards west or east due south (Matius et al., 2021).

4.2.4.5 Effect of orientation and angle of solar panel to the solar radiation flux and wattage at 1 p.m.

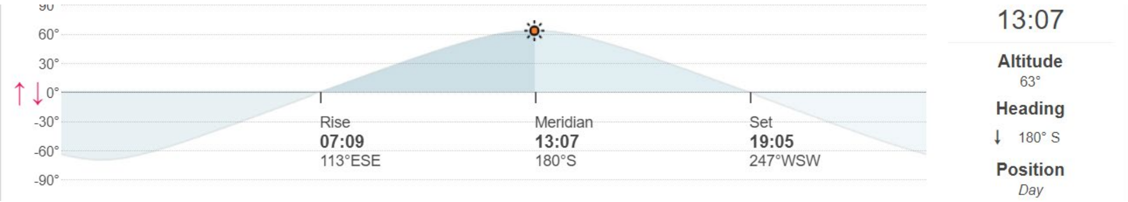
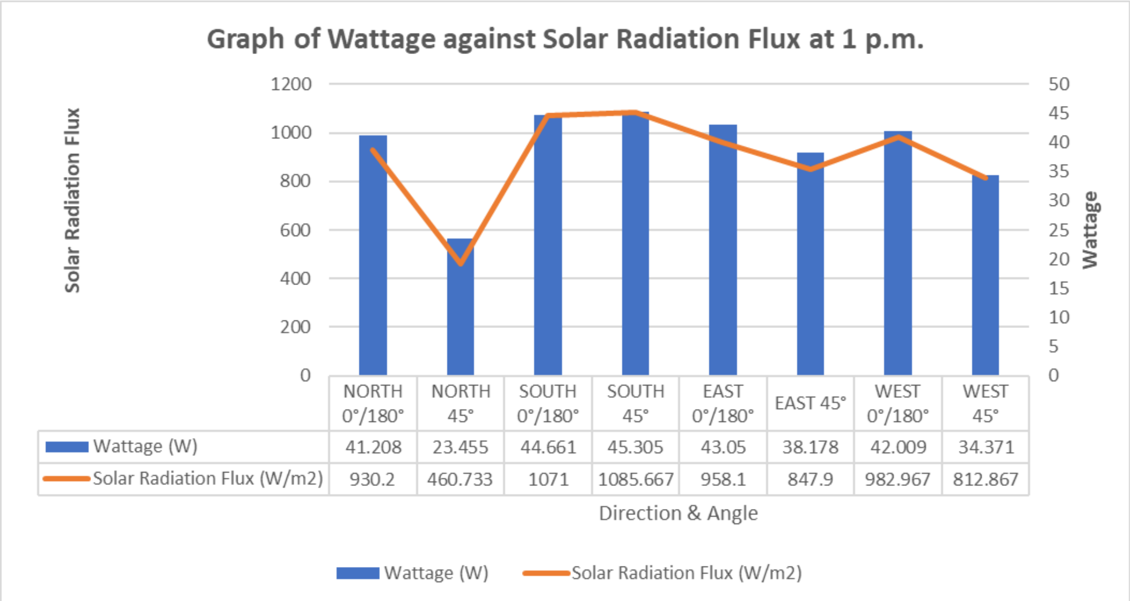


Figure 4.18 The sun direction at 1.00 p.m.

(Source: https://www.timeanddate.com/sun/@1735254?month=12&year=2022)



	NORTH 0°/180°	NORTH 45°	SOUTH 0°/180°	SOUTH 45°	EAST 0°/180°	EAST 45°	WEST 0°/180°	WEST 45°
Wattage (W)	41.208	23.455	44.661	45.305	43.05	38.178	42.009	34.371
Solar Radiation Flux (W/m2)	930.2	460.733	1071	1085.667	958.1	847.9	982.967	812.867

Figure 4.19 Wattage against Solar Radiation Flux at 1.00 p.m.

Table 4.5 The surrounding condition at 1.00 p.m.

Time	Direction & Angle	Ambient Temperature (°C)	Module Temperature (°C)	Humidity (%)	Weather Condition
1.00 p.m.	NORTH 0°/180°	34.5	50.3	39	Sunny
	NORTH 45°	36.1	49.2	42	Sunny
	SOUTH 0°/180°	35.2	51.2	34	Sunny
	SOUTH 45°	37.333	50	43	Sunny
	EAST 0°/180°	34.5	48.533	36	Sunny
	EAST 45°	37.2	50.3	40	Sunny
	WEST 0°/180°	38.6	54.9	35	Sunny
	WEST 45°	35.1	50.3	42	Sunny

1.00 p.m. was also another peak sun hours. According to Figure 4.19, the sun direction during this time was at South. Hence, from the Figure 4.20, we can notice that at Souths 0° and 45° were producing the highest two wattage readings. Moreover, this direction also receive the most sunlight as their solar radiation flux readings were the highest as well. Other direction and angle were also having a not low wattage reading with an average of 39 W except North 45° because it was exactly located behind the sun hence it cannot receive high sunlight coverage causing it to have the lowest solar radiation flux and wattage reading.

4.2.4.6 Effect of orientation and angle of solar panel to the solar radiation flux and wattage at 2 p.m.

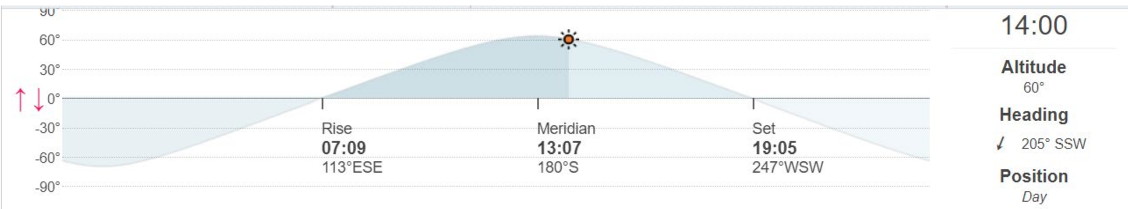


Figure 4.20 The sun direction at 2.00 p.m.

