Photo Voltaic Powered Sailing Boat

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Abstract
Diesel engines are used for sailing boats which create heavy ecological problems. To overcome this problem, we propose a Photo Voltaic-powered sailing boat that uses solar energy converted from a Photo Voltaic (PV) panel, Buck-Boost converter and a Permanent Magnet Direct Current (PMDC) motor. A PV panel is connected with a Buck-Boost converter which is used to fed the PMDC motor to drive the propeller of the sailing boat. Buck-Boost converter converts the DC variable output voltage of PV panel into a DC constant output voltage that is applied to the PMDC motor. This PMDC motor will drive the propeller of the Photo Voltaic Powered Sailing Boat. A Buck-Boost converter with high proficiency is used to sustain constant output voltage to the connected PMDC motor, even in the case of rainy days. For firing the MOSFET of Buck-Boost converter a PWM signal is produced using ARM Processor to maintain constant output. A PV panel with Buck-Boost converter is simulated using Mat Lab / Simulink and it is implemented in hardware.

Introduction

Diesel engine powered sailing boat creates a heavy ecological problem. To overcome this problem, we propose Photo Voltaic-powered sailing boat that uses solar energy converted from a PV converter and it is fed to PMDC motor. A PV panel is attached with a Buck-Boost converter and fed to PMDC motor[1].The main objectives of this work are (i) to extract the maximum power from the PV panel and implement a buck-boost converter to feed the PMDC motor to drive the sailing boat (ii) to maintain constant output voltage even in rainy days through controlling the firing angle of MOSFET using ARM Processor[4].

Material and Methods

Proposed Model: The block diagram of the proposed Photo Voltaic-powered sailing boat with a buck-boost converter is shown in figure 1.

The power that is produced by the PV panel is determined by the strength of the sunlight. Buck-Boost converter provides the constant voltage regardless of either it is a sunny day or cloudy day with an ARM processor LPC2148. It interfaces the PV panel with PMDC motor of the sailing boat. The Buck-Boost converter module and PV panel is modelled and simulated using Mat Lab/Simulink. The output of the Buck-Boost Converter is connected to the PMDC motor and the output of the PMDC motor is coupled to the propeller of the boat with the help of a coupler.

The schematic of the proposed Photo Voltaic-powered sailing boat with a buck-boost converter is shown in figure 2. Solar (or photovoltaic) cells in PV panel arrangement convert the sun’s energy into direct current voltage. This output is variable as sunlight is variable so, this output is given to the buck-boost converter to convert the variable direct current voltage constant direct current voltage. The load to the buck-boost converter is the Permanent Magnet DC motor.[2]

