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INTEGRATED GREEN SUBMERSIBLE PUMPING SYSTEM FOR FUTURE GENERATION

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Abstract. *In the system solar power has been used for cultivation. Solar photovoltaic cells convert solar energy into electricity through solar photovoltaic (SPV) effect. Generated DC voltage then converted in to AC voltage by pump controller, this AC voltage is used as the input of Variable Frequency Drive (VFD). The VFD acts as a motor controller that controls the submersible pump motor by varying the frequency and voltage of its input power supply. The VFD is associated with pump controller. Regulated three phase AC voltage is the output of the pump controller which is directly connected with submersible pump. The water thus drawn from bore wells by a solar water pump is pumped to supply for irrigation purpose as required. This system is full off-grid interfaced system appropriate for the village areas. The main goal of this system is to use solar energy at a minimum running cost. The solar powered project is completely eco friendly and the plant is relatively clean with small maintenance. This project helps to reduce the cost of electricity, as well as minimize the overall agricultural cost.*

Key words: *variable frequency drives (vfd), submersible pump, solar panel, irrigation, pump controller*

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1. INTRODUCTION

Water is the basic human necessity but a large Nepalese population is depleted of access to hygienic, safe and adequate water. Nepal is a landlocked country and most of the villages in Nepal have to rely on small brooks flowing from the mountains and have to travel hours to get safe water. Still, safe and unpolluted water is unavailable. One of the main reasons for this is due to the fact that the water level is deteriorating from the normal ground level and from the surface naturally and by anthropogenic deposits. This gives rise to many difficulties for the rural regions on getting sufficient collected water from normal tube wells and by using pumps by renewable energy source[1]-[4]. Normally, , to fix such problems submersible pumps are used. These pumps are the best for collecting water in those places with very low water levels, still a strong challenging point to sustain is the unavailability of electricity. The common issue in those rural regions of Nepal communities is suffering each day from power cut and driving the submersible pumps have become their nightmare which is vividly affecting their irrigation process. The solar photovoltaic system (SPV) has been implemented in order to overcome electricity issues [5]-[8]. This system is implemented using renewable sources of energy and has become an almost successful project which is meeting the need for water without any obstacle to the villagers, using completely green energy [9]-[12]. Water head ranges 45 to 50 meters with water discharge 36,000 liters per hours.

Now, this paper discusses the execution and implementation of an integrated solar photovoltaic system, generation of electricity for running submersible pump with minimum running cost [10]-[18].

SPV contains few photovoltaic cells in series-parallel combination for achieving the required voltage. The solar photovoltaic cells arranged in series-parallel in panel absorb the solar energy [19]-[22] and process it into electrical energy as DC voltage. The DC voltage however does not remain steady because of the change the intensity of sunlight through day time. Pump controller maintains constant voltage during operating time to provide water for farming work [23]-[25].

2. PUMP INSTALLATION AND OPERATION

The solar submersible pump installation has been performed by these steps: initially try to survey the purpose and nature of the irrigation requirement of the specific village as well as the climate and nature of soil of this particular area. After that, hydraulic analysis of the pumping system is required to calculate the depth of underground water level. Wind flow and wind pressure also play a vital role, therefore wind flow calculation must be required. In this project the solar module shielded the wind flow up to 150 Km/h [26]. The reason for the sailing effect is the strong wind flow up to 150Km/h along the ground level which is extremely detrimental to photovoltaic installations. Therefore, during the installation, the behavior of the structure and PV module at 140Km/h to 150Km/h wind pressure was observed through wind tunnel test, and the solar panels passed the test successfully. As the structures were laid by PVH (PVHardware), they will not be affected by bad weather. The working temperature of the solar module is -20°C to 55°C with IP65 protection. Determination of the peak photovoltaic power is required to drive 7.5 HP submersible pumps. The size of the suitable PV panel is set to get the required output power. During PV array layout, minimum impact of shadow effect must be considered for optimum and uninterrupted electrical output. Shadows occur because of permanent structures, trees, or other types of civil constructions. Inter row spacing of solar module is also the cause of shadow effect. To avoid shadow effect due to row spacing the following methodology:

$$\text{Row Spacing} = \text{Height of solar module} \times \frac{COS\ of\ azimuth\ angle}{\tan\ of\ altitude\ angle} \quad (1)$$

In this project Row Spacing = 4meters × $\frac{Cos\ 85°}{Tan\ 15°}$ = 4meters × $\frac{0.087}{0.26}$ = 1.34 m (1.5 m approx.)

With the help of this method, electric power has been generated through solar panel. The photovoltaic arrays are made up of a combination of solar panels which convert sunlight into electricity, used for driving the motor and submersible pump set. The solar energy is supplied to the electrical motor to run the pumping system through cables. The pumping system draws water from the bore well. By the rotation of the shaft of the motor which is attached to the pump, the pump starts to collect the underground water and supply the fields. This system demands a shadow-free area for installation of the solar panel.

