Design and Optimization of a Solar-Powered Water Pumping System for Irrigation and Water Storage Purpose

By

Md. Shahrior Tanvir
16321141
Minhazur Rahman Badhon
17121020
Shaeera Tasfia Islam
17121096
Md. Samid Bin Hasan
19321048

A thesis submitted to the Department of Electrical & Electronic Engineering in partial fulfillment of the requirements for the degree of
Bachelor of Science in EEE

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BRAC University
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Declaration

It is hereby declared that

1. The thesis submitted is my/our own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I/We have acknowledged all main sources of help.

Student's Full Name & Signature:

Md. Shahrior Tanvir 16321141	Minhazur Rahman Badhon 17121020
Shaeera Tasfia Islam 17121096	Md. Samid Bin Hasan 19321048

Approval

The thesis/project titled "Design and Optimization of a Solar-Powered Water Pumping System for Irrigation and Water Storage Purpose" submitted by

1. Md. Shahrior Tanvir (16321141)
2. Minhazur Rahman Badhon (17121020)
3. Shaeera Tasfia Islam (17121096)
4. Md. Samid Bin Hasan (19321048)

Of Summer, 2021 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science In EEE on 9th June 2021.

Examining Committee:

Supervisor:
(Member)

____

Dr. Md. Mosaddequr Rahman
Professor and Chairperson, Dept. of EEE
BRAC University

Program Coordinator:
(Member)

____

Dr. Abu S.M. Mohsin
Assistant Professor, Dept. of EEE
BRAC University

Departmental Head:
(Chair)

____

Dr. Md. Mosaddequr Rahman
Professor and Chairperson, Dept. of EEE
BRAC University

Abstract

The paper proposes a solution in the field of agriculture by introducing an effective way of irrigation. Renewable energy source is used in this off grid system as it is designed for isolated areas and places where water and utility supply are limited. A solar pumped hydro storage system is designed and optimized in this paper to ensure an uninterrupted irrigation system and accessibility of water in all the seasons. The surplus water is stored in the hydro storage for further usage with the help of a DC Motor driven by solar-power. In the system the output power of PV modules runs a DC motor and this motor runs the pump to lift water and irrigate the lands. The motor runs the pump to lift water from underground and uses the water to irrigate the fields. The pump again pumps the extra water from underground to fill the hydro storage for the rest of the day after completing irrigation. In our case we are considering the local ponds nearby the lands as the hydro storage of the system. In dry season when the groundwater level goes lower or at the time of water scarcity the pump uses the previously stored water in the hydro storage (pond) to irrigate the fields. Furthermore, the solar panels used for power supply will be levitated on the water storage. So that the solar panels do not occupy extra places in irrigated field. The paper brings a solution of this issue by considering the local ponds as the hydro storage to give uninterrupted water supply for irrigation during the whole year. The system cuts the cost of irrigation as there is no longer usage of diesel fuel, price of photo-voltaic modules, and the rate of solar irradiance in Bangladesh makes the system more efficient.

Keywords: Irrigation; Renewable energy; Hydro storage system; Photovoltaic (PV) module; Irradiance; Maximum power point.

Dedication

This thesis is dedicated to our beloved parents who brought us into this world and raised us from childhood, our teachers who taught us everything we have learned, our friends who always supported us, and specially to our supervisor who has supported us from the beginning our engineering degree. Without his supervision, it would not be possible for us to finish this thesis.

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Acronyms

PV – Photo-Voltaic

MPP- Maximum Power Point

DC- Direct Current

LPM- Liter per Minute

PI- Panicle Initiation

Chapter 1

Introduction

The agricultural sector of Bangladesh is facing challenges to meet up the increasing demand of irrigation water during the dry seasons in the remote areas. Lack of proper irrigation results in poor harvest which affects the economy of the country severely as agriculture plays a vital role in driving the economy. Mostly farmers use ground water along with surface water for irrigating fields. Due to unplanned lifting up of the ground water, farmers of many areas are not being able to gather the required amount of water for irrigation. Moreover, use of motor pumps run by fossil fuel for irrigating the lands is not a solution. Using fossil fuel is very costly and it is a limited source of energy which is also a significant threat to the environment as it increases the atmospheric temperature of the earth by carbon emission. Besides using motor pumps supported by grid electricity puts enormous pressures on the power grid and results in load shedding in most of the areas as the grid electricity demand is increasing rapidly for growing population, urbanization and industrialization. Continuous uplifting of the underground water without proper planning causes groundwater depletion, drying of wells and ultimately increases the cost of pumping water. Therefore, a well-planed affordable and eco-friendly irrigation system using sustainable source of energy has become necessary to increase the crop production during the dry seasons.

Solar energy is a renewable source of energy and the most reliable one which can be employed to act as the primary source of energy to solve the problems regarding irrigation of the lands. Using stand-alone photo-voltaic (PV) system in the sector of agriculture for irrigation is now being popular day by day around the world. Researchers of different countries are working for designing and implementing stand-alone solar powered water pumping system to their respective countries to ensure continuous water supply during every season. Use of solar power ensures the use of green energy in the system.

This paper proposes a solar powered water pumping system along with an all-purpose water storage. The goal is to design a PV pumping system to fulfill the demand of water for irrigating fields by following a specific pattern which will also allow to store extra water in the storage for later needs. In the paper, a particular place and crop has been chosen to design the whole system as in one specific area and for a specific crop the water demand varies. The paper presents a complete water management system during the dry season for a particular crop and reduces the water wastage.

Irradiation calculation, water flow rate calculation, panel choosing, pump choosing, storage calculation and water management according to the growth of the crop in a fixed irrigation schedule has been included in the system designing. The storage acts as a system backup as it will be able to provide the water during dry seasons if the PV pumped system fails to meet up the daily demand of water for irrigation. A local pond alongside the field has been chosen to act as the hydro storage to minimize the system cost of designing a new storage and to prevent reducing land areas for cultivation. In the design, the solar panels are also made floated on the surface of the pond. The results are also analyzed and the system cost is also calculated.

The system ensures an uninterrupted irrigation process in the dry seasons. It can be implemented to the remote areas of the country even where electricity supply is still not available. The system is designed to be environmental friendly and cost efficient.

1.1 Motivation

Renewable energy is the present and the future of energy usage. A solar-powered water pumping system could be a sustainable solution for outlying farmers, depending on government donations and the national grid for electrical energy. In this critical period of climate change, fossil fuel usage is not convenient as it emits carbon dioxide and affects the ozone layer, increasing the earth's net temperature. Recognizing the issue, renewable energy is obvious to use not to affect the environment. Renewable energy is the key to a sustainable society. Solar energy is the ultimate source of all the energy. To reduce the cost of pumping systems, solar power is the most effective system. Fossil fuel will go out of order in no time. Eventually, people will turn to renewable energy to survive.

Water storage system implementation is for the people who live near the irrigation field. The multi-purpose storage system is for regular water usage, and the pump provides underground water which can be consumed. To use less space in the area, we implemented the solar panel floating on the pond.

1.2 Literature Review

In this progressive generation, all the advanced methods used in the agriculture side rely on the national grid system. Decades after decades, farmers who live in the countryside fall behind on modern technology and depend on traditional methods. Solar-powered water pumping systems can unfold the opportunity to not depend on the modern irrigation process used in urban areas. Multiple research showed the performance study of a solar-powered water pumping system.

In July 2019, Zavala et al. proposed a couple of approaches based on simultaneous usage of PV irrigation systems in diverse production sectors concerning energy availability. The outcome of the study showed simultaneous use of the system optimize the energy use efficiency to 18.4 %, where individual usage reduces only 15.4 % of PV energy. This case study also showed the cost-effectiveness of usage simultaneous usage of PV irrigation systems is better than individual usage [1].

In 2019, Phillips-Brenes et al. provided a port-Hamiltonian framework and simulation of a solar-based pumped- hydro storage model under ideal conditions of constant solar radiation. The system is a green source open loop energy system as photo-voltaic energy is used as the primary source of energy. The storage system uses the potential energy of the stored water and converts it into electrical energy to meet up the demand during peak hours which the national grid fails to meet during dry seasons [2].

A proposal of photo-voltaic pumped hydro storage micro grid design reduces the cost of a regular photo-voltaic battery system. The Reservoir system will be placed on the ground level and store water as gravitational potential energy. Stored water will be used again in a turbine to produce green energy to reduce energy costs and for irrigation purposes. Mousavi et al. proposed system showed 31% electricity cost-saving than the existing pumping system [3].

Singh et al. implemented a water PV water pump for irrigation and water storage purpose at Indore, Madhya Pradesh in India. The solar intensity is 5.63 kWh/m^3 per day, and the solar-powered water pumping system can supply 35,000 L of water per day by 60 M head. This study showed solar-powered water pumping system is reliable, does not affect the environment, and could improve the living quality in a remote area [4].

It is better to use solar energy than diesel fuel. However, diesel fuel is cost-saving, but solar energy produces green energy with zero carbon emission, and the energy is reusable. Moreover, the maintenance cost of a solar pump is less than a diesel pump. Joynal et al. considered 30 % additional solar panel for loss, heat, dust, and aging factor [5].

A massive number of water crises emerge from February to April and September to November, and the irrigation process faces a lot of water crises in these months. Shafiq et al. discussed the irrigation process in Shibpur, Narshingdi, a city of Bangladesh, and the outcome of using the PV power system.

Their study proposed that 40000 L water is necessary for irrigation of multiple crops in 1 acre per day. They have used 28 solar panels in December and 30-32 solar panels from September to April [6].

From October to March, the optimum tilt angle is 39.80° and from April to September is 10.70° in the Rangpur division. The concept of two seasonal optimum tilt angles has been discussed in Nadim et al.'s paper. They also showed two seasonal optimum tilt angle system increases in solar energy from one tilt angle system by 3.3 % [7].

Hossain et al. describe the use of the CROPWAT model in the western area of Bangladesh. According to this method, the ratio of required water supply for Amon rice is 0.34: 0.33: 0.326 from 20th October to 15th November. As rice is fond of water, the suitable irrigation time is after three days from field saturation [8].

1.3 Objective

The main objective of our thesis is to design and optimization of a solar-powered water pumping system for irrigation and water storage purpose. Additionally, we wanted to introduce a method of water management system for amon rice irrigation.

In the very remote area of Bangladesh, the utility supply is unavailable. The absence of a utility supply introduced solar energy. Solar-powered Water pumping system supposed to provide the electrical energy to run a DC water pump. In the rural area, the outlying farmer who does not have any institutional or technical education, we want to help them by introducing the solar-powered water pumping system and the water management system of amon rice. During the dry season, lack of rainfall creates a crisis of water. In order to overcome the crisis, we have introduced multipurpose water storage. The primary objective of this storage is to provide water during less rainfall and also for the neighborhood. The ultimate goal of this system is to provide an easy and effective solution for the irrigation process.

1.3 Scope of work

In this fast-growing economics, it is necessary to adopt the recent machinery and get updated with future technology. The solar-powered water pumping system is a straightforward yet very effective way for irrigation. This system occupies minimal space on land, and it is very cost-effective so that the terminal farmer can utilize the benefit of the pumping system.

Dinajpur is a North-Western district in Bangladesh. In Barapukuria, Dinajpur, there is a coal mine company named Barapukuria Coal Mine Company Limited. This coal mine company requires a lot of water for industrial purposes, so the underground water level is supposed to go under the average water level. In order to get enough water supply, a thirty (30) meter pump head is necessary to irrigate the field. For our research work, we have introduced a water management method for Amon rice which is 0.25:0.40:0.3:0.05 is the water supply ratio for the irrigation field. In Bangladesh October to March is usually dry season, and the rainfall is lowest in these months. As we take Amon rice for our research and the irrigation month is from November to February for maximum outcome energy, the optimum tilt angle for this particular season is 39.80°. To provide sufficient power for the submersible pump, we estimated nineteen

(19) solar panels, and to reduce the irrigation field occupancy, we placed these panels over the water storage area. Amon rice is a water-loving crop, so undeniably, it needs plenty of water. The submersible water pump supplies sufficient water for the time of cultivation to provide this considerable amount of water.

1.4 Thesis organization

In this thesis the sections have been organized in following order:

Chapter 2 discuses about the agriculture of Bangladesh and the selection of our zone and corps.

Chapter 3 explains the components that we have used in this thesis and the required calculation of the selecting the components.

Chapter 4 describes the theoretical background, water management process and the calculations for the optimization.

Chapter 5 discuss the system design that we have implemented and the method of doing this project.

Chapter 6 explains the result analysis that we have done in this thesis.

Chapter 7 provides conclusion.

Chapter 2

Climate and Agriculture in Bangladesh

2.1 Agriculture of Bangladesh

Agriculture plays a vital contribution in Bangladesh's economy. Around 19.6 % of national GDP comes from the agriculture and 63 % people are engaged in this sector. Agriculture in Bangladesh highly dependent on weather. Bangladesh is a blessing child of nature. The land is very fertile, so a lot of crops can grow naturally. Rice, Jute, Tea are the main crops that grows in Bangladesh. Rice is the staple food for Bangladeshi people, so most of the farmers grow rice [19]. In recent years, Bangladesh become solvent and self-sufficient in terms of producing rice. Jute and tea is the main exported earner for Bangladesh's agriculture. Other earning corps are lentils, sugarcane, oil seed which are contributing immensely in Bangladesh's economy [20].

2.2 Irrigation

Irrigation is an artificial water supply process, redirecting water from river, lake, barrage, channel, dams or other devices. In modern period, submersible water pump pumps water from ground to field [21]. Irrigation process soften the soil and make the land suitable for cultivation. Water management is a crucial part of Bangladesh's agriculture [21]. According to Asian Development Board (ADB) to establish an irrigation system mentioned steps should be followed.

- Ensure water users receive reliable and equitable supplies
- Establish a transparent and equitable system for recovering some proportion of the costs associated with delivering water
- Strengthen the assessment, planning, financing, and implementation of operations and maintenance (O&M)

About 70% of poor people in Bangladesh poor live in rural areas. Less crops and lower food production cut short the development in agriculture. The government's goal for food security and poverty reduction includes promoting agricultural expansion. Irrigation systems that are efficient and long-lasting are mandatory for increasing agricultural production and introduce crop variety [22].