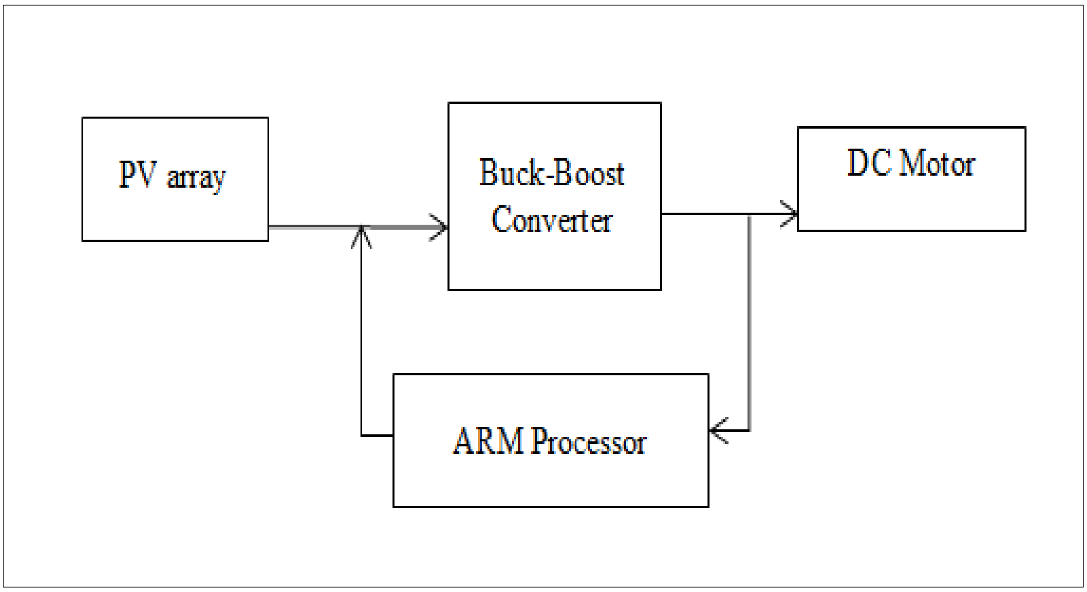

Figure 1: Block diagram of Photo Voltaic Powered Sailing Boat

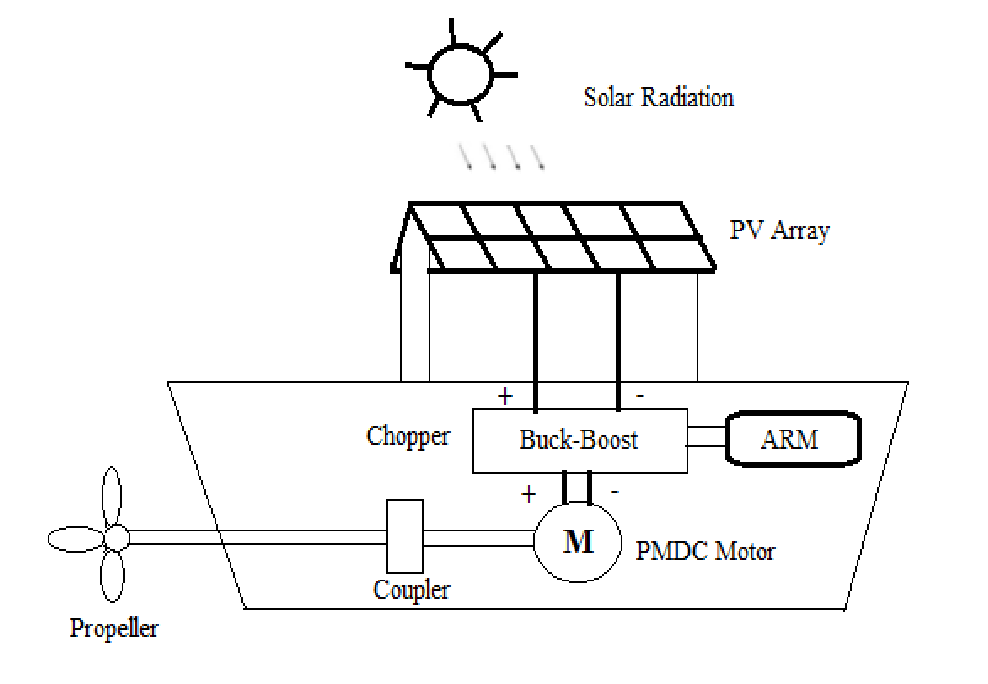

Figure 2: Schematic of Photo Voltaic-powered sailing boat

Photo Voltaic Powered Sailing Boat PMDC Motor: A PMDC motor is a type of DC motor that consists of a permanent magnet to form the magnetic field instead of the stator winding that is necessary for the DC motor operation. The principle of working of PMDC Motor is when a current carrying conductor is placed in a magnetic field, it experiences a force. The stator is usually made from steel in cylindrical form. The rotor consists of armature winding that is placed in the slots of armature. The rotor is made up of laminated silicon steels. To continue the torque accomplishing on the rotor, PMDC motors include a commutator that is set to the rotor shaft.

Specifications: The PMDC Motor is powered by Buck-Boost Converter. A PMDC motor has the specification as shown in table 1.

Table 1
Specifications of PMDC Motor

Supply Voltage	**12 (Volts)**
Current	1.5 (Amps)
Speed	1500 (rpm)

Mat Lab Modelling of PV Panel: A PV panel[5] of 33 watts was simulated by Mat Lab/ Simulink. It consists of 42 solar cells. Six solar cells are connected in series to form a subsystem by masking & seven such subsystems are connected in series to make it a PV panel of 42 solar cells. The value of V_{oc} for a single solar cell is 0.62 volt. Shunt resistance is 0.0015 ohm. The value of I_{sc} is 7.34 ampere.

For six solar cells V_{oc} = 6*0.62 =3.72 Volts (single subsystems).

For a PV panel (seven subsystems) V_{oc} = 7*3.72 = 26.04 Volts.

The current for a PV panel I =1.3 Amps. (seven subsystems)
The power of a PV panel = V_{OC} * I
= 26.04 *1.3
= 33.8 Watts

The solar insolation i.e the amount of electromagnetic energy incident on the surface of the earth is taken as 1000 Watts/m^2.The value of load resistance is obtained from the voltage and current corresponding to maximum power, $R_L = \frac{V_m}{I_m} = 17.52\ \Omega$.

Buck-Boost Converter:

DC to DC Buck-Boost Converter: A Buck (step-down) converter combined with a Boost (step-up) converter forms the Buck-Boost converter. The buck-boost converter operates in boost mode[2] when, the input voltage V_S < output voltage V_O, i.e., output current < input current. In Buck mode, the input voltage V_S > output voltage V_O i.e. the output current > input current. A MOSFET whose gate is triggered by a PWM signal is used as switch in the circuit.

During both the operating modes of a Buck-Boost converter, when the switch is turned on, the input voltage source supplies current to the inductor and the capacitor delivers current to the load resistor. When the switch is opened, the inductor supplies current to the load via the diode D. When the generated voltage from PV array is high the converter is functioned in buck mode to decrease the voltage to a specific value and when the generated voltage from PV array is low, the converter is functioned in boost mode to increase the voltage to a specific value.[3]

