Program for *2019 IEEE Electrical Power and Energy Conference (EPEC)*

Time	Cartier I	Cartier II	International I	International II	Symposia Theatre	Session
Wednesday, October 16						
07:30-17:30						
08:30-10:30					OP&P1: *Opening Session & Plenary Session 1*	
10:30-11:00	MB: *Morning Break*					
11:00-12:30					PL2: *Plenary Session 2*	R1: *Registration Day 1*
12:30-14:00	L1: *Lunch Day 1*					
14:00-15:30		TS2: *Power Electronic Devices and Converters*	HQ2a: *HQ Session 2 (Private Session)*	TS1: *Energy Storage Technologies*	HQ1a: *Hydro Quebec session: Cyber Security and Confidentiality*	
15:30-16:00	AB: *Afternoon Break*					
16:00-17:30	W1: *Workshop 1*	TS4: *Cyber Security and Data Driven Methods in Power Systems*	HQ2b: *HQ Session 2 (Private Session)*	TS3: *Power System Modelling*	HQ1b: *Hydro Quebec session: Cyber Security and Confidentiality*	
17:30-19:30						WR: *Welcome Reception*
Thursday, October 17						
07:30-17:30						
08:30-10:30					OP&PS3: *Opening Session & Plenary Session 3*	
10:30-11:00	MB: *Morning Break*					
11:00-12:30					PL4: *Plenary Session 4*	R2: *Registration Day 2*
12:30-14:00	L2: *Lunch Day 2*					
14:00-15:30	IS1: *Insdustry Session 1*	TS6: *Power Electronics in Power Systems*	HQ4a: *HQ Session 4 - Private Session*	TS5: *Power System Planning*	HQ3a: *HQ Session 3 - AI and Data Science for the Power Grid*	
15:30-16:00	AB: *Afternoon Break*					
16:00-17:30	W2: *Workshop 2*	TS8: *Power System Economics II*	HQ4b: *HQ Session 4 - Private Session*	TS7: *Power System Economics*	HQ3b: *HQ Session 3 - Private Session*	
Friday, October 18						
08:30-11:00						
09:00-10:30	IS2: *Industry Session 2*	TS10: *Machine Learning and Artificial Intelligence Applications*		TS9: *Distribution Systems and DERs*		R3: *Registration Day 3*
10:30-11:00	MB: *Morning Break*					
11:00-12:30	WIE: *WIE Panel*	TS11: *Microgrids*		TS12: *Electric Mobility*		

Wednesday, October 16

Wednesday, October 16 7:30 - 17:30

R1: Registration Day 1

Wednesday, October 16 8:30 - 10:30

OP&P1: Opening Session & Plenary Session 1

8:30-9:15 Welcome and opening remarks

9:15-9:55: KEYNOTE: **Cybersecurity Roadmap at ENEL** by Yuri Rassega, Chief Information Security Officer, ENEL

9:55-10:30: KEYNOTE: **The threat we may not know - Critical infrastructure OT security** by Ronald Keen, Department of Homeland Security, US

Wednesday, October 16 10:30 - 11:00

MB: Morning Break

Wednesday, October 16 11:00 - 12:30

PL2: Plenary Session 2

11:00-11:45: **Impact économique de la transformation du secteur énergétique et les ajustements du cadre réglementaire/Economic Impact of the transformation of the Energy Sector and of corresponding regulatory framework** by Pierre-Olivier Pineau, HEC, Montréal

11:45-12:30: **Micro-réseau Lac-Megantic; Contrôle efficace du bâtiment par la gestion innovante de l'énergie / Lac-Megantic microgrid and efficient building command for innovative energy management** by Patrick Martineau, Daniel Couture, Alain Sayegh, Hydro-Québec

Wednesday, October 16 12:30 - 14:00

L1: Lunch Day 1

Wednesday, October 16 14:00 - 15:30

HQ1a: Hydro Quebec session: Cyber Security and Confidentiality

14:00-14:30: ***Cybersecurity and Privacy***, **Annie Dulude** (Hydro-Quebec) and **Sebastien Gambs** (Univeriste du Quebec a Montreal)

14:30-15:00: ***Cybersecurity in the distribution grid: a cosimulation perspective***, **Paul Berthier** (RHEA Inc.)

15:00-15:30: ***DRAGOS security***, **Daniel Soucy-Michaud** (DRAGOS)

(Some presentations will occur in French, simultaneous translation provided)

HQ2a: HQ Session 2 (Private Session)

Custormer Focused Applications

TS1: Energy Storage Technologies

14:00 ***Recursive Least Square Estimation Approach to Real-Time Parameter Identification in Li-ion Batteries***

Sheikh Arif Raihan and Balakumar Balasingam (University of Windsor, Canada)

In this paper, we consider the problem of equivalent circuit model (ECM) parameter identification in Li-ion batteries. Accurate estimation of the ECM parameters is critical for the safety, efficiency and reliability of the battery system. Existing approaches to solve this problem depend on information and parameters, such as, battery capacity, state-of-charge (SOC) and open circuit voltage (OCV) characterization parameters. Such reliance on other parameters makes the ECM identification less accurate. In this paper, we present a real-time approach to ECM identification. The proposed approach relies only on the measured voltage across the battery terminal and current through the battery. Also, the proposed approach is unaffected by the amount of hysteresis in the battery. Further, robustness in parameter identification is achieved through the inclusion of the measurement noise covariance matrix. The proposed algorithm was tested on simulated as well as real world battery data and found to be accurate within 1% uncertainty.

14:18 ***A Scaling Approach for Improved Open Circuit Voltage Modeling in Li-ion Batteries***

Mostafa Shaban Mohamed Ahmed and Balakumar Balasingam (University of Windsor, Canada)

Open circuit voltage (OCV) vs. state of charge (SOC) characterization is an important step in the battery management system (BMS) design. The OCV-SOC relationship is very non-linear that is often represented using a polynomial that has log and inverse terms that are not defined around SOC equal to zero or one. The traditional response to this problem was only at the software level, i.e., whenever the SOC approaches zero, a smaller value is replaced and whenever SOC approaches one, it was replaced with a value that is slightly less than one. In this paper, we present a formal scaling approach to represent open circuit voltage OCV-SOC characterization in Li-ion batteries. We show that, through formal modeling and optimization, the traditional approach to OCV-SOC modeling can be significantly improved. The proposed approach is tested on data collected from Li-ion battery over various temperatures for OCV-SOC characterization and the results are presented.

14:36 ***Performance Analysis of Coulomb Counting Approach for State of Charge Estimation***

Kiarash Movassagh, Sheikh Arif Raihan and Balakumar Balasingam (University of Windsor, Canada)

In this paper, we consider the problem of the state of charge estimation for rechargeable batteries. Coulomb counting is one of the traditional approaches to SOC estimation and it is considered one of the reliable approaches to SOC estimation as long as the battery capacity and initial SOC is known. In this paper, we formally derive and quantify the SOC estimation error due to the following four types of error sources: (i) current measurement error; (ii) error due to the approximation of current integration with respect to time; (iii) uncertainty in the knowledge of battery capacity; and the (iv) error (drift) in timing oscillator. We analyze the individual effect of these four types of errors on the estimated SOC. Further, We show numerical simulations to illustrate the effect of these errors on the estimated SOC.

14:54 ***Determination of Cycling Frequency with the Highest Impact on Lifetime of Super Capacitor***

Mahdi Soltani (Vrije Universiteit Brussels (VUB), Belgium); Joris Jaguemont (Vrije Universiteit Brussel, unknown); Joeri Van Mierlo and Peter Van den Bossche (Vrije Universiteit Brussel, Belgium)

Super Capacitors (SCs) are appealing in industrial application for energy recovery (to replace mechanical energy storage like flywheels or springs). In some applications, the energy flowing back from the load is sinusoidal ripple currents. The lifetime performance of SCs in these applications is questionable and the frequency level which has the most impact on the lifetime need to be determined. As the threshold frequency differs for different SC cells, the determination of frequency that accelerates the aging process is a key factor for appropriate cell selection for these applications. In this study a method for threshold frequency determination is defined and then experiments are performed to study the impact of this frequency on the super capacitor aging. The result reveals that a low frequency current ripple for the selected SC cell creates aging mechanisms.