(Source: https://www.timeanddate.com/sun/@1735254?month=12&year=2022)

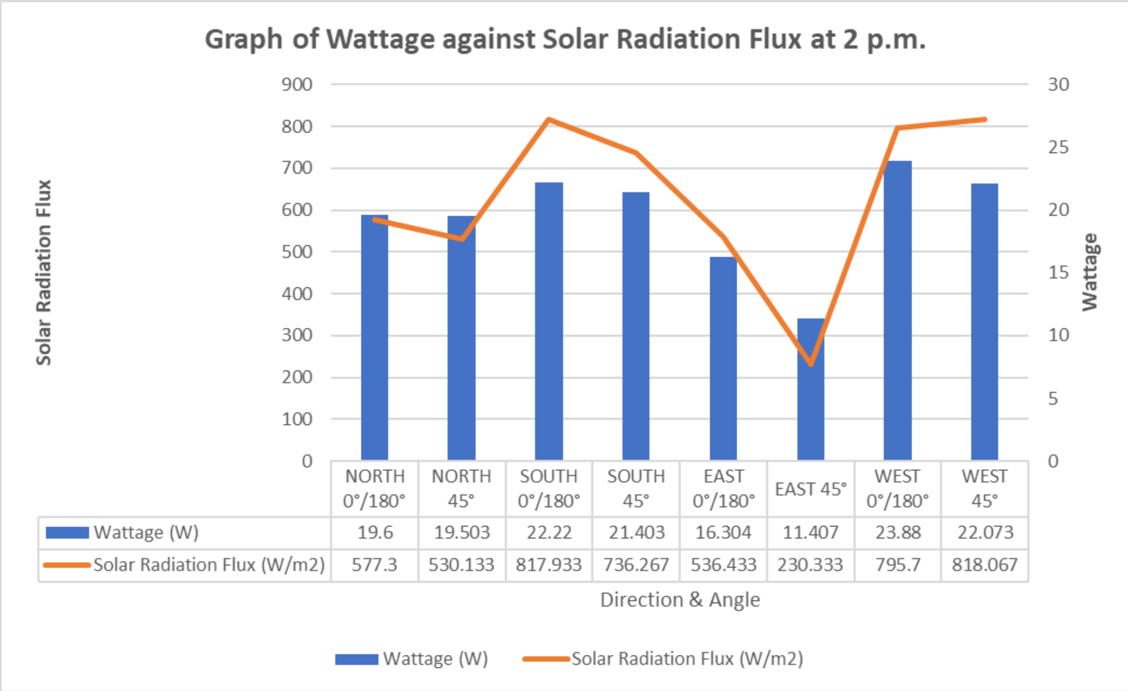


Figure 4.21 Wattage against Solar Radiation Flux at 2.00 p.m.

Table 4.6 The surrounding condition at 2.00 p.m.

Time	Direction & Angle	Ambient Temperature (℃)	Module Temperature (℃)	Humidity (%)	Weather Condition
2.00 p.m.	NORTH 0°/180°	36.93	48.37	33	Sunny
	NORTH 45°	37.567	48.4	35	Sunny
	SOUTH 0°/180°	38.033	45.167	38	Sunny
	SOUTH 45°	38.933	43.733	38	Sunny
	EAST 0°/180°	35.4	45.333	33	Sunny
	EAST 45°	34.433	44.067	33	Sunny
	WEST 0°/180°	38.2	46.733	37	Sunny
	WEST 45°	38.833	49.167	35	Sunny

According to Table 4.6, during 2.00 p.m., the weather condition was sunny. Hence, the reading will not be affected by the weather. The sun will be at south-southwest as shown in Figure 4.21. Therefore, from the Figure 4.22, it can be noticed that West 0° had the highest wattage reading then followed up by 45°. After that, South 0° and 45° were the third and fourth highest. East both angles were having the lowest wattage as the solar panel was not facing the sun and at 45° it will only receive very low solar radiation which causing it to generate low electricity because the sun was at the opposite direction to the solar panel. The effect of shunt resistance becomes particularly prominent at low light levels. As the light intensity diminishes, so do the bias point and current through the solar cell, and the solar cell's equivalent resistance may begin to approach the shunt resistance. When these two resistances are similar, the proportion of total current passing via the shunt resistance increases, causing the fractional power loss due to shunt resistance to increase (Bunea et al., 2006).

4.2.4.7 Effect of orientation and angle of solar panel to the solar radiation flux and wattage at 3 p.m.

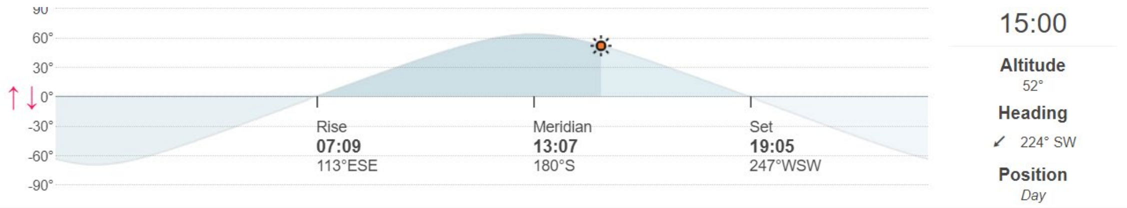


Figure 4.22 The sun direction at 3.00 p.m.

(Source: https://www.timeanddate.com/sun/@1735254?month=12&year=2022)

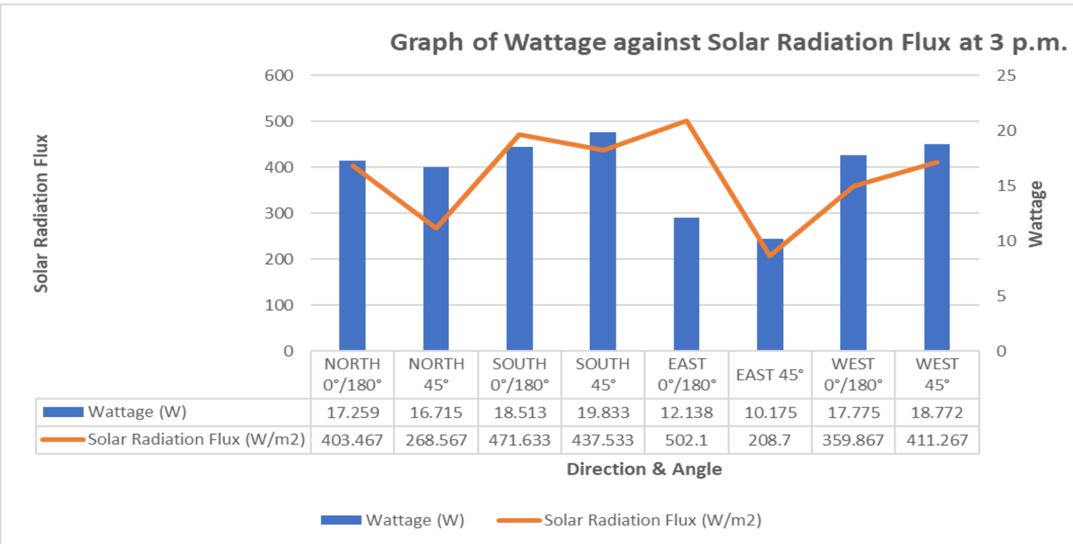


Figure 4.23 Wattage against Solar Radiation Flux at 3.00 p.m.

Table 4.7 The surrounding condition at 3.00 p.m.