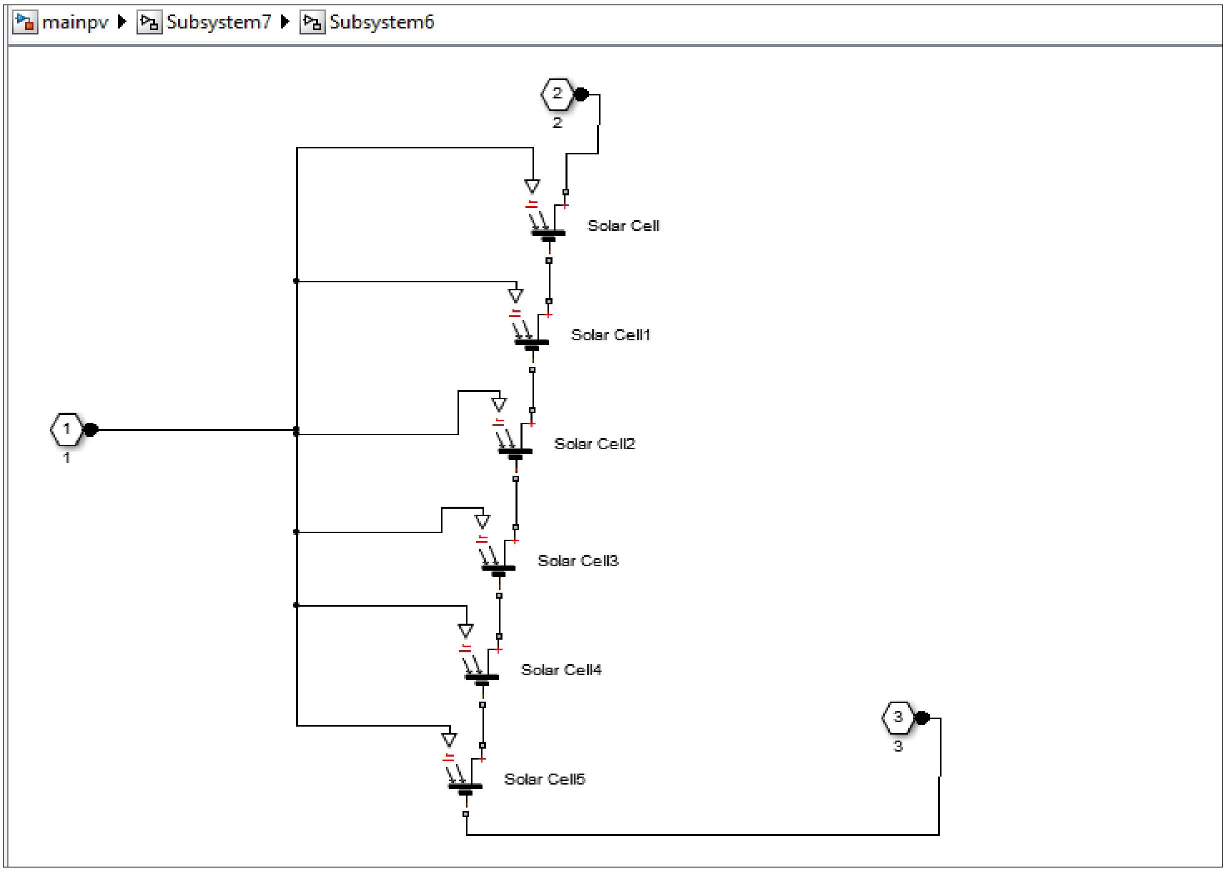

Figure 3: Mat Lab modelling of a subsystem

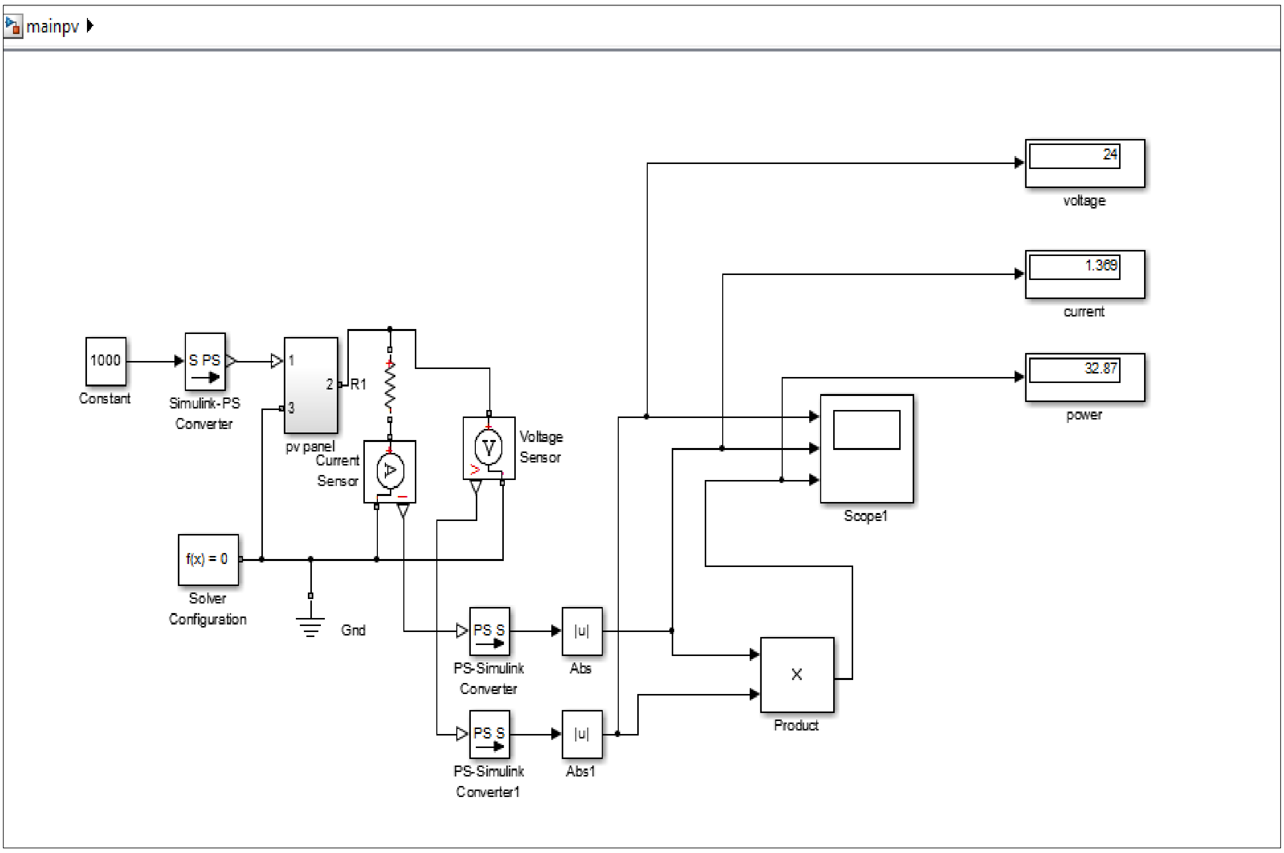

Figure 4: PV Panel Simulink Model Simulation Result

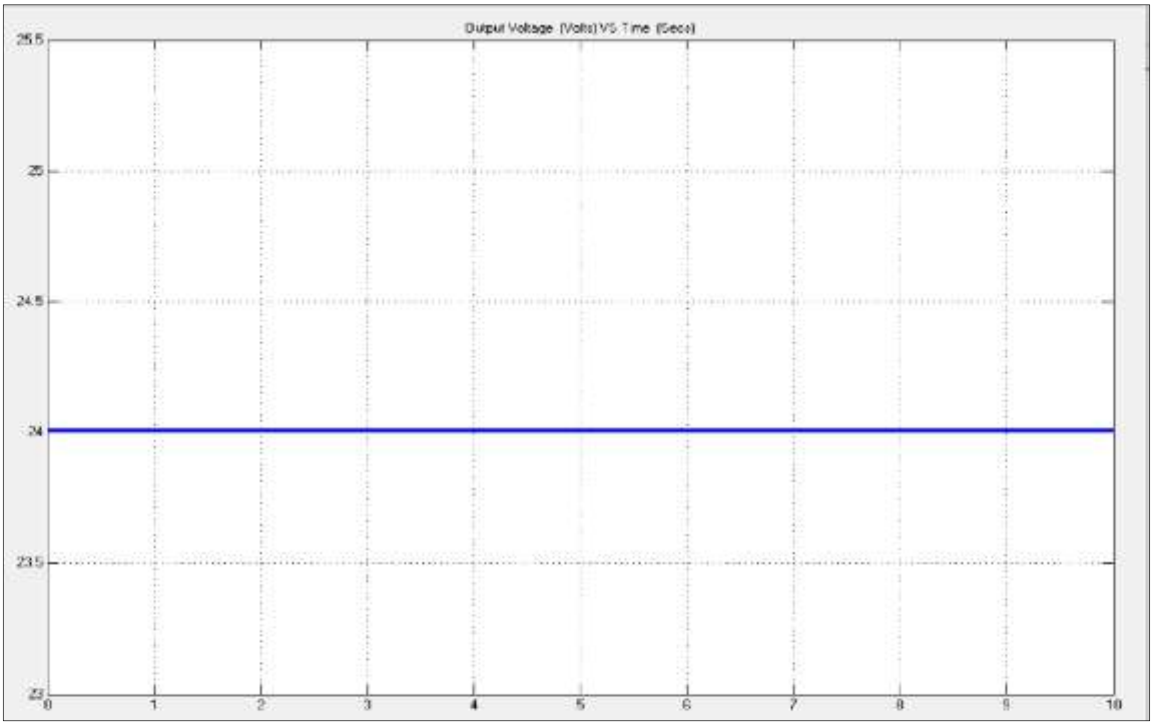

Figure 5: Output Voltage of the PV Panel

