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PV-Based Water Pumping System Without Storage Battery

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***Abstract*— In the rural area, where there is no electricity supply from the grid, PV-based water pumping systemis Very popular. The conventional PV-based water pumping system stores electrical energy generated by solar panel in the storage battery. A DC to AC inverter is used to drive the water pump coupled with conventional AC motor. The efficiency of this type of water-pump system low due to the power losses during charging and discharging process and life of the very is very short. In this paper a stand-alone Photovoltaic (PV) systems is presented for water pumping without using storage battery which can be used for irrigation and drinking water. The proposed systems without battery can provide a cost-effective use of solar energy. Simulation model of the proposed scheme is developed and proto-type hardware is fabricated. The simulation results and hardware results shows the technical feasibility of the proposed scheme.**

***Keywords* - PV based water pumping, Battery less, DC-DC converter**

I. INTRODUCTION

This paper presents the utilization of stand-alone Photovoltaic (PV) systems for water pumping system without using storage battery for rural area. In rural area where electricity supply from National grid is not available, solar energy is found to be used water pumping application. In conventional water pumping system, the power from PV panel is used through battery and inverter as shown in Fig.1

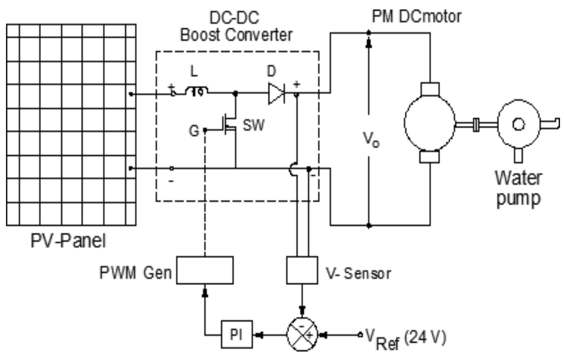

Fig 1: Conventional water pumping system withsolar PV using battery and Inverter

In this system, the energy output from the solar PV panel is stored in DC battery. An inverter is used to convert DC voltage from battery to AC voltage and ac motor coupled pump is driven through the inverter to pump the water whenever required. Water can be pumped even in night time because of storage battery. However, the system is expensive because of the use of inverter and battery. Also, the battery used in the system has some disadvantages even though the renewable source i.e. solar energy is used. The main disadvantages if the battery are:

- Power loss during charging and discharging.
- Less efficiency
- The battery is expensive
- It has a short life.
- It pollutes the environment with lead acidcontamination if not properly disposed.

In this paper, a battery less PV system is proposed which could be cheaper and more efficient with compare to conventional system with battery and inverter. Fig.2 shows the control logic of the proposed scheme.

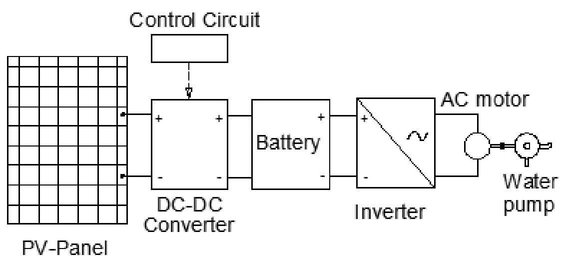

Fig 2: Control logic of the proposed scheme

The proposed scheme consists of a PV array, DC to DC converter (Boost converter) and DC motor coupled with the pump. The DC-DC converter is controlled to give a constant DC output voltage of 24V at varying irradiance and temperature on thesolar panel. The output voltage from the dc-dc boost converter is sensed and compare with reference voltage of 24V. The error so obtained is passed through a

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properly tuned PI controller which gives command signal to PWM generator, which generates proper gate pulses for power electronic switch of the converter to produce constant output voltage of 24 V. This constant 24V drives a dc motor coupled with thewater pump. Water can be pumped during day and stored in tanks and water can be used whenever it is required.

II. MODELING OF PROPOSED SCHEME

I. PV Solar Panel

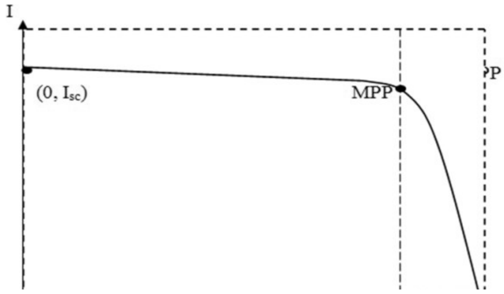

Fig 3: V-I Characteristics of practical PV panel

Photovoltaic (PV) solar panel converts energy content in the sun light into electrical energy using semiconducting materials that exhibit the photovoltaic effect. The photovoltaic effect is the production of voltage and electric current in a material upon exposure to light and is a physical and chemical phenomenon.

