Simulation Model of Boost Converter Used in Photovoltaic System

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Abstract: This work introduces an approach to the design of a boost converter for a photovoltaic (PV) system. In recent years, attention towards renewable energy such as wind and solar power has increased dramatically. With the shortage of the energy and ever increasing of the oil price, research on the renewable and green energy sources, especially the solar arrays and the fuel cells, becomes more and more important. How to achieve high step-up and high efficiency DC/DC converters is the major consideration in the renewable power applications due to the low voltage of PV arrays and fuel cells. In this paper simulation of boost converter for solar energy conversion system is presented. This converter has advantages like improved power factor, fast response and reduced hardware.

Keywords: Boost converter, Solar cells, PV cells, MATLAB, Simulation.

1. Introduction

Photovoltaic (PV) sources are used today in many applications from satellite power systems to battery chargers and home appliances. PV is an important green energy source because it has the advantages of being pollution free, low maintenance, with no noise or wear due to the absence of moving parts. The power produced by a solar panel depends on two factors; irradiation and temperature. As irradiation and temperature levels change rapidly, the voltage produced fluctuates and becomes inconstant. A converter is therefore required to produce a constant voltage that is matched to the requirements of the load and supplied efficiently. A maximum power point tracker (MPPT) is a system that directs the converter to track the maximum power of a solar panel and deliver it to load. Photovoltaic (PV) sources are one of the significant players in the world’s energy portfolio and will become the biggest contributions to the electricity generation among all renewable energy candidates by year 2040 because it is truly a clean, emission-free renewable electrical generation technology with high reliability. Many tracking algorithms and techniques have been developed. The perturbed and observed method [1] and the Incremental Conductance method [2], as well as variants of those techniques [3, 4] are the most widely used. The perturbed and observe method is known for its simple implementation, but it deviates from and observe method oscillates close to a maximum power point (MPP) in the atmospheric conditions are constant or slowly changed. However, when weather rapidly changes the perturb and observe method fails to track the maximum power point effectively [4, 5].

2. PV Cell System

Photovoltaic (PV) is the field of technology and research related to the application of solar cells for energy by converting sunlight directly into electricity. Photovoltaic are generally known as a method for generating solar power by using solar cells packaged in photovoltaic modules, often electrically connected in multiples as solar photovoltaic arrays to convert energy from the sun into electricity.

In the simple words the photons from sunlight knock electrons into a higher state of energy, creating electricity. The term photovoltaic denotes the unbiased operating mode of a photodiode in which current through the device is entirely due to the transduced light energy. Virtually all photovoltaic devices are some type of photodiode. Solar cells produce direct current electricity from light, which can be used to power equipment or to recharge a battery lead acid. PV cells have a single operating point where the values of the current (I) and Voltage (V) of the cell result in a maximum power output. These values correspond to a particular resistance, which is equal to V/I as specified by Ohm’s Law. A practical photovoltaic energy conversion system block diagram is shown in Fig. 1.
DC converters are devices that convert a dc voltage to a different dc mode power supply. DC converters base on linear regulator and switching regulator. For linear regulator, transistor is operated in linear (active) mode. Figure shows the linear regulator circuit. Output voltage given by this equation

\[ V_o = V_{in} - V_{ce} \]  

(1.1)
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Where $V_{IN}$ and $V_O$ is an input and output voltage and $V_{CE}$ is a voltage across the transistor. The transistor can be conveniently modeled by an equivalent variable resistor, as shown in Figure 2 (b). The power loss is high at high current due to this equation:

$$P_o = I_L^2 \times R_L$$  \hspace{1cm} (1.2)

or

$$P_o = V_{CE} \times L$$  \hspace{1cm} (1.3)

Where $P_o$ is output power, $I_L$ load current, $V_{CE}$ is voltage across the transistor and $R_L$ is load resistance. For switching regulator, transistor is operating in switched-mode. When switch is open, no current flow in it and when switch is closed no voltage drop across it. Figure 3 (a) shows a switching regulator circuit and Figure 1.3(b) shows its equivalent Circuit.
Fig 3 (a) A Switching Regulator Circuit (b) Equivalent Circuit

Since $P=IV$, no losses occur in switch. For ideal switch, power losses are zero and 100% transferred from source to load. Switching regulator is the basis of all DC-DC converters.

4. Boost Converter Analysis

A simple boost converter consists of an inductor, a switch, a diode, and a capacitor as shown in Figure 2, the Boost converter circuit operation can be divided into two phases. Phase 1 begins when the switch $SW$ is turned on at $t = T_{on}$ as shown in Figure 3. The input current which rises flows through inductor $L$ and switch $SW$. During this mode, energy is stored in the inductor. Phase 2 begins when the switch is turned off at $t = T_{off}$. 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 $R$, and the supply of $V_{in}$ as shown in Figure 2. The inductor current falls until the switch is turned on again in the next cycle. The reversing of the inductor voltage polarity in phase 2 allows the $V_{out}$ to be greater than $V_{in}$

$$V_{out} = \frac{1}{1 - k} V_{in}$$

where $V_{out}$ is the output voltage, $k$ is duty cycle, and $V_{in}$ is input voltage which in this case will be the solar panel voltage.

In order to operate the converter in continuous conduction mode (CCM), the inductance is calculated such that the inductor current $I_L$ flows continuously and never falls to zero as shown in Figure 3. Thus, $L$ is given by:

$$L_{\text{min}} = \frac{(1 - k)^2 kR}{2f}$$

where $L_{\text{min}}$ is the minimum inductance, $k$ is duty cycle, $R$ is output resistance, and $f$ is the switching frequency of switch $SW$. 
The output capacitance to give the desired output voltage ripple is given by:

\[ C_{\text{min}} = \frac{k}{RfV_r} \]

where \( C_{\text{min}} \) is the minimum capacitance, \( k \) is duty cycle, \( R \) is output resistance, \( f \) is switching frequency of switch \( SW \), and \( V_r \) is output voltage ripple factor. \( V_r \) can be expressed as:

\[ V_r = \frac{\Delta V_{\text{out}}}{V_{\text{out}}} \]

5. Simulation Results

Simulation is done using Matlab and the results are presented. Boost converter for solar energy conversion system in open loop.
6. Conclusion

This paper presents simulation of loop open controlled boost converter system for photovoltaic installation system. Matlab models for open loop are developed using the blocks of simulink and the same are used for simulation studies.

References


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