Evaluating the Effect of Interleaving and Maximum Power Point Tracking (MPPT) in boost converter for Photovoltaic (PV) Power Generation System using MATLAB

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***Abstract*— The output power of the photovoltaic (PV) system is small and varies with the variation of the atmospheric conditions. To match the output of the PV system with the load requirements power conditioning systems are required. This paper deals with the usage of conventional dc-dc converter, interleaved boost converter and interleaved boost converter with maximum power point tracking (MPPT) for the power conditioning of the PV system using MATLAB/SIMULINK software. The results of simulations were compared with hardware results and the performance analysis is carried out based on efficiency and settling time. The simulation is carried out under same specification of components to compare the results of all models.**

Keywords- Conventional boost converter, interleaved boost converter, interleaved converter with MPPT, PV array characteristics, comparison of converters, P & O MPPT technique.

I. INTRODUCTION

The increased energy consumption of mankind leads to the global warming and exhaustion of conventional energy sources. The usage of renewable energy sources such as solar, wind, geothermal, tidal, etc becomes essential to meet out the increasing power demands. Out of this solar energy becomes a most promising energy source because of its clean, inexhaustible, cost free and non polluting nature. The usage of semiconductor materials for the PV panels and power conditioning devices eliminates vibration, wear and tear and provides a noise free operation. Further the life time of PV array is more than 20 years [1].

The output power of PV array varies with variation of solar irradiation and temperature. For a particular solar insolation the PV array produces the maximum power at a particular point called maximum power point. The maximum power point varies with variation of atmospheric conditions such as insolation and temperature. The maximum power point cannot be maintained for varying atmospheric conditions without varying the system parameters. Power conditioning circuits containing dc-dc converters with MPPT techniques are used to overcome the above problem by adjusting the voltage and current levels to match the PV source to load [2]. The efficiency of the PV panel is very low. The efficiency of the PV system can be increased either by increasing PV module efficiency or by increasing the converter efficiency. The PV module efficiency can be increased by using new materials and new methods of fabrication. The power converters are controlled using MPPT techniques for controlling the output voltage.

The converter efficiency can be increased by using interleaving, soft switching and MPPT techniques. [3]. The commonly used power converter is the conventional boost converter. The input current ripple and the output voltage ripple reduce the efficiency of the conventional boost converter. The interleaving technique is used to improve the efficiency, transient response and reliability of boost converters [4-6]. The P & O MPPT technique is used to improve the efficiency of the system.

This paper contains six more major sections. First section deals with PV array characteristics, second section with conventional boost converter and its design, third section with interleaved converter and its design, fourth section deals P&O MPPT technique, fifth section with the simulation and the sixth section with hardware design and its performance.

II. CHARACTERISTICS OF PV ARRAY

The power conversion unit of a photovoltaic system is the PV cell. The I-V characteristics of the PV cell for different illumination and temperature are shown in Fig. 1 and Fig. 2. From the characteristic two important values can obtained. The short circuit current (Isc) value which is the maximum current at zero voltage and the open circuit voltage (Voc) value which is the maximum voltage at zero current. For each point on the I-V curve the power output is obtained by finding the product of current and voltage. The maximum power point (P_m) is the point where the product of I and V is maximum on the I-V curve [7].

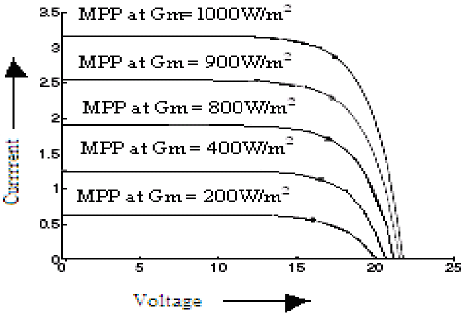

Figure 1. I-V curve of solar Cell under Different illumination

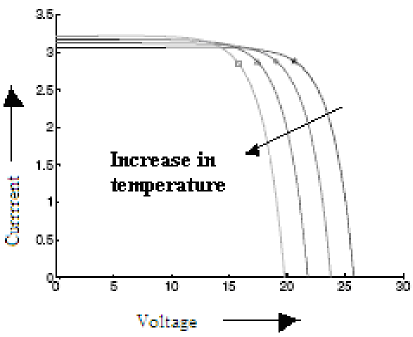

Figure 2. I-V curve of solar Cell under different Temperature

The output power characteristics of solar cell for varying illumination and temperature are shown in Fig.3 and Fig.4. The open circuit voltage (Voc) and short circuit current (Isc) increases with increase in intensity of radiation. The increase in temperature causes some increase in short circuit current and decrease in cell voltage of 2.2mV per degree rise of temperature [8].

