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New Bidirectional Dc–Dc Converter Topology For Renewable Sources

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Abstract— This paper presents a new resonant dual active bridge (DAB) topology, which uses a tuned inductor–capacitor–inductor (*LCL*) network. In comparison to conventional DAB topologies, the proposed topology significantly reduces the bridge currents, lowering both conduction and switching losses and the VA rating associated with the bridges. The performance of the DAB is investigated using a mathematical model under various operating conditions.

I. INTRODUCTION

Demand for clean and sustainable energy sources has dramatically increased during the past few years with growing population and industrial development. For a long time, fossil fuels have been used as the major source of generating electrical energy. Environmental consequences of

these resources have made it necessary to benefit from clean energy sources such as wind and solar. Therefore, distributed generation (DG) systems based on renewable energy sources have attracted the researchers' attention. The DG systems include photovoltaic (PV) cells, fuel cells and wind power [1]–[3]. However, the output voltages of these sources are not large enough for connecting to ac utility voltage. PV cells can be connected in series in order to obtain a large dc voltage. However, it is difficult to ignore the shadow effect in the PV panels [4]–[6]. High step-up converters are a suitable solution for the aforementioned problem.

Each PV panel can be connected to a particular high step-up converter. Therefore, each panel can be controlled independently. These converters boost the low-input voltages (24–40 V) to a high-voltage level (300–400 V) [7]. The main features of high Among the many types of bidirectional dc– dc converters that could be used in a V2G system, the DAB converter is a preferred option, as it has a small component count, offers isolation, and allows for high power operation [6], [7].

In addition, it has the ability to accommodate a wide range of voltage levels, as it may be controlled to operate in buck or boost modes. However, a conventional DAB converter using single phase-shift (SPS) control [8] draws a large reactive current component at low operating power levels, which increases the converter conduction losses. This current component also necessitates the use of a larger dc-link capacitor [9], [10]. Therefore, various techniques have been used to lower the reactive current levels. In [11], pulse width modulation (PWM) of the higher voltage bridge was used ith SPS to extend the zerovoltage-switching (ZVS) range to increase the converter low-load efficiency, through a reduction in the reactive current. Triangular and trapezoidal modulation schemes were investigated in [12] in an effort to reduce the current and, therefore, the conduction losses. Primarily, this resulted in a reduction in the switching losses by achieving zero current switching in some of the switches [13]. In [14], the reactive power was reduced by using equal PWM on each bridge, as well as a phase shift between the bridges.

Similar control techniques to that in [11] were used in [15]–[17], except that the

PWM was actively controlled by an algorithm. Bridge losses A composite modulation scheme was proposed, whereby the control algorithm transitioned from dual PWM, at low phase-shift values, through to single PWM which varied linearly to a maximum for a phase-shift value of $\pi/2$ at full power. This provided significant improvements in low-load efficiency without a loss in the full-power capacity. For a dc conversion ratio of 2:1, the efficiency varied from 77% at a 3% load through to approximately 90% at full load. However, this converter required a more complicated control system than SPS. Furthermore, a number of resonant type DAB converter topologies, consisting of series resonant networks, have been proposed. These topologies exhibit an extended softswitching range and lower eddy current losses in the transformer windings, due to improved current waveforms [19]–[22]. However, regardless of the control and resonant schemes employed, all existing DAB converter topologies inherently draw a large reactive current component at full power and, therefore, incur large conduction losses.

II. EXISTING BIDIRECTIONAL CONVERTER

A zero voltage switching (ZVS) technique for bidirectional dc/dc converters. The dc/dc unit considered consists of two distinct bidirectional dc/dc cells paralleled at both input and output and whose two input bridges are coupled by means of passive inductive branches. A multiangle phase-shift modulation method is proposed which simultaneously achieves bidirectional power control, power sharing, and ZVS of all the electronic devices over the full power range without the need for auxiliary switches.

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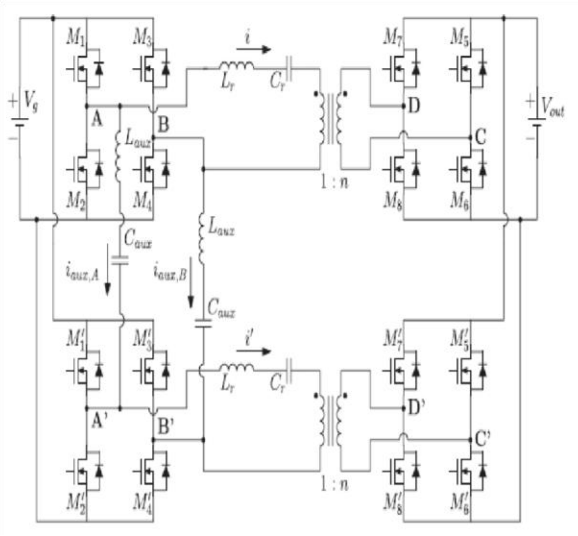

fig 1 zero voltage switching (ZVS)

