Single Input-Multi Output Non-Isolated DC-DC Converter for Electric Vehicle Application

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***Abstract*—In a two wheeler Electric Vehicle DC-DC Converter plays a major role in stepping down the voltage of battery to feed the components of vehicle. The battery voltage 60V is stepped down to 12V to function horn and headlight. 5V is used for hall sensor and buzzer. So a buck converter of 60V/12V, 100w rating is designed to feed horn and head light of the vehicle. The designed circuit is simulated in Matlab/Simulink and results are presented.**

***Index Terms*- Single Input Multi Output DC-DC Converter, Electric Vehicle**

Nomenclature

V_s = input supply to the proposed converter
I_s = input current flow to the proposed converter
I_{L1} = current flowing through inductor L_1 of converter 1
I_{L2} = current flowing through inductor L_2 of converter 2
V_{d1} = voltage across diode D_1 of converter 1
V_{d2} = voltage across diode D_2 of converter 2
V_g = gate pulse applied to switch
V_{S1} = voltage stress across the switch
V_0 = output voltage of proposed converter
I_0 = current flowing through the load

I. INTRODUCTION

Paper [1] presents a bi-directional SIMO DC-DC buck converter for electric vehicles. This topology has three switches for two outputs and it steps down to two different voltage levels. The control strategies, design principles, and small signal analysis has been done and MATLAB/Simulink results are presented. The proposed single-input double output synchronous dc-dc buck converter [2] has low components with two dc controlled output voltages. The model is explained in detail along with control strategy and modulation approach. The simulation results are presented.

The dc–dc converter market is undergoing drastic changes because of low voltage and high power density applications. Paper [3] presents various SIMO non isolated dc–dc converters based on single switch. Integration of three level buck and boost converters whose output voltages are regulated simultaneously are shown in [4]. The voltage stress across the semiconductor device is half of the boost output voltages which results in improved efficiency.

The principle of topology synthesis in [5] states that integrated SIDO and DISO dc–dc converters developed provide good cross regulation while the number of diodes, inductors, and capacitors is reduced.

In this paper, a single input Dual output DC-DC converter is proposed for EV applications. Section I gives introduction and section II gives description of single input single output converter. Section III gives design equations. Simulation results of SISO converter are given in section IV. Proposed converter and Simulation results of SIDO converter are given in section V. Section VI gives conclusion and future scope.

II. SINGLE INPUT SINGLE OUTPUT CONVERTER

A. Power Circuit Description

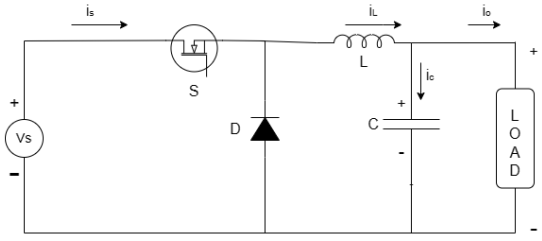

Fig 1 Power circuit diagram of Buck Converter

Figure 1 shows the power circuit of Single input single output (SISO) Converter. In this Circuit a switch, diode, inductor and capacitor is present. The Operating modes can be divided into two-modes: 1. When switch is ON, 2. When switch is OFF.

B. Modes of operation

MODE 1:

During Mode1 Switch "S" is ON state. This Mode begins when the switch S is turned ON at t = 0. The equivalent circuit is shown in Figure 2. Input current rises and flows through L, C and Load.

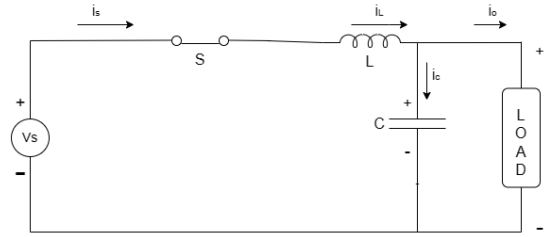

Fig 2 Mode 1of Buck Converter

MODE 2: (t_1-t_2)

In Mode 2, Switch "S" is in OFF state as indicated in figure 3. This mode begins when switch S is Turned OFF at t = t_1. Freewheeling diode D starts to conduct due to stored energy in begins to fall. This mode ends when switch is turned ON again.

