Automatic Forward and Backward Mode Transition by using a Bidirectional LLC Resonant Converter

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ABSTRACT

This paper proposes an improved bidirectional LLC resonant topology with a new control scheme. All the switches in the proposed topology can achieve soft switching. Compared with traditional isolated bidirectional dc–dc converters such as dual active bridge converter, the reverse energy and turn-off loss are reduced dramatically, and the conversion efficiency can be much improved with the proposed new control scheme, the power flow direction and output power of the proposed converter can be changed automatically and continuously, which is attractive for energy storage systems to balance the energy and to keep the dc-bus voltage constant. Performance of the proposed circuit is validated by the experimental results from a 1-kW prototype. Over 97% efficiency is achieved at full load condition based on the prototype.

Index terms-*Bidirectional LLC resonant, Dual active bridge converter, zero voltage soft switching.*

I .INTRODUCTION

More and more research efforts have been focused on how to use the clean energy in an efficient way in recent years for energy saving and environment protection. The distributed generation systems (DGSs) with clean renewable energy resources like photovoltaic, wind power, and fuel cell are widely adopted around the world. However, the intermittent nature of these clean renewable energy resources may cause fluctuation between power generation and consumption. So energy storage systems (ESSs) are required in DGSs to deal with the intermittent outages and make the system more stable and reliable. Batteries and super Capacitors are the most popular energy storage components considering the price and performance.we adopted this approach Peng ,F.Z.,H.,Su,G,J. and Lawer,J,S. “A New ZVS Bidirectional DC-DC Converter for fuel Cell and Battery Application This paper presents a new zero-voltage-switching (ZVS) bidirectional dc-dc converter .Compared to the traditional full and half bridge bidirectional dc-dc converters for the similar applications, the new topology has the advantages of simple circuit topology with no total device rating (TDR) penalty , soft switching implementation without additional device, high efficiency and simple control.

These advantages make the new converter promising for medium and high powerapplications especially for auxiliary power supply in fuel cell vehicles and power generation where the high power density,low cost, low weight ,and high reliability power converters are required .the operating principle ,theoretical analysis, and design guidelines are provided in this paper .The simulation and the experimental verifications are also presented.

Galvanicisolation is usually requiredforsafety consideration. Besides, voltagevariation ofboththerenewableenergy resources and energystoragecomponentsiswide, so thevoltage gain rangeofthebidirectional DC-DCconvertershouldbeas wideaspossible. Manyisolatedbidirectional topologieshavebeen proposed andstudiedinrecentyears,andthedualactive bridge(DAB)converter isoneofthemostpopular topologies for its simplicity and high power density [5]-[19]. However,itsuffersfromhighcirculating energy andhigh turnoffpowerloss.Alotofcontrolmethodshave beenproposedtominimizethecirculatingenergyor extend itssoft switchingrangeby phase shift ordutycyclecontrol, butthecontrolmethodsarecomplexandcan’tsolveallthe disadvantagesatthe sametime

II.EXISTING SYSTEM

This project proposes a TL *LLC* converter with a pulse width and amplitude modulation (PWAM) control method. The switching frequency is constant and equal to its resonant frequency, thus the converter can achieve soft switching for all switches easily. With three different control schemes, the converter can achieve a wide voltage gain. The proposed bidirectional TL *LLC* resonant converter is shown in Figure, which has a hybrid full-bridge structure with MOSFETS $M1$–$M6$ in the transformer primary side and a full bridge structure with MOSFETs $Q1$–$Q4$ in the secondary side, D1 and D2 are the body diodes of $Q1$ and $Q2$, D5–D8 are the body diodes of MOSFET$M5$–$M8$, respectively.

MOSFETs$M1$ to $M4$ are connected in series to form a TL switching leg I, $M5$ and $M6$ are series connected to form bridge leg II. "A" and "B" are the midpoints of bridge leg I and II. "C" and "D" are the midpoints of secondary-side full bridge. n is the transformer turns ratio. In order to achieve bidirectional power flow, MOSFETs $M7$ and $M8$ are used as clamp switches instead of conventional clamp diodes. The input source $V1$ is in the transformer primary side, while the energy storage element $V2$ is in the transformer secondary side. Lr is the resonant inductor, Cr is the resonant capacitor, and Lm is the magnetizing inductor of the transformer. Capacitor $C3$ is the flying capacitor. The operation principle in forward mode and backward mode are presented. A prototype with maximum 20-A is output current.

