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MPPT Based Boost Converter for Photovoltaic Application

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ABSTRACT

This article introduces "MPPT based Boost converter for PV systems". The primary aim of this study is to efficient energy conversion by utilizing PV source. The Boost converter furnishes requirements like 1) high transformation ratio with lesser number of elements. 2) Minimization on heavy stresses across switch. The description of operating principle of analysis is expressed within this article. The PV modeling along with MPPT algorithm and Boost converter are simulated in the MATLAB Simulink.

Keywords: Boost converter, Continuous current mode (CCM), Maximum power point tracking (MPPT), Photovoltaic system.

I. INTRODUCTION

In the fast growing world day by day the energy consumption is increased. The energy obtained from fossil fuels is not energy to fulfill the demands and it produces by products also. The best alternative for fossil fuel is solar energy. The solar is excellent available source for power generation. It is pollution free and freely available. But output carries from the solar PV panel is non-linear in the sense low as well as fluctuating, so it is not capable to access the grid [1-3].

To extract maximum power from the panel MPPT algorithm is used in many systems. Peak power (P_{Peak}) generation is mainly depends upon irradiation and temperature. It radiation rises the power (P_{peak}) falls. Hence, the fluctuation of power is mainly depending on the temperature and irradiation level. So, maximum power can be track by employing MPPT algorithm [4-5]. By integrating PV array and MPPT with traditional boost converter is work as small micro grid. But the classical boost converters operated with higher duty cycle to attain high transformation ratio results in heavy conduction losses [6-8].The switched capacitor technique based converters and voltage lift technique based converters can attain high transformation ratio, but the voltage across switch is equals to output voltage and additional conduction losses caused due to transient current switch [9-13]. Coupled inductor based converter can attain high voltage gain increasing the terms ratio. It causes higher voltage notches on the switch due to leakage energy. Additional clamping circuit is required to recycle the energy [14]. Various step-up converters with passive clamp circuit have been proposed to additional switch produces conduction losses and increases cost of converter [15].To attain high transformation ratio step-up converters based on multiplier cell have been proposed. But the main drawback is; its ratio is limited and to attain higher transformation ratio requires an additional cell which causes circuit complexity and cost increases [16]. PV integrated voltage lift DC-DC converter based on multiplier cell can also provide large voltage conversion ratio and higher efficiency [17-18]. Another PV and MPPT integrated isolated structure based converter can attain high voltage gain. But to attain more voltage gain additional interleaving cells are necessary. Which increase overall cost of converter [19-20].

In this paper, MPPT based Boost converter for PV systems is introduced. This converter provides,

1) High transformation ratio.
2) Low voltage stresses across elements.
3) One polarity output voltage.
4) Unidirectional output current.
5) Easy to analyze.
6) Easy to understand.
7) Low cost.
8) Higher efficiency.

II. SYSTEM DESCRIPTION

The block diagram of the proposed system is shown in Fig.1. The PV panel acts as an input source for the proposed Boost converter. The power generated by solar panel i.e. voltage ‘V’ and current ‘I’ is sensed by MPPT controller. Later these values can be processed according to the P and O algorithm, which tracks the maximum power point of the PV panel to extract the maximum power from the panel. According to the processed values, this algorithm sets appropriate duty cycle for the switch.

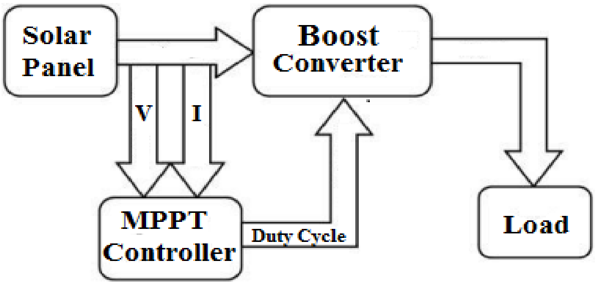

fig.1. block diagram of the proposed system

The main purpose of the proposed Boost converter is to convert lower level input DC voltage to higher level output DC voltage by varying duty cycle ‘D’. The output of the converter is fed to the load.

III.MODELING OF PV CELL

The equivalent circuit configuration of the PV cell is unveil in Fig.2. The ‘I_L’ represents cell photocurrent, I_D is the diode current, R_s & R_{sh} are the series & shunt resistances. Where value of R_{sh} is very large & value of R_s is very small. PV module is formed by connecting number of cells.

