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A Double Input DC to DC Buck-Boost Converter for Low Voltage Photovoltaic/Wind Systems

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Abstract: A Double input DC to DC converter for low voltage energy sources applications is proposed in this paper. The proposed converter is buck-boost converter which can step up or step down the input voltage according to output voltage required at load end. The converter is able to boost up voltage of energy sources such as solar photovoltaic and wind energy system of relatively low voltage. The converter is designed considering double input, in which same or different type of two inputs can be used individually or simultaneously. Modes of operation of converter are described in detail and simulation experimental results are presented.
Keywords*:* DC/DC Buck-Boost Converter**,** Solar PV, Wind energy system, Pulse width modulation.

I. Introduction

The output voltage of a solar cell is very less. In order to generate a high voltage source, series connection of cells is required. But as number of cells increase, it becomes bulky, costly, and inefficient and also it requires long sized wire from panel to charge controller and battery. These problems can be minimized by using a suitable type of converter for solar cell array and or wind energy source of relatively less voltage[1,2].

Climatic conditions are not always same during an interval of time. According to availability of energy sources (wind or solar PV systems), the output power may vary. The inputs may be working independently or simultaneously which is described in paper in detail[1]. According to input voltage condition, the proposed converter can be made work like step up or step down dc to dc converter. So here DC/DC Buck-boost converter is used. The proposed converter can be fed by two inputs of relatively same and low voltage energy sources like Solar/Wind, individually or simultaneously on the basis of availability or requirement of energy source. The same system can be made work multi-input converter also, in that case converter may work as buck or step down.

The paper is organized such that solar/wind system & their characteristics and proposed converter with control schemes are described in Section II and III respectively, while the complete model and simulation data, experimental results are described in Section IV & V respectively.

II. Solar/Wind Energy System And Their Characteristics

The voltage of an individual solar cell is typically 0.5 volts. In order to generate high voltage, several cells are connected in series. To generate around 18volts, 36 solar cells are required to be connected in series. Voltage of solar panel varies as numbers of series cells vary while current varies as number string of solar cells vary. Voltage and current of Panel depends on temperature and insolation respectively.

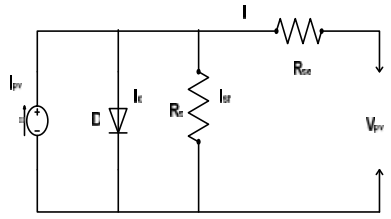

Fig.1. Equivalent circuit of solar cell.

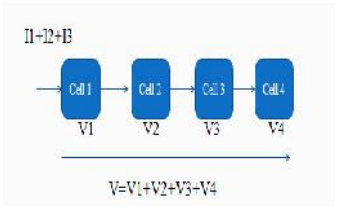

Fig.2. Solar cells connected in series to give high voltage

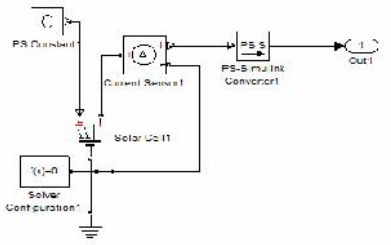

Fig.3. Simulation model on MATLAB-Simulink

Wind energy system mounted with DC generator can be used as input source for converter. AC generator can be also used but AC output of generator must be converted into DC voltage using rectifier before feeding to converter. The generator, to be used is constant voltage and variable speed type. The typical characteristics of wind energy and solar PV system are shown below respectively[1].

