Design & Economic Analysis of a Solar Powered Water Pumping System for Crop Irrigation

Inspiring Excellence

A Thesis submitted to the

Dept. of Electrical & Electronics Engineering, BRAC University

in partial fulfillment of the requirements for the

Bachelor of Science Degree in Electrical & Electronics Engineering

By

Jafrin Binte Joynal 11321019

Nuzhat Tabassum Raka 12121077

Hosaifa Mohon Mithu 12221016

Labiba Tanjim Iqbal 12321025

Supervised by

Dr. Md. Mosaddequr Rahman

Department of Electrical and Electronic Engineering

August, 2017

DEDICATION

Every challenging work needs self efforts as well as guidance of elders especially those who were very close to our heart.

Our humble effort we dedicate to our sweet and loving

Parents

Whose affection, love, encouragement and pray of day and night

make us able to get such success and honor,

Along with our hard working and respected

Supervisor

Also we dedicate our work to the **Farmers of Bangladesh** whose hard work and restless effort

pays off when they provide us food and contribute to our economy.

DECLARATION

We hereby declare that the research work titled "Solar powered pumping system" is submitted to the Department of Electrical & Electronics Engineering of BRAC University in partial fulfillment of the Bachelor of Science in Electrical & Electronics Engineering. This is our original work and it has not been submitted elsewhere for the award of any other degree or any other publication.

Signature of Supervisor

____

Dr. Md. Mosaddequr Rahman

Signature of Authors

____

Jafrin Binte Joynal (11321019)

____

Nuzhat Tabassum Raka (12121077)

____

Hosaifa Mohon Mithu (12221016)

____

Labiba Tanjim Iqbal (12321025)

ACKNOWLEDGEMENT

We want to express deepest gratitude to our thesis supervisor Dr. Md. Mosaddequr Rahman, Professor, Dept. of Electrical & Electronic Engineering, BRAC University for his supportive guidance and feedbacks for completion of the thesis. Without his continuous support and consistent help our thesis would not have been possible.

ABSTRACT

Agricultural technology is changing rapidly. Farming machinery, products are constantly being improved. Studies show that, PV systems in agriculture are the best solutions to the remote areas agricultural need. Solar energy source has the potential to provide energy services with zero emission. Since it is renewable energy source, it has abundant supply. The solar power pumping system can be used in remote or rural areas in Bangladesh where electricity is not that much available. Solar powered pumping system can be used for irrigations or for delivering water. Diesel powered pumping system has a cheap capital cost; however it is expensive and problematic to maintain and operate. On the other hand, solar powered pumping system is almost completely opposite. It has a high initial cost but it is considerably cheaper to run. A properly designed solar pumping system will be efficient, simple and reliable. This system will be cost effective and can meet up the need of the water in agriculture.

Table of Contents

List of Figures

Chapter 01

Introduction

Bangladesh, a developing country of south-east Asia, has an agricultural economy. This country has a large population and half of the people of this country depend on agriculture. About 59 percent cultivable land needs irrigation. During dry season in December-April, irrigation is essential for rice and winter vegetable cultivation. On the other hand, Bangladesh has severe energy crisis. Only 55 percent has access to electricity. Most of the power supply is limited to urban areas; rural people hardly get access to electricity. Due to shortage of electricity, it is difficult to meet the demand of electricity for irrigation. So, solar pump for irrigation is a good alternative to grid electricity.

1.1 Background

Solar pumps are cost-effective, environment-friendly and have good potential in places with high water table. Solar water pumps, along with appropriate agricultural technologies and water conservation at the local level, have huge potential in Bangladesh; as they provide water for irrigation to villages. Such local level provision for water results in less wastage and doesn't call for electric or diesel pumps thereby reducing farmers' expenditure. Another important aspect of solar water pumps usage is that the irrigation water is accessible at a reasonable cost to poor and marginal farmers who have to buy water from water sellers at prohibitive prices. Irrigation is a major input cost in agriculture. The use of solar-powered pumps can decrease the input cost up to minimum. For a small and marginal farmer, this is considerable and can be a game changer in making small and marginal farming more remunerative. Solar pumps are an attractive alternative technology for irrigation, which serves as a cost effective mode of irrigation with low maintenance requirements.

In addition, solar water pumps operate with zero carbon foot print. The environmental impact caused by the use of diesel pump is often not known to people. There are three types of irrigation systems. That are- Direct System, Direct system with battery and Hybrid System. Direct systems are basically electrical irrigation system and it also can be used with battery for giving continuous supply to the system. But the systems are not cost effective and it also pollutes the environment. Typically, diesel powered irrigation system are used in areas where connecting to the electricity grid is difficult. There are three types of pumps are used for irrigation, such as- Low Lift Pump (LLP), Shallow Tube Well (STW) and Deep Tube Well (DTW).DTW is mainly operated by electricity and LLP, STW uses diesel. A solar powered water pumping system initially costs more but it requires far less maintenance and labor. Since, solar energy is renewable energy and it is abundant, it can provide us the power that the pump needs to run and provide water to the crops. So, zero carbon footprints, accessible irrigation water for poor farmers and lower cost of inputs are the important benefits of solar water pumps.

Solar powered pumping system is economically viable option for irrigation these days. This new technology in agricultural system can reduce the electricity crisis for crops and domestic animals as well as it can be beneficiary for the farmers in remote areas of Bangladesh.

1.2 Motivation

In Bangladesh, many farmers had to face a lot of problems regarding irrigation. In summer, due to lack of rainfall drought happens and there is interruption of electricity due to load shedding. As a result, crops do not get the required water, and it dies. Farmers had to face a huge loss for it. So, to avoid this problem; solar powered pumping system is the best solution. Solar energy can be of great use in irrigation. We can store the solar energy and can run the water pump to provide necessary water to the crops for irrigation.

1.3 Literature Review

Electrical and diesel-powered water pumping systems are widely utilized for irrigation applications in Bangladesh. The need for the optimum utilization of water and energy resources has become a vital issue during the last decade, and it will become more essential in the future. Photovoltaic energy conversion is one of the best ways to harvest the solar energy [1]. Researchers around the world have investigated on the solar powered pumping system. The use of solar photovoltaic energy is considered to be a primary resource for the countries located in tropical regions, where direct solar radiation may reach up to 1000 W/m^2.

In Egypt, Mahmoud and Nather[2] investigated the performance of solar powered pumping system using batteries for sprinkling and dripping irrigation systems. It has been concluded that it can be used efficiently for water pumping in agriculture sectors. The cost of the water pumped by photovoltaic systems is much less than that of water pumped using conventional grid connected and diesel powered pumping methods. They also concluded that this system can operate more effectively compared to other traditional irrigation systems during potential sunshine hours. This system also improves the quality of life and promotes socio-economic development in rural area. In related work, Mankbadi and Ayad[3]discussed the performance of small capacity direct SPWPS under the meteorological conditions of Egypt and reported that small capacity direct SPWPSs are most suitable for domestic water pumping applications. Meah et al. [4] presented the economical in rural locations facing a shortage of electricity. After economic analyzing, it is shown that Photovoltaic pumping system for irrigation in Bangladesh is more feasible than Diesel engine pumping system. In economic viewpoint, PV pumping system for only one season irrigation is a little bit higher than the diesel engine pumping system due to high cost of PV module and its components[12].Solar powered pumping system has been proven to be a technically and economically feasible option in developed nations such as the USA, Germany, Australia, etc.

1.4 System Overview

A photovoltaic system or solar power system is a power system designed to supply usable solar power by means of photovoltaic. It consists of an arrangement of several components, including solar panels to absorb and convert sunlight into electricity. Among the two types of PV panel- Mono crystalline and Poly crystalline Panels, we choose the poly crystalline panels because it is cost effective and it is also efficient. A typical solar-powered pumping system consists of solar panels connected to an electric motor that runs an electric pump. Electricity for the motor is generated on-site through a solar panel which converts solar energy to direct-current (DC) electricity. Because the nature of the electrical output from a solar panel is DC, a solar-powered pump requires a DC motor if it is to operate without additional electrical components. Due to the increased complexity and cost, and the reduced efficiency of an AC system, most solar-powered pumps have DC motors. Solar irrigation pump works best on sunny days; but water is also required in the cloudy days. We are not using any storage tank for our system, as it is not economic. So we have considered 30% days as cloudy days in a month and rest of the days as sunny days. For this reason, we designed it in such way that our system can always give the desire water output to fulfill daily water requirement for irrigation.

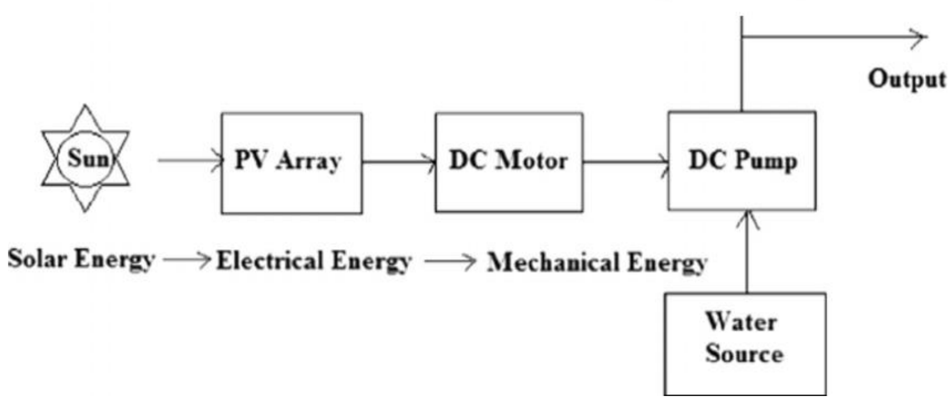

Figure 1.4: Block diagram of a direct coupled Solar Powered Pumping System

1.5 Scope of Work

The deficit in electricity and high diesel costs affects the pumping requirements of community water supplies and irrigation; so using solar energy for water pumping is a promising alternative to conventional electricity and diesel based pumping systems. In our research work, we have developed a model theoretically but it can be implemented practically. Moreover, in our system we haven't used battery and storage tank because it is not economically viable. But battery can be used in the system to ensure the power and storage tank can be used to store some waters.

1.6 Thesis Organization

In Chapter 1, we have explained the reason behind choosing our thesis topic. Background, Literature review, scope of work is shortly discussed. An overview of the system has also been discussed.

In Chapter 2, we discussed about different solar powered pumping systems.

In Chapter 3, we have discussed about the field trip from which acquired many information about diesel system and the irrigation process. It also gave us knowledge about how much the farmers are aware about the solar powered pumping system.

In Chapter 4, this chapter describes the whole design of the system, its components and block diagram of the complete system.

In Chapter 5, we showed the solar radiation calculation which helped us to determine the flow rate based on irradiation and from this calculation we were able to proceed to the system design. And we analyzed the whole design of the system.

In Chapter 6, we have shown the economic analysis of the system which clearly shows that solar powered pumping system is economical and cost efficient rather than the diesel powered pumping system.

In Chapter 7, finally the report concludes in this chapter with advantage and disadvantage of solar pumping system.

Chapter 2

Solar powered pumping system

Crop farming has been the way of life for Bangladesh and thousands of acres of arable lands are dedicated to crop farming. Farming requires uninterrupted and cost effective methods of water dispersion. Energy crisis and scarcity of diesel had been major disruptive factors and drawback to irrigation system resulting in reduced crop yields. Around 45 percent of Bangladesh's work force is employed in agriculture, which represents an important sector in the country's economy. Solar powered pumps are a reliable irrigation alternative for farmers as solar technology helps reduce costs, protect the environment and lower expensive diesel fuel imports. An agricultural solar water pump system can drastically improve electric bill by collecting the rays of the sun and converting them into electricity to power. With the promotion of new energy utilization, recently the usage of solar water pump has been more and more increased. In our research, we are focusing on this system and trying to develop a design that can be economically feasible. There are three types of solar powered pumping system-

1. Direct System
2. Battery coupled System
3. Hybrid System

2.1 Direct System

The deficit in electricity and high diesel costs affects the pumping requirements of community water supplies and irrigation; so using solar energy for water pumping is a promising alternative to conventional electricity and diesel based pumping systems. Solar water pumping is based on photovoltaic (PV) technology that converts solar energy into electrical energy to run a DC or AC motor based water pump. There are three basic types of solar-powered water pumping systems- battery-coupled system, direct-coupled system and hybrid system. A variety of factors must be considered in determining the optimum system for a particular application

In direct coupled pumping systems, electricity from the PV modules is sent directly to the pump, which in turn pumps water through a pipe. The amount of water pumped is totally dependent on the amount of sunlight hitting the PV panels and the type of pump. Because the intensity of the sun and the angle at which it strikes the PV panel changes throughout the day, the amount of water pumped by this system also changes throughout the day. During optimum sunlight periods, pump operates at or near 100 percent efficiency with maximum water flow. However, during early morning and late afternoon, pump efficiency may drop by as much as 25 percent or more under these lowlight conditions. During cloudy days, pump efficiency will drop off even more. To compensate for these variable flow rates, a good match between the pump and PV module(s) is necessary to achieve efficient operation of the system. Without batteries, the PV pumping system is very simple. It consists of just three components: the solar array, a pump controller and the pump. Many use storage tank to storage extra water for three-five days. But it is economical not to use storage tanks. Direct coupled system can be designed by considering certain things that will make the system economical and efficient.