2.1. Performance Ratio and Plant yield calculation

Total generated energy by a solar energy operated plant per annum to meets the consumers demand is called Plant yield.

$$\text{Performance ratio of a plant (PR)} = (1-\alpha) \times (1-T) \times (1-S) \times (1-V) \times \acute{\eta}_{inverter} \quad (2)$$

$$\text{Plant Yiled} = P_{sun} \times P_{rated} \times PR \times 365 \quad (3)$$

Where P_{sun} is the average solar irradiation per day, (Kwh/m^2/day) is the solar radiation received by a surface at the panel installation area with that specific time. P_{rated} is the amount of DC power production under standard test conditions of the particular solar module. α is the manufacturer's tolerance that means the permissible limits of variation in the physical dimensions of component or object of the pump. The value of α is 0.96 for 17 stages submersible pump [27]. T is the % of losses of efficiency due to diverse factors like ohmic losses, PV losses due to the temperature & irradiance. S denotes solar module soiling loss. Significant factors impacting the rate of soiling are wind velocity of the atmosphere angle and direction of the panel, humidity, fog, dew, geographical location of the pane. The losses generated due to soiling vary from 1.5% to 6.2%, solely depending on the location of the PV plant. V is the Power cable's impedance loss. The efficiency of inverter is denoted by $\acute{\eta}_{inverter.}$

2.2. Methodology of Total Dynamic Head Calculation

Factors that have helped with the model improvement of total dynamic head (TDH) were recognized. The factors are -vertical rise, pumping level, static water level, drawn down, dynamic water level, pump depth, well depth, friction losses due to (insert coupling), threaded adapter (plastic to thread), standard tee (flow-through Run), standard tee (flow-through Side), gate valve and swing check valve. The schematic representation of the research is shown in Fig.1.

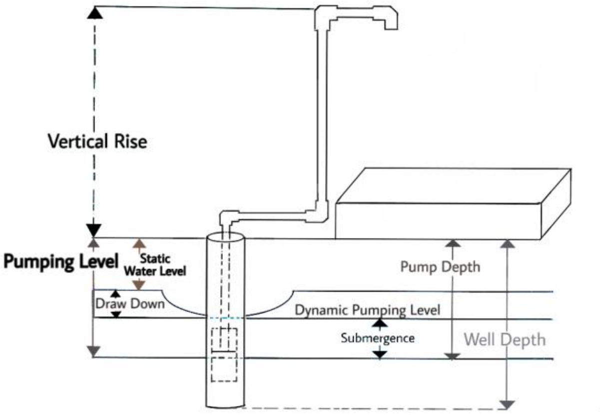

Fig. 1 Schematic diagram of Total Dynamic Head of a Submersible pump

Frictional loss calculation is shown from the data obtained from Table 1.

Table 1 Practical data related with Submersible pump installation

Parameters	Acronyms	Value (m)
Friction loss	F_L	0.55m
Pumping level	P_L	158.50m
Total length of pipe	L_T	281.03m
Vertical Rise	V_R	61.11m
Fittings equivalent of pipe	F_E	0.91m
Number of same fittings	N_f	4 fittings

Frictional loss in meters

$$F_L = [L_T + \sum(N_f \times F_E)] \times F_H \times 30.48^{-1} \quad (4)$$

In this project the value of vertical rise and pump level are predetermined, so the modified equation of Total Dynamic Head can be shown as:

$$TDH= P_L + V_R\, [L_T + \sum(N_f \times F_E)] \times F_H \times 30.48^{-1} \quad (5)$$

$$\text{Total Dynamic Head (TDH)} = P_L + V_R + F_L \quad (6)$$

Application of Equation (4) by substituting the values in Table 1, gave a value of 737.31 feet (224.88 m)

$$TDH= P_L + V_R\, [L_T + \sum(N_f \times F_E)] \times F_H \times 30.48^{-1} = 224.88 \text{ m}$$

For calculating the pump capacity following factors has been considered in the model village of Nepal with population of 2347.

Total water demand = 70 kLit
Average solar energy per day = 6 hrs.
Average water required per hour = 12 kLit
Water required per minute 12000 /60 = 200 Lit/minute,
Power rating in Watt = HP x 746 Watt = 7.5× 746 = 5595 Watt. (7)

2.3. Pump capacity design

Daily water demand = 70 Lpcd
7.5 HP pump discharge = 600 Lpm for 48 m Head.
Total water discharge in an hour
$600 \times 60 = 36,000$ Lit.
In 6 Hrs.= $36,000 \times 6 = 216,000$ Lit. (8)

2.4. Pump Specification

Power rating of pump = 7.5 HP or 5.59 Kw.
Water discharge = 600 Lpm
Water head = 48m
Voltage: 280- 440V.
Stages: 19
Housing material: stainless steel pump
Bush material: gun metal.
Insulation class: B
Bore size: 4 inch or 101.6 mm
Coating: CED (Cathodic Electro-Deposition)
Protection Class: IP68.

