Implementation of Soft Switching Two Phase Boost Converter for Photovoltaic System

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ABSTRACT:The aim of this paper is to analyse the soft switching two phase boost converter for photovoltaic (PV) system. The important parameters that affect the system performance are input current and voltage ripples. The advantages of two phase boost converter include increased efficiency, reduced size and improved reliability. This converter can be used in such applications for interfacing. By adopting soft switching method, reduction in switching losses and also reduction in ripples can be achieved so that system efficiency is improved.The simulation study of two phase Soft Switching boost converter fed by PV source is carried out using MATLAB and results are presented in this paper.The comparative analysis is also made among the two phase converter with different inductor coupling.The hardware implementation of two phase soft switching boost converter with directly coupled inductor has been carried out and the results are presented.

Keywords: Twophase converters, ZCS, ZVS, Soft Switching converters, PV System, MATLAB.

I. INTRODUCTION

   Photovoltaic (PV) energy source is a sustainable energy source. They are recyclable, abundant, distributed throughout the earth and pollution free. The hindrance factor is its high installation cost and low conversion efficiency. A proper high efficiency interface is required to transmit the power from PV panel to load. Two phase soft switching boost converter is used as interfacing to reduce the switching loss and ripples [1].In this paper two phase soft switching boost converter is used as power conversion device for photovoltaic system. To increase the output voltage of PV source the two phase boost converter is connected to the PV system.Moreover the input current ripple and stress on power devices are decreased because the input current is divided into two parallel inductors [1]-[7]. Two phase boost converter is used for high power application.

   The current rating of switching device is reduced by interleaved method which distributes the input current to each phase. It can also reduce input current ripple, output voltage ripple and size of passive components. Soft switching technique is used to reduce the switching loss [8]. The complete system with two phase boost converter is simulated using MATLAB-SIMULINK and the results are presented. The comparative analysis has been made among the two phase converter with uncoupled, directly coupled and inversely coupled inductor for ripple reduction.

II. CONFIGURATION OF TWO PHASE BOOST CONVERTER

   The conventional two phase boost converter consists of two single boost converters that are connected in parallel as shown in Fig 1. Each switch turns ON with shifting of 360/N. Each inductor current magnitude is decreased by 1/N. The input current ripple is decreased because sum of inductor L_1 and L_2 are input current [1].
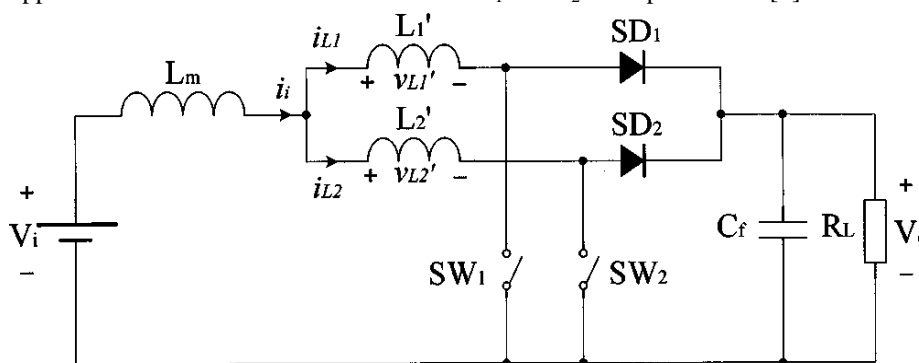

Fig. 1 Conventional Two-Phase Boost Converter

Fig 2 shows the circuit of soft switching two phase boost converter. Switching technique is similar to conventional two phase boost converter. Freewheeling diode, resonant inductor L_r and resonant capacitor C_r are used to soft switching for the reduction of switching loss. And two diodes D_1 and D_2 are used to transmit energy to output side [1].
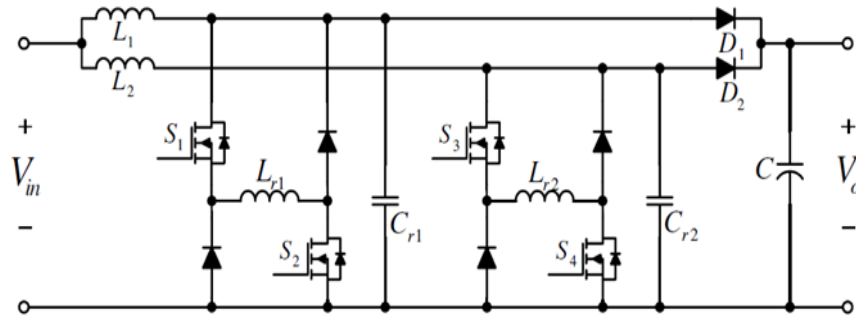

