ZVS/ZCS Bidirectional DC-DC Converter for DC Uninterruptable Power Supply

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ABSTRACT
An Isolated ZVS/ZCS bidirectional DC-DC converter for DC Uninterruptable Power supplies is presented in this paper. The usual way to avoid a computer shutdown during the mains failure is to connect an ac uninterruptible power supply (UPS). Alternatively, in this paper, a simple and high efficiency dc UPS is presented by an isolated bidirectional soft-switching dc-dc converter. The bidirectional dc-dc converter operates under zero-current switching (ZCS) /Zero voltage switching conditions by utilizing the leakage inductor of the transformer. ZVS/ZCS operation is achieved in battery-backup and charging modes, which significantly reduces the power losses in the bidirectional converter. The principle of operation is analyzed and simulated by using MATLAB simulink.

Keywords
ZVS, ZCS, DC-DC converter, UPS, Simulation

1. INTRODUCTION
Uninterruptible power supply (UPS) systems provide uninterrupted, reliable, and high quality power for vital loads. They protect sensitive loads against power outages as well as extreme voltage conditions. UPS systems also suppress line transients and harmonic disturbance. Applications of UPS systems include medical facilities, life support systems, data storage and computer systems, emergency equipment, telecommunications, industrial processing, and online managementsystems [2]–[10].
Generally, an ideal UPS should be able to deliver uninterrupted power and simultaneously provide the necessary power conditioning for a particular power application. Therefore, it should have the following features: regulated sinusoidal output There are many industrial applications in which a mains failure can cause serious damage, not only to the equipment, but also to the process involved. A common case is information loss caused by the utility shutdown in PCs.

Nowadays, many company buildings usually have an uninterruptible power supply (UPS) that feeds the equipment of the whole building. However, in many other cases, each individual user has to connect a personal UPS to the computer in order to avoid an unexpected shutdown. There are many commercial products of this type, but in general, all of them are ac UPS [1]-[3]. Their output voltage is an ac voltage that substitutes the mains voltage. However, the problem can be solved in other ways by providing the dc output voltage of the power supply directly from the battery. That is the DC UPS [5].

Particularly, this approach can be very feasible, if there is only an isolated dc-dc converter in the PC power supply. Thus, several DC UPS systems were proposed: tri-port converter [6] and integrated converter [7] and ZCS bidirectional converter [1]. However, they suffer from high switching losses because the hard-switching operation of the switching devices increases the power losses and ZCS soft switched bidirectional DC-DC converter has removes current tails across the switches S3,S4 in [1] The major drawback in the circuit [1] is that in the charging mode, the switches S1,S2 in does not operates in soft switching ZVS/ZCS. In ZCS bidirectional DC-DC converter [1] major drawback in charging mode. This drawback is overcomes by introducing additional resonant components Inductor, Capacitors in Battery charging side to obtain ZVS condition.

In this paper, to deal with the aforementioned problems, we suggest a simple and high efficiency ZVS/ZCS DC UPS system by presenting a new isolated ZVS/ZCS soft-switching bidirectional DC-DC converter. Battery-backup and charging modes are achieved only through the bidirectional DC-DC converter, which simplifies the circuit structure and power efficiency of the dc UPS system. Zero-voltage switching (ZVS) operation is achieved in battery-backup and ZCS is achieved in charging modes, which significantly reduces the switching losses in the bidirectional DC-DC converter and it will improve the overall efficiency.

2. PROPOSED DC UPS SYSTEM
Fig. 1 shows the overall structure of the proposed DC UPS system. The proposed ZVS/ZCS DC UPS system consists of a 12-V battery, an isolated bidirectional DC-DC converter, and a single phase full-bridge diode rectifier.

The DC UPS system has three operation modes: normal, backup, and charging modes. When the main utility line is properly functioning, the bidirectional converter does not work.
The utility line supplies the electrical power through the single-phase full-bridge diode rectifier to the PC power supply in the normal mode. If there is an eventual failure in the utility line, the bidirectional converter operates in backup mode, maintaining the output voltage with fast dynamic response. The switches S_1 and S_2 are driven symmetrically. The energy stored in the 12-V battery is transferred through the L_p ,transformer T. At the primary side, the switches S_1 and S_2 are turned on at zero-voltage. At the secondary side, the body diodes of S_3 and S_4 switches are utilized as the output rectifying diodes.

As shown in Fig. 2, there are two operating modes in the proposed DC-DC converter during the backup mode. When the switch S_1 is turned on, the body diode D3 of S_3 switch is turned on. Primary side switches are turned on and turned off under Zero voltage switching condition by introducing additional resonant capacitor Cr1 with a series inductor Lp in primary.

