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HIGH STEP-UP SINGLE-STAGE SCI DC-DC CONVERTER USING PULSE WIDTH MODULATION

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ABSTRACT

In battery operated vehicles, the battery voltage has to be stepped up to very high value to drive the motor. Hence it is planned to build up a mainly efficient high step up Switched Inductor Capacitor (SIC) dc-dc converter for such applications. In SIC converters, an LC-circuit with high quality factor (Q-factor) is employed to increase the dc input voltage to required high voltage level. For this, MOSFET power switch is employed to make and break a high current pulse through the inductance. When current is made to flow through inductance, energy is stored in inductance and when this current is cut the stored energy in inductance is transferred to capacitance, which results In a high voltage across capacitor. Closed loop PID control is also provided to achieve the desired output voltage.

Keywords: DC–DC converter, resonant, single-stage, switched-capacitor inductor (SCI).

I. INTRODUCTION

The basic switched-mode dc–dc converters counting buck ,boost, buck–boost, cuk, zeta, and sepic have been used in various electronic application due to their many compensation such as simple structure, excellent performance, high efficiency, easy design, and simple control circuit. The resonant converters such as single-ended and bridge type are also very popular in the last decade. And the basic switched-capacitor (SC) converters also have wide application as their advantages of nonmagnetic components employed and small size and high power density.

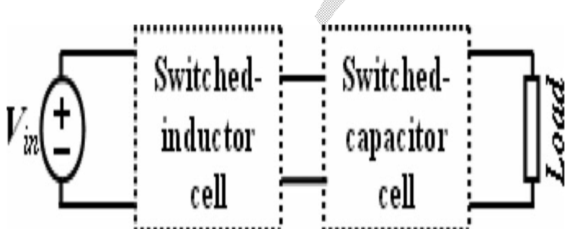

Figure.1 Conventional SC/switched-inductor converter.

II.NEW FAMILY OF SCI CONVERTERS

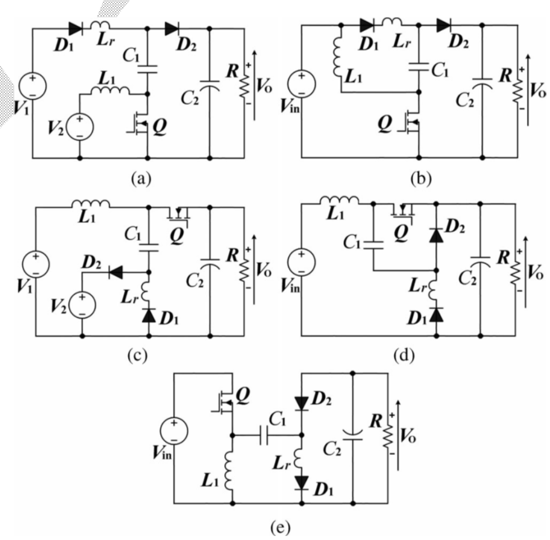

Figure..2 (a) Dual-input step-up converter (b) Single-input step-up converter. (c) Dual-input step-down converter. (d) Single-input step-down converter. (e) Inverting step-up converter.

