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Symmetric Dual Switch Converter for DC Motor Speed Control

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ABSTRACT
In different applications, there is a need of high step-up DC-DC converters. Here introduced a high step-up DC-DC converter having dual switch and symmetrical topology that is also used for DC motor speed control. Dynamic voltage balance is also attained using this topology. Under steady and dynamic conditions, voltage is balanced across switches. Simple structure of this converter is the main advantage. But this converter needs a necessity of keeping parameter's constant. Deviations cause a huge voltage stress for both switches. A passive lossless clamp circuit can be used here to reduce the resonance. This Symmetrical dual switch converter used to drive a DC series motor at rated speed is simulated and validated in MATLAB/SIMULINK version 2017a. The converter provides a voltage gain of 9.8 for input voltage 20 V using Dspace ds1104 controller.
Keywords - DC-DC converter, high step-up, symmetric , voltage balance, voltage gain

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I. INTRODUCTION

The development in the industrial sectors and the rapid increasing population of the recent years demands the need for energy sources. Now days, non-renewable sources are used as the source for electrical energy generation. Most among them is fossil fuels. Meanwhile, the use of non-renewable resources can adversely affect the environment and it must be rectified. The renewable sources like solar, wind have to be used for the future requirements. Many researchers have attracted to this concept. Non-conventional resources are inevitable for the generation and distribution systems [2].

For the Industrial applications, including generation distribution power systems various DC-DC converters with high gain is used. High gain can be achieved by the charging and discharging operation of the converter [1]. The problem of inductance leakage can cause the spikes of voltage in the circuit. This problem can be solved by the introduction of clamp circuit. The stored energy due to the leakage is reused by the load. The diode may having the problem of reverse recovery and It also be avoided. This leakage even causes the switching losses[3].There is a need of achieving a high gain and at the same time achieving high efficiency. It is a limitation to the conventional boost converters. The converter with different operations and topology to meet the requirements of the recent applications is needed[2]. The contents of each section may be provided to understand easily about the paper.

Transformers with high frequencies demanded converters having different topology with high gain and good efficiency for their requirements. There is a chance of inductance leakage can cause the spikes of voltage in the circuit. The diode may having the problem of reverse recovery and It also be avoided. This leakage even causes the switching losses [5]. Basically, the boost converters are used widely used in such applications.

As per the theory, a boost converter is capable of creating a high gain of voltage by using wide range of duty ratio. But practically this capability of conversion is limited by parasitic parameters effect dramatically. Moreover, the converters need to more economical parallel to other factors. [4] Proposes a passive lossless clamp for a DC-DC converter with dual switch to reduce the resonance and equalize the voltage stress across both switches. This type of clamping is appropriate for the steady state and not for the dynamic conditions.

The voltage balance and the symmetric switching is not attained if the circuit having asymmetric structure during dynamic state. The noise conduction during common mode can also be reduced using this symmetric structure.

So here presents a DC-DC converter with simple dual switch circuit and the structure is symmetric. Due to the symmetric structure, the voltage is balanced for both switches under steady state conditions and dynamic conditions. Less complex structure, high voltage gain, less voltage stress across both switches, less output ripples, high efficiency are the attractions of this DC-DC converter. Besides, this dual switch converter attains an application of speed control of DC motor.

II. WORKING PRINCIPLE

The motivation behind this dual switch converter is to maximize the voltage gain by using the lesser number of components and having the reduced voltage stress across the semiconductor devices. The presented converter consist of two switches S_1, S_2, L_1 and L_1 two inductors, four capacitors C_{i1}, C_{i2}, C_{o1}, C_{o2} and two diodes D_1, D_2, and output resistor R_L. V_i is the input voltage and output voltages are denoted as V_0 .

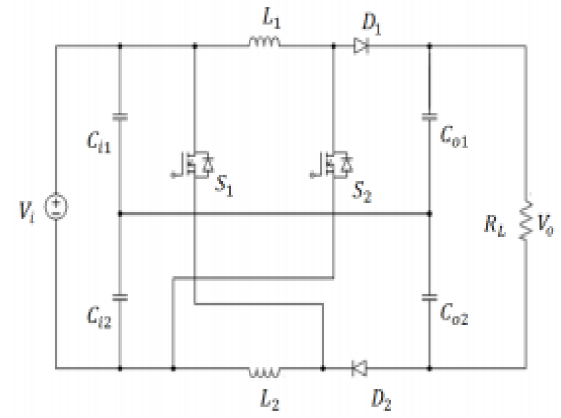

Fig.1 Configuration of Proposed Converter

The working waveform of the converter is shown in Figure 5. The switching period Ts is divided into two working modes. Also the equivalent circuit of different working modes is explained below.

