A NOVEL APPROACH FOR INTEGRATED PUSHPULL CONVERTER USING ZVT-PWM TECHNIQUE IN DC UPS

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Abstract:

This paper is a novel approach for integrated push pull converter performing the combined functions of Uninterruptible Power Supply (UPS) and Switch Mode Power Supply (SMPS) using Zero – Voltage Transition (ZVT) Pulse Width Modulation (PWM) Boost and Buck converters .The integrated push pull converters has high voltage main power input supply and low voltage back up supply. The output is a DC obtained from main input via the push pull converter during normal operation and back up battery via another push pull converter at the failure of the main supply. High conversion efficiency is achieved in normal, backup and charging modes as there is a only double dc-dc voltage conversion in each mode. The converter circuit is simple with four switching transistors, a relay for switching mode. For the converter circuit, boost and buck converters used at the secondary side of the push pull transformer using a new class of ZVT-PWM is proposed where both transistor and rectifier operate with zero voltage switching and subjected to minimum voltage and current stresses. These approaches offer substantial improvement in efficiency, size and cost over the conventional cascade of UPS and SMPS due to less number of voltage conversions, high frequency switching and removal of design redundancy. The design and simulation results of the above-proposed approaches are presented.

Key Terms: PUSHPULL, UPS, SMPS, ZVT-PWM, BOOST, BUCK

1. Introduction

The traditional way to protect the computer against power failure is to add an UPS proceeding the input of switching power supply [1-2] however UPS is often large and bulky due to the use of main frequency. Besides the system conversion efficiency from ac input of UPS to DC output power supply will be low due to multiple voltage conversions and inversions. Therefore it would be desirable to integrate the external UPS into the computer switching power supply to form a DC UPS, so the designed will have high efficiency due to double voltage (pushpull) conversions. The system cost will also reduce substantially due to removal of the redundant inverter and rectifier. The DC UPS will be of small size, which is slightly larger than conventional switching power supply but much smaller than the UPS. While this feature enables full utilisation of power transistor. The conversion efficiency in back up operation will be unacceptably low when voltage of the back up battery much lower than the main input, because the high voltage MOSFET will have on resistance too large for low voltage, high current switching.The proposed converters accept high voltage main input and low voltage back input with separated converter circuits for main and battery input. Rating of each switching transistor can be optimally selected thus enabling the converter to achieve high conversion efficiency [2] in all modes of operation. The converter can also be extended to provide multiple outputs with isolation.

2. Circuit Operation

2.1. Push pull Converter

The circuit of the proposed integrated pushpull converter is shown in Fig.1.

The Fig.1 has two power inputs V_{AC} (main ac voltage) and V_b (battery voltage). Main input produces a high input voltage V_{c1} across the input capacitor C1, when rectified by D_{in} or preferably full wave rectifier. The converter has three modes of Operation[1] namely normal mode, backup mode, charging mode. When the main power input V_{ac} is functioning properly the switch SW1 will be closed and MOSFET's Q_3 and Q_4 are turned OFF to operate the converter in normal mode. The equivalent circuit and waveform of the converter in normal mode is shown in fig.1a &1b. The circuit functions as pushpull converter delivering the power from the input to load with power flow controlled by duty cycle T1 and T2 of MOSFETs Q_1 and Q_2. The battery voltage$V_b$should be Chosen to be higher than (V_{c1} n_2/n_1) to prevent diode D_2 from conducting when Q_1 and Q_2 are in conduction. Such a choice will make the back up converter disappearing from the equivalent circuit.

When input power failure is detected, MOSFET Q_1 and Q_2 are switched OFF and switch SW1 is closed to operate the converter in backup mode. The equivalent circuit and waveform of the converter in back up mode is as shown in fig 3a &3b. The power flow is now from the back up battery V_b to the load and it is controlled by the duty cycle T3 and T4 of MOSFET Q_3 and Q_4. As the battery voltage V_b is much lower than the main input voltage V_{c1}, the switch current I_{Q3} &I_{Q4} in backup mode will be much higher than the switch current I_{Q1} &I_{Q2} in normal mode, therefore a low voltage, low R_{ds} MOSFET should be chosen for Q_3 and Q_4. Number of turns n_2 in primary of backup converter should be chosen to be much smaller than n_1 in the main converter. Circuit diode D_1 in fig 1 is used to prevent the floating input capacitor C_1 from being charged up by the positive peak of V_{p1} during the turn on transition of Q_3 and Q_4 through the body diode of Q_1 &Q_2 in backup mode. The capacitor C_b in fig1 is used to decouple the interconnection inductance of V_b, which can lead to large V_{ds2} when large current is being switched off in backup mode if not by-passed.