2.5. Panel Design

1m length $\times$ 2m width panel = 0.15 kW
Total wattage of 7 number of panel= 1kW
For 7.5 HP load total number of 150 watt panel required = $(7.5 \times 746) \div 150 = 38$ nos. (9)
Area required for panel fittings = $1 \times 2 \times 38 = 76$ Sqm (10)
Add 100% more space for gap between the panel and area around it.
So the total working area = 76 Sqm $\times$ 2 = 152 Sqm. (11)

3. Technical Specifications of Solar Water Pump Controller System

In this project, 3 phase solar pump controller are used as an electronic device which is the combination of inverter, maximum power point tracking (MPPT) and variable frequency drive (VFD). The maximum output pressure of the pump controller is greater than 0.55 bar.

The system works at its optimum condition throughout the day by any intensity of sunlight. The starting current of induction motor is very high and non linear in nature than the running current of the motor which is almost regulated. The VFD in controller eliminates the high starting current of the induction motor. Because of the smooth start using VFD, the starting method of the motor is very smooth. For 7.5 HP submersible pumps the IP rating of VFD is IP 65 with enclosure for endure severe environments. Variable frequency drive shall be suitable for operating at voltage range of 415V with ±10% tolerance and the input supply frequency of 50 HZ with ±5% tolerance. The frequency regulation shall be ±0.1% of rated maximum frequency under steady state and ±5% during transient condition. The output frequency variation of drives shall be 2.5 Hz to 50 Hz. Maximum overload range of VFD is 150% of rated current for 60s and can work properly under the ambient temperature range -10 to +40°C with 95% of maximum humidity.

4. Pump Efficiency Calculation

Flow rate (Q) = 120 m^3/s
Water head (H) = 48m
Input power to pump = 21KW
Hydraulic KW is given by:

$$\frac{\text{Q in } {}^{\text{m3}}/_{\text{sec}} \times \text{Total head in m} \times \text{Density in } {}^{\text{kg}}/_{\text{m3}} \times \text{g in m2/s}}{1000}$$

$$=\frac{\left(\frac{120}{3600}\right)\times 48\times 1000\times 9.81}{1000} = 15.69 \text{ kW} \quad (12)$$

Pump efficiency =Hydraulic kw/ Input power to the pump = (15.69÷21) ×100= 74.71%

This efficiency is sufficient for farming on that area. The submersible pump with diameter of the outlet is 4 inches and water discharge 600 LPM. The irrigation problem in this area is resolved with the submersible pump that runs for an average of 6 hours per day.

The polluted PV cells power reduced to about 12% while the naturally cleaned cell lost about 8% compared to the clean cell [28].

Table 2 shows a series of statistical data obtained from the agricultural field prevailed by direct measurements. This table also indicates how the pump efficiency varies with the water head and also the maximum efficiency for a particular water level.

Table 2 Optimum efficiency

Water Head (m)	Pump Efficiency (%)
25	38
30	47
35	62
40	80
45	75
50	78
55	75
60	70
65	65

The relationship of efficiency with the inlet width of the pump diffuser is clearly stated in Fig. 2. This figure also shows the locations of optimum operating point efficiency and the forecast of maximum efficiency.

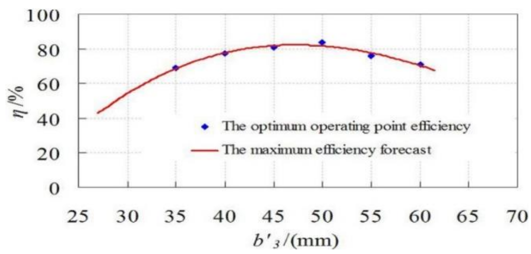

Fig. 2 Pump maximum efficiency curve with maximum operating points

Table 3 The optimum flow rate with different inlet and corresponding efficiency

Diffuser inlet Width (b_3) in mm	Single-stage Head (H) in m	Efficiency (%)
40	16	77.4
45	17.01	81.0
50	17.20	83.7
55	13.87	75.9

Table 3 indicates the results of various experiments revealed that the efficiency of a submersible pump that varies with different parameters like width of the diffuser inlet, water flow and the water head. The diffuser inlet width is measured by the inside caliper and measuring tape. Inside caliper consists of measuring two adjustable jaws or legs for measuring the dimension of diffuser inlet width. The right side of the caliper has an adjustable screw and nut. The method of measuring diffuser inlet width with inside caliper is that first the jaws of the caliper were adjusted with the diffuser inlet width with the help of adjustable screw and nut of the caliper. Then the gap in the lower part of the jaws is measured with either a scale or a measuring tape, that reading is the diffuser inlet width.

