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*Research Paper*

# DOUBLE BOOST CONVERTER FOR PHOTOVOLTAIC POWER-GENERATION SYSTEMS

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Photovoltaic (PV) system is capable of solving problems of global warming and energy exhaustion due to excess energy utilization. In this paper, a double boost converter for photovoltaic (PV) power generation system is proposed. The topology is used to increase efficiency and to reduce switching losses. The present topology is verified for 289 W prototype.

Keywords: Double boost converter, Maximum Power-Point Tracking (MPPT), Photovoltaic (PV) power generation system, Resonant converter

## INTRODUCTION

A photovoltaic (PV) system consists of a number of cells. These cells absorb sunlight and convert it into electricity. Each cells produce a certain amount of power, hardly enough to power up certain applications. They are capable of avoiding unnecessary fuel expenses and they also avoid air pollution or waste. By using photovoltaic (PV) systems, there is also reduction in noise because of the use of semiconductors. Solar cell can have a life cycle of more than 20 years and it also reduces the maintenance and management expenses.

By changing the irradiance and temperature, we can easily change the output power of cell and its efficiency is low. The Power Conditioning System (PCS) which transfers power from photovoltaic (PV) array to load requires high efficiency. Generally a single phase PV PCS consist of a dc/dc conversion stage along with tracking maximum power-point and under low irradiance guarantees the dc-link voltage [1] and [2]. The paper proposes MPPT module in the feedback loop based on P&O algorithm which makes the system more efficient compared to the traditional open loop PV generation system.

The overall efficiency of PVPCS can be increased by using the double boost converter [3]. In the proposed topology switching losses can be reduced by using the boost converter without using the additional switches required for soft switching [4]-[7].

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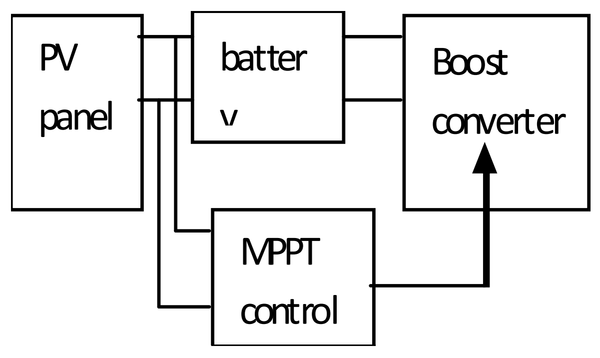
The drawback is that during resonance mode voltage is high across the switch and it depends on the parameters of resonant components and resonant inductor current. In this paper, the resonant current is reduced by using an interleaved method with high efficiency, the PV array output power can be boosted.

This paper presents the principle of operation of the boost converter, theoretical analysis and its simulation results. A simulation results for 289 W prototype of the boost converter is built and is verified with the theoretical analysis. The block diagram for the proposed topology is given in Figure 1.

Figure 1: Block Diagram of Proposed Topology




## PROPOSED TOPOLOGY

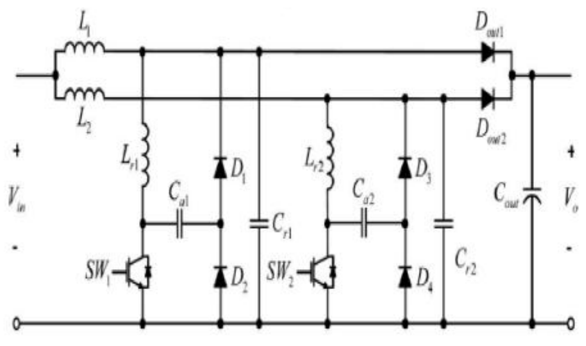
### Proposed Double boost Converter

The double boost converter consists of two parallel connected single phase boost converters. It is then connected to a output capacitor as shown in Figure 2. It also consists of inductors, resistors, capacitors, diodes and switches. The duty ratio considered here is 0.9.

### Principle of Operation of Boost Converter

The working of the converter is based on one

Figure 2: Proposed Single Switch Double Boost Converter



switching cycle of its steady state operation. The duty ratio to the MOSFET switches is given by tracking maximum power point using the perturb and observe algorithm.

