

Design And Development Of Buck and Boost DC-DC Converters with LC filter For BLDC Motor Used In Electric Vehicle

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Abstract: This paper presents design and development of buck and boost converter for BLDC motor used in electric vehicle. An electric vehicle working with BLDC motor energized from battery with the help of buck and boost converter, in which battery is used as source of energy. Present work portray 24V battery is used to run the BLDC motor using buck and boost converters. If the battery is completely charged the voltage of the battery is more than 24V and if the battery is low, then the voltage is below 24V. This high and low voltage condition of the battery will affect the motor drives. Using DC-DC converters we can supply constant voltage and current to BLDC motor for its smooth running.

Index Terms - DC-DC converter, Buck Converter, Boost Converter, Buck-Boost Converter, Buck-Boost regulator.

I INTRODUCTION

Now a day's electric vehicles play a major role in the world economy. All the developed and developing countries planned to adopt electric vehicles in their transportation system. The main constituent of the electric vehicle is motor and the battery. To smooth run of a motor we have to provide proper energy. Sometimes the supplied energy may contain harmonics, ripple voltage and glitches. Due to the effect of above, motor and motor drives not functioning properly. This will end up with drain of source energy.

To avoid the effects of voltage and current, we have to provide constant energy to the motor for its smooth rotation. This leads to improve in the performance of the battery and motor. To improve the lifespan of motor and battery dc-dc converters plays a major role. By using the dc-dc converters the efficiency of the motor and battery will be increased. The overall effects will increase the performance of the electric vehicle.

Below block diagram will help to know the working of buck and boost converters for the application of electric vehicles.

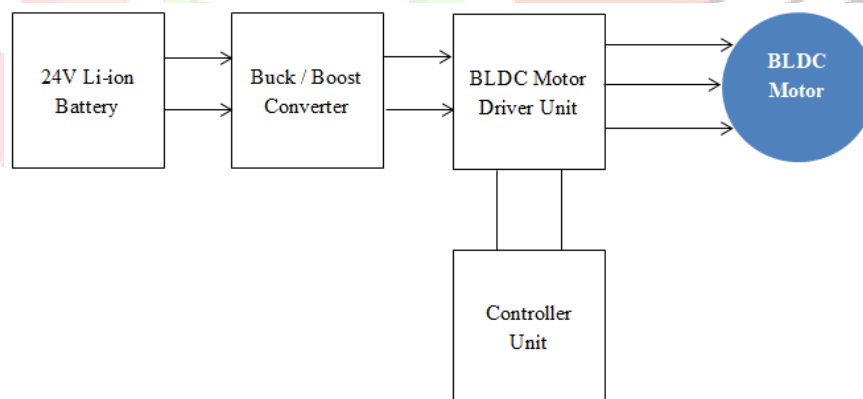


Fig. 1. Block Diagram of Buck-Boost Converter For BLDC Motor Used In Electric Vehicle.

In this work we are using 24v battery as a source of energy for the BLDC motor, if the battery is completely charged the available voltage is more than 24v (i.e. >28v). If the battery is in less charged or low then the voltage in battery is less than 24v (i.e. >20v<24v). The smooth working of the BLDC motor requires 24v, if the voltage is more or less than 24v, which causes on motor drives and it leads to failure of the drivers. The temperature of the motor increases due to increase or decrease in the voltage. To avoid the voltage & Current fluctuation we use dc-dc converters.

Here we are using buck converter to reduce the voltage during full charge condition and boost converter to boost the voltage during low charge condition. While using the dc-dc converters due to physical and other conditions harmonics or glitches will be available in the converter outputs. To reduce the harmonics or glitches in the output, here we are using LC filter for smooth DC output. The inductor and capacitor filters will help us to remove the glitches in the dc output and this will increase the efficiency of the BLDC motor.

The overall activity will be controlled by the micro controller. Switching of the MOSFET's in the driver circuit done accordingly as per the control signals of the microcontroller.

II DESIGN OF BUCK CONVERTER:

The buck converter is shown in the figure 1.1, the output voltage of the converter is always less than the input voltage. In the buck circuit, the transistor switch Q1 is placed in series with the DC input voltage. The transistor Q1 interrupts the DC input voltage providing a variable width pulse, to a simple average LC filter. When the transistor switch Q1 is closed, the DC input voltage is applied across the output filter inductor L1, and the current flows through the inductor to the load. When the switch is open, the energy stored in the field of the inductor L1 maintains the current through the load.