15:12 ***Nonlinear Modeling of All-Solid-State Battery Technology Based on Hammerstein-Wiener Systems***

Yousef Firouz and Joeri Van Mierlo (Vrije Universiteit Brussel, Belgium); Peter Van den Bossche (Erasmushogeschool Brussel & Vrije Universiteit Brussel, Belgium); Yuki Katoh (Toyota Motor Europe NV/SA, Belgium)

All-solid-state battery technology are one of the promising competitors of current liquid electrolyte-based lithium ion batteries due to high energy density characteristic. However, due to low ionic conductivity of solid materials, all-solid-state batteries become hot topic for research. In this paper we have developed a methodology based on block-oriented nonlinear system that is able to detect, quantize and model the battery voltage distortion. Two solid-state coin cell with different ionic conductivity at cathode interface are manufactured and excited with multisine signal. The Best Linear Approximation (BLA) method has been used to separate linear frequency response function (FRF) from nonlinear distortion which have been modeled with structural nonlinear modeling technique.

TS2: Power Electronic Devices and Converters

TS2.1 14:00 ***Study on Conductivity Degradation of High-k VDMOS Caused by Ferroelectricity***

Jingjie Lin, Junji Cheng and Xingbi Chen (University of Electronic Science and Technology of China, P.R. China)

The remanent polarization effect is considered for the simulation of Hk-VDMOS (high-k vertical double-diffused metal-oxide-semiconductor). When the Hk-VDMOS is converted from off-state to on-state, a part of N-pillar near the Hk-pillar will be depleted due to the remanent polarization of the Hk insulator. Then, according to the simulation results for 300 V devices, the electron current channel will be severely narrowed and the conduction voltage drop will be increased by 30.4%. Hence, the ferroelectric effect significantly impairs the conductive ability of the Hk-VDMOS.

TS2.2 14:18 ***Measuring of Dynamic On-State Resistance of GaN-HEMTs in Half-Bridge Application Under Hard and Soft Switching Operation***

Benedikt Kohlhepp, Daniel Kübrich and Thomas Dürbaum (Friedrich-Alexander University Erlangen-Nürnberg (FAU), Germany); Marvin Tannhäuser and Andreas Hoffmann (Siemens AG, Germany)

GaN-HEMTs convince with very good properties and therefore attract a large amount of attention within the power electronics community. However, due to trapping effects, some devices show dynamic on-state resistance during switching operation. As for switch mode power supply designers the internal device structure is not visible, measuring the on-state resistance under the intended operating conditions is the only method to get this information. To characterize the dynamic on-state resistance, this paper uses a novel clamping circuitry to measure the dynamic resistance accurately. Implementing a high resolution digitizer card guarantees accurate results. This measurement setup allows for measuring the on-state resistance under hard and soft switching conditions with the parameters of the targeted application. In inverter applications, each switch operates under both hard and soft switching, thus the transition between these two operating modes is investigated in detail as well.

TS2.3 14:36 ***Model Predictive Control on Grid Connected Fifteen-Level Packed U-Cell (PUC15) Inverter***

Saeed Arazm (Power Electronic, Canada); Innocent Kamwa (Hydro-Québec/IREQ, Canada); Kamal Al-Haddad (Ecole de technologie supérieure, Canada)

This paper presents the finite control-set model predictive control (FCS-MPC) on grid connected packed U-cell 15-L inverter (PUC15) to control the injected current to the grid and voltages at the flying capacitors to balance the voltage. PUC15 is consists of 8 switches in which 4 switches are operated in complimentary way. The size of flying capacitors by this robust control method is considerably reduced due to its optimized switching pulses. The number of voltage levels generated in PUC15 with 8 switches are the highest level compared with the other converters that lead to reduce the total harmonic distortion (THD). Moreover, through application of MPC on PUC15 to connect the photovoltaic cells to the point of common coupling (PCC) active and reactive power are controlled as well as amplitude of injected current. Matlab Simulink has been used to validate the FCS-MPC method on PUC15 and the results show the proper dynamic performance of controller through abrupt altering the conditions such as DC sources and power factor.

TS2.4 14:54 ***Adaptive ANN Based Single PI Controller for Nine-Level PUC Inverter***

Mohamamd Babaie and Mohamamd Sharifzadeh (École de Technologie Supérieure, Canada); Kamal Al-Haddad (Ecole de technologie supérieure, Canada)

This paper presents an Adaptive Proportional Integral (API) control strategy to regulate the capacitors voltage and load current of Nine-Level Packed U-Cell (PUC9) inverter in stand-alone mode of operation. PI is a linear control method which has been widely used in power converter topologies due to simple implementation. However, applying PI method to the power converters as nonlinear systems causes several problems like steady state error, difficulties of control factors tuning and instability in presence of uncertainties and disturbances. In the proposed API method, a single PI controller is used to adjust both capacitors voltage and load current amplitudes. A Multilayer Perceptron (MLP) Artificial Neural Network (ANN) is also trained by Artificial Bee Colony (ABC) algorithm to adapt the capacitors voltage references so that eliminates steady state error of PI and stabilizes the PUC9 voltages and current in presence parameters variations. Simulation results obtained by MATLAB/Simulink confirm high performance of the API.

Wednesday, October 16 15:30 - 16:00

AB: Afternoon Break

Wednesday, October 16 16:00 - 17:30

HQ1b: Hydro Quebec session: Cyber Security and Confidentiality

16:00-16:30: ***The Future of Securing IEDs using the IEC 62351-7 Standard for Monitoring***, **Alessandro Di Pinto** (Nozomi Networks)

16:30-17:00: ***Quantum Cryptography***, **Claude Crepeau** (McGill Univeristy)

17:00-17:30: ***Research in the Cybersecurity Industrial Research Chair***, **Mourad Debbabi** (Concordia University)

(Some presentations will occur in French, simultaneous translation provided)

HQ2b: HQ Session 2 (Private Session)

Custormer Focused Applications

TS3: Power System Modelling

TS3.1 16:00 ***Estimating Power Flow Directions Using Off-Line PF Analysis and Artificial Neural Networks***

Ali R. Al-Roomi (Dalhousie University & College of Engineering, Canada); Mohamed E. El-Hawary (Dalhousie University, Canada)

Real electric power systems are dynamic where many output variables could change at any time by influences of many input variables. Such these output variables are the directions of active and reactive power flows on each branch. These directions could be identified by analyzing their online fundamental signals received from some field-mounted instrument devices. If any of these devices fails to operate or if there is any interruption in the communications and protocols of any hierarchical level of their energy management system (EMS), then some of power flow directions will not be identified. This study tries to estimate these dynamic directions without depending on their instrument devices. The technique proposed in this paper is processed through two stages: 1) creating a huge off-line power flow (PF) solutions database by randomly changing the settings of power system components, and then 2) training artificial neural networks (ANNs) to have the ability to predict the power flow directions based on the settings of generators and loads, and the status of branches. The results shows that the novel technique proposed in this paper is highly significant, and thus it could open the door wide for many other applications.

TS3.2 16:18 ***Novel Highly Precise Power Loss Estimators That Directly Solve Power Balance Equality Constraints***

Ali R. Al-Roomi (Dalhousie University & College of Engineering, Canada); Mohamed E. El-Hawary (Dalhousie University, Canada)

Realistic network's branches (including transformers and lines) are not lossless mediums. These power losses happen due to: 1) dissipation as a heat by series resistance, 2) absorption as a leakage flux by series reactance, and 3) dissipation/absorption by magnetizing conductance and susceptance. Thus, knowing these essential measurements are very important issues in many power system applications and studies, such as: power system operation, protection, reliability, and electricity markets. The existing power loss estimators have many weaknesses, such as: complicated methods, many static assumptions, and slack unit dependents. If the existing configuration of any network is randomly changed from its base state, then these estimators may produce significant and unacceptable errors. More than that, some applications require to solve a set of power balance equality constraints, such as: optimal power flow, economic load dispatch, and unit commitment. This paper introduces a totally different technique that has the ability to solve all the preceding problems steadily and directly. In this approach, a large number of randomly configured off-line power flow solutions are used to create a huge database to train artificial neural networks. Through some numerical experiments, this technique proves itself as a highly effective tool to inexpensively and precisely estimate both active and reactive power losses.

TS3.3 16:36 ***Estimating Complex Power Magnitudes Using a Bank of Pre-Defined PFs Embedded in ANNs***

Ali R. Al-Roomi (Dalhousie University & College of Engineering, Canada); Mohamed E. El-Hawary (Dalhousie University, Canada)

Measuring complex power magnitudes (or apparent power) of transmission, sub-transmission, and distribution lines is a very important practice. It is used in many analysis, including: power system operation, protection, reliability, and electricity markets. Realistic networks could contain many sensors and instrument devices to provide online measurements of these variables. The communication between field, control, and supervisory levels is done through different protocols that could be integrated with different automation and energy management systems. Thus, the chance of failure to any of these different layers of online measurement is always exist; which is a familiar task assigned to maintenance departments. This paper tries to solve this crucial problem by estimating these measurements without depending on any of those online hardware. The idea here is to train artificial neural networks (ANNs) based on a database created from a large number of off-line power flow solutions. The numerical results show that this instruments-free power estimator (IFPE) is highly significant and effective tool to predict any apparent power directly by just knowing the power settings of units and loads, and the present status of branches.

