MER BASED BI-DIRECTIONAL THREE WIDING DC- DC CONVERTERS WITH ZVS

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Abstract: *This letter presents a high-power-density multi-input dc–dc convertor interfaced with energy storage parts like a battery associated an ultra-capacitor. The convertor consists of 3 half-bridges and a high-frequency multi-winding electrical device. Bi-directional power flow between input and output is achieved by adjusting the phase-shift angles of the voltages across the 2 sides of the electrical device. Soft-switching is enforced naturally by snubber capacitors and electrical device outpouring inductance. Operation principles area unit analysed intimately. Simulation and experimental results area unit provided to verify the performance of the projected convertor.[1-10]*

*Key Words—***MER- Multiple Energy Storage Systems, Bi-directional power flow, multi-input converter, soft-switching.**

1. INTRODUCTION

MULTI-INPUT dc–dc converters area unit accustomed mix different kinds of energy sources to get a regulated dc output voltage. These became widespread attributable to increasing applications in renewable energy generation [1]–[5] and hybrid electrical vehicles [6], [7]. The target of this letter is to develop a high-power-density dc–dc device to interface with multiple- energy storage parts like batteries and ultra-capacitors. Compared to alternative multi-input dc–dc converters [1]–[7], the projected device has the subsequent features: 1) the facility will flow in either direction between every individual input and output, 2) the utilization of triple half-bridges minimizes the quantity of change devices and their associated gate-drive parts,3) soft-switching is achieved naturally while not auxiliary devices and parts, and 4) electrical isolation is enforced. Operating principles of steady-state power-flow management area unit analysed supported the developed multi-winding electrical device model. Soft-switching conditions area unit provided within the letter. Finally, the performance of the projected device is verified by simulation and experimental results on a 6-kW science laboratory unit.[11-21]

2. PROPOSED MULTI-INPUT DC–DC CONVERTER

Fig. 1 shows the projected multi-input dc–dc convertor. It may be viewed as Associate in Nursing extension of a single-input isolated dc–dc convertor [8]. The circuit consists of 2 half-bridges on the low-tension facet (LVS), a three-winding coupled electrical device, and a half-bridge on the high voltage facet (HVS). The energy storage parts like twelve V forty two V batteries Associate in Nursing an ultra-capacitor bank may be interfaced at the LVS, and a traction motor drive, as an example, may be connected to the HVS through a dc–ac electrical converter. The nominal dc-bus voltage of the HVS may be between 288–400 V. The electrical device has 3 functions: 1) mix input dc sources in magnetic kind, 2) offer electrical isolation, and 3) improve voltage from the LVS to the HVS. The escape inductance of the electrical device is employed as Associate in Nursing energy storage and transferring part between the LVS and therefore the HVS. The worth of the escape inductance is set by the geometry of the windings. Fig. 2(a) is that the designed natural object of a three-winding electrical device for the projected convertor. Solely the correct half the electrical device is illustrated as a result of symmetrical characteristics.[22-35]

