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Photovoltaic Pumping System Fed by DC-DC Push Pull Converter

N.Chandrasekaran, A.Karthikeyan

Abstract: ***This paper is to design a photovoltaic DC motor pumping system powered by DC-DC push pull converter whose output can be used for irrigation purpose. The charge controller of the system will regulate the output voltage of photovoltaic module and charge the battery. The push-pull type DC-DC converter will increase the battery output voltage and supply the terminal voltage for the DC pump as per the requirement according to the design values. The photovoltaic module is used as a source which converts the light energy received from sun radiation into electrical energy. The produced electrical energy from the photovoltaic is in Direct Current form. So here, the DC pump is used as a load instead of AC pump where the inverter is to be placed which converts the DC into AC. In between the source and load, the charge controller, battery and push-pull type DC-DC converter are connected. The photovoltaic dc pump can be used for low power applications. The motor pump operating under DC power has many advantages than AC pump.***

Keywords: Photovoltaic, Pump, Inverter, Converter, Charge Controller.

I. INTRODUCTION

The solar-powered pumping system are often used anyplace however it's acceptable for rural areas of the nation that is facing energy crisis just like the developing countries of the world. However, due to geographical position, india has ample sunshine throughout the year that makes it ideal location for utilization of alternative energy. Tiny farms, villages, and animal herds in developing countries need hydraulic output power of but a less than several of those potential users are too far from an electrical grid to economically faucet that supply of power, and engine-driven pumping tends to be prohibitively expensive as well as unreliable due to the high value of purchased fuel and lean maintenance and repair capabilities [1],[2]. Though the installation value of solar battery-powered pumping system is quite that of gas, diesel, or propane-powered generator primarily based pumping system, however it needs way less maintenance value. However, by scrutiny installation prices (including labor), fuel prices and maintenance prices over ten years with alternative typical fuel primarily based pumping system, the solar PV water pumping system [1].

Fig.1. Solar water pumping

The costs of solar materials are also considerably getting reduced day by day. The main objectives of this work are to design a solar based DC motor coupled pumping system and to eliminate need for placing inverter in the system configuration. This kind of pumps can be especially used in use in remote rural areas where the electricity is not available. The efficiency of this DC pump is better when comparing with AC motor pump. Solar based DC motor pumps are utilising the energy from the sun which is available in abundance,eco friendly and the source is renewable.One can also get uninterrupted power which results in proper regulation of motor throughout the day and requires less or no maintenance. Photovoltaic cells can be effectively used to power the motor pumping system in the cities and rural areas which will reduce the stress of power demand on the present power stations [10],[11]. Hereby, this work aims to provide an expansion in the use of green energy and reduce the power crisis. This work could also help to provide proper pumping arrangements for low power applications like irrigation.

II. BLOCK DIAGRAM

A. Description of the System

The solar based pumping system consists of Solar photo voltaic cell, charge controller, battery, DC-DC converter and DC pump. Solar panels are used to tap the energy from sun and convert it into useful energy. Solar energy is a renewable form of energy. It will be available every day and everywhere. It is the main example for the availability of plenty of energy with the nature. It does not cause any pollution to the environment and it is eco-friendly. Solar power is available free of cost hence, it can be used as the source for water pumping system. Energy from sun is obtained using a solar photo voltaic cell and is given to the charge controller.

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* Correspondence Author
N.Chandrasekaran*, Department of Electrical and Electronics Engineering, PSNA College of Engineering &Technology, Dindigul, Tamilnadu. India. Email: chandrasesekaran283@gmail.com
A.Karthikeyan, Department of Electrical and Electronics Engineering, PSNA College of Engineering &Technology, Dindigul, Tamilnadu. India. Email: janakarthi@rediffmail.com

The charge controller is used to give a regulated supply of power to the motor.