2.3 Area Selection

Bangladesh is an agricultural country. The economy of our country depends on agriculture. Crops are produced almost every district in our country. Though we can choose any area in our country, we want to choose a remote area where agriculture is the main focus and for our study purpose we choose Dinajpur district. The district is located in 25.63° north latitude. 60% people main occupation is agriculture here. The economy of Dinajpur mainly depends on agriculture. A well-known proverb about Dinajpur- “paddy piled up high, sheds full of cows, ponds brimming with fish” [9]. Net cropped area of Dinajpur region is 527440 ha and these lands comprise three districts; Dinajpur, Thakurgaon and Panchagarh [10]. Crops that produce in Dinajpur mainly are rice, wheat, maize, potato, tomato, brinjal etc. As transplanted Amon rice is produced in Dinajpur in winter season, there will be a little amount is rainfall which is not enough for production and rivers are also dried up in that season, so we can use solar powered water pump for irrigation.

Figure 2.3.1: Map of Dinajpur District, Bangladesh

2.4 Climate of the location

There is a variance in the climate of Dinajpur. Especially in Bangladesh we experienced 6 different seasons. It consists of hot, wet and humid tropical climate. Dinajpur has wet (April-October) and dry (November-March) climate for irrigation. Its annual average temperature is 25 °C (77 °F) and July is the hottest month and January is the coldest month [9].

2.5 Crop Selection

Dinajpur is famous for rice and wheat production. We choose Amon rice for our study. Amon rice is two types: broadcast Amon and transplanted Amon. In Bangladesh the harvesting time of rice: Aus (July-August), broadcast Aman (November-December), transplanted Aman (November-January), local Boro (April-May), and high yielding Boro (May-June) [16]. So, we choose transplanted Amon to produce in Dinajpur district and we will irrigate our land from November to January. In 2017-18, broadcast Amon was cultivated in 365456 ha and transplanted Amon was cultivated in 936212 hector [12]. In Dinajpur broadcast Amon is not cultivated rather there transplanted Amon is produced. Transplanted Amon was produced 1.432 M. Ton/hector in 2017-18 and total transplanted Amon is produced 1340511 M. Ton in our country [12]. In 2016-17 transplanted Amon was produced 19049 M. Ton in Dinajpur in 10430 hector [12]. So, transplanted Amon is one of the major crops of Dinajpur and for this reason we choose transplanted Amon.

Chapter 3

Theoretical Background

3.1 PV System

Photovoltaic are the devices which convert light energy into electrical energy. PV cells are semiconductor diodes which convert light energy into electrical energy. Most of the cases PV cells made of silicon. PV cell consists of metallic grid which from one of the electric contacts, and allows light to fall on the semiconductor. Anti-reflection layers that is silver nitrate is coated in between the metallic grid, this anti-reflective layer allows the light to be completely absorbed but it presents the light and allows maximum amount of light fall on PN junction increase light transmitted in the semiconductor. The other electrical contact is the metallic layer which is behind the PV cells when light falls on the PN junction in between the metallic grid and falls on PN junction.

Figure 3.1.1: Solar cell, PV solar panel, and PV panel array

3.1.1 How PV Panel Works

Solar energy's contribution to the world's total energy supply has expanded dramatically over the previous two decades. The sun's energy is the most abundant and unrestricted source of energy on the planet. We will need the assistance of the second most abundant element on the planet, sand, to use this energy. To be used in solar cells, the sand must be transformed to 99.99 percent pure silicon crystals. Raw silicon is transformed to a gaseous silicon compound, which is then combined with hydrogen to produce highly pure polycrystalline silicon. These silicon ingots are molded and then transformed into silicon wafers, which are incredibly thin slices of silicon. For example, P type doping occurs when three valence electrons of boron are injected into pure silicon, resulting in one hole for each atom. When these two types of doped materials are combined, some electrons from the N side migrate to the P region and fill the holes left over, forming a depletion region with no free electrons or holes. As a result of the electron migration, the N side boundary becomes slightly positively charged, while the P side becomes negatively charged. An electric field will undoubtedly arise between these charges as a result of this. The requisite driving force is generated by this electric field.

To be used in solar cells, the sand must be transformed to 99.99 percent pure silicon crystals. For example, N type doping if we inject boron with three valence electrons into pure silicon there will be one hole for each atom which is called P type doping. When these two kinds of doped materials join together some electrons from the N side will migrate to the P region and fill the holes available by this way depletion region is formed there are no free electrons and holes, due to the electron migration the N side boundary becomes slightly positively charged and P side becomes negatively charged. For this an electric field will definitely be formed between these regions. This electric field produces the required driving force. When sun light strikes the PN junction sun light fall into the N region of the PV cell. Photon is enough sufficient to generate electron hole pairs in the depletion region. The electric field in the depletion region create drives the electrons and holes out of the depletion region. The concentration of electrons in the N region and holes in the P region a potential difference will create between them. When we connect any load between these regions, electrons will start flowing through the load, then electrons will recombine with the holes in the P region after completing their path, by this way photovoltaic cell continuously gives direct current. The top N layer is very thin and heavily doped on the other hand P layer is thick and lightly doped which increase the performance of the cell. Due to the sun light striking the electron hole pairs are generated in a wider area the thin top layer, more light energy can reach the depletion region. Photovoltaic cells are interconnected. Copper strips link the top negative side of this cell to the back side of the cell.

3.1.2 DC Motor

A DC motor is electrical motors that converts direct current electrical energy into mechanical energy. Motor converts electrical energy to mechanical energy with the help of magnets. The most types rely on the forces Produced by magnetic field. Nowadays DC motor is widely used all over the world for its simple mechanism. DC motors are driven using DC power supply. The input voltage is constant of a DC motor. Magnetic field is produced by using high-strength permanent magnet and when the electric flows through it, rotor spin and creates a magnetic field. DC power system is still present in vehicles, toys, cranes, air compressors and the things those speed needs to be controlled. The advantage of DC motor is that it has high starting torque to overcome the inertia of standstill. It is the minimum torque that is required to make the change from static position to moving condition. This is the main advantage of a DC motor. Secondly, using AC motor, speed cannot be controlled but using DC speed can be controlled according to the requirement.

Thirdly, the installation process of DC motor is very easy and maintenance is also easy and can be repaired easily. If a setup of DC motor is need to be replaced, it can be done easily while it is very much difficult to replace an AC motor and sometimes whole setup need to be changed.

3.1.3 Submersible pump

In the hydraulic world, submersible pumps are the most popular pumping devices. The impeller is at the center of the system. A set of curved vanes are installed inside shroud plates. The impeller is submerged in water at all times. When the impeller rotates, the fluid around it rotates as well. The water particles experience centrifugal force as a result, and the water travels radially out. Because rotational mechanical energy is imparted to the fluid, water pressure and kinetic energy will rise at the impeller's discharge side. Water is being displaced on the suction side, resulting in a negative. Low pressure aids in the reintroduction of fresh water into the system. The impeller is housed inside a casing, which collects the water flowing out and directs it in the same direction as the impeller's spin to the discharge nozzle.

3.2 Solar Irradiation Calculation

The total of all intensity levels obtained during a specific time period is referred to as cumulative energy. Total energy generation for a specific time period can be computed. Time period can be a single day, a week, a month, or even a year. Numerical Intensity integration can be utilized for a certain time period, considering the available hours from sunrise to sunset. By applying the following formulas the total emitted solar energy incident can be calculated-

$$E_{inc} = A \int_{T_{SR}}^{T_{SS}} I_{inc}\, dt \quad \text{(3.2.1)}$$

Where, Area of the panel is represented by A and the incident solar energy is referred to $I_{inc.}$ The sunrise and sunset time is denoted by T_{SS} and $T_{SR.}$

The incident solar energy is calculated by using the formula-

$$I_{inc} = I*\cos\delta *\cos\theta \quad \text{...} \quad (3.2.2)$$

Where θ is denoted as the angle between incident sunlight and the panel plane, δ is angle of declination. The value of θ can vary from time to time of a day and also for different seasons. For fixed axis the value of both δ and θ varies from time to time.

The solar irradiance is obtained from the following relation-

$$I = I_0 * (0.7)^{AM^{0.678}} \quad \text{.......................................} \quad (3.2.3)$$

AM is the air mass and the value of I_0 is 1367 W/m2 as it is the value of solar irradiance in space, outside the earth's atmosphere.

From the equation given below.

$$\alpha = \sin^{-1} (\sin\delta \sin\gamma + \cos\delta \cos\gamma \cos\omega) \quad \text{.....................} \quad (3.2.4)$$

The angle of incidence of sunlight is calculated at any point of time of a specific day. The latitude angle is represented by φ, hour angle is ω and the declination angle is δ which is calculated by using the formula -

$$\delta = 23.45° \sin\{\frac{360}{365} (n + 284)\} \quad \text{..........................} \quad (3.2.5)$$

Where, the n is the number of day of the year. January 1 as day 1 and December 31 being day number 365.

The hour angle is calculated by using these formulas, Hour angle refers to the number of hour obtained from sunrise to sunset [23].

$$\omega = \omega_S - 15 (t - T_{SR}) \quad \text{.......................................} \quad (3.2.6)$$

ω_S is calculated by using,

$$\omega_S = \cos^{-1} (-\tan\gamma \tan\delta) \quad \text{...} \quad (3.2.7)$$

3.3 Flow rate calculation

The required flow rate varies monthly as the solar insolation varies. The required flow rate of a month is calculated using the average solar insolation of that specific month.

$$\text{Solar Insolation} = \frac{\text{Total solar incident energy(KWh)}}{\text{1000KW}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.3.1)}$$

$$\text{Required Flow rate} = \frac{\textit{Daily water requirement}}{\textit{Solar insolation}*60} \quad \text{LPM} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.3.2)}$$

Chapter 4

System Design and Methodology

4.1 System Design

The solar pumping water system is a widespread yet effective method for irrigation purposes. In our system design, we have implemented four parts. These are:

- **Submersible pump:** To lift the groundwater, we choose a submersible pump with a pump head of 30 meters. The maximum input power is 6750 watts. The maximum output voltage of this pump is 450 volts, and the maximum current is 20 ampere.
- **Solar Panel:** We have selected a solar panel model to supply a maximum power of two hundred fifty (250) watts to the submersible pump. It can provide 30.6 volts and 8.71 amperes at the maximum power supply. The efficiency of the panel is 15.37%. We will implement a total number of thirty-nine (39) panels.
- **Water storage:** The water storage we have selected has a length of thirty-nine (45) meters and a width of thirty-eight (45) meters, so the area is one thousand four hundred eighty-two (1482) square feet, and the depth is two (2) meters. The density of this pond is four thousand fifty (4050) cubic meters. Two thousand nine hundred sixty-four cubic meters pond can hold up to 4050000 Liters of water.

- **Irrigation field:** We have chosen one (1) hector field to cultivate Amon rice for irrigation.

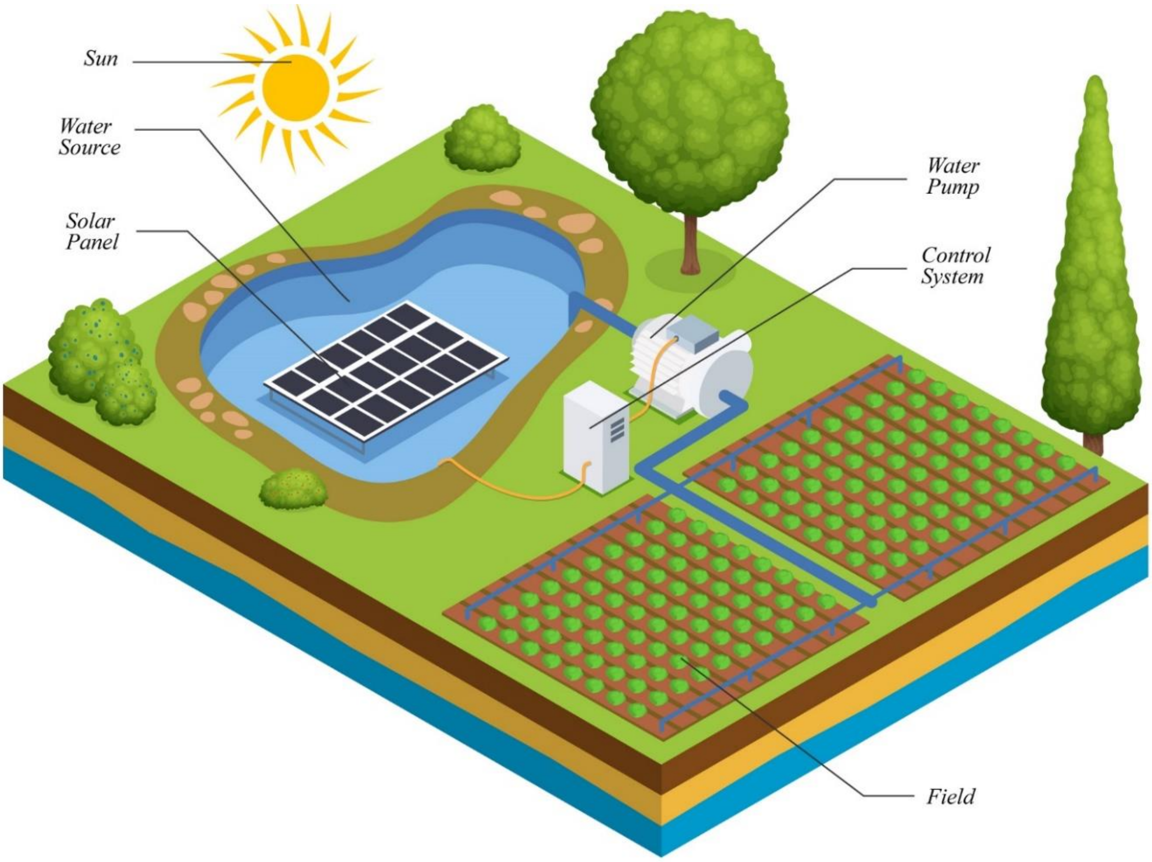

Figure 4.1.1: Solar-Powered Water Pumping System with Control System

We choose a system where the pump will run only in daylight because we did not attach any battery with the solar panel. The panel will be energized by sunlight and supply electricity to the DC water pump. DC water pump is a submersible pump that pulls water from underground. The pump will run in daylight, but it will not pull the same amount of water from underground. In the peak hour, it will supply the maximum water that the pump can pull out, but in low light or the verge of a day, the pull rate of water becomes low. The pump efficiency also varies from dust, cloud, and aging.

