Study of the present scenario of Solar Irrigation in Bangladesh and Design of a new Irrigation Model to make the Solar Irrigation system more Feasible

MS THESIS

Institute of Energy

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Thesis on

Study of the present scenario of Solar Irrigation in Bangladesh and Design of a new Irrigation Model to make the Solar Irrigation system more Feasible

A thesis is submitted to the Institute of Energy at the University of Dhaka in partial fulfillment of the requirements for the Degree of Masters of Science in Renewable Energy Technology

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Dedication

To

Teacher and the source of human knowledge of our

Prophet Muhammad (peace be upon him)

To

Like fatherhood Highest ... And my dear father

To

granule my heart first ... my mother compassionate

Declaration

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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____

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All praise and thanks to almighty Allah who is our creator, sustainer, nourisher, protector and curer. May His choicest of blessings and salutations be upon our beloved prophet Muhammad *sallā Allāhu ʿalayhi wa-sallam*, his family members, his companions, and all those who follow his path with utmost sincerity until the Day of Judgment.

We feel honored in expressing our heartfelt indebtedness and gratitude to our respected supervisor Dr. Md. Habibur Rahman. He guided us with his continuous encouragement, technical suggestions and valuable instructions throughout the study period.

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The Authors

Abstract

Bangladesh has a primarily agrarian economy. Irrigation plays a very important role in our agriculture as well as on our economy. During dry season, irrigation of the whole country faces an acute crisis due to load shedding of 1248 MW. As Bangladesh has good solar resources, with high availability during the peak irrigation season. Therefore, solar pumping of water for irrigation presents an innovative and environment-friendly solution for its largely agro-based economy. Infrastructure Development Company Ltd (IDCOL) is providing financial support to solar irrigation. Already 450 irrigation pumps are installed by IDCOL in different divisions of Bangladesh. In this paper, 450 project's data are analyzed and the findings are shown by different important graphs. Different division's radiation, water head and required water are mainly focused in the analysis which will be very supportive for upcoming irrigation projects. To accomplish the analysis on solar irrigation a practical field visit has been made at Poradaho, Kushtia.Thisis a project of Bright Green Energy Foundation (BGEF) and financed by IDCOL. After visiting the project and talking with the farmer, a comparison between solar pump and diesel pump is found which is very significant. In addition, the idea of mini-grid along with irrigation is originated considering the huge load shedding of that area. People of that area remain without electricity for approximately 6-8 hours in a day. For this mini-grid purpose, a small survey was also conducted on 50 houses of that rural area about their electricity demand during the time of load shedding. The mini-grid will be power by the extra energy coming from the irrigation panel. This is done simply by changing the run time of the motor in an efficient way. The run time of the motor varies with different seasons. HOMER software is used to calculate the cost analysis of the proposed model for irrigation along with ac min-grid. In this model, two welfares derive at a time. The first one is that rural farmer can get water for irrigation with a lower installment which is shown in the paper. The second one is the demand of electricity of rural people during load shedding can also be fulfilled from the ac mini-grid. Therefore, the overall cost will be minimized and the new irrigation system will be more feasible for rural farmers as well as for the owner also.

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Chapter 1

Introduction

Introduction

1.1 An overview of Irrigation in Bangladesh

In Bangladesh adaptation of irrigation techniques is reported to play a vital role in the improvement in the field of food grain. In this regard we need huge number of pumps in ruralareas of the country for irrigation in upcoming days. Present pumps are mostly diesel engineoperated where electricity from the national grid is not sufficient to maintain them properly.On the other hand, there is a great problem for grid connected irrigation pumps becausesupply of electricity in Bangladesh is not regular due to deficiency of electrical energy andelectricity has not served in every irrigational zones of Bangladesh. Both diesel and gridoperated pumps are generating huge amount of GHG which is very detrimental for theexistence of our environment. Conventional irrigation system is dependent on fossil fuel or hydro carbon which is limited in nature. This is right juncture to think the alternative,renewable, green energy like solar energy which is abundant in nature. Alternative to theconventional method, solar energy is very suitable sustainable option.

1.2 Literature Review

Growth in crop production in the country primarily depends on the irrigation development. Due to absence of adequate surface water in the dry season, irrigation is heavily dependent on ground water. With the increase in groundwater use few factors limit crop growth in irrigated area.

This are-

1. Expansion of irrigated area
2. Inefficient water distribution and
3. Inadequate supply limits crop growth in irrigated fields.

In Bangladesh, the cost of irrigation can be as high as 40% of a farmer’s total production costs, and lack of timely irrigation leads to a 37% average decrease inyields of rice. Conversely, efficient irrigation can increase both the productivity and profitability of crops.

To make a better irrigation system we need to improve efficiency to minimize irrigation water conveyance loss and to disseminate crop-specific water management knowledge. It is also important improving access to and promoting efficient, low-cost and smaller irrigation devices in the project areas. Moreover, most cases the conventional irrigation methods are to lift ground water and used to supply this water directly to the crop fields. Sometimes surface water is also used for irrigation. In both the cases, diesel and grid electric engines are used to power the pumps. As we know in Bangladesh adaptation of irrigation techniques is reported to play a vital role in the improvement in the yield of food grain. It is worthwhile to note that the demand of diesel for irrigation has caused a miss - match in the demand for petroleum products. Bangladesh has small proven oil reserves, and thus imports much of its oil products. The average annual consumption of high speed diesel oil is 285,510 metric tons [1]. which cost is 1256 crore, which is 7% of total imported oil. Again most of which is used for operating irrigation equipment. The total subsidy for diesel for 2012 is estimated to be BDT 116.9 billion BDT (US$1.4 billion), which is the highest amongst the petroleum subsidies [2].The price of diesel is increasing day by day due to increasing the oil price in international market which impacts Bangladesh's agriculture. If the oil crisis in Bangladesh becomes more severe, sufficient food cannot be produced and many people will starve due to want of food. In Bangladesh, there are 68,000 villages and each village has at least 10 irrigation farms. It is roughly estimated that the number of diesel engines in Bangladesh is more than 700,000 which are used for irrigation and consumes a lot of diesel fuel. So both the government and the farmers have to pay a huge amount of money for operating irrigation equipment which impacts our economy. On the other hand, there is a great problem for grid connected irrigation pumps. Electricity is a scarce service in Bangladesh. Natural gas, diesel oil, furnace oil, coal and hydro are the major types of fuel that are used in electricity generation in Bangladesh. Average annual consumption of furnace oil, which is mainly used as fuel for electricity generation, is 34,443 metric ton[1]. For a sustained development electricity production should be double than its annual GDP.

For Bangladesh as this thumb rule was not followed so growth faced a real obstacle due to lack of power generation in every year. Supply of electricity in Bangladesh is not regular due to deficiency of electrical energy. Supply of electricity to grid connected irrigation pumps remain uncertain due to demand-supply gap. During dry season's Irrigation the whole country faces an acute crisis due to load shedding of 1248 MW. Due to declined fuel availability, their predicted gradual extinction in the next few decades and the resultant price volatility due to demand-supply gap, the attention must be centered towards renewable, readily available and non-polluting method like solar energy which is abundant in Bangladesh due to its geographical location.

1.3 Rationale of the Study

Bangladesh has a primarily agrarian economy. Agriculture is the single largest producing sector of the economy since it comprises about 18.6% (data released on November, 2010) of the country's GDP and employs around 45% of the total labor force [3]. It holds lots of agricultural land and the amount of total cultivable land is 8.52 million hectares. About 37.266% million metric ton crops and other vegetables are cultivated in various seasons in this land. About 70% people lives in rural areas and they are directly linked with irrigation [4].Bangladesh's energy infrastructure is quite small, insufficient and poorly managed. The per capita energy consumption in Bangladesh is one of the lowest (321 kWh) in the world. Bangladesh's installed electric generation capacity (public, private and import) was 11203 MW in May, 2015 [5]; a maximum output delivered was 7712 MW[5], only three-fourth of which is considered to be available. Only 62% of the population has access to electricity with a per capita availability of 321 kWh per annum. The electricity generation rate is shown in Figure 1.1. The government's vision of electrifying the entire country by 2020 through grid expansion is not realistic due to inaccessibility and low consumer density in many rural areas, as well as financial constraints. To reach the government's vision of universal electrification, renewable energy sources, in particular solar energy will have to play a vital role for off-grid electrification.

Within the reach of the national grid Bangladesh is still reeling under 600-1200 MW of 'load shedding'. A situation which deteriorates during irrigation seasons, when the demand-supply gap reaches up to 1500 MW. Domestic and industrial sectors consume about 43% and 44% electrical energy respectively, i.e. a total of about 87% of power consumption occurs in these two sectors. Out of this, a large part of electrical energy is consumed for lighting. All power sector experts acknowledge that the maximum power gap occurs primarily during the evening. A way to manage the evening load is the introduction of energy efficient lights/lighting systems. A summary of energy access based on presence of expenditure for electricity is shown in Table 1.

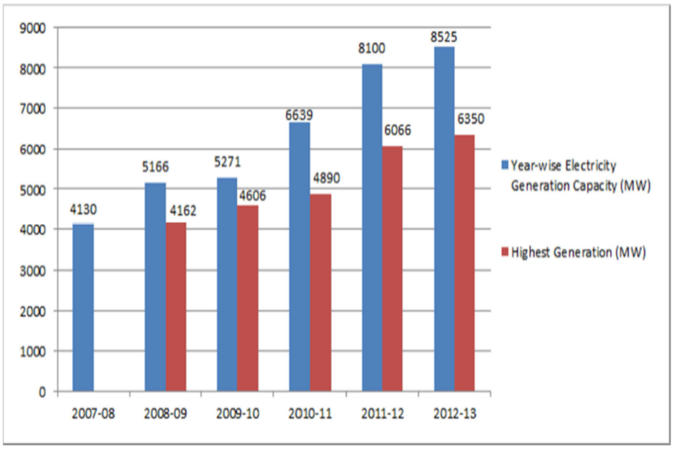

Figure 1.1:Year wise electricity generation capacity and Highest Generation

Table 1. Energy access based on presence of expenditures for electricity (HIES* 2010).

	Total	Rural	Urban
National	55.26%	42.49%	90.1%
Barisal	40.12%	31.62%	82.33%
Chittagong	60.34%	48.84%	92.31%
Dhaka	67.34%	47.36%	96.15%
Khulna	54.13%	45.55%	83.83%
Rajshahi	51.88%	46.94%	75.53%
Rangpur	30.07%	24.44%	68.68%
Sylhet	47.22%	39.09%	88.94%

Table 1:Energy access based on presence of expendituresfor electricity

Irrigation is the lifeline of agriculture in Bangladesh. Irrigation plays a vital role in this country for half of the year when water scarcity seriously handicaps farming operation. Farmer, now a days, cultivate irrigation based different high value crops throughout the year. In advanced farming, irrigation is no limited to one season only. At present irrigation system is operated by conventional power system and diesel run irrigation pump. As the country is facing acute power crisis a diesel running irrigation cost is high. There is a good prospect for solar powered irrigation system in Bangladesh. Existing state owned and private conventional power plants generate only 4000 to 5000 MW of electricity a day, whereas the country's total demand is about 6000 to 7000 MW. The demand is growing by 500 MW a year due to increasing industrialization, other developments and demands.

During Boro season 120 million acre rice field in Bangladesh is irrigated 1.33 million different types of water pumps among which 87% are diesel operated which require 800 million liter diesel per year. It is estimated that solar irrigation system can save 760 MW of electricity power and 800 million liter of diesel every year. Solar irrigation system can save all these power to use in other development purpose for the government of Bangladesh. This project will be implemented with the help of Infrastructure Development Company Ltd. (IDCOL) [8]. Irrigation is the lifeline of agriculture in Bangladesh. Irrigation plays a vital role in this country for half of the year when water scarcity seriously handicaps farming operation. Farmer, now a days, cultivate irrigation based different high value crops throughout the year. In advanced farming, irrigation is no limited to one season only. At present irrigation system is operated by conventional power system and diesel run irrigation pump. As the country is facing acute power crisis a diesel running irrigation cost is high. There is a good prospect for solar powered irrigation system in Bangladesh. Existing state owned and private conventional power plants generate only 4000 to 5000 MW of electricity a day, whereas the country's total demand is about 6000 to 7000 MW. The demand is growing by 500 MW a year due to increasing industrialization, other developments and demands. During Boro season 120 million acre rice field in Bangladesh is irrigated 1.33 million different types of water pumps among which 87% are diesel operated which require 800 million liter diesel per year. It is estimated that solar irrigation system can save 760 MW of electricity power and 800 million liter of diesel every year. Solar irrigation system can save all these power to use in other development purpose for the government of Bangladesh.

This project will be implemented with the help of Infrastructure Development Company Ltd. (IDCOL) [8]. Solar photovoltaic (PV) systems are in use throughout the country with over 2.9 million household-level installations having a capacity of 122.2 MW (April 2014). Scaling-up of solar PV systems assisted by the development partners are being implemented through Infrastructure Development Company Limited (IDCOL), Rural Electrification Board (REB), Local Government Engineering Department (LGED), Bangladesh Power Development Board (BPDB), NGOs and Private Organizations implementing solar energy program. There is a strong potential for solar energy within the country. Dissemination of solar home systems (SHSs) is being promoted mainly by IDCOL, private sector companies and NGOs based on the direct-sale approach and provision of refinancing funds for micro-financing of SHSs to participating organizations (mostly NGOs) through IDCOL. Bangladesh is situated between 20.30°-26.38° north latitude and 88.04°-92.44° east longitude [6] which is an ideal location for solar energy utilization. Daily average solar radiation varies between 4 to 6.5 kWh per square meter. Bangladesh has 15 MW solar energy capacities through rural households and the annual solar radiation availability in Bangladesh is as high as 1700 kWh/m2 [7]. Maximum amount of radiation is available on the month of April-May and minimum on December-January. Different R&D Organizations, Institutes and Universities are collecting solar insolation at different parts of Bangladesh.

1.4 Objective

The irrigation system is defined as a system that distributes water to targeted area. Basically, it is meant for agriculture purposes. The efficiency of the irrigation is based on the system used. Since antiquity, the human life is based on agriculture and the irrigation system is one of the tools that boost agriculture. There are many other types of irrigation system all over the world but these irrigations are encountering many problems. In fact, there are few modern systems but they mostly fail in one way to another. The automation plays an important role in the world economy; therefore, engineers struggle to come out with combined automatic devices in order to create complex systems that help human in its activities so that the system automatically processes itself without any human intervention. So we would like to develop an automatic irrigation system.

Basically, the paper consists of electrical part and mechanical part. The electrical part consists of photovoltaic, which is meant to generate power and the power is stored in the rechargeable battery. The mechanical part consists of pump to pump out the water from the water source.Water is recognized as a source of human life, as well as plants and animals. Therefore, the water needs to be managed properly without any waste. The proper management of any liquid is very significant, especially in our case of water management of the irrigation system.

1.5 Thesis Outline

This thesis contains six chapters as follows.

Chapter 1 explains the introduction that includes the background behind this work. It also outlines the objectives and describes the literature review from recent issues and gives a brief review about the past projects.

Chapter 2 describes the theoretical concept that are related in this work.

Chapter 3 provides a description and discussion on the Prospect of Solar Irrigation in Bangladesh.

Chapter 4 presents the practical results from the performance study of a Solar Water Pumping system.

Chapter 5 presents a proposed design of feasibility analysis using Homer Softwareand the work methodology in the proposed system.

Chapter 6 summarizes the overall conclusion for this thesis and a few future recommendations.

Chapter 2

Major Components of Solar Water pumping and AC Mini-grid System

Major Components of Solar Water pumping and AC Mini-grid System

Major Components of Solar Water pumping:

2.1 Pump and Motor Technology:

2.1.1 Ratings of a Pump:

The rating of a pump is given in terms of water discharge rate (Gallon per minute GPM, liter/s or cusec (cubic foot per second). 1 cusec = 28.32 liter/s) and the head. The capacity of the driving motor is given in Horse Power (HP) or in Watt.

2.1.2 Basic Pump Operating Characteristics

"Head" is a term commonly used with pumps. Head refers to the height of a vertical column of water. Pressure and head are interchangeable concepts in irrigation, because a column of water 2.31 feet high is equivalent to 1 pound per square inch (PSI) of pressure.

2.1.3 Total Dynamic Head

The total dynamic head of a pump is the sum of 1) the total static head, 2) the pressure head, 3) the total friction head, and 4) the velocity head. An explanation of these terms is given below and graphically.

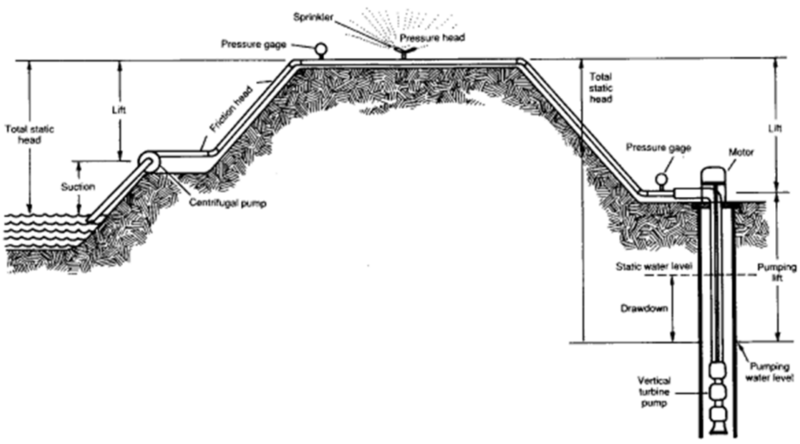

Figure 2.1:Total Dynamic Head(TDH)

Total Static Head

The total static head is the total vertical distance the pump must lift the water. When pumping from a well, it would be the distance from the pumping water level in the well to the ground surface plus the vertical distance the water is lifted from the ground surface to the discharge point.

Pressure Head

Sprinkler and drip irrigation systems require pressure to operate. Center pivot systems require a certain pressure at the pivot point to distribute the water properly. The pressure head can be converted from pounds per square inch (PSI) to feet of head by multiplying by 2.31.

Friction Head

Friction head is the energy loss or pressure decrease due to friction when water flows through pipe networks. Loss of head due to friction occurs when water flows through straight pipe sections, fittings, valves, around corners, and where pipes increase or decrease in size. Values for these losses can be calculated or obtained from friction loss tables.

Velocity Head

Velocity head is the energy of the water due to its velocity. This is a very small amount of energy and is usually negligible when computing losses in an irrigation system.

Suction Head

A pump operating above a water surface is working with a suction head. The suction head includes not only the vertical suction lift, but also the friction losses through the pipe, elbows, foot valves and other fittings on the suction side of the pump. There is an allowable limit to the suction head on a pump and the **net positive suction head (NPSH)** of a pump sets that limit.