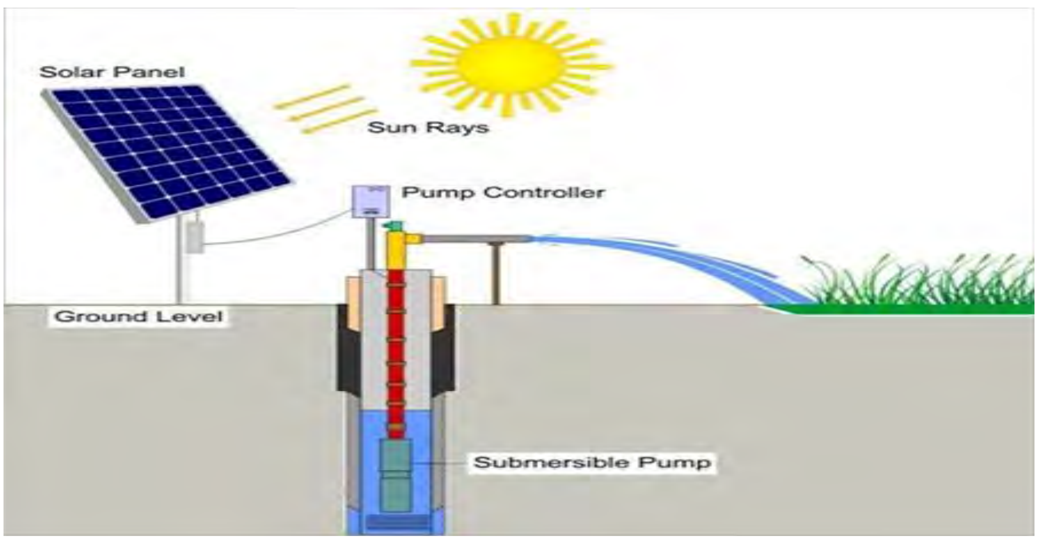

Figure 2.1: Direct solar system

Advantages: The system is economical because it does not have battery or tanks. It has a simple design. It does not require maintenance as it does not have battery/tanks. Cost effective and simple system is efficient and gives the maximum output.

Disadvantages: The system has no backup; in case of shortage of power required to the pump, the system lacks battery. Again, it has no storage tanks, so in the cloudy days there will be less pumping from the system and can be a shortage of water. And if the tank is added to the system, it can store water on these days.

2.2 Solar water pumping system with Battery

Most solar water pumps run directly off solar panels or PV direct in the whole world and do not require batteries for storage purpose. There are two storage technologies, one is battery and another is water tank. Most of the time people use water tank because it is less cost and less complexity than using batteries and in this system electrical power have to be converted into potential power. Though it happens in most cases, but using batteries has also some importance. Mainly, we can talk about the night and rainy days when the PV panels cannot work. Solar panels are totally inactive without sun rays. As we know that Photo voltaic are able to produce electricity only when the sunlight is available, therefore stand-alone systems obviously need some sort of backup energy storage which makes them available through the night or bad weather conditions. When we need extra pressure on water, we can use the energy which is stored in the batteries. There are many kinds of batteries which can be used. We only show you two types such as,

1. **Lead acid batteries**
   For this system, from many storage technologies, one can use the lead-acid battery to storage energy. The lead-acid battery continues to be the workhorse of many PV systems because it is relatively inexpensive and widely available. In addition, to energy storage, the battery also has ability to provide surges of current that are much higher than the instantaneous current available from the array, as well as the inherent and automatic property controlling the output voltage of the array so that loads receive voltages within their own range of acceptability.

2. **Deep cycle batteries**
   As batteries are one kind of balancing system component, those are very important. An important BOS (Balance of system) component of the PV system is energy storage capacity. Often, the application will require electrical energy on demand so that the solar panels are used to charge batteries (during sunlight hours), in turn, the batteries then provide electricity when required. Deep-cycle batteries are most appropriate for PV application as they can withstand cycles of up to 80% discharge.

Though we don’t use this process, it’s probably looked like the following figure.

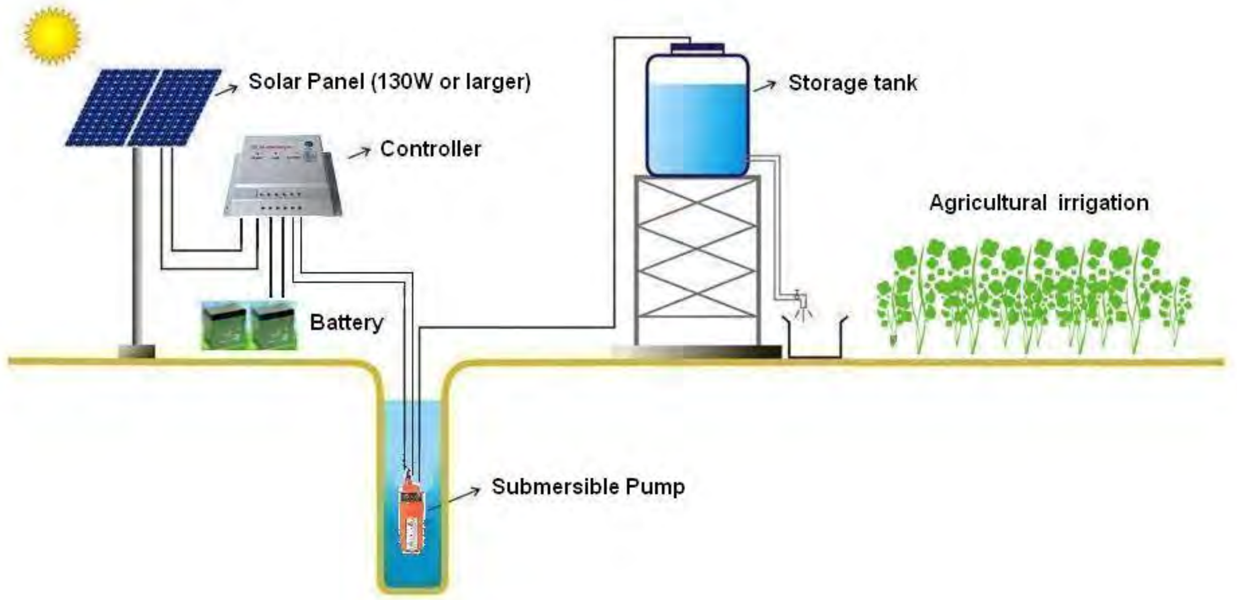

Figure 2.2: Solar water pumping system with batteries**.**

Advantage:

1. Batteries are creating another method of managing the solar power.
2. Maximize self-consumption of solar power.
3. Reduce network costs which control us when we use power and how much we pay for it.
4. Keep the motor on, if we lose power. It's the backup plan for when the power goes out.

Disadvantage:

1. Batteries are more expensive and less effective than the water tank.
2. Reduce efficiency of the whole system.
3. Batteries also require regular maintenance.
4. Have no longer lasting warranty.
5. Increase maintenance costs and labor costs.
6. Make a complex system.
7. No backup during an outage.
8. Does not create energy surplus.

2.3 Solar Hybrid System

In some applications, it is both economical and desirable to use a hybrid system, whereby the PV supplies some or most of the load, but with a diesel or petrol generator as a backup. This allows the PV system to be designed to quite a low availability, usually resulting in considerable savings on battery capacity and to a lesser extent on PV panels. Obviously, for many applications, particularly in remote areas, generators and PV are quite incompatible. However, for applications such as homesteads, where on-site labor is available for maintenance, they should be seriously considered, especially when a system design falls within the region.

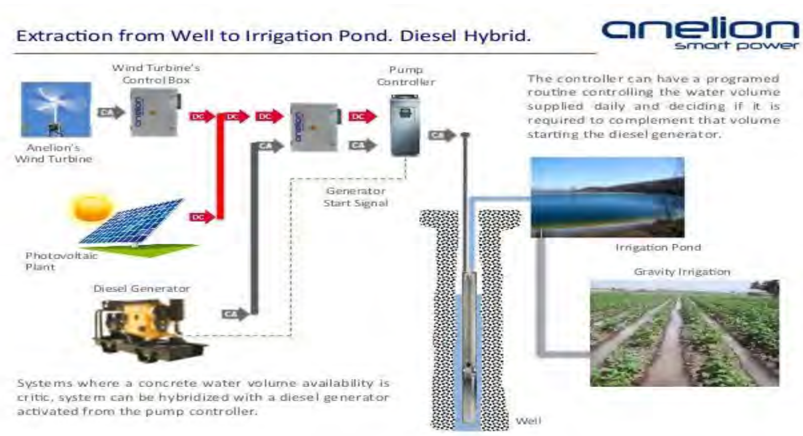

Figure 2.3: Hybrid solar system.

The main advantage of the system is it requires less initial cost and has simple design.

Disadvantages of the system are its maintenance cost is very high, it also increases carbon footprint which leads to global warming, since it is not renewable energy we should maintain it efficiently.

We chose the direct coupled system for our research. Because the system is economical, requires fewer components and has a simple design. We considered 30% cloudy days in every month and rest of the days as sunny day. The solar irradiance is calculated from which we got the flow rate and decided the pump. We used submersible centrifugal pump for our system and the system meets the water requirement.

Chapter 3

Field Study

3.1 Location:

For our field study for the system, we selected Dhanbari upazilla of Tangail district. We visited the upazilla and roamed different rural areas under the upazilla.We saw the irrigation system and the crop and harvesting there. Then we talked with the farmers who live and work there for ages. Most of the farmers, who gave interviews, 26 out of 34, lived and worked in the Dhanbari rural area. Farmers in this area mostly use river water as well as have wells beside their fields for constant water supply. Therefore, the field study was conducted where farmers are using pumps to get water from well.

Figure 3.1: Dhanbari upazilla, Tangail.

3.2 Interviews

The main approach in gathering information and data was by using a questionnaire. 34 farmers were interviewed on their farms. As a result of this, it was easier to observe their situation and take additional notes if needed. From their interviews we knew about the scarcity of water during summer and in winter too. They suffer so much because of different problems and it cause economic problem to them. Those who run the electric pumping system, their big problem is load shedding. Moreover, the cost of fuel and the maintenance cost of the pumping system is very costly to some farmers. Yet they manage it somehow to cultivate the crops. They mainly use the Diesel powered pumping system. When we asked about the solar powered pumping system, we found out that they hardly have any knowledge about the system.

3.3 Irrigation and Farming

Most of the farmers had a field size of less than two acres, and 88 % had their water source less than 100 m away from their field. As seen, river was the most encountered water source; although, many of those farmers mentioned that they want a well instead, partly due to the bad water quality in the river. Maximum farmers use basin method where as other farmers use drip method for irrigation. Their main energy source is electric power. Rice and mustard is their two main cultivated crop. Besides these they also grow potato and other vegetables.

Figure 3.2: Cultivation of Mustard in Dhanbari upazilla

3.4 Economy and Problems

Almost all of the farmers explained that their main economic issue was the high fuel costs. The average investment cost of a pump was 5,500tk and the average fuel costs for all of the farmers was , thus spending more than seven times on fuel in a year than on the purchase of a new pump. In addition, the average pump maintenance cost was 12,000tk/year, which is approximately of the pump investment cost. More than half, said that they were not able to receive bank loans to invest in new equipment and of them paid with own capital if they were to invest. Farmers with drip irrigation earned, on average, times more per acre irrigated field than farmers with basin irrigation.

3.5 Knowledge and Opinion

Solar powered irrigation system was quite unknown to the interviewees. Hardly, one or two of them had heard about solar powered irrigation system. Though everyone was very interested, but most of them lacked knowledge about the technique and therefore were a bit doubtful. Besides they were anxious about maintenance cost and the availability of water during cloudy days. After assuring them about its performance, they were keen to use the solar powered pumping system for the irrigation purpose.

Chapter 4

Designing Process of Solar Powered Pumping System

4.1 <u>Water requirement:</u> The first thing we need to consider while designing a solar water pump system is to determine the water requirement. For our irrigation system at first, we need to find out the average requirement of water for the crops grown on the field. This requirement differs from place to place so we need to be more specific where we want to implement our system. We have decided to implement our system on Tangail, Bangladesh. For our location we need 30 m^3/day (meter cube per day) which is the maximum requirement of our specific location. Our field size is 4 acres which is equal to 1.6034 Hectares and also equivalent to 9.90 Bighas. Crops grown on the field are Rice and mustard throughout the whole one year.

