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Special Issue: Interfacing Techniques for Simulation Tools in Smart Grid

Guest Editorial

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The tools and methods available today for the modelling and simulation of power systems inevitably reflect the established engineering approaches of this field, and there is a broad spectrum of excellent simulation tools for electric transmission and distribution grids that cover the needs of traditional power system engineering. However, in light of the possibilities offered and the challenges posed by modern smart grid solutions, the scope of power systems has to become broader, including multiple (physical) domains and detailed information communication technology (ICT)-based control schemes. Different computer simulation programs were developed to satisfy the individual modelling needs of different studies in power systems and smart grid. A need was, however, quickly recognized to interface various programs to exploit their complementary strengths for model validation and to exchange data between different simulation tools. The objective of this Special Issue is to address the key interfacing techniques for the combination of different simulators in smart grid studies. This issue contains 25 papers on the following topic areas:

Interfacing of electromagnetic transient (EMT) simulation programs with transient stability (TS) and other simulation programs

'*Variable Time Step Application on Hybrid Eletromechanical–Eletromagnetic Simulation*' by Jorge Jardim *et al.* proposes a variable time step solution for hybrid simulation of power system transient stability program (TSP) and electromagnetic transients program (EMTP). The corresponding interface communication protocol is implemented to demonstrate the effectiveness of the solution.

'*Optimum Design of Hybrid HVDC Circuit Breakers Using a Parallel Genetic Algorithm and a MATLAB-EMTP Environment*' by Javier A. Corea-Araujo *et al.* uses a multicore environment for the optimum selection of hybrid high-voltage DC (HVDC) circuit breaker parameters to obtain a transient response of the hybrid design with voltages, currents and fault clearance times within specified limits.

'*Real-Time Electromagnetic Transient and Transient Stability Co-Simulation Based on Hybrid Line Modelling*' by Philippe Le-Huy *et al.* presents a new approach to co-simulation based on an electromagnetic transient and transient stability (TS) hybrid line model for real-time (RT) hardware-in-the-loop applications. In the presented co-simulation scheme, the detailed and external systems are linked through a simple hybrid line model that accounts for wave propagation in both electromagnetic and TS simulation paradigms.

'*Development of a Hybrid Simulator by Interfacing Dynamic Phasors with Electromagnetic Transient Simulation*' by Kumara Mudunkotuwa *et al.* proposes an interfacing method based on a generic transmission line to interface an electromagnetic transient (EMT) simulator with a dynamic phasor (DP) simulation program. The hybrid DP–EMT simulator offers flexibility in deciding the harmonic contents to be preserved in the DP domain and reduction in computing time of large networks compared with EMT simulation.

'*Interfacing an EMT-Type Modular Multilevel Converter HVDC Model in Transient Stability Simulation*' by Xuekun Meng *et al.* proposes a hybrid electromechanical and EMT) simulation algorithm interfacing the EMT-type modular multilevel converter (MMC) HVDC model into transient stability simulation. The proposed hybrid simulation algorithm offers high fidelity simulation results for the fast transient phenomenon of the MMC HVDC using the EMT program (EMTP).

Interfacing issues in hardware-in-the-loop simulation

'*Combined Control and Power Hardware-in-the-Loop Simulation for Testing Smart Grid Control Algorithms*' by Marios Maniatopoulos *et al.* presents a step-by-step hardware in-the-loop (HIL) testing method for smart grid control algorithm verification in distribution networks. The combined power component HIL (PHIL) and controller HIL (CHIL) simulation technique is employed to demonstrate an optimal centralised coordinated voltage control (CVC) algorithm through lab tests. The testing results allow the final implementation of the algorithm from laboratory to the actual field to be made with higher certainty.

'*Co-Simulation Platform for Integrated Real-Time Power System Emulation and Wide Area Communication*' by Adeyemi Charles Adewole *et al.* develops a co-simulation platform comprising of a power system hardware-in-the-loop (HIL) simulator interfaced to a communication network to investigate the impact of adverse communication network conditions on a phasor measurement unit (PMU) based wide-area monitoring, protection, and control system. The experiment results show that the co-simulation platform gives a more realistic option for performance testing and analyses of the interaction between the power system and communication network in smart grids.

'*Interfacing Technique and HIL Simulation of Real-Time Co-Simulation Platform for Wind Energy Conversion System*' by Feng Jia *et al.* uses power system real-time digital simulator and GH Bladed simulator to co-simulate doubly-fed induction generator (DFIG) wind energy converge conversion system to show detailed turbine dynamics and generator controller effects. The issues of signal delay and system stability for interfacing two simulators are investigated in this paper.