2.2 The most common commercially available configurations of motor–pump subsystems

2.2.1 Submerged motor–pump unit

This is often called a submersible centrifugal motor–pump. This type is probably the most common type of solar pump used for village water supply.The advantages of this configuration are that it is easy to install, can lift water at various power level. Either AC or DC motors can be incorporated into the pumpset although an inverter would be needed for ac systems. If a brushed DC motor is used then the equipment will need to be pulled up from the well (approximately every 2 years) to replace brushes. If brushless DC motors are incorporated then electronic commutation will be required. The most commonly employed system consists of an AC pump and inverter with a photovoltaic array of less than 1500Wp. The following figure shows such a motor-pump system

Submersed motor pump unit

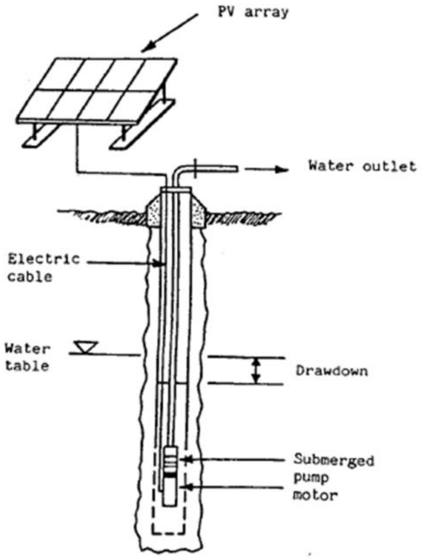

Figure 2.2:A Submersible Pump System

2.2.2 Submerged centrifugal pump with surface mounted motor

Although this type of system is advantageous for maintenanceof the motor, the power losses in the shaft bearings and its high cost make it unattractive. It gives easy access to the motor for brush changing and other maintenance. The following figure shows a system of this category.

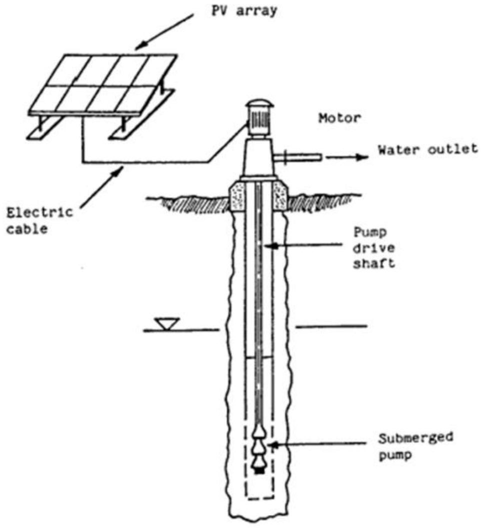

Figure 2.3:Submerged Centrifugal Pump with Surface mounted Motor

2.2.3 Floating motor–pump

This type of pumping unit is recommended for pumping surface water for irrigation and drainage. It is portable and the chance of dry running is minimal. Most of these types use a single stage submersed centrifugal pump. The most common type utilizes a brushless DC motor.

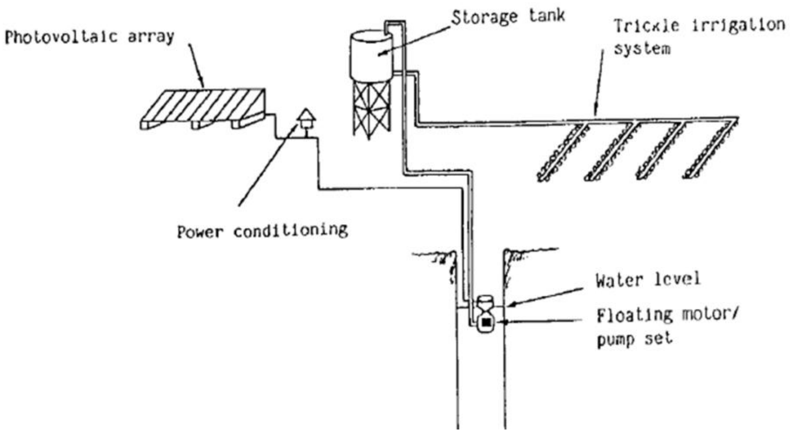

Figure 2.4: Floating Motor-Pump for Ground water

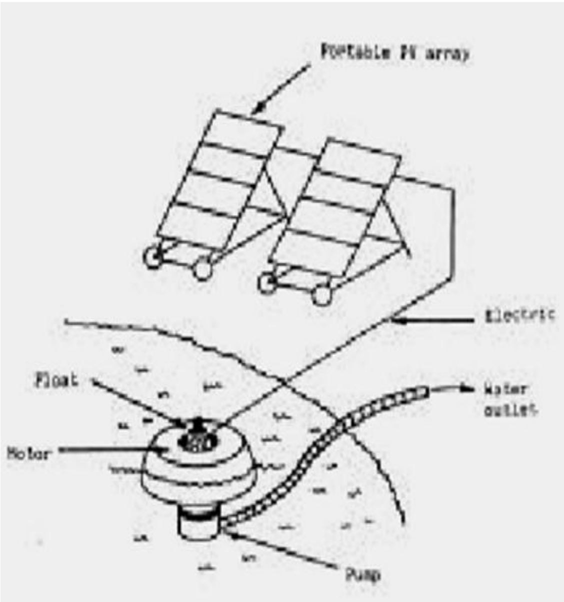

Figure 2.5: Floating Motor-Pump for Surface Water

2.2.4 Positive displacement pump (volumetric pump)

This type of pump is driven by a shaft from a surface-mounted motor, and is suitable for high head and low flow rate applications. The output is proportional to the speed of the pump. At high heads the frictional forces are low compared to the hydrostatic forces often making positive displacement pumps more efficient than centrifugal pumps for this situation.

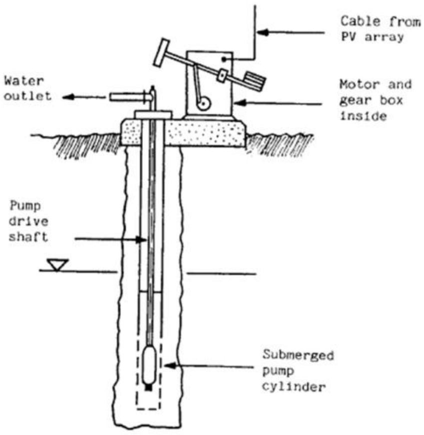

Figure 2.6:Positive Displacement Pump

2.2.5 Surface mounted motor–pump unit

This type of unit has a self-priming mechanism and is recommended for low head duties. The suction head should be as long as 6 meters. The pump may be centrifugal or positive displacement. Brushless DC motors are the most attractive for smaller pumping applications and AC motors are more attractive for larger installations. Although the use of primary chambers and non-return valves can prevent loss of prime, in practice self-start and priming problems are experienced. It is impractical to have suction heads of more than 8 meters.

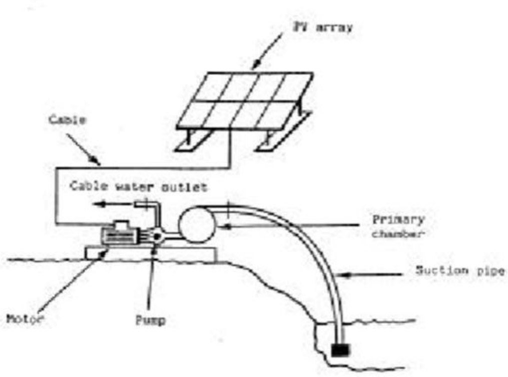

Figure 2.7: Surface mounted motor-pump unit

2.3 Classification of Pumps

2.3.1 Volumetric (positive displacement)

These pumps operate by mechanically advancing a sealed quantity of water by using several mechanisms such as pistons, cylinders, and elastic diaphragms. The flow rate of a positive displacement pump is directly proportional to the motor speed and power input. At low power input a positive displacement pump will raise a quantity of water to the same vertical lift as high power input, except at slower rate. Because of this, positive displacement pumps have a high starting torque as they must always work against the full system pressure even at low speeds.

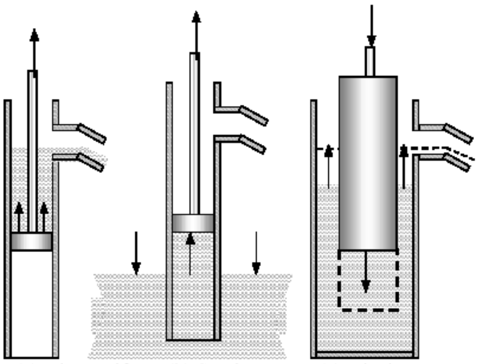

Figure 2.8: Positive Displacement Pump

Diaphragm pumps

Diaphragm pumps are sometimes called submersible positive displacement pumps and are often used for small applications, such as pumping small quantities of water from deeper wells or water tanks where surface pumps are limited by their suction head. Diaphragm pumps generally use DC motors. They require periodic maintenance depending on the depth of head pumped and their operational hours. The brushes of the DC motor must be changed every 2,000–4,000 hours and the elastic diaphragm must be replaced every 12 to 24 months depending on the hours of use.

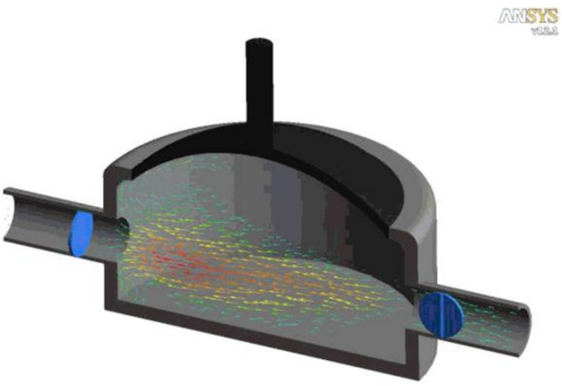

Figure 2.9: Diaphragm Pump

Jack pump

Jack pumps function much like windmills except that they are powered by electric motors. Like the windmill, the reciprocating jack is connected by a long sucker rod to a cylinder. Jack pumps require regular maintenance, especially because the leathers on the plunger at the end of the long sucker rod can wear out easily and must be replaced every 6 to 24 months depending on the hours of use. Jack pumps are generally used for medium applications at medium depth.

Figure 2.10: Jack Pump

Piston pumps

Piston pumps are generally connected to a surface-mounted motor and used to pump water from shallow wells, surface water sources, and pressurized storage tanks, orthrough long pipes. The suction head is limited to 6 meters. They are not tolerant to silt, sand, or abrasive particles because the piston seals are easily damaged. Filters may be used to remove the dirt.

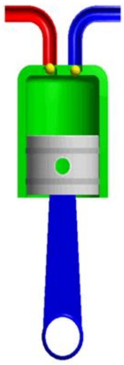

Figure 2.11:Piston Pump

Rotary vane pumps

Rotary vane pumps (sometimes called helical rotor pumps) operate according to a displacement principle for lifting or moving water by using a rotating form of dispenser. They contain spinning rotors with vanes that seal against the casing walls. Such pumps are mostly surface-mounted because of suction head limitations. The suction head is limited to 6 meters. Rotary vane pumps are not tolerant to silt, sand, or abrasive particles, so filters may be used to remove dirt. The unique advantage of helical rotor pumps over centrifugal pumps is their ability to operate efficiently over a wide speed ranges and heads, whereas the efficiency of centrifugal pumps deteriorates from the rated speed.

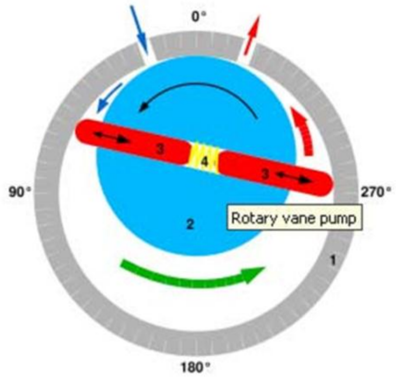

Figure 2.12: Rotary vane pump

2.3.2 Centrifugal (rotodynamic) pumps

These pumps are designed for a fixed head, meaning their efficiency decreases when the pumping head deviates from the design point. Unlike volumetric pumps, a significant decrease in a rotodynamic pump's power supply can cause it to fail at delivering water from the borehole because its vertical lifting capability is directly proportional to the power input. Generally, positive displacement pumps are best for low flows (less than 15 m^3/d) and high pumping heads (30–150 meters). Submersible centrifugal pumps are best for high flow rates (25–100 m^3/d) and medium heads (10–30 meters).

Axial flow pump

Axial flow pumps are sometimes called ***propeller pumps***because the mechanism is similar to a propeller in a pipe. Because such impellers are designed for high flow and low head applications, they are most suitable for irrigation purposes. Generally, axial flow pumps are designed at 2.5–25.0 m^3/min discharge and 1.5–3.0 meters head for vertically mounted applications.

Figure 2.13: Axial Flow pump

Radial flow pump

Radial flow pumps are often called centrifugal pumps. Centrifugal pumps, which are available with either AC or DC motors, can be surface-mounted, floated, or submersible. Such pumps can lift medium to large volumes of water (to about 200 m^3/d) from shallow to deep wells (to 150–200 meters). Series of impellers are used for surface mounted and submersible centrifugal pumps to create a large pressure differential to attain the required pumping head.

Mixed flow pump

Mixed flow pumps are sometimes called *vertical turbine pumps*. These pumps have internal blades in the impeller that partially propel the water, similar to the axial flow impeller. Vertical turbine pumps generally consist of submerged stacked impellers powered by a long drive shaft from a surface-mounted motor.

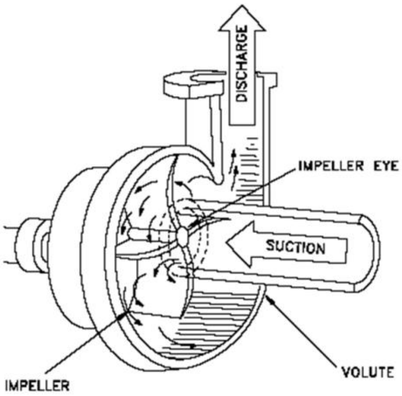

Figure 2.14:Mixed Flow Pump

Major Components of AC Mini Grid

AC mini grid is comprises of many major components which are the essential parts for a complete grid system.

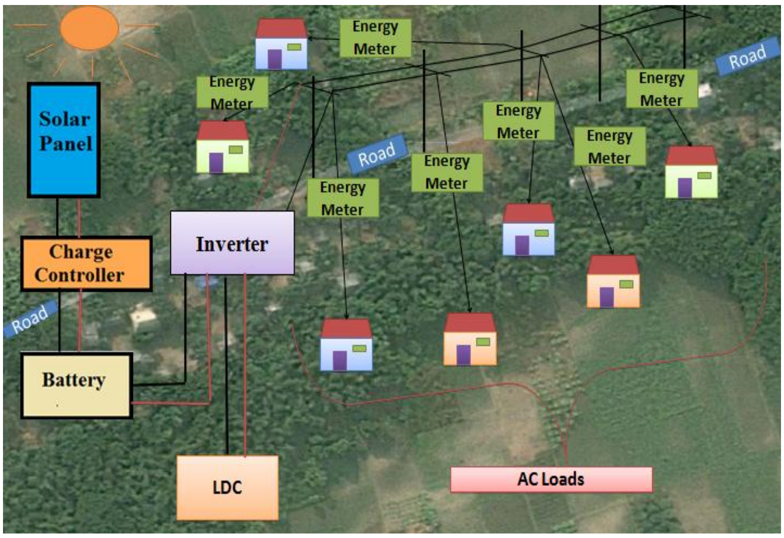

Figure 2.15:Major Components of AC Mini grid

2.4Solar PV

2.4.1 Ideal solar cell

In a solar cell, a p-n junction is fabricated in a thin layer of semiconductors. Due to the solar radiation, the photon of the light which have the energy greater than the band gap(which is an energy range in a solid where no electron states can exists) will produce a photo current or electricity and also some of the photon are absorbed by the p-n junction. This photo current is the output of a ideal solar cell [11].

Equivalent circuit of an ideal solar cell

Ideal equivalent circuit of a solar cell consists of a current source and a single diode which is parallel with the source [11].

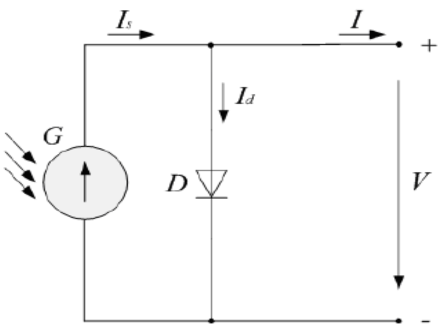

Figure 2.16: Ideal equivalent circuit of a Solar cell

In the figure 2.16, G is the solar radiance, Isis the photo generated current, I_d is the diode current, I is the output current and V is the terminal voltage.

Characteristics Equation

For, the output current

$$I = I_s - Io(e^{\frac{qV}{nkT}} - 1)$$

Where, *Io* is the diode reverse bias saturation current, *q* is the electron charge, *m* is the diode ideality factor, *k* is the Boltzman's constant and *T* is the cell temperature [11].

Short circuit current, $I_{sc} = I = I_s$ or $V = 0$

Open circuit voltage, $V = Voc = \frac{nkT}{q} \ln\left(1 + \frac{Isc}{Io}\right)$ for I = 0

The output power, $P = V[Isc - Io(e^{\frac{qV}{nkT}} - 1)]$

Equivalent circuit of a Practical solar cell

An ideal solar cell may be modeled by a current source in parallel with a diode; in practice no solar cell is ideal, so a shunt resistance and a series resistance component are added to the model[11]. The resulting equivalent circuit of a solar cell including a series and a shunt resistance is given below.

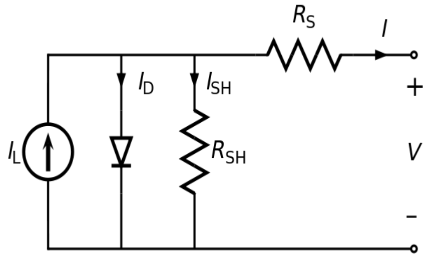

Figure 2.17:Equivalent circuit of a practical solar cell

Characteristic equation

From the equivalent circuit it is evident that the current produced by the solar cell is equal to that produced by the current source, minus that which flows through the diode, minus that which flows through the shunt resistor[11].

$$I=I_L-I_D-I_{SH}$$

Where, I is output current ,I_L is photo generated current, I_D is diode current, I_{SH} is shunt current.

The current through these elements is governed by the voltage across them,

$$Vj = V + IRs$$

Where, Vj = voltage across both diode and resistor RSH
V = voltage across the output terminals (volt)
I = output current (ampere)

R_S = series resistance

By the Shockley diode equation the current diverted through the diode is:

$$I_D = I_0 \left\{ \exp\left[\frac{qV_j}{nkT}\right] - 1 \right\}$$

Where,

Io = reverse saturation current (ampere)
n = diode ideality factor (1 for an ideal diode)
q = elementary charge
k = Boltzmann's constant
T = absolute temperature

Short circuit current, $I_{SC} \approx I_L$

Open circuit voltage, $Voc = \frac{kT}{q}\ln(\frac{Isc}{Io} + 1)$

2.4.2I-V Curve of a Solar Cell

This curve shows the I-V characteristics of a solar cell.