Fig. 3 depicts the I-V characteristic curve of solar cellof a practical photovoltaic device, where it is clearly shown that when voltage is short circuited to zero, the current (I_{sc}) flows. On the other hand, when the circuit is open, there's no current flow and the point is known as the open circuit voltage (V_{oc}).

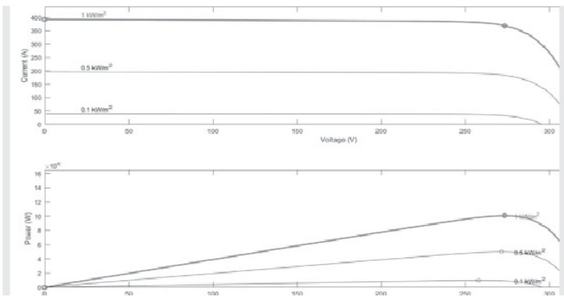

Fig 4: Effect of irradiance on I-V and P-V curve respectively

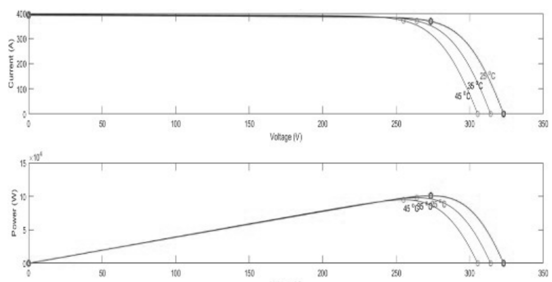

Fig 5: Effect of temperature on I-V and P-V curverespectively

Fig.4 shows the effect of change in irradiance on I-Vand P-V curves and Fig.5 shows the effect of changein temperature on I-V and P-V curves. The PV-panelmodel available in the Simulink library is used in thesimulation study.

III. DC-DC Boost Converter

DC-DC Boost Converter is power electronic circuits that convert a DC voltage to DC voltage of higher average value. Fig.6 shows the circuit of DC-DC boost converter.

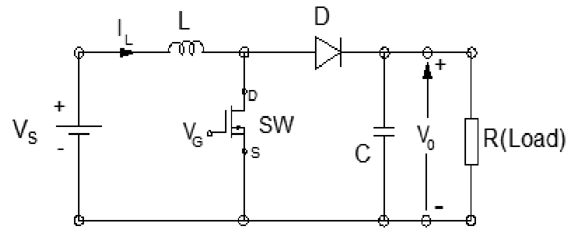

Fig. 6 Circuit diagram of DC-DC boost converter

The main principle is to store the charge in a capacitor through a diode so that the voltage across the capacitor becomes greater that the input dc voltage due to the action of blocking diode. By controlling the ON and OFF periods of the power electronic switch, the average voltage across the capacitor can be controlled to a desired value. When the switch is closed, no current flows through the diode. The supply current passes through the inductor thus by storing energy. At the same time, the capacitor discharges to supply voltage to the load. When the switch is open, the capacitor gets charge through the inductor and the inductor releases the energy. Fig.7 shows the responses of inductor current (I_L) and output voltage (V_0) during On period t_1 and Off period t_2.

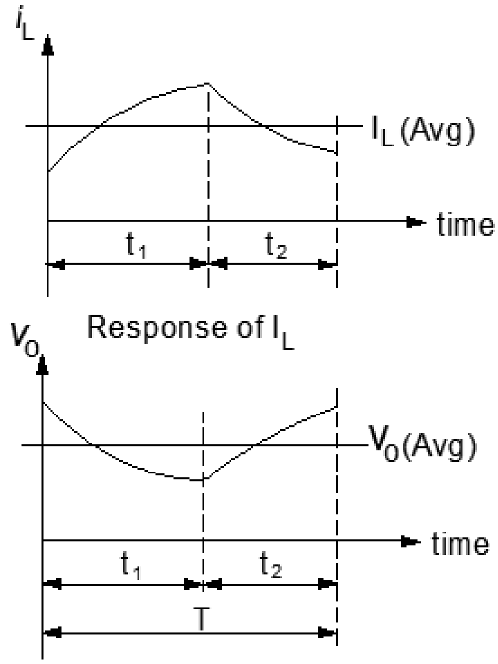

Fig.7 shows the responses of inductor current (I_L)and output voltage (V_0)

During On period (t_1), energy stored by the inductor is given by:

$W_{ON} = V_S . I_D . t_1$

During Off period (t_2), energy released by the inductor is given by:

$W_{OFF} = (V_0 - V_S.) I_D . t_2$

Assuming that there is no power loss in the circuit:

$V_S . I_D . t_1 = (V_0 - V_S.) I_D . t_2$

$$\text{or } V_0 = \frac{t_1 + t_2}{t_2} V_s \quad (1)$$

If the duty cycle of the converter is defined as:

$$D = \frac{t_1}{t_1 + t_2} \quad (2)$$

$$\text{or } V_0 = \frac{V_s}{1-D} \quad (3)$$

This shows that if the switch is always open, then D is zero and the output voltage is equal to the input voltage.