In these concepts are implemented via a multi angle phase-shift modulation that simultaneously achieves bidirectional power control, power sharing among the cells, and ZVS of all the electronic devices over the entire power range. The starting point of the proposed technique is the minimum current operation concept treated, here generalized into a method for controlling the amount of reactive power exchanged by the resonant tank with the output bridge. The approach is tested on the dc/dc unit detailed, which consists of two bidirectional dual-bridge series resonant converter (DBSRC) cells paralleled at both input and output and with the two input bridges coupled by means of passive inductive branches. The resonant topology has been selected for this paper as an interesting example that benefits directly from the combination of the foregoing concepts for full ZVS operation of both input and output bridges, without requiring extra auxiliary switches.

Existing works, in fact, either limit the investigation of multi angle modulation to the single DBSRC cell, or focus on the coupled DBSRC cell without exploiting the benefits of the additional control degrees of freedom provided by the multi angle modulation. A three-port bidirectional converter based on the series resonant topology is presented, with each resonant cell employing a conventional phase shift modulation for power flow control. However, simultaneous ZVS operation of the input and output bridges is only ensured at unity conversion ratios.This paper presents a zero voltage switching (ZVS) technique for bidirectional dc/dc converters consisting of two or more modules operating in parallel. The technique employs a multi angle phase-shift modulation combined with passive inductive coupling between the two input bridges of the DBSRC cells in order to enable full ZVS operation of all the electronic devices over the entire power range and without the need for additional semiconductor devices.

III. PROPOSED TOPOLOGY

Proposed topology presents a new resonant dual active bridge (DAB) topology, which uses a tuned inductor–capacitor– inductor (LCL) network. In comparison to conventional DAB topologies, the proposed topology significantly reduces the bridge currents, lowering both conduction and switching losses and the VA rating associated with the bridges. The performance of the DAB is investigated using a mathematical model under various operating conditions.

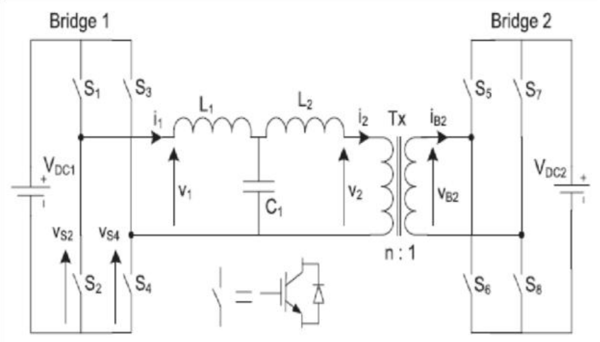

Fig 2: resonant DAB converter

Here proposes a novel DAB topology, which utilizes a resonant network to minimize the reactive power requirement of the converter over the entire load range. The proposed converter employs a tuned inductor–capacitor–inductor (LCL) network, which includes the leakage inductance of the isolation transformer, to significantly reduce the magnitude of bridge currents and, therefore, the switch and copper losses. A simple control scheme is employed, where each bridge is driven with equal PWM while maintaining the phase shift between the bridges fixed at 90° or -90°, to regulate the direction and magnitude of power flow.

A schematic of the proposed resonant DAB converter is shown in Figure, in which $S1 - S8$ represent semiconductor switches. For simplicity, the active load on the secondary side is represented by a voltage source, VDC2. In practice, this voltage source, which is connected to the output of the secondary converter, can be a battery pack used for storing or retrieving energy. Furthermore, in a practical system, $L2$ may be incorporated with the leakage inductance of the transformer rather than employing a discrete inductor. The primary side full-bridge converter, Bridge 1, of the proposed resonant DAB, is operated at a fixed frequency, fs , and converts dc supply voltage VDC1 to a three-level pulse-widthmodulated ac voltage source$v1$.

Similarly, Bridge 2 is operated at the same frequency as the primary and converts its dc supply voltage VDC2 to a pulse width modulated ac voltage source $vB2$. These two ac voltage sources are connected together through an isolation transformer and an $L1C1L2$ network, which is tuned to fs .

Traditional resonant DAB converters employ quasi-resonant networks, comprising inductors and capacitors to reduce switching losses by improving the soft switching range. These converters exhibit multiple operating or resonant modes within a switching cycle, and typically complex modulation schemes are employed to control the switches in order to achieve soft switching. However, as a result of the tuned (resonant) $L1C1L2$ network employed, the proposed system does not exhibit multiple operating modes as both the resonant and switching frequencies are identical and can be controlled using a simple PWM scheme.

