DESIGN OF BUCK-BOOST CONVERTER FOR SOLAR FED AC MOTOR

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ABSTRACT

This research paper focuses particularly the design and simulation of buck boost converter. It includes the theoretical derivations and parameters equations with design and examples. Simulation results for buck boost converter are shown on the behalf of input parameters. In this project we have done analysis of equations of a buck boost converter and proposed the design of components and simulation of the converter. Changing the values of switching frequency and duty cycle for observing the changes in output voltage has been added with simulation graph. Simulation procedures in PSIM are also added in this paper. We have achieved performance parameter equations for this converter. The design and investigation of this converter is completed through mathematical examples and we have generated the circuits for simulating buck boost converter. We have also achieved different output voltage curves with respect to change in input parameters. The output graphs for this converter are all appropriate.

Keyword : *AC Motor, Arduino Uno, Buck-Boost Converter, Design, Driver, MOSFET, PSIM.*

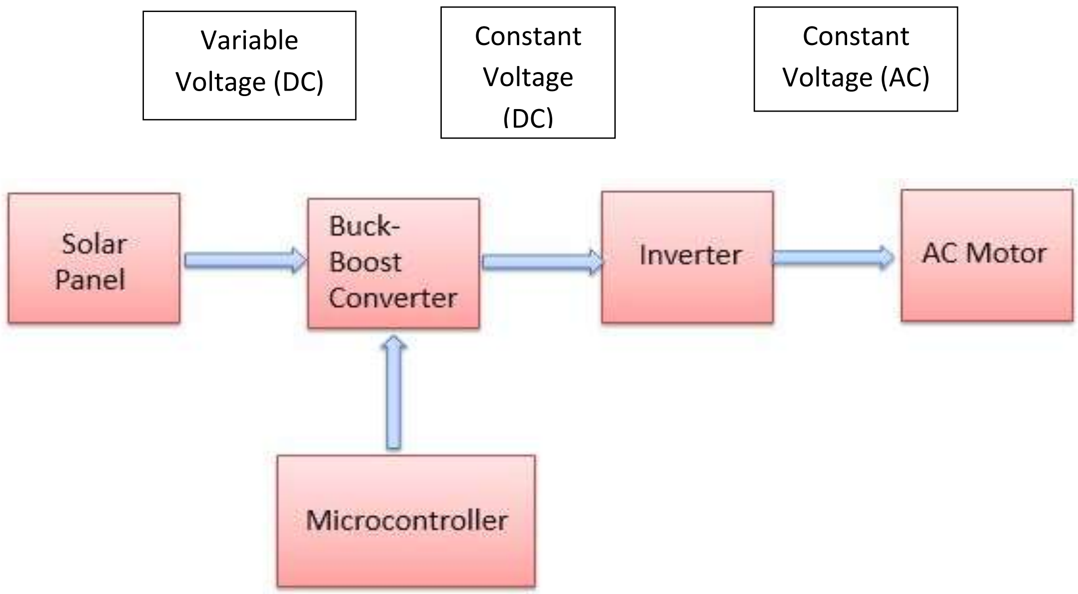
I. INTRODUCTION

World is moving towards the renewable power sources which produces less pollution and promising reliable energy generation for example solar base power generation. Applications of DC/DC Buck-Boost converter are wide, it includes electric vehicles, PV systems, fuel cell, power supplies etc. with high switching frequency.

For the control of electric power, the conversion of electric power from one form to another is necessary and the switching characteristics of the power devices permit these conversions. The static power converters perform these functions of power conversion. Primarily a continually increasing demand from power systems has placed power consumption. To carry on with these demands we have worked towards developing efficient conversion techniques and also have resulted in the posterior formal growth of an interdisciplinary field of power electronics [1].

A buck boost converter is a DC/DC converter which provides an output voltage that may be less than or greater than input voltage. The polarity of output voltage is opposite to that of input voltage. This converter is also known as inverting regulator [1]. The output of solar panel is input for buck boost converter. This converter consists of dc voltage input source from solar panel Vs, controlled switch S, inductor L, diode D, filter capacitor C and load resistance R.

II. Proposed Block Diagram



Solar panel gives variable DC voltage output. This voltage is given to buck-boost converter which gives constant voltage output to battery which is getting charged. Battery fed supply to inverter which converts this constant DC voltage to constant AC voltage which is given to AC motor.

III. System Description

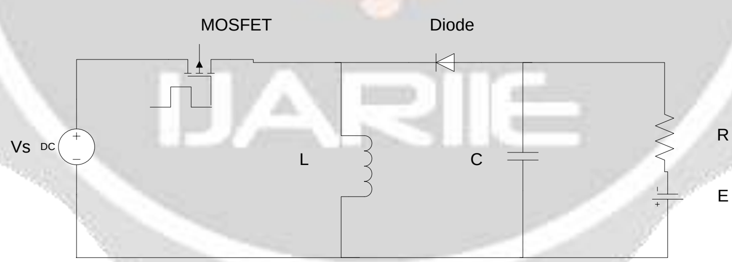


Fig. 1: Buck-Boost Topology

Buck-Boost converter consists of 3 circuits:

1. Power Circuit
2. Driver and Isolation Circuit
3. Control Circuit

3.1 Power Circuit

The power circuit is dependent on the switching frequency as the inductor design is dependent on switching frequency. The variation in the inductor might cause the output voltage to be unstable.

