RTDS Technologies

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engineer power

RTDS Applications and Technology Conference

May 16-19, 2017
Winnipeg, Canada

Event Guide

WELCOME

Welcome to the 2017 RTDS Applications and Technology Conference (ATC)! This groundbreaking event will provide a forum for users of the RTDS Simulator to share their experience. Attendees will hear about many exciting new applications of the Simulator, participate in practical sessions demonstrating various capabilities of the technology, and make connections with other users.

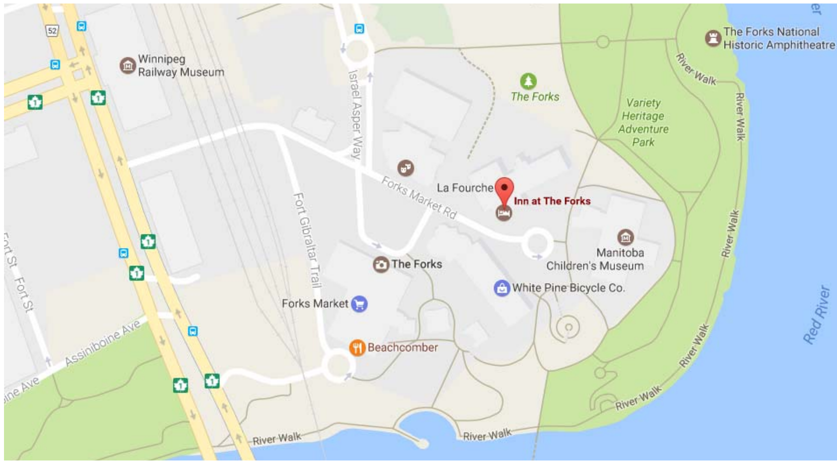
The 2017 RTDS ATC comes at a very exciting time—shortly after the release of NovaCor: the newest generation of simulation hardware for the RTDS Simulator.

The event is located in Winnipeg, Manitoba, Canada—a worldwide hub for power systems research, and the home and birthplace of the RTDS Simulator. The Conference will take place at Inn at the Forks, a world-class event venue at the historic site where Winnipeg's two rivers meet. It will feature a tour of the RTDS Technologies headquarters as well as several technical demonstrations on brand new NovaCor hardware.

On behalf of the team at RTDS Technologies and Nayak Corporation, we hope this event helps to improve your use of the RTDS Simulator!

VENUE

Inn at the Forks
2nd Floor Ballroom
75 Forks Market Road, Winnipeg, Manitoba



PARKING AND TRANSPORT

Parking is free for delegates in either the Inn at the Forks hotel parking lots or the Forks Parkade.

Be sure to register your license plate at the hotel front desk.

Transportation has been arranged to bring delegates to the RTDS Technologies facility tour from the venue and will return delegates to the Inn at the Forks hotel after the networking dinner is over (~9:00 PM). Cars can be left at the Forks until after the networking dinner. If you would rather drive yourself, parking has been arranged on Innovation Drive for the facility tour and in the Investors Group Field parking lot for the networking dinner.

WIFI

Password: RTDSATC17

PROGRAM

Tuesday, May 16, 2017

8:00 AM - 9:00 AM	Registration and Breakfast
9:00 AM – 9:30 AM	Welcome Address
9:30 AM – 10:00 AM	**Introduction to NovaCor: A Revolution in Real Time** Paul Forsyth • RTDS Technologies Inc.
10:00 AM – 10:30 AM	Coffee Break
10:30 AM – 11:00 AM	**Introduction to NovaCor: Hardware Overview** Tyler Seredynski • RTDS Technologies Inc.
11:00 AM – 11:30 AM	**Introduction to NovaCor: Software Overview** Shaun Warkentin • RTDS Technologies Inc.
11:30 AM – 12:00 PM	Open Discussion
12:00 PM – 1:00 PM	Lunch Break
1:00 PM – 1:30 PM	**Hardware-In-Loop Testing of a Completely Digital IEC 61850-Based Teleprotection Scheme Using the RTDS Simulator** Charles Adewole • Cape Peninsula University of Technology

PROGRAM

Tuesday, May 16, 2017

1:30 PM – 2:00 PM	**High Speed Digital Distance Relaying Scheme using FPGA and IEC 61850** Shane Jin • University of Saskatchewan
2:00 PM – 2:30 PM	**Advanced Power Hardware in the Loop Test Setup for Evaluation of Utility Applications of Emerging Power Electronic Apparatus** Ahmadreza Momeni • Quanta Technology Kahveh Atef • San Diego Gas and Electric
2:30 PM – 3:00 PM	Coffee Break
3:00 PM – 3:30 PM	**RTDS-FPGA-Based Real-Time Simulation Platform for Modern Power Systems** Ramin Mirzahosseini • University of Toronto
3:30 PM – 4:00 PM	**IEEE Working Group P2004** Mischa Steurer • Florida State University
6:00 PM – 7:45 PM	**Hermetic Code Tour of the Manitoba Legislative Building**

For more information on our workshops and extracurricular activities, turn to the back of the booklet!

PROGRAM

Wednesday, May 17, 2017

8:30 AM - 9:00 AM	Registration and Continental Breakfast
9:00 AM – 9:30 AM	**General-Purpose Data Recording** Mark Stanovich • Florida State University
9:30 AM – 10:00 AM	**Using the RTDS to Test Integrated Systems** Dan Kell • TransGrid Solutions
10:00 AM – 10:30 AM	Coffee Break
10:30 AM – 12:00 PM	**Grid Modernization Workshop: Modeling Distribution Networks with Renewables and Distributed Energy Resources** Melanie Dyck • RTDS Technologies Inc. Onyi Nzimako • RTDS Technologies Inc.
12:00 PM – 1:00 PM	Lunch Break
1:00 PM – 1:30 PM	**Performing Hybrid Simulation Studies Using TSAT-RTDS Interface (TRI)** Pouya Zadehkhost • Powertech Labs
1:30 PM – 2:00 PM	**Proven Strategies and Key Concepts to Develop Successful Microgrid Control Systems** Niraj Shah • SEL Engineering Services Inc.
2:00 PM – 2:30 PM	**Evaluation of Solar Inverter using Power-hardware -in-the-loop Simulation (PHILS)** Carl Ho • University of Manitoba

PROGRAM

Wednesday, May 17, 2017

2:30 PM – 3:00 PM	**Open Protocol Communication with the RTDS Simulator** Eric Xu • RTDS Technologies Inc.
3:00 PM – 3:30 PM	Depart for tour of RTDS Technologies facility
3:30 PM – 5:00 PM	**Tour of RTDS Technologies facility**
5:00 PM – 9:00 PM	**Conference Networking Dinner** Investors Group Field *Business casual dress code recommended.* *NO high heels on the football field!*

Thursday, May 18, 2017

8:30 AM – 9:00 AM	Registration and Continental Breakfast
9:00 AM – 9:30 AM	**Validation of Transmission Line Protection System Using MPLS Ethernet Communications Using an RTDS Power System Model** Michael Bryson • Schweitzer Engineering Laboratories
9:30AM - 10:00 AM	**RTDS Application Experiences at Southern California Edison An SVC Controller Modeling in RTDS** Jun Wen, Ling Xu • Southern California Edison

