Design and Fabrication of Solar Agricultural Water Pumping System and Cost Comparison with a Diesel Pump

Md. Saifur Rahman¹, Juwel Chandra Mojumder¹, Md. Yousuf Mia², Romel Barua³, Anamul Hossain⁴

¹, ², ³, ⁴ Department of Mechanical Engineering, Chittagong University of Engineering & Technology (CUET), Bangladesh

E-mail: jamilme55@gmail.com¹, juwel099@gmail.com¹, yousufme07@yahoo.com², rome07cuet@gmail.com³, kmanamul@hotmail.com⁴

Abstract

Bangladesh is an agricultural country. Most of our economy depends on agriculture. Irrigation system of water is very important factor for cultivation. But every year irrigation system is collapsed due to shortage of energy source. So an alternative source of energy is very essential for our economy. Also Bangladesh is an under developed country. In many regions of our country where the energy like diesel, octane, petrol etc. are not available or so expensive. So, solar energy is very effective in these places. Solar energy is a renewable energy that comes from sun’s heat energy. Our main aim focuses to run a water pump by using solar energy. Our water pumping system consists of a solar panel, charge controller, DC centrifugal pump and a battery. Solar panel converts this light energy into electrical energy. Then DC power from solar panel is passed through the digital solar charge controller. A 12V dc battery is charged through the charge controller. Then a 10W dc centrifugal pump is connected to battery output. Finally pump supply water to the reservoir or agricultural land. We also made a comparison between solar water pump and diesel pump based on cost.

Keywords: Agriculture, Energy, Solar panel, Pump, Cost

1. Introduction

There are two sources of energy such as renewable and nonrenewable source. A nowadays nonrenewable source of energy is mostly used such as fossil fuel. However, the amount of fossil fuel is limited on earth. using of fossil fuel already has created environmental pollution which causes global warming effect. The exhaust gas have been produced during combustion of fossil fuel contain CO₂, CO and other harmful gas. These gases are results greenhouse effect. Sources of renewable energy such as solar energy, wind energy, tidal energy and so on. All of them, solar energy is more efficient compared to others.

For investigations the performance of solar pump, many researchers designed and analyzed various systems. Solar water pumping system was first made in 1979. Solar pumping technology continues to improve. In the early 1980s the typical solar energy to hydraulic (pumped water) energy efficiency was around 2% with the photovoltaic array being 6-8% efficient and the motor pump set typically 25% efficient. Today, an efficient solar pump has an average daily solar energy to hydraulic efficiency of more than 4%. Photovoltaic modules of the mono crystalline type now have efficiencies in excess of 12% and more efficient motor and pump sets are available. A good sub-system (that is the motor, pump and any power conditioning) should have an average daily energy throughput efficiency of 30-40%.

There are various activities in rural Bangladesh which totally depend on the use of solar energy if these could be performed more quickly and efficiently by using simple devices, it would increase productivity without making and demand on commercial energy sources. In Bangladesh research and development work to harness solar energy in the form of heat has been going on for many years at Dhaka University, Bangladesh Agriculture University, BUET, Solar Park of Dhaka College and BCSIR Laboratories. There are more than 10,000 solar powered water bore pumps
in use around the world today. They are widely used on farms and outback stations in Australia to supply bore water to livestock. In developing countries they are used extensively to pump water from wells and rivers to villages for domestic consumption irrigation of crops.

A typical solar powered pumping system consists of a solar panel array that powers an electric motor, which drives a bore pump. The water is often pumped from the ground or stream into a storage tank that provides a gravity feed. No energy storage is needed for these systems. PV powered pumping systems are a cost-effective alternative to wind systems.

2. Objectives of the project

1. To design and fabricate a solar agricultural water pumping system
2. To make a cost comparison of solar pump with diesel pump

3. Descriptions

A Solar panel is devices which receives sun light and then convert into electrical energy. My project is to run a water pump by solar electricity for agricultural irrigation. Every year Bangladeshi farmers face a great problem during irrigation due to power crisis. Farmers cannot continue irrigation properly. As a result, the production of paddy decreases a great amount which affect our gross economy. Solar energy may be a solution of this problem. Solar electricity from solar panel can be used as alternative energy to continue irrigation. A number of attempts have been made by scientists to utilize solar energy for irrigation water pumping. It is mainly a problem of conversion of heat energy available from the sun, to mechanical energy. Some ingenious methods have been devised to utilize the available energy at low temperatures. This paper reviews past efforts to develop solar thermal water pumping systems which employ either conventional pumps or unconventional pumps, and emphasizes how the system modifications were made to suit different pumping conditions and requirements. Photovoltaic (PV) modules (i.e. solar electric panels) produce electricity from sunlight using silicon cells with no moving parts.