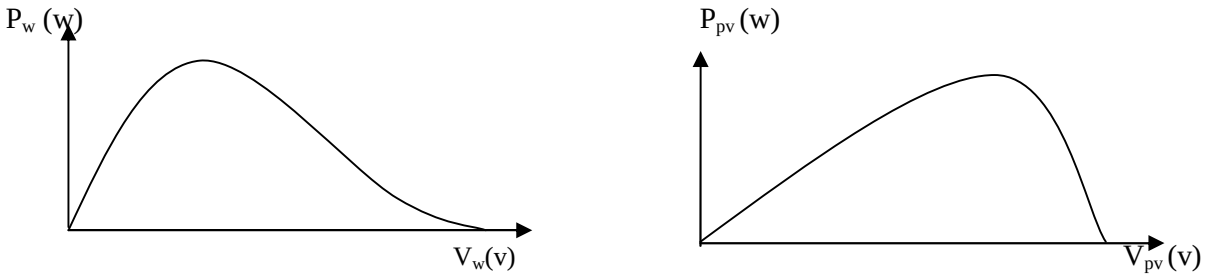

Fig.4. P-V Characteristics of wind system and solar PV system respectively.

III. Proposed Converter

The proposed DC to DC converter is Buck-Boost type, which has inputs as solar/wind. The modes of operation with availability and non availability of energy inputs or on the basis of energy requirement by load are described here.

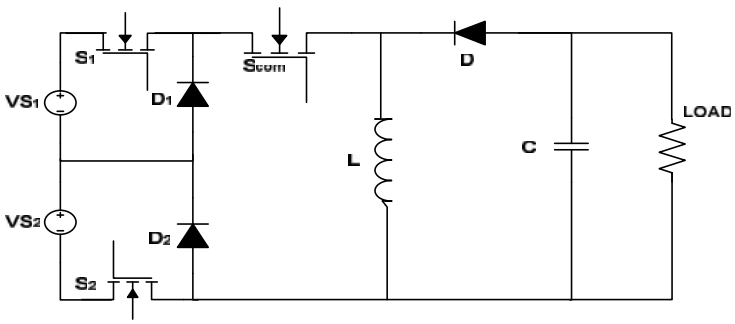

Fig.5. Proposed double input DC/DC Buck-Boost Converter.

A. Modes of operation of DC/DC converter.

1. When both sources are available simultaneously.

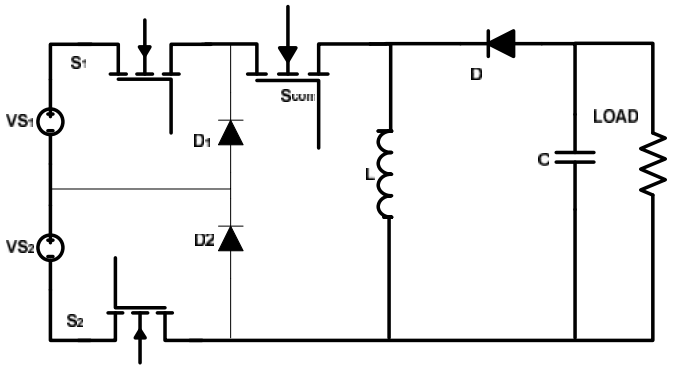

Fig.6. MODE (1)-Both sources are ON or available

The equivalent circuit of buck-boost converter in bold lines is shown in fig. 6 for the case when both input sources are available in operation Mode (1). Both the auxiliary switches S1 & S2 are ON and S_{com} switch is commutating as in conventional dc to dc converter to maintain desired output voltage and fetch power from both the energy sources connected in series.
There may be possibility of unavailability of one or both of the sources due to climatic conditions or may be less energy required at output end, the auxiliary switches can be made ON or OFF whenever required for these cases[1].

2. When only source VS1 is switched ON or Available.

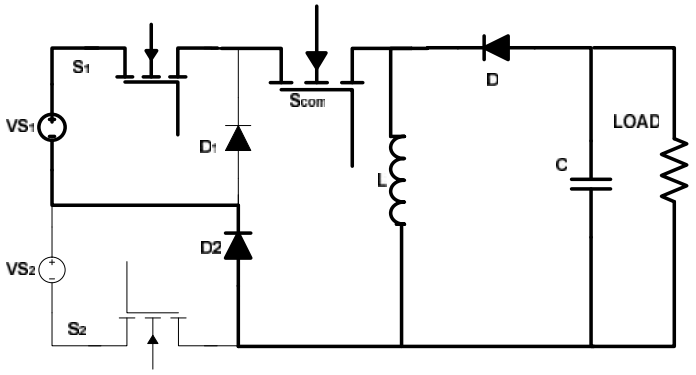

Fig.7. MODE (2) - Source VS1 only is ON or available.