The main power input V_{ac} is functioning properly, SW1 can be opened to operate the converter in the charging mode. The equivalent circuit of the converter in the charging mode is another push pull converter shown in fig 2a &2b. As V_{c1} and V_b and windings n_1 and n_2 are in opposite polarities the input voltage is effectively (V_{c1}- V_b) and effective number of turns of the primary winding is (n_1- n_2). Input current I_{Q1} will then flow through D_1 and the body diode D_2 of Q_3 and will be switched by Q_1 and Q_2. The input current can flow whether Q_3 and Q_4 is on/off. The power to the output is controlled by the duty cycle T1 and T2 of MOSFETs Q_1 and Q_2. As the battery V_b is in series with the main input V_{c1}, the battery charging current $-I_b$ will be equal to the average input current I_{Q1} from V_{c1}. The disadvantages of the proposed converter, the charging current is load dependent and cannot be controlled independently. The converter thus cannot provide battery charging when there is no load. The closing of SW1 to switch the converter back to normal mode can stop charging. Note that although the primaries of the transformer T1 are in opposite polarities during the charging mode operation, the increase of copper losses are in insignificant because the number of turns n_2 is much smaller than n_1 and copper area per turn of n_2 is much larger than n_1.

	Normal Mode	Back up Mode	Charging Mode
Q_1&Q_2	PWM	OFF	PWM
Q_3& Q_4	OFF	PWM	---
SW1	ON	ON	OFF

Table.1

The states of MOSFETs Q_1,Q_2,Q_3 and Q_4, SW1 in different modes of operation are summarised in Table1.

The Table 1 indicates that there is four MOSFETs in the push pull converter. Only two PWM controllers are required for control because in any mode of operation, there is only two MOSFETs being switched, the output of the PWM controllers can be diverted to either two of the four MOSFETs according to the mode of operation.

2.2. ZVT – Circuit Operation

Fig (a) shows the circuit diagram of the Boost ZVT-PWM converter. It differs from the conventional Boost PWM converter by possessing an additional network consisting of resonant inductor (Lr), an auxiliary switch S1 and diode D1. To simplify the analysis input filter inductance and output capacitance is assumed large enough to consider as an ideal dc voltage and current sources. The main switch S and auxiliary switch S1 are off, if S1 is turned on, Lr current linearly rams up until it reaches I_i, where D is turned OFF. Even though Lr current continues to increase due to resonance between Lr and Cr. Cr is discharged until the resonance brings its voltage to zero, where the anti parallel diode of S starts to conduct. Whenever anti parallel diode of S is ON, to achieve ZVS the turn on signal of S should be applied while its body diode is conducting. Now S1 is turned off and its voltage is clamped at V_o due to conduction of D_1, during this time period S is turned on, the energy stored in the resonant inductor is transferred to the load during this time interval [3]. Lr current decreases linearly until it reaches zero, now D_1 is turned OFF. The operation of the circuit at this stage is identical to that of PWM-Boost converter. After some instant S is turned off, I_i linearly charges Cr to V_i voltage; this interval is identical to the free wheeling stage of the boost PWM converter.

In addition to the power switch, the rectifier diode in the converter is also commutated under soft switching, this feature makes the ZVT-PWM technique particularly attractive for high voltage conversion application. Both power switch and rectifier diode are subjected to minimum voltage and current Stresses, the auxiliary switch can be very

Small compared with the main switch, as it only handles small amount of resonant transition energy. In addition to the advantages, these techniques also ensure that for the whole load and line range high power capability. Fig (b) shows the circuit diagram of the, Buck ZVT-PWM converter, whose circuit operation will be similar to that of the boost converter, The only difference is the average value of the dc output voltage is less than the input voltage, where the boost converter, we are getting the average value of the dc output voltage greater than that of the corresponding dc input voltage.

3. Result

The simulation has been done for the above-specified approach considering the normal, back up, charging modes for all cases using PSIM, the circuit has been modelled using SIMCAD.graphs shown 1a, 2a, 3a are three modes of normal, charging. And back up with boost converter and 1b, 2b, 3b are graphs for three modes with buck converter. Fig (a) and (b) are ZVT – PWM boost and buck converters.