5. Pump Control Technology

The frequency regulation system is very effective for the flow of water at a certain pressure during the operation of the pump, which is placed as VFD of the project. At the same time this technology prevents water wastage, as well as power consumption control. The operation of VFD depends on the variation in the input voltage and frequency of the pump motor. A variable frequency drive (VFD) is a kind of motor controller that runs an electric motor by altering the frequency and voltage of its power supply. The VFD also has the potential to control ramp-up and ramp-down of the motor, during the start or stop, sequentially. A variable frequency drive can modify the power provided to meet the energy requirement of the driven equipment, and this is how it conserves energy or optimizes energy consumption. VFD for AC motors has been the reform that brought the application of AC Pump motors back into influence. The AC-induction motor can have its speed modified by changing the frequency of the voltage used to power it. These indicate that, if the voltage applied to an AC motor is 50 Hz (used in countries like India), this motor can operate at its rated speed.

A Pump controller will manage the regulated voltage, so no battery is required in this project for backup protection. A voltage regulator is employed to supply continuous power to the microcontroller. The microcontroller will regulate the switching of the pump which will further provide water to the crops as per their necessities. The water level in the overhead water tank is controlled by a water level controller which will run the pump executing it to supply water from the water reservoir. AC pumps are utilized in this system as they are cost-effective and efficient. The pumps require AC supply, whereas the solar panels provide DC power. Therefore, an inverter is used to alter this DC supply to AC supply.

Fig. 3 shows the simulated waveform has been done with the help of Matlab/Simulink Software. This software has been used to make this project more acceptable. In Fig. 4 the vertical axis indicates the flow rate in m^3/s and in Lpm with separate diagram and horizontal axis indicates the time. The relationship between the flow rate and time is shown by the simulation. Pump flow rate is in both cubic meter per sec and liter per minute. Both curves show that the pump starts to deliver the water after almost 0.12 sec, which is too fast. The pump flow rate is 5.35×10^{-3} [m3/sec] and 320 [lpm], respectively, which then increases to 5.85×10^{-3} [m3/sec] and 350 [lpm], which is slightly higher than the actual calculated value.

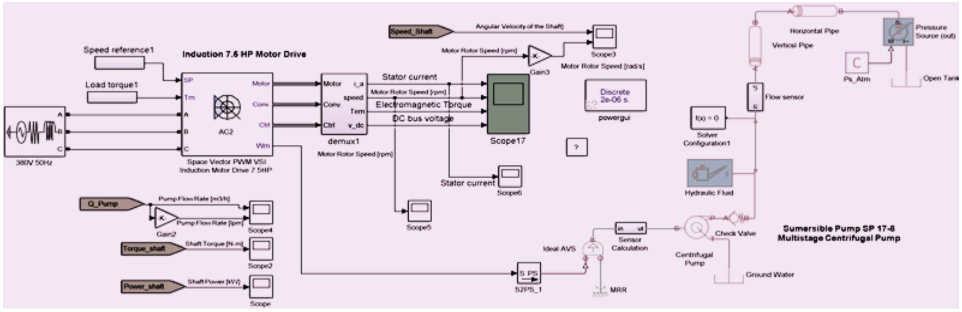

Fig. 3 Simulated waveform of the output voltage without pump controller

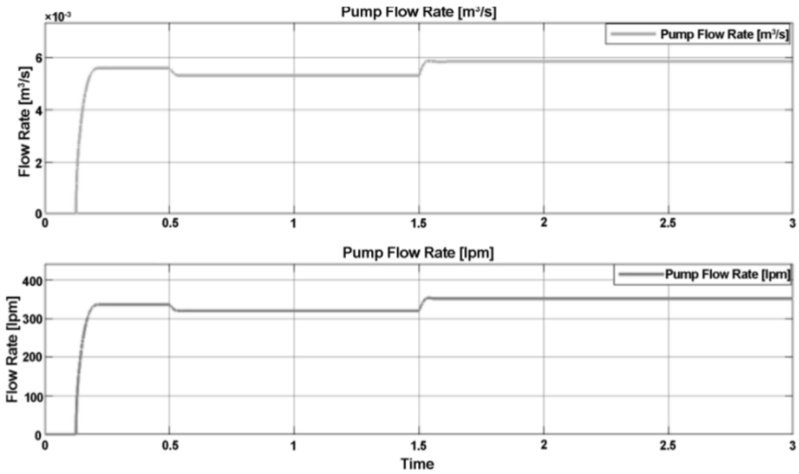

Fig. 4 Pump flow rate in [m3/s] and [lpm] against time

The bright sunlight provides illuminance of 98000 lux on a perpendicular time when the voltage directly coming from the solar array without the influence the pump controllers is fluctuating in nature. The generated voltage (DC) is unregulated and deepens upon the intensity of light. So, the output voltage is not constant throughout the day. This means that as the intensity of light decreases, the amount of voltage generated also decreases. The value of the voltage is almost constant as the intensity of light changes by using solar pump controller. When the sunshine varies during the solar hours or day time, the power input to the controller also varies and the variable frequency drive (VFD) generates variable ratio to control the input voltage of the pump and the speed of the motor. Thus pump controller always maintain constant speed.