TS3.4 16:54 ***Fast Calculation of Steady Temperature Rise for Running Three-Phase Cable Group in Ducts Based on Transfer Matrix***

Yongchun Liang (Hebei University of Science and Technology, P.R. China)

This paper studied a method based on transfer matrix and superposed thermal field to achieve a fast calculation for steady state temperature rise for three-phase cable group in ducts. The interaction of cable groups was discretized into the combination of single action in multi-loop cables. The interaction between two pairs was described by transfer coefficient, and the transfer matrix was obtained to represent the thermal characteristics of cable groups. Finally, the fast

calculation was realized by combining a simple iteration of "temperature-loss". The extraction process of transfer matrix by FEM and the application of fast calculation method was illustrated, and the result of the fast calculation method was compared with that of FEM, which proved the feasibility, simplicity and accuracy of the fast calculation method presented in this paper.

TS3.5 17:12 ***Composite Load Model and Transfer Function Based Load Model for High Motor Composition Load***

Hla U May Marma (Memorial University of Newfoundland, Canada); Xiaodong Liang (University of Saskatchewan, Canada)

There are two common forms of dynamic load models suitable for power system dynamic studies: a composite load model and a transfer function based load model. The composite load model typically refers to a combination of an induction motor and a static load in the form of ZIP (constant impedance, constant current, and constant power) load. In this paper, the two types of load models are derived for a high motor composition load, and their performance is compared and analyzed through several case studies considering both voltage and frequency dependency of the load models.

TS4: Cyber Security and Data Driven Methods in Power Systems

TS4.1 16:00 ***Detection of False Data Injection Attacks on Wide-Area Under-Frequency Load Shedding Protection Schemes***

Mohsen Khalaf (University of Waterloo, Canada); Amr Youssef (Concordia University, Canada); Ehab El-Saadany (Waterloo University, Canada); Magdy Salama (University of Waterloo, Canada)

In this paper, we first investigate the problem of cyber attacks on Wide-Area Protection (WAP) schemes. As a case for study, false data injection (FDI) attacks on wide-area Under-Frequency Load Shedding (UFLS) protection schemes are considered. Our analysis shows that attackers can drive the system out of stability by manipulating frequency measurements that are supplied to the control center by each local system. Then, we propose a detection strategy based on an unknown input estimator using Kalman filter, where frequencies as well as the power disturbance of system generators are estimated and compared with the received values. Then, a decision is made whether there is an attack or not based on the cumulative error residual. The effectiveness of the proposed approach in detecting FDI on wide-area UFLS protection schemes is confirmed through simulation using the IEEE 14 bus benchmark system.

TS4.2 16:18 ***Impact of Electric Vehicles Botnets on the Power Grid***

Omniyah M Gul M Khan (University of Waterloo, Canada); Ehab El-Saadany (Waterloo University, Canada); Amr Youssef (Concordia University, Canada); Mostafa Shaaban (American University of Sharjah, United Arab Emirates)

The increased penetration of Electric Vehicles (EVs) in the transportation sector has increased the requirement of Fast Charging Direct Current (FCDC) stations to meet customer's speedy charging requirements. However, both charging stations and EVs connection to the communication infrastructure as well as the power grid makes it vulnerable to cyber attacks. In this paper, the vulnerability of the EV charging process is initially studied. We then show how a botnet of compromised EVs and FCDC stations can be utilized to launch cyber attacks on the power grid resulting in an increase in the load at a specific time. The effect of such attacks on the distribution network in terms of line congestion and voltage limit violations is investigated. Moreover, the effect of the botnet of the transmission network is also studied. Simulation results demonstrate the possibility of line failures, and power outage; and hence, the system's vulnerability to cyber attacks is established.

TS4.3 16:36 ***Robust Feature Extraction and Ensemble Classification Against Cyber-Physical Attacks in the Smart Grid***

Chengming Hu, Jun Yan and Chun Wang (Concordia University, Canada)

Intrusion detection systems (IDS) are crucial in threats monitoring for the cyber-physical security of electrical power and energy systems in the smart grid with increasing machine-to-machine communication. However, the multi-sourced, voluminous, correlated, and often noise-contained data, which record various concurring cyber and physical events, are posing significant challenges to the accurate distinction by IDS among events of inadvertent and malignant natures. To tackle such challenges, this paper proposes a robust end-to-end framework based on Stacked Denoising Autoencoder (SDAE) and Ensemble Machine Learning to extract new noise and attack-informed feature sets from cyber-physical system data and incorporate different sources of information for reliable event classification. The proposed framework first leverages SDAE to create lower-dimensional features that allow reconstruction of a noise-free input from noise-corrupted perturbations. By combining attack and noisy inputs, we extracted new, automatically-engineered features that can preserve and present information on normal, fault, and attack events against different synthetic but realistic noises for better classification. Considering the heterogeneous nature of the inputs, which are composed of PMU measurements, system logs, and IDS alerts, we further introduced ensemble learning-based multi-classifier classification with the Extreme Gradient Boosting (XGBoost) technique to classify the samples based on the SDAE-extracted features. Normalization and oversampling were also both performed to improve the uniformity and balance of the data. On a realistic dataset of 37 sub-types of normal, fault, and attack collected from co-simulations on a hardware-in-the-loop (HIL) testbed security testbed, the results have shown that the proposed SDAE+XGBoost solution achieves over 90% classification accuracy with the SDAE features and ensemble classifiers, an effective 8% increase over the state-of-the-art.

TS4.4 16:54 ***Probabilistic Models for Residential and Commercial Loads with High Time Resolution***

Sami M. Alshareef (Ontario Tech University, Canada); Walid Morsi (Ontario Tech University)

This paper develops the annual load profiles for residential load and two types of commercial loads, located at the same climate zone characterized as mixed-marine. Each annual load profile is generated based on a probabilistic approach, in an hourly scale, and assessed based on external validity indices relying on both supervised learning and unsupervised learning. Furthermore, the paper presents a method to increase the daily resolution of each generated profile from 24 samples per day representing 24 hours, to 120 samples in each hour, increasing the daily profile to 2,880 samples. For illustration, the proposed method is applied on the generated residential and one of the commercial load profiles. This study contributes to the literature by developing numerical load profiles for residential and commercial loads. The residential load profile can be used to represent the electricity consumption in the residential sector while the commercial load profiles can be utilized to represent the electricity consumption in the commercial sector.

TS4.5 17:12 ***Probabilistic Modeling of Plug-in Electric Vehicles Charging from Fast Charging Stations***

Sami M. Alshareef (Ontario Tech University, Canada); Walid Morsi (University of Ontario Institute of Technology, Canada)

In this paper, a probabilistic charging demand profile of plug-in battery electric vehicles charging from a fast charging station is presented. Different vehicles' models are utilized, such as the Chevrolet Bolt, the Tesla Model S, and the Nissan Leaf. Two different parameters are considered, the daily distance travelled, and the battery state-of-charge. The Markov Chain Monte Carlo, relying on Metropolis-Hastings sampler, is utilized to estimate the aforementioned parameters based on exponential and Weibull distributions. The convergence of the algorithm is assessed based on the Gelman-Rubin approach. Distributions for the parameter of daily distance travelled were selected by comparing the data of daily mileage driven, corresponding to three types of electric vehicles collected in a mixed and marine climate zone, with theoretical empirical cumulative distributions calculated from seven standard distribution functions. The battery state-of-charge depends on the parameter of daily distance travelled and estimated by taking the difference between the battery total range and the daily distance traveled. The results have shown that the best distribution is exponential for Chevrolet Bolt and Nissan Leaf whereas Weibull represents the best distribution for Tesla Model S. The best distribution has been determined by calculating the Sum of Squares Error.

W1: Workshop 1

DER - Interconnection and Integration Standards

Mark Siira (ComRent), Michael Ropp (Northern Plains Power), Geza Joos (McGill University)

This tutorial will cover an overview of the IEEE 1547 Series of Standards, including new interconnection requirements from IEEE 1547, Test procedures from IEEE P1547.1 and integration guidelines from other standards including IEEE P1547.2 (Application Guide), IEEE Std 2030.2 and IEEE P1547.9 (Energy Storage) and IEEE Std 2030.7. The discussion will include material on integration and verification.