4.2 <u>Water source:</u> The second thing is we need to determine the water source from where we will supply our water to the field. The available water source may be ground water, surface water or rain water. The common sources are the well, borehole, river, pond and spring. We are going to use Well as our water source since our allocated location have a well which insufficient for our requirement throughout the whole year. Before choosing well we also consider static water label and dynamic water label of the well.

- **Static water level**:
  Static level is the distance from the surface of the water to the top of the well. This static water level can change over time depending on season.

- **Dynamic water level**:
  Dynamic static level is the distance from the top of the well to the surface of the water when pump is running. We measure dynamic water level while pump run because normally it decreases when pump runs. The water level

may vary due to the various season so we need to do some observation or test so that the dynamic water level remains same for the whole year. It is important not to exceed the capacity of the source because this can lead to the pump running dry and risking severe damage.

4.3 System layout:

To get a picture of the system at first, we need to design a sketch of the whole system which is very important before moving to the real one. The sketch will include where the different component should be located will also include distance and elevation between the components.

The components are:

- Solar panel /array
- System Controller
- Pump
- motor
- Water source
- Pipelines

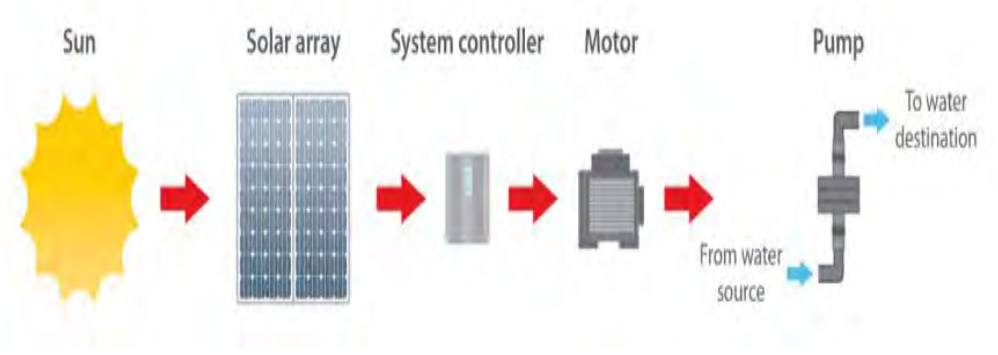

Figure 4.1: Basic components of a solar powered pumping system

4.4 Insolation and solar panel location:

Solar Irradiation means the total amount of solar radiation energy received on a given particular horizontal surface per unit time per unit area. The solar radiation depends on a place depends on the time of the year and the place's latitude and longitude. Tangail's alatitude& longitude is 24.3917 degree North and 89.9948 degree East respectively.

4.5 Determining flow rate for the pump:

Our pump is designed based on our flow rate which is based on the sun peak hours for the chosen designed month and the daily requirement. In Tangail, the irrigation duration for rice is four month from December to March. For our design, we choose the month January which has the least amount of insolation. This is because to ensure that the system is not undersized for any month of the year. We also take average radiation of the whole month and find a date January 17 to calculate our insolation.

The designed flow rate for the pump can be calculated using the equation1.

Designed flow rate = Daily Water needs ÷ peak sun hours (1)

4.6 Finding Total Dynamic Head (TDH):

Total dynamic head for pump (TDH): Total dynamic head is the total amount of pressure when water is flowing in a system. It comprised of two parts: The Vertical rise and friction loss.

- **Vertical rise**: it must be determined what the vertical rise is from the liquid's starting point to its ending point. As the liquid level in the tank decreases, the vertical rise will increase, and consequently, the total dynamic head will increase.

- **Friction Loss**: To calculate the friction loss you first need to know what your desired flow is. Each flow rate will have there will be, so 5GPM going thru 1 inch pipe will have a higher friction loss than 1GPM going thru 1 inch pipe. After your flow rate, you need to know what type of pipe you are using, the schedule of the pipe, and the length of the pipe, both vertically and horizontally. You also need to know how many elbows, valves, connections, and anything else that comes into contact with the liquid.

- **Pressure head**: The pressure at the delivery point in the tank. If the delivery point is on the top of the tank, this parameter can be set as zero.

The formula for vertical rise is-

Vertical rise =Dynamic head +Tank Elevation +Tank height. (2)

Length of pipe=vertical rise + distance from well to field. (3)

$$\text{Frictional loss} = \frac{\text{friction of selected diameter}}{100\text{m}} * \text{length of pipe} \quad (4)$$

TDH =vertical raise + pressure head + friction losses. (5)

4.7 Pump Selection:

Pump Selection for the system:

Submersible pump: Submersible pumps are designed for medium flow application. The submersible pump has an in-built protection against dry run. However, the surface pumps are very sensitive to dry run. A dry run of 15 minutes or more can cause considerable damage to a surface pump. Submersible pumps are easier to install and are better protected from the environment.

Centrifugal Pump: Centrifugal pump uses high-speed rotation to suck in water through the middle of the pump. These pumps have an impeller that spins the water to subject it to a centrifugal force. They are efficient for flow in excess of 40l/minute and lifts generally less than 40-50m. The major drawback with them is that at reduced speeds such as those that occur during low-sun conditions, centrifugal pumps lose efficiency in a disproportionate manner.

Surface Pump: These are suitable for areas where the water level is within 7m below ground level. A surface centrifugal pump is normally placed at ground level. A surface pump can draw from a river, irrigation ditch, pond, or water tank, but not from a deep well. These pumps are designed for high flow rates and low head.

- Surface pump Advantage: Low cost, efficient for low lift and high flow rates

  Disadvantage: Can be damaged by running dry

- Centrifugal Pump Advantage: For higher heads and high flow rate.

  Disadvantage: Efficiency Low for low sun intensity

- Submersible Pump Advantage: Regular maintenance not required

  Disadvantage: Efficiency very low for flow rates below 30 l/minute.

This part is the most difficult part for a design, before choosing a pump we need to consider our flow rate, depending on the water requirement and the source from where we will pump water. However, there are several option for our requirement we choose the best one for our design. we select the pump by reading configuration of the pump which are designed for different flow rate and TDH. We have also decided the size of the pump by investigating the performance curves. After selecting the size, we determine the peak power of the pump. Peak power requirement is the factor used when selecting the solar panels.

Considering the advantages and disadvantages, we chose submersible centrifugal pump for our design, name-

“PS 600 C-SJ8-5”

4.7.1 Technical data for pump: Technical data is shown in Appendix.

4.8 Solar panel selection and panel layout:

The solar panel can be decided depending on the requirement of the peak power, operating current voltage of the pump. We have decided to use SYFD-SPC 180W 2 polycrystalline photovoltaic PV solar panel module. Here, we consider 30% oversize the panel due to cover power losses from heat, dust and aging. Then we arrange parallelly and in series according to our requirement.

4.8.1 Panel Specification:

Specifications Maximum Power: 180W .Optimum Operating Voltage (Vmp): 16.8V Optimum Operating Current (Imp): 10.71A Open-Circuit Voltage (Voc): 20.3V Short-Circuit Current (Isc): 11.71A Dimensions: 1302*796*35mm In Weight: 14KG.

4.8.2 Solar specification:

Back Contact solar panels for off-grid and on-grid systems 2. Sunpower cells from USA Sunpower Corporation 3.19%-23% high efficiency. 4.Back contact solar cells looks more beautiful and amazing. The high efficiency solar PV module adopts the world's highest efficiency cell with efficiency up to 23%, and efficiency of the module is 25-30% higher than the traditional ones, this cell’s positive pole and the negative pole are on the same side, the cell’s front side can absorb maximum sunlight , so that it can get the maximum power.

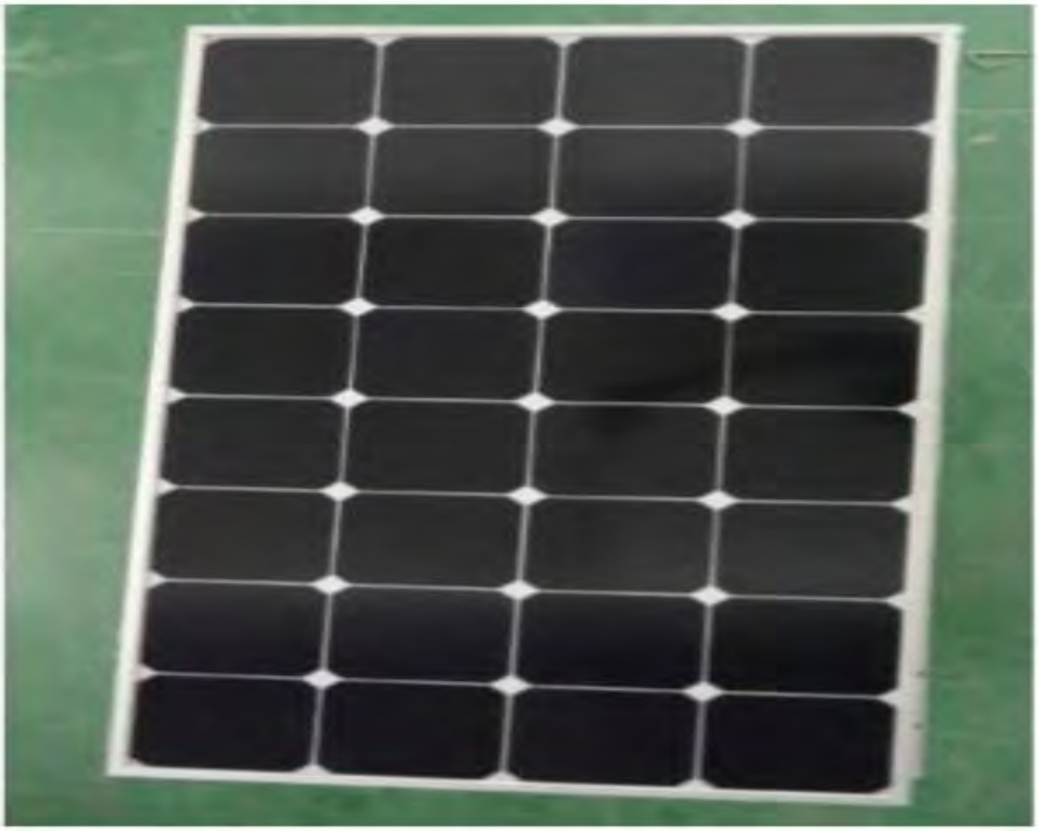

Figure 4.4: SYFD-SPC 180W 2

To achieve enough peak power from the panels the system is to oversized with 25%.This is shown below

Required solar panel peak power =pump peak power * 1.25 (6)

Amount of panels = Required solar panel peak power /Panel peak power. (7)

4.9 Summary of the system:

	A	B
1	Components	
2	**Submersible pump**	
3	Peak power requirement	0.7KW
4	Required voltage	48V
5	Max Input voltage	150V
6	Max Input current	13A
7	**Solar panel**	
8	Peak power	180W
9	Optimum operating Voltage	16.8V
10	Optimum operationg current	10.71A
11	**Solar panels configuration**	
12	5 conncetions are in series.	
13	Peak power	1000.36W
14	Voltage	84V
15	Current	10.71A
16	**Pipe**	
17	Type	Pvc
18	Length	19m
19	Diameter	38.1mm
20	**Irrigation System**	
21	Type	Basin

Table 4.1: System ratings

The Table above shows the summary of main components of our project. The system is not completed, as other components such as wiring, mounting, safety components etc. have to include. We must also need to consider the protection of the system.

