American Journal of Modern Energy
2022; 8(1): 6-17
http://www.sciencepublishinggroup.com/j/ajme
doi: 10.11648/j.ajme.20220801.12
ISSN: 2575-3908 (Print); ISSN: 2575-3797 (Online)

Design of Solar Powered Water Lifting System for Irrigation at Chaukune Ward No.1, Surkhet, Nepal

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To cite this article:
Sagar Giri, Bibek Karki, Bikash Adhikari. Design of Solar Powered Water Lifting System for Irrigation at Chaukune Ward No.1, Surkhet, Nepal. *American Journal of Modern Energy*. Vol. 8, No. 1, 2022, pp. 6-17. doi: 10.11648/j.ajme.20220801.12

Received: December 24, 2021; **Accepted**: January 12, 2022; **Published**: March 11, 2022

Abstract: Despite the availability of enough water in Nepal, there is difficulty in irrigation in most of the places. This is due to difficult terrain in hilly and mountainous region. Hand water pumping is possible only in terai region and grid electricity has not reached in most parts of hilly and mountainous region. For these reasons, solar water pumping from appropriate source is the best option. The main objective of this project was to design a solar powered water pumping system at Chaukune ward no 1, Surkhet district. The targeted area had water demand of 400.171 m^3 per day, which was supplied from a perennial river, Budhakhola. With a distance of 732 m between the pump and reservoir, a circular reservoir of diameter 11 m, height 13 m and thickness 0.3 m was designed at an elevation of 219 m from the water surface. Solar module of rated power 87.48 kW (18 in series, 18 in parallel) was selected. The volume of storage tank is 1200.513 m^3, which is sufficient to store water for 3 days. The upfront cost, operation and maintenance, replacement cost of diesel pump are about 2-4 times higher than solar photovoltaic pump. The solar pumping system does not emit greenhouse gases. Solar water pumping is found to be economically viable and environment friendly in comparison to electricity or diesel based systems for irrigation.

Keywords: Circular Reservoir, Environment, Grid Electricity, Irrigation, Pump Efficiency, Solar Pumping

1. Introduction

Nepal has unique geographic terrain with steep valleys which makes difficulty in retaining water. Mostly, the land of hilly and mountainous regions of the country has this situation. Generally, monsoon season (June-August) is the only season for rainfall. For the rest of the time, people have to rely on pumping water from nearby sources (by using electricity), irrigation canals with non-uniform flow of water, manual collection or hand pumping to some extent which makes difficulty in irrigating the field and also results in less crop yields. One of the most abundant environment friendly source of energy in the world is solar energy. The photovoltaic (PV) is a mature technology to convert sunlight into electricity. The efficiency of the PV cell has increased significantly in the last 25 years. About 1460 MW of solar PV systems were installed in worldwide in 2005 that represents a growth of 34% over 2004 installations. Annual PV domestic shipments in the USA in 2005 were 104 MW, which is 33% more than 2004. [11]

Solar pumping does not require electricity or any fuels. It eliminates the use of diesel or propane based water pumping systems which are very costly and create noise and air pollution. A diesel generator emits CO_2 during operation and grid based electricity (usually generated with coal, oil or natural gases) also emits CO_2. In contrast, a solar based water pump system does not result in greenhouse gas emissions. It has been noted that the overall upfront cost, operation and maintenance cost, replacement of diesel pump are about 2-4 times higher than that of solar photovoltaic pump [7]. In case of cloudy days, solar pump cannot uplift water to their full potential. So, for such days, reservoir tanks placed at higher location can be designed. Tanks can be used for water storage replacing the need of installing batteries. Solar pumping of water for irrigation is mostly essential in the fields where farmers are suffering where there is far or no river, no streams and no irrigation canals. Proper and adequate irrigation can improve intensity of crop production in higher rate, can enable multiple cropping practices and reduce the vulnerability to changing rainfall patterns.

Even though Nepal being second richest country in the world in water resources, many people are lacking access to clean drinking water and most of the farmers are suffering from improper irrigation. Due to the lack of irrigation facility, farmers cannot practice multiple crops production according to season and are not able to increase their crop production. Few farmers who are getting irrigation facility (generated from hydroelectricity/diesel) are not fully satisfied due to its cost and pollution it creates to the environment. The farmers of Chaukune rural municipality ward no. 01, Surkhet are facing the problem of irrigation. The water source for irrigation is limited and very far from land, so at present farmers are mostly dependent on seasonal rain and hand pump to some extent. So, an installation of solar photovoltaic water pumping system is required here. Using solar energy as an alternative source of energy not only provides irrigation facility but also is economic and environment friendly. The conventional water pumping systems require fuel for its operation. In a country like Nepal, where fuel needs to be imported, this adds a lot to the life-cycle cost of the water pumping system.

The main objective of this project was to design a solar pumping system for irrigation in Chaukune rural municipality, Surkhet. In addition, the specific objectives were to calculate the total amount of water required per day, to design the size of tank required for storing water, to select appropriate pump, motor, controller and to calculate the required number of solar panels.

2. Literature Review

The photovoltaic water pumping is emerging technology. The high capital cost of generating electrical power using photovoltaic cells compared to the conventional coal, gas, and nuclear powered generators have made this method of pumping very uncommon [1]. Despite its main disadvantage which relate to the cost, PWPS possesses great advantages for instance the non-interruption of the supply due to the great availability of the solar resource, the convenience of exploiting solar resource in remote and uncovered areas by national grid or in desert. [1]. Solar photovoltaic pumping water supply systems usually do not include a battery backup system, which allows it to be maintenance free and also reduces complexity and capital costs. In rural part of Nepal, considering reliance, ease of operation as well as economic evaluation, solar pumping is found to be the most feasible way to pump water for water supply. [13]

2.1. Principles of Solar Pump

2.1.1. Photoelectric Effect

When electromagnetic radiation, such as light, hits a material, emission of electrons occurs. This effect is known as photoelectric effect. This effect occurs when incoming photons interact with a conductive surface (such as silicon cell, metal film, etc.) and electrons in the material become excited and jump from one conductive layer to another as shown in Figure 1.

