
Article:
Siddiqui, K.M., Padmanaban, S., Benbouzid, M. et al. (2025) Recent applications of power electronics & drives in renewable power generation. IET Renewable Power Generation, 19 (1). e70088. ISSN: 1752-1416

https://doi.org/10.1049/rpg2.70088

IET Renewable Power Generation

WILEY

IET The Institution of Engineering and Technology

GUEST EDITORIAL OPEN ACCESS

Recent Applications of Power Electronics & Drives in Renewable Power Generation

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Received: 16 January 2023 | **Accepted:** 6 May 2024

1 | Introduction

Renewable energy systems (RESs) are becoming increasingly popular for power generation because they are clean and can meet power demand at the local level. It reduces bottlenecks in the power grid and also reduces the dependency from hydro and thermal power plants for the optimal power flow management. Worldwide, at least a 20% penetration of distributed RESs is considered necessary over the next decade. The intermittent nature of RESs results in systems with delays in dynamics, non-linearties, power quality issues, etc. Over the last few decades, power quality issues have become increasingly important in grid-connected renewable energy systems. In addition to the intermittent nature of RESs, the widespread use of non-linear electronic devices further complicates the problem. With the advent of power electronic converters with robust control technology, RESs can be massively connected to the grid for power supply or used as stand-alone systems in remote location. Using more efficient control strategies not only improves the performance of these systems, but also improves power quality during generation, distribution, and consumption on the consumer side of utility systems.

The ever-declining fossil fuel resources and the increasing concerns for the environment have led to intensive research into the generation and use of RESs. Innovative processes for generating and using renewable energy are becoming increasingly attractive. Many applications integrate renewable energy sources into existing utility grids, micro-grids, or isolated loads. Power electronics and drives are one of the most important components of modern renewable energy system applications. Increased efficiency and electro-mechanical robustness of power semiconductors can improve many types of power conversion and generation. This has also led to the developments of electric vehicles and energy storage systems that are largely integrated with RESs.

In this special issue titled "Recent Applications of Power Electronics & Drives in Renewable Power Generation", the utilization of advanced power electronics and drives technology for facilitating renewable power generation has been focused on.

2 | Papers in the Special Issue

In this special issue, we had received large number of papers and out of those only 14 research papers have been accepted. The editorial board has selected research papers with utmost care and believes that all the research papers will be highly useful for academic fraternity to all over the world. The editorial has made great efforts to choose high quality research papers and feel that all the selected research papers will keep high impact. The research papers have been classified in the 7 parts and which are as follows:

2.1 | Novel Converter Topologies Applications in RESs

Tayyab et al. [1] proposed an innovative nine-level inverter for renewable energy applications. In this topology, authors have used a single dc source, one diode, two capacitors and ten switches to provide quadruple boost output voltage without requiring any backend H-bridge. This contributed to reduced voltage stress across the ten switches and the maximum stress is limited to only two times the input voltage. A nearest level control modulation technique has been applied to demonstrate the suitability of the developed inverter through numerical simulation and lab-scale experimental prototype.

Khalid et al. [2] addressed the multilevel converter demand for vehicle to home (V2H) application by proposing a compact inverter. In the developed topology, no diode has been used and only eight switches and a single dc source has been utilized to generate the 11-level of output voltage and current waveform. Being structurally simple, the proposed topology can increase the voltage two voltage levels using an additional switch only. It operates with lower switching loss as least switching transition is ensured by design. The complete power loss analysis is performed for the proposed inverter. Detailed validation studies are provided to elucidate the unique features of the developed topology over the existing literature.

Jouzdani et al. [3] addressed the high boosting capability power converter demand for renewable energy system (RES) applications by proposing a non-isolated soft-switching boost converter. Key features of this topology are the utilisation of built-in transformer and coupled inductors together with reduced number of power semiconductor devices. To obtain high boosting capability, voltage multiplier cell has been used. The input current ripple has been reduced by utilizing the interleaved structure. A simple closed-loop voltage controller is used for generating the switching signals of the power switches.

Varesi et al. [4] proposed an innovative modular multi-phase DC-DC converter that is capable of high boosting and suitable for low-power applications, for example, domestic solar PV. The developed topology ensures continuous source current and provides common-ground point, which makes the topology particularly attractive for PV applications. As high duty cycle is not needed for high boosting of the voltage output, the proposed topology can provide enhanced efficiency through reducing the switching losses associated with high duty cycle.

2.2 | Reliability and Availability Analysis of Power Electronics Converters of RESs

Ren et al. [5] proposed a highly efficient hybrid nine-level with inverter for RES application that has higher dc voltage utilization ratio. By utilizing a hybrid-device topology based on Si and SiC composed of only ten switches and a switched capacitor, the developed topology can provide nine-level output, which makes this topology less expensive than full SiC-inverter. To ensure the neutral point voltage balancing, a control scheme is developed that maintains collaboration between the dc-link capacitors and the flying capacitor. Finally, using a lab-scale prototype, the developed inverter and control scheme are validated.

