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DESIGN AND IMPLEMENTATION OF MULTIPORT BIDIRECTIONAL DC-DC CONVERTER FOR HYBRID ENERGY STORAGE SYSTEMS

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ABSTRACT

Multiport dc/dc converters are widely used in hybrid energy generation systems, microgrids and electric vehicles to provide stable power to key loads with high power density. In this project, a multiport isolated bidirectional dc–dc converter is anticipated for hybrid energy storage system in microgrids. Microgrids are connected to the nearby renewable energy generation systems as solar, wind, etc. These systems do not provide pure DC voltage for conversion into AC required by the grid. Hence a single stage DC-AC-DC conversion is required. For energy management and single stage power conversion, multiport BDC is the best choice. Also to minimize the switching losses and henceforth to improve the efficiency of the converter system, Zero Voltage Switching (ZVS) can be achieved for all switches in any direction of power flow in the whole load range with decoupled duty cycle control and phase shift.

Keywords: DC-bus microgrid, hybrid energy management, hybrid energy storage, multiport bidirectional converter.

INTRODUCTION

With the rapid development of electric vehicles and distributed renewable energy power systems, microgrid plays a major role in distributed generation. Energy storage system is an essential part of the microgrid. Battery is the most mature technology for Electrical Energy Storage (EES). It possesses high energy density [1]. On the other hand, its dynamic response is slow which makes it unsuitable to satisfy the requirements of sudden changes on load or power. Meanwhile, a super capacitor has short charging/discharging time and high power density. Therefore, the hybrid system combined with the battery and the super capacitor can be used to improve the performance of the energy storage system. Battery is used for energy storage, while super capacitor is used for transient energy storage and fast supplement.

To ensure the hybrid system to be highly efficient, safe, reliable, the design should consider two aspects: construction and energy management strategy. For construction, multiport dc–dc converters are the optimum choice particularly for systems where diverse sources and storage elements are to be integrated.

An isolated bidirectional multiport DC-DC converter is proposed to serve for two main purposes such as to provide galvanic isolation between the converter units using high voltage transformer and to prevent voltage mismatch by providing phase shift between the converter voltages.

DESCRIPTION OF CONVERTER TOPOLOGY

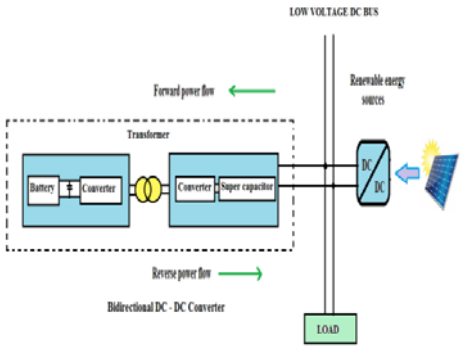

Figure-1. Block diagram of the system.

During the steady state operation, when DC bus voltage is less than the battery voltage, battery is discharged and forward power flow is possible. When DC bus voltage is greater than the battery voltage, battery is charged and reverse power flow is possible. During forward mode of operation, energy transfers between battery and DC bus through the phase shift transformer [6-7]. During the reverse mode of operation, energy is transferred from the DC bus to the supercapacitor through the second converter. Now, the supercapacitor is charged and the converter works in buck mode. Meanwhile, the DC bus charges the battery through the phase shift transformer.

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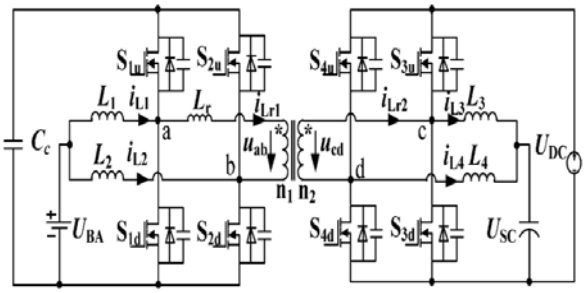

Figure-2. Topology of the multiport converter.

