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PERFORMANCE ENHANCEMENT OF HIGH VOLTAGE GAIN TWO PHASE INTERLEAVED BOOST CONVERTER USING MPPT ALGORITHM

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ABSTRACT

This paper proposes the simulation and implementation of performance enhancement of two phase interleaved boost converter using Maximum Power Point Tracking (MPPT) algorithm to achieve maximum power for Photo Voltaic (PV) application. The output current is divided by two phase since current stress on each switch is reduced. Each switch is turn on by same frequency with phase difference of π. The output of PV panel is affected by temperature and insulation level, Hence conversion efficiency is very low. To improve the efficiency, additionally the MPPT controller is used in our proposed converter to efficiently draw the maximum power from the solar panel. The maximum power point is identified using Perturb &Observe (P&O) algorithm. The Perturb &Observe algorithm suitably to track the maximum power output of two phase interleaved boost converter with proper duty ratio. This paper present simulation and implementation procedure for two phase Interleaved Boost Converter with MPPT algorithm. The simulation results are obtained by using MATLAB/SIMULINK. The simulation results for non-isolated two stage interleaved high voltage gain boost converter were compared with and without MPPT. The MATLAB/simulink simulation results are presented to validate proposed converter. The hardware prototype of 12volt input 102 volt output has been developed.

Keywords: *PV, MPPT P& O algorithm, Coupled Inductor, Two phase, Voltage multiplier cell.*

1. INTRODUCTION

The solar energy is one of the most promising energy due to its infinite power, Non depletable and clean source of energy. Thus modern solar technologies penetrate market faster rate. The solar energy greatest Impact on our lives is photovoltaic. The power from the sun intercepted by earth is approximately 1.8 x 1011MW[2]. This is thousand of time more than the present power consumption. Hence solar power can meet the present and future power demand. The photovoltaic is used to produce the electricity, where power lines cannot reach. The photovoltaic (PV) power generation systems have very much popular commercial and residential areas [3][4]. For low input voltage from PV panel cannot make higher efficiency at PV inverter.[5].Several converter topologies are proposed to increase PV output voltage as we required. [6-8]. The coupled inductor boost converter with high turns ratio [9] were also proposed. The single phase boost converters are provide more input current ripple, which in turn increases the conduction loss of the switch. To minimize the current stress, voltage stress and input current ripple interleaved technique is used.[10]. The combination of coupled inductor with voltage multiplier cell will increase the efficiency of boost converter by recycle the inductor energy and also reduces the voltage stress across the switch.[11][12].For high power and high voltage gain application two or three phase interleaved boost converters are proposed [13][1]. But the efficiency of PV panels are approximately very low due to temperature and isolation level. Many researches are going on to improve the efficiency of PV panel. To make use of efficient operation of PV panel, the maximum power point tracker (MPPT) is used. There are two ways to get maximum output from PV panel one is mechanical tracking another one is electrical tracking. The Mechanical tracking is obtained the direction of PV panel oriented in such a way that to get maximum power from the sun. The electrical tracking is obtained by manipulating the load to get maximum output under changing condition of irradiation and

temperature. The selection of the algorithm depends on the time duration, cheaper and simpler .Many methods have been proposed to determine the maximum power point of PV panel. [14][15].The proposed MPPT algorithm includes;

Perturb&Observe

Incremental Conductance

Constant reference voltage/current

Among them P&O and ICT algorithm can track maximum power point, good dynamic response and also it incorporate change in temperature and irradiation. Among these two techniques P&O algorithm easy to implement and cost effective method. Hence P&O MPPT algorithm is suggested. This paper proposes the simulation of two phase interleaved boost converter with MPPT and without MPPT for PV application.

2. ANALYSIS OF TWO PHASE INTERLEAVED BOOST CONVERTER

The proposed interleaved boost converter consists of two interleaved boost converter connected in parallel. Using this topology two phase interleaved boost converter input current ripple and current stress across the switch get reduced. The voltage gain of proposed two phase interleaved boost converter is increased by use of input coupled inductor and output voltage multiplier cell. The input interleaved inductor reduces the voltage stress across the switch. The input side of boost converter have primary of coupled inductor and the secondary is connected to voltage multiplier cell.