Time	Direction & Angle	Ambient Temperature (°C)	Module Temperature (°C)	Humidity (%)	Weather Condition
3.00 p.m.	NORTH 0°/180°	33.7	40.53	41	Cloudy
	NORTH 45°	33.733	40.867	44	Cloudy
	SOUTH 0°/180°	34.333	39.4	42	Sunny
	SOUTH 45°	34.9	42	38	Sunny
	EAST 0°/180°	34.733	43.7	35	Sunny
	EAST 45°	34.5	42.367	39	Sunny
	WEST 0°/180°	34.667	37.833	42	Cloudy
	WEST 45°	35.267	39.9	43	Cloudy

As in shown in Figure 4.23, at 3.00 p.m., the sun direction was at Southwest (SW), 225°, halfway between south and west, was the opposite of northeast. Figure 4.24 shows that South 45° hence having the highest reading then follow by west 45° then south 0° and west 0°. The reading of west was lower than expected due to cloudy weather. The shadow cast by clouds or the shift in wavelengths caused by dust deposition in the atmosphere decreases the intensity of sunlight and the productivity of the solar cell (Jenan Basher et al., 2018). Since north and east were opposite of the sun direction, hence both were having the lowest reading and east was getting the lowest wattage values for both angles due to low sunlight coverage.

4.2.4.8 Effect of orientation and angle of solar panel to the solar radiation flux and wattage at 4 p.m.

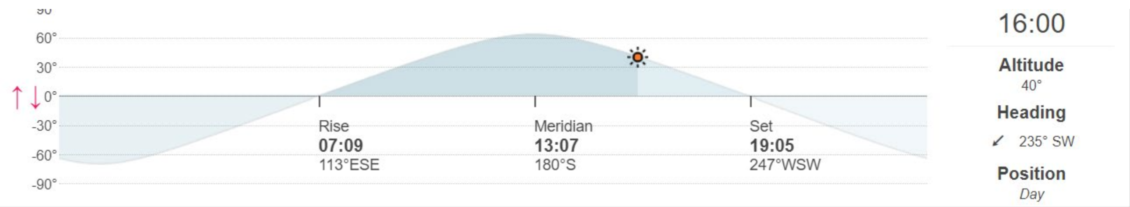


Figure 4.24 The sun direction at 4.00 p.m.

(Source: https://www.timeanddate.com/sun/@1735254?month=12&year=2022)

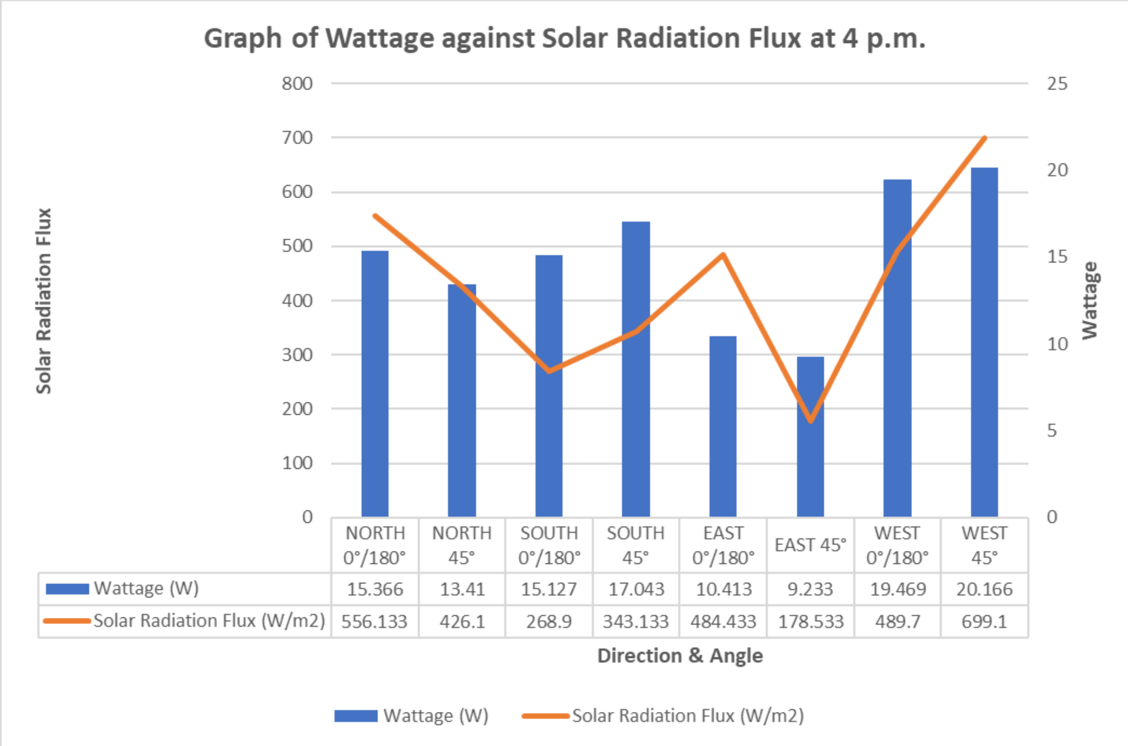


Figure 4.25 Wattage against Solar Radiation Flux at 4.00 p.m.

Table 4.8 The surrounding condition at 4.00 p.m.

Time	**Direction & Angle**	**Ambient Temperature (°C)**	**Module Temperature (°C)**	**Humidity (%)**	**Weather Condition**
4.00 p.m.	NORTH 0°/180°	36.3	44.17	36	Sunny
	NORTH 45°	36.9	44.633	39	Sunny
	SOUTH 0°/180°	34	37.8	45	Cloudy
	SOUTH 45°	34	37.6	43	Sunny
	EAST 0°/180°	34.3	41.867	38	Sunny
	EAST 45°	34.9	42.8	34	Sunny
	WEST 0°/180°	36.3	41.1	40	Sunny
	WEST 45°	37.233	42.467	39	Sunny

By the time of 4.00 p.m., the sun direction was still at Southwest (SW) but nearer to west. Hence, the wattage values at west were the highest then followed up by south. As the sun orientation is away from South, hence causing the wattage production to be slightly lower. Since 4 p.m. was not the peak sun hours anymore, the results will not be as high as during the peak even though the weather condition is sunny. East was still having the two lowest results due to the solar panels were facing opposite direction to the sun while North was having an average wattage value due to its direction which was in middle that causing the result to be not too low and high. Due to the very low solar radiation flux density, it caused the overall voltage and current production by the solar radiation to be very low as well. Low current and voltage levels reduce the cell's output power and efficiency (Jenan Basher et al., 2018).

