Simulation of PV Array with Boost Converter: Closed Loop Model

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Abstract: *Research on the renewable and green energy sources especially the solar arrays and the fuel cells, become more and more important, With the shortage of the energy and ever increasing of the oil price. 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. This paper presents the simulation of a DC-DC boost converter which uses solar system as input source. In general The recent upsurge in the demand of PV systems is due to the fact that they produce electric power without hampering the environment by directly converting the solar radiation into electric power. However the solar radiation never remains constant. It keeps on varying throughout the day. The need of the hour is to deliver a constant voltage to the grid irrespective of the variation in temperatures and solar isolation. A circuit such that it delivers constant and stepped up dc voltage to the load is designed. The operation principle of boost converter working in continuous conduction mode (CCM) has been introduced. The PV array with the boost converter is then coupled. Circuit model for close loop system may be conveniently implemented using the MATLAB's Simulink toolbox environment. This converter has advantages like improved power factor, fast response and reduced hardware.*

Keywords: Boost converter; Solar cells, PV cells; continuous   conduction   mode   (CCM); Matlab/Simulink

1. Introduction

Nowadays, many renewable energy sources such as solar photovoltaic (PV) and wind energy are well developed and have been put in the limelight as the alternative energy as part of effort in limiting the dependency on the conventional energy sources like fossil fuels, coal, and natural gas. These energy sources have attracted many researches due to the fact that both of this energy is free and sustainable besides environmental friendly. From previous research , it has been indicated that these energy sources especially PV is simply easy to integrate with existing topology of switched mode DC-DC power converters. The massy usage of the fossil fuels, such as the oil, the coal and the gas, result in serious greenhouse effect and pollute the atmosphere, which has great effect on the world. Meanwhile, there is a big contradiction between the fossil fuels supply and the global energy demand, which leads to a high oil price in the international market recently. The energy shortage and the atmosphere pollution have   been   the   major   limitations for the human   development.

How to find renewable energy is becoming more and more exigent. Normally a solar panel will Only produce approximately 16V in full, nearly normal sunlight and it will limit the maximum power production to Only few hours charging batteries at 12V . 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. A DC-DC boost converter controlled by PWM control technique is placed between the solar panel and the batteries, in order to boost up the voltage of solar panel to charge the batteries at any time even when the panel voltage is less than battery charging voltage. Since solar cells are costly, DC-DC boost converter takes a role in solving this situation. Boost converter is one of the four basic topologies in switched mode DC-DC converters which produce different outputs according to the different topologies. This paper proposes a basic circuit of DC-DC boost converter . Generally, boost converter operates in two basic modes of work operation, i.e. continuous conduction mode (CCM) and discontinuous conduction mode (DCM)[4]. The state of the converter in which the inductor current is never zero for any period of time is called (CCM) meanwhile, in the (DCM); the inductor current is zero during a portion of the switching period. Unlike closed-loop response, open-loop response cannot compensate for disturbance or noise. In contrast, closed-loop response can provide such compensation besides this system do not require an accurate system model, something that is difficult to obtain in practice.

2. PV Cell System

A photovoltaic system is a system which uses one or more solar panels to convert solar energy into electricity.
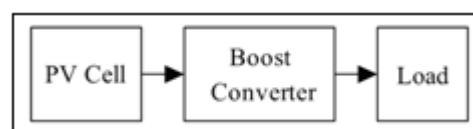

Figure 1: Block Diagram

The density of power radiated from the sun at the outer atmosphere is 1.373 kW/m . Final incident sun light on the earth surface has the peak density of 1 kW/m2 at noon in the tropics. Solar cell can convert the energy of sunlight directly in to electricity[1] A simplified equivalent circuit of a solar cell consists of a current source in parallel with a diode variable resistor is connected to the solar cell generator as a load.