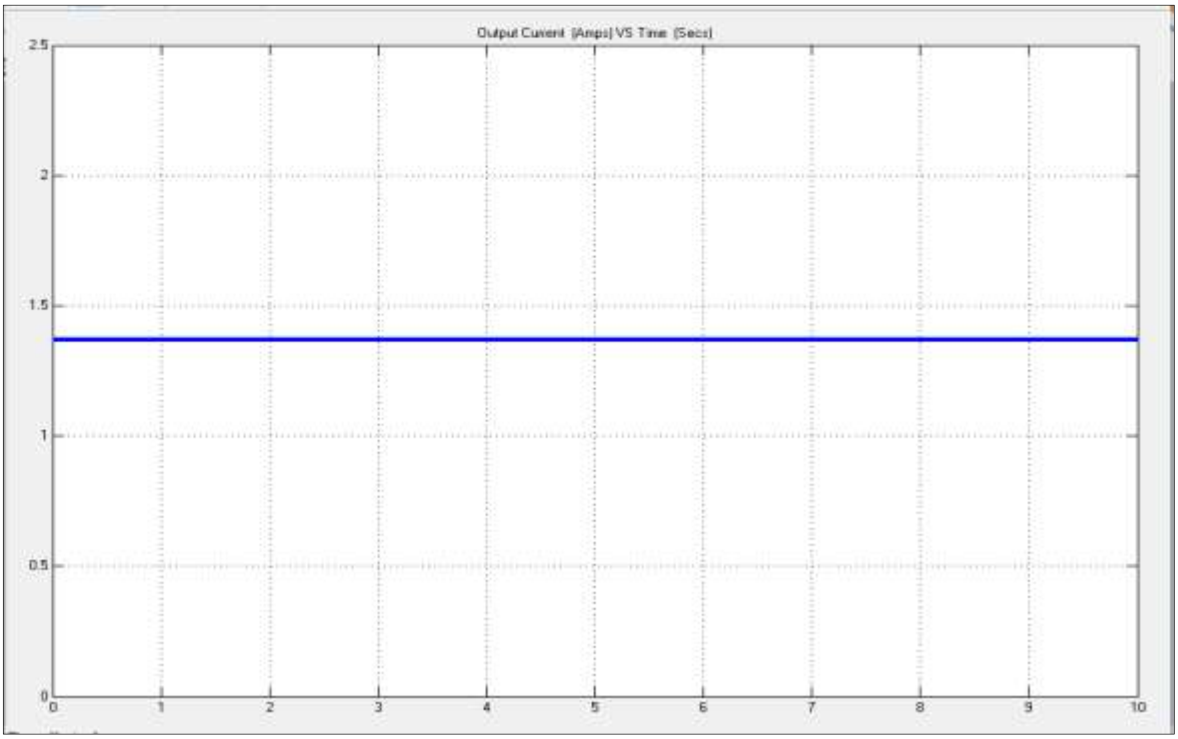

Figure 6: Output Current of PV Panel

Table 2
Specification of the PV Panel

Panel	No. of cell	Max power (Watts)	O.C voltage (V_{oc}) (Volts)	S.C Current (I_{sc}) (Amps)	Max voltage (Volts)	Max current (Amps)
1	42	33	0.62	7.34	24	1.37