But after using the submersible pump controller the output voltage of the controller is almost constant. The voltage vector of the inverter is supplied to pump motor and it holds a steady ratio of the voltage to frequency (V/Hz). It obtains feedback data from the driven motor and corrects the output voltage or frequency to the preferable values. The control system is entirely based on SVPWM (Space Vector modulated PWM) and soft computing based algorithm. This project is solely an integrated system and not design-based work. The solar inverter with MPPT VF drive will give the maximum torque even at minimum sunlight. No battery is required in this project. The panel is directly connected to the pump controller and the output of the controller is connected to the Submersible pump motor. The DSP will track a particular point at which the maximum power can be extracted from the solar module or array by changing the PWM technique with modulation frequency so that the pump motor will always run maximum power extracting from the panel and with a steady torque for a large range of intensity of sunlight throughout the solar hours. Thus, Maximum power can be obtained from the panel by altering the PWM and modulation frequency so that the motor always runs by deriving most of the power from the panel and at a steady torque for the ample range of intensity of sunlight from morning till evening. This method provides 35% more energy, and therefore gets 35% more pumping water. This comparative excess water has greatly improved the agriculture on that area. This project was created to solve the agricultural obstacle for a particular area.

Fig. 5 shows the output power or shaft power of the pump [kW] against time [sec]. The shaft power of the pump gives the same results as the motor speed, as shown in the full load shaft power is 5.5 Kw.

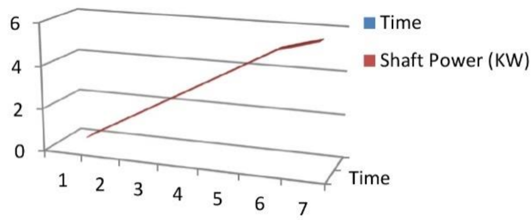

Fig. 5 Shaft power (Kw) of pump vs time (Sec)

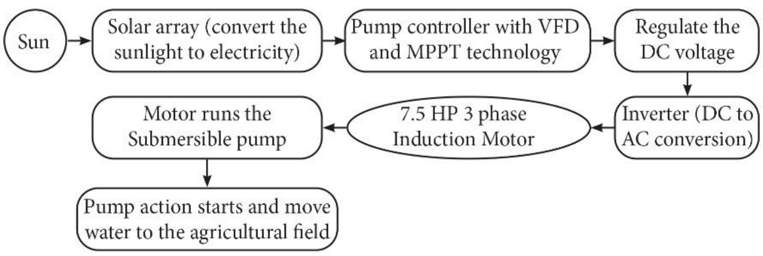

Fig. 6 Single line block diagram of Submersible pump operation.

Fig. 6 shows the single line diagram of the control circuit of the submersible pump. When sunlight falls on solar array, voltage is generated in photovoltaic manner and it is unregulated DC voltage. This voltage is connected to the appropriate 3 phase AC voltage of the pump motor through the pump controller. The output terminals of the pump controller are directly connected with the pump motor. The pump controller provides the rated power with specified voltage to motor. The pump motor is fully submerged in underground water. The motor is hermetically sealed and close-coupled to the body of the pump. The submersible pump pushes water to the upper surface of the ground by converting the rotating mechanical energy of the motor into kinetic energy. This can be achieved by the water being pulled into the pump, initially in the intake, where the rotation of the impeller pushes the water through the diffuser. From the diffuser it goes to the upper ground surface. After that the submersible pump is driven by motor and the water moves to the upper surface of the soil at high pressure through certain pipelines. Latter the water is used for farming.

Table 4 Test result

Panel voltage DC (Volt)	Load Voltage (Volts)	LOAD (submersible pump) KW	Load current (Amp)
24 Volt	414 volt	5.595	13 Amp

Real time experimental results are directly available from Table 4. The results were obtained by connecting the metering deviances directly to the pump circuit. The experimental result of this project shows that the theoretical value of the efficiency is 74.74% s as almost equal to the efficiency which is calculated by the practical data.

$$\text{Input electrical power} = \sqrt{3} \times V_L \times I_L \times \text{COS}\ \emptyset \qquad (13)$$
$$= \sqrt{3} \times 414 \times 13 \times 0.8\ \text{KW}$$
$$= 7457.5\ \text{W}$$

Output electrical power = 5595 W (7.5HP)

$$\text{Practical efficiency} = \frac{5595}{7457.5} \times 100 = 75\%$$

Pump Performance Curve

The characteristic curve of submersible pump is the relation between the flow rate produced vs total head. The pump performance curve, basically a performance data, helps to choose the proper rating of the pump for a particular project.

Pump performance curve in Fig. 7, indicates the relation between total head (m) and the water flow rate (m^3/s). The flow rate decreases with increasing the total head of the pump, so that the curve is drooping in nature that means if the total head increased then the flow rate of water will be decrease and the maximum water flow available with minimum water head.

