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Design and Simulation of Soft Switched Converter with Current Doubler Scheme for Photovoltaic System

Mr. Ekbal I. Malnas[1], Mr. Shamkumar B.Chavan[2], Dr. Mahesh S. Chavan[3]
[1]*M. Tech. Scholar, Department of Technology, Shivaji University, Kolhapur, India*
[2]*Assistant Professor, Department of Technology, Shivaji University, Kolhapur, India*
[3]*Professor, KIT College of Engineering, Kolhapur, India*

Abstract: *This paper focuses on simulation of high gain, robust soft switched converter with current doubler rectifier scheme which shall be applied for photovoltaic application. The proposed converter system converts variable photovoltaic power into constant dc power with improvement in current rating.In this paper the simulation results of soft switched converter for photovoltaic is shown. Since PV module acts as voltage source at open circuit and current source at short circuit therefore to extract maximum power Maximum Power Point Tracing (MPPT) algorithm is implemented. To increases PV voltage to desired level boost converter is also implemented. The simulation is carried out on SIMULINK/ Sim power systems.*
Keywords: *PV-constant DC conversion, soft-switching, current doubler, Boost converter, converter model in Sim Power Systems.*

I. Introduction

The converter plays vital role in PV-system applications and its working depends mostly on the component reliability and its maintenance. Therefore, improved switching scheme with highly reliable components are required in order to increase life time of converter.

The converters in photovoltaic systems should have high efficiency, high gain and robustness against all mechanisms, as these links are preceded by other links and applications depending upon the topology. Also the hard switched converters, used widely are not reliable and have many disadvantages like EMI problems, generation of circulation currents in IGBT etc. Therefore this paper focuses on development of high gain, robust, soft switched converter with current doubler rectifier scheme which shall be applied for photovoltaic application. The proposed scheme will be proved to be advantageous over existing hard switched converters.

Efficient availability of solar photon energy is approximately 8 hour per day and environmental condition also affect the solar power therefore maximum utilization in less time is necessary, that can be possible by improving input current rate since it will reduces the charging time of battery.

II. PV Converter Configuration

Fig. 1 shows the generalized block diagram of proposed PV converter system. This system is developed by considering control unit having firmware for MPPT algorithm to extract maximum power from PV module and it will monitor and regulate operation of the system.

Boost circuit is used to increase input voltage from PV to desired level which is connected to converter circuit. Phase shift soft-switching scheme is used for converter switches, Therefore Soft-switching converter topology is used in this paper to remove EMI and to minimize circulating current in IGBT [1].The current rating of the transformer and the output current ripple are reduced by adopting the current doubler type rectifying circuit at the secondary side of the DC-DC converter [2].

Proposed system consist of sections like boost converter, soft switched converter, transformer, rectifier and MCU. These are described briefly,

Boost circuit is used to boost the input from PV to desired level. The converter circuit in proposed system is used for converting variable dc signal to constant value which works with soft switching scheme. Capacitor across power switch and transformer leakage inductance play important role in switching. Transformer used in proposed work is step-down type which increases the output current by stepping down the input voltage and rectifier circuit is used to convert variable input from transformer to constant dc with increasing current. Microcontroller unit is use to develop MPPT algorithm to draw maximum power from PV. All controlling action is performed by controller unit. Driver circuit is used to drive MOSFETs and IGBTs. LCD unit is used to display output current and voltage. Battery is used to store PV power.