4.2.4.9 Effect of orientation and angle of solar panel to wattage at all time

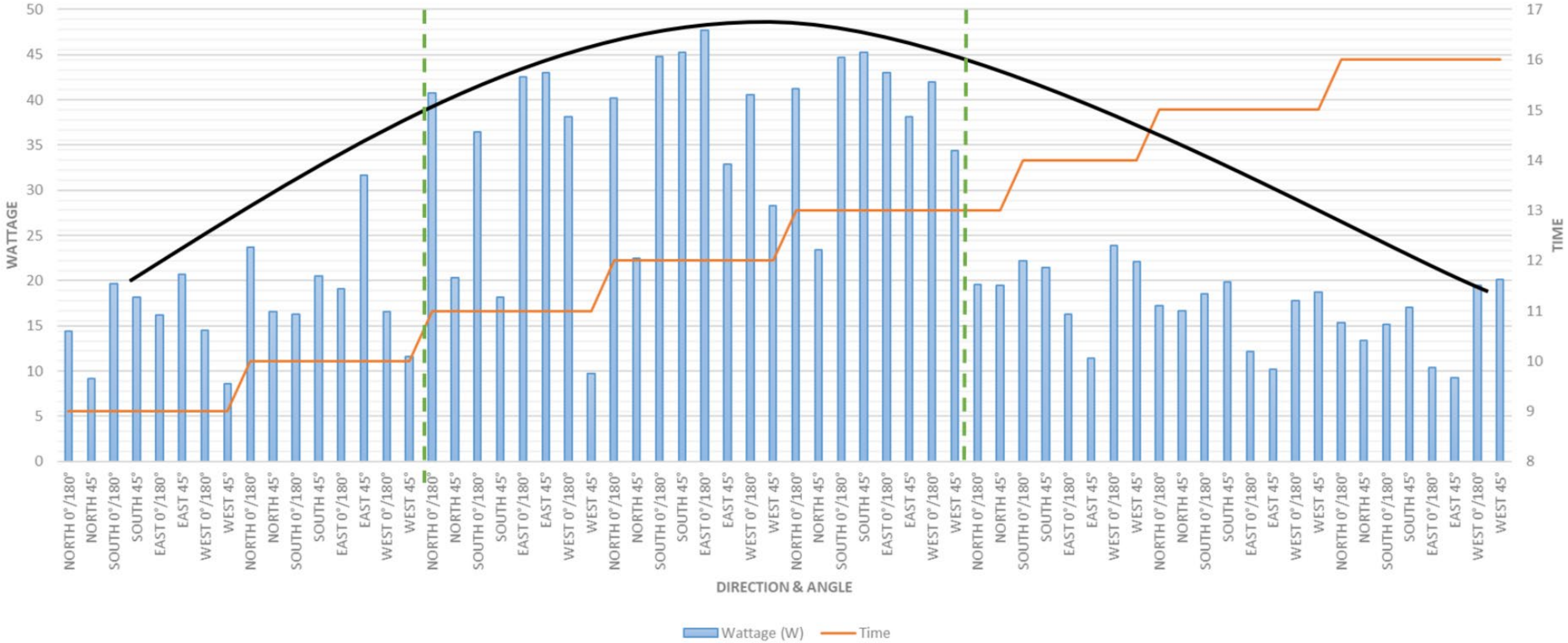


Figure 4.26 Wattage against direction & angle of solar panel at different time.

The peak sun hours in Malaysia range between 4 to 6 hours. However, additional factors such as shading, pollution, the wet season, dust, and energy loss may also affect energy output (Bhol et al., 2015). Experiments show that dust pollution has a major effect on the efficiency with which solar photovoltaic modules generate electricity (Jiang et al., 2011). As in the graph, we can noticed that the highest wattage readings at in between 11.00 a.m. to 13.00 p.m. as shown in the middle of the Figure 4.27. This were the peak sun hours during the measurement was taken. During the result was took, it was the monsoon season in specically the Northeast Monsoon Season (NEM) during December near the end of the year where the maximum rainfall is recorded (Wong et al., 2018). Hence the peak sun hours were lesser than the expected 4 to 6 hours. Other than the peak sun hours, the wattage reading was low due to the solar radiation flux was low and some other factors which can affect the results taken such as the high humidity, temperatures include ambient and module and weather conditions. Hence, the best time to do solar charging is during 11.00 a.m. to 1.00 p.m. during the moonson season in which the weather is not as good as the non-moonsoon season.

4.2.5 Analysis of solar water pump

The water will be using the energy from the battery. For this project, the battery is charged by the solar panels to ensure it is using renewable energy. Few key factors best characterise the functioning and performance of a water pump which are flow rate, pressure, head, power, and efficiency. The parameter considered for the solar water pump for aquaculture is the water flowrate.

Table 4.9 showed the volume of water collected within the time, the flowrate and velocity calculated. The reason why five seconds result was not recorded due to the operation was too short. Hence, the result was taken started from 10 seconds. As in the Table 4.9 and Figure 4.28, both the flowrate and velocity of the water can be observed that was reducing as the time for operating the water pump is increasing. The average flowrate is 0.0787 l/s, and the average velocity is 0.6955 m/s.

Table 4.9 Time taken to collect water by water pump, its flowrate and velocity.

Time (s)	**Volume of water (ml)**	**Flowrate (l/s)**	**Velocity (m/s)**
10	900	0.0900	0.7958
15	1240	0.0827	0.7309
20	1600	0.0800	0.7074
25	1900	0.0760	0.6720
30	2190	0.0730	0.6455
35	2460	0.0703	0.6215

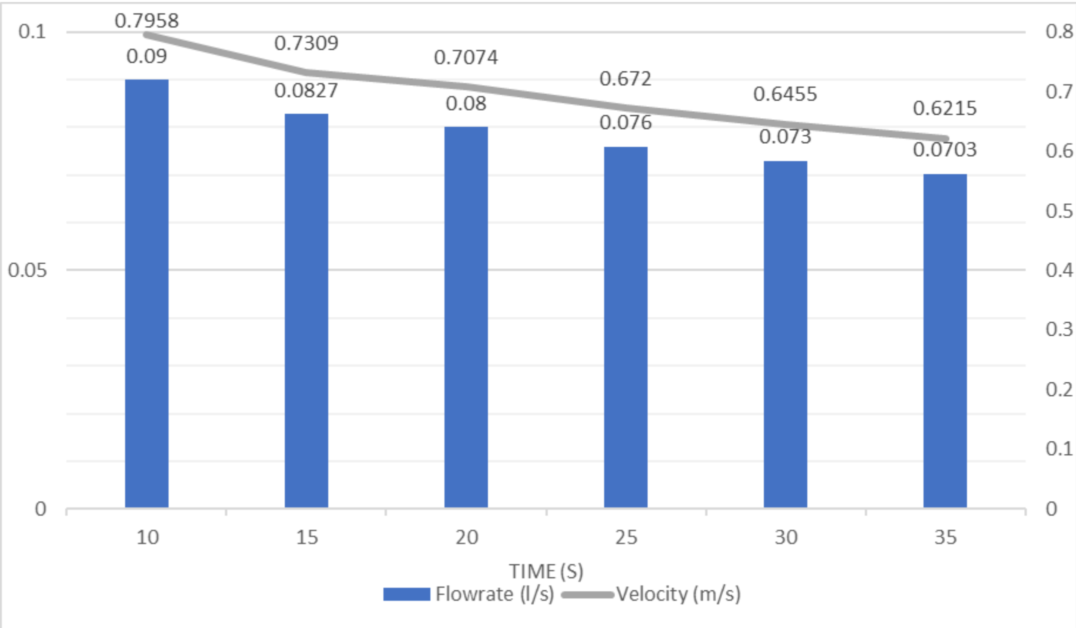


Figure 4.27 Graph of Flowrate and Velocity against Time of the Water Pump.