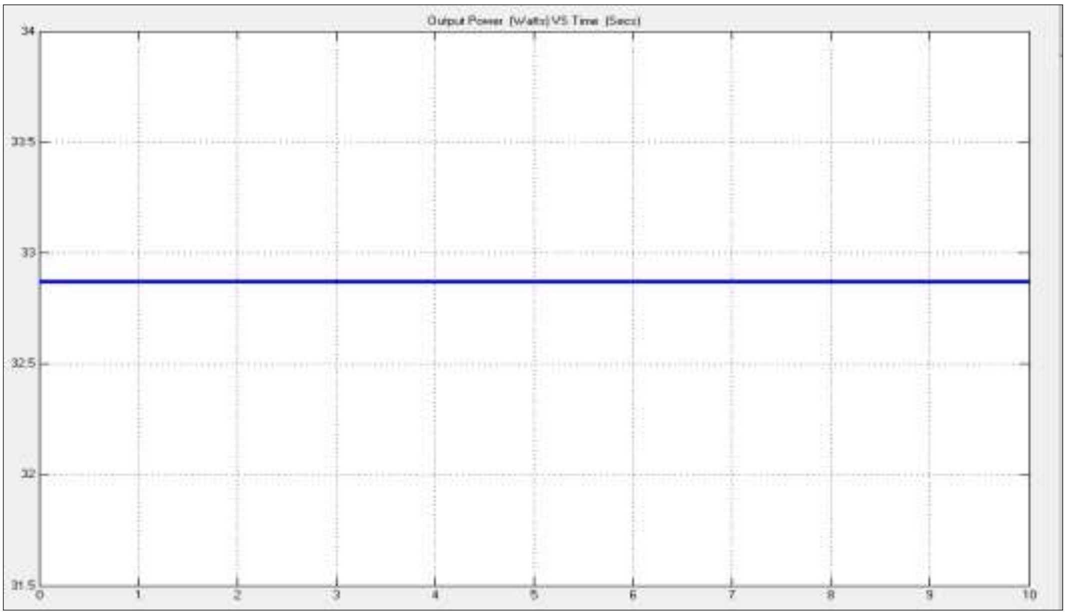

Figure 7: Output Power of PV Panel

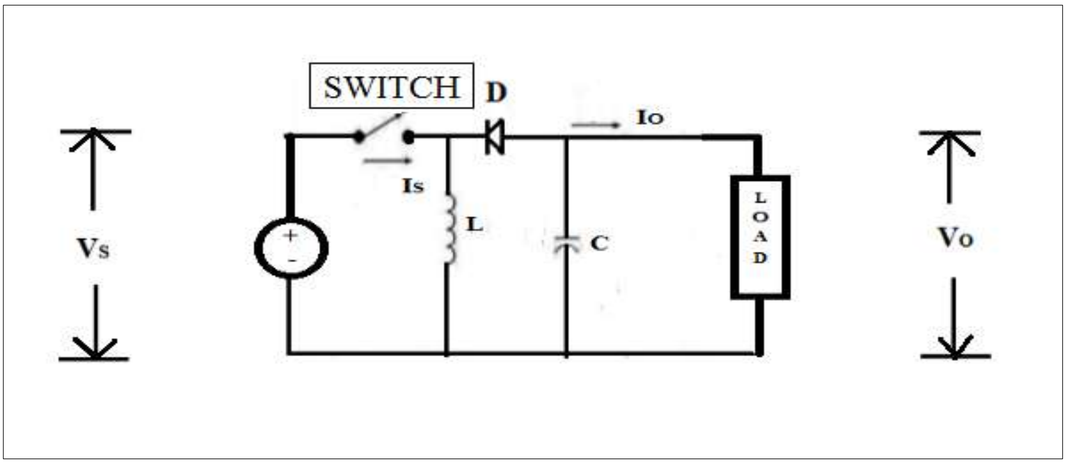

Figure 8: Buck-Boost Converter

The duty ratio of the converter (α) is given in equation (1) where t_1 is the on-time of the converter switch and T_1 is the switching period of the converter switch.

$$\alpha = \frac{t_1}{T_1} \quad (1)$$

The chopping ratio (Y) is given by equation (2) and (3),

$$Y = \frac{V_0}{V_s} \quad (2)$$

where V_o is the output voltage and V_S is the supply voltage.

$$Y = \frac{\alpha}{1-\alpha} \quad (3)$$

As per IEC harmonics standard, current ripple factor is bounded within 30% and voltage ripple factor is bounded within 5%.

$$\frac{\Delta I}{I} = 30\% \quad (4)$$

$$\frac{\Delta V_0}{V_0} = 5\% \quad (5)$$

The equation of inductor and capacitor for a buck-boost converter is:

$$L = \frac{\alpha V}{f \Delta I} \quad (6)$$

$$C = \frac{\alpha}{fR\left(\frac{\Delta V_0}{V_0}\right)} \qquad (7)$$

Mat Lab Modelling of Buck-Boost Converter

Input voltage V_s =24 (Volts)
Inductor L =1X 10^{-3} (Henry)
Capacitor C =1000 X 10^{-6}(Farad)
Resistor R =50 (Ohms)
Duty cycle D =50 %
Frequency f =20 (KHz)

