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Comparison Of DC-DC Boost Converters Using SIMULINK

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Abstract: *Now-a-days with the inadequacy in energy and continually enlarging fuel cost, investigation on the renewable energy becomes more and more important. A boost converter is a switch mode dc to dc converter in which the output voltage is greater than the input voltage. Different traditional converters like boost converters tolerate high transient current and conduction losses as the switching frequency is varied. Ripple occurs in DCDC converters due to the switching transients. In order to overcome the above-mentioned drawbacks, the interleaved boost converter is used. The comparison between conventional and interleaved boost converter was simulated and analyzed using MATLAB/SIMULINK.*

Keywords: *Interleaved Boost converter, Maximum Power Point Tracking (MPPT), photovoltaic (PV) power generation, Perturbation and Observation(P&O)*

I. Introduction

The massive consumption of a natural fuel such as the oil, the coal and the gas pollutes atmosphere and results in serious greenhouse effect on the world. On the other hand, there is a huge denial in the middle of the fossil fuels supply and the global energy demand. Some limitations for the human development have been maximized as energy shortage and the atmosphere pollution. So, the recyclable source of renewable energy source wind, solar wave can be selected for high step-up operation.

The renewable energy sources are considered to be environmentally friendly and harness natural process. These sources can provide an alternate cleaner source of energy helps to negate the certain forms of pollutions. Generally, the applications of high step-up dc-dc converter involves the following requirements as high step-up voltage gain, low input current and output voltage ripple, high current handling capability and high efficiency. The conventional coupled inductor and switched capacitor based converters perceive high step-up gain because the turns ratio of the coupled inductor can be engaged as various control freedom to boost the voltage gain. In anyway, the input current ripple is comparably large by employing single-stage single phase coupled inductor-based converters, which compress the activity of the input electrolytic capacitor. [2]

Solar PV installations tend to be expensive when compared with conventional fossil fuel power generation, but benefit from having no associated fuel cost. However, in order to maximize the return on investment, it is important to maximize the amount of electricity generated by the PV system. Power electronic devices that significantly increase the system efficiency. So, to transfer power from the PV array to load a high efficiency power conditioning system is necessary.

II. System Overview

Energy sources with low output voltage such as fuel cell and photo-voltaic (PV) generation system attracts many researchers because they appear to be the possible solutions to the environmental problems. The output power of the solar cell is easily changed by the surrounding conditions such as irradiation and temperature, and also its efficiency is low. DC – DC converters are important component as power electronics interfaces for photovoltaic generators and other renewable energy sources. DC-DC converter is a switching converter which inherently introduces a certain amount of ripple in the current thereby reducing the efficiency. Interleaved topology improves the converter performance by reduce current ripples.

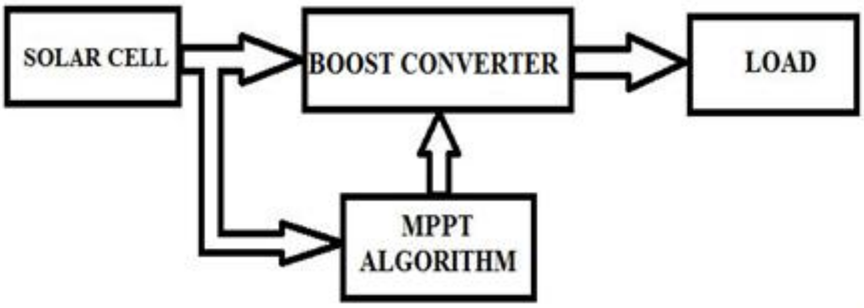

Fig 1: Block diagram of system overview

2.1 Solar Cell

Solar cells are composed of semiconductor materials like silicon. The semiconductor materials are particularly treated thereby forming an electric field with positive and negative terminals. When the light energy from the sun's rays fall on the cell a photo current starts flowing which mainly depends upon the solar irradiance. The equivalent circuit model of the PV cell shown in the Fig 2. Solar PV modules collect the sun's energy and convert it into direct current (DC) electricity. The amount of electricity produced is proportional to the amount and intensity of sunlight. Solar power system is the one which can be conveniently installed and transported. It also has the perfect characteristics of self-control, self-protection, needing no attention, compact structure, elegant outline. [1]

PV module represents the fundamental power conversion unit of a PV generator system. The output characteristics of PV module depends on the solar insulation, the cell temperature and output voltage of PV module. Since PV module has nonlinear characteristics, it is necessary to model it for the design and simulation of maximum power point tracking (MPPT) for PV system applications. The mathematical PV models used in computer simulation have been built for over the past four decades. Almost all well-developed PV models describe the output characteristics mainly affected by the solar insulation, cell temperature, and load voltage.