In the proposed system, the direction and magnitude of power flow is regulated by controlling the pulse width of voltages $v1$ and $vB2$, while keeping the phase shift between them constant. This is achieved by operating switches $S1$ and $S2$ of Bridge 1 in anti phase at the switching frequency fs with a duty cycle of 50% to generate voltage $vS2$. Switches $S3$ and $S4$ are operated in the same way, except that $vS4$ lags $vS2$ by a displacement of $\alpha1$ degrees. The resulting voltage $v1$, driving the network, is equal to the difference between $vS2$ and $vS4$. Thus, $\alpha1$ modulates the pulse width of the ac voltage $v1$. Bridge 2 is controlled in a similar way, using a phase displacement of $\alpha2$, to produce a pulse-width-modulated ac voltage $vB2$ which is offset from $v1$ by a phase shift φ. The tuned (resonant) $L1C1L2$ network presents a high impedance to harmonics generated by the converters, and therefore, the currents $i1$ and $iB2$ are approximately sinusoidal as shown by dotted lines.

Under tuned conditions, the magnitudes of the bridge currents $i1$ and $iB2$ are proportional to $vB2$ and $v1$, respectively. In addition, $i1$ will be leading $vB2$ by 90◦, whereas $iB2$ will be lagging $v1$ by 90◦, thus causing the bridge currents to align with the voltages when φ is +-90◦. As such, the power flow of the proposed resonant DAB can be regulated by controlling $\alpha1$ and $\alpha2$, while maintaining φ fixed at • +-90◦ to minimize the VA rating of the bridges.

IV. MATLAB IMPLEMENTATION RESULTS

Matlab simulink model used to show the implementation results of our proposed converter shown in fig 3.

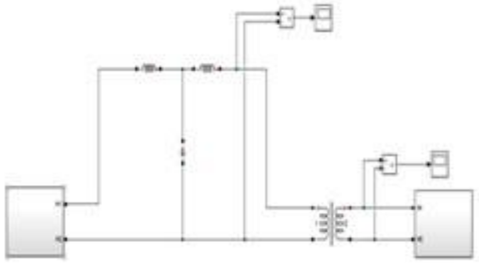

Fig 3 simulink model

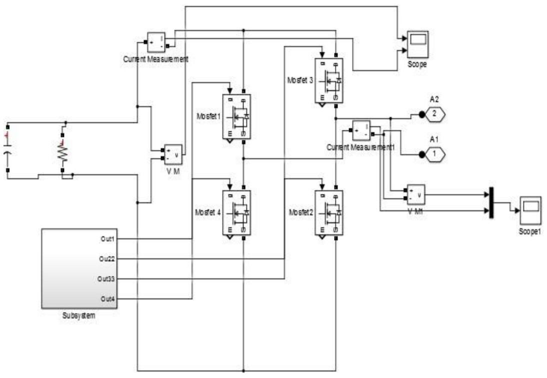

Fig 4 topology

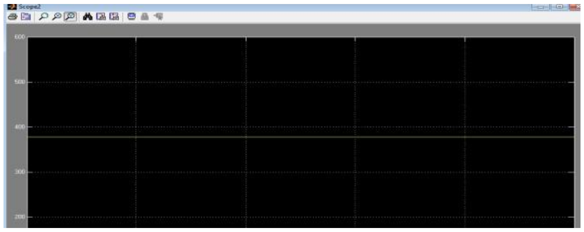

Fig 5 dc waveform

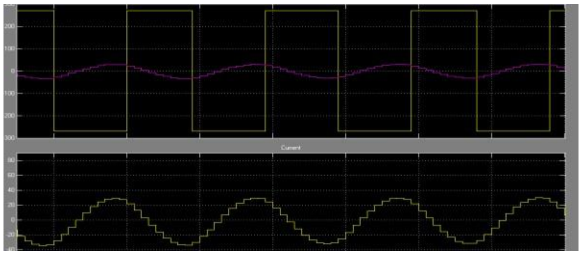

Fig 6 ac waveform

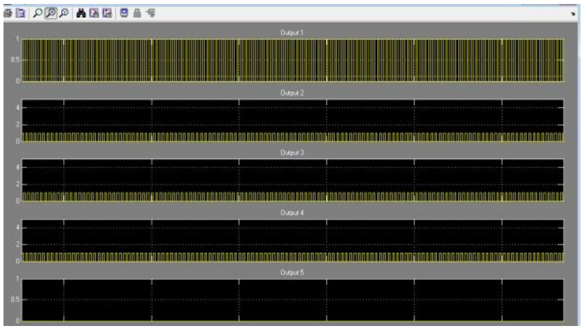

Fig 7 switching pulses

V. CONCLUSION

A new dual DAB topology that employs an *LCL* resonant network has been described. A mathematical model has been presented to accurately predict the performance of the proposed topology. Experimental results of a 2.5-kW prototype DAB, operated under various conditions, have also been presented to demonstrate the improved performance of the converter. Results indicate that the proposed DAB topology has lower bridge currents and, consequently, offers higher efficiency over a wider supply voltage and load range in comparison to conventional DAB topologies.

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