PROGRAM

Thursday, May 18, 2017

10:00 AM – 10:30 AM	Coffee Break
10:00 AM – 10:30 AM	**Manitoba Hydro Simulation Centre Development for Nelson River HVDC Systems** Kelvin Kent, Zhibo Wang • Manitoba Hydro
11:00 AM – 11:30 AM	**Model and System Validation through a 15 MVA Hardware-in-the-Loop and Grid Emulator at Clemson University** Johan Enslin • Clemson University
11:30 AM – 12:00 PM	**Hardware-in-the-Loop Testing of a Sub Harmonic Protection Relay to Mitigate SSR Conditions Associated with Power System Components** Krish Narendra, Nuwan Perera • ERL Phase Power Technologies
12:00 PM – 1:00 PM	Lunch Break
1:00 PM – 3:00 PM	**Small Time-Step Modelling Workshop** Christian Jegues • RTDS Technologies Inc.
3:00 PM – 3:30 PM	Coffee Break
3:30 PM – 4:00 PM	**Testing Time Domain Incremental and Traveling-Wave Protection Elements and Schemes** Yajian Tong • Schweitzer Engineering Laboratories

PROGRAM

Thursday, May 18, 2017

4:00 PM – 4:30 PM	**Evaluation of the Accuracy of Real-time Simulator Models of VSC Converters Determined from Frequency Scanning** Aniruddha Gole • University of Manitoba
4:30 PM – 5:00 PM	**Control and Protection System Tests for a Fixed Capacitor in Australia** Farid Mosallat • Manitoba HVDC Research Centre

Friday, May 19, 2017

8:30 AM – 9:00 AM	Continental Breakfast
9:00 AM – 10:30 AM	**Protection and Automation Workshop** Dean Ouellette, Eric Xu • RTDS Technologies Inc.
10:30 AM – 11:00 AM	Coffee Break
11:00 AM – 11:30 AM	**Synchronous Condenser Replica Controller HIL Test Setup – An SCE Apparatus Facility for Training and Operations Support** Stephany Su • Southern California Edison
11:30 AM – 12:00 PM	**Power System Stability Analysis Using Wide Area Measurement System** Ramakrishna (Rama) Gokaraju • University of Saskatchewan
12:00 PM – 1:00 PM	Lunch Break

PRESENTATIONS

Introduction to NovaCor - A Revolution in Real Time

Paul Forsyth • RTDS Technologies Inc.

RTDS Technologies has just released their 6th generation of custom built simulator hardware – NovaCor™. The release of NovaCor provides a very exciting step in the evolution of the RTDS® Simulator. The presentation will provide some background leading up to the new development and will move on to describe the general structure and performance of the new platform. Concrete examples will be given to illustrate the enhanced capabilities of NovaCor compared to the previous generation hardware.

Paul Forsyth received his B.Sc. degree in Electrical Engineering from the University of Manitoba, Canada in 1988. He then worked for several years in the area of reactive power compensation and HVDC at ABB Power Systems in Switzerland. He also worked for Haefely-Trench in both Germany and Switzerland before returning to Canada in 1995. Since then, he has been employed by RTDS Technologies where he holds the title of VP, Marketing & Sales.

Introduction to NovaCor - Hardware Overview

Tyler Seredynski • RTDS Technologies Inc.

A look behind the scenes of RTDS Technologies' newest simulator hardware. Building on a long history of innovation we proudly present to you our first multi-core system. What's the POWER8? How did it help make this transition possible? What new challenges had to be overcome to bring about this new revolution in RTDS hardware?

Tyler Seredynski graduated with a B.Sc. in Electrical and Computer Engineering and has been with RTDS for 4 years. He has contributed to many areas of the company including model development, embedded development, customer support, and commissioning. The last two-and-a-half years however have been dedicated to the development of NovaCor as the POWER8's firmware developer. When not working Tyler is a travel and culture-seeking circus-star, or so he likes to think.

Introduction to NovaCor - Software Overview

Shaun Warkentin • RTDS Technologies Inc.

RSCAD 5 has been updated with support for our new NovaCor Hardware. Learn how Draft and the compile process has been optimized, and find out details about other supporting changes in RSCAD.

After earning his Bachelor of Computer Science (Honours) degree from the University of Manitoba in 2004, **Shaun Warkentin** joined RTDS Technologies Inc. as a Software Developer. Shaun has been primarily involved with the development of new features for the RSCAD software suite as well as its maintenance.

Hardware-In-The-Loop Testing of a Completely Digital IEC 61850-Based Teleprotection Scheme Using the RTDS Simulator

Charles Adewole • Cape Peninsula University of Technology

This presentation details the design, implementation, and testing of a teleprotection (communication-assisted) 'proof-of-concept' testbed using IEC 61850 Sampled Values and GOOSE messages. A POTT scheme was implemented using the SV outputs from IEC 61850 Merging Units and RTDS GTNET cards (with the SV and GOOSE protocols) as the inputs to IEDs configured for distance protection. The required exchange of the SS-SS permissive trip signal between the IEDs was published using GOOSE messages. Performance, interoperability, and interchangeability tests of the SV component of the testbed was carried out using HIL simulations with the RTDS for various fault types, fault locations, and fault resistances. Similarly, a comparison of the results obtained for permissive trip signal publishing using GOOSE messages with that obtained using proprietary protocols was carried out.

Adeyemi Charles Adewole obtained his B.Eng. (Hons.) in Electrical and Electronic Engineering from the Federal University of Technology, Akure in 2006, and his Master's and Doctorate Degrees in Electrical Engineering from the Cape Peninsula University of Technology in 2012 and 2016 respectively. His research interests are in substation automation, real-time digital simulations, wide area monitoring, protection, and control. Dr. Adewole is a Member of the IET, the IEEE, and the South African Institute of Electrical Engineers.

PRESENTATIONS

High Speed Digital Distance Relaying Scheme using FPGA and IEC 61850

Shane Jin • RTDS Technologies Inc.

Full-cycle Fourier and cosine phasor filtering systems are typical implementations of numerical distance relays with a response time of close to one cycle. Fast sub-cycle numerical distance elements are useful, especially for EHV/UHV transmission systems (400 kV and above). Fast sub-cycle numerical relaying methods such as half-cycle Fourier method, phaselets, least squares error, traveling wave, and wavelet based methods have been proposed in the literature. In this paper, firstly improvements to the phaselet-based distance relaying method are proposed by taking the magnitude errors and the phase angle errors into account. An adaptive Mho characteristic based on the phasor estimation errors is used to achieve a fast and secure trip decision. The quality of the estimated values in time domain is analyzed mathematically using a transient monitoring index. Secondly, the scheme is implemented on a field programmable gate arrays (FPGAs) board, which provides fast computation speeds due to its powerful parallel processing units. The proposed relay is tested using hardware-in-the-loop simulations and a real time digital simulator (RTDS). Thirdly, the Ethernet-based protocols (IEC 61850 Sampled Value and Generic Object Oriented Substation Events protocols) are implemented on the FPGA and used to verify the performance of the proposed relay in digital substation environments.

Shane Jin received his B.Eng. (Hons.) degree in electrical engineering from the Beijing Institute of Technology (BIT), Beijing, China, in 2009 and the M.Sc. degree in electrical engineering from the University of Saskatchewan, Saskatoon, SK, Canada, in 2012. He is currently pursuing the Ph.D. degree in the Department of Electrical and Computer Engineering, University of Saskatchewan. His current research interests are high speed digital relaying, power system automation, real time simulation of power systems, and parallel and distributed computing.