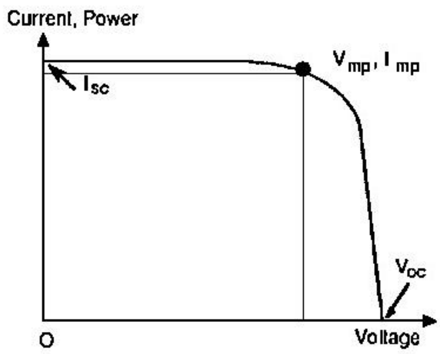

Figure 2.18: I-V characteristic of solar cell

Here, Voc shows the open circuit voltage of a solar cell and Isc shows the short circuit current of an ideal solar cell.

Here, Isc = short circuit current
Voc = open circuit *voltage*
Vmp = voltage at max power
Imp = current at max power

2.4.3 Series and Parallel connection of Solar Cell

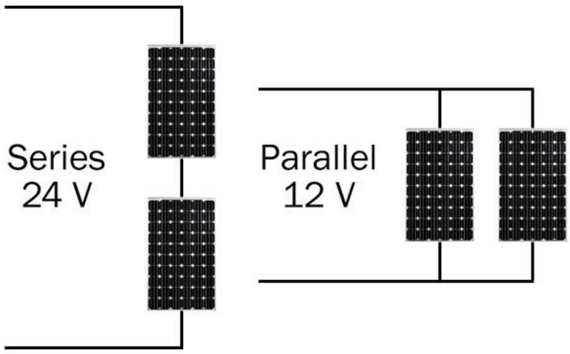

Figure 2.19: Series and Parallel connection of Solar Cell [12]

We can connect panels both in series and parallel. When we connect panels in series, output voltage will increase and when we connect panels in parallel output current will increase. Therefore, we can connect panels parallel and series according to our requirement of output power.

2.5 Battery

In case of solar system batteries provide electrical storage as a backup power for the loads that are ran by solar panel. For example, in a battery based solar system, the energy produced daily by the solar panels is stored in the batteries bank, which is then used by loads at night or on cloudy days.

Batteries are used in standalone PV systems to buffer the energy between the varying supplies from the PV array to a varying load demand. Through cost and performance consideration as balances made between the average generating capacities of the PV, the battery storage capacity and the load demand [9].

Figure 2.20: Batteries

2.5.1 Two types of battery used in PV systems

The lead-acid and the nickel-cadmium are the two types of batteries used in PV system each with advantages and disadvantages.

Lead-Acid Battery

The lead-acid battery is the principle battery technology for PV systems due to its relative cheap price and wide availability. It does require maintenance and has a finite life depending on construction. The depth of discharge for lead acid batteries should under no circumstances exceed 80V and the battery should not be left in this condition for long. When fully discharged, a lead-acid cell will have a terminal voltage of l.9V giving a discharged 12V battery voltage of 11.4V. When in the fully charged condition the lead-acid cell terminal voltage will be 2.4V and a fully charged 12V battery will have a voltage 14.4V. Lead-acid battery capacity is reduced by 0.6% per ^{0}C below 25^{0}C. When not in use lead-acid batteries slowly discharge, typically losing 2% of nominal capacity per month, increasing with Temperature [9].

Nickel Cadmium Battery

The Nickel cadmium cell consists of a positive plate of nickel packed with nickel hydroxide and a negative plate of cadmium immersed in a solution of potassium hydroxide in water. These batteries don't have problems of electrolyte depletion and stratification and often have a dry electrolyte. A completely discharged cell will have a terminal voltage of 1.1 V and can be left in this state for long periods without damage. A completely charged cell will have a terminal voltage of 1.5V. Loss of capacity is typically 0.25% of rated capacity per ^{0}C below 25^{0}C. Due to their cost (about five times that of lead acid batteries) NiCd batteries remain only used in small PV applications such as consumer goods [9].

2.6Charge Controller

Most stand-alone solar power systems will need a charge controller. The purpose of this is to ensure that the battery is never overcharged, by diverting power away from it once it is fully charged. Only if a very small solar panel such as a battery saver is used to charge a large battery is it possible to do without a controller. Most charge controllers also incorporate a low-voltage disconnect function, which prevents the battery from being damaged by being completely discharged [13].

Figure 2.21:Charge controller with Solar panels,battery and loads [14]

2.6.1Features of a Charge controller

- Low voltage Disconnect(LVD)
- High voltage Disconnect(HVD)
- Specific gravity status
- Low level electrodes

2.7 Inverter

The solar inverter is a critical component in a solar energy system. It performs the conversion of the variable DC output of the Photovoltaic (PV) module(s) into a clean sinusoidal 50- or 60 Hz AC current that is then applied directly to the commercial electrical grid or to a local, off-grid electrical network[16].

Figure 2.22:Inverter [15]

2.7.1 Two basic types of inverter

- Stand alone
- Grid connected.

Each has different operating and performance characteristics. The basic objective of the stand alone inverter is to supply a variable AC load from a DC battery and the basic objective of the grid connected inverter is to feed the variable PV DC supply to the AC grid[9].

Stand Alone inverter

Many types and sizes of standalone inverters are available. Any continuous power rating from 150W to 40KW is available with short term over-load capability of up to four times the continuous rating. The simplest, most robust and also the least expensive DC to 5OHz AC inverter is the square wave version. A 50Hz oscillator is used with a transistor to switch the battery voltage on and off through a transformer to give a square wave. The square wave is a very crude approximation to a sine wave with the result that substantial harmonic distortion is produced, wasting energy. Most loads cannot tolerate harmonic currents without over-heating and efficiency reduction, although the effects of this can be reduced through the use of a filter. If another switch is introduced to give three voltage levels instead of just two then the harmonic distortion is reduced, this is the modified sine wave inverter. With more switches the multistep sine inverter can produce a pure sine wave through the use of a small filter at high efficiency but also higher cost. An alternative configuration to achieve low distortion and high efficiency is the high frequency PWM inverter which uses fewer switches and so is cheaper than the multi-step inverter[9].

Grid Connected Inverter

Inverters for grid connection have traditionally been in the power rating 10KW-1MW and have been line commutated using thyristors. In the event of grid failure the inverter ceases to function through failure of the switching devices. Thyristor based inverters are reliable and cost effective above 10KW but produce significant harmonic distortion. Modern grid connected inverters incorporate a PV MPP (Maximum power point) tracking high frequency DC-DC step-up converter and a DC to AC switching circuit. The AC output is connected to the grid through an isolation transformer. A supervisory and control circuit tracks the PV MPP and monitors the inverter for safe operation[9].

2.8Transmission line

A transmission line is a material medium or structure that forms a path for directing the transmission of energy from one place to another, such as electromagnetic waves or acoustic waves, as well as electric power transmission[19]. At the substation, the high voltage electricity is converted to lower voltages suitable for consumer use and then transmitted to end users through relatively low-voltage electric distribution lines.

2.8.1 Transmission Line Components

A variety of components are required to successfully deliver electricity from generating stations to local residential and commercial areas. The primary components include the transmission structures, conductors, insulators, and ground wires.

2.8.1.1 Transmission Structures

Transmission Towers

Transmission structures are one of the most visible elements of the electric transmission system. They support the conductors used to transport electric power from generation sources to customer load. Transmission lines carry electricity over long distances at high voltages, typically between 115 kV and 765 kV (115,000 volts and 765,000 volts) [17].

Two Types of Tower

The two different types of tower are mentioned below:

- Lattice Steel Towers (LST).
- Tubular Steel Poles (TSP)

- **Lattice Steel Towers (LST)**

This type of tower consists of a steel framework of many structural components that are bolted or welded together [17].

- **Tubular Steel Poles (TSP)**

This type of tower are hollow steel poles fabricated either as one piece or as several pieces fitted together [17].

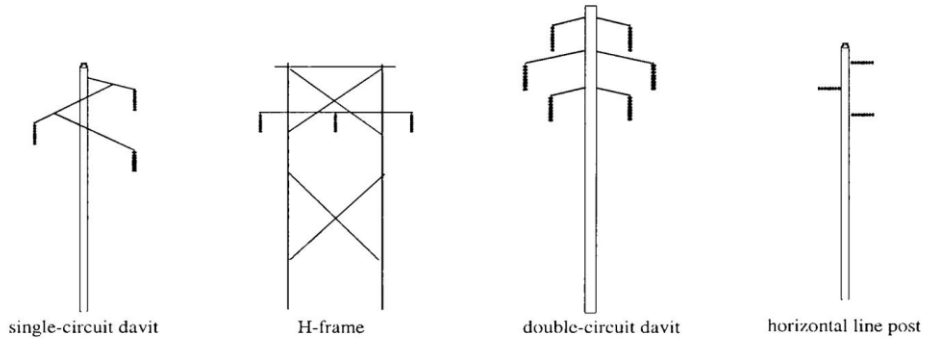

Figure 2.23: Different tower structures

2.8.1.2 Conductors (wires)

A conductor is a material which permits a flow of energy. A material which allows the flow of charged particles is an electrical conductor. A material which allows the transfer of thermal energy is a thermal conductor or heat conductor [18]. Insulation is provided by air.

Figure 2.24: Conductors

Two main types of conductor

- Copper conductor.
- Aluminum conductor.

Different types of aluminum conductors manufactured

- All Aluminum stranded conductors (AAC)
- Aluminum conductors, aluminized steel reinforced
- Aluminum conductors galvanized steel reinforced (ACSR)
- All Aluminum Alloy stranded Conductors (AAAC)
- Aluminum conductors galvanized steel reinforced for extra high voltage (400 kV or above) (ACSR).[15]

Mostly used conductor in overhead line

Aluminum conductor steel-reinforced (ACSR) is a specific type of high-capacity, high-strength stranded conductor typically used in overhead power lines. The outer strands are high-purity 1350 or 1370 aluminum alloy, chosen for its excellent conductivity, low weight and low cost. The center strands are of steel for the strength required to support the weight without stretching the aluminum due to its ductility. This gives the conductor an overall high tensile strength.

Figure 2.25:Sample cross-section of high tension power line,showing 7 strands of steel surrounded by 4 layers of aluminum [10]

ACSR cables are available in several specific sizes, with multiple center steel wires and correspondingly larger quantities of aluminum conductors. For example, an ACSR cable with 72 aluminum conductors that requires a core of 7 steel conductors will be called 72/7 ACSR cable.

The higher resistance of the steel core is of little consequence to the transmission of electricity in large diameter conductors since it is located below the skin depth (8.5 or 9 mm for 60 or 50 Hz) where only a small amount of AC current flows.

2.9 Insulator

An electrical insulator is a material whose internal electric charges do not flow freely, and which therefore does not conduct an electric current, under the influence of an electric field. A perfect insulator does not exist, but some materials such as glass, paper and Teflon, which have high resistivity, are very good electrical insulators. Insulators are used in electrical equipment to support and separate electrical conductors without allowing current through themselves[20]

2.9.1 Two common types of insulators

- **Horizontal post-type**
- **Suspension-type**

- **Horizontal post-type**

This type of insulator supports the conductor to the side of the structure.

- **Suspension-type**

This type of insulator suspends the conductor below the structure.

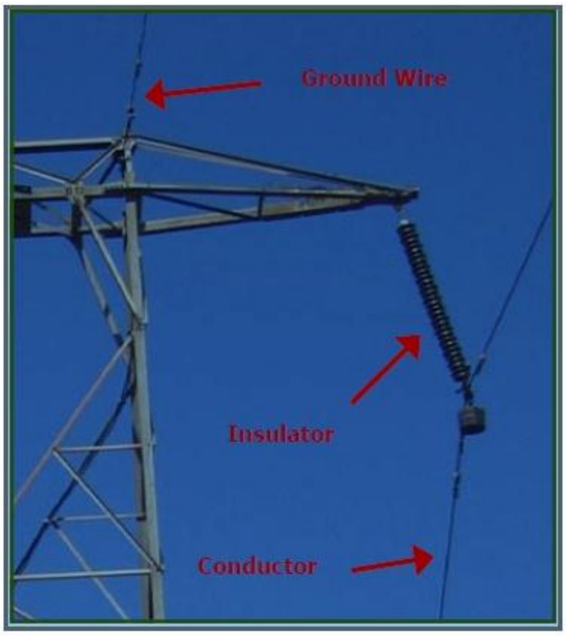

Figure 2.26: Insulator along with conductors and ground wire

2.10 Ground wires

The term "ground" refers to a connection to the earth, which acts as a reservoir of charge. A ground wire provides a conducting path to the earth which is independent of the normal current-carrying path in an electrical appliance. As a practical matter in household electric circuits, it is connected to the electrical neutral at the service panel to guarantee a low enough resistance path to trip the circuit breaker in case of an electrical fault (see illustration below). The ground wire and a fuse or breaker are the standard safety devices used with standard electric circuits [21].

Figure 2.27 : Ground wire

2.10.1Types of grounding systems include

- Solidly grounded systems.
- Low-resistance grounding (LRG) systems.
- High-resistance grounding (HRG) systems.

2.10.1.1 Solidly grounded systems

Solidly grounding refers to connecting the neutral or grounding point on a device to natural ground (earth) via a highly conductive medium, i.e. copper wire and rod so that the ground resistance is very low or at least less than 25 ohms.

2.10.1.2Low-resistance grounding systems

Low-resistance grounding systems use a neutral grounding resistor (NGR) to limit the fault current to 25 A or greater. Low resistance grounding systems will have a time rating (e.g. 10 seconds) that indicates how long the resistor can carry the fault current before overheating. A ground fault protection relay must trip the breaker to protect the circuit before overheating occurs.

2.10.1.3High-resistance grounding systems

High-resistance grounding (HRG) systems use an NGR to limit the fault current to 25 A or less. They have a continuous rating, and are designed to operate with a single-ground fault.

This means that the system will not immediately trip on the first ground fault. If a second ground fault occurs, a ground fault protection relay must trip the breaker to protect the circuit. On an HRG system, a sensing resistor is used to continuously monitor system continuity. If an open-circuit is detected (e.g., due to a broken weld on the NGR), the monitoring device will sense voltage through the sensing resistor and trip the breaker. Without a sensing resistor, the system could continue to operate without ground protection (since an open circuit condition would mask the ground fault) and transient over voltages could occur.

2.10.2 Grounding consists of three basic components

- Ground conductor
- The connection/bonding of the conductor to the ground electrode
- The ground electrode itself

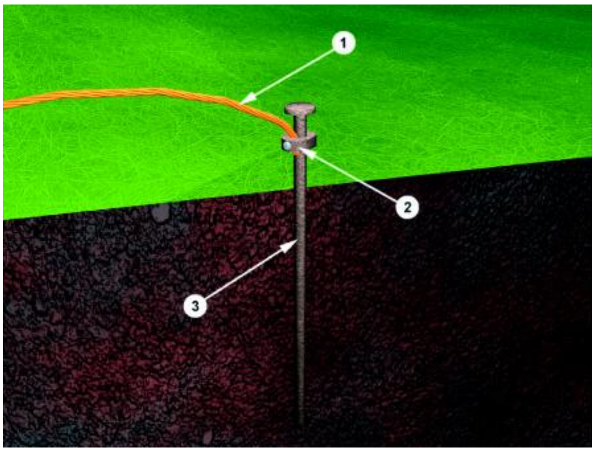

Figure 2.28:Grounding system

2.11 Earthing

Earthing in electricity is the process of installing a protective earth wire into the surface of the earth to limit chances of an electric shock occurring in electrical objects with insulation faults. In addition to limiting electric shocks, earth connections are important in electric gadgets, which require surge suppression and protection from electromagnetic interference.

2.11.1 Types of earthing system

It distinguishes three families of earthing arrangements, using the two-letter codes TN, TT, and IT [22].

- The first letter indicates the connection between earth and the power-supply equipment (generator or transformer).

  T : direct connection of a point with earth;
  I : no point is connected with earth (isolation), except via a high
  impedance.

- The second letter indicates the connection between earth and the electrical device being supplied

  T : direct connection with earth, independent of any other earth connection
  in the supply system;
  N: connection to earth via the supply network.

- TN NETWORK
- TN-S NETWORK
- TN-C NETWORK
- TN-C-S NETWORK
- TT NETWORK
- IT NETWORK

Chapter 3

Present Scenario of Solar irrigation in Bangladesh

Prospect of Solar Irrigation in Bangladesh

Bangladesh has good solar resources, with high availability during the peak irrigation season. As a result, solar pumping of water for irrigation presents an innovative and environment-friendly solution for its largely agro-based economy. The country has about 1.71 million irrigation pumps, of which 83% run on diesel. The remaining 17 % are electricity-operated. The demand for irrigation is concentrated during February-March. So much so that during the peak irrigation period 2000 MW of power demand is solely required for running the electric pumps. The diesel-run irrigation pumps on the other end consume more than half a million tons of diesel. This comes at a great cost to the exchequer as Bangladesh imports 100% of its diesel requirement which is then distributed to the users at a highly subsidized price.

On the basis of life cycle costs, solar irrigation pumps are much more attractive compared to diesel pumps. In addition to this, PV pumping systems allow low operating cost, unattended operation, low maintenance, easy installation, and long life. These advantages are especially important in remote rural areas which are yet to be grid connected.

The initial high cost is the biggest barrier to adoption. To overcome this, IDCOL has been experimenting with both a 'water as a service' (community) model and 'individually owned small size pumps' model.

To accelerate the number of installations, a large part of the capital cost is being provided as a combination of grant and soft loan. IDCOL is providing financial support to solar irrigation projects based on a debt, equity and grant ratio of 30:20:50. As the uptake of solar pumps increases, the aid amount will be gradually reduced.

Solar based irrigation systems are innovative and environment friendly solution for the agro-based economy of Bangladesh. The program is intended to provide irrigation facility to off-grid areas and thereby reduce dependency on fossil fuel. IDCOL has approved 459 solar irrigation pumps of which 324 are already in operation[26]. The remaining pumps are expected to come into operation shortly.IDCOL has a target to finance 1,550 solar irrigation pumps by 2017. The World Bank, KfW, GPOBA (Global Partnership on Output-Based Aid), JICA (Japan International co-operation agency), USAID (United States Agency for International Development), ADB (Asian Development Bank) and Bangladesh Climate Change Resilience Fund (BCCRF) are supporting this initiative [24].

There are 37 PO's (partner organization) of IDCOL are working for different solar irrigation projects in Bangladesh.
Bright Green Energy Foundation (BGEF) is one of the active PO of IDCOL.