Fig.7 in bold lines is showing equivalent circuit of operation MODE (2), here Auxiliary switch S2 is OFF, while S1 is ON, so only source VS1 is delivering energy to battery. Switch S_{com} is commutating as traditional switch with higher duty cycle to maintain output voltage as source VS2 is cut OFF.

3. When only source VS2 is switched ON or Available.

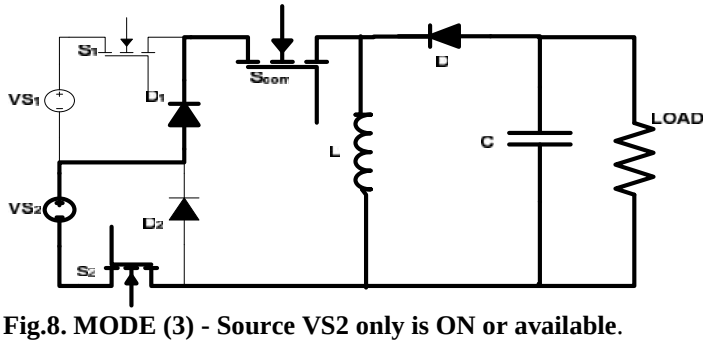

Fig.8. MODE (3) - Source VS2 only is ON or available.

Fig.8 in bold lines shows the operation MODE (3).This is the similar case as of previous, here also only single source is delivering energy to battery but now energy is delivered by source VS2 hence auxiliary switch S1 is OFF while S2 is ON and switch S_{com} commutating with higher duty cycle again as here also one of the source named VS1 is cut OFF.

4.Both sources are unavailable.

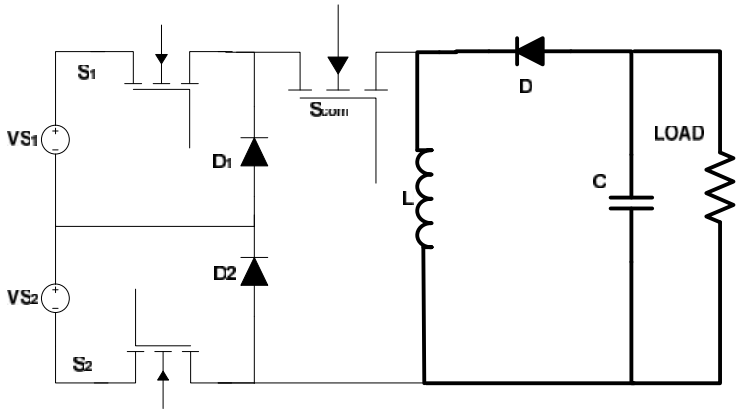

Fig.9. MODE (4) – Both sources are unavailable.

In this case both auxiliary sources are unavailable due to climatic conditions or some kind of faults the converter works as shown by bold lines in fig. 9 in operation MODE (4). The power is supply to battery by stored energy in inductor and capacitor.

B. Control techniques for converter.

There are many techniques to control the duty cycle of main/ commutating switch S_{com}, say sliding mode control, PID controller, PWM control scheme using DSP or others techniques etc.

Three switches are used in this converter one commutating or main switch named as S_{com} and two auxiliary switches named S1 &S2.

1.Commutating switch control

Here, single pulse PWM technique is used to control the Commutating switch. For this purpose a proportional and integral (PI) controller is used. The measured voltage and set reference voltage when pass through summing point, a error signal generates which is fed to PI-controller which produce a actuating reference signal. The signal is than compared with a repeating sequence signal or carrier wave, a train of pulses generates with a required duty cycle to maintain reference voltage constant.