Advanced Power Hardware in the Loop Test Setup for Evaluation of Utility Applications of Emerging Power Electronic Apparatus

Ahmadreza Momeni • Quanta Technology
Kahveh Atef • San Diego Gas and Electric

This presentation will outline the use of RTDS for testing and evaluation of integrating emerging power electronic apparatus in SDG&E's distribution system. Several power hardware in loop (PHIL) test setups are implemented at SDG&E's Integrated Test Facility (ITF) to enable performance testing and verification of grid-tie and stand-alone PV inverters, bi-directional power converters of energy storage systems, and also specially designed power electronic based power conditioning units for distribution systems such as: solid-state voltage regulators, active filters and power balancing apparatus. The ITFs key objective is to ensure integrating and utilization aspects of new technologies are fully tested and verified prior to field deployment of the devices. The facility also supports on-going research and development projects, as well as inter-departmental projects of various business units associated with introducing new control, protection and communication technologies. RTDS provides the ability to integrate new power electronic devices (PEDs) and intelligent electronic devices (IEDs) utilized as part of advanced control and communication schemes into the simulation environment representing an entire SDG&E selected circuit and/or a distribution substation or even a control region. The PEDs and IEDs, therefore get tested, in an environment that best represents the field conditions to simulate and determine any impact of power system events on the device or scheme performance. Two PHIL test setups that are presently available and being utilized at ITF will be described, namely:

A Flexible Smart Inverter Test bed, that is used to test various aspects of interconnecting multiple PV and Energy Storage inverters in parallel or in an area, to verify controlling capabilities and communication features of smart inverter functionalities in distribution systems.

A Distribution Secondary Circuit Test bed, that was used to verify technologies and aggregation schemes proposed for managing power quality and voltage/reactive power levels on secondary circuits, downstream of service transformers.

Both test beds mainly used RTDS for representing distribution circuits and to simulate transient events (e.g. faults or sudden load/generation changes, or other contingencies). High power amplifiers are used to connect PEDs and IEDs, or to represent service transformers for connecting commercial and residential loads to the simulated model.

PRESENTATIONS

Ahmad Momeni, Principal Consultant in Protection and Controls, has extensive experience in applied R&D efforts for control and power system design and analysis. Within the recent years, his work has been concentrated on advanced distribution automation systems, microgrid controls, and emerging power technologies. He has experience in testing and integration engineering, data analysis and modeling for power engineering applications, real-time system simulation and testing, and programming with C/C++, VB.Net, C#, and PLCs. Prior to joining Quanta Technology, he has been a post-doctoral research fellow at University of Toronto and University of New Brunswick. He is the recipient of the NSERC Industrial R&D Fellowship, Fonds de Recherche du Quebec Award, and Power-Shift Atlantic Research Fellowship.

Kahveh Atef is a licensed professional engineer and received his bachelors in Electrical Engineering from California State Polytechnic University Pomona in 2009. He currently leads a team in charge of implementing and maintaining advanced energy storage systems while also managing a research and development lab known as the Integrated Test Facility.

RTDS-FPGA-Based Real-Time Simulation Platform for Modern Power Systems

Ramin Mirzahosseini • University of Toronto

The ongoing proliferation of distributed energy resources and power electronic converters at distribution level of modern power systems causes control and protection issues and therefore conducting real-time simulation studies is an indispensable and essential step to verify performance of control devices and protection relays prior to installation. Conducting these studies for modern distribution systems faces computational challenges due to (i) large number of nodes, components and therefore size of differential algebraic equations, (ii) short transmission lines, (iii) large number of repetitive-switching devices, i.e., power electronic converters and (iv) small real-time simulation time-step requirement due to high switching frequency of these converters.

FPGA features parallel and reconfigurable computing that can be utilized to design an application-specific hardware to overcome the computational challenges associated with real-time simulation of modern distribution systems. However, the existing power system component models are not suitable for FPGA-based real-time simulation due to inherent differences between CPU- and FPGA-based computing. We develop (i) new component models, tailored to exploit parallel processing capabilities of FPGAs, and (ii) an FPGA-based real-time simulator suitable for modern distribution systems. This simulator is connected to the industry standard real-time simulator, i.e., RTDS, to form a versatile real-time simulation platform in which the distribution system is simulated in the FPGA-based simulator and the rest of the power system is simulated in the RTDS. This platform is applicable to real-time simulation studies of microgrids, virtual power plants, wind farms, solar farms and also all-electric ship and aircraft power systems. In this presentation the FPGA-based power system component models and the FPGA-based real-time simulator are introduced and their capabilities are explained.

Ramin Mirzahosseini received the B.Sc. and M.Sc. degrees in electrical engineering from Sharif University of Technology, Tehran, Iran, in 2009 and 2011, respectively. He is currently working toward the Ph.D. degree at the University of Toronto, Toronto, ON, Canada. His research interests include high performance FPGA-based computing for real-time simulation of the power system EMTs, and power electronics.

IEEE Working Group P2004

Mischa Steurer will provide a short introduction to the newly established IEEE Working Group (WG) P2004 he chairs. In the next couple of years, this WG will develop a "Recommended Practice for Hardware-in-the-Loop (HIL) Simulation Based Testing of Electric Power Apparatus and Controls". The goal of this WG is to provide established practices for the use of the method of Hardware-in-the-Loop (HIL) Simulation based Testing to be generically applicable in synergy (in conjunction) with any specific testing standard (if applicable). The presentation will provide information about the structure of the WG and upcoming meetings.

General-Purpose Data Recording

Mark Stanovich • Florida State University

This presentation discusses our experiences and techniques for data recording during simulations and HIL experiments at FSU-CAPS that leverage various RTDS components including the GTNET, GTFPGA, and RSCAD runtime environment.

Recording data generated during simulations and HIL experiments is critical for understanding and reporting results. The RTDS runtime environment provides facilities for recording data (e.g., Plot in the RSCAD runtime). However, these built-in facilities are not practical for recording large amounts of data and recording data over long time intervals. One issue is the loss of interaction with the Runtime during captures, which prevents the collection of results through sequences of Runtime inputs as a single, continuous sequence of events. Another issue is the inability to vary the sampling rate for different signals and to vary these over the duration of the capture. Additionally, limitations on the number of points that can be captured may restrict how data are collected. Other difficulties stem from the need to capture relatively infrequent events, such as faults. While means exist for internally triggered plots, this can be impractical for capturing infrequent events in some cases, due to the need to disable Runtime interaction while waiting for the event to trigger the plot capture. Thus, a more flexible means for capturing data with the RTDS has considerable utility.

A complimentary tool for capturing data leveraging the GTNET and GTFPGA cards is presented. This tool provides flexibility to accommodate the needs described above, as well as a way to capture high-resolution data continuously for long periods of time—down to the time step—while not encumbering the RTDS Runtime. Recording a large number of signals at a high sampling rate (e.g. at every time-step) throughout an entire simulation or HIL experiment can help reduce the probability of missing data for important events but also results substantial amounts of data. Fortunately, commodity computer hardware including persistent storage devices are very economical and enable much larger amounts of data to be recorded. However, recording data in real-time comes with inherent timing constraints, which results in design challenges to ensure such timing constraints are met and data is not lost. These challenges are especially prevalent when leveraging commodity hardware and software that is not specifically designed to meet timing constraints. With the help of the Linux kernel and the PREEMPT_RT modifications, these challenges are significantly reduced and have made developing a general-purpose data recording capability practically achievable.

