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Multiphase Boost-Half-Bridge DC-DC converter and its Working Mode Analysis

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Abstract. This paper presents the multiphase boost-half-bridge (BHB) DC-DC converter for high power applications. Detailed working mode analysis of multiphase DC-DC converter has been analyzed. Analysis is made possible by simulating multiphase BHB DC-DC converter on MATLAB using simpower tool. The working mode of this converter is described and has been verified by simulation results. Finally, the simulation results are found to be satisfactory.

Keywords: The multiphase boost-half-bridge (BHB) DC-DC.

1. INTRODUCTION

Nowadays, there is an increasing need for isolated step-up DC-DC converters for high power applications. Usually, multiphase DC-DC converter has numerous merits over single phase. The major advantages are that currents are shared among phases to reduce current stress on devices, and that an interleaving control scheme reduce size of passive components with an increased effective frequency and low current ripple amplitude. Therefore the multiphase DC-DC converter topology could be one of the options for such applications. Number of topologies, for applications of high power have been proposed, consisting of isolated DC-DC converters (Cha, *et al*. 2008), (Oliveira and Barbi, 2005) (Cha, *et al*. 2010), (Andersen and Barbi, 2009). (Prasad, *et al*. 1992), (deSouza *et al*. 2005,) (Oliveira, and Barbi, 2005), (Kim, *et al*. 2010), (Lai, 2005). They can be categorized as current-fed (Cha, *et al*., 2008), (Oliveira *et al*. 2005), (Cha, *et al*. 2008). (Lee *et al*. 2010), (Andersen *et al*. 2009) (Prasad *et al*. 1992, deSouza *et al*. 2005), (Oliveira, *et al*. 2005, Kim, *et al*. 2010, Lai, 2005). Classification of current-fed topology, proposed from the primary-side configuration, can be classified into three basic topologies up to now and these are: half-bridge (Cha, *et al*. 2008), full-bridge (Cha, *et al*. 2008), and push–pull (Andersen *et al*. 2009). All three phase current-fed DC-DC converters mentioned above have some advantages and disad vantages over each other based on their configuration and working operation. The BHB converter has been presented meanwhile in (Fathy *et al. 2006,* Kim, *et al*. 2007, Choi *et al*. 2005, Watanabe *et al. 2002,* Zeng *et al. 2002,* Yoon *et al*. 2011). The boost half bridge with voltage rectifier at secondary side of HFT has additional benefits, which are presented in (Kim *et al*. 2007).

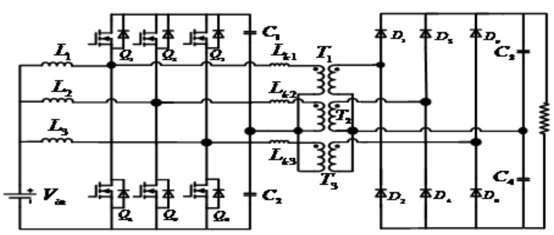

Fig. 1: Multiphase DC-DC Converter

2. SYSTEM DESCRIPTION

Fig. 1 shows generalized circuit of multiphase DC-DC converter using BHB and parallel voltage rectifiers on the secondary side of three high frequency isolated transformers. As shown in **Fig. 1,** there are three high frequency transformers (HFTs) which are connected in star connection. Each BHB cell is connected in parallel. Voltage rectifiers are connected in parallel to increase output current rating at secondary side of HFTs.

The method applied to three-phase boost half bridge DC-DC converter for switching purpose is interleaved asymmetrical PWM switching. Due to asymmetrical PWM switching, duty cycles D and 1– D are produced for switches of BHB cell, and the phase difference among each phase is 120°. The formula for an average magnitude of inductive current is:

$$I_{L,av} = \frac{V_o^2}{V_S R_o}\frac{1}{P} \quad (1)$$

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Where number of diode is represented by "P" or switch legs used to enhance power output while connected in parallel at output side. Value of inductor current ripple is:

$$\Delta I_L = \frac{V_S}{L\, f_S} D \qquad (2)$$

The formula for magnitudes of positive and negative peak of primary winding current are:

$$I_{Lk,+pK} = \frac{2V_0}{(1-D)R_o}\frac{N_S}{N_p}\frac{1}{P} + \frac{D^2 V_S}{(D^2+(1-D)^2)L_k f_S} \qquad (3)$$

$$I_{Lk,-pK} = \frac{2V_0}{DR_o}\frac{N_S}{N_p}\frac{1}{P} + \frac{(1-D)DV_S}{(D^2+(1-D)^2)L_k f_S} \qquad (4)$$

From equation 3 and equation 4, it is obvious that the magnitude of positive or negative peak is decreasing by increasing "P" (Changwoo *et al.* 2011).

