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New Generation Solar PV Powered Sailing Boat Using Boost Chopper

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Abstract

The objective of this paper is to establish technical and economical aspects of the application of stand-alone photovoltaic (PV) system in sailing boat using boost chopper in order to simplify the power system and minimize the cost. Performance and control of dc-dc converter, suitable for photovoltaic (PV) applications, is presented here. This converter is mainly boost converter feeding a dc load. However, for integration purpose only one inductor is sufficient for power conversion in the converter. Here, the boost converter extracts complete power from the PV source and feeds into the load. Furthermore, the PV panel provides the essential protection to the passengers of boat from the straight sunshine and also from the rainwater.

***Keywords**: solar sailing boat (electric vehicle), DC-DC power conversion (boost chopper), MOSFETs, voltage control, PV*

1. Introduction

Transport in water ways is definitely one of the most indispensable life sustenance features of the modern society; practically all this energy comes from fossil fuels, it creates heavy ecological problems in all large cities. The main solution of these problems lies in the proper use of the renewable energy sources, and there are many plausible examples of this kind, like solar powered sailing boat which uses only solar energy converted by Photo Voltaic Converters (PVCs) and feeding a dc load [1, 2]. It is important to generate the pollution-free, Eco friendly natural energy. Electricity generated from photovoltaic (PV) power systems is a major renewable energy source which involves almost zero greenhouse gas emission and doesn't consume any fossil fuel [3-5]. Photovoltaic energy is an efficient source of energy: it is renewable, inexhaustible and pollution free, for that, it is more and more rapidly been used as an energy source. In standalone photovoltaic generator (PVG), the generated energy is used either directly or associated with a storage in battery or in an energy reserve, e.g. hydraulic. In connected PVG, it may be associated with inverters and voltage step-up or step-down systems (i.e. choppers). A PVG with good efficiency can be carried out if it constantly converts maximum available solar power all the time even in case of rainy day [6]. Here this converter is essentially boost converters feeding a dc load. However, on account of the integration there is only one inductor is sufficient for power conversion in this converter. Here, the boost converter extracts complete power from the PV source and feeds into the load [7-9].

2. The Proposed Method

Recent research has dealt with most of the DC/DC converters in order to find the most compatible type in terms of overall power system efficiency. Schematic diagram of proposed photovoltaic powered sailing boat with boost chopper is shown in Figure 1. Solar energy conversion into electrical power is naturally performed by solar cells [10, 11]. The PV generator transfers the descendent solar radiation to a direct voltage and current. These ends provide a boost chopper. The load of chopper is the separately exited motor [12].

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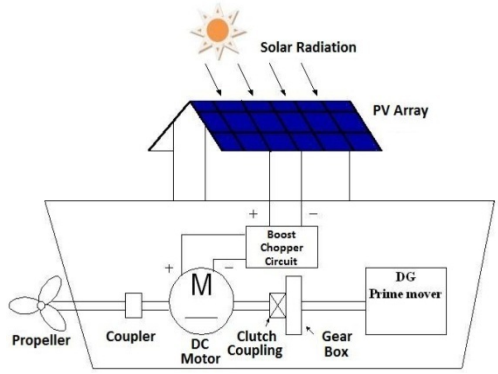

Figure 1. Schematic Diagram of PV powered Sailing Boat

Solar panels are rarely connected to the electrical equipment directly, except grid connected system. Power generated from the solar panel depends on the strength of the sun light. Boost converter is providing the necessary supply on the sunny day as well as cloudy day. Output of the motor also connected to a propeller through a coupler. On the other hand another side of the motor shaft is connected with a diesel generator (DG) prime mover through another clutch coupler. When solar PV does not generate necessary power then pressing the coupler this DG prime mover is connected with the motor shaft. Moreover, this DG generator is connected as a backup protection. Cost competitive cover design with fluorides in place of glass is to be good alternatives when considering cost and weight reduction of PV modules [13, 14]. If the entire weight of a boat is lower, the energy is desired reasonably less [15-17]. Additionally, the PV panel provides the necessary shedding to the passengers of boat from the direct sunlight and also from the rain.

