Designing of DC To DC Converter For Electric Vehicle

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Abstract- *This paper focuses especially on the designing of dc-dc converters. Topologies of dc-dc converter are discussed and simulation results are shown.*

Keywords- DC to DC Converter (DC-DC), Electric Vehicles, Simulation, Ancillary Loads, MATLAB, Switching Regulator.

I. INTRODUCTION

The large number of automobiles in use around the world has caused and continues to cause serious problems of environment and human life. Air pollution, global warming, and the rapid depletion of the earth's petroleum resources are now serious problems. Electric Vehicles (EVs) have been typically proposed to replace conventional vehicles in the near future. DC-DC converters are often wont to interface the elements within the electrical power train by boosting or chopping the voltage levels. Converter steps down battery voltage to provide required voltage to ancillary loads in electric vehicle. Due to the automotive constraints, the power converter structure has to be reliable, lightweight, small volume, with high efficiency, low electromagnetic interference and low current/voltage ripple. Thus, in this paper we will study step down dc-dc converter topologies.

II. BLOCK DIAGRAM

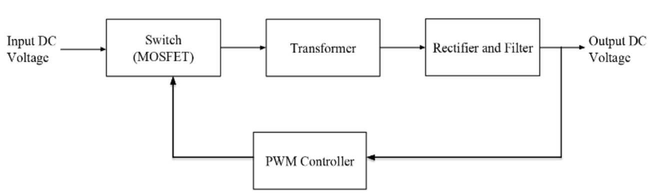

Fig 1: DC-DC Converter Block Diagram

The dc converters are often used as switching mode regulators to convert a dc voltage, usually unregulated, to a regulated dc output voltage. The regulation is generally achieved by PWM at a set frequency and therefore the switching driver is generally BJT, MOSFET, or IGBT. The power regulator are often inductor based, switch-mode power converter, a switch capacitor charge pump or a linear regulator.

III. TOPOLOGIES OF DC-DC CONVERTER

There are different topologies of switching-mode regulators, In this paper we focuses especially on step down topologies of dc-dc converter :

- Buck Converter
- Flyback Converter
- Forward Converter
- Half-Bridge Converter
- Full-Bridge Converter

3.1 Buck Converter :

A buck converter is a step down dc-dc converter consisting primarily of inductor and two switches (generally a transistor switch and diode) for controlling inductor. It fluctuates between connection of induction to source voltage to mount energy in inductor then discharging the inductor's energy to the load.

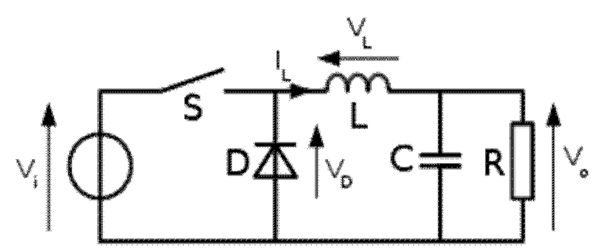

Fig 2 : Buck Converter Circuit

When the switch pictured above is closed (i.e., On-state), the voltage across the inductor is VL= Vi- Vo. The current flowing through inductor linearly rises. The diode doesn't allow current to flow through it, since it's reverse-biased by voltage. For Off case (i.e., when switch pictured above is opened), diode is forward biased and voltage is VL= -Vo (neglecting drop across diode) across inductor. The inductor current which was rising in ON case now decreases.

3.2 :Flyback Converter :

Flyback converter is a versatile topology which can be used where multiple outputs are needed from a single output supply. Not only that, a flyback topology allows the designer to change the polarity of the output at the same time. In Flyback converter electrical isolation is in both input and output.