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A family of SCI converters is shown in Fig. 2. Each of the circuits uses only one active switch *Q* and a very small resonant inductor *Lr* which is working to limit the current peak caused by capacitor *C*1 when the switch *Q* is turned ON. The two energy storage components *C*1 and *L*1 are alternately connected in parallel and series according to different switching states. shows the dual-input step-up converter member. The two energy storage components *C*1 and *L*1 are charged in parallel by input sources *V*1 and *V*2 , correspondingly, when switch *Q* is turned ON, and discharging in series to output terminal when *Q* is turned OFF. When the values of the inductor *L*1 and the capacitor *C*1 both are large practically and the switching regularity is high enough, the voltage across the capacitor *C*1 can be regarded as constant and is equal to the input voltage level *V*1 , and the current flowing though *L*1 can be also regarded as constant. Based on volt–second equilibrium across *L*1 , the voltage level association of the output and inputs. can be expressed as $VO = V1 + 1(1 - d)V2$ (1) where *d* is the duty ratio of the converter, *V*1 and *V*2 are input voltages, and *VO* is the output voltage. . 2(b) shows the single-input step-up converter member. It is actually the special version of the dual-input step-up converter when its two input terminals both are connected to the same power source *V*in , i.e., $V1 = V2 = V\text{in}$. Its voltage transfer relationship therefore can be derived from (1) and expressed as $VO = 2 - d\ (1 - d)V\text{in}$. (2) Fig. 2(c) shows the dual-input step-down converter member. Its two energy storage components *C*1 and *L*1 are charged in series by the difference levels of the two input sources *V*1 and *V*2 when the switch *Q* is turned OFF, and discharge in parallel to output terminal when *Q* is turned ON. The situation for the normal operation of this converter is that the level of *V*1 is higher than *V*2 . Based on the same assumption]'p/ that *L*1 and *C*1 both are large reasonably and the switching frequency is high enough, the voltage across the capacitor *C*1 can be regarded as constant and is the same as the output voltage level *VO* . And the voltage level relationship of the output and inputs can be also derived by using volt–second balance across *L*1 and then expressed as $VO = V1 - (1 - d)V2$. (3)The single-input step-down converter member shown in is the special version of the dual-input step-down converter [see Fig. 2(c)] when its lower level input terminal *V*2 is connected together with the output terminal *VO* as the new output, i.e., $V2 = VO$. Its voltage transfer relationship therefore can be derived from (3) and expressed as $VO = 1(2 - d)V\text{in}$. (4)In addition to aforementioned members, the new family also includes an inverting step-up converter member as shown in Fig. 2(e). When switch *Q* is turned ON, *L*1 and *C*1 are charged in parallel and discharges in series when switch is turned OFF. Therefore, the voltage across *C*1 is the same as input voltage *V*in. The voltage transfer relationship also can be derived using the same method abovementioned and expressed as $VO = -1(1 - d)V\text{in}$. (5) However, there is no member in Fig. 2 that can provide high step-down and inverting step-down output levels.

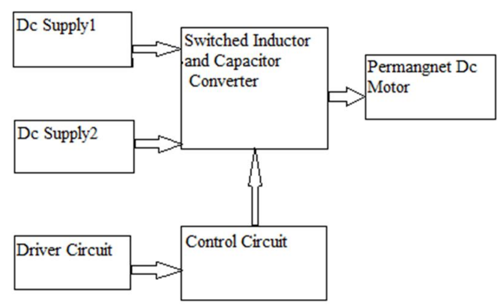


Figure.3Block diagram of converter circuit

II. Modes of operation

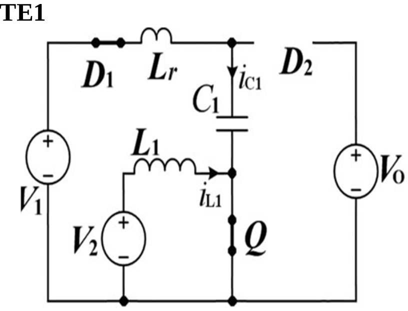
The operation of the proposed converter is as follows:

I State1: Switch S and Diode D1 ON, Diode D2 OFF (t0-t1)

II State2: Switch S ON Diodes D1 and D2 OFF (t1-t2)

IIIState3: Switch S and Diode D1 OFF, Diode D2 ON (t2-t3)

STATE1



State I : Working

When the switch is turned ON, diode D2 is reverse biased and D1 is forward biased. The resonant inductor Lr is connected in series with C1 to form a resonant tank. The input voltage V1 is developed across the resonant tank that causes the resonant current Ic1 gradually increases from zero in

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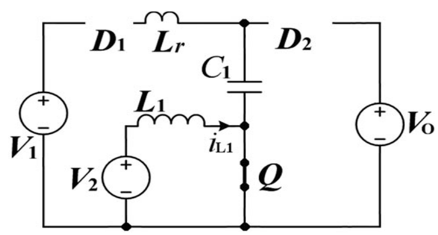
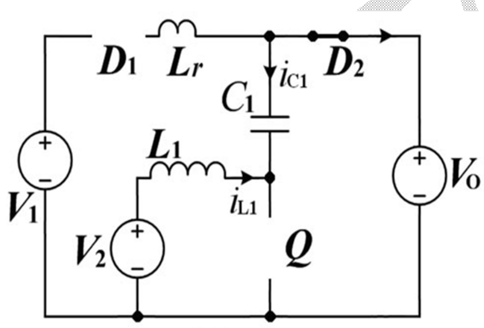
a sinusoidal manner; C1 begins to be charged and its voltage increases from its minimum value.