3. Research Method

3.1. Mathematical Representation of Boost Converter

The step-up dc-dc converter, commonly known as a boost converter, is shown in figure below. For integration purpose only one inductor is sufficient for power conversion in the converter. The input voltage 230V is required in the load terminals for PV powered sailing boat system. So, the boost converter is suitable for this purpose.

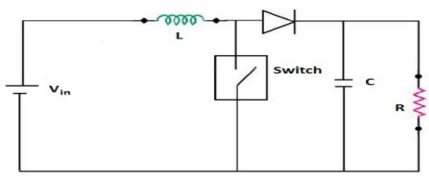

Figure 2. Circuit diagram of a Boost Converter

$$q_1 + q_2 = 1 \quad (1)$$

$$V_{in}(t) = q_2 V_{out} = (1 - q_1)V_{out} \quad (2)$$

$$I_{out}(t) = q_2 I_{in} = (1 - q_1)I_{in} \quad (3)$$

$$< V_{in} >= D_2 V_{out} = (1 - D_1)V_{out} \quad (4)$$

$$< I_{out} >= D_2 I_{in} = (1 - D_1)I_{in} \quad (5)$$

Let, $V_{in} =< V_{in} >$ and $I_{out} =< I_{out} >$

$$V_{out} = \frac{1}{(1-D_1)} V_{in} \tag{6}$$

$$I_{in} = \frac{1}{(1-D_1)} I_{out} \tag{7}$$

The input and output power must always be equal, as must their averages. There are no places for energy to be lost in this converter. Switch-1 carries Iin when on. When it is off, switch-2 must be on and switch-1 must block Vout. Therefore 1 must be a forward–conducting, forward –blocking device. Switch-2 can be a diode.

Now, Assuming that the inductor current rises linearly from I1 to I2 in time t1 [18],

$$V_{in} = L.\frac{I_2-I_1}{t_1} = L.\frac{\Delta I}{t_1} \tag{8}$$

$$t_1 = L.\frac{\Delta I}{V_{in}} \tag{9}$$

And the inductor current falls linearly from I_2 to I_1 in time t_2,

$$V_{in} - V_{out} = -L.\frac{\Delta I}{t_2} \tag{10}$$

$$t_2 = \frac{\Delta IL}{V_{out}-V_{in}} \tag{11}$$

Let Ripple in inductor current:

$$\Delta I = I_2 - I_1 \tag{12}$$

$$\Delta I = \frac{V_{in}t_1}{L} =. \frac{(V_{out}-V_{in})t_2}{L} \tag{13}$$

Substituting,

$$t_1 = D.T, \;\; t_2 = (1-D).T \tag{14}$$

$$.\frac{V_{in}}{V_{out}} = (1-D) \tag{15}$$

Duty cycle,

$$D = \frac{t_1}{T} = t_1 f \tag{16}$$

$$L = V_{in}\frac{t_1}{\Delta I} \tag{17}$$

Substituting the value of t_1,

$$L = V_{in}\frac{D}{f\Delta I} \tag{18}$$

And,

$$C = \frac{D}{fR(\Delta V_o/V_{out})} \tag{19}$$

3.2. Designing Calculation and Specification for Required Model

Usually it has been seen that a single 1HP dc motor is sufficient for carrying 4 passengers weighing approximately 350kg in a PV powered sailing boat and if the converter efficiency is considered as 85% then,

I/P to the chopper= (1×746)/0.85= 877.64 Watt

I/P to the chopper= o/p of PV panel

If single panel is of 300 watt.

No of panel= (1×746)/ (0.85×300)=2.92≈3.

3.2.1. Modeling of PV Array Using Matlab

Here in the Matlab simulation of a PV module the parameters of the solar cells are being taken as per photovoltaic module P672300WB 300-watt Module [19]. The value of Voc for the module is 44.72 volt. As 72 solar cells are being connected in series so individual for a solar cell it is coming 44.72/72=0.62 volt. Six solar cells are connceted in series first, then they are masked into a subsystem & three in a series are being added to make it 18 and then two subsystems of 18 are connected in series to make 36. Then two subsystems of 36 are being connected to make it a module of 72 solar cells and finally 3 modules are coneected in series [20-26].