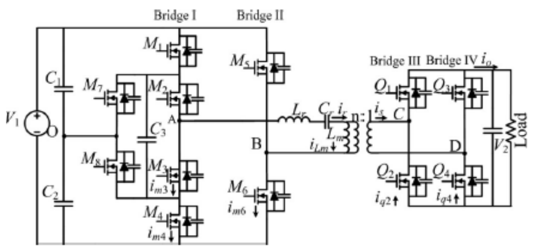


Fig -1

DRAWBACKS IN EXISTING SYSTEM

- Traditional isolated bidirectional dc–dc converters such as dual active bridge converter, the reverse energy and turn-off loss are increased dramatically,
- Conversion efficiency is less.

III.PROPOSED SYSTEM

The DAB converter has been analyzed extensively with output power above 1 kW and switching frequency below 100 kHz. Under these conditions, resonant intervals responsible for achieving ZVS occupy a sufficiently small percentage of the switching period to allow their exclusion from converter analysis. However, at higher frequencies and lower output power levels, the resonant interval resulting in primary side ZVS corresponds to a significant portion of the switching period and must be included in the analysis of converter operation. This study seeks to examine the nature of this ZVS interval across a full range of load conditions and use the resulting analysis to develop a simple, high-efficiency control strategy for the unregulated DAB converter. But compared with proposed system it has less efficiency

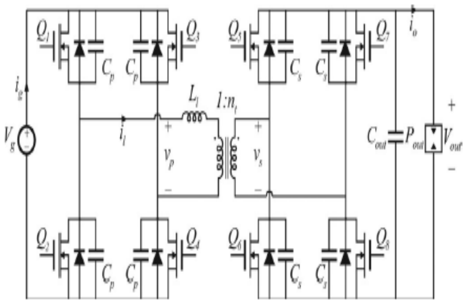
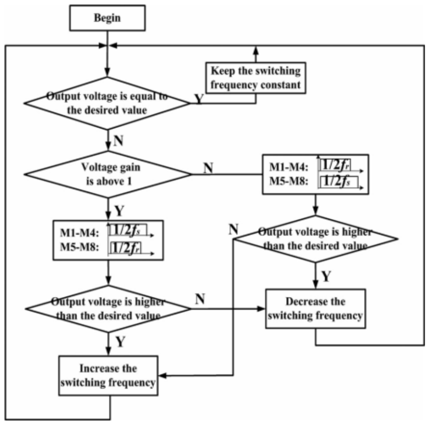


Fig-2

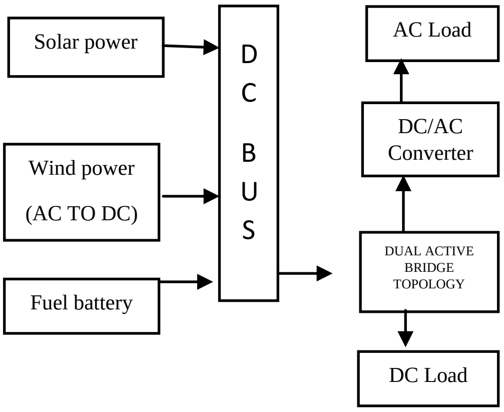
DAB TOPOLOGY



The turn-off power loss is related to the turn-off current,which can be reduced by operating the DAB topology in resonant mode with an extra resonant capacitor, i.e., dual bridge series resonant converter

DAB topology in existing system is to eliminate turnoff loss with 97%.But in proposed system we eliminate turnoff loss at 100%.