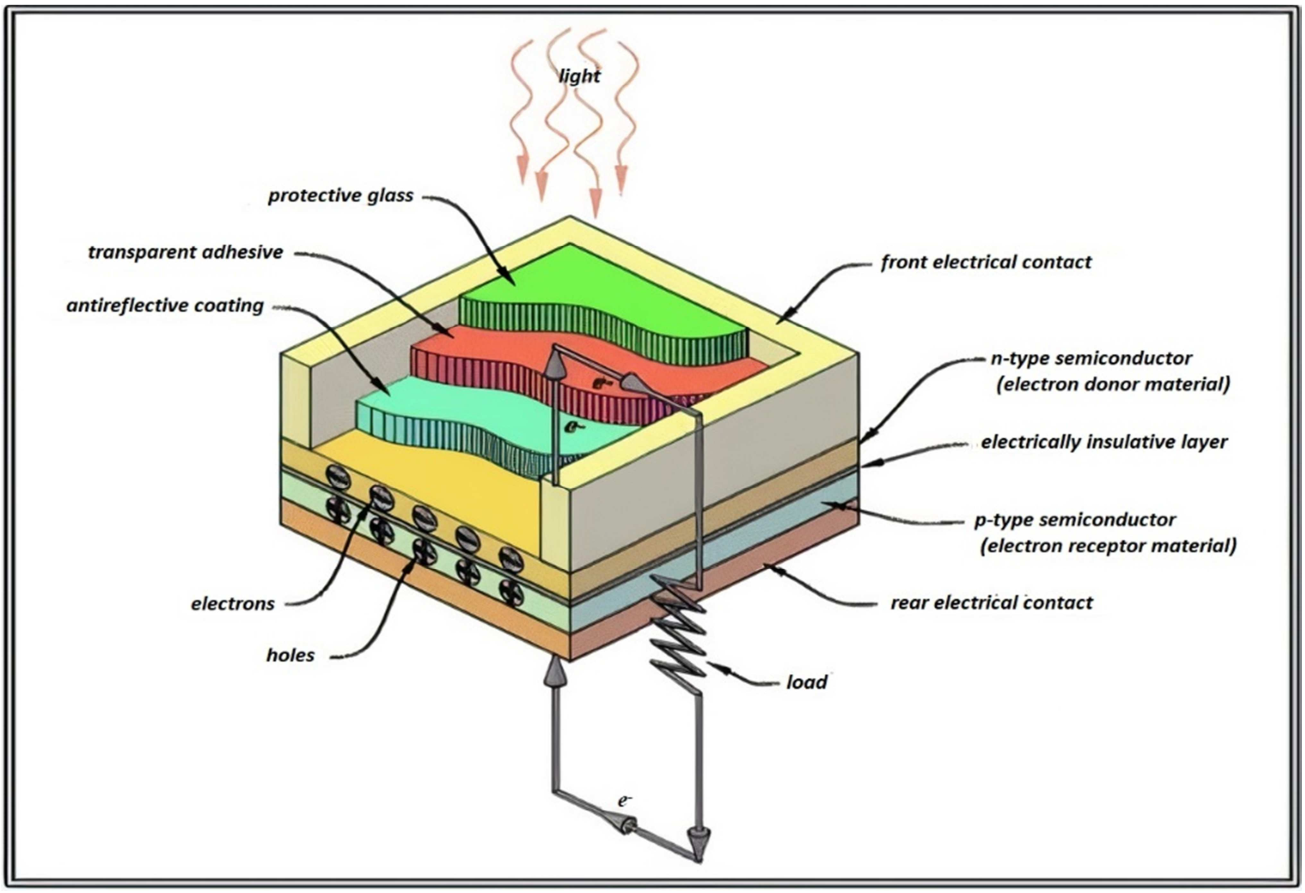

Figure 1. *The photoelectric effect and subsequent electron motion [Source: NRCS-USDA].*

Here, electrons are excited and moves from p-layer to n-layer resulting in voltage difference across the electrical circuit and hence causing electrons to flow through rest of the circuit to maintain a charge balance. The behavior of electrons in solar cells creates a voltage, which can be utilized in field like water pumping.

Principle:

Solar water pumping system consists of PV cells, which works on the principle of photovoltaic effect and converts solar energy into electricity. Then the electrical energy is converted into mechanical energy and hence mechanical energy into hydraulic energy by the pump. This pumping system is a function of pressure, power and flow to the pump. The photovoltaic array supplies the power needed to pump the water. For design purposes, pressure is regarded as the work done by the pump to lift a certain amount of water to the reservoir tank and the elevation difference between water source and reservoir tank determines the work of the pump. [6]

However, a single PV cell does not produce enough amount of electricity. Therefore, numbers of PV cells are mounted on the supporting frame and are electrically connected to each other to form a PV module i.e. solar panel. [2] Current produced is directly dependent on the incident light. PV module produces DC electricity. So, when AC power is required, inverter is connected in the solar power system. Figures 2, 3 and 4 shows the block diagram of directly coupled photovoltaic DC and AC water pumping system without and with battery respectively.

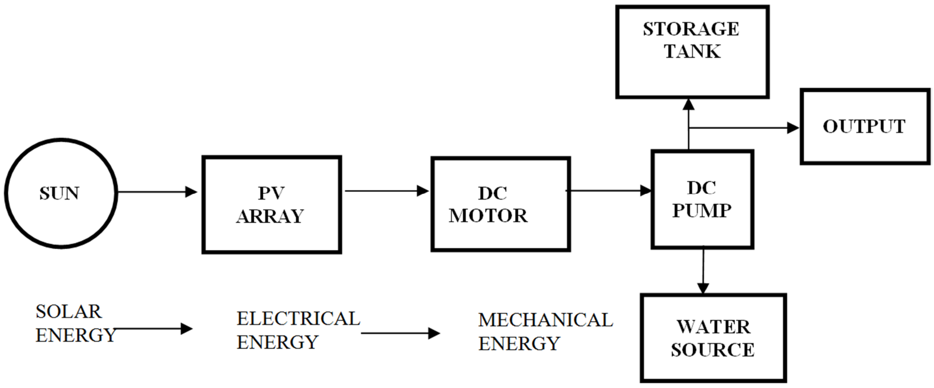

Figure 2. *Block Diagram of a Directly Coupled Photovoltaic DC Water Pumping System.*

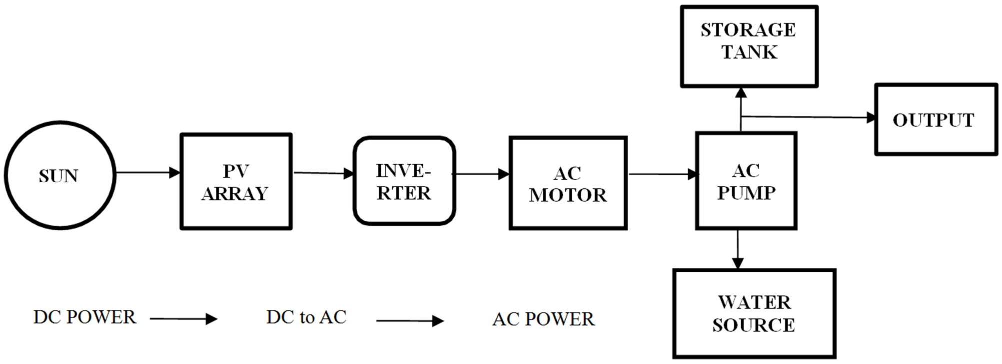

Figure 3. *Block Diagram of a Directly Coupled Photovoltaic AC Water Pumping System.*