Sections/Topics:

- DER - definition, history, deployment and justification for the standards (M. Siira)
- Interconnection rules and requirements - evolution, needs and description (M. Ropp)
- Voltage and frequency ride-through - needs and implementation (M. Ropp)
- DER aggregation and islanding - microgrids and DERMS (G. Joos)
- Interoperability, verification and testing - requirements (M. Siira)
- Integration issues - standards and regulatory requirements (M. Siira)

Wednesday, October 16 17:30 - 19:30

WR: Welcome Reception

Thursday, October 17

Thursday, October 17 7:30 - 17:30

R2: Registration Day 2

Thursday, October 17 8:30 - 10:30

OP&PS3: Opening Session & Plenary Session 3

8:30-9:00: Opening remarks

9:00-9:45: **La donnée au coeur de l'intelligence d'affaires / Data at the heart of business intelligence**, by Nicolas Di Gaetano, Hydro-Québec

9:45-10:30: **Building safe artificial intelligence**, by David Krueger, MILA

Thursday, October 17 10:30 - 11:00

MB: Morning Break

Thursday, October 17 11:00 - 12:30

PL4: Plenary Session 4

11:00-11:45: **Technological vision of the hydroelectric development of the future**, Jean-François Rochefort (Hydro-Québec)

11:45-12:30: **Blockchain in the energy sector**, Tom Marynowski, Hydro-Québec

Thursday, October 17 12:30 - 14:00

L2: Lunch Day 2

Thursday, October 17 14:00 - 15:30

HQ3a: HQ Session 3 - AI and Data Science for the Power Grid

14:00-14:30: ***Demand prediction with machine learning: New York case study***, **Pierre Dinonne** (Hydro-Quebec)

14:30-15:00: ***OpenBDLM, a dam monitoring tool***, **James A. Goulet** (Ecole Polytechnique de Montreal)

15:00-15:30: ***Applications of Data Science and Virtual Machines in Azure***, **Robert Luong** (Microsoft)

(Some presentations will occur in French, simultaneous translation provided)

HQ4a: HQ Session 4 - Private Session

IoT and Digital Grid

IS1: Insdustry Session 1

Digital Transformation for the Utilities

TS5: Power System Planning

TS5.1 14:00 ***Ranking of Routes for Electrical Transmission Lines Using GIS and Image Processing Techniques***

Imtiaz A Khan and Kshirasagar Naik (University of Waterloo, Canada); Mohamed Ahmed (University of Waterloo & IBM Canada, Canada); Mustafa Al-tekreeti (University of Waterloo, Canada)

Selecting a route for an electrical transmission line is the first step of building a new transmission line. The most common practice of selecting a route involves ranking possible route options, which is a complex process that demands many decision considerations to be taken into account. The ranking process is mainly done manually by humans using printed maps and field surveys that makes it time-consuming and prone to errors. In this paper, we study the most common decision considerations that affect the process of ranking a set of route options. We classify these decision considerations into four main categories. Then, we propose a methodology to automate the process of ranking routes for an electrical transmission line using GIS (Geographic Information System) and image processing techniques. We evaluate the effectiveness of the methodology by comparing the results obtained with industrial results of an actual project in Saskatoon, Canada. The preliminary results are very promising. Out of five route options, our methodology ranks the top two options accurately, and it successfully identifies the least preferred route options.

TS5.2 14:18 ***Planning of a Northern Isolated Microgrid***

Alexandre B Nassif and Ryan Anderson (ATCO, Canada); Farzam Nejabatkhah (University of Alberta, Canada)

There have been strong drivers toward lessening diesel dependency in remote communities. These off-grid communities can be difficult to access, and often face challenges with diesel supply. More importantly, governments are striving to improve the environmental outlook in these areas. Tying this need with associated high operational costs and fuel handling challenges, alternative sources of energy and energy storage have emerged as a viable option to reduce diesel consumption. This paper presents the experience of a Canadian electric utility in planning the application of utility scale photovoltaic generation and Battery Energy Storage Systems to supplement existing diesel generators in a remote isolated community in Alberta. Economic drivers and opportunities to partner with first nations have sparked stakeholder attention and positioned the project as a national interest. Technical and economic studies were conducted to address all aspects of the project. These include forecasting load, sizing and siting each alternative generation option, customizing dispatch strategies, and determining required spinning reserve from diesel generators through time-domain studies. This paper covers the size and location optimization of the PV and BESS assets and dispatch strategies.

TS5.3 14:36 ***A Study of the Potential for a Submarine Interconnection in the Gulf of St. Lawrence***

Catherine Bittar (McGill University, Canada); Antoine Pacarar (University McGill, Canada); Kevin-Rafael Sorto-Ventura and Francois Bouffard (McGill University, Canada)

This paper proposes a mathematical model for planning the grid topology of multi-terminal submarine HVDC networks for bulk renewable energy transmission and power system interconnections. The proposed model is a mixed integer nonlinear optimization problem. The decision variables are points of connection, presence and number of links between connections points, and the nominal voltage level of the grid. Respecting the power balance and power flows are the main physical constraints on the problem. Case studies were conducted for the case of the Gulf of St. Lawrence in Eastern Canada. Results demonstrated that larger interconnections are a more profitable way of connecting isolated networks to larger ac grids.

TS5.4 14:54 ***Interconnection of Northern Canadian Communities to the Manitoba Hydro Power System: Evaluation of AC and DC Alternatives***

Nuwan Herath and Xiaoquan Xu (University of Manitoba, Canada); Nandaka Jayasekara and David Jacobson (Manitoba Hydro, Canada); Shaahin Filizadeh (University of Manitoba, Canada)

The communities in the Northern region of Canada have been using local power generation methods based on fossil fuels for a considerable time. These communities have land access only during the winter months, which poses problems in transportation of fuel. Power demands of these regions are increasing and to cater the increasing demands, it is essential to connect these communities to the main grid. One option will be to extend the existing ac power system to these regions. Another option is to use an HVDC Lite option based on a multiport VSC system. This paper studies the feasibility of both the ac and dc options using computer simulations. Merits and disadvantages of the two alternatives are assessed and outlined based upon simulation-based study results.

TS5.5 15:12 ***Identifying Seasonality in Time Series by Applying Fast Fourier Transform***

Hmeda Musbah (Canada, Canada); Mohamed E. El-Hawary and Hamed Aly (Dalhousie University, Canada)

The importance of studying time series is that most forecasting models assume that the time series must be stationary. In addition, non-stationary time series can cause unexpected behaviors or create a non-existing relationship between two variables. The aim of this study is to shine new light on the Fast Fourier Transform (FFT) technique through an examination of its efficiency in identifying the trend and seasonality by applying it to many time series. A comparison between the FFT technique and Autocorrelation Function (ACF) has been conducted as well. The results show that the FFT technique has acceptable performance in identifying the trend and seasonality. The most obvious observation is that, unlike the FFT technique, the ACF has limitations in determining the exact time of the seasonality that repeats itself.

TS6: Power Electronics in Power Systems

TS6.1 14:00 ***UHVDC Islanded Operation System Ultra-low-frequency Oscillation and Its Countermeasures***

Wei Li and Aniruddha Gole (University of Manitoba, Canada); Xiangning Xiao (Huabei University of Electric Power, P.R. China)

There exists serious governor control instability in the islanded operation system of large capacity UHVDC with its matching hydraulic power generators. Ultra-low-frequency oscillations (ULFO) will happen because of the inconsistent control features between UHVDC and frequency regulation of generators. Using frequency domain analysis, there exists a frequency band of negative damping in the hydraulic turbine control system. The larger value of water starting time

constant, the more serious negative damping exists in the frequency control system. And if the forward gain of governor becomes larger, the negative damping will be more remarkable. Effective frequency control strategies for UHVDC islanded system are proposed in this work by withdrawing a part of primary frequency control functions of generators or coordinating the hydraulic generator governors and UHVDC frequency limitation controller (FLC). Using the proposed strategies, islanded system frequency is mainly controlled by UHVDC FLC, which can successfully suppress the ULFO. Verification simulations are carried out and the simulation results prove the effectiveness of the proposed strategies.