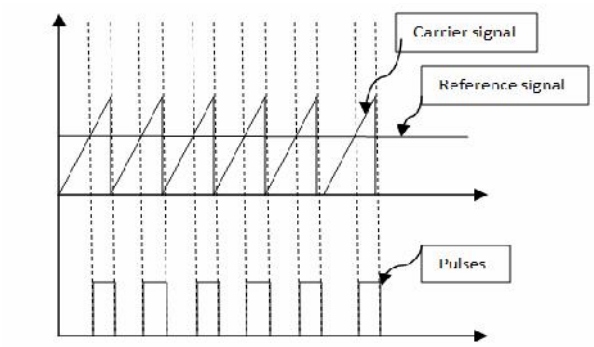

Fig.10. PWM Technique for main switch control.

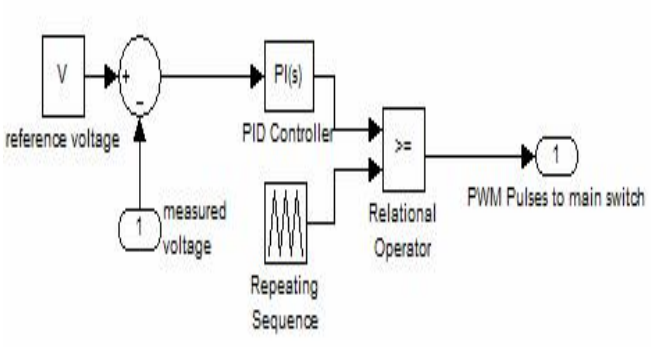

Fig.11. control logic circuit for auxiliary switches.

2. Auxiliary switch control

Control scheme for auxiliary switches contain a simple logic circuit based on mathematical calculation.

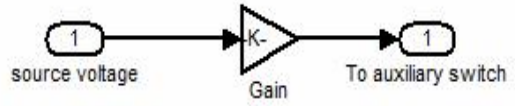

Fig.12. control logic circuit for auxiliary switches.

C. Equations.

Volt-second equation of inductor for a complete cycle:-

$(vs1+vs2)*DT - v_{out}(1-D)\,T=0$ (1)

$V_{out} / (vs1+vs2) = -D / (1-D)$ (2)

D. DC/DC converter with multi-input.

The same double input converter can be made multi input converter as shown in fig.6 below.

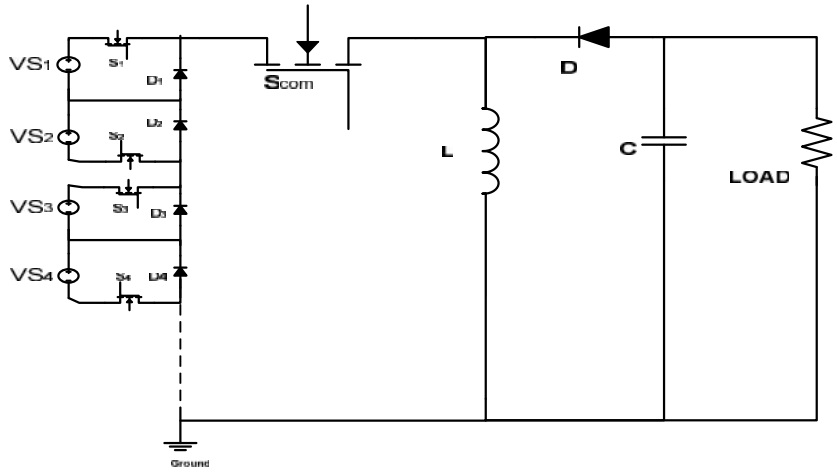

Fig.13. Multi-input DC/DC buck boost converter

As in this case input voltage is increasing due to connection of sources in series eqn (1) & eqn (2), which may be higher than output voltage. This condition forces DC/DC converter to work as Buck converter. It very cost efficient and efficient as only single converter is handling many energy sources and elements used in converter are reduced in comparison with traditional converter.