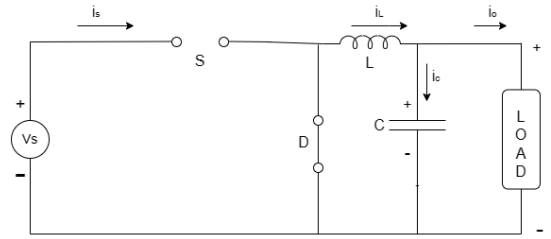

Fig 3 Mode 2 of Buck Converter

III. DESIGN EQUATIONS

The inductor is designed by

$$L = \frac{V_{in}D(1-D)}{f\Delta i_L} \quad \text{..... equation (1)}$$

The capacitor is designed by

$$C_0 = \frac{D(1-D)V_{in}}{8Lf^2\Delta V_0} \quad \text{..... equation (2)}$$

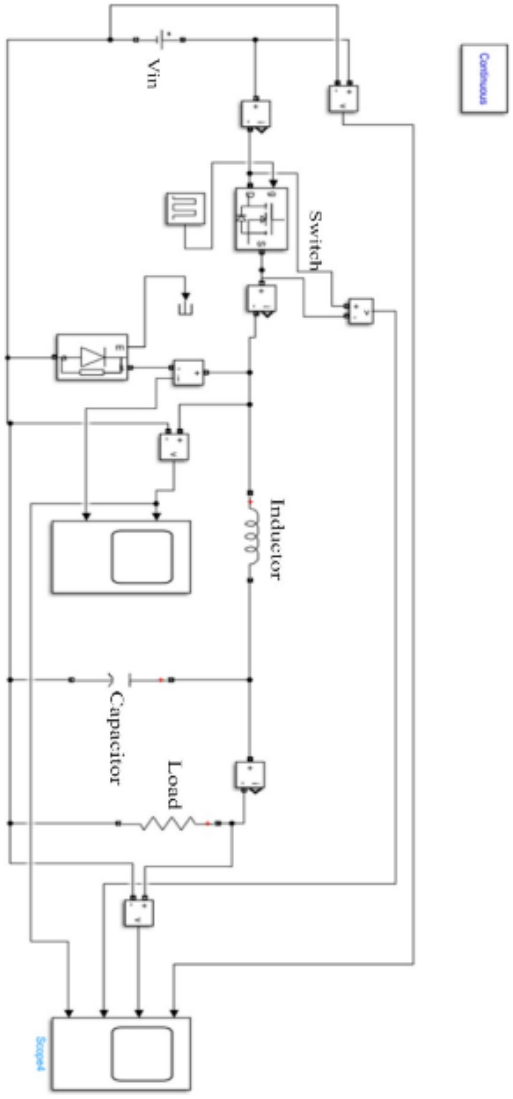

Fig 4: Matlab/Simulink circuit of SISO Converter

The voltage gain is given by

$$\frac{V_0}{V_{in}} = D \quad \text{..... equation (3)}$$

The load value is given by

$$P = VI = \frac{V^2}{R} = R = \frac{V^2}{P} \quad \text{..... equation (4)}$$

The input current is given by

$$I_1 = \frac{P_{in}}{V_{in}} \quad \text{..... equation (5)}$$

The output current is given by

$I_0=\frac{P_0}{V_0}$ ……. equation (6)

The voltage across the switch is given by

$V_S=V_{in}$ ……. equation (7)

IV. SIMULATION RESULTS

The designed Single input single output converter circuit is simulated in matlab as shown in figure 4. The parameters are input voltage =60V, output voltage = 12V, inductor, L=1mH, C=10µF. Power=100W, Switching Frequency = 50KhZ.

A. Input and output voltages, switch and diode voltages of the designed converter ($V_{in}V_0V_sV_d$)

The input and output voltage of SISO converter are taken in figure 5. For 60V input, an output of 12V is achieved. The voltage across the switch and diode is also shown. When the switch is ON, the diode is OFF and vice versa. This is clearly shown in figure 5.

