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Guest Editorial

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We are proud to present the first *IET Generation, Transmission & Distribution* Special Issue on Cyber-Physical Power Systems. Cyber-physical power systems, also known as smart grids, provide unprecedented opportunities for improved efficiency, reliability, consumer-centricity and resilience of energy delivery through the integration of information technology within the power grid. Thus, the design mantra for smart grid evolution can be described, in part, as "knowledge is power".

Advanced measurement devices and metering provide unprecedented opportunities for informed decision-making. Information no doubt plays an important role in enhancing power system operation, but questions naturally arise as to what implications and opportunities this more integrated cyber-physical system has for efficient, clean and consumer-centric operation of the power grid. This Special Issue aims to study the design, modeling, simulation and control of modern power systems from a cyber-physical perspective.

Cyber-physical systems represent an emerging class of engineering system that exhibit a tight integration of sensors, communications and decision-making (cyber) within (physical) infrastructure such as a power system. Although the tight integration provides several operational advantages in terms of efficiency, situational awareness and ability for complex decision-making, the integration must be well planned to promote system longevity, robustness, scalability and cyber security. Thus the field of cyber-physical power systems provides a rich environment in order to study novel techniques and approaches to harness data acquisition, communications and control technologies to improve power systems, as we know them today. This Special Issue includes ten papers that provide a cyber-physical approach to power systems research and development studies.

Paper 1 by Yanliang Cui *et al.* investigates the pinning control issue for group consensus of large-scale systems with communication topology changes and other network disturbances. Specifically, the authors propose an event-triggered H-infinity Markovian switching pinning control law for greater efficiency. A node selection principle is firstly designed to choose appropriate control nodes, and a centralised pinning control protocol is proposed to drive LSSs achieving group consensus. For reducing control command updates, an event-trigger is employed to determine whether control signal needs to be adapted. Illustrative examples are provided to demonstrate the proposed analysis results.

Paper 2 by Selvarasu Ranganathan *et al.* presents a multi-objective self-adaptive firefly algorithm that determines the placement of flexible alternating current transmission system (FACTS) devices. The algorithm identifies the appropriate type, best possible locations and optimal parameters of FACTS devices including static var compensators, thyristor controlled series compensators and unified power flow controllers. The objectives aim to improve the power system performance by placement of FACTS devices through minimising real power loss, improving voltage profile and enhancing the voltage stability. Effectiveness of the proposed SAFA is tested on standard IEEE 30 and IEEE 57 bus systems with different objectives.

Paper 3 by Haijian Shao *et al.* focuses on short-term wind speed forecasting for improved stability of the grid. Challenges of forecasting are often due to the complex and stochastic nature of wind speed distribution in meteorological interactions. The authors develop a technique that makes use of wavelet decomposition and the AdaBoost neural network for improved predicting on wind farm plant data. Based on the real data provided by sampling a wind turbine (type-FD77) on a wind farm plant in East China, the experimental evaluation demonstrates that the proposed strategy can significantly enhance model robustness and effectively improve the prediction accuracy.

Paper 4 by Tai-Zhou Bei *et al.* proposes a robust Frequency-Locked Loop algorithm for grid synchronisation of single-phase application under distorted grid conditions. This proposed algorithm relies on a frequency-adjustable Quadrature Signal Generator and a cascaded adaptive complex filter, as well as a robust frequency adaptive controller. Furthermore, the proposed algorithm is able to provide the same attenuation ratio for the orthogonal voltages. By introducing the normalised blocks and the cascaded adaptive complex filter, the proposed algorithm effectively eliminates the influence of voltage fluctuation and the harmonics on the frequency adaptive, and thus has good performance in aspects of rapidity and robustness even in the hostile envelopments caused by frequency variation, amplitude fluctuation and harmonic distortion. The effectiveness of the proposed method is illustrated in a real-time experimental testbed.