PRESENTATIONS

Mark Stanovich received his PhD degree in computer science from the Florida State University in 2015. He is currently a postdoctoral researcher in the Power Systems group at the Center for Advanced Power System, Florida State University. His current research focuses on evaluation of controls through automated hardware-in-the-loop methods.

Using the RTDS to Test Integrated Systems

Dan Kell • Trans Grid Solutions

Today's power systems are becoming more integrated and complex. Furthermore, there is a heightened awareness of security concerns and the impact of outages. RTDS is being used as a tool to perform real-time testing of control systems prior to being put into operation for the first time or prior to implementing logic changes on existing systems.

As part of this testing, we are seeing clients require more detailed models of their ac systems, which move far beyond a simple ac equivalent network. This presentation will discuss the role of ac system modeling and its implementation on the RTDS and the overall importance of the RTDS in the full O&M lifecycle of your system.

Dan Kell is a professional electrical engineer with a wide range of engineering experiences including utility and international consultancy activities, with a focus on HVDC and FACTS.

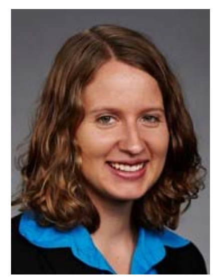
PRESENTATIONS

Grid Modernization Workshop: Modeling Distribution Networks with Renewables and Distributed Energy Resources

Melanie Dyck, Onyi Nzimako • RTDS Technologies Inc.

The operation of distribution networks with wide-scale, actively managed, Distributed Energy Resources (DERs) has generated a demand for more sophisticated study tools, development aids, and test facilities to analyze technical operational issues related to the bi-directional power flow on distribution networks. This workshop discusses the challenges of modeling distribution networks, characterized by tightly coupled transmission lines, unbalanced phase loads, and power electronic interfaced renewables and distributed generating sources, on a real time simulator. The topics that will be discussed in the Grid Modernization Workshop include:

- The RTDS Distribution Mode, developed to permit the modeling of large distribution feeders in real time.
- Modeling microgrids with renewables and distributed generation.
- Control and Power Hardware in the loop applications for distribution and microgrid networks integrated with renewables and distributed energy resources.



Melanie Dyck joined RTDS Technologies in 2014 after receiving her Bachelor of Science degree in Electrical Engineering from the University of Manitoba, Canada. She currently holds the title of Simulation Specialist, Distribution Networks and has been working on the development of distribution mode for the RTDS Simulator. Her current interests are distributed energy resources and distribution systems.

Onyi Nzimako joined RTDS Technologies in 2010 after receiving her B.Sc. degree in Electrical Engineering from the University of Manitoba, Canada. She currently holds the title of Senior Simulation Engineer, Renewable Applications and works on developing power and control system models. Her current interests are in the area of modeling renewable energy systems and Hardware in the Loop applications.

PRESENTATIONS

Performing Hybrid Simulation Studies Using TSAT-RTDS

Pouya Zadehkhost • Powertech Labs

Electro-magnetic Transient (EMT) simulation packages have been traditionally used to study a detailed representation of a small portion of system while transient stability tools employ simplified, phasor-domain representation of bulk power systems in planning and operation studies. As the number of power electronic devices such as HVDC and FACTS systems grows, there is a strong need to close the gap between EMT and transient stability studies to accurately represent complex behaviours of such devices and their interactions with the system in large-scale power systems dynamic studies. To this end, hybrid simulation is a promising approach wherein a small part of system is represented by a detailed, three-phase model while phasor-domain modeling is used for rest of system. By combining advantages of EMT and transient stability studies, hybrid simulation facilitates analyzing system-wide dynamic behaviors using high level of details which is not available in typical EMT or transient stability studies. In this regard, Powertech Labs in collaboration with Korea Electric Power Research Institute (KEPRI) and Yonsei University has developed TSAT-RTDS Interface (TRI), which is a tool for performing hybrid simulation studies using TSAT and RTDS. In TRI, user divides system into a number of islands connected through boundary branches. Each island is modeled and simulated in either TSAT or RTDS. At each transient stability integration time-step, TRI exchanges boundary injections between simulation tools. Flexible structure of TRI makes it possible to model any part of system in RTDS or TSAT, or user may use multiple TSAT instances or RTDS racks to simulate large systems. As a result, impact of low-frequency oscillations on RTDS model (which is typically ignored) may be investigated in a hybrid simulation environment.

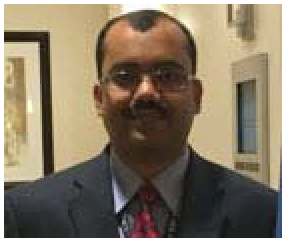
Pouya (Sajjad) Zadehkhost received his B.Sc., M.Sc., and Ph.D. degree in electrical engineering from K.N.T. University, Sharif University, and University of British Columbia, respectively. He is currently working at Software Technologies group at Powertech Labs. His research interests include power systems dynamic studies, system planning and operation.

PRESENTATIONS

Proven Strategies and Key Concepts to Develop Successful Microgrid Control Systems

Niraj Shah • SEL Engineering Services Inc.

By using a combination of MIT case study and important concepts this presentation will cover essential steps for successful microgrid control. A microgrid needs to provide resilient and reliable power. To do so, the complete microgrid control system—including devices, configuration, communications, and cybersecurity—must be stable, proven, and thoroughly tested (using hardware-in-the-loop testing, if possible) before it is brought online. The concepts discussed in this presentation will help you reduce microgrid risks and avoid possible pitfalls.



Niraj Shah is a branch manager for the SEL engineering services Inc (Subsidiary of Schweitzer Engineering Laboratories, Inc. (SEL)). He received his bachelor of engineering degree in instrumentation & control from Gujarat University (India). He is a member of the International Society of Automation (ISA) & IEEE. He joined SEL in 2007. He has more than 19 years of experience in process control, substation automation, electrical power distribution automation (DA), Power Management System (PMS), High Speed Load shedding systems, applications engineering, configuration, and onsite commissioning. His expertise includes PMSs, SCADA, HMIs, energy monitoring systems (EMSs), DA control and simulation, programmable logic controller (PLC) and distributed control system (DCS) programming.

Evaluation of Solar Inverter using Power-hardware-in-the-loop Simulation (PHILS)

Carl Ho • University of Manitoba

Solar energy is classified as an environment friendly renewable resource and it is potentially to mitigate the energy crisis. Photovoltaics (PV) is an effective solar energy conversion technique which can directly turns solar energy into electricity using semiconducting materials without having impact on the environment during the conversion. In a modern PV inverter, there is consist of semiconductors, magnetic devices, controllers, other passive and mechanical devices such as relays. Characteristics of the active and passive components are non-linear, and some non-linear controls such as sliding mode control and boundary control have been used in PV inverters. Moreover, the power source, PV panel, behaves non-linear as well, it makes challenges for a Real Time Digital Simulation (RTDS) system to simulate impacts of a PV inverter or a PV farm for a power grid due to the nonlinearities.

