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Monday, December 5

Monday, December 5 7:00 - 8:00

Opening Session

Monday, December 5 8:10 - 9:00

Keynote 1

Monday, December 5 9:10 - 10:00

Keynote 2

Monday, December 5 10:10 - 11:40

WIE Panel

Monday, December 5 11:50 - 13:30

S1: AC/DC Power Quality

Chair: Walid Morsi (Ontario Tech University (UOIT), Canada)

11:50 ***An Improved Z-Source Multilevel Converter with Fewer Number of Switches, Less THD, and High Efficiency.....1***

Abolfazl Babaei (University of Manitoba, Canada); Waldemar Ziomek (PTI Transformers LP, Canada); Aniruddha Gole (University of Manitoba, Canada)

In this paper, a suitable structural design for a zsource multilevel converter is proposed. The main goal of the proposed structure is to achieve better results in terms of efficiency and losses and as well as using a fewer number of components. The proposed structure is examined in PSCAD software under a resistive and resistive inductive load to check the efficiency and the value of Total Harmonic Distortion (THD). The results prove that the proposed Z-source converter has less THD and higher efficiency than the other existing structure. The further detailed information from simulation results is shown that the proposed Z-source increases the efficiency up to almost 5% for the resistive load and up to 10% for the resistive and inductive load.

12:10 ***A Novel Totem-Pole Buck LED Driver with Minimal Power Processing.....7***

Sanchayan Das (National Institute of Technology, Warangal, India); Chinthamalla Ramulu and Manikanta Kuraganti (National Institute of Technology Warangal, India)

This paper proposes an totem-pole power factor correcting LED driver topology with minimal power processing. Minimal power processing is achieved through by-passing majority portion of the power directly to the load and process the minimum power required through a buck converter to maintain constant output current. As the power is processed only once and the usage of totem-pole topology

improves the overall driver efficiency. The output power is maintained constant using two switches. One is used for by-passing the current directly from the source to the load and the other one is used to supply current from the storage capacitor to the load as per requirement. The required storage capacitor value is also very less when compare to standard LED driver capacitance. So, electrolytic capacitors are eliminated with film capacitors. The buck converter and PFC stage totem-pole boost converter both function in DCM. The DCM operation allows the use of much low valued inductor. As the totem-pole boost PFC stage is operated in DCM mode the power factor of the driver remains very close to unity. The proposed LED driver simulated at the power level of 60w.

12:30 *Selective Harmonic Elimination in Cascade H-Bridge Multilevel Voltage Source Inverters Using A Hybrid Optimization Algorithm.....13*

Hamed Madani (Islamic Azad University, Iran); Hamidreza Mosaddegh and Xiaodong Liang (University of Saskatchewan, Canada)

To eliminate harmonics from output voltage waveforms of a multilevel voltage source inverter, the pulse width modulation (PWM) technique for selective harmonic elimination (SHE) can be performed at a low switching frequency, which reduces switching losses and increases the energy conversion efficiency in medium voltage and high power applications. The SHE strategy provides the optimal output voltage by maintaining the desired fundamental voltage component while eliminating lower order harmonics. This paper presents a hybrid optimization method based on the combination of the genetic algorithm (GA) and the simulated annealing (SA) to achieve a faster and more accurate optimal solution for the harmonic elimination problem. The advantages of the proposed hybrid algorithm compared to some other optimization methods include the speed that reaches the global minimum and the acceptable convergence rate considered in the performance analysis of the inverter. Simulation results show the superiority of the proposed hybrid algorithm by comparing either GA or SA alone.

12:50 *Study of the Bus Voltage Magnitude to Monitor Power Quality in the Distribution System.....18*

Christopher R Men, Douglas E Dow and Afsaneh Ghanavati (Wentworth Institute of Technology, USA)

Power quality disturbances can be observed as sags, swells, transients, and harmonics, and can affect customers at varying levels of intensity. It is the responsibility of the utility to supply customers with power, however power quality disruptions can occur during distribution. Traditionally, only voltage information is used to conduct power quality monitoring at the distribution level. It is common to record the RMS values of the bus voltages and to identify abnormal operations based on when a sag or swell occurs. This paper proposes a tool consisting of an algorithm and an accompanying graphical user interface (GUI) that can display historical voltage bus data, analyze the data, and provide the user with information that details voltage behavior outside of a user-defined threshold. The GUI gives the user the interactive ability to import data and set the desired threshold. The algorithm then detects events in the imported data outside of the chosen threshold. It also provides the user with event durations, magnitudes, local maximums, and area. The efficacy of the algorithm was verified by comparing the output determined by the algorithm versus the conclusion drawn by a human observer. Additionally, this paper provides a brief overview of two power quality curves: the Computer and Business Equipment Manufacturers' Association (CBEMA) curve, and the Information Technology Industry Council (ITIC) curve. These curves have been utilized in

past decades as the common mechanisms to identify voltage variations and the duration of disturbances. Although these curves have proven to have great merit for use as tolerance curves, they may not capture all the necessary details of the events for power quality characterization.

13:10 ***A Dynamic Series Voltage Regulator for Load Protection in Bipolar DC Power System.....24***

Ramin Babazadeh Dizaji (Concordia University, Canada); Mohammad Hassan Ghaderi (University of Texas at Dallas, USA); Mohsen Ghafouri (Concordia University, Canada); Mohsen Hamzeh (University of Tehran, Iran)

The low-voltage DC distribution systems are comprised of various components with a wide range of power ratings. In such systems, compared with unipolar configurations, bipolar structures bring considerable superiority in terms of efficiency, safety, and compatibility. However, the scarcity of protection methods has restricted the expansion of bipolar DC grids. In line with this trend, this paper presents a dynamic series regulator (DSVR) for the protection of sensitive loads in bipolar DC distribution systems. The proposed DSVR injects dynamic voltage for a set of selected sensitive loads to suppress the probable voltage abnormalities in the system. Therefore, it provides desirable satisfaction of voltage quality metrics in bipolar DC power systems. The proposed DSVR is composed of a multi-active bridge converter with one primary and two secondary windings followed by two full-bridge DC-DC converters. To evaluate the feasibility and effectiveness of the proposed concept, various simulations of several case studies are carried out in the PLECS (Plexim) software.

S11: HVDC, FACTS, and High-Power Converters

Chair: Vijay K. Sood (Ontario Tech University, Canada)

11:50 ***Robust PID Controller Design for DC-DC Converters: The Buck Converter.....30***

Siddhartha Vishwanatha (CVR College of Engineering, India); Yogesh Vijay Hote (Indian Institute of Technology Roorkee, India)

In this paper, a new robust PID controller design approach for uncertain models is presented. The most popular Kharitonov's theorem and stability boundary locus (SBL) method are utilized to design robust controller to achieve the robust stability and performance. The main advantage of this approach is that only four transfer functions are sufficient for the controller design from the family of interval plant transfer functions. Here, voltage mode control of perturbed DC-DC buck converter has been taken as an example for investigation of proposed PID controller performance. The presented theory is verified through simulations in MATLAB/SIMULINK environment and validated through experimental results using DSPACE DS1104.

12:10 ***Negative-Sequence Current Control with a Hybrid Three-Level Modular Multilevel Converter.....38***

Levi Bieber (University of British Columbia, Okanagan, Canada); Paul Yoo (University of British Columbia Okanagan, Canada); Liwei Wang and Juri Jatskevich (University of

British Columbia, Canada)

The new class of hybrid cascaded multilevel converters (HCMCs) brings numerous benefits to the field of voltage-source-converter high-voltage direct-current (VSC-HVDC) technology. The HCMCs enable highly efficient and compact AC/DC converter stations with a simpler physical implementation compared to the state-of-the-art modular multilevel converter (MMC) technology due to their tighter physical spacings of semiconductor and capacitor components. However, there is a question whether the HCMCs can provide negative-sequence current suppression control to AC grids during unbalanced operations, e.g., single-phase-to-ground faults. This paper demonstrates both normal and fault operation scenarios for an emerging HCMC, the recently pro-posed hybrid three-level converter (H3LC), to verify its utility even under highly unbalanced grid conditions. The H3LC is shown to reliably ride through highly unbalanced grid conditions while suppressing the negative-sequence current.

12:30 *Hybrid CPU-GPU-Based Electromagnetic Transient Simulation of Modular Multilevel Converter for HVDC Application.....44*

Walid Ali Hatahet and Liwei Wang (University of British Columbia, Canada)

Modular multilevel converter (MMC) is one of the key components for in modern high voltage DC (HVDC) transmission systems. Fast and accurate electromagnetic transient (EMT) simulation of the MMC is crucial to capture the finest dynamics and transients required for proper planning, design and control prototyping of multiterminal DC (MTDC) grids. This paper proposes a hybrid high-performance computing platform for the simulation of the HVDC transmission system based on graphics processing unit (GPU). An EMT program is developed to implement the discrete time model for the two-terminal modular multilevel converters. The high computational power of the hybrid CPU-GPU platform is utilized to simulate all components in the HVDC system by capturing the detailed dynamics and transients. Moreover, a parallel GPU-based simulation algorithm is presented in the paper. The proposed algorithm provides an advanced solution for balanced distribution of simulation tasks on both the CPU and GPU to exploit the available resources on GPU at low communication latency without any compromise of the simulation accuracy. The results obtained from the proposed hybrid platform show high accuracy compared to the results obtained from Matlab/Simulink/Simscape/Specialized Power System model using the same network parameters. The proposed CPU-GPU MMC model is shown to achieve a speed up of 27.5 folds, compared the sequential algorithm of MMC model implemented in CPU.

12:50 *Comparison of Different Types of FCLs Effect on the Transient of VSC MT-HVDC System.....50*

Jalal Sahebkar Farkhani (Aalborg, Denmark); Kaiqi Ma (University of Aalborg, Denmark); Zhe Chen (Aalborg University, Denmark); Claus Bak (Aalborg University Denmark, Denmark)

Low impedance and lack of zero crossing during the fault become great challenges in DC systems especially in the multi-terminal (MT) high voltage direct current (HVDC). High short circuit current threatens the power electronic devices and stability in the DC systems. Fault current limiters (FCLs) are promising solution to address the fault current problems. This paper investigates the effect of different types of FCLs on a transient performance, fault current limitation, fault current suppression time (TFCS) on the MT-HVDC system. First the performance of different types of FCLs based on the inductor are presented. The conventional inductive FCL (IFCL), bypass FCL (BPFCL) and series-parallel FCL (S-PFCL) performance

compare with each other and a case study without FCL (WFCL) during the faults. Two kinds of transient fault are considered to analyze the FCLs performance based on the permanent and temporary faults in this study. Result shows the different types of FCL can affect the transient of the DC systems. The case study is performed by using PSCAD/EMTDC software.

