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Controlled Operation of a Converter Combining KY Converter and Buck Converter

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ABSTRACT: In this paper, controlled operation of a buck boost converter is explained. Buck- boost converter is obtained by combining a KY converter and a synchronously rectified (SR) buck converter. This converter always possess positive output voltage. This converter always operates in continuous conduction mode thereby , it decreases the current stress on the output capacitor and also the output voltage ripple. During duty cycle D, input voltage for KY converter comes from input voltage source and during 1-D input voltage for KY converter comes from SR buck converter.

KEYWORDS*:* KY converter, synchronosly rectified (SR) converter.

I.INTRODUCTION

Buck boost converters have wide range of application on these days. It is often required to have a constant voltage of 12V. Sometimes the voltage may vary from 11.1V to 14V , in such cases we need to stabilize it. However the buck or boost converter alone can fulfil the requirement. Buck boost converter is more relevant in such situations Boost converter helps to maintain 12V if it is less than 12V and vice versa.

Over the years portable industry has been developed widely. Power consumption increased a lot therefore, the power system demand is at its peak. The converter explaining in this paper is a DC-DC converter. DC- DC converters are used to control and convert the dc power from one voltage to another voltage more efficiently. The large use of low voltage portable devices results in the emergence of new converters. To maintain longer battery life for portable devices efficient power management techniques are needed. One of the advantage of this converter is that it is compact in size and thereby cost reduces.

II. LITERATURE SURVEY

Many applications require voltage bucking or boosting converters such as portable devices, car electronic devices etc. Battery used in this devices has large variations in output voltage. In order to generate a stabilized output voltage input power supply should processed. There are several types of buck boost converters such as single ended primary inductor converter (SEPIC), cuk converter, Luo converter etc. KY converter has been introduced to conquer the disadvantages of aforementioned converters.

Buck boost converter combines the principles of buck converter and boost converter. Buck converter produces an output voltage less than input voltage and vice versa. Battery charge used may change widely. During starting battery is fully charged and gradually it decreases as battery is used up. Therefore during starting period battery voltage will be greater than the required voltage and as time goes up it reduces. In such cases we use buck boost converter. This converter has non pulsating inductor current which decreases the current stress on output capacitor. Therefore he corresponding output voltage to be small and also this converter has positive output voltage.

Single ended primary inductor converter (SEPIC) is a DC-DC converter, which can buck or boost the voltage. Output voltage has same polarity as that of input voltage. The proposed converter is used for low power applications. Even though it is used for voltage conversion application, the voltage boosting range is not so high. The voltage across the two energy transferring capacitors C_1 and C_2 are D times of the input voltage, where d is the duty cycle of the proposed converter. This converter always operates in CCM mode due to the positive and negative inductor currents.

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KY converter is named by the inventors K I Hwu and Y T Yau. Compared to other converters KY converters has high efficiency and fast transient response. It boosts the voltage by varying the duty cycle. KY converter is mostly used for low power applications.

This paper shows the controlled operation of a KY and synchronously rectified buck converter. Apart from other traditional converters this is suitable low power application and for portable products. When duty cycle varies from 0 to 0.5 proposed converter acts as a buck converter and from 0.5 to 1 it acts as a boost converter. Voltage conversion ratio of this converter is 2D. For KY converter it is 1+D, it only possess boosting operation.

III.STRUCTURE AND OPERATIONAL PRINCIPLE

Fig 1 shows a converter combining KY and SR buck converter. Both the converter use the same power switches. SR buck converter consists of two switches S_1 and S_2, inductor L_1 and energy transferring capacitor C_1. KY converter consists of two switches S_1 and S_2, output inductor L_2 , power diode D_1 ,energy transferring capacitor C_2 and an output capacitor C_0. During duty cycle D input for KY converter comes from input voltage source and during 1-D it comes from SR buck converter.