Stage 2: Switch S_2 is turned on ZVS due to energy stored in Cr2 in first stage. During this stage power flow through the battery, S_2, L_2, body diode of D_4 and output capacitor C_0. In this stage Cr_2 Cr_1 will be charged up to $V_{battery.}$ Due to stored energy in capacitor, the S_2 will turn off ZVS condition.

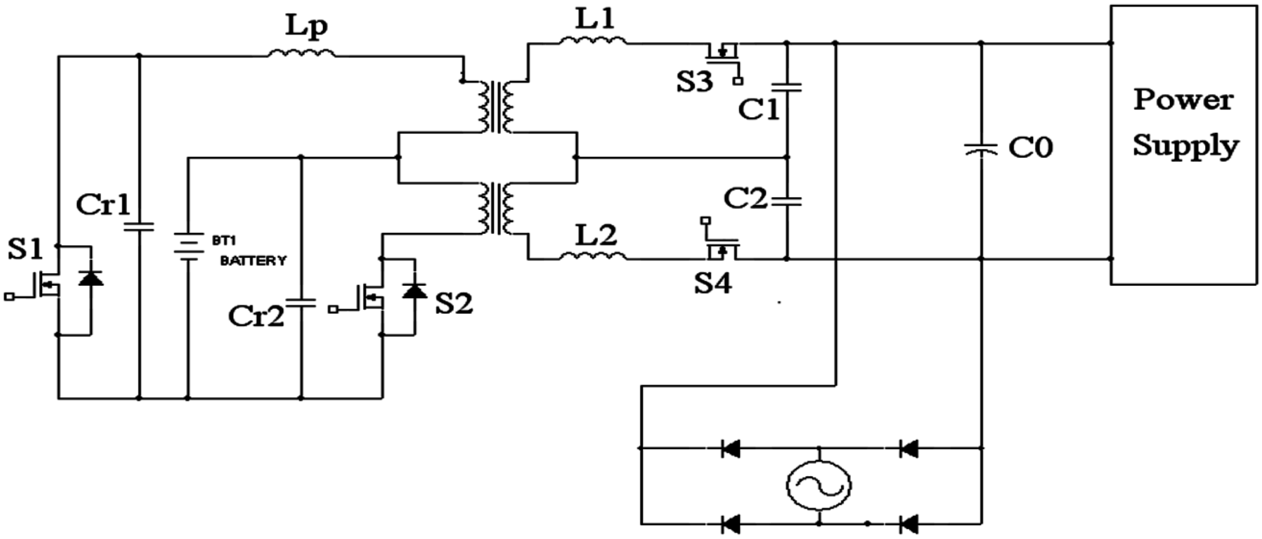

Fig 1: Proposed ZVS/ZCS Bidirectional DC-DC converter

2.1 Back-up mode

In this mode power line is failure to supply DC to the UPS. The storage battery will provide the DC voltage required to the power supply system. Fig.2a,2b illustrates the stage1 and stage 2 of backup modes.

Stage 1: S_1 is turned on with ZVS due to the resonant capacitor Cr1. The power flow through battery, S_1, L_p, L_1, D_3 to the output capacitor. This stage ends when S_1 is turned off under zero voltage switching. During this stage capacitor Cr_2 charges to $V_{battery}$.