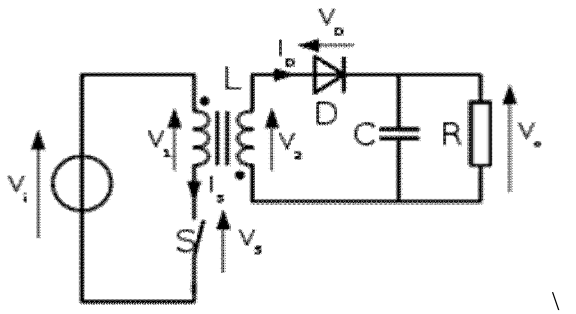

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Fig 3 :Flyback converter circuit

When the switch is closed the primary of the transformer is directly connected to the input voltage source.The primary current and magnetic flux in the transformer increases, storing energy in the transformer. The voltage induced within the secondary coil is negative, therefore the diode is reverse-biased.The output capacitor supplies energy to the output load.

When the switch is opened the primary current and magnetic flux drops. The secondary voltage is positive, forward-biasing the diode, allowing current to be due the transformer. The energy from the transformer core recharges the capacitor and supplies the load.

3.3 : Forward Converter :

The forward converter is a DC/DC converter that uses a transformer to increase or decrease the output voltage (depending on the transformer ratio) and provide galvanic isolation for the load. With multiple output windings, it's possible to supply both higher and lower voltage outputs simultaneously.While it's superficially sort of a flyback converter, it operates in a very fundamentally different way, and is generally more energy efficient.

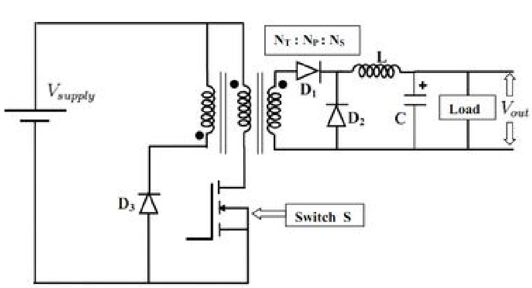


Fig 4 : Forward converter circuit

Forward Converter Circuit consists of a control circuit which features a high speed switching device, a transformer whose primary side is connected to the feedback loop and secondary side is connected to the filtering circuit. The rectified output from the transformers secondary winding is connected to the load.As per the above block diagram, when the switch is turned ON, the input is applied to the primary winding of the transformer and a voltage is appeared at the secondary winding of transformer. Therefore, the dot polarity of the windings of transformer is positive, due to this the diode D1 gets forward biased. Then the output voltage of the transformer is fed to the low pass filter circuit which is connected to the load. When switch is turned OFF, the current in the windings of transformer comes down to zero (assuming the transformer to be ideal).

3.4 : Half-Bridge Converter :

A half-bridge converter is a type of DC-DC converter that, like flyback and forward converters, can supply an output voltage either higher or lower than the input voltage and provide electrical isolation via a transformer. Although more complex than a flyback or forward converter, the half-bridge converter design can yield higher output power (potentially up to 500W) and use parts that are smaller and less expensive.

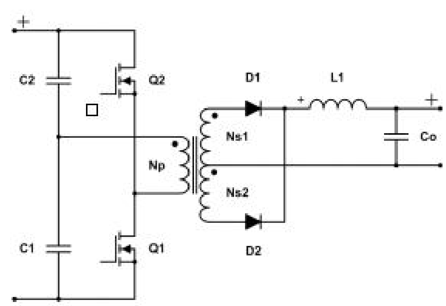


Fig 5 : Half-Bridge converter circuit

The primary side capacitors are wont to produce a continuing mid-point voltage – half the input voltage – across the primary winding. This means that the switching elements need only withstand half the voltage that those of an equivalent forward converter must handle.The converter’s two switching elements alternate back and forth, switching the voltage (0.5 Vin) across the primary winding. The primary therefore experiences a positive and negative voltage swing, which necessitates a full-wave bridge circuit for the output. This is an advantage of half-bridge converters; they fully utilize the core flux and the secondary winding.Additionally, due to its full-wave nature, the secondary side of the circuit operates at twice the frequency of the essential switching frequency. This allows for the inductor and capacitor on the secondary side to be much smaller than a forward converter, saving cost and space.

3.5 : Full-Bridge Converter :

A full bridge converter is one among the commonly used configurations that provide isolation additionally to stepping up or down the input voltage. Other functions may include reversing the polarity and providing multiple output voltages simultaneously.