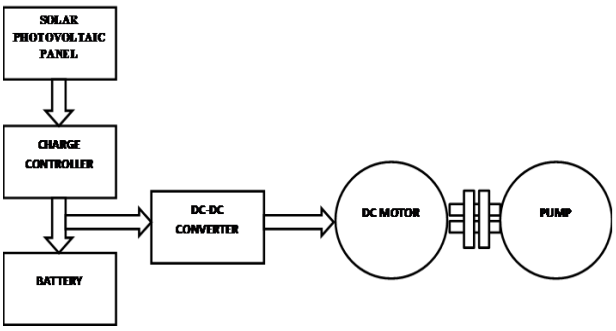


Fig.2. Block diagram of DC pumping system

Charge controller also supplies power to the battery which will be simultaneously charged. The battery provides backup power supply during night and cloudy weather. The energy stored in the battery will be fed to the motor pump for its operation during the absence of sun light. Solar based pumping system is eco-friendly and it also provides a means to utilize the solar energy which is being wasted in large amounts. Solar based pumping system then reduces the dependence for power on other non-renewable energy sources.

B. Solar Panel

A photovoltaic cell is defined as an electrical device which convert light energy into electrical energy in DC form by the principle of photovoltaic effect [1],[2],[3]. It is made by combinations of photoelectric cell (in that its electrical characteristics-e.g. current, voltage, or resistance vary when light is incident upon it) which, when placed to light, can produce and carry an electric current without any external voltage source [1],[2,][3]. Solar modules are having a group of photovoltaic cells that can develop electrical power from the irradiance of sun. The specifications of the solar panel are given the following table I

Table I : Specifications of Solar Panel

S.No	Parameter	Rating
1	No. of Cells	72
2	Power	250W
3	Open circuit voltage	22V
4	Short circuit current	14.2A

Combination of cells in an oriented group, all together in one plane, form a solar panel of photovoltaic or "solar photovoltaic module", as peculiar from a "solar thermal module" or "solar hot water panel"[1],[2],[3]. The electrical energy produced by solar modules, called as solar power, is an example of solar energy. An array is a group of connected solar modules (such as prior to installation on a pole-mounted tracker system).

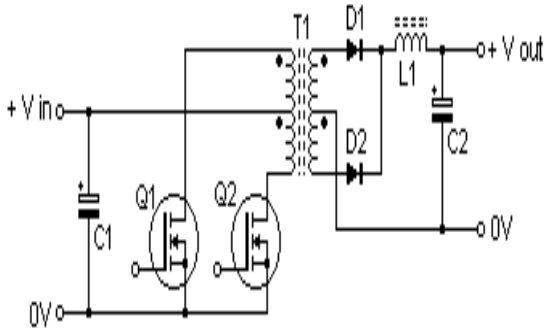
C. Battery

Electric energy can be stored in batteries and can be used in future [1],[6] whenever there is absence of power supply. A rechargeable battery is storage battery which can supply the electric power during absence of main power. It consists of one or multiple electrochemical cells, and it is also one of the types of energy accumulator. The rechargeable batteries are manufactured in many different shapes and sizes, ranging from button type cells to megawatt systems connected to stabilize an electrical distribution network [1],[6]. The different combinations of chemicals are generally used for making batteries, including: Lead Acid, Nickel Cadmium (Ni-Cad), Nickel Metal Hydride (Ni-MH), Lithium ion (Li-ion), and Lithium ion polymer (Li-ion polymer). The battery of this research work is charged during the day time and utilizing the power during the absence of sunlight and then it will feed power to run the motor. Hence, it acting as a backup power source.

D. Push-Pull Converter

The push pull converter is one of the types of feed forward converter which has been shown in the Fig.3. When switch Q_1 switched on, current flows through upper half of the primary of the transformer T_1 primary and the magnetic field in the transformer T_1 get expanded. The expanding magnetic field in the transformer T_1 induces a voltage across the secondary of transformer T_1, such that the polarity of diode D_2 is forward biased and the diode D_1 reverse biased. Diode D_2 conducts and charges the output capacitor C_2 through the inductor L_1. The inductor L_1 and the capacitor C_2 also form an LC filter network.