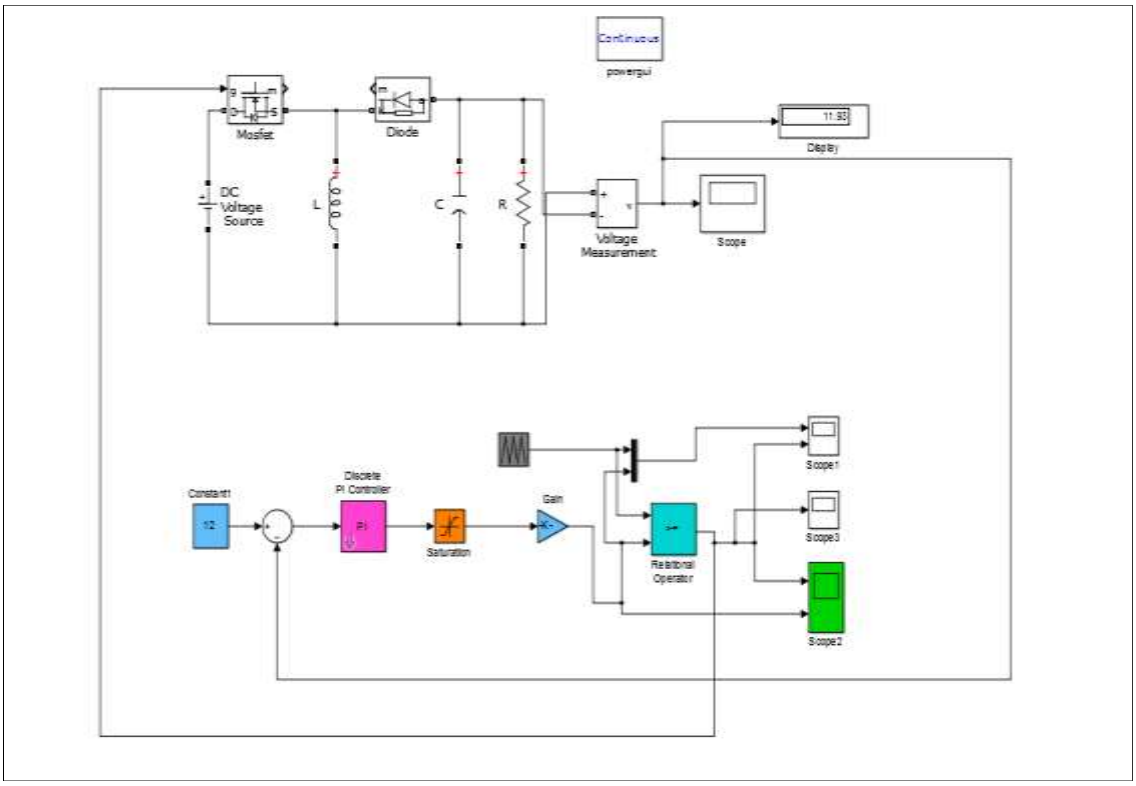

Figure 9: Mat Lab Simulink Model of Buck-Boost Converter

Simulation Result

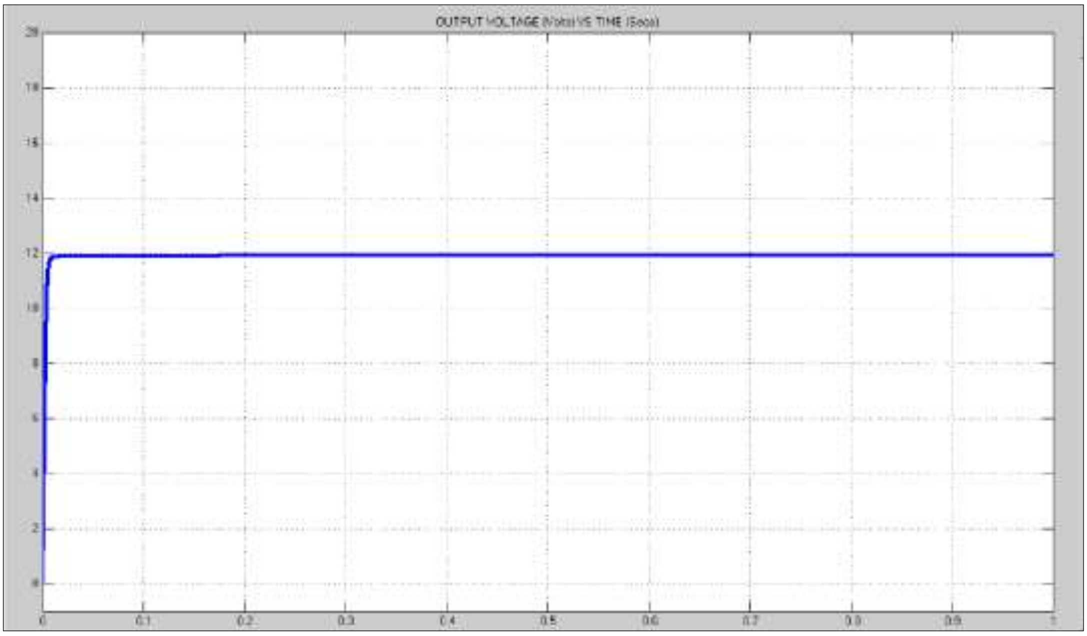

Figure 10: Output Voltage of Buck-Boost Converter

Circuit Diagram

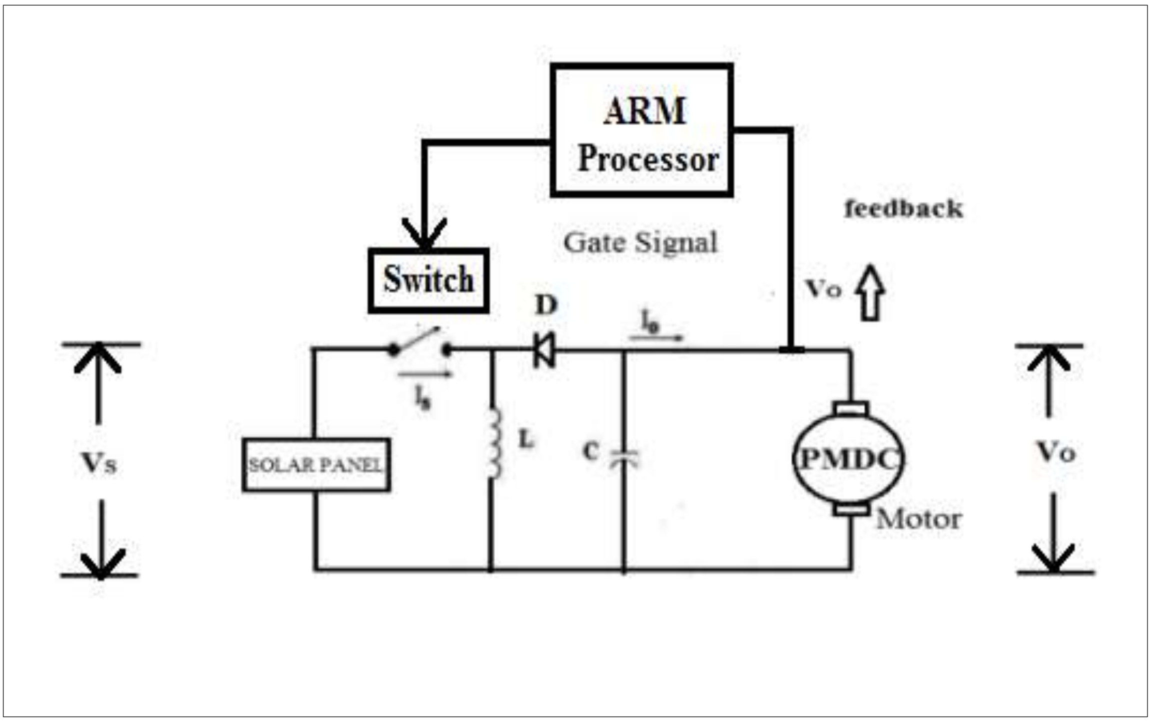

Figure 11: Circuit Diagram of Photo Voltaic Powered Sailing Boat

Mat Lab Modelling of PV Panel with Buck-Boost Converter