The present scenario data for different divisionshas been collected and given in the following graphs[23]:

3.1 Average pump head for different divisions in Bangladesh

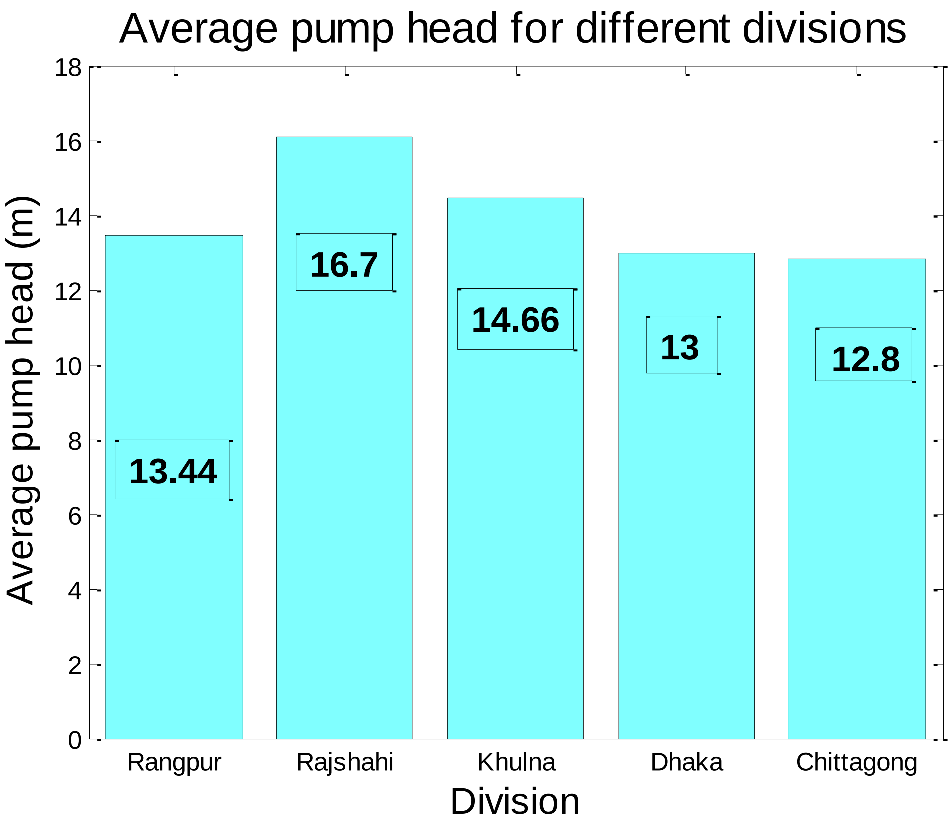

Figure 3.1:Average pump head for different divisions

Figure 3.1 shows the average pump head for different divisions in Bangladesh. The highest pump head is required at Rajshahi division and the value is 16.7m. On the other hand, Chittagong division needs only 12.8m pump head for solar irrigation. It is the lowest pump head among different divisions. Around 450 solar irrigation pumps are installed by IDCOL and 37 pumps are installed in Rajshahi division. Rangpur is one of the leading divisions for solar pumping with 13.44m pump head and almost 200 pumps are already installed in this division. Therefore, it is veryimportant for every upcoming irrigation project in different divisions to consider the above pump head before installation as the pump capacity increases with the pump head.

3.2 Average pump head vs Average pv capacity

IDCOL authority has helped us providing various information about their different project which differs from various aspect. They are water flow (m^3/day),equipment supplier, pump capacity (kW),PV capacity(kWp),pump head (m).Here a graph has been shown on pump head vs PV capacity.

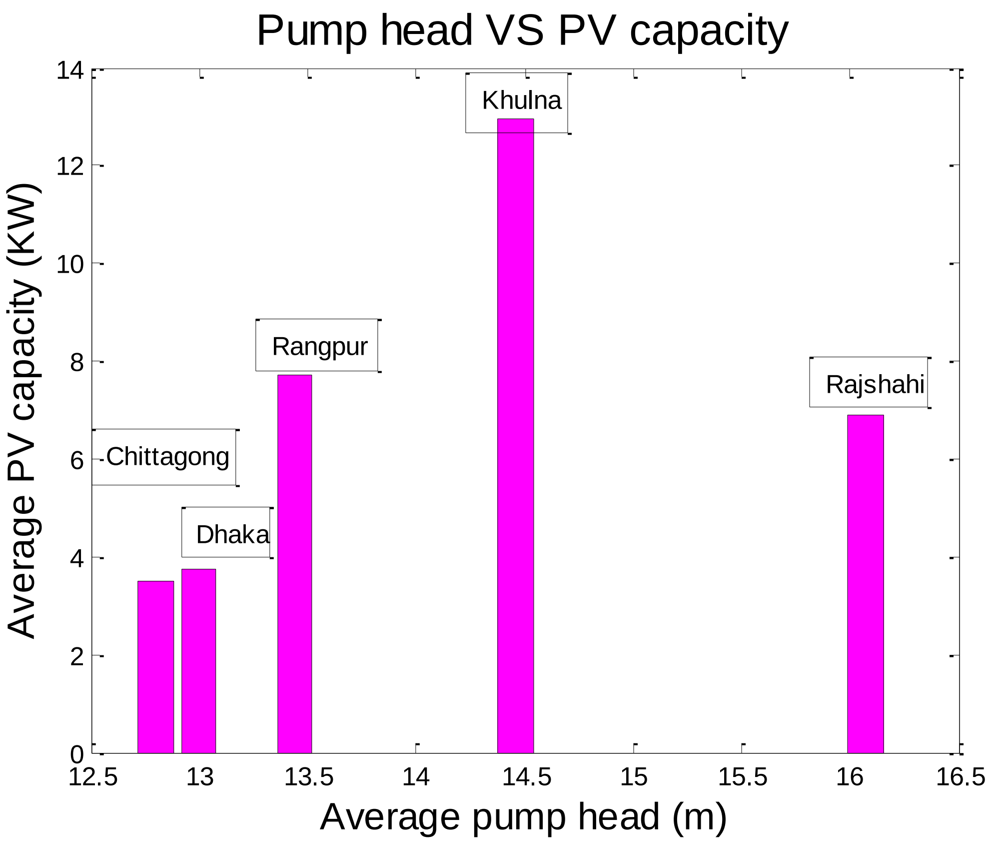

Figure 3.2: Pump head vs. PV capacity

It is important to determine the PV capacity for solar irrigation projects. Figure 3.2 shows how the PV capacity varies with different pump heads in different divisions of Bangladesh. Total 450 solar pumps are installed in five divisions of Bangladesh. It is seen from the graph that average PV capacity increases with the average pump head in every division of Bangladesh except Rajshahi. The maximum average pump capacity 13kw is needed for a solar irrigation project with average 14.2m pump head in Khulna division. Only average 3.75kw pump is required for a minimum average pump head of 12.8m. So it can be concluded that place or division with higher pump head will require the higher PV capacity. Khulna division has the maximum average PV capacity and it is at the top of chart with 205 solar irrigation projects.

3.3Pump capacity vs PV capacity

It has been seen that PV capacity greatly varies with pump capacity.This information has been given by IDCOL authority. Here a graph has been shown on pump capacity vs PV capacity.

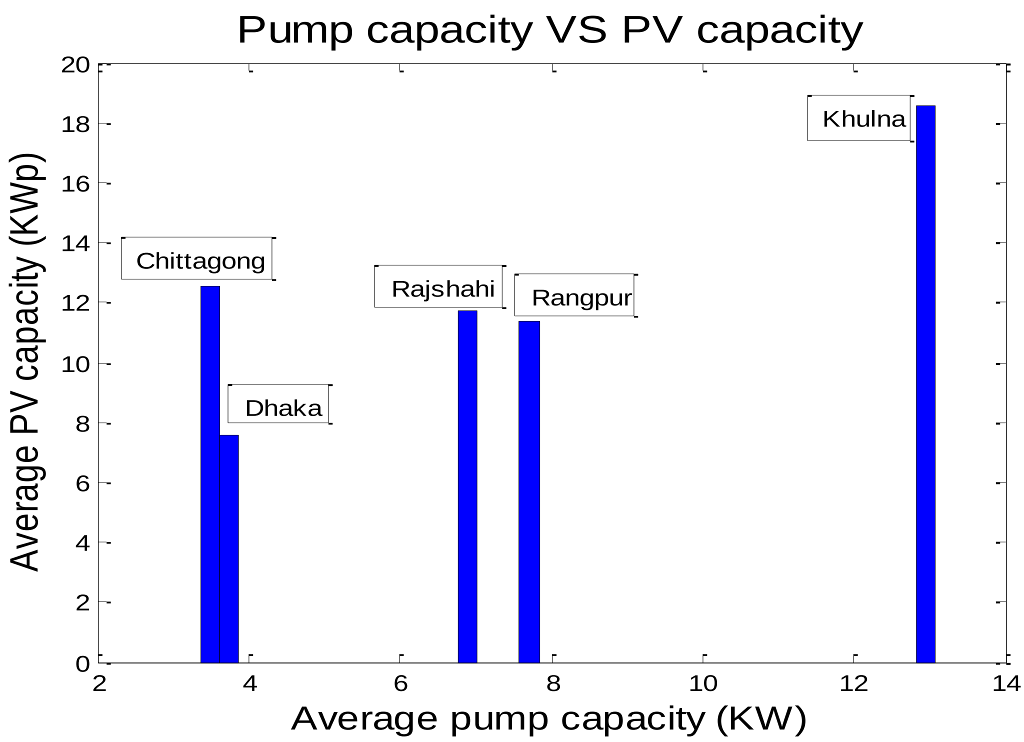

Figure 3.3: Pump capacity vs. PV capacity

It is desired that higher PV capacity will be required for higher rating of pump capacity. Figure 3.3 shows that among different divisions the maximum average pump capacity 13 KW is found for Khulna division and it takes almost 19 kWp PV for running this higher rating pump. In case of Dhaka division, average pump capacity is 3.75 KW and it requires only 7.5 kWp PV panel to the project. But Chittagong division shows a different figure from the rest. Here 12.5 kWp PV capacity is required for supporting only 3.5 KW pump. Insufficient solar radiation is the reason behind this kind of problem. Therefore, this types of issue should be kept in mind before installing a solar pump in such divisions. Though the PV capacity increases with the increase of pump capacity sometimes it may show different scenario depending on the solar radiation for different divisions.

3.4 Average water flow per day for different divisions

Similarly it has been found that in different divisions water flow is not the same.A graph has been shown on average water flow per day for different divisions.

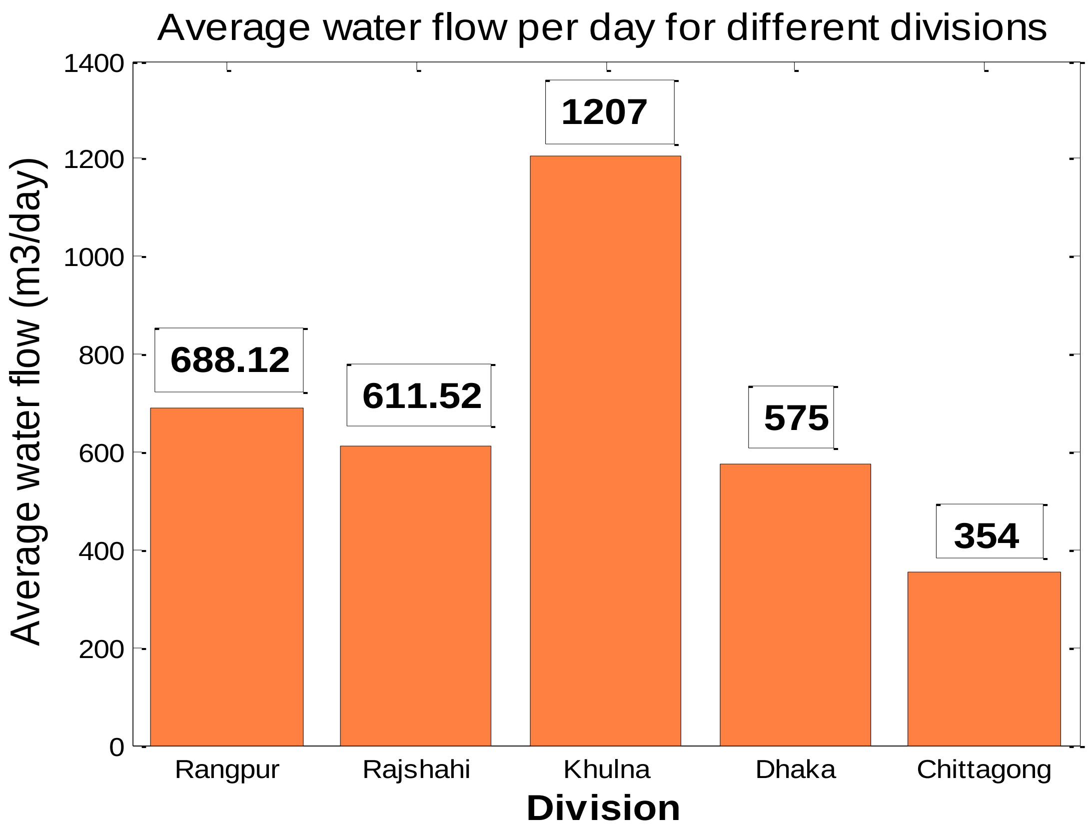

Figure 3.4: Average water flow per day

Already 450 solar irrigation projects have been installed by IDCOL in different divisions of Bangladesh. As the average sunshine hour and water head is not same for all areas in Bangladesh, therefore the average water flow per day is not equal for all divisions. Figure 3.4 shows that the highest average water flow (m^3/day) has been found at Khulna division. In addition, 46% of the total installed pumps are at Khulna. So the higher rate of water flow can be a blessing reason behind this number. Chittagong has the lowest average water flow per day and only two irrigation projects has been installed so far. Rangpur is at 2nd position in the figure with average water flow of 688.12 m^3per day. As a result, 44% of total installed pumps are found at Rangpur.

3.5 Total no. of pump installed by different EPC contractors

EPC Contractors	Total no. of Installed Pump
Nahean Enterprise	01
MREL	07
EPGL	07
RREL	62
ESPL	31
GHEL	06
BTEL	13
GRAM	05
SolarGaon	97
Sherpa	15
JSF	79
Solar E Technology Ltd	21
EEL	31
GSEL	03
UEL	12
NREL	02

Table 2:Total no. of installed pump

3.6 Total no. of installed pump in different divisions

Because of some geographical issue and radiation factor total number of installed pump varies in different divisions.A graph has been shown on total number of installed pump in different divisions.

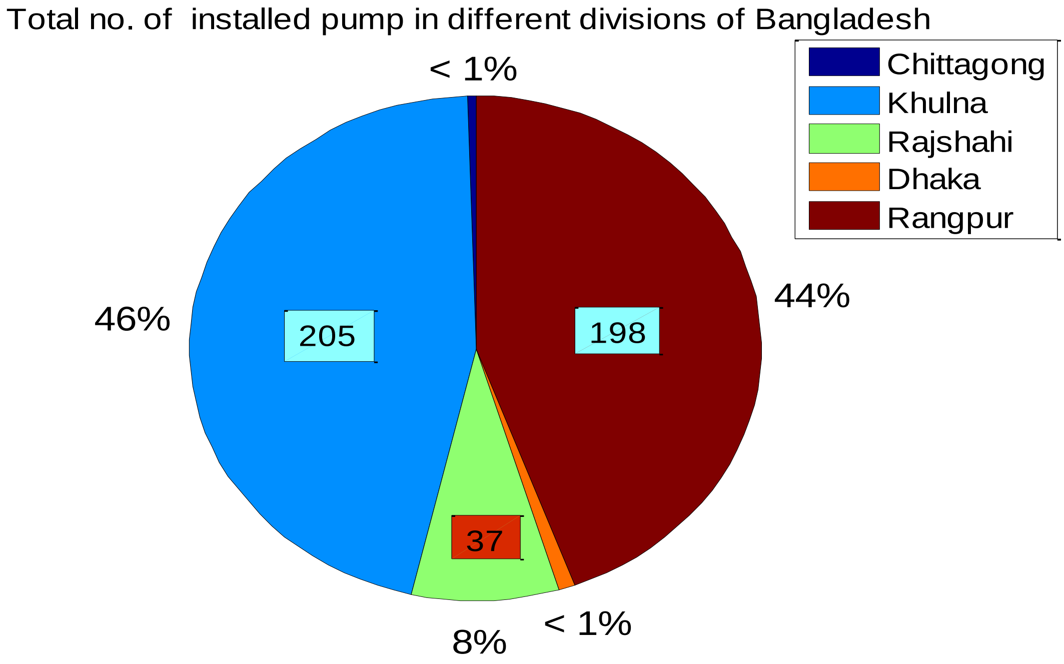

Figure 3.5: Total no. of installed pump in different divisions of Bangladesh

As Bangladesh is an agricultural country and it receives sufficient solar energy that's why solar irrigation becomes popular day by day. Infrastructure Development Company Limited (IDCOL) has installed almost 450 solar irrigation projects in different divisions of Bangladesh. Solar irradiation, water head, water flow per day and irrigation water demand are some of important issues for feasible solar irrigation. Considering these issues all divisions are not same preferable for solar irrigation. Figure 3.5 show that 46% of the total pumps are installed at Khulna and the number is 205 pumps out of 450 pumps. With the number 198 out of 450 Rangpur is at 2nd position and it covers almost 44% of the total installed pumps. The contribution of Rajshahi is 8% of the total pumps and the number is 37. From figure 3.5 it is clearly observed that Dhaka and Chittagong division are listed below with less than 1% contribution in solar irrigation.

3.7 Monthly average sunshine hour of Teghoria village (District Kushtia)

It is very important factor in solar irrigation sector to know about the average sunshine hour. This data has been collected from IDCOL authority.A graph has been presented here on monthly average sunshine hour in different divisions.