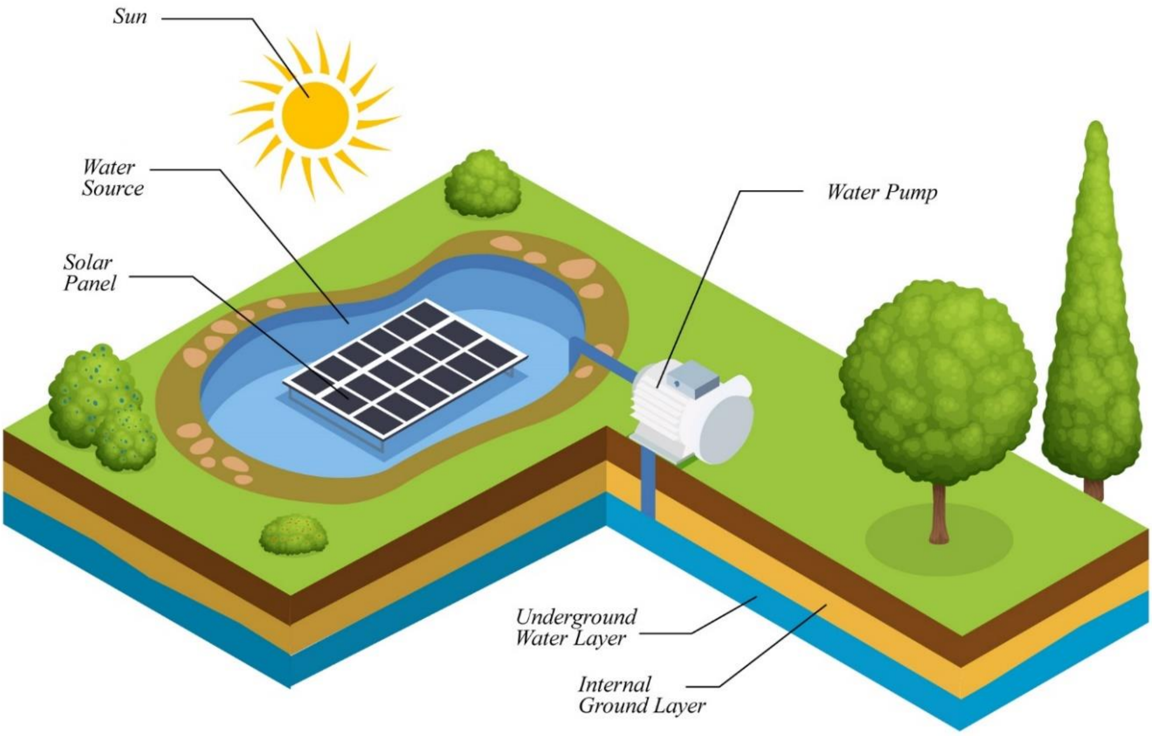

Figure 4.1.2: Solar-Powered Water Pumping System Collecting Underground Water

We have considered running the irrigation process from October to March. So the optimum tilt angle for solar panels is 39.80º. To save the occupancy of irrigation fields, we implemented solar panels floating on the water storage. The DC water pump pumps groundwater to the field, and during the time when the field does not need water, the pump supply water to the water storage.

The floated panels will be oriented in 2 parallel strings and 19 panels in series strings on the water storage area. Each of the panels will provide 250 watts of energy to the pumps.

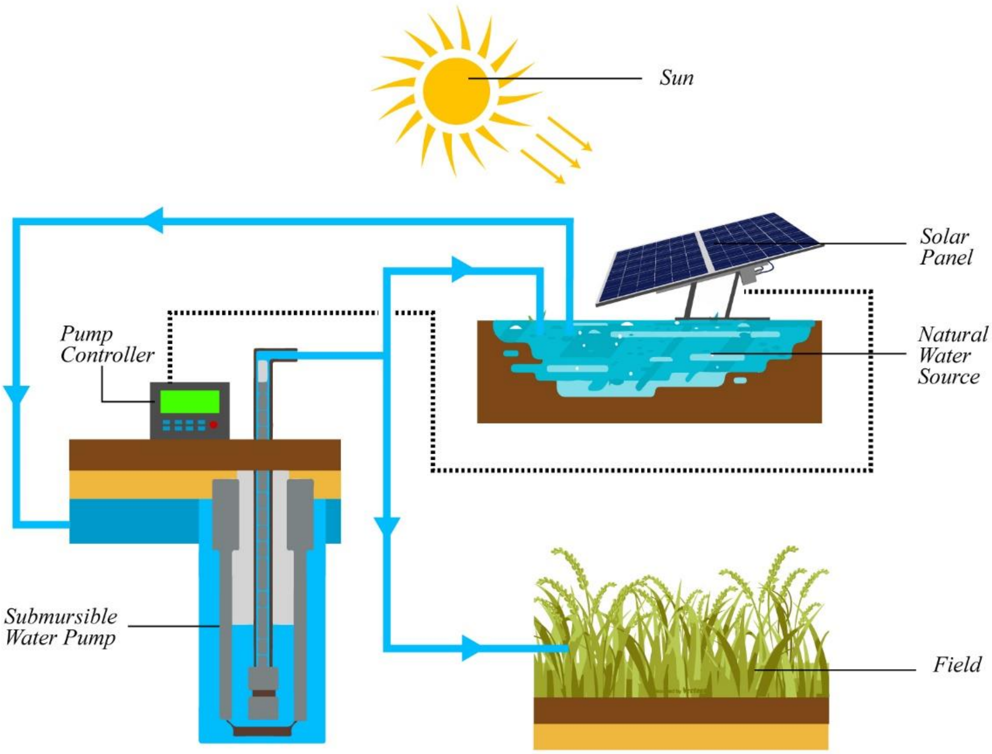

Figure 4.1.3: Water and Energy Flow Diagram of Solar-Powered Water Pumping System

When there is rainfall, the storage will also collect the rainwater. The stored water also can be supplied to the irrigation field by the DC water pump. The water storage will be used for multi-purpose reasons apart from the irrigation process. We need outmost 0.50 acre of land for the water storage, and locally this type of storage can be found near the irrigation field. The water storage can be a pond or a small lake that runs through the area.

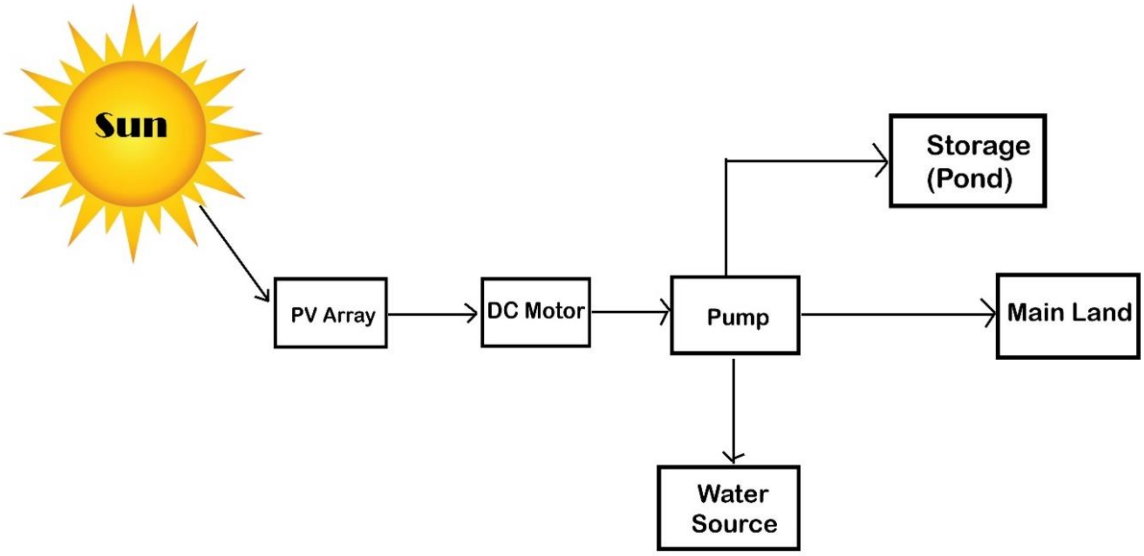

Figure 4.1.4: Flow Chart of Solar-Powered Water Pumping System.

4.2 Water Required

Our selected area Dinajpur is a dry area. Soil needs much water to grow crops in north-western part of Bangladesh specially in Rangpur, Dinajpur area. Different crops water requirement in a season will be different. We grow many kinds of crops in our country. For our research purpose, we have chossen Amon rice that we will produce in 1 hector land and we need to find out the water requirement for Amon rice in Dinajpur district. From a research paper named "Assessment of Crop and Irrigation Water Requirements for Some Selected Crops in Northwestern Bangladesh" we find a bar chart where we can see water requirement for some selected crops in Rangpur, Dinajpur and Sayedpur districts. The bar chart is given below:

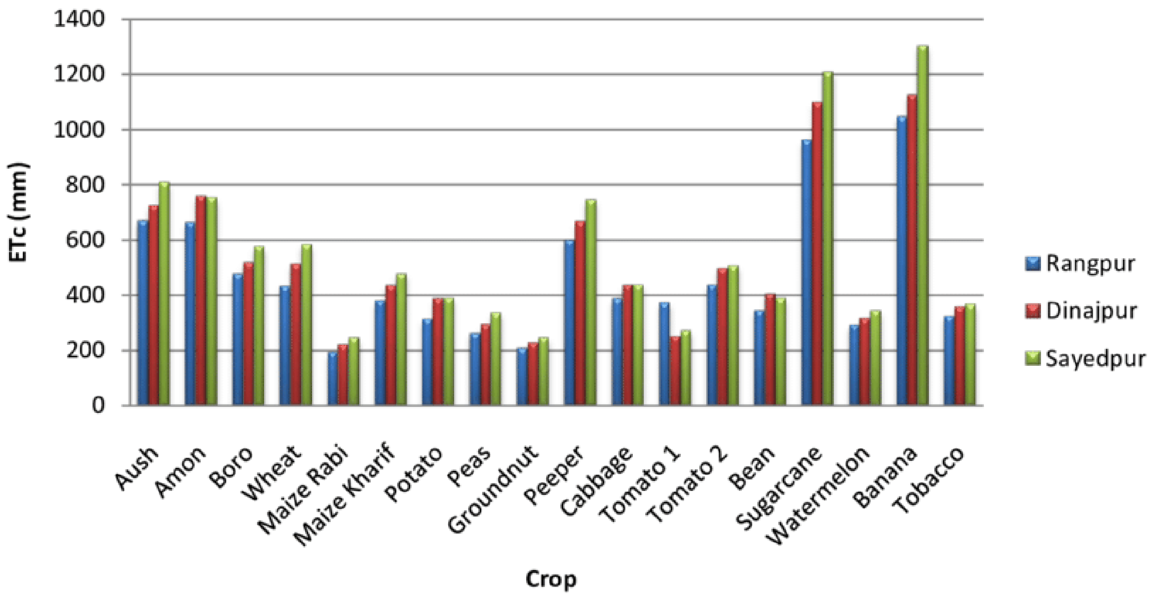

Figure 4.2.1: Water requirement for the selected crops in Rangpur, Dinajpur, Sayedpur [15]

In Figure 4.2.1, we can see the crop water requirement for various crops expressed in mm per Hector. From the data given in the paper we take this bar chart, we can see that their research was done targeting 1 hector area.

From this figure, the water demand for Amon in Dinajpur is approximately 750mm in its lifetime. It is without calculating the rainfall. Rainfall is also a source of water supply. So if we want to design and optimize a pump that will be used for irrigation, we need to subtract net rainfall in the irrigation season from the water requirement we find.

4.2.1 Rainfall during Cultivation Period

In Bangladesh the harvesting time of rice in different seasons are: Aush (July-August), transplanted Amon (November-January), local Boro (April-May), and high yielding Boro (May-June) [16]. So we need 3 months (November to January) for Amon rice to cultivation. To calculate the daily water requirement for irrigation to design the system rainfall during the chosen season of Amon has to be calculated. So we need to consider net rainfall from 19th November to 13th February of 2020.

