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

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Abstract

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

1. Z. Rehman, I. H. Al-Bahadly and S. C. Mukhopadhyay "Multi input DC-DC Converters in Renewable Energy Applications- An Overview," Journal of Renewable and Sustainable Energy Reviews, 41, pp 521-539 January 2015. (Cited by 18 till 29th March 2017). Journal Impact Factor: 6.798 (29th March 2017).
2. Z. Rehman, I. H. Al-Bahadly and S. C. Mukhopadhyay "Renewable Energy Harvesting for low Power Wireless Monitoring Networks", Journal of Clean Energy Technologies vol. 5, No 6, pp. 448-453, November 2017.

Journal (In Press)

1. Z. Rehman, I. H. Al-Bahadly and S. C. Mukhopadhyay "A Single Stage-Single Inductor Multiport DC-DC Converter for low power Electronics Devices" Submitted to Journal of Power Electronics, 2017.

Conference Publications

1. Z. Rehman, I. H. Al-Bahadly and S. C. Mukhopadhyay "Dual Input-Dual Output Single Inductor dc-dc Converter", Proceedings of 41st International Annual Conference of the IEEE Industrial Electronics Society, IECON 2015, pp 004848-004853, 2015.
2. Z. Rehman, I. H. Al-Bahadly and S. C. Mukhopadhyay "Dual Input-Dual Output Single Inductor dc-dc Converter for Renewable Energy Applications," Proceedings of 4th International Conference on Renewable Energy and Research Applications ICRERA, pp 783-788, 2015.
3. Z. Rehman, I. H. Al-Bahadly and S. C. Mukhopadhyay, "A Non-Isolated DC-DC converter for Renewable Energy Based Portable Measuring Instruments," Proceedings of IEEE Instrumentation and Measurement Technology Conference I^2MTC pp. 936-941, 2013.
4. I. H. Al-Bahadly, Z. Rehman, and Joshua Pirihi, "Combining small scale Wind and Hydro Generation," Proceedings of International Conference on

Sustainability, Green Buildings, Environmental Engineering & Renewable Energy SGER, pp 122-133, 2016.

5. I. H. Al-Bahadly, James Tingey and Z. Rehman "Portable Energy Unit for Natural Energy disaster" Proceedings of International Conference on Sustainability, Green Buildings, Environmental Engineering & Renewable Energy SGER, pp 134-140, 2016.

Seminars and Presentations

1. Z. Rehman "Renewable Energy Harvesting for low Power Wireless Monitoring Networks". Presented at the 5th International Conference on Power Science and Engineering, (ICPSE 2016), Venice, Italy.
2. Z. Rehman, "Combining small scale Wind and Hydro Generation," Presented at International Conference on Sustainability, Green Buildings, Environmental Engineering & Renewable Energy (SGER, 2016), Kuala Lumpur, Malaysia.
3. Z. Rehman, "Portable Energy Unit for Natural Energy disaster" Presented at the International Conference on Sustainability, Green Buildings, Environmental Engineering & Renewable Energy (SGER, 2016), Kuala Lumpur, Malaysia.
4. Z. Rehman "Dual Input-Dual Output Single Inductor dc-dc Converter", Presented at 41st International Annual Conference of the IEEE Industrial Electronics Society, IECON 2015, Yokohama, Japan.
5. Z. Rehman, "Dual Input-Dual Output Single Inductor dc-dc Converter for Renewable Energy Applications," Presented at the 4th International Conference on Renewable Energy and Research Applications (ICRERA, 2015), Palermo, Italy.
6. Z. Rehman, "A Non-Isolated DC-DC converter for Renewable Energy Based Portable Measuring Instruments," Presented at the IEEE Instrumentation and Measurement Technology Conference (I^2MTC 2013), Montevideo, Uruguay.
7. Z. Rehman "Multi-port converters for Renewable Energy Applications", Presented at SEAT PG Seminar Day Program, 2015.
8. Z. Rehman "Design of a non-isolated DC-DC converter" Presented at SEAT Doctoral Seminar Day Program, 2014.

9. Z. Rehman "A Non-Isolated DC-DC Converter for Renewable Energy Based Portable Measuring Instrument", Presented at EICS Cluster Seminar Series, SEAT, 2013.
10. Z. Rehman "Multi Input Power Electronics Circuitry for Integration of Renewable Energy Sources" PhD Conformation Seminar 2013.
11. Z. Rehman "A Single Inductor Dual Input-Dual Output DC-DC Buck Converter for Standalone Hybrid Energy System" Presented at IEEE Post Graduate Seminar, SEAT, Massey University, 2013.

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Abbreviated Terms

School of Engineering and Advanced Technology	SEAT
Higher Education Commission	HEC
Giga Watt	GW
Annual Energy Outlook	AEO
Hybrid Energy System	HES
Renewable Energy System	RES
Photovoltaic	PV
Power Electronics	PE
Single input-Single Output	SISO
Dual input-Single Output	DISO
Single input-Dual Output	SIIDO
Dual input-Dual Output	DIDO
Pulsating Source Cells	PSC
Multi-Input Converter	MIC
Three Port Converter	TPC
Multiport Converter	MPC
Pulsating Voltage-Source Cell	PVSC
Pulsating Current-Source Cell	PCSC
Pulse Width Modulation	PWM
Pulse-Skipping Modulation	PSM
Pulse-Frequency Modulation	PFM
Single input Multi Output	SIMO
Single Inductor Multi Output	SIMO
Continuous Conduction Mode	CCM

Multi Input Multi Output	MIMO
Multi Input	MI
Multi Output	MO
Discontinuous Conduction Mode	DCM
State Space Averaging	SSA
Relative Gain Array	RGA