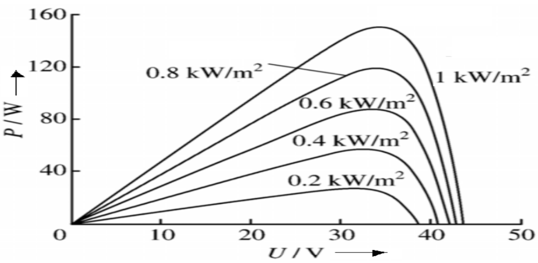

Figure 3. P-V curve of solar cell under different illumination

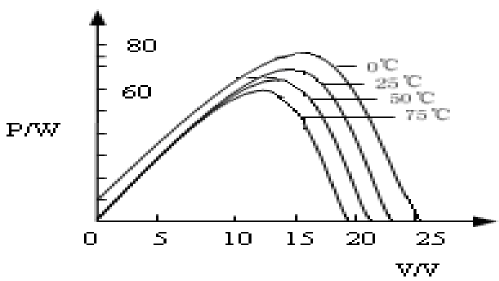

Figure 4. P-V curve of solar cell under different temperature

III. DC-DC CONVERTERS

The switching characteristics of DC-DC converters are used to convert dc voltage of one level (normally unregulated voltage) to dc voltage of another level (regulated voltage). The conversion is carried out using a circuit containing storage elements such as inductors and capacitors and power devices like transistors, MOSFETs, IGBTs and diodes.

The converters perform important work in PV power generation systems for MPPT and interfacing PV system output with varying types of loads. There are three basic types of DC-DC converters based on the relation between the output voltage and input voltage.

- Buck converter: Produce output voltage lower than input voltage.
- Boost Converter: Produce output voltage higher than input voltage.
- Buck boost Converter: Produce both higher and lower output voltages.

The DC-DC converters operate in two modes namely continuous conduction mode and discontinuous conduction mode depending on the nature of the inductor current. In continuous conduction mode the output voltage produced depending on the input voltage and duty cycle. In discontinuous conduction mode the output voltage produced depends on inductor value, load current and switching period [9].

IV. CONVENTIONAL BOOST CONVERTERS

It is a DC-DC converter in which the output voltage will be greater than the source voltage. Boost converters are used in situations where array voltages are lower than battery voltages. Because of the simplicity in circuit, reduced voltage stress on devices and high efficiency boost converters are used as DC-DC converters in the PV applications [10].

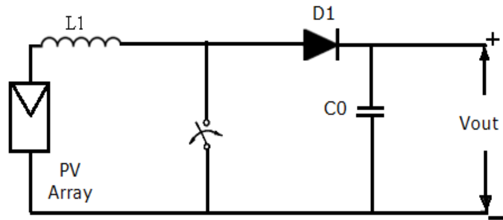

Figure 5. Boost Converter

The requirements of DC-DC converter used for PV power generation systems are

- High Voltage gain
- High current handling capacity
- High efficiency
- Low value of input current

To provide high gain, boost converters should be operated at extreme duty cycle which causes poor dynamic response during line and load variations. The rectifier diode

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must handle high amplitude short pulse current which causes reverse recovery and high Electro Magnetic Interference [EMI] problem. In high step up DC-DC converters the input current values will be high. To reduce the conduction loss MOSFETs of low value of forward on state resistance should be used. But the boost converter should be capable of operating at high output voltage. This leads to complication in the selection of power devices. The above problem can be rectified by using interleaved boost converters which can provide high output voltage operating at normal duty cycle [11].

For an ideal boost converter

$$V_0/V_i=1/(1-D) \quad (1)$$

Where D is the duty cycle, which is the ratio of the on time to the sum of on time and off time of the switching device.

$$L > V_{in} / (2I_{in}f) \quad (2)$$

$$L_{min} = D\,(1-D)^2R/2f \quad (3)$$

$$C \;= V_0D/(\Delta V_0R)f \quad (4)$$

V_i - the input voltage in V
V_o - the output voltage in V
R - Load Resistance in Ohms
ΔV_0 -Change in output voltage in V

V. INTERLEAVED BOOST CONVERTER

Interleaving technique is based on the sharing of input current among parallel converters which improves the aspects like maintenance, heat dissipation, reliability and fault tolerance.