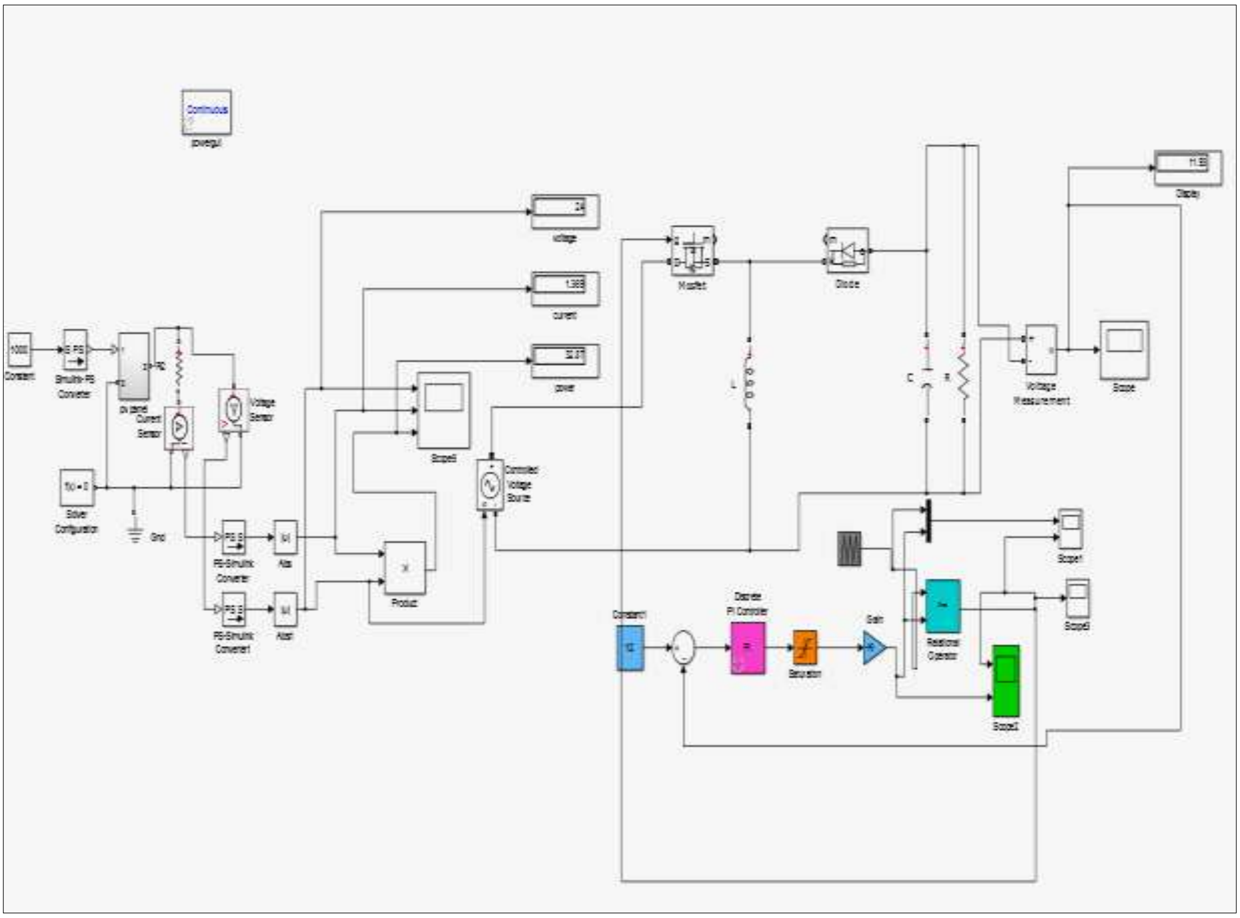

Figure 12: Mat Lab Simulink Model of PV and Buck-boost Converter

PV panel with Buck-Boost converter circuit is modelled and simulated in Mat Lab/Simulink. The Output voltage of PV panel is 24 Volt which is fed to the Buck-Boost converter. The output voltage of the Buck - Boost Converter is measured as 11.93 Volt. It is given to the PMDC motor as the supply voltage.