Javad et al. [6] proposed an improved interleaved converter with symmetrical structure that is capable of enhanced voltage gain. Using a combination of coupled inductor and switched capacitor, the proposed topology can offer high voltage gain at a moderate duty cycle, thereby making the system more efficient through reduced switching loss. An added benefit of the proposed topology is that the voltage stress across the power semiconductor switches is low, which allow low resistance (thereby low conduction loss) switches to be used. A 30 V input and 400 V output experimental prototype-based performance verification is provided.

Moghassemi et al. [7] proposed an innovative switching control strategy to improve the power quality of distribution network through photovoltaic energy fed quasi-Z source inverter-based dynamic voltage restorer circuit. The developed control strategy ensures lower voltage stress across the capacitors and switches while at the same maintains wider voltage gain. Comprehensive tests results are provided to demonstrate the suitability of the proposed controller in mitigating various power quality disturbances, for example, voltage sag, swell and interruption. In addition, lower total harmonic distortion is also achieved which makes the controller suitable to satisfy various appropriate international standards.

2.3 | Reliability and Maintainability Analysis for Grid-Connected RESs

Agrawal et al. [8] proposed a congestion management strategy by customer participation and generator rescheduling. The overall architecture is composed of a cascaded combination of artificial neural network as the filtering module and deep learning network as the congestion module. The developed approach provides an instant and efficient solution to manage congestion with minimum cost through effective generation rescheduling. Validity of the proposed method is shown through the IEEE 30-bus power system.

Ahmed et al. [9] proposed an enhanced delayed signal cancellation method for the grid-integration of distributed RES. The developed method can easily be integrated into the conventional cascaded delayed signal cancellation phase locked loop, making it suitable as a grid-synchronization tool for grid-connected converters. The developed method is very well suited to estimate the fundamental frequency positive and negative sequence components, making it as an integral part of the grid-connected converter control system.

Priyadarshi et al. [10] demonstrated experimental realization of a fixed-frequency sliding mode controller for multilevel inverter-based grid-connected photovoltaic system. The developed controller considers the current tracking error as the sliding surface. Then, using Lyapunov function approach, the total control signal is calculated. In addition, for maximum power tracking, a gravitational search algorithm optimized maximum power tracking method is also proposed. Comprehensive experimental verifications are provided which show that the proposed controller can

increase the efficiency of the overall system compared to the conventional counterpart.

2.4 | Advances in Modeling, Control and Optimization Including AI Methods for Power Electronics and Drives

Bendib et al. [11] proposed an enhanced power flow control method for micro-grid with droop-controlled voltage source inverters. In the developed approach, an enhanced second-order generalized integrator frequency locked loop (ESOGI-FLL) is used for power calculation. In contrast to the existing power computation methods, the proposed approach can robustly estimate the actual power with fast convergence speed as it does not require any low-pass filter. In addition, it also provides enhance filtering performance with respect to low- and sub-harmonics.

2.5 | Reliability Assessment for Power Electronics Components of RESs

Bhaskar et al. [12] developed a high gain DC-DC converter utilising parallel linked legs for RES applications. A key benefit of the proposed topology is that it eliminates some of the conventional components of high gain converters such as coupled inductor, transformer, voltage multiplier and switched inductor/capacitor. The developed topology can achieve good voltage gain over a large duty cycle range. In addition, the proposed topology can easily be extended by adding additional legs for higher power rating and voltage gain. Moreover, inductors and switches current rating can be reduced by increasing parallel legs.

2.6 | RESs Based Electric Vehicle Charging Stations

Amir et al. [13] developed an improved charging control scheme for electric vehicle fast charging station that is integrated in a stochastic power system within a smart micro-grid. Owing to high current demand of fast chargers, their integration in micro-grid can be challenging. This challenging issue has been solved in this work by developing an online reinforcement learning-based controller with the aid of deep neural network. Comprehensive validations are provided to show the suitability of the developed online charging controller.

2.7 | Impact of Component Reliability on Overall Grid-connected RESs Performance

Jayati et al. [14] considered a grid connected MG with DERs as a proposed test system. Different commonly used physics based meta-heuristic techniques such as simulated annealing (SA), harmony search (HS), slime mould algorithm (SMA), gravitational search algorithm (GSA), black hole optimization (BHO), sine cosine algorithm (SCA), multi-verse optimization (MVO) and lightning search algorithm (LSA) are implemented on proposed MG test system for population size 25 and 500 iteration have been used. Authors examined the 24-h scheduling and total cost reduction of an MG with multiple assets, including load demand, market price, and renewable energy sources such as solar PV systems, WT, FC, and MT using eight physics-based optimization techniques. In future these optimization techniques may be implemented for vehicle to grid (V2G) vehicles for cost optimization and battery charging and discharging.