3.1.1 Selection for Switching Frequency

The frequency must be high enough to make power circuit small and minimize distortion. At the same time, it should be low enough to keep efficiency high. Meeting these criteria, switching frequency of 31 kHz has been selected.

3.1.2 Inductor Design

- Load Resistance: $R = \frac{V^2}{P} = \frac{12^2}{12\times 2} = 6\ \Omega$
- Required Output Voltage: V_0 = 12 V
- Required Battery Charging Current: I_0 = 2 A

For Boost Mode:

- Input voltage: V_s = 9 V
- Frequency: F = 31372.55 Hz

ΔI_L = 35% of output current = 35% × 2 = 0.7 A

$$V_0 = \frac{V_s \times \alpha}{1-\alpha}$$

$$\therefore\ \alpha = 60\ \%$$

$$\therefore L = \frac{V_0 \times (1-\alpha)}{\Delta I_L \times F}$$

$$\therefore L = \frac{12\ (1-0.6)}{0.7 \times 31372.55}$$

∴ L = 220 μH

For Buck Mode:

- Input Voltage: V_s = 15 V
- Frequency: F = 31372.55 Hz

ΔI_L = 48.65% of output current = 48.65% × 2 = 0.973 A

$$V_0 = \frac{V_s \times \alpha}{1-\alpha}$$

$$\therefore\ \alpha = 44\ \%$$

$$\therefore L = \frac{V_0 \times (1-\alpha)}{\Delta I_L \times F}$$

$\therefore L = \frac{12\,(1-0.44)}{0.973 \times 31372.55}$

∴ L = 220 μH

3.1.3 Capacitor Design

For Boost Mode:

- Input voltage: V_s = 9 V
- Frequency: F = 31372.55 Hz
- ΔVc = 3.82 V
- $\alpha = 60\ \%$
- I_0 = 2 A

$\therefore C = \frac{I_0 \times \alpha}{\Delta Vc \times F}$

∴ C = 10 μF

For Buck Mode:

- Input Voltage: V_s = 15 V
- Frequency: F = 31372.55 Hz
- ΔVc = 2.80 V
- $\alpha = 44\ \%$
- I_0 = 2 A

$\therefore C = \frac{I_0 \times \alpha}{\Delta Vc \times F}$

∴ C = 10 μF

The values of L and C are taken greater than calculated values. As above formulae are for critical condition and buck-boost converter is in continuous mode, values are considered greater.

3.1.4 Fast Recovery Diode

As switching frequency is 31 kHz, Diode should have enough recovery time to change its state from previous state. Also the voltage drop across the diode should be minimum to enhance the efficiency of system. Thus ultra-high recovery and more efficient diodes are required for systems with switching frequency greater than or equal to 31 kHz.

3.1.5 Selection of Switch

As its operating temperature is 175$^{\circ}C$, MOSFET can be switched at much higher frequencies. The limit on this is caused by two factors: transit time of electrons across the drift region and the time required to charge and discharge the input Gate and electrolytic capacitances. MOSFET is superior to BJT as its switching time is less hence switching losses are less at particular frequency. MOSFET is faster and more energy efficient switch. So MOSFET IRF530PbF is used as a switching device.

3.2 Driver and Isolation circuit

As Microcontroller is unable to provide sufficient amount of current to drive the MOSFET, driver is used to enhance the current capability. IR2110 can support switching frequency more than 100 KHz. It can drive both high side and low side MOSFET simultaneously. It can supply maximum 2A current which have disadvantage that it does not provide ground isolation. To provide ground isolation we have selected opto-coupler TLP250 which provide isolation between microcontroller and power board.

Opto-coupler TLP250 has features like Choice of CMR performance of 15 kV/μs, 5 kV/μs, and 1000 V/μs. +5 V CMOS compatibility, Low input current capability of 5 mA.

3.3 Control circuit

In DC-DC converters, the average DC output voltage should be controlled to equal with desired level, though input voltage and load may fluctuate. Switched mode DC-DC converters utilize one or more switches to transform DC from one level to another. One of the methods for controlling the output voltage employs switching at a constant frequency and adjusting duty cycle of switch to control the average DC output voltage; this method is known as Pulse Width Modulation (PWM) switching.

The Arduino UNO is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital I/O pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC to DC adapter or battery to get started. It can provide required stability for controlling duty cycle of PWM generation.