13:10 ***A Modified Modulation of WE-Type Multilevel Inverter for Enhanced Output Voltage Capability.....56***

Mohammad Ali (KIng Fahd University of Petroleum & MInerals, Saudi Arabia); Muhammad Khalid (King Fahd University of Petroleum and Minerals, Saudi Arabia)

A peak output voltage with a unity modulation index is desired at the output of the multilevel inverters with boosting capability. The operation of the inverter at a lower modulation index leads to lower boosting in the fundamental component of the output voltage, and hence an underrated inverter performance is achieved. Recently, an 11-level WE-Type inverter with 1.25 boosting was proposed. It was found that the level formation was hindered due to improper capacitor voltages if the modulation index was greater than 0.94, thus rendering the boosting capability to 1.175. In this work, a modified pulse width modulation is implemented on this inverter, which will enhance its capability of maximum boosting of 1.25 by making it operational at the unity modulation index. The analysis of the work is presented and supported by simulation results in MATLAB/Simulink environment.

Monday, December 5 11:50 - 13:50

S2-S3: Cyber Security

Chairs: Bingxian Mu (University of New Hampshire, USA), Mostafa Taha (Carleton University, Canada), Chengcheng Zhao (Zhejiang University, China)

11:50 ***Virtualized Experiential Learning Platform for Substation Automation and Industrial Control Cybersecurity.....61***

Moein Manbachi, Jay Nayak, Mohamed Hammami and Alejandro Gonzalez Bucio (British Columbia Institute of Technology, Canada)

With the rapid spread and advent of Industry 4.0 tools and technologies, including IoT, Machine Learning, cloud, virtualization, and digital twins, many organizations around the globe have recently started to either retrain their workforce or hire experts from other industries with relevant experience to incorporate such technologies into their systems. In many cases, this transition requires hands-on experience that could be gained through hands-on training programs. However, providing such programs has become challenging with remote working routines. A Virtualized Experiential Learning Platform (VELP) has been developed recently by BCIT's Smart Microgrid Applied Research Team with the support of Future Skills Centre and industrial partners in order for trainees to get hands-on experience in critical energy infrastructure studies such as substation automation systems, microgrids, and industrial control cybersecurity. Through virtualization technologies such as digital twins, real-time simulation, and cloud, trainees can gain an adequate level of experience working with virtualized as well as physical assets and systems remotely. This paper primarily reviews VELP's features and functionalities. It then describes the steps for developing

a reliable and secure virtualized experiential learning platform. Last but not least, the paper explains VELP's tools for industrial control cybersecurity training and proposes a cyber-secure topology with its components to keep such virtualization platforms cyber-secure against cyber threats.

12:10 ***On Propagation of Cyber-Attacks in Wide-Area Measurement Systems.....67***

Hamed Sarjan and Amir Ameli (Lakehead University, Canada); Mohsen Ghafouri (Concordia University, Canada)

Power grids are critical cyber-physical systems that employ advanced Information and Communication Technologies (ICTs), e.g., Wide Area Measurement Systems (WAMSs), to deliver the energy to end users reliably and efficiently. WAMSs are used to collect real-time data from Phasor Measurement Units (PMUs) to improve the operator's situational awareness, as well as to enhance real-time monitoring and control of power systems. The WAMS, however, is vulnerable to cyber-attacks due to susceptibility of its components---such as PMUs and Phasor Data Concentrators (PDCs)---and lack of embedded security mechanisms in its communication protocols. Some more-destructive cyber-attacks, such as malware injection, can propagate themselves into the components of a WAMS through the communication network. Thus, in such attacks, an attacker can compromise a larger number of components, resulting in more-severe consequences. Therefore, investigating propagation of cyber-attacks in WAMSs and devising effective countermeasures for this problem are of paramount importance. On this basis, this paper initially develops a model to analyze cyber-attack propagation in WAMS. Then, the impacts of the attacker's capability and network operator's defensive ability on attack propagation are investigated in detail. Such a study can elucidate the required security measures and defensive strategies to prevent the spread of cyber-attacks in WAMSs. Finally, a Learning-Based Framework (LBF) is developed to estimate the attacker's capability. The simulation results corroborate the effectiveness of the proposed LBF in estimating the attacker's capability.

12:30 ***Detection of FDI Attacks on Voltage Regulation of PV-Integrated Distribution Grids Using Machine Learning Methods.....73***

Masoud Ahmadzadeh, Ahmadreza Abazari and Mohsen Ghafouri (Concordia University, Canada)

The integration of photovoltaic (PV) panels in power distribution systems (PDSs) has provided the grid with the capability to regulate voltage through the injection or absorption of reactive power. The deployment of information and communication technologies (ICTs), which is required for this voltage regulation scheme, has made the PDS prone to a variety of cyber attacks, e.g., false data injection (FDI) attacks. To counter these attacks, this paper proposes a data-driven detection framework to identify FDI attacks against voltage regulation of PV-integrated PDS. To regulate the voltage at a desired location, e.g., the point of common coupling (PCC), the voltage measurements are sent to a centralized controller and the calculated control signals are transmitted back to PVs to be added to their internal control schemes. During this transmission of data, an attacker manipulates the measurement data and launches an FDI attack leading to an unacceptable voltage profile and operation of protection systems. To detect these attacks, a machine learning (ML)-based framework based on a support vector machine (SVM) is developed in this research. In this regard, a dataset of different operating points, e.g., loading conditions, is collected to train this supervised framework. The performance of the trained framework for attack detection has been compared with other supervised and unsupervised ML-based techniques in the case of FDI attacks against modified

IEEE 33-bus PDS. The obtained results demonstrate the superior performance of the proposed framework in detecting FDI attacks.

12:50 ***Cyber-Security Vulnerabilities of the Active Power Control Scheme in Large-Scale Wind-Integrated Power Systems.....79***

Mostafa Ansari (Concordia University, Canada); Mohsen Ghafouri (Assistant Professor, Canada); Amir Ameli (Lakehead University, Canada)

The vast integration of wind energy, particularly doubly-fed induction generators (DFIGs), can harden the frequency control of modern power systems. This problem, which occurs due to the inertial decoupling of the generators from the grid, is often mitigated by wind farms active power controller (WFAPC) that enables the frequency response of wind turbines (WTs). The operation of this controller requires the deployment of communication and cyber layers in the wind farms (WFs), which consequently make them prone to cyber threats. In this paper, the vulnerabilities of WFAPC are identified, and the attack scenarios based on those vulnerabilities as well as their corresponding impacts on the frequency response have been investigated. Initially, the dynamic model of the wind-integrated power system is obtained and a WF's frequency response strategy has been selected. Then, the possible attack scenarios are modeled and discussed using simulations, which are performed in MATLAB/SIMULINK. The results demonstrated that even a simple cyber-attack against WFAPC can severely damage the stability of the grid and WF, and consequently result in equipment damage or blackout.

13:10 ***Detection and Mitigation Methods of Attacks on Low-Inertia Hybrid Microgrids: A Short Survey.....85***

Ahmadreza Abazari and Mohsen Ghafouri (Concordia University, Canada); Ribal Atallah (Hydro Quebec Research Institute, Canada); Chadi Assi (Concordia University, Canada)

Hybrid microgrids (MGs) are used to integrate renewable energy sources (RESs) into power grids and provide the capability to operate autonomously, meet environmental criteria, and serve the grid loads. As such, sophisticated control schemes are required to address these operational issues. Mentioned control strategies generally require up-to-date communication structures which make MGs more vulnerable to cyber intrusions. Given the increasing popularity of MGs among stakeholders and consumers, this paper studies cyber-physical security in hybrid MGs from the viewpoint of low-inertia hybrid MGs. In this survey, initially, we provide an overview of the terminology used in the context of hybrid microgrid security, e.g., existing communication networks, control strategies, cyber layers, and threats against renewable energy sources. Then, the gradient evolution of detection and mitigation methods, which can help in discovering proper future research directions, are studied.

13:30 ***A Secure Time-Based Bad Data Detection Algorithm for State Estimation.....91***

Roy McCann (University of Arkansas, USA); Hamdi Albunashee (Open Systems International, Canada)

Conventional state estimation (SE), which is essential for energy management systems (EMS), has been proven vulnerable to a crafted false data injection attack (FDIA). This research investigates the formulation

of FDIA and shows that the attack utilizes the fact that the exact measurements vector is used by the SE and bad data detector but at different time stamps (before and after the execution of the state estimation process). This paper proposes a time-based bad data detection (TB-BDD) algorithm that detects the FDIA. The proposed algorithm is validated in real-time environments to verify the algorithm's effectiveness, which can be deployed in the EMS without a significant change to the SE framework.

S4: Data Analytics, Artificial Intelligence, and Machine Learning

Chair: Shichao Liu (Carleton University, Canada)

11:50 *An Android-Based Application to Detect COVID-19 and Pneumonia Using Deep Learning.....97*

Shuva Chowdhury, Faijul Abedin, Istiak Ahamed Saif and Amirul Ahsan Simon (North South University, Bangladesh); Riasat Khan (North South University, Bangladesh & New Mexico State University, USA)

The novel coronavirus disease has produced destructive effects on human life, taking away millions of lives. The biggest bottleneck in detecting the COVID-19-affected patient is the limited availability and time-consuming features of conventional RT-PCR tests and the lack of specialized sample extraction laboratories. Early detection of this virus may help in the advancement of a medication approach and disease control strategies. In this research, we have developed an Android smartphone application that can detect pneumonia and COVID-19 from chest X-ray photographs using convolutional neural network deep learning algorithms (VGG16 and VGG19). The COVID-19, pneumonia, and healthy chest X-ray images are collected from various repositories of a public database, Kaggle. After applying the data augmentation technique, 9,000 chest X-ray photographs were used for training, including 3,000 images for COVID-19, pneumonia, and normal cases. For testing, 3,000 chest X-ray photographs were collected, with 1,000 images for all three cases. VGG16 model achieved better performance than the VGG19 with a training accuracy of 98.31% and validation accuracy of 95.03%. Next, the deep learning-based automatic classification framework is deployed into a smartphone application. Finally, the application has been tested and assessed by a focused group, and analytical results have been presented.

12:10 *An Accelerated and Risk-Free AC Power Flow Method with Machine Learning Based Initiation.....103*

Ming Dong and Daniel Wiebe (Alberta Electric System Operator, Canada); Jian Shi (University of Houston, USA)

In recent years, the dynamics of power system has increased drastically due to faster load and generation variations. This has imposed challenges to both power system operation and planning. As a result, reducing the power flow computation time has become highly desired, especially for large power networks. In previous research works, the linearization approach may introduce errors in cases where the linear assumptions do not hold true; the conventional pure data-driven approach requires significant training effort and can be risky to systems with high variability due to its "black-box" nature. This paper proposes a risk-free method to accelerate AC power flow with machine learning based initiation: first, 4 machine learning models are used for estimating the initial PF solution; then the initial PF solution is taken

as the warm-start point and fed into the Newton-Raphson stage to accelerate its converging speed. Comprehensive experiments are conducted on 4 power networks covering small to large sizes. The experiment shows the PF solution time can be reduced by 24% to 64% with lossless accuracy. The approach also demonstrates great robustness to system scenario change.