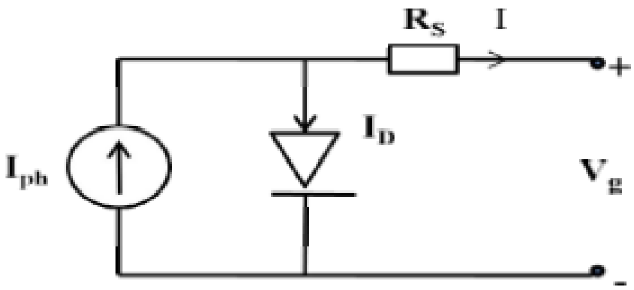

Fig 2: Equivalent circuit model of the solar cell

$$Id = Io\left[exp\frac{Vd}{Vt} - 1\right] \quad (1)$$

$$Vt = \frac{KT}{q} \times nI \times Ncell$$

(2)

Where,

Id = Diode current, Vd = Diode voltage,

Io = Diode saturation current, K = Boltzmann constant,

q = Electron charge, T = Cell temperature

2.2 DC-DC Converter

A dc/dc converter is an electronic circuit that converts a source of dc from one voltage level to another. Power levels range from very low (batteries) to very high level (high-voltage power transmission). The most common DC/DC converters encountered in low power applications cannot be extended to high power transmission application due to poor performances those converters exhibit. High step-up dc/dc converter involves the following requirements as high step-up voltage gain, low input current and output voltage ripple, high current handling capability and high efficiency. DC-DC converters are mainly classified into isolated converters and non-isolated converters.

2.2.1 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. By the law of conservation of energy, the input power has to be equal to output power. The main working principle of boost converter is that the inductor in the input circuit resists sudden variations in input current. When switch is ON, the inductor stores energy in the form of magnetic energy and discharges it when switch is open. The capacitor in the output circuit is assumed large enough that the time constant of RC circuit in the output stage is high. Vin is the input voltage and Vout is the output voltage as shown in Fig, 3.[4] Then the output voltage,

$$Vout = \frac{\mathrm{Vin}}{1-\mathrm{D}} \tag{3}$$

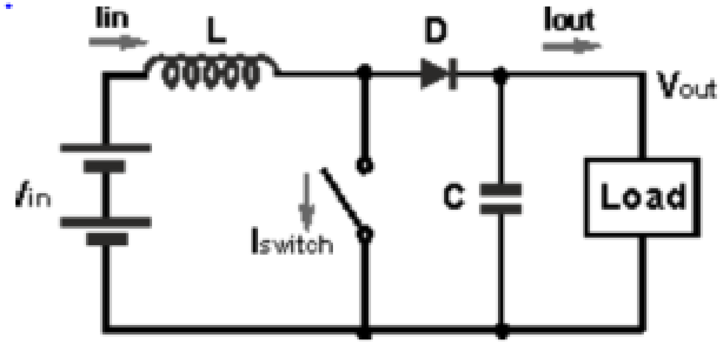

Fig 3: Boost converter

2.2.2 Interleaved Boost Converter

Boost converters are widely used as power-factor-corrected pre-regulators. Interleaving adds additional benefits such as reduced ripple currents in both the input and output circuits. Higher efficiency is realized by splitting the output current into two paths, substantially reducing losses and inductor AC losses. In high power applications, interleaved operation of two or more boost converters has been proposed to increase the output power and to reduce the output ripples. Fig. 4 shows the basic interleaved boost topology. [3]

The interleaved boost converter consists of two single-phase boost converters connected in parallel. The two PWM signal difference is 180 when each switch is controlled with the interleaving method. Because each inductor current magnitude is decreased according to one per phase, we can reduce the inductor size and inductance when the input current flows through two boost inductors. The input current ripple is decreased because the input current is the sum of each current of inductor L1 and L2.