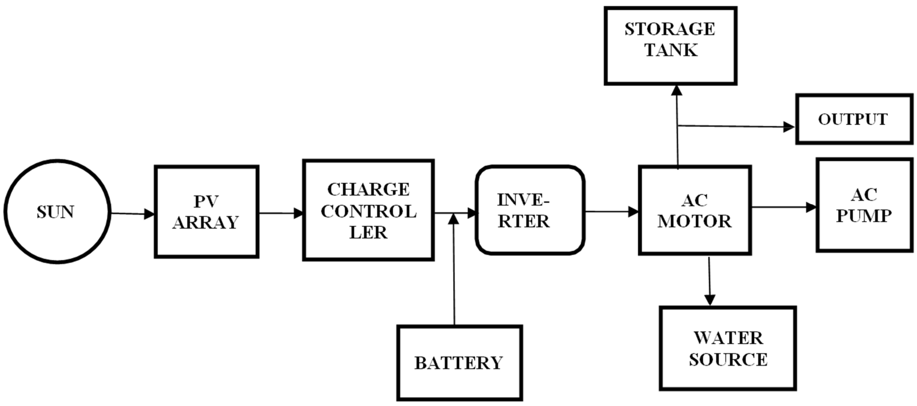

Figure 4. *Block Diagram of a Photovoltaic Water Pumping System with Battery Storage.*

2.1.2. PV Generator

PV generator of solar pump consists of PV modules connected in either series or parallel combination. A PV module consists of solar cells, which converts solar energy into electrical energy. For the same amount of power, array size depends on the efficiency of the cell. The level of efficiencies (in production) is about 7%, 15% and 17% for amorphous, polycrystalline and monocrystalline silicon respectively. [10]

2.1.3. Motor for PV Based Pumps

As PV module produces direct current, DC motors are most commonly used in low power solar water pumping system (<5KW). These DC motors are of 2 types: (i) with brushes and (ii) without brushes. DC motor with brushes requires frequent maintenance due to commutator and sliding brushes. So, for a low power solar water pumping system, a permanent magnet synchronous (PMSM) brushless DC motor coupled to a centrifugal pump is better alternative than (i). And, use of induction motor (IM) which requires an inverter to be used between PV array and motor is reliable, maintenance-free with greater efficiency. [6]

2.1.4. Solar Panel

Solar PV cells are made up of semi-conducting materials that convert sunlight ray to electricity. Group of cells combine to form module, group of modules combine to form panel and hence array as shown in Figure 5. Sizing of PV panel determines the electrical energy, which is used to charge and operate the pumping motor. If the size of PV panel increases, output energy of overall system sizing also increases and amount of water to pump also increases. [5] So, selection of the panel depends upon area of the farmland and types of seed to be grown.

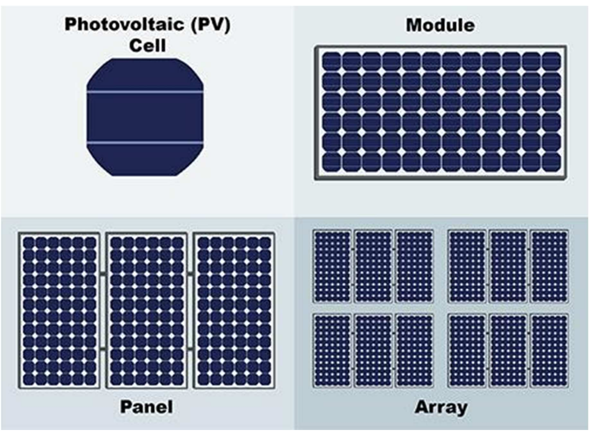

Figure 5. *PV cell to array.*

2.1.5. Solar Pump

There are different types of solar pumps. According to their application, solar pump can be divided into 3 types:

i. Submersible pump:
   a) Can pump water from high depth (300m) [12].
   b) Water-proof motor connected directly to multi-stage impellers.
   c) Brush less DC operation possible with electronic commutation.

ii. Surface pump (draws water from springs, ponds, rivers, tanks).

iii. Floating water pump (draws water from reservoirs with adjusting height ability).

According to pumping principle, it can be divided into 3 types: 12.

i. Centrifugal pumps:

Here liquid is sucked by the centrifugal force created by the impeller and the casing directs the liquid to the outlet as the impeller rotates. The liquid leaves with a higher velocity and pressure than it had when it entered.

ii. Screw pumps:

Here, a screw traps the liquid in the suction side of the pump casing and forces it to the outlet.

iii. Piston pumps:

Here motion of the piston draws water into a chamber using the inlet valve and expels it to the outlet using the outlet valve.

The selection of pump in a solar water pumping is dependent on factors like water requirement, water height, and water quality. [14]

2.1.6. Water Supply Source

Water supply source can be river, stream, pond, deep drilled wells, etc. But, water source must recharge faster than water pumping rate. If pumping rate is faster than the recharging rate of water source, reservoir gets dry and can damage the pump [6]. For this project, a perennial river (Budhakhola) is selected as it is closest to our targeted area. The river is shown in Figure 6.

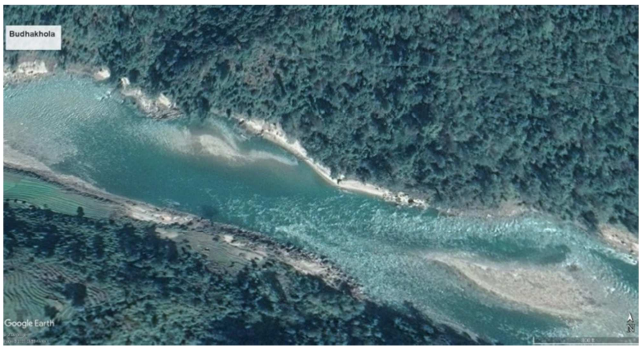

Figure 6. *Budhakhola river.*

2.1.7. Controller

If an AC motor is used, a controller is mandatory. A controller effectively isolates the PV array from the pump–motor system for greater safety and provides optimal voltage/current to the pump-motor according to the site conditions which provides safe operating conditions. It also protects the pump-motor from running dry and helps in conservation of water. [11]

2.2. Working

The working mechanism of solar powered water pumping system is shown in Figure 7.

