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Multiport Power Electronics Circuitry for Integration of Renewable Energy Sources in Low Power Applications

A thesis presented in partial fulfilment of the requirements for the degree of

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In

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at Massey University, Palmerston North

New Zealand

Zubair Rehman

2017
The increasing demand for electricity and the global concern about environment has led energy planners and developers to explore and develop clean energy sources. Under such circumstances, renewable energy sources (RES) have emerged as an alternative source of energy generation. Immense development has been made in renewable energy fields and methods to harvest it. To replace conventional generation system, these renewable energy sources must be sustainable, reliable, stable, and efficient. But these sources have their own distinguished characteristics. Due to sporadic nature of renewable energy sources, the uninterrupted power availability cannot be guaranteed. Handling and integration of such diversified power sources is not a trivial process. It requires high degree of efficiency in power extraction, transformation, and utilization. These objectives can only be achieved with the use of highly efficient, reliable, secure and cost-effective power electronics interface. Power electronics devices have made tremendous developments in the recent past. Numerous single and multi-port converter topologies have been developed for processing and delivering the renewable energy.

Various multiport converter topologies have been presented to integrate RES, however some limitations have been identified in these topologies in terms of efficiency, reliability, component count and size. Therefore, further research is required to develop a multiport interface and to address the highlighted issues.

In this work, a multi-port power electronics circuitry for integration of multiple renewable energy sources is developed. The proposed circuitry assimilates different renewable sources to power up the load with different voltage levels while maintaining high power transfer efficiency and reliability with a simple and reliable control scheme.

This research work presents a new multiport non-isolated DC-DC buck converter. The new topology accommodates two different energy sources at the input to power up a variable load. The power sources can be employed independently and concurrently. The converter also has a bidirectional port which houses a storage device like battery to store the surplus energy under light load conditions and can serve as an input source in case of absence of energy sources.
The new presented circuitry is analytically examined to validate its effectiveness for multiport interface. System parameters are defined and the design of different components used, is presented.

After successful mathematical interpretation, a simulation platform is developed in MATLAB/Simscape to conduct simulations studies to verify analytical results and to carry out stability analysis.

In the final stage, a low power, low voltage prototype model is developed to authenticate the results obtained in simulation studies. The converter is tested under different operating modes and variable source and load conditions.

The simulation and experimental results are compiled in terms of converter’s efficiency, reliability, stability.

The results are presented to prove the presented topology as a highly reliable, stable and efficient multiport interface, with small size and minimum number of components, for integration of renewable energy sources.
Research Outputs

Journal Publications


Journal (In Press)


Conference Publications


Seminars and Presentations


Awards

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3. HEC Pakistan MS leading to PhD Scholarship (2012-2017).
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<td>School of Engineering and Advanced Technology SEAT</td>
<td>Higher Education Commission HEC</td>
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<td>Giga Watt GW</td>
<td>Annual Energy Outlook AEO</td>
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<td>Hybrid Energy System HES</td>
<td>Renewable Energy System RES</td>
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<td>Photovoltaic PV</td>
<td>Power Electronics PE</td>
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<td>Single input-Single Output SISO</td>
<td>Dual input-Single Output DISO</td>
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<td>Single input-Dual Output SIIDO</td>
<td>Dual input-Dual Output DIDO</td>
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<td>Pulsating Source Cells PSC</td>
<td>Multi-Input Converter MIC</td>
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<td>Three Port Converter TPC</td>
<td>Multiport Converter MPC</td>
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<tr>
<td>Pulsating Voltage-Source Cell PVSC</td>
<td>Pulsating Current-Source Cell PCSC</td>
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<td>Pulse Width Modulation PWM</td>
<td>Pulse-Skipping Modulation PSM</td>
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<tr>
<td>Pulse-Frequency Modulation PFM</td>
<td>Single input Multi Output SIMO</td>
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<td>Single Inductor Multi Output SIMO</td>
<td>Continuous Conduction Mode CCM</td>
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Multi Input Multi Output  MIMO
Multi Input  MI
Multi Output  MO
Discontinuous Conduction Mode  DCM
State Space Averaging  SSA
Relative Gain Array  RGA