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 ratingassociated with the bridges. The performance of the DAB isinvestigated using a mathematical model under various operatingconditions.

1. Introduction

Demand for clean and sustainable energy sources has dramaticallyincreased during the past fewyearswith growingpopulation and industrial development. For a long time, fossilfuels have been used as the major source of generating electricalenergy. Environmental consequences of these resourceshave made it necessary to benefit from clean energy sourcesuch 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 outputvoltages of these sources are not large enough for connectingto ac utility voltage. PV cells can be connected in series in orderto obtain a large dc voltage. However, it is difficult to ignore theshadow effect in the PV panels [4]–[6]. High step-up convertersare a suitable solution for the aforementioned problem. EachPV 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 highAmong the many types of bidirectional dc–dc converters thatcould be used in a V2G system, the DAB converter is a preferredoption, as it has a small component count, offers isolation, and allows for high power operation [6], [7]. In addition, it has theability to accommodate a

wide range of voltage levels, as itmay 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 operatingpower levels, which increases the converter conduction losses. This current component also necessitates the use of alarger dc-link capacitor [9], [10]. Therefore, various techniqueshave been used to lower the reactive current levels. In [11], pulsewidth modulation (PWM) of the higher voltage bridge was used with SPS to extend the zero-voltage-switching (ZVS) range toincrease the converter low-load efficiency, through a reductionin the reactive current. Triangular and trapezoidal modulationschemes were investigated in [12] in an effort to reduce thecurrent and, therefore, the conduction losses. Primarily, this resultedin 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 controltechniques to that in [11] were used in [15]–[17], except that thePWM 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 whichvaried linearly to a maximum for a phase-shift value of $\pi/2$ atfull power. This provided significant improvements in low-loadefficiency 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, thisconverter 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 soft-switching range andlower eddy current losses in the transformer windings, due toimproved current waveforms [19]–[22]. However, regardless ofthe control and resonant schemes employed, all existing DABconverter topologies inherently draw a large reactive currentcomponent at full power and, therefore, incur large conductionlosses.

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.

Fig 1. Existing configuration

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.

2. 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

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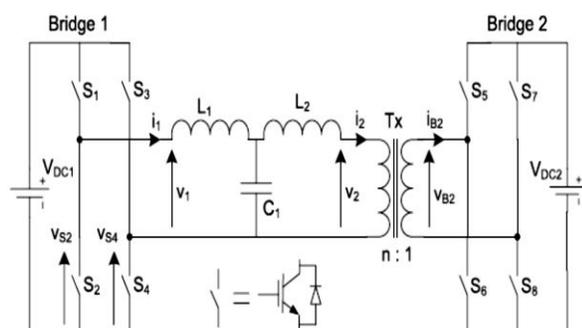
discrete inductor. The primary side full-bridge converter, Bridge 1, of the proposed resonant DAB, is operated at a fixed frequency, fs, and converts dc supply voltage $VDC1$ to a three-level pulse-width-modulated ac voltage source $v1$.

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 (i.e., duty cycle) of the ac voltage $v1$ in the range of 0–50% as $\alpha1$ changes from 0∘ to 180∘. 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.

3. MATLAB IMPLEMENTATION RESULTS:

Matlabsimulink model used to show the implementation results of our proposed converter shown in Fig . 3
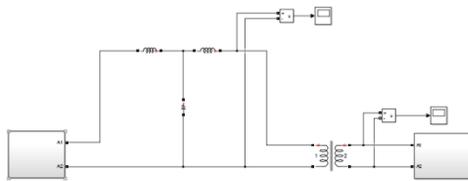
Fig. 3. Simulink Model
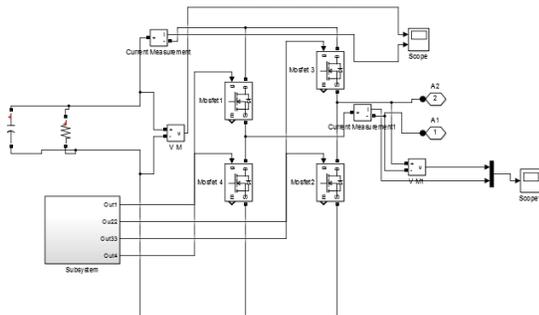
Fig. 4. Topology
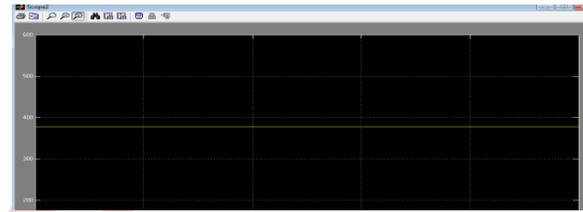
Fig. 5. DC waveform
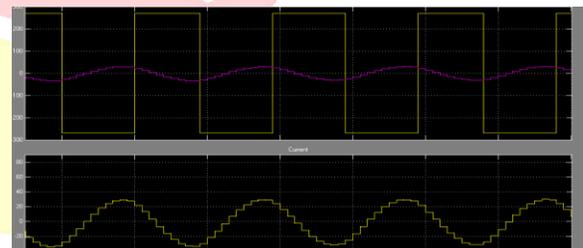
Fig. 6. AC waveform
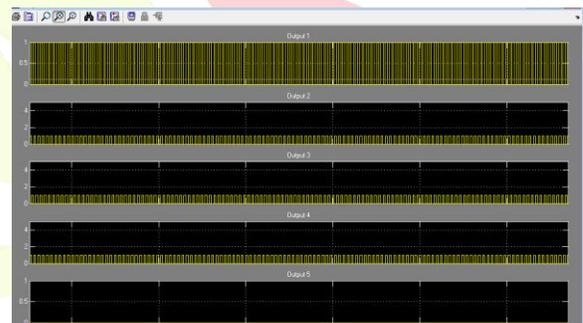
Fig. 7. Switching Pulses

4. CONCLUSION

A new dual DAB topology that employs an *LCL* resonantnetwork has been described. A mathematical model has beenpresented to accurately predict the performance of the proposedtopology. Experimental results of a 2.5-kW prototype DAB, operatedunder various conditions,

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have also been presented todemonstrate the improved performance of the converter. Resultsindicate that the proposed DAB topology has lower bridgecurrents and, consequently, offers higher efficiency over a widersupply voltage and load range in comparison to conventional DAB topologies

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