2.1 . Mode 1

Figure 3 shows the equivalent circuit of this mode. Switches S_1 and S_2 in this mode are turned ON and the diodes D_1 and D_2 are not conducting during this time interval. The inductors named L_1, L_2 of the circuit charged using input voltage V_i , so the current flowing through the inductor increases.

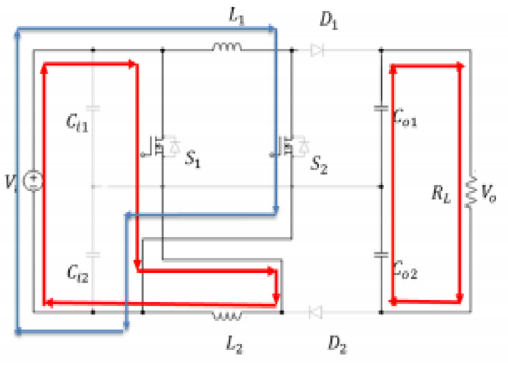

Fig.2 Mode 1

2.1 . Mode 2

In this mode, diodes D1, D2 are forward biased. The discharging of load is attained through the two inductors L1 and L2. The circuit of this mode shown in Figure 3.

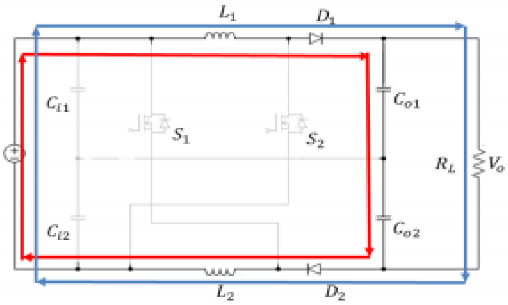

Fig.3 Mode 2

2.1 . Mode 3

During this mode, inductor current becomes zero. The Figure 4 (b) shows the graphical wave forms of DCM operation of the same converter. The first two modes are common for both CCM and DCM operation. The only difference is seen in the mode 3. During this mode, the current flow through the inductor is zero and is shown in Figure 5. The load is charged using capacitor voltages V_{CO1} and V_{CO2}.

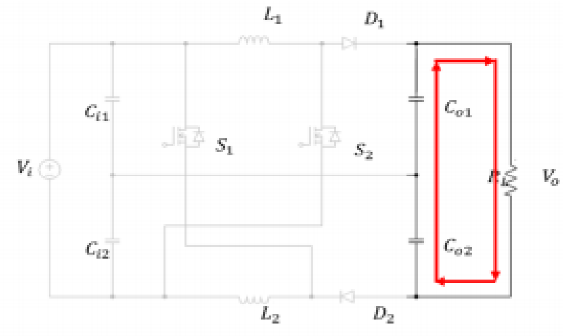

Fig.4 Mode 3

Figure 5 shows the theoretical waveform in CCM and DCM operations.

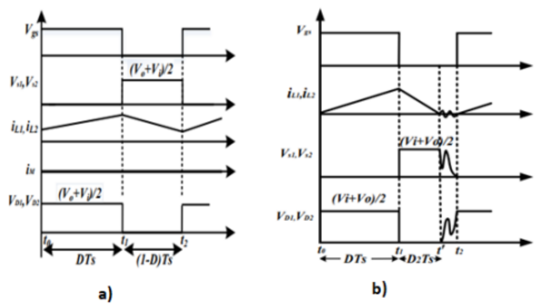

Fig.5 Theoretical waveform in CCM and DCM

2.2 Design Consideration of Main Components

The input voltage is taken as 20 V. The pulses are switched at the rate of 50 kHz with a duty ratio of 0.81. In order to operate the converter, its components should be designed approximately. It consists of inductors and capacitors. The input voltage is taken as 20 V. The pulses are switched at the rate of 50 kHz and having a duty ratio of 81% . The voltage across output load is taken as V_0= 200 V with output power as 200 W. G is the gain of converter.

A. DUTY RATIO

For any practical applications, the dc-dc converter must be operated at lower duty ratios to get maximum efficiency. The duty ratio is taken as D = 81 % .

$$G = \frac{V_0}{V_{in}} \quad (1)$$

$$D = \frac{G-1}{G+1} \quad (2)$$

B. INDUCTOR

At a voltage gain of 10, assume inductor current ripple rate r as 13.5% of input current I_{in} and both inductors are of same value. The value of inductor is set as L=240 µH .

$$L = \frac{V_i * D * T_s}{\Delta I_{L1}} \quad (3)$$

The inductor L is designed as 0.4 mH.

C. CAPACITORS

The output capacitors are of equal values. The valueof capacitor is set as 470 µF.

$$C >= \frac{D * I_o}{\Delta V_{co} * f_s} \quad (4)$$

D. LOAD RESISTOR

Taking P_0 as200 W and output power as 200 V, load resistance is calculated as,

$$R = \frac{{V_o}^2}{P_o} \quad (5)$$

The value of resistor is set as R= 200 Ω.

