

Guest Editorial

Smart Grid Technologies and Development in China

BUILDING a strong smart grid has been listed as one of the goals in the Chinese government's Nation Twelfth Five-Year Plan. In 2010, the State Grid Corporation of China, as the largest utility in the world, announced plans to invest \$250 billion in electric power infrastructure upgrades from 2011 to 2015, among which \$45 billion is earmarked for smart grid technologies. Another \$240 billion will be added to complete the smart grid projects from 2016 to 2020. Another Chinese national utility—China Southern Power Grid, also launched its smart grid roadmap in 2011 to build a smart, efficient, reliable, and green grid in the next ten years. Ultimately, the goal of the Chinese government is to build a strong national smart grid capable of transmitting power from conventional and renewable energy sources to the remote load centers. Besides the advances in substations and distribution systems, ultrahigh voltage (UHV) (1000 kV ac and ± 800 kV dc) transmission is a salient feature in the Chinese smart grid definition and development compared to the other countries.

This special section includes 16 papers focusing on various topics from demand-side management, microgrids, and distribution to UHV transmission systems in China. A brief introduction to each of the accepted papers is provided below.

I. RENEWABLE ENERGY INTEGRATION

“Assessment Method and Indexes of Operating States Classification for Distribution System With Distributed Generations” by Li *et al.* defines and categorizes a set of critical attributes for the operating states of distribution systems with distributed generations. The operating states of distribution systems are defined as external stability, reliability, integrity, economy, etc. Criteria for the classification of those operating states are also proposed. Finally, a control strategy is proposed accordingly to support the associated decision-making.

“A Robust Two-Level Coordinated Static Voltage Security Region for Centrally Integrated Wind Farms” by Ding *et al.* addresses the critical challenges to secure operation of power grids caused by integration of large amounts of wind power. A robust master-slave two-level coordinated static voltage security region based method is proposed. In addition, a hierarchically iterative coordination method is used to calculate the voltage security range of each wind farm. A real system is tested to show the effectiveness of the proposed method.

“A Probabilistic Method for Determining Grid-Accommodable Wind Power Capacity Based on Multi-Scenario System Operation Simulation” by Xu *et al.* investigates the penetration limit of wind power in power systems. A probabilistic method is presented to consider the uncertainty from a multitude of wind power and demand scenarios. A real power system in China and standard test systems are used to verify the validity and effectiveness of the proposed approach.

“Key Technologies for Integration of Multitype Renewable Energy Sources—Research on Multi-Timeframe Robust Scheduling/Dispatch” by Chen *et al.* proposes an optimal scheduling and complementary approach and a new framework for multimescale robust scheduling. The real data of Hainan power grid show that the proposed approach has the potential of implementation in practice.

II. DEMAND RESPONSE

“Optimal Dispatch of Air Conditioner Loads in Southern China Region by Direct Load Control” by Luo *et al.* presents a new direct load control model for scheduling air conditioner loads (ACLs) in Southern China. The objective of the model is to minimize the mismatch between the total scheduled and the instructed ACLs shedding while minimizing the disturbance of the residents’ thermal comfort. The thermal comfort of the residents is captured through a standardized model and a fuzzy adaptive imperialist competitive algorithm is employed to solve the model effectively.

“Interactive Dispatch Modes and Bidding Strategy of Multiple Virtual Power Plants Based on Demand Response and Game Theory” by Wang *et al.* specifically investigates the operation models of multiple virtual power plants. A game-theoretic model is used to analyze the competition among the market participants. Results including transferred load, compensation capacity, optimal bidding strategy, and profits for each VPP can be obtained.

III. ELECTRIC VEHICLE

“Diffusion Model of PEV Charging Load and its Application on ACE Correction” by Liu *et al.* uses statistical methods to model the charging load of plug-in electric vehicles (PEVs). In comparison with previous work, the proposed model considers the interactions among various charging factors. A control algorithm is designed to take advantage of

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the distributed charging power of PEVs to facilitate the area control error (ACE) correction.

“A Hierarchical Framework for Coordinated Charging of Plug-In Electric Vehicles in China” by Xu *et al.* shows a hierarchical charging scheme at all levels (e.g., transmission systems, distribution systems, and charging stations) and across multiple timescales (i.e., day-ahead and real-time). Case studies on Guangdong Province, China, clearly demonstrate the effectiveness of the proposed framework in reducing system peak demand and charging costs.

“Integrated Energy Exchange Scheduling for Multi-Microgrid System With Electric Vehicles” shows an interesting two-stage integrated energy exchange scheduling strategy to consider electric vehicles as storage devices. With the prices generated from the model, a price-based decentralized scheduling strategy is developed for the microgrid central controller. The simulation results are able to show that this scheduling strategy can reduce the electricity cost and number of switches between charging and discharging efficiently.

IV. MICROGRIDS

“A Novel Frequency and Voltage Control Method for Islanded Microgrid Based on Multienergy Storages” by Tang *et al.* illustrates a new energy storage control method with combined V/f droop control and P/Q droop control. The line parameter uncertainty is considered. The results are obtained from a real microgrid testbed.

“A Highly Integrated and Reconfigurable Microgrid Testbed With Hybrid Distributed Energy Sources” by Wang *et al.* presents a novel microgrid testbed that consists of various distributed generation units and diverse energy storage systems. The deployment of diverse distributed energy sources and highly reconfigurable structure of the microgrid can be of great value for various research purposes.

V. ULTRA-HIGH VOLTAGE TRANSMISSION

“An Optimal Reactive Power Control Strategy for UHVAC/DC Hybrid System in East China Grid” by Miao and Cheng discusses the dramatic voltage increase issue in Eastern China Grid due to the low power demand during holidays. A two-step voltage control strategy is proposed to address the problem. First, the reactive power interchange is minimized between the UHV alternating current and the direct current (dc) grids. Then multi-dc power modulation is executed to further control the reactive power flow between the dc converter stations and the 500 kV ac grid. The case studies show that such a control strategy can effectively mitigate the voltage increases accordingly.

VI. INFORMATION COMMUNICATION TECHNOLOGY

“Cascading Failure Analysis Considering Interaction Between Power Grids and Communication Networks” by Cai *et al.* includes modeling of the communication networks in power grid simulations. The proposed framework is further used in cascading failure analysis. The simulation results illustrate the need for considering the interdependence between the power grid and the related communication infrastructures.

“A UHV Grid Security and Stability Defense System: Considering the Risk of Power System Communication” by Yu *et al.* considers the risk of power system communication failures in assessing the security and stability of a UHV grid. The effect of communication latency on grid stability is assessed quantitatively and qualitatively. Correspondingly, a framework of a UHV grid security and stability defense system considering the risk of the communication system is proposed.

VII. OTHERS

“A Trust Region SQP Method for Coordinated Voltage Control in Smart Distribution Grid” by Sheng *et al.* tries to address the voltage control problem for distribution systems with integration of distributed generators. To solve the formed mixed-integer nonlinear programming problem, a trust region sequential quadratic programming method integrated with the branch and bound approach is used. A number of case studies are carried out to test the proposed method.

“Unit Commitment Model in Smart Grid Environment Considering Carbon Emissions Trading” by Zhang *et al.* presents a comprehensive unit commitment model that considers both demand-side resources such as demand response, electric vehicles, and carbon emission trading. The experimental results further discuss the impact of demand-side response and carbon emission trading on unit commitment solutions.

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