Fig.1

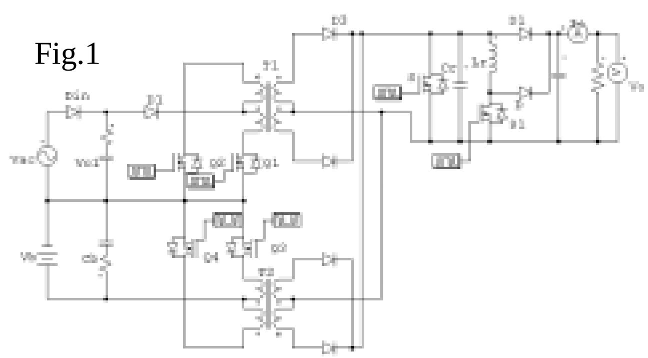


Fig.2

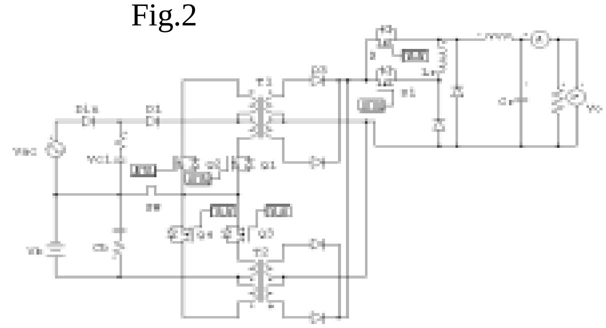
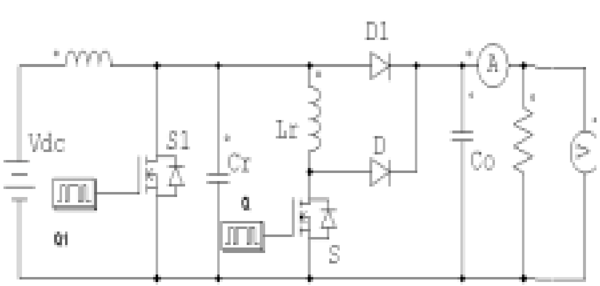
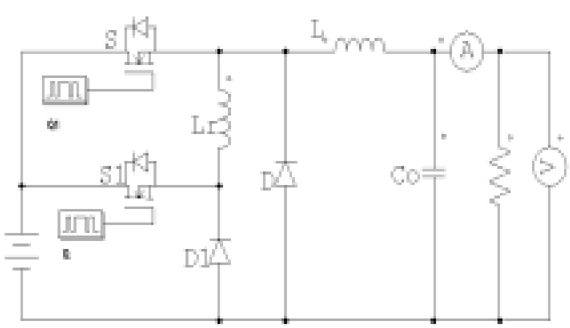


Fig. a





Note:Fig.1- integrated pushpull with boost converter.

Fig.2-integtated pushpull with buck converter.

Fig.a,b-only ZVT-PWM boost and buck converters.

