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Review on Converter Design for MPPT in SPV System

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Abstract— **The use of fossil fuel results increased global warming which attracting lots of interest to the green energy sources recently. As compare to fossil fuels solar energy is everlasting source of energy while fossil fuels and conventional sources of power are limited. Now a day's solar energy or solar photovoltaic's (PV) gaining more attention of the researchers and market players of this field. The only drawback of the solar PV (SPV) system is its high capital cost, which may be compensated by increasing its power output. Maximum power point tracking (MPPT) is the optimum solution to extract maximum SPV generated power. MPPT is nothing but the tracking of maximum available power of an SPV system by means of the DC-DC converter. DC-DC converters play very important role in case of MPPT or it is heart of the MPPT system. In this paper design of a non isolate DC-DC buck-boost converter is presented for solar module of 250 Watt made by Tata Power Solar India Limited for tracking maximum power. Testing is done is MATLAB/SIMSCAPE environment and results show that designed converter is tracking maximum power output.**

Key words— **Buck-Boost Converter, DC-DC converters, MPPT, Solar PV. MATLAB, SIMSCAPE.**

I. Introduction

Solar PhotoVoltaic (SPV) materials and devices are that converts sunlight into electrical energy. A single PV (Photovoltaic) device is known as a cell. To obtain significant power output of PV cells, they are connected in an array to form larger units known as solar modules or solar panels. Such arrays are connected to the electrical grid as part of a complete Solar PV system. Arrays can range in vivid power capacity form a few hundred watts to hundreds of kilowatts. Due to this modular structure, PV systems can be built to meet almost any electric power requirement.

Maximum power point tracking (MPPT) is an essential part of solar photovoltaic (PV) system to draw maximum available power which is generated by the solar PV. The concept of MPPT is based on maximum power transfer theorem. When the impedance of source is equal to the load impedance then only, source or solar PV delivers maximum power to the load. Impedance matching is done through DC-DC converter, whereas the duty cycle of the converter is decided by the MPPT algorithm. Nonetheless, DC-DC converter design is a key aspect in any tracking scheme.

II. Role of DC-DC Converter in MPPT Operation [1]

The DC/DC converters are widely used in regulated switch mode DC power supplies. The input of these converters is an unregulated DC voltage, which is obtained by PV array and therefore it will be fluctuated due to changes in radiation and temperature. In these converters the average DC output voltage must be controlled to be equated to the desired value although the input voltage is changing. From the energy point of view, output voltage regulation in the DC/DC converter is achieved by constantly adjusting the amount of energy absorbed from the source and that injected into the load, which is in turn controlled by the relative durations of the absorption and injection intervals. These two basic processes of energy absorption and injection are controlled by PWM technique.

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In this paper a basic design of DC-DC converters has been presented.

III. MODELING OF PV SYSTEM

The output of PV cell is a function of photon current that can be also determined by load current depending upon the solar insolation during its operation equation [2].

$$I_{pv} = I_{ph} - I_s\left[\exp\left\{\frac{V_{pv}+I_{pv}R_s}{N\times V_T}\right\}-1\right] - I_{s_2}\left[\exp\left\{\frac{V_{pv}+I_{pv}R_s}{N_2\times V_T}\right\}-1\right] - \frac{V_{pv}+I_{pv}R_s}{R_{sh}} \quad \ldots(1)$$

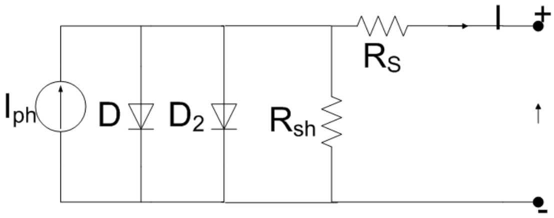

Fig. 1. Equivalent circuit of a two diode model of a PV cell.

Where:

I_{ph} is the solar induced or photon generated current:

$$I_{ph} = I_{ph0}\frac{I_r}{I_{r0}} \quad \ldots\ldots\ldots (2)$$

I_r is the irradiance (light intensity or insolation) in W/m^2 falling on the cell.

I_{ph0} is the measured solar-generated current for the standard irradiance I_{r0}.

I_s is the saturation current of the first diode.

I_{s2} is the saturation current of the second diode.

V_T is the thermal voltage,

$V_T = kT/q$

k is the Boltzmann constant.