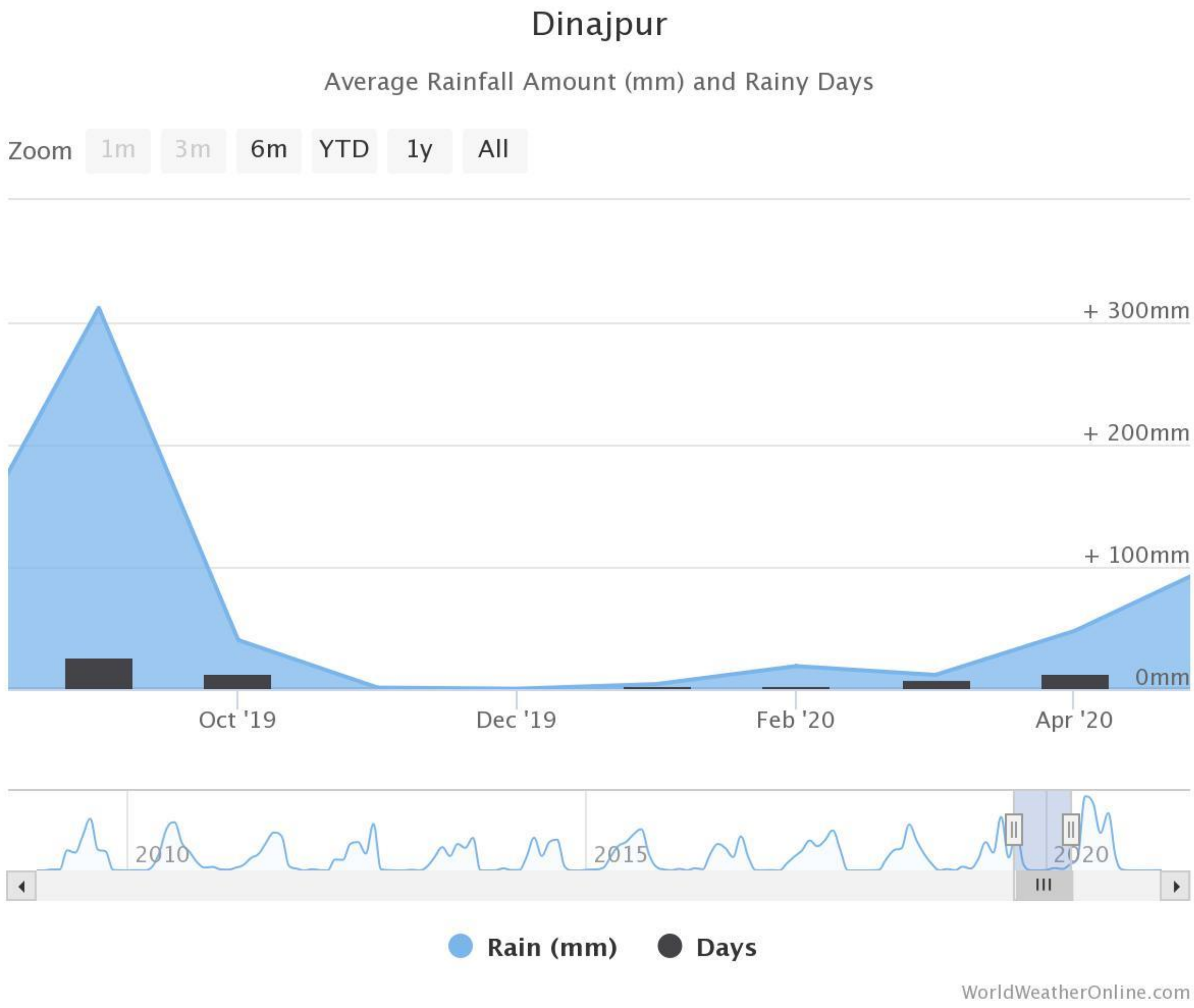

Figure 4.2.1.1: Rainfall in Dinajpur district for some specific months [17]

We have to consider the months November '19 to 13th of February '20 and the net rainfall we get from an online source from November '19 to 13th of February '20 is 8.9mm in Dinajpur district [17].

4.3 Required Flow Rate

Required flow rate is calculated from the solar insolation by considering the 15^{th} day of the each month. Form the solar irradiance plot, the solar insolation is calculated by using the formula no 3.3.1. The required flow rate of each month is determined by the equation 3.3.2. Maximum flow rate is 655.1 L/min in February and lowest flow rate is 596.1 L/min in the month of September was obtained. The system is designed based on the solar irradiance and flow rate values of the month and a pump has been chosen to match the required values of the flow rate.

4.4 Pump Selection

To meet up the daily required flow rate a submersible pump has been chosen considering the pump hand according to the chosen area. The pump head has to be 30m for the Dinajpur district as the water level is pretty low. From table 5.2.1 lowest flow rate is 596.1 liters per minute in the month of February and highest flow rate is 655.1 liters per minute in the month of September. Therefore, a submersible pump of 30m pump head has been chosen depending on the highest and lowest flow rate. In this paper, SHAKTI PUMP - **Solar 48 DCSMP 6750** is selected for the system. The specifications of the pump is given below,

Pump (Pump Motor)	
Pump type	SOLAR SUBMERSIBLE PUMP
Output Power	7.5 HP
Rated Voltage (V)	450
Rated Current (A)	20
Head(m)	30
Pump Efficiency (%)	97

Pump Controller	
Controller type	SHAKTI SUD 3P, 20A, 720Vdc, 7.5HP
Maximum input voltage at solar array (vdc)	450
Rated output voltage	200-450
Maximum current	22

Table 4.4.1: Specifications of pump and motor of Shakti pump 48 DCSSP 6750

4.5 Panel Selection

250W solar panels of Grameen-Shakti has been chosen for the system. The reason behind choosing 250W panel is that these panels are mostly available in the market all the time and for its affordable price. The specification of the chosen panel are given below-

Cell specification (Standard condition, 1000W/m2 and 25˚C)	
Maximum Power , P_{max}	250W
Maximum power point voltage, V_{mpp}	30.6V
Maximum Power point current, I_{mpp}	8.17A
Open circuit voltage, V_{oc}	37.2V
Short Circuit Current, I_{sc}	8.82A
Module Efficiency, η	15.37%
Cells per module	72
P_{max} Temperature Coefficient	-0.40%/℃
V_{oc} Temperature Coefficient	-0.32%/℃
I_{sc} Temperature Coefficient	-0.05%/℃
Operating Temperature	-40~+85℃
Nominal Operating Cell Temperature (NOCT)	45±2℃
De rating factor, ηD	10%
edging factor, ηe	10%

Table 4.5.1: Specification of Solar Panel

4.6 Panel Loss Calculation

The panel loss calculation has been done to obtain the panel power after losses so that the number of panels needed to supply the input power of the pump motor can be determined.

4.6.1 Voltage drop

From the panel specification char, it can be said that, if the temperature increases 1℃ the open circuit voltage coefficient V_{oc} is -0.32%/℃, Rated V_{oc} = 37.2 V.

Open circuit voltage drop per ℃ temperature rise = 37.2*0.32% = 0.11904 V

According to the specification, nominal operating cell temperature is 45℃.

The standard temperature is considered 25℃. So, temperature rise = (45-25) ℃ = 20℃

For 20℃ temperature rise, V_{oc} drop = 0.11904 * 20 = 2.3808 V

Here, Voltage drop percentage = (2.3808/37.2)*100 = 6.4%

Considering 2% line loss,

Total voltage loss percentage is = (6.4+2) % = 8.4%

Panel maximum load voltage is V_{max} = 30.6 V

After loss, estimated voltage V_{panel} = (3.06*8.4) % = 28.02V = 28 V.

4.6.2 Current Loss

For current loss, the De rating factor, ηD and edging factor, ηe are counted

So, Total loss= 10+10 = 20%

The rated current for the chosen panel I_{max} = 8 A

After calculating the loss panel current is

$$I_{panel} = (8- (8*20\%))\ A$$

$I_{panel} = 6.4A$

4.6.3 Panel power Calculation Considering Loss

Panel power, P_{panel} = 28V *6.4.A

= 179 W

So, the ratio is =179/250 = 0.716

4.7 Panel Orientation

4.7.1 Panel Number

The selected motor has rated power of, P_{motor} = 6750 W

Number of panel needed = 6750 /179 = 37.71= 38

For benefit of implementation, we have taken **39 panels**.

4.7.2 Panel connection

Rated voltage of the motor = power/rated current = 6750/20 =337.5 V

Rated current of the motor = 20A

So,

Number of panels have to be connected in series,

No of panels in series= Estimated output voltage/ voltage at MPP

No of Panels in series = 337.5/28= 12.5= 13 (approximately)

Number of panels have to be connected in parallel,

No of panels in parallel = Estimated output current/ current at MPP

No of panels in parallel 20/6.4 = 3

So the system has, Panels in series= 13

Panels in parallel= 3

Total number of panels = 39

After loss panel voltage V_{panel} = 28 V, after loss panel current I_{panel} = 6.4A

Total panel power, P_{panel} = 39*28*6.4 = 6988.8W, where the pump motor input power is 6750 W.

Panel setup- As calculation the system will have total number of 39 modules and the modules are oriented in such a way that, there are 3 parallel strings each having 13 modules in series. The panel will provide the input power of the pump motor to run the system after considering the loss of the PV panel.

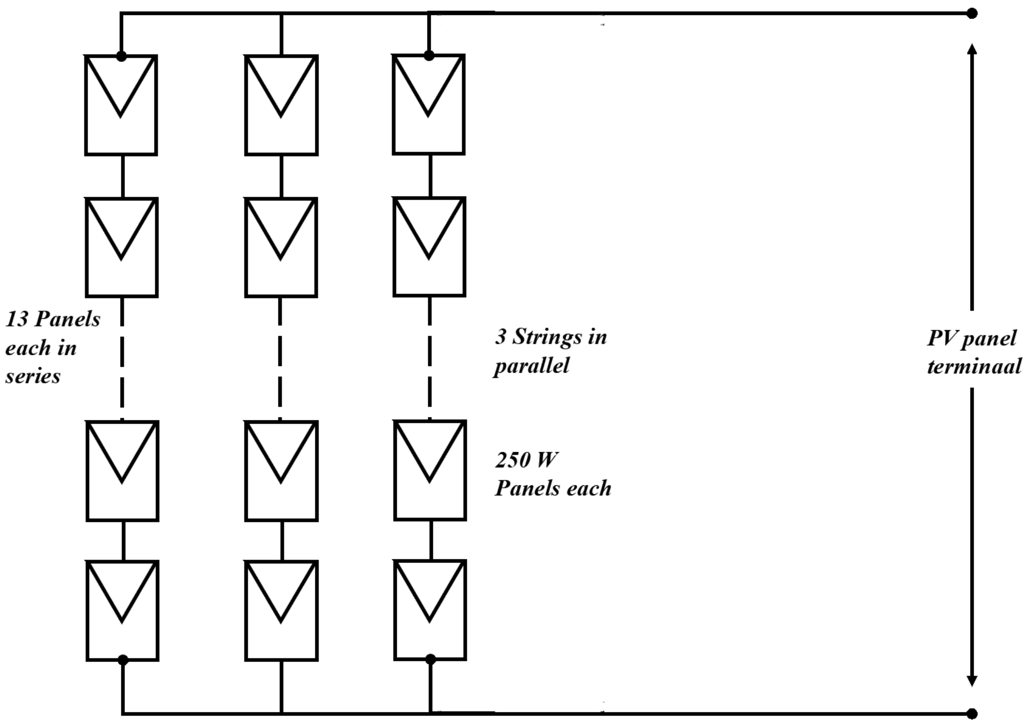

Figure 4.7.1: PV module orientation in series and parallel

4.8 Water Storage

We want to select a pond as our storage for storing water near our irrigation land. We want to store half of the water that requires in an irrigation season. The reason is if we do not pick up water that we required in irrigation, we will supply it from the storage. Secondly, in winter, solar energy may not be available each day as the weather in winter may be foggy and the sun may not be seen the time we pick. So, we will supply water in that particular situation from storage if necessary. We need to make a storage that will store the half of the total water that we need in a season. As we need 7406919 liters of water, we will store 3700000 liters in storage. If we store half of the total water during the gap of our irrigation, we will store that amount in our storage.

4.9 Methodology

In this thesis we have followed these method to execute our work

1. Finding targeted place and find a suitable corp.
2. Find out optimum tilt angle for the place.
3. From optimum tilt angle find solar irradiation.
4. Calculate required water.
5. Calculate flow rate based on solar insolation per month.
6. Pump selection.
7. Panel selection.
8. Panel orientation.
9. Calculate flow rate based on input power of motor.
10. Water management according to irrigation base calculation.
11. Storage area calculation.

Chapter 5

Result Analysis

5.1 IV characteristic

The IV characteristics of the PV cell has been plotted to observe the relation between PV voltage and PV current.

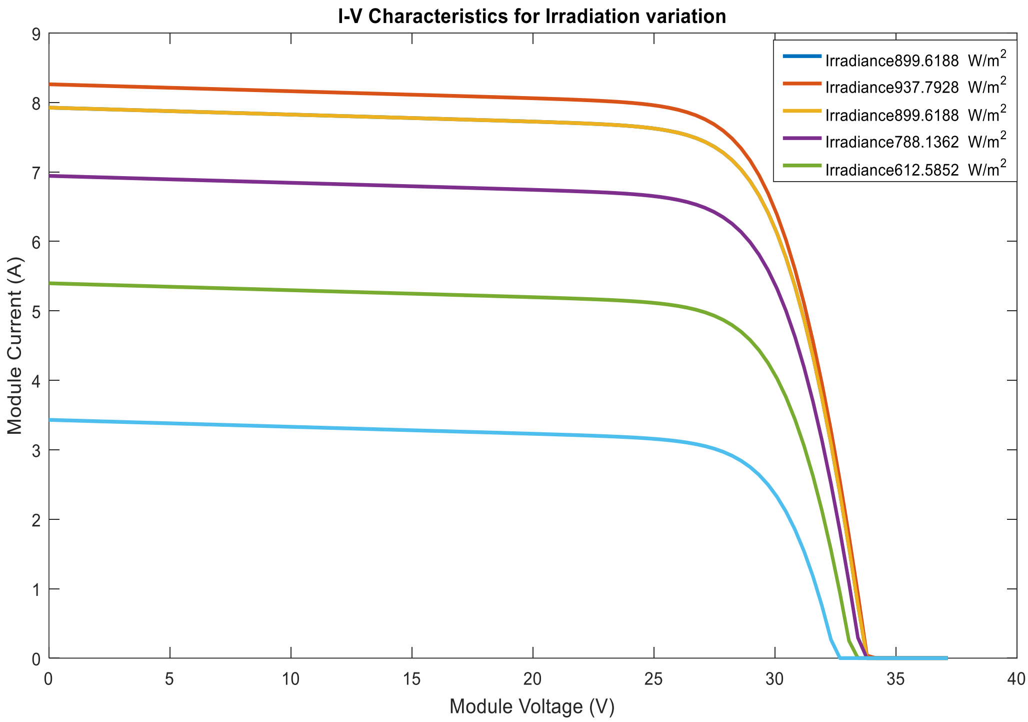

Figure 5.1.1: Plots of I-V characteristics curves of the PV panels, for varying solar irradiance calculated for the 15th day of the November month, considering the optimized tilt angle of 39.80˚