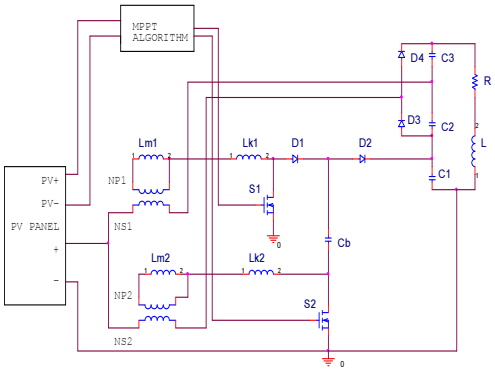


Fig.1 Circuit diagram of PV based two phase interleaved boost converter with MPPT

The primary of coupled inductor is denoted by magnetizing inductor L_{m1},L_{m2} and primary leakage inductor L_{k1},L_{k2}.The boost converter consist of main switch MOSFET (Metal Oxide Semiconductor Field Effect Transistor) S_1 and S_2 and Diodes D_1,D_2 and D_3 along with voltage lift capacitor C_b. Each switch is turn on by same switching frequency with phase difference of π.

The proposed converter is working with continuous conduction mode of operation, hence input current ripple get reduced due to antiphase ripple cancellation. The maximum ripple cancellation occur at duty ratio of 0.5 therefore The duty cycle of proposed converter must be chosen greater than or equal to 0.5.

The proposed system consist of PV panel , MPPT P&O algorithm and two phase interleaved boost converter. The output voltage voltage from PV panel gets boosted using two phase interleaved boost converter and it is fed to RL load. The MPPT controller track the maximum output from PV panel by selecting better duty ratio. The operation of each interleaved boost converter of two phase interleaved boost converter has three modes of operation,

A. Mode I

Both interleaved boost converter switch's S_1 and S_2 are in on, boost converter diode D_1 ,D_2 and voltage multiplier cell diode D_3 and D_4 are in off state. The magnetizing and leakage inductor current of both boost converter starts to rise.

$$V_{in} = V_{Lm1} \text{----------(1)}$$
$$V_{in} = V_{Lm2} \text{----------(2)}$$

B. Mode II

The first boost converter switch S_1 is on ,there by inductor current i_{Lk1}, i_{Lm1} still increasing. The second boost converter switch S_2 is off, the stored energy in inductor release to secondary side of coupled inductor through output capacitorC_3 and diodeD_4.

$$V_{in} = V_{Lm1} \text{----------(3)}$$
$$V_{in} = V_{Lm2} + V_{D2} + V_{C1} - V_{Cb} \text{----------(4)}$$

C. Mode III

The second boost converter switch S_2 is on,there by inductor current increases sharply. The first boost converter switch S_1 is off, the stored energy in primary leakage inductor i_{Lk1} release to secondary side of coupled inductor through output capacitorC_2 and diodeD_3. The stored energy in magnetizing inductor iLm1 release the energy to voltage lift capacitor C_b through diode D_1.

$$V_{in} = V_{Lm2} \text{----------(5)}$$

$$V_{in} = V_{Lm1} + V_{D1} + V_{Cb} \text{----------(6)}$$

The necessary parameters to analyze boost converter are,

D. Voltage gain

The voltage gain of the two phase interleaved boost converter is defined as the turns ratio of output voltage by input voltage.

$$Voltage\ Gain = \frac{V_o}{V_{in}} = \frac{2(n+1)}{1-D} \text{---------(7)}$$

From equation (7) voltage gain is the function of duty ratio(D) and turns ratio(n) of coupled inductor.

E. Magnetizing inductor

The magnetizing inductor L_{m1} and L_{m2} of two phase interleaved boost converter values are chosen based on safe operating condition , Which is the function of duty ratio(D) , turns ratio (n) and switching frequency f_s and load resistance R.

$$L_m = \frac{D(1-D)^2 R}{2(n+1)(2n+2)f_s} \text{ --(8)}$$

F. Voltage lift capacitor

The selection of lift capacitor is most important for reducing ripple content in output voltage of boost converter. The value of lift capacitor is depends up on output current (I_o),switching frequency (f_s) and ripple voltage of lift capacitor (C_b).

$$C_b = \frac{I_o}{f_s \Delta V_{Cb}} \text{ ------ (9)}$$

G. Voltage stress across the main switch

The voltage stress across the main switch's are derived from the following equation,

$$Voltage\ across\ Switch\ S_1 = S_2 = \frac{1}{1-D} V_{in} \text{ ----- (10)}$$

The voltage across the main switch is function of input voltage and duty ratio. For the proposed two phase interleaved boost converter voltage across switch is low as compared to one phase and conventional boost converter.