At first the switch is off and the output of cell is transferred to load, inductor current reduces. Now the switch is turned on because of inductor *Lr*. The current $i_{Lr}$ starts to increase and when it becomes equal to the main inductor current $i_L$, the diode output becomes zero. At this point, inductor *Lr* and capacitor *Cr* resonates and voltage of capacitor *Cr* reduces to zero. Diodes *D*1 and *D*2 are turned on now and inductor current flows through main inductor *Lr* and the diodes. The main inductor current increases. Again the switch turns of because of capacitor *Ca*. Two current loops are formed in which voltage across *Cr* increases to output voltage *Vo* and energy stored in inductor *Lr* is transferred to *Ca*. Now current across inductor $i_{Lr}$ becomes zero. Voltage across capacitor *Ca* starts to decrease and energy is transferred again back to inductor *Lr*. When voltage *Ca* becomes zero, anti-parallel diodes turn on making two current loops. The energy is transferred to output through inductor current $i_L$ and it decreases linearly. The inductor current $i_{Lr}$ transmits energy to load. When the current $i_{Lr}$ goes to zero the operation ends.

## Design Example

Table I shows the parameters for the proposed double boost converter.

Table 1: Experimental Parameters

| Parameter | Symbol | Value | Unit |
|---|---|---|---|
| Input voltage | *Vin* | 48 | V |
| Output voltage | *Vout* | 224 | V |
| Power | *P* | 289 | W |
| Main inductor | *L*1, *L*2 | 540 | µH |
| Resonant inductor | *Lr*1, *Lr*2 | 40 | µH |
| Resonant capacitor | *Cr*1, *Cr*2 | 30 | µF |
| Auxiliary capacitor | *Ca*1, *Ca*2 | 30 | µF |
| Output capacitor | *Cout* | 30 | µF |

## MODELLING OF PHOTOVOLTAIC SYSTEM

A solar cell is a p-n junction fabricated in thin wafer of semiconductor. Photovoltaic system converts solar energy to electricity directly by using solar cells or other similar devices. This technology is developed in 20th century. A simple example can be a calculator. The common model used in modelling this photovoltaic cell is single diode circuit model.

Figure 3a: Diode Circuit Model on a PV Cell

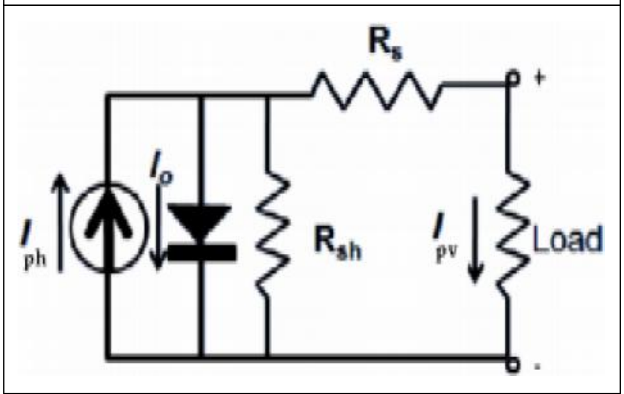



Figure 3a shows the equivalent circuit of a PV cell.

$I_{ph}$ is the current source which represents the cell photocurrent. $R_{sh}$ is the intrinsic shunt resistance and $R_s$ is the intrinsic series resistance of the cell. $R_{sh}$ is very large when compare to $R_s$ and hence can be neglected.

PV modules consist of large number of PV cells grouped and interconnected in parallel-series combination to form PV arrays. The photocurrents depend on solar irradiation.