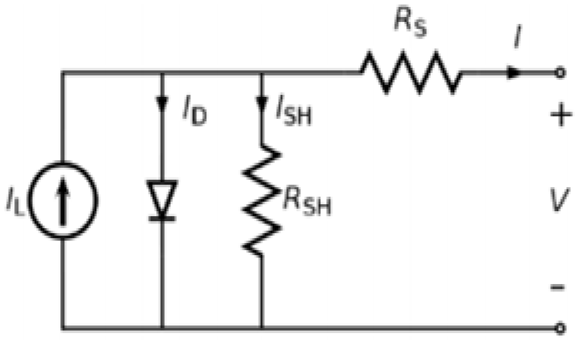

Fig.2. Equivalent circuit configuration of PV cell

The current output of PV module is

$$I = I_L - I_D - I_{SH} \tag{1}$$

Module photo-current Iph,

$$Iph = [Isc + Ki(T - 298)]\,\frac{Ir}{1000} \tag{2}$$

Module reverses saturation current Irs,

$$Irs = \frac{Isc}{e^{\frac{qVoc}{NsknT}} - 1} \tag{3}$$

The current output of PV module is,

$$I = Np * Iph - Np * Io\left(\frac{\left\lfloor e^{\frac{V}{Ns}} + I * Rs \right\rfloor}{(NPn * Vt)} - 1\right) - I_{SH} \tag{4}$$

The shunt current is given by,

$$I_{SH} = \frac{\left(V * \frac{Np}{Ns}\right) + (I * Rs)}{Rsh} \tag{5}$$

MPPT & P & O Algorithm:

The flowchart of P and O algorithm is shown in Fig.3. Mainly output of array is depends on the irradiation & temperature level of individual PV cells. At, anomalous cell irradiation & temp. It is detectable that PV panel on peak operating point called as maximum power point.

$$\frac{\,}{\,} = 0 \tag{6}$$

Case-I (PV array as CS)

Current of array is uniform in the left domain of MPP & array works as uniform current source.

$$>0 \quad \text{For } V<V_{mp} \tag{7}$$

Case-II (PV array as VS)

On contrary, In the right domain of MPP the current of array starts to decay & array workd as uniform voltage source.

$$<0 \quad \text{For } V>V_{mp} \tag{8}$$

The MPP of array varies according to the irradiation & temp. To attain maximum output from PV array, tenacious follow-up of MPP should be required. Through MPPT algorithm, high voltage can be achieved which is further used to separate duty cycle of converter. In this paper P & O is presented from the graph, we can easily understand the process of miniature perturbation. If PV system's voltage is perturbed by little enhancement of ΔV which results in the small change in ΔP. Now, suppose ΔP is positive, then there is need to perturb of PV voltage in the similar direction of the enhancement. In conflict, ΔP is negative, there is need to perturb PV voltage in the opposite direction of enhancement. The developed simulink model of 'P' and 'O' MPPT algorithm is unveil in Fig.4.