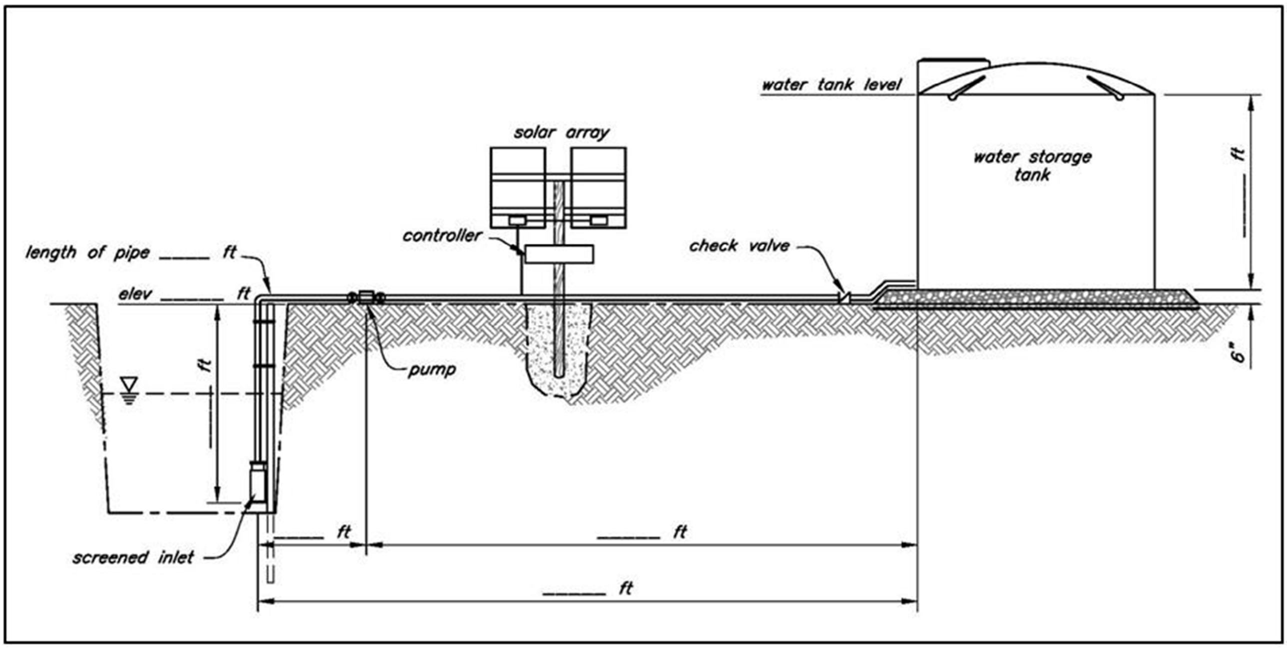

Figure 7. *Schematic working diagram [Source: NRCS-USDA].*

There are numbers of solar panels along with solar trackers. A controller is set up, which is connected between solar array and water pump. There are mainly three types of controllers viz, Simple 1 or 2 control, Pulse with Modulated (PWM) and Maximum Power Point Tracking (MPPT). A solar charge controller is fundamentally a voltage or current controller to charge the battery and keep electric cells from overcharging. Water pumped from the river is then stored in water reservoir which is kept at higher altitude.

(a) Screened inlet

It filters the water and prevents blockages from solid particles.

(b) Pumping equipment

It consists of one or more pumps that provide water flow to the pressure required by the irrigation system.

(c) Control equipment

It controls from valves opening and connect the pump to the injection control fertilizer, pH and electrical conductivity of irrigation water, etc.

(d) Solar array

It is the collection of multiple solar panels that generate electricity as a system.

(e) Check valve

Check valve is used to prevent backflow and water hammer. It is basically one-way valve in which the flow can run freely one way but the valve closes if the flow turns.

(f) Storage tank

An overhead storage tank is used to store water pumped by solar pump during peak sun hours for use whenever required.

2.3. Economic and Environmental Aspect

The survey done by UNICEF on 2016 shed light to the economic and environmental aspect of solar pumping system as shown in table 1. (UNICEF, 2016)

Table 1. *Comparison of water pumping technologies.*

	Hand pump	Motorized pumps (diesel or other fuel)	Solar Powered Water Pump
Initial cost (per beneficiary)	$10-20	$20-50 (varies according to context and size of system)	$10-90 (varies according to context and size of system)
Pumping depth	Up to 80m	Up to 600m	Up to 250m
Installation	Simple	Moderately complex	Moderately complex
Popularity with beneficiaries	Less popular – major effort required to collect water and breaks down regularly. Cheap to maintain.	Less popular – minimal effort required to collect water and breaks down regularly. Expensive to maintain.	More popular – minimal effort required to collect water and rarely breaks down. Cheap to maintain.
Operating costs	None	Significant day to day operating costs are required (cost of fuel and paying an operator)	None – unless system is manually operated3, in which case a part-time operator is necessary
Durability	Poor – breaks down frequently and requires regular maintenance. Average lifespan of 1-5 years.	Poor – breaks down frequently and regular maintenance is required. Average lifespan of 5-10 years.	High – rarely breaks down and little maintenance is required. Average lifespan of 10+years.
Pollution	No greenhouse gas emissions	Significant greenhouse gas emissions	No greenhouse gas emissions
Other considerations	Only suitable for shallow water depths and requires time and physical labor (usually from women and children).	Noisy, heavily reliant on reliable fuel supply	Requires consistent sun exposure throughout the year, reduced output when cloudy

In the last 30 years, the cost of photovoltaic-powered water pumping systems is decreasing by about 400 percent and this trend continues. Photovoltaic technology also continues to improve the power conversion efficiency of the photovoltaic cell. Increment in photovoltaic cell efficiency decreases the cost of photovoltaic power because fewer modules are required to produce the same amount of power. [9]

2.4. Operation and Maintenance

When solar powered systems are correctly sited and installed, they last for longer period of time. Pump itself can last for 5-15 years, solar panels have lifespan of about 25-30 years, control panels can last for about 7 years. But lifespan of these all components depend on their brand. As per the survey taken by UNICEF, just 13% of all solar powered systems had experienced a major malfunction since installation. (UNICEF, 2016) [3].

The functionality of solar pump since installation and severity of solar pump malfunction if solar pump malfunctioned is shown in Figure 8 and Figure 9.