Power-hardware-in-the-loop simulation (PHILS) system consists of a Power source being interfaced with the Real Time Digital Simulator (RTDS). The loop acts as an interface to exchange power between the system emulated in RSCAD environment with the actual devices. The interface is basically built of amplifiers and analog/digital cards of low power levels (e.g. ±10V). The bidirectional interface amplifier required in the loop acts as a device to sink or source the power flow between software and hardware environment. This "Virtual Reality" approach can link an actual power electronics apparatus, such as PV inverter, to a public grid network in the RTDS. Therefore, PV inverter manufacturers can evaluate products with different grid conditions and situations to ensure the reliability. Public utility companies can benchmark and evaluable PV inverters using PHILS before any actual installation for a solar farm. The presentation will demonstrate a PHILS testbed using the RTDS for evaluating a real single phase PV inverter. Moreover, design and implementation issues, system analysis and experimental results will be discussed.

Dr. Carl Ho received the PhD degree in electronic engineering at the City University of Hong Kong in 2007. His PhD research was focused on dynamic voltage regulation and restoration technology for power quality and energy saving issues. Since 2007, he has been at ABB Switzerland Ltd., Switzerland, for 7 years. In the company, he was appointed as different positions, including principal scientist and research project manager of solar inverter technology developments, and R&D Principal Engineer of UPS product developments. In 2014, he joined University of Manitoba as Assistant Professor and Canada Research Chair in Efficient Utilization of Electric Power. He established the Renewable Energy Interface and Grid Automation (RIGA) Lab at the U of M. He has published more than 60 IEEE academic papers and filed more than 20 patent applications. Most of his invented technologies are used in commercial products. Dr. Ho is currently an IEEE Senior Member and an Associate Editor of the IEEE Transactions on Power Electronics and the IEEE Journal of Emerging and Selected Topics in Power Electronics.

Open Protocol Communication with the RTDS Simulator

Eric Xu • RTDS Technologies Inc.

Various communication protocols are being widely utilized in our current electrical power systems. The protocols currently supported by RTDS are reviewed. A newly developed stand-alone utility that is used for simulating IEC 61850 MMS Server, DNP3 and Modbus Master is discussed.

Eric Xu joined RTDS in 2009 after graduated from University of Manitoba with the Distinguished Award. Since joined, Eric has been involved in technical support, user training and GTNET component models development. Eric is a Registered Professional Engineer in the Province of Manitoba and a member of IEEE. He is also an active member of IEC Technical Committee 57 Working Group 10 which is the section working on the development of the communication standards for substations – functional architecture and general requirements. Eric currently serves as the Lead Simulation and Automation Engineer in the protection and automation group.

Validation of Transmission Line Protection System Using MPLS Ethernet Communications Using an RTDS Power System Model

Michael Bryson • Schweitzer Engineering Laboratories
Tariq Rahmen • San Diego Gas and Electric

San Diego Gas & Electric is evaluating replacing their existing Time Division Multiplexed (TDM) Synchronous Optic NETwork (SONET) communications network used for protective relay communications with a newer Ethernet based system, Multiprotocol Label Switching (MPLS). This evaluation is due to the older TDM SONET communication systems becoming obsolete and difficult to maintain and also Ethernet communication systems are becoming more reliable and deterministic for critical infrastructure data needs such as transmission line protection systems using a communications based protection scheme.

Packet routing in an Ethernet Wide Area Network (WAN) is fundamentally less predictable than the deterministic march of data bits in TDM or serial data transmission. MPLS network latency or time delay variations raise concerns for protective relaying applications. High latency slows tripping; current differential line protection (87L) is particularly sensitive to jitter or variation in latency and to asymmetry or difference in latencies in the two or more directions of protection data exchange. This presentation will describe the technical requirements developed by San Diego Gas & Electric for critical EHV teleprotection applications and discuss TDM SONET versus MPLS Ethernet communications. To validate the design and in preparation for field installation, laboratory testing was performed using an RTDS® system model, MPLS routers, and networks with protective relays. This presentation will also discuss the laboratory testing approach, test results of the MPLS proposed solution, redundancy, and single points of failure in the communications system. The discussion will include the impact on the protection scheme due to channel asymmetry, latency, failover, and channel availability, as well as tools available for monitoring the MPLS communications link for troubleshooting and analysis.

Mike Bryson received his Bachelor of Science in Electrical Engineering (BSEE) from the University of Idaho. Mike is a power system protection engineer with 27 years of experience at Schweitzer Engineering Laboratories (SEL) in Pullman, WA. He has experience in power system protection, protective relay development, modeling, simulation and testing. Mike has used RTDS systems at SEL to develop protection algorithms in SEL relays and to model, simulate and test unique and challenging customer protection and control systems. He is a member of IEEE, author of several technical papers and presentations, a recipient of several patents and a registered PE.

PRESENTATIONS

RTDS Application Experiences at Southern California Edison An SVC Controller Modeling in RTDS

Jun Wen, Ling Xu • Southern California Edison

Southern California Edison (SCE) has one of the largest RTDS setup in the world, and has applied RTDS in many applications, such as Bulk Power System modeling, protective relay testing, FACTS controller testing, battery controller hardware in the loop testing, and solar inverter power hardware in the loop testing. This presentation will discuss in great details of the SVC controller modeling work that was completed last year. Southern California Edison (SCE) owns a +440/-110 Mvar SVC at its Devers 500 kV substation. The SVC is used to support SCE's transmission grid by controlling voltage at its 500 kV bus. SCE observed some power oscillation issues around Devers region and proposed to use SVC to stabilize the grid. Before implementing any Power Oscillation Damping (POD) function in the SVC controller, an accurate SVC controller model has to be developed and tested in RTDS to prove the concept. The ideal approach is to purchase an SVC control replica cubicle and connect it with RTDS. However, this approach requires a significant amount of investment and lacks flexibility during tests. The vendor provided an accurate SVC model in PSCAD when it was commissioned. Instead of purchasing a real controller, SCE decided to model it in RSCAD to replicate the PSCAD control. The biggest challenges are the control blocks in PSCAD are all black boxes. By testing each control block and investigating the logic between each block, an SVC controller is developed in RSCAD and tested. The tests show a good match between RSCAD and PSCAD, which demonstrates the controller developed is a good approximation of the actual device. SCE's grid modernization efforts and how RTDS may be applied to support grid modernization will

Dr. Ling Xu is a Power Systems Engineer and RTDS lab lead in Southern California Edison (SCE). He is responsible for the RTDS modeling, testing and lab management. Before he joined SCE, he was working in GE Grid Solutions (formerly Alstom Grid) for three years. At GE, he was a Power Systems Engineer in the FACTS team, where he was responsible for SVC design, testing, and various studies. Dr. Ling Xu obtained his Ph.D. degree from the University of South Florida in 2013 and Master's degree from the University of Alabama in 2009. His research interests include FACTS, HVDC, and renewable energy integration.

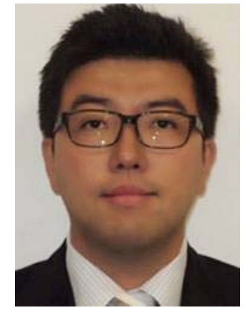
Dr. Jun Wen has more than 10 years of industry experiences in power system analysis, grid application development and integration, and power electronics product design and development. Currently, she is a Senior Manager in Grid Modernization Planning and Technology at Southern California Edison, where her responsibilities include special assessment and research projects for power system planning, operations, engineering, and renewable integration.