IV. Complete Model Of System.

In future only renewable energy sources will remains which will fulfill our energy demand, so more efficient, cost effective alternatives are required to be searched. Many researches are going on everyday to develop new technologies in this field. As these energy sources of free of cost so that it is required to exploit them as more as possible efficiently, saving conventional energy sources keeping needs of future generation in mind.

The complete system consists of several double inputs DC/DC converter module connected to DC bus. Wind energy system mounted with DC generator or AC generator with rectifier circuit and or solar PV panel which are fed to double input DC/DC converter which can step up or step down the input voltage. The output of converter is connected to battery banks and DC bus.

The power distributed from DC bus can be inverted using Inverter and then AC load can also be fed. So both type of load can be beneficiated.

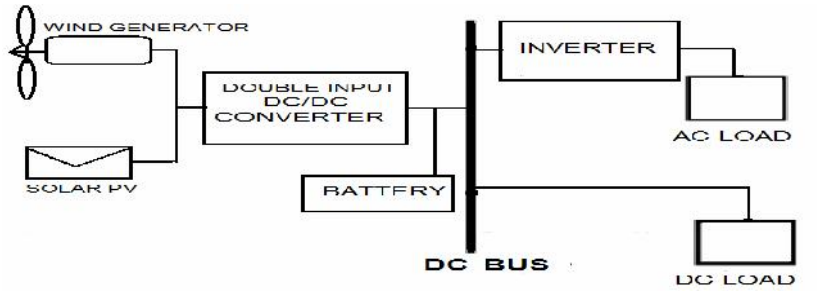

Fig.14. Single module connected to DC bus.