The converter units are distributed symmetrically on both sides of the transformer. The left side (primary side) is defined as the battery side. On this side, inductors L_1, L_2 and switches S_{1u}, S_{2u}, S_{1d}, S_{2d} (including body diodes and parasitic capacitors) compose a two-channel interleaving Buck/Boost construct, in which the low-voltage port is connected to the battery. U_{BA} is defined as the battery voltage. The right side (secondary side) is defined as the dc-bus side. On this side, inductors L_3, L_4 and switches S_{3u} , S_{4u}, S_{3d}, S_{4d} (including body diodes and parasitic capacitors) compose a two-channel interleaving Buck/Boost construct, in which the high-voltage port is connected to the dc bus and the low voltage port is connected to the super capacitor. U_{DC} is the dc-bus voltage and U_{SC} is the super capacitor voltage. The converter also has an internal high-voltage port on the battery side, which is connected to a filter capacitor *Cc* without any power input or output. Performance of the converter can be improved by controlling the voltage of this port. So, it is also supposed that the converter is named as a "3 + 1"−port bidirectional converter.

SIMULATION RESULTS

The simulink model of multiport BDC is shown in Figure-3. The multiport BDC is connected to the Dc bus connecting the source and the load. A resistive load is connected across the terminals of the DC bus.

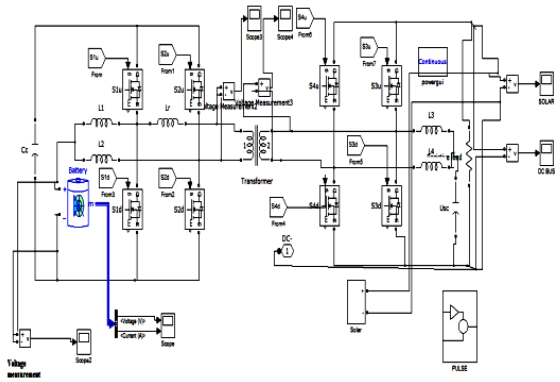

Figure-3. Multiport BDC block.

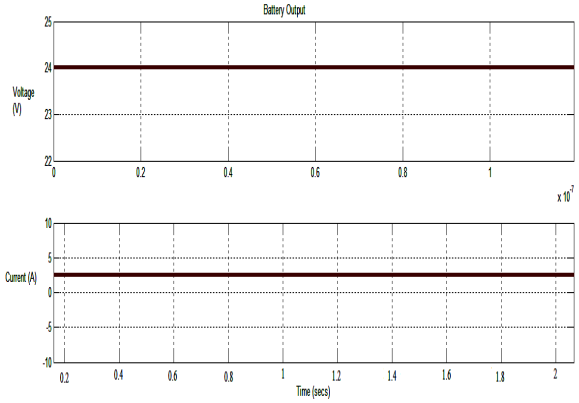

Figure-4. Battery output.

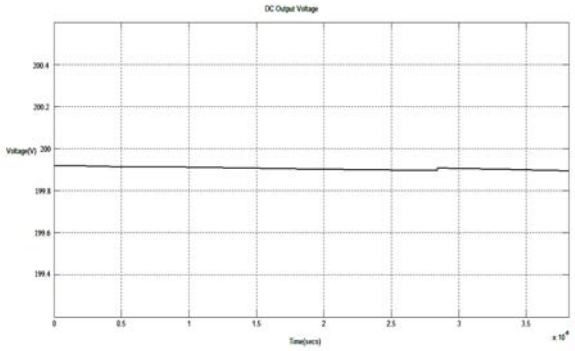

Figure-5. DC bus output voltage.

CONCLUSIONS

The proposed multiport bidirectional dc-dc converter, which can be named as a "3 + 1" port bidirectional converter consists of four ports, among which one high voltage port is connected to the dc bus, two low voltage ports to battery and supercapacitor respectively, and the accessional fourth port for voltage matching control. The multiport bidirectional converter and the hybrid energy storage control strategy can realize proper transmission and distribution of energy. The converter units on both sides of the transformer use interleaving control so that the output current ripple is small. Also, compared to the conventional multiport topology without the fourth voltage matching port, reactive power and circulating current are greatly reduced in this proposed topology.

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