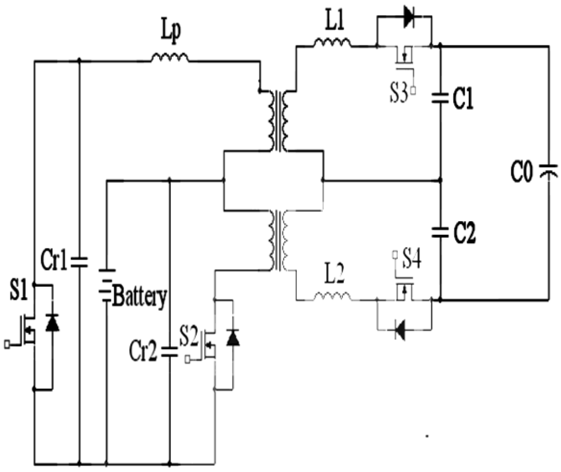

Fig 2 (a): Stage 1

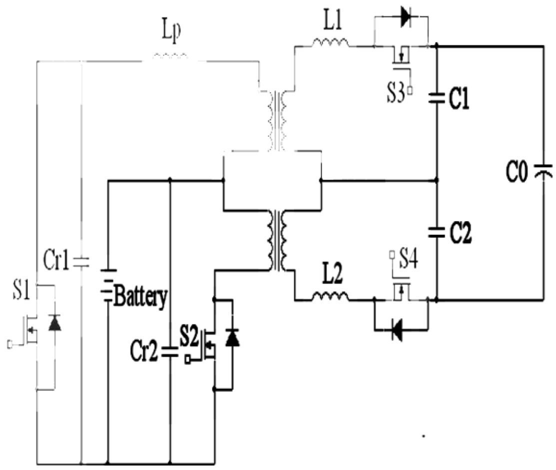

Fig 2 (a): Stage 1

2.2 Charging mode

In this mode bridge rectifier provides DC voltage required to the UPS system. In this operating mode battery will be charged by means of switches S_3,S_4. Fig.3a, 3b illustrates that stage 1, and stage 2 modes of charging.

Stage 1: when S_3 is turned on under ZCS by the resonance of C_1, the power flow through S_3,L_1,L_p body diode of S_1 and battery. During this stage capacitors C_2, Cr_1, Cr_2 are charged to Vbattery. This stage ends at S_3 turn off by ZCS

Stage 2: when S_4 is turned on under ZCS, which is obtained by the energy stored in C_2 with series inductor L_2. During this stage body diode of S_2 acts as rectification in charging mode. The power flow through S_4,L_2, body diode of S_2 ,and battery. This ends when S_4 is turned off in ZCS condition.

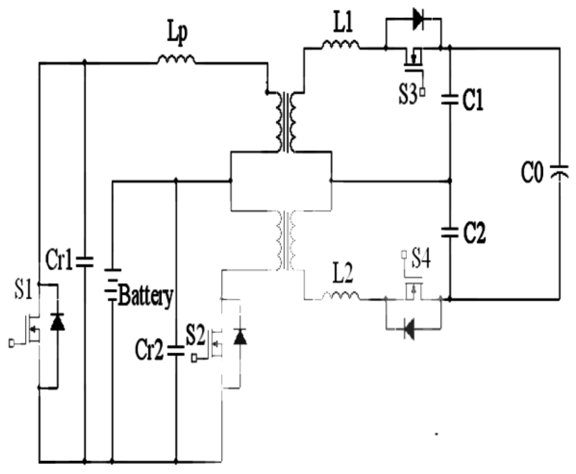

Fig 3(a): Stage1

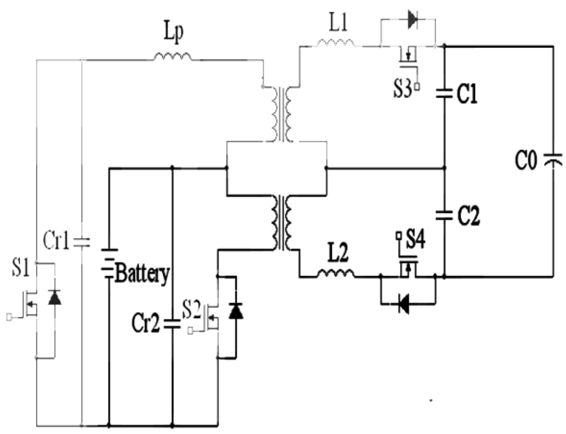

Fig 3(b): Stage 2

3. SIMULATION EVALUATION OF PROPOSED DC UPS SYSTEM

The design and simulation of proposed ZVS/ZCS bidirectional DC-DC converter by using Matlab simumlink was performed. The results are compared with the ZCS bidirectional concept in order to show the performance.

Simulation parameters considered are as follows :

Vbattery : 12 V, 20 Ah , Lithium Ion
Duty cycle : 0.45
Switching frequency: 7 kHz
Load voltage: 110 V – 170V
Output power: 500W- 1kW

Fig 4 illustrates that voltage through transformer in back-up mode. Fig.5 shows that load voltage across output capacitor. Fig.6 shows that voltage thorugh transformer,Fig.7 the output voltage in charging mode. The generated pulses in back-up mode is depicted in fig.8. Switching frequency is equal in both the modes.