3. MODELLING OF PV PANEL

The PV panel is modeled in two way, one is use of electric equivalent circuit and Writing MATLAB program. The equivalent circuit of PV panel consist of ideal current source in parallel with ideal diode.

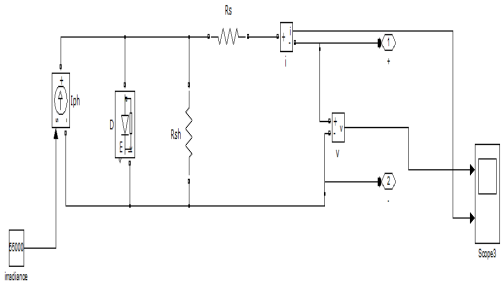


Fig.2 Simulation circuit of PV model

$$The\ current\ generated\ by\ the\ photon = I_{sc} = I_o \left(e^{\frac{qV_{kt}}{KT}} - 1 \right) \text{--(11)}$$

The current represent the current generated by photon under constant temperature and constant irradiation. If light is incident on the PV panel, the free charge carriers are produced. The positive and negative charge carriers isolated by space charge region. Hence voltage generated in output terminal.

4. MODELLING OF MPPT

The concept behind the "perturb and observe" (P&O) method is to modify the operating voltage or current of the photovoltaic panel until you obtain maximum power from it. For example, if increasing the voltage to a panel increases the power output of the panel the system continues increasing the operating voltage until the power output begins to decrease. Once this happens, the voltage is decreased to get back towards the maximum power point. This perturbuance continues indefinitely.

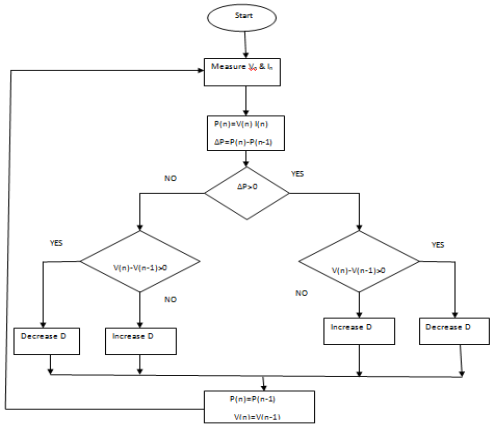


Fig.3 Flow chart of MPPT P&O algorithm

Thus the power output value oscillates around a maximum power point and never stabilizes.

The P&O algorithm obtained by getting input values of voltage, current and initial value of duty cycle. The voltage and current obtained from PV module. The duty cycle initial value decided by DC-DC boost converter. The output power of n^{th} instant calculated from voltage and current. To make the comparison of power and voltage of n^{th} instant and $n\text{-}1^{th}$ instant. If the difference in power (ΔP) is zero, take previous duty cycle value. If the difference in power (ΔP) is negative increase the duty cycle provided voltage comparison is positive, and reduce the duty cycle if the voltage comparison is negative. If the difference in power (ΔP) is positive increase the duty cycle provided voltage comparison is negative, and reduce the duty cycle if the voltage comparison is positive. Hence the algorithm decides to increase or decrease the duty cycle depends on the output of PV. This P&O algorithm coding written in embedded MATLAB

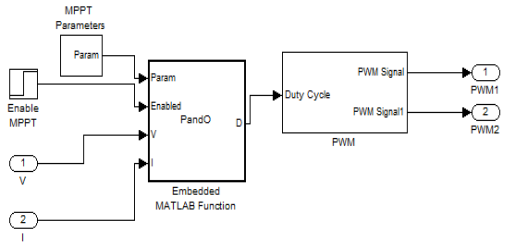


Fig.4 Simulation circuit of MPPT P&O algorithm

5. SIMULATION OF TWO PHASE INTERLEAVED BOOST CONVERTER

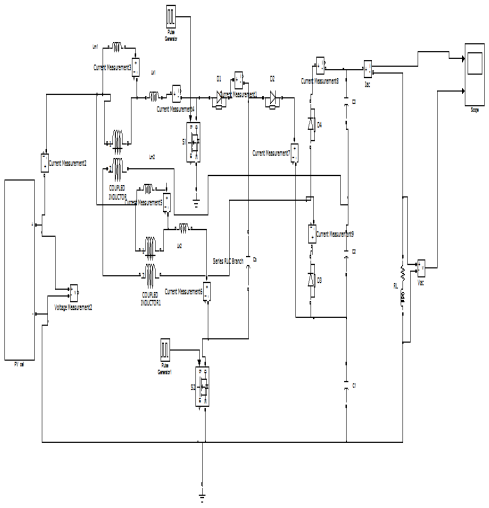


Fig.5 Simulation circuit of PV based two phase interleaved boost converter without MPPT

The Proposed two stage interleaved boost converter simulation is carried out through MATLAB simulink.