Bridge converter has three main stages:

1. The Square wave generator

2. Energy transfer network

3. Rectifier network

The basic circuit consists of 4 active switching devices like MOSFETs, IGBTs, Bipolar transistors or thyristors, and their associated drive circuits. In the isolated bridge converter, a transformer is employed to supply isolation additionally to stepping up or down of the voltage. MOSFETs are widely used for the high power bridge converters because of their simple and low power gate drive circuits as compared to the bipolar transistors.

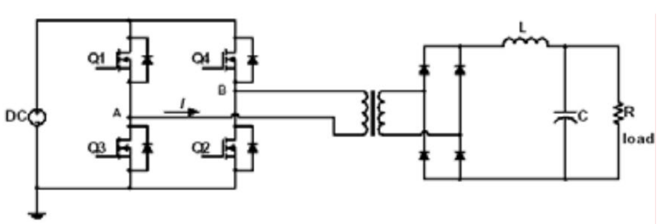


Fig 6: Full-Bridge converter circuit

The two pairs of MOSFETS are wont to drive the transformer primary symmetrically. Q1 and Q4 conduct in first switching period and therefore the other pair of transistors Q2 and Q3 conduct during subsequent one. As one pair conducts, the other one remains in the off state. The output voltage is decided by the transistor duty cycle, the transformer's turn's ratio, input voltage. As full bridge output is controlled by unipolar switching using four switching devices, care must be taken to avoid DC within the transformer since these increase losses and can also saturate the transformer.

IV. DESIGN ANALYSIS OF DC-DC CONVERTERS

4.1 Performance Parameters :

There are quantities of important performance parameters which decide the output characteristics of the dc-dc converters. These parameters should be understood before designing a perfect dc-dc converter.

4.2 Operating frequency :

The operating frequency determines the performance of the switch. Switching frequency selection is generally determined by efficiency requirements. There is now a rising trend in research work and new power supply designs in increasing the switching frequencies. The higher is that the switching frequency, the smaller the physical size and component value. At higher frequencies the switching losses within the MOSFET increase, and thus reduce the general efficiency of the circuit. At lower frequencies the required output capacitance and inductor size increases, and the volumetric efficiency of the supply degrades. The trade-off between size and efficiency has got to be evaluated very carefully.

4.3 Inductor Selection :

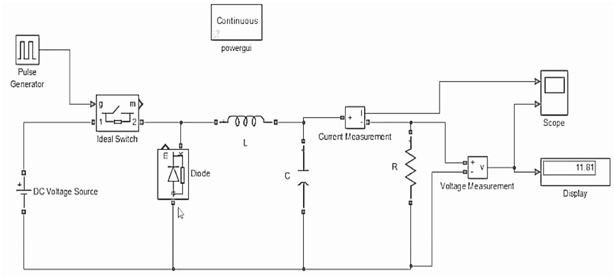
The role of the inductor is to limit the present slew rate (limit the present in rush) through the facility switch when the circuit is ON. The current through the inductor cannot change abruptly. When the current through an inductor trends to fall, it tends to sustain the current by acting as a source. This limits the otherwise high peak current that might be limited by the resistance alone. The key advantage is when the inductor is employed to drop voltage, it stores energy. Also the inductor controls the percent of the ripple and determines whether or not the circuit is working within the continuous mode

4.4 Capacitor Selection :

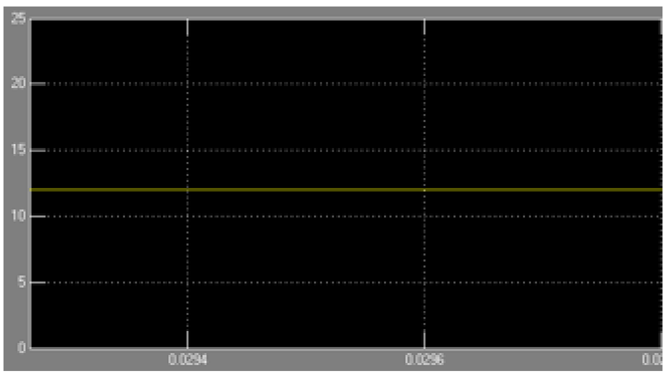
The primary criterion for choosing the output filter capacitor is its capacitance and equivalent series resistance, ESR. Since the capacitor's ESR affects the efficiency, low ESR capacitors are going to be used for best performance. For reducing ESR, it's also possible to attach few capacitors in parallel. The output filter capacitors are chosen to satisfy an output voltage ripple specifications, also because the ability to handle the specified ripple current stress.

