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Implementation Of Reduced cost PV Powered Water Pumping With PMDC Motor For Coconut Farms

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Abstract: This paper contracts with design method to reduce the cost of the solar photovoltaic (SPV) array fed water pumping system employing PMDC motor drive coupled to a centrifugal water pump for coconut farm application unlike convectional solar powered water pumping system. The proposed system employs batteries to drive the motor. As the coconut farms needs to be irrigated every ten days or so. Batteries are charged during the ten days periods by means of PV array. Hence number of PV panel required for changing the battery is reduced by a factor of 10 which reduces the cost of the overall system as panels forms the major cost. A DC-DC boost converter is used to increase the voltage of the battery to meet the rating of the motor. The proposed system is simulated using MATLAB/Simulink and simulation results are presented to validate the suitability of the system

Keywords: **Boost converter, SPV array, Battery, PMDC motor**

I. INTRODUCTION

As a result of depleting conventional sources of electrical power worldwide, usage of renewable source likes wind, tides, sunlight etc. have become essential of these days. Among these the solar photovoltaic (SPV) panels have prominent advantages and universally used. The main advantages of PV are low maintenance, easy to install, no fuel is required and simple and reliable. The solar photovoltaic panels are utilized in water pumping system. The water pumping system is used for irrigation purpose.

The solar water pumping system comprises of solar panel, boost converter, batteries, DC motor, pump and MPPT. The advantages of pumps which are driven by PV panel are high reliable, low maintenance, simple fitting etc. The PV panel convert light energy from the sun to electrical energy. The converted energy is given to the DC-DC converter. The batteries are used for storing the power. The electric current generated by the PV panel during day light hours charges the batteries which in turn supplies power to the DC motor for pumping the water. During the night time water is pumped with the help of batteries by detaching the solar panel. The number of PV panels can be reduced by using the batteries to attain the low cost .

The PMDC motor is used for water pumping system rather than induction motor. The PMDC motor pump can operate directly from the batteries. The main benefits of PMDC motor are convenient and portable, easy to operate and has more efficient whereas AC motor pumps are inability to operate at low speeds and poor position control.

The DC-DC converter that steps up voltage from its input (supply) to the output (load).Power for the boost converter can come from any suitable DC source , such as batteries, solar panel, rectifier etc. The boost converter provides high output power and has lower operating duty cycles and lower voltage on MOSFET.

Photovoltaics are the best method for generating electrical power by converting the energy from the solar using semi conducting materials. Photovoltaic system employes solar panel, each compraising a number of solar cells, which generate electrical power . solar cell produce direct current electricity from sun light which can be used to power equipments or to recharge a battery . The main advantages of pv is no pollution and no green house gas emission and major disadvantages that the power output dependent on direct sun light The electrical efficiency of a pv cell is physical property which represents how much electrical power a cell can produce for a insulation

$$\eta = \frac{P_{max}}{E.A_{cell}} \qquad (1)$$

The efficiency is measured under ideal laboratory condition and represents maximum achievable efficiency of the pv

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material .actual efficiency is influed by the output voltage ,current junction temperature , light intensity and spectrum.

II. Proposed System Configuration

The topology of the proposed SPV array fed water pumping system using PMDC driveis shown in Fig.1. It consists of the SPVarray, the boost converter feeding the PMDC coupled to a centrifugal water pump. The SPV array output power is optimized by P & O MPPT technique. The design and control of the proposed system are elaborated in the following.

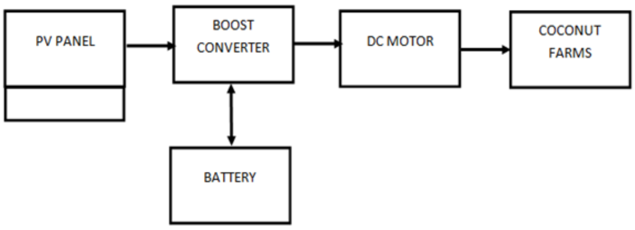

Fig. 1.Block diagram

III. Control of the Proposed System

In the proposed system, maximum power of the SPV array is tracked using P & O MPPT technique and the boost converter feeding the PMDC is operated. The control at the various stages are discussed in brief in the following sub-sections.