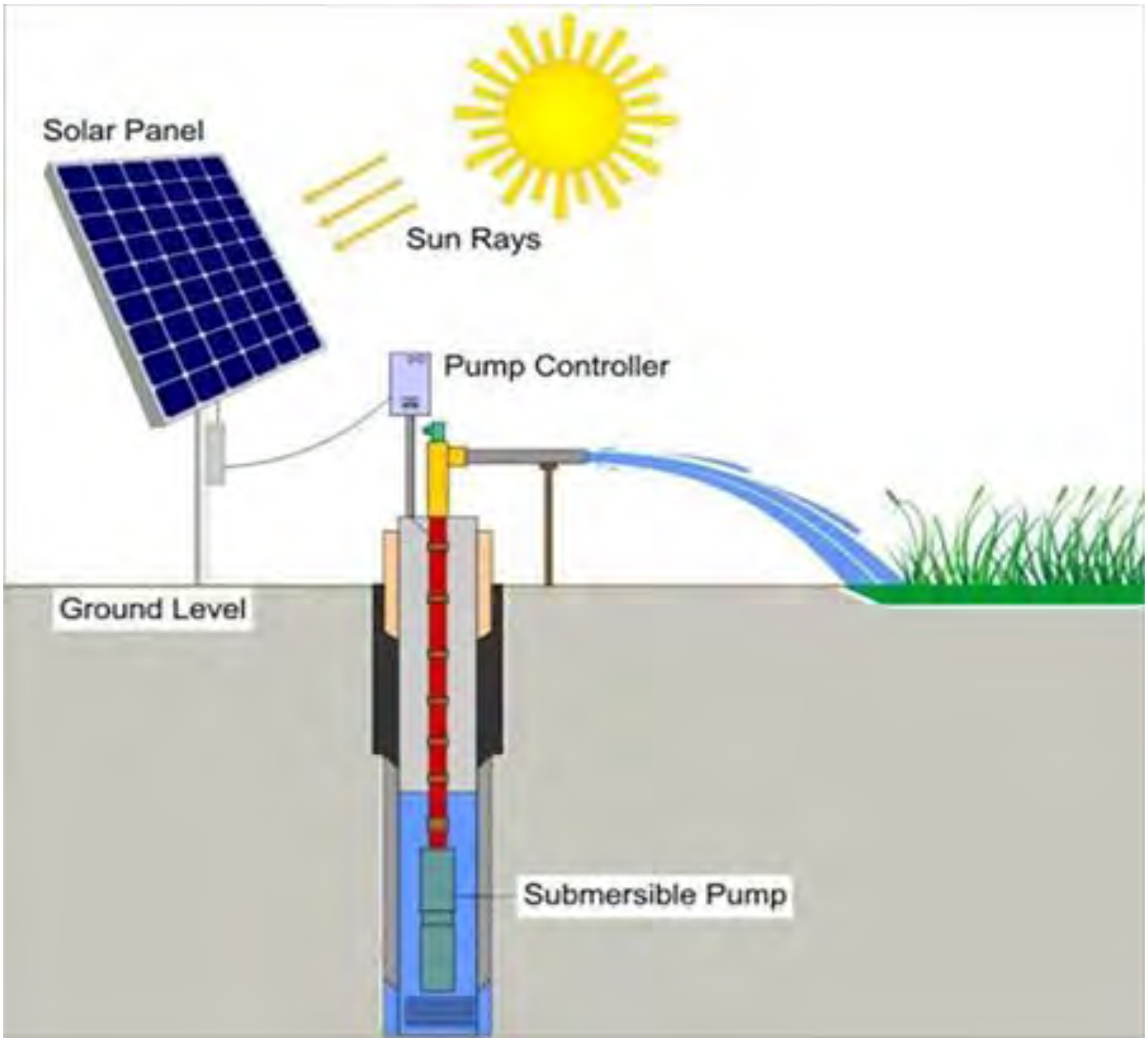

Figure 4.5: Solar Powered Pumping System

Chapter 5

Design and Analysis

5.1Solar radiation :

5.1.1 Solar constant

Solar constant is the intensity of solar radiation hitting one square meter of the earth.

Or it is the intensity of radiation from the spherical black body, whose temperature is 5785°K and diameter is 696·106 m, per square meter on a spherical surface whose radius is 150.109m and with the Sun placed at its center.

$$G_{sc} = \sigma T^4 . \left(\frac{4\pi R}{4\pi D}\right)^2 = 1367\ W/m^2$$

Where

σ= 5.67·10-8 W/m2.K4 is the Stefan-Boltzmann constant.

R= 696·106 m is the Sun radiuses

D=150 ·109 m is the average distance between the Sun and the earth

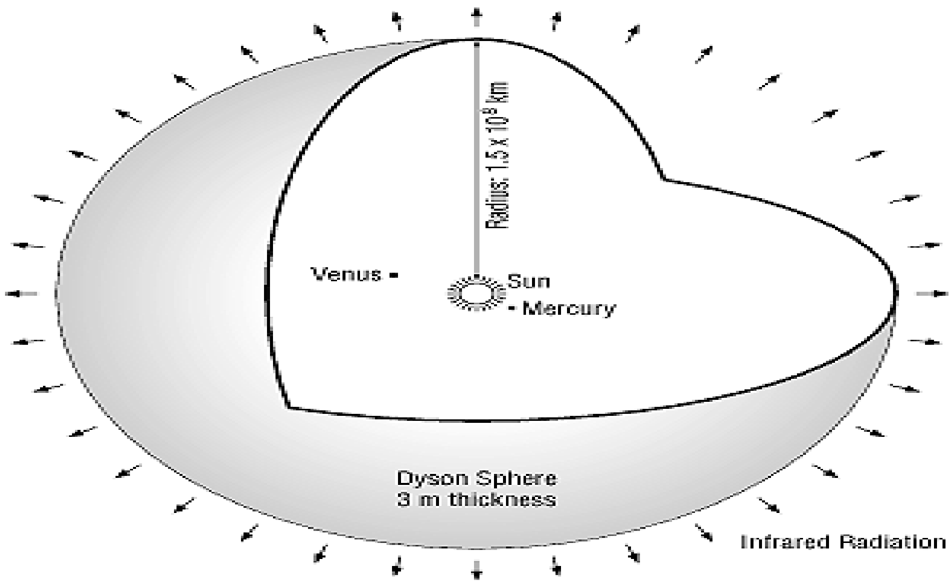

Figure 5.1: solar radiation intensity of the earth

5.1.2 Latitude φ

Latitude is used to state how far north or south, relative to the equator.

•If on the equator Latitude is zero.

•If near the North Pole or the South Pole latitude is nearly 90 degrees.

Latitude is the angle measured at the center of the Earth, between the Equator plane and where you are. It is expressed either north or south, and varies from 0° to 90°.

φ=24.4degree

5.1.3 Longitude 'L'

Longitude shows the location in an east or west direction, relative to the Greenwich meridian. Longitude is the angle at Centre of the Earth, between where our and Greenwich. It can be measured either east or west and varies from 0° to 180°.

L = 89.9 degree

5.1.4 Declination δ

Declination is the angle made between the plane of the equator and the line joining the two centers of the earth and the sun.

$$\delta \approx 23.45 \cdot \sin\left(360 \cdot \frac{284 + n}{365}\right)$$

Where n is the number day of the year starting from 1st January. Using monthly average daily global solar radiation, we can get the monthly average extra-terrestrial daily radiation. Here, n is the number typical of day of the month. The total solar radiation on a tilted surface is made up of the direct or beam solar radiation, diffuse radiation and ground reflected radiation, assuming isotropic reflection. As a consequence, the monthly average daily solar radiation on a tilted surface with these declinations will be worked in our system. The day number of the month is universally assumed as follows in the table 5.1.

Table 5.1: Day numbers and standard mean day of the month

Month	n for i:th Day of Month	For the Average Day of the Month		
		Date	n, Day of Year	δ, Declination
January	i	17	17	-20.9°
February	31 + i	16	47	-13.0°
March	59 + i	16	75	-2.4°
April	90 + i	15	105	9.4°
May	120 + i	15	135	18.8°
June	151 + i	11	162	23.1°
July	181 + i	17	198	21.2°
August	212 + i	16	228	13.5°
September	243 + i	15	258	2.2°
October	273 + i	15	288	-9.6°
November	304 + i	14	318	-18.9°
December	334 + i	10	344	-23.0°

*The average day of the month means that we took the minimum radiation day of the month.

As we consider the date January 17th, so our corresponding n= 17 (number day of year). Our system is straight forward and minimal data inputs are required and these include day of year and site latitude. We consider 17thjanuary which has the least amount of insolation because we ensure that the system is not undersized for any month of the year.

The Declination varies between -23.45°≤δ≤23.45° and is positive during summer and negative during winter. On the same day the declination is equal everywhere on the earth.

So, for n=17, our declination is -20.916°.

Counting all n for all month of a year, we can see declination is different from each other. Figure shows below that the variation of the declination angle of whole year.

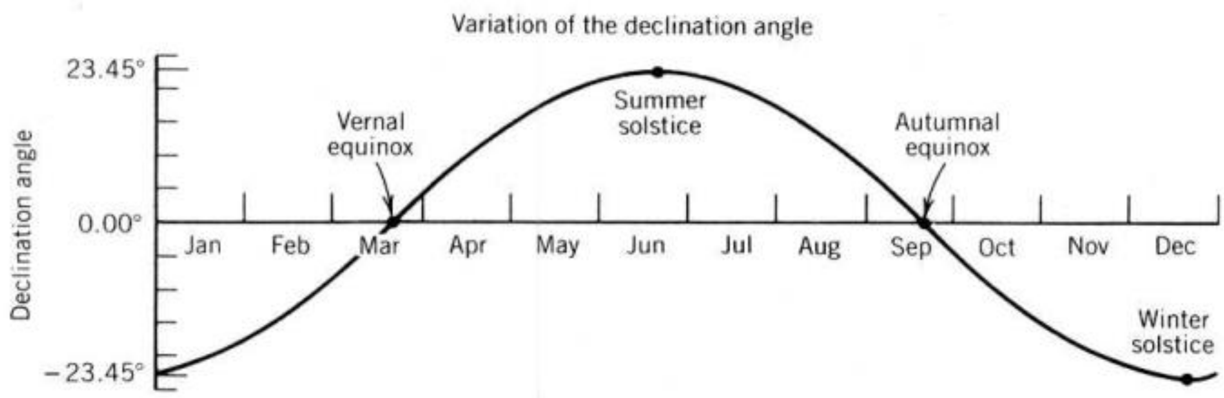

Figure 5.2: variation of the declination angle in different month

5.1.5 Zenith Angle θz

Zenith Angle, θz is incidence angle of sunbeam on a horizontal surface. It is found by inserting β=0 in incidence angle equation.

$$\theta_z = (\varphi - \delta) \cdot \frac{3.1416}{180}$$

During the same day, zenith angel determines amount of radiation received by surface.. By calculating we get the zenith angle, $\theta_z = 0.79°$.

5.1.6 Sunrise angle, w_s

The sunrise hour angle is the hour angle when the zenith angle is 90.

$$\cos \omega_s = -\tan \varphi \cdot \tan \delta$$

Considering this equation, our sunrise angle is 80.02°.

5.1.7 Solar altitude,

Solar altitude refers to the angle of the sun relative to the Earth's horizon. The value of the solar altitude varies based on the time of day, the time of year and the latitude on earth. Regions close to the equator have a higher solar altitude than regions near the earth's pole.

$$\sin\alpha = \cos\varphi \cdot \cos\delta \cdot \cos\omega + \sin\varphi \cdot \sin\delta$$

Using this equation we have measured the value of different solar altitude, sinα from 7.00am to 5.00pm where n=17.

5.1.8 Air mass, AM

The ratio of the path length, which beam radiation passes through the atmosphere, to the path it would pass through if the sun were at the zenith, directly at the overhead.

$$AM = \frac{1}{\sin\alpha}$$

Air mass is calculated with this equation and we get AM= 14.038 in our system in one requirement, it is calculated in many times during morning to evening.

Solar radiation, I

Integrating extraterrestrial radiation over a specific time, usually an hour or half an hour, We obtain half hourly radiation.

$$\boldsymbol{I = 1367 * (0.7)^{AM^{0.678}}}$$

Solar radiation I is shown below in the graph where we consider the day 17thjanuary of the year from morning till evening.

The data shown in figure 5.3 are the radiation values for a PV panel surface fixed at a tilt angle equal to the latitude of the location (Tangail) where n=17,we considered.