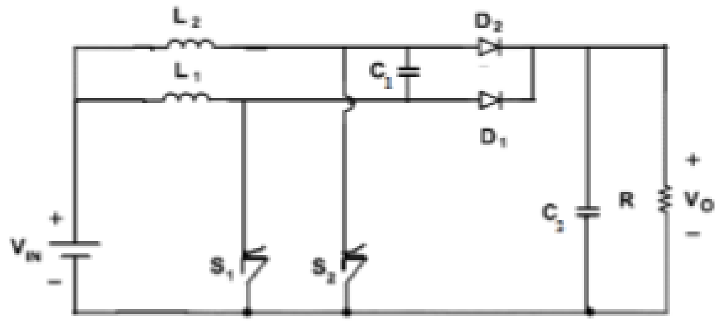

Fig 4: Interleaved boost converter

2.3 Maximum Power Point Tracking

In view of enhancing the efficiency of solar panel, it is necessary to increase the radiation falling on it. Thus, it is necessary to implement solar tracking system because the sun changes its position throughout a day. There are mainly two types of solar tracking system i.e. single-axis tracking and dual-axis tracking. But the sun tracking system requires electric motors, gear box, and light sensors for the accurate tracking. This tracking system increases the cost and complexity of the system and hence it is not suitable for house-hold and small scale applications. The maximum power point tracking (MPPT) technique requires only some electronic circuits like voltage measurement and current measurement circuits to transfer the maximum power to the load. This technique overcomes the drawbacks of sun tracking system that is the usage of electric motors, gear box, and light sensors. [7]

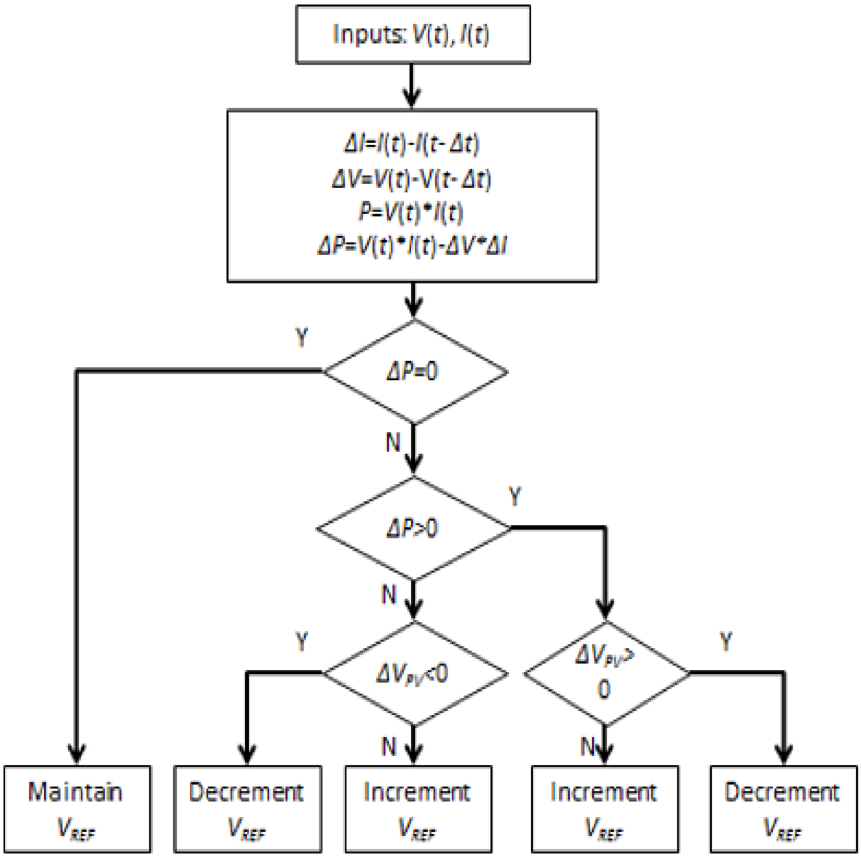

Fig 5: Flow chart of perturb and observe method

The basic principle of MPPT technique involves that it uses an algorithm. The algorithm includes measurement of voltage and current then the calculation of power. Based on the different conditions of algorithm the duty cycle of power electronic switch of the DC-DC converter is adjusted to maintain the requirement of load. The P&O technique is used for MPPT. The P&O algorithm is based on the calculation of the PV power and voltage by sampling the PV current and voltage. The flow chart is as shown in Fig. 5. In this approach, the module voltage is periodically given a perturbation and the corresponding output power is compared with that at the previous perturbing cycle.