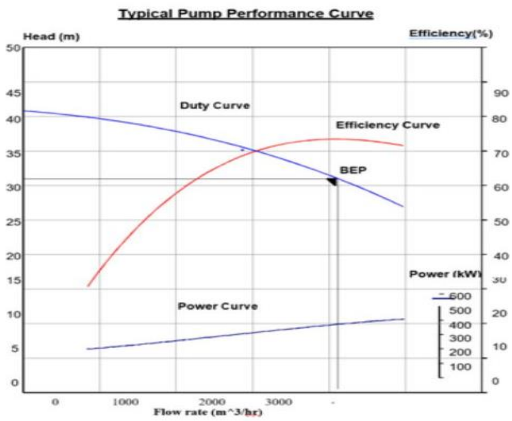

Fig. 7 Pump performance curve

Determining the optimum operating point

The best operating point of a submersible pump is typically analyzed by the fluid flow and the total head at maximum working efficiency. The optimum operating point of the submersible pump is present in case of impeller type where Q is the pump flow, N is the pump speed in rpm, η is the hydraulic efficiency, ψ is the impeller outlet exclusion coefficient, D is the impeller outlet diameter, P is the theoretical head correction factor, β is the impeller blade outlet angle, the characteristic equation of the impeller can be derived from the basic equation of submersible pump as follows:

Pump flow Q = 50gm/m
Impeller outlet diameter D = 150mm
Theoretical head correction factor = P = 1.42
Impeller outlet exclusion ψ = 26mm
Impeller blade outlet angle cot β = cot 65°
Hydraulic efficiency η = 81.4%
Pump speed in rpm (n) = 3200 RPM

$$H = \left(\frac{\eta h}{(1+P)g}\right) \times \left(\frac{\pi DN}{60}\right)^2 - \left(\frac{\eta h}{(1+P)g} \times \frac{Ncot\ Cot\beta N}{60cot\beta\psi\eta}\right) \times Q \quad (14)$$

$$H = \left(\frac{81.4 \times h}{(1+P)g}\right) \times \left(\frac{\pi DN}{60}\right)^2 - \left(\frac{\eta h}{(1+P)g} \times \frac{Ncot\ Cot\beta N}{60cot\beta\psi\eta}\right) \times Q$$

Water flow measurement was done with the help of magnetic flow meter; whereas the total head of the water was measured manually with the help of measuring tape. Fig. 8 and Fig. 9 show the decreasing and increasing rate of water head respectively where horizontal axis represents total head and vertical axis indicates water flow rate.

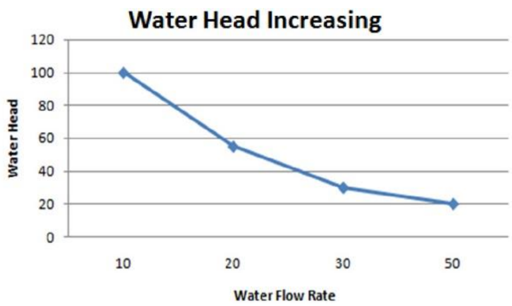

Fig. 8 Total water head vs flow rate curve (decreasing mode)

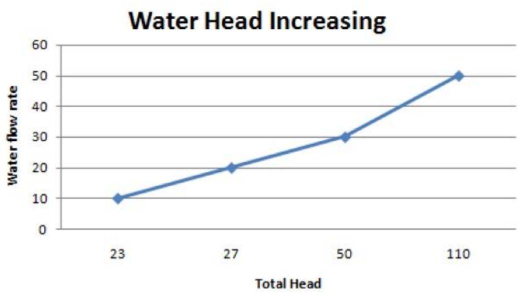

Fig. 9 Total water head vs flow rate curve (increasing mode)

Fig. 10 to Fig. 14 show the different parts of the solar submersible pump unit and also the installation method of the pump.

Fig. 10 Overall solar integrated submersible pump

Fig. 11 Pump outlet

Fig. 12 Pump installation technique

Fig. 13 Pump controller

Fig. 14 Variable frequency drive

6. Degradation of Solar Power and Efficiency

One of the disadvantages of solar systems is that the output of all solar panels beings to degrade over time. As the year progresses, the output of solar panels also start to decline due to micro cracks developed in silicon solar cells. As the degradation gradually increases, the panels become completely crippled. The main causes of solar panel degradation are materials expanding and contracting at different rates with temperature changes and this puts joins between different materials under strain and causes slow deterioration. Solar panels are damaged due to nature's humidity and excessive heat. As per specification of monocrystalline solar cell depreciation of required output power and efficiency will be minimum compared to the other type of cells, but still the warranty period means that after 20 years both the quality and efficiency of the panel will decrease at a certain rate. Solar panel efficiency means the ratio of the amount of light energy falling on the panel to the converted electrical energy. Panels are typically about 20% efficient as per specification. This plant will give at least 97% normal power in the first year. The next 10 years it will run with 91% of total power and will continue to provide 83% of the total power for up to 20 years.