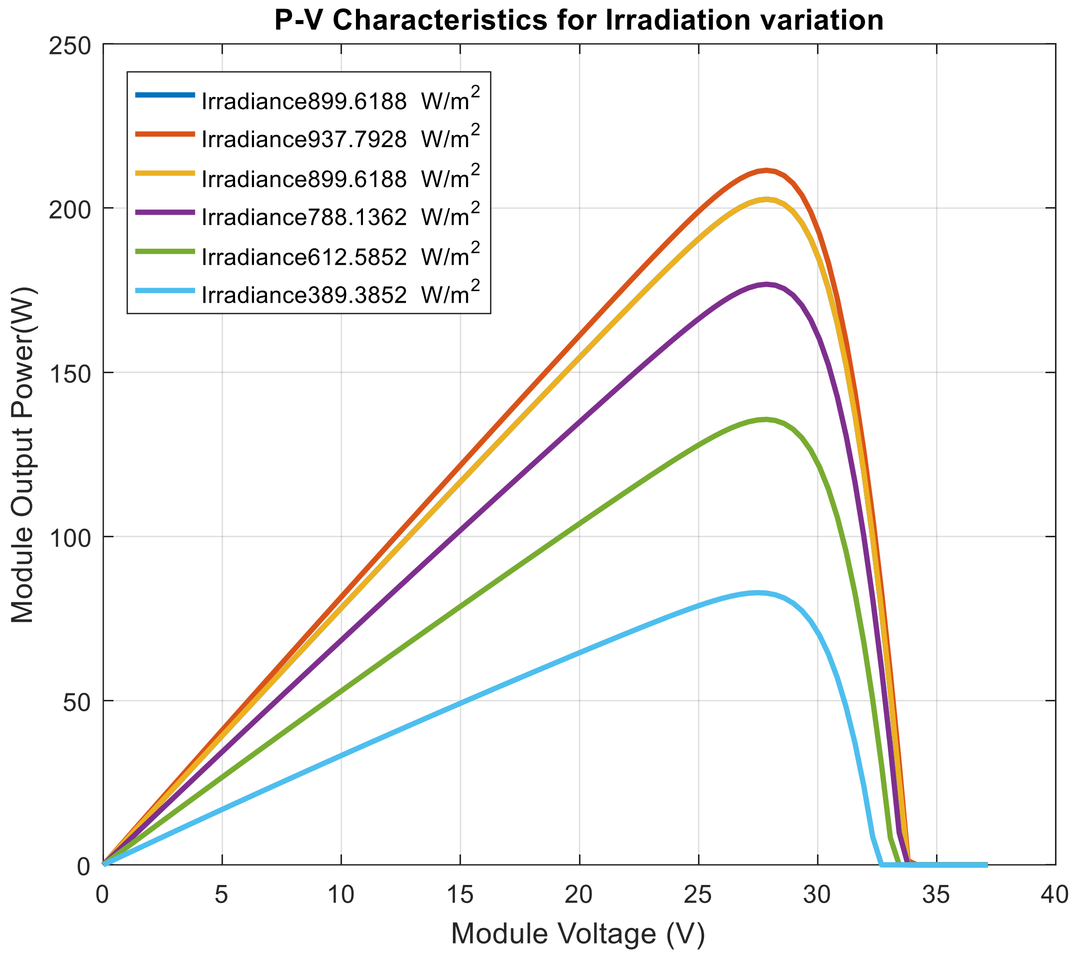

Figure 5.1.2: Plots of P-V characteristics curves of the PV panels, for varying solar irradiance, calculated for the 15th day of the November month, considering the optimized tilt angle of 39.80˚

5.2 Solar Irradiance Comparison Using Different Tilt Angles

Our calculations are based upon the values of daily radiation on a horizontal surface in Dinajpur, Bangladesh. We assume one optimum tilt angel for six months and another tilt angle for the remaining tilt angle. A mathematical model is developed to calculate solar radiation on an inclined surface as a function of the tilt angle. Our study shows that the monthly optimal tilt angle allows maximum solar radiation collection. In the research it is shown that optimal solar radiation collection is approximately achieved if the tilt angle of solar collectors is seasonally adjusted. Annual optimal tilt angle is found to be approximately equal to the latitude of the location. Comparison of the solar irradiance of a year applying a fixed tilt angle for whole year and in another process, we used two tilt angles diving the whole year into two [23].

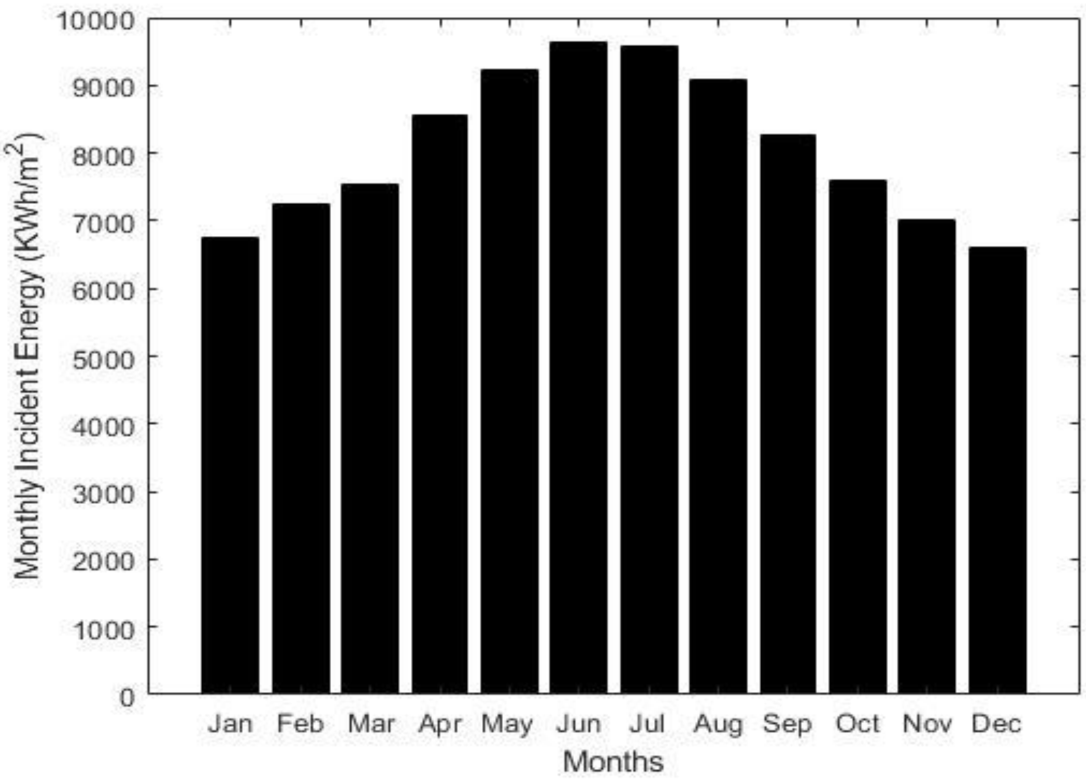

Figure 5.2.1: Annual Solar Irradiance Using Optimum Tilt Angle (April to September-10.70° and October to March- 39.80°)

Solar irradiance calculation of the same year is calculated by using fixed tilt angle according to the location of the chosen area. We obtained this figure using fixed tilt angle 23.30° [7].

Fixed tilt angel Calculation:

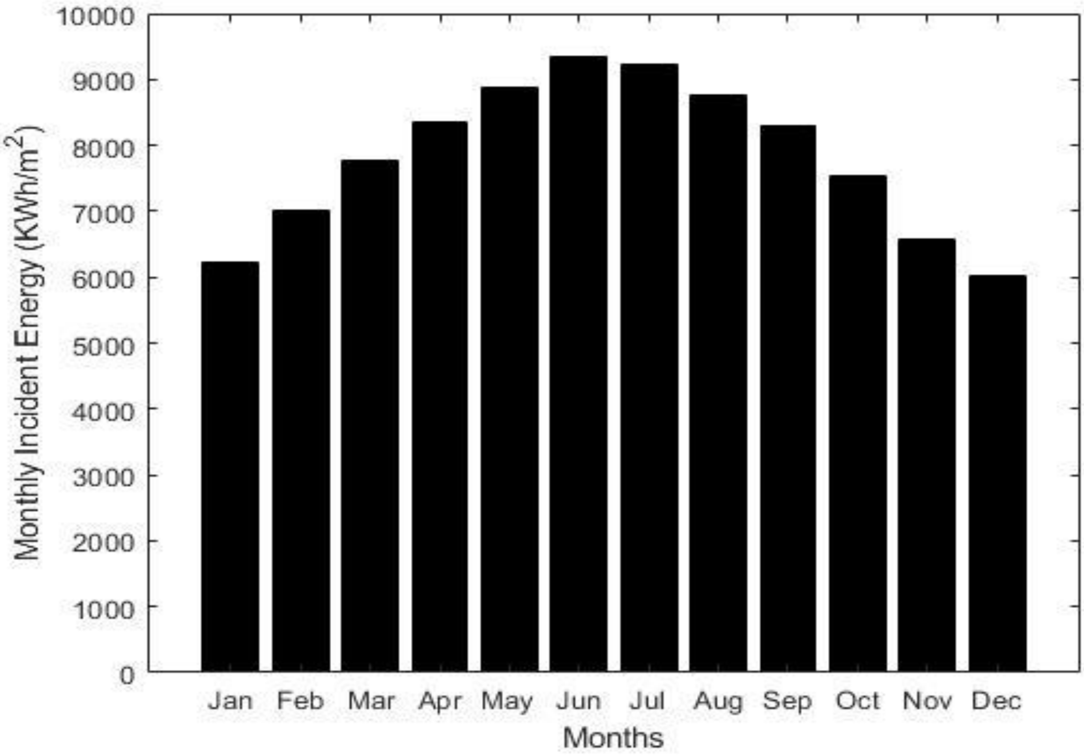

Figure 5.2.2: Annual Solar Irradiance Using Fixed Tilt Angle (January to December-23.30°)

By using two different tilt angel irradiance we got total 97071watt/m^2. One the other hand, when we used fixed tilt angel irradiance, we got total 94002 watt/m^2. Finally, after analyzing 3.26% irradiance increased by using two different optimum tilt angels.

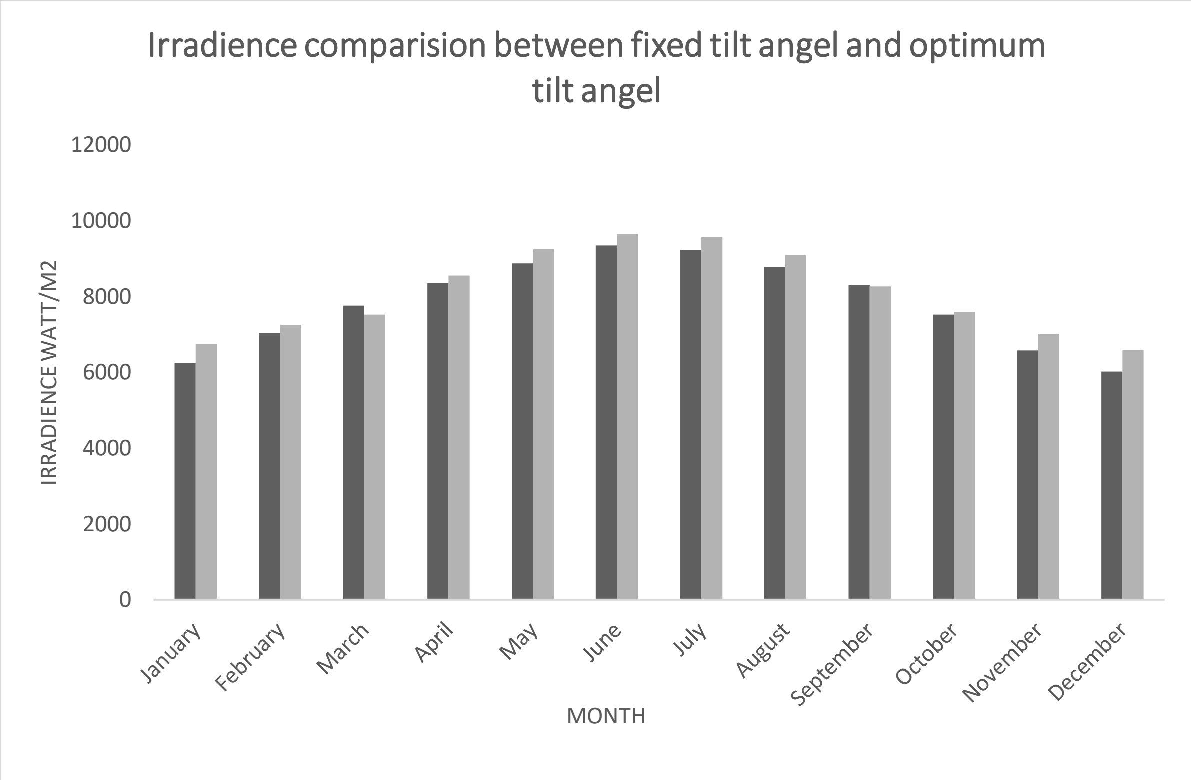

Figure 5.2.3: Irradiance Comparison Between Fixed Tilt Angle and Optimum Tilt Angle

5.3 Net water required after considering rainfall

The total rainfall we get in 8.9 mm from 1st November '19 to 10th of February '20. So, the solar water pump needs to supply (750-8.9) mm which is almost 741mm (approx.)

We know, 1 Acre= 100 decimals

1 decimal= 40.469 Square meters

1 hector=2.47 Acres=2.47*100 decimals=247 decimals=247*40.469 Square meters.

=9995.843 Square meters.

1mm of water per square meter means every square meter receives 1 Liter of water.

In that way, 741mm water in 1 square meter receives 741 Liters of water. 1 hector of land is 9995.843 square meters. So, we need 741 mm in three months in 1 hector.

So Net water is needed =9995.843*741=7406919.66 Liters in 3 months.

In one (1) irrigation daily water requirement = 250000 liters.

5.4 Required Flow Rate

The required flow rate of a month daily is used to find the maximum water requirement and minimum water requirement. By doing the calculation using formula from equation 3.3.1 & 3.3.2 the range of flow rate is obtained.

Month	Tilt Angle	Solar Insolation	Flow Rate LPM
January	39.80^o	6.8015	612.75
February	39.80^o	6.9966	596.1
March	39.80^o	6.7705	615.46
April	10.70^o	6.9033	603.86
May	10.70^o	6.9747	597.8
June	10.70^o	6.9273	602.12
July	10.70^o	6.8054	612.74
August	10.70^o	6.6343	628.45
September	10.70^o	6.3678	655.1
October	39.80^o	6.5795	633.33
November	39.80^o	6.6229	629.40
December	39.80^o	6.5963	631.47

Table 5.4.1: Required Flow Rate Calculation on Basis of Monthly Solar Insolation

Maximum flow rate is 655.1 L/min in September where irradiance is lowest. Lowest flow rate is 596.1 L/min in the month of February where irradiance is maximum. The system is designed based on the solar irradiance and flow rate values of the month and a pump has been chosen to match the required values of the flow rate.