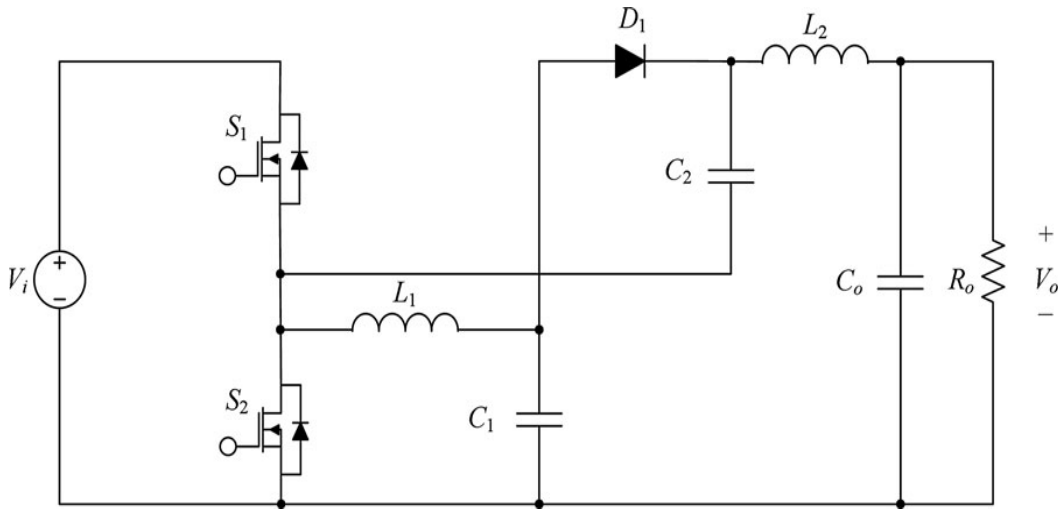

Fig. 1 Proposed converter

Mode 1

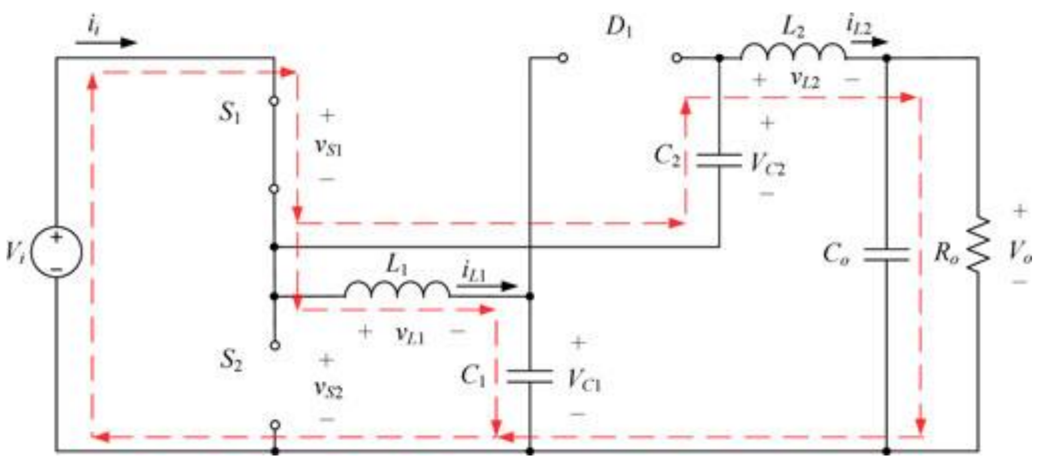

Fig. 2 Mode 1 operation of proposed converter

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Some assumptions and symbols has to be considered before explaining the operating principle 1)all the components are considered as ideal ,2) voltage drop across the switches and diode during turn on time is negligible, 3) C_1 and C_2 are large enough to keep V_{C1} and V_{C2} constant, 4)input voltage is denoted as V_i and output voltage as V_0, 5) DC output current is expressed as $I_{0.}$

Mode 1 : During this period switch S_1 is turned on and S_2 is turned off. L1 and L2 are both magnetized.
C1 is charged, and therefore, the voltage across C1 is positive and C2 is reversely charged, hence the voltage across C_2 is negative.