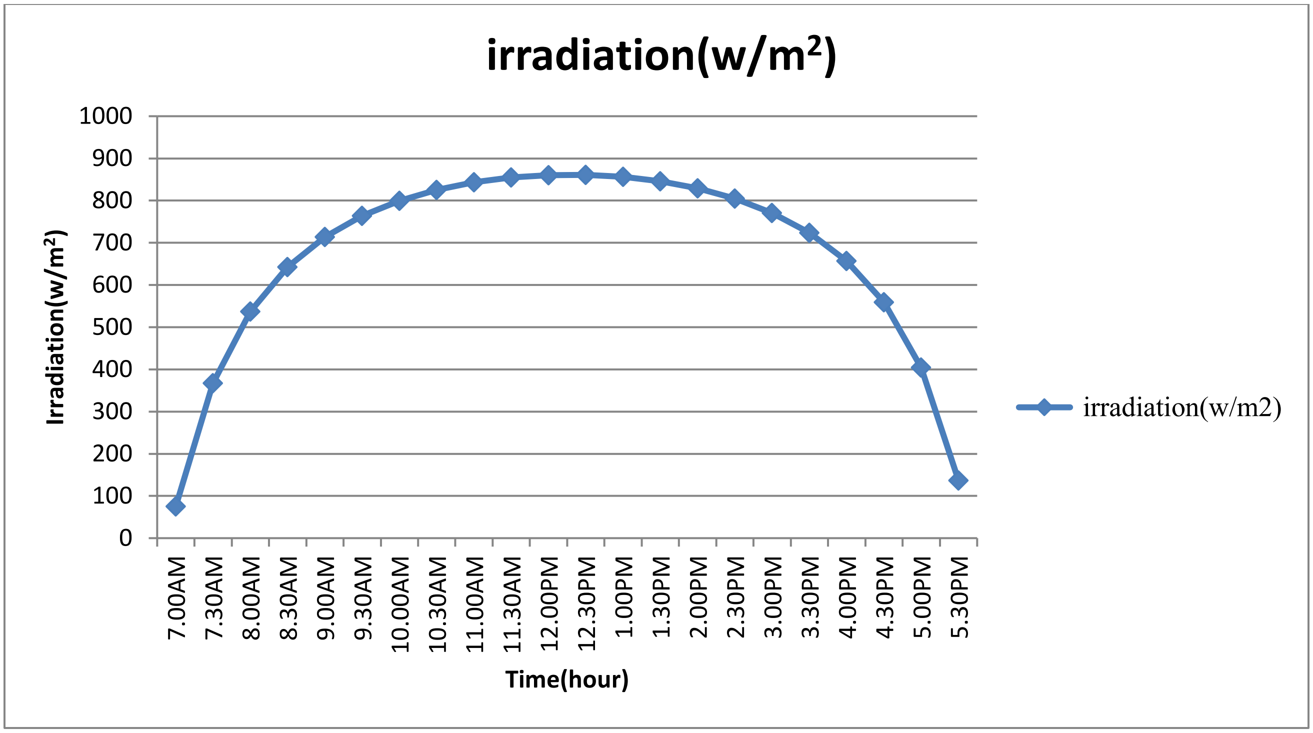

Figure 5.3: Time *vs*. Solar Irradiation curve at n=17

5.2 Light incident of solar panel, G

Changing the light intensity incident on a solar cell changes all solar cell parameters, including the short-circuit current, the open circuit voltage, the FF, the efficiency and the impact of series and shunt resistances. The light intensity on a solar cell is called the number of suns, where1 sun corresponds to standard illumination at AM 1.5 or $1kW/m^2$.

Amount of light incident on solar panel,

$$G = A * I$$

Solar cells experience daily variations in light intensity, with the incident power from the sun varying between 0 to $1kW/m^2$. At low light level the effect of the shunt resistance becomes increasingly important. Consequently, under cloudy conditions, a solar cell with a high shunt resistance retains a greater fraction of its original power than a solar cell with a low shunt resistance.

Light incident of solar panel is shown below in the figure from morning to evening and here also our n=17. By this graph calculation, we can measure the total light incident throughout the day.

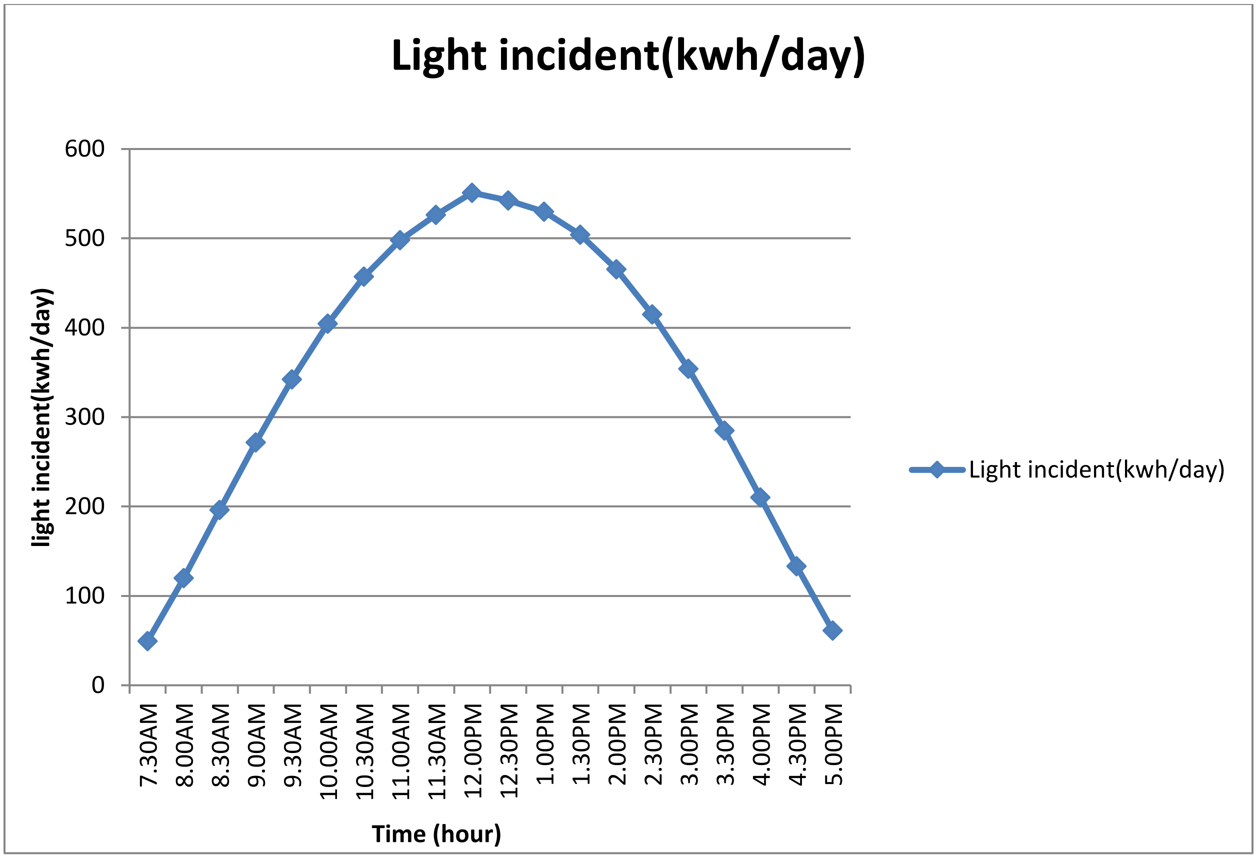

Figure5.3: Time vs. light incident at n=17

Light incident throughout the day is, 3346.32Wh/m^2or 3.346 kWh/m^2, which value, we use to calculate our flow rate in sun peak hour.

5.3 Output power, Pout

Photovoltaic power is consider as 880 W and we calculate the least panel's power by using the light incident of solar panel.

panel's output power, **Pout = 880*($\frac{G}{1000}$)*0.75**

when,

Standard Measurement Intensity= 1000 W/m^2

Light incident throughout the day= 3.346kWh/m^2

Solar insolation = light incident on panel / peak intensity (kW)

$= \frac{3.346\ kWh}{1kw}$

= 3.346 h

Solar insolation and the peak sun hours are almost same. So, the designed flow rate is calculated by this peak sun hour

Designed flow rate = Daily water needs / peak sun hours

= $40m^3$ / 3.346h

=11.95 m^3 /h ≈12 m^3/h

As we earlier select the submersible pump for designing our process, that this pump is suitable for medium water flow. Observing its advantage and disadvantages, we chose submersible centrifugal pump for our design, name- **"PS 600 C-SJ8-5".** In the following graph, we are showing the solar submersible pump system for 4" wells. Here, we have observed 9m for different powers to determine the flow rate of pump.

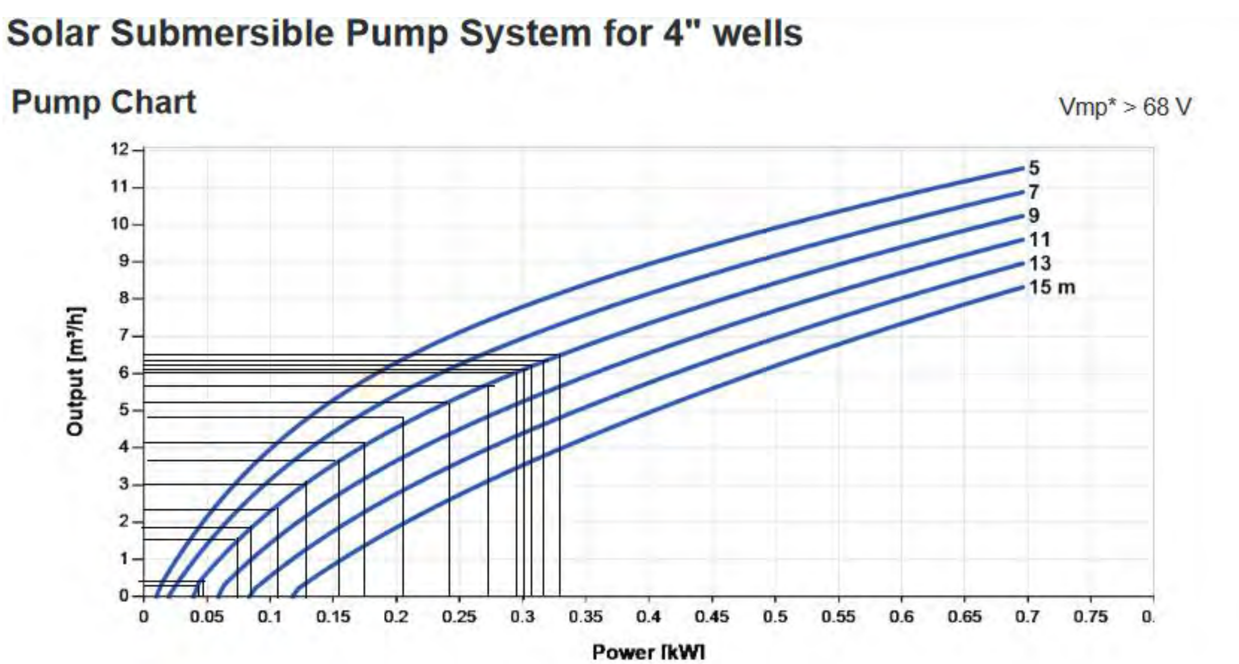

Figure 5.4 : Pump power VS flow rate output curve

5.4 Flowrate calculation

By using this value of output which is equal to our considering flowrate, we can show a curve according to the time. So, the whole day flowrate is from 8.00am to 5.00pm is shown below,

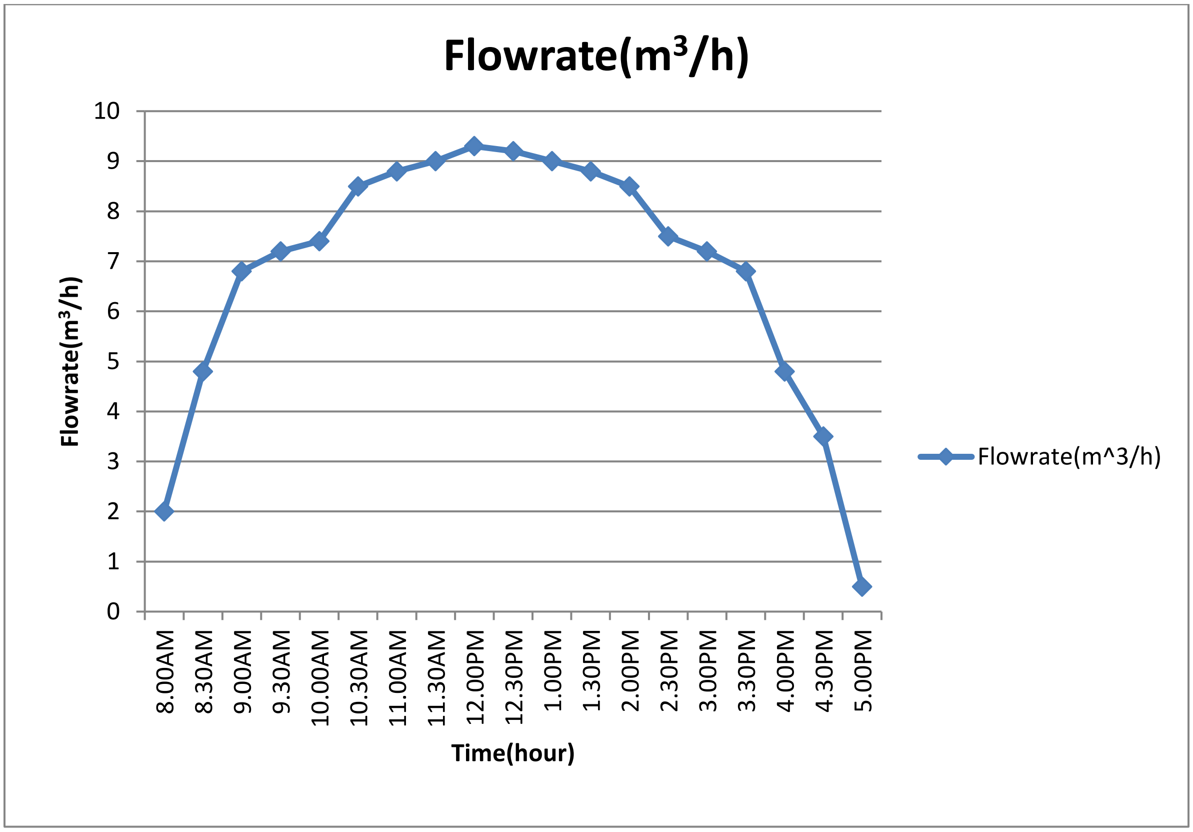

Figure 5.5: Time VS Flow rate curve at n=17

We consider the flow rate throughout the day by integrating all the flow rates during morning to evening.