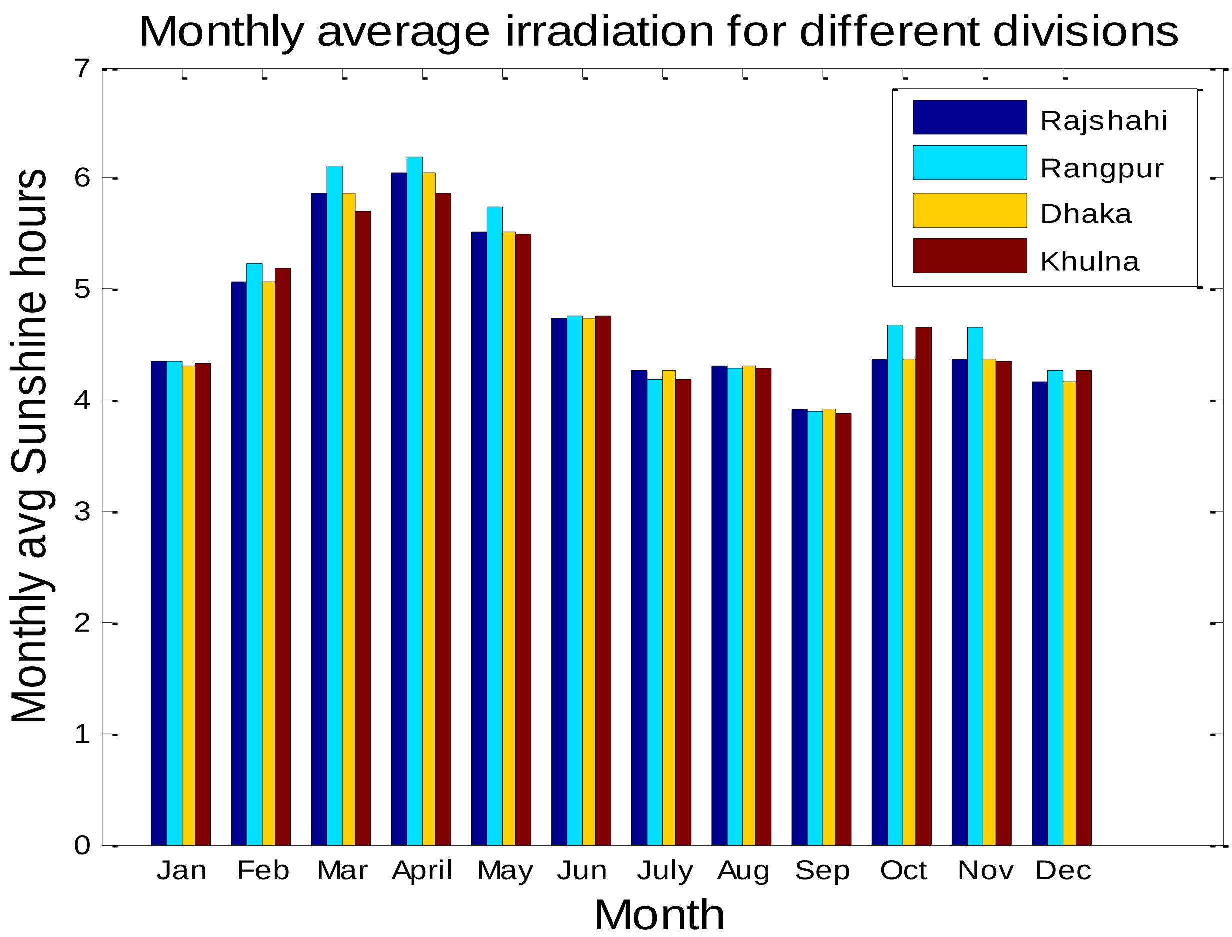

Figure3.6:Monthly average radiation for different divisions

Figure 3.6 shows the monthly average sunshine hour for different divisions of Bangladesh over the year. From the figure it is found that the maximum monthly average sunshine hour is 6.2 at Rangpur. The highest average sunshine hour is found at the season of March, April and

May. In June, July month monthly average sunshine hour becomes very low due to the heavy rainfall.Almost in every month the average sunshine hour is same for Rangpur and Khulnadivision. May be that's why most of the irrigation pumps has been installed at that divisions. July, August and September are the months of low radiations. The average sunshine hour for these months is near about 4.2 hours. The sunshine hour for Dhaka division in consistently poor over the year compare to other divisions.

3.8 Average water required in different divisions in Bangladesh

Average rainfall, average solar radiation and water head are not same for all divisions in Bangladesh. Therefore, the average required water for irrigation per month is not same for all divisions. This data has been collected from IDCOL authority.A graph has been presented here on average water required in different divisions of Bangladesh.

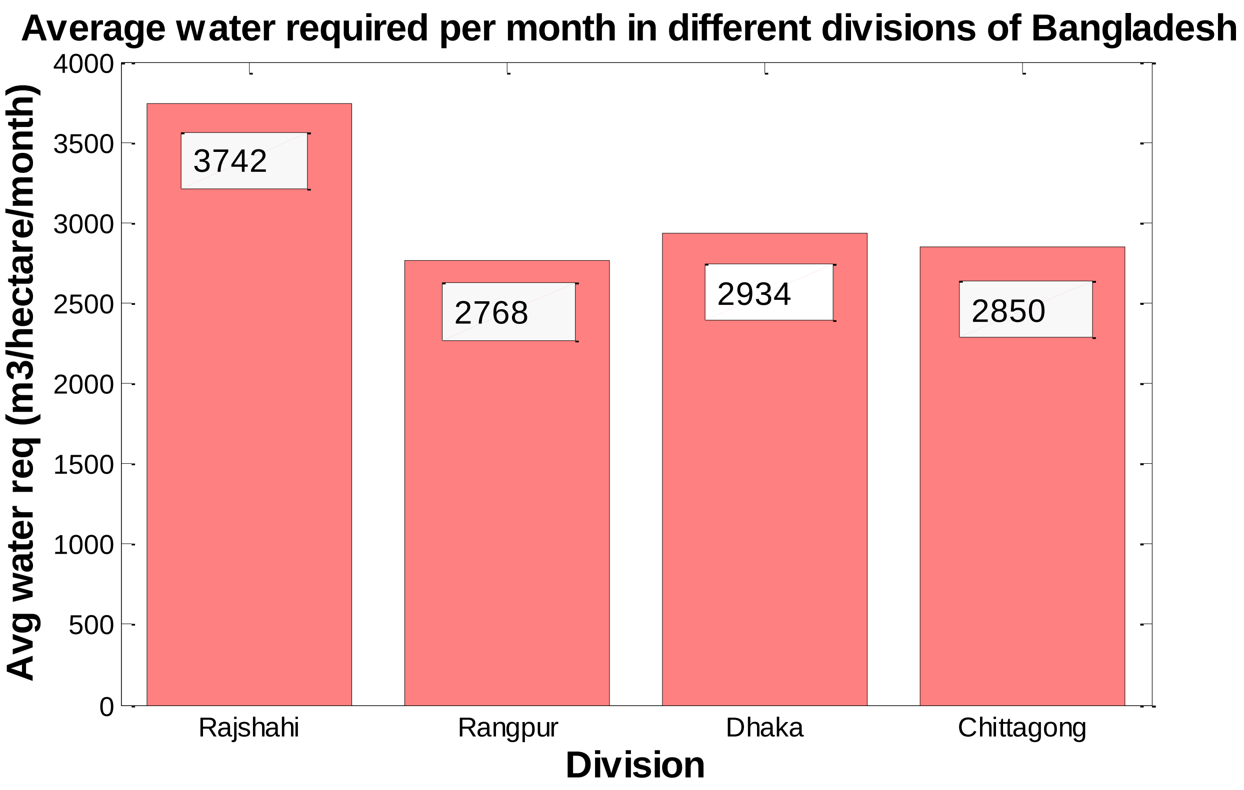

Figure 3.7 : Average water required per month

Figure 3.7 shows the average water required (m^3/hectare/month) for different divisions of Bangladesh. From the figure it is seen that Rangpur requires least average water for irrigation per month per hectare land. On an average 2768 m^3 water is needed per hectare per month for irrigation purpose. 198 pumps are installed out of total 450 pumps by IDCOL at Rangpur. Less amount of required water helps Rangpur to achieve this. Rajshahi division needs 3742 m^3/hectare/month which is the maximum amount of average required water among all divisions and as a result only 37 solar pumps are installed at Rajshahi. Therefore, amount of required water per month is a important factor for solar irrigation.

3.9 Average water required for different crops in different divisions

Different crops are needed different amount of water to be grown. Data has been collected from IDCOL authority to know the water requirement for different crops.A graph has been presented here on average water required for different crops in different divisions of Bangladesh.

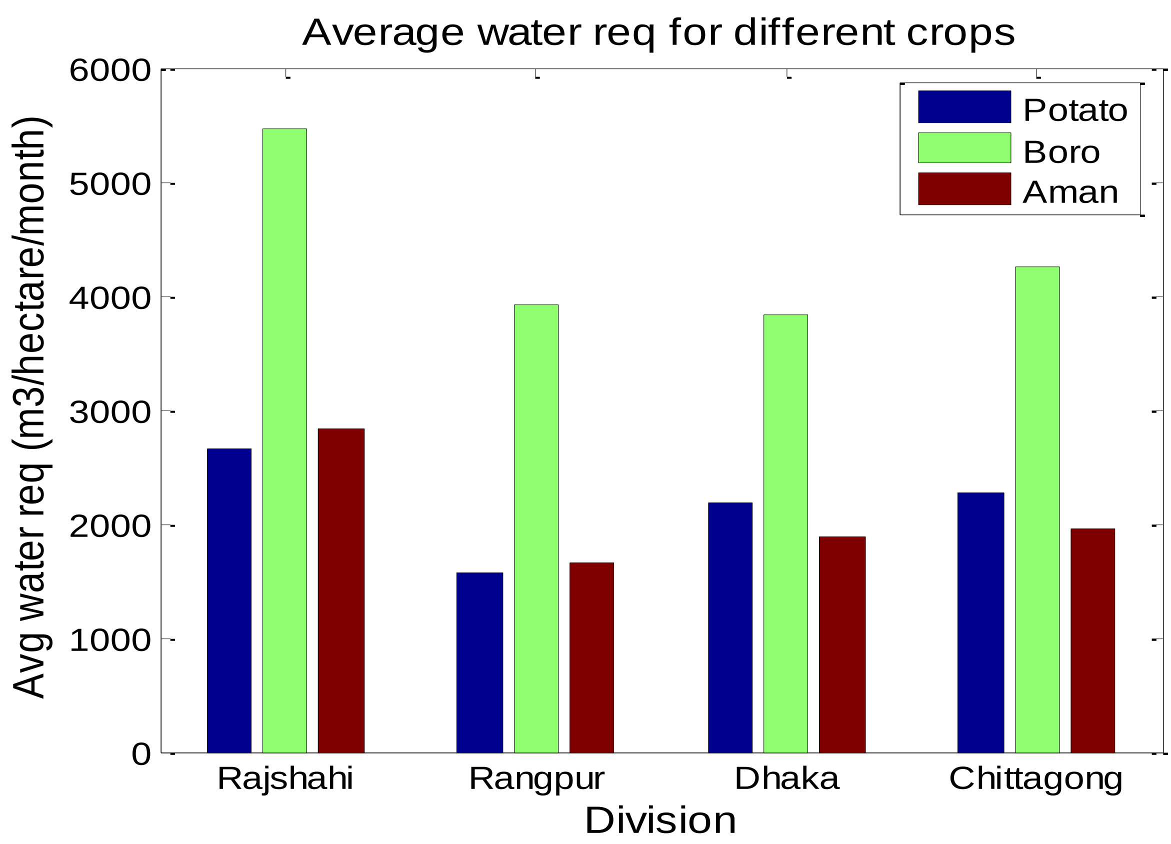

Figure 3.8: Average water required for different crops

Potato, Boro and Aman are the main crops of Bangladesh which requires huge amount of water for irrigation. These three major crops are totally dependent on solar irrigation. Figure 3.8 shows the amount of average water required for these three main crops. It is seen that in every division Boro requires the highest amount of water for irrigation compare to other crops. It needs almost 5500 m^3 water per month per hectare for irrigation. That means Boro costs much for irrigation compare to other crops. Therefore, farmers are not willing to cultivate Boro in their land. Farmers switch to other crops for low cost which requires less amount of water. Potato requires only 1600 m^3 water per hectare per month which costs less than other crops. Amount of water required for three crops are almost same for different divisions.

3.10 Water consumption by different crops over the year

Monthly average water consumption by different crops (m3/hectare/month)

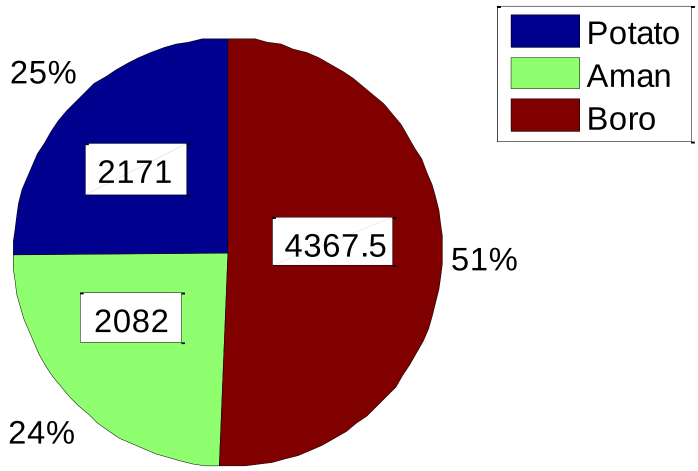

Figure 3.9:Water consumption by different crops

In figure 3.9, the pie chart shows the month amount of water consumption by different crops. In rural area total amount of irrigation water is consumed by main three crops – Potato, Boro and Aman. Figure 3.9 shows that 51% of irrigation water is consumed by Boro rice. Potato and Aman consumes almost same amount of water for irrigation per month per hectare. Boro consumes 4367.5 m^3water per month per hectare for irrigation. As a huge amount of water is consumed by Boro that's why farmers has to pay a lot for Boro irrigation. This cost is an alarming issue for solar irrigation. This is because it may discourage farmers to cultivate Boro rice.

Chapter 4

Performance Study of a Practical Solar Water Pumping System

Performance Study of a Practical Solar Water Pumping System

4.1 Introduction

In the face of tremendous social, economic and political pressure to solve power crisis in Bangladesh it has become critically important to look for energy solutions beyond the conventional sources like domestic natural gas, coals, hydroelectricity and imported fuels. Irrigation plays a vital role in our social economy.Solar irrigation can be the best solution.In this regards IDCOL helps us a lot by giving proper information about their different survey.Bright Green Energy Foundation (BGEF) is one of the partner organization of IDCOL.One of the project of BGEF has been visited by ourselves.Our main focus is to study the performance of a practical solar water pumping system.Different features of a working water pump has been studied.Farmers have shared their feelings about their experience using solar pump and diesel pump.A survey has been made of about almost 50 houses and according to their words load shedding is the biggest problem though the area is grid connected. The most feasible way out of this multi-dimensional crisis is to increase our reliance on renewable energy like solar power.

Solar based irrigation systems are innovative and environment friendly solution for the agro-based economy of Bangladesh. The program is intended to provide irrigation facility to off-grid areas and thereby reduce dependency on fossil fuel. IDCOL has approved 459 solar irrigation pumps of which 324 are already in operation. The remaining pumps are expected to come into operation shortly[26].IDCOL has a target to finance 1,550 solar irrigation pumps by 2017. The World Bank, KfW, GPOBA, JICA, USAID, ADB and Bangladesh Climate Change Resilience Fund (BCCRF) are supporting this initiative[24].
There are 37 PO’s of IDCOL are working for different solar irrigation projects in Bangladesh.Bright Green Energy Foundation (BGEF) is one of the active PO of IDCOL.

4.2 Description of BGEF

Bright Green Energy Foundation (BGEF) is one of the leading organizations in the country to provide pollution free renewable energy to the underprivileged rural people of Bangladesh through innovative monthly installment based financing model. BGEF has focused its primary work for the expansion of Solar Home System (SHS), Solar Irrigation Pump (SIP), Bio-gas Plant & Improved Cook Stoves (ICS) in rural Bangladesh. During the dry season irrigation is very necessary for cultivation. Most of the power is limited to the rural areas of Bangladesh. Usually rural irrigation system relies on Low Lift Pump (LLP), Shallow Tube Well (STW) and Deep Tube Well (DTW). LLP and STW mostly use diesel and DTW is mainly operated by electricity. A solar powered irrigation pump is a best possible source to overcome this seasonal irrigation problem. The solar pumps reduces farmers' dependence on diesel supply, which is often costly particularly in remote rural areas. BGEF has started installing Solar Irrigation pump in rural off grid areas to support the agricultural sector of the country. Already BGEF installed three (3) submersible pumps in the western part of Bangladesh (Kushtia) and replacing diesel run pumps. On an average these pumps are producing approximately 16 Lac liters of water from ground water source each day.

Among several projects of BGEF we selected a large project which is situated at Kushtia. The following figure is the photograph of the project signboard.

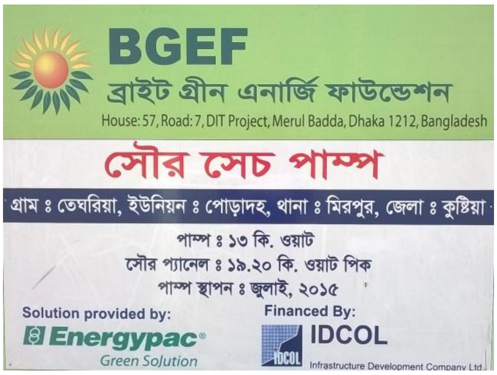

Figure 4.1:BGEF

4.3 Description of the project

Location	Tegoria, Kushtia
Water head	10-20m
Solar Panel Capacity	19.2KWp
Water discharge rate	15-18 lac lit/day
Crop	Different
Tracking	No
Area coverage	125 bigha
Borewel pipe dia	12m
Pump	13K
Duration	6am - 6pm
Farmer	30-40

Table 3: Description of the project

4.4.1 Crops over the year and Financial Structure

Among all the projects we have visited one of the biggest project in Kushtia. With the very close discussion with farmers we have to know that they try three different crops over the year. December to march is the best timing for them to harvest Boro; March to June is the best timing for them to try for Aush; and July to September is the best timing to harvest Aman.2500 taka has to pay by the farmers for Aush, 1500 taka is for Aman,3500 taka is for Boro. Farmers are benefitted because they have to pay the whole money in three installmentin stead of one at a time.

4.4.2 Water supplying process

As Kushtia is quite a low lying land, water is found in just 60 ft. below the ground. Still the pump we visited had boring up to 240 ft. The boring has been this deep because of the uncertainty of water level which may go down below a lot more than

60 ft. The240 ft. boring is divided into 120 ft. of filter and 120 ft. of blank pipe. It is not that the filtered pipe runs along 120ft and after that it is 120 ft. blank pipe rather it is a hefty mixture of the both.

When water was raised by the pump,the water first was thrusted to a 12 inch diameter pipe. Then the water travels through 8 inch diameter pipe which leads to a header tank.Through an 8 inch diameter pipe which goes underground, the water travels to the rising valve.This valve determines how much water gets out of the system.Between Header tank and rising valves there are gas pipes which takes out the gas bubbles remaining in water.

