Technical University of Denmark

Guest Editorial: Special Issue: Smart Grid Voltage Control

Sun, Hongbin; Guo, Qinglai; Ilic, Marija D.; Wu, Qiuwei; Sun, Kai; Du, Pengwei

Published in:
I E T Generation, Transmission and Distribution

Link to article, DOI:
10.1049/iet-gtd.2017.1608

Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

IET Generation, Transmission & Distribution

Special Issue: Smart Grid Voltage Control

Guest Editorial

ISSN 1751-8687
E-First on 20th October 2017
doi: 10.1049/iet-gtd.2017.1608
www.ietdl.org

Hongbin Sun, Qinglai Guo, Marija D. Ilić, Qiuwei Wu, Kai Sun, Pengwei Du

Voltage control is facing new challenges in the context of smart grids. The first challenge comes from rapidly fluctuating voltages that are due to the uncertain and variable nature of renewable energies which are increasingly integrated into smart grids. It is important to mitigate the voltage fluctuation; otherwise voltage violations and even cascading tripping of wind turbines may occur. Another challenge results from the fact that more high voltage direct current (HVDC) lines are paralleled with high voltage alternating current (HVAC) lines and fed into load centres. This new network configuration may lead to voltage stability issues, especially when there is a fault on the DC side. The third challenge lies in the voltage control demand in micro-grids, especially when they are working in an islanded mode.

This Special Issue on Smart Grid Voltage Control contains 11 high-quality papers that are relevant to several important topics in the voltage control, such as reactive power optimization for wind and HVDC, voltage control for active distribution grids and micro-grids, voltage control with demand side management, stability issues in the voltage control and field applications of voltage control systems.

Reactive power optimization for wind and HVDC

Wind power has a strong stochastic nature that should be considered in the reactive power optimization. The paper *Solution of Reactive Power Optimization Including Interval Uncertainty Using Genetic Algorithm* by Cong Zhang *et al.* considers the uncertainty in the input data of a power system and designs a genetic algorithm based solution to an uncertain bi-objective reactive power optimization. The Pareto front was established as the solution. In comparison with the chance-constrained programming method, this method is more efficient.

As for the HVDC integration, the paper *Second Order Cone Programming (SOCP) Relaxation Based Optimal Power Flow with Hybrid VSC-HVDC Transmission and Active Distribution* by Tao Ding *et al.* develops an OPF model with the hybrid voltage-source converter (VSC)-HVDC transmission and active distribution networks to optimally schedule the generation output and voltage regulation of both networks. A second-order cone programming (SOCP) relaxation approach is applied for an efficient solution.

Moreover, optimal sizing of reactive sources can further improve the effect of reactive power optimisation. The paper *Optimisation of Dynamic Reactive Power Sources Using Mesh Adaptive Direct Search* by Weihong Huang *et al.* proposes a new approach for solving an optimal sizing of dynamic reactive power sources by using the mesh adaptive direct search algorithm interfaced with a power system simulator. Both a single contingency and multiple contingencies are considered in this method.

Voltage control for micro-grids

Islanded micro-grid voltage and frequency control is very important for the grid operation. The paper *Decentralised Secondary Voltage and Frequency Control Scheme for Islanded Microgrid Based on Adaptive State Estimator* by Guannan Luo *et al.* proposes a decentralised secondary voltage and frequency control based on the state estimation principle and cooperative strategy in an islanded microgrid. The proposed secondary control is implemented in a fully decentralised structure such that each distributed generation requires its own information only.

DC micro-grids propagate in parallel with AC micro-grid development. The paper *Energy Management in DC Microgrid with Energy Storage and Model Predictive Controlled AC-DC Converter* by Md Rana proposes effective energy management and model predictive controller control techniques for a photovoltaic-based DC microgrid. The real-time controller hardware-in-the-loop experiment validates the effectiveness of the proposed control strategy for energy management in the microgrid.

Voltage control with demand side management

Direct and indirect control both can be used in the demand side management. The paper *Switching Model Analysis and Implementation of Electric Spring for Voltage Regulation in Smart Grids* by Mohammad Abido proposes a new switching model for steady-state and dynamic analysis of an electric spring to make a better utilization of demand side resources in voltage regulation. Hardware-in-loop simulation results have validated the proposed controller design approach to enhance greatly the reliability of the distribution network considered.

For the indirect control, the paper *Multi-Agent Transactive Energy Management System Considering High Levels of Renewable Energy Source and Electric Vehicles* by Divsheli Hasanpor presents a real-time pricing based on Cournot oligopoly competition model to indirectly control demand and supply in the presence of high levels of renewable energy sources (RESs) and electric vehicles (EVs) to compensate RESs' fluctuations in addition to satisfying voltage regulation constraints.

Stability issues in the voltage control

The paper *Voltage Stability Analysis in Radial Smart Distribution Grids* by Hamdi Abdi *et al.* presents two novel fast voltage stability indices (VSIs) applicable to the radial distribution smart grids (SGs) based on the real-time measured voltage data only. The comparison results demonstrate that the proposed VSIs are fast and effective to identify the most sensitive node of the radial grids to the voltage collapse.

The paper *Measurement-based Voltage Stability Assessment for Load Areas Addressing n-1 Contingencies* by Kai Sun *et al.* utilizes real-time synchro-phasor measurements on N boundary buses and online state estimation on the load area to estimate the voltage stability margin of power transfer to each boundary bus under an anticipated $N-1$ condition. Its effect is demonstrated on a Northeast Power Coordinating Council 48-machine, 140-bus power system.