4. Methodology

This chapter explains detail about the methodology of the whole system and flow of step that used in solar agricultural water pumping system. This chapter also describes further more about the planning of the whole project. This project is based on solar energy. Solar energy is available and unlimited around the world. In this project solar energy is converted into electrical energy that is used to run a dc pump for collecting water from underground level. This water is supplied to crops land for irrigation. Sunlight is incident on solar panel which supply dc current. A solar charge controller is used after solar panel to regulate current and voltage. A battery is also used to restore electricity to supply current. Then current is passed by wire to dc pump. DC pump is settled to the ground level. DC pump collect water and store to reserve tank. A float switch is used to stop the motor when the tank is full of water. Then water is passed to narrow canal to crops land.

4.1 Flow chart

5. Importance

In developed country solar electricity is widely used for various purposes, for example: solar water heating, solar power plant, solar powered car, solar powered air conditioner, solar water pump, solar boat etc. In Bangladesh solar electricity is not so popular compared to developed country. But some institute and organization such as Grameen Shakti, BRAC try to spread out the using of solar electricity. Bangladesh power development board can not generate sufficient electricity for supplying electricity throughout the country especially rural areas and hill tract areas. In the “boro” season PDB cannot supply sufficient electricity. So a solar agricultural water pumping system may be a good system for irrigation.
6. Advantages of solar pump set
   i. No fuel cost-uses abundantly available free sun light.
   ii. No conventional grid electricity required.
   iii. Highly reliable and durable-free performance.
   iv. Easy to operate and maintain.
   v. Eco-friendly.
   vi. Saving of conventional diesel.

7. Application of solar pump set
   i. Livestock Watering: Cattle-Sheep-Poultry-Exotics
   ii. In addition to these, SWT System have been used for pumping in
   iii. Irrigation both small-scale traditional and drip
   iv. Orchard and tree nursery watering
   v. Fish ponds
   vi. Pollution monitoring and remediation wells
   vii. Wildlife water supply

8. Limitations and scope
   Bangladesh power development board can not generate sufficient power. As a result BPDB is unable to transmit
electricity to hill track area as well as north Bengal rural areas. So farmers of rural areas depend on river, canal or
pond water. Otherwise they depend on shallow machine which run by fossil fuel. As a result the production cost of
paddy is very high. When river or canal is dried up, farmers cannot irrigate to their land. So the production rate of
paddy decreases. Solar water pumping system will be very effective for irrigation. But solar water pumping system
must be cheaper than any other irrigation system. This system must be made within low cost as much as possible.
Solar panel is very expensive. If farmers of a village make a organization together to contribute a solar water
pumping system, then this pumping system will be cheaper.

9. Experimental set up
   Solar irrigation pumping system is very easy to install. It is free from environmental pollution. There is no
maintenance cost for the system. It's initial setup cost is quite large, but if we connect several solar panels with
several pump in series than the cost will be less in respect of long term service, because a solar pump can run
continuously without any need of electricity. So a large amount of crops produced in terms of conventional diesel
pump & there is no fuel cost. The system consists of a solar panel, a digital solar charge controller, a 12V dc battery &
a dc pump.

10. Digital Solar charge controller
   Solar charge controller is designed to protect 12V lead-acid or gel-cell battery from being overcharged by solar
panel, which prevents discharge of battery during night time. This controller reduces overall system maintenance
and prolongs your battery life. It will continuously display the charging current or battery voltage in charging
proceeding from LCD digital meter. It also automatically indicates the battery condition from LED bar-graph.
This controller is designed to work with all kinds of 12volts solar panels for indoor use.

   Features:
   i. Digital voltage and current: Continuous display for battery and solar panels
   ii. Battery type selected: select the gel-cell or lead-acid battery by selector switch
   iii. Protection of battery: Protect batteries from solar over charged and maintains battery in fully charged state.
   iv. Safety circuit protection: short circuit and reverse polarity protection
   v. Reverse leakage protection: protect batteries from solar power discharge
   vi. Over temperature protection: over temperature protection and auto resume

10.1 A 12V Lead-Acid battery
   An alternative to large storage capacities is to install a battery backup system in conjunction with the solar system.
Battery Backup systems are required by some on-demand pump systems where water must be available 24 hours per
day 7 days per week but battery systems involve more initial cost and require more maintenance than direct solar
systems. The higher cost and increased maintenance can be avoided in most applications by proper direct solar
system sizing.
10.2 DC pump
The pump, driven by a 12 volt dc motor, draws water from wells or rivers, then pours water into the reservoir or storage tank, or directly to irrigation systems and fountain systems. Based on the requirements and installation conditions, different types of pumps can be used. In solar pumping system, selection of pump is essential, which directly affects the economy and stability of the whole system. Submersible pumps which have widely application and speed-regulating range, are common in solar pumping systems, and it also can increase daily working time and water now rate of the solar pumping system. If the users require low head and high water flow, can choose self-priming pump, while they require high head and low water flow can be chosen volume delivery pumps.