TS6.2 14:18 ***The Case Against Phase-Locked Loops in Weak AC Grids***

Ishita Ray (University of Tennessee, Knoxville, USA); Tolbert Leon M. (The University of Tennessee, USA)

With increasing deployment of inverter-based sources in microgrids, inverter control methods are constantly being modified and improved. What remains constant, however, is the phase-locked loop (PLL). Regardless of the control technique adopted and the type of microgrid, a PLL is used to synchronize the output PWM signal of the inverter with the main grid or other inverters. But as penetration of inverter-based sources increases and grids become weaker, the impact of PLLs on controller behavior becomes more pronounced. The issues caused by these influences are described in this paper to make a case for finding a solution for inverter synchronization that better fits the needs of inverter-dominated microgrids than PLLs. Simulation results from a study of a low-voltage microgrid supported by parallel inverters are also presented to demonstrate some of these characteristics.

TS6.3 14:36 ***Average Voltage Regulation in Droop-Controlled MTDC Grids***

Aram Kirakosyan (University of Waterloo, Canada); Ehab El-Saadany (Waterloo University, Canada); Mohamed El-Moursi (Masdar Institute, United Arab Emirates); Magdy Salama (University of Waterloo, Canada)

Proper voltage regulation is vital for the operation of the Multi-Terminal High Voltage Direct Current (MTDC) systems as the former parameter is a direct indicator of the power balance in such grids. This paper investigates the issues with the control of the MTDC voltage when the average voltage regulation approach is used. Specifically, the system performance is evaluated when large communication latencies are present in transferring the required voltage information. For this purpose, eigenvalue analysis is conducted in Matlab/ Simulink environment. Furthermore, alternate implementations of the control approach under study are discussed and their performances are compared by means of time-domain analysis conducted using SimPowerSystem toolbox.

TS6.4 14:54 ***Modeling and Step Response Analysis of Back-to-Back VSC for LFAC Transmission***

Okechukwu Efobi, Wei Li, Aniruddha Gole and Mukesh K. Das (University of Manitoba, Canada)

Low frequency AC (LFAC) is being proposed as an intermediate transmission technology between HVAC and HVDC. It could be attractive as a means for connecting offshore wind farms to the grid, in lieu of VSC-HVDC. Its single converter station could even be located onshore. Because it could operate at a fraction of 50/60 Hz frequency, LFAC could transfer significantly more power and for longer distances, without compensation, than HVAC. Unlike HVDC, LFAC could have the advantage of employing conventional AC circuit breakers for fault current interruption. Thus, it could be readily used for multi-terminal connections. This paper presents state space modeling of an ideal back-to-back VSC (frequency converter). Eigenvalues of the linearized model are used for stability and step response analysis of the converter. PSCAD/EMTDC simulations are then used to verify the accuracy of the derived model. This state space model could be applied in the analysis of LFAC systems.

Thursday, October 17 15:30 - 16:00

AB: Afternoon Break

Thursday, October 17 16:00 - 17:30

HQ3b: HQ Session 3 - Private Session

AI and Data Science for the Power Grid

HQ4b: HQ Session 4 - Private Session

IoT and Digital Grid

TS7: Power System Economics

TS7.1 16:00 ***On the Importance of Detailed Thermal Modeling for Price Forecasting in Hydro-Thermal Power Systems***

Mari Haugen (SINTEF Energy Research, Norway); Arild Helseth (Sintef Energy Research, Norway); Stefan Jaehnert and Birger Mo (SINTEF Energy Research, Norway); Hossein Farahmand and Christian Naversen (Norwegian University of Science and Technology (NTNU), Norway)

This paper presents a framework for long-term price forecasting in hydro-thermal power systems comprising two modeling layers. A long-term hydro-thermal model expresses the expected future cost as a function of hydro reservoir levels to an operational short-term model. The short-term model re-optimizes the weekly decision problem with more details and a finer time resolution. To cope with the high computation times, we decompose the weekly decision problem into daily sub-problems by interpolating in the weekly cost functions from the long-term model. The short-term model is refined by adding detailed constraints on the operation of thermal power plants. We assess the importance of detailed modeling of thermal power plants in a case study of the Nordic power system.

TS7.2 16:18 ***Assessing the Rate Impact of Conservation and Demand Management: A New Mathematical Model***

Jessie Ma and Bala Venkatesh (Ryerson University, Canada)

While numerous studies examine the casual relationships of electricity rates on conservation and of conservation on variable costs, little work has been done on the missing links of conservation on fixed costs and on overall electricity rates. This paper presents a new model to scientifically quantify these two gaps and complete the economic picture of conservation. This knowledge can equip government policymakers and conservation program designers at utilities to create more efficient and effective programs. New mathematical models of the full systems-level rate impact of different forms of conservation are presented. Four common forms of conservation were analyzed for their impacts on total fixed and variable costs and rates: peak shaving (S1); off-peak reduction (S2); peak shifting (S3); and time independent conservation (S4). These were all measured against the base case without conservation (S5). A test system based on the electricity system in Ontario, Canada was created and analyzed over a 21-year period. The results show that different forms of conservation have different impacts on fixed and variable costs and rates, and the most useful metric for the economic impact of conservation is the change in utility rates, inclusive of fixed and variable components. For conservation programs to lower rates, they must decrease the peak demand, which will lower fixed costs by deferring capital investments, and increase utilization, which will lower rates by increasing consumption during off-peak times.

TS7.3 16:36 ***A Review of the Convexification Methods for AC Optimal Power Flow***

Shaojun Huang and Konstantin Filonenko (University of Southern Denmark, Denmark); Christian Veje (University of Southern Denmark & Center for Energy Informatics, Denmark)

This paper reviews existing convexification methods for AC optimal power flow (OPF), which is normally nonlinear, nonconvex, and very hard to solve. Different types of convexification methods are reviewed, from conventional methods like DC OPF, to relaxation methods, like convex relaxation (semidefinite program - SDP, second order cone program - SOCP, quadratic convex - QC), strengthened convex relaxation, and convex hull, and finally convex restriction methods. The focus is given to relaxation methods due to the great attention in recent research. The exactness of the relaxation methods and the sufficient conditions that guarantee the exactness are reviewed as well. This gives an insight into these relaxation methods and helps to select suitable and efficient relaxation method for different applications.

TS7.4 16:54 ***Locational Marginal Pricing for Distribution Networks: Review and Applications***

Carlos Sabillon (Ryerson University, Canada); Amr Adel Mohamed (Ryerson & Center for Urban Energy, Canada); Bala Venkatesh (Ryerson University, Canada); Ali Golriz (IESO, Canada)

Many distribution networks are operating based on uniform energy price rate for all the system nodes. However, with high penetration of distributed energy resources (DER), energy storage (ES) and flexible demands (FD), there is a big opportunity to optimally operate the distribution networks. In this context, distribution locational marginal pricing (DLMP) can be employed, similar to that of whole-sale electricity market, as the distribution pricing mechanism. The main advantage of DLPM that it can count for the network losses and congestion, so it can ensure a competitive and fair participation for all the entities, such as DERs and FDs, on the distribution side. With introduction of transactive energy system (TES) on wider scale in modern power systems, there will be a big necessity to adopt a robust pricing mechanism such as DLMP to consider both technical and economic concerns of distribution networks. In this paper, a brief review has been conducted on DLMP and its application. Further, an illustrative example is provided to demonstrate the several attribute for the operation of distribution networks and its impacts on the DLMP values.

TS7.5 17:12 ***Diesel Reduction Opportunities in a Remote Isolated Community***

Alexandre B Nassif and Ryan Anderson (ATCO, Canada)

Diesel dependent remote communities have been the focus of many Canadian initiatives in recent years. Often, these areas house first nation communities and can be deprived or resources such as electricity and natural gas due to restricted accessibility. This could result in shortage of diesel because of the delivery difficulties. Driven by United Nations goals, countries across the globe have focused in developing these areas to improve the outlook of their residents. This includes the implementation of alternative sources of electricity. This paper presents the experience of a Canadian electric utility in investigating diesel reduction options in one of its largest remote communities. Currently, this system is diesel dependent and, due to the load growth, is facing risks of not having enough diesel supply to produce energy for an entire year. These alternatives are focused both on reducing electric technical losses, reducing electricity consumption, and offsetting some of the consumption through adopting solar (PV) generation.