The simulation diagram of PV based two stage interleaved boost converter shown in figure.5. The input supply voltage of proposed converter is obtained from PV panel. The PV panel simulation model carried by using equivalent circuit of PV.The simulation circuit constructed by MOSFET S_1,S_2 and coupled inductors with turns ratio of one,diodes D_1 to D_4 and capacitors C_1 ,C_2 ,C_3 and C_b.The PWM signals of switch S_1 and S_2 are shown in figure The PWM signal for each is displaced by 180^o with switching frequency of 40KHz duty ratio of 0.55.

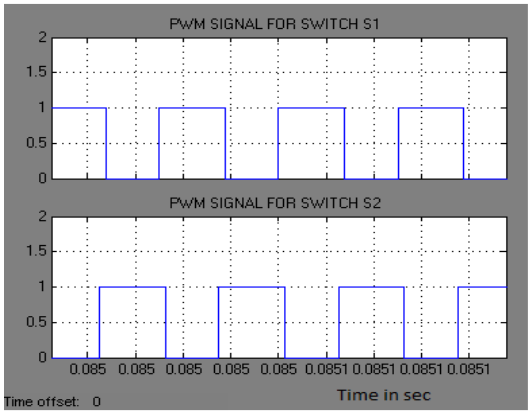


Fig.6 PWM signal for switch S1 and S2

The output voltage of PV panel is shown in figure7. The RMS value of output voltage from PV panel is 15 Volt. The output current of PV cell is proportional to irradiance. The simulated model PV panel is very good approximation of PV. The PV output voltage oscillates between 6 volt and 18 volt.

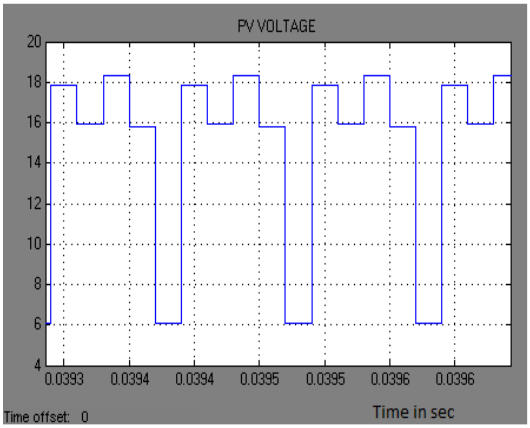


Fig.7 PV voltage waveform for two phase interleaved boost converter without MPPT

The input current waveform indicated in figure8. from this current waveform input current ripple can be calculated.

The maximum and minimum value of input current is 49.5 amp and 37.4 Amp. The input ripple current value is 0.278 Amp.

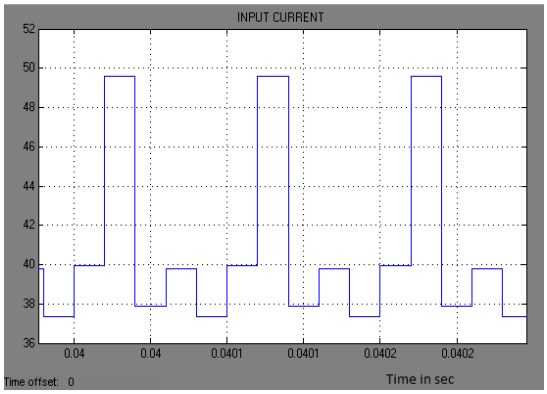


Fig.8 Input current waveform for two phase interleaved boost converter without MPPT

From figure.9 input magnetizing inductor current ripple can be calculated. The input inductor current lies between maximum value of 22.5 Amp and minimum value of 19.3 Amp. The ripple current value of input inductor is 0.153 Amp.