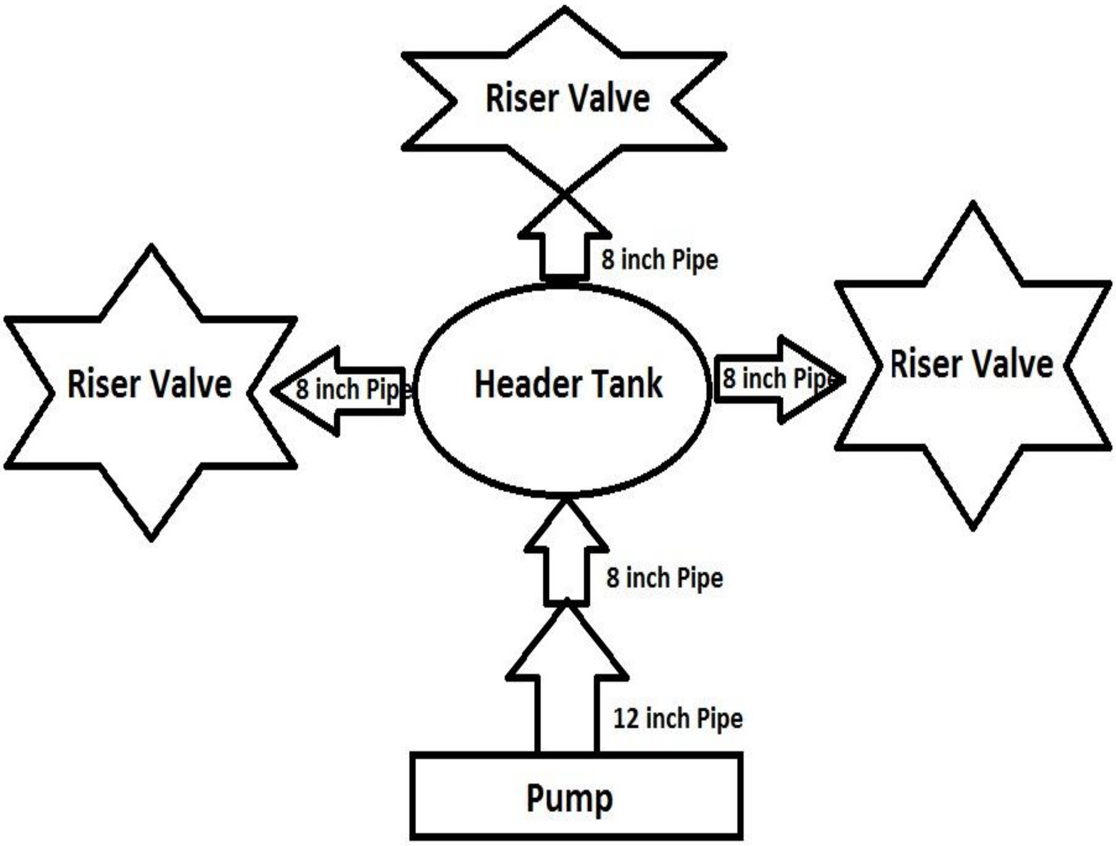

Figure 4.2: Water Supplying Process

Figure 4.3:Water Flow controller (Riser)

4.4.3 Discussion with Farmers

As we visited that project not to see the real pictures but also come close with farmers so that we can imagine the actual scenario of that project. Cultivating Boro is expensive while much cannot be earned by selling them. As a result cultivating Boro is not as profitable as cultivating Aush and Aman. Farmers prefer cultivating tobacco, wheat, Lentils. But in real scenario cultivating tobacco for a long term is unhealthy for the soil.

Figure 4.4: Discussion with Farmers

Noticeable findings from the site visit:

- The Owner still treats it as a loss project
- Comparison between solar pump vs diesel pump

- Use of extra energy
    1. Battery charging station
    2. Rice husking
    3. Mini grid
- Utilization of land under panel
- Farmers interest about solar irrigation
- Problems with solar irrigation

4.5 Comparison between diesel pump vs solar pump

While talking with farmers various information has been collected about diesel pump and solar pump.They have shared their experience about growing crops using those. Here the difference has been shown between them:

<table>
<tr><th>Issues</th><th colspan="2">Diesel pump</th><th>Solar pump</th></tr>
<tr><td>Land area</td><td colspan="2">1 bigha</td><td>1 bigha</td></tr>
<tr><td>Irrigation</td><td colspan="2">1 time</td><td>1 time</td></tr>
<tr><td rowspan="3">Cost

1bigha and 1 irrigation</td><td>Engine rent</td><td>Diesel price</td><td rowspan="2">3 months, total 50 times irrigation cost= 3500 tk</td></tr>
<tr><td>200 tk</td><td>70 tk/lit
*2</td></tr>
<tr><td colspan="2">Total=340 tk</td><td>Only 70 tk</td></tr>
<tr><td>Cost per season per bigha(Boro)</td><td colspan="2">25 irrigations
(200*25)+(50*70)

= 8500tk</td><td>50 irrigations

Only 3500tk</td></tr>
<tr><td>Labor</td><td colspan="2">1</td><td>None</td></tr>
<tr><td>Quality of crop</td><td colspan="2">Good</td><td>Better</td></tr>
<tr><td>Availability of water</td><td colspan="2">Not available</td><td>Available</td></tr>
</table>

Table 4:Comparison between diesel pump vs. solar pump

Explanation:

While calculating farmers cost for irrigation using diesel pump we found that Engine rent for each irrigation is 200tk.While diesel price per liter is 70taka.We also found that each irrigation needed 2 liter of diesel. So assuming that a Boro season requires 25 irrigation the total cost incurred using a diesel pump is (200*25)+(70*2*25)=8500 taka.

In contrast irrigation using a solar pump requires only 3500 taka per season which brings down per irrigation cost a lot.

4.6 Measured Data of Teghoria village (District Kushtia)

We have visited puradaho, Kushtia for studying a practically working solar water pumping system. Our main focus is to collect data which includes radiation of that day time to time; output PV current and voltage; Inverter output and most importantly actually water discharge rate. We are presenting here a details by graphical analysis.

Time	Air Temp °c	Radiation (W/m^2)	PV output I_L (A)	PV output V_L(V)	Inverter Output I_L (A)	Inverter Output V_L (V)	Water discharge Rate (Lit/min)	Frequency (Hz)
11:00	38	860	23.70	569	25.56	232	3100	45
11:20	38	928	23.88	569	26.11	234.2	3100	48.5
11:40	37	939	24.00	570	25.52	234.8	3000	48.5
12:00	38	926	23.72	579	25.12	233.9	2400	48.4
12:20	38	882	23.68	572	25.23	212.9	3000	48.1
12:40	39	962	23.43	569	25.54	235.2	3100	48.5
01:00	37.5	864	22.8	561	24.7	224.4	3000	41.5
01:20	37	910	23.27	563	24.85	229.2	2700	47.9
01:40	38	865	23.14	561	24.74	268.6	3100	48.1
2:00	38	737	23.74	566	25.45	232.2	3100	48.2
2:20	38	864	23.20	569	25.54	232.14	3100	47.6
2:40	37	820	23.14	565	25.43	244.68	3000	47.6

3:00	37	825	23.15	564	25.40	230.84	3000	47.4
3:20	36	752	22.60	560	25.32	229.18	3000	46.8
3:40	36	778	23.04	558	25.30	229.50	3000	46.8
4:00	35	740	22.82	557	25.31	228.44	3000	46.4

Table 5: Measured Data of Teghoria village (District Kushtia)

4.7 Graphical representation of measured data from the practical solar water pumping system

As we have collected various data in several days but we have just focused a particular day because of the result optimization. Several important factors has been measured from the plant. Air temperature, radiation, PV output, inverter output, water discharge rate and efficiency of the system (motor+pump) are measured at 20 minutes interval. Then we have tried to present the scenario of irrigation by showing some graphs given below.

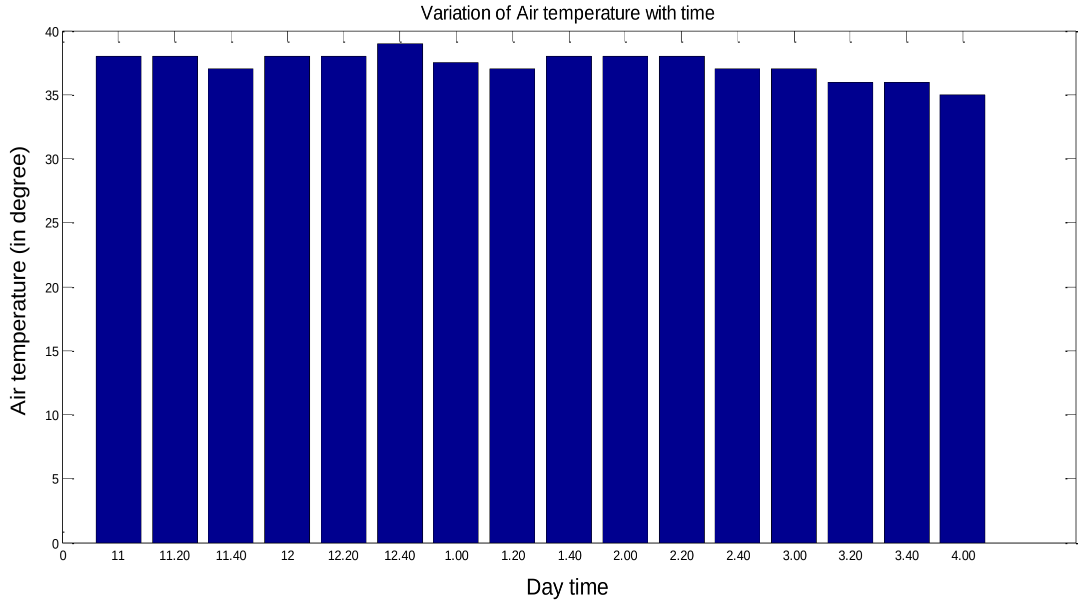

Figure 4.5:Time vs Air temperature

Figure 4.5 shows the air temperature (in degree) of that area from on a typical day of July. The highest temperature 39 degree is found at 12.40pm and the lowest temperature 35degree is measured at 4.00pm.

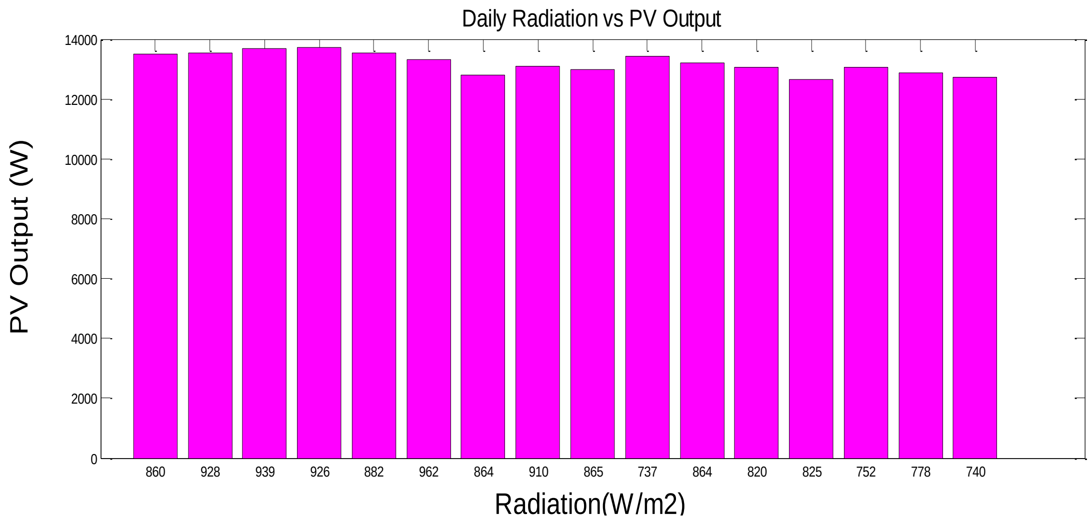

Figure 4.6: Radiation vs PV output

From the figure 4.6 it is seen that the output of the PV increases with the increase of radiation. The average radiation is found 856 W/m^2 of that particular day. The rating of the PV is 19.2 kWp and it serves 13.68 KW when the radiation is 939 W/m^2. For the lowest radiation 740 W/m^2 the PV shows 12.71 KW as output.

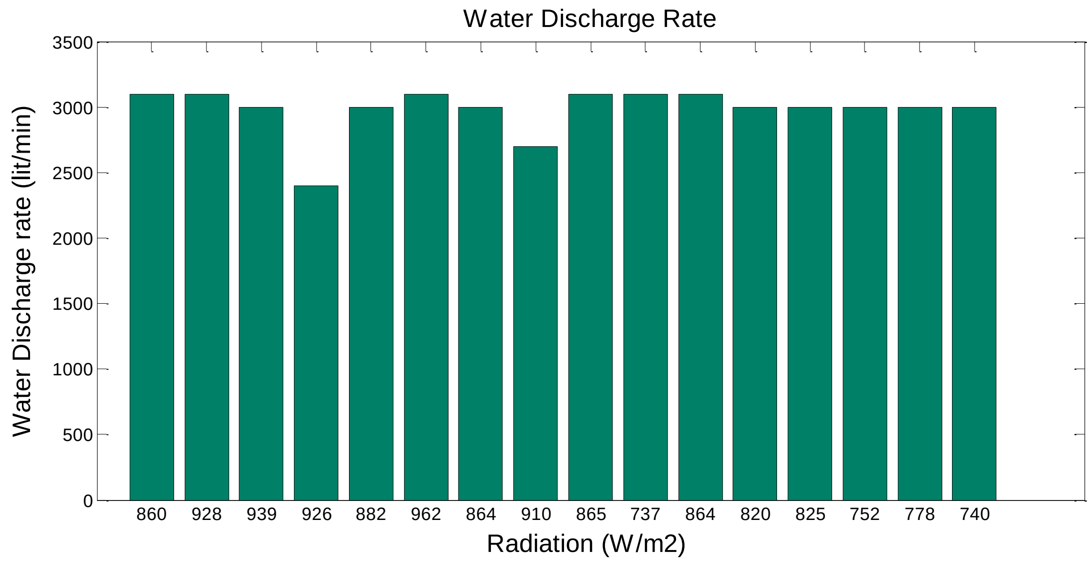

Figure 4.7: Radiation vs Water discharge rate

We found a built-in meter which is called flow meter with the system to measure the water discharge rate (lit/min). Figure 4.7 shows the variation of water discharge rate with the variation of solar radiation.As the average radiation is 856 W/m^2 and the other radiations does not vary too much so that the water discharge rate is approximately same over the measured period. The value of the average water discharge rate is 2982 lit/min.

4.8 Controversy

From discussion with the farmers,we have found the following controversies:

- Diesel pumps cost higher but still farmers go for diesel pump.
- Though solar pump costs very low, still it is a loss project
- Farmers say, land remains without crop for maximum one month. So why they are talking about use of extra energy.
- Crop under panel

4.9Important discussion on the controversy

From the site visit and farmer's comments it has been seen that the small percentage of the farmers who uses solar pump were found to be reluctant about payment for using the facility. " আল্লাহ'রপানিআল্লাহদিসে"is farmers claim when date of payment arrives. As a result the water output is not fully utilized and the project does not seem to be economically viable. Hence, the yearly average efficiency of the system becomes far more less than expected.

4.10 Efficiency of the system:

Motor + Pump

Inverter output = (motor+ pump)'s Input = VI cosϴ = 25.56*232*0.8 = 4743.936 W

(Motor+ Pump)'s output = 3100 lit/min = 3100*8*60 = 1488000 lit/day

1488000 lit/day = (1488000*18.25)/367 =72223.40 Wh/day , Water head = 18.25 m

72223.40 Wh/day = 72223.40*0.0416666667 = 3009.30 W

$$Efficiency = \frac{System\ output}{System\ input} = \frac{3009.30}{4743.93} = 63.43\ \%$$

After all the efforts from IDCOL and PO's the mentioned site carried quite a lot of fully functional diesel engines. It reflects that many of the farmers are still using diesel engine to irrigate their land. This is partly because of the literacy level and ignorance of the farmers.The farmers failed to understand the economic impact of using solar pump.

So, we present here a model to utilize the redundant electricity for a mini-grid.

Chapter 5

A Proposed Model of Solar Water Pumping to Reduce Cost

A Proposed Model of Solar Water Pumping to Reduce Cost

5.1 Design of the proposed model

After observing the present scenario of solar irrigation in Bangladesh including prospects, challenges and constraints, we tried to find out a viable solution to make our solar irrigation more sustainable.Considering all the aspects of grid networks and solar irrigation in Khustia, here we proposed a new irrigation model for that particular area. The main system will be divided into two parts-

- **Solar irrigation for cultivation.**
- **AC mini grid for fulfilling the demand of rural people.**

As our firstpriority is solar irrigation, so that we design the system considering the water pump as the primary load. From the analysis we found that farmers do not need water for irrigation every day in a month and battery is not required to run the water pump. Therefore, we do not need to run the motor every day. We will get a good amount of extra/unused electricity while the motor is off. Finally, we tried to make an AC mini grid using this extra energy for the domestic load of the rural people. We conducted a survey on the load demand for summer and winter season.

In our proposed model, the whole year has been divided into two sector. Summer seasonand winter season.

Winter Season:

During winter season our fertile land becomes so dry that farmers need to provide water in the land whole day.Alongside the rural people will be served by electricity if needed by the autonomy factor of batteries. Assurance has been given by the farmers that they do not need water everyday in winter season for irrigation. Therefore, the motor can berun in one day interval in winter season. Energy found from this interval can be stored in the battery for serving domestic load.

Summer Season:

During summer season motor will be turned-on for 4 to 5 hours every day.Due to rainfall and soil fertility, water requirement for summer is less than the winter season.After that rest of the hours of radiation is used to charge the batteries meeting the electricity demand for the rural people.

5.2 Specification for the proposed model for irrigation

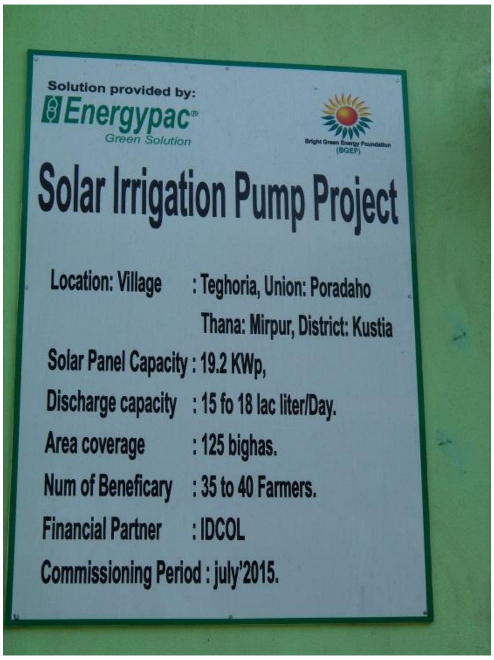

Figure 5.1: Specification for the proposed model for Irrigation

5.3 Calculation for solar irrigation

Load Calculation for winter season:

Load (Motor)- Size – 13 KW

Working hour per day - 8 hours (9.00am – 5.00pm) [28].

