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Siddiqui, K.M. orcid.org/0000-0002-9468-7397, Padmanaban, S. orcid.org/0000-0003-3212-2750, Benbouzid, M. orcid.org/0000-0002-4844-508X et al. (7 more authors) (2025) Recent applications of power electronics & drives in renewable power generation. IET Renewable Power Generation, 19 (1). e70088. ISSN 1752-1416

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Recent Applications of Power Electronics & Drives in Renewable Power Generation

Khadim Moin Siddiqui[1] | Sanjeevikumar Padmanaban[2] | Mohamed Benbouzid[3] | Ram Khelawan Saket[4] | Pooya Davari[5] | Hafiz Ahmad[6] | Farhad Ilahi Bakhsh[7] | Ganesh Kumar Venayagamoorthy[8] | Korhan Cengiz[9] | John D. McDonald[10]

[1]Electrical & Electronics Engineering Department, S.R. Instiute of Management & Technology, Lucknow, Uttar Pradesh, India | [2]Electrical Engineering Department, University of South-Eastern, Porsgrunn, Norway | [3]Electrical Engineering Department, Brest University, Brest, France | [4]Electrical Engineering Department, Indian Institute of Technology (BHU), Varanasi, India | [5]Applied Power Electronic Systems Department, Aalborg University, Aalborg, Denmark | [6]Controls and Instrumentation Department, University of Sheffield, Derby, UK | [7]Electrical Engineering Department, National Institute of Technology, Srinagar, J&K, India | [8]Electrical and Computer Engineering Department, Clemson University, Clemson, USA | [9]Electrical Engineering Department, Biruni University, Istanbul, Turkey | [10]Grid Solutions Department, GE, Renewable Energy, Boston, USA

Correspondence: Khadim Moin Siddiqui (siddiquikhadim@ieee.org)

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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.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The authors have nothing to report.

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Guest Editor Biographies

Khadim Moin Siddiqui, Ph.D., received his B.Tech. Degree in Electronics Engineering from Azad Institute of Engineering & Technology (AIET), Lucknow (Uttar Pradesh Technical University, Lucknow) in 2007, M.Tech. Degree in Power Electronics & Drives with honors (Electrical Engineering) from Madan Mohan Malaviya Engineering College, Gorakhpur (Gautam Buddha Technical University, Lucknow) in 2012 and Ph.D. Degree in Electrical Engineering funded by Technical Education Quality Improvement Program Phase-II from Institute of Engineering & Technology, Lucknow (Dr. A.P.J. Abdul Kalam Technical University, Lucknow) in 2017. He has published more than 52 research papers in international journals, 20 papers presented in the national as well as international conferences and published 8 worke book chapters. He has received best research paper awards in one national and in two international conferences. He has published four books in English in the field of Electrical Engineering & Technology. He has also published one book in Russian, German, French, Italian, Portuguese and Spanish Languages. Currently, he is working as an Associate Professor in the Department of Electrical & Electronics Engineering, S.R. Institute of Management & Technology, Lucknow. He has more than 15 years of academic experience. He is the editorial board member of two international journals and reviewer of many reputed journals such as Elsevier's Mechanism and Machine Theory, IEEE Industry Applications Society, International Journal on Electrical Engineering and Informatics, Indonesia, Global Journals, USA, IET Renewable Power Generation, IET Generation, Transmission and Distribution and an active reviewer of IEEE International and National Conferences. He is IEEE Student Branch Counselor of S.R. Institute of Management & Technology, Lucknow. He is also the advisor of IEEE Power & Energy Society (PES), Power Electronics Society, Engineering in Medicine and Biology Society Student Chapters at the same insitute. He is also the executive committee member of IEEE Signal Processing Society Chapter, IEEE UP Section and IEEE Young Professionals. He is a VoLT graduate from IEEE MGA. He is an active volunteer of IEEE Region 10, IEEE UP Section and organized many programs of national as well as international levels such as webinars/FDPs/QIP/Conference. He has authored more than 70 research papers in various national, International Conference and Journals. He is an IEEE Senior Member from November 2020. He has delivered expert lectures in the field of power electronics & drives, signal processing in many institutions. He has attended and participated in more than 40 FDPs/STTPs/webinars. He has chaired sessions in many international conferences. He has been given young professional star of the March Month award in 2021 and outstanding chapter advisor award 2021 by IEEE UP Section, India. He is the lead guest editor of a special issue in IET Renewable Power Generation, and guest editor in IET Generation, Transmission & Distribution (GTD). He has also served as a lead Guest Editor in Distributed Generation & Alternative Energy Journal. He has also served as a Editor in IEEE UP Section (R10) Newsletter. His research areas of interest include electrical machines, fault diagnosis and health monitoring of induction motors and power transformers, signal processing, multilevel inverters and smart grid, renewable energy, energy efficiency and conservation.