Fig 2 Soft Switching Two-Phase Boost Converter

III. SYSTEM DESCRIPTION

The two phase boost converter is analysed in this paper. Since it is two phase boost converter each switch has switching gap of 180 degree. Each inductor current repeats linear increment and decrement with 180 degree based on switching pattern. At zero voltage across the resonant capacitor the switch is turned OFF, thus it operate with zero voltage switching (ZVS). At zero current through the resonant inductor the switch is turned ON, thus operate with zero current switching (ZCS) [5].The block diagram in Fig. 3 reveals that the system consists of PV source and two phase boost converter and load and each block is simulated using MatLab and the results are presented.
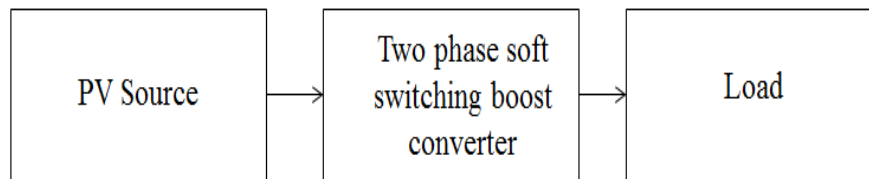

Fig 3 Block diagram of system

The interleaved boost converters with coupled inductors are modeled using the following equations [9]-[12].The equivalent value of inductance is given by the expression

$$L_{eq} = \frac{DViT}{\Delta I_{phase}} \quad (1)$$

Self-inductance and mutual inductance are given by

$$L_m = \beta L \quad (2)$$
$$L_s = (1 - \beta)L \quad (3) \qquad\qquad \text{Where}$$
$$L = \frac{1+\beta\frac{D}{1-D}}{1+\beta-2\beta^2} \quad (4)$$

The value of capacitor is given by

$$C = \frac{DV_0 T}{R\Delta V_0} \quad (5)$$

The PV panel is modeled using one diode model which consists of a current source in parallel with a diode, a shunt resistance and a series resistance as shown in Fig 4. The modeling equations are given through $[6] - [9]$, taken from [13].
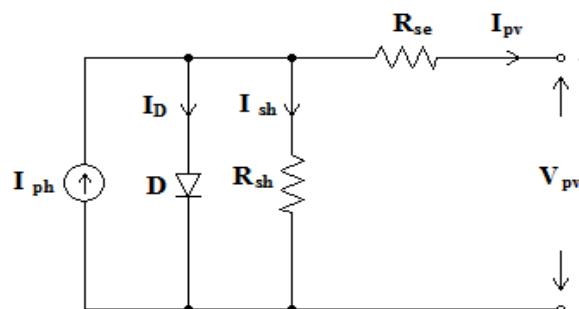

Fig 4 One diode model of SPV module

The modelling equations are:

$$I_o = \frac{I_{sn} + K_i dT}{e^{[(V_{ocn} + K_v dT)V_{ta}]} - 1} \quad (6)$$

$$I_{pv} = [K_i dT + I_{pvn}] \frac{G}{G_n} \quad (7)$$

$$V_{ta} = \frac{\frac{q}{aKN_s}}{T} \quad (8)$$

$$I_m = I_{pv} N_{pp} - I_0 N_{pp} \left\{ e^{\left\{ \frac{V_{ta}}{N_{ss}} x \left(R_s \frac{N_{ss}}{N_{pp}} I + V \right) \right\} - 1} \right\} \quad (9)$$

The simulation results for the system shown in Fig 3 are presented in detail in Section IV.

