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Special Issue: Planning and Operation of Resilient Distribution System for Integrated Multi-Energy

Guest Editorial: Planning and operation of resilient distribution system for integrated multi-energy

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Introduction

Resilience is the ability of power systems to prepare for and adapt to low-probability, high-impact incidents and withstand and recover rapidly from disruptions. With the ageing of electricity distribution infrastructure and increasing threats of weather-related incidents and natural disasters, the need to effectively enhance the resilience of the electricity distribution system has become urgent and has attracted worldwide attention.

Although there are an increasing number of publications related to enhancing resilience strategies, resilience is an emerging concept in power systems. Existing practices are mostly focused on deploying distributed energy resources (DERs) and microgrids, hardening the existing infrastructures and building redundant capacities. However, from a broader perspective, resilience enhancement of power distribution system is a systematic engineering, involving long-term system planning and upgrading (e.g., deployment of smart grid technologies and intelligent switches), short-term proactive scheduling, real-time robust and resilient control of DERs, and post-event restoration and recovery strategies. Based on this point, this Special Issue in *IET Energy System Integration* focuses on soliciting the most recent and original technologies, scheduling and control strategies for improving the resilience of power distribution system. Eight papers are presented in this Special Issue, covering various aspects related to resilience enhancement of power distribution system, including fault-tolerant frequency measurement, robust scheduling of integrated electricity and district heating systems, robust control of DERs, efficient methods for safety verification as well as novel graph theory-based approach to restore the distribution systems after multiple simultaneous faults. A brief introduction of these 8 papers is provided below.

Papers in the special issue

In ‘Fault-tolerant grid frequency measurement algorithm during transients’, Zhan *et al.* proposes a two-stage fault-tolerant grid frequency measurement algorithm. The first stage is a transient detector, and it can detect the occurrence of system transient faults instantaneously. The second stage is an intelligent frequency estimator, which adapts its measurements according to the transient detector. The new algorithm provides a fundamental solution to improve the reliability and resilience of time critical power systems control and protection applications.

In ‘Interval optimal scheduling of integrated electricity and district heating systems considering dynamic characteristics of heating network’, Chen *et al.* propose an interval optimal scheduling model for integrated electricity and district heating system to optimise the operation of two coupled energy systems considering the dynamic characteristics of heating network, wind power and load uncertainties. The dynamic characteristics of a heating network will effectively help the integration of wind power and reduce operation costs.

In ‘Optimal coordinative operation strategy of the electric–thermal–gas integrated energy system considering CSP plant’, Chen *et al*. propose an optimal coordinative operation model for the electric-thermal-gas integrated energy system. The concentrating solar power (CSP) and the virtual thermal energy storage characteristic of thermal network are considered to reduce the operating cost and promote the penetration of wind power.

In ‘Integration of wind power generation through an enhanced instantaneous power theory’, Sahoo *et al.* propose a novel current decomposition technique based on enhanced instantaneous power theory for controlling the grid-interfacing converter to realise an improved power quality in wind power generation system and to provide the requisite reactive power support. The proposed approach increases flexibility and reliability in grid/microgrid operation.

In ‘Model predictive control for voltage restoration in microgrids using temporal logic specifications’, Taousser *et al.* propose a model predictive control for voltage restoration in microgrids using temporal logic specifications. During a disturbance, the proposed control could restore the voltage at a critical load bus back above a certain value within a required time, thus avoids unnecessary relay protection actions. The voltage stability and resilience of distribution system could be improved significantly by the proposed control.

In ‘Robust control approach for the integration of DC-grid based wind energy conversion system’, Sahoo *et al.* propose a novel control approach for a dc-grid based wind energy conversion system in a poultry farm considering parallel operation of multiple DERs. A 17-level hybrid cascaded multilevel inverter is proposed for the microgrid operation offering more voltage levels with less nonlinearity. The proposed wind energy conversion system eliminates the requirement of voltage and frequency synchronisation and improves the reliability of microgrids.