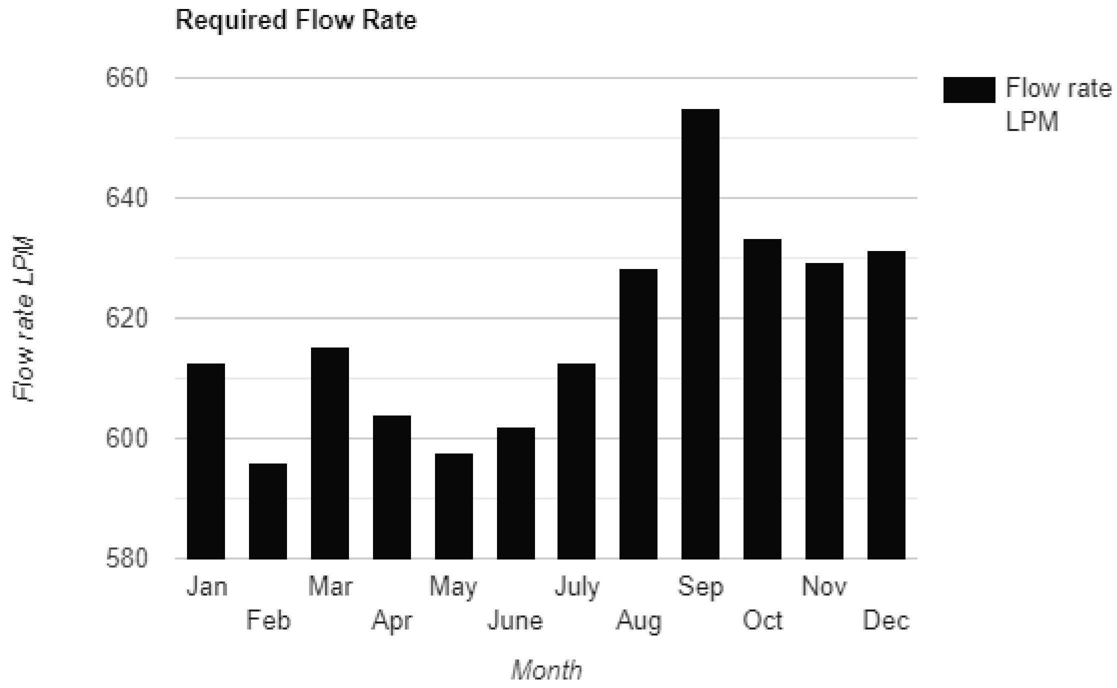

Figure 5.4.1: Required Flow Rate per Month on Basis of Solar Insolation

From the above curved, it is visible that the highest water flow requirement is in the month of September as the solar insolation is minimum.

5.5 Calculation of water flow rate

In our research crop cultivation period is from November to February. A typical day of November month (15th November) is chosen to demonstrate the relation between solar irradiance and the water flow rate throughout the sunny hours.

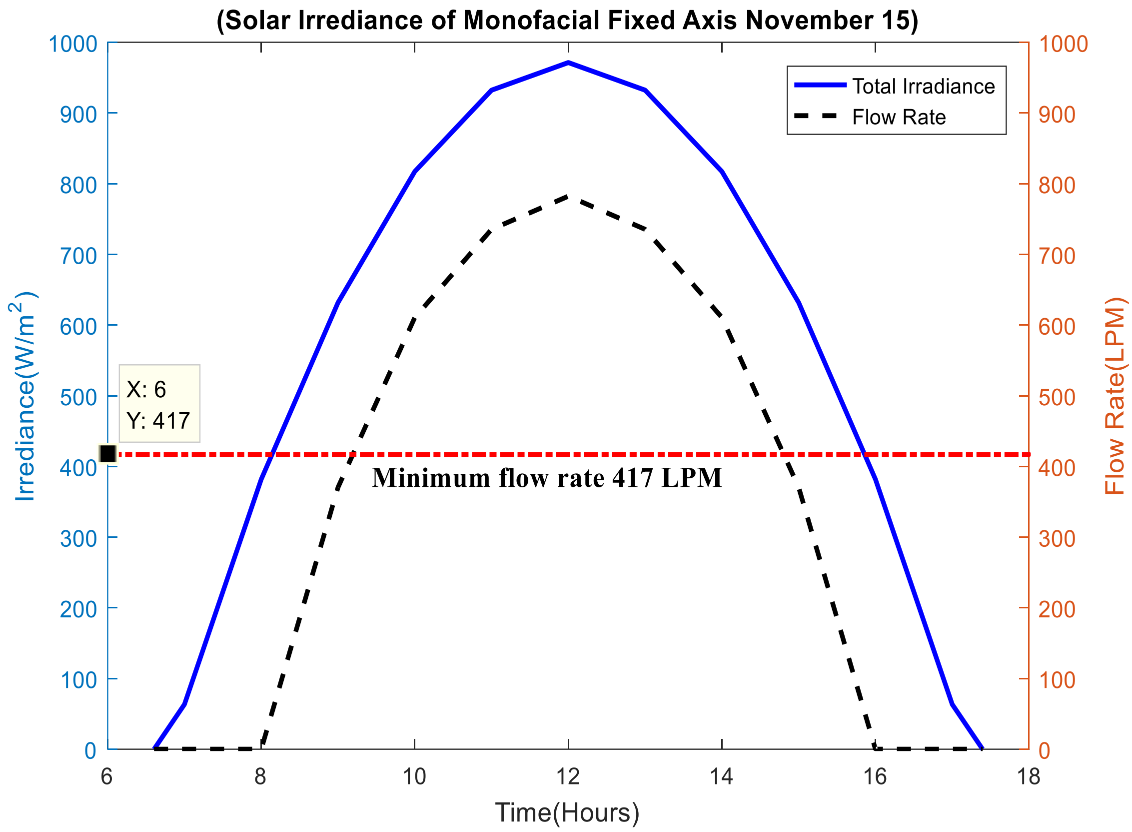

Figure 5.5.1: Plots of incident solar irradiance (solid line) and the water flow rate of the pump (dash line), calculated for November 15, with the tilt angle set at 39.80°.

Figure shows that plot of daily solar power and the flow rate with respect to time of the day in a single plot. For our thesis we have chosen 15th November, the time duration from 7.00am morning to 5.00pm evening is considered to plot it. Here the maximum solar irradiation shows the value at 12.00 noon. Flow rate is direct proportional to solar irradiance. If solar irradiance increase flow rate increase. If solar irradiance decrease flow rate decrease. From the graph after determining the flow rate for each of the time duration, the total water collection value for a day is calculated. Here for the month of November it meets the daily water requirement and it can get 2, 50,000 liters of water for an entire day from 7.00am to 5.00pm duration. The minimum requirement of the water for this month is 417 L/min.

As November was chosen as the critical month for the system, flow rate calculation of the chosen 6750 W pump is obtained for a typical day of the month. The flow rate calculation was based on the panel number, output power of the panel after loss and the input power of the motor. The table shows the change in flow rate according to the change in input power depending on solar intensity.

From the previous calculation, the solar panel output power after loss = 179 W

Rated panel power=250

So after calculating the power losses, panel output efficiency = 179/250=0.716

The pump input power = 0.7168* Panel output power … … … … … … … … (5.5.1)

Time	Daily intensity for tilt angel 39.80°	Maximum Output power of the panel P_{panel} (watt)	Pump input power = $0.7168*P_{panel}$ (watt)	Flow Rate (L/min)
7.00	54.54	261.5432976	187.4742357	0
8.00	379.9	2083.330954	1493.331628	0
9.00	632	4852.505736	3478.276112	370.4
10.00	818	6953.388	4984.188518	610.7
11.00	933.3	8398.254072	6019.868519	735.4
12.00	972.4	9138.670008	6550.598662	782.3
13.00	933.3	9138.670008	6019.868519	735.4
14.00	818	6953.388	4984.188518	610.7
15.00	632	4852.505736	3478.276112	370.4
16.00	379.9	2083.330954	1493.331628	0
17.00	54.54	261.5432976	187.4742357	0
Total Water				252918 L

Table 5.5.1: Flow rate calculation from the daily intensity of a specific day of November 15 with the optimized tilt angle 39.80°

By plotting the motor input power versus flow rate curve, the flow rate is calculated from different input power of the motor depending on the daily solar intensity.

Given data by the pump manufacturer,

	Input Power (Wp)										
Head (m)	6700	6550	6019	4948	5450	3478	3350	2600	2200	1650	1500
	FLOW in L/min										
30	800	782.3	735.4	610.7	685	370.4	350	190	0		

Table 5.5.2: Motor Configuration by Manufacturer

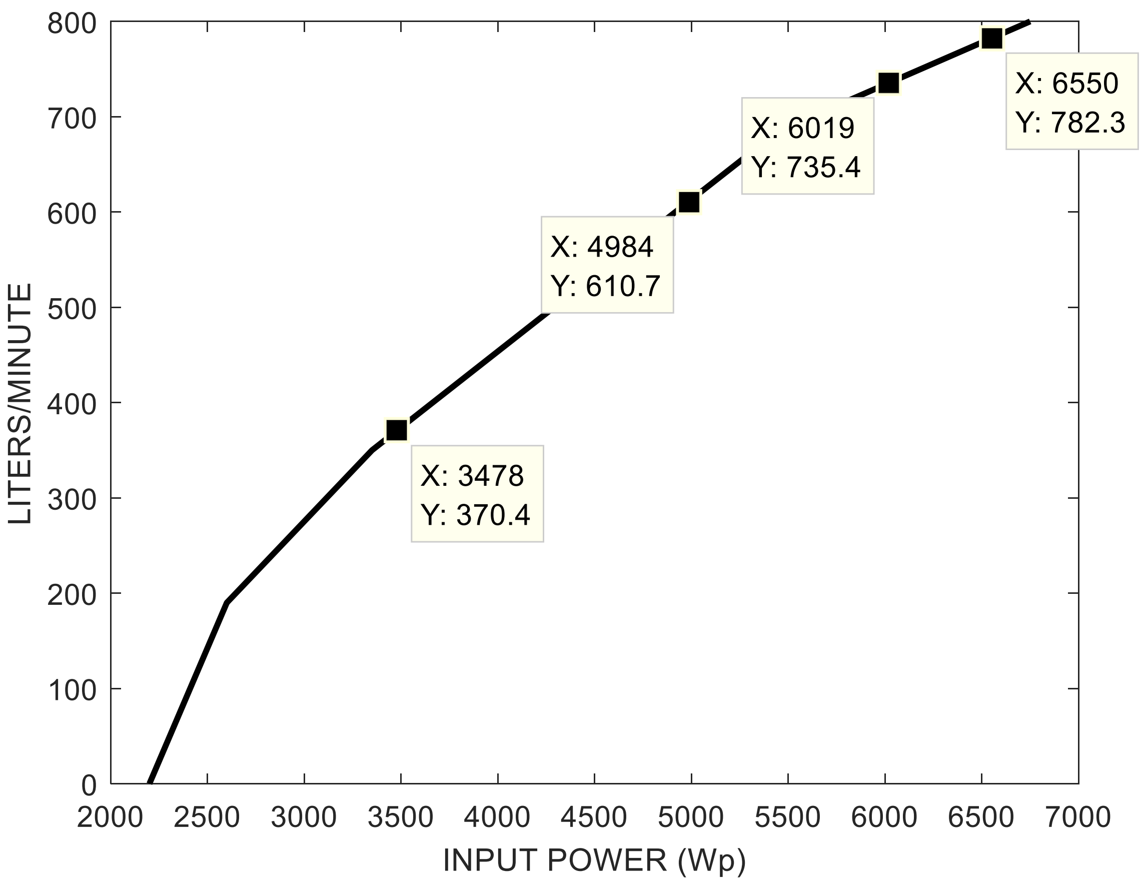

Figure 5.5.2: Plotting of input power versus flow rate of the pump motor

5.6 Irrigation Days Calculation

In one irrigation we can supply 252918 liters we and will store 3700000 liters. To fulfill the storage we will need total days= (3700000/252918) = 15 days (Approximation).

So, between the gaps of irrigation we will store water in storage and it will take 15 days.

Total days of irrigation in field	Total days we store water in storage
31	15

Table 5.6.1: Total days of irrigation and storing water

Solar energy will be collected in winter season according to our study. As we know, winter is the coldest season in our country and sometimes the weather in Dinajpur area might be foggy. Solar energy may not be collected in that season, according to theoretical study. For that reason, the water demand in one irrigation may not be fulfilled. Secondly, underground water level decrease during dry winter season and as a result sometimes water may not be collected as required. Considering these two situations, we designed a storage and we will store water in the storage during the gap of the irrigation days. We will store half of the total water that is required during the irrigation season. We will use the water if we cannot pick up water from the underground for the situations mentioned above. We can increase the production of rice. Rest of the days we will use pump for irrigating other fields if necessary.

5.7 Water Management

As we know, we need to supply 82299.11 liters of water per day, but we cannot supply water every day in land. The reason is the whole land need certain amount of water after different stage. From a research writing named [16] we can see that a fixed percentage of total water is required before different stage of growth. This paper gives a general idea of common rice production methods. But our exact area is Dinajpur and we found how much water is required in Dinajpur for Amon rice. So, we only follow the percentage of water is required in different stage of growth from this paper. The table is showing below:

Stages of growth	% of total water requirement (approx.)
Nursery	5
Main field preparation	20
Planting to panicle initiation	40
Panicle formation to flowering	30
Flowering to maturity	5

Table 5.7.1: Water Requirement of rice at different growth stages [18]

Here we can see that, for the first stage of growth which is called nursery. Nursery is the bed for planting paddy husk to facilitate uprooting near the irrigation land. We need 5% of total water in this stage of growth. Main field preparation is going at the same time while nursery stage is done so that after completing nursery stage, we can sow the seed plant in the main field. So we need water for both nursery and main field preparation at the beginning. Main field preparation stage will need 20% of the total water that require. When the leaf stem bulges and conceals the developing panicle is called panicle initiation stage. Then the tip of the developing panicle emerges from the stem and continues to grow. This is the third stage of growth and it requires 40% of the total water. When the panicle is fully visible, flowering begins. Flowering can continue for about 7 days. This stage requires 30% of the total water. Maturity stage takes usually 30 days. It starts at flowering and ends when the grain is mature and ready to be harvested. Flowering to maturity stage requires 5% of the total water estimation.