STATE 2 Working



After the resonance stops, both the diodes are overturn biased and the switch continues to conduct. The inductor current Il1 continues to rise linearly through the switch. Since there is no current flowing through C1, its voltage is maintained at the maximum value.

STATE 3 Working



When switch is turned OFF, diode D2 is forward biased and D1 is reversely biased. The capacitor C1 , the inductor L1 , and input source V2 are connected in series and discharge the maximum voltage to output Vo .

III. DETAILED ANALYSIS AND DESIGN CONSIDERATIONS

There are two inductors employed in each converter member of the new family, the energy transfer inductor $L1$ and the resonant inductor Lr . The function of $L1$ is to transfer energy while Lr is just used to limit the current peak caused by the capacitor $C1$ when the switch Q is turned ON. Specifically, when switch Q is turned ON, the capacitor $C1$ begins to be charged or to discharge, the charging or discharging current will soar to a very high peak at the moment of Q being ON if there are not any measures to limit it. For this reason, a small inductor Lr is added and connected in series with $C1$ to form a resonant tank with the resonant frequency fO =

$1/2\pi\sqrt{LrC1}$ during the switching ON period. With the resonant inductor, the charging or discharging current of $C1$ gradually increases from zero when switch Q is turned ON. In order to ensure that the current changes back to zero before switch Q is turned OFF, the switch conduction time should be longer than half of a period of the resonant frequency, i.e.,*dTS1π*√(where *TS* and *d* are the switching cycle period and duty ratio, respectively).

A. State Analysis for the Dual-Input Step-Up Converter

For all members of the new family of SCI converters, there are three working states for each of them in one period of switching cycle. Taking the dual-input step-up converter member