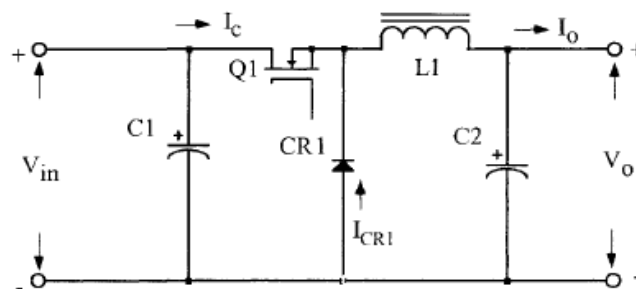


Fig. 2. Buck Converter Schematic for BLDC Motor Used In Electric Vehicle.

Duty cycle can be calculated by

$$D = \frac{V_{out}}{V_{in}}$$

Critical Inductance L_c Can be calculated by

$$L_c = \frac{(1-D)R}{2f} \text{ in Henry}$$

Critical Capacitance C_c Can be calculated by

$$C_c = \frac{1-D}{16f^2L} \text{ in Farad}$$

The Inductance and Capacitance of the buck converter is always greater than the critical values.

Parameters used for simulation of circuit:

- $L = 1\text{mH}$ ($L > L_c$)
- $C = 1000\mu\text{F}$ ($C > C_c$)
- $R \text{ Load} = 2.4 \Omega$
- DC Input for Buck Converter = 28V
- DC Output from Buck Converter = 24.06V
- Output Current = 10.03A

III DESIGN OF BOOST CONVERTER:

The boost converter is shown in the figure 1.2, the output voltage of a converter is always greater than the input voltage. The boost converter stores energy in the inductor L1 and then delivers the stored energy along with the energy from the DC source to the load. When the transistor switch Q1 is closed current flows through the inductor L1 and transistor switch Q1, charging inductor L1, but does not deliver any current to the load. When the switch is open, the voltage across the load equals to the DC input voltage plus the energy stored in the inductor L1. The energy stored in L1 then discharges, delivering current to the load.

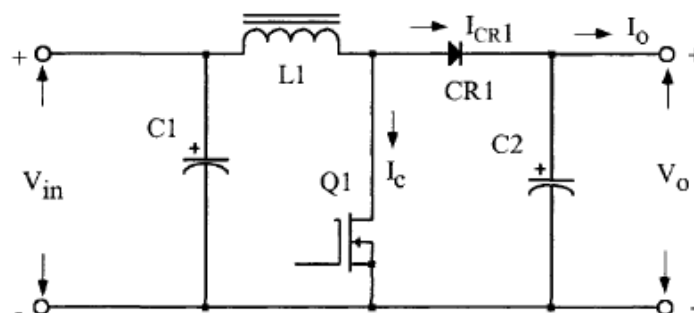


Fig. 3. Boost Converter Schematic for BLDC Motor Used In Electric Vehicle.

Duty cycle can be calculated by

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

Critical Inductance L_c Can be calculated by

$$L_c = \frac{(1-D)DR}{2f} \text{ in Henry}$$

Critical Capacitance C_c Can be calculated by

$$C_c = \frac{D}{2Rf^2} \text{ in Farad}$$

The Inductance and Capacitance of the boost converter is always greater than the critical values.

Parameters used for simulation of circuit:

- $L = 1\text{mH}$ ($L > L_c$)
- $C = 1000\mu\text{F}$ ($C > C_c$)
- $R_{\text{Load}} = 2.4\ \Omega$
- DC Input for Boost Converter = 21V
- DC Output from Boost Converter = 24.35V
- Output Current = 10.14A

IV CIRCUIT DESIGN

Motor Specification

- Voltage = 24VDC
- Current = 10A
- Resistance = 2.4 Ω
- Power = 240W
- RPM = 2300