In interleaved converters the input current and output voltage waveforms have lower ripple amplitude and lower harmonic contents. The cancellation of low order frequency harmonics leads to the usage of reduced size of components. The conduction losses and EMI also reduced [12].

The performance of the interleaved boost converter depends on the number of phases, inductors, output capacitor, power switches and the output diodes. In interleaved design the components should be identical in all the phases. The ripple current in the interleaved converter decreases with increase in number of phases. For a two phase interleaved converter the reduction in ripple will be 12% compared to the conventional boost converter.

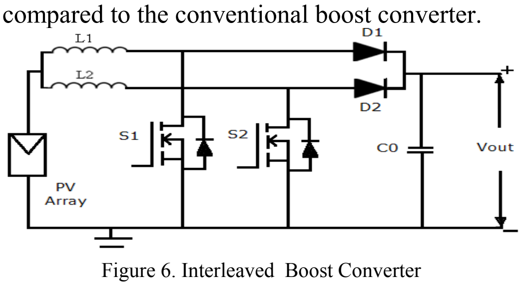

Figure 6. Interleaved Boost Converter

If the number of phases is increased more and more, the ripple reduction will be less with increased cost and complexity of the circuit. To have better performance with reduced cost and complexity two phase interleaved converter is a suitable one.

The gating pulses of the switches are phase shifted by 360/n where 'n' is the number of phases. For a two phase converter the phase shift of the gating pulses are 360/2=180º. The duty ratio depends on the number of phases. For a two phase interleaved boost converter a duty ratio of 0.45 produces the minimum ripple [12-14].

VI. MAXIMUM POWER PIONT TRACKING

The process of keeping the operating point of the PV panel at maximum power for the corresponding radiation is known as MPPT. To transfer maximum power from the PV panel to Load duty cycle of the power electronic converters can be changed by MPPT Techniques. The simplest and commonly used type of MPPT is the P&O MPPT technique. In this algorithm the array terminal voltage and current are sensed and processed as per Fig.7.

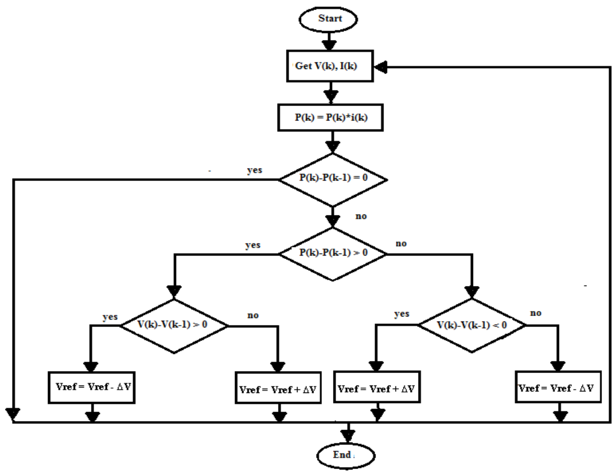

Figure 7. Flow chart for P&O MPPT technique

The power output is calculated. The present PV output power is compared with the power of previous perturbation cycle. The PV voltage and current are perturbed periodically after comparing. If the PV operating voltage varies and change of power dP/dV>0, the algorithm moves the operating point in the same direction, and if the change of power dP/dV<0, the algorithm moves the operating point in the opposite direction and if the change in power is zero dP/dV=0 that represents the condition of maximum power point there will not be any change in the position of the operating point [15-16].