Flow rate throughout the day,

$$\left\{\frac{1}{2}Y_1 + Y_2 + Y_3 + \cdots\cdots\cdots + Y_{n-1} + \frac{1}{2}Y_n\right\} * \Delta x$$

= **63.175** m^3/h

We get this flow rate in our 1st measurement which is very high from our requirement. As our desired flow rate is $40m^3/h$, and the result from the graph gives us much higher rate of water flow, we cannot take this because heavy water flow can harm our crops and whole irrigation system.

So, we have checked this flow rate again to adjust our requirements. For this, we have to decrease the motors capacity. Now, we have changed the pump power from 880W to 600W in this process, $\left(880 * \frac{2}{3} \approx 600\right)$ and now calculated the flow rate assuming 600W power and showing in the graph as follows.

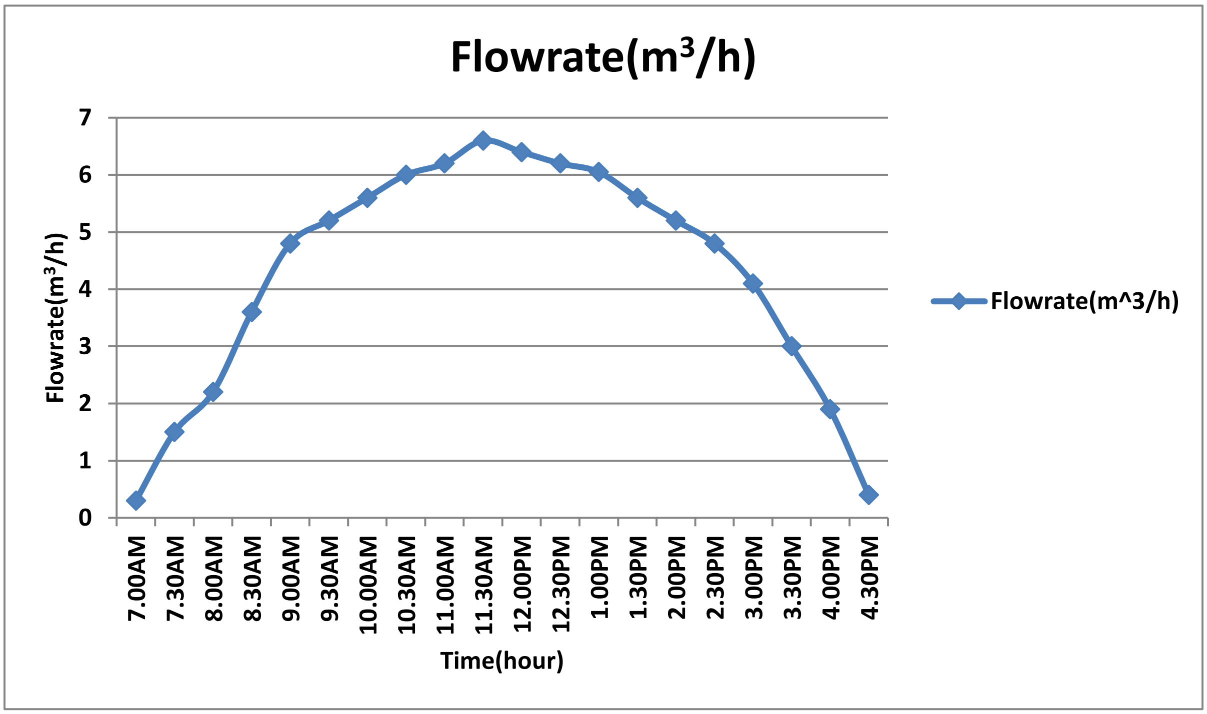

Figure 5.6: Time vs. Flow rate curve at n=17

With this two times observation, we have got energy throughout the day which almost equal to our requirements. When we fulfill fields water level where and how much is needed for the different crop, then we can design a better irrigation system. For this reason, we decided to choose the 2nd measurement of the second flow rate curve.

Flow rate throughout the day,

$$\left\{\frac{1}{2}Y_1 + Y_2 + Y_3 + \cdots\cdots\cdots + Y_{n-1} + \frac{1}{2}Y_n\right\} * \Delta x$$

$= 42.65\ m^3/\text{h}$

Which is satisfied our requirements. It's because $40m^3/h$ is our system requirement and here we get $42.65m^3/h$, which is almost near to 40. So, finally we measure our pump's power is 600W. Because of so many losses happens during working, panel's and pump's power is adjusted to run the whole system.

5.5 Power flow

Now, we observe the power of motor is as 600 W. and as we know, solar panel's power is converted to the motor's power. Here, electrical power is converted to the mechanical power. Through this conversion, some losses may happen and for this power can be less from our expectation. So, to adjust motors power, panel's power should have to be greater than motor's power.

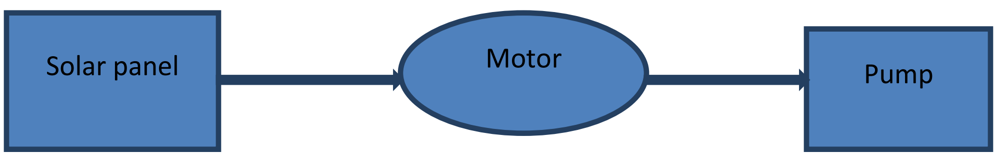

Figure 5.7: Power flowing from panel to pump

5.5.1 Losses

In the whole system power is converted in two times. The two conversions are such as potential power to electrical power and the electrical power to mechanical power. In first conversion, we cannot observe any loss because it is natural system. On the other hand, when 2nd conversion is done, so many losses can occur such as dust factor loss, degradation of panel efficiency loss, voltage drop and line loss etc.

As a result, when panel's power is converted to motor's power, different losses may occur. If we assume this for our system,

Degradation of panel efficiency 10%

Dust factor 10%

Line loss 2%

If 2 $\frac{mV}{°C}$per cell is the drop voltage, then Pout= V*I= 30*600mV = 21.6 V;

For 36*2=72 cells 0f 36-44V and if I is fixed, then (V-V) / V = {(2*20) / 600} * 100 =6.6%

Total loss = 10%+10%+2%+7% = 29% or 30%

We know, P_{panel} = P_m/ 0.7

= 600 W / 0.7

= 857 W

So, our panel's power should be adjusted with this and we have to measure some solar panels which power is at least 900W in total.

For this we have selected to set up a circuit with 5 PV panels where only series connections are present. The whole circuit sets up is as like the five panels are in series connections. That's how we can match our voltage and current measurements.

5.6 Panel Connection

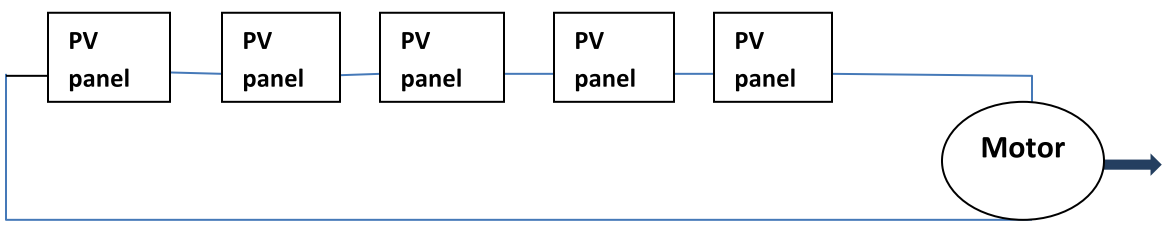

Figure 5.8: PV Panels connections with Motor

In series connection, the voltage is all together 5*16.8= 84V, panel's output power is ≈ 900W, motor's output power is 600W and the current is 10.71A which is acceptable for our allover design.

<u>Analysis of the system</u>

<u>5.7 Analysis of the system:</u>

Step 1 – **Water requirement**

The water requirement of the in this system is determined by the water requirement for the cultivated crops. For our location in Tangail, Bangladesh we need 30m^3/day (meter cube per day) which is the maximum requirement of our specific location.

Step 2- **Type of water source**

The water source used in this system is well and the specification of this well is given below.

- Static water level : 6m
  The interviewed farmer's information the mean static level is 5.7m,therefore we set our static level to 6m.
- Dynamic water level:8.7m
  Most of the farmer used big pump which exceed the daily water requirement of their system as they exactly don't know the dynamic water level. Based on this, it is assumed that the refilling rate for the well is enough. For this we take 8.7m as our dynamic head.

Step 3-**System layout**

All the necessary distance and components are presented in the figure below.

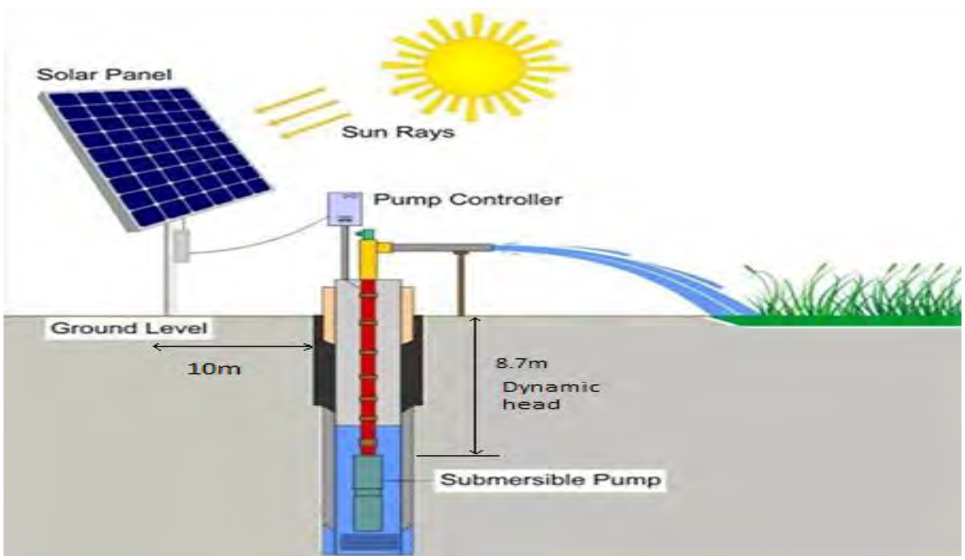

Figure 5.9: System layout of the design SWPS

- Distance from solar panel to the pump is 10m.
- A submersible pump is selected for the design as the dynamic head is set to 8.7m.

Step 4- **Insolation and solar panel location**

The location for the system is Tangail,Dhanbari upazilla Bangladesh. The system will be used over the whole year. Especially from December to march. Tangail's altitude & longitude is 24.3917 degree North and 89.9948 degree East respectively.

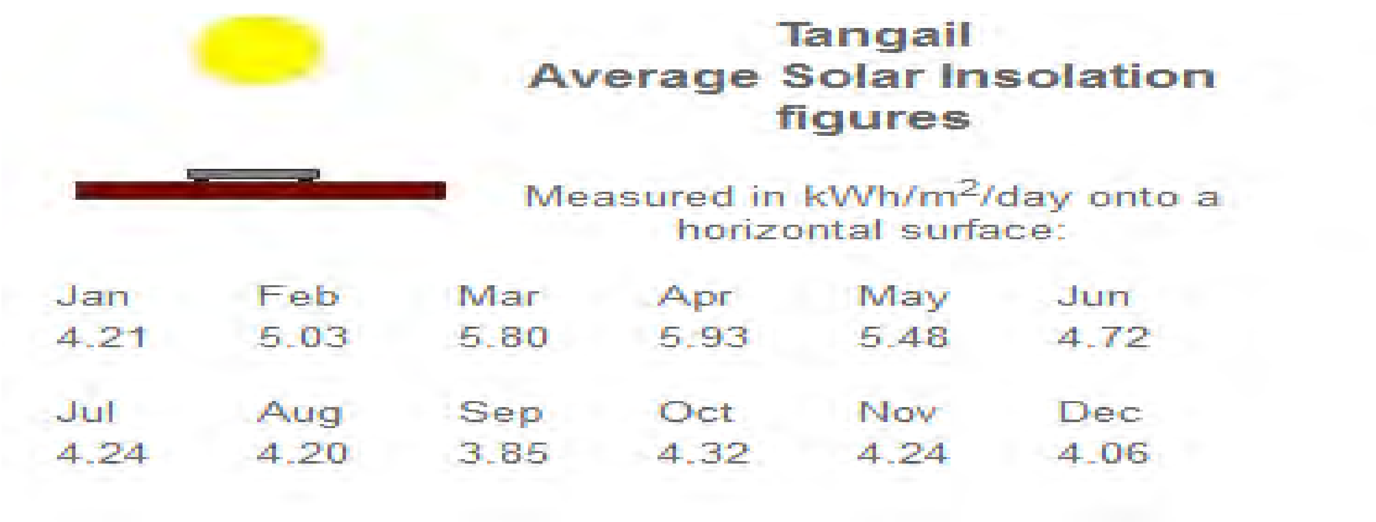

Figure 5.10: Average insolation throughout the whole year .