Fig.1a

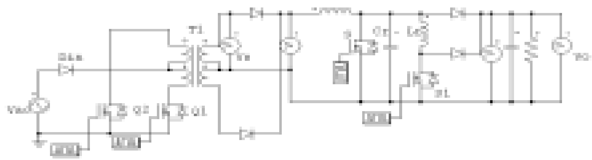


Fig.1b

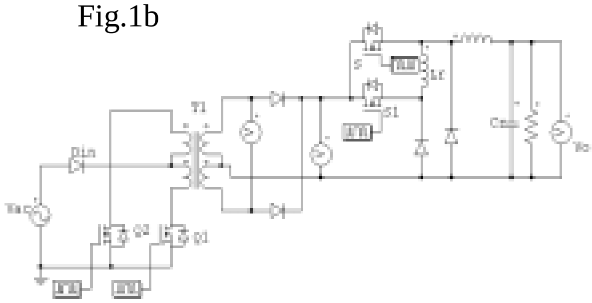


Fig.2a

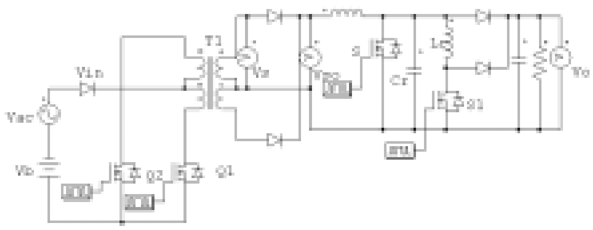


Fig.2b

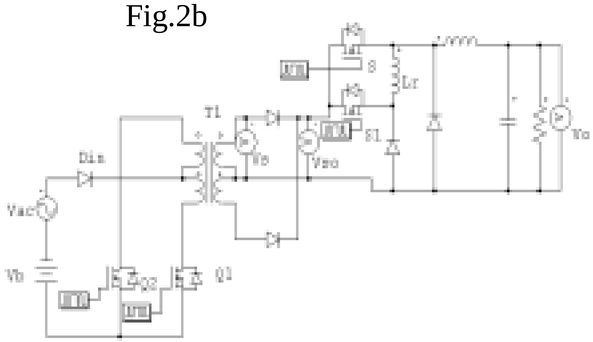


Fig.3a

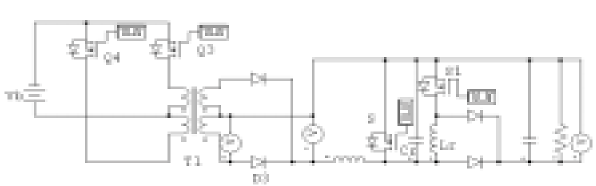


Fig.1a

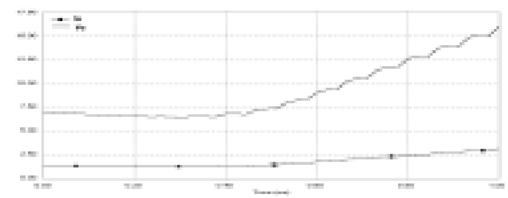


Fig.1b

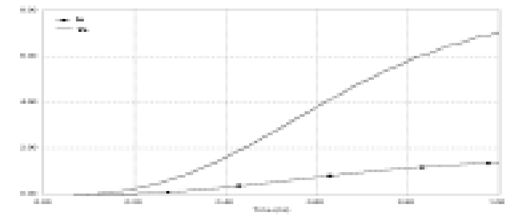


Fig.2a

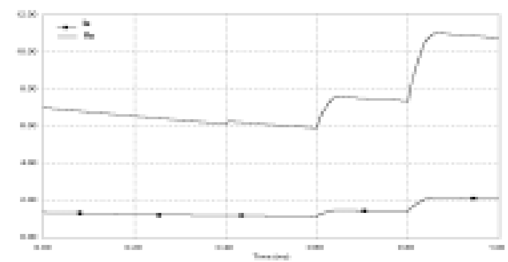


Fig.2b

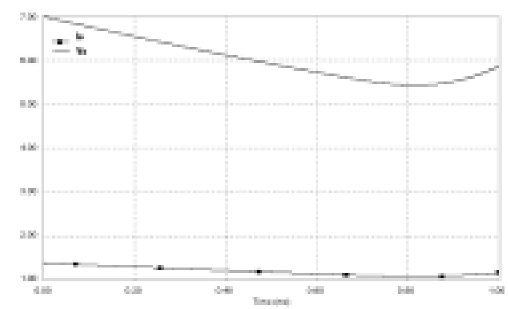


Fig.3a

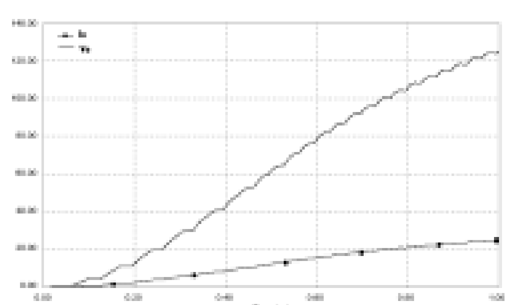


Fig.3b

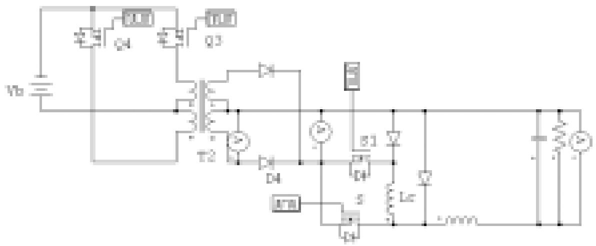
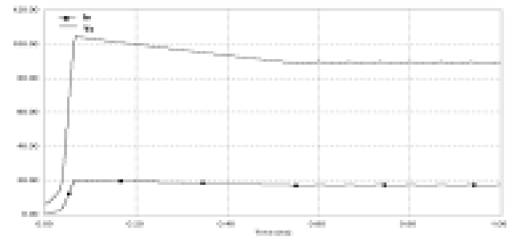


Fig.3b



Note:

Fig.1a-Normal mode with boost converter.