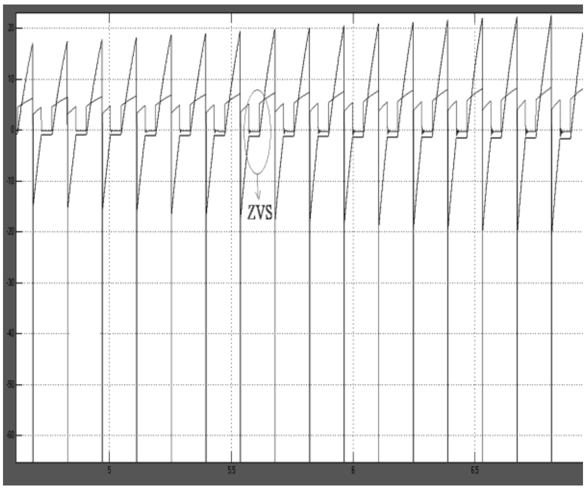

Fig 4: Voltages through transformer

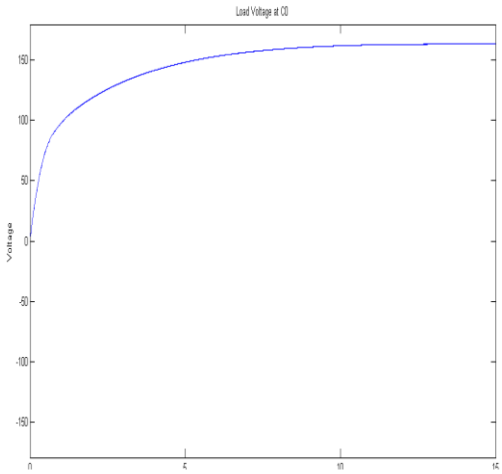

Fig 5: Load voltage in back-up mode

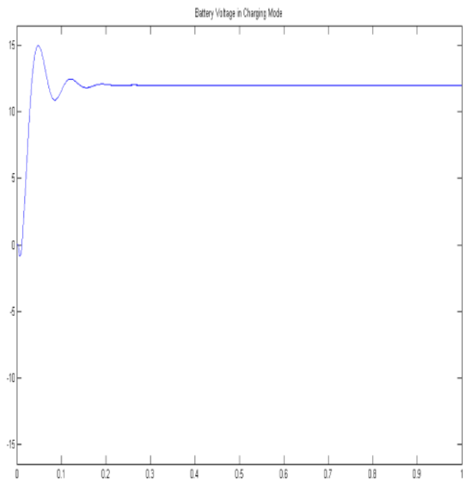

Fig 6: Load voltage in charging mode

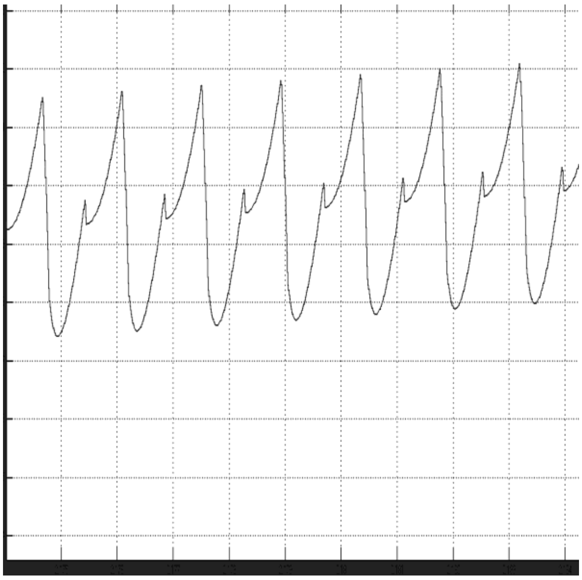

Fig 7: Current through transformer in Charging mode

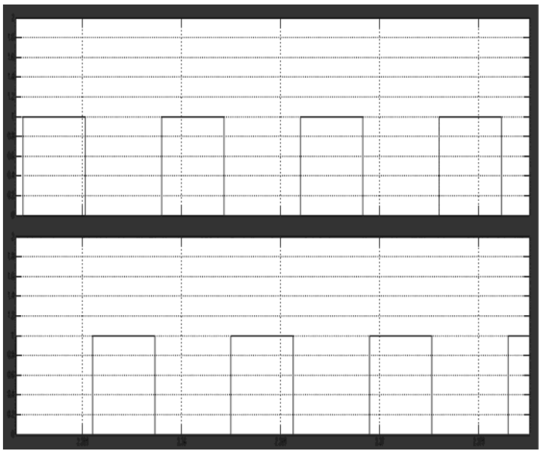

Fig 8: Generated Pulses to the switches

4. CONCLUSION

The main proposal is a new ZVS/ZCS bidirectional DC-DC converter for DC uninterruptable power supply systems. Zero voltage switching condition is obtained in back-up mode and Zero current switching condition is obtained in charging mode. By addapting resonant elements to ZCS bidirectional DC-DC converter, the ZVS/ZCS bidirectional dc-dc converter has been proposed. The simulation results are obtained by using Matlab Simulink. The result shows that switching stresses in back-up mode are reduced and the output voltage increases.

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