In this simulation, the boost converter duty ratio and the average power generated by the PV are measured and compared to the value during the previous sample. The sample rate is 100Hz. The change in duty ratio and change in average power are multiplied together and then compared to zero. If the product is positive, the duty ratio is incremented by 1%. If the product is negative, the duty ratio is decremented by 1%. If the product is zero, the control toggles between incrementing and decremented the duty ratio by 1%. This prevents the simulation from getting stuck at one duty ratio, and does not appear to add additional oscillation around the equilibrium point. The duty ratio is limited between 0 and 90% to keep the boost converter in a suitable operating range.

III. Design Parameters

The circuit of both the topology has been designed in MATLAB/Simulink with the help of the blocks available in the Simulink library. Parameters of the simulations are listed in TABLE 1.

Table 1: Parameters of Simulations

PARAMETERS	CONVENTIONAL BOOST CONVERTER	INTERLEAVED BOOST CONVERTER
INDUCTANCE	**1.5mH**	**3.6mH**
CAPACITANCE	**0.12mF**	**0.25mF**
RESISTIVE LOAD	**15ohm**	**15ohm**

Boost converter design equations are given as,

$$Vout = \frac{\mathrm{Vin}}{1-\mathrm{D}} \tag{4}$$

$$L = \frac{\mathrm{Vin} \times \mathrm{D}}{\mathrm{f} \times \Delta \mathrm{I}} \tag{5}$$

$$C = \frac{\mathrm{Iout} \times \mathrm{D}}{\mathrm{f} \times \Delta \mathrm{V}} \tag{6}$$

Where,

Vin = Input Voltage, Vout = Output Voltage,
ΔV = Ripple Voltage, Iout = output current,
ΔI = Ripple Current, F = frequency,
D = Duty Ratio, L = Inductance,
C = Capacitance

IV. Simulation Model

In Fig.6 the model of PV panel as a constant dc source created using the subsystem block from Simulink library browser, which included all functions of PV panel. The model has three inputs irradiance, temperature and voltage input and the output of the block gives the current. This model generates current and receives voltage back from the circuit. The configuration of MPPT controller is shown in Fig. 7. The inputs of MPPT controller are voltage and current of the PV module for controlling the duty cycle of the boost converter. Fig. 8 and Fig. 9 present a SIMULINK diagram of a both conventional boost and interleaved boost converters.

