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Isolated Bidirectional DC–DC Converter for SuperCapacitor Applications

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Abstract. This paper proposes a new bidirectional DC/DC converter for supercapacitor applications. The proposed converter has a parallel structure in supercapacitor side (where voltage is low and current is high) and a series structure in the other side. This structure increases efficiency of the converter. For current sharing in the parallel side of the proposed converter, two different methods are recommended and compared in this paper: Current balancing transformer (CBT) and two separate inductors (TSI). Simulation and experimental results show performance of the proposed converter.

Key words

Current sharing, parallel primary, bidirectional converter, supercapacitor, fuel cell.

1. Introduction

Currently fuel cell electric vehicles (FCEV) are considered as an attractive option for future cars because of environmental issues and alternative energy requirements. However since fuel cell stack has a slow response, using an auxiliary energy storage device such as battery or supercapacitor (SC) is recommended in the fuel cell (FC) applications [1-3]. While the battery has a large energy density and SC has a high power density, FC-Battery hybrid and FC-SC hybrid systems offer different features. However, FC-SC-Battery hybrid systems in Fig. 1 have been shown to have superior features [2-3].

Because of charge dependent voltage of SC, a bidirectional DC/DC converter is needed for bidirectional power exchange between SC and other parts of the system for different voltage levels [2-4]. Isolated full-bridge converter in Fig. 2 is a common DC/DC converter topology [5-6]. For high power applications, parallel isolated full-bridge converters have been proposed [7]. In fuel cell applications, generally low voltage is required to be boosted to higher voltages. Fig. 3 shows the primary parallel isolated boost converter proposed in [8] which is suitable for high voltage gain applications. This converter is composed of full-bridge stages with parallel primary connections (where current is high and voltage is low) and a single rectification stage with series secondary connection (where current is low and voltage is high). Current sharing is ensured by the series connection of transformer secondary windings and small cascaded current balancing transformer (CBT) on the primary side.

In this paper, the unidirectional converter presented in [8] is modified to handle bidirectional power flow in energy storage applications. For this purpose, the diode bridge rectifier on the secondary side has been replaced with a full bride inverter. In addition a detailed analysis has been carried out comparing two different current balancing configurations. Using two separate inductors (TSI) instead of current balancing transformer (CBT) is recommended due to cost and simplicity. It has been shown that the current sharing performance is similar in both cases.