BLOCK DIAGRAM;



IV WORKING PRINCIPLE

For G<1, the resonant inductor Lr , resonant capacitor Cr and transformer magnetizing inductor Lm1 form the LLC resonant tank, and the auxiliary inductor Lm2 is used to help to achieve ZVS for secondary side switches. The operation of the proposed topology along with the control scheme is symmetrical for forward mode with G>1 and backward mode with G<1 by simply swapping the input and output side. When energy generated in distributed system exactly matches the load power, the energy transferred between the battery and the dc bus will be zero. When energy generated in distributed system exactly matches the load power, the energy transferred between the battery and dc bus will be zero

a) SWITCHING OPERATIONS

Mode 1 (t0 –t1) : The equivalent circuit M1, M4, M5, and M8 turn ON at t0 with ZVS. The voltage across the auxiliary inductor Lm2 is equal to Vo, so iLm2 increases linearly. Voltage across the transformer magnetizing inductor Lm1 is equal to Vb, and its current increases linearly, too. In this mode, Lr resonant with Cr and ir is always larger than iLm2. This mode ends when M5 and M8 turn OFF at t1 when ir is equal to iLm2, so M5 and M8 turn OFF with ZCS.

Mode 2 (t1 –t2): The output is disconnected from the resonant tank, and energy to the load is supplied by the output capacitor. In this mode, Cr, Lr , and Lm2 form the resonant tank, so iLm2 and ir are the same. As the resonant period is quite long, ir will increase very slowly due to large inductance of Lm2 .

Mode 3 (t2 –t3):M1 and M4 turn OFF at t2. ir plus iLm1 charge the parasitic capacitors of M1 and M4, and discharge the parasitic capacitors of M2 and M3 until the voltage across M1 and M4 reaches the input voltage, then current in the primary side begins to flow through the body diodes of M2 and M3. Then, current in the secondary side begins to flow through the body diodes of M6 and M7, so they will turn ON with ZVS.

b)CONVERTER CHARACTERISTICS ANALYSIS

Vp is the equivalent output voltage of the renewable energy resources, such as PV panels. Vb is the battery terminal voltage and Vo is the dc-bus voltage which is also the output voltage of the bidirectional dc–dc converter.

Due to different control schemes, the characteristic of voltage gain G is different from the traditional unidirectional LLC converter. It will be discussed firstly. When G is above 1, the operating principle is similar to the traditional LLC resonant converter with the control scheme.

When G is below 1 with control scheme, though M1 and M4 turn OFF after half the resonant period, the current will still flow. Through the body diodes of M1 and M4 after they turned OFF since the current through M1/M4 is stillnegative at t1 . So, the converter is always operating in CCM mode, which is similar to that with synchronous controls analyzed

c) SOFT SWITCHING

It is known from traditional LLC resonant converter, that there is a boundary between the capacitive region (ZCS) and inductive region (ZVS) for the primary side MOSFETs when the switching frequency is below the resonant frequency. Operation in the capacitive region should be avoided for reliable operation.

In the proposed topology, the transformer magnetizing current iLm1 also provides extra inductive current, the inductive region will be wider and it is easier to achieve ZVS. For simplicity, the design for traditional LLC resonant converter can be adopted for G>1 of the proposed converter.

For G < 1, there is also a boundary between the inductive region and capacitive region. Operation of the primary side switches should always be in ZVS region to avoid the capacitive switching. So, the turn-on current of primary side MOSFETs should be negative, and should always be satisfied. The expressions of magnetizing currentand resonant current in a half switching cycle are given, and Ipeak is the peak value of the equivalent current, which is derive

ADVANTAGES:

- Different voltage gain achieves different applications.
- Achieve soft switching for all the power devices
- High efficiency

APPLICATIONS

- Vehicular applications
- Renewable applications

CONCLUSION

In the proposed topology switching characteristics is increased and completely eliminated the turnoff loss.At the percentage of 100 we occur the output without any losses.

A bidirectional LLC resonant topology along with a new control scheme. An auxiliary inductor is added to make the topology symmetrical in any operating modes. All the switches in the primary side and secondary side turn ON and OFF with the same switching frequency, but the pulse width is different based on the required voltage gain. And the switching frequency is used to regulate the output power and the power flow direction. Therefore, the proposed topology can automatically switch between the forward mode and the backward mode, which is quite attractive for energy storage system applications. The detailed operation principle and topology characteristics are analyzed. Experimental results from 1-kW prototype verify the theoretical analysis.Efficiency above 100% was achieved at full load condition.

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