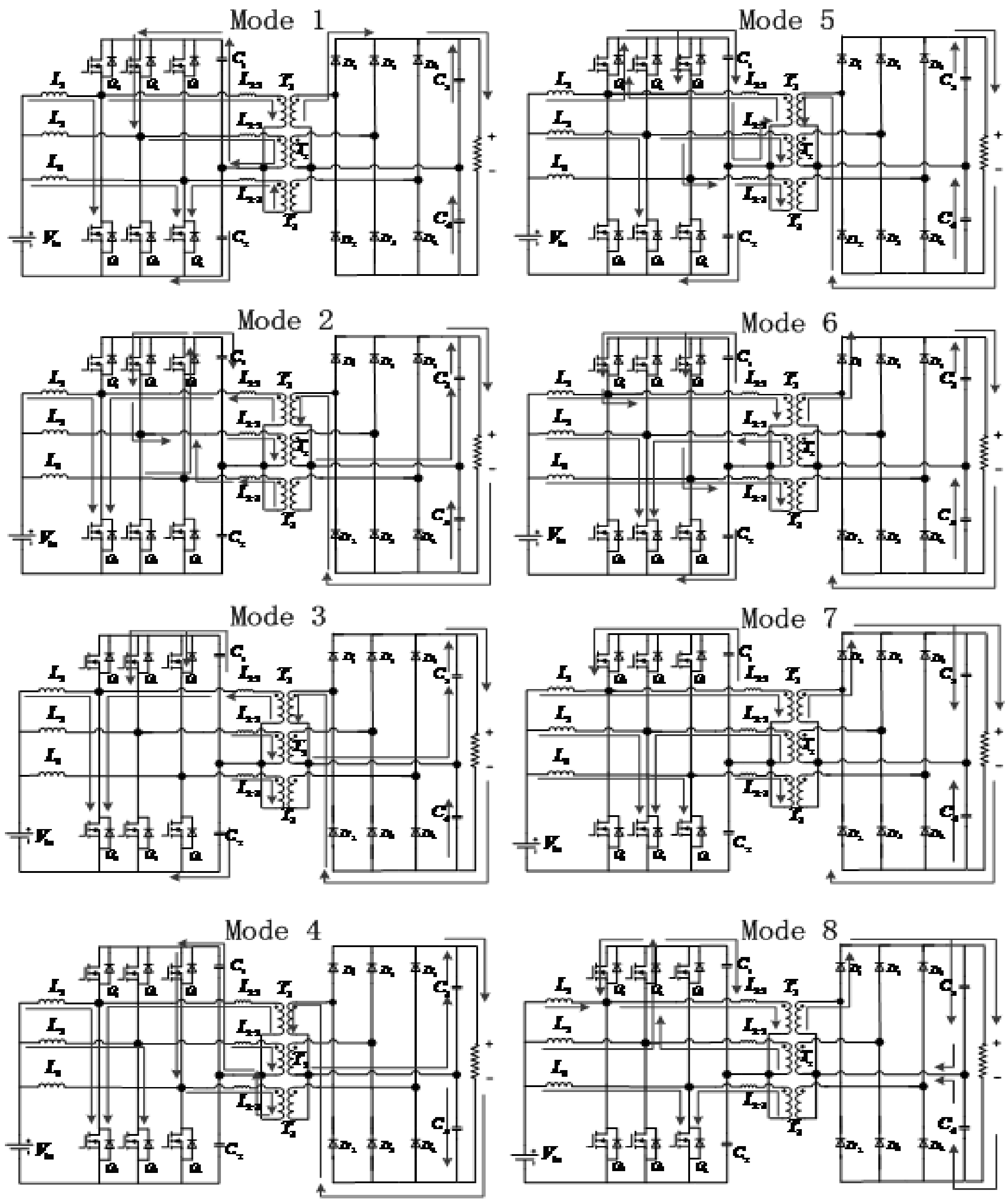

Fig. 2: Working modes of proposed topology

3. WORKING MODE ANALYSIS

Fig. 2 shows the working modes of proposed multiphase DC-DC converter over one switching period. The operation modes include eight switching modes which can be explained as under:

Mode1: In this mode, Q_2starts to conduct, the primary current direction of T_2 is changed to be a positive value;D_3 starts to conduct naturally and C_1 begins to discharge.