TS8: Power System Economics II

TS8.1 16:00 ***DC to DC Converter Based Asymmetrical Multilevel Inverter with Reduced Number of Components***

Jiwanjot Singh (National Institute of Technology (NIT), Silchar, Assam, India); Lalit Saini (National Institute of Technology (NIT) Kurukshetra, India); Ratna Dahiya (National Institute of Technology (NIT) Kurukshetra, Canada); Vijay K. Sood (Ontario Tech University, Canada)

In this paper, the variable voltage method has been presented to minimize the components of an asymmetrical multilevel inverter (AMI). AMI consists of one main bridge and many auxiliary bridges to increment the number of levels (NOLs) in the output voltage which minimizes the total harmonic distortion (THD). However, the number of auxiliary bridges increases the space for installation, cost and components. To overcome these drawbacks a buck converter (BC), having low rating compared to the rated value of AMI is attached to the auxiliary bridge. This method gives possibility to obtain the higher NOLs with a reduced number of components of AMI. A comparative study is done with existing AMIs topologies to show the effectiveness of the variable voltage method on the basis of the number of semiconductor switches, a variety of DC sources, number of DC sources, and total standing voltage. In this paper, simulation is performed in the MATLAB/SIMULINK environment. The output voltage and THD have been calculated by simulation of 9-level and 15-level multilevel inverter. The hardware implementation for the 9-level multilevel inverter has been done using a low-cost microcontroller. The simulation results are verified by comparing them with those obtained experimentally.

TS8.2 16:18 ***Reduction of Harmonics in a Hybrid PV/Wind Microgrid Using a Modified Multilevel Inverter***

Mamatha Sandhu (Chitkara University & Punjab Engineering College, (Deemed.) Chandigarh, India); Tilak Thakur (Punjab Engineering College Technical University, India)

In Recent years, renewable energy resources are widely used for generation of electricity. Solar energy is abundantly available on the earth since it is free from pollution. For remote and distributed applications, wind energy has found to be the greatest amount of cost-effective technology for renewable energy at mass level demand in the market of power distribution. Hybrid applications, where more than one renewable source is utilized, which include solar and wind energy sources have attractive demands in remote areas. The proposed method is a hybrid PV/wind and battery system which makes use of a boost converter for both the sources along with a MPPT to extract maximum energy. Here modified cascaded H bridge multilevel 7-level inverter is designed for total harmonic reduction which provides minimum switches that helps to improve the cost. A Low pass filter is used in series with the multilevel inverter for filtering the harmonics. A multi carrier pulse width modulation technique with phase opposition disposition is implemented for improved harmonic reduction. MATLAB/SIMULINK is used for simulation. A hybrid system balances the energy distribution that helps sources to complement each other. Hybrid energy system is an excellent solution for harmonic reductions and grid integration for continuous power supply.

TS8.3 16:36 ***High-Performance Multilevel Power Factor Correction Boost-Buck Converter***

Ali Sunbul (UOIT, Canada & Taibah University, Saudi Arabia); Ahmed Sheir (UOIT, Canada); Vijay K. Sood (Ontario Tech University, Canada)

This paper introduces a multilevel power factor correction converter in a 2-stage configuration. The first stage is a 3-phase, 3-level boost rectifier based on the Vienna rectifier. Compared to the other types of rectifier, Vienna rectifier has the lowest number of active switches and passive components size, while being able to reach a higher efficiency and lower THD. Furthermore, the switching loss is further reduced by using simplified space vector modulation, which allows for only one switch transient per state transient. In order to overcome its high boosting ratio and regulate its output voltage within the required range of battery charging in electric vehicles, a high efficiency 4-switch converter is cascaded with the Vienna rectifier. This converter has the advantages of employing storage-less passive components and providing for zero current switching (ZCS) among all of its switches. The peak efficiency of this converter is nearly 99%; hence, it will not affect the total system efficiency. A description of the converter configuration is first introduced. Then, the simulation results are presented to verify the validity of the proposed configuration.

TS8.4 16:54 ***Cascaded Modular Converter with Reduced Output Voltage Ripple***

Ahmed Sheir (UOIT, Canada); Vijay K. Sood (Ontario Tech University, Canada)

In this paper, two cascaded modular converter configurations are compared: CMC and MLC. The non-isolated version offers a simpler construction, control method, better modularity and better power management architecture. The isolated version is considered better in a photovoltaic (PV) application as it can handle the difference in irradiance conditions i.e. due to partial shading without affecting the symmetry of its output voltage and current. Combining the advantages of differential-mode converters and multilevel inverters, CMCs can produce naturally filtered output voltage and current with lower voltage stress across its components while allowing for better power management. Moreover, a modified switching pattern is introduced to further reduce the sizing of the passive components (LC filters). This is done by shifting the triangular carrier associated with each dc-dc module which results in much lower average output ripples. Thus, lower switching frequency and / or converter size can be achieved. A brief description of the converters construction and operation is introduced. Then, Matlab / Simulink model is constructed to validate the converters ability to produce lower output ripples.

TS8.5 17:12 ***Analysis and Control of a Novel Transformer-less Grid-Connected Single-Stage Solar-Inverter Using PR-Controller***

Sivanagaraju Gangavarapu, Manisha Verma and Akshay Rathore (Concordia University, Canada)

This paper proposes a novel grid-connected transformer-less inverter topology with boost converter followed by flyback inductor inverter. The proposed inverter is of common-ground type, hence the leakage current flow between PV-panel and ac-grid is zero which is desired in transformer-less inverters. The proposed inverter provides symmetrical voltage gain both positive and negative, hence any simple PWM technique can be implemented. The proposed inverter detailed steady state analysis, and the design equations are presented. The inverter small-signal model is developed, and the detailed design of PR-controller is presented for inverter closed-loop operation with grid. The inverter analysis and the designed controller are verified with the both simulation and experimental results

W2: Workshop 2

Smart Grid Interoperability and Cyber Security Standards

Mark Siira (ComRent), Michael Ropp (Northern Plains Power), Candace Suh-Lee (EPRI)

This tutorial will provide an overview of IEEE 2030 Smart Grid Interoperability Reference Model, how it is used and how it is evolving. We will touch on the increasingly prevalent issue of Cyber Security. We will provide an overview of Cyber Security and how it is being deployed in various domains of the electric power System.

Sections/Topics:

- Smart grid - definition, history and justification for the guide (M. Siira)
- Interoperability - definition, needs, perspectives and applications (M. Siira)
- Reference models - link between power, communications and information technologies (M. Siira)
- Cybersecurity - threat description, analysis and countermeasures (C. Suh-Lee)
- Application of the guide to power systems - frequency regulation (M. Ropp)

Friday, October 18

Friday, October 18 8:30 - 11:00

R3: Registration Day 3

Friday, October 18 9:00 - 10:30

IS2: Industry Session 2

Weather Hardening Our Energy Supply

TS10: Machine Learning and Artificial Intelligence Applications

TS10.1 9:00 ***A Proposed Adaptive Intelligent Controllers for Tidal Currents Turbine Driving DDPMSG for Improving the Output Power Generated***

Hamed Aly, Fawaz Alhaddad and Mohamed E. El-Hawary (Dalhousie University, Canada)

Smart grid and renewable energy are considered as important topics these days and in the near future due to the climate changes and environmental issues. Tidal current energy is promising to reduce the production of CO2 emission. The tidal current power is fluctuating and intermittent due to the tidal current speed. This work is proposing intelligent adaptive controllers to improve the quality of the tidal current generated output power. The proposed controllers are of PI types controllers and take their signals from the tidal speed, tidal generated power and the required nominal tidal output power and adjust the controllers parameters to improve the quality of the generated output power. These controllers are tested using Simulink/Matlab. The results prove the effectiveness of the proposed controllers in improving the generated output power. The tidal turbine with these proposed controllers could work under different severe conditions.

TS10.2 9:18 ***Photovoltaic Array Reconfiguration to Reduce Partial Shading Losses Using Water Cycle Algorithm***

Abdelhamid Mahmoud (Ain Shams University, Egypt); Mohamed Shamseldein (Ain Shams University, Canada); Hany Hasanien (Ain Shams University, Egypt); Almoataz Abdelaziz (Ain Shams University & Faculty of Engineering, Egypt)

Partial Shading (PS) increases the power losses in Photovoltaic (PV) arrays significantly. Consequently, PS is considered one of the biggest challenges that face the operation of PV systems. PV arrays dynamic reconfiguration is a promising technique used to reduce PS losses. This paper proposes the Water Cycle Algorithm (WCA) as a new optimization technique for large PV array reconfiguration to reduce PS power losses. The proposed algorithm is preferred over the existing algorithms when dealing with large PV arrays under irregular partial shading patterns.

TS10.3 9:36 ***Power System On-line Transient Stability Prediction by Margin Indices and Random Forests***

Yuchuan Chen, Seyed Mazhari, Chi Yung Chung, Sherif Faried, Bingzhi Wang and Bo Hu (University of Saskatchewan, Canada)

This paper addresses a novel approach for on-line transient stability prediction for power systems. In the proposed framework, the feasible instability classes (ICs) of a power system is first identified by off-line simulation considering the uncertainties of load and all potential contingencies. Accordingly, after contingencies, the stability margins (SMs) for each possible IC can be rapidly calculated using direct methods. These SMs are chosen as features for the prediction models trained by random forests, which further demonstrate a better prediction performance compared with other features of previous machine learning based method. The proposed approach is validated on two IEEE test systems and compared with existing methods.