Modelling of PV Array

The building block of PV arrays is the solar cell, which is basically a p-n junction that directly converts light energy into electricity

The current source I_{ph} represents the cell photo current; Rj is used to represent the non-linear impedance of the p-n junction; R_{sh} and R_s are used to represent the intrinsic series and shunt resistance of the cell respectively. PV cells are grouped in larger units called PV modules which are further interconnected in series-parallel configuration to form PV arrays or PV generators.
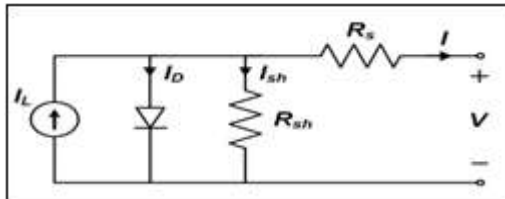
Figure 2: Equivalent Circuit of PV cell

The PV mathematical model used to simplify our PV array is represented by the equation:

$$I = n_p I_{ph} - n_p I_{rs} [\exp(\frac{q}{KTA} * \frac{V}{n_s}) - 1]$$

where I is the PV array output current; V is the PV array output voltage; n_s is the number of cells in series and n_p is the number of cells in parallel; q is the charge of an electron; k is the Boltzmann's constant; A is the p-n junction ideality factor; T is the cell temperature (K); I_{rs} is the cell reverse saturation current. The factor A in equation determines the cell deviation from the ideal p-n junction characteristics; it ranges between 1-5.

The cell reverse saturation current I_{rs} varies with temperature according to the following equation

$$I_{rs} = I_{rr} [\frac{T}{T_r}]^3 \exp(\frac{qE_G}{KA} [\frac{1}{T_r} - \frac{1}{T}])$$

Where T_r is the cell reference temperature, I_{rr} is the cell reverse saturation temperature at T_r and E_G is the band gap of the semiconductor used in the cell.

The temperature dependence of the energy gap of the semiconductor

$$E_G = E_G(0) - \frac{\alpha T^2}{T + \beta}$$

The photo current I_{ph} depends on the solar radiation and cell temperature as follows

$$I_{ph} = [I_{scr} + K_i(T - T_r)] \frac{S}{100}$$

where I_{scr} is the cell short-circuit current at reference temperature and radiation, K_i is the short circuit current temperature coefficient, and S is the solar radiation in mW/cm^2.

The PV power is given by

$$P = IV = n_p I_{ph} V [(\frac{q}{KTA} * \frac{V}{n_s}) - 1]$$

3. Physical model of boost converter

The proposed scheme is applied to a boost converter, as shown in Fig. 2. The parameters of the proposed scheme are represented by: a solar cell as DC input voltage source V_{in}, controllable switch, filter inductor L, filter capacitor C, load resistor R, and a PWM block that controlled duty cycle represented by d
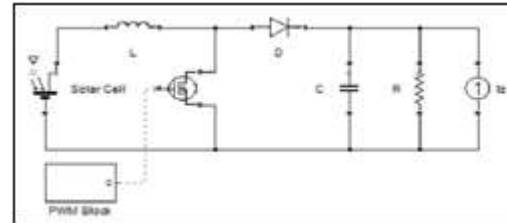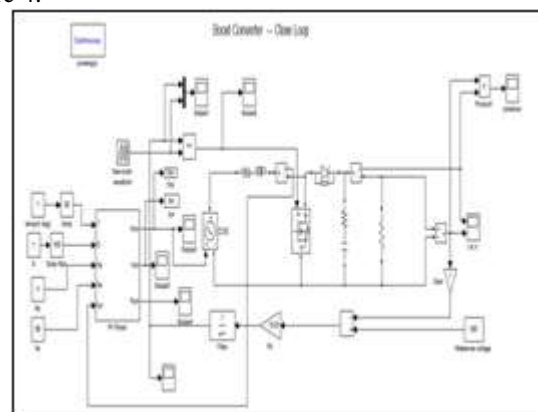

Figure 3: DC-DC boost converter

A current generator represented by I_z is added in parallel with the load resistor so that the response of the converter to the load changes can be examined. The proposed scheme is considered to operate in continuous conduction mode (CCM). When the switch is ON, the diode is reversed biased, thus isolating the output stage and the input supplies energy to the inductor. Otherwise, the output voltage receives energy from the inductor as well as from the input, when the switch is OFF. The controllable switch is considered as being ideal, and the losses in the capacitance and inductive elements are neglected. The relation between input and output voltage of the boost converter is

$$\frac{V_0}{V_{in}} = \frac{1}{(1-d)}$$

4. Design and simulations

The proposed model of closed loop DC-DC boost converter is then implemented in SIMULINK block diagram as in figure 4.