12:30 ***Forecasting of Solar Energy Generation via Dynamic Model Ensemble.....109***

Xijuan Sun and Di Wu (McGill University, Canada); Menghan Jia (Zhejiang University, China); Yuxuan Xiao (College of Letters an Science, USA); Benoit Boulet (McGill University, Canada)

Solar energy has attracted attention in many countries because of global warming and environmental degradation issues. Using solar energy assists to reduce carbon emissions and slow the pace of global warming. With the widespread application of solar energy in society, stable generation of solar energy is essential to people's daily life and the functioning of society. However, various external conditions on which solar energy depends, such as temperature and cloud cover, are uncontrollable. Thus, without proper forecasting, solar energy generation is not reliable, and accurate prediction of solar energy generation is the key to ensure the power supply of society. In this work, we propose a dynamic ensemble model with several base learners to forecast solar energy generation. Specifically, in the training phase, multiple base learners are trained to forecast one-hour ahead solar energy generation by considering 24-hour historical data. In the testing phase, for each test sample, we select an ensemble of base learners with different weight contributions. Such an ensemble is chosen by considering the performance of base learners on the neighboring samples of the test sample in the training set. The final forecast of our proposed model is the weighted average of predictions of the selected base learners. Experiments on the solar energy generation dataset from Australia demonstrate the effectiveness and robustness of our proposed method, where our model outperforms all baselines.

12:50 ***Power System Anomaly Detection via Ensemble of Encoder and Decoder Networks.....116***

Xijuan Sun and Di Wu (McGill University, Canada); Arnaud Zinflou (Hydro-Quebec, Canada); Benoit Boulet (McGill University, Canada)

With the wide application of different types of electrical appliances, the security of power grids has become particularly significant for the secure operation of power grids. Hacking and false data injection from adversaries threaten power grids' normal operations, causing economic loss. Hence, anomaly detection is essential for keeping power systems working properly and efficiently. Anomaly detection on power grids often requires modeling the distribution of normal data. In this work, we propose a novel anomaly detection method by using multiple en- coders and decoders to reconstruct input data and learn the data distribution of normal samples. Specifically, multiple encoder- decoder-encoder networks are employed. The model maps input samples into a latent space and then reconstructs output samples from latent vectors. The extra encoder finally maps reconstructed samples into their latent representations. During the training phase, parameters are optimized by minimizing reconstruction loss and encoding loss. During the training process, training samples are re-weighted so that our model can focus on missed correlations among features of normal data. Experiment results on network intrusion and power system datasets demonstrate the effectiveness of our proposed method, where our model consistently outperforms all baselines.

13:10 ***Electric Vehicle Charging Behavior Prediction Using Machine Learning Models.....123***

Prashanth Rajagopalan (University of North Dakota, USA); Prakash Ranganathan (University of North Dakota, United Kingdom (Great Britain))

The global spread of the COVID-19 pandemic has significantly impacted the electric vehicle (EV) industry. The lockdown restriction has resulted in a significant shift in the use of public charging infrastructures. This paper investigates the effects of COVID-19 on electric vehicle users' charging behavior before, after, and during COVID-19 lockdown restrictions, using the data from a public charging facility from the City of California. In this study, we performed data visualization using K-means and hierarchical clustering analysis. This work uses the vehicle's connection and disconnection time to identify common charging pattern identification and charging behavior where K- means clustering outperforms the hierarchical clustering for all three different scenarios modelled. In addition, prediction of collective charging session duration is achieved using Machine Learning Models, Random Forest and XgBoost. We achieved a mean absolute percentage error (MAPE) of 0.146 and 0.151 percent for XgBoost and Random Forest respectively.

13:30 ***Minimalistic LSTM Models for Next Day Hourly Residential HVAC Energy Usage Forecasting.....129***

Rahman Heidarykiany and Cristinel Ababei (Marquette University, USA)

Accurate electrical energy demand forecasting is essential to optimization and operation approaches aimed at reducing the cost of electricity at the consumer and utility level. Machine learning models, such as long short-term memory (LSTM) models, have been increasingly employed in energy usage prediction for different time-horizons into the future. The prediction accuracy of such models depends a multitude of model architecture and model training parameters, that are often left at their default values or the strategy of selecting them is not even reported. In this paper, we present a thorough investigation of the impact of fifteen different such parameters on the performance of LSTM models used to forecast HVAC energy usage in typical residential homes for 24 hours. The objective is to arrive at a select number of practical LSTM models, which are trained and tested on data generated from the equivalent of a 21 year long simulation of a testbed based on the IEEE 13 node test feeder. Our investigation reveals several remarkable characteristics that the highest ranked in terms of prediction accuracy LSTM models have in common: models can use as few as two layers, training should use more equivalent years of data available, batch size should include 24 days of data, and the best optimizer used during training is RMSprop.

S6-S7: Power System Protection and Wide Area Protection

Chairs: Balakumar Balasingam (University of Windsor, Canada), Vijay K. Sood (Ontario Tech University, Canada)

11:50 ***A Novel Zero-Crossing Point Calibration-Based Data Synchronization Approach for an Underground Cable Fault Localization Platform.....137***

Md Salauddin and Tongkun Lan (University of Saskatchewan, Canada); Chi Yung Chung (The Hong Kong Polytechnic University, China); Seok-Bum Ko (University of Saskatchewan, Canada); Seyed Mahdi Mazhari (University of Tehran, Iran)

The double-ended measurement-based approach has been widely incorporated in the underground fault localization domain due to high localization accuracy. However, this approach generally requires costly GPS time receivers to synchronize the data at both ends, while the GPS would face satellite invisibility, atmospheric condition problems, and the installation constraint for deep underground cable. This paper proposes a zero-crossing point-based approach, where the zero-crossing point before the fault time from both ends of the cable is identified and calibrated to synchronize the measurements. With the proposed method, the measurements could be synchronized at a low cost without a GPS device. The performance of the proposed technique is evaluated via simulations of an underground cable system modeled in PSCAD, followed by a discussion on results.

12:10 *Comparative Study of Phasor Estimation Techniques Applied on Distance Protection.....143*

Fillipe de Almeida Andrade (UFRB, Brazil); Huilman Sanca Sanca (Federal University of the Recôncavo of Bahia & UFRB, Brazil); Francisco das Chagas Souza Junior (IFRN, Brazil); Pedro Henrique Aquino Barra (UFRB, Brazil)

In this paper, a comparative analysis of phasor estimation techniques applied to distance protection in electric power transmission lines is presented in order to highlight their main characteristics under different fault situations. Phasor estimation is one of the primary steps in analyzing electromagnetic transients and protecting electrical power systems. Therefore, high performance is crucial for better system operation. Three techniques are implemented and analyzed in this paper: the FullCycle Discrete Fourier Transform (FCDFT), Half-Cycle Discrete Fourier Transform (HCDFT), and Full-Cycle Cosine. In order to compare the performance of the implemented techniques, a 230 kV electrical power system with a 180 km transmission line is simulated under different fault situations. The simulation results showed that the FCDFT presented the best performance compared to HCDFT and Full-Cycle Cosine. However, the FullCycle Cosine technique achieved a higher speed to detect changes in the circuit's behavior, implying a faster response to the distance protection.

12:30 *Fast and Reliable Load-Shedding Scheme for Wastewater Treatment Plant - A Case Study.....149*

G. M. Asim Akhtar (Schweitzer Engineering Laboratories, Inc., USA); Muhammad Waqar Waqar Ahmed (Schweitzer Engineering Laboratories Inc, Canada); Will Allen (Schweitzer Engineering Laboratories Inc, USA); Perry Zhang (The City of Calgary, Canada); Kyle Jensen (Stantec Inc, USA); Sujay Dasgupta (Schweitzer Engineering Laboratories Inc, USA)

Innovations in the fields of automation and networking have helped traditional power system substations evolve. Intelligent electronic devices (IEDs) accompanied by optimized and smartly engineered communications networks have provided engineers with opportunities to better design and implement various algorithms. Therefore, in the event of a disturbance or fault, the power system stability and process survivability are maintained.

Power systems are proven to have more stable operation while connected to a utility; however, the challenge arises when the power system is islanded and suffers from a loss or an excess of generation. In an

islanded configuration, fast and selective shedding of loads and/or generators based on system topology is critical in responding to system disturbances to avoid blackouts and ensure minimum process downtime.

This paper presents a real-world implemented load-shedding scheme (LSS) for a North American wastewater treatment plant. The LSS was deployed in two tiers of primary and secondary controls via redundant substation-hardened controllers. The primary shedding system is based on calculation of a predictive power deficit or surplus for various predetermined contingency events. The primary system issues shedding decisions upon contingency detection, whereas the secondary shedding system is based on triggers asserted by underfrequency and/or overfrequency protective relays.

The paper also provides an overview of the implemented network scheme; however, a detailed discussion regarding engineering and performance will be included in the authors' future work.

12:50 *Bay Control Unit in an IEC 61850 Environment: A Generalized and Systematic Process Flow for Optimized Configuration.....157*

G. M. Asim Akhtar (Schweitzer Engineering Laboratories, Inc., USA); Muhammad Sheraz (Schweitzer Engineering Laboratories Inc, USA); Muhammad Waqar Waqar Ahmed (Schweitzer Engineering Laboratories Inc, Canada)

The bay control unit is a fundamental component of an electric power substation that is required to perform various bay operations based on predefined control logic. It acts as an interface between the operator and the field devices in the bay. With the advent of substation automation systems, especially in IEC 61850 environments, communications settings have become a core requirement for data exchange among the devices. In order for a bay control unit to perform the required automation and control functions in an IEC 61850 environment, communications settings need to be based on an optimized process flow. This paper presents an optimized procedure for configuring a bay control unit in an IEC 61850-based substation automation system with emphasis on referring to the right engineering document to set a given parameter. This paper is based on a commissioned 110 / 13.8 kV substation with a double-busbar scheme and a substation automation system that uses IEC 61850 protocols. The paper discusses practical aspects of configuring an intelligent IEC 61850-based bay control unit and explains the role and importance of required engineering documents.