'*Testing and Validation of Wide-Area Control of STATCOM Using Real-Time Digital Simulator with Hybrid HIL–SIL Configuration*' by Ahmed S. Musleh *et al.* develops a simulation interface by combining software-in-the-loop (SIL) and HIL) for wide-area monitoring and control (WAMC) studies. The design makes the investigated WAMC experimental testbed more realistic and closer to the industrial standard.

'*Real-Time Hardware-in-the-loop Simulation for Islanding Detection Schemes in Hybrid Distributed Generation Systems*' by Qiushi Cui *et al.* implements a distributed generation islanding detection scheme and tests it through HIL simulation of commercial relay.

'*Real-Time Hardware- and Software-in-the-loop Simulation of Decentralised Distribution Network Control Architecture*' by Ville Tuominen *et al.* presents a laboratory test set up developed to evaluate the functionality of a novel decentralised distribution automation architecture. Vital parts of this test set up are physical intelligent electronic devices (IEDs) interfaced with the real-time simulator system as HIL test devices, and substation automation units (SAUs) are interfaces with the test set up as SIL test systems.

'*Design and Implementation 0f Hardware-In-The-Loop Simulation System for Testing Control and Operation of DC Microgrid with Multiple Distributed Generation Units*' by Jianhui Meng *et al.* proposes and tests a HIL integrated framework for testing control and operation of the DC microgrid.

'*A Contribution to Stability Analysis of Power Hardware-In-the-Loop Simulators*' by Olivier Tremblay *et al.* establishes a new basis for understanding the stability of PHIL systems considering their hybrid (analogue/digital) nature. A new method of assessing the stability of a PHIL system based on discrete-time impedance frequency responses is thus presented.

'*Interfacing Solutions for Power Hardware-in-the-Loop Simulations of Distribution Feeders for Testing Monitoring and Control Applications*' by Niels Blaauwbroek *et al.* designs a power hardware-in-the-loop (PHIL) interface that allows integration of a physical low-voltage feeder within a larger real-time simulated distribution network. A data acquisition and processing system is presented that acquires all the true system states of both the physical feeder and the real-time simulated network.

Interfacing issues in real-time digital simulators

'*Synchronisation Mechanism and Interfaces Design of Multi-FPGA-Based Real-Time Simulator for Microgrids*' by Peng Li *et al.* investigates and proposes solutions for the interfacing issues including system topology determination, time-step synchronisation mechanism and precise communication for multi-field programmable gate array (FPGA) based real-time simulator. A modified microgrid benchmark including photovoltaics and a battery is simulated to validate the designed simulator interfaces.

Co-simulation of transmission-distribution-communication models

'*Co-Simulation of Distributed Control System Based on JADE for Smart Distribution Networks with Distributed Generations*' by Yilong Duan *et al.* introduces the Java agent development framework (JADE) platform from the field of intelligent control, uses it to connect the power simulation software with the communication simulation software, and implements the seamless integration of co-simulation and distributed control system.

'*Integration of Open Source Tools for Studying Large-Scale Distribution Networks*' by Gustavo Valverde *et al.* integrates the open source simulation tools OpenDSS and Quantum GIS (QGIS) to enable the usage of geographical information systems (GIS) for distribution network simulations on an open source platform. The performance of the simulation tool is demonstrated on a real circuit in Costa Rica with more than 10,000 customers.

'*Technique to Interconnect and Control Co-simulation Systems*' by Stephen Broderick *et al.* introduces the Run Time Scheduler (RunTS) technique to interconnect Improved Network Simulator (INSim) and OpenDSS for smart grid electric vehicle simulations.

'*Open-Source Python-OpenDSS Interface for Hybrid Simulation of PV Impact Studies*' by Ali Hariri *et al.* develops an open-source Python-OpenDSS simulation tool suitable for performing impact study of photovoltaic integration in distribution systems.

'*Multi-Location Virtual Smart Grid Laboratory with Testbed for Analysis of Secure Communication and Remote Co-simulation: Concept and Application to Integration of Berlin, Stockholm, Helsinki*' by Christian Wiezorek *et al.* introduces the development of the Virtual Smart Grid Lab (VSGL) to seamlessly connect geographically distributed laboratories with distinct competences. A novel communication platform is setup to facilitate the co-simulation environment.