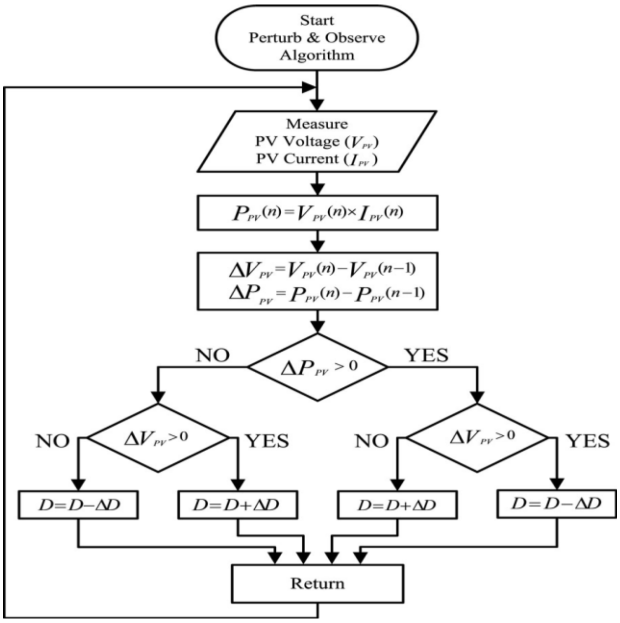

Fig.3. Flowchart of Perturb & Observe Algorithm

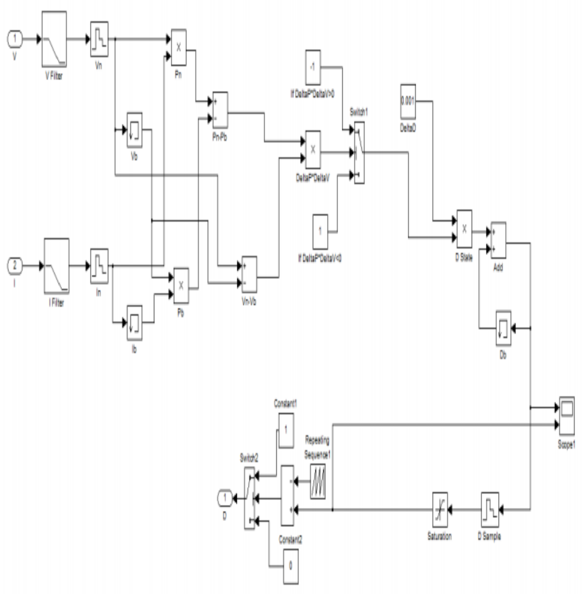

Fig.4. Simulink model of P & O algorithm

IV.CIRCUIT CONFIGURATION AND ITS OPERATION

The presented converter configuration is shown in Fig.5. This converter is driven by single switch ‘S’, one energy storage inductors L, capacitor C and the diode D are employed.

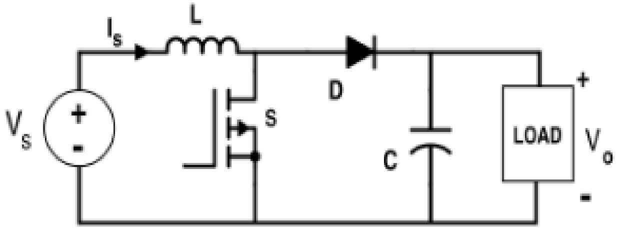

Fig.5. Boost converter

Shown in Fig.5 the Boost converter produces smaller impedances as compared to impedance of the load. So it is very difficult to attain open circuit voltage provided by PV module. It step-up the low level input voltage to high level output voltage. Fig.5 represents the circuit diagram of DC-DC boost convertor.

Interval-I

Boost converter circuit operation can be divided into two intervals. Interval I begins when the switch S is turned on at t = Ton. The input current which rises flows through inductor L and switch S. During this mode, energy is stored in the inductor. Fig.6. unveils the interval-I operation.

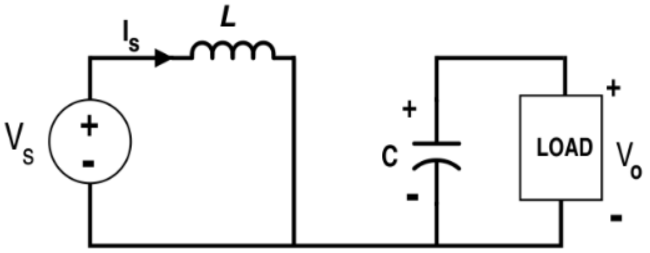

Fig.6. CCM Mode-I operation

Interval-II

Interval II begins when the switch is turned off at t = Toff. The energy stored in the inductor causes its voltage to swap polarity and maintain current flow in the circuit, which is now directed through inductor L diode D, capacitor C, load, and the supply of Vs. Fig.7. unveils the interval-II operation.

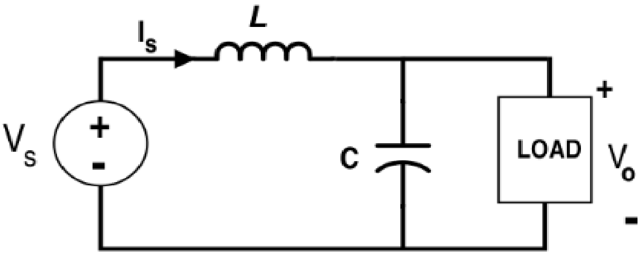

Fig.7. CCM Mode-II operation

The inductor current falls until the switch is turned on again in the next cycle. The reversing of the inductor voltage polarity in interval-II allows the Vo to be greater than Vs.