13:10 *A Routine to Represent the Frequency-Dependent Nodal Admittance Matrix of Short Cables on Complex Structures in the ATP-EMTP Using the Lumped Parameter Model and the CST Studio Suite.....164*

Pablo Torrez Caballero (Sao Paulo State University, Brazil); Antonio Roberto Panicali (CPQD, Brazil); Eduardo F Costa (CPqD - Research and Development Center in Telecommunications, Brazil); Ricardo Hiroshi Minoda (Fundação CPqD & Unicamp, Brazil); José Pissolato Filho (Universidade Estadual de Campinas (UNICAMP), Brazil); Felipe Ricordi Gismoti Guimaraes, Carlos Andre Carreiro Cavaliere, Vinicius Zimmermann Silva and Marcos Leonardo Ramos (PETROBRAS, Brazil)

Simulation of current distributions in groups of cables directly in the time domain using finite element method software is a computationally expensive task. The time to carry out these simulations in the time

domain increases as the structures become large and complex, and the frequencies involved become in the order of power frequencies. In contrast, the time to solve these same simulations in the frequency domain is relatively low. One issue with frequency domain simulations is the inclusion of nonlinear elements. This paper proposes a routine that combines finite element method software and circuit solvers. Our approach drastically reduces simulation times and can include nonlinear elements. First, we use CST Studio Suite to compute the frequency-dependent nodal admittance matrix of a group of cables. The ATP-EMTP does not have an interface to work directly with frequency-dependent data. Therefore, for the simulation of short cables, we compute an equivalent multi-conductor pi circuit, which has a nodal admittance matrix similar to the nodal admittance matrix calculated by the CST Studio Suite. The resulting pi circuit is coded into a custom PCH file that the ATP-EMTP recognizes as one of its native transmission line models, the coupled pi circuit. We use this methodology to simulate a phase-to-ground fault in an electrical panel within a ship. Our methodology shows the distribution of fault currents among cables, shieldings, and the hull.

13:30 ***Shunt Capacitor Bank Fault Detection and Localization Using Sub-Cycle Algorithm.....170***

Mohsen Tajdinian (Shiraz University, Iran); Behzad Behdani (Delft University of Technology, The Netherlands); Ali Goodarzi (Fars Electricity Distribution Company, Iran); Harold R. Chamorro (RTH Royal Institute of Technology, Colombia); Vijay K. Sood (Ontario Tech University, Canada)

Fast internal detection and location in Shunt Capacitor Banks (SCBs) can lead to the prevention of damages to other SCBs' elements and consequently avoid undesirable performance and effects in power system operation. This paper targets the performance of phasor-based algorithms of failure detection and fault location of SCBs. Being dependent on the fundamental phasor components which usually are calculated based on the Discrete Fourier Transform (DFT), the failure detection and fault location algorithms suffer from almost one-cycle delay. This paper provides sub-cycle phasor estimation based on the least-square technique. The proposed algorithm is evaluated for different configurations of SCBs considering different fuse protection designs. The proposed method provides a criterion for relay decision making in the case of multiple faulty phases condition. The proposed method is designed to monitor and detect consecutive failures based on the existence data of commercial relays. Performance evaluations are conducted under different circumstances namely voltage unbalance conditions, and multiple internal fault locations.

Monday, December 5 11:50 - 13:30

SS1: Special Session - Approaches for Robust Battery Management Systems

Chairs: Balakumar Balasingam (University of Windsor, Canada), Seyed Masoud Mohseni-Bonab (Hydro-Quebec Research Institute, Canada)

11:50 ***Approach for Rigorous Evaluation of a Battery Fuel Gauge.....176***

Prarthana Pillai and Balakumar Balasingam (University of Windsor, Canada)

A battery management system (BMS) is crucial for the safe and reliable operation of a battery pack. During

use, it is important to monitor the remaining charge in the battery, known as the state of charge (SOC), to preserve battery health and lifetime. However, the SOC of a battery cannot be directly measured and it is approximated by the battery fuel gauge (BFG) using several empirical approaches. The accuracy of the SOC calculated by the BFG is affected by (i) temperature (ii) charging/usage history (iii) hysteresis and relaxation effects. Evaluating the SOC values reported by a BFG remains a challenging problem due to the fact that it is not possible to know the true SOC value. Consequently, indirect measures were developed to evaluate the SOC estimates reported by a BFG. In this paper, three BFG evaluation metrics: the Coulomb counting (CC) metric, the open circuit voltage (OCV) metric and the time-to-voltage (TTV) metric are demonstrated. The present paper is focused on demonstrating the implementation details of the above three BFG evaluation metrics. The proposed metrics are modified versions of previously reported ones to make the BFG evaluation more robust. Voltage and current data generated from a battery simulator and a BFG based on the extended Kalman filter algorithms were employed to demonstrate the proposed evaluation scheme. The battery in the simulator is set to an R-int approximation of the equivalent circuit model (ECM) and the BFG is set to assume the knowledge of the ECM model parameters. Voltage and current measurements were simulated based on a noisy model with zero mean and known standard deviation. Under these assumptions, the BFG under evaluation produced less than 1% error in SOC and less than 15 minutes in TTV error. These values, produced under the known model assumption, can be taken as a benchmark for the same voltage and current measurement noise statistics.

12:10 ***Open-Circuit Voltage Modelling Toolbox for Battery Management Systems.....182***

Prarthana Pillai and Balakumar Balasingam (University of Windsor, Canada)

Open circuit voltage-state of charge (OCV-SOC) characterization is essential to battery management systems. The past two decades have seen the development of numerous models and approaches for OCV-SOC characterization. While some complex models may represent the OCV-SOC relationship more accurately than others, their advantage may be lost in practical systems that are restricted to a limited amount of computing resources. Also, some advanced OCV-SOC models require extensive data processing and coding. An automatic way to characterize the OCV-SOC curve of a battery and to obtain its parameters is currently unavailable. Therefore, this paper presents a Battery Modeling Toolbox capable of modelling the OCV--SOC curve using linear models from the literature. The toolbox allows the selection of OCV-SOC models from several options based on the requirements of the end user. The toolbox described in this paper will be a useful asset to researchers and scientists developing new battery chemistries; battery management system designers; academics; and graduate student researchers.

12:30 ***Fast Offline Battery Capacity Estimation Approach with Performance Bounds.....188***

Sneha Sundaresan, Sooraj Sunil and Balakumar Balasingam (University of Windsor, Canada); Krishna R Pattipati (University of Connecticut, USA)

Capacity of a battery is a measure of the amount of charge, in Ampere hours (Ah), stored in the battery. With the battery ageing processes, the capacity of the battery reduces. Consequently, it is essential to have an accurate knowledge of battery capacity in order to perform crucial battery management tasks. For example, in the field of battery reuse, the estimated residual capacity of batteries will help in determining a suitable secondary application for the retired battery pack. Existing literature on offline capacity estimation are often based on low-discharge or 1C rate discharge of the battery. This means that a minimum of one hour wait is required before an estimate of capacity is made. In this paper, a novel approach is proposed for fast offline estimation of battery capacity using the knowledge of the open-circuit voltage

(OCV) - state of charge (SOC) curve of the battery. The proposed approach consists of a novel method to estimate the battery OCV by applying a current profile that is optimized to reduce the uncertainty in OCV estimation. For capacity estimation, a constant current pulse is applied for a short duration. The capacity estimation accuracy is theoretically derived as a function of this current duration. The proposed fast capacity estimation approach is shown to be able to estimate the battery capacity within as short as 1 minute duration with an estimation error standard deviation of 0.02 Ah.

12:50 ***Fast OCV Characterization Approach for Battery Reuse Applications.....194***

James Vu Nguyen, Prarthana Pillai and Balakumar Balasingam (University of Windsor, Canada)

This paper considers the problem of open circuit voltage (OCV) to state of charge(SOC) characterization in rechargeable batteries for battery reuse applications. The traditional approach to OCV-SOC characterization is done by collecting voltage and current data through a slow discharge and charge process; this process usually takes about 60 hours. Such OCV-SOC characterization is performed on a few sample batteries because the OCV-SOC characterization is the same for new batteries coming out of the same manufacturing process. However, the characteristics of a battery may change as it is used for years in different environmental and usage conditions. Hence, they may need to be re-characterized before secondary use. Unlike primary characterization, the secondary characterization may have to be done faster in order to save time and cost. This paper presents a new and faster approach for OCV-SOC characterization. The proposed approach in this paper consists of constant current profiles that halves in magnitude after a specified time. Such reducing current magnitude allows to fully deplete the battery; similarly, the battery is charged back with a reducing current profile in order to make sure the battery is fully charged back. The resulting current profile reduces the total characterization time by 1/5. It was hypothesized that the changing current magnitude may result in hysteresis voltage bias. For this, a new OCV modelling approach consisting of separate resistance estimation at each pulse was developed. The proposed approach was tested using data collected from four cylindrical Li-ion batteries. Compared to traditional OCV modelling approach, the proposed approach results in 3\% of SOC error and takes 20\% of the time.

13:10 ***Novel Table-Based Kalman Filter for State of Charge Estimation of Batteries.....200***

Sooraj Sunil, Sneha Sundaresan and Balakumar Balasingam (University of Windsor, Canada); Krishna R Pattipati (University of Connecticut, USA)

This paper considers the problem of state of charge (SOC) estimation in rechargeable batteries. Traditionally, the SOC is estimated based on available quantifiable measures such as current, voltage, or both. The current and voltage-based approaches are, in general, susceptible to several uncertainties as well as practical limitations. Meanwhile, the fusion of both estimation approaches through nonlinear filtering techniques tends to preserve their respective benefits and improves the overall SOC estimation process. However, there are general solutions to the nonlinear filtering problem instead only sub-optimal approximations, which compels the selection of appropriate filter to be a concern while designing SOC algorithms. Additionally, the practical implementation of filter-based approaches would require high-precision storage systems to store the model parameters. For restrictive computational scenarios, the round-off errors could induce numerical instabilities. Therefore, this paper presents a novel table-based Kalman filter (TKF) for the problem of SOC estimation. The TKF constructs a table to describe the usual nonlinear functional relationship between the open-voltage voltage (OCV) and the SOC through inflection

points of the OCV-SOC curve. The table-based approximation is also advantageous as the system model can be described linearly in terms of the table components. The resulting linear system model would allow us to apply the Kalman filter directly rather than its computationally expensive nonlinear variants. The results show that a 16-point table can have a maximum error of approximately 0.01. Further, it highlights that the TKF with 32 points has a comparable error performance to the state-of-the-art nonlinear filtering approach.

Tuesday, December 6

Tuesday, December 6 7:00 - 8:00

Keynote 3

Tuesday, December 6 8:10 - 9:40

S10: Electric Mobility

Chair: Xianke Lin (Ontario Tech University, Canada)

8:10 ***Identifying Degradation Indicators for Electric Vehicle Battery Based on Field Testing Data.....206***

Kei Long Wong (Macao Polytechnic University, Macao); Ka Seng Chou (Macao Polytechnic University & University of Bologna, Macao); Davide Aguiari (Università di Bologna, Italy); Rita Tse and Su-Kit Tang (Macao Polytechnic University, Macao); Giovanni Pau (Technology Innovation Institute - ARRC, Italy & University of Bologna, Italy)

State of health estimation of battery is crucial to ensure the safety and durability of electric vehicles. This paper presents six methods to extract the battery health indicator from electric vehicle field testing data. The methods for extracting health indicators from the discharge cycle show the ability to cope with the variable driving condition. In total, 157 health indicators are extracted from the collected data. Pearson correlation coefficient and Spearman's rank correlation coefficient are used to measure the correlation between the health indicators and the state of health. The results suggest that health indicators extracted by the presented methods have high correlations to the battery state of health.

