

Dual Active Bridge Converter with Fuzzy Controller for EV Applications

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Abstract— The popularity of electric vehicles is rapidly increasing due to their benefits such as reduced carbon footprint, fuel economy, and nearly silent operation. However, building a controller for an electric vehicle is challenging as it involves factors such as selecting an appropriate power electronics drive, implementing regenerative braking, managing the battery, and choosing a power converter. In electric vehicles, the DC-to-DC converter is an essential component, and researchers are working on developing bidirectional DC to DC converters and their control units. Due to its high-power density, ease of implementation of zero-voltage switching, quick access to cascading and parallelism, and bidirectional power flow, the dual active bridge (DAB) converter is a favored option for this. This paper presents a bidirectional dual active bridge converter controlled by fuzzy logic controller for managing the electric vehicle's battery during grid-to-vehicle charging and vehicle-to-grid discharging. The MATLAB simulation results are presented. A comparative of developed controller with conventional controller is also presented.

Keywords— bidirectional DC to DC converter, dual active bridge, DAB, battery charging

I. INTRODUCTION

A DAB Converter is a DC-DC converter is constructed with two H-bridges, each consisting of power switches and a transformer, to convert DC voltage between different levels. It has four operational modes: forward, reverse, active clamp, and zero voltage switching (ZVS). In the forward mode, the input voltage is fed to the DC link of the first bridge, and the output is taken from the DC link of the second bridge. In the reverse mode, the input voltage is given to the DC link of the second bridge, and the output is taken from the DC link of the first bridge. The DAB converter is often used in high-power density, high-efficiency, and fast dynamic response applications. However, because of their complex control algorithms and high component count, they are more expensive and difficult to

design compared to other types of DC-DC converters.

A detailed review of DC-to-DC converters is presented in [1] along with a comparative study indicating advantages, disadvantages, applications and voltage gain. According to the major categories, galvanic isolation is required for high step-up voltage ratios because it improves switching device utilization and lowers circulating reactive power [2]. The power transfer analysis of DAC converter and its operating modes through its operating modes controlled by the gate driving waveform [3, 4]. The performance of these converters is characterized by knowing power flow handling, efficiency and accuracy. Bi-directional dual active bridge (DAB) DC-DC converters are favored among DC-DC converters for improving overall efficiency, power flow, and for rapid response in applications for electric vehicles as well as other applications [5]. The control of DAB converter is done with phase shift switching strategy [6]. Here, a DAB converter is connected in series with a bidirectional non-isolated buck boost converter. The single-phase shift switching control technique achieves zero voltage switching over entire operating range [7]. It knocks higher efficiency of 97% plus against conventional converter having efficiency near 95% [8]. For distributed energy resources and the smart grid, a dual active bridge DC-DC converter offers a high level of reliability and resistance to system disruptions [9]. When the micro grid was used in islanded mode, the converter assures a constant DC bus voltage [10].

The performance of dual active bridge converter is further improved by implementing the converter with high frequency center tapped transformer and modified phase shift control [11]. The secondary side's center-tapped inductor can supply the switches with extra soft-switching current. Such an improved dual active bridge converter is appropriate solution for renewable energy applications subjected to large variations in input voltage [13, 14]. Reduced soft-

switching current at small loads and an excess of reactive power at high loads are resolved by the modified phase shift control scheme, which improves the converter's reliability and feasibility [12].

The use of dual active bridge converter simplifies connection of low voltage PV system with high voltage DC bus in renewable energy systems [15]. Even V2G and G2V interface configurations are simplified with DAB converter [16]. DAB converter can find application in battery management of electric vehicles wherein it can manage charging and discharging operation of battery. Researchers have obtained the maximum efficiency of DAB converter to be around 93% [17].

II. DUAL ACTIVE BRIDGE CONVERTER

Figure 1 depicts the dual active bridge converter's circuit. Two totem-poled switching devices make up each full-bridge, and they are each powered by complementary square-wave pulses. By phase-shifting the pulses of one bridge with regard to the other, the power flow in the dual active bridge may be controlled.

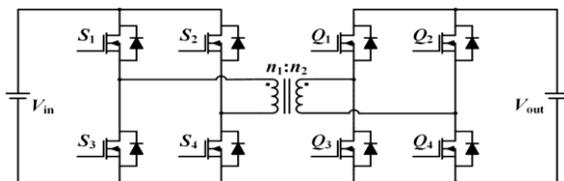


Figure 1: Circuit scheme of dual active bridge converter

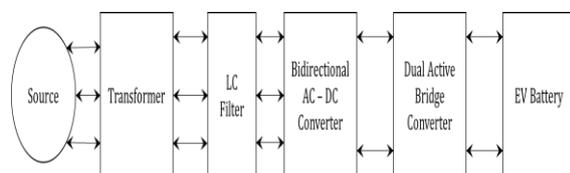


Figure 2: DAB converter-based EV – Grid Interface

The figure 2 shows the overall system of dual active bridge converter for EV battery charging. The control logic of the fuzzy logic controller is shown in figure 3. The control system consists of fuzzy logic designer toolbox. The fuzzy controller has two inputs and single output. Input membership function of the controller is Gaussian type and the output membership is triangular type. The error signal required to be given to fuzzy logic block is generated by taking the difference of actual and reference values of the DC link voltage. The change

in error is obtained from input of error through memory block which stores past data of input (error signal). Error & change in error inputs are given to fuzzy controller and single output of fuzzy controller bounded between + 2 to - 2. This output of fuzzy controller is further combined with parks transformed signals of current and the pulses for the dual active bridge IGBTs are generated.