V. SIMULATION RESULTS OF DC-DC CONVERTERS

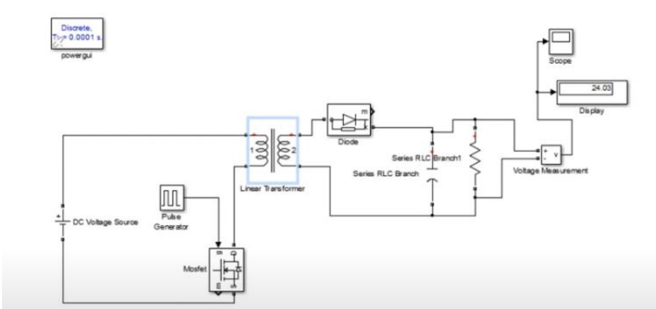
5.1 Buck Converter :



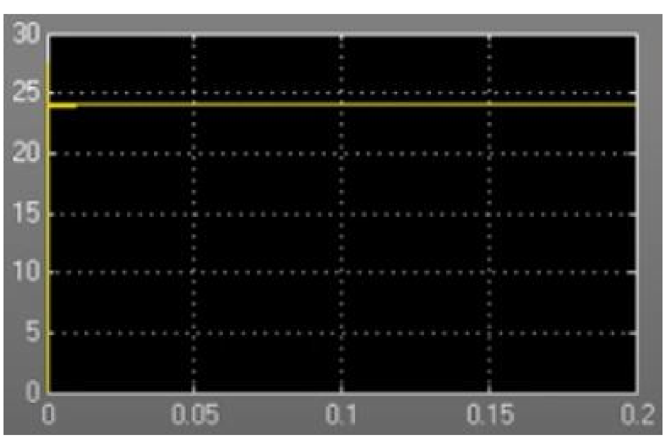
Input Voltage : 30v
Output Voltage : 12v



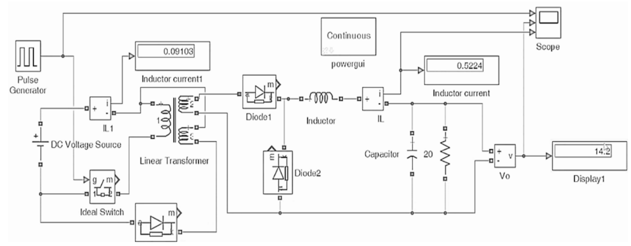
5.2 Flyback Converter :



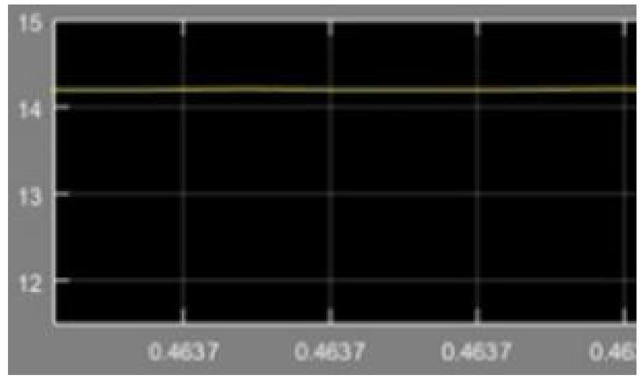
Input Voltage : 100v
Output Voltage : 24v



5.3 Forward Converter :



Input Voltage : 100v
Output Voltage : 15v



VI. CONCLUSION

From the simulation results it is found that in case of the buck, flyback, forward, half-bridge, and full-bridge converters, the desired output voltages can be obtained by selecting proper values of inductor, capacitor and switching frequency. We have studied the simulation in MATLAB of the different topologies of dc-dc converter.

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