A. MPPT Technique

The location of MPP in the I-V characteristics of SPV array is not predicted in advance and always varies dynamically with irradiance and temperature. There are observable voltage shifts where the MPP occurs.

Therefore, the MPP needs to be located by tracking algorithms. The P&O method of MPPT tracking, which is also known as 'hill climbing' method is very advantageous and commonly used because of its simplicity and the ease of implementation .It is also called three step operations method.

The duty ratio of Boost converter is routinely regulated through this MPPT controller. Thus MPPT produces PWM pulses for the switch of Boost converter. This method includes other advantages such as low implementation complexity and no periodic tunings.

IV. Boost Converter

A boost converter is a switch mode DC to DC converter in which the output voltage is greater than the input voltage. It is also called as step up converter. The name step up converter comes from the fact that analogous to step up transformer the input voltage is stepped up to a level greater than the input voltage. By law of conservation of energy the input power has to be equal to output power (assuming no losses in the circuit).

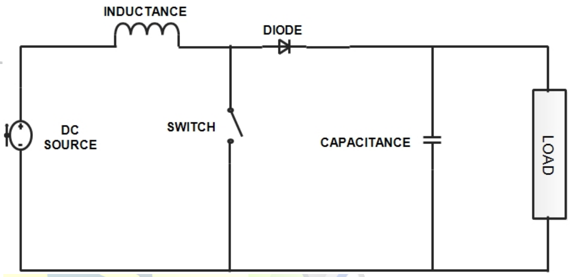

Fig. 2. Basic boost converter

$$\text{Input power (Pin)} = \text{output power (Pout)} \quad (2)$$

The DC input to a boost converter can be from many sources as well as batteries, such as rectified AC from the mains supply, or DC from solar panels, fuel cells, dynamos and DC generators.

V. Operation of Boost Converter

The main working principle of boost converter is that the inductor in the input circuit resists sudden variations in input current. When switch is OFF the inductor stores energy in the form of magnetic energy and discharges it when switch is closed. The capacitor in the output circuit is assumed large enough that the time constant of RC circuit in the output stage is high. The large time constant compared to switching period ensures a constant output voltage

$$V_o(t) = V_o(\text{constant}) \quad (3)$$

VI. Modes of Boost Converter

The boost converter can be operated in two modes

a) Continuous conduction mode in which the current through inductor never goes to zero i.e. inductor partially discharges before the start of the switching cycle.

b) Discontinuous conduction mode in which the current through inductor goes to zero i.e. inductor is completely discharged at the end of switching cycle.

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A. MODE 1

The high frequency square wave applied to the MOSFET gate at start up. During this time MOSFET conducts, placing a short circuit from the right hand side of L1 to the negative input supply terminal. Therefore a current flows between the positive and negative supply terminals through L1, which stores energy in its magnetic field. There is virtually no current flowing in the remainder of the circuit as the combination of D1, C1 and the load represent a much higher impedance than the path directly through the heavily conducting MOSFET

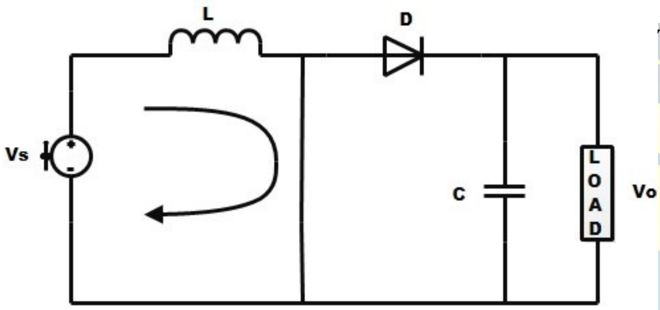

Fig. 3.Boost converter in switch ON mode

B. MODE 2

The current path during the low period of the switching square wave cycle. As the MOSFET is rapidly turned off the sudden drop in current causes L1 to produce a back e.m.f. in the opposite polarity to the voltage across L1 during the on period, to keep current flowing. This results in two voltages, the supply voltage VIN and the back e.m.f.(VL) across L1 in series with each other.