VII. SIMULATION RESULTS

Simulation model of boost converter with ac output with active load

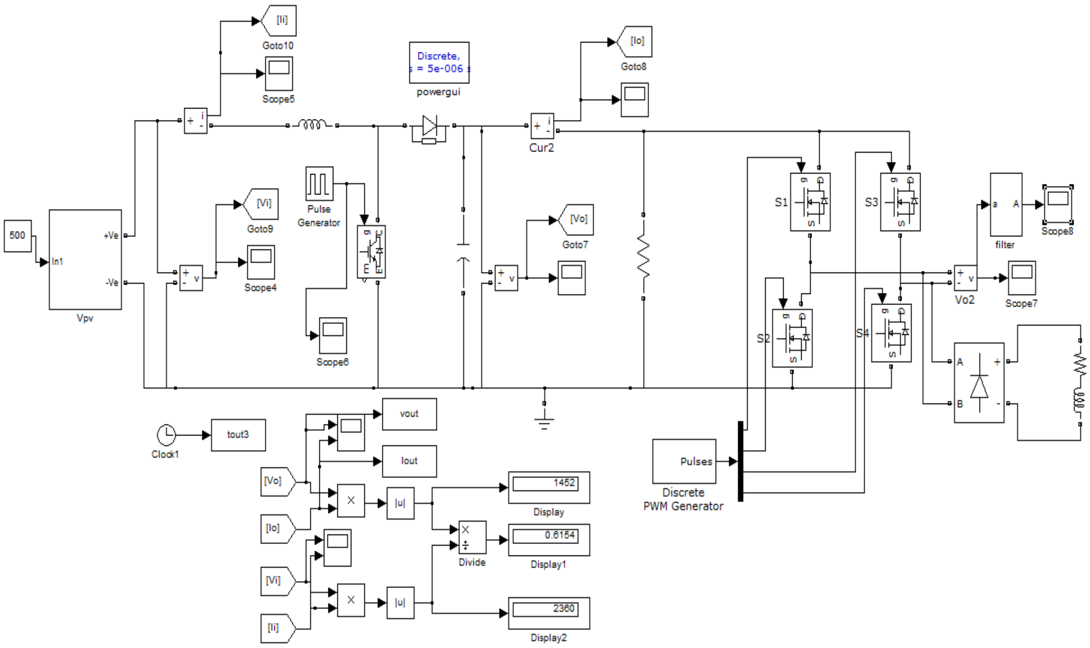

Figure 8. Simulation of Boost converter

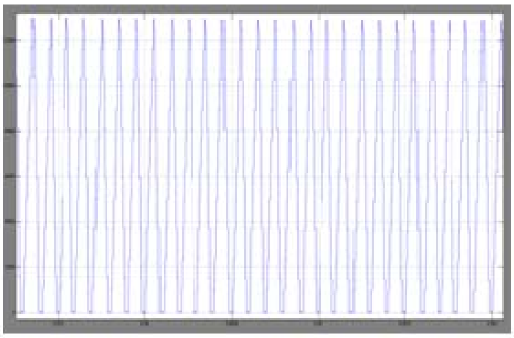

Figure 9. Boost converter inductor current wave form

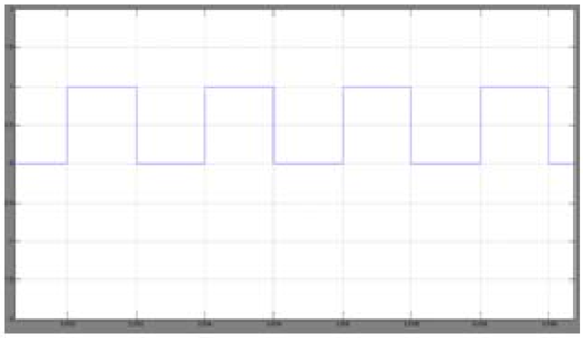

Figure 10. Boost converter Gate trigger pulse waveform

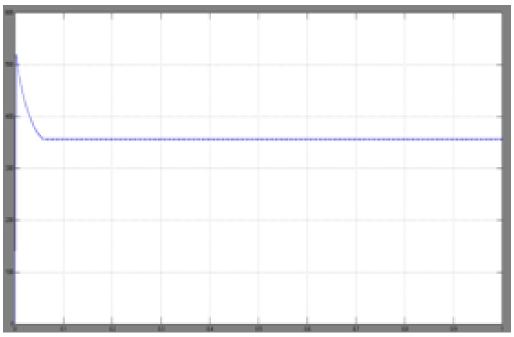

Figure 11. Boost converter output voltage wave form

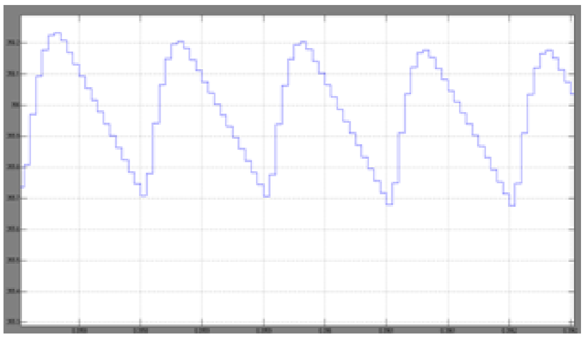

Figure 12. Boost converter output voltage ripple wave form

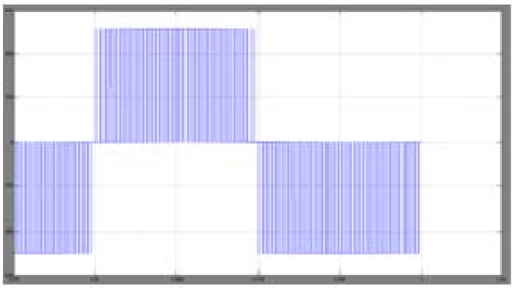
Figure 13. Inverter output voltage wave form

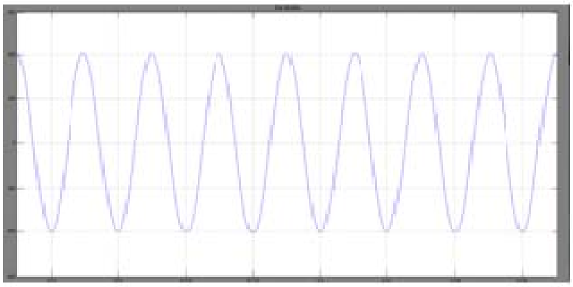
Figure 14. Filtered Inverter output voltage wave form