Manitoba Hydro Simulation Centre Development for Nelson River HVDC Systems

Kelvin Kent, Zhibo Wang • Manitoba Hydro

The Manitoba Hydro HVDC Transmission system currently consists of two Bipoles (Bipole I and Bipole II) which transfer ~75% of Manitoba Hydro generation from northern Manitoba to southern load center. A third HVDC transmission link (Bipole III) will be placed in service in 2018 and is currently under construction. To facilitate Bipole III commissioning, system integration, and to support ongoing operation, maintenance and further development of HVDC and AC system, Manitoba Hydro decided to establish Manitoba Hydro Simulation Centre (MHSC) with RTDS real-time digital simulators and purchase Exciter control replica used for synchronous condensers, and Bipole III full control replica. Furthermore, Manitoba Hydro is currently developing replica controls for existing Bipole I and Bipole II which are used for operation support, RTS and PSCAD model validation, and Bipole III multi-infeed studies. Through the presentation the following topics will be discussed: development of the Manitoba Hydro Simulation Centre, justification and primary functions of control replicas, and Manitoba Hydro Experience in developing HVDC control replicas with different generation of control hardware and architecture.

K.L. Kent obtained B.Sc. (EE) and M. Eng. degrees from the University of Manitoba in 1986 and 1994 respectively. Since 1986 he has been working at Manitoba Hydro and is presently working in HVDC Engineering. His interests include HVdc systems, power system simulation, and harmonic analysis. He is a registered Professional Engineer in the Province of Manitoba, Canada.



Zhibo Wang obtained B.Sc. (EE) from the University of Manitoba in 2007. Since graduated, he has been working as Electrical Engineer at NewFlyer Industry, Senior Generation Engineer at BC Hydro and Generation and Generation Engineer at Manitoba Hydro. Presently, he is working in the HVDC Engineering at Manitoba Hydro. His interests include HVdc and FACTs systems, Hydro and Wind generation, power system simulation, and real time HIL control testing. He is a registered Professional Engineer in the Province of Manitoba, Canada.

Model and System Validation through a 15 MVA Hardware-in-the-Loop and Grid Emulator at Clemson University

Johan Enslin • Clemson University

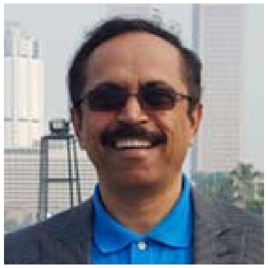
The presentation provides case studies and process of model and system validation using the Clemson University's Duke Energy eGRID real-time emulator in the SCE&G Energy Innovation Center in Charleston SC. With the ongoing penetration of SmartGrid and DER technology on the T&D feeders, including Wind, PV, GridEdge and Energy Storage technologies, the facility is used to validate the performance and operation of these devices at full power levels. The power stages and controls are validated in an integrated approach. The presentation will provide real project case studies and results on several industry and DOE projects.

Dr. Johan H Enslin is the Duke Energy Endowed Chaired Professor in Smart Grid at Clemson University in North Charleston SC and Executive Director for the Energy Systems Program at the Zucker Family Graduate Education Center. He comes as the founding Director for the Energy Production and Infrastructure Center (EPIC) and the Duke Energy Distinguished Chair in Power System at UNC Charlotte. Enslin has combined a 36-year career with leadership in industry and academia, in the US, Europe and South Africa. He served as a senior executive for private business operations and a professor in electrical engineering. Dr. Enslin initiated and led grid modernization and renewable energy integration teams and executed multi-disciplinary power system projects. Over the course of his career Johan worked for more than 90 US, European, Asian and African power utilities, governments and industries. He authored and co-authored more than 300 technical journal and conference papers for IEEE and other organizations, and has written several chapters in scientific books. Johan is a life-long leader in the IEEE and CIGRÉ working groups and committees. He holds more than 25 provisional and final patents. He received the 2014 Charlotte Business Journal Energy Leadership Award. He is a registered Professional Engineer in South Africa, Fellow of the SAIEE and Fellow of the IEEE.

Hardware-in-the-Loop Testing of a Sub Harmonic Protection Relay to Mitigate SSR Conditions Associated with Power System Components

Krish Narendra, Nuwan Perera • ERLPhase Power Technologies

Worldwide expeditious installation of renewable and distributed energy resources (DERs) is occurring. To achieve faster execution of these projects, most of the existing transmission systems are being upgraded with the addition of various compensating devices such as SVCs, series capacitors, shunt compensators to support wind farms, large PV systems, and other DERs. In this context, the operation of the power grid due to the additional energy resources is posing new challenges in the field of power system protection, monitoring, and control. One of the major issues faced by the utilities with regards to interconnection of DERs into the grid is sub harmonic resonance (SSR) conditions generated due to the interaction of various elements in the power system. In recent literature, several SSR events have been reported in the existing installations with wind turbine and series compensated systems. Lack of knowledge and availability of suitable protection methodology have led some of these events to damage the hardware components. This presentation describes the use of an industrial sub harmonic protection relay to mitigate SSR conditions associated with the interaction of various power system components such as windfarms, series compensated lines, etc. Results will be presented based on the investigations carried out using hardware-in-the-loop testing of the relay.



Dr. Narendra has over 25 years of experience in power system protection, monitoring, control and analysis. He is responsible for innovative design, implementation, quality and commercialization of protective relays and disturbance monitoring recorders using advanced digital signal processing technologies on embedded systems, and in Windows development environments.

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Dr. Narendra has been a valued IEEE member for over 15 years. He is actively participating in the IEEE PRSC working groups, and is a member of the PRTT of NASPI. He is a member of the CIGRE C4-B5 working group and NERC SMS committee. He has published over 35 papers in various IEEE/IEC journals and conferences, and is an innovator of several patents. His areas of interests include power systems disturbance analysis, protection, micro grid protection, sub-harmonics in power systems, SSR (sub synchronous resonance), ferroresonance, HVDC controls, neural networks, artificial intelligence, fuzzy logic, phasor technology (PMUs), and the application of IEC 61850 protocols for protection and control.

Nuwan Perera received the B.Sc. Engineering degree from University of Moratuwa, Sri Lanka, in 2003 and the M.Sc. and Ph.D. degrees from University of Manitoba in 2007 and 2012 respectively. He is responsible for designing protection & control solutions, leading power system studies, providing the technical specifications for development projects and providing the technical support for the application & sales teams. He is a senior IEEE Member involved with IEEE PSRC Working Groups. His research interests are in power system protection, distributed generation and embedded systems. He is a registered Professional Engineer in the Province of Manitoba.

Small Timestep Modelling Workshop

Christian Jegues • RTDS Technologies Inc.

This workshop reviews the motivation, fundamental concepts and challenges behind real time simulation using a small time-step on the RTDS. A brief overview of control schemes for three-phase voltage-sourced converters is also provided. This workshop includes an exercise in which a two level VSC is simulated and controlled using Sinusoidal PWM.

Christian Jegues joined RTDS Technologies in 2014 after receiving his Bachelor of Science degree in Electrical Engineering from the University of Manitoba, Canada. He currently holds the title of Simulation Specialist, and works in the customer support group at RTDS Technologies.