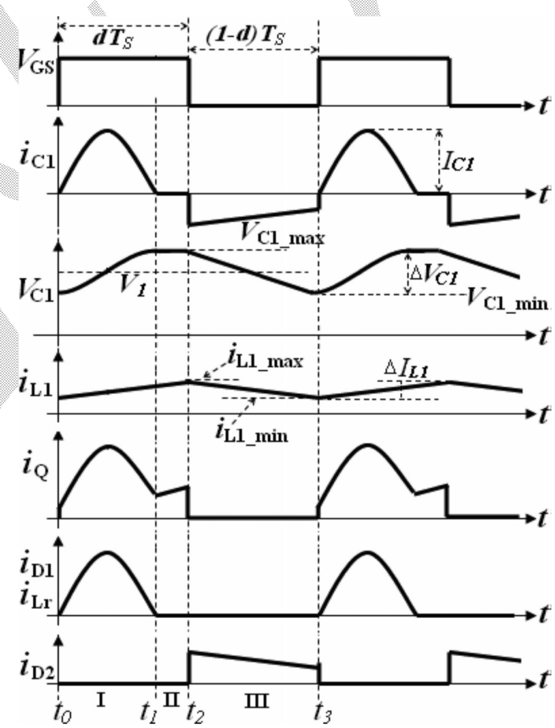


Diagram of proposed converter

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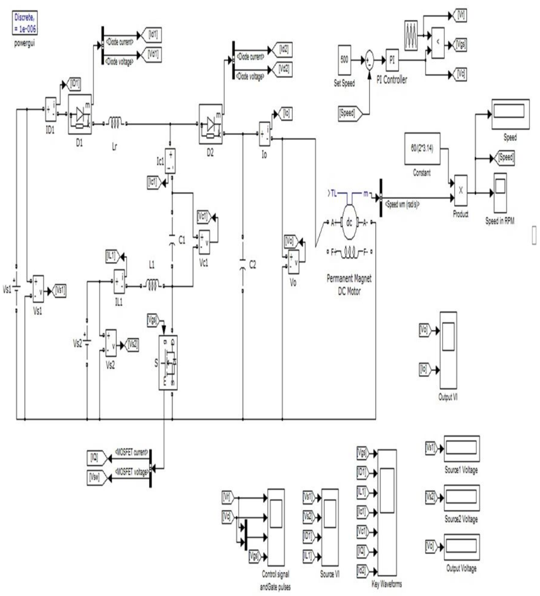
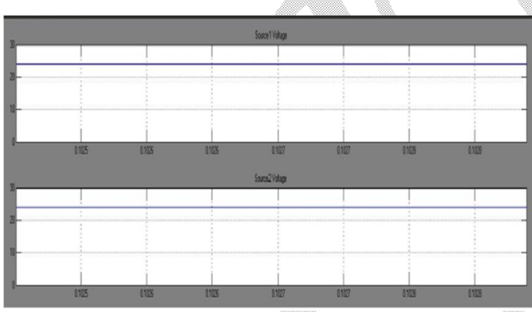
VI. SIMULATION RESULTS



Source voltage v1 and v2



Source Currents I1 and I2

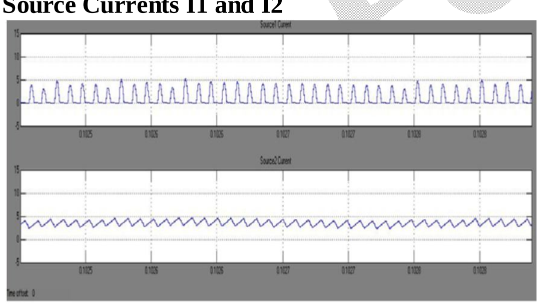
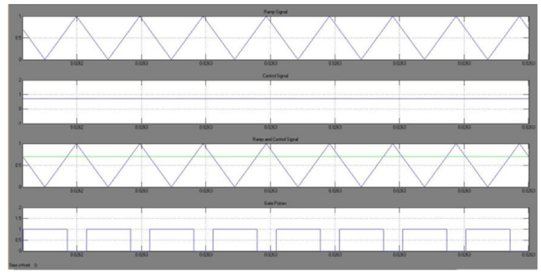
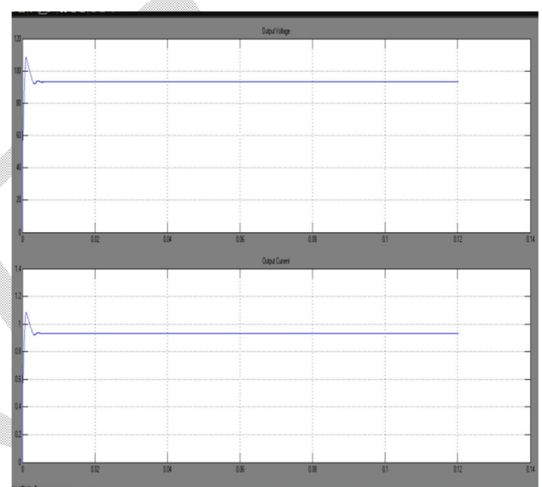


Fig.12.Control signal waveforms





Output Voltage Vo and Current Io
Fig.13.Output voltage and current waveforms

IV. CONCLUSIONS

A family of single-stage SCI converters with different voltage gains has been proposed in this paper. The proposed converters employ two energy transfer components (one SC and one inductor) and do not use the cascade method like conventional SC/switched-inductor converters. The energy stored in the two components both directly come from input power sources and then directly been released to output terminal. This design can meet the high efficiency requirement with a simple structure. A resonance method is used in this paper to limit the current peak caused by the SC. Detailed analysis and design considerations are also introduced. Compared with traditional switched-mode converters, the proposed converters can provide higher or lower voltage gains and the switch stress is lower. The family includes two dual-input members which can be used in two power sources applications. The simulation and experimental results of the converter members [see Fig. 1(a) and (b)] confirm their functionality and verify the

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theoretical analysis presented. Furthermore, the measured results of efficiency and voltage under different output power are compared with conventional converters, which indicate that the proposed step-up converters 1(a) and (b)] can meet high efficiency and good voltage regulation. The other members of the proposed family have also been simulated and their operations have been confirmed. The same conclusion can be made to other members of the proposed family because of similar structure and the same design philosophy. Of course, there are also some regrets for the family of converters. For instance, the output voltage of the single-input step-up converter member [see Fig. 2(b)] is always higher than twice the input voltage and is only suitable for high voltage gain applications. Similar problem is also found in the high step-down member [see Fig. 3(a)]. In addition, there is no member in the family that can provide both higher and lower voltage levels than input voltage under different duty ratios. However, all these regrets will be the direction of the further.