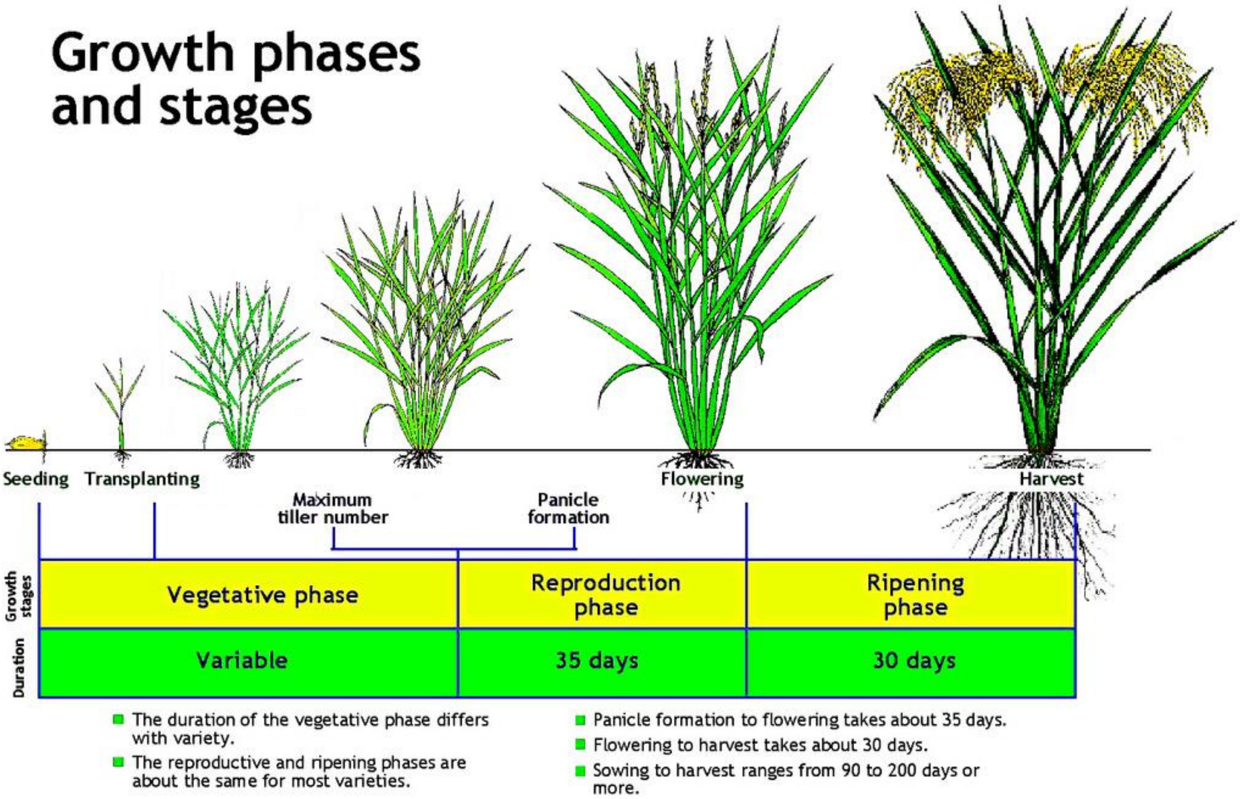

Figure 5.7.1: Growth phases and stages [18]

From Figure 5.7.1, Panicle formation to flowering takes 35 days and flowering to maturity takes 30 days. We know, to produce rice we need total of three and half months. So, rest of the days for other stages. Nursery and main field Preparation stages water should be supplied at the beginning which means 25% of water we need to supply at the beginning. This phase is 15 days (approx.) long. So we need to supply 25% water in the first 15 days and planting to panicle initiation phase is 20 days (approx.) lengthy. In this phase, we need to supply 40% water. Again, Panicle formation to flowering takes about 35 days. So in next 35 days we need to supply 30% of total water in our irrigation field. After panicle formation to flowering stage, 30 days later the last stage will come which is flowering to maturity. We can show the phases, duration of the phases, % of the total water and the exact amount of water in a table.

Phases	Duration of Phase	% of total water to store	The amount of water we need to store in our storage(In Liters)
1.Nursery and main field Preparation	15 days	25	1851730
2.Planting to panicle initiation	20 days	40	2962768
3. Panicle formation to flowering	35 days	30	2222076
4. Flowering to maturity	30 days	5	370346

Table 5.7.2: Growth phases and stages

Now, we cannot supply water daily in the irrigation land because it is not effective in any way. Firstly, if we supply water daily as per day water requirement, the soil will be dry and the crops will be wasted. Secondly the irrigation will not be effective and the storage plan will not be succeeding. So, we need to propose a system through which we can get the best output. From a website named 'Bangladesh Rice Research Institute' we can find that, if 5-7 cm irrigation can be applied in a field at one time, then the next irrigation will be provided after 3 days of disappearing the standing water in the field [13]. Soil saturation is mostly attained by providing irrigation with about 1 cm water depth a day. So, if we provide irrigation 5 cm water in two days back to back by 2.5 cm each day, it will be okay each day the soil will saturate 1 cm water. Suppose we provide 2.5 cm irrigation in a day. We need to supply 741 mm of water in one season. So in one irrigation, we will supply 25 mm water in field.

We know,

1 Acre= 100 decimals

1 decimal= 40.469 Square meters

1 hector=2.47 Acres=2.47*100 decimals=247 decimals=247*40.469 Square meters.

=9995.843 Square meters.

1mm of water per square meter means every square meter receives 1 liter of water. So, 25 mm of water per square meter receives 25 liters of water.

In one irrigation, we need to supply water in 1 hector = 9995.843*50 = 249896 Liters

In one irrigation a day, we need to supply 249896 liters and our pump can pick up 252918 liters. So, our calculation almost matches with the requirement.

Phases	% of total water in different phases	The amount of water we need in phase(In Liters)	Total number of irrigation(The amount of water we need in phase/ 248940 Liters) (Approximation)	Duration of Phase	The gap between after each two irrigation (Approximation)
1.Nursery and main field Preparation	25%	1851730	8	15 days	2 days
2. Planting to panicle initiation	40	2962768	12	25 days	2 days
3. Panicle formation to flowering	30	2222076	9	35 days	7 days
4. Flowering to maturity	5	370346	2	30 days	5 days

Table 5.7.3: Growth phases with irrigation steps

In the first phase (Nursery and main field preparation) of irrigation, we need to supply 1851730 liters and in one irrigation we will provide 252918 liters in a day. We need supply 8 days to fulfill the requirement. So, we will supply 2 days continuously and then rest of the two days we will store water in our storage for other purposes. In planting to panicle initiation, we will need to provide 2962768 liters and if we supply water 2 days and then store water in storage for two days then our required water will complete in this phase. Panicle formation to flowering needs total of 9 irrigation and days are total 35 days. We can supply water 2 days continuously and then take 7 days break. In these days, we will store water and can use for other purposes. Flowering to maturity will need only 2 irrigations and we can provide the irrigation 5 days gap.

Following figures represent the change in current and power as a function of applied voltage for different values of solar irradiation in November, using the optimal angle of 39.80°. The daily intensity data for the 15th day of November month is created these two graphs.

The whole water management process is represented by an algorithm and shown in flow chart-

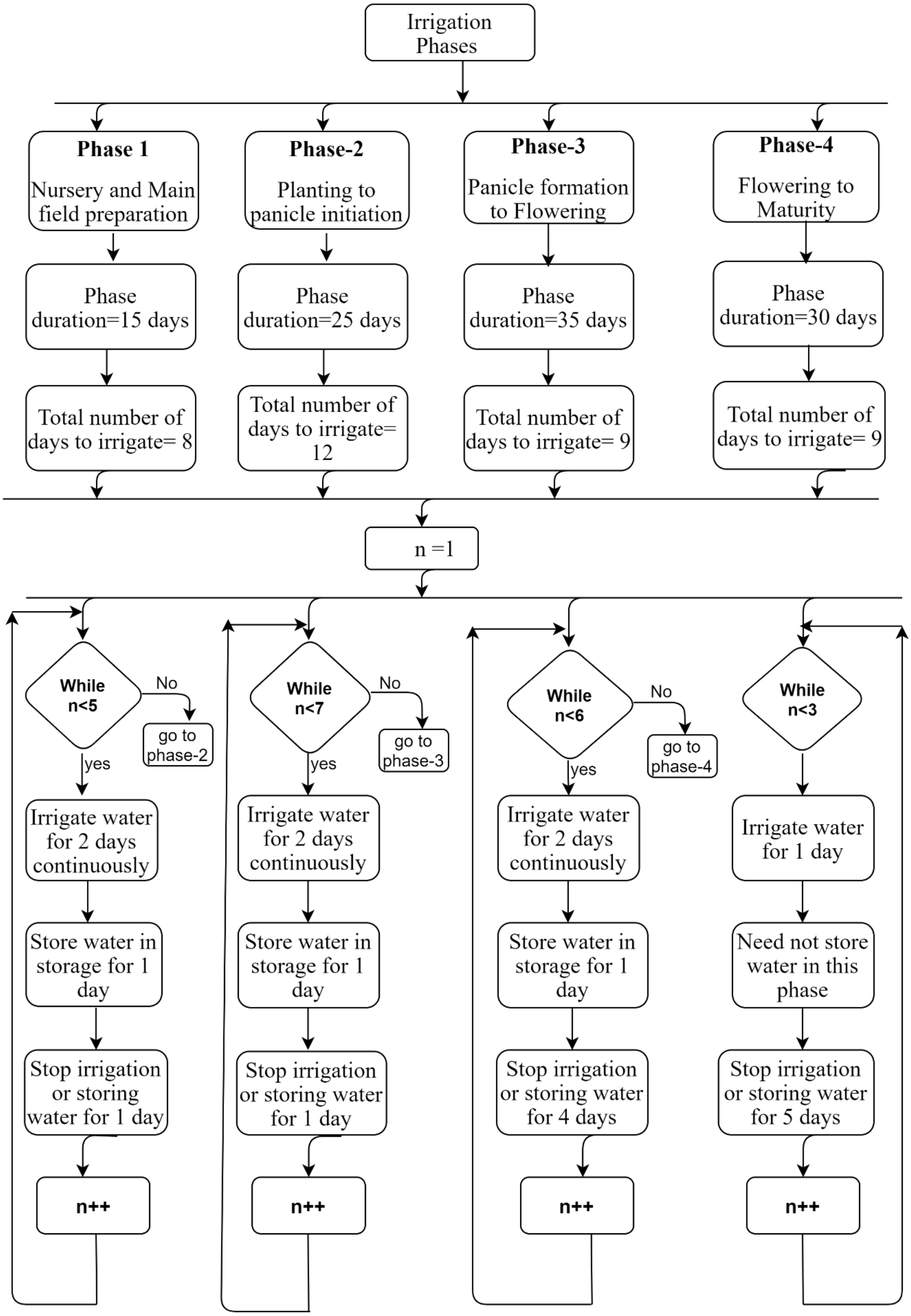

Figure 5.7.2: Flow Chart of Water Management System

From the flowchart it is clear that phase-1 will start and after phase 1 loop is complete then we will go to phase to and so on. If we go to phase-1 loop, inside the loop we will see, we will irrigate 2 days continuously, then store water in the storage for 1 day and then we stop irrigation or storing water for 1 day. This loop will continue 4 times and we can complete 8 irrigations and store water for 4 days in phase-1. In phase-2, again we irrigate 2 days continuously, then store water for 1 day and we stop irrigation or storing water for 1 day. This loop will continue 6 times and in 24 days we will irrigate 12 times that meets our requirement. In this phase, we can store water for 6 days. In phase-3, again we irrigate 2 days continuously, then store water for 1 day and we stop irrigation or storing water for 4 days. This loop will continue 5 times and in 35 days we can irrigate 10 times but we will irrigate only 9 times that meets our requirement. In this phase, we can store water for 5 days. In phase-4, we will store water for 1 day and take a break for 5 days and then we will irrigate again for 1 day. In this phase we will not store water. We need to store water for 15 days and in first 3 phases, we will store (4+6+5) = 15 days that fulfils our requirement.

5.8 Storage Area Calculation

If we select a pond which length is 45 meters, width is 45 meters and its depth is 2 meters, then the density will be

Density of the pond= 45*45*2= 4050 Cubic meters

Now, we know 1 cubic meter can store 1000 Liters of water.

1 Cubic meter = 1000 Liters

4050 Cubic meters= 4050*1000 Liters = 4050000 Liters

Our selected pond can store 4050000 Liters of water. We will store 3700000 liters, so we take a bigger pond than our requirement.

Our selected area for pond:

Length is 45 meters and Width is 45 meters. So the area of the pond will be

Area= 45*45 square meters = 2025 square meters

We know,

1 square meter = 10.764 Square foot

So, 2025 Square meters = 10.764*2025 = 21797.1 Square foot

Again,

435.6 square foot= 1 decimal

So, 21797.1 Square foot = (21797.1/ 435.6) decimals = 50.04 decimals= 0.50 Acre

So, we need almost 0.50 Acre of land for the pond and this type of pond are available nearby the irrigation land and we will use the pond as the storage for our pump water.

Chapter 6

Future Work & Conclusion

6.1 Conclusion

In this study, we have designed an optimized and cost effective solar powered water pumping system stand-alone photovoltaic (PV) system for irrigation in winter season when the rainfall is less and any other source of irrigation are not that much available. This work based on the cultivation period of transplanted Amon rice (November-January) because in the winter season the rivers are dried up and rainfall also very much less and the demand for underground water is much high. As in the remote areas where the electricity is not that much available, we tried to design a solar powered water pumping system that will be helpful to produce crops in dry season.