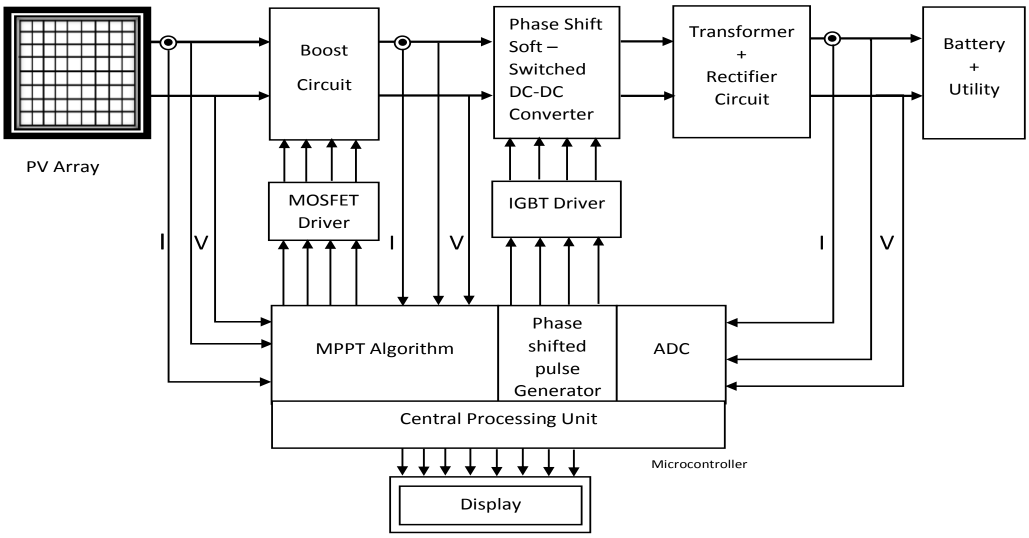

Fig. 1 Generalized block diagram of Proposed PV converter.

III. Simulation Circuit Diagram

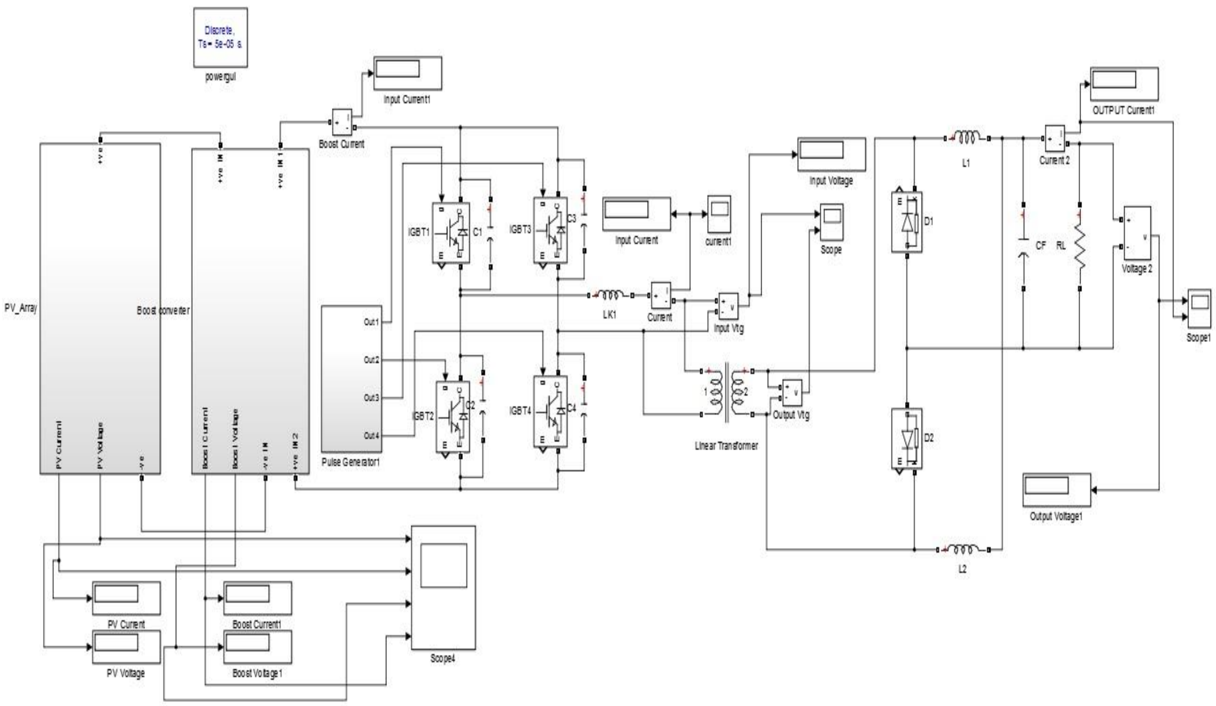

Fig. 2 Simulation model of proposed PV inverter system.