Buck Converter

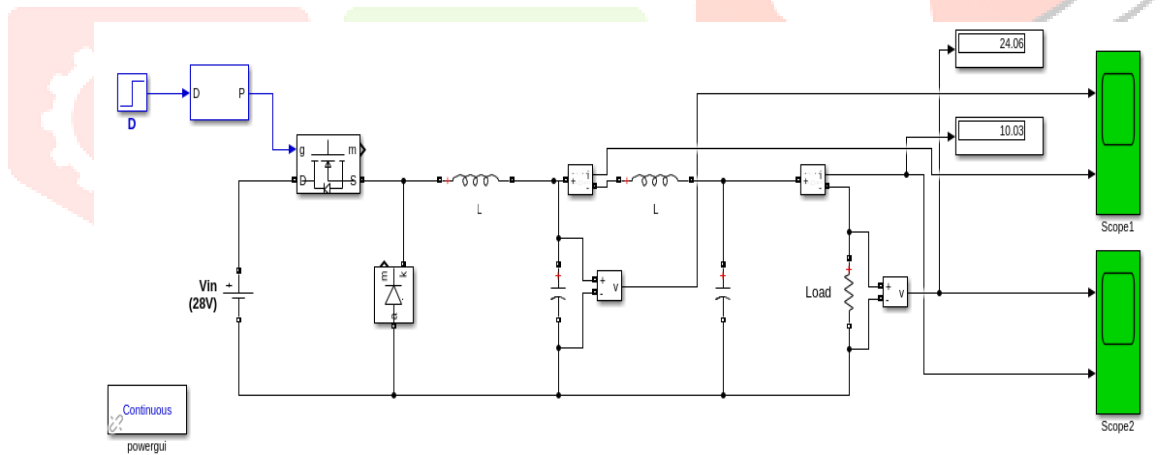


Fig. 4. Buck Converter with LC filter for R Load.

Boost Converter

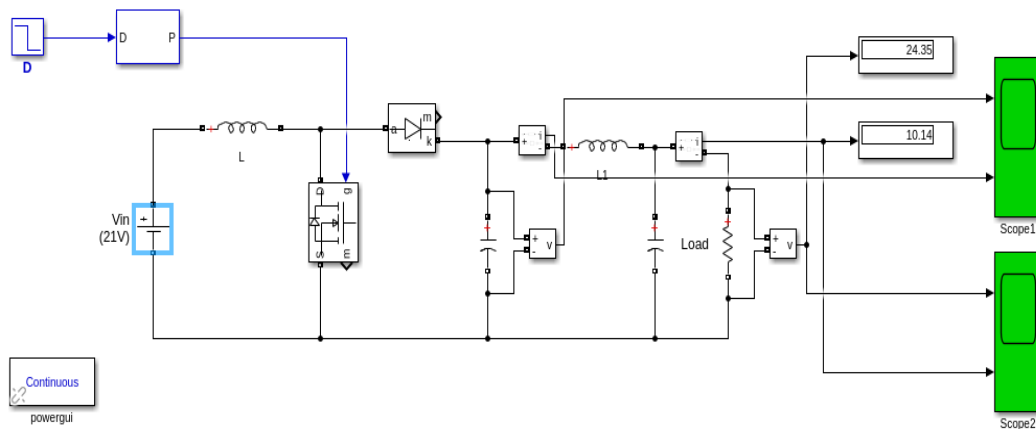


Fig. 4.1. Boost Converter with LC filter for R Load.

In this work the model has been created and simulated with Simulink/Matlab Software. The Buck and Boost converter is constructed with MOSFET, Diode, Inductor and Capacitor for Load Resistor along with LC filter. The buck converter is to step down the input voltage and current available from the source. Boost converter is to step up the input voltage and current available from the source.

The main working principle of buck and boost converter is that the inductor in the input circuit resists sudden variations in input current. When switch is ON the inductor stores energy from the input in the form of magnetic energy and discharges it when switch is closed. The capacitor in the output circuit is assumed large enough that the time constant of RC circuit in the output stage is high. The large time constant compared to switching period ensures that in steady state a constant output voltage $V_o(t) = V_o(\text{constant})$ exists across load terminals. LC filter removes the available glitches at the output of the converters, this leads to get the constant DC at the output.

V RESULTS

Buck Converter Output Results

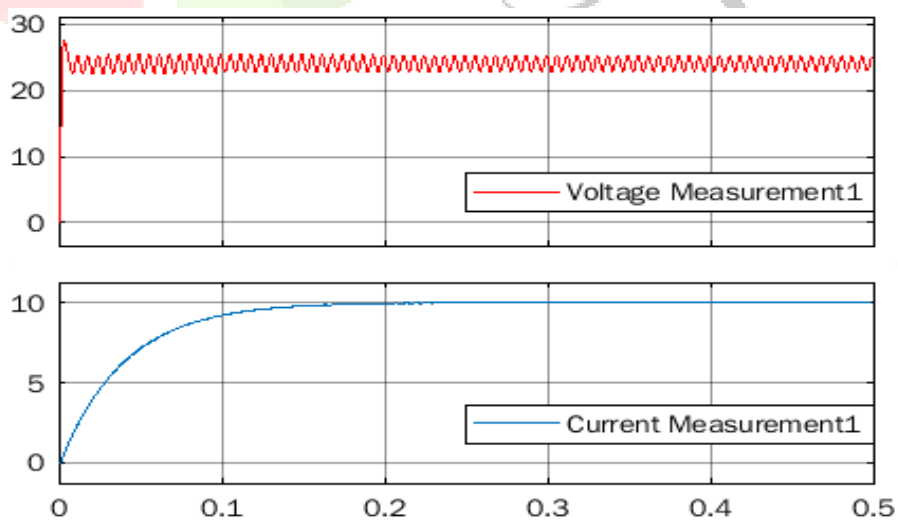


Fig. 5. Output voltage and current waveform of buck converter without LC filter.