8:30 ***Voltage Oriented Control for Electric Vehicle Regenerative Power Regulation.....212***

Shibajee Nath (Nottingham University Malaysia, Malaysia); Aaruththiran Manoharan (& University of Nottingham Malaysia Campus, Malaysia); Mumtaj Begam Kasim Rawthar (University of Nottingham Malaysia Campus, Malaysia)

Electric Vehicles have been designed to address the increased carbon emissions made by fossil fuel-powered vehicles. On the other hand, electric vehicles have a longer battery charging time and shorter

driving range. The use of regenerative braking systems (RBS) can help solve these problems. To ensure effective regenerative energy storage, it is crucial to regulate the regenerative power using a power electronic system. This paper proposes the use of a three-phase voltage source converter (VSC) and controller. Mathematical model of the plant system is analyzed and used to synthesize the controller for the VSC. Voltage oriented control (VOC) method is used. It consists of two loops: the outer voltage and the inner current loop. Initially, the conventional VOC method was used, however, found to perform poorly because of high overshoot and instability; thus, an improved version of the controller is presented to overcome the issues. Feedback to the voltage loop PI controller and a different set of PI controller parameters was formed. The system was simulated in MATLAB/Simulink environment to evaluate the performance. The proposed VSC show improved overshoot by 70% and steady-state time by 55%, contributing to better efficiency of the regenerative system. With this, the range and life-cycle of an EV can be increased by achieving greater amount of recovered kinetic energy from the RBS.

8:50 ***Comparative Economic Analysis of Conventional and Plug-In Battery Electric Vehicles in Canada.....218***

Muhammad Muaz ur Rehman (Ontario Tech University, Canada); Walid Morsi (Ontario Tech University (UOIT), Canada)

Conventional vehicles typically use gasoline for their internal combustion engines (ICEs). On the other hand, plug-in battery electric vehicles (PBEVs) use electricity to charge their batteries and hence they do not need gasoline. With the soaring gasoline prices in Canada and around the world, the interest in electric vehicles from the public and the government has increased. However, given the wide range in prices of PBEVs, the high maintenance cost of conventional vehicles and the volatility in gasoline prices, there is a need for an economic comparative analysis to address the following two main questions: (1) What should be the minimum ownership period of a PBEV to be economic than a conventional vehicle? (2) At what prices of gasoline, do the PBEVs become more economic than conventional vehicles? The work in this paper addresses these questions to assist customers in making the right decision when they intend to purchase a new vehicle. The results have shown that the longer the ownership period is, the PBEVs become more economical compared to conventional vehicles. The study has shown that the total ownership cost savings may reach up to $88,482 over 15 years.

Tuesday, December 6 8:10 - 10:10

S5: Data Analytics, Artificial Intelligence, and Machine Learning

Chair: Bo Chen (Zhejiang University of Technology, China)

8:10 ***Phase Identification of Smart Meters Using a Fourier Series Compression and a Statistical Clustering Algorithm.....224***

Jeremy J Chiu, Albert Wong and James Park (Langara College, Canada); Joe Mahony, Michael Ferri and Tim Berson (Harris SmartWorks, Canada)

Accurate labeling of phase connectivity in distribution systems is important for maintenance and operations but is often erroneous or missing. In this paper, we present an algorithm to identify which smart meters must be in the same phase using a hierarchical clustering method on voltage time series data.

Instead of working with the time series directly, we apply the Fourier transform to represent time series in their frequency domain, remove 98% of the Fourier coefficients, then cluster the remaining coefficients to estimate which meters belong in the same phase. We validate results by verifying they do not change phase in time and by comparing our results to available network-distribution data.

8:30 *Application of Reinforcement Learning to Wind Farm Active Power Control Design.....229*

Xuanhe Zhang, Hamed Badihi and Ziquan Yu (Nanjing University of Aeronautics and Astronautics, China); Mohamed Benbouzid (University of Brest, France); Ningyun Lu (Nanjing Univ of Aeronautics and Astronautics, China); Youmin Zhang (Concordia University, Canada)

Wind power is becoming a key player of the world's energy landscape thanks to its cleanliness, abundance and huge potential. At the same time, it attracts an increasing attention when it comes to its efficient production and financial viability, which otherwise may restrict its development in the foreseeable future. Indeed, enhancing energy production efficiency to reduce costs and improve the ability of the system to resist faults are research areas of great interest. With the advancement of machine learning and artificial intelligence along with increasing computational power at hand, reinforcement learning enables achieving an optimal control solution in an application environment after continuous attempts and updates. In this paper, a novel solution based on reinforcement learning is applied to the control of offshore wind farms. An intelligent agent is designed to explore the environment, and after training, it effectively maintains the necessary balance between power generation and load, which in turn regulates the wind farm-grid frequency when enough wind is available. The trained agent is tested under different loads, realistic wind fields, as well as fault scenarios. All simulation results show that the agent accurately understands the environment and load requirements, mitigates the impact of faults, and thus, improves the stability of the grid frequency.

8:50 *Detection of Key Component Defect for Electric Transmission Tower by Deep Texture Analogy.....235*

Jinze Li (North China Electric Power University & School of Control and Computer Engineering, China); Hua Wu and Fang Fang (North China Electric Power University, China)

There are many key components in the transmission line, which often occupies a small size in aerial images, and the defects are also different. In this paper, we propose a new technique to identify the key components by deep texture analogy, which depends on the deep neural network model SSD combined with the feature fusion module(FFM). Using the trained model of SSD+FFM to extract the feature map to compare. Due to the difference in the content structure and texture between images, the number of feature mismatches is increased in the compare process. The block matching base on the nearest field search method, which enhanced by bidirectional constraint can effectively reduce mismatching, and acquire the spatial different flow map between the analogy images. Extracting the significantly spatial different zone of texture defects, and finally the defect region is outlined. Test and analysis results show that, the method proposed in this paper can effectively identify multiclass defects of key components, greatly improving the intelligence level of the overall inspection.

9:10 ***Deep Learning for Segmentation of Critical Electrical Infrastructure from Vehicle-Based Images*****.....241**

Yasmina Souley Dosso, Ethan Rizcallah, Rafik Goubran, Felix Kwamena and James R Green (Carleton University, Canada)

Regular monitoring of critical electrical infrastructure is a necessary but laborious task to ensure infrastructure resilience. Typically, a worker must perform the inspection on site, following a checklist. The advent of highly instrumented autonomous vehicles provides an opportunity to automate inspections through repurposing of sensors typically used for navigation. Furthermore, the high frequency of data capture from passing cars can provide unprecedented temporal resolution for monitoring critical infrastructure. Motivated by this opportunity, we here evaluate the state of the art in deep learning algorithms for segmentation of critical electrical infrastructure from ground-based image, which differs from other studies that have largely focused on aerial images. Google Street View (GSV) images are used as a proxy for images captured by vision-based autonomous vehicles to evaluate two state-of-the-art models. ACU-Net, originally trained on power line segmentation from unmanned aerial vehicle (UAV) imagery, is here adapted for use on ground-based imagery. Similarly, HRNet-OCR, a scene segmentation model for ground-based imagery, is used to simultaneously capture both power utility poles and powerlines. This study demonstrates that models trained exclusively on wires or power poles can be successfully adapted for a segmentation of the complete critical electrical infrastructure as a step towards fully automated inspection and increased infrastructure resilience.

9:30 ***A New Data Mining Application in Smart Monitoring Systems Using Self Organizing Map Neural Network to Distinguish Disk Space Variations in Distribution Transformers*****.....248**

Omid Elahi, Reza Behkam and Gevork Gharehpetian (Amirkabir University of Technology, Iran); Morteza Nazari Heris (23287 Park Place Drive & Lawrence Technological University, USA)

Online monitoring of electric power components in smart grids is of great importance to enhance reliability. Fault detection at primary levels in distribution transformers, the chief components to maintaining the integrity of modern power networks, prevents following significant destructive damages and high costs of failures in smart grids. Data-driven structure in smart grids provides accessibility to data related to the condition of transformers in data centers. Frequency response analysis (FRA), an efficient and sensitive technique to identify transformer defects, can be utilized in online monitoring. However, a trustworthy and consistent code for interpreting frequency responses has not yet been proposed by standards. This study proposes a self-organizing map (SOM) neural network as an intelligent interpreter using appropriate feature groups obtained from suitable statistical indices (SIns). In order to distinguish the severities and locations of disk space variation (DSV) defects as common faults in transformers, an experimental setup including 20 kV windings of a 1.6 MVA distribution transformer and an impedance analyzer are provided. The promising performance of SOM in detecting DSV faults with 100% accuracy shows that the proposed method is capable of identifying faults using high dimensional and nonlinear FRA data sets.

9:50 ***Electrical Power Consumption Forecasting with Transformers*****.....255**

Jun Wei Chan and Chai Kiat Yeo (Nanyang Technological University, Singapore)

Until recently, state of the art (SOTA) deep learning methods for time series prediction problems, such as electricity load forecasting, have been based on recurrent neural networks (RNN), convolutional neural networks (CNN), or combinations thereof. However, RNNs involve sequential computations that cannot be parallelized on machine learning accelerators, while CNNs require very deep networks to capture long distance relationships. This paper proposes a sparse transformer based method for time series prediction. The proposed model achieves comparable accuracy to the SOTA method, TSRNN, on the London Smart Meter dataset while achieving up to 10 times faster inference speed.

S8: Renewable Sources of Energy and Cogeneration

Chair: Ziyou Song (National University of Singapore, Singapore)

8:10 *A Regression Model-Based Short-Term PV Power Generation Forecasting.....261*

Shahab Karamdel, Xiaodong Liang, Sherif Faried and MD Nasmus Sakib Khan Shabbir (University of Saskatchewan, Canada)

Solar photovoltaic (PV) modules have been increasingly integrated into power systems. However, their intermittency and variability have considerable impacts on power grids and could jeopardize the grid's stability when the penetration is high. Developing accurate PV power generation forecasting methods is a key to enhancing reliable and secure grid operation. In this paper, a data-driven regression model-based short-term PV power generation forecasting is proposed, where nineteen regression models (including both deterministic and probabilistic predictors) from five regression families are evaluated, and performance assessment indices, such as RMSE and R-squared, are adopted to find the best models. To further improve the performance of forecasting models, hyperparameter optimization and tuning are conducted using MATLAB Regression Learner App. A real-world historical dataset of PV power generation is used to train and further test the models. It is found that the interactions linear, medium Gaussian support vector machine (SVM), and the ensemble of bagged trees outperform other regression models in this study. The proposed method can be utilized by the system operator for effective scheduling future power systems.