PWM Signal: The gate signal for the MOSFET in Buck-Boost Converter is triggered by a PWM signal. The PWM signal is generated using the ARM Processor. The ARM Processor is programmed in such a manner that whenever the input voltage of the Buck-Boost converter increases or decreases it provides a constant output voltage. In a Buck-Boost converter, the duty ratio (α) is maintained between 80% to 95%, so that an output voltage of 12 Volts is maintained. The PWM pulse has ON time of 90% and OFF time of the remaining 10%. So, that a constant voltage is maintained at the output side of the Buck-Boost converter. The generation of PWM signal is done in Mat Lab/Simulink and it is shown in figure 14.

Hardware Implementation: Photo Voltaic-powered sailing boat using Buck-Boost Converter is proposed and implemented in hardware. The variable voltage generated from the PV panel is made constant and fed to the PMDC motor with the help of the Buck-Boost Converter. The hardware implementation of the Photo Voltaic Powered Sailing Boat is shown in figure 15.

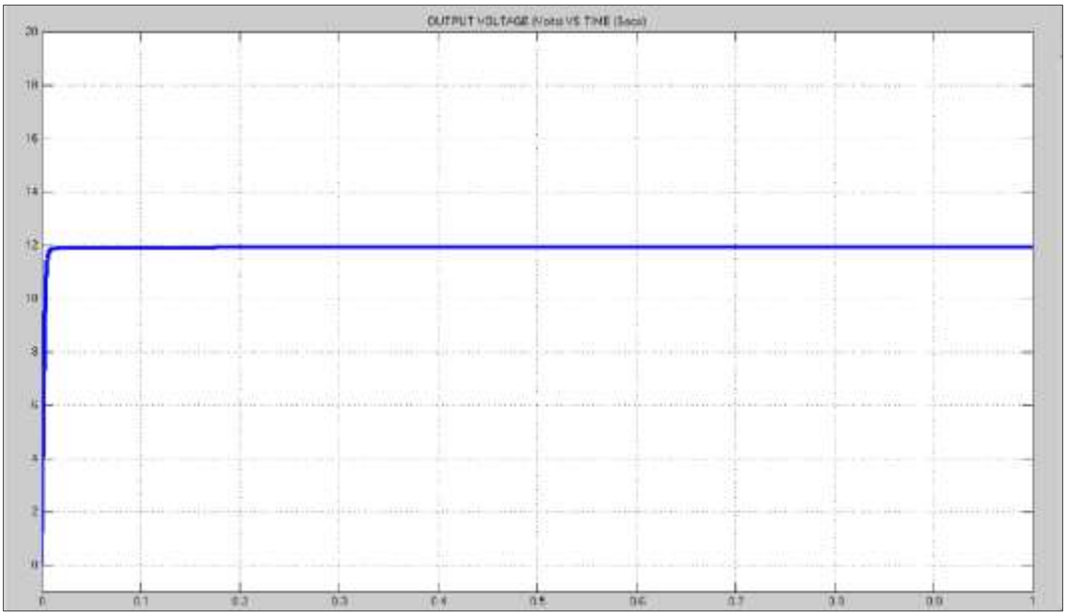

Figure 13: Output Voltage of Photo Voltaic Powered Sailing Boat

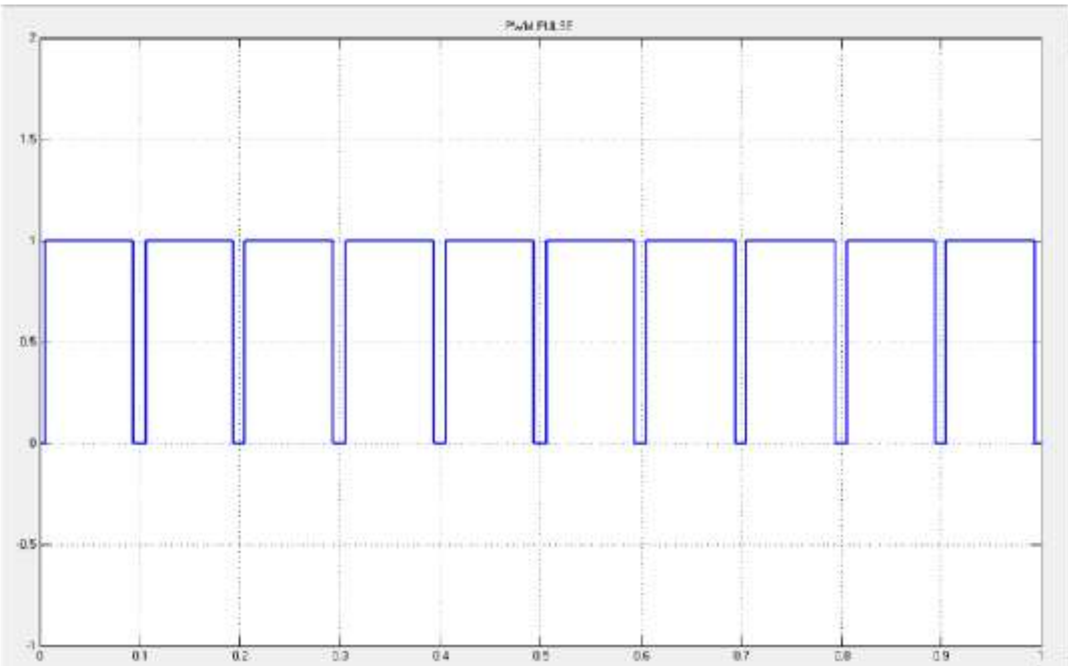

Figure 14: PWM Signal for Buck-Boost Converter

Figure 15: Hardware Implementation of the Photo Voltaic Powered Sailing Boat

Conclusion

Solar panels are placed at the top of the proposed Photo Voltaic-powered sailing boat using Buck-Boost Converter and so no extra space is required. The effectiveness of the proposed Photo Voltaic-powered sailing boat is tested and found that during day-time, sunlight is sufficient to operate the Photo Voltaic-powered sailing boat and hence fuel is not required. The payback period of Photo Voltaic-powered sailing boat is less compared with a fuel run boat.

References

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