III. CONTROL STRATEGY

The duty cycle of switches S_1, S_2 are 0.81. The pulse is shown below.

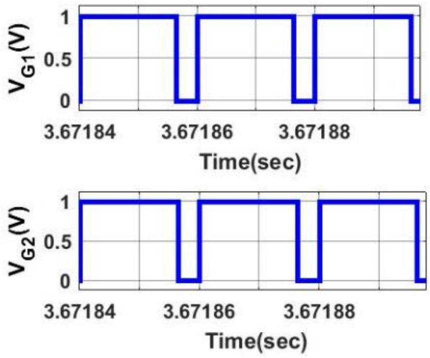

Fig.6 Switching pulse to s1 and s2

IV. SIMULATION RESULTS

The presented converter is simulated in MAT LAB/SIMULINK by choosing the parameters listed in Table1 and the simulink models are shown in figure 8 and figure 9. The simulation results of the converter are shown in the following figures.

Table.1 Simulation parameters

Parameters	Specification
Input voltageV_i	20V
Switching frequency f_s	50kHz
Inductors L_1, L_2	240μH
Capacitors C_{i1}, C_{i2}	100μF
Capacitors C_{o1}, C_{o2}	470μF
Rated Power P_o	200W

An input voltage given as V_i of 20 V produce an output voltage V0 of 200 V across the load for an output power P_0 of 200 W. The switches are MOSFET/Diode with constant switching frequency of 50kHz.

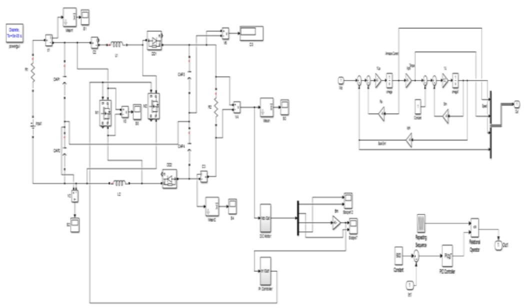

Fig.7 Simulink Model

Gate pulse to the switches, voltage across the switches and diodes are shown in figure 8.

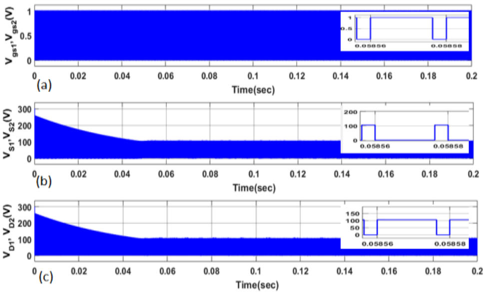

Fig.8 a) gate pulse b) voltage across switches c) voltage across diodes

Figure 11 shows the input voltage (V_I) and input current (I_I) and its zoom version. Supplied the input voltage (V_I) of 20 V.

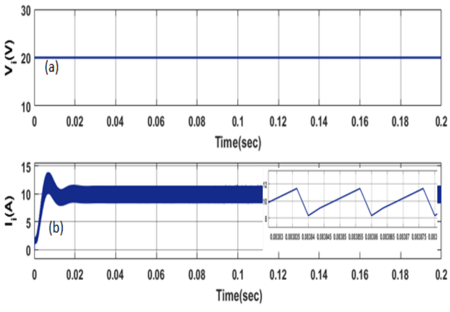

Fig.9 a)Input voltage b) Input current

Input current (II) is about 10 A and high input current ripple in the range of 3 A is obtained.

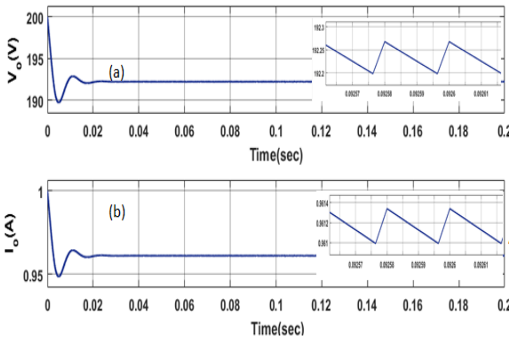

Fig.10 a)Output voltage b) Output current

Figure 12 shows the voltage across the load (V_0) and the output current (I_0) and its zoom version. Output voltage (V_{02}) is about 192 V and has a ripple of 0.6 V.

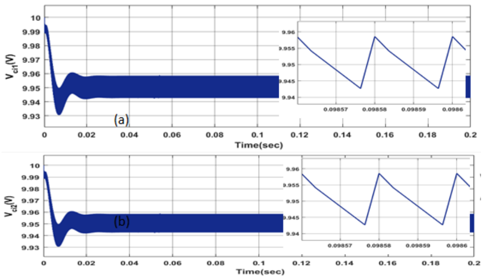

Fig.11 voltage across input capacitors

Output current (I_{02}) is about 0.96 A and output current ripple is in a small range. limitations, and possible applications of the paper.