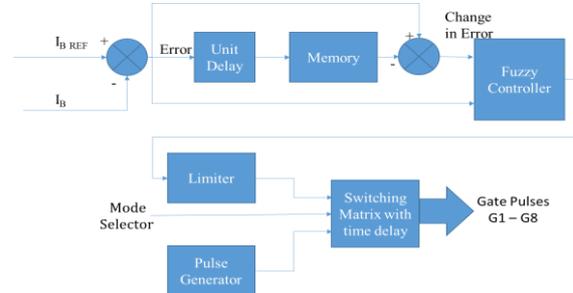


Figure 3: Fuzzy Logic Controller for DAB converter

III. RESULTS AND DISCUSSION

The simulation results are presented with two modes of power transfer namely grid to vehicle and vehicle to grid. In vehicle to grid (V2G) power transfer mode, power is injected into the grid. Figure 4 shows the graph of grid power in vehicle to grid mode. The graph of power transferred from vehicle to the grid is shown in figure 7. The positive values of grid power and DAB power indicates that the power is being fed to the grid. The power flow from vehicle to grid is also reflected in terms of reduced SoC of the battery as seen in figure 6. As the power flow is directed from battery to the grid, the state of charge of battery reduces with respect to time. The DC link voltage is indicated in figure 5. The DC link voltage is maintained constant around 720V which is taken as input by bidirectional AC-DC converter for grid interface.

In grid to vehicle power transfer mode, EV battery is charged from grid. The graph of grid power in G2V mode is shown in figure 8. The negative value of grid power indicates that the power is given by the grid. The graph of DC link voltage for charging EV is shown in figure 9. The DC link voltage is maintained constant at 565V which is further used by DAB converter to charge the EV battery. The corresponding battery charging is reflected in terms of increasing SoC of the battery as seen in figure 10. Here, the battery is seen getting charged with increase in SoC value. The negative value of power in figure 11 indicates that the power is absorbed by the battery.