8:30 *A Novel Hybrid Control Strategy with Gain Scheduling for Photovoltaic Emulators.....267*

Imasha Dilshani Balahewa, Sathira Tennakoon, Hasitha Perera and S Kumarawadu (University of Moratuwa, Sri Lanka)

Photovoltaic (PV) emulators are widely used at present in real-time research and experimentation on solar PV systems. There are different control strategies for PV emulators found in the literature and this paper presents a microcontroller-based solar PV emulator which consists of a DC-DC buck converter and lookup table-based implementation capable of mimicking the non-linear characteristics of different types of solar PV modules at different temperatures, irradiation levels and loads. It uses a novel hybrid control strategy with gain scheduling. Here, a voltage reference or a current reference is used as the control input depending on the operating point and gain scheduling is used to account for any instability introduced by the varying operating point. The entire system has been simulated in MATLAB Simulink and implemented in hardware. Further, it was tested using the Kyocera KC200GT solar PV module and the experimental results show that it precisely replicates the I-V characteristics of a given solar PV module.

8:50 ***An Improved Droop Controller for Virtual Synchronous Generators.....273***

Mingjun Wang (University of British Columbia, Canada); Erfan Mostajeran (The University of British Columbia, Canada); Seyyedmilad Ebrahimi and Juri Jatskevich (University of British Columbia, Canada)

The concept of virtual synchronous generators (VSGs) has been developed in the literature as an effective approach for controlling power-electronics-based wind power generation. Therein, the converters are controlled to emulate the classic synchronous generators with droop characteristics and to regulate their inertia and damping for better dynamic response. In this paper, a new droop controller is proposed for VSGs which has the capability to regulate the converter frequency after disturbances for maximum power harnessing. The performance of the proposed controller is evaluated through simulation studies carried out in MATLAB/Simulink. It is demonstrated that the new droop controller improves the capability of the VSGs for maximum power point extraction by enabling smooth transition between different operating modes after a frequency disturbance in the grid.

9:10 ***Challenges in Adopting Successful Waste-To-Energy Policies in EU Countries: Indonesia Study Case.....278***

Subkhi Abdul Aziz and Nidya Judhi Astrini (National Research and Innovation Agency, Indonesia); Elisabeth Rianawati (Institut Teknologi Bandung & Resilience Development Initiative, Indonesia); Anthony Halog (University of Queensland, Australia); M Indra Al irsyad (National Research and Innovation Agency, Indonesia)

The waste problem is homework for all countries, especially high-populated developing countries like Indonesia. The country is predicted will be the 5th largest country generating waste, while most of the waste will be landfilled. Our study aims to review challenges for Indonesia in adopting waste management measures, especially waste-to-energy policies, in Germany, Netherlands, and Denmark, which are considered as frontrunners in processing waste to energy. Several waste management policies in EU countries have been partially implemented in Indonesia. The full implementation requires several top-down and bottom-up approaches involving the participation of informal sectors and their associations. Indonesia should also identify other technologies than refused-derived fuels to optimize waste usage for energy.

9:30 ***Optimized Hybrid Neural Network for Wind Speed Forecasting.....284***

T. M. Rubaith Bashar, Mohammad Munem, MD. Safayet Islam and Murad Hossain (Rajshahi University of Engineering & Technology, Bangladesh); Tasnim Shawkat (Rajshahi University of Engineering and Technology, Bangladesh); Md. Habibur Rahaman (Memorial University of Newfoundland, Canada)

Though wind power capacity all over the world is increasing rapidly, the availability of wind power generation mostly reclines on wind speed, which is a random variable with stochastic nature. Therefore, robust technique with powerful feature extraction capability is required to predict wind speed accurately. In this paper, we have recommended a hybrid model using convolutional neural network (CNN) and long-short term memory (LSTM). where CNN is used for extracting fuzzy input features and LSTM to catch the sequence to predict wind speed accurately. As deep learning models are associated with multiple hyper-parameters with great impact, Bayesian optimization algorithm is used for hyper-parameter tuning.

Additionally, the performance of some established machine learning models are added on the same data-set. It is observed that, the proposed Bayesian optimized CNN-LSTM hybrid model surpasses the other four established models like SVM, ANN, CNN and LSTM in terms of different performance evaluation metrics like mean absolute error, root mean error and root mean square error.

Tuesday, December 6 8:10 - 9:40

S9: Microgrids and Isolated Grids

Chair: Hima Dhulipati (Carleton University, Canada)

8:10 *A Cooperative Robust Fractional-Order PID Controller for Frequency Control in Islanded Microgrids.....290*

Masoud Babaei Vavdareh and Mohsen Ghafouri (Concordia University, Canada); Amir Ameli (Lakehead University, Canada)

The low inertia of microgrids, particularly when they operate in islanded mode, complicates the balancing of load and generation. As a result, islanded microgrids are exposed to various instability conditions, e.g., ones that result in large frequency deviations. To address this issue, this paper develops a cooperative control scheme based on a robust fractional order technique for regulating the frequency of an islanded microgrid which includes a variety of generation units, such as a generator, battery energy storage systems (BESSs), a wind turbine, and photovoltaic (PV) panels. The proposed controller is able to stabilize the microgrid in the presence of uncertainties, such as parametric uncertainties and disturbances. The performance of the proposed controller has been validated through simulations, and through comparison, it has been demonstrated that it outperforms optimal proportional integral derivative (PID) and fractional-order proportional-integral-derivative (FOPID) controllers.

8:30 *Evaluation of Multifunctional PV Inverters Operation During Faults.....296*

Alexandre Hugo da Silveira (Universidade Federal do Rio Grande do Sul, Brazil & Pontifícia Universidade Católica do Rio Grande do Sul, Brazil); Fausto Libano, Roberto Chouhy Leborgne and Maicon Jaderson Silveira Ramos (Universidade Federal do Rio Grande do Sul, Brazil)

The increased interest in distributed energy resources, especially frequency inverter-based ones, brought new challenges. This paper studies the performance of a multifunctional inverter connected to a distribution grid in faulty operating conditions. The DER system includes a conventional power generation from a PV source, an active filter for harmonics, power factor correction and phase balancing for non-linear and unbalanced loads connected at the same point of common coupling (PCC). A model of the multifunctional inverter is proposed, and the analysis in a CIGRÉ low voltage test grid is performed for fault conditions. The inverter operation is analyzed according to IEEE Std 1574:18. Therefore, the inverter must be disconnected very fast for faults that produce severe voltage sags, to avoid damage. On the other hand, for faults that produce more shallow voltage sags, the inverter must operate safely, complying with the fault ride-through (FRT) standards.

8:50 *Coordinated Energy-Sharing Scheme for DC Electric Spring and Hybrid Battery Energy Storage Source in Modern DC Microgrids.....302*

Danial Moeini (ETS, Canada)

Despite all the advantages related to the concept of DC microgrids, there are still challenges regarding their operation and control in the presence of massively integrated naturally intermittent renewable energy resources. In this paper, an energy-sharing scheme is proposed for coordinating the role of a DC electrical spring (DCES) and a hybrid battery energy source system (hybrid BESS) for improving the DC bus voltage when the main source of the DC microgrid is a PV system. The hybrid BESS includes a Li-Ion chemical battery and a supercapacitor that gives in total the capability of properly responding to any given production command signal. The simulation results conducted on a test case show that DCES can effectively and positively contribute to the power shortage compensation process caused by a drop in PV production, dampen the oscillations, and release the stress from the hybrid BESS.

SS2: Special Session - Estimation and Control in Industrial Cyber-Physical Energy Systems under Uncertainties

Chairs: Bo Chen (Zhejiang University of Technology, China), Shichao Liu (Carleton University, Canada)

8:10 *An Adaptive Event-Triggered Distributed PID Control for State of Charge Balancing of Multiple Batteries Based Electric Vehicles.....307*

Pengcheng Chen, Shichao Liu and Hicham Chaoui (Carleton University, Canada)

This work designs a distributed proportional integral-derivative (PID) controller integrated with the adaptive event-triggered (AET) mechanism to cope with the state of charge (SoC) balancing issue while ensuring the stability of the voltage of DC bus in multiple batteries based electric vehicles (EVs). The SoC balancing is realized by the distributed PID controller in the multiple bidirectional DC-DC converter buck-boost circuit, so that the battery with the high SoC value releases more energy and absorbs less energy, and the battery with low SoC absorbs more energy and releases less energy. Meanwhile, the adaptive event-triggered strategy configured with each battery proposed in this work can adjust the release threshold according to the deviation of each SoC from the average value, which can greatly reduce unnecessary waste of communication resources while achieving SoC balancing. A three-battery based EVs with time-varying operating mode is

8:30 *Design Optimization of Hybrid Battery Based Gensets.....313*

Abba Muhammad Abdulazeez, Hicham Chaoui and Shichao Liu (Carleton University, Canada)

This paper proposes an analytical method using a lithium-ion battery and generator data to provide insights and planning into a hybrid genset's optimal operational load, peak shaving, and fuel consumption difference with a standalone genset. The overview analysis is between the standalone genset and a battery-fused diesel generator. Further investigations into other factors (such as power output load, battery depth of discharge (DOD), battery charge and discharge time (number of operations in a day), battery total cycle

and life span of the battery) play a significant role in the results. A numerical simulation was carried out to monitor the hybrid genset operation, whereby the battery DOD and the number of cycles were compared. Another simulation was performed to find the incremental results for a 135 Kw genset by varying the different battery DOD and the generator load difference. The simulation results indicate that the DOD decreases while the number of battery cycles increases, thereby enhancing the battery durability but is subjective to the daily operation time and load on the system. The combined results reveal that the battery unit will always generate adequate efficiency support for gensets.

8:50 *Power System State Fusion Estimation Based on Maximum Correntropy Criterion.....319*

Changsheng Wu (Shanghai Dianzi University, China); Xiaoliang Feng, Yaguang Guo and Jingjing Yan (Henan University of Technology, China)

By using the observations from multiple sensors, the fusion estimation of power system states, such as voltage, current, phase angle and other variables can be realized. When the observation information is affected by non-Gaussian noises, especially by some heavy tailed impulse noise, the performance of the fusion filter estimation based on Kalman filter will decline. Based on maximum correntropy criterion (MCC) and combining two fusion methods of parallel fusion and sequential fusion, this paper studies two power system state fusion estimation methods that can be used in non-Gaussian noise environment, named maximum correntropy parallel Kalman fusion filter (MC-PKFF) and maximum correntropy sequential Kalman fusion filter (MC-SKFF) respectively. The validity and the performance comparison of the two proposed methods are verified by the simulation example of three-phase voltage state estimation in power system.

9:10 *Outlier-Detection-Based EKF for Power Systems.....325*

Haoli Gu, Zhongyao Hu, Jianbin Wang, Bo Chen and Li Yu (Zhejiang University of Technology, China)

In this paper, a mixed outlier detection (MOD) method in extended Kalman filter (EKF) is proposed for state estimation in power system. Firstly, a discrete multi-machine state space model is developed. Then, the vulnerability of traditional EKF method in the face of outliers is analyzed, as well as the motivation of using MOD method. Subsequently, we apply MOD to the iterative process of EKF to obtain our outlier-detection-based EKF (ODB-EKF). It needs to establish a time-varying detection matrix based on the parts of predictions and measurements. In this matrix, projection statistics and least squares methods are used to detect the outliers in two parts respectively. Subsequently, the data will be updated according to the results of the MOD method. Finally, the numerical simulation results based on the parameters of the IEEE 39 bus test system show the good performance of the proposed ODB-EKF against the outliers.