3 | Conclusion

This special issue deals with the contemporary applications of power electronics and drives in renewable power generation. All the selected research papers are based on advanced applications of power electronics and drives. The research papers have been classified into seven categories as: novel converter topologies applications in RES, reliability and availability analysis of power electronics converters of RESs, reliability and maintainability analysis for grid-connected RESs, advances in modeling, control and optimization including AI methods for power electronics and drives, reliability assessment for power electronics components of RESs, RESs based electric vehicle charging stations, and impact of component reliability on overall grid-connected RESs performance. Major research papers based on experimental validations and novel power electronics topologies have been presented. The AI based power electronics applications have also been presented by the authors. Papers based on renewable energy source based fast electric vehicle charging stations have also been selected. The gird connected RESs have also been presented in detail by the authors. Some authors presented modeling, control and optimization methods. Overall, the editorial thinks that the outcome of this special issue has been achieved via diverse research papers in the allied field of power electronics and drives.

Acknowledgements

First of all, we would like to express our sincere gratitude to Prof. David Enfield, chief editor, IET Renewable Power Generation and managing editor Ms. Nageen Matub for accepting our special issue proposal and for their support during the period. We also Thankful to Ms. Sophie Robinson, Current Managing Editor of IET Renewable Energy Generation for her time to time support. We also thank all contributors who submitted innovative new ideas and scientific results in this special issue. We greatly acknowledge the contribution of the anonymous reviewers who have devoted their valuable time from their busy schedules and provided insightful comments in enhancing the quality of manuscripts and helping us in selecting good manuscripts for this special issue.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The authors have nothing to report.

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Sanjeevikumar Padmanaban (M'12–SM'15, IEEE) received a Ph.D. degree in electrical engineering from the University of Bologna, Bologna, Italy, in 2012. He was an associate professor at VIT University from 2012 to 2013. In 2013, he joined the National Institute of Technology, India, as a faculty member. In 2014, he was invited as a visiting researcher at the Department of Electrical Engineering, Qatar University, Doha, Qatar, funded by the Qatar National Research Foundation (Government of Qatar). He continued his research activities with the Dublin Institute of Technology,

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Pooya Davari (S'11–M'13–SM'19) received the B.Sc. and M.Sc. degrees in electronic engineering in 2004 and 2008, **respectively**, and the Ph.D. degree in power electronics from QUT, Australia, in 2013. From 2005 to 2010, he was involved in several electronics and power electronics projects as a development engineer. From 2013 to 2014, he was with QUT, as lecturer. He joined Aalborg University, in 2014, as a Postdoc, where he is currently an associate professor. He has been focusing on EMI, power quality and harmonic mitigation analysis and control in power electronic systems. He has published more than 160 technical papers. Dr. Davari served as a guest associate editor of IET journal of Power Electronics, IEEE Access Journal, Journal of Electronics and Journal of Applied Sciences. He is an associate editor of Journal of Power Electronics, associate editor of IET Electronics, Power Electronic Devices and Systems, editorial board member of Journal of Applied Sciences and Journal of Magnetics. He is member of the International Scientific Committee (ISC) of EPE (ECCE Europe) and a member of Joint Working Group six and Working Group eight at the IEC standardization TC77A. Dr. Davari is the recipient of a research grant from the Danish Council of Independent Research (DFF-FTP) in 2016, and recipient of 2020 IEEE EMC Society Young Professional Award for his contribution to EMI and Harmonic Mitigation and Modeling in Power Electronic Applications. He is currently editor-in-chief of Circuit World Journal. He is founder and chair of IEEE EMC Society Chapter Denmark.

Hafiz Ahmed (senior member, IEEE and fellow, Higher Education Academy) received the Ph.D. degree in automatic control from the University of Lille 1, Villeneuve-d'Ascq, France, in 2016. From 2016 to 2021, he was with Clemson **University**, Clemson, SC, USA, Asia Pacific University, Dhaka, Bangladesh, North South University, Dhaka, Coventry University, Coventry, U.K., and Birmingham City University, Birmingham, U.K. Since April 2021, he has worked with the Nuclear Futures Institute, Bangor University, U.K. Currently, he is working as the Group Head, Controls and Instrumentation Department, University of Sheffield, Derby, U.K. His research interest includes applied control engineering with special focus in energy and environment. He was a recipient of the European Embedded Control Institute (EECI) Ph.D. Award, in 2017, and the Best Ph.D. Theses Award from the Research Cluster on Modelling, Analysis, and Management of Dynamic Systems (GDR-MACS) of the National Council of Scientific Research (CNRS) in France, in 2017. He is an associate editor of the International Journal of Electrical Engineering and Education. He is also

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