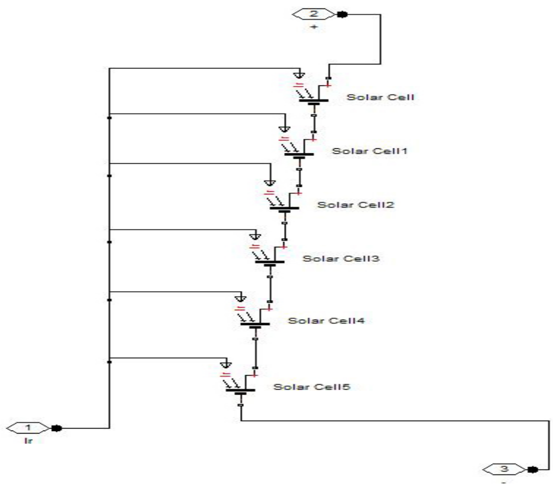

Figure 3. Modelling of Six solar cells are connceted in series

The solar insolation is taken as 1000w/m^2. For getting maximum power voltage and maximum power current the value of load resistance should be (Vm / Im) 13.15Ω.

Table 1. Specification of Single PV module

No. of cells per Module	Maximum Power (watt)	Open Circuit Voltage (Voc) Volt	Short Circuit Current (Isc) Amp	Maximum Power Voltage (V)	Maximum Power Current (A)	Weight (Kg) (Aprox)	Dimensions (Length × Width × Depth) (Aprox)
72	300	44.72	8.62	35.86	8.18	23	77 mm× 39 mm× 1.5 mm

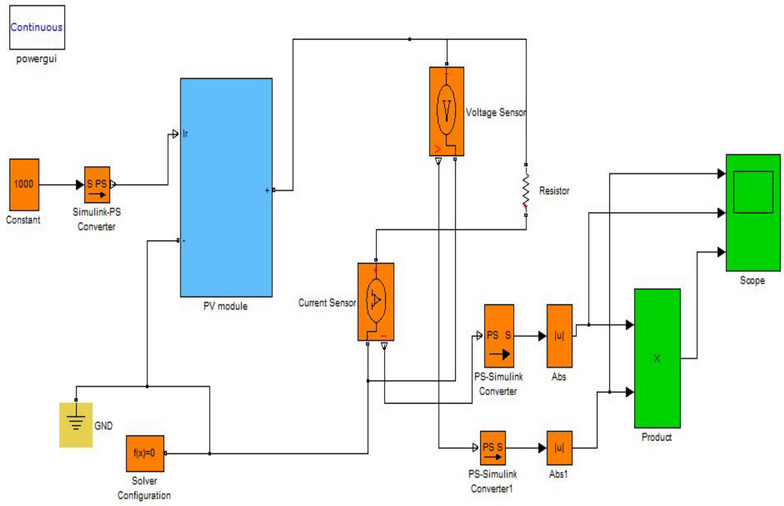

Figure 4. Flow chart algorithm of PV module under Matlab Simulink

3.2.2. Modeling of Boost Converter

After that the module is connected with a boost converter to make the Voc value boosted upto 230volt.In doing that the parameters of boost converter is taken as follows [27]:

Fs=100khz, $\frac{\Delta I1}{I1} = 30\%$(According to IEC harmonics should be bounded within 30%.),

$\frac{\Delta Vo}{Vo} = 5\%$ (According to IEC harmonics should be bounded within 5%),

I/p voltage is taken as,Vin=35.86×3=107.58volt ≈108 volt (aprox).

O/p voltage is taken as ,Vo=230volt, O/p load current is taken as.Io=3.88A (aprox).

So from the above data duty cycle is to be calculated as,D=53%

Current ripple ΔI= 0.3 amp, Inductor value,L=0.492 mH, Capacitor value,C=1.78 uF, Resistor Value,Ro=59.27Ω.