This data we received by the solar irradiation calculation by country and city website. We can see the annual chart of solar radiation in that area and the average radiation in Tangail is 4.67 KWh/m^2.The angle and direction of the panel should also be considered in order to maximize their production.

Step 5-**Designed flow rate for the pump.**

The designed flow rate for the pump will be calculated using Equation 1. The designed month is 17^{th} January.

Designed flow rate = $\frac{40}{3.336}$ =11.99≈12 m^3/h.

Step 6-**Total dynamic head of the pump**

Total vertical rise is calculated using Equation 2.

Vertical rise =8.7+0+0= 8.7m

Total length of the pipe is calculated in Equation 3.

Length of the pipe = 9m+10m = 19m

Now friction loss can be calculated using equation 4.

Friction loss = $\frac{0.9}{100} * 19 = 0.171m$

Total dynamic head is calculated using Equation 5.

Total dynamic head= 8.7+0.171=8.871≈9m.

Step 7-**Pump selection**

With the known TDH and design flow rate; the pump can be selected. As previously stated, a submersible pump is probably the best option for this configuration. we select lorentzs **"PS 600 C-SJ8-5"**

Step 8-Solar panel selection

Solar panel is selected using Equation 6.

Required solar peak power=0.7*1.25=0.875 KW ≈0.88 KW

Amount of solar panel is calculated using Equation 7.

Amount of panel=$\frac{880}{180} = 4.8 \approx 5\ panels.$

Chapter 6

Economic Analysis

For any system to run properly and without interruption, economic analysis is a must. It takes into account the opportunity costs of resources employed and attempts to measure in monetary terms the private and social costs and benefits of a project to the community or economy. For our solar powered system, we did our economic analysis on the basis of our country's measurement.

Inflation Rate: Inflation rate (i) is a measurement of the rise in price of a good or service over a period of time reflected as a percentage. It is usually measured on a monthly and annual basis.

Discount Rate: Discount rate (d) is a multiplier that converts anticipated returns from an investment project to their current market value (present value).

Present Worth: Present Worth (PW) of an item is defined as the amount of money that would need to be invested at the present time with a return of 100d% in order to be able to purchase the item at a future time, assuming an inflation rate of 100i% [14].

Initial Cost: A project's initial costs (Co) are those that are incurred during the design and construction process. They include planning, preliminary engineering, and project design, environmental impact report, final engineering, land acquisition, construction costs, including improvements to existing facilities, equipment and vehicle purchase, decommissioning costs for facilities that are no longer needed and many more.

6.1 Life Cycle Cost (LCC):

Life cycle cost (LCC) is defined as the sum of the PWs of all the components [14]. It summarizes all recurring and one-time (non-recurring) costs over the full life span or a specified period of a good, service, structure, or system which includes purchase price, installation cost, operating costs, inflation rate, discount rate, initial cost, maintenance and upgrade costs, and remaining (residual or salvage) value at the end of ownership or its useful life which is under financial cost and easy enough to calculate rather than environmental and social costs which are more difficult to quantify and assign numerical values.

6.2 Economic Analysis of Solar and Diesel Pumping System:

In this section, we will be discussing about the LCC(life cycle cost) of the two system- solar and diesel in the perspective of our country. We will differentiate and hence try to find the life cycle cost through the economic analysis between the two systems.

For Solar Pumping System:

Inflation Rate, i =5.31(From Bangladesh Bank Website, Feb 2017 inflation rate)

Discount Rate, d=10%(assuming)

Present Worth(PW)=$(\frac{1+i}{1+d})^n$*Co (For solar system)

Here the table of economic analysis of the solar system is given below:

Item name	Life cycle(year)	Quantity	Initial Cost(BDT)	PW (BDT)
PS- 600(pump)	10	1	2,00,000	3,29,359.72
SYED-SPC-180W-2(Panel)	25	5	2,00,000	2,50,000
PVC pipe()	5	1	150000	4,45,682.66
Wire	2		2000	13,939.3
Labor			33,000	1,14,909.53
Life Cycle Cost, LCC				11, 53,891.21

Table 6.1: Economic analysis of solar pumping system

Table no.6.1 shows our overall solar system's life cycle cost. It shows that our pump's estimated life cycle is 10 years and its initial cost is 2,00,000tk which will be 3,29,359.72tk within its estimated lifecycle, known as present worth(PW). Panel's life cycle is 25 years with initial cost 2,00,000tk and present worth is 2,50,000tk. Pipe's life cycle is 5 years with initial cost 1,50,000tk and present worth is 4,45,682.66tk. Wire's life cycle is 5 years with initial cost

1,50,000tk and present worth is 4,45,682.66tk. Labor's initial cost is 33,000tk and present worth is 1,14,909.53tk. Total life cycle cost is 11,53,891.21tk.

For Diesel Pumping System:

$$PW = \left(\frac{(1-x)^n}{(1-x)}\right) \cdot Co(\text{For diesel})$$

Where, $x = \frac{1+i}{1+d} = \frac{1.053}{1.10} = 0.95$

Item name	Life Cycle(year)	Initial Cost(BDT)	PW(BDT)
Pump	2y	70,000	4,87,875.48
Fuel		20,790	2,82,752.59
Maintenance Cost		20,000	2,72,008.26
Accessories and Installation		5,000	68,002.06
Operator's Salary		60,000	8,16,024.80
Life Cycle Cost, LCC			19, 26,663

Table 6.2: Economic analysis of diesel pumping system

Table no.6.2 shows overall diesel system's life cycle cost. It shows that pump's estimated life cycle is 2 years and its initial cost is 70,000tk which will be 4,87,875.48tk within its estimated lifecycle, known as present worth(PW).Fuel's initial cost is 20,790tk and present worth is 2,82,752.59tk. Maintenance cost will initially cost 20,000tk and present worth is 2,72,008.26tk. Accessories and Installation initial cost 5,000tk and present worth is 68002.06tk. Operator's salary will initially cost is 60,000tk and present worth is 816024.80tk. Total life cycle cost is 1926663tk.

From above tables we can see that solar system is more convenient than diesel. Though the initial of solar system is pretty high but it will be convenient for long run for the farmers whereas diesel's initial cost is not that high but in the long run it will be really hard to maintain for its high price as it can be seen from the above two tables. That's why solar system is more economical than diesel.

6.3 Discussion

For any system to run diesel fuels are economic but they come with adverse effects on environment and health too. Diesel exhaust is a complex mixture of gases and fine particles. The primary pollutants emitted from diesel engines include -Particulate matter (PM), Carbon monoxide (CO), Nitrogen oxides (NOx), Hydrocarbons (HC), Volatile organic compounds (VOCs), Other chemicals that are classified as "hazardous air pollutants" under The Clean Air Act. Health studies show that exposure to diesel exhaust primarily affects the respiratory system and worsens asthma, allergies, bronchitis, and lung functions. There is some evidence that diesel exhaust exposure can increase the risk of heart problems, premature death, and lung cancer. As it emits CFC, greenhouse effect also occurs which is really alarming. Though for irrigation system, the initial cost of diesel fuel system may seem cheap, but maintenance cost gradually increases as time goes by. On the other hand, solar power irrigation system might seem a bit costly at the beginning, but it's maintenance cost is not that much high over time. Besides one can get maximum output from this system which may not occur in diesel running system. Besides solar irrigation system is eco-friendly as well as health friendly. Only using sun light and radiation through proper observation, it is cleaner, less noisy and pollutant free.

Chapter 7

Conclusion

7.1 Advantages & disadvantages of solar pump:

A solar powered pump is a pump running on the power of the sun. It makes efficient use of solar energy and converts it into electrical energy for pumping water to great heights. A solar powered pump can be very environmentally friendly and economical in its operation. This system operates on power generated using solar PV (photovoltaic) system. The photovoltaic array converts the solar energy into electricity, which is used for running the motor pump set. The pumping system draws water from the open well, bore well, pond etc. The water pumping system can be used to irrigate land, when the water is to be pumped from a depth of well or a pond.

Advantages of Solar powered Pumping System:

Saves Money: The only cost associated with the pump is the initial cost. Although solar pumps are more expensive than those that run off house's electricity, they cost nothing to run, once set up. If the pump were using electricity, we would have to pay for the energy to run the pump.

Saves Energy: It helps in saving energy as no energy but sun light is needed for operating the pumps. Besides solar-powered pumps don't need to be tethered to an external power source, they're more convenient than corded pumps. One can put a solar pump almost anywhere and won't have to deal with the added time and labor required to run and bury wires.

Reduces Pollution: Using a solar pump may reduce pollution. If any electrical power comes from oil or coal production, then any use of solar, including a solar pump, reduces the use of these fossil fuels. According to the U.S. Environmental Protection Agency, any solar technology has a negligible effect on air quality and does not produce a discharge that would pollute the water.

Electrical Outlets Not Needed: Solar pump can be put in any spot without concern for where the nearest electrical outlet is located. If crop field is not near a power outlet, then a solar pond pump lets to put in a pump without having to run a long electrical cord around yard or hiring an electrician to run electricity out to field.

Can be operated lifelong: It is highly reliable and durable. As only sun light is needed and for simple structure, it is user friendly and highly sustainable.

- It is also useful for clean, drinking water sanitation and also irrigation.
- It reduces the dependence on rain is reduced.
- It creates wealth for farmers by increasing no of crops.

7.2 Disadvantages of Solar Powered Pumping System:

Must Have Sun:

The main disadvantage to using a solar pump is that it must have several hours of direct sunlight every day to work. If the crop field has shade most of the day, then a solar pond pump may not work. Also, the solar panel will need regular cleaning to keep it running efficiently. Any dust, dirt and other debris on the solar panel will reduce its ability to capture the sunlight and turn it into energy. Clean the solar panel as needed with a dry or damp cloth per the care instructions that came with the pump.

Flow Rate:

A significant disadvantage of a solar pond pump is its relatively limited ability to move water compared to similar corded pumps. Solar pumps typically have a flow rate that is much lower than a corded pump, so they don't move enough water quickly enough for large ponds. The flow rate of some pumps may also decrease during periods of low light, when their solar cells are producing less power. Pumps with a battery back-up may be able to keep pumping at full power even in low light.

Conclusion

We all know that Bangladesh is poor developing country with a large population. According to this huge population country's food production is not enough. Bangladesh is an Asiatic country and our main food is based on paddy and wheat. For producing different crops and vegetables, we have to use different renewable and non-renewable energy. Here, in our experiment, we use renewable solar energy directly by the solar panel instead of diesel.

In the irrigation process, mainly farmers are directly involved to grow in the field, though they have limited knowledge about solar water pump. They normally use diesel to run the motor for watering, which is not much expensive like solar pump. But in our research, we can observe that for a long term investment, like almost 20 or 25 years cultivation, solar water pump is much better than the diesel pump. In solar pump, there is no maintaining cost. We have to invest money only one time and then can be use it more than 20 years. Moreover, Bangladesh has a suitable climate because almost more than half of the year, it has fully hot sunny days. So, we can easily use the solar energy for irrigation for producing more food.

As our country has the potential to give us solar energy, that's why we are interested to do research on it. After 11 months of researching, we have found so many important things with some difficulties. We have done with the designing process, the technological analysis, economic analysis and select solar panel ratings, motor ratings and pump ratings according to our analysis and their calculations for showing power and flow rate and so on. After observing all these things, we can say that solar water pump is the most suitable and essential for technological and economic development of our country.

