Non-Isolated DC-DC Converters in Fuel Cell Applications: Thermal Analysis and Reliability Comparison

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Abstract: An alternative energy source that has appeared beyond expectations and has seen a lot of progress is the fuel cell. A proton exchange membrane (PEM) fuel cell is chosen for analysis and requires a DC-DC boost converter as an interface between the fuel cell and the load to provide a high-gain regulated voltage. Although great effort towards developing different converter topologies has been made during recent decades, less attention has been devoted to the reliability and thermal performance assessment of the present converters. In this paper, five non-isolated DC-DC converters are analyzed in terms of both thermal behavior and reliability. The temperature estimation of semiconductor devices as a critical part of the thermal analysis has been made via a detailed thermal model and the reliability is evaluated by means of a power cycling test. Finally, a performance score has been attributed using the TOPSIS ranking methodology and considering all the criteria (e.g., the number of components and cost) at the same time. The results indicated that the floating interleaved boost converter is always at the top of the list, even if the weight of the indicators is changed. When the weight of the cost criterion is higher than the reliability criterion, the multi-switch boost converter will be in second place. If the weight of the reliability criterion is greater than cost, the interleaved and multi-switch converter are ranked second and third, respectively. Additionally, the Cuk converter with a closeness coefficient of zero is always associated with the most unfavorable performance.

Keywords: fuel cell; DC-DC converter; Norris–Landzberg; power modules; proton exchange membrane; reliability; thermal analysis

1. Introduction

Population growth and the excessive use of electrical appliances have an enormous influence on electricity consumption mainly coming from fossil fuels. Alternative energy sources have gained considerable attention in many countries in recent decades, owing primarily to greenhouse gas emissions, global warming, and ozone layer depletion. Although there is a great effort to replace all the traditional energy sources with wind and solar energies, fuel cells are becoming even more important and have gained a favorable position as a leading source of power. Moreover, fuel cells are one of the effective technologies to integrate green hydrogen into the power system. Given the fact that the fuel cell is compact, lightweight, and non-polluting, it is very suitable for applications such as electric vehicles and emergency power systems [1].

Compared to wind and solar power generation, the advantage of using a fuel cell is that it can be used anywhere as there are no environmental or geographical constraints to use it [2]. These features have enabled fuel cells to be used from watts to megawatts for applications such as the space industry [3], portable applications [4], remote area power supplies [5], and communication applications [6].