This is due to the motor is generating heat when it is operating. Temperature effects must be taken into account when using DC motors in any kind of application. Motor performance will vary with temperature. When the temperature of a motor rises, the resistance rises along with it, and the torque constant and voltage constant drop. This occurs because an increase in temperature causes a drop in the magnetic field density. Consequently, the torque constant also decreases when the magnetic field density drops.

Hence, this will cause the operation of the water pump to be lesser effective as time goes on.

The operation of the water pump will use an amount of electricity. Hence, the battery is important to provide the electricity. When the battery is being used for a certain time, its percentage will decrease. Hence, the used of solar panels to recharge the 12V SLA battery as shown in the Figure 4.29. The charging of the battery was run under good weather condition that is sunny. Before the charging, the battery percentage is 45% which is 11.98V. To let it fully charge to 100%, 12.7V, it took 3 hours and 45 minutes for the 55% of battery capacity at the 45° facing East in the morning and change to South when the time near to afternoon. However, when the same condition of battery being charged at 180°, it took a lesser time which is 3 hours and 30 minutes to finish the 55% of charging. The input voltage from the solar panels is within the range of 14V to 16V. In general, the charging is faster at lower battery levels. When the battery approaches a full charge, the charging current decreases gradually. Hence, we can find out that charging battery for each 1% at 45° requires 4.09 minutes for at 180° requires 3.82 minutes.

Table 4.10 Different angle of charging a 45% battery to 100% and the time required to charge.

Angle of solar panels during charging	**Total time**	**Time for charging 1% of battery (minutes)**
45°	3 hours and 45 minutes	4.09
0°/180°	3 hours and 30 minutes	3.82

Figure 4.28 The charging of the battery.

When the water pump had operated for 150 seconds which is 2 minutes and 30 seconds, it caused the 12V battery to has a battery percentage drop of 3.33% which meant using the water pump for 1 second will use 0.022% of the battery. In order to make the battery percentage drop to 45%, the water pump can be operating for around 41 minutes and 20 seconds. This 41 minutes and 20 seconds water pump usage required a charging time nearly to 3 and half hours in equivalent to 1 minute of charging 0.26% of battery capacity.

A normal aquarium size which is 10 gallon is 0.0394 m^3 which mean in this type of aquarium will have 39.35 l 0f water. With the average flowrate of the water pump which is 0.0787 l/s, the water pump will require around 500 seconds of time to finish remove the water that is equivalent to 8 minutes and 20 seconds. This will used up 11% of battery and needed an approximately 43 minutes of charging time. With the 20-gallon size aquarium, the size is 0.07089 m^3 and has 70.89 l of water. With the exact same flowrate, it will take 900.76 seconds which is equivalent to 15 minutes and 1 seconds. This will used up 20% of battery and needed an approximately 77 minutes or 1 hour and 17 minutes of charging time. The water pump will require about with the 50-gallon size aquarium, the size is 0.2017 m^3 and has 201.75 l of water. With the exact same flowrate, it will take 2563.53 seconds which is equivalent to 42 minutes and 44 seconds. This will used up 55% of battery and needed an approximately 210 minutes or 3 hours and 30 minutes of charging time. Hence, it can be concluded that the larger the size of aquarium, the longer the time taken to finish drawing the water and longer charging time as shown in Figure 4.30. For this project, the most suitable aquarium size to be used is the 10 gallons because the motor will not be able to sustain the long usage time due to small size and overheat.

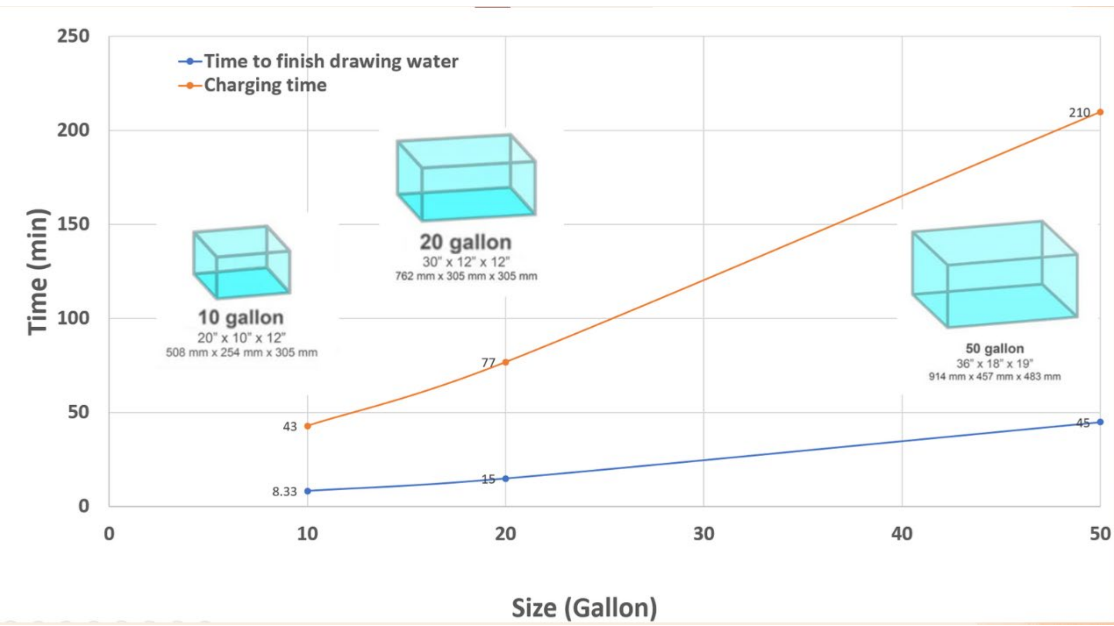


Figure 4.29 Time taken for finish drawing water and charging usage time for different size of aquarium.

CHAPTER 5

CONCLUSION

5.1 Conclusion

As conclusion, the main objective of this project is to design and fabricate a mobilized solar water pump for aquaculture is successfully achieved through the success of the water pump that is light to carry away and able to transport the fluid from one place to another. The fabricated solar water pump was successfully operated to withdraw water from the inlet and discharge it out through outlet with the average flowrate of 0.0787 l/s and it is powered only by using a sunlight. This is achieved by charging the battery with solar panels. This solar water pump was designed with commercial use in mind, but its compact size makes it ideal for residential use. The solar charging station is well-designed and practical. By adjusting the position of the holder to either 0° or 45°, the solar panel may get optimal sunlight exposure from whatever direction and at whichever angle will result in the most amount of energy production for the system. The second goal, which was to evaluate the solar energy power supply in terms of wattage, was also met after research on the angle and direction was conducted. The results getting from the evaluation were used for charging the battery for the usage of water pump. As a result of it, the battery is encouraged to charge when the solar panels are facing South with the 0° during the peak sun hours which are 11 a.m. to 1 p.m. The charging will take about 4 hours to charge 55% of the battery. For a variety of causes, the water pump's performance falls short of expectations. The pumping process requires additional research to make it quicker and more efficient.