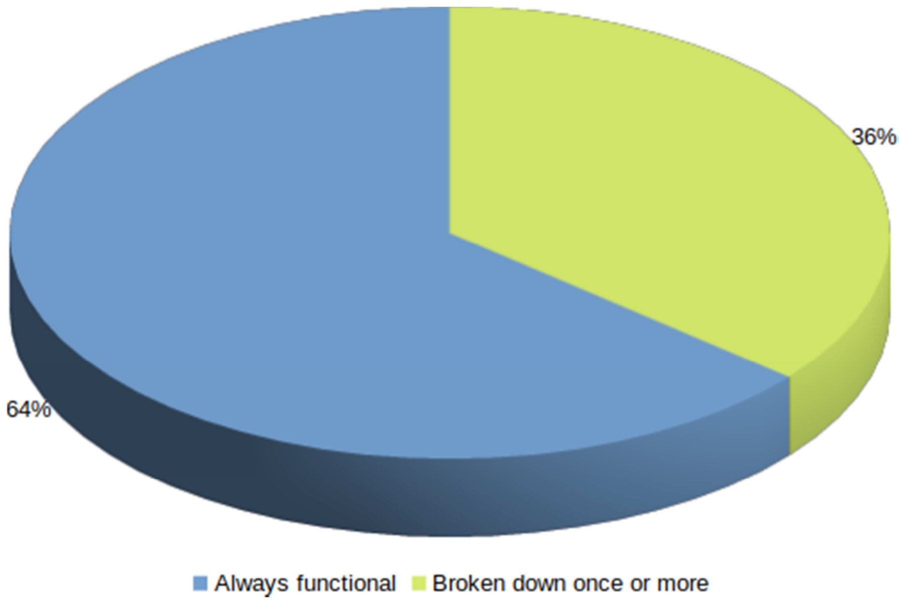

Figure 8. *Functionality of solar pump since installation.*

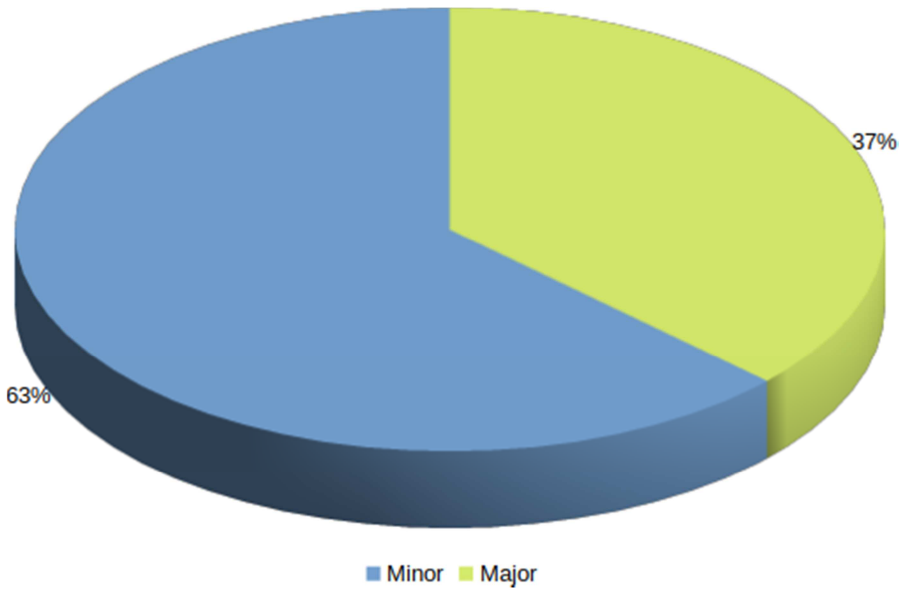

Figure 9. *Severity of solar pump malfunction if solar pump malfunctioned.*

Major causes of malfunction:

Malfunction of the system is caused mainly due to borehole running dry, issues with wiring or electrical components, motor issues, lightening and vandalism or theft as shown in Figure 10.

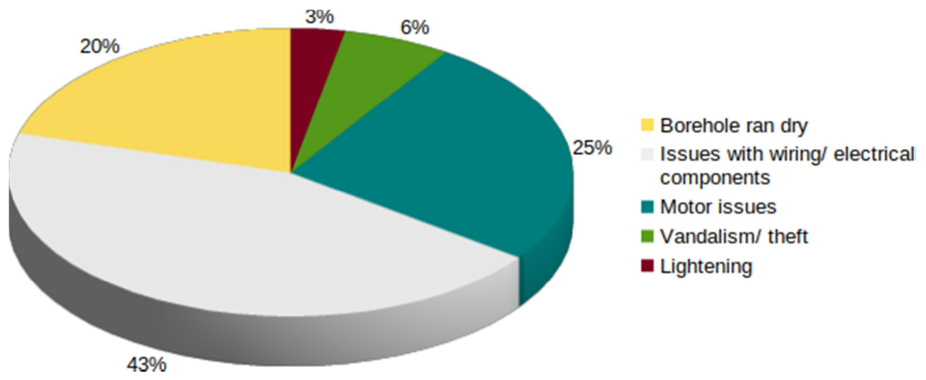

Figure 10. *Main causes of solar pump malfunction.*

3. Materials and Methods

3.1. Study Area

The area to be considered for this project is Chaukune rural municipality, ward no 01 located in Surkhet district, Karnali zone. It is bordered by Salyan district to the east, Doti district to the west and Jajarkot, Dailekh and Achham district to the north and Bardiya banke, Kailali to the south. The climate of this region is mostly upper tropical and sub-tropical to some extent. The elevation of Chaukune rural municipality is 1656 meters and the river Budhakhola is located at lower elevation that makes irrigation difficult in this area. One fitting solution to this problem can be using solar powered pumping system that is both cheap in the long run and environment friendly. The map of the study area is shown in Figure 11.