11. Data collection and analysis
11.1 Data collection method
i. At first solar panel was setted at highest pick point of the sun in the roof
ii. A solar charge controller was connected to the panel through the connector plug
iii. After that a 10 watt dc pump was connected from the output of the controller
iv. We have measured voltage and current through the multi-meter at various conditions for various span of the day
v. After getting all the data, we measured power and plotted various graphs

11.2 Data analysis by graph

Result: Current increases rapidly with the change of voltage
Fig 3: Battery charge rate (dated at 25-09-12)

**Result:** Voltage increases rapidly with the change of time

Fig 4: Head vs. flow rate (dated at 26-09-12)

**Result:** Flow rate increases rapidly with respect to head

Fig 5: Power vs. time (dated at 26-09-12)

**Result:** Power is produced with a short of time

Fig 6: Impeller speed vs. power (dated at 26-09-12)

**Result:** Power is produced slowly with respect to impeller speed
12. Cost analysis

12.1 Sizing of solar pumps
The hydraulic energy required (kWh/day) = volume required (m³/day) x head (m) x water density x gravity/(3.5 x 10⁶)
= 0.002725 x volume (m³/day) x head (m)
The solar array power required (kwp) = Hydraulic energy required/Av. Daily solar irradiation
Where, F = array mismatch factor = 0.85 on average
And E = daily subsystem efficiency 0.25 – 0.40 typically

12.2 Estimating Solar Electric (PV) System Size: Area of Solar Panel
On average (as a general "rule of thumb") modern photovoltaic (PV) solar panels will produce 8 - 10 watts per square foot of solar panel area. For example, a roof area of 20 feet by 10 feet is 200 square-feet (20 ft x 10 ft). This would produce, roughly, 9 watts per sq-foot, or 200 sq-ft x 9 watt/sq-ft = 1,800 watts (1.8 kW) of electric power.

12.3 Converting Power (watts or kW) to Energy (kWh)
One kilowatt-hour (1 kWh) means an energy source supplies 1,000 watts (1 kW) of energy for one hour. Generally, a solar energy system "Virri" 11 provide output for about 5 hours per day. So, if you have a 1.8 kW system size and it produces for 5 hours a day, 365 days a year: This solar energy system will produce 3,285 kWh in a year (1.8 kW x 5 hours x 365 days).
If the PV panels are shaded for part of the day, the output would be reduced in accordance to the shading percentage. For example, if the PV panels receive 4 hours of direct sun shine a day (versus the standard 5 hours), the panels are shaded 1 divided by 5 = 20% of the time (80% of assumed direct sun shine hours received). In this case, the output of a 200 square-foot PV panel system would be 3,285 kWh per year x 80% = 2,628 kWh per year.

13. Cost calculation
For solar pump
Let assume, area of land = .03 acre = .03 x 4048.327 m² = 121.44 m²
So, capacity of water required for one time irrigation = 121.44 x .03 m³ = 3.6432 m³ = 3643.2L
Flow rate = .032 L/s for 2m head
Time required for one time irrigation = 31.625 hr = 15.8 hr /day
Cost:
- Solar panel – Tk.1700 (20W @85/W)
- DC pump – Tk. 500 (10 W)
- Charge controller –Tk.1000
- Battery - Tk. 1100 (12V)
Total: Tk. 4300 for .03 acre land
So, for 1 acre, total cost = Tk. 4300 x 33.3 = Tk. 143190
We know, solar pump sustain 20 years (on an average)
So, cost of irrigation for 1 acre land for one season =143190/40 =Tk.3579.75
For diesel pump:

Specification of diesel pump
- Type: Centrifugal pump
- Max” Suction Head = 60-70 ft
- Speed = 1400 rpm
Cost:
- Diesel cost for 1 acre for one season = Tk. 4575
- Lub. Oil cost for 1 acre for one season = Tk.240
- Diesel pump cost for 1 acre for one season =Tk. 300
- Maintenances cost for same criteria = Tk. 154
So, cost of irrigation of 1 acre land for one season by diesel pump = Tk.5269.

Saving
So, savings by solar pump = Tk. (5269 – 3579.75) = Tk.1689.25/acre for one season
7. Conclusion
Solar energy is one of the effective renewable energy. Day after day the amount of fossil fuel is decreasing but on the other side solar energy is free and unlimited. It has no environmental pollution. In our country, there are a lot of scopes to use solar energy. For this reason, I have completed this project. In our country solar water pump used in agriculture will be a very good step. Bangladesh is under developed country. In many regions of our country where the energy like diesel, octane, petrol etc are not available. So, solar energy is very effective in these places. Although solar panel is expensive but it has no fuel cost. If the government of Bangladesh helps farmers, then it will be superior. After all, I can say that my project will be very helpful to our country’s economy. The main purpose of this my project is to reduce cost and to make it as a general mass use. From the cost analysis of the project, I compared the total irrigation cost of solar pump with diesel pump and finally found that total cost of solar pump is cheaper than the other one. So, if we utilize the solar pump in our agricultural area, it will be helpful to our country’s economy.

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