$$V_{L1} = V_i - V_{C1} \qquad (1)$$

$$V_{L2} = V_i + V_{C2} - V_0 \qquad (2)$$

Mode 2

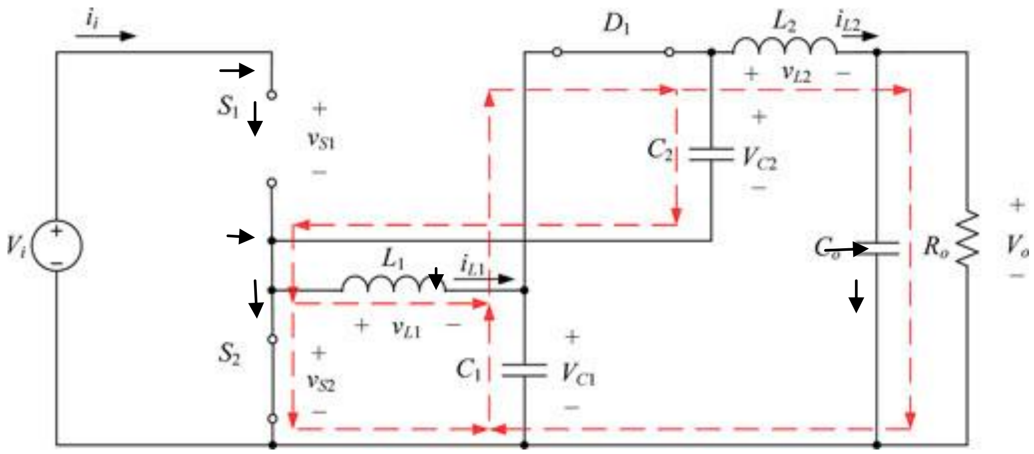

Fig. 3 Mode 2 operation of proposed converter

Mode 2 : During mode 2 switch S_2 is turned on and S_2 is turned off. During this mode, the energy stored in L1 and C1 is released to C2 and the output through L2 . This causes the L_1 and L_2 to be demagnetized , C_1 to be discharged and C_2 to be charged. It is explained by the following equations.

$$V_{L1} = -V_{C1} \qquad (3)$$

$$V_{L2} = V_{C2} - V_0 \qquad (4)$$

$$V_{C2} = V_{C1} \qquad (5)$$

By simplifying the equation (1) and (3)

$$(V_i - V_{C1})DT_S + (-V_{C1})(1 - D)T_S == 0 \qquad (6)$$

$$V_{C1} == D\,V_i \qquad (7)$$

Sequentially by simplifying (2) and (4)

$$(V_i + V_{C2} - V_0)DT_S + (V_{C2} - V_0)(1 - D)T_S == 0 \qquad (8)$$

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By substituting (5) and (7) in to (8), voltage conversion ratio can be obtained as

$$\frac{V_0}{V_i} = 2D \qquad (9)$$

The proposed converter can be operate in buck mode when D is less than 0.5 and in boost mode when D lies between 0.5 to 1.From (5),(7) and (9) voltage across C_1 and C_2 can be expressed as

$$V_{C1} = V_{C2} = 0.5V_0 \quad (10)$$

IV DESIGN PARAMETERS

1) Required output voltage , V_0 = 12V
2) Input voltage , V_i =10V or 16V
3) Rated dc load current , I_0 = 3A
4) Switching frequency , f_s =200KHz

INDUCTOR DESIGN

$$\Delta i_{L1} = \Delta i_{L2} = 0.5 I_{o-rated} \qquad (11)$$

The peak-to-peak values of i_{L1} and i_{L2} are expressed as Δi_{L1} and Δi_{L2} . Therefore Δi_{L1} and Δi_{L2} are 1.5A.From (10) V_{C1} and V_{C2} are 6V. Highest input voltage is 16V and corresponding minimum duty cycle is 0.375.From equation (12) and (13) L_1 and L_2 should be greater than 12.5μH.

$$L_1 \geq \frac{D_{min}(V_i - V_{C1})}{\Delta i_{L1} f_s} \qquad (12)$$

$$L_2 \geq \frac{D_{min}(V_i + V_{C2} - V_0)}{\Delta i_{L2} f_s} \qquad (13)$$

CAPACITOR DESIGN

Energy transferring capacitors C_1 and C_2 is taken large value to keep V_{C1} and V_{C2} almost constant. Variations in V_{C1} and V_{C2} are very small , that is less than 1% of V_{C1} and V_{C2}. It is almost 60Mv.

$$C_1 \geq \frac{I_{0rated} D_{max}}{\Delta V_{C1} f_s} \qquad (14)$$

$$C_2 \geq \frac{I_{0rated} D_{max}}{\Delta V_{C1} f_s} \qquad (15)$$

D_{max} represents the maximum duty cycle. Maximum duty cycle is required for the input voltage 10V and it is 0.6.