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,

Dublin, Ireland, in 2014. Further, he served as an associate professor with the Department of Electrical and Electronics Engineering, University of Johannesburg, Johannesburg, South Africa, from 2016 to 2018. From March 2018 to February 2021, he has been an assistant professor at the Department of Energy Technology, Aalborg University, Esbjerg, Denmark. He continued his activities from March 2021 as an associate professor with the CTIF Global Capsule (CGC) Laboratory, Department of Business Development and Technology, Aarhus University, Herning, Denmark. Presently, he is a full professor in electrical power engineering at the Department of Electrical Engineering, Information Technology, and Cybernetics, University of South-Eastern Norway, Norway. He has authored over 750 scientific papers and received the Best Paper cum Most Excellence Research Paper Award from IET-SEISCON'13, IET-CEAT'16, IEEEEECSI' 19, IEEE-CENCON'19, and five best paper awards from ETAEERE'16 sponsored Lecture Notes in Electrical Engineering of Springer book. He is a fellow of the Institution of Engineers, India, the Institution of Electronics and Telecommunication Engineers, India, and the Institution of Engineering and Technology, UK. He received a lifetime achievement award from Marquis Who's Who—USA 2017 for contributing to power electronics and renewable energy research. He is listed among the world's top two scientists (from 2019) by Stanford University, USA. He is an editor/associate editor/editorial board for refereed journals, in particular, IEEE Systems Journal, IEEE Transaction on Industry Applications, IEEE Access, IET Power Electronics, IET Electronics Letters, and Wiley-International Transactions on Electrical Energy Systems, subject editorial board member—Energy Sources—Energies Journal, MDPI, and the subject editor for the IET Renewable Power Generation, IET Generation, Transmission and Distribution, and FACETS Journal (Canada).

Mohamed Benbouzid received his Ph.D. degree in electrical and computer engineering from the National Polytechnic Institute of Grenoble, Grenoble, France, in 1994, and the Habilitation à Diriger des Recherches degree from the University of Amiens, Amiens, France, in 2000. After receiving the Ph.D. degree, he joined the University of Amiens, Amiens, France, where he was an associate professor of electrical and computer engineering. Since September 2004, he has been with the University of Brest, Brest, France, where he is a full professor of electrical engineering. Prof. Benbouzid is also a distinguished professor and a 1000 Talent Expert at the Shanghai Maritime University, Shanghai, China. His main research interests and experience include analysis, design, and control of electric machines, variable-speed drives for traction, propulsion, and renewable energy applications, and fault diagnosis of electric machines. Prof. Benbouzid is an IEEE fellow and a fellow of the IET. He is the editor-in-chief of the International Journal on Energy Conversion and the Applied Sciences (MDPI) section on electrical, electronics and communications engineering. He is a subject editor for the IET Renewable Power Generation.