'*Multifunctional Cyber-Physical System Testbed Based on a Source-Grid Combined Scheduling Control Simulation System*' by Haibo Zhang *et al.* establishes a cyber-physical testbed to integrate industry supervisory control and data acquisition with a source-grid co-simulation system. The testbed employs a multi-time scale interface to meet different data exchange rates and virtual remote terminal units to separate real-time digital simulation results.

'*An Open-source Framework for Power System Transmission and Distribution Dynamics Co-simulation*' by Renke Huang *et al.* develops an open-source co-simulation framework 'framework for network co-simulation' (FNCS) which is a middleware interface and framework that manages the interaction and synchronisation of the transmission and distribution simulators. The paper also introduces a decoupled simulation approach that links existing transmission and distribution dynamic simulators through FNCS.

Coupled simulation of infrastructures

'*Graph-Based Computational Framework for Simulation and Optimisation of Coupled Infrastructure Networks*' by *Jordan Jalving et al.* presents a graph-based computational framework that facilitates the construction, instantiation, and analysis of large-scale optimisation and simulation applications of coupled infrastructure networks. The framework integrates the optimisation modelling package PLASMO and the simulation package DMNetwork (built around PETSc).

Transient stability-constrained optimal power flow

'*Solution Techniques for Transient Stability-Constrained Optimal Power Flow – Part I and Part II*' contributed by IEEE Power and Energy Society (PES) Task Force on Interfacing Techniques for Simulation Tools, reviewd solution techniques for the emerging transient stability-constrained optimal power flow (TSF-OPF) problem. Three different classes of solution techniques: dynamic optimisation-based, single machine infinite bus equivalent (SIME) method, and computational intelligence, are discussed in details.

Summary

Much attention has been focused recently on the interfacing issues for smart grid simulation tools. This Special Issue includes some state-of-the-art research papers to identify the emerging research paradigms in this area. In addition to the interfacing issues existing in power system EMT-TS and HIL simulations, the interface design and implementation among power system simulator, communication simulator, intelligent control simulator, and other infrastructure simulators such as natural gas simulator are also well addressed in the special issue. We hope the Special Issue can arouse more interest towards improving smart grid simulation in our community.

Xiaoyu Wang is an Associate Professor of the Department of Electronics at Carleton University, Ottawa, Canada. He serves as a Board Member of the IEEE Canada Conference Editorial Board from 2016 to 2018. He is also the chair of the IEEE Power and Energy Society (PES) Task Force on Interfacing Techniques for Simulation Tools. He is a recipient of the Ontario Early Researcher Award in 2017.

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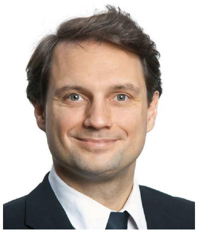
Antonello Monti received his M.Sc degree (summa cum laude) and his PhD in Electrical Engineering from Politecnico di Milano, Italy in 1989 and 1994 respectively. He started his career in Ansaldo Industria and then moved in 1995 to Politecnico di Milano as Assistant Professor. In 2000 he joined the Department of Electrical Engineering of the University of South Carolina (USA) as Associate and then Full Professor. Since 2008 he is the director of the Institute for Automation of Complex Power System within the E.ON Energy Research Center at RWTH Aachen University. Dr. Monti is author or co-author of more than 300 peer-reviewed papers published in international journals and in the proceedings of international conferences. He is a Senior Member of IEEE, Associate Editor of the *IEEE System Journal* and Associate Editor of *IEEE Electrification Magazine*. Dr. Monti is the recipient of the 2017 IEEE Innovation in Societal Infrastructure Award.



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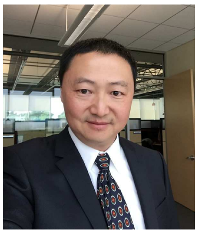

Yi Zhang received Ph.D. degree from Shanghai Jiao Tong University in 1998 and joined RTDS Technologies Inc. in 2000. Currently is the manager of simulation and model development. He has over 20 years of experience in electromagnetic transients analysis and real time simulation. Dr. Zhang also serves as an adjunct professor at the University of Manitoba, and as an editor of *IEEE Transactions on Power Delivery*.

Dr. Jun Wen has more than 10 years of industry experiences in power system analysis, grid application development and integration, and power electronics product design and development. Currently, she is a Senior Manager in Grid Modernization Planning and Technology at Southern California Edison, where her responsibilities include special assessment and research projects for power system planning, operations, engineering, and renewable integration. She also manages SCE's Power System Lab which has one of the largest RTDS set up in the world.

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