Energy Required - (13*8) = **104 kWh per day**

PV sizing:

Assume, The average peak sun hour = 4.2

PV Capacity $= \frac{Daily\ Energy * derating\ factor}{Avg\ peak\ sun\ hour * Wire\ loss * inverter\ eff}$

$= \frac{104 * 1.4}{4.2 * 0.98 * 0.96}$

PV Capacity $= \mathbf{36.848\ kWp}$

Inverter sizing:

Assume, efficiency 80%

$= 13 * 1.25 = \mathbf{16.25\ kw}$

5.4 Calculation for AC mini grid System

Summer Season:

From survey of the villages near the project site,

Assume,

Light = 10W

Fan = 20W

TV = 40W

Total domestic load demand $= 25.4\ kwh\ per\ day$

Battery sizing:

Assume, Total domestic load $= 40\ kwh\ per\ day$

to ensure availability of electricity as demand

Total Ampere hour per day $= \frac{Daily\ Energy}{System\ Nominal\ voltage}$

$$= \frac{40\ kwh}{48\ v}$$

$= 833.33\ Amp\ hour\ per\ day$

Corrected load

$$= \frac{833.33\ Amp\ hr\ per\ day}{Battery\ loss * Charge\ cotroller\ loss * inverter\ eff * wiring\ loss}$$

$$= \frac{833.33}{0.9 * 0.98 * 0.96 * .98}$$

$= 1004.27\ Amp - hr\ per\ day$

Size of Battery $= \frac{Amp-hr}{Day} * \frac{Days\ of\ Autonomy}{Depth\ of\ Discharge}$

$$= \frac{1004.27}{Day} * \frac{2}{0.6}$$

$= 3347.57\ Amp\ hour\ (Ah)$

Battery in parallel $= \frac{3429.35\ Ah}{200\ Ah}$

$= 17\ Batteries$

Battery in Series $= \frac{System\ nominal\ voltage}{Battery\ voltage}$

$$= \frac{48}{12}$$

$= 4\ Batteries$

Total number of batteries $= (17 * 4)\ Batteries$

$= \mathbf{68\ Batteries}$

<u>Winter Season:</u>

Total domestic load demand $= 8.34\ kwh\ per\ day$

Batteries that calculated for summer $= \mathbf{68\ batteries}$ where the load is 25.4 kWh

Therefore, **68 batteries are also sufficient for winter season because the load is only 8.34 kWh**

<u>Conductor:</u>

In our design we choose ACSR - **Tharasher**Conductor out of different types of aluminum conductors. Characteristics of the **Tharasher**are given below:

- Diameter : 0.045771 m
- $R_{at\ 27C}$: 0.0266 ohm/km
- Ampacity : 1000A

5.5 Calculation using HOMER software

5.5.1 About Homer

HOMER is a computer model that simplifies the task of designing distributed generation (DG) systems - both on and off-grid. HOMER's optimization and sensitivity analysis algorithms allow us to evaluate the economic and technical feasibility of a large number of technology options and to account for variations in technology costs and energy resource availability. HOMER can model both the technical and economic factors involved in the project. It can provide an important overview that compares the cost and feasibility of different configurations; then designers can use more specialized software to model the technical performance.

- solar photovoltaic (PV)
- wind turbine
- hydro power
- biomass power
- generator: diesel, gasoline, biogas, alternative and custom fuels
- micro turbine
- fuel cell

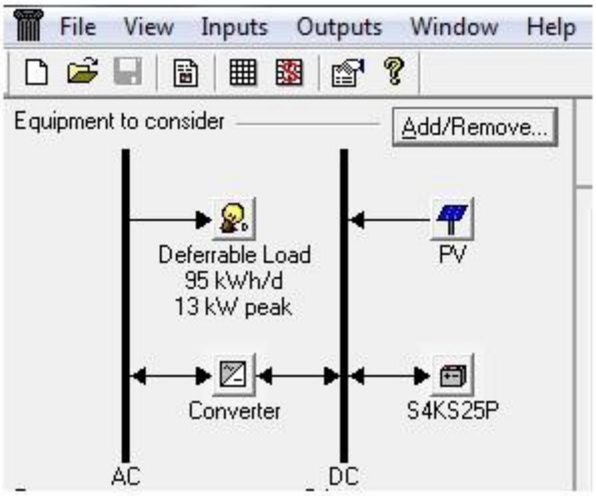

Figure5.2 : Considering necessary equipment

Some important parameters of Homer

5.5.2 Primary load

Primary load is electrical load that the system must meet immediately in order to avoid unmet load. In each time step, HOMER dispatches the power-producing components of the system to serve the total primary load.

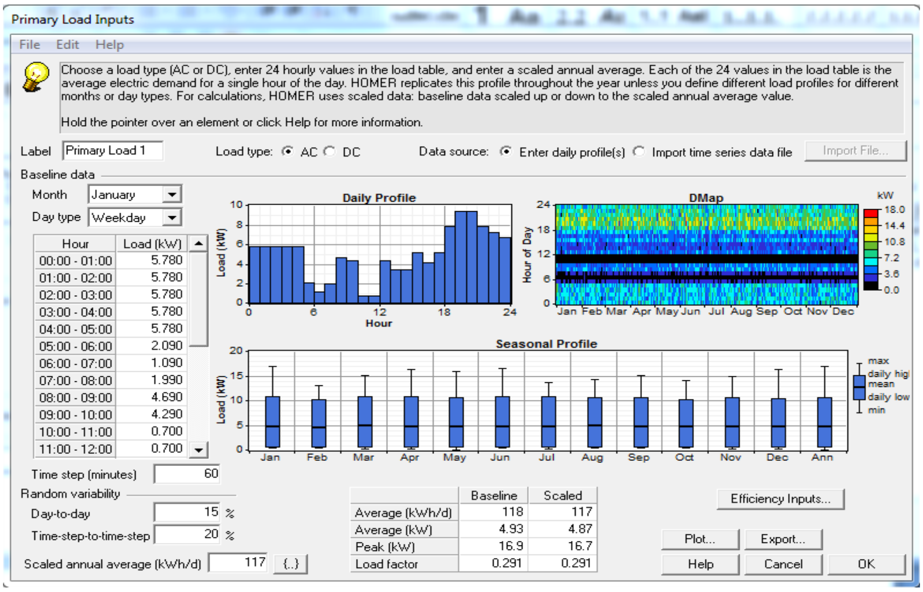

Figure 5.3: Primary Load input

5.5.3 Deferrable load

Deferrable load is electrical load that must be met within some time period, but the exact timing is not important. Loads are normally classified as deferrable because they have some storage associated with them. Water pumping is a common example - there is some flexibility as to when the pump actually operates, provided the water tank does not run dry. Other examples include ice making and battery charging.

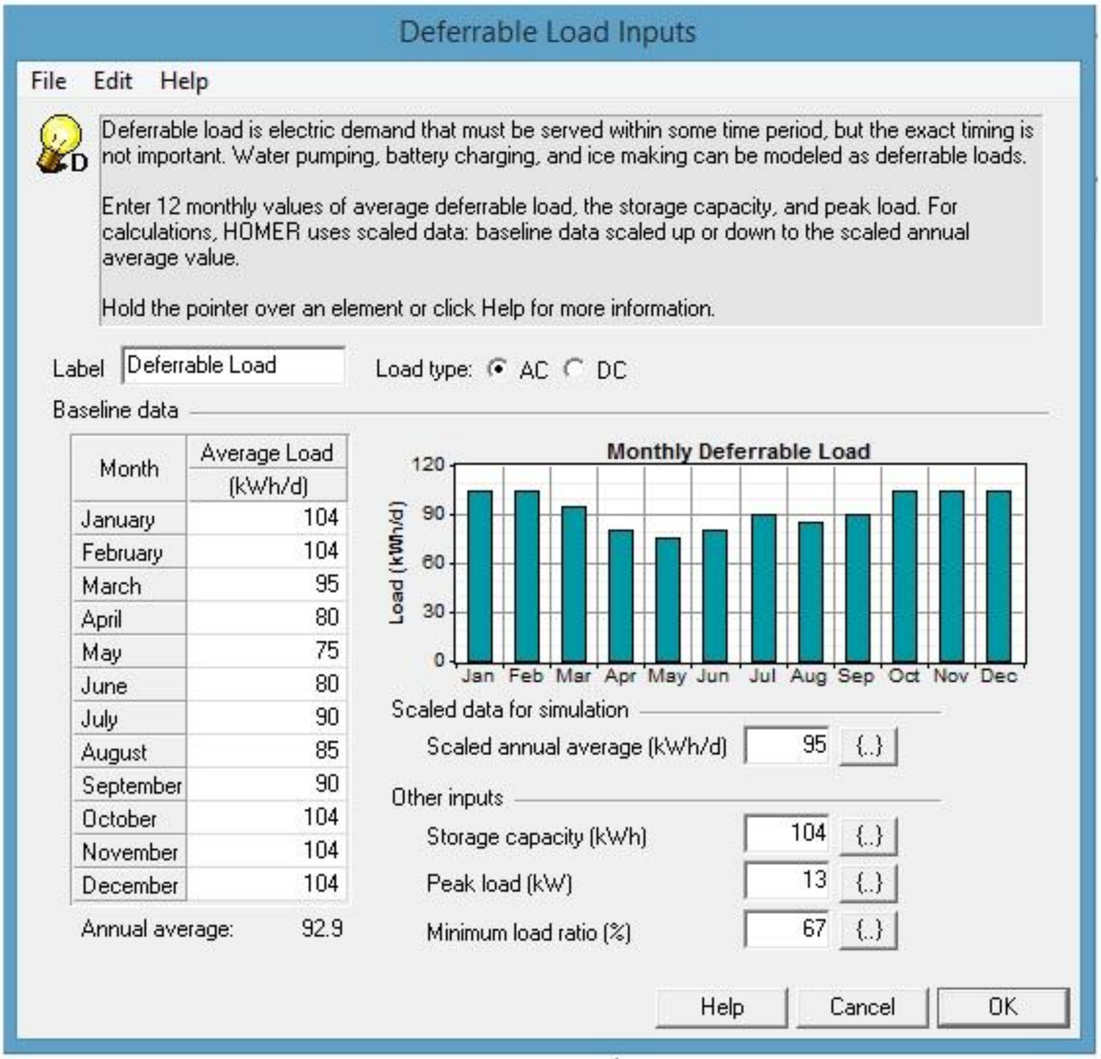

Figure 5.4: Deferrable Load input

5.5.4 PV Input

PV input is to provide the PV information for instance capital, replacement, operation & maintenance cost and also the sizes of PV etc. When specifying the capital and replacement costs, it is necessary to account for all costs associated with the PV subsystem, which includes [3].

- PV panels
- mounting hardware
- tracking system
- control system (maximum power point tracker)
- wiring
- installation

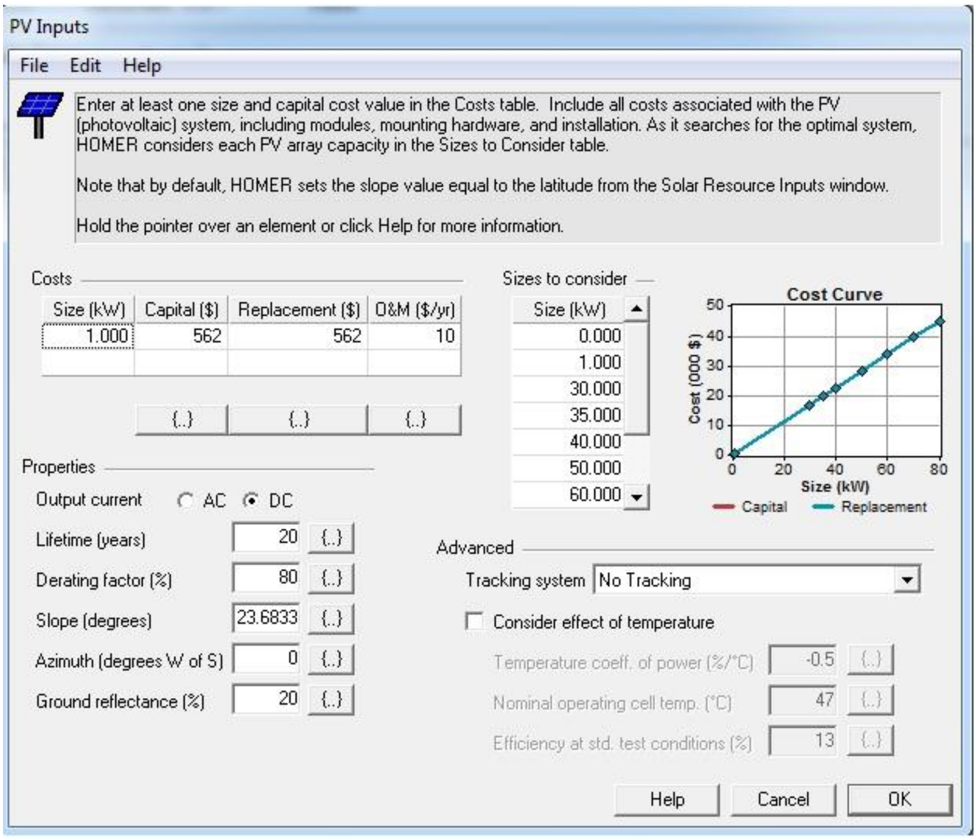

Figure 5.5: PV input in HOMER

5.5.5 Battery Input

Battery input is used to choose the type of battery, specifying its costs including capital, replacement, operation & maintenance cost and also the sizes etc.

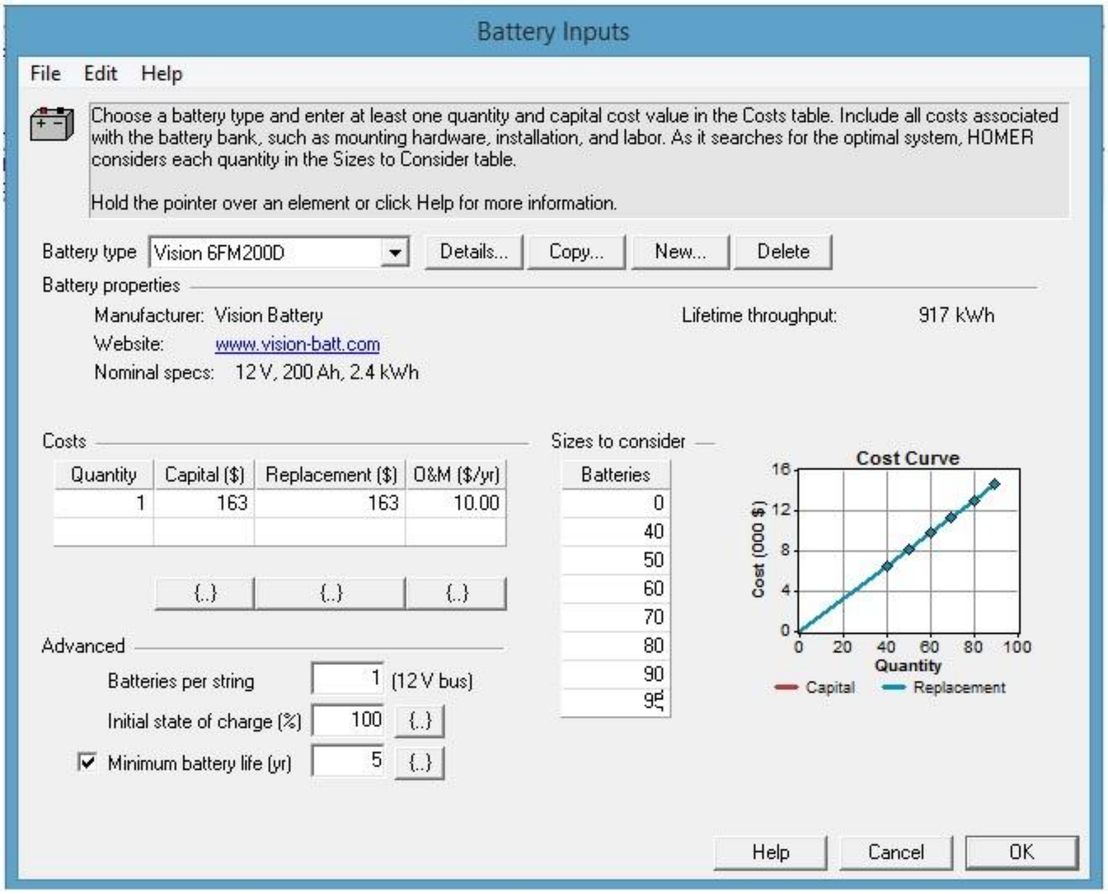

Figure 5.6: Battery input

5.5.6 Converter Input

Any system that contains both AC and DC elements requires a converter. This converter input allows to define the cost curve of the converter and choose the sizes for HOMER to consider as it searches for the optimal system.

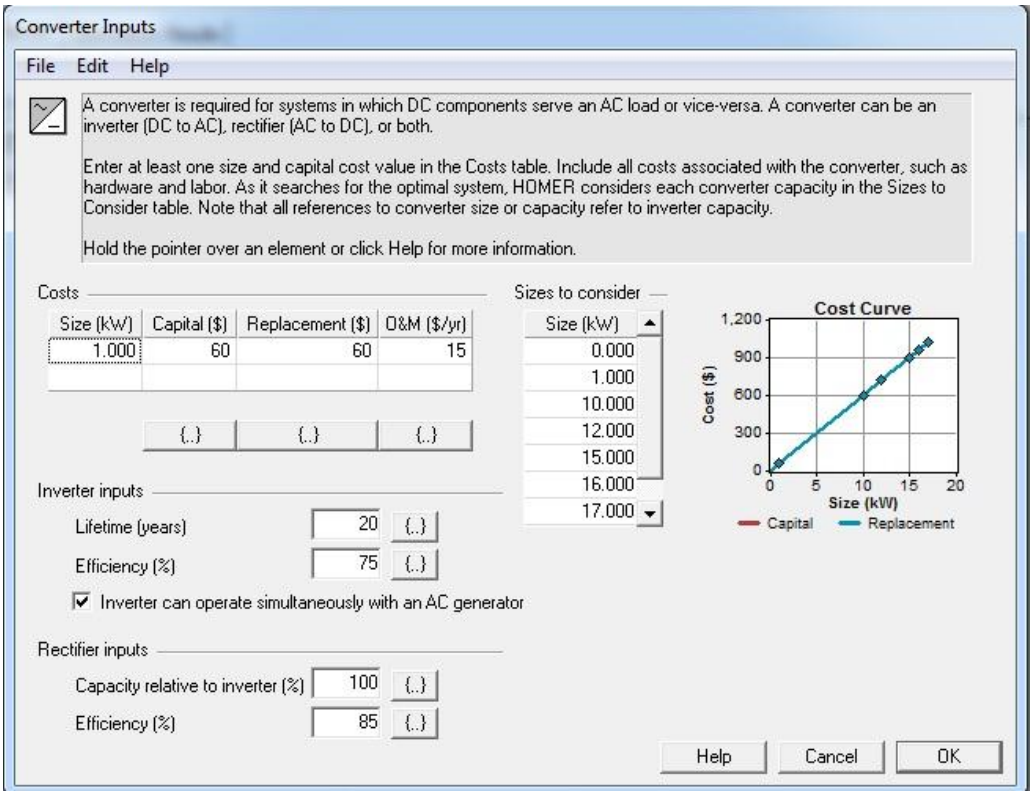

Figure 5.7: Converter Input

5.5.7 Solar Resource Input

Solar Resource Input is used to give input the daily solar radiation data. Homer uses solar resource inputs to calculate PV array power for each hour of the year.