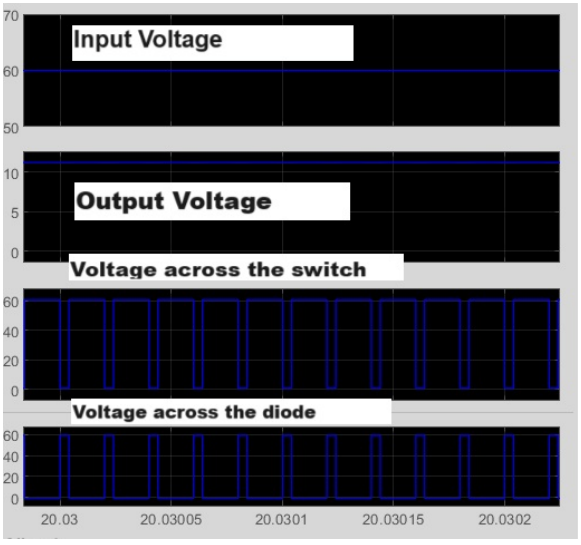

Fig 5: Input and output voltages of SISO Converter

V. SINGLE INPUT DUAL OUTPUT CONVERTER

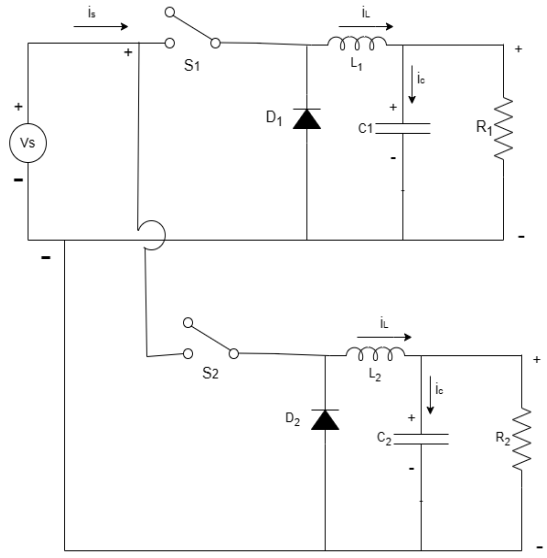

Fig 6(a): Power circuit of Single input Dual Output Buck Converter

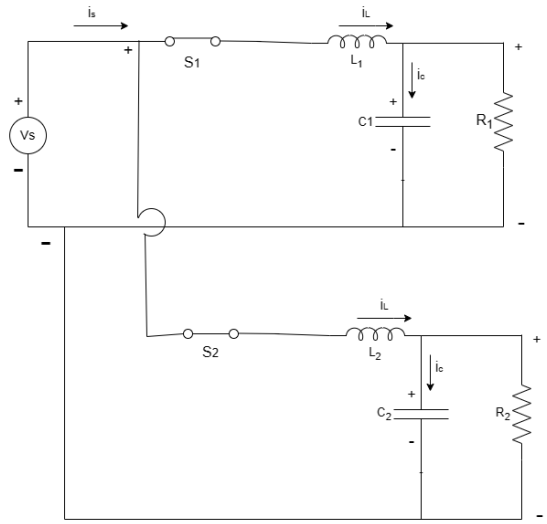

Fig 6(b): Mode 1 of SIDO buck converter

The designed buck converter in fig 4 is a single input single output converter. This converter can feed only one output at a time. In EV, we have multiple components which work on low voltage DC. Therefore, we have designed single input dual output buck converter as shown in figure 6a and its modes are shown in figure 6b and 6c which helps in functioning

two components at a time. This can be extended to multi outputs.

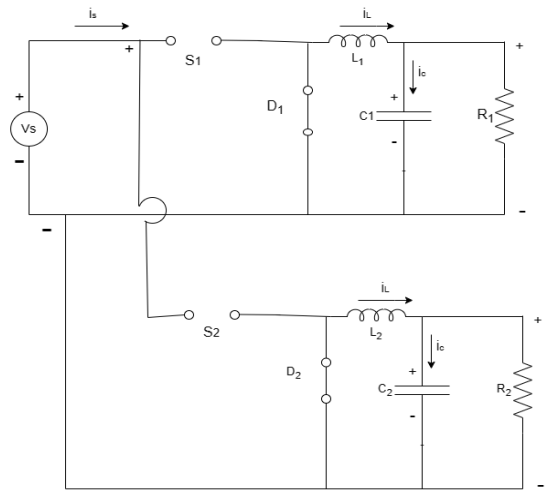

Fig 6(c): Mode 2 of SIDO buck converter

Figure 7 shows Matlab/Simulink circuit of Single input Dual Output Buck Converter. The gate pulse is applied at 50KhZ switching frequency at 0.2 duty ratio. The corresponding input and output voltages are noted along with switch and diode stress are shown in figure 8. The input for parallel converters is taken from same battery and fed to two components.