For this purpose, the water requirement is calculated and a proposed water management system based on agricultural research is established. For designing the system, we first determined an optimum tilt angle for panel that will be useful for keeping the panel size minimum which will supply the water we need in one irrigation. Then we calculated irradiance, found the water flow rate. Then we have chosen panel that will provide the solar power we need. The panel will be floating on our storage. Next we have chosen the submersible pump according to our flow rate. Finally, we designed a storage to collect half of the total water requirement to offset the limitations and use the water from the storage during the foggy period. For other crops and remote areas where electricity is not available, solar powered water pumping system can be designed too. Stored water can be used for other purpose and the gap between irrigation can be utilize for producing other crops in winter season.

6.2 Future Work

A solar-powered water pumping system is future-proof, and many refinements can be implemented in this system.

We can use our water storage for water storage purposes and energy storage purposes for producing electricity. The stored water can turn water turbine which will be implemented under the surface and generate electricity. These generated electricity can reduce the electrical energy and also can be provided to house or farm.

To achieve maximum output power from the solar panel, we can use four (4) quarter optimum tilt angles in a year. We can divide the phase into January to March, April to June, July to September, and October to December, and tilt angles are 35.30°, 6.40°, 11.00°, and 40.60°, respectively.

The multi-sector irrigation process can benefit the outlying farmer as it can save both space and energy where the cost remains the same. The IoT-based farming system can make the farmers' livelihood easy, and the profit can be inflated because automatic implementation of water can maximize the outcome of irrigation. The sensors used in IoT can detect the humidity, soil moisture, and fertility of the soil and initiate steps to make the best outcome from farming [14].

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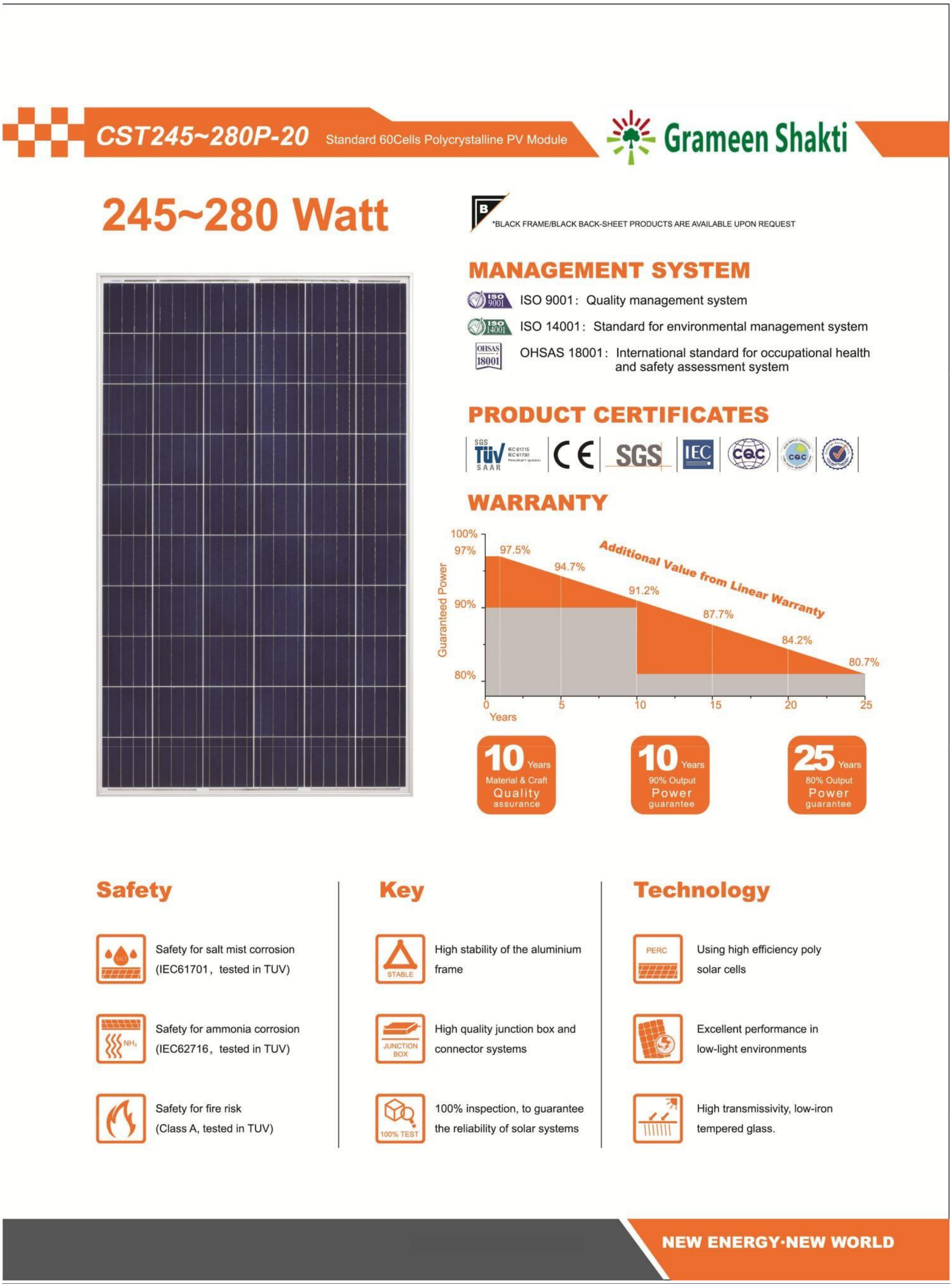
Appendix A.



CST245~280P-20
Standard 60Cells Polycrystalline PV Module
Grameen Shakti
245~280 Watt
*BLACK FRAME/BLACK BACK-SHEET PRODUCTS ARE AVAILABLE UPON REQUEST
MANAGEMENT SYSTEM
ISO 9001: Quality management system
ISO 14001: Standard for environmental management system
OHSAS 18001: International standard for occupational health and safety assessment system
PRODUCT CERTIFICATES
WARRANTY
100%
97%
90%
80%
Guaranteed Power
97.5%
94.7%
91.2%
87.7%
84.2%
80.7%
Additional Value from Linear Warranty
0
5
10
15
20
25
Years
10 Years Material & Craft Quality assurance
10 Years 90% Output Power guarantee
25 Years 80% Output Power guarantee
Safety
Safety for salt mist corrosion (IEC61701, tested in TUV)
Safety for ammonia corrosion (IEC62716, tested in TUV)
Safety for fire risk (Class A, tested in TUV)
Key
High stability of the aluminium frame
High quality junction box and connector systems
100% inspection, to guarantee the reliability of solar systems
Technology
Using high efficiency poly solar cells
Excellent performance in low-light environments
High transmissivity, low-iron tempered glass.
NEW ENERGY·NEW WORLD

CST245~280P-20 Standard 60Cells Polycrystalline PV Module

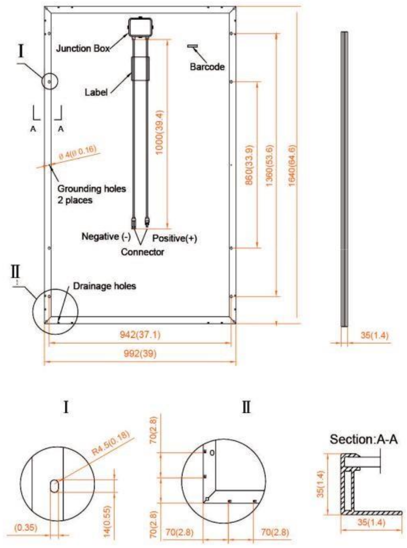
Electrical Characteristics（STC）

Module Type	CST245P-20	CST250P-20	CST255P-20	CST260P-20
Maximum Power- Pmax(W)	245	250	255	260
Open Circuit Voltage - Voc(V)	37.1	37.2	37.4	37.7
Short- Circuit Current - Isc(A)	8.70	8.82	8.94	9.09
Voltage at Pmax -Vmp(V)	30.4	30.6	30.8	30.9
Current at Pmax - Imp(A)	8.06	8.17	8.28	8.41
Module Efficiency -ηm（%）	15.06	15.37	15.67	15.98

Module Type	CST265P-20	CST270P-20	CST275P-20	CST280P-20
Maximum Power- Pmax(W)	265	270	275	280
Open Circuit Voltage - Voc(V)	37.9	38.1	38.3	38.5
Short- Circuit Current - Isc(A)	9.17	9.32	9.46	9.54
Voltage at Pmax -Vmp(V)	31.2	31.3	31.4	31.7
Current at Pmax - Imp(A)	8.49	8.63	8.76	8.83
Module Efficiency -ηm（%）	16.29	16.60	16.90	17.21

STC: Irradiance 1000W/m^2, Cell Temperature 25℃, Air Mass 1.5

Power Tolerance(W)	(0,+4.99)
Maximum System Voltage(V)	1000
Maximum Series Fuse Rating (A)	20



All Dimensions in mm(inch)

Temperature Characteristics

Pmax Temperature Coefficient	-0.40%/℃
Voc Temperature Coefficient	-0.32%/℃
Isc Temperature Coefficient	+0.05%/℃
Operating Temperature	-40～+85℃
Nominal Operating Cell Temperature(NOCT)	45±2℃

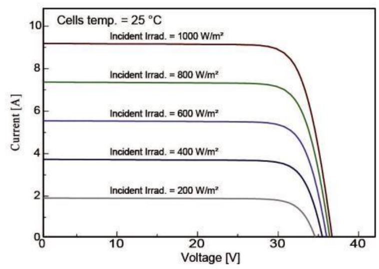
Mechanical Specifications

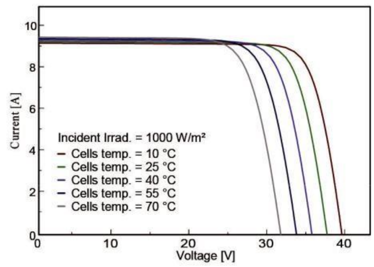
External Dimensions	1640×992×40mm	1640×992×35 mm
Weight	20 kg	19.5 kg
Solar Cells	Poly crystalline 156×156mm (60pcs)	Poly crystalline 156×156mm (60pcs)
Front Glass	3.2 mm tempered glass, low iron	3.2 mm tempered glass, low iron
Frame	Anodized aluminum alloy	Anodized aluminum alloy
Junction Box	IP67	IP67
Output Cables	4.0 mm^2,cable length:1000 mm	4.0 mm^2,cable length:1000 mm
Connector	MC4 Compatible	MC4 Compatible
Mechanical Load	5400 Pa	5400 Pa

Packing Configuration

	1640×992×40mm		1640×992×35mm	
Container	20'GP	40'GP	20'GP	40'GP
Pieces per Pallet	26	26	30	30
Pallets per Container	12	28	12	28
Pieces per Container	312	728	360	840

I-V Curve（CST265P-20）

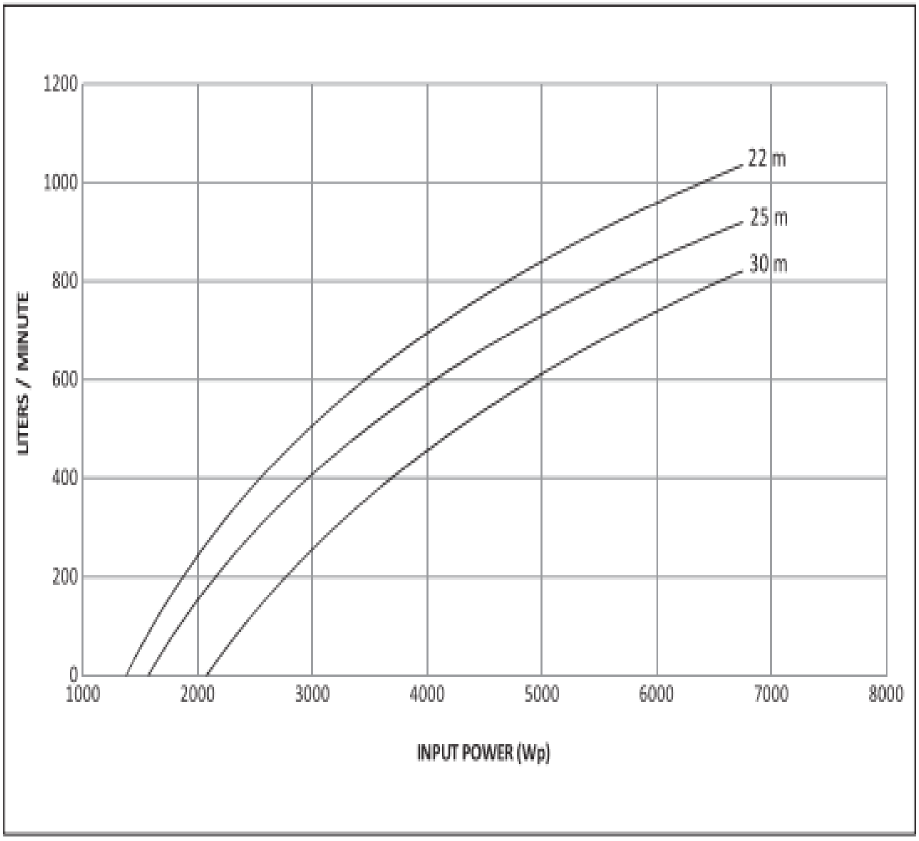




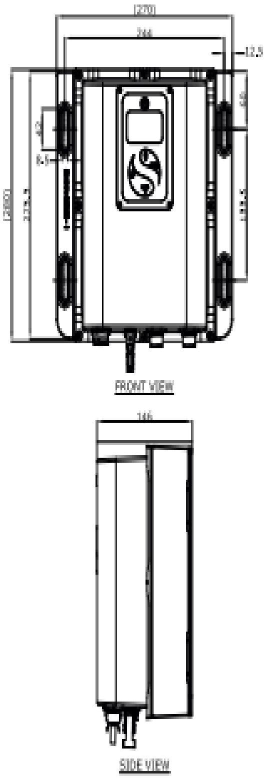
[redacted] NEW ENERGY·NEW WORLD

SOLAR 48 DCSMP 6750

PUMPSET CODE : 9500001392
DISCHARGE (LPD) : 297000
DISCHARGE (LPW) : 44
DUTY HEAD : 30 METER



SHAKTI SUD 3P,20A, 450 VDC, 7.5HP 9600000021



	INPUT POWER (Wp)						
	6750	5450	3350	2600	2200	1650	1500
HEAD (m)	FLOW IN LPM						
30	800	685	350	190	0		
25	900	780	500	368	200	0	
22	1010	900	600	447	300	150	0