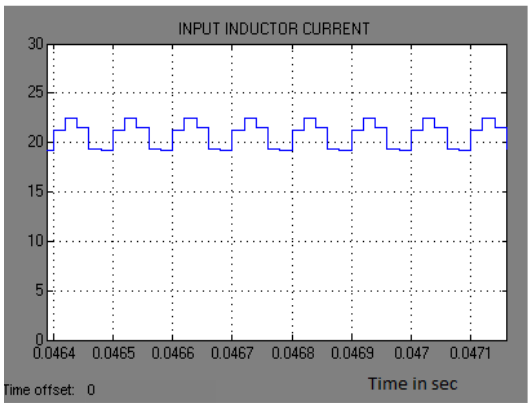
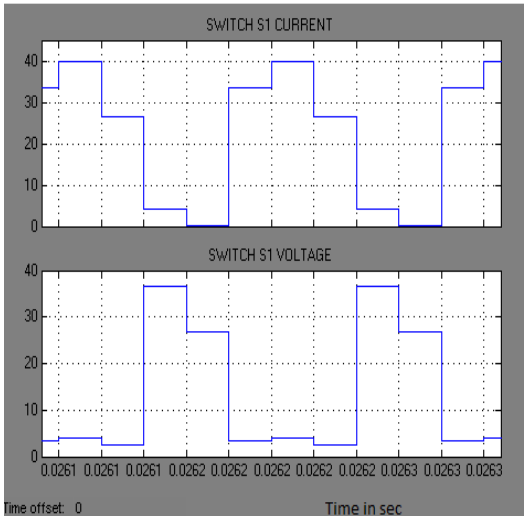


Fig.9 Input inductor current waveform for two phase interleaved boost converter without MPPT

Figure.10 Shows that switch S_1 voltage and current. The voltage stress across the switch S_1 measured is 37.2 volt. The measured value of voltage across the switch is equal to calculated one. The current through switch measured is 39.9 Amp. The voltage stress and current stress on the switch which is measured in figure.9 is less compared to one phase interleaved boost converter.



interleaved boost converter without MPPT

The output current, voltage and power waveform of proposed PV based two phase interleaved boost converter are shown in figure.11.

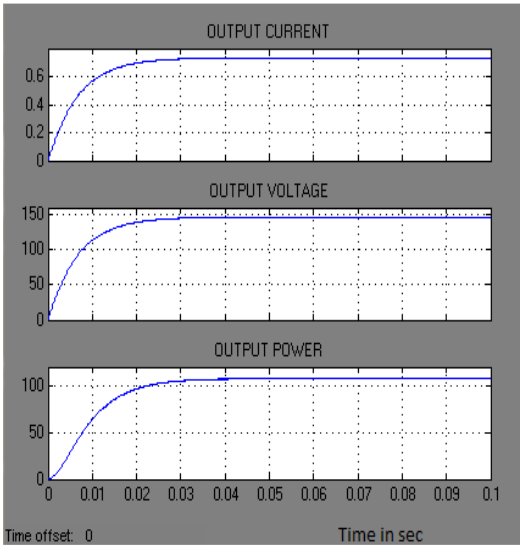


Fig.11 Output current,voltage and power waveform for two phase interleaved boost converter without MPPT

The output voltage of proposed boost converter is 147 Volt it is nearly 10 times gain of input voltage. The output current and power of the proposed boost converter is 0.735 Amp and 107.5 watt. The output voltage, current and power settled at 0.04 sec.

6. SIMULATION OF TWO PHASE INTERLEAVED BOOST CONVERTER WITH MPPT

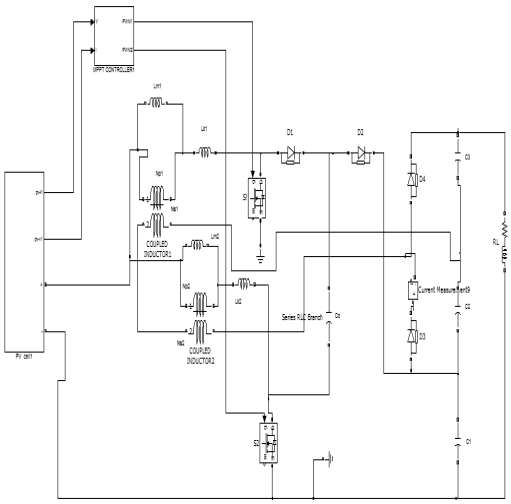


Fig.12 Simulation circuit of PV based two phase interleaved boost converter with MPPT

The simulation diagram of PV based interleaved two stage boost converter with MPPT shown in figure.12. When compared to simulation diagram in figure.5 MPPT P&O algorithm is added this simulation diagram. The MPPT is carried out by writing coding of P&O algorithm in embedded MATLAB function. The input values Voltage and current of MPPT is obtained from PV panel. The initial, maximum and minimum value of duty cycle (D) of two phase interleaved boost converter is assumed in MPPT algorithm.