From equations (14) and (15) value of capacitor C_1 and C_2 should not be less than 150µF. Output capacitor is taken as 470µF.

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V. PI CONTROL OF THE CONVERTER

Converter is controlled by using a PI controller which helps to eliminate the forced oscillation and steady state error. Integral mode has negative effect on speed of the response and overall stability of the system. Derivative mode helps to predict the effect of error in near future and can decrease the response time of the controller. The propotional gain K_P is obtained by varying the value from zero to 80% of required output voltage. Integral gain K_i is obtained by varying the value from zero to obtain a value close to output voltage.

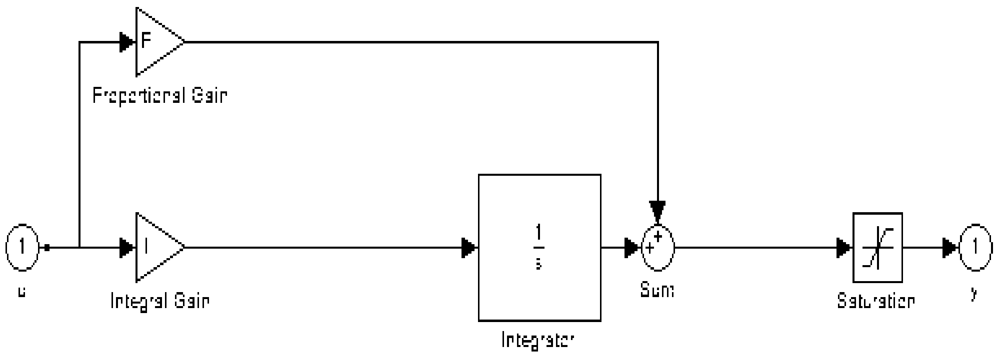

Fig . 8 Block diagram of a PI Controller

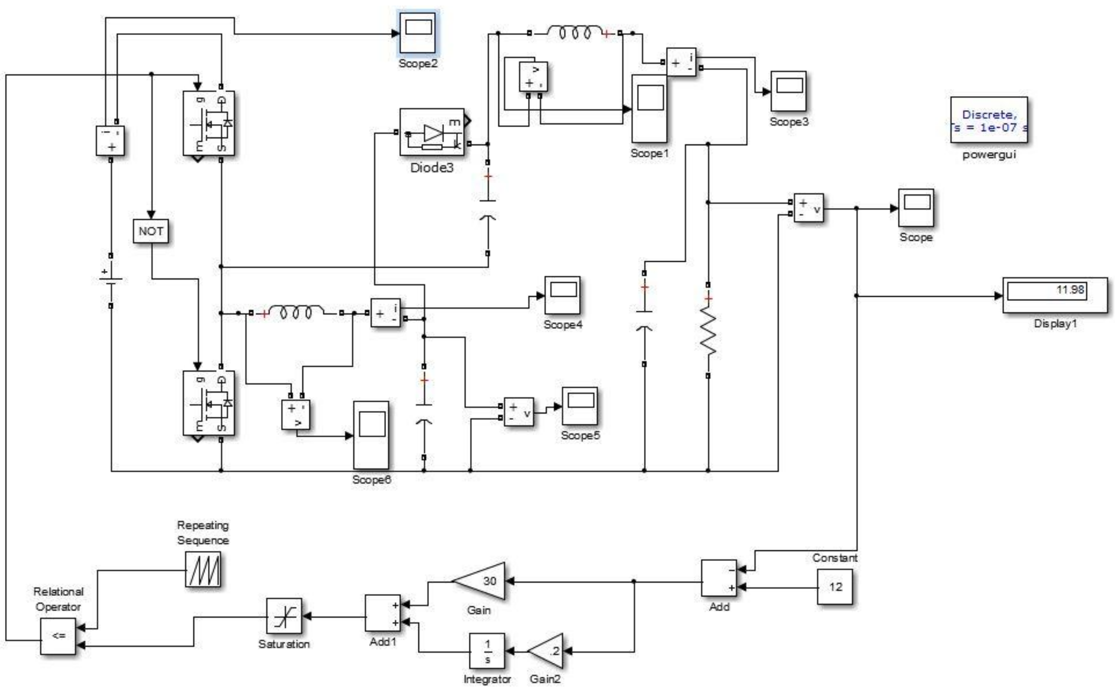

Fig. 9 Simulation diagram of the modified converter

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V SIMULATION RESULT