Fig.3. DC-DC Push Pull converter



When the switch Q_1 is turned off, the magnetic field in the transformer T_1 collapses, and switch Q_2 conducts, current flows through the lower half of the primary of the transformer T_1 primary after a period of dead time (dependent on the duty cycle of the PWM drive signal), and the magnetic field in T_1 get expanded [4],[5]. So, the direction of the magnetic flux is opposite to that produced when Q_1 conducted.

The expanding magnetic field induces a voltage in the secondary of transformer T_1, such that the polarity of the diode D_1 is forward biased and diode D_2 is reverse biased [5]. Diode D_1 conducts and charges the output capacitor C_2 through inductor L_1.

The switch Q_1 conducts after a dead time and the cycle is repeated [5].The mathematical model of the Push-Pull DC-DC converter is given by the eqn.(1)

$$\frac{V_o}{V_d} = 2\frac{N_2}{N_1} D \qquad (1)$$

where,

V_o-Output voltage

V_d-Input voltage

N_1-No. of turns in primary winding

N_2-No. of turns in secondary winding

D-Duty ratio

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E. Charge Controller

A charge controller is a circuit that can limit the rate at which electric current is drawn from electric batteries [1],[4].

It can prevent the battery from overcharging and may also prevent against overvoltage, otherwise battery performance or lifetime get reduced, which may possess a safety risk. It is also preventing completely draining ("deep discharging") a battery, or perform controlled discharges, depending on the battery technology, to protect the life of battery. The terms "charge controller" or "charge regulator" may refer to either a stand-alone device, or to control circuitry integrated within a battery pack, battery-powered device, or battery recharger [5],[9].

III. RESULTS AND DISCUSSION

Based on the climatic condition, the average hourly temperature data of dindigul city in Tamilnadu, India is shown in Fig.4.The temperature of the dindigul city for the whole year in the range that is enough for the photovoltaic cell and its operation.

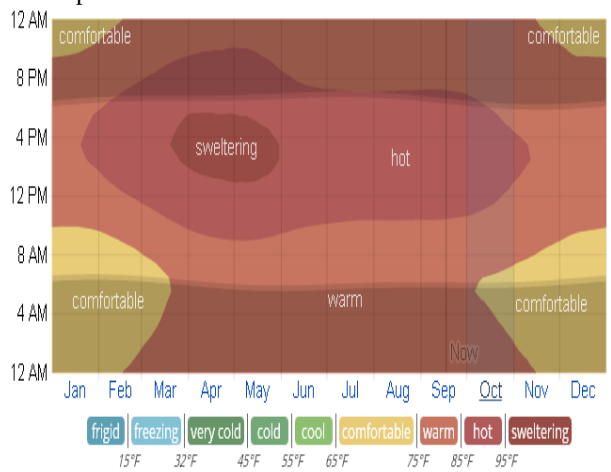

Fig.4. Average hourly temperature data

Polycrystalline type photovoltaic module is used. The photovoltaic module can produce up to 240W and the module has 72 cells in it. The PV Module parameters has an open circuit voltage of 22 v and a short circuit current of 14.2 A respectively. The experimental setup for the observation of climatic condition and the measurement are shown in Fig.5 and Fig .6