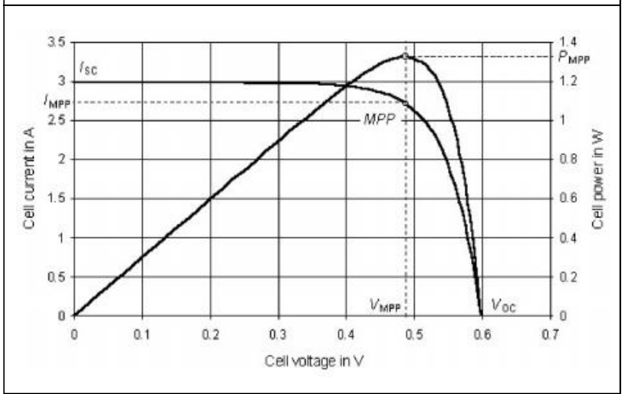
$$I_{ph} = (I_{sc} + k(T_k - T_{ref})) * {}^{a}/1000 \qquad ...(1)$$

where $k$ is the temperature coefficient of short circuit current, $T_{ref}$ is the reference temperature and $T_k$ is the actual temperature in Kelvin respectively. As temperature changes, saturation current varies and is given by:

$$I_s = I_{rs}(T_k/T_{ref})\text{^}3 * \exp(q * E_g(1/T_{ref} - 1/T_k)/K * A) \qquad ...(2)$$

where $I_{rs}$ is the reverse saturation current of cell at solar irradiation and reference temperature, $E$ is the band gap energy of semiconductor and $A$ is the ideality factor. Expression for reverse saturation current is given by

Figure 3b: I-V and P-V Characteristics of a Solar Cell



$$I_{rs} = I_{sc} / \exp(q * V_{oc} / N_s * K * A * T_k) - 1) \quad ...(3)$$

where $V_{oc}$ is the open circuit voltage of cell, $N_s$ is the number of cells in series. Figure 3b shows the I-V and P-V characteristics of a solar cell.

## PERTURB AND OBSERVE ALGORITHM

As the solar insolation and temperature changes, output power of PV module also changes. When we look at the PV characteristics, there is a point where maximum power can be obtained .PV module operates at this point and this point is called maximum power point. In this paper we use Perturb and Observe method to track the maximum power.

This algorithm uses measured parameters and simple feedback arrangement. In this, perturbation is given to the module voltage and its output power is compared with previous perturb cycle. The perturbation is continued in same direction if power increases. Once it reaches the peak power, it starts to decrease in the next instant reversing the perturbation as shown in Figures 4a and 4b.

Figure 4a: Power versus Voltage Plot for P&O Algorithm

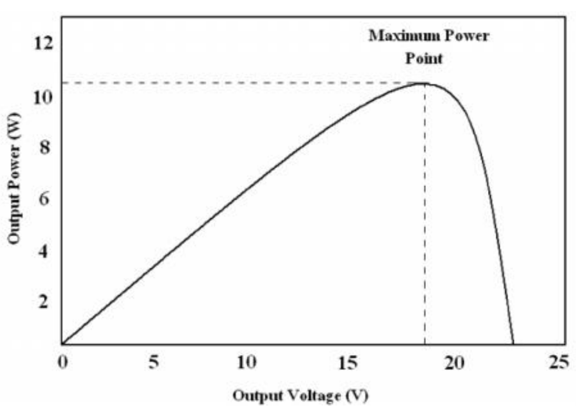
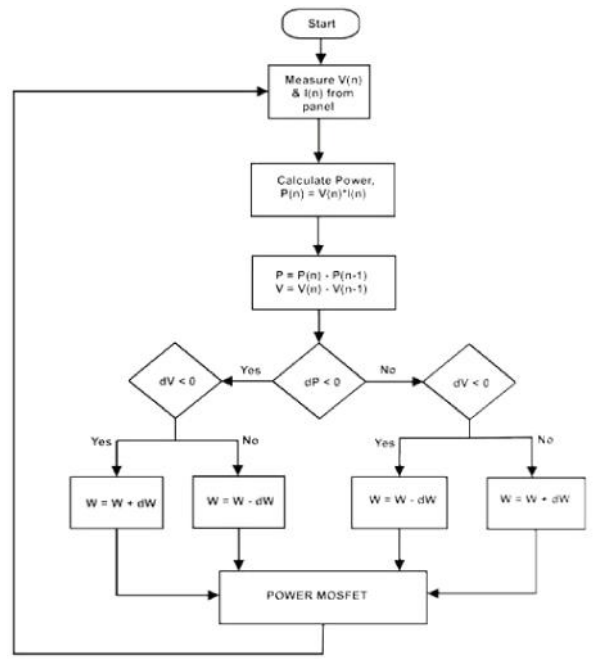



Figure 4b: Flowchart of MPPT Algorithm




By using the P&O algorithm, we can get the maximum voltage required to operate the PV cell. Stable condition can be obtained when the algorithm reaches the maximum power. Any variation in the PV cell changes the duty ratio which is then fed to the switch.