The total for the charging station and the water pump came to less than RM400. The examination of performance patterns in wattage demonstrates a rising tendency from 9 a.m. to 1 pm, when less solar energy is blocked by clouds, and a negative trend from 2 p.m. to 4 p.m., when more clouds block the sun's rays. Further, the research shows that the solar panel can provide the maximum average wattage value whether it is oriented south 45° or 180°, namely during the hours of 12 p.m. and 1 p.m. Finally, the average water pump flowrate is 0.0787 l/s, with the flowrate decreasing with time for several reasons.

5.2 Recommendation

The solar water pump for aquaculture might need some tweaks to increase its usefulness, reliability, and safety. During the testing phase, the limits were apparent. Firstly, the motor for the water pump is small and hence it is not enough to provide powerful pumping of water. By changing the motor to a higher RPM motor can increase water flow and decrease pumping time hence making it more efficient. The next improvement can be done is make the inlet of the pump to be larger than the outlet. Due to the low pressure at the suction port, the low density of water, and the sluggish flow rate, the input of the pump is often bigger than the output. In order to avoid cavitation and maintain a constant pressure head at the inlet, it is common practise to connect the suction port to a bigger pipe diameter than the outlet. This is done so that the inlet can handle the same volume of water as the outlet, which is a lot faster. Maintaining the pump's outlet pressure is aided by a wider orifice diameter, which in turn reduces suction resistance and increases the efficiency of the pump.

To maximise power production from the solar charging station, a solar tracking system may be built to move it in the direction of the sun throughout the day. This method also has the downside of being manual and dependent on human assistance. If this system has to include sensing devices, it may be simplified by employing a more dependable sensor. To find a solution, further research into the programming of sensors in Internet of Things (IoT) systems is required. Temperatures around 25 ℃ are considered the sweet spot for maximum efficiency in photovoltaic solar panels. This is the greatest time to use solar photovoltaic cells since that's when they can soak up the most sunshine. Using the pump and pipelines, water is sprayed via the sprinklers located on the front of the photovoltaic modules. It was found that simultaneously cooling the front and rear surfaces of the PV panels was the most effective method of cooling. The solar panels' efficiency may be improved as a result of the lower module temperature.

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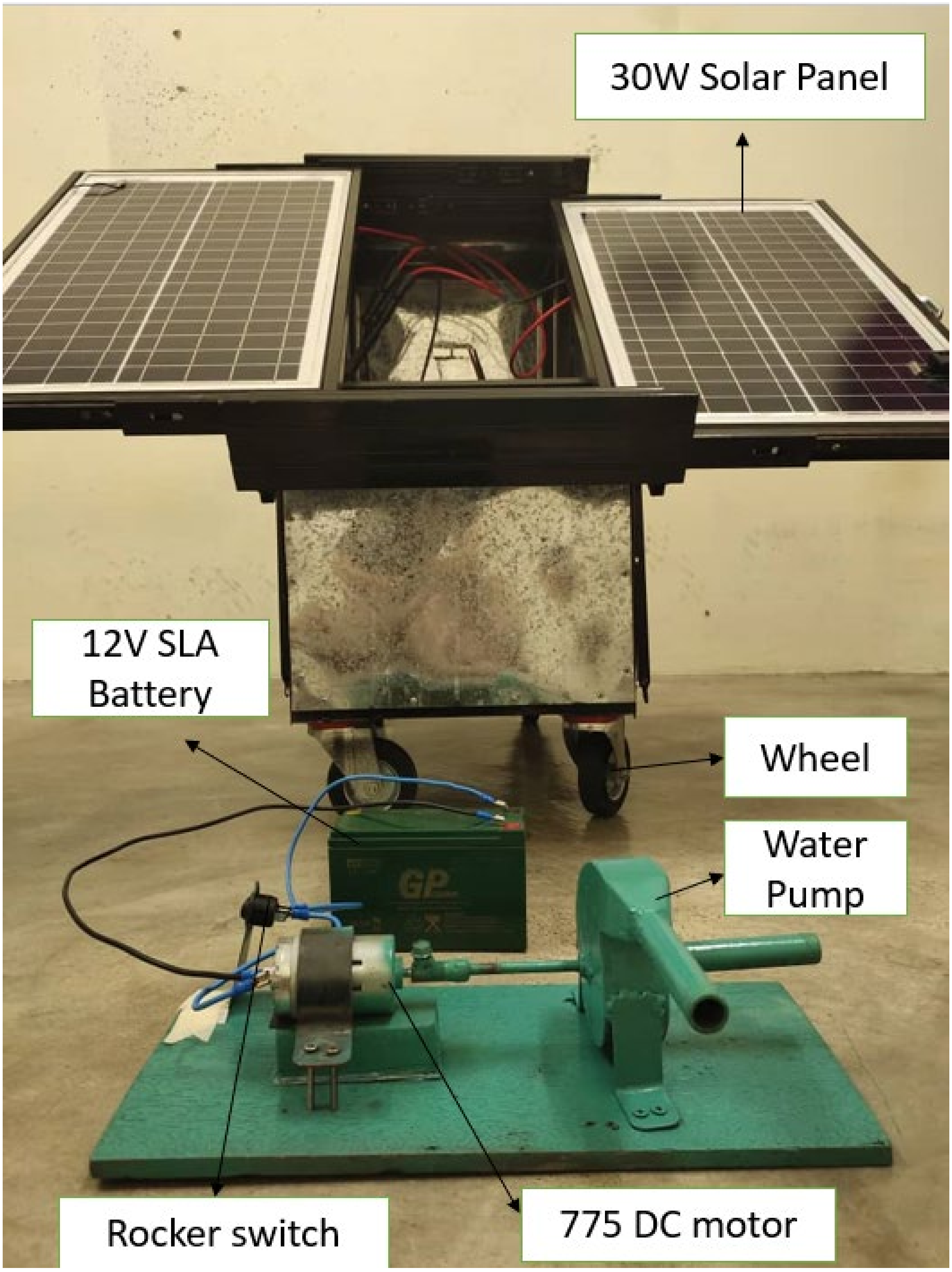
APPENDICES