7. Cost Analysis and Payback Calculation

Although the initial cost of solar power is a bit higher, it is comparatively more profitable than conventional electricity. This project proves that the use of solar power instead of conventional electrical power is profitable.

Table 5 Cost of overall project

SL No	Name of material	Cost in Indian currency (INR)
1	Monocrystalline Solar panel (Number of panels: 38, Maximum power=150)	55/- per watt. (40x150) = 6000/-(PER panel). Total panel cost: 6000(each) x 38=228000
2	Phase: 3 Phase. Motor Power: 7.5 HP or 5.5 Kw, Voltage: 280- 440V. Submersible pump	26000/-
3	Solar pump controller with AC drive for 7.5HP submersible pump	16000/-
4	Cost of mounting structure with installation cost	72000/-
5	Cost of cable	15000/-
6	Labor cost	20000/-
	Total Cost	382000/-

Submersible pump consumes 7.5 HP or 5595 watts load for 6 hours hour for one month. And the total electricity bill per unit of the consumer or tariff rate is 9 RS/- (Indian rupee). Indian currency is prevalent in the market of India and Nepal.

Consider, 1unit = 1kWh.

Total kWh in a month's = 5595 Watts × 6 Hrs × 30 Days = 1007100 watt/hour. (15)

So total consumed units. 1007100 /1000 units

Total average units per months = 1007 units.

Cost of per unit is 9.

So, total cost or electricity bill= 1007 × 9 = 9063 RS/-. (Indian rupee) (16)

Average annual electricity cost = 9063 ×12 =108756 Rs/-(Indian rupee) (17)

Initial fixing and investment cost of solar system is comparatively very high, but the warranty period of PV panels is long, almost 20 years. Manufacturers assure the concert guarantee for pump controllers and other accessories for about 5years. Various manufacturers also offer linear performance guarantee for submersible pump for 5 years. Overall investment cost of the project is 382000/- as per Table 6. Average annual cost of electricity for conventional energy source is 108756 Rs/-. If the depreciation of solar power is not estimated then payback will be around 3.5 years, but if the depreciation of solar power is taken into account, the pay back will come in 5 years.

8. CONCLUSION

In village area of Nepal the accessibility of electricity by conventional supply system is very poor as well as maintenance of electrical power system not is not much better as frequent power supply cut off is a common incident, more over the cost of electricity is very high for common people. By eliminating the dependence on conventional electricity and using solar power, it is possible to improve the quality of agriculture by supplying the required amount of water throughout the day. Solar energy is the main input of the pump and it takes no money to get solar energy. So, this project reduces the running cost of electricity. Moreover, daily maintenance cost of this project is very low because the only maintenance is cleaning the dust from the panel from time to time. This method does not require much human resources throughout the day and it is possible to use the stored ground water properly for better quality of agriculture. As a result, the cost of farming in that village has dropped significantly, and the economic development of the people of that area has been remarkable. In addition to agricultural job, the water obtained in this way meets the demand for daily life in the area.

REFERENCES

[1] S. Rahman, *Alternative Energy Sources: The Quest for Sustainable Energy*. IEEE Power and Energy Magazine, 2007.

[2] R. Foster, M. Ghassemi and A. Cota, *Solar energy: renewable energy and the environment*. CRC Press, 2009.

[3] S. Miric and M. Nedeljkovic, "The Solar Photovoltaic Panel Simulator", *Rev. Roum. Sci. Techn. Électrotechn. et Énerg*., vol. 60, no. 3, pp. 273–281, 2015.

[4] R. Kumar, B. Singh, "Buck boost converter fed BLDC motor drive for PV array based water pumping", In Proceedings of the IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), Mumbai, India, 2014, pp. 1–6, 16–19.

[5] H. Wang and D. Zhang, "The stand-alone PV generation system with parallel battery charger", In Proceedings of the International Conference on Electrical and Control Engineering (ICECE’10), Wuhan, China, 2010, pp. 4450-4453.

[6] M. Kolhe, "Techno-economic optimum sizing of a stand-alone solar photovoltaic system", *IEEE Trans. Energy Convers*., vol. 24, no. 2, pp. 511–519, 2009.

[7] D. Debnath and K. Chatterjee, "A two stage solar photovoltaic based standalone scheme having battery as energy storage element for rural deployment", *IEEE Trans. Ind. Electron*., vol. 62, no. 7, pp. 4148–4157, 2015.

[8] S. Krithiga and N. G. A. Gounden, "Power electronic configuration for the operation of PV system in combined grid-connected and stand-alone modes", *IET Power Electron*., vol. 7, no. 3, pp. 640–647, 2014.