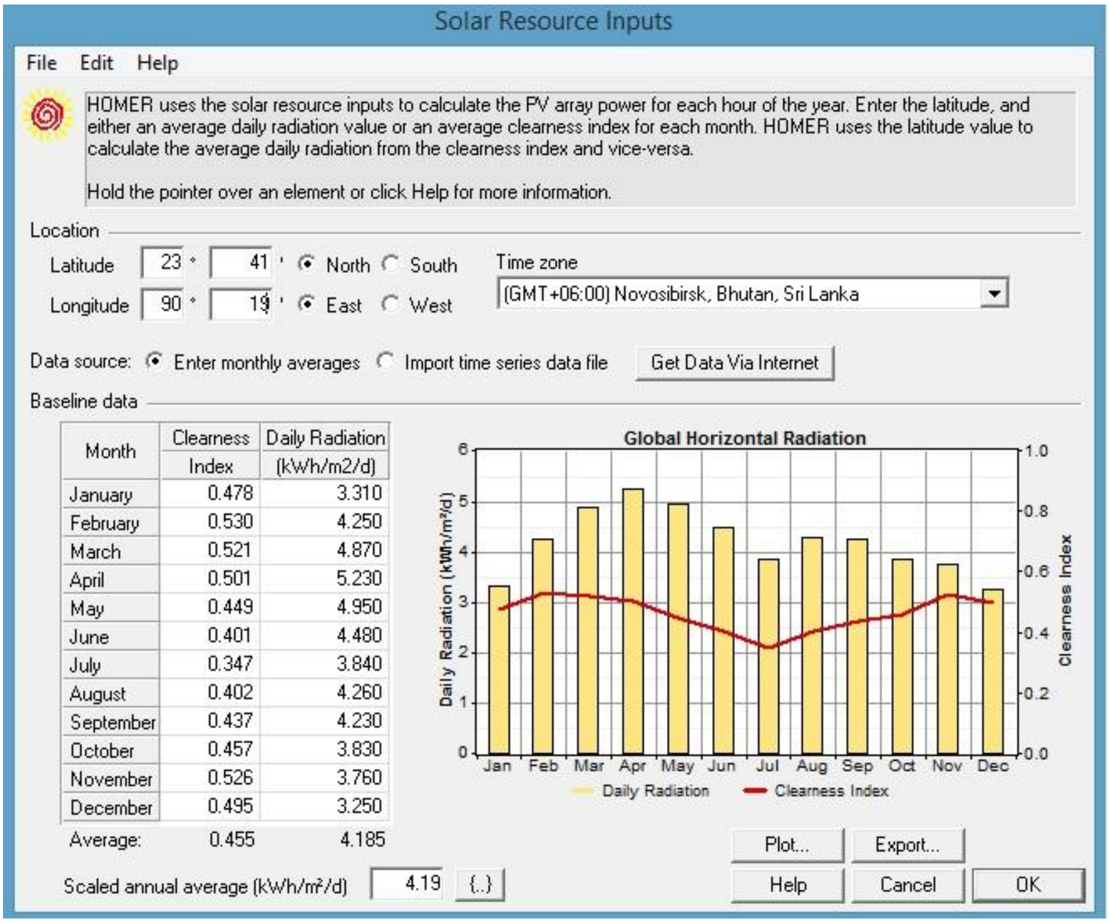

Figure 5.8: Solar resource input [25]

5.5.8 Cost of Energy (COE)

It is the average cost per kWh of electricity. The COE is a convenient metric with which to compare systems in HOMER.

5.5.9 Net Present Cost (NPC)

The total net present cost of a system is the present value of all the costs that it incurs over its lifetime, minus the present value of all the revenue that it earns over its lifetime. Costs include capital costs, replacement costs, O&M costs, fuel costs, emissions penalties, and the costs of buying power from the grid. Revenues include salvage value and grid sales revenue. HOMER calculates the total NPC by summing up the total discounted cash flows in each year of the project lifetime.

5.5.10 Sensitivity Analysis

Multiple values for a particular input variable can be entered in HOMER. HOMER repeats its optimization process for each value of that variable and it can be seen how the results are affected. An input variable for which multiple values are specified is called a sensitivity variable,and we can define as many sensitivity variables as we want.

5.6 Output from the calculation in HOMER

Cost of Energy (COE) is one of the important parameter to determine per unit cost to produce 1kwh energy based on your given design. **The COE of our posed design is 0.203 US dollars which is equivalent to 16.24 in BDT. That means the cost of energy is 16.24 tk/kwh.**

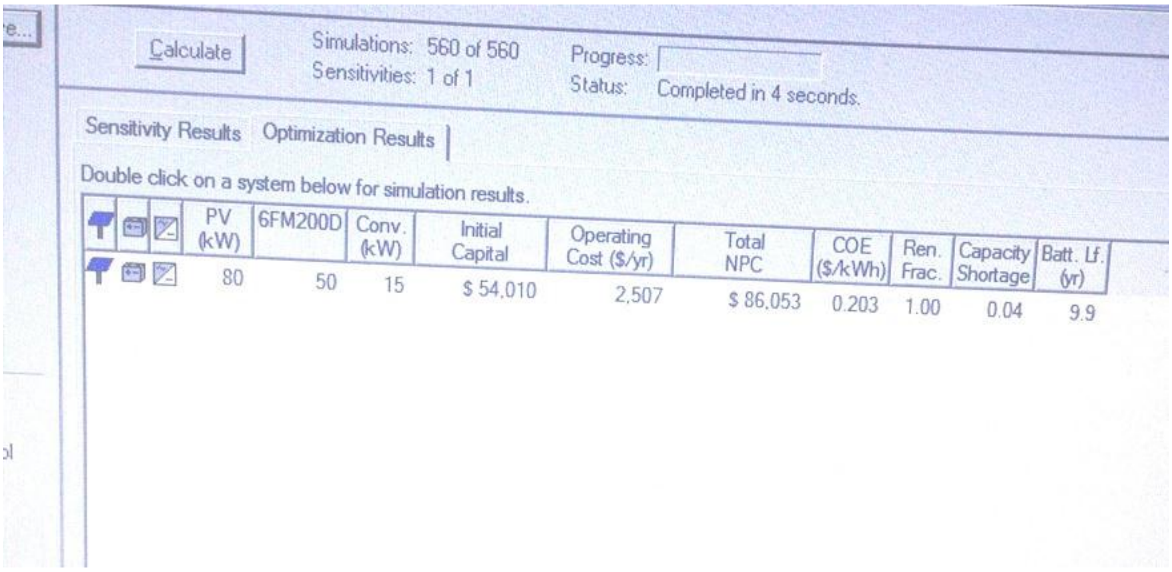

Figure 5.9: Cost of Energy based on the proposed design

5.7 Total system at a glance

The following figure shows the total system including different inputs and outputs from the HOMER analysis.

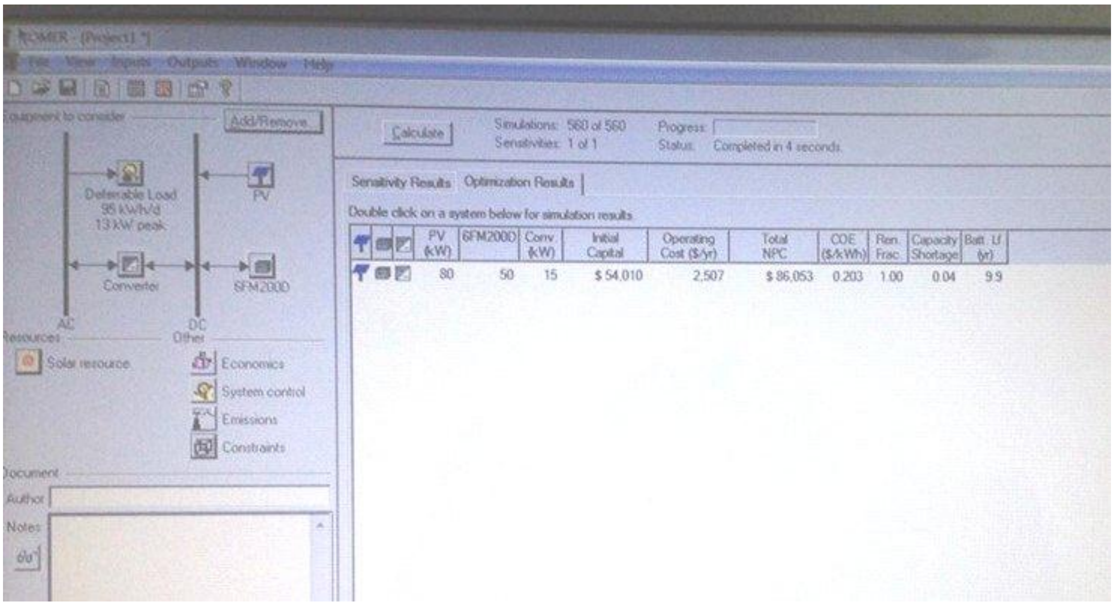

Figure 5.10: Inputs and outputs in HOMER window

Chapter 06

Results and Discussion

Results and Discussion

6.1 Important findings

After analyzing some recent data from IDCOL on solar irrigation in Bangladesh for different divisions and visiting a practical solar water pumping system at Kustia and measuring the performance of the system, some important findings regarding solar irrigation in Bangladesh are presented here. In this paper, the result is divided into different points as given below:

- Important concerns of solar irrigation in Bangladesh for different divisions
- Showing a comparison between diesel pump and solar pump at the particular area surveyed
- Proposing an ac mini-grid along with the existing solar water pumping system with some special features
- Fulfilling the electricity demand of the rural people in both summer and winter season at the time of load shedding in that particular area
- Minimizing the cost by the addition of an ac mini-grid which makes the total system more feasible for the rural farmer as well as for the solar pump owner

6.2 A brief discussion on the result

6.2.1Planning to set a new solar irrigation system

Before planning to set a new solar water pumping system some important concerns should keep in mind. As there are seven divisions in Bangladesh so the radiation, water head and water demand for crops are not same for geographical reason. Therefore some important concerns found from the data analysis are given below which will help to set up a feasible solar pump for different divisions in Bangladesh.

- Almost 200 solar pumps are installed at Rangpur division out of 450 pumps and the average pump head is 13.44m for Rangpur.
- PV size in KW increases with the increase of pump head.
- Division with higher pump head will require the higher pump capacity.
- Highest average water flow (m^3/day) has been found at Khulna division is 1207m3/day and 46% of the total installed pumps are at Khulna.
- Rangpur is at 2nd position in the figure with average water flow of 688.12 m^3per day and 44% of total installed pumps are found at Rangpur.
- 205 solar pumps are installed at Khulna division.
- The maximum monthly average sunshine hour is 6.2 at Rangpur division.
- The sunshine hour for Dhaka division in consistently poor over the year compare to other divisions.
- Rangpur requires least average water for irrigation per month per hectare land among seven divisions.
- It is seen that in every division Boro requires the highest amount of water for irrigation compare to other crops. It needs almost 5500 m^3 water per month per hectare for irrigation.

6.2.2 Comparison between diesel pump and solar pump

Near the project area some diesel based pumps are still running. We talked to the rural farmers who are using these diesel pumps about the cost of the diesel based irrigation. According to the farmers and solar project owner's words an important comparison has been done between solar pump and diesel pump. The following table shows the important comparison.

Issues	Diesel pump		Solar pump
Land area	1 bigha		1 bigha
Irrigation	1 time		1 time
Cost **1bigha and 1 irrigation**	Engine rent	Diesel price	3 months, total 50 times irrigation cost= 3500 tk
	200 tk	70 tk/lit *2	
	Total=340 tk		**Only 70 tk**
Cost per season per bigha(Boro)	25 irrigations (200*25)+(50*70) **= 8500tk**		50 irrigations **Only 3500tk**
Labor	1		None
Quality of crop	Good		Better
Availability of water	Not available		Available

6.2.3 Addition of the ac mini-grid with existing system

A simple block diagram of the proposed model is given below where both solar pump and a mini-grid are connected with the solar panel.

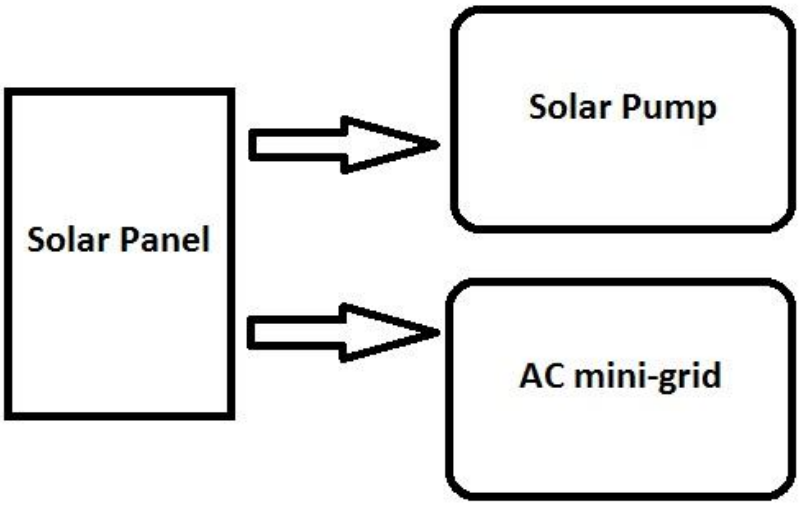

Figure 6.1: Model of incorporation of ac mini-grid with existing system

6.2.4 Providing electricity to the rural people in both summer and winter season

In the proposed model, an ac mini-grid is incorporated with the existing system. Therefore, some extra energy can be stored in battery and this extra energy is delivered to the rural people for their domestic load because of huge load shedding in that area. From the survey, we found the electricity demand of rural people for different seasons.

Assume,

Light = 10W

Fan = 20W

TV = 40W

For summer season- Total domestic load demand $= 25.4\ kwh\ per\ day$

For winter season- Total domestic load demand $= 8.34\ kwh\ per\ day$

Electricity demand for both season can be fulfilled from the extra energy from mini-grid.

6.2.5 Making the system more feasible in term of cost by adding an ac mini-grid

After getting the load demand of the rural people, HOMER software is used to analyze the feasibility of the proposed model in terms of cost of energy (COE). The result from the HOMER software is given below:

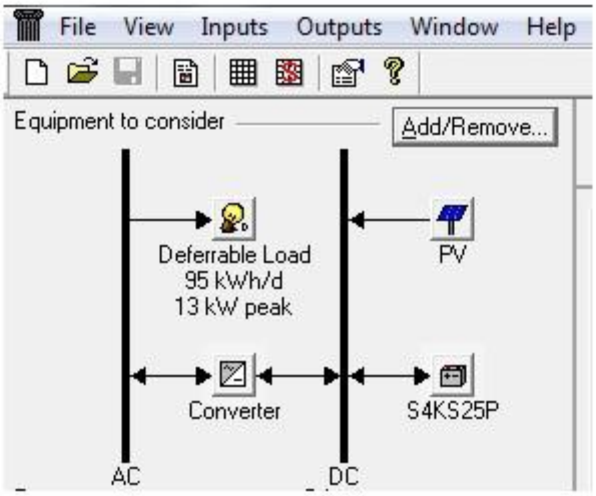

Figure 6.2: Simulation of the proposed model

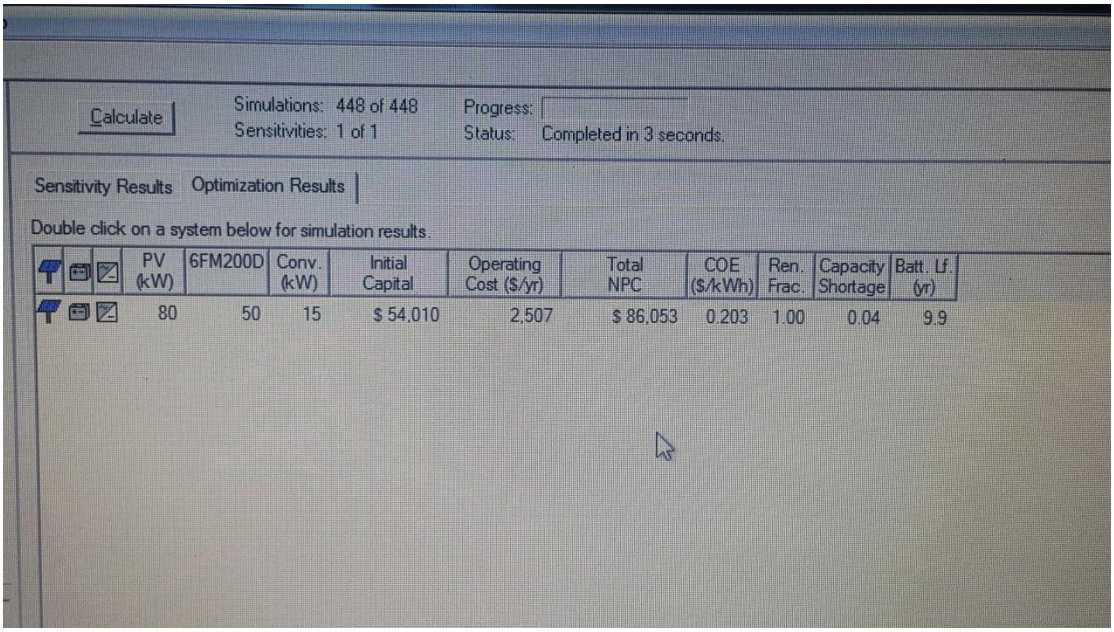

Figure 6.3: Result from the simulation done by HOMER

According to the information which is provided by BGEF, practical field analysis and simulation using HOMER software the following cost analysis has been made.

	Excluding mini-grid	**Including mini-grid**
Cost of energy	Cost of Energy 24 tk/kwh	Cost of Energy 16.24 tk/kwh
Monthly installment (Boro crop-3months)	3500tk	2368 tk

Table 6 : Cost of energy calculation

The charge of electricity from the rural people can be considered as an extra profit to the owner.

6.3 Conclusion

As agriculture is the single largest producing sector of the economy which comprises about 18.6% (data released on November, 2010) of the country's GDP and employs around 45% of the total labor force [27],irrigation plays a vital role in this sector. In addition, considering load shedding and off-grid areas of Bangladesh IDCOL is providing financial support to solar irrigation projects in different areas of Bangladesh. In this paper, almost 450 irrigation project’s data has been analyzed of different divisions. Some important concerns are shown by graphical representation from the analysis which can be very helpful for upcoming irrigation projects of Bangladesh. Comparison between diesel pump and solar pump are found from the practical visit of a project at Khustia under IDCOL. A small survey was also conducted on 50 houses of that area about their electricity demand during load shedding. Considering different aspects of that project and attitude of the farmers and owner, a new model of irrigation is proposed in this paper. Furthermore, the new model consists of an ac mini-grid system with the existing previous one. According to the new model, some extra energy is stored in the mini-grid and it is serve to the rural people during the time of load shedding. In this way, rural people get electricity as their demand. On other hand, the overall cost of the irrigation system is also minimized which was found from HOMER software. It was found from the practical visit that though the cost of solar based irrigation is less than the diesel based irrigation, owner of the project and farmers are not happy with solar irrigation for different reasons. In this new model, both party become more interested about solar irrigation as the installment for the crops decreases at a good rate. Rural people become more efficient as they get electricity for the duration of load shedding. It can also change the life style of the rural people.

Therefore, Irrigation along with ac mini-grid can be a great approach to make the solar irrigation system more feasible in Bangladesh. It has been suggested in this paper that the irrigation system is incorporated with an Mini grid system which means that the electricity will have alternative uses all the year round

6.4 Future Recommendation

1. If we can ensure the distance between panel and ground is about 4 feet, this place under panel can be utilized by cultivating Ginger , Garlic.
2. Extra electricity after serving domestic load demand can be used by charging Auto bike or Easy Bike which is renowned in villages.

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