V.STEADY STATE ANALYSIS OF BOOST CONVERTER

When the switch S is ON,

$$V_S = V_L \tag{8}$$

$$L\frac{di}{dt} = V_s = \text{Constant supply voltage}$$

$$\frac{di}{dt} = \text{Constant}$$

$$= \text{Current increases with constant slop}$$

When the switch S is OFF,

$$V_s = V_L + V_c \tag{9}$$

$$L\frac{di}{dt} = V_s - V_c \tag{10}$$

$$\frac{di}{dt} = \frac{Vs - Vc}{L} \tag{11}$$

Now, current decreases and must reach at a value equal to the value of the current at the initial stage when switch S is just switched on according to steady state stability.

Current increment during switch on

$$I_{max.} - I_{min.} = \frac{V_s}{L} DT \tag{12}$$

Current decrement during switch off

$$I_{max.} - I_{min.} = \frac{V_s - V_C}{L} (1- D)\, T \tag{13}$$

According to the inductor volt sec balance,

$$V_s\, DT = (V_s - V_C)\,(1- D)\, T \tag{14}$$

$$V_c = \frac{V_S}{1-D} \tag{15}$$

$$V_0 = \frac{V_S}{1-D} \tag{16}$$

$$\text{Average Inductor Current} = \frac{I_{max} + I_{min}}{2} \tag{17}$$

$$\text{Input Power} = P_{IN} = \frac{I_{max} + I_{min}}{2} V_s \tag{18}$$

$$\text{Output power } P_{OUT} = \frac{V_O^2}{R} = \frac{V_S^2}{(1-D)^2 R} \tag{19}$$

Assume there is no switching loss,

$$P_{IN} = P_{OUT} \tag{20}$$

$$I_{max.} + I_{min} = 2\,\frac{V_S}{(1-D)^2 R} \tag{21}$$

From Equations 14 and 6, we can get,

$$I_{min} = \frac{V_S}{(1-D)^2 R} - \frac{V_S}{2L} DT \tag{22}$$

$$I_{max} = \frac{V_S}{(1-D)^2 R} + \frac{V_S}{2L} DT \tag{23}$$

For the continuous conduction mode (CCM) $I_{min} = 0$

$$L_{min} = \frac{D\,(1-D)^2}{2} TR \tag{24}$$

Ripple voltage across the capacitor

$$\Delta V_c = \frac{\Delta Q}{C} \tag{25}$$

Where, Δ Q is the charge accumulated during the switch on condition

$$\Delta V_c = DT \frac{V_0}{R} \frac{1}{C} \tag{26}$$

$$\Delta V_c = DT\, \frac{V_S}{(1-D) RC} \tag{27}$$

A. Selection of Inductor

The inductor value of the Boost converter are calculated using

$$L = \frac{V_s}{fs\,\Delta IL} \tag{28}$$

Where,

fs - Switching frequency

ΔIL - input current ripple

Current ripple factor (CRF) is the ratio between input current ripple and output current. For good estimation of inductor value CRF should bound within 30%.The current rating of inductor should be always higher than that of the maximum output current.

B. Selection of Capacitor

The capacitor value can be obtained from

$$C = \frac{Iout}{(fs\Delta Vo)D} \tag{29}$$

Where,

ΔVo - Output voltage ripple which is usually considered as 5% of output voltage which yields,

$\Delta Vo/Vo = 5\%$.

VI.RESULTS AND DISSCUSSION

In order to verify virtue of the Boost converter 30V/550V case is simulated in the MATLAB simulink. For this transformation ratio, the input voltage is 30V and output voltage is 550V, the output power of the converter is up to 600W. The duty ratio of the Boost converter is set by MPPT controller is about 0.44. Simulink model of the Boost converter is unveil in Fig.9, Fig.10, Fig.11, Fig.12, Fig.13, Fig.14, and Fig.15. Illustrates the simulated results of input voltage, voltage stress on the switch, diode voltage, output voltage, output current and output power respectively.