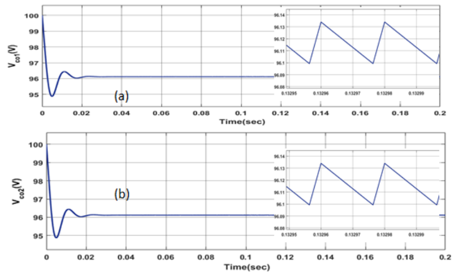

Fig.12 voltage across output capacitors

The voltage across input capacitors C_{I1} and C_{I2} are shown in figure 13.The magnitude of V_{CI1}=10 V and V_{CI2}=10 V. The voltage across the capacitors connected in output side C_{o1} and C_{o2} are shown in figure 14.The magnitude of V_{Co1}=100 V and V_{Co2}=100 V.

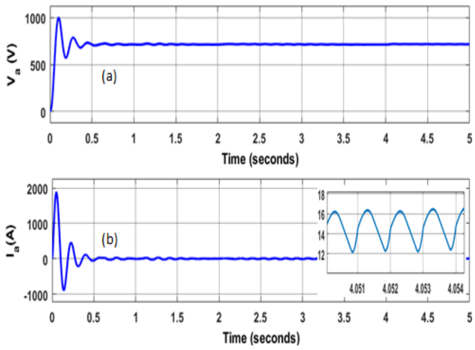

Fig.13 a) Armature voltage b) Armature current

Figure 13 and figure 14 are shows the DC motor outputs. Speed in rpm, torque, armature voltages, armature current etc. are shown in graph.

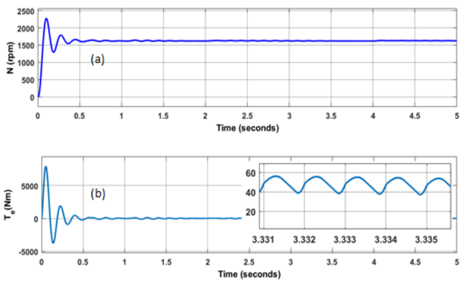

Fig.14 a) Armature voltage b) Armature current

V. ANALYSIS

Fig.15 shows the graph drawn with the efficiency and power output of the converter. The efficiency curve is clear that it increases initially and then the curve decreases after reaching the maximum peak of the curve. The peak value of this curve shows the maximum efficiency of the converter that is around 93%.

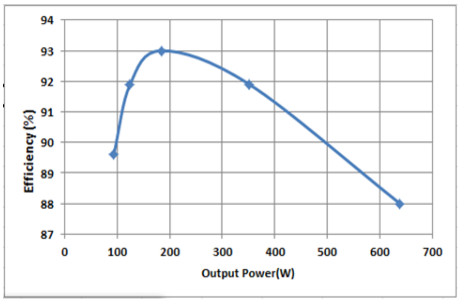

Fig.15 Efficiency v/s output power graph

According to diagram, the gain of the dual switch boost converter is at the peak when the duty cycle is equal to 80%.

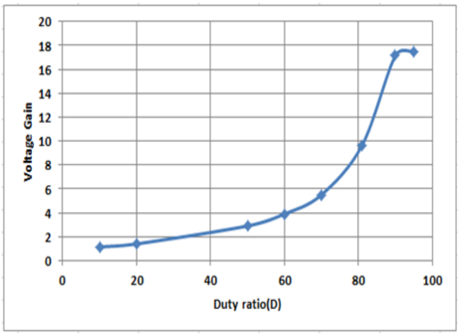

Fig.16 Efficiency v/s output power graph

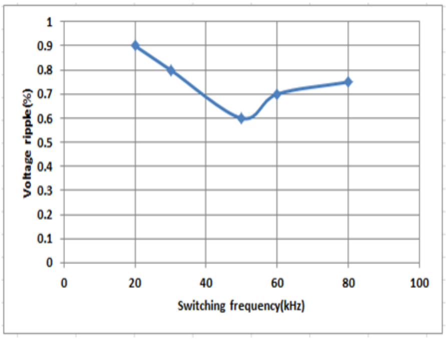

Fig.17 Efficiency v/s output power graph

VI. CONCLUSION

A DC-DC converter with less complex structure and high voltage conversion ratio is proposed. It also has the advantages of high efficiency, voltage balancing, less voltage stress, less output voltage ripple. But this converter having high input current ripple and further improvement has to be developed for this topology. The converter has an efficiency of 92 %. The performance of this dual switch DC-DC converter is evaluated in details. This dual switch symmetric converter can drive a DC motor and attain its speed control in closed loop. The speed of the DC series motor is controlled in 1600 rpm.

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