IV. SIMULATION RESULTS

The proposed scheme is simulated in Mat-Lab Simulink. The solar PV panel and DC motor considered in the simulation are rated as follow.

PV-Panel:

Peak power = 50 Wp
V(open)= 2 V
Voltage at Max power point = 17.6 V
for irradiance of 1000W/m^2 at temp = 25^0 C

DC Motor:

Type : Permanent magnet DC motor
Power = 20 Watt

Rated voltage = 24V DC

Fig.8 shows the simulation model of the proposed scheme developed in Mat-Lab Simulink. The PV- panel model available in the Simulink library is used in the simulation study. Irradiance is kept constant at 1000 W/m^2 from 0 to 0.05 sec and it is ramped down to 300 W/m2 in 0.075 sec. It is then kept constant till 0.175 sec and again raped up to 1000 W/m^2 in 0.2 sec and kept constant till 0.25 sec. The temperature is kept constant at 25^0 C. The output voltage from the PV panel is supplied to DC-DC boost converter and the converter is controlled to produce a constant DC voltage of 24V at varying irradiance conditions. The constant DC output voltage from the DC-DC boost converter drives the permanent magnet DC motor.

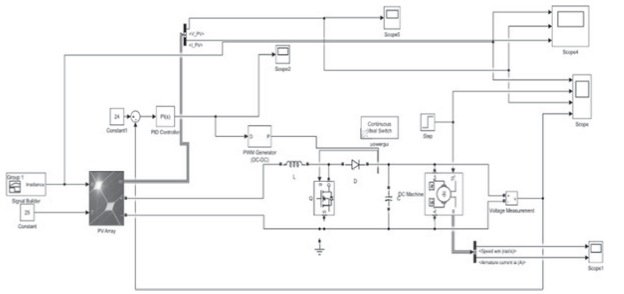

Fig.9 Simulation model of the proposed scheme in Mat-Lab Simulink

The simulation results are shown in Fig.10 and

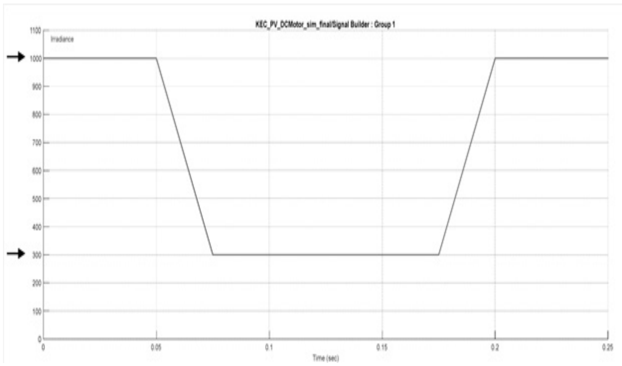

Fig.10 Variation of solar irradiance

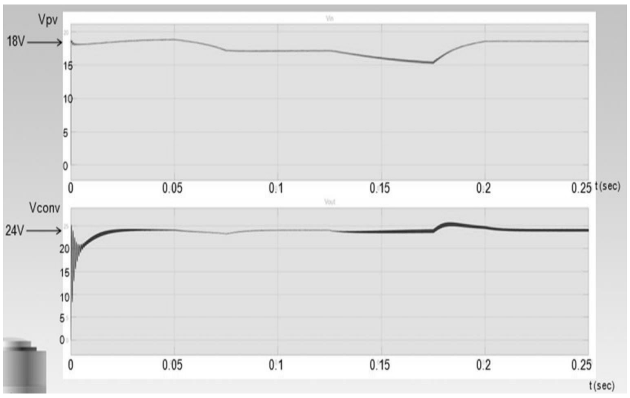

Fig.11 plots of variable DC voltage output from PV panel and constant DV voltage output from DC-DC converter

Fig.10 shows the varying solar irradiance input given to the PV panel model and Fig.11 shows the corresponding variable DC output voltage and the output DC voltage from the controlled DC-DC boost converter. It is clear from the simulation results that the output voltage from the DC-DC boost converter is fairly constant at 24V even the output voltage from PV panel is varying with varying irradiance.

V. PROTEUS SIMULATION AND HARDWARE RESULTS

Before fabricating the proto-type hardware of the proposed scheme, the scheme is simulated in Proteus simulation program to decide values and ratings of various components to be used in hardware fabrication. Fig.12 shows the simulation model of the proposed scheme developed in Proteus. Fig.13 and Fig.14 shows results from the Proteus simulation.