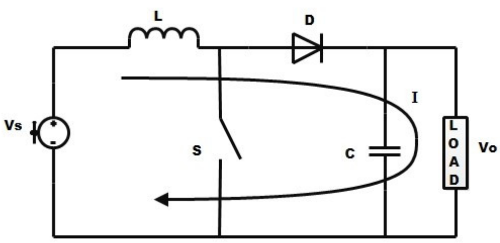

Fig. 4.Boost converter in switch OFF mode

This higher voltage (V_{IN} $+V_L$), now that there is no current path through the MOSFET, forward biases D1. The resulting current through D1 charges up C1 to V_{IN} $+V_L$ minus the small forward voltage drop across D1, and also supplies the load.

VII. DESIGN OF BOOST CONVERTER

The duty cycle is calculated by

$$\propto = 1 - \frac{V_S}{V_c} \quad (4)$$

The ripple current(ΔI) was calculated by

$$I_L = \frac{I_O}{(1-\propto)} \quad (5)$$

$$\frac{\Delta I_L}{I_L} = 0.1$$

The inductance value(L) was calculated by

$$L = \frac{(V_{S*\propto})}{(F_S * \Delta I)} \quad (6)$$

The ripple voltage was calculated by

$$\frac{\Delta V}{V_O} = 0.01 \quad (7)$$

The output resistance(R_O) was found by

$$R_0 = \left(\frac{V_O}{I_O}\right) \quad (8)$$

The capacitance value(C) was calculated by

$$C = \frac{\left(\frac{\propto}{V_O}\right)}{(F_S * R_O * \Delta V)} \quad (9)$$

VIII. SIZING OF PHOTOVOLTAIC PANEL

The design of Solar PV array fed water pumping system has various components. The design procedure for various components of the proposed system is discussed in the following sub-section.

TABLE I

SPECIFICATIONS OF THE PROBLEM

Parameters	Values
Panel power	100watt
Battery capacity	160Ah
Battery Voltage	12V
Time Of Charging	6 hours/day
Converter Efficiency	0.9

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Operating Factor	0.75

The energy required for the pv panel is calculated by

Energy required = battery capacity *voltage

= 300*84
= 25200 wh

The total wattage of pv panel is given by

Total wattage of PV panel = $\frac{energy\ required}{time\ of\ charging}$

$= \frac{25200}{60}$
= 420 w

The total wattage of pv panel by considering DC to DC converter losses

Total wattage of pv panel $= \frac{420}{0.9*0.75}$

= 622.5 w

The number of pv panel required is calculated by

Number of pv panel required for 30w each$= \frac{622.5}{100}$

=6.2
≅7nos

TABLE II
DATA SHEET PARAMETER

Parameter	Values
Voltage at maximum power (V_{mp})	17.70v
Current at maximum power(I_{mp})	1.70A
Open circuit voltage (V_{oc})	21.40v
Short circuit current(I_{sc})	2.00A
Tolerence	±5%
Maximum system voltage	1000V

IX. Sizing of Battery

The energy required to operate the load is

Energy required to operate the load = $power * time$

$= 3730 * 4$

= 14920 wh

Actual energy required by considering converter losses is

Actual energy required= $\frac{energy\ required\ to\ operate\ the\ load}{converter\ efficiency}$

$= \frac{14920}{0.9}$
=16577.79Ah

The required charge capacity is calculated by

Required charge capacity = $\frac{actual\ energy\ required}{Battery\ voltage}$

$= \frac{16577.77}{84}$
= 197Ah

We know that depth of discharge for battery= 0.7

Therefore, battery capacity = $\frac{Required\ charge\ capacity}{Depth\ of\ discharge} = \frac{197}{0.7}$

= 158.73Ah

The market availability of battery = 281.9

≅300Ah

X. Simulation Circuits and its Waveforms

The proposed system is simulated in MATLAB/Simulink Fig 4. Is the simulation diagram which consist of panel, boost converter and Battery bank . Simulation results are Shown in fig 5,6. And the fig 7 consist of battery bank , boost converter, and DC Motor Pump. The simulation results are shown in fig 8.