Fig 2. Shows the simulation model of proposed converter system by considering maximum power is drown from PV model. The simulation is carried out in MATLAB/ SIMULINK the model [3]. This contains various blocks such as PV cell, Boost converter, DC-DC converter, Phase shift PWM generator and Rectifier circuit. Simple circuit-based photovoltaic model has proposed in [4].

The PV cell generally acts as a Current dependent voltage source the output is depends upon current which follows the insolation and irradiance [5].

In this model, a current source I_{SC} which operates on solar radiation and PV cell temperature. A diode acts as constant voltage source since inverse saturation current I_D is generated. A series resistance R_s and a shunt resistance R_p which takes into account the resistive losses was considered. The mathematical equation of PV model [6] is

$$I_{SC} - I_D - \frac{V_D}{R_p} - I_{PV} = 0; \qquad (1)$$

Thus,

$$I_{PV} = I_{SC} - I_D - \frac{VD}{Rp}; \qquad (2)$$

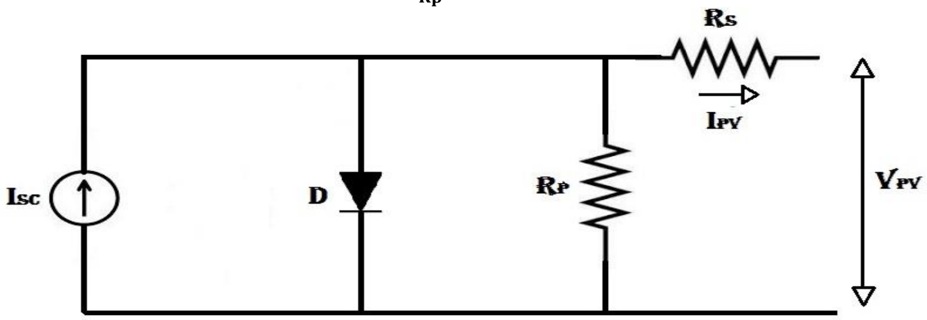

Fig. 3 Equivalent electronic circuit of an ideal Solar Cell.

The boost converter which is simulated in MATLAB/SIMULINK is as shown in Fig. 4. It works on the principal of store and release energy. Inductor L stores energy from PV cell and is delivered to an output capacitor C by controlling the switching of MOSFET. To avoid back effect of charge stored by capacitor, a Schottky diode D is used. Since high switching frequency is required we used Schottky diode. Operation of boost converter is mainly depend on switching frequency fs and duty cycle D [7].

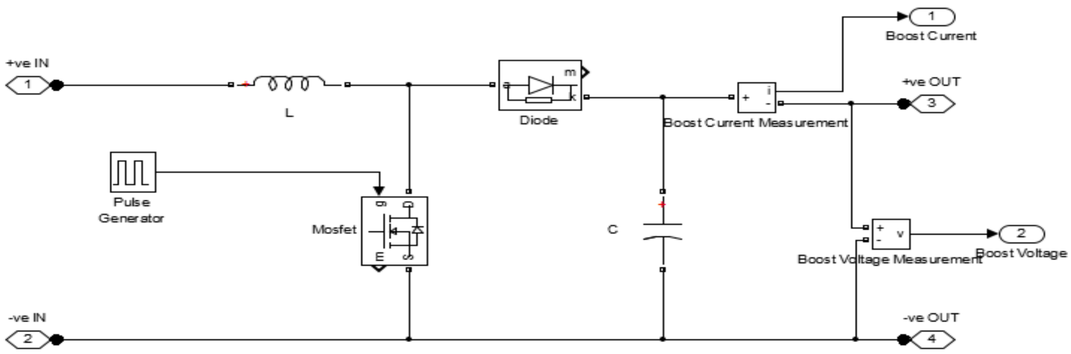

Fig. 4 Simulation Model of Boost converter.

$$\mathbf{D} = \mathbf{1} - \frac{\mathbf{V_{in(\mathit{min})}} \times \eta}{\mathbf{V_{out}}} \qquad (3)$$

$$\mathbf{L} = \frac{\mathbf{V_{in}} \times (\mathbf{V_{out}} - \mathbf{V_{in}})}{\Delta \mathbf{I_L} \times \mathbf{f_s} \times \mathbf{V_{out}}} \qquad (4)$$

$$\mathbf{C_{out(min)}} = \frac{\mathbf{I_{out(max)}} \times \mathbf{D}}{\mathbf{f_s} \times \Delta \mathbf{V_{out}}} \qquad (5)$$

An output of boost converter is regulated and delivered to next stage DC-DC converter. Since hard switching affects performance of power switches [9], soft switching scheme is used for improving reliability of converter.