TS10.4 9:54 ***Machine Learning-Based Demand and PV Power Forecasts***

Anindita Golder and Jneid Jneid (McGill University, Canada); Junyuan Zhao (Mcgill University, Canada); Francois Bouffard (McGill University, Canada)

In recent years, predicting the performance of the power system is of high-priority to alleviate potential uncertainties. Achieving accurate load prediction at the customer and at the renewable energy resources levels will lead to more efficient balance of supply and demand. In this paper, we investigate different models including Support Vector Machines (SVM), Multi-Layer Perceptrons (MLP) and Long Short-Term Memory (LSTM). The models were used for two tasks: predicting the Load Demand and the PV generation. For the Load Demand prediction models, the dataset considered was the aggregated load demand for 40 randomly chosen homes in Austin, Texas and the weather in Austin, Texas. For the PV generation Model, the dataset considered was the PV generataion of Yulara Plant in Australia and the weather conditions for the site. The MLP model gave us the best results for the Load Prediction (RMSE of 4.46) closely followed by the LSTM and the LSTM model gave us the best result for the PV Prediction (RMSE of 14.04).

TS10.5 10:12 ***Ensemble-Based Deep Learning Model for Non-Intrusive Load Monitoring***

Junfei Wang (Western University, Canada); Samer El Kababji (Western University & Smartegrators Ltd., Canada); Connor Graham (London Hydro, Canada); Pirathayini Srikantha (York University, Canada)

Climate change and environmental concerns are instigating widespread changes in the modern electricity sector due to energy policy initiatives and advances in sustainable technologies. With the deluge of information resulting from the ubiquitous communication and computational capabilities present in all aspects of our society, system operators and consumers have elevated situational awareness and are able to make informed context-based decisions. We capitalize on this information-centric nature of the advanced metering infrastructure (AMI) in the power grid to enable non-intrusive load monitoring for individual consumers with high accuracy. We propose a novel ensemble based deep learning model to disaggregate smart meter readings and identify the operation of individual appliances. We show through comprehensive practical and comparative studies the superior performance of the proposed model.

TS9: Distribution Systems and DERs

TS9.1 9:00 ***Grid Support Functions Impact on Residential Voltage Profile for Updated Canadian Interconnection Standard***

Nayeem Ninad (Renewable Energy Integration, CanmetENERGY, Natural Resources Canada, Canada); Kevin Abraham (CanmetENERGY, NRCan, Canada); Sanjayan Srikumar and Pavithran Gurunathan (Renewable Energy Integration, CanmetENERGY, Natural Resources Canada (NRCan), Canada); Dave Turcotte (CanmetENERGY, Natural Resources Canada, Canada)

The high penetration of distributed energy resources (DERs) (especially PV) presents a number of technical challenges for power system operation; one of them being overvoltage. To better manage the grid operation, the interconnection standards around the world are including requirement of grid support functions (GSFs) for these DERs. The recently updated Canadian interconnection standard, CSA C22.3 No. 9 also included advanced GSFs requirements for these DERs. This paper investigates the impact of high PV penetration on the voltage profile of Canadian suburban residential neighborhood. The initial base case is established with the consideration of the legacy PV inverter (unity power factor operation) in 216 houses in which case voltage violation is observed in the network. Then the voltage profile of the neighborhood is compared for three separate scenarios with different GSFs; fixed power factor, Volt-Var and Volt-Watt. Each GSF is configured according to the CSA C22.3 No. 9 standard. These functions can mitigate/reduce the overvoltage issues in different proportions, e.g., voltage violation does not occur for fixed power factor operation. The impact of these GSFs on the customer PV production (active power) and the loading of the network component are also analyzed in this paper.

TS9.2 9:18 ***Laboratory Assessment of DER Inverter Grid Support Functions for Updated Canadian CSA C22.3 No. 9 Interconnection Standard***

Nayeem Ninad (Renewable Energy Integration, CanmetENERGY, Natural Resources Canada, Canada); Estefan Apablaza-Arancibia and Janos Rajda (Renewable Energy Integration, CanmetENERGY, Natural Resources Canada (NRCan), Canada); Dave Turcotte (CanmetENERGY, Natural Resources Canada, Canada)

With the rapid increase in renewable energy integration in the electric grid, grid codes around the world are getting updated with requirements of grid support function (GSF) for the distributed energy resources (DER). The Canadian interconnection standard CSA C22.3 No. 9 recently underwent revision and recently completed the public review process. This revised standard included advanced GSFs for DER systems and the test procedures (mostly referring to IEEE 1547.1 or UL 1741 SA) for assessing these DER GSFs. Two commercial solar/photovoltaic (PV) smart inverters were tested at the CanmetENERGY inverter test facility following the test procedures from UL 1741 SA and using the parameters from CSA C22.3 No. 9. This paper presents the important aspects of the test procedure while doing standard compliance tests for the selected GSFs. Test results, issues requiring future consideration and comments are presented in this paper.

TS9.3 9:36 ***Minimizing Distribution System Power Loss Using Behind-the-Meter Type 3 Generators***

Mehran Amigh, Ilamparithi Thirumarai-Chelvan and T. Aaron Gulliver (University of Victoria, Canada)

This paper considers power loss reduction in distribution systems by integrating behind-the-meter, type 3 distributed generation (DG) sources. Power loss is estimated using the forward/backward sweep (FBS) method, and the loss reduction is maximized using particle swarm optimization (PSO). Power factor, and DG location and size are used as optimization parameters. The IEEE 33 bus distribution system and PSS SINCAL software are used to evaluate the proposed solution. Results are presented which show that for the same DG penetration in a distribution system, behind-the-meter, type 3 DG sources can significantly reduce the power loss. Thus, utilities not only benefit from investment cost savings but also higher efficiency in their distribution systems. DG sources are typically renewable energy sources, so environmental concerns are also mitigated.

TS9.4 9:54 ***Load Restoration in Primary Distribution Networks Using the Binary Particle Swarm Optimization***

Hossam El-Din Mohsen El-Dakroury and Ahmed Gad (Ain Shams University, Egypt); Almoataz Abdelaziz (Ain Shams University & Faculty of Engineering, Egypt)

Among the various components installed in the electrical power systems, distribution feeders are the most susceptible to temporary and permanent faults. Line faults are generally inevitable because they occur due to severe weather conditions and/or other natural events. The disconnection of customers from the utility grid affects the reliability indices of the distribution system and might cause several economic and technical problems. This paper proposes an optimized load restoration algorithm for primary distribution networks. The algorithm uses the metaheuristic Binary Particles Swarm Optimization (BPSO) technique to minimize the load shedding while maintaining the radiality of the network and without violating the bus voltage operational constraints. The proposed algorithm has been implemented and tested on the 118-bus distribution system by considering a variety of faults at different locations; the simulation results are exceeding, or at least in accordance with, those published in the literature.

TS9.5 10:12 ***Optimal Prosumer Asset Planning Considering Energy Storage and PV Units***

Eleonora Achiluzzi, Kirushaanth Kobikrishna, Abenayan Sivabalan, Carlos Sabillon and Bala Venkatesh (Ryerson University, Canada)

The use of renewable energy sources and battery energy storage system (BESS) has increased among customers in the distribution system, transforming traditional loads into active prosumers. Therefore, methodologies are needed to provide prosumers with tools to optimize their investments and increase business opportunities. In this paper, a mixed integer linear programming (MILP) formulation is proposed to solve for optimal sizes of prosumer assets, considering the use of a BESS and photovoltaic (PV) units. The objective is to minimize the total cost of the system which is defined as the combination of solar PV system investment, BESS investment, maintenance costs of assets, and the cost of electricity. The developed method defines optimal sizes of PV units, power and energy capacities of the BESS, and the optimal value for initial energy stored in the BESS. The proposed model was tested for three cases. The three cases provide a varying combination of the use of grid power and the use of prosumer assets. The optimal values from each case were compared with each other and the results show that there is potential to achieve more economic plans for prosumer asset sizes.