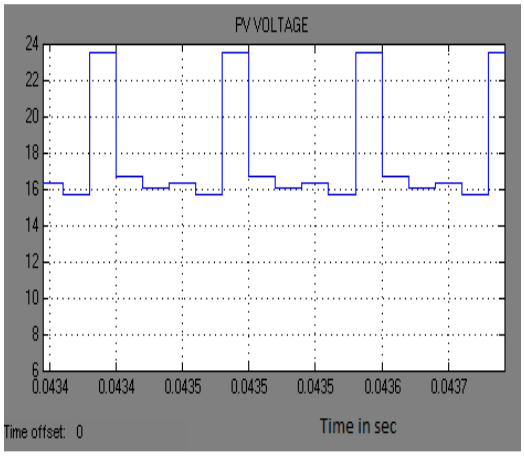


Fig.13 PV voltage waveform for two phase interleaved boost converter with MPPT

The output voltage from PV is get increased for the same irradiance and load. It can be concluded by comparing the PV voltage of figure.7.

The figure.14 shows that PWM signal for switch S_1 and S_2.Both PWM signals are having phase difference of 180^o. The PWM signals are generated by switching frequency of 40KHz but duty ratio is selected by MPPT algorithm based maximum power output.

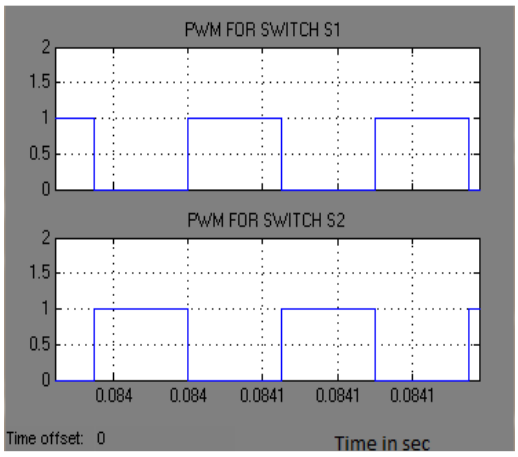


Fig.14 PWM signal for switch S1 and S2 for two phase interleaved boost converter with MPPT

The input current waveform indicated in figure15.The input current ripple is calculated from this current waveform .The maximum value of input current is 40.05 amp and the minimum value is 32.3 Amp. The input ripple current value is 0.214 Amp.

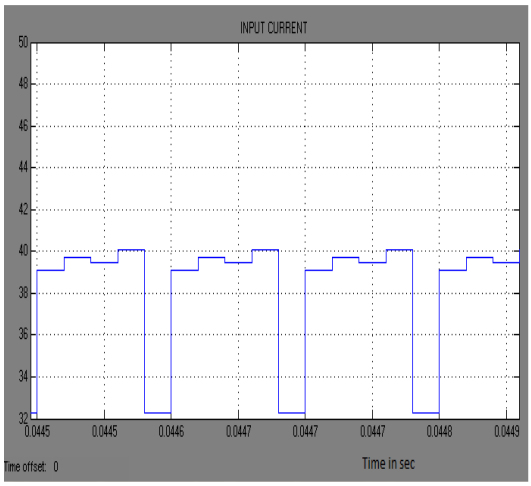


Fig.15 Input current for two phase interleaved boost converter with MPPT

The figure.16 shows that input inductor current with respect time. The input inductor current oscillates between 15.8 Amp and 12.7 Amp. The ripple current of magnetizing input inductor is 0.217 Amp.

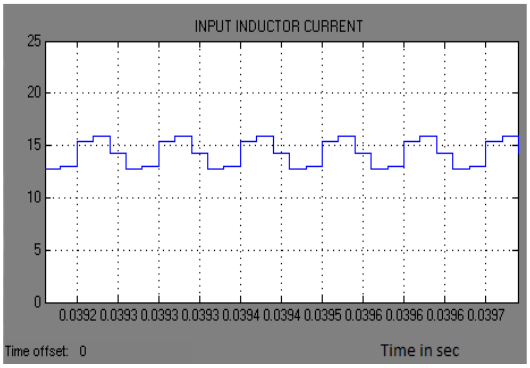


Fig.16 Input inductor current for two phase interleaved boost converter with MPPT

Figure.17 Shows that switch S_1 voltage and current. The voltage stress across the switch S_1 measured is 28.3 volt. The voltage stress across the switch is less compared to without MPPT. The current through switch measured is 39.0 Amp.