Appendix A Overall system of the solar water pump for aquaculture



Appendix B Raw data of the solar panel's measurement

TIME	AMBIENT TEMPERATURE			MODULE TEMPERATURE			AMPS			VOLTS			WATTAGE			SOLAR RADIATION FLUX			HUMIDITY	WEATHER	
9	29.5	29.5	29.5	39.9	39.9	39.9	0.73	0.73	0.73	19.8	19.81	19.82	14.454	14.4613	14.4686	335.6	336.4	337.1	68	cloudy	
10	32.9	32.9	32.9	46.9	46.9	46.9	1.18	1.17	1.17	20.2	20.2	20.2	23.836	23.634	23.634	596.3	667.4	640.8	55	sunny	
11	35.9	35.9	35.9	50.1	50.1	50.1	1.99	1.99	1.99	20.5	20.5	20.5	40.795	40.795	40.795	787.4	684.1	814.6	46	sunny	
12	36.1	36.1	36.1	48.8	48.8	48.8	1.95	1.95	1.95	20.6	20.6	20.6	40.17	40.17	40.17	917.2	981.2	934.2	38	sunny	NORTH 0°/180°
13	34.5	34.5	34.5	50.3	50.3	50.3	2.02	2.02	2.02	20.4	20.4	20.4	41.208	41.208	41.208	913.8	945.3	931.5	39	sunny	
14	37	36.9	36.9	48.5	48.3	48.3	1	1	1	19.6	19.7	19.5	19.6	19.7	19.5	554.3	582.5	595.1	33	sunny	
15	33.7	33.7	33.7	40.6	40.5	40.5	0.92	0.87	0.87	19.4	19.5	19.5	17.848	16.965	16.965	398	399.3	413.1	41	cloudy	
16	36.3	36.3	36.3	44.2	44.1	44.2	0.79	0.78	0.79	19.5	19.5	19.6	15.405	15.21	15.484	526.1	567.4	574.9	36	sunny	

TIME	AMBIENT TEMPERATURE			MODULE TEMPERATURE			AMPS			VOLTS			WATTAGE			SOLAR RADIATION FLUX			HUMIDITY	WEATHER	
9	29.6	29.6	29.6	39.7	39.7	39.7	0.47	0.47	0.47	19.47	19.48	19.49	9.1509	9.1556	9.1603	229.4	227.3	225.3	67	cloudy	
10	36.5	36.5	36.5	46	46	46	0.83	0.83	0.83	20	20	20	16.6	16.6	16.6	449.1	438	336	45	cloudy	
11	31.3	31.3	31.3	42.8	42.8	42.8	0.99	0.99	0.99	20.5	20.5	20.5	20.295	20.295	20.295	405.9	401.1	425.4	47	sunny	
12	35.8	35.8	35.8	49.6	49.6	49.6	1.13	1.13	1.13	19.9	19.9	19.9	22.487	22.487	22.487	495.5	523.7	380.7	38	sunny	NORTH 45°
13	36.1	36.1	36.1	49.2	49.2	49.2	1.19	1.2	1.2	19.6	19.6	19.6	23.324	23.52	23.52	542.1	418.8	421.3	42	sunny	
14	37.4	37.6	37.7	48.3	48.4	48.5	1.01	0.98	0.99	19.7	19.6	19.6	19.897	19.208	19.404	522.7	530	532.7	35	sunny	
15	33.8	33.7	33.7	40.8	40.9	40.9	0.87	0.88	0.88	19.1	19.1	19	16.617	16.808	16.72	261.3	247.1	297.3	44	cloudy	
16	36.8	37	36.9	44.8	44.7	44.4	0.7	0.71	0.7	19.1	19.1	19	13.37	13.561	13.3	448.3	404.1	425.9	39	sunny	

TIME	AMBIENT TEMPERATURE			MODULE TEMPERATURE			AMPS			VOLTS			WATTAGE			SOLAR RADIATION FLUX			HUMIDITY	WEATHER	
9	33.3	33.3	33.3	39.8	39.8	39.8	0.96	0.96	0.96	20.5	20.5	20.5	19.68	19.68	19.68	453.6	453.7	450.6	63	cloudy	
10	34.9	34.9	34.9	44.1	44.1	44.1	0.81	0.81	0.81	20.1	20.1	20.1	16.281	16.281	16.281	397	386.6	390.1	53	cloudy	
11	33.5	33.5	33.5	44.3	44.3	44.3	1.78	1.78	1.78	20.5	20.5	20	36.49	36.49	36.49	859.5	848.3	912.6	44	sunny	
12	34	34	34	46.2	46.2	46.2	2.14	2.14	2.14	20.9	20.9	20.9	44.726	44.726	44.726	1089	1067	1068	36	sunny	SOUTH 0°/180°
13	35.2	35.2	35.2	51.2	51.2	51.2	2.12	2.12	2.12	21	21.1	21.1	44.52	44.732	44.732	1063	1085	1065	34	sunny	
14	38.2	38	37.9	45.1	45.2	45.2	1.1	1.1	1.1	20.2	20.1	20.1	22.22	22.22	22.22	817.6	820.2	816	38	sunny	
15	34.4	34.3	34.3	39.3	39.5	39.4	0.9	1	0.9	19.7	19.9	19.9	17.73	19.9	17.91	473.5	470.9	470.5	42	sunny	
16	33.9	34.1	34	37.8	37.8	37.8	0.8	0.7	0.8	19.7	19.8	19.7	15.76	13.86	15.76	254	280.8	271.9	45	cloudy	

TIME	AMBIENT TEMPERATURE			MODULE TEMPERATURE			AMPS			VOLTS			WATTAGE			SOLAR RADIATION FLUX			HUMIDITY	WEATHER	
9	34.1	34.1	34.1	40.3	40.3	40.3	0.89	0.9	0.9	20.3	20.3	20.3	18.067	18.27	18.27	500.7	515.1	527	63	cloudy	
10	32.7	32.7	32.7	43.1	43.1	43.1	1.02	1.01	1.01	20.2	20.2	20.2	20.604	20.402	20.402	479.6	480.5	478.3	53	cloudy	
11	33.1	33.1	33.1	40.2	40.2	40.3	0.89	0.89	0.89	20.4	20.4	20.4	18.156	18.156	18.156	433.6	460.4	622.4	54	cloudy	
12	34.8	34.8	34.7	49.9	49.9	49.9	2.21	2.21	2.21	20.5	20.5	20.5	45.305	45.305	45.305	903.5	908.9	932	39	sunny	SOUTH 45°
13	37.5	37.5	37	50	50	50	2.21	2.21	2.21	20.5	20.5	20.5	45.305	45.305	45.305	1106	1083	1068	43	sunny	Starting direction
14	38.9	38.9	39	43.5	43.8	43.9	1.1	1.1	1	20	20.1	20.1	22	22.11	20.1	731.9	739.8	737.1	38%	sunny	
15	34.9	34.9	34.9	42	42	42	1	1	1	19.9	19.8	19.8	19.9	19.8	19.8	439.7	437.3	435.6	38	sunny	
16	34	34	34	37.6	37.6	37.6	0.9	0.8	0.9	19.7	19.7	19.6	17.73	15.76	17.64	341.5	345.3	342.6	43	sunny	