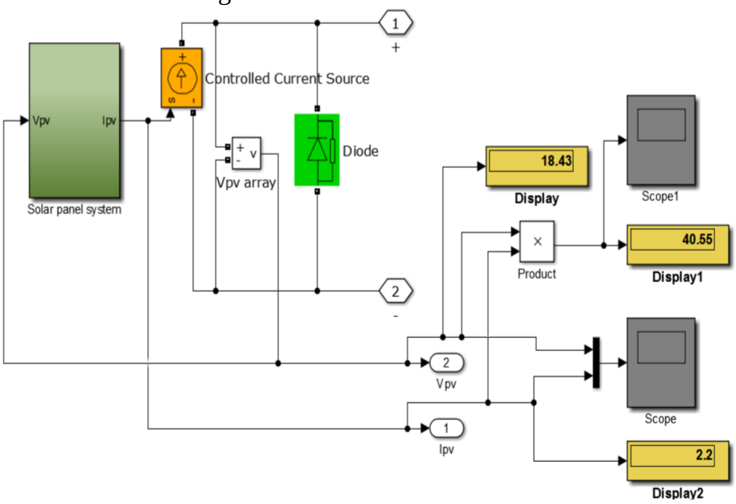

Fig 6: PV subsystem model

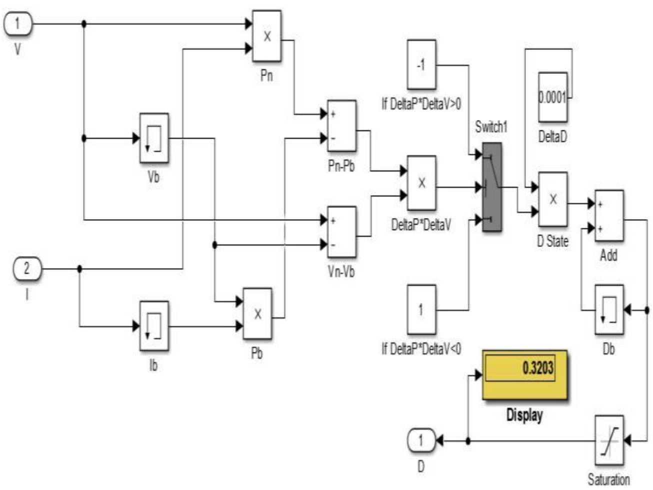

Fig 7: Simulink model of P&O MPPT converter control

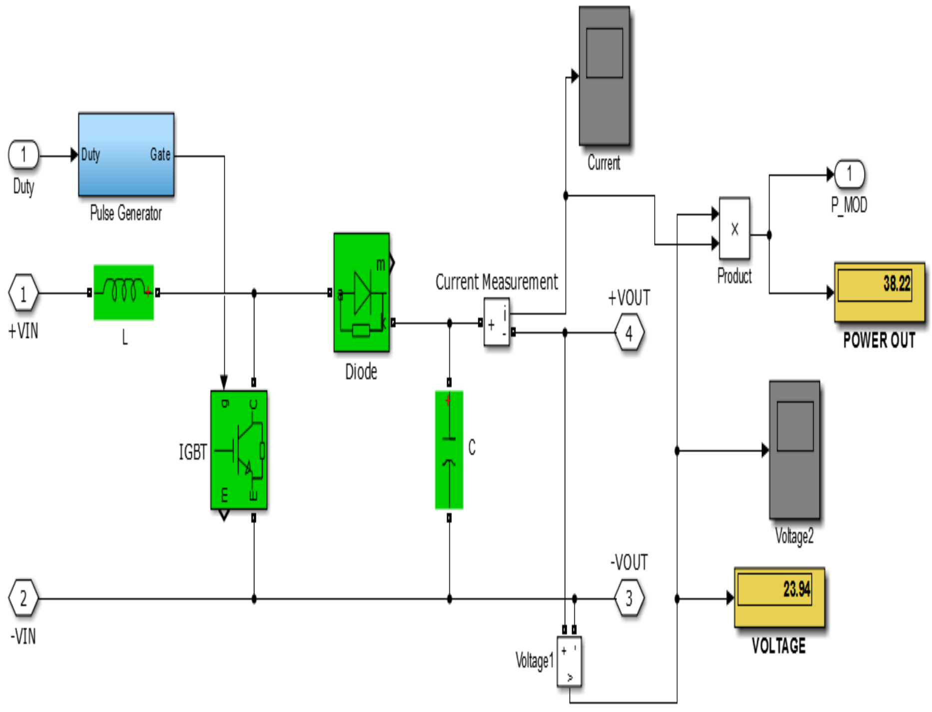

Fig 8: Simulink Model of Conventional Boost Converter

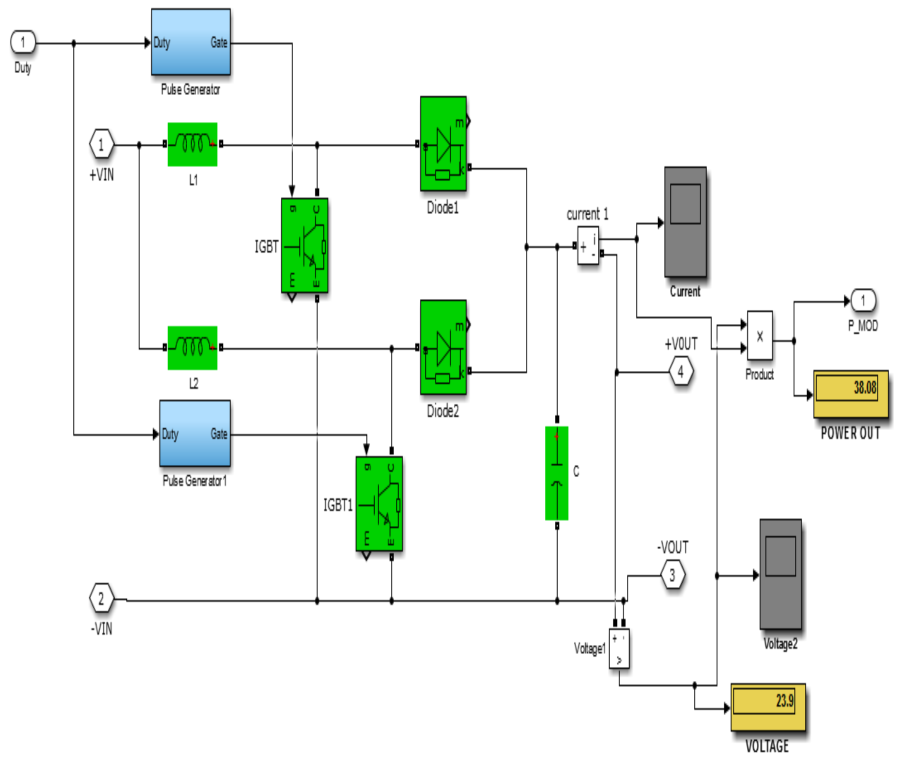

Fig 9: Simulink Model of Interleaved Boost Converter

V. Result Analysis

This paper presents a comparison between conventional and interleaved topology of boost converter. Fig. 10 shows the power output waveform obtained from a solar model with MPPT for a conventional boost converter topology and hence the power output of the converter is less than the solar power output.