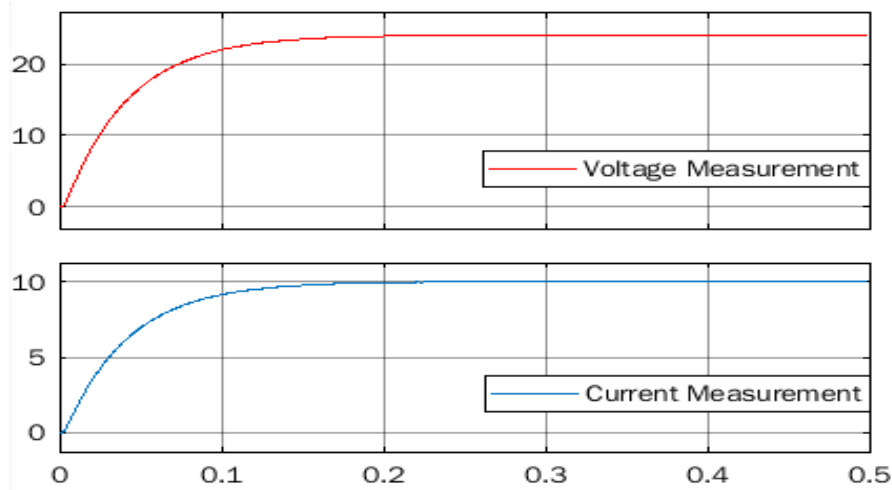


Fig. 5.1. Output voltage and current waveform of buck converter with LC filter.

Boost Converter Output Results

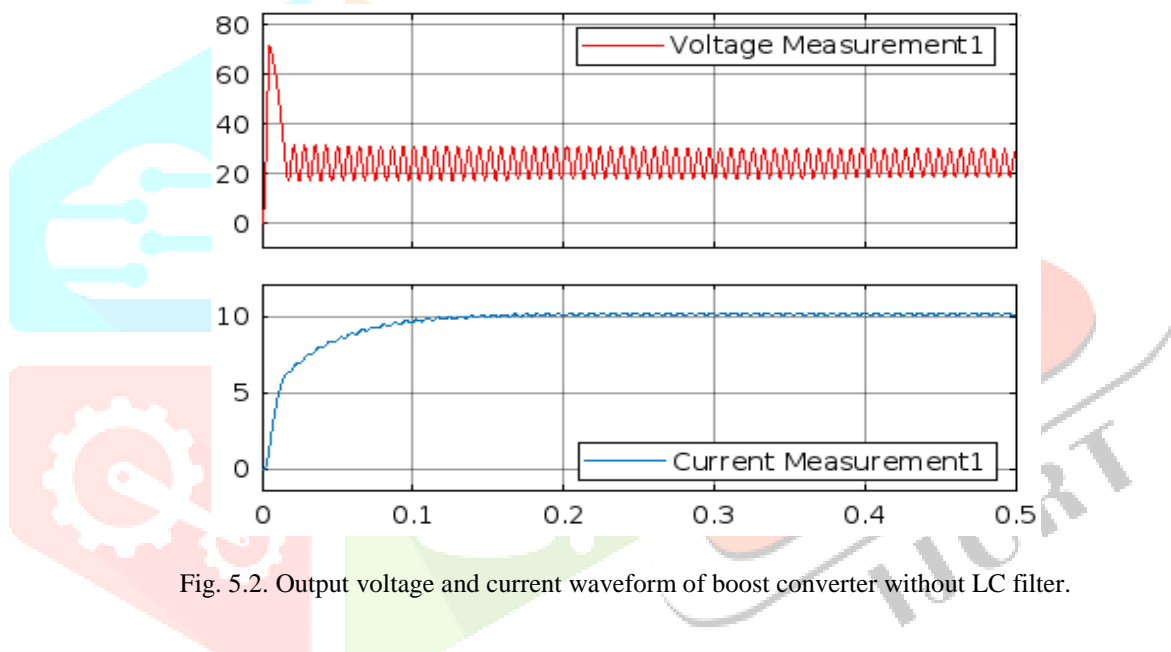


Fig. 5.2. Output voltage and current waveform of boost converter without LC filter.