Figure 4: grid power

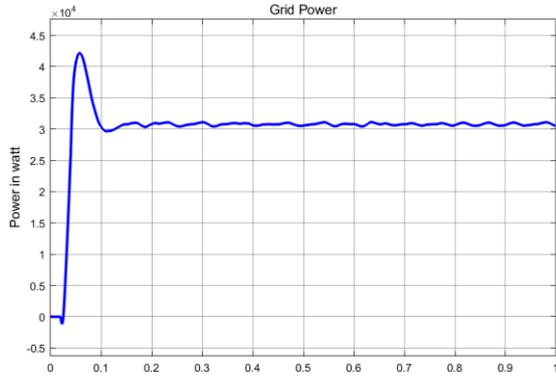


Figure 8: Grid Power

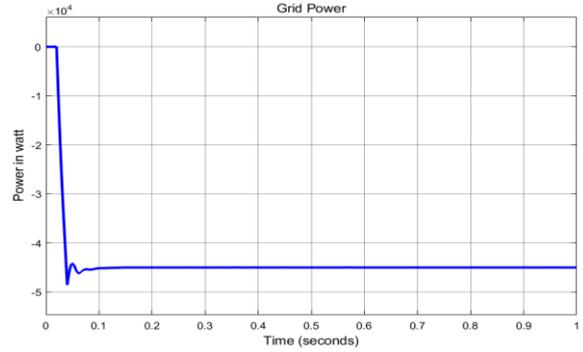


Figure 5: DC link Voltage

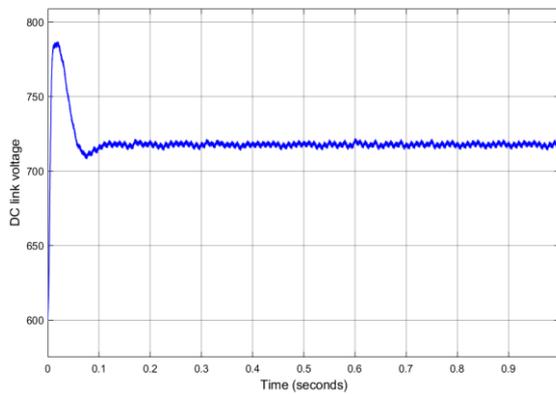


Figure 9: DC link voltage

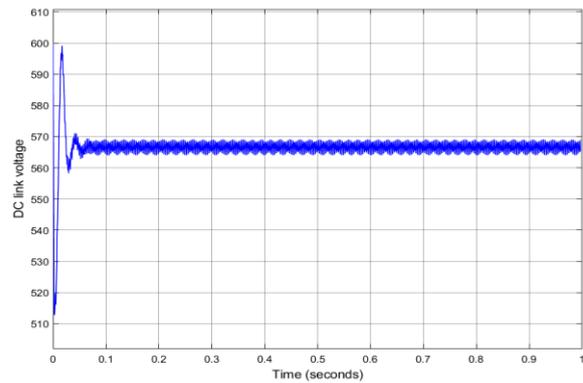


Figure 6: Battery SOC, current and voltage

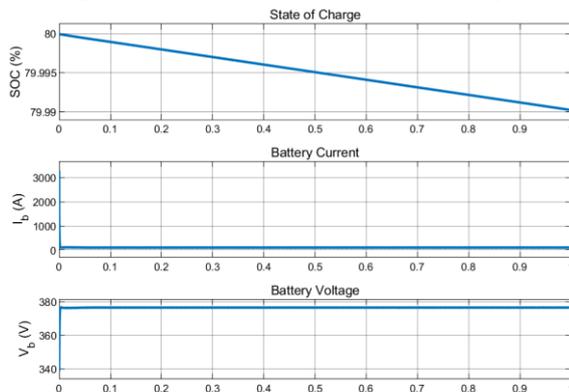


Figure 10: Battery SOC, current and voltage

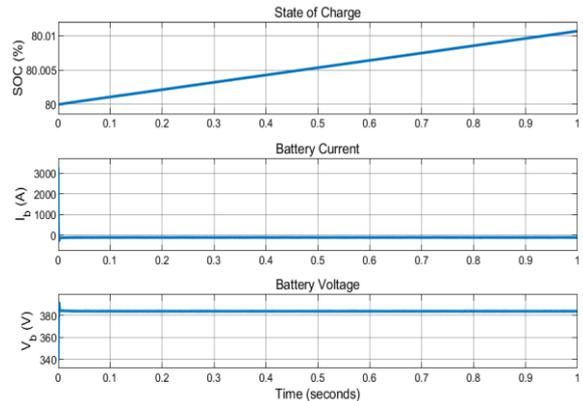


Figure 7: Power supplied by the battery

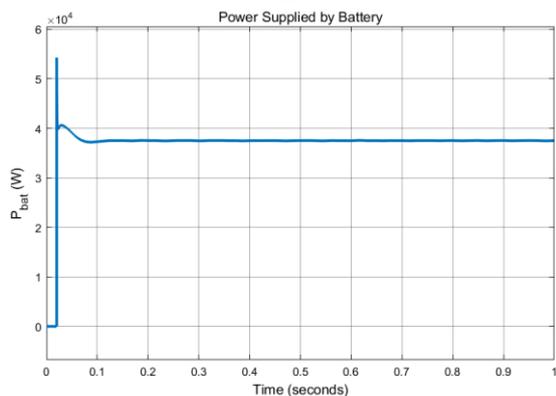


Figure 11: Power supplied to the battery

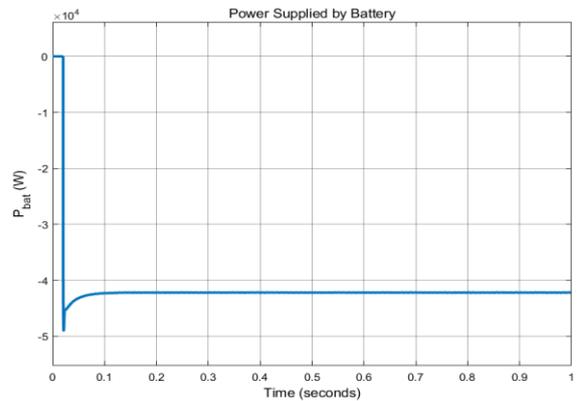
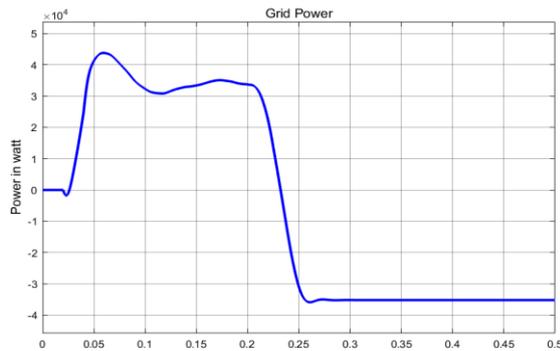


Figure 11: grid power with mode change at 0.2 S



The figure 11 shows the graph of grid power when the operating mode is changed from V2G to G2V. The shift in operating mode is reflected in the sign of power. From the overall results, it can be said that the fuzzy logic controller for dual active bridge converter smoothly allows the transition between operating modes. The disturbances in the power are seen to be minimum.

IV. CONCLUSION

Fuzzy logic control of a dual active bridge converter for providing the interface between electric vehicle and grid is discussed here. The fuzzy logic controller gives improved voltage regulation at the DC link during power flow in either direction i.e., grid to vehicle or vehicle to grid. The high-power density and isolation of the converter control approach make it useful for a variety of applications. With little mathematical modelling and no linearization assumptions, the suggested controller is simple to develop and execute, avoiding complicated design.

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