IV. SIMULATION RESULTS AND INFERENCE

Using equations (6)-(9), PV panel consists of 36 mono crystalline silicon solar cells have been simulated using MATLAB. The simulated I-V and P-V characteristics are presented in Fig 5.
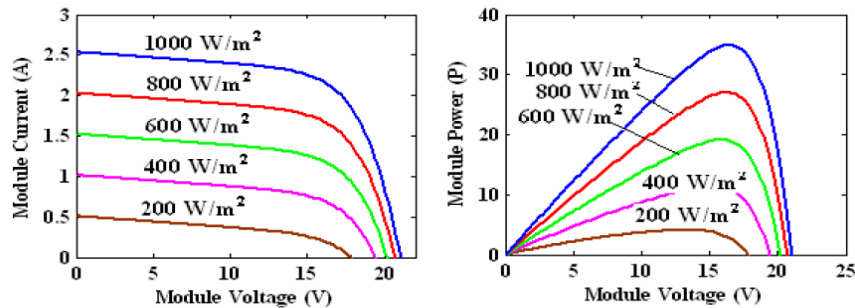

Fig 5 Simulated V-I and V-P characteristics for various Insolation levels with T=250

The soft switching two phase boost converter shown in Fig 2 has been simulated with MATLAB. Table I shows the design parameters of the soft switching multi-phase boost converter [1].

TABLE I Simulation Parameters for two phase soft switching boost converter

Parameters	Values
Input Voltage, V_i	16 V
Output Voltage V_0	32 V
Inductor, L	200μH
Capacitor, C	200μF
Resonant inductor, L_r	0.1μH
Resonant capacitor, C_r	20nF
Switching frequency, f_s	10kHz

Fig. 6 shows the simulation model of two phase boost converter and gating pulse for each switch is shown in Fig 7 and Fig 8.
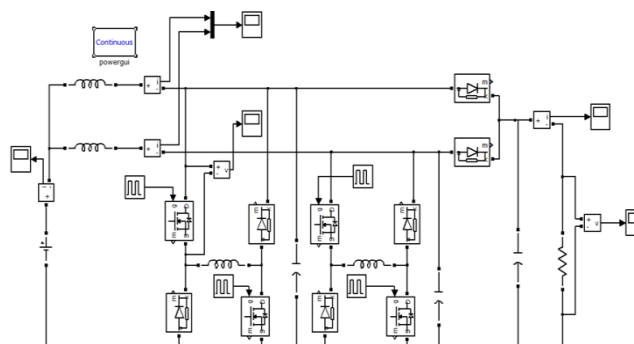

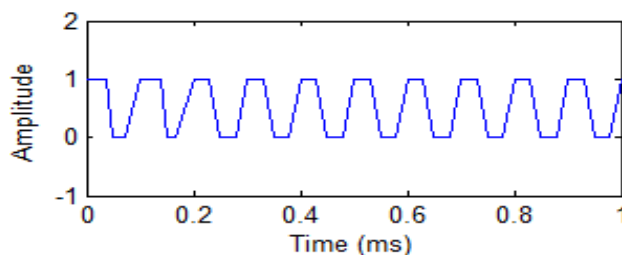Fig 6 Two-Phase Boost Converter-Simulation Model
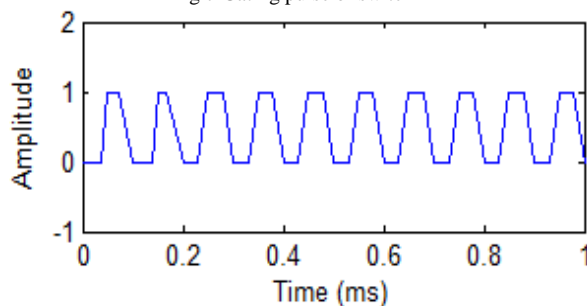
Fig 7 Gating pulse of switch 1

Fig 8 Gating pulse of switch 2

To reduce the input current ripple further, uncoupled inductors L_1 and L_2 in Fig.2 is replaced by directly coupled and inversely coupled inductors and the comparative analysis have been made among the three types of inductor coupling [14] and the results are presented namely, two phase soft switching converter with uncoupled inductor, directly coupled inductor and inversely coupled inductors. Table II represents the comparative ripple analysis of input current and output voltage in two phase converter and soft switching two phase boost converter.

TABLE II COMPARISON OF OUTPUT VOLTAGE AND INPUT CURRENT RIPPLE PERCENTAGE

Parameters	Two phase boost converter	Soft switching Two phase boost converter
Input Current ripple	0.24%	0.16%
Output Voltage ripple	0.02%	0.012%
Efficiency	93.8%	95.3%

From Table II it is seen that the ripples are reduced in case of soft switching two phase boost converter and the efficiency of the system is also increased.