REFERENCES

[1] K. W. Exchange, *Classical Switched Mode and Resonant PowerConverter*. Kowloon, Hong Kong: Hong Kong Polytechnic Univ., 2002, pp. 15–56.

[2] B. W. Williams, “Basic DC-to-DC converters,” *IEEE Trans. Power Electron* vol. 23, no. 1, pp. 387–401, Jan. 2008.

[3] Y. Ren, M. Xu, J. Sun, and F. C. Lee, “A family of high power density unregulated bus converters,” *IEEE Trans. Power Electron.*, vol. 20, no. 5, pp. 1045–1054, 2005.

[4] K. W. E. Cheng and P. D. Evans, “Parallel-mode extended-period quasiresonant convertor,” *IEE Proc.-B*, vol. 138, no. 5, pp. 243–251, Sep. 1991.

[5] C. K. Tse, S. C. Wong, and M. H. L. Chow, “On lossless switched capacitor power converters,” *IEEE Trans. Power Electron.*, vol. 10, no. 3, pp. 286–291, May 1995.

[6] J. M. Henry and J. W. Kimball, “Switched-capacitor converter state model generator,” *IEEE Trans. Power Electron.*, vol. 27, no. 5, pp. 2415–2425, May 2012.

[7] Y.Yuanmao and K. W. E. Cheng, “Level-shiftingmultiple-input switched capacitor voltage-copier,” *IEEE Trans. Power Electron.*, vol. 27, no. 2, pp. 828–837, Feb. 2012.

[8] K. W. E. Cheng, “Zero-current-switching switched-capacitor converters,” *IEE Proc.-Electr. Power Appl.*, vol. 148, no. 5, pp. 403–409, Sep. 2001.

[9] E. H. Ismail, M. A. Al-Saffar, and A. J. Sabzali, “A family of single switch PWM converters with high step-up conversion ratio,” *IEEE Trans. Circuits Syst. I, Reg. Papers*, vol. 55, no. 4, pp. 1159–1171, May 2008.

[10] B. Axelrod, Y. Berkovich, and A. Ioinovici, “Switched-capacitor/ switched-inductor structures for getting transformerless hybrid DC–DC PWM converters,” *IEEE Trans. Circuits Syst. I, Reg. Papers*, vol. 55, no. 2, pp. 687–696, Mar. 2008.

[11] A. A. Fardoun and E. H. Ismail, “Ultra step-up DC–DC convert with reduced switch stress,” *IEEE Trans. Ind. Appl.*, vol. 46, no. 5, pp. 2025– 2034, Sep./Oct. 2010.

[12] Y.-P. Hsieh, J.-F. Chen, T.-J. Liang, and L.-S. Yang, “Novel high step-up DC–DC converter with coupled-inductor and switched-capacitor techniques for a sustainable energy system,” *IEEE Trans. Power Electron.*, vol. 26, no. 12, pp. 3481–3490, Dec. 2011.

[13] S. Xiong, S.-C. Tan, and S.-C. Wong, “Analysis and design of a high voltage- gain hybrid switched-capacitor buck converter,” *IEEE Trans. Circuits Syst. I, Reg. Papers*, vol. 59, no. 5, pp. 1132–1141, May 2008.

[14] R. C. N. Pilawa-Podgurski, D. M. Giuliano, and D. J. Perreault, “Merged two-stage power converter architecture with soft charging switched capacitor energy transfer,” in *Proc. IEEE Power Electron. Spec. Conf.*, 2008, pp. 4008–4015.

[15] J. C. Rosas-Caro, J. M. Ramirez, F. Z. Peng, and A. Valderrabano, “A DC-DC multilevel boost converter,” *IET Power Electron.*, vol. 3, no. 1, pp. 129–137, 2010.