In ‘Review on set-theoretic methods for safety verification and control of power system’, Zhang *et al.* presents a thorough review on set-theoretic methods for safety verification and control of power system. The methods are categorised into set operation-based and passivity-based methods according to their underlying mathematical principle. The reviewed methods provide solutions to handle unknown-but-bounded uncertainty in power system operations.

In ‘Distribution system restoration using graph theory after multiple faults’, Vedullapalli *et al.* propose a novel graph theory-based approach to restore the distribution systems (DSs) after multiple simultaneous faults due to extreme weather conditions. The proposed algorithm also gives the order in which the faults have to be cleared, depending on the priority of the disconnected load and inconvenience caused to the public. The proposed approach can help utilities for crew dispatching and minimising the interruption time for areas affected by the faults.

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Guest Editor Biographies

Guodong Liu received the PhD degree in electrical engineering from the University of Tennessee, Knoxville, TN, USA, in 2014. Since 2014, he has been a R&D staff in the Electrical and Electronic System Research Division at Oak Ridge National Laboratory, Oak Ridge, TN, USA, where he currently leads projects on microgrid planning and operation, renewable energy integration and active distribution network management. He is a senior member of IEEE. His research interests include power system operation and planning, power system reliability and security assessment, distributed energy resources and microgrids.

Xue Li is currently an Associate Professor at the School of Electrical Engineering, Northeast Electric University, China. She received her M.S. and PhD degrees in Computer Engineering from the University of Tennessee, Knoxville, TN, USA in 2011 and 2015, respectively. She had also spent three months as a visiting scholar at Mälardalen University, Sweden in 2017. Her research interests include high performance computations in power systems, integrated energy systems and power market.

Aleksandar Dimitrovski received the B.S. degree in electrical engineering from Ss. Cyril and Methodius University, Skopje, Macedonia, in 1987, the M.Sc. degree in applied computer sciences from the University of Zagreb, Zagreb, Croatia, in 1992, and the PhD degree in electrical engineering with an emphasis in power from Ss. Cyril and Methodius University, in 1997. He was with Schweitzer Engineering Laboratories, Pullman, WA, USA, and Washington State University, Pullman. He was a Chief Technical Scientist with the Oak Ridge National Laboratory, Oak Ridge, TN, USA, and a Joint Faculty with The University of Tennessee at Knoxville, Knoxville, TN, USA. He is currently an Associate Professor with the University of Central Florida, Orlando, FL, USA. His current research interests include modelling, analysis, protection, and control of uncertain power systems and hybrid magnetic–electronic power control devices.

Kevin Tomsovic received the B.S. degree from Michigan Technological University, Houghton, MI, USA in 1982, and the M.S. and PhD degrees from the University of Washington, Seattle, WA, USA in 1984 and 1987, respectively, all in electrical engineering. He is currently the CTI Professor with the Department of Electrical Engineering and Computer Science, University of Tennessee, Knoxville, TN, USA, where he also directs the National Science Foundation (NSF)/Department of Energy (DOE) Research Center, for Ultra-Wide-Area Resilient Electric Energy Transmission Networks (CURENT), and has also served as the Electrical Engineering and Computer Science Department Head from 2008 to 2013. He was on the faculty of Washington State University, Pullman, WA, USA, from 1992 to 2008. He held the Advanced Technology for Electrical Energy Chair with Kumamoto University, Kumamoto, Japan, from 1999 to 2000, and was the NSF Program Director with the Electrical and Communications Systems Division of the Engineering Directorate from 2004 to 2006.

Fei Ding is a Senior Research Engineer at the National Renewable Energy Laboratory (NREL). Her research interests include renewable energy grid integration, grid edge resources aggregation and control, grid resilience and security. She is leading multiple projects on developing advanced models and controls for managing grid-edge resources to enhance grid flexibility, reliability, and resilience, and developing new advanced distribution management system and distributed energy resource management system applications to modernise emerging distribution grids.