Simulation of Interleaved boost converter

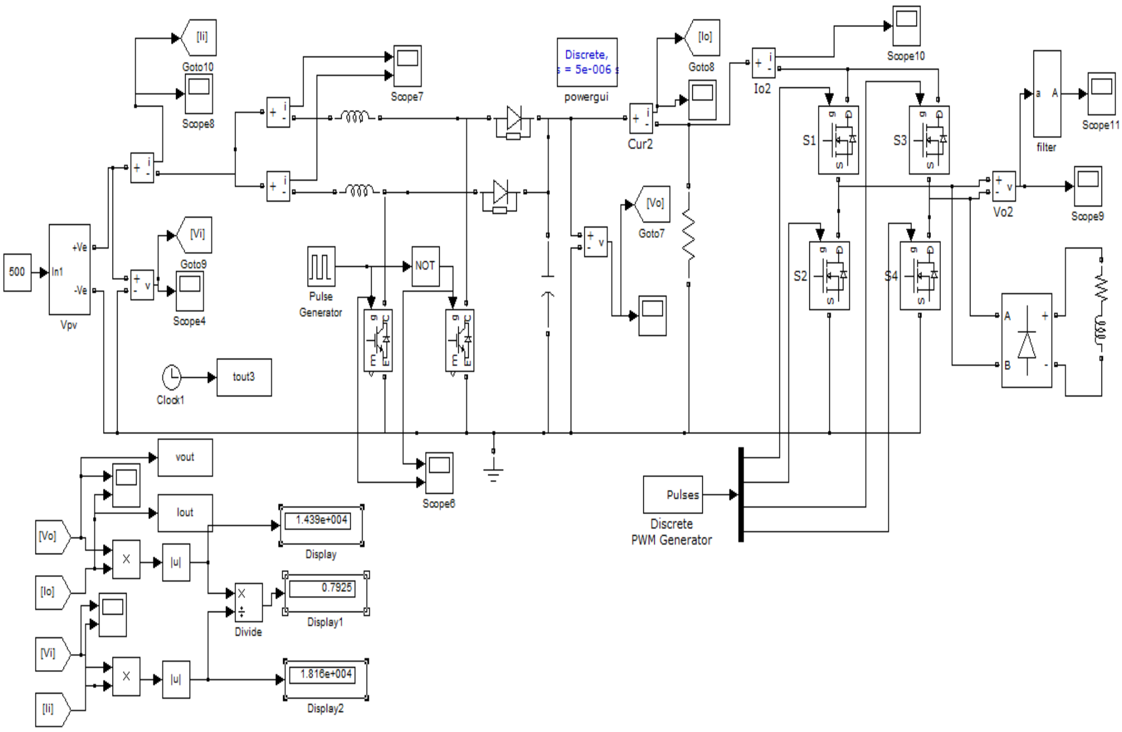

Figure 15. Simulation of Interleaved Boost converter

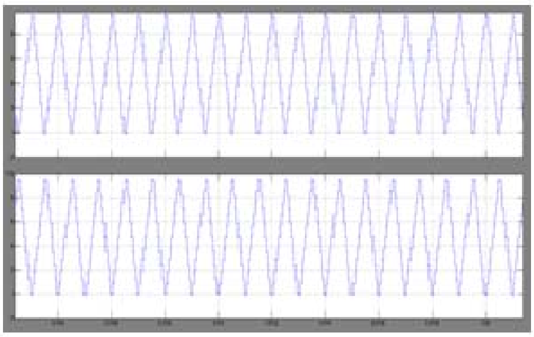
Figure 16.Interleaved converter inductor current wave form

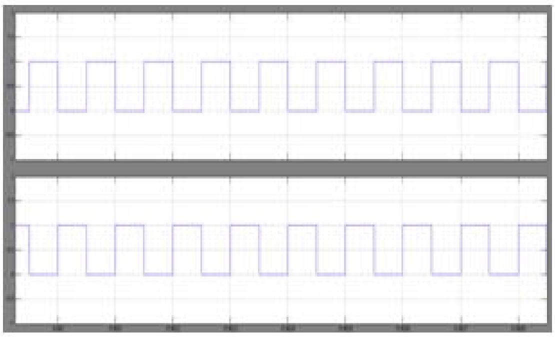
Figure 17. Interleaved converter gate pulse wave form