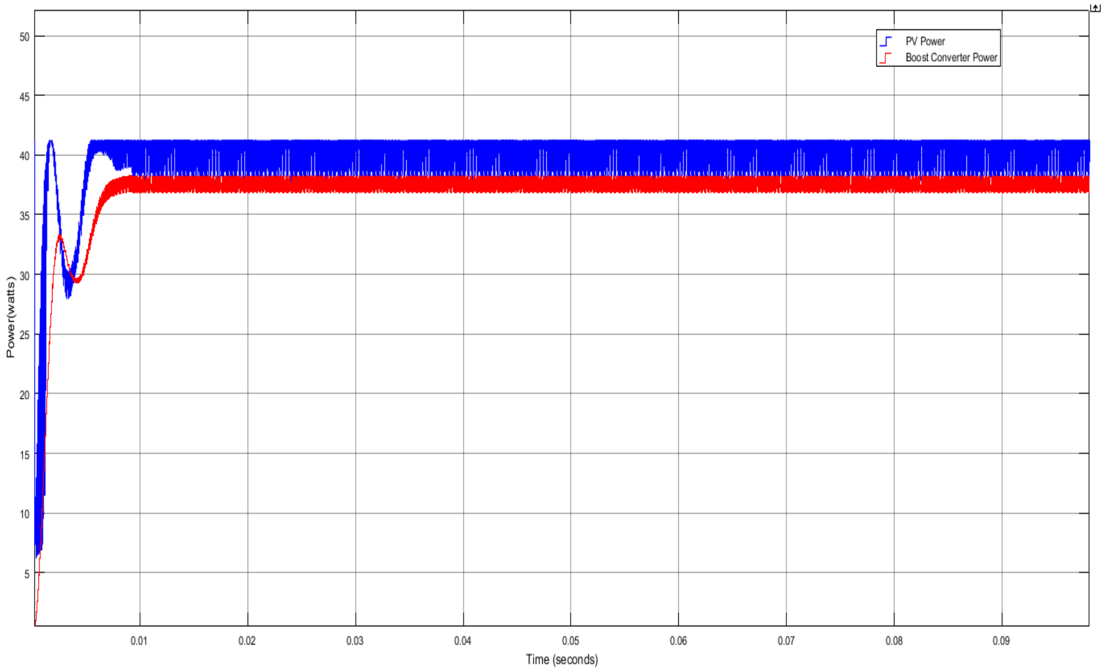

Fig 10: Power Output of Conventional Boost Converter

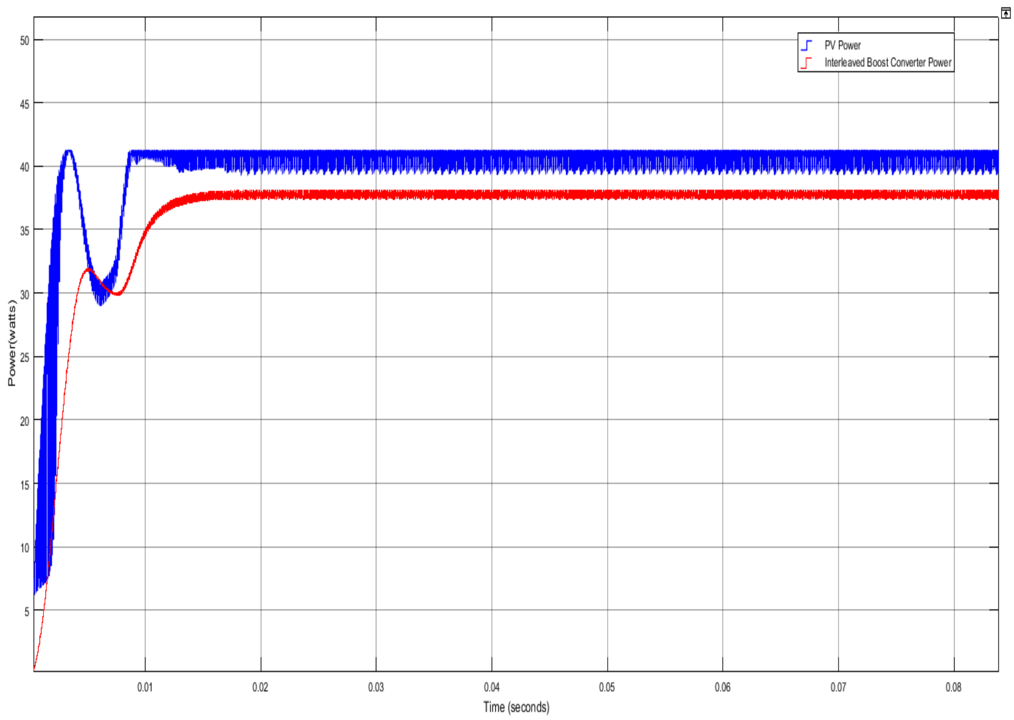

Fig 11: Power Output Of Interleaved Boost Converter

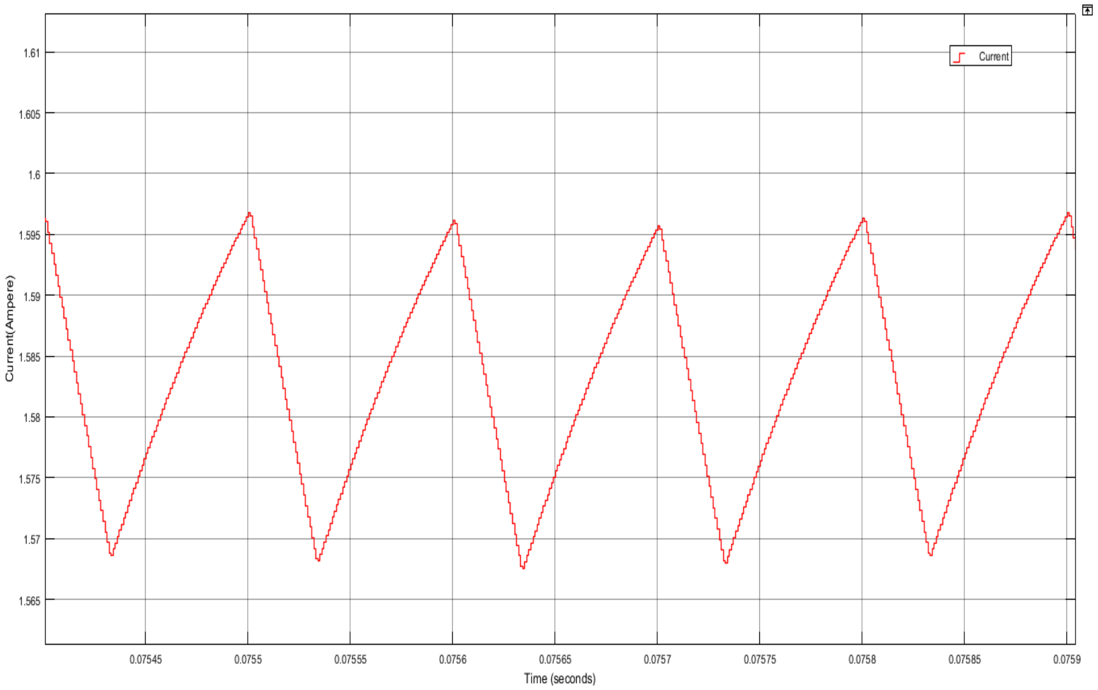

Fig 12: Current Wave Form Of Conventional Boost Converter

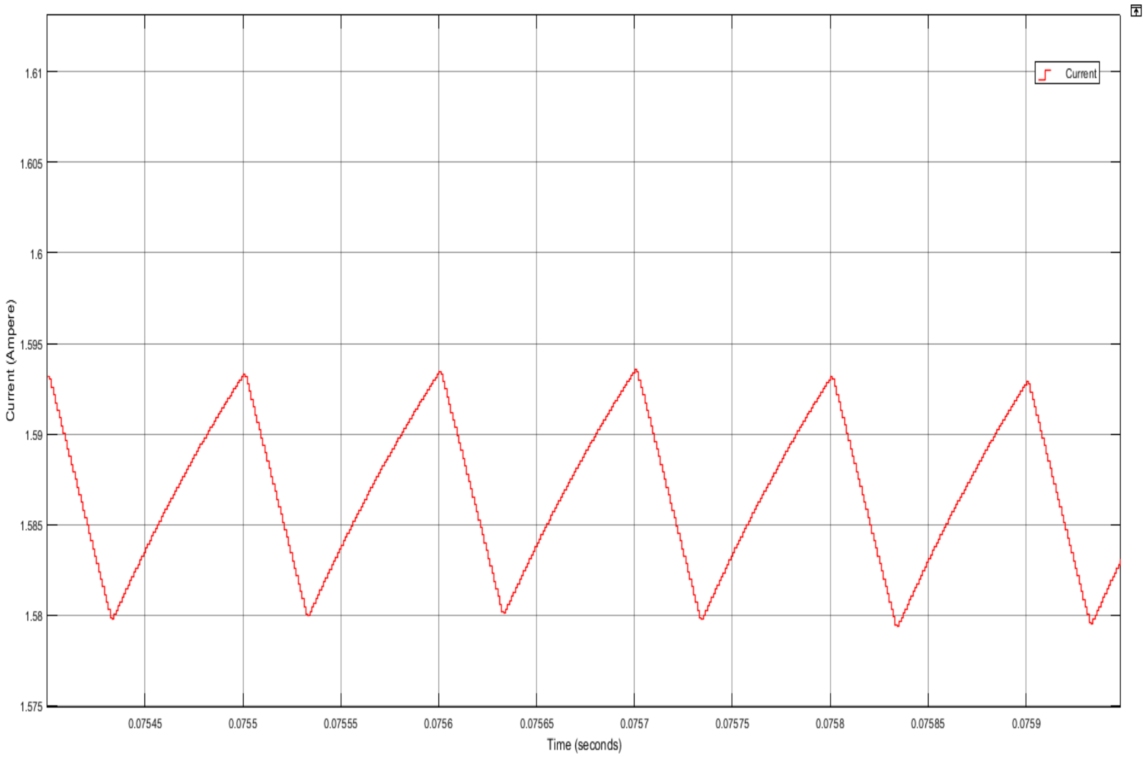

Fig 13: Current Wave Form of Interleaved Boost Converter

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The power output of an interleaved boost converter topology is shown in Fig. 11. The waveform obtained from an interleaved boost converter topology with MPPT shows that the output power is tracked at the point where maximum power is present. The waveform rises at the initial point and then it is maintained constantly as the converter