Tuesday, December 6 10:00 - 11:40

Industrial Panel

Wednesday, December 7

Wednesday, December 7 7:00 - 8:00

3MT Competition

Wednesday, December 7 8:00 - 9:30

S13: Distributed Systems and Energy Resources

Chair: Yuanye Chen (North China Electric Power University, China)

8:00 *Distributed Cooperative Control of Flywheel Energy Storage Systems for Power Distribution.....330*

Zikang Ding (North China Electric Power University, China)

Flywheel energy storage systems (FESS) are playing increasingly important roles in areas such as wind power fluctuation smoothing and grid frequency regulation due to their fast charging and discharging characteristics. In this paper, we propose a distributed control method applied to power distribution for flywheel energy storage systems. The total power is allocated according to the amount of energy that remains in the flywheel unit, and a dynamic average consistency algorithm is used to estimate the average reference power and the average energy. For local current control of individual flywheel, proportional integral (PI) algorithm is used, where the reference current is obtained from the power distribution. The feasibility and effectiveness of consistency are verified by numerical simulations.

S14: Energy Management and Energy-Aware Control

Chair: Xianke Lin (Ontario Tech University, Canada)

8:00 *An Efficient Energy-Aware Controller for Small-Scale Solar-Worked Devices Using Ratioed Pro-Energy Predictor.....336*

Murad Al-Omary, Aiman Albatayneh and Mustafa Jaradat (German Jordanian University, Jordan); Rafat Aljarrah (Princess Sumaya University for Technology, Jordan)

Currently, the management of energy is considered a requirement not only for large-scale solar energy systems but also for small-scale solar-worked devices. This is attributed to the increase in the desire of building sustainable cities and societies in light of the future expected energy supply shortage. The well-management contributes to operating these devices without huge consumption of energy. Thus, fulfilling an abundance of energy. The controller, as an important part of the energy management toolbox, would

perform its task with a help of the predictors. This paper develops a controller with a predictor called "Ratioed Pro-Energy". This predictor is precise compared to the previous ones in the literature. Accordingly, the controller will become more efficient in managing energy and reducing consumption while maintaining the stability of the functionality of these devices. For a simulation period of one week, the controller with the Ratiod Pro-Energy predictor repeated the active working mode four times larger than the controller with the Pro-Energy predictor. This is accompanied by a reduction of three times and one time for the over-required functions mode and readiness mode respectively.

8:20 *Day-Ahead Scheduling of Integrated Energy Systems Considering Carbon Emissions.....342*

Weiyou Wang, Yuanye Chen and Fang Fang (North China Electric Power University, China)

The forecast-based day-ahead scheduling can effectively reduce the integrated energy systems (IES) operating cost. In this paper, a day-ahead IES scheduling problem considering carbon emissions is studied. Firstly, an IES system model is established, and the optimization objectives of operating cost and carbon emissions, energy balance equations and constraints are established according to the model. A day-ahead scheduling operating cost considering the existence of prediction errors is established. Then, based on the proposed model, the day-ahead scheduling problem of IES considering carbon emissions is formulated as a multi-objective optimization. The problem can be readily solved by the non-dominated sorting genetic algorithm-Ⅱ (NSGA-Ⅱ). Finally, some simulations are carried out, and the results show that the effectiveness of the proposed day-ahead scheduling strategy, reducing the operating cost by 84.57%.

S15: Transactive Energy and Electricity Markets

Chair: Seyed Masoud Mohseni-Bonab (Hydro-Quebec Research Institute, Canada)

8:00 *Coordinated Trading of Capacity and Balancing Products in Multi-Area Local Flexibility Markets.....348*

Ángel Paredes and Jose Aguado (University of Malaga, Spain)

In a scenario with high penetration of renewable and distributed energy resources, Local Flexibility Markets (LFMs) emerge to enhance operation of distribution networks. They deal with new consumption patterns, flexibility, and storage systems to mitigate imbalances and congestions. In recent years, efforts toward the definition of stand-alone LFMs have been made, enabling energy trading in isolated systems. This paper present an alternative solution for congestion and imbalance mitigation using capacity and balancing flexibility products. Products prices are defined considering their intrinsic relation with traditional markets, what enhances compatibility and enables full deployment of this local structures. Besides of that, using the properties of an adaptive ADMM algorithm, the market clearing problem is solved under a Multi-Area setting while information privacy is preserved. The feasibility of the proposed approach is demonstrated on a radial network based on the IEEE 34 bus system, where the solution for the two-area LFM is found in four tens iterations. Furthermore, the scalability analysis provides shows a linear relation between the number of areas and the convergence

8:20 ***A Novel V2V Charging Scheme to Optimize Cost and Alleviate Range Anxiety.....354***

Samira Hosseini, Abdulsalam Yassine and Yassine Abdulsalam (Lakehead University, Canada)

Nowadays, electric vehicles (EVs) as a source of clean energy are expected to replace vehicles with internal combustion engines. However, the high cost of installation has prevented the development of charging infrastructure to meet the rising number of EVs. Furthermore, the immature and uneven distribution of charging stations (CSs) has resulted in a lack of charging infrastructure in regions such as highways and rural areas. Therefore, due to range anxiety and a lack of CSs, the adoption of EVs is increasing these days steadily. To address these issues, the new concept of vehicle-to-vehicle (V2V) charging has received attention. In this paper, one algorithm for V2V power charging is proposed to support V2V power exchanges in a distributed power system with both demander and supplier EVs separated into a number of zones, where V2V power exchanges are optimal for matching EVs together to trade energy. In our algorithm, a Hungarian matching algorithm is used to match EVs so that the cost of demander EVs is minimized. The simulation results stem from realistic parameters obtained from real-life data for the suggested methodology is compared to the traditional method of assigning EVs to CSs, and the findings reveal that our efficient, realistic, and practical V2V matching algorithm presents an intelligent and complete framework for managing and allocating energy between EVs.

Wednesday, December 7 8:10 - 9:40

S12: Smart Grids

Chairs: Seyed Masoud Mohseni-Bonab (Hydro-Quebec Research Institute, Canada), Chengcheng Zhao (Zhejiang University, China)

8:10 ***A Flexible System-Level Hydrogen Transportation System Operating Structure Interacting with Urban Transportation System.....360***

Elahe Sahraie (Université Laval, Canada); Innocent Kamwa (University Laval, Canada)

Electrification of hard-to-abate sectors through green hydrogen is a promising strategy for achieving the Paris Agreement's decarbonization targets. However, hydrogen transportation problem remains a pressing concern in a system-level operation of hydrogen energy system (HES) in an integrated electric power and hydrogen system (IPHS). This paper presents a system-level operation structure for hydrogen transportation system (HTS). Proposed structure is intended to facilitate the coordination between HTS and the remaining parts of an IPHS by using a decomposed operation structure, which allows for different timescales to be set for each party. In the proposed structure, hydrogen tube trailers (HTs) are used to deliver hydrogen across the urban transportation system (UTS) using an extended version of a vehicle routing problem (VRP) coupled with a new set of constraints for incorporating the traffic density of roads and their availability. Furthermore, certain constraints have been considered to align with the priority of supplying sensitive loads. As part of the proposed HTS operating structure, a trade-off between system reliability and cost-affordability is also managed by assigning the adjustable weights to each parties' representative in HTS operating objective. The proposed structure is intended to minimize the operating costs of HTS in an interaction with IPHS as well as minimize the delay costs as a penalty in the event of hydrogen load loss. The proposed HTS operating structure is formulated in the form of a mixed integer

linear problem and is then solved by Gurobi solver using YALMIP toolbox in MATLAB.

8:30 *Time-Synchronization Attack on Data Aggregation in Wide-Area Damping Controllers.....368*

Masoud Zadsar and Mohsen Ghafouri (Concordia University, Canada); Amir Ameli (Lakehead University, Canada); Bassam Moussa (Hydro-Quebec Research Institute (IREQ), Canada)

The advent of wide-area measurement systems (WAMSs) in modern power systems enables deployment of wide-area damping controllers (WADCs) to effectively deal with dominant oscillation modes. However, the reliance of WAMSs on information and communication technologies (ICTs) exposes WADCs to potential cyber attacks. To come up with effective countermeasures, extensive knowledge about the existing vulnerabilities and possible cyber attacks is required. On this basis, this paper presents an attack model against WADCs by exploiting the vulnerabilities in the time-alignment strategies utilized by phasor data concentrators (PDCs) to aggregate the stream of phasor measurements. In this attack, the adversary manipulates data timestamp of phasor measurement units (PMUs) to compromise PDCs functionality, causing dropout in the WADC's critical phasor measurements data. To obtain the targeted PMUs and manipulated timestamp, a stochastic mixed-integer linear (MIL) model is developed from adversary prospective considering uncertainty of communication delay. The time-domain dynamic study on two-area Kundur test system demonstrates that the developed attack can jeopardize the WADC performance and even cause system instability.

8:50 *UKF-Based State Estimation for Smart Grids Under FDI Attacks.....374*

Jin Li and Youmin Zhang (Concordia University, Canada)

False data injection attacks (FDIAs) targeting smart grids compromise the integrity of monitoring data and data acquisition systems (SCADA), posing a significant threat to the safe operation of the grid. The residual threshold method is usually used to detect whether the power system is under attack. However, the attack sequence carefully constructed by the attacker has concealed characteristics and can avoid false data detection mechanisms. Therefore, based on the unscented Kalman filter (UKF) state estimation, it is judged whether the power supervisory control and data acquisition system is attacked. The standard IEEE-14 node test system is used for simulation experiments, and the results show that this method can effectively detect FDIAs for power systems.

Wednesday, December 7 9:30 - 11:00

S16: Demand Response

Chair: Mingxi Liu (The University of Utah, USA)

9:30 *Advanced Contextual-Targeted Building Flexibility Based on Signature Labelling for Demand Response.....380*

Petros Tzallas (Centre for Research Technology (CERTH), Greece); Alexios Papaioannou (Information Technologies Institute / Centre of Research and

Technology Hellas, Greece); Asimina Dimara (Centre for Research and Technology Hellas & University of the Aegean Cultural Technology and Communication Intelligent Systems Lab, Greece); Stelios Krinidis (Centre for Research and Technology Hellas, Greece); George Pavlidis (Centre for Research Technology (CERTH), Greece); Christos Nikolaos Anagnostopoulos (University of the Aegean, Greece); Dimosthenis Ioannidis (Information Technologies Institute, Greece); Dimitrios Tzovaras (Centre for Research and Technology Hellas, Greece)

The residential sector is constantly rising the energy demand and results in stressing the power grids while increasing the need for more power generation units. Consequently, building flexibility is of key importance for the energy supply and response of the grid. In this paper, a novel method to identify potential flexible events within the end-users energy consumption patterns is proposed. A contextual-based unsupervised algorithm is exploited to detect flexible motifs. Consequently, this a priori knowledge is utilized to predict the load patterns that are flexible applying a supervised technique. Eventually, experimental results show case that the proposed method is feasible and accurate for building flexibility and may be utilized for demand response schemes.