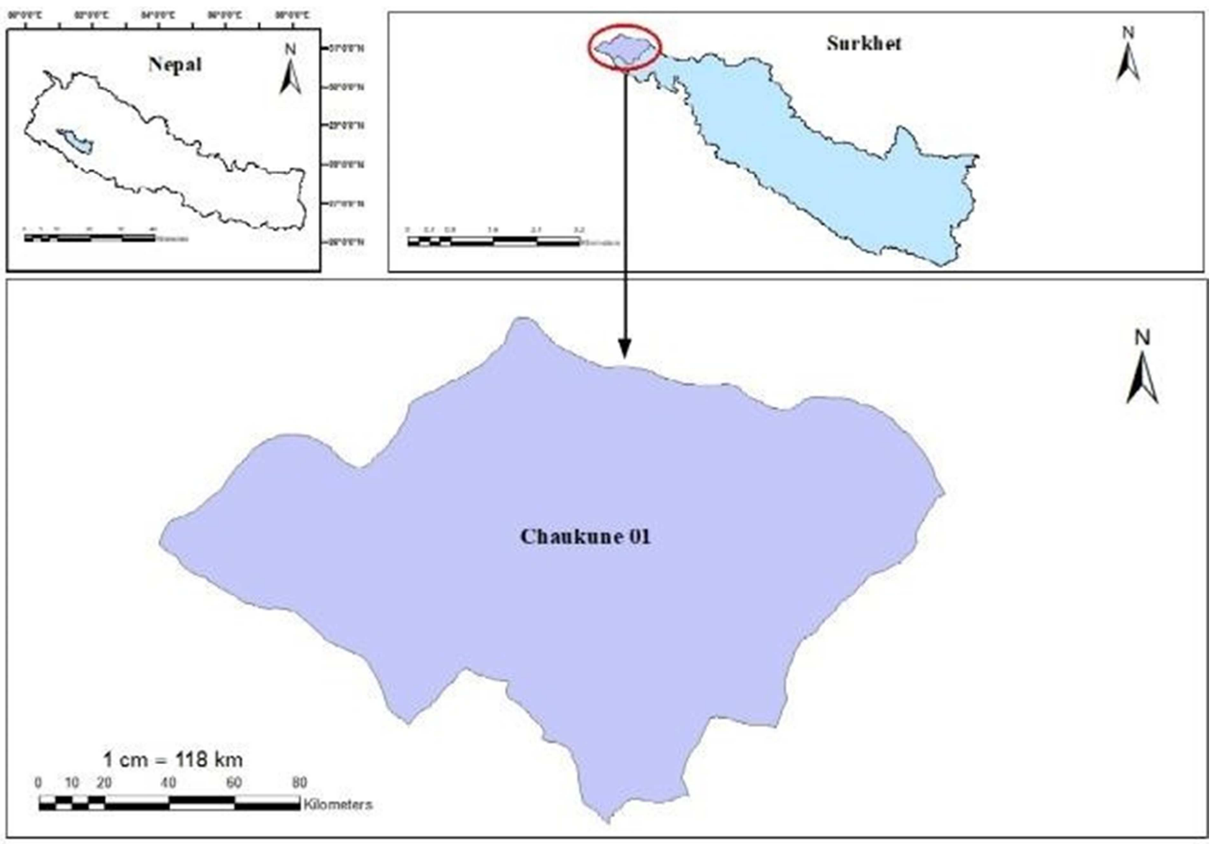

Figure 11. *Study area.*

3.2. Methodological Framework

The study was based on the secondary sources of data. For the design process of solar powered pumping system, firstly the overall water requirement of the operation was determined alongside the topography, location of the delivery point, amount of solar insolation, total dynamic head, size of the pump, peak power requirement and size of the storage tank. The overall methodology is shown in the form of flowchart in Figure 12.

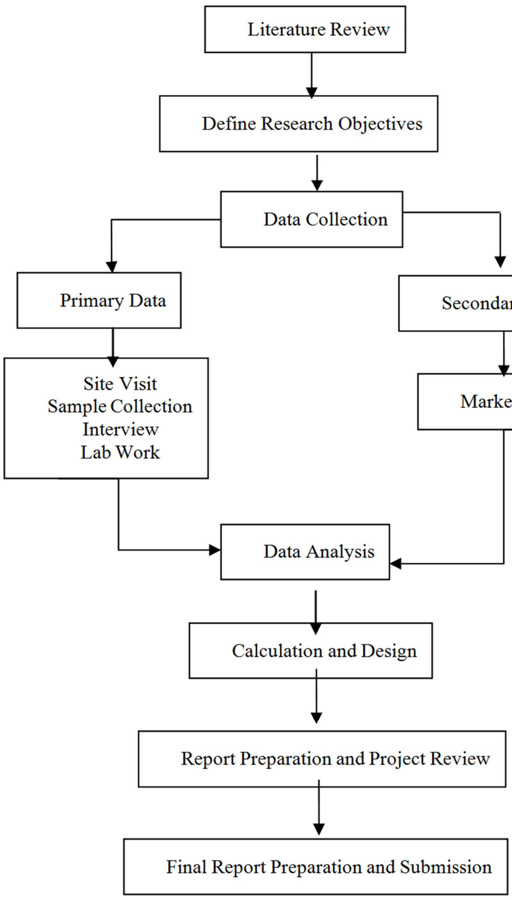

***Figure 12.** Methodological framework of study.*

4. Results and Discussion

To design the system, following components are determined first:

4.1. Water Source and Water Requirement

Budhakhola is the source of water for pumping. Availability of water along with its quality varies in every season. However, the stream flows year-round with sufficient flow to supply the planned system and the water quality is suitable for irrigation system. In order to avoid debris, sediments, etc. to enter to the intake, proper screening materials are used at suction points. While designing a solar powered water pumping system, determining the total water requirement for the operation is the first and most important step. The water required for a day is 400,170.85l, which is calculated by:

Water requirement per week=Total farm area * required liter of water for 1m^2 per week (1)

where,

Total farm area (A)=14.8 ha=148,000 m^2

And, 1m^2 area needs 5 gallons water per week. [8]

4.2. System Layout

Based on the site-specific data, layout of the entire system is kept as shown in Figure 13.

i. Intake (suction point)=0.5m in depth
ii. Pump location=7m away from the river (on dry surface)
iii. Water tank place=at an elevation of 219m from water surface
iv. Water discharge point=1m above the tank bottom
v. panel's location=at a distance of 5m from battery (south facing)
vi. Depth of water source=1.5m
vii. Distance between pump and water tank=732m

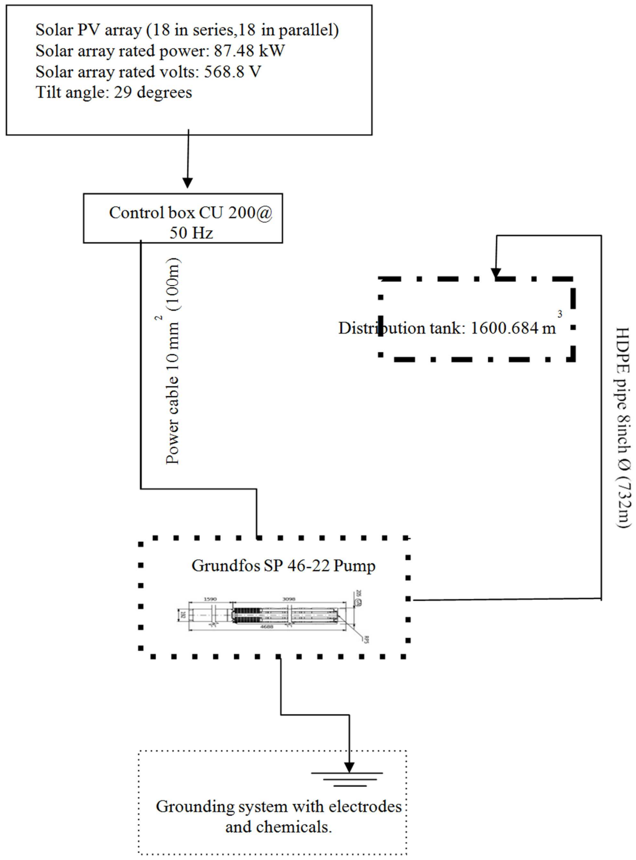

***Figure 13.** System layout of the project.*

4.3. Water Storage Tank/Reservoir

A storage tank is used to store water during peak energy production time to fulfill the water demand during cloudy weather or maintenance periods. Here, the total storage capacity of the tank designed is sufficient to hold the water pumped for 3 days. With the help of volume of water to be stored, height of tank to be designed is calculated by using simple mathematical formula:

$$V = \left(\frac{\pi D^2}{4}\right) \times H \quad (2)$$

where,

V=Volume of reservoir (m^3) D=Diameter of reservoir (m) H=Height of reservoir (m)

Circular storage tank is selected over rectangular storage tank because of the following reasons:

i. structural strength (can withstand outward directed force of water stored within it, force of wind, rain, etc.)

ii. easier in cleaning and economical
iii. round structure minimizes the surface area through which heat can radiate. i.e., they keep the stored water at constant temperature for longer period than that of box-shaped tanks. As a result, water is less affected by ambient temperature fluctuations.