Dr. R.K. Saket (S'99–M'16–SM'19) is currently a professor with the Department of Electrical Engineering, Indian Institute of Technology (Banaras Hindu University) Varanasi (Uttar Pradesh) India. Previously, he was a faculty member at Government Engineering College, Rewa (Madhya Pradesh) India, Birla Institute of Technology and Science, Pilani (Rajasthan), India, University Institute of Technology, Rajiv Gandhi University of Technology, Bhopal (Madhya Pradesh), India, and Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad (Uttar Pradesh), India. He has provided his industrial services to Electrical Safety Division of the M.P. Electricity Board, Government of Madhya Pradesh, Ujjain Division (Madhya Pradesh) India as an electrical safety engineer. He has more than 20 years of academic, industrial and research experience. He is the author/co-author of approximately 140 scientific articles, book chapters and research papers in indexed international journals and prestigious conference proceedings. He has supervised 12 Ph.D. research scholars and 45 M. Tech. students in different areas of the reliability engineering. He has delivered many technical talks and honored as a resource person of the power system reliability engineering. His research interests include reliability engineering, electrical machines & drives, power system reliability, reliability enhancement of industrial components & systems, and reliability aspects in renewable energy systems.Professor Saket is a fellow of the Institution of Engineers (India), senior member of IEEE (USA), member of IET (UK), and a life member of the Indian Society for Technical Education, New Delhi (India). He is an editorial board member of the IET Renewable Power Generation (UK), IEEE Access (USA), Journal of Electrical Systems (France), and Engineering, Technology and Applied Science Research (Greece). He has received many awards, honors, and recognition for his academic and research contributions including the prestigious Gandhian Young Technological Innovation Award–2018 appreciated by the Hon'ble President of India at Rashtrapati Bhavan, New Delhi, India; Design Impact Award–2018 by Padma Vibhushan Ratan Tata at Mumbai, India, and Nehru Encouragement Award–1988 & 1990 by the Hon'ble Chief Minister of MP State Government Bhopal, India.

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

actively involved in organizing special issues and sessions at various international journals and conferences.

Farhad Ilahi Bakhsh (senior member, IEEE) received B. Tech degree in electrical engineering and M. Tech. degree in power systems & drives from Aligarh Muslim University (AMU), Aligarh, India in 2010 and 2012, respectively. Then he pursued Ph.D. from the Indian Institute of Technology Roorkee, India in 2017. During his Ph.D. he developed a new method for grid integration for wind energy generation systems which has been recognized worldwide. He served as an assistant professor in the Department of Electrical & Renewable Energy Engineering, School of Engineering & Technology, Baba Ghulam Shah Badshah University, Rajouri, J & K, India. He developed an automatic solar tracking system which has been appreciated by IEEE India Council, Centre for Embedded Product Design, Centre for **Electronics** Design and Technology, Netaji Subhas Institute of Technology in association with IEEE Delhi Section & IEEE CAS, Bangalore Chapter. Currently, he is serving as an assistant professor in the Department of Electrical Engineering, National Institute of Technology Srinagar, Jammu & Kashmir, India. He is the founder and counselor of the IEEE Student Branch, at NIT Srinagar. Recently, he won the "10 for 10 Typhoon HIL Award" from Switzerland, Europe. He delivered several keynote talks, invited talks and expert lectures at the National and International levels in conferences, workshops, STC, etc. He has more than 50 published papers in internationally reputed journals, and international and nationally reputed conferences. Many times, he got the best paper awards at international conferences. Moreover, he has Indian and Australian-granted patents on his credit. He is the associate editor of Distributed Generation & Alternative Energy Journal; lead guest editor of IET Generation, Transmission and Distribution Journal; lead guest editor of IET Power Electronics Journal; guest editor of IET Renewable Power Generation Journal; guest editor of Renewable Energy Focus, Elsevier; and guest editor in Recent Advances in Electrical & Electronic Engineering. His research areas of interest includes performance analysis and new applications of variable frequency transformer, application of power electronics & drives in renewable energy systems (solar & wind), multilevel converters, alternate energy vehicles (electric/ hybrid) and multi-phase drives.