PRESENTATIONS

Testing Time Domain Incremental and Traveling-Wave Protection Elements and Schemes

Yajian Tong • Schweitzer Engineering Laboratories

When testing distance and directional elements, we need to verify the operation of these elements with sources that generate signals that are realistic and have meaningful transition from pre-fault and fault conditions. To achieve this objective, we use real-time digital simulators that apply voltages and currents to the relays in real time or in playback mode with transitions according to the fault point on wave and power system parameters. The main advantage of this approach is that these simulators can be programmed to emulate thousands of fault scenarios in a short time. SEL-T400L, Time Domain Line Protection, uses incremental and traveling wave quantities to provide ultra-high speed protection. Incremental quantity elements are in the hundreds of hertz domain, and therefore we used RTDS to verify the performance of these elements. Traveling Wave (TW) based protection elements operate in the hundreds of kilohertz domain. The challenge when testing TW-based protection schemes is to apply realistic secondary voltage and current signals to the relay terminals that accurately represent the TWs produced during power system disturbances. RTDS models the power system at time intervals on the order of tens of microseconds and power amplifiers reproduce test signals with bandwidths of tens of kilohertz. These simulators are adequate to test phasor-based and time domain incremental quantity-based protection elements, but they are not suitable for testing TW protection schemes. Because TWs are sharp changes in currents and voltages, the test signals must have transition times on the order of a few microseconds. To achieve this level of performance, we used a TW source that generates TW signals with microsecond rise times and nanosecond timing accuracy. This source is capable of testing one or two relays, has the ability to generate multiple TWs for emulating faults at different fault locations, and is suitable for end-to-end testing when connected to GPS satellite clocks. This presentation includes details about time domain protection and the experiences and challenges that we had while developing and testing this state of the art protection technology.

Yajian Tong holds a master's degree in electrical and computer engineering, and is currently an Associate Research Engineer with Schweitzer Engineering Laboratories, Inc., Pullman, WA.

PRESENTATIONS

Evaluation of the Accuracy of Real-time Simulator Models of VSC Converters Determined from Frequency Scanning

Aniruddha Gole • University of Manitoba

The traditional method for modelling the semiconductor switch in a real-time digital simulator is the 'R' approach, where the switch is modeled as a variable resistor, taking on a small value for conducting and a large value for the non-conducting state. This value change requires a time-costly admittance matrix re-formulation, which, particularly when simulating Voltage Source Converters (VSC) operating at high switching frequencies, makes it difficult to run in real-time. Thereby, an alternative as 'LC' approach is proposed [1], which models the switch as a small inductor () for the 'ON' state and a small capacitor in series with a resistance () for the 'OFF' state. For a given time step , the values are chosen such that ; which means that the admittance matrix is unchanged when the switch operates, making the computation extremely fast and amenable to real time implementation. Only the history terms need to be updated. However, with the 'LC' approach, there is a concern that replacing the 'ON' and 'OFF' resistances with inductances and capacitances, may produce unexpected error in converter frequency response.

This paper further investigates this issue by conducting impedance frequency scans on an electromagnetic transients (EMT) simulation model of a system containing a VSC converter modeled with the 'R' and 'LC' approaches in rtds, and comparing it with the analytical impedance scan obtained from a small signal model of the same system [2]. To conduct the frequency scan, a harmonic current containing several equi-magnitude frequency components is injected at the node at which the impedance of the system is to be measured [3]. A discrete Fourier Transform of the measured resultant voltage is carried out to yield the voltage components at the various injected frequencies. The impedance scan is then obtained by dividing the harmonic components of voltage by those of the current. By the comparison between different impedance results, it is shown, that with a proper choice of parameters and a sufficiently small time-step, the 'LC' approach leads to a highly accurate, yet high speed simulation suitable for real-time simulation.

Prof. Ani Gole is Distinguished Professor and NSERC Industrial Chair in Power Systems Simulation at the Department of Electrical and Computer Engineering, at the University of Manitoba. He has over 35 years' experience in the development of modelling tools for power networks incorporating power-electronic equipment such as HVDC and FACTS converters. He is one of the original developers of the widely used PSCAD/ EMTDC simulation program. For his contributions to the modelling of Flexible Ac Transmission System (FACTS) devices, Dr. Gole was awarded the IEEE PES Nari Hingorani FACTS Award in 2007. Dr. Gole is a Fellow of the IEEE, a Fellow of the Canadian Academy of Engineering and is a Registered Professional Engineer in the Province of Manitoba, Canada.

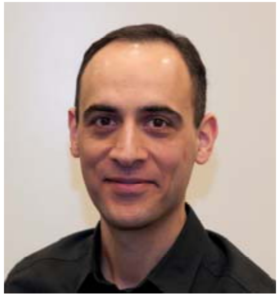
Control and Protection System Tests for a Fixed Capacitor in Australia

Farid Mosallat • Manitoba HVDC Research Centre

In 2015-2016, a fixed series capacitor (FSC) installation in Australia became ready for commissioning. This was part of a plan to increase the transmission capacity of a 275kV interconnector line between two provinces in Australia. Design and planning studies had identified concerns such as possible sub-synchronous oscillations in one of the interconnected areas as a result of this modification in the network. In order to prevent such issues from occurring or to clear them by appropriate actions, additional protective relays were added to the line protection scheme and necessary strategies were included in the FSC control system.

As part of the controller factory acceptance test (FAT) stage, real-time hardware-in-the-loop (HIL) simulations were carried out using RTDS. That allowed for verifying the performance of the FSC controller. The settings selected for the line protective relays were also examined in that manner through simulating several fault scenarios.

In this presentation, the procedure followed in those tests will be outlined and the aspects that needed to be considered in the HIL simulations will be explained.



Farid Mosallat, Ph.D., P.Eng., joined the Manitoba HVDC Research Centre in 2005, where he is currently the Engineering Research & Development Manager. Farid completed the Ph.D. degree at the University of Manitoba in 2012. He received the B.Sc. degree from Tabriz University (Tabriz, Iran) and the M.Sc. degree from Sharif University of Technology (Tehran, Iran) in 1996 and 1998, respectively. Farid is specialized in applications of power electronics in power systems, including HVDC transmission (voltage-sourced converters and LCC-based), FACTS devices, and wind power generation using Type-3 and Type-4 wind turbine -generators. He also has experience in AC system performance studies, including contingency analysis, transient stability simulations, etc. Prior to joining the Centre, Farid worked as an Automation and Drives Engineer in the manufacturing sector, and was involved in the design, installation and commissioning of electrical distribution and control systems for material handling equipment such as shipyard cranes, and stacker/ reclaimer systems.

Protection and Automation Workshop

Dean Ouellette, Eric Xu • RTDS Technologies Inc.

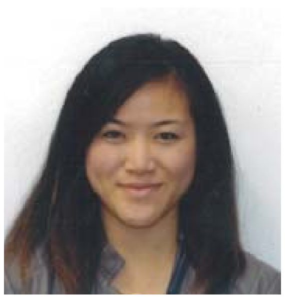
A hands-on tutorial is arranged to introduce the enhancement done to the GTNETx2-GSE for supporting the IEC 61850 Edition 2. Various new features will be exercised by using the RTDS simulator and the GTNETx2 card. The newly developed stand-alone utility, the Protection and Automation Suite will also be used to simulate IEC 61850 MMS Servers.

Dean Ouellette graduated from Red River Community College in Manitoba, Canada with a diploma in Electrical Engineering Technology in 1986. His employment experience includes Manitoba Hydro, British Columbia Hydro, Schweitzer Engineering Labs, NxtPhase T&D and RTDS Technologies Inc. Dean is currently the Manager for Protection and Automation products at RTDS and is an active participant in IEEE/PSRC working groups and standards development.