[9] I. J. Balaguer-Álvarez and E. I. Ortiz-Rivera, "Survey of distributed generation islanding detection methods", *IEEE Latin Amer. Trans*., vol. 8, no. 5, pp. 565–570, 2010.
[10] C. A. Hill, M. C. Such, D. Chen, J. Gonzalez and W. M. Grady, "Battery energy storage for enabling integration of distributed solar power generation", *IEEE Trans. Smart Grid*, vol. 3, no. 2, pp. 850–857, 2012.
[11] W. Xiao, F. F. Edwin, G. Spagnuolo and J. Jatskevich, "Efficient approaches for modeling and simulating photovoltaic power systems", *IEEE J. Photovoltaics*, vol. 3, no. 1, pp. 500–508, 2013.
[12] S. Jain, A.K. Thopukara, R. Karampuri and V.T. Somasekhar, "A Single-Stage Photovoltaic System for a Dual-Inverter-Fed Open-End Winding Induction Motor Drive for Pumping Applications", *IEEE Trans. Power Electron*., vol. 30, no. 9, pp. 4809–4818, 2015.
[13] Le An and D.D.-C. Lu, "Design of a Single-Switch DC/DC Converter for a PV-Battery-Powered Pump System With PFM+PWM Control", *IEEE Tran. Ind. Electron.*, vol. 62, no. 2, pp. 910–921, 2015.
[14] Q. Yan, X. Wu, X. Yuan, Y. Geng and Q. Zhang, "Minimization of the DC Component in Transformer less Three-Phase Grid-Connected Photovoltaic Inverters", *IEEE Trans. Power Elec*., vol. 30, no. 7, pp. 3984–3997, 2015.
[15] A. Sangwongwanich, Y. Yang and F. Blaabjerg, "High-Performance Constant Power Generation in Grid-Connected PV Systems", *IEEE Trans. Power Elec*., vol. 31, no. 3, pp. 1822–1825, 2016.
[16] L. Campanhol, S. Silva, A. Junior and V. Bacon, "Dynamic performance improvement of a grid-tied PV system using a feed-forward control loop acting on the NPC inverter currents", *IEEE Trans. Ind. Electron*., vol. 64, no. 3, pp. 2092–2101, 2017.
[17] A. Radwan and Y. Mohamed, "Power Synchronization Control for Grid-Connected Current-Source Inverter-Based Photovoltaic Systems", *IEEE Trans. Energy Conv*., vol. 31, no. 3, pp. 1023–1036, 2016.
[18] G. N. Tiwari and S. Dubey, *Fundamentals of Photovoltaic Modules and Their Applications*, Centre for Energy Studies, Indian Institute of Technology (IIT) Delhi, New Delhi, India, *RSC publishing*, 2010, pp. 99–100.
[19] P. Singh and N.M. Ravindra, "Temperature dependence of solar cell performance an analysis", *Solar Energy Materials & Solar Cells*, vol. 101, pp. 36–45, 2012.
[20] A. M. Nader, D. Abderrahmane and A. Said, "Optimization of the performance of a photovoltaic pumping system by neuro fuzzy and direct torque control", *Rev. Roum. Sci. Techn. – Électrotechn. et Énerg*., vol. 59, no. 3, pp. 279–289, 2014.
[21] P.K.R. Reddy and J.N. Reddy, "Photovoltaic energy conversion system for water pumping application", *Int. J. Emerg. Trends Electr. Electron.*, vol. 10, no. 2, pp. 2320-2369, 2014.
[22] S. Biswas and M. Tariq Iqbal, "Dynamic Modeling of a Solar Water Pumping System with Energy Storage", *Hindawi Journal of Solar Energy*, vol. 2018, ID 8471715, 2018.
[23] S.S. Chandel, M. Nagaraju Naik, V. Sharma and R. Chandel, "Degradation analysis of 28 year field exposed Mono-c-Si photovoltaic modules of a direct coupled solar water pumping system in western Himalayan region of India", *Renew. Energy*, vol. 78, pp. 193–202, 2015.
[24] S. Lal, P. Kumar and R. Rajora, "Techno-economic analysis of solar photovoltaic based submersible water pumping system for rural areas of an Indian state Rajasthan", *Sci. J. Energy Eng.*, vol. 1, no. 1, pp. 1-4, 2013.
[25] S.S. Chandel, M. Nagaraju Naik and R. Chandel, "Review of solar photovoltaic water pumping system technology for irrigation and community drinking water supplies", *Renewable and Sustainable Energy Reviews*, vol. 49, pp. 1084-1099, 2015.
[26] Z. Zhang and T. Stathopoulos, "Wind loads on solar panels mounted on flat rooftops: Progress and limitations", In Proceedings of the 2014 World Congress on Advance in Civil, Environmental, and Materials Research (ACEM 14), Busan, Korea, 2014.
[27] K. Ragu and P.V. Mohanram, "Tolerance design of multistage radial flow submersible pumps", *MECHANIKA*, vol. 1, no. 63, pp. 64-70, 2007.
[28] M. T. Chaichan, B. A. Mohammed and H. A. Kazem, "Effect of pollution and cleaning on photovoltaic performance based on experimental study" *Int. J. Sci. Eng. Res.*, vol. 6, no. 4, pp. 594-601, 2015.