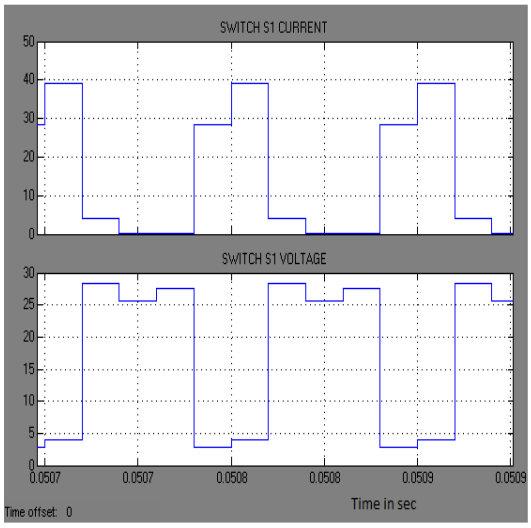


Fig.17 Current and voltage of switch S1for two phase interleaved boost converter with MPPT

The output current, voltage and power waveform of proposed PV based two phase interleaved boost converter with MPPT are shown in figure.18 The output voltage of proposed boost converter is 154 Volt. The output current and power of the proposed boost converter is 0.77 Amp and 118 watt. From the above comparison table we conclude that two phase interleaved boost converter with MPPT provide better result while analyzed parameter such as input current ripple, voltage and current stress across the switch, output voltage , current and power. The two phase interleaved boost converter with MPPT work extracts output power of 118 watt which is 10 watt more than without MPPT work.

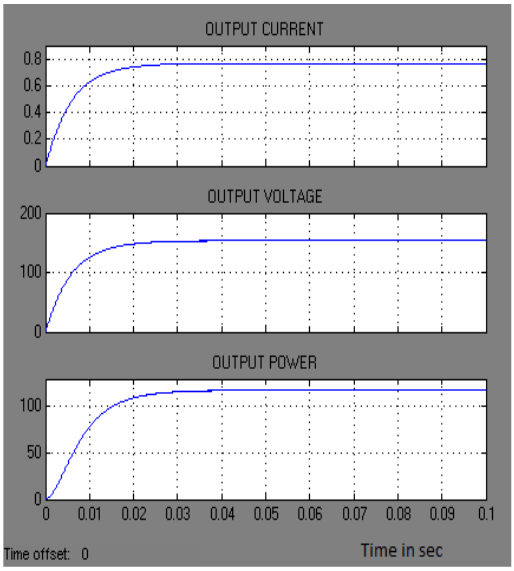


Fig.18Output current ,voltage and power of two phase interleaved boost converter with MPPT

TABLE .I COMPARISON BETWEEN TWO PHASE INTERLEAVED BOOST CONVERTER WITH AND WITHOUT MPPT

Parameter	With MPPT	WithoutMPPT
Input current ripple (Amp)	0.214	0.278
Inductor current ripple (Amp)	0.217	0.153
Voltage stress (Volt)	28.3	37.2
Current stress (Amp)	39.0	39.9
Output power (Watt)	118	107.5
Output Voltage (Volt)	154	147
Output Current (Amp)	0.77	0.737

Hence Interleaved boost converter with MPPT best suited for PV application.

7. HARDWARE CIRCUIT DIAGRAM AND PROTOTYPE OF TWO PHASE INTERLEAVED BOOST CONVERTER

The hardware circuit diagram consist of two phase interleaved boost converter, controller PIC16F877A,PV panel, power supply and driver circuit. The main switch MOSFET IRFP250 is used with voltage and current rating of 200 Volt ,33 Amp and on-state resistance of 0.085ohm. The PIC16F877A controller is used to generate the PWM signal for MOSFET switch. The optocoupler MCT2E is used isolate controller and power circuit .It consists of gallium arsenide infrared emitting

diode driving a silicon photo transistor in a 6-pin dual in line package.