S16: Power System Stability and Control

Chair: Mingxi Liu (The University of Utah, USA)

9:30 ***Small-Signal Stability Assessment with Transfer Learning-Based Convolutional Neural Networks.....386***

Miguel Ramirez-Gonzalez (ZHAW Zurich University of Applied Sciences, Switzerland); Lukas Nösberger (ZHAW, Switzerland); Felix Rafael Segundo Sevilla and Petr Korba (Zurich University of Applied Sciences, Switzerland)

An approach for the small-signal stability assessment (SSSA) of power systems using a Convolutional Neural Network (CNN) model with transfer learning is presented in this paper. The concept of permutation feature importance (PFI) is included in model development to identify and drop the most irrelevant features in a given dataset, which minimizes the input information required by the model to achieve a certain performance and reduces the set of measurement locations for the related application. Then, a transfer learning approach using weight initialization and feature extraction is applied to leverage the knowledge of a pretrained model when a new independent dataset (obtained from the integration of converter-interfaced generation) is considered. Simulation results demonstrate that the transfer learning-based CNN model is able to exploit previous knowledge and provide a superior performance, as compared to the traditional rebuilt-from-scratch model.

9:50 ***Impact of PV Variability Towards the Frequency Response in Deloaded Mode.....392***

Azazul Islam (Bangladesh University of Engineering and Technology, Bangladesh); Atik Jawad (Bangladesh University of Engineering and Technology, Bangladesh & University of Liberal Arts Bangladesh, Bangladesh); Nahid-Al- Masood (Bangladesh University of Engineering and Technology, Bangladesh)

One of the major concerns for integrated photovoltaic systems in power grid is frequency instability in the absence of rotating mass. Among possible solutions, PV deloading can provide support without any additional requirement or equipment inclusion. But as deloading depends on MPPT point of operation, environmental effects like change in irradiance or temperature value can hurt PV generation and frequency support. Setting deloading percentage considering a static condition may not provide expected support under such intermittent condition as frequency support will vary. Therefore, it is crucial to find out whether a deloading percentage is effective under changing environmental parameters. To this end, this paper investigates this dynamic behavior in frequency support and its relation with PV variability in deloaded mode. In addition, a methodology is proposed to estimate minimum irradiance and temperature up to which a specific deloading percentage can provide frequency support without any under frequency load shedding requirement. The approach utilizes linear regression analysis (LRA) algorithm which is subjected to varying frequency and generation support condition. The proposed method is implemented for several deloading cases on modified IEEE 39 bus test system in DIgSILENT PowerFactory. The findings indicate a specific PV deloading percentage results in a minimum PV power requirement to avoid load shedding. This minimum PV power corresponds to a specific range of irradiance and temperature in which this deloading can provide acceptable support. Furthermore, this paper also provides insights on the improvement rate of minimum PV power requirement with deloading. As a result, this methodology can be used to decide whether a certain deloading percentage can supply desired support in any situation. Thus, this paper will work as a guideline to grid operators to select proper PV deloading for frequency regulation considering variability in PV power generation.

10:10 ***Large Signal Stability of Grid-Tied Virtual Synchronous Generator Using Trajectory Reversing.....398***

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

This paper proposes the utilization trajectory reversing based algorithm to study the large signal stability of virtual synchronous generator (VSG) based Micro-grid. The algorithm is used to provide an estimation of enlarged region of asymptotic stability (ROA) of the VSG. To overcome the complexity of finding a proper expression to represent the enlarged ROA, the algorithm utilizes convex hull algorithm which expresses the enlarged ROA by a set of finite number of inequalities and equations. Moreover, this paper proposes a new technique to generate uniformly distributed initial points needed by the algorithm. The proposed technique provides an easy and direct method to balance the computation time with the number of required initial points. A test case is conducted of VSG connected to an infinite bus to validate the accuracy of the proposed technique and algorithm.

S17: Active Distribution Systems

Chair: Chao Shen (Carleton University, Canada)

9:30 ***Grey Wolf Optimizer for Optimal Distribution Network Reconfiguration.....405***

Haifa Souifi (ClairiTech Innovations, Canada); Hsan Hadj Abdallah (University of Sfax, Tunisia)

The distribution network reconfiguration (DNR) has recently been brought to light as one of the most

attractive strategies to enhance the performances of distribution systems. In this respect, this paper focuses on solving the DNR problem using a GWO (Grey Wolf Optimizer) algorithm. The proposed method was applied in an IEEE 69-bus test system to reduce its active power losses while satisfying the buses voltages, branches currents and radial topology constraints as well. To thoroughly assess the total active power losses of the distribution system, the Backward/Forward approach was developed in this study. Furthermore, the union-find with path compression technique was used to check the radiality constraint. So as to reveal its efficiency and suitability in solving the DNR issue and reaching the optimal solution, the proposed GWO algorithm was compared to the GA (Genetic Algorithm) and CF-PSO (Constriction Factor-Particle Swarm Optimization) as well. Moreover, it was validated against several techniques developed in recent literature. The research results disclosed that after performing reconfiguration, a significant reduction of total power losses evaluated at 56.17% was obtained and the voltage profile was generally improved.

S17: Digital Transformation of Power and Energy Systems

Chair: Chao Shen (Carleton University, Canada)

9:30 ***A Digital Twin Model for COP Prediction in Refrigeration System Using Combined Machine Learning Method.....412***

Dongxu Zhou and Zhengyi Zhu (State Grid Jiangsu Electric Power Co., Ltd. Nanjing Power Supply Branch, China)

Accurate prediction of coefficient of performance (COP) in refrigerant system is beneficial to the overall system performance evaluation and dynamic operation optimization. In this paper, a digital twin model of COP prediction in refrigeration system based on combined machine learning method is proposed. Firstly, several influencing factors are selected guided by the mechanism knowledge, and the correlation coefficients between impact factors and COP value are calculated to further verify their importance in COP prediction. Secondly, the convolutional neural network (CNN) and multilayer perceptron (MLP) with intrinsic weight optimization are used to capture the characteristics between the influencing factors and COP, while the long short term memory (LSTM) method is used to capture the characteristics of the time series data. Meanwhile, the weights of the CNN, LSTM and MLP methods are optimized in real time by the particle swarm optimization (PSO) algorithm to minimize the difference between the COP value of physical system and the predicted COP value of digital twin model to realize online self-update. Finally, simulation results show that the MAE, MAPE and RMSE obtained by the proposed method are respectively 7.01%, 1.71% and 0.08% lower than those obtained by CNN method, 0.92%, 0.24% and 0.01% lower than those obtained by LSTM method, and 2.41%, 0.58% and 0.02% lower than those obtained by MLP method, which have proved that the prediction result of proposed digital twin model for COP prediction is more accurate.

S17: Efficiency and Conservation

Chair: Chao Shen (Carleton University, Canada)

9:30 ***Survey-Based Policies to Integrate Local Lamp Manufacturer Interests and Energy Efficiency in Indonesia.....418***

Vetri Nurliyanti and M Indra Al irsyad (National Research and Innovation Agency, Indonesia); Qatro Romandhi and Tri Anggono (Ministry of Energy and Mineral Resources, Indonesia); Nidya Judhi Astrini (National Research and Innovation Agency, Indonesia)

Indonesia was once one of the main players in incandescent lamp markets. However, Indonesian lighting manufacturers cannot compete with cheaper imported compacted fluorescent (CFL) and light-emitting diode (LED) lamps; consequently, their market share has significantly reduced. Several manufacturers refused obligated standards related to safety and performance to avoid additional certification costs and keep producing low-quality and low-cost lamps. The obligation absence also allows low-quality imported lamps to overwhelm the Indonesian market and detract from the energy-saving benefits of LED lamps. Our study conducted surveys and interviews with lighting manufacturers and related institutions to define problem complexity and solutions on a causal loop diagram. After that, we proposed policy reformations to strengthen local lamp manufacturers and, at the same time, to enhance energy savings in the lighting sector.

S17: Wireless Power Transmissions

Chair: Chao Shen (Carleton University, Canada)

9:30 ***Analyzing the Impacts of High Voltage Insulators on Equivalent Parameters of Wireless Power Transfer: Simulation and Experimental Studies.....424***

Sadjad Shafiei, Seyed Saeid Heidari Yazdi, Tleukhan Mussin and Yussuf Shakhin (Nazarbayev University, Kazakhstan); Alireza Namadmalan (University o Galway, Ireland); Mehdi Bagheri (Nazarbayev University, Kazakhstan)

The impacts of high voltage (HV) insulators on equivalent circuit parameters of wireless power transfer (WPT) system is evaluated and analyzed in this study. Flat spiral coils are inserted under the HV insulators and convey power to charge monitoring devices' battery at the top of the power line towers. All the external metal objects over the magnetic flux path are identified, and their material type, relative permeability, and conductivity are explained. An equivalent circuit for the WPT system is specified, and its parameters are calculated with and without the presence of external metal objects. In this sense, 3-D finite element method (FEM) simulations are conducted in ANSYS Maxwell. The variation of the magnetic flux within the airgaps is displayed, the eddy current induction initiation over the external metal objects is shown, and changes in the equivalent circuit parameters of the WPT system are clearly discussed. The results of the simulation study are then validated through experimental studies by means of fabricated flat spiral coils.

S18: Electrical Machines & Drivers

Chair: Hima Dhulipati (Carleton University, Canada)

9:30 *Reducing Dependency on Rotor Time Constant in a Rotor Flux Oriented Vector Controlled Induction Motor Drive Based on Its Static Model.....430*

Himanshu Swami (Indian Institute of Technology Delhi, India); Amit Kumar Jain (IIT Delhi, India)

This paper proposes a modified control algorithm for three phase squirrel cage induction motor. The proposed algorithm is based on the static or steady state model of a vector-controlled drive with rotor flux orientation and controls the machine dynamics over one fundamental cycle. The algorithm proposes current mode control on the direct axis and voltage mode control on the quadrature axis, unlike, state of the art vector-controlled drive where current mode control is used on both the axes. This offers two advantages. First, the control algorithm becomes independent of the rotor time constant, which is always varying, thereby reducing the dependency on rotor time constant of the motor. Second, one proportional integral controller is reduced in the control algorithm. The proposed scheme is validated through simulation using a fractional horse power squirrel cage induction motor. The proposed technique is also compared with the conventional vector control.

9:50 *Type 4 Wind Turbine Design and Development of Grid Code