Tables III represents the comparative ripple analysis of input current and output voltage various inductor coupling namely as uncoupled, directly coupled and inversely coupled inductor.

TABLE III COMPARISON OF OUTPUT VOLTAGE AND INPUT CURRENT RIPPLE PERCENTAGE WITH DIFFERENT INDUCTOR COUPLING

Type of Converter	Output voltage ripple (%)	Input current ripple (%)
Two phase converter with non-coupled inductor	0.03%	0.16%
Two phase soft switching converter with directly coupled inductor	0.01%	0.04%
Two phase soft switching converter with inversely coupled inductor	0.028%	0.12%

From Table III it is understood that ripples have been reduced when directly coupled inductors are used.

V. HARDWARE IMPLEMENTATION

Table IV shows the components that are used to implement the hardware.

TABLE IV DEVICES USED FOR HARDWARE IMPLEMENTATION

Device/Components	Specifications/Values
Switches	IRFP460(N channel MOSFET)
Diode	1N5408
Inductor(E core)	200µH
Mutual inductors (each)	12mH
Filter Capacitor	200µF
Load Resistance	50Ω

The pulses for triggering the switches were generated by using PIC18F4550 microcontroller. The gating pulses were given to the devices through an opto-coupler circuit by employing MCT2E opto-coupler to provide the necessary isolation between the power circuit and the microcontroller circuit. The converter was operated using SPV panel as the source. The corresponding outputs were obtained and analyzed to verify the results obtained by simulation with PV panel at the input side.

The ripple parameters of input current and output voltage of directly coupled two phase soft switching converter were measured using single phase clamp-on Power Quality Analyzer. The Power Quality Analyzer also gives a measure of the ripple percentage in both the current and voltage on both the input and output sides. It is found that the input current ripple was less compared to other coupling and it is found to be 0.04%.The hardware setup of soft switching two phase boost converter is shown in Fig 9.
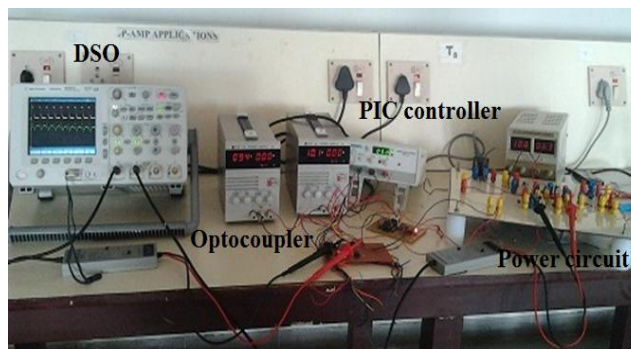

Fig 9 Hardware Setup of two phase soft switching boost converter

Fig 10 shows the output voltage and output current waveforms that are observed the DSO.
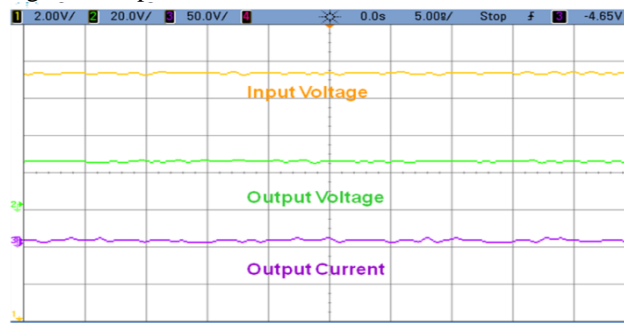

Fig 10 Output voltage and Output current waveforms observed on DSO

Fig 11 shows the soft switching phenomenon of two phase boost converter.

Fig 11 Soft Switching phenomenon observed on DSO

VI. CONCLUSION

In this paper, soft switching two phase boost converter for PV system interface has been analysed. Compared to conventional boost converter the input current ripple and output voltage ripple are reduced. Since the converter operates with soft switching principle the switching loss is also reduced and efficiency is high compared with conventional converter. The comparison has been made for different inductor coupling types. It is found that the ripples are further reduced with the use of directly coupled inductors at input side. The hardware implementation of two phase soft switching boost converter has been carried out and the results are presented.

ACKNOWLEDGMENT

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