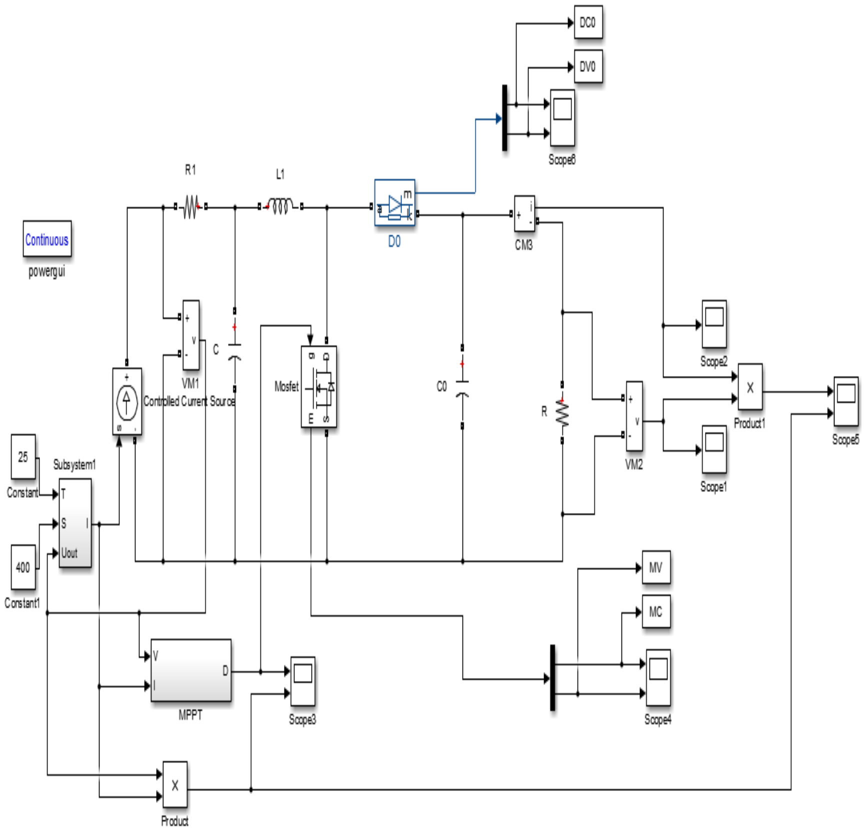

Fig.9. Simulink model of the Boost converter

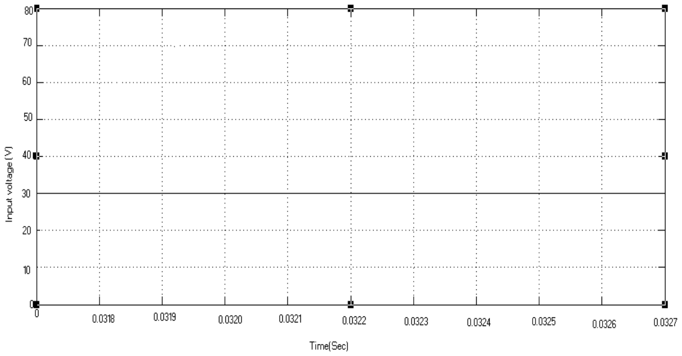

Fig.10. Input voltage of the Boost converter

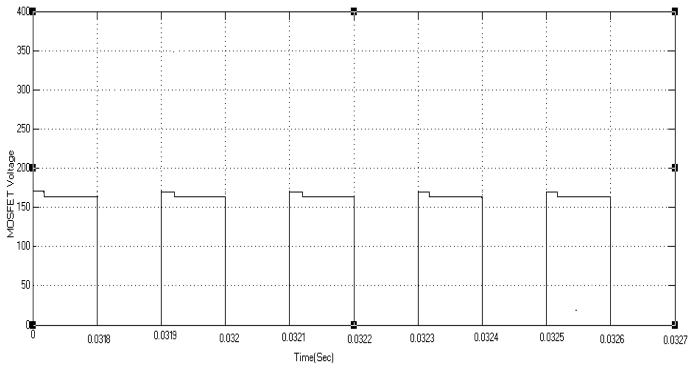

Fig.11. Voltage stress across the switch ‘S’