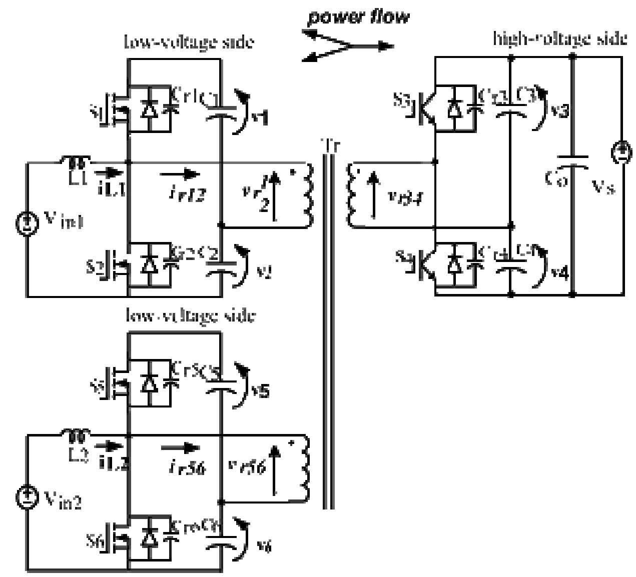

Fig. 1. Proposed multiple-input ZVS bi-directional dc–dc converter

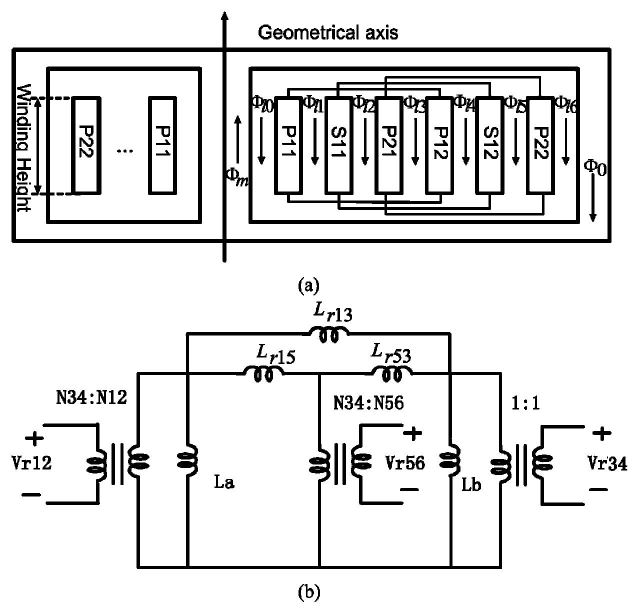

Fig. 2. (a) Designed physical structure of a three-winding transformer and (b) derived delta-type model for three-winding transformer.

Windings P11 and P12, S11 and S12, P21 and P22 are connected in parallel to allow higher current. And are fluxes flowing across the core. , represents fluxes between windings. Based on this winding con- figuration and the duality theorem, a type electric transformer model is developed in Fig. 2(b). And are the leakage inductances between winding. The " " type transformer model is convenient for analysis of the converter operation principles, and the " " type transformer model is suitable for soft-switching analysis When power flows from the LVS to the HVS, the device works in boost mode to stay the HVS at a desired high price. Within the different direction of power flow, the device works in buck mode to charge the energy storage parts. The subsequent assumptions are created to modify the analysis.[36-48]

• The inductance of and ar massive enough to keep up the currents flowing through them to be constant.

• All shift devices are thought of ideal.

• The output filter capacitors – are massive enough that are constant.

Based on Fig. 3, the operation over one full shift cycle will be divided into six stages. The electrical device current of every stage springs and summarized in Table I.

The "Y" kind electrical device currents, and will be derived by the " " transformation, as shown in Fig. 3. Therefore, the output power from and will be derived as (1), shown at rock bottom of the page. The output power springs consequently

$$P_0 = P_1 + P_2 = \frac{\phi_{13}(\pi - |\phi_{13})}{\mathrm{con}_{13}} V_{12}V_{34} + \frac{\phi_{53}(\pi - |\phi_{53}|)}{\mathrm{con}_{53}} V_{56}V_{34}.$$

$$\begin{cases} P_1 = \dfrac{\int_0^{2\pi} I_{r12}(\theta)V_{r12}(\theta)\,d\theta}{2\pi} = \dfrac{\phi_{13}(\pi - \phi_{13})}{\mathrm{con}_{13}} V_{12}V_{34} + \dfrac{\phi_{15}(\pi - \phi_{15})}{\mathrm{con}_{15}} V_{12}V_{56} \\ P_2 = \dfrac{\int_0^{2\pi} I_{r56}(\theta)V_{r56}(\theta)\,d\theta}{2\pi} = \dfrac{\phi_{53}(\pi - \phi_{53})}{\mathrm{con}_{53}} V_{56}V_{34} + \dfrac{\phi_{51}(\pi - \phi_{51})}{\mathrm{con}_{51}} V_{56}V_{12} \end{cases}$$