Synchronous Condenser Replica Controller HIL Test Setup – An SCE Apparatus Facility for Training and Operations Support

Stephany Su • Southern California Edison

Southern California Edison is installing 3×80 MVA Synchronous Condensers at Santiago substation. As part of this project, SCE procured a complete replica of the controls including the excitation system and the HMI. The protection & control schemes and the exciter will be connected to RTDS model of the synchronous condenser and the SCE network in a Hardware-in-loop (HIL) setup. The set up will be used for testing the controller settings before and during the commissioning. The future objectives of the facility include ongoing operational support and operator training. The presentation will discuss the details of the project and the



Stephany Su is an apparatus engineer who works at Southern California Edison on various projects that improve the ever changing electric grid. After spending time at NASA's Jet Propulsion Laboratory as a radio frequency engineer, Stephany ignited interest in working in a laboratory environment. From working on projects that prove the existence of gravitational waves using GPS and lasers, to working on Flexible AC Transmission Projects on the power grid, Stephany has been exposed to a spectrum of engineering practices. Southern California brings an opportunity for renewable energy, where Stephany studied a plethora amount of renewable generation interconnection studies. Sponsoring projects from start to finish, Stephany really enjoys being a part of the project growth, challenges, and ultimately commission.

Power System Stability Analysis Using Wide Area Measurement System

Ramakrishna (Rama) Gokaraju • University of Saskatchewan

The most common practice to prevent power system instabilities is with local generator out-of-step protection. Unfortunately, out-of-step protection operation of generators may not be fast enough, and an instability may take down nearby generators and the rest of the power system by the time the local generator relay operates. Hence, it is important to assess power system stability over transmission lines as soon as the transient instability is detected instead of relying on purely

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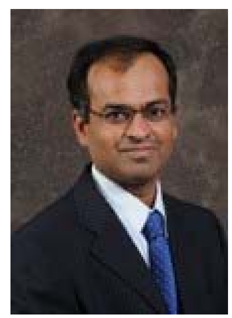
localized out-of-step protection in generators. This presentation will discuss a synchrophasor-based out-of-step prediction methodology at the transmission line level using wide area measurements from optimal phasor measurement unit (PMU) locations in an interconnected system. The proposed scheme was used to predict the first swing out-of-step condition in a Western Systems Coordinating Council (WSCC) 9 bus power system. A coherency analysis was first performed in this multi-machine system to determine the two coherent groups of generators. The coherent generator groups were then represented with a two-machine equivalent system, and the algorithm then applied to the reduced equivalent system. Electromagnetic transient simulations with an RTDS were used to test the accuracy of the proposed algorithm with respect to predicting transient instability conditions. The studies show that the proposed method is computationally efficient and accurate for larger power systems. The proposed method was also implemented with actual PMU measurements from a GE N60 relay. The testing was carried out with an interface between the relay and the RTDS. The WSCC 9 bus system was modeled in the RTDS and the analog time signals from the optimal location in the network communicated to the relay. The synchrophasor data from the PMUs in the N60 were used to back-calculate the rotor angles of the generators in the system. Swing curves for the coherent group of generators were found from time series prediction. The test results with the actual PMUs match quite well with the results obtained from virtual PMU-based testing in the RTDS.



Ramakrishna (Rama) Gokaraju graduated with Distinction in Electrical and Electronics Engineering in April 1992 from the Regional Engineering College (National Institute of Technology), Trichy, India. He obtained M.Sc. and Ph.D. degrees in Electrical & Computer Engineering from the University of Calgary, Calgary, Canada in June 1996 and May 2000, respectively. During 1999 to 2002, he was a Research Scientist with the Alberta Research Council and a Staff Software Engineer with IBM Toronto Lab. He joined the Department of Electrical & Computer Engineering at the University of Saskatchewan as an Assistant Professor in July 2003, received tenure and became Associate Professor in July 2009, and became a professor in July 2015. Dr. Gokaraju's current areas of research are in high speed digital relaying, wide-area-based power systems protection and control, renewable energy integrated systems, and real-time simulation approaches. Dr. Gokaraju is a registered professional engineer in the Province of Saskatchewan.

WORKSHOPS

Three workshops will be led by RTDS Technologies simulation specialists throughout the conference.

Wednesday 10:30 AM – 12:00 PM	**Grid Modernization Workshop: Modeling Distribution Networks with Renewables and Distributed Energy Resources** Melanie Dyck • RTDS Technologies Inc. Onyi Nzimako • RTDS Technologies Inc.
Thursday 1:00 PM – 3:00 PM	**Small Time-Step Modelling Workshop** Christian Jegues • RTDS Technologies Inc.
Friday 9:00 AM – 10:30 AM	**Protection and Automation Workshop** Dean Ouellette • RTDS Technologies Inc.

Delegates who wish to take part in the workshops should download the latest version of RSCAD.

RSCAD can be downloaded at **support.rtds.com/clientarea** by using your own company login information or the following credentials:

Login I.D.: RTDSATC17
Password: SimulatingIsFun

ACTIVITIES

Tuesday 6:00 PM – 7:45 PM	**Hermetic Code Tour** Manitoba Legislative Building
Wednesday 3:30 PM – 5:00 PM	**Tour of RTDS Technologies facility**
Wednesday 5:00 PM – 9:00 PM	**Conference Networking Dinner** Investors Group Field *Business casual dress code recommended.* *NO high heels on the football field!*

Hermetic Code Tour - Manitoba Legislative Building

450 Broadway

Have you ever wondered why the Manitoba Legislative Building has sphinxes on the roof? Do you know the true identity of the Golden Boy? Join Dr. Frank Albo, academic inspiration behind The Hermetic Code, for an unforgettable tour of magic, mystery and architectural wonder. Meet inside the Manitoba Legislative Building and begin to unlock mysteries of Canada's most unique architectural landmark.

Dr. Albo will take you along step-by-step to reveal a trail of occult clues concealed in the building's architecture including: hidden hieroglyphic inscriptions, numerological codes, and Freemasonic symbols so intelligently masked they have escaped historians and visitors for nearly a

Delegates may walk to the Legislative Building (450 Broadway) from Inn at the Forks. Please be there at 5:45 PM sharp. A walking group will meet in the lobby of Inn at the Forks at 5:15.

ACTIVITIES

Tour of RTDS Technologies Facility

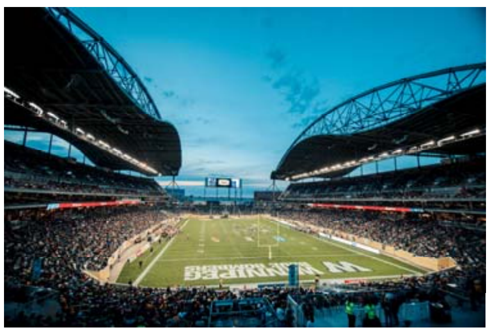
150 Innovation Drive

Join us for an exciting tour of the worldwide RTDS Technologies headquarters! This is a great opportunity to learn more about the company, see where the RTDS Simulator is assembled and shipped all over the world, and meet our staff.

The RTDS facility tour will feature a special on-site technical demonstration from a simulation specialist!

Conference Networking Dinner

Investors Group Field



Join us for an exciting evening event at Investors Group Field—home of the Winnipeg Blue Bombers football team! Delegates can enjoy on-field time with Coach Paul LaPolice and Defensive Back Maurice Leggett. Dinner will be in the Pinnacle Club on site.

Business casual dress is recommended—no high heels on the field! T-Shirts will be provided if delegates would like to change once on site.

Parking is free in the University parking lot. Transportation has been arranged to bring delegates to the RTDS facility tour and networking dinner. Delegates will return to Inn at the Forks after the networking dinner.