The paper *Mode Identification of Low Frequency Oscillations in Power Systems Based on Fourth Order Mixed Mean Cumulant and Improved TLS-ESPRIT Algorithm* by Tao Jin *et al.* proposes a method to identify the low-frequency oscillation modes of a single-channel measurement of the power system based on the combination of the fourth-order mixed mean cumulant and the improved total least square-estimation parameter space rotation invariant technique (TLS-ESPRIT). The simulation results show that the proposed method has better anti-noise performance and higher accuracy of fitting than other methods reported in literature.

Field applications of voltage control systems

The paper *Balancing Distribution Systems with Three-phase Active Front End Rectifiers: Field Experiment Results* by Philip Douglass describes field tests of alternative methods to control three-phase active rectifiers to reduce voltage unbalance in low-voltage (LV) distribution systems. The tests show that per-phase control of active power of two residential loads can significantly reduce unbalance throughout an LV feeder.

Summary/Conclusion

All of the papers selected for this Special Issue show a deep understanding of the emerging voltage problems, and more importantly, the development of more advanced voltage control methods for both transmission and distribution grids. We believe that this Special Issue will provide readers with new theories, technologies and field tests for the smart grid voltage control.

Hongbin Sun received his double B.S. degrees from Tsinghua University Beijing, China in 1992, and his Ph.D from the Department of Electrical Engineering, Tsinghua University in 1997. He is now Changjiang Chair Professor of Education Ministry of China, full professor of electrical engineering in Tsinghua University. From 2008 to 2009, he was a visiting professor with the School of EECS at Washington State University, Pullman, USA. He is a Fellow of the IET. He is serving as chairman of IEEE Task Force on Voltage Control for Smart Grids and IEEE Working Group on Energy Internet. In the past 20 years, he led a research group in Tsinghua University to develop a commercial system-wide automatic voltage control systems, which has been applied to PJM interconnection, the largest regional power grid in the USA, and to almost all electrical power control centers in China. He has published more than 400 academic papers. He won the China National Technology Innovation Award in 2008, the National Distinguished Teacher Award in China in 2009, and the National Science Fund for Distinguished Young Scholars of China in 2010. His research achievements on system-wide voltage control was listed as 'Top-10 Science and Technology Progresses of Chinese Universities' in 2016. His research interests include electrical power control center applications, smart grid and Energy Internet.

Qinglai Guo received his B.Sc. in 2000 and Ph.D in 2005 from Tsinghua University, Beijing, China and is currently an associate professor in the Department of Electrical Engineering, Tsinghua University. His research interests include energy management systems, voltage stability and control, and cyber-physical systems. He is an IEEE senior member and the co-chair of IEEE Task Force on Voltage Control for Smart Grid. In 2015, he was awarded the National Science Fund for Excellent Young Scholars. He is an editorial member of *IEEE Transactions on Smart Grid, IET Renewable Power Generation, IET Cyber-Physical Systems: Theory & Applications, Journal of Modern Power Systems and Clean Energy, and Protection and Control of Modern Power Systems*.

Marija D. Ilić is currently a professor at Carnegie Mellon University, Pittsburgh, PA, USA, with a joint appointment in the Electrical and Computer Engineering and Engineering and Public Policy Departments. She is also the Honorary Chaired Professor for Control of Future Electricity Network Operations at Delft University of Technology in Delft, The Netherlands. Her main interest is in the systems aspects of operations, planning, and economics of the electric power industry. Most recently she became the director of the Electric Energy Systems Group at Carnegie Mellon University (http://www.eesg.ece.cmu.edu); the group does extensive research on mathematical modeling, analysis and decision-making algorithms for future energy systems. She is leading the quest for transforming today's electric power grid into an enabler of efficient, reliable, secure and sustainable integration of many novel energy resources. She has co-authored several books in her field of interest. Prof. Ilić is an IEEE Fellow and Distinguished Lecturer.

Qiuwei Wu, is an associate professor with the Department of Electrical Engineering, Technical University of Denmark (DTU). His research interests are renewable energy integration, electric vehicles, active distribution networks, electricity market and integrated energy systems. He is an Editor of IEEE Transactions on Smart Grid and IEEE Power Engineering Letters, and an Associate Editor of International Journal of Electrical Power and Energy Systems, IET Renewable Power Generation, and Journal of Modern Power Systems and Clean Energy.

Kai Sun is an associate professor at the Department of EECS, University of Tennessee in Knoxville. He received his B.S. degree in automation in 1999 and his Ph.D. degree in control science and engineering in 2004 from Tsinghua University, Beijing, China. Dr. Sun is an IEEE senior member, an associate editor of *IET Generation, Transmission & Distribution* and an Editor of IEEE *Transactions on Smart Grid*. He was a project manager in grid operations and planning areas at the EPRI, Palo Alto, CA from 2007 to 2012. He is a recipient of the 2016 NSF CAREER award. His research interests include stability, dynamics and control of power grids and other complex systems.

Dr. Pengwei Du is lead engineer – renewable integration with the Electric Reliability Council of Texas (ERCOT). Prior to this, he was a senior research engineer with Pacific Northwest National Laboratory (PNNL). Dr. Du holds four U.S. patents. Dr. Du was an adjunct professor at Washington State University (Tri-Cities) in 2012, and has been adjunct faculty at University of Texas (Austin) since 2016. Dr. Du is the recipient of IEEE PES Power System Dynamic Performance Committee Prize Paper Award in 2016. Dr. Du is an associate editor of *IET Generation, Transmission & Distribution*, and vice-chair for IEEE Power & Energy Society Bulk Power System Planning Subcommittee.