## SIMULATION RESULTS AND DISCUSSIONS

The MATLAB simulation software is used for the proposed topology to analyse its operational characteristics. The design parameters can be used as given in TABLE I. The simulink model of a PV module with MPPT Of Boost converter module is shown in Figure 5a.

The simulink model of the PV module and its I-V curve is shown in Figures 5b and 5c respectively.

Figure 5d shows the output waveform of the double boost converter.

Figure 5a: Simulink Model of PV Module with MPPT of Boost Converter

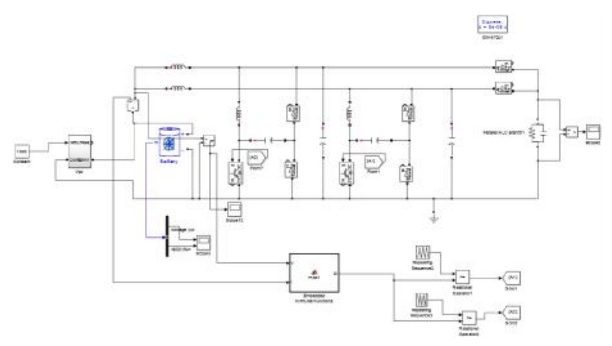


Figure 5b: Simulink Model of PV Module

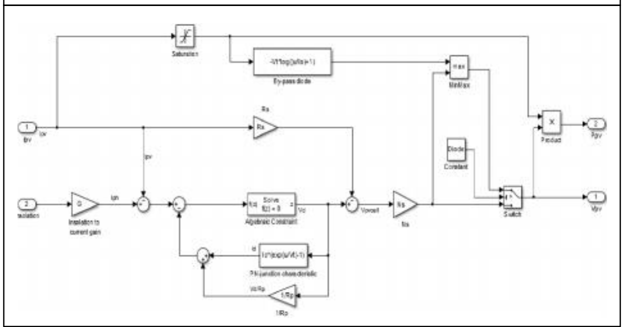


Figure 5c: I-V Curve of a PV Module

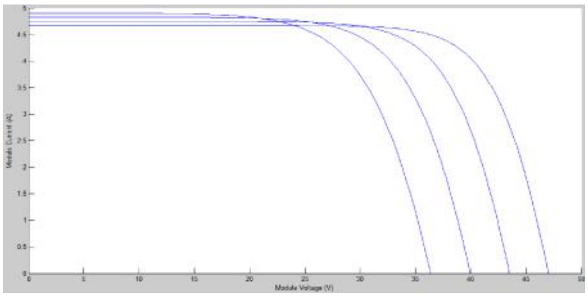
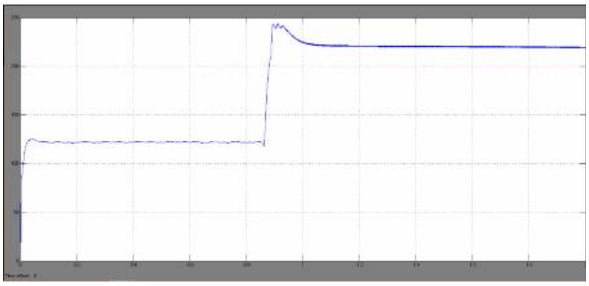


Figure 5d: Simulation Waveform of the Proposed Double Boost Converter



## CONCLUSION

In the paper, for the PV simulator we used the MPPT control. MPPT control is done by using perturb and observe method. By simulating the proposed topology in MATLAB/SIMULINK, it was confirmed that the efficiency of the double boost converter is better compared to traditional open loop PV generation systems. It also provides high response when compared to the single boost converter.

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