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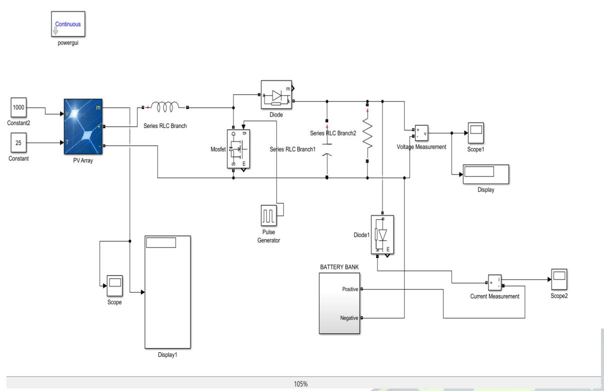

Fig. 4. Simulink model of pv based boost converter

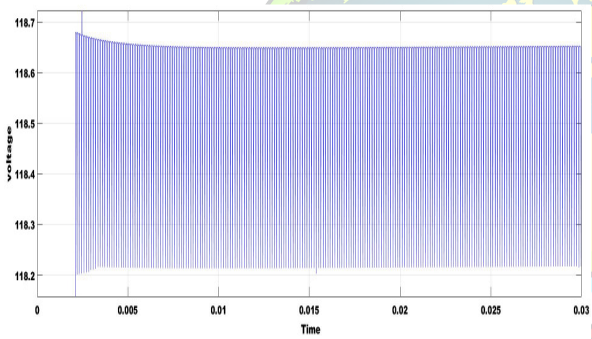

Fig. 5.Output Voltage Of Boost Converter

The output voltage waveform of boost converter has been plotted by keeping time(s) in x axsis and voltage (v) in y axsis and obtained the value as 118.3v approximately.

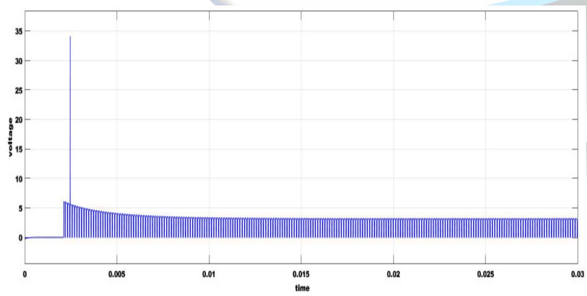

Fig. 6.Output Voltage Of Battery

The output voltage waveform of battery has plotted by keeping time(s) in x axsis and voltage (v) in y axsis and obtained the value as 34A approximately.

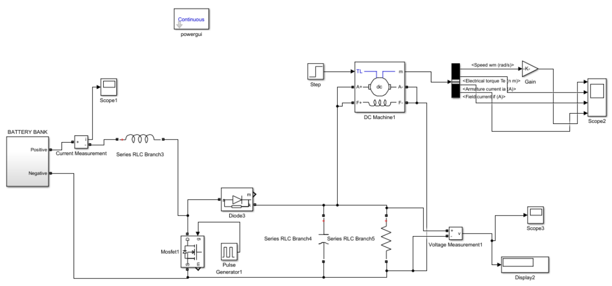

Fig. 7. Simulink Model of Battery Based DC Motor Pump

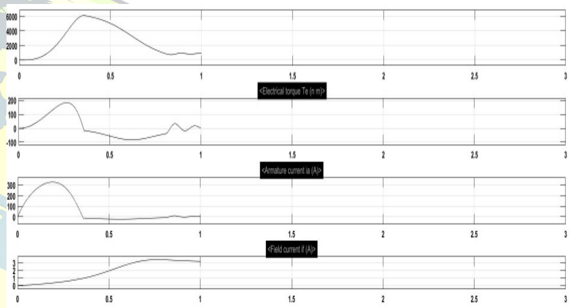

Fig. 8. Output Of DC Motor Pump

The output waveform of speed, armature current, field current and torque of DC motor pump has been plotted .The obtained value of speed is 1300 approximately .

XI. Conclusion

The proposed system has been designed and simulated in the MATLAB/SIMULINK environment. It is observed from the simulation results that PMDC motor runs smoothly after the battery voltage has been boosted to the rated voltage. Also batteries are charged with PV panels whose rating is roughly one sixth of the actual panel requirement if the motor is directly run from PV panels. Therefore the cost of the system is reduced significantly even after including the cost of the batteries. Therefore the proposed system is well suited for applications like irrigating coconut farms which do not require daily water pumping.

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