UTS UNIVERSITY OF TECHNOLOGY SYDNEY

Synthesis, Analysis and Development of Three-Port DC/DC Converters

by

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Hamzeh Aljarajreh declare that this thesis, is submitted in fulfillment of the requirements for the award of Doctor of Philosophy, in the School of Electrical and Data Engineering/Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis. This document has not been submitted for qualifications at any other academic institution. This research is supported by the Australian Government Research Training Program.

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Abstract

The increasing adoption of renewable energy sources such as solar energy, wind energy, and fuel cells has made higher demands on power electronic converters. These converters serve as an electrical interface among various renewable energy sources, energy storage units, and output loads to perform efficient power conversion, effective power conditioning, and fast control whilst complying with the safety and reliability requirements of the system.

Using many single-input, single-output (SISO) converters to connect different sources and loads is a straightforward approach widely adopted in the industry. Although this approach offers apparently easier control and modularity, it leads to relatively complex configuration, high cost, and lower conversion efficiency. Multiple-input, multiple-output converters (MIMO) are capable of converting power from multiple power sources to multiple loads individually or simultaneously by using simplified circuitry and an appropriate control strategy.

The main goal of this thesis is to conduct a systematic topological study to derive all possible basic and non-isolated three-port converters (TPCs), using power flow diagrams that could be used for the future development of DC distribution systems. Unlike most reported TPCs with one bidirectional port, this thesis considers up to two bidirectional ports. It provides an analytical tool and framework for all power flow combinations and corresponding converter configurations, including selection and design. After eliminating the impractical configurations due to indirect connection to some ports and multiple conversion stages, suitable converter configu-

rations are identified and corresponding circuit realizations are demonstrated. The significance of this work is to show which configuration has fewer power conversion stages between any two ports. Furthermore, it shows whether all ports are fully or partially controlled, and it presents the appropriate configuration for specific applications. Three of the investigated configurations are taken as an example to analyse further and verify the principles of operation and working conditions experimentally. The proposed circuits are able to work in seven different modes for a PV-battery-powered DC bus system where smooth and fast transitions between different modes are achieved. Furthermore, a decision flowchart is presented to demonstrate how to select different modes practically.

List of Publications

- **H. Aljarajreh,** D. D. -C. Lu, Y. P. Siwakoti, and C. K. Tse, "A Non-isolated Three-Port DC/DC Converter with Two Bidirectional Ports and Fewer Components," in *IEEE Transactions on Power Electronics.*

- **H. Aljarajreh,** D. D.-C. Lu, Y. P. Siwakoti, C. K. Tse, and K. W. See, "Synthesis and Analysis of Three-Port DC/DC Converters with Two Bidirectional Ports Based on Power Flow Graph Technique," *Energies,* vol. 14, no. 18, p. 5751, Sep. 2021.

- **H. Aljarajreh,** D. D. -C. Lu, Y. P. Siwakoti, R. P. Aguilera and C. K. Tse, "A Method of Seamless Transitions Between Different Operating Modes for Three-Port DC-DC Converters," in *IEEE Access,* vol. 9, pp. 59184-59195, 2021.

- **H. Aljarajreh,** D. D. Lu and C. K. Tse, "Synthesis of Dual-Input Single-Output DC/DC Converters," *2019 IEEE International Symposium on Circuits and Systems (ISCAS),* 2019, pp. 1-5.

- M. R. Al-Soeidat, **H. Aljarajreh,** H. A. Khawaldeh, D. D. -C. Lu and J. Zhu, "A Reconfigurable Three-Port DCDC Converter for Integrated PV-Battery System," in *IEEE Journal of Emerging and Selected Topics in Power Electronics,* vol. 8, no. 4, pp. 3423-3433, Dec. 2020.

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