Friday, October 18 10:30 - 11:00

MB: Morning Break

Friday, October 18 11:00 - 12:30

TS11: Microgrids

TS11.1 11:00 ***A Comprehensive Review on Microgrid Architectures for Distributed Generation***

Haytham Abdelgawad and Vijay K. Sood (Ontario Tech University, Canada)

In the recent years, there has been a growing interest in the concept of microgrids to integrate distributed generation systems like solar photovoltaic (PV) and wind to reduce greenhouse gas (GHG) emissions, to provide higher reliability for critical loads and to supply electricity in areas not served by existing grid infrastructure. A microgrid (MG) is a portion of the electrical system which views generation and associated loads as a subsystem, with the ability to operate both grid connected or islanded from grid, thus maintaining a high level of service and reliability. The existing grid infrastructure, the distributed energy resources to be integrated, as well as specific customer-oriented requirements will determine the best fitting architecture to constitute a microgrid. In this review, most common microgrids architectures based on AC, DC and hybrid AC/DC buses are analyzed. Furthermore, comparisons are made between different microgrid architectures. Positive and negative features of different architectures are given as a guide for further microgrid system studies.

TS11.2 11:18 ***Temporary Faults Behaviour in Multi-Terminal Low-Voltage DC Microgrids***

Khaled Saleh (CanmetENERGY - Varennes & Natural Resources Canada, Canada)

Multi-terminal low-voltage DC (MT-LVDC) microgrids are subjected to faults with low current magnitudes. Although such faults do not disturb microgrids' steady-state operation, their continuous existence can lead to permanent power losses and personnel hazard. Yet, given that faults are often temporary, instantaneous de-energization of the entire microgrid upon fault detection can result in prolonged loss of infeed, i.e., additional energy losses. This paper investigates the behaviour of temporary faults in MT-LVDC in comparison to permanent ones under various conditions. Case studies conducted on a +-750V, TN-S grounded, MT-LVDC microgrid reveal that existing fault detection schemes cannot detect and distinguish between temporary and permanent faults.

TS11.3 11:36 ***Bi-Directional Use of Fault Current Limiters for Microgrid Integration and Protection***

Keaton A. Wheeler (Primary Engineering and Construction & University of Saskatchewan, Canada); Sherif Faried (University of Saskatchewan, Canada)

This paper presents an investigation into the use of superconducting fault current limiters (SFCLs) for microgrid integration into distribution networks and their associated protection systems. SFCLs are investigated for their suitability to prevent loss of coordination between the main distribution network's fuse and recloser protection infrastructure when microgrid integration is present. Additionally, SFCLs are investigated for their suitability in aiding internal microgrid overcurrent protection by assessing their capability of use for bi-directional short circuit current flow. The evaluation is demonstrated through use of the EMTP-RV software with a typical distribution network and microgrid as a test bench.

TS11.4 11:54 ***Control of Green Configuration for Isolated Telecom Tower Base Station Application***

Rezkallah Miloud (ETS & Institut Technologique de Maintenance Industrielle (ITMI), Canada); Ambrish Chandra (Ecola de Technologie, Superieure, Canada); Zoe Feger and Hussein Ibrahim (Cegep de Sept-Îles & Institut Technologique de Maintenance Industrielle, Canada)

In this paper hybrid Wind/Solar/Diesel configuration as the solution to minimize the use of diesel fuel in isolated Telecom tower base stations is studied.To achieve high performance from wind turbine (WT) and solar panels (PVs), DC-DC boost converters are controlled using perturbation and observation (P&O) technique. All DC loads are fulfilling from the DC bus through controlled DC-DC buck converter. To balance the power in the system, lead acid batteries are connected to the DC bus through controlled DC-DC buck/boost converter. The AC-DC interfacing voltage source converter (VSC) is controlled to regulate constantly the AC voltage and frequency using the symmetrical components technique.Diesel generator (DG) is connected to the AC bus through static transfer switch. The performance of the proposed configuration, as well as, the the control strategies, are tested using Matlab/Simulink under load and weather condition change.

TS11.5 12:12 ***Energy Flexibility for an Institutional Building with Integrated Solar System: Case Study Analysis***

Fatima Amara and Vasken Dermardiros (University of Concordia, Canada); Andreas Athienitis (Concordia University, Canada)

Buildings with renewable energy systems and sizeable energy storage capacity can provide significant energy flexibility. Defining appropriate load management strategies requires estimating this flexibility accurately. However, this is no easy task, since the energy flexibility depends on the building structure, heating/cooling system, meteorological conditions, occupant activities, demand response strategy, among other factors. This paper focuses on the thermal storage flexibility of a building component: a concrete floor with an embedded radiant hydronic system. An approach based on a combined adaptive Auto-Regressive model with exogenous inputs (ARX) is used to quantify the thermal energy available in the concrete slab. The model describes the relationship between: (a) the geothermal pump system and weather variables and (b) the temperatures of the indoor air and the concrete surface slab. These temperatures are then used to assess the state of charge (SOC) of the slab. The SOC indicator is critical to reducing heating energy use during peak periods. The performance of the model is evaluated by comparing it with test scenarios: results show that the proposed model can accurately quantify the energy flexibility of the building through performance indicators. Finally, tests using real data confirm the validity of the model as a tool to estimate energy flexibility.

TS12: Electric Mobility

TS12.1 11:00 ***Toward a Reliability Model of Electric Vehicle Fleet for Power System Adequacy Assessment Considering Repairable AMIs***

Ali Hajebrahimi (Laval University, Canada); Innocent Kamwa (Ireq, Canada)

Plug-in electric vehicle (PEVs) in demand response programs (DRPs) have indicated a great potential to enhance power system reliability by reducing their charging demand. However, PEVs often fail to reduce their load due to some external factor. Herein, an analytical approach for reliability modeling of aggregated PEVs, the so-called electric vehicle fleet (EVF), is presented. A systematic method based on frequency and duration approach is utilized to model an EVF similar to that of a multi-state conventional unit, where the probability, frequency of occurrence, and departure rate of each state are acquired. The proposed methodology is capable of considering uncertainty of customer participation in DRPs for both flexible and inflexible PEVs. Interval data, which is the core deliverable of advanced metering infrastructure (AMI), is essential for PEVs to participate in DRPs. Thus, the impact of AMI failure is investigated on the implementation of EVFs in reliability assessment. Several important factors such as different penetration level of EVFs are taken into account in the analysis. The hourly historical data is employed to achieve the customer's participation regime. The Roy Billiton test system and IEEE-RTS are used to trace the capability of proposed EVF reliability model.

TS12.2 11:18 ***Optimized Electric Vehicles Charging in an Urban Village Network Considering Transformer Aging***

Chitchai Srithapon (Provincial Electricity Authority (PEA), Thailand); Prasanta Ghosh (Syracuse University, USA); Apirat Siritaratiwat and Rongrit Chatthaworn (Khon Kaen University, Thailand)

Electric vehicle (EV) replacing internal combustion engine may be the solution to the PM2.5 pollution issues. However, uncontrolled increase of EVs would challenge the power -distribution-system operation, which includes reduction of distribution transformer lifetime. Therefore, it is necessary to implement some level of control over EV charging procedure especially in the urban village. In this paper, we present an optimization method for EV charging considering a transformer age factor in urban village environment. The optimized strategy focuses on the reduction of the charging cost, energy losses and peak load power. The optimization problem is solved using the Genetic Algorithm (GA) in MATLAB. As a case study, we have used data from the village Udon Thani, Thailand to demonstrate the applicability of the proposed method. Simulation results show reduction in EV charging cost and network energy losses. In addition, application of the proposed method prolongs transformer lifetime, which benefit both EV owner and distribution system operator.

TS12.3 11:36 ***Impact of Spatial-Temporal Driver's Behaviours on PEV Charging Demand***

Yasser O Assolami, Ahmed Gaouda and Ramadan El-shatshat (University of Waterloo, Canada)

This paper investigates the impact of the driver's dynamic behaviors on the demand of charging Plug-in Electric Vehicles (PEVs). The presented work in this study focuses on modeling the temporal-spatial characteristics of the driver's daily activities based on obtaining all statistical valuable information from the National Household Travel Survey (NHTS) data. The proposed work considers multiple trips per day and takes into account driver's movement, driving duration, driven distance, and parking duration. The trip chain, bases on the Monte Carlo Markov Chain (MCMC) process, is developed to properly model the driver states during the day. Charging facilities are assumed to be available at home, work, and DC Fast Charging Stations (FCSs), within charging levels of 3.7 kW, 6.6 kW, and 50 kW, respectively. In this work, the impact of PEV charging at multi locations is discussed, and is followed by studying the impact of PEV market share versus Tesla S. The proposed work overcomes the disadvantages in the oversimplified models of PEV charging demand by providing a more robust and realistic representation of driver behaviors.

WIE: WIE Panel

Diversity and Inclusion in the Climate Change Sector