Figure 4: The complete simulink circuit showing the coupling of PV array with boost converter

The PV array has been designed taken into consideration its dependence upon the irradiance, temperature, number of PV cells connected in series and parallel. The detailed internal circuit of the PV array showing the design is given below in figure 5.
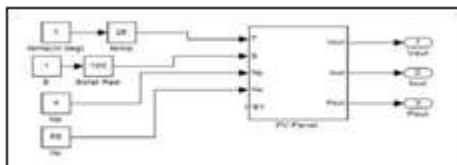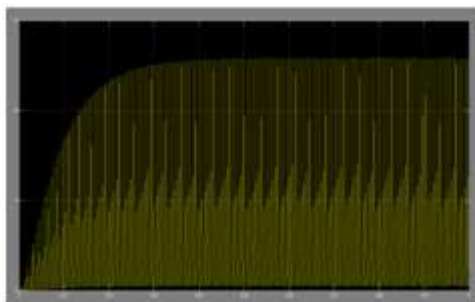
Figure 5: PV Panel Block Diagram

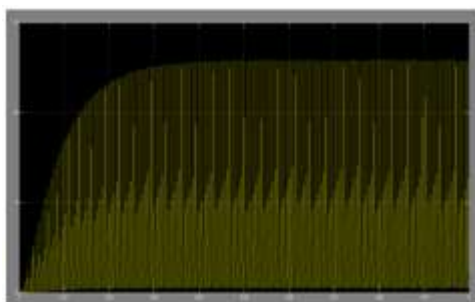Table 1 specification of DC-DC boost converter

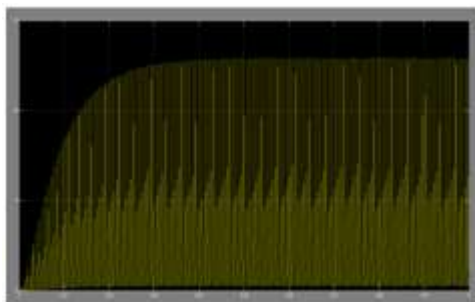| Parameter	Value
Vin	12V
V_0	50V
Inductor, L	3.64Mh
Capacitor, C	7.6µF
Resistor, RL	200Ω,,
Duty cycle, D	0.76
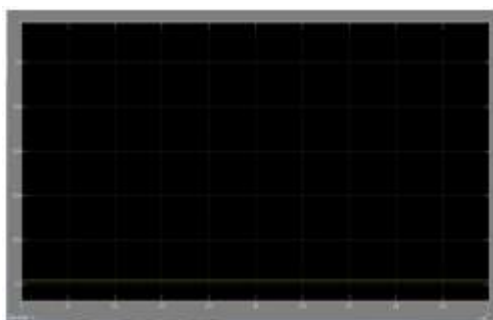
Figure 6: Input Voltage

Figure 7: Output Power

Figure 8: Output Voltage

Figure 9: Output Voltage

Results of the closed loop DC-DC boost converter simulated in the MATLAB/SIMULINK environment is as shown in figure 6,7,8,9.

5. Conclusion

This paper presents simulation of closed loop controlled boost converter system for solar installation system. Matlab models for closed loop systems are developed using the blocks of simulink and the same are used for simulation studies. The closed loop system is able to maintain constant voltage. This converter has advantages like reduced hardware and good output voltage regulation. Thus the boost converter is capable of improving the voltage level from 12 V to the required level.

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