References

[1] http://www.sciencedirect.com/science/article/pii/S1364032110004016?via%3Dihub

[2] http://www.sciencedirect.com/science/article/pii/S030626190200140X?via%3Dihub

[3] http://www.sciencedirect.com/science/article/pii/019689048890043X

[4] http://www.sciencedirect.com/science/article/pii/S1364032106001584?via%3Dihub

[5]https://www.google.com/search?q=solar+altitude+definition&oq=solar+&aqs=chrome.2.69i57j35i39l2j0.10106j0j4&client=ms-android-huawei&sourceid=chrome-mobile&ie=UTF-8,sciencing.com/solar-altitude-23364.html

[6] https://en.m.wikipedia.org/wiki/solar_zenith_angle

[7]https://www.google.com/search?q=solar+radiation+calculation&oq=s&aps=chrome.1.69i57j35i39l2j69i59j69i60l2.1180j0j4&client=ms-android-huawei&sourceid=chrome-mobile&ie=UTF-8

[8]https://www.star.nesdis.noaa.gov>emb

[9]https://www.researchgate.net

[10]https://www.google.com/url?sa=t&source=web&rct=j&url=http://www.uprm.edu/aret/docs/ch_4

[11]http://www.google.com/url?sa=t&source=web&rct=j&url=http://photovoltaic-software.com/PV-solar-

[12] Haque M.M., Photovoltaic water pumping system for irrigation, 4thInternational Conference on Mechanical Engineering, December 26-28, Dhaka, Bangladesh: I , pp.21-26, 2001

[13] https://www.bb.org.bd

[14] Messenger Roger A. , Ventre Jerry, Photovoltaic Systems Engineering, second edition, pp.148-149.

Appendix

Solar Radiation Calculation:

```
del= -0.393;
fy=(24.4*pi)/180;
ws= 80;
w=-80+((6.5-6.72)/11.15)*2*80
sinalpha= sin (del)*sin (fy)+cos(del)*cos(fy)*cos((w*pi)/180)
AM= 1/(sinalpha)
I=1367*(0.7)^((AM)^0.678)
G= sinalpha*I*cos(del)
Pout=(880*(G/1000))*0.75
```

Output power calculation:

7am:

W= -75.98

Sinα =0.0456

AM =21.94

I =75.577

G =3.1816

Pout =2.0998

7.30am:

W = -68.80

Sinα =0.1454

AM =6.8532

I =366.914

G =49.457

Pout =32.642

8am:

W = -61.6323

Sinα =0.2415

AM =4.1408

I =536.849

G =119.76

Pout =79.045

8.30am

W= -54.4572

Sinα= 0.3308

AM= 3.0227

I= 642.4636

G= 196.3405

Pout= 129.5848

9.00am

W= -47.2825

Sinα= 0.4125

AM= 2.4243

I= 713.5219

G= 271.8844

Pout= 179.4437

9.30am

W= -40.1076

Sinα= 0.4852

AM= 2.0609

I= 763.5622

G= 342.2509

Pout= 225.8856

10.00am

W= -32.9327

Sinα= 0.5479

AM= 1.8252

I= 799.5299

G= 404.6457

Pout= 267.066

10.30am

W= -25.7578

Sinα= 0.5995

AM= 1.6682

I= 825.3211

G= 457.0339

Pout= 301.6424

11.00am

W= -18.5830

Sinα= 0.6392

AM= 1.5645

I= 843.2430

G= 497.9048

Pout= 328.6172

11.30am

W= -11.4081

Sinα= 0.6664

AM= 1.5005

I= 854.6854

G= 526.1679

Pout= 347.2706

12.00pm

W= -4.2332

Sinα= 0.6808

AM= 1.4689

I= 860.4512

G= 551.1041

Pout= 357.1287

12.30pm

W= 2.9417

Sinα= 0.6819

AM= 1.4664

I= 860.9213

G=542.3433

Pout= 357.9466

1.00pm

W= 10.1166

Sinα= 0.6700

AM= 1.4926

I= 856.1262

G= 529.8552

Pout= 349.7044

1.30pm

W= 17.2915

Sinα= 0.6450

AM= 1.5503

I= 845.7510

G= 503.9482

Pout= 332.6058

2.00pm

W= 24.4664

Sinα= 0.6075

AM= 1.6461

I= 829.0778

G= 465.2775

Pout= 307.0831

2.30pm

W= 31.6413

Sinα= 0.558

AM= 1.7921

I= 804.8406

G= 414.8640

Pout= 273.8103

3.00pm

W= 38.8161

Sinα= 0.4973

AM= 2.0110

I= 770.9332

G= 354.1375

Pout= 233.7307

3.30pm

W= 45.9910

Sinα= 0.4263

AM= 2.3459

I=723.821

G= 285.0265

Pout= 188.1175

4.00pm

W= 53.1659

Sinα= 0.3461

AM= 2.8891

I= 657.2794

G= 210.1604

Pout= 138.7059

4.30pm

W= 60.3408

Sinα= 0.2581

AM= 3.8747

I= 559.4011

G= 133.3664

Pout= 88.0218

5.00pm

W=67.5157

Sinα= 0.1635

AM= 6.1155

I= 404.5852

G= 61.1139

Pout= 40.3352

5.30pm

W= 74.6906

Sinα= 0.0639

AM= 15.6457

I= 136.8040

G= 8.0773

Pout= 5.3310

8.00am

G=119.76

Pout= 0.09

FR= 2.0

8.30am

G=196.34

Pout= 0.16

FR= 4.8

9.00am

G=271.88

Pout= 0.22

FR= 6.8

9.30am

G= 342.25

Pout= 0.27

FR= 7.2

10.00am

G= 404.64

Pout= 0.32

FR= 7.4

10.30am

G= 457.03

Pout= 0.36

FR= 8.5

11.00am

G= 497.90

Pout= 0.39

FR= 8.8

11.30am

G= 526.16

Pout= 0.42

FR= 9.0

12.00pm

G= 551

Pout= 0.44

FR= 9.3

12.30pm

G= 542.34

Pout= 0.43

FR= 9.2

1.00pm

G= 529.85

Pout= 0.423

FR= 9.0

1.30pm

G= 503.94

Pout= 0.4

FR= 8.8

2.00pm

G= 465.27

Pout= 0.37

FR= 8.5

2.30pm

G= 414.86

Pout= 0.33

FR= 7.5

3.00pm

G= 354.13

Pout= 0.28

FR= 7.2

3.30pm

G= 285.02

Pout= 0.22

FR= 6.8

4.00pm

G= 210.16

Pout= 0.17

FR= 4.8

4.30pm

G= 133.36

Pout= 0.107

FR= 3.5

5.00pm

G= 61.11

Pout= 0.05

FR= 0

Flow rate throughout the whole day, F= {(0.5*2)

+4.8+6.8+7.2+7.4+8.5+8.8+9+9.3+9.2+9+8.8+8.5+7.5+7.2+6.8+4.8+(3.5*0.5)}*0.5

= 63.175 m^3/h

Flow rate calculation:

7.30am

G= 49.45

Pout= 0.029

FR=0.3

8.00am

G= 119.76

Pout= 0.0718

FR= 1.5

8.30am

G= 196.34

Pout= 0.117

FR= 2.2

9.00am

G= 271.88

Pout= 0.163

FR= 3.6

9.30am

G= 342.25

Pout= 0.205

FR= 4.8

10.00am

G= 404.64

Pout= 0.24

FR= 5.2

10.30am

G= 457.03

Pout= 0.27

FR= 5.6

11.00am

G= 497.90

Pout= 0.298

FR= 6

11.30am

G= 526.16

Pout=0.315

FR= 6.2

12.00am

G= 551.10

Pout= 0.33

FR= 6.6

12.30pm

G= 542.34

Pout= 0.32

FR= 6.4

1.00pm

G= 529.85

Pout= 0.31

FR= 6.2

1.30pm

G= 503.94

Pout= 0.30

FR= 6.05

2.00pm

G= 465.27

Pout= 0.27

FR= 5.6

2.30pm

G= 414.86

Pout= 0.25

FR= 5.2

3.00pm

G= 354.13

Pout= 0.21

FR= 4.8

3.30pm

G= 285.02

Pout= 0.17

FR= 4.1

4.00pm

G= 210.16

Pout= 0.13

FR= 3

4.30pm

G= 133.36

Pout= 0.08

FR= 1.9

5.00pm

G= 61.11

Pout= 0.036

FR=0.4

Flow rate throughout the whole day, F = {(0.5*0.3) +1.5+2.2+3.6+4.8+5.2+5.6+6.0+6.2+6.6+6.4+6.2+6.05+5.6+5.2+4.8+4.1+3.0+1.9+ (0.4*0.5)} *0.5

= 42.65 m^3/h

Economic Analysis:

i=Inflation Rate

d=Discount Rate

PW=Present Worth Factor

Co= Initial Cost

i=5.31(From Bangladesh Bank Website, Feb 2017)

d=10%(assuming)

Solar System:

PW= (((1+i)/(1+d))^n)*Co (for solar system)

Pump: 1year-Co=2, 00,000

10y=129359.718

20y=83669.765

PW=213029.483

Panel: PW=2,50,000

PVC Pipe:

1y- Co=1,50,000

5y=120635.7135

10y=37019.835

15y=78027.0474

20y=62752.3215

PW=508434.919

Wire:

1y-Co=2000

2y=1833.090

4y=1680.109

6y=1539.896

8y=1411.3897

10y=1293.5978

12y=1185.64

14y=1086.69

16y=996.003

18y=912.882

20y=836.6976

PW=14775.9905

Labor:

For system setup=10,000

For pump Replacement(20y)=5,000

For Wire Replacement:

Co=10,000

1y=9,570

2y=9,158.49

4y=8,387.83

6y=7,681.95

8y=7,035.51

10y=6,443.46

12y=5,901.239

14y=5,404.644

16y=4,949.83

18y=4,533.30

20y=4,151.82

For pipe Replacement (10y)=8,000

1y=7,656

5y=6,710.23

10y=5,154.77

15y=4,137.85

20y=3,321.4578

PW=1, 14,909.53

Diesel system:

Fuel:

Co=20790

PW=((1-x^n)/(1-x))*Co

x=0.957

1y=20,790

2y=40,686

3y=59,726.53

4y=77,948.28

5y=95,386.51

6y=112074.89

7y=128045.67

8y=143329.71

9y=157956.53

10y=171954.40

11y=185350.36

12y=198170.29

13y=210438.97

14y=222180.09

15y=233416.36

16y=244169.44

17y=254460.16

18y=264308.37

19y=273733.11

20y=282752.59

Maintenance cost:

1y=20000

2y=39140

3y=57456.98

4y=74986.32

5y=91761.91

6y=107816.15

7y=123180.06

8y=137883.31

9y=151954.33

10y=165420.29

11y=178307.22

12y=190640.01

13y=202442.49

14y=213737.46

15y=224546.752

16y=234891.24

17y=244790.92

18y=254264.91

19y=263331.52

20y=272008.26

Accessories cost:

1y=5000

2y=9785

3y=14364.24

4y=18746.58

5y=22940.47

6y=26954.03

7y=30795.01

8y=34470.82

9y=37988.58

10y=41355.07

11y=44576.80

12y=47660.00

13y=50610.62

14y=53434.36

15y=56136.68

16y=58722.81

17y=61197.73

18y=63566.22

19y=65832.88

20y=68002.06

Operator's salary:

1y=60000

2y=117420

3y=172370.94

4y=224958.98

5y=275285.753

6y=323448.47

7y=369540.18

8y=413649.95

9y=455863.00

10y=496260.89

11y=534921.67

12y=571920.05

13y=607327.48

14y=64112.40

15y=673640.3

16y=704673.73

17y=734372.77

18y=762794.73

19y=789994.56

20y=816024.80

Technical data of pump

Technical Data

Controller PS600

- Control inputs for dry running protection, remote control etc.
- Protected against reverse polarity, overload and overtemperature
- Integrated MPPT (Maximum Power Point Tracking)
- Battery operation: Integrated low voltage disconnect

Power	max. 0,70 kW
Input voltage	max. 150 V
Optimum Vmp**	> 68 V
Nominal voltage (battery operation)	48 V
Motor current	max. 13 A
Efficiency	max. 98 %
Ambient temp.	-30...50 °C
Enclosure class	IP65

Motor ECDRIVE 600-C

- Maintenance-free brushless DC motor
- Water filled
- Premium materials, stainless steel: AISI 304/316
- No electronics in the motor

Rated power	0,7 kW
Efficiency	max. 92 %
Motor speed	900...3 300 rpm
Insulation class	F
Enclosure class	IP68
Submersion	max. 150 m

Pump End PE C-SJ8-5

- Non-return valve
- Premium materials, stainless steel: AISI 304
- Optional: dry running protection
- Centrifugal pump

Pump Unit PU600 C-SJ8-5 (Motor, Pump End)

Borehole diameter	min. 4,0 in
Water temperature	max. 50 °C

Figure 4.3: Technical Data of PS 600 C-SJ8-5