Ganesh Kumar Venayagamoorthy (S'91–M'97–SM'02) was a professor of electrical and computer engineering at the Missouri University of Science and Technology, Rolla, MO, USA, from 2002 to 2011. He is currently the Duke Energy Distinguished Professor of Power Engineering and a professor of Electrical and Computer Engineering and Automotive Engineering with Clemson University, Clemson, SC, USA. He is also the founder and director of the Real-Time Power and Intelligent Systems Laboratory at Clemson University. He is an honorary professor with the School of Engineering, University of KwaZulu–Natal, Durban, South Africa. He is the top author of the College of Engineering and Science at Clemson University, according to the Elsevier Expert Portal, and was the most cited researcher of Clemson University by ResearchGate in November and December 2015. He has been involved in over 65 sponsored projects over U.S. $10 million. He has authored over 475 refereed technical articles. His publications are cited about 10,000 times with an h-index of 51. His current research interests include the development and innovation of advanced computational methods for smart grid operations, including intelligent sensing and monitoring, power system optimization, stability and control, and signal processing. Dr. Venayagamoorthy is a fellow of the Institution of Engineering and Technology (IET), U.K., and the South African Institute of Electrical Engineers. He received the U.K. IET Generation, Transmission and Distribution Premier Award for the best research paper published in 2010/2011 for the paper titled "Wide Area Control for Improving Stability of a Power System With Plug-In Electric Vehicles" in 2012. He engages in the leadership and organization of many conferences, including the general chair of the Annual Power System Conference in Clemson since 2013, and the pioneer and chair/co-chair of the IEEE Symposium of Computational Intelligence Applications in Smart Grid since 2011. He is the chair of the IEEE Power & Energy Society Working Group on Intelligent Control Systems and the founder and chair of the IEEE Computational Intelligence Society Task Force on Smart Grid. He has served as an editor/guest editor of several IEEE and Elsevier journals.

Korhan Cengiz, Ph.D., SMIEEE was born in Edirne, Turkey in 1986. He received the B.S. degree in electronics and communication engineering from Kocaeli University, Turkey and business administration from Anadolu University, Turkey in 2008 and 2009, respectively. He took his M.S. degree in electronics and communication engineering from Namik Kemal University, Turkey in 2011, and the Ph.D. degree in electronics engineering from Kadir has University, Turkey in 2016. Since 2018 and also in the Electrical-Electronics Engineering Department, Trakya University, Turkey. Currently, he is working as Associate Professor, Biruni University, Istanbul, Turkeye. He is the author of over 40 articles including IEEE Internet of Things Journal, IEEE Access, three book chapters, two international patents and one book in Turkish. He serves several book and journal editorial positions in Springer, Elsevier and IEEE. He presented 10+ keynote talks in reputed IEEE and Springer conferences about WSNs, IoT and 5G. His research interests include wireless sensor networks, wireless communications, statistical signal processing, indoor positioning systems, power electronics and 5G. He is an editor of the Turkish Journal of Electrical Engineering and Computer Sciences. He is senior member, IEEE since August 2020. Dr. **Cengiz's** awards and honors include the Tubitak Priority Areas Ph.D. Scholarship, the Kadir has University Ph.D. student scholarship, best presentation award in ICAT 2016 Conference and best paper award in ICAT 2018 Conference.

John D. McDonald, P.E., is smart grid business development leader for GE's Grid Solutions business. He has 47 years of experience in the electric utility transmission and distribution industry. He received his B.S.E.E. and M.S.E.E. (power engineering) degrees from Purdue University, and an M.B.A. (Finance) degree from the University of California-Berkeley. He is a life fellow of IEEE (member for 50 years), and was awarded the IEEE Millennium Medal, the IEEE Power & Energy Society (PES) Excellence in Power Distribution Engineering Award, the IEEE PES Substations Committee Distinguished Service Award, the IEEE PES Meritorious Service Award, the 2016 CIGRE Distinguished Member Award, the 2016 CIGRE USNC Attwood Associate Award, and the 2021 CIGRE Honorary Member Award. John is past president of the IEEE PES, the VP for technical activities for the US National Committee (USNC) of CIGRE, the past chair of the IEEE PES Substations Committee, and the IEEE Division VII past director. John was on the board of governors of the IEEE-SA (Standards Association), is an IEEE foundation director, and is a founding board member and treasurer of the Smart Energy Consumer Collaborative (SECC). John received the 2009 Outstanding Electrical and Computer Engineer Award from Purdue University. John teaches a smart grid course at the Georgia Institute of Technology, a smart grid course for GE, and smart grid courses for various IEEE PES local chapters as an IEEE PES distinguished lecturer (since 1999). John has published 150 papers and articles, has co-authored five books and has one US patent.