Fig.5. Experimental setup for the observation of climatic condition

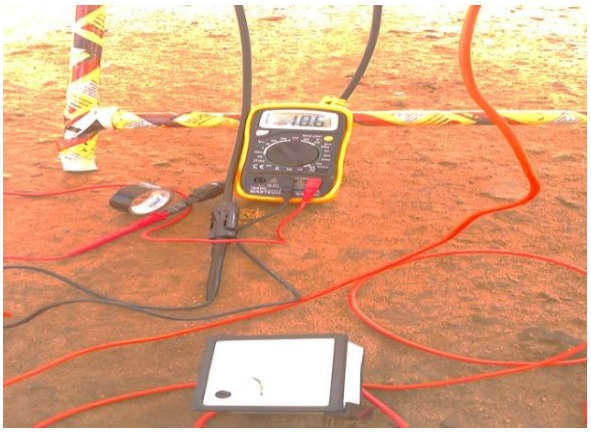

Fig.6. Measurement of readings at different durations

The experiment for the measurement of voltage, current and power has been done for the whole day .The measurement started at morning 6 am and completed the process at evening 6 pm on the same day. It is found from the measurement that the power output is more at the mid of the day when solar insolation is at its maximum. Table I gives the readings measured at different timings in a particular day.

Table I1: Readings measured at different timings

Time	Voltage(V)	Current(A)	Power(W)
6 am	9.5	0	0
8 am	13	1.5	19.5
10 am	16	4.5	72
12	16.5	9	148.5
2 pm	15	3	45
4 pm	15	1.5	22.5
6 pm	14.5	0.20	2.9

The DC motors has many advantages when comparing to AC motors when it is used for low power applications. DC motors are distinguished by their ability to operate from direct current [6]. Nowadays the DC motors have been popular in the industry control area for a long time, because they have many good characteristics such as high starting torque characteristic, high response performance, easier to be linear control etc. The torque T developed by the motor is proportional to the armature current and air gap flux [8]. Consequently the back EMF of the motor is being proportional to speed. The rating of the DC shunt motor used in this work is given in the table III.

Table III : Specifications of DC Motor

S.No	Parameter	Value
1	Power	0.5hp
2	Voltage	150v
3	Current	5A
4	Speed	1500rpm

Fig.7given below shows the DC motor with pump arrangement.

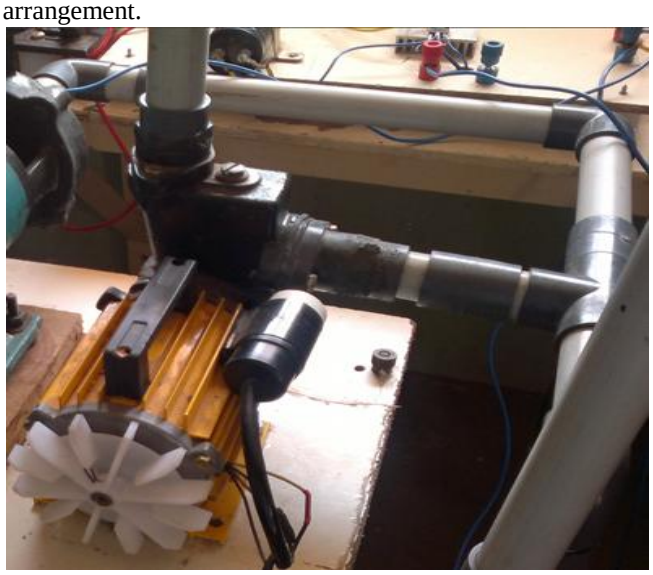

Fig.7. DC motor with Pump

The output from the solar panel is given to charge controller. The output of the solar panel is not constant at all time due to the variation in the irradiation of the sun. In order to apply the constant input to the system, the charge controller is place between the source and the load. The charge controller supplies to both DC to DC converter as well as battery. The experimental set up which shows the charge controller is given in Fig.8

Fig.8. Experimental setup with charge controller

The output from the charge controller is fed to DC to DC converter before applied to load. The DC output from the solar panel is not enough for the operation of pump. The DC to DC converter is used to step up the voltage received from solar panel to the required level. The duty ratio of the DC to DC converter used to change the magnitude of the input voltage. The PWM based pulses are applied to the gate of the DC to DC converter circuit. The PWM circuit along with isolation circuit is used for this purpose. The experimental setup of PWM circuit along with isolation circuit is shown in Fig.9 The PWM output waveform is shown in Fig.10