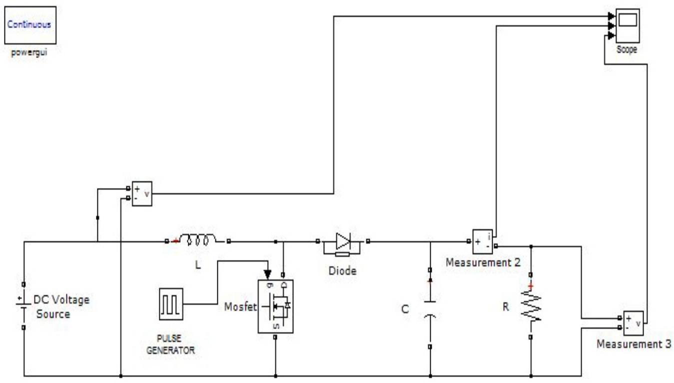

Figure 5. Flow chart algorithm of Boost converter under

3.2.3. Modeling of PV With Buck Converter

Modeling of PV array and boost converter is already discussed earlier. From the above discussion it has been seen that input of the chopper is the output of PV panel. Now the pv model and the buck converter is being implemented in the same circuit using matlab simulink.

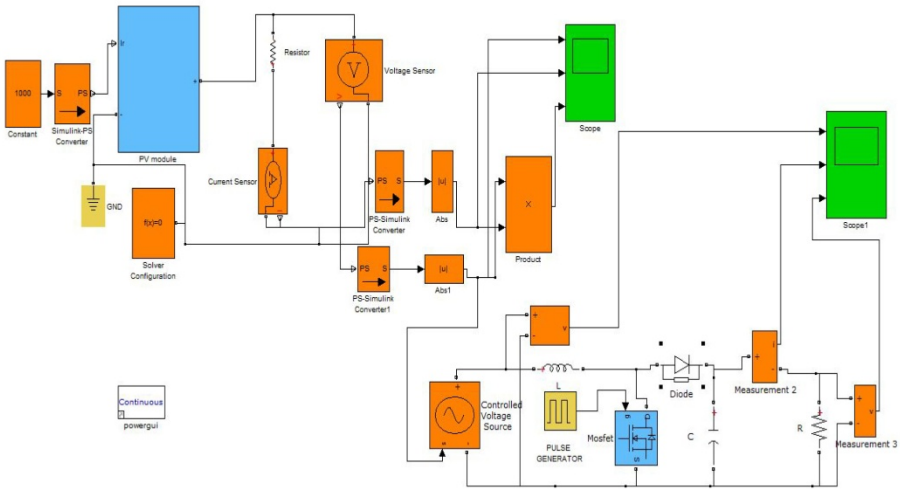

Figure 6. Flow chart algorithm of PV with Boost converter under Matlab simulink

4. Results and Discussion

As discussed earlier 3PV module are connected in series to generate 877.64 Watt. Now it has been shown in Table 2, that each PV module can generate maximum power voltage and current are of 35.86 Volt and 8.18 Amp respectively. So the maximum power output voltage of the PV array is 107.58 Volt. But according to the simulation graph the voltage is approximately 108.25 Volt and current is 8.2 Approximately.