TIME	AMBIENT TEMPERATURE			MODULE TEMPERATURE			AMPS			VOLTS			WATTAGE			SOLAR RADIATION FLUX			HUMIDITY	WEATHER	
9	31.6	31.5	31.5	40.4	40.4	40.4	0.8	0.8	0.8	20.3	20.3	20.3	16.24	16.24	16.24	464.7	482.3	502.4	70	cloudy	
10	30.8	30.8	30.9	41.9	41.9	41.9	0.92	0.93	0.93	20.5	20.5	20.5	19.065	19.065	19.065	403.1	432.8	449.9	54	cloudy	
11	36.9	36.9	36.9	45.9	45.9	45.9	2.08	2.08	2.08	20.6	20.4	20.4	42.848	42.432	42.432	917.4	1061	1055	41	sunny	
12	36.2	36.2	36.2	47.9	47.9	47.9	2.25	2.25	2.25	21.2	21.2	21.2	47.7	47.7	47.7	1043	1014	1022	35	sunny	EAST 0°/180°
13	34.5	34.5	34.5	48.4	48.6	48.6	2.1	2.1	2.1	20.5	20.5	20.5	43.05	43.05	43.05	999.8	971.4	903.1	36	sunny	
14	35.5	35.4	35.3	45.4	45.3	45.3	0.84	0.85	0.84	19.4	19.3	19.3	16.296	16.405	16.212	536.1	546.3	526.9	33	sunny	
15	34.9	34.7	34.6	43.6	43.7	43.8	0.63	0.63	0.63	19.2	19.3	19.3	12.096	12.159	12.159	490.7	516.2	499.4	35	sunny	
16	34.3	34.3	34.3	41.8	41.9	41.9	0.55	0.55	0.55	19	18.9	18.9	10.45	10.395	10.395	465.8	491.5	496	38	sunny	

Appendix B Continued

TIME	AMBIENT TEMPERATURE			MODULE TEMPERATURE			AMPS			VOLTS			WATTAGE			SOLAR RADIATION FLUX			HUMIDITY	WEATHER	
9	27.7	27.7	27.9	36.1	36.1	36.1	1.03	1.01	1.02	20.3	20.4	20.3	20.909	20.604	20.706	365	361.6	360.1	73	cloudy	
10	33.3	33.3	33.3	46.9	46.9	46.9	1.52	1.53	1.54	20.7	20.7	20.7	31.464	31.671	31.878	923.9	909.9	821.6	48	sunny	
11	34.6	34.6	34.6	44.3	44.3	44.3	2.03	2.03	2.03	21.2	21.2	21.2	43.036	43.036	43.036	1000.5	988.4	988.6	45	sunny	
12	35.8	35.8	35.8	51.2	51.2	51.2	1.62	1.62	1.62	20.3	20.3	20.3	32.886	32.886	32.886	744.6	728.3	749.7	33	sunny	EAST 45°
13	37.2	37.2	37.2	50.3	50.3	50.3	1.89	1.89	1.89	20.2	20.2	20.2	38.178	38.178	38.178	902.6	831.1	810	40	sunny	
14	34.6	34.4	34.3	44.1	44.1	44	0.61	0.61	0.61	18.8	18.7	18.6	11.468	11.407	11.346	234.3	230.2	226.5	33	cloudy	
15	34.5	34.5	34.5	42.5	42.3	42.3	0.55	0.56	0.55	18.5	18.4	18.5	10.175	10.304	10.175	210.9	209.7	205.5	39	sunny	
16	34.9	34.9	34.9	42.8	42.8	42.8	0.51	0.49	0.5	18.5	18.5	18.4	9.435	9.065	9.2	181.4	178	176.2	34	sunny	

TIME	AMBIENT TEMPERATURE			MODULE TEMPERATURE			AMPS			VOLTS			WATTAGE			SOLAR RADIATION FLUX			HUMIDITY	WEATHER	
9	30.3	30.3	30.3	38.1	38.1	38.1	0.7	0.71	0.71	20.5	20.5	20.5	14.35	14.555	14.555	361.6	355.1	364.6	66	cloudy	
10	32.6	32.6	32.6	46.9	46.9	46.9	0.83	0.83	0.83	19.88	19.99	19.9	16.5004	16.5917	16.517	665.1	670	648.6	54	sunny	
11	36.3	36.3	36.3	48.8	48.8	48.8	1.86	1.86	1.86	20.6	20.6	20.6	38.316	38.136	38.136	903.2	902.4	928	46	sunny	
12	35.7	35.7	35.7	48	48	48	1.96	1.96	1.96	20.7	20.7	20.7	40.572	40.572	40.572	927.2	737.7	859	39	sunny	WEST 0°/180°
13	38.6	38.6	38.6	54.9	54.9	54.9	2.01	2.01	2.01	20.9	20.9	20.9	42.009	42.009	42.009	1047	913.1	988.8	35	sunny	
14	38.3	38.2	38.1	46.6	46.7	46.8	1.2	1.2	1.2	19.9	19.9	19.9	23.88	23.88	23.88	798.6	796.9	791.6	37	sunny	
	34.6	34.7	34.7	37.9	37.8	37.8	0.91	0.91	0.91	19.6	19.5	19.5	17.836	17.745	17.745	355.7	360.9	363	42	cloudy	
16	36.2	36.3	36.4	41.1	41.1	41.1	0.98	0.98	0.98	19.9	19.9	19.8	19.502	19.502	19.404	457.6	482.4	529.1	40	sunny	

TIME	AMBIENT TEMPERATURE			MODULE TEMPERATURE			AMPS			VOLTS			WATTAGE			SOLAR RADIATION FLUX			HUMIDITY	WEATHER	
9	30	30	30	38.2	38.2	38.2	0.44	0.44	0.44	19.53	19.54	19.54	8.5932	8.5976	8.5976	169.2	188.6	148.8	68	cloudy	
10	34.1	34.1	34.1	45.6	45.6	45.6	0.6	0.6	0.6	19.4	19.39	19.39	11.64	11.634	11.634	354.1	373.4	373.9	49	sunny	
11	34.3	34.3	34.3	40	40	40	0.47	0.48	0.48	20.5	20.5	20.5	9.635	9.84	9.84	344.2	344.1	320.9	57	cloudy	
12	36.2	36.2	36.2	49	49	49	1.4	1.39	1.41	20.2	20.2	20.2	28.28	28.078	28.482	689.1	655.7	642.4	40	sunny	WEST 45°
13	35.1	35.1	35.1	50.3	50.3	50.3	1.71	1.71	1.71	20.1	20.1	20.1	34.371	34.371	34.371	811.4	810.7	816.5	42	sunny	
14	39.1	38.9	38.5	49.1	49.2	49.2	1.1	1.1	1.1	20.1	20	20.1	22.11	22	22.11	822.5	820.2	811.5	35	sunny	
15	35.3	35.3	35.2	40	39.9	39.8	0.94	0.94	0.95	19.9	19.9	19.9	18.706	18.706	18.905	406.8	411.3	415.7	43	cloudy	
16	37.2	37.2	37.3	42	42.6	42.8	0.99	1.03	1.01	20	20	19.9	19.8	20.6	20.099	702.4	709.8	685.1	39	sunny	

Appendix C Experimental works using the solar charging station


(a)


(b)


(c)


(d)


(e)

Figure C.1 Data measurement when the a) solar radiation flux reading taken at 45°. b) solar radiation flux reading taken at 0°, c) temperature reading taken, d) humidity reading taken, e) voltage and current reading taken,