T is the solar cell operating temperature.

q is the elementary charge on an electron.

N is the quality factor (diode emission coefficient) of the first diode.

N_2 is the quality factor (diode emission coefficient) of the second diode.

V_{pv} is the voltage across the solar cell electrical ports.

The PV panel output is also dependents on solar insolation and temperature. A solar cell modeled on the basis of two diode model has been given in MATLAB in SIMSCAPE library.

Solar cell given in MATLAB library is used for modeling and simulation. Fig. 2 shows the solar cell available in MATLAB SIMSCAPE library.

Fig. 2. Solar cell available in MATLAB/SIMSCAPE library.

The solar PV array used for testing is made by Tata Power solar TP250 and the parameters given in datasheet [3] is given is table I

TABLE I
PARAMETERS OF SOLAR MODULE GIVEN IN DATASHEET [3].

Datasheet data: Performance at standard test conditions, STC: 1000 W/m^2, 25 °C.	
Nominal Power P_{MPP} of module	250 W
Short Circuit current I_{sc} of module	8.71 A
Open Circuit Voltage V_{oc} of module	37.3 V
Number of series connected cell in module	60
V_{MPP} of module	30.2
I_{MPP} of module	8.3

Solar cell is simulated on the basis of short circuit current and open circuit voltage, 5 parameters. Solar cell parameters used for simulation are given in table II.

TABLE II
SOLAR CELL MODELLING ON THE BASIS OF 5 PARAMETERS USED IN SIMULATION.

Parameters	**Value**
Short Circuit current I_{sc} of cell	8.71 A
Open Circuit Voltage V_{oc} of cell	0.6217 V
I_{r0} of cell	1000 W/m^2
N of cell	1.5
R_s of cell	0.0008 Ω
Number of series connected cell in module	60

The value of first diode's quality factor (N) is taken as 1.5 and series resistance R_s is taken as 0.0008 Ω.

Beside these 5 parameters, temperature dependence parameters taken for simulation are given in table 3.3.

TABLE III
TEMPERATURE DEPENDENCE PARAMETERS USED IN SIMULATION.

Parameters	**Value**
First order temperature coefficient for I_{ph}, T_{IPH1}	0.02 1/K
Energy gap, EG	1.1 eV
Temperature exponent for Is, T_{XIS1}	3
Temperature exponent for Rs, T_{RS1}	1
Standard temperature, T	25^{0}C
Device measurement temperature, T_{meas}	25^{0}C

On the basis of parameters given in table II and III simulation results obtained are shown in table IV. Current vs. voltage (I-V) characteristic obtained is shown in Fig. 3 and power vs. voltage (P-V) characteristic is shown in Fig. 4 at standard test conditions, STC: 1000 W/m^2, 25 °C.

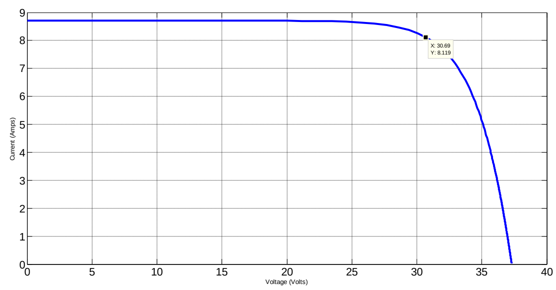

Fig. 3. I-V characteristic of solar module at 1000 W/m^2 insolation and 25^{0}C temperature.

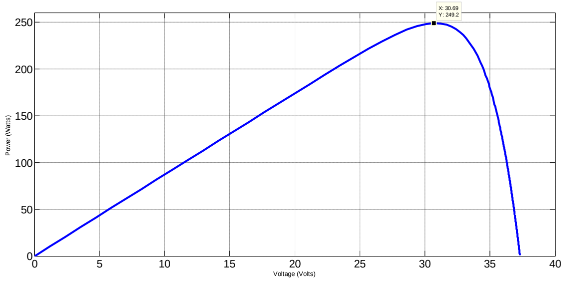

Fig. 4. P-V characteristic of solar module at 1000 W/m^2 insolation and 25^{0}C temperature.

TABLE IV
PARAMETERS OF SOLAR MODULE OBTAINED BY MATLAB SIMULATION.