IV. Results And Discussions

Simulation results of a PV converter system are as follows:

Fig. 5 shows current and voltage waveforms of PV cell. The PV cell is designed to deliver 48V and 3.3A current. The system is simulated by considering a maximum power point.

The boost converter is so designed in such way that it will deliver 96V. Boost converter is connected to DC-DC converter. Pulse generator is used to switching MOSFET of boost converter.

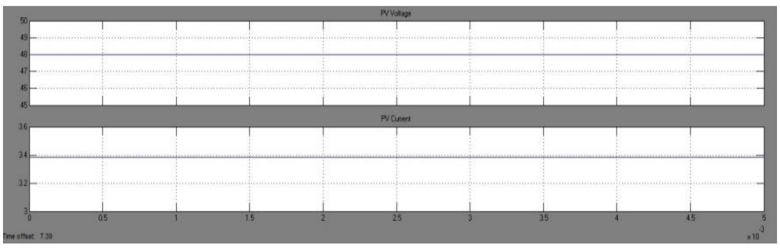

Fig. 5 Output voltage and current of PV.

Phase shift pulse generated signal is as shown in Fig 6.This signal is generated with pulse width of 45%. To obtain soft-switching some short of delay is provided between alternate IGBTs. The delay time is depend on charging and discharging characteristics of capacitor which is place across each IGBTs. High switching frequency is used for converter switches.

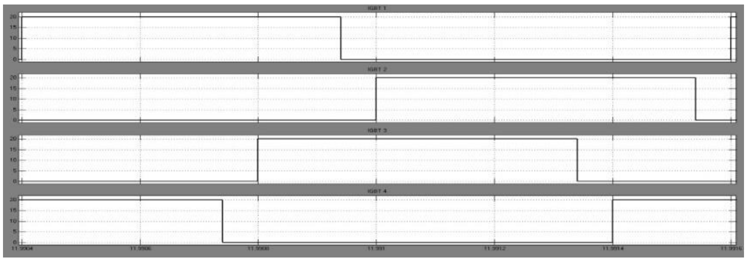

Fig. 6 Phase Shift pulse Generated Signal.

Fig. 7 shows input and output waveform across transformer. High switching frequency allows reduction in power supply volume and weight of transformer [8]. ZVS scheme with soft switching for operating at high frequency can improve the efficiency, stress on the semiconductor switch and improving the reliability of converter. Transformer output is directly connected to current doubler rectifier circuit.

Fig. 7 Input-Output Voltage across transformer.

Output voltage and current waveform is as shown in fig. 8. From output waveform it is seen that current is doubled which reduces the charging time of a battery.

Fig. 8 Output voltage and current.

Parameters	Specification
Insolation	1000 Watt/m^2
Temperature	25^{0}C
PV Voltage	48 V
PV Current	3.3 A
Output voltage	19.8 V
Output current	6.6 A
Boost Inductor (L)	420mH
Boost Capacitor(C)	1000 µF
Duty Cycle(D)	70%
Efficiency of Boost(η)	80%
Switching Frequency(f_s)	250KHz
Transformer turn ratio	23:10
Magnetizing inductance	1.38mH
Leakage inductance(L_{lk})	7.5uH
External capacitor across IGBT	50nF
Filter Inductor(L_1,L_2)	10uH

Table 1 Parameter specifications

V. Conclusion And Future Work

This paper describes the design and simulation of the phase shift full bridge converter with a current doubler, which can be used for charging purpose. It can be concluded that the developed and simulated converter may contribute to the higher system efficiency and longer battery life due to its lower ripple current characteristics. Actual hardware will be implemented with soft switching scheme for converter. Proper Controlling scheme will be deployed.

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