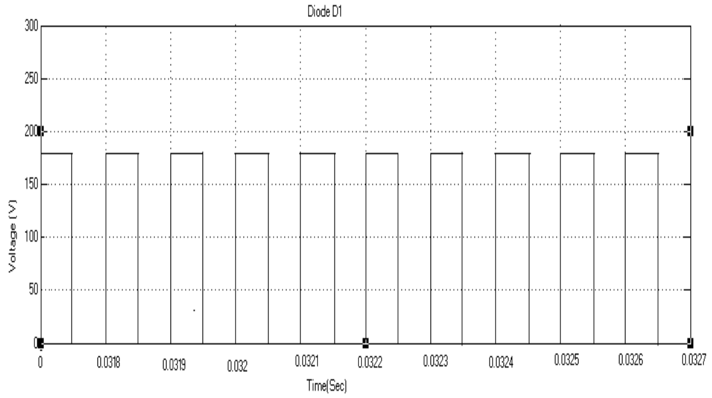

Fig.12. Voltages on diode D0

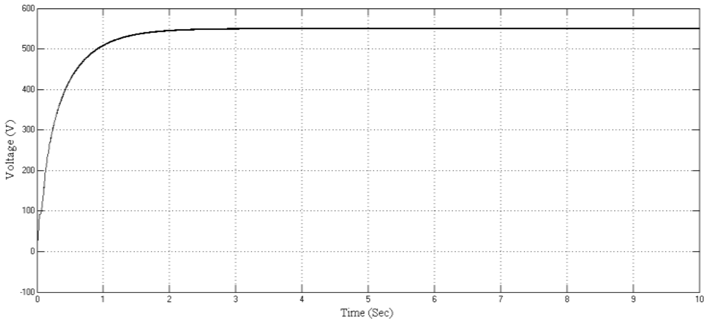

Fig.13. Output voltage of the Boost converter

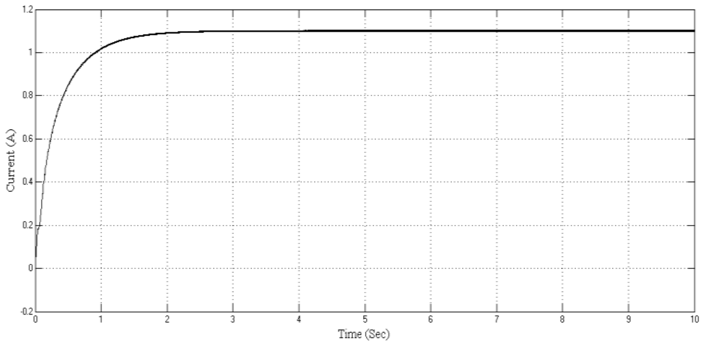

Fig.14. Output Current of the Boost converter

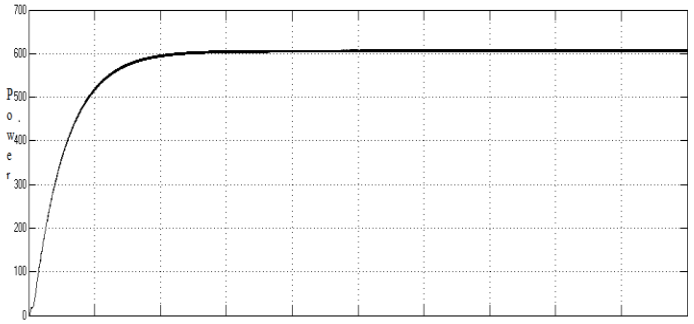

Fig.15. Output Power of the Boost converter

TABLE. I. SPECIFICATION OF BOOST CONVERTER

Component	**Parameters**
Maximum output power	600W
Input voltage (V_{in})	30V
Output voltage (V_o)	550V
Output current (I_o)	1.1A
Capacitor C	2.08μF
Output Capacitor C_0	140μF
Inductor L_1	205μH

V.CONCLUSION

In this paper, the non isolated boost converter with high step up voltage gain based on MPPT for PV application is studied. The proposed converter topology is able to produce the high static gain with fast response and low switching voltage stress. The proposed converter is validated using MATLAB Simulink. The simulation result shows the performance of the proposed converter is efficient for high voltage gain operations.

VI. ACKNOWLEDGEMENTS

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