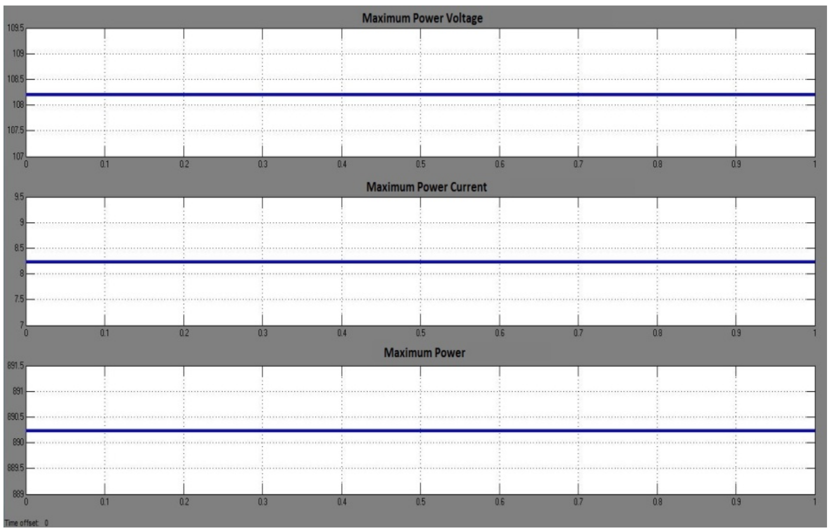

Figure 7. Simulation result of maximum voltage, current and Power

Similarly, from the above calculation output voltage for the buck converter is 230 Volt. But form the simulation result the output voltage is 234Volt and output current is 3.94 Amp.

All the experimental values are nearly same as with the theoretical ones. The slight difference in the values is not hampering the proposed model.

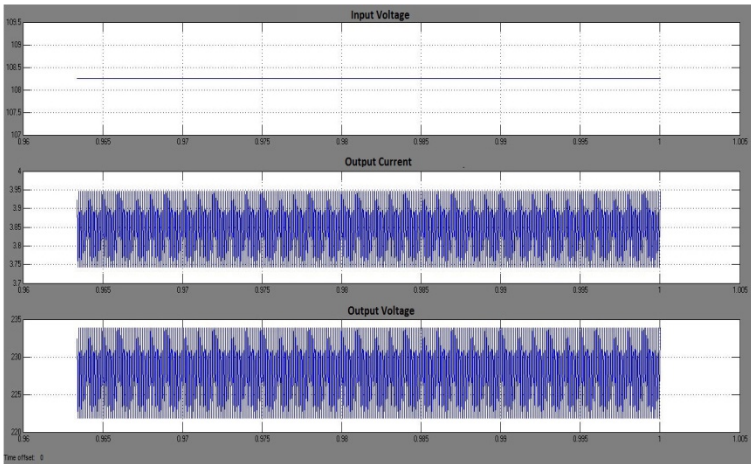

Figure 8. Simulation result of Boost converter

Likewise, After combining both the PV and converter circuit in Matlab simulink the Output voltage of PV array 107.9 Volt which is also the input voltage of buck converter. Now the output of the buck converter is 233Volt (Aprox).

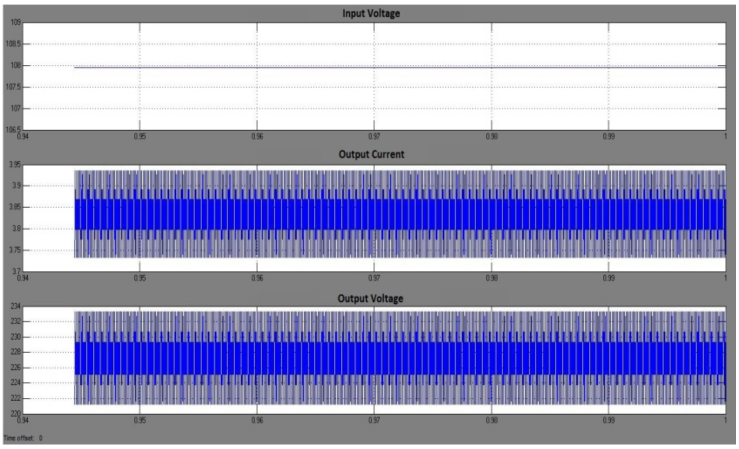

Figure 9. Simulation result of PV with Boost

5. Conclusion

Solar pv powered sailing boat using boost converter is proposed here. converters were implemented. The effectiveness of the proposed control scheme is also tested and then the following conclusions were drawn from this study: 1) This is a new and innovative application which is fully environmental friendly. 2) This scheme is almost polution less. 3) Upper portion of the boat is unused, so solar panels are implemented in that portion. For that extra space is not required. 4) Fuel cost not required in the morning, as sun light is available in day time. 5) Energy pay back period will be lesser than diesel run boat. 6) Furthermore, the PV panel provides the essential protection to the passengers of boat from the straight sunshine and also from the rainwater.

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