Paper 5 by Mingdong Wang *et al.* proposes a grey prediction-based control method for generator speed control to address power system stability issues in the presence of various perturbations. The performance of the proposed control method and that of conventional PID controllers are compared by simulation, which indicates that the proposed control method can effectively improve the dynamic performance of the system. Furthermore, a control system performance index evaluation system is established to quantitatively analyse the performance of the proposed grey prediction-based control method. The effectiveness of the proposed grey prediction control method for turbine speed control system is further illustrated by comparing its performance with the conventional PID controller according to extension assessment.

Paper 6 by Aashish Kumar Bohre *et al.* develops a method for the optimal installation of multi-Distributed Generation (DG) in the deregulated power market environment to manage performance, operation and control of the distribution system in order to achieve technical and economic benefits simultaneously. In the proposed method, several performance evaluation indices such as active and reactive power loss indices, voltage deviation index, reliability index and shift factor indices are used to develop a novel multi-objective function (MOF) used to find optimal sizing and placement of DGs using genetic algorithm and particle swarm. The performance of the proposed method is evaluated in both a 33-bus radial system and a 69-bus radial distribution system. The simulation results illustrate that the proposed method is effective for reducing power losses, improving voltage profile, enhancing reliability of the system, achieving more economic benefits, and increasing available transfer capability (ATC) and load balancing capacity of the system.

Paper 7 by Karthikarajan Senthilnathan *et al.* proposes a novel model of unified power quality conditioner (UPQC) based on current source converters (CSC) topology with left shunt configuration. The proposed model consists of PV source and ultra-capacitor with buck-boost converter that is utilised for maintaining the constant DC-link current. The compensation during sag, swell, unbalance and fault conditions is addressed by the proposed UPQC-CSC model and the control algorithm for UPQC is

based on synchronous reference frame theory and hysteresis loop for the pulse generation. The performance of the proposed model is evaluated by interfacing the Simulation Interface Toolkit (SIT) server of the host computer to LabVIEW and MATLAB/Simulink using a transmission control protocol/Internet protocol communication network. The simulation results illustrate the effectiveness of the proposed system in compensating voltage at sag, swell, unbalance and fault conditions in distribution network.

Paper 8 by Shouxiang Wang *et al.* introduces a new approach to improve the reliability of cyber-physical distribution systems. The new smart feeder remote terminal units (FRTUs) deployment approach is formulated as a mixed-integer non-linear programming problem which minimises the sum of the life cycle cost of the FRTUs and customer interruption cost while satisfying the average service availability index (ASAI). The approach is studied on the benchmark RBTS-BUS4 distribution system and the more complex China Southern Power Grid 62 bus distribution system. Also the performance of the approach is compared with a genetic algorithm approach.

Paper 9 by Michel Bessani *et al.* studies the impact of operators' response time on the reliability of cyber-physical power distribution systems. A new stochastic model of operator response time is developed and utilised along with data for traditional electrical and communication component failure in sequential Monte Carlo simulation (SMCS) studies. The SMCS studies are performed on a three feeder test system to determine the impact of operator response time on several reliability indices, such as failure rate, availability, SAIDI, and SAIF.

The final paper by Mohammand Heidari *et al.* proposes a hybrid medium access control (MAC) protocol, called ALARM, which uses cyber and power system properties to manage time-driven and event-driven distribution system applications. The paper presents a formulation of ALARM that uses an architecture in which event-driven applications can be prioritised based on importance and a single contention-based slot in the super-frame is devoted to applications that require priority access. The proposed protocol is studied on the IEEE 37 bus test feeder for several event-driven scenarios.

Summary/Conclusion

It is clear that the field of cyber-physical power system modelling, design, simulation and control is a growing area in which information technology innovation interacts with operations technology and regulation. This Special Issue is intended to provide an overview of the area through select snapshots of research and development contributions in the field. We hope that this collection inspires continued technological progress, greater debate, and increased interaction between the many forces affecting and affected by the field of smart grid.

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