is similar to that of a boost converter. Fig. 12 and Fig. 13 shows the current waveform of conventional and interleaved converter respectively. It is found that the current ripple of interleaved boost converter is less than that of conventional boost converter.

Table 2: Comparison Results

	CONVENTIONAL BOOST CONVERTER	**INTERLEAVED BOOST CONVERTER**
OUTPUT POWER	**38.25W**	**37.5W**
CURRENT RIPPLE	**0.03A**	**0.0135A**
VOLTAGE RIPPLE	**0.7V**	**0.2V**
POWR RIPPLE	**1.3W**	**0.6W**
POWER LOSS	**2.3W**	**2.9W**

A comparison has been made for two different topologies of boost converter, so that the better performance of the topologies can be concluded. The obtained comparison result has been shown in TABLE 2.

VI. Conclusion

In general, various DC-DC converter topologies have been used in the energy systems. DC-DC converter is a switching converter which inherently introduces a certain amount of ripple in the current thereby reducing the efficiency. Usually this ripple is minimized by using a filter at the output terminals. While this is a solution, the magnitude, cost and life of the filter dependent on the types of converter used. Hence the interleaved boost converter has been used. This method of approach can be used to reduce current ripples by 45% and voltage ripple by 30% of conventional boost converter, and there by increasing the efficiency. But this method introduces certain amount of losses at the output power, this can be improved by using soft switching techniques.

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