Fig.1b-Normal mode with buck converter.

Fig.2a-charging mode with boost converter.

Fig2b- charging mode with buck converter.

Fig3a – back up mode with boost converter.

Fig3b – back up mode with buck converter.

Note: In the above right side column waveforms are shown for the corresponding equivalent circuits shown in left side column.

Note: WTB – Without Boost Converter,

WB – With Boost Converter,

WTBU – Without Buck Converter,

WBU- With Buck Converter,

N.M – Normal Mode,

B.M – Back Up Mode

C.M. – Charing Mode

4.Simulation

	Integrated Push pull Converter			
	WTB	**WB**	**WTBU**	**WBU**
N.M	**13.5**	**16.89**	**13.5**	**8**
B.M	**91**	**128**	**91**	**85**
C.M	**9.8**	**11**	**9.8**	**6**

Load Volltage in Volts V_o

	Integrated Push pull Converter			
	WTB	**WB**	**WTBU**	**WBU**
N.M	**2.80**	**3**	**2.80**	**1.80**
B.M	**18**	**24**	**1.8**	**1.8**
C.M	**2**	**2.4**	**2**	**1.4**

Load Current in Amperes I_o

4.1. Note:

From the above simulation results of load voltage and current, by using ZVT – PWM buck and boost converters in the secondary side of integrated pushpull, we can achieve any desired load voltage and current by changing the firing angle of the boost and buck converters, which will leads to increase the operational ratings of the pushpull converter

5. Conclusion

The operation, design, simulation results of an integrated Push pull converter with Zero Voltage Transition – PWM Converters for high frequency DC UPS application are presented. This designed converter features simple circuit, high efficiency, small size and low cost compared with the conventional cascade of a ups and switching power supply, in addition to this, due to presence of ZVT-PWM converters, we have step up or step down the output voltage of the transformer secondary in the proposed integrated converters, so that this proposed converter should find application in personal computers, work stations, regulated dc power supplies, dc motor speed control, regenerative braking of dc motor. Proposed, integrated push pull converter used for high output voltage at high power ratings.

Nomenclature

C_1 - Capacitor across main input supply.
C_b - Capacitor across back up battery.
C_r - Resonant capacitor.
D - Main diode in secondary side.
D_{in} -Full bridge diode.
D_1 - Diode in series with the primary winding.
D_2 - Diode across the back up battery MOSFET.
D_1 - Auxiliary diode in secondary side.
D_3 - Diode in series with the secondary winding.
I_b - Battery charging current.
I_{Q1} - Current flowing through Q_1.
I_{Q2} - Current flowing through Q_2.
I_{Q3} - Current flowing through Q_3.
I_{Q4} - Current flowing through Q_4
$L._r$ - Resonant inductor.
n_1 - No. of turns of first primary winding.
n_2 - No. of turns of second primary winding.
n_3 - No. of turns of secondary winding.
Q_1&Q_2 - Normal mode MOSFET.
Q_3&Q_4 - Back up mode MOSFET.
R_{ds} - Drain to source resistance of MOSFET.
S - Main switch in secondary side.
S_1 - Auxiliary switch in secondary side.
SW1 -Relay switch for mode conversion.
V_{ac} - Voltage across main supply.
V_{c1} - Voltage across capacitor C_1.
V_b - Voltage across the battery.
V_{P1} - Positive peak charged voltage of C_1.
V_{ds2} - Drain to source voltage of Q_2.

References

1) Kwok-Kai and Yim-Shu Lee "An Integrated Flyback Converter for dc uninterruptible power supply"- IEEE Trans Power Electronics, vol II, No, 2, March 1996.
2) J. Perkinson "UPS systems: A Review ", in Proc, Third IEEE Appl, Power Electron Conf. Exposition 1998, pp 151-154.
3) Guichao Hua, Ching-Shan Leu, Yimin Jiang, and Fred C. Y. Lee "Novel Zero-Voltage –Transition PWM Converters"- IEEE Trans Power Electronics, Vol 9, No, 2, March 1994.
4) Keith.H.Billings,"Switched mode power Supply Handbook", McGraw Hill, Singapore, 1989.
5) Abraham. I. Pressman, "Switching power supply design", McGraw-Hill, Singapore, 1999.
6) Ned Mohan, Undeland and Robbins, "Power Electronics converters, Applications and Design", John Wiley & Sons, Singapore, 2001.