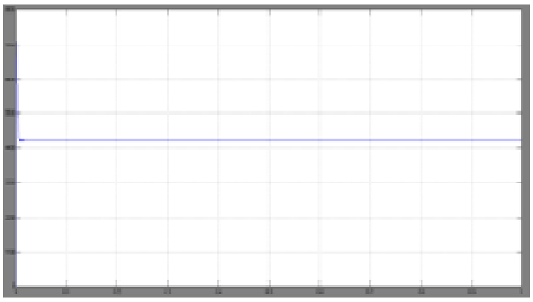

Figure 18 .Interleaved converter output voltage wave form

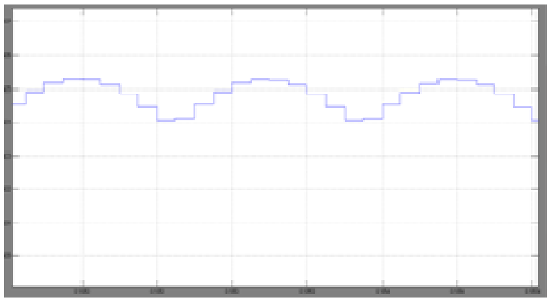

Figure19. Interleaved converter output voltage ripple waveform

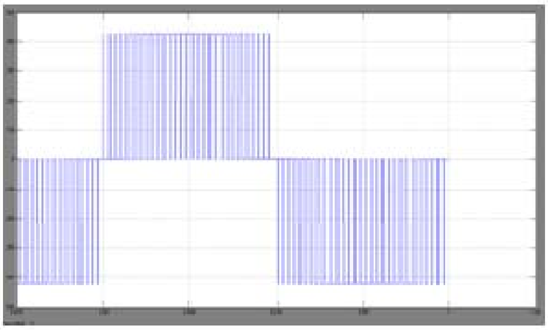

Figure 20. Inverter output voltage wave form

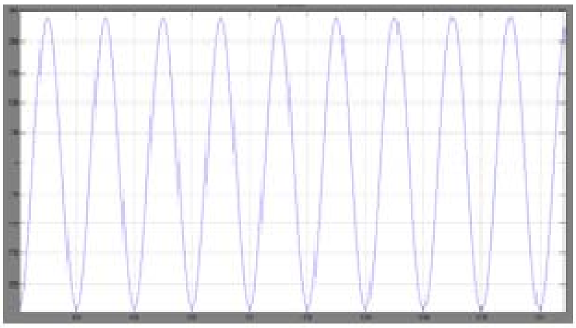

Figure 21. Filtered Inverter output voltage wave form