Mode2: The gate pulse signal is removed for Q_6, and then the parasitic diode of Q_3starts to conduct. V_{C1} increases until it reaches its maximum value.

Mode3: Energy on L_{k1} releases to zero, the current through capacitor C_1 reverse its direction to negative, $Q_3$is turned on and the primary current direction of T_3 is changed to be a positive value.

Mode4:Q_5 begins to conduct so that L_2 now stores energy from voltage source, current flows through loop C_1- Q_3 - L_{k3} - T_3 - C_1.

Mode5: The gate pulse signal is removed for Q_4 and then the parasitic diode of Q_1starts to conduct. The current through L_{k1} decreases to zero and reverses its direction at the end of this switching mode.

Mode6: The switch Q_1 starts to conduct. The current through C_1 reverses its direction and begin to discharge.

Mode7: The current through C_3 changes its direction to be a negative value.

Mode8: The gate pulse signal is removed for Q_5, and then the parasitic diode of Q_2 starts to conduct. The current through L_{k2}decreases to zero and reverses its direction at the end of this switching mode.

4. SIMULATIONS RESULTS

The multiphase boost-half-bridge DC-DC converter is simulated on MATAB using simpower tool. Above said configuration is simulated by considering the turn ratios of each high frequency transformer as 1:5. The specifications for the simulated model are represented in **(Table 1. Fig. 3)** represents the input currents through inductors and output voltage.

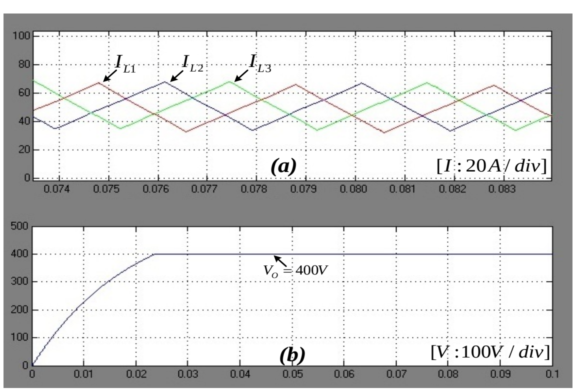

Fig. 3: Inductor currents and output voltage

Table 1: Specification for Simulation

Parameters	Value	Parameters	Value
P_O	5 kW	L_1 ~L_3	12 μH
V_O	400 V	C_1, C_2	20 μf
V_{in}	45 V	f_s	40 kHz

5. CONCLUSION

Based on simulation results it can be concluded that the power balance sharing can be obtained between input and output, using identical high frequency transformers in multiphase BHB DC-DC converter configuration. Moreover, the working modes of proposed multiphase converter are described in detail. Furthermore, it is also concluded that the operation of multiphase BHB DC-DC converter has been classified into eight different modes.

6. LIST OF SYMBOLS AND ACRONYMS:

BHB Boost half bridge
HFT High frequency Transformer
PWM Pulse width modulation
ZVS Zero voltage switching
V_{in} Voltage input
V_O Voltage output
P_O Power output
f_s Switching frequency
L_1, L_2, L_3 Input inductance
Q_1~Q_6 Switch 1~Switch 6
C_1, C_2 Input capacitance
C_3, C_4 Output capacitance
T_1, T_2, T_3 Transformers 1, 2 and 3
L_{k1}, L_{k2}, L_{k3} Leakage inductances of transformers1, 2 and 3
D_1~D_6 High frequency diodes
V_{ref} Reference voltage
I_{ref} Reference current
i_{L1}, i_{L2}, i_{L3} Input inductor currents

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