Performance at standard test conditions, STC: 1000 W/m^2, 25 °C.	
Nominal Power P_{MPP} of module	250 W
Short Circuit current I_{sc} of module	8.71 A
Open Circuit Voltage V_{oc} of module	37.3 V
Number of series connected cell in module	60
V_{MPP} of module	30.69 V
I_{MPP} of module	8.119 A

IV. DC-DC CONVERTER DESIGN

In recent years, DC-DC converters are wide utilized in switched mode power supplies. These converters are typically used either to step down or boost up an unregulated DC input voltage. There are various DC-DC converter topologies like buck, boost, buck-boost, Cuk and full bridge converter. This paper presents a review on the design of buck, boost, buck-boost and cuk converter.

4.1 Buck Converter

Buck converter is basically a step-down converter used to regulate dc power supplies. It consists of voltage source, inductor, power electronic switching device (usually MOSFET), diode and a capacitor to smoothen the output. It produces lower average output voltage compared to average input voltage, by varying the duty ratio T_{on}/T of the switch. The duty cycle is calculated by equation:

$$D = \frac{V_o}{V_i}$$

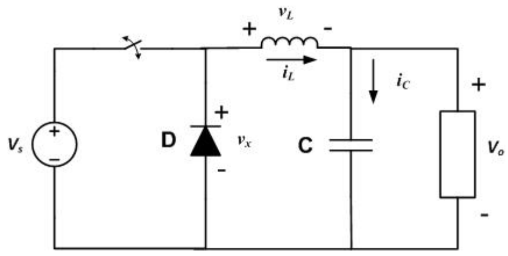

Fig. 5. Functional circuit of Buck Converter

4.2 Boost Converter

Boost converter is another simple step-up converter consisting of voltage source, diode, power electronic switch (MOSFET) and a capacitor. It raises the dc output voltage up-to the desired level compared to dc input voltage. Duty cycle is calculated by equation:

$$D = 1 - \frac{V_i}{V_o}$$

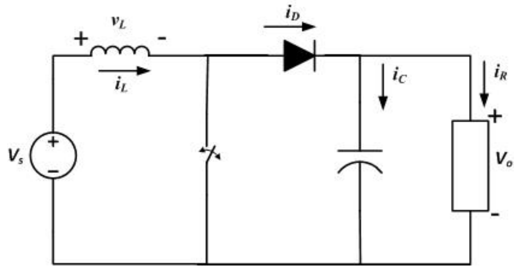

Fig. 6. Functional circuit of Boost Converter

4.3 Buck-Boost Converter

Buck-boost converter is basically a cascaded connection of a buck converter and a boost converter, i.e. it can step-down and step-up the average input voltage to the desired average output voltage, where the polarity of the output voltage is opposite to the input voltage. The duty cycle is calculated by equation:

$$D = \frac{V_o}{V_o - V_i}$$

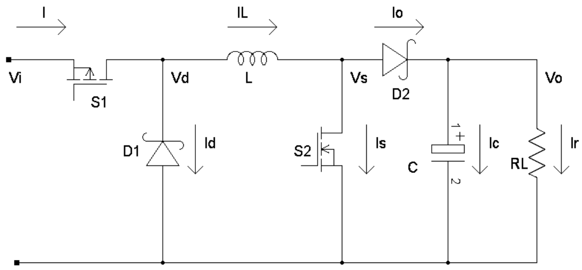

Fig. 7. Functional circuit of Buck-Boost Converter

4.4 Cuk Converter

Cuk converter is a energy storing and transferring converter. It consists of capacitor instead of inductor. The duty cycle is calculated by equation:

$$D = \frac{V_o}{V_o - V_i}$$

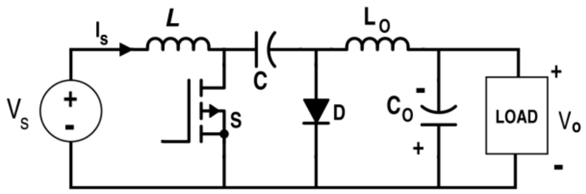

Fig. 8. Functional circuit of Cuk Converter

V. CONCLUSIONS

This paper concerns with review of DC-DC buck, boost, buck-boost and cuk converters to operate PV system for maximum power extraction. The input voltage is settled near to V_{MPP} where solar PV delivers maximum power. With the help of PWM technique duty cycle is kept corresponding to maximum power point. These converters can easily implement with any of maximum power point tracking technique for changing environmental condition.

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