Simulation of Interleaved boost converter with MPPT control

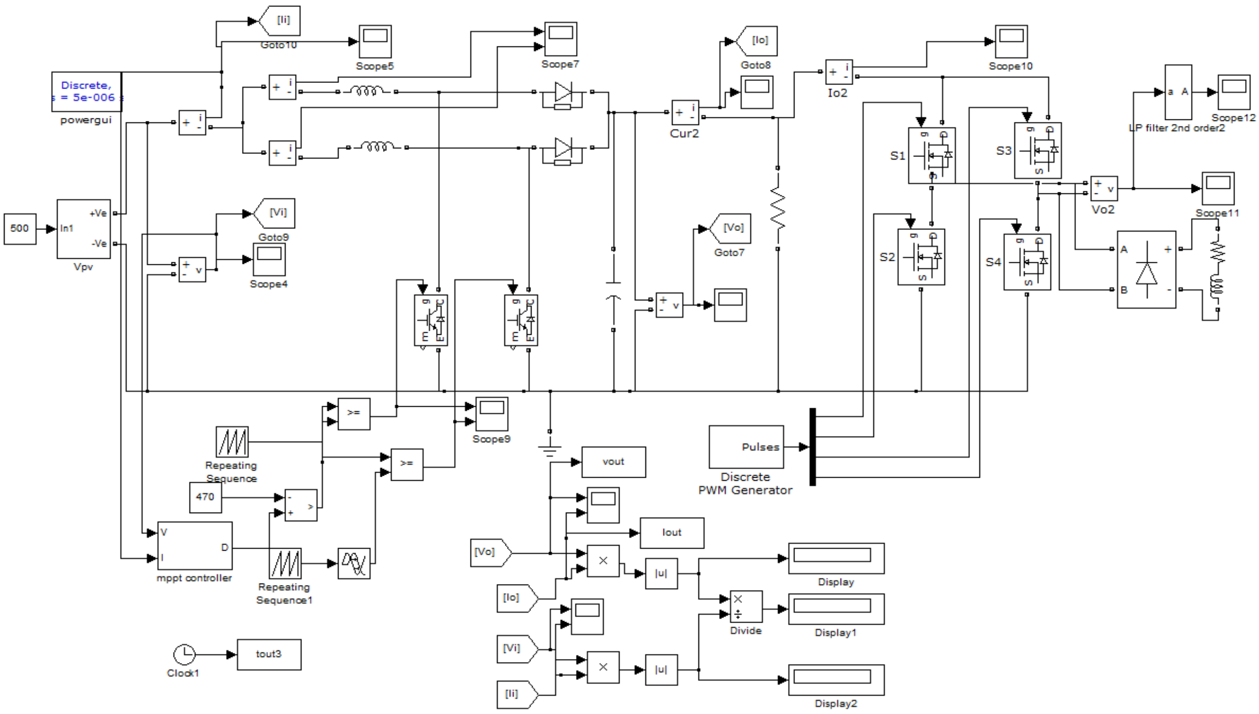

Figure 22. Simulation of Interleaved Boost converter with MPPT control

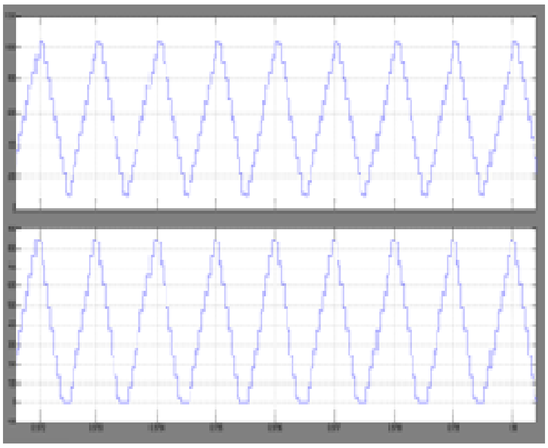

Figure 23. Inductor current wave form (MPPT)

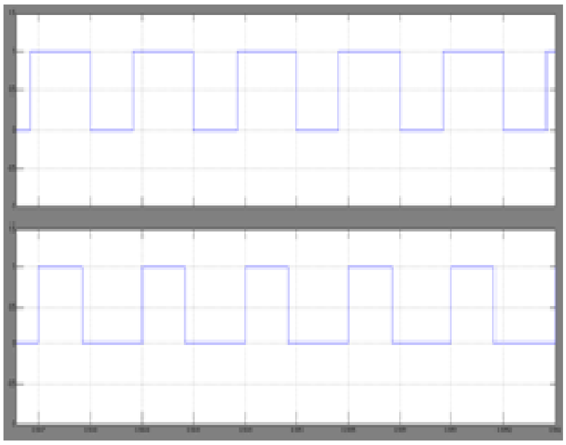

Figure 24. Gate pulse waveform (MPPT)