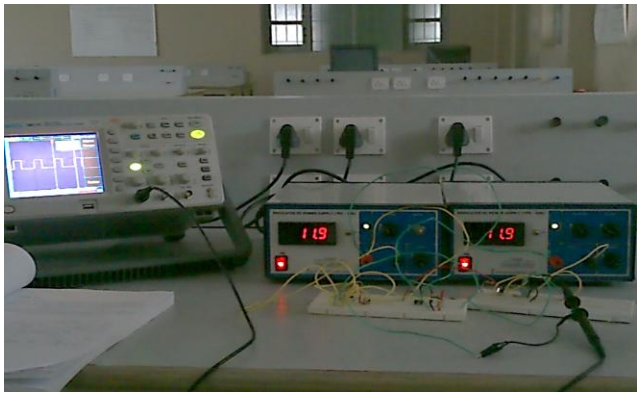

Fig.9. Experimental setup of PWM and isolation circuit

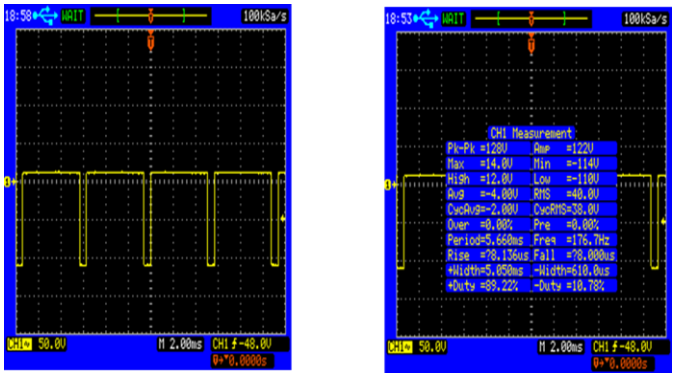

Fig.10. PWM output waveform

The overall DC to DC push pull converter based water pumping system with solar energy utilization is found better choice for the current situation. The total system of DC pumping system works well and gives more water output than AC pumping system. The efficiency of this pumping system is also better than any other motor based pumps.

IV. CONCLUSION

This work is an initiation for utilizing the solar energy in water pumping sector. The solar powered DC motor water pumping system with DC to DC push pull converter works better than AC motor pumping system. The overall cost of the pumping system is less .The DC pump requires less maintenance. The output quantity of water is more than AC motor pump. There is no problem about harmonics and power factor in DC motor pump .The inverter is not required for this pumping system. In whole, the DC motor based pumping system is the best option for irrigation purpose under the existing power crisis.

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AUTHORS PROFILE

N. Chandrasekaran has received his B.E degree from Bharathiar University in the year 1998 and got M.E. degree from Anna University Chennai, in the year 2004. He has secured first rank in M.E and got gold medal. He achieved his Ph.D from Anna University Chennai, in the year 2014. He published 13 papers in National Conferences and 6 papers in International Conferences. He also published 21 research papers in International journals. His areas of interest include Power Electronics and Control of Drives, Renewable Energy systems and Control systems. He is a life member of ISTE and member of IEEE. He has 20 years of teaching experience. Currently he is working as a Professor in the department of Electrical and Electronics Engineering at PSNA College of Engineering and technology, Dindigul, Tamil Nadu, India.

A. Karthikeyan has obtained his B.E degree from Madurai Kamaraj University in the year 2000 and done M.E. degree at Govt. College of Tech. Coimbatore, in the year 2007. He published 4 papers in National Conferences and 4 papers in International level Conferences. He also published 5 research articles in International journals. His areas of interest include Power systems, Electrical machines and Measurement systems. He is a life member of ISTE. He has 17 years of teaching experience. Currently he is working as an Assistant Professor in the department of Electrical and Electronics Engineering at PSNA College of Engineering and technology, Dindigul, Tamil Nadu, India.