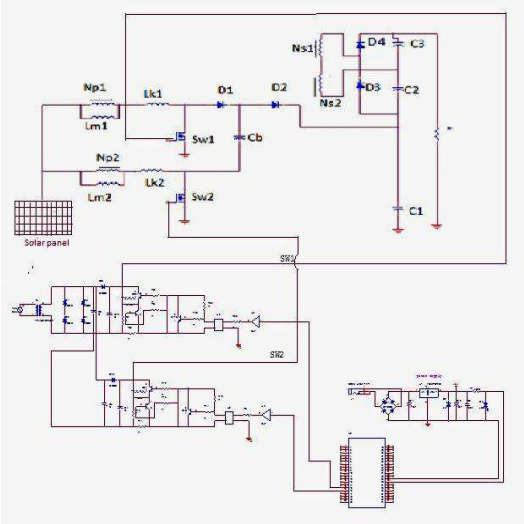


Fig.19 Experimental circuit diagram of two phase interleaved boost converter photography

The Darlington pair driver is used for driving PWM signal which is generated from controller. In Darlington, pair two transistors are connected together in series so that current amplified by the first is amplified further by second transistor. The overall current gain is equal to two individual gains multiplied together. Finally drived PWM signal applied to Gates of MOSFET switch.The prototype of proposed two phase interleaved boost converter with a input of 12 volt and output of 102 volt has been developed. The hardware setup consist of coupled inductor(1),two phase interleaved boost converter(2),PIC microcontroller PIC16F877A(3), Driver circuit(4), Battery(5),PV panel(6) and power supply transformer(7).

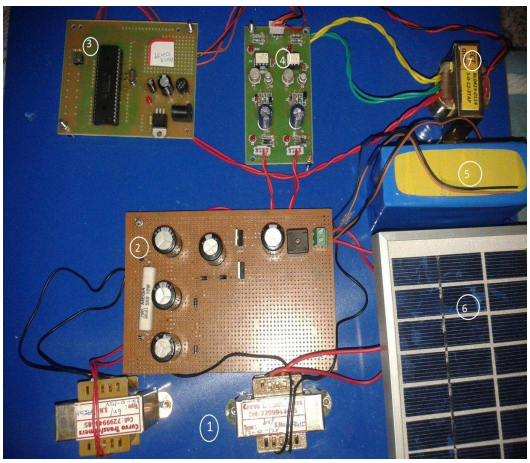


Fig.20 Prototype of two phase interleaved boost converter photography

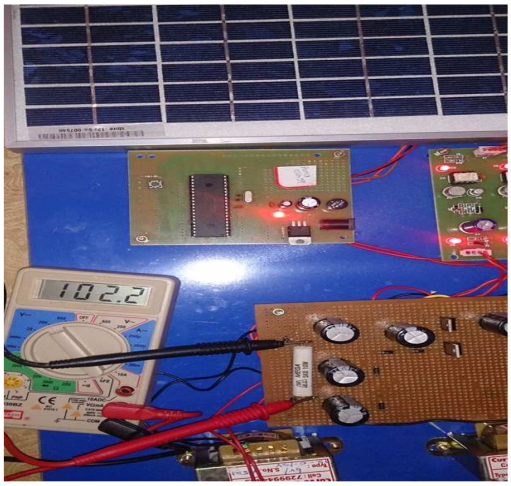


Fig.21 Prototype of two phase interleaved boost converter output volt

The experimental result for output voltage and output voltage ripple of two phase interleaved boost converter are shown in figure.21.

8. CONCLUSION

This paper has presented comparative study of two phase interleaved boost converter with MPPT and without MPPT. The performance parameters such as input current ripple, input inductor current ripple, voltage &current stress for the switch, output voltage, output current and output power are compared. From that result it is concluded that two phase interleaved boost converter with MPPT input current ripple is reduced 0.064 amp ,voltage stress on switch is reduced to 10.9 volt and current stress through switch reduced to 0.9 amp. The output voltage is increased to 7 volt, output current increased to 0.033 amp and output power is increased to 10 watt. A prototype of two phase interleaved boost converter with input of 12 volt and output of 102 volt has been developed. Hence two phase interleaved boost converter with MPPT performance enhanced successfully.

The proposed work is limited for the use of P&O algorithm. If the power obtained oscillates around the maximum power point in steady state operation, it can track in the wrong direction under rapidly varying irradiance levels.

The proposed concept is extended by use of adaptive P&O algorithm and Incremental Conductance algorithm to obtain maximum power point tracking under rapid varying irradiance levels.

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