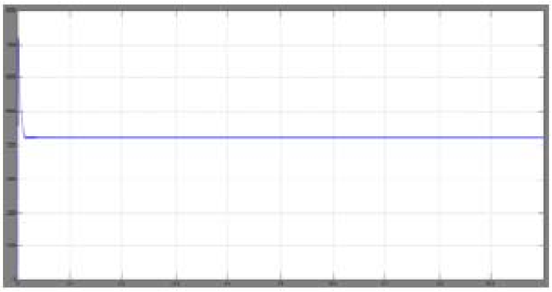

Figure 25.Converter output voltage wave form (MPPT)

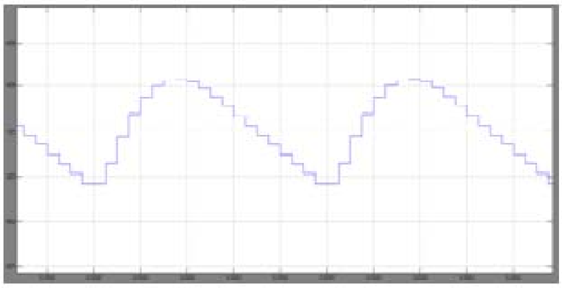

Figure 26. Output voltage ripple waveform (MPPT)

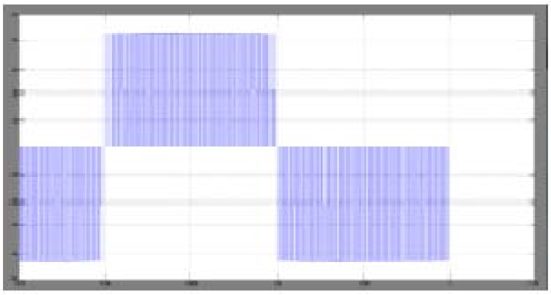

Figure 27 . Inverter output voltage wave form (MPPT)

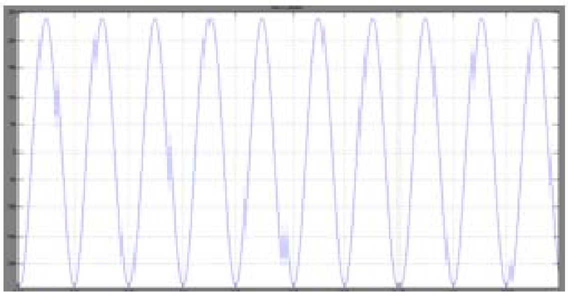

Figure 28. Filtered Inverter output voltage wave form (MPPT)

TABLE 1.COMPARISION OF CONVERTERS BASED ON SIMULATION

S.No	**Converter Type**	**L in H**	**C in MF**	**R in Ω**	**Switching frequency (KHz)**	**Settling time in (Sec)**	**Efficiency**
1	Boost Converter	30e-6	5e-6	10	10KHz	0.06	62.4%
2	Interleaved Boost Converter	10e-6	5e-6	1	10KHz	0.02	79.2%
3	Interleaved Boost Converter with P & O MPPT	10e-6	5e-6	1	10KHz	0.02	94.2%

VIII. HARDWARE SETUP

Figure 29.Interleaved converter with MPPT control

IX. HARDWARE SPECIFICATIONS

PV panel-100W/ 12V
Inductor-30mH
Capacitor-1000uf
Switches-IRF840 MOSFET
Microcontroller-ATmegs8

X. CONCLUSION

The simulation was carried out for boost converter, Interleaved boost converter, Interleaved boost converter with MPPT control with same specifications in simulation to find the effect of interleaving and MPPT. It was found that the performance of interleaving is better than single boost converter. The application of MPPT control increases the efficiency of the interleaved converter and reduces ripple in output. The efficiency found by hard ware set up is less than that of the efficiency found by simulation. The simulation efficiency is 94% for interleaved boost converter with MPPT control. But it was only 79% in the hardware setup. This paper will help to have an idea about the effect of interleaving and MPPT in improving the performance of PV system.

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