V. Simulation Model, Data And Experimental Results Of Converter

A. Model of converter on MATLAB-simulink

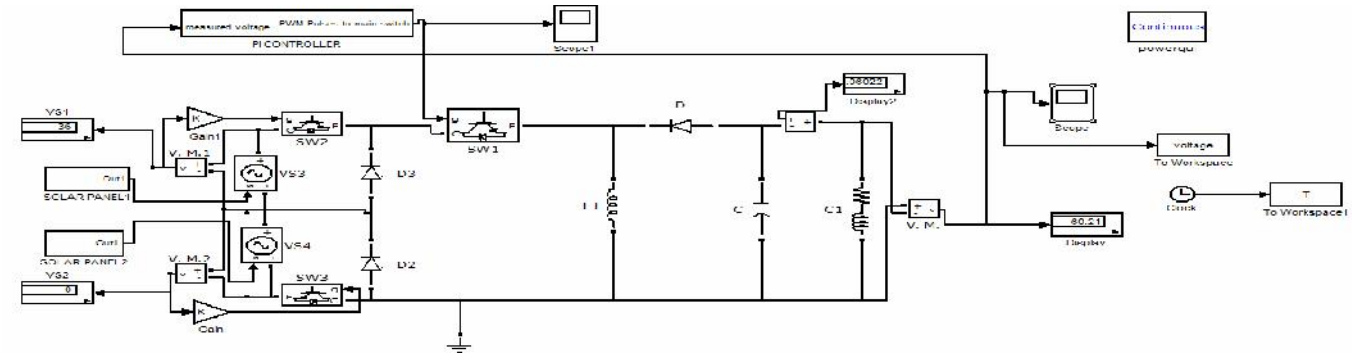

Fig.15. MATLAB-Simulink model of double input DC/DC buck boost to converter

A. Simulation data.

1. VS1, VS2=36V
2. Inductance of inductor, L=25mH.
3. Capacitance of capacitor, C=100µH.
4. Switching frequency=1 kHz.

B. Experimental results

1. Output voltage= 60 V
2. 0utput current = 0.6 A
3. Output load= R-100Ω and L-10m

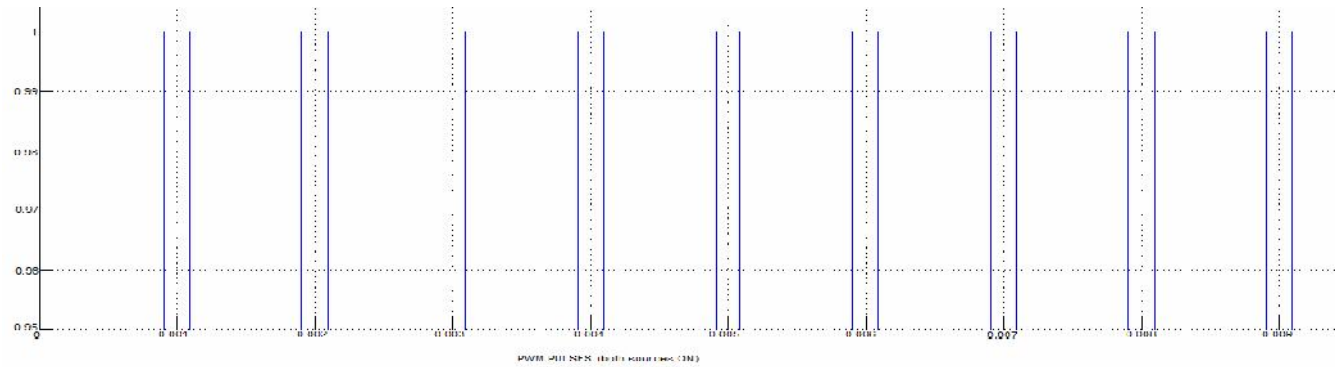

Fig.16. PWM pulses when both sources are ON

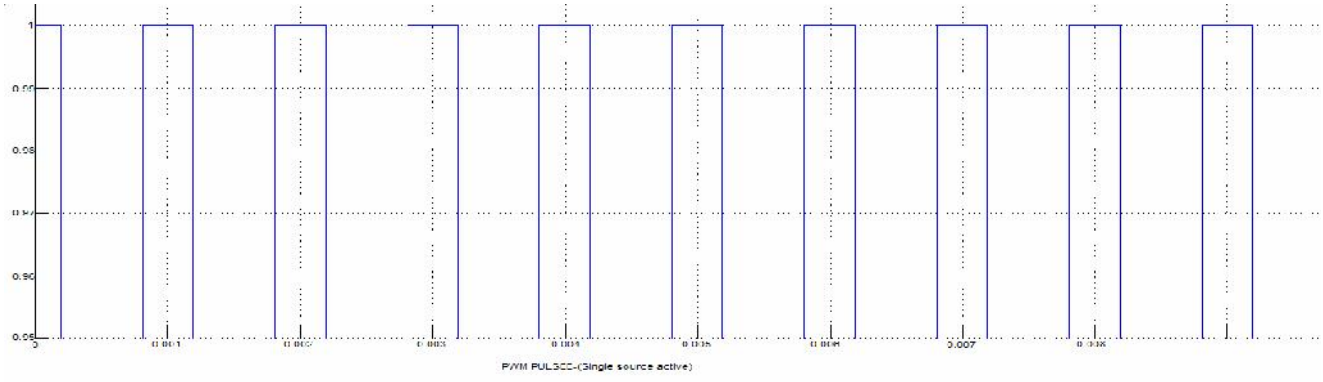

Fig.17. PWM pulses when single source only ON.