TRANSFORMER CURRENT DESCRIPTION OF EACH STAGE

Operation stage	Transformer current		
	Ir_{13}	Ir_{53}	Ir_{15}
Stage I $(0, \phi_{15})$	$\frac{V_1+V_4}{\omega L_{r13}}\theta + I_{r13}(0)$	$\frac{-V_6+V_4}{\omega L_{r53}}(\theta-\pi-\phi_{13}) + I_{r53}(\pi+\phi_{13})$	$\frac{V_1+V_6}{\omega L_{r15}}\theta + I_{r15}(0)$
Stage II (ϕ_{15}, ϕ_{13})	$\frac{V_1+V_4}{\omega L_{r13}}\theta + I_{r13}(0)$	$\frac{V_5+V_4}{\omega L_{r53}}(\theta-\phi_{15}) + I_{r53}(0)$	$\frac{V_1-V_5}{\omega L_{r15}}(\theta-\phi_{15}) + I_{r15}(\phi_{15})$
Stage III (ϕ_{13}, π)	$\frac{V_1-V_3}{\omega L_{r13}}(\theta-\phi_{13}) + I_{r13}(\phi_{13})$	$\frac{V_5-V_3}{\omega L_{r53}}(\theta-\phi_{13}) + I_{r53}(\phi_{53})$	$\frac{V_1-V_5}{\omega L_{r15}}(\theta-\phi_{15}) + I_{r15}(\phi_{15})$
Stage IV $(\pi, \pi+\phi_{15})$	$\frac{-V_2-V_3}{\omega L_{r13}}(\theta-\pi) + I_{r13}(\pi)$	$\frac{V_5-V_3}{\omega L_{r53}}(\theta-\phi_{13}) + I_{r53}(\phi_{53})$	$\frac{-V_2-V_5}{\omega L_{r15}}(\theta-\pi) + I_{r15}(\pi)$
Stage V $(\pi+\phi_{15}, \pi+\phi_{13})$	$\frac{-V_2-V_3}{\omega L_{r13}}(\theta-\pi) + I_{r13}(\pi)$	$\frac{-V_6-V_3}{\omega L_{r53}}(\theta-\phi_{15}-\pi) + I_{r53}(\pi)$	$\frac{-V_2+V_6}{\omega L_{r15}}(\theta-\pi-\phi_{15}) + I_{r15}(\pi+\phi_{15})$
Stage VI $(\pi+\phi_{13}, 2\pi)$	$\frac{-V_2+V_4}{\omega L_{r13}}(\theta-\pi-\phi_{13}) + I_{r13}(\pi+\phi_{13})$	$\frac{-V_6+V_4}{\omega L_{r53}}(\theta-\pi-\phi_{13}) + I_{r53}(\pi+\phi_{53})$	$\frac{-V_2+V_6}{\omega L_{r15}}(\theta-\pi-\phi_{15}) + I_{r15}(\pi+\phi_{15})$

The inductor currents and voltage of HVS can be found to be

$$\begin{cases} V_{34} = \dfrac{\phi_{13}(\pi-|\phi_{13}|)R}{\mathrm{con}_{13}} V_{12} + \dfrac{\phi_{53}(\pi-|\phi_{53}|)R}{\mathrm{con}_{53}} V_{56} \\ I_{L1} = \dfrac{\phi_{13}(\pi-|\phi_{13}|)}{\mathrm{con}_{13}} \dfrac{V_{34}}{D} + \dfrac{\phi_{15}(\pi-|\phi_{15}|)R}{\mathrm{con}_{15}} \dfrac{V_{56}}{D} \\ I_{L2} = \dfrac{\phi_{53}(\pi-|\phi_{53}|)}{\mathrm{con}_{53}} \dfrac{V_{34}}{D} + \dfrac{\phi_{51}(\pi-|\phi_{51}|)R}{\mathrm{con}_{51}} \dfrac{V_{12}}{D} \end{cases}$$