3.3.1 Arduino Voltage Sensor Module

This module is based on resistance points pressure principle, and it can make the input voltage of red terminal reduce 5 times of original voltage. The max Arduino analog input voltage is 5 V, so the input voltage of this module should be not more than 5 V x 5 = 25 V (if for 3.3 V system, the input voltage should be not more than 3.3 V x 5 = 16.5 V). Because the Arduino AVR chip have 10 bit AD, so this module simulation resolution is 0.00489 V (5 V / 1023), and the input voltage of this module should be more than 0.00489 V x 5 = 0.02445 V.

IV. SOLAR PANEL

Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat. The sun is the most abundant and unlimited source of energy. The sun functions as a global source of energy and has tremendous potential. As a result, solar energy is one of the most important non-conventional sources of energy that are utilized in India. The output of solar panel periodically changes as per sun radiations and hence it produces variable DC voltage. This variable output voltage is given to buck-boost converter to get constant DC voltage. Our solar panel gives output power 75 W, output voltage 21 V and output current 4.5 A.

V. INVERTER

An inverter converts fixed DC voltage to a variable AC voltage. The output may be a variable voltage and variable frequency. Inverters find wide use in induction motor and synchronous motor drives and UPS etc. The DC power input to the inverter is obtained from buck-boost converter. The AC power output is then given to AC machines.

Table 1: System parameter

Table 1 describes the system parameters used for simulation as well as hardware.

Parameters	Values
Frequency	31 KHz
Inductor	220 µH
Capacitor	10 µF
Diode	1N4007
MOSFET	IRF530

VI. Simulation Results

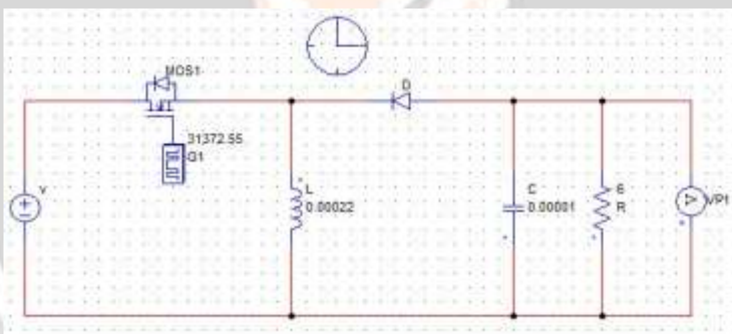


Fig. 2: Circuit Diagram of Buck-Boost Converter in PSIM software.

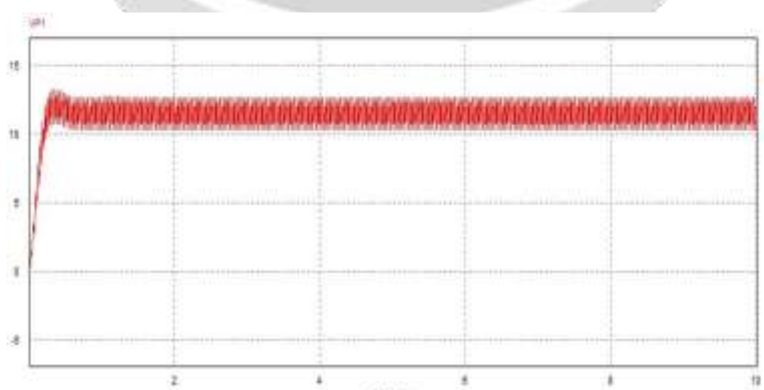


Fig. 3: Output for 15 V Input (Buck Mode)

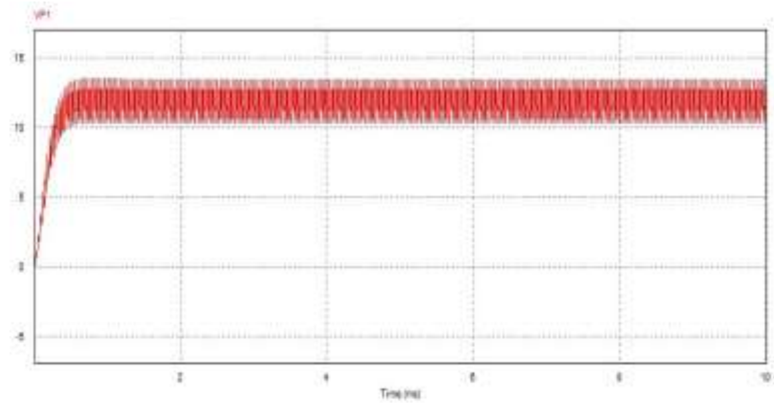


Fig. 4: Output for 9 V Input (Boost Mode)

VII. CONCLUSION

The demand for a buck-boost converter is increasing day by day as demand for charging from solar panels grows. From the simulation results it is found that in case of buck-boost converters, the desired output voltages can be obtained by selecting proper values of inductor, capacitor and switching frequency. This project gives the opportunity to study new skills and increase practical knowledge in circuit designing and problem solving skills which has greatly improved knowledge and understanding through the education route which may help us to progress in electrical and electronics.

VIII. REFERENCES

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