Reservoir with the dimensions as tabulated in table 2 was designed. The dimensional drawing of top and front view of storage tank is shown in Figure 14.

Table 2. *Specifications of reservoir.*

Specifications	Values (in meters)
Diameter	11
Height	13
Thickness	0.3

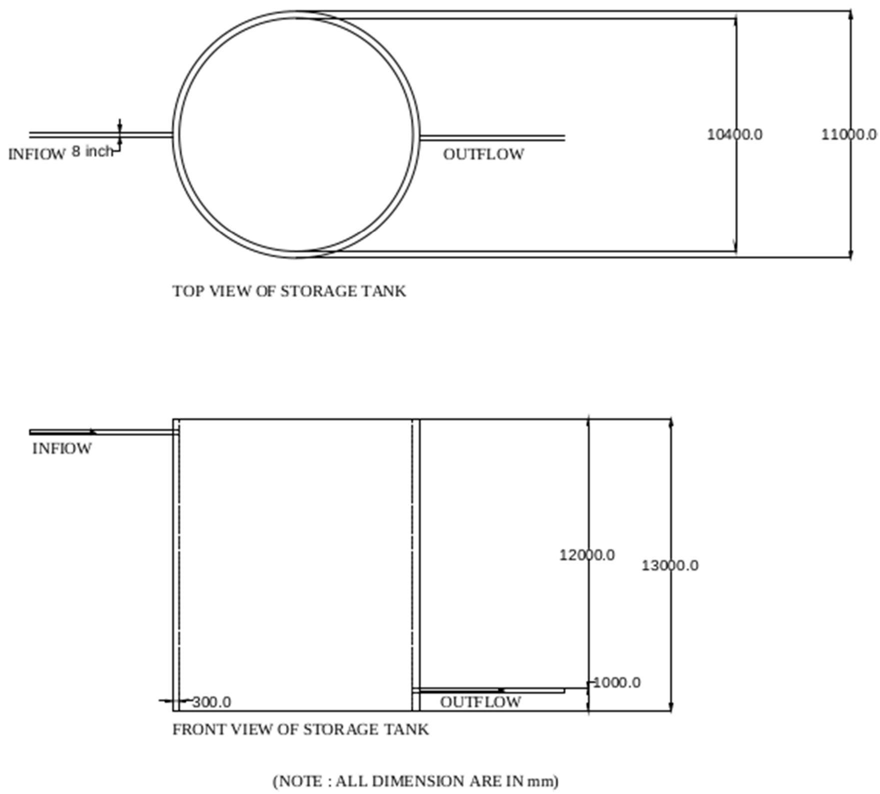

Figure 14. *Top and front view of storage tank.*

4.4. Solar Insolation and PV Panel Location

Solar energy received in particular area varies weekly, monthly and hence seasonally. Taking all the months/ seasons into consideration, solar insolation hence received is sufficient (>5kW/m^2) except for the month of Nov, Dec and Jan when paddy is not cultivated. Table 3 and Figure 15 shows the monthly (average) variation of solar insolation. weatherspark.com [4].

Table 3. *Average peak sun hours in different months.*

Months	Solar Insolation (kWh/m^2)
January	4.26
February	5.17
March	6.27
April	7.23
May	7.7
June	7.1
July	6
August	5.5
September	5.53
October	5.35
November	4.67
December	4.1

Brighter period of the year lasts for 2.4 months (6th April – 19th June) with an average daily incident shortwave energy per m^2 above 7.0 kWh. Similarly, the darker period of the year lasts for 2.8 months (11th Nov – 4th Feb) with an average daily incident shortwave energy per m2 below 4.7 kWh. May 22, (with an average incident shortwave energy of 7.8 kWh) is considered as the brightest day of the year whereas December 24, (with an average incident shortwave energy of 4.0 kWh) is considered as the darkest day of the year.

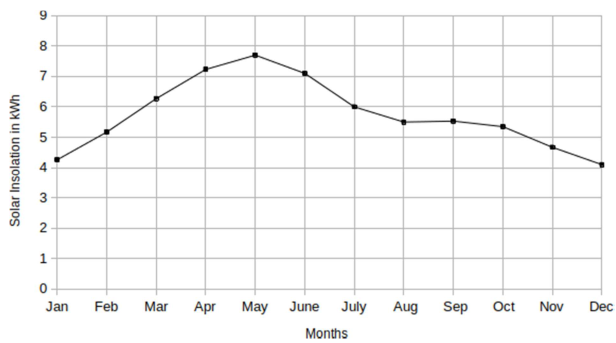

Figure 15. *Solar insolation in different months.*

While locating the PV panels and pumping systems, considerations were made to place PV panels where there is no obstructions by shadows of trees, hills, etc. And, fencing was done to protect from theft, vandalism and damages by livestock and wild animals. Here, the installed solar panels are stationary and south faced in order to receive maximum solar energy during the daytime. The solar array is placed close to the pump to minimize the electric wire length (and thus any energy loss) as well as installation costs.

4.5. Design Flow Rate of the Pump

Design flow rate of the pump is calculated to be 69.72 m^3/h, by using the mathematical expression:

$$\text{Design flow rate of the pump}=\frac{Daily\ water\ required}{Peak\ sun\ hours}$$

TDH of the pump

The total dynamic head of the pump is calculated to be 220.33 m. Where, Total Dynamic Head=Static height + Static lift + Friction loss

By using Hazen William's formula,

$$h_{f\left(\frac{m}{100m}\right)} = \frac{608{,}704{,}451}{d_{mm}^{4.8655}} \times \left(\frac{Ql/min}{C}\right)^{1.85} \tag{3}$$

4.6. Pump Selection and Associated Power Required

Multi-stage submersible pump is suitable for pumping clean, thin, non-aggressive liquids without solid particles or fibers. The pump is made entirely of Stainless steel and is suitable for horizontal and vertical installation. It is fitted with a built-in non-return valve. [15]

Required hydraulic power of the pump,

$$P_h = \frac{Q\rho gn}{3600} \tag{4}$$

where,

Q=flow rate of the pump

ρ=density of water ($1000kg/m^3$)

g=acceleration due to gravity ($9.81\ m/s^2$) h=total dynamic head of liquid (m)

The input parameters shown in table 4 were provided to the Grundfos software (https://www.grundfos.com/) for selecting suitable pump.