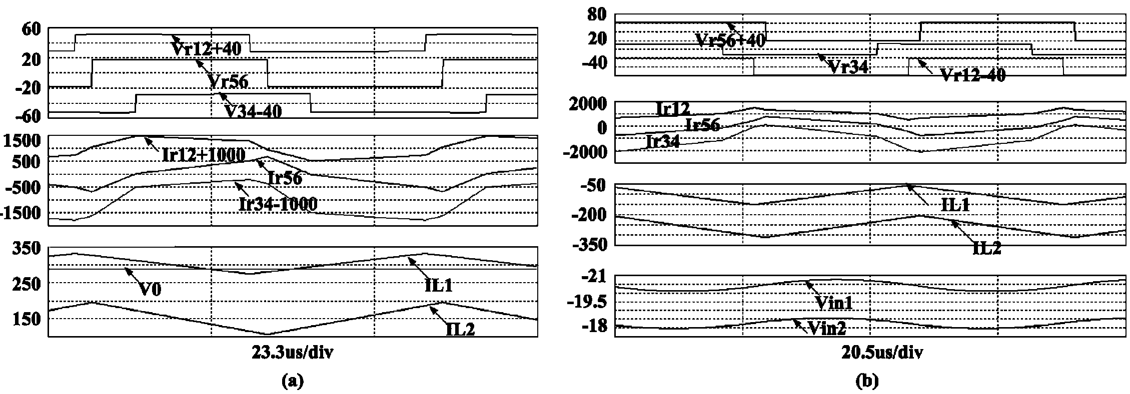

Fig. 3 Simulated waveforms

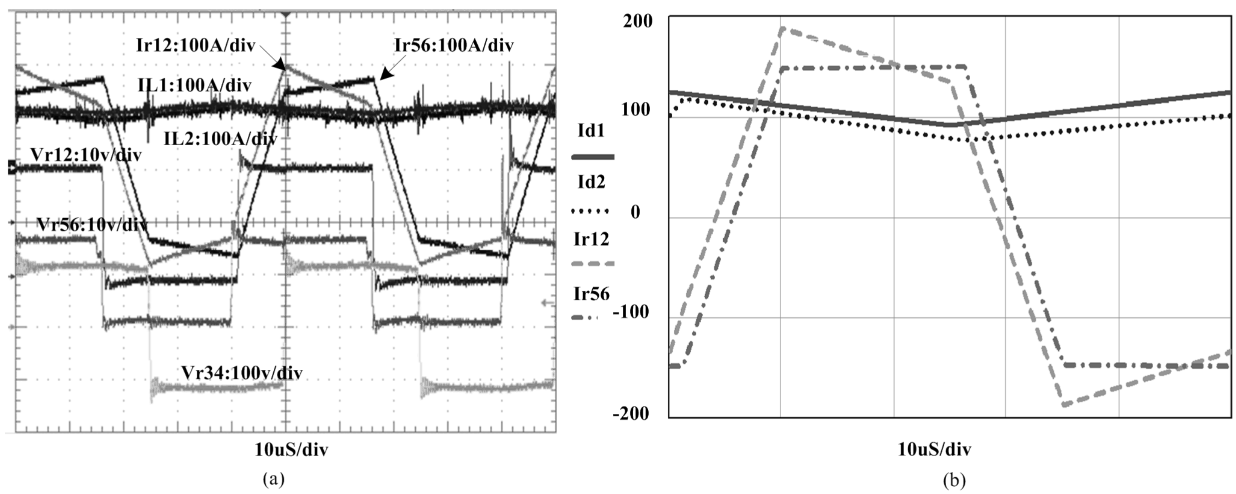

Fig.4 Simulated waveforms

$$\begin{cases} f_1 = I_{L1} - I_{r12}(t_1) > 0 \\ f_2 = I_{r12}(t_4) - I_{L1} > 0 \\ f_3 = I_{r53}(t_3) > 0 \\ f_4 = -I_{r34}(t_6) > 0 \\ f_5 = I_{L2} - I_{r56}(t_2) > 0 \\ f_6 = I_{r56}(t_5) - I_{L2} > 0. \end{cases}$$

Functions to denote the soft-switching conditions for six switches and, respectively.

3. SIMULATION

Circuit simulation results in boost mode and buck mode are presented in Fig. 5 to verify the theoretical analysis. The parameters used for simulation are described as follows:[49-65]

$$L_1 = L_2 = \ 5\ \mu\text{H},$$

Switching frequency f_s 20 kHz, transformer turns ratio

$$N_{12} : N_{56} : N_{34} = 1 : 1 : 12, L_{r13} = L_{r53} = 0.3\ \mu\text{H} ;$$

H. is selected intentionally larger to restrict the power flow between two sources. Filter capacitors – are selected to be 0.01 F. Resonant capacitors C_{r1}–C_{r6} are 3

The entire on top of mentioned element values square measure supported the primary-referred equivalent circuit. The nominal output voltage with the electrical device magnitude relation is chosen to be twelve 288 V. an oversized filter capacitance is needed since it has to provide an oversized charging/discharging current throughout operation and maintain a continuing voltage. If the present flowing into electrical condenser – is outlined as severally, it will be calculated within the following equation:

$$i_{c1}(t) = \begin{cases} I_{L1}(t) - I_{r13}(t), & 0 \leq x < 0.5Ts \\ 0, & \text{otherwise} \end{cases}$$
$$i_{c2}(t) = \begin{cases} I_{L1}(t), & 0 \leq x < 0.5Ts \\ -I_{L1}(t) + I_{r13}(t), & \text{otherwise} \end{cases}$$
$$i_{c5}(t) = \begin{cases} I_{L2}(t) - I_{r53}(t), & 0 \leq x < 0.5Ts \\ 0, & \text{otherwise} \end{cases}$$
$$i_{c6}(t) = \begin{cases} I_{L2}(t), & 0 \leq x < 0.5Ts \\ -I_{L2}(t) + I_{r53}(t), & \text{otherwise} \end{cases}$$

and will be derived equally. If the voltage ripple of every capacitance is chosen to be one V, Then the capacitance will be calculated as

$$C_n = \frac{\left| \int_0^{T_s} i_{cn}\, dt \right.}{1\ \text{V}}$$

4. CONCLUSION

A high-power-density multi-input ZVS bi-directional dc–dc device has been planned during this letter. The circuit model of the multi-winding electrical device, power flow management, and therefore the soft- change conditions of the switches are provided. It's shown that 2 energy sources with totally different dc voltage levels is combined to deliver power at the same time in either direction. Additionally, high power potency, high responsibility, and long life-cycle operation is achieved by the optimum power sharing between the sources. The projected device is applied in fuel-cell/hybrid-electrical vehicles, and renewable energy distributed systems system

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