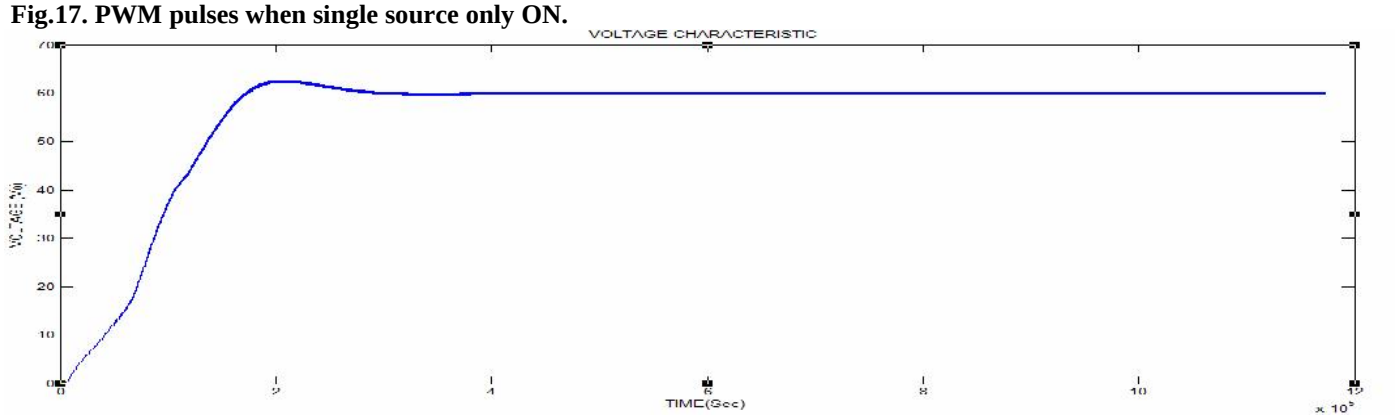

Fig.18. Output voltage of converter (single source ON only)

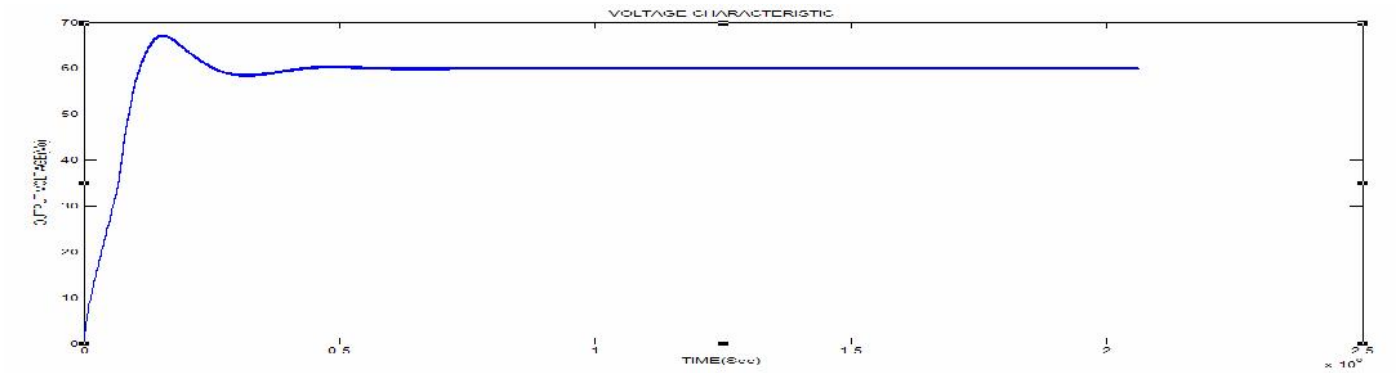

Fig.19. Output voltage of converter (both sources ON)

VI. Conclusion

The proposed converter is able to maintain constant voltage at load end. Variation in output voltage can be made by variation in reference voltage and thus duty cycle can be varied. In traditional converter only one input source is used but in the proposed converter two energy sources can be used as input individually or simultaneously, which results in less cost, compact and efficient. High voltage output at converter end also reduces size of wire from panel to charge controller and battery also. The converter is able to work as multi input also in that case it may works as buck converter.

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