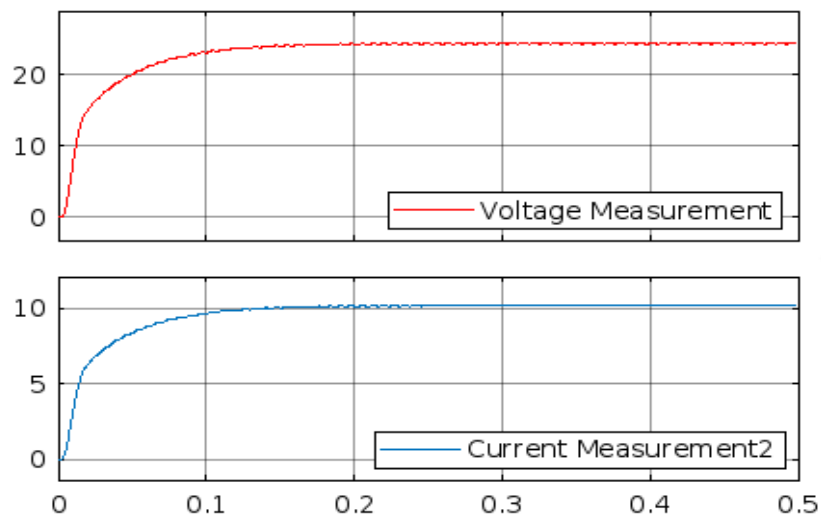


Fig. 5.3. Output voltage and current waveform of boost converter with LC filter.

The buck converter the output voltage v/s time has been measured using Simulink and shown in Fig. 5 and 5.1. Simulation carried out by initializing 180KHz as frequency. By the simulation we are getting DC 24.06V & 10.03A constant output. For boost converter also the output voltage v/s time has been measured using Simulink and shown in Fig. 5.2 and 5.3. Simulation carried out by initializing 180KHz as frequency. By the simulation we are getting DC 24.35V & 10.14A constant output.

VI CONCLUSION

The output response of a Buck and Boost converter with and without LC filter for BLDC Motor has been simulated. The simulated result is studied and this work is proposed to use for electric vehicles under low and high voltage conditions of the battery.

REFERENCES

- [1] Norazila Binti Md Posdzi¹, Norsa'adah Binti Mahmor¹, Rasidah Binti Abdul Rani¹ "Design buck converter with variable switching frequency by using matlab simulink simulation" IJSRD - International Journal of Technology, Innovation & Humanities | Vol. 1, No. 1, 2020, pp, 1-6.
- [2] Atul Kumar and Prerna Gaur, "Operation of DC/DC Converter for Hybrid Electric Vehicle" International Journal of Electronic and Electrical Engineering. ISSN 0974-2174, Volume 7, Number 4 (2014), pp. 335-340.
- [3] Noori Bawi Dawood, "Review of Different DC to DC Converters Based for Renewable Energy Applications" International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056 Volume: 03 Issue: 03 | Mar-2016 www.irjet.net p-ISSN: 2395-0072.
- [4] Ozwin Dominc Dsouza, Manjunatha Babu P, Babu Naik G, Shilpa G, "7.5W Current Mode Control Of Isolated Flyback Converter" International Journal of Informative & Futuristic Research (IJIFR), Volume - 3, Issue -7, March 2016, Continuous 31st Edition, Page No.:2634-2648, ISSN: 2347-169.
- [5] B.J. Jayareshma*, N. Preethi and N. Kumar "Hybrid Multi-Port Converter Based Electric Vehicles Using Renewable Energy with Microcontroller" Journal of Environmental Science, Computer Science and Engineering & Technology An International Peer Review E-3 Journal of Sciences and Technology, JECET; March 2014-May 2014; Vol.3.No.2, 1048-1060. E-ISSN: 2278-179X.
- [6] Jaw-Kuen Shiau and Chien-Wei Ma, "Li-Ion Battery Charging with a Buck-Boost Power Converter for a Solar Powered Battery Management System "Energies 2013, 6,1669-1699;doi:10.3390/en6031669.
- [7] Ananda A S, Manjesh "Analysis and Study of Total Harmonic Distortion in Five Phase PWM Inverter using LC filter with neutral point DC link capacitor voltage balancing scheme", International Conference on Magnetic, Machines and Drives- 2014.
- [8] Hybrid Electric Vehicle Solutions by TEXAS INSTRUMENTS.
- [9] Lisa Dinwoodie "Isolated 50 Watt Flyback Converter Using the UCC3809 Primary Side Controller and the UC3965 Precision Reference and Error Amplifier".
- [10] Nisha Kasundra, Ankit Kumar, "Design and Simulation of Flyback Converter in MATLAB using PID Controller" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 5, Issue 2, February 2016.