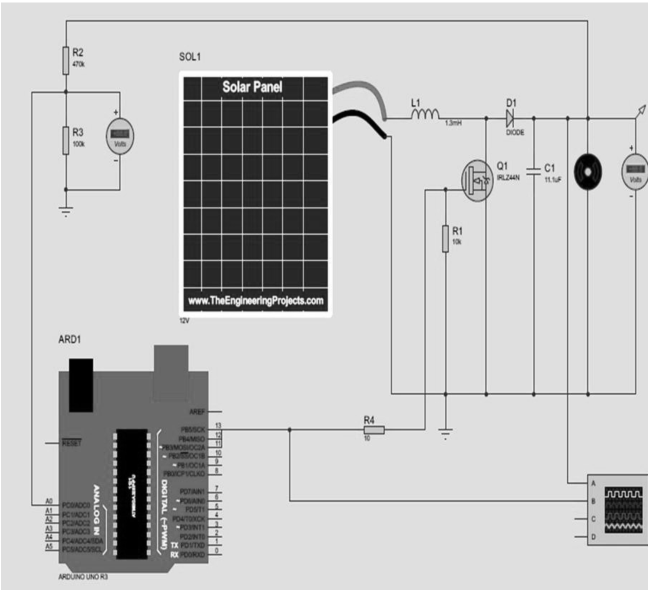

Fig.12 Simulation model of the proposed scheme developed in Proteus

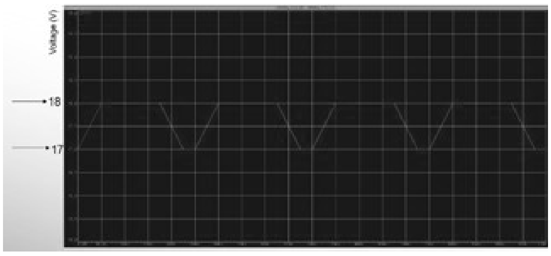

Fig.13 Variable DC voltage input to boost converter

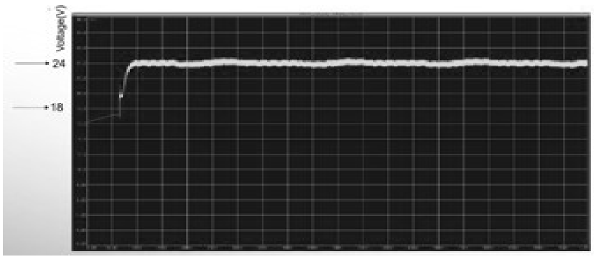

Fig.14 DC output voltage from boost converter

Fig.15 shows the fabricated proto type hardware of the proposed scheme. It is tested for varying solar irradiance input given to the PV panel model and the output voltage from the DC-DC boost converter is found to be constant at 23.5 V and the DC motor under test runs at a constant speed and the water is pumped with fairly constant discharge.

The ratings of various components to be used for hardware fabrication are found to as follow:

Components	Rating/type	Qty
Resistor	$100k\Omega$, 470kΩ, 10Ω	1
Capacitor	$10\mu F$	1
Inductor	1.2mH	1
MOSFET	(IRF540N)	1
Diode	6 Amp	1
DC Motor	24V, 20 watt	1

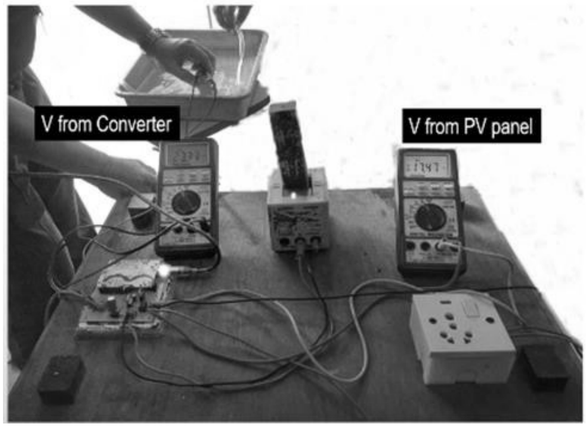

Fig. 15 Fabricated prototype hardware of the proposed scheme.

VI. CONCLUSION

PV based water pumping system without storage battery can be practically implemented in rural area. The proposed scheme is successfully simulated in Matlab Simulink and Proteus. Even the output voltage from PV panel is varying and less than 24 V, a constant voltage of 24 V required for the DC motor has been obtained by controlling the DC-DC Boost converter. The prototype hardware is successfully designed, fabricated and tested.

VII. REFERENCES

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