Table 4. *Input for Pump selection.*

Specifications	Values
Application	Solar water solutions
Location	Surkhet District, Bheri, Nepal
Type of system	Solar
Installation	Bore hole
Water volume	400.2 m^3/day
Static lift above ground	219 m
Dynamic water level	0.5 m
Month for sizing	January
Maximum ambient temperature	300.13 K
Minimum ambient temperature	273.13 K
Sun tracking	Fixed
Solar Inverter RSI	Standard range 3*380VAC
Switch Box	I050
Control unit	CU200 control unit

The specifications of the pump generated with the help of software are enlisted in the table 5:

Table 5. *Pump Specification generated by software.*

Specifications	Values
Pump	Stainless steel EN 1.4301 AISI AISI 304
Pump speed	3450 rpm
Pump outlet	R4
Average water production per watt per day	4.5 L/Wp/day

The dimensional drawing of the selected pump with the help of software is shown in Figure 16.

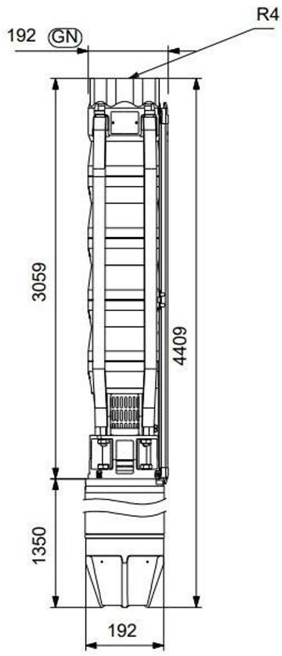

Figure 16. *SP 46-22 Pump.*

4.7. PV Panel Selection and Array Layout

The GF 270 is a polycrystalline solar module. The module is equipped with MC4 plugs for easy connection. It must be mounted on a support structure, tilted at an angle (29 degree) ensuring optimum utilization of the solar energy. The specifications of solar panel generated with the help of software is tabulated in the table 6.

Table 6. *PV Panel Specifications.*

Specifications	Values
Solar modules	18 in series and 18 in parallel
Solar array rated power	87.48 kW
Solar array rated volts	568.8 V
Sun tracking	No (Fixed)
Tilt angle	29 degree

4.8. Motor, Controller and Cable Selection

Here, motor power is calculated by,

Motor power, $P_m = \frac{P_h}{\eta_m}$

Where, η_m=motor-pump efficiency and is assumed to be 75%.

The motor with following specifications with the help of parameters in table 7 was selected.

Table 7. *Motor specifications.*

Specifications	Values
Motor	Cast iron DIN W.-Nr. 0.6025
Motor Type Motor Diameter	ASTM 35-40 MMS8000 8 inch
Power Required by pump (P2)	55 kW
Rated voltage	3 x 380-400V
Rated current	132-129 A
Rated Speed Main frequency Windings	3470-3490 rpm 60 Hz PVC

The CU 200 control unit is a combined status, control and communication unit especially developed for the SQFlex system. Furthermore, the CU 200 enables connection of a level switch. The CU 200 incorporates cable entries for power supply connection, pump connection, earth connection, level switch connection. Communication between the CU 200 and the pump takes place via the pump power supply cable. This is called mains borne signaling (or Power Line Communication), and this principle means that no extra cables between the CU 200 and the pump are required. It is possible to start, stop and reset the pump by means of the on/off button. The CU 200 control unit offers system monitoring, alarm indication. The CU 200 offers alarm indications for dry running, service needed in case of no contact to pump, overvoltage, over-temperature, overload, insufficient energy supply etc.

The controller with following specifications was selected with the help of software as shown in table 8 and the dimensional drawing is shown in Figure 17.

Table 8. *Controller Specifications.*

Specifications	Values
Power Consumption	5 W
Rated Voltage AC	1 x 90-240 V
Rated Voltage DC	30-300 V

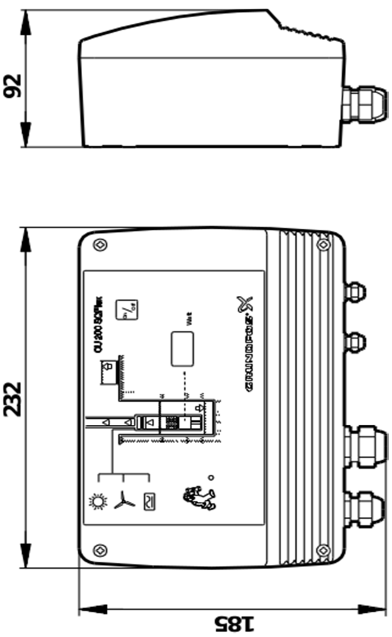

Figure 17. *CU 200 @ 50 Hz.*

In addition, the power cables that connects solar array and pump is shown in table 9.

Table 9. *Specifications of Cable Selected.*

Specifications	Values
Cable size	10 mm^2
Cable length	100 m
Cable loss	4%

4.9. PV Array Mounting and Foundation Requirements

The selected site falls within the tolerance wind speed of 85mph (or less) so it is good for mounting PV panels. Ground mounting was done since it provides flexibility for optimum tilt angle. Ground mounting (as in Figure 18) also provides natural convection to cool the solar module using air. It is also easier for safe installation and maintenance.

Figure 18. *Ground mounting.*

4.10. Comparison of Software Design and Manual Design Data

The comparison between software design data and manual design data is shown in table 10.

Table 10. *Comparison between Software Design and Manual Design Data.*

Specifications	Software design	Manual design
Motor power	55 kW	55.8 kW
Friction loss (m)	0.80	0.83
Total dynamic head (m)	219.8	220.33
No. of solar panels @270Wp	324	351

5. Conclusions and Recommendations

SP 46-22 pump was selected with flow rate of 71m^3/h to fulfill the water demand is 400.171 m^3/day. The water pumped for peak sun hours (5.74 hours) is 407.54 m^3, which is greater than water demand so this pump is appropriate. The volume of storage tank is 1200.513 m^3, which is sufficient to store water for 3 days. The number of solar modules required is 18 in series and 18 in parallel with rated power of 87.48 kW. And, the implementation of this project is expected to result in more positive impacts on the environment as well as on the economic status of the communities in the targeted area. Performance of the system should be monitored regularly by technical personnel along with concerned authorities at an appropriate interval. Workshops and training should be given to the local people regarding the system so that they can be able to maintain and repair it at local level. Furthermore, lab test for water quality should be done and water treatment unit should be incorporated in the design if required.

Acknowledgements

First of all, we would like to express our sincere and deepest gratitude to our supervisor Dr. Bikash Adhikari, Department of Environmental Science and Engineering, Kathmandu University, for his continuous support and supervision throughout this research project. His ideas, knowledge and efforts are heavily embedded in this research project. We would also like to thank the Department of Environmental Science and Engineering, School of Science Kathmandu University for their constant support during this project. We would like to thank our families and friends who supported directly or indirectly with unconditional love and care throughout this project work.

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