CONCLUSION

The introduction to Electric Vehicle is given at the beginning. Later the architecture of Ola S1 pro EV is discussed. A single input dual output converter is designed to feed multiple outputs in 2-wheeler electric vehicle. The simulation results of buck converter 60V/12V, 100w rating to feed horn and head light of the vehicle are presented.

FUTURESCOPE

Since Electric Vehicle usage is increasing, suitable converters are needed for 2 wheeler EV application. Single input multi output DC-DC converters are essential to meet DC components needs. Therefore more research is carried out in batteries. Also, Solar energy is abundant in nature. Solar based EVs are future to charge the battery. Suitable controller mechanisms need to be deployed for efficient use of battery.

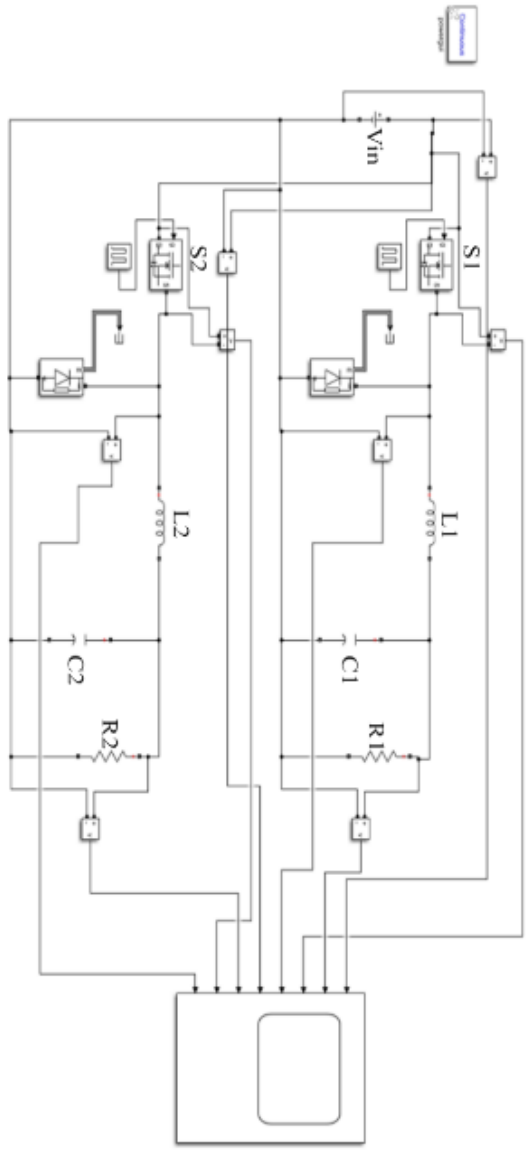

Fig 7: Matlab/Simulink circuit of Single input Dual Output Buck Converter

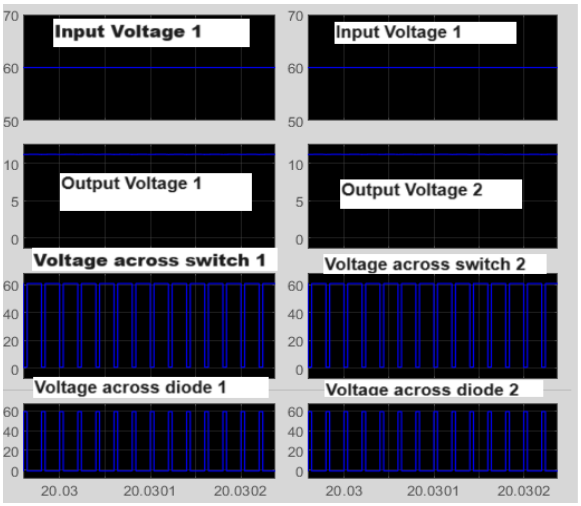

Fig 8: Input and output voltages of Single input Dual Output Buck Converter

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