Simulated result of the modified converter is shown in Fig 10.For the time 0 to 0.5s input is given as 10V and from 0.5s to 1s input is taken as 16V. PI controller acts in an effective manner to maintain the voltage constant at 12V. Controller will change the duty ratio automatically to keep the output voltage constant.

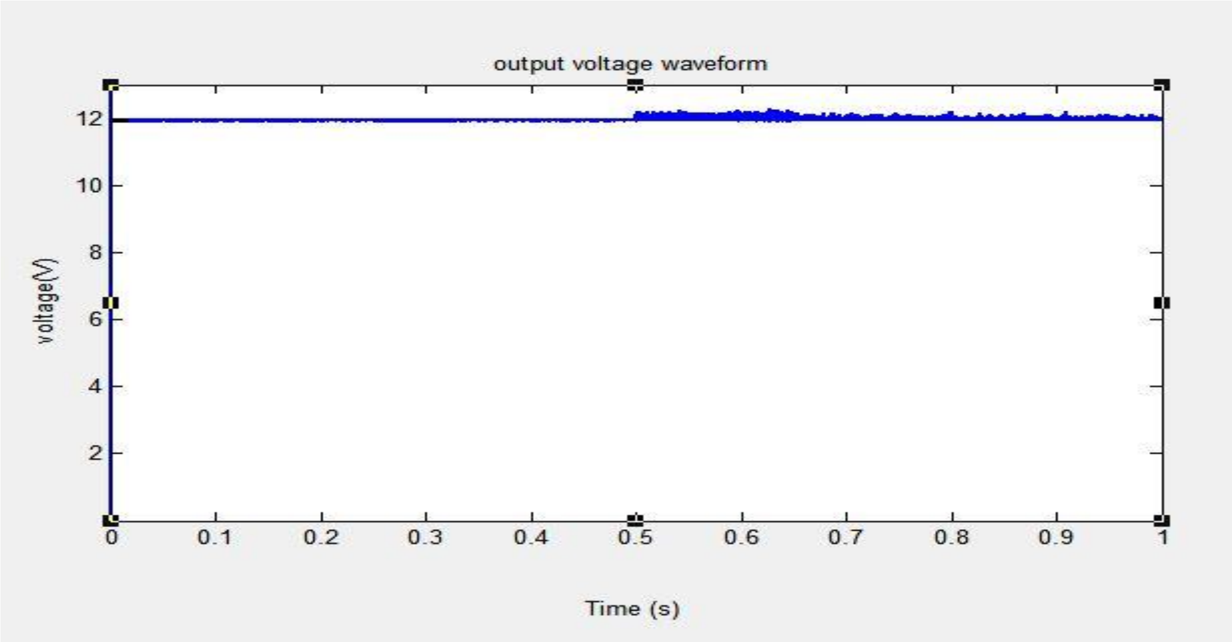

Fig .10 Output waveform of the converter. Simulated result of the converter for 1 second. For the time zero to 0.5sec it will act as a boost converter where input = 10V. For 0.5 to 1 sec it will act as buck converter, input given = 16V.

VI.CONCLUSION

Required output voltage is obtained with the help of KY and SR buck converter. This converter always operates in continuous conduction mode therefore duty cycle will not vary over wide range , hence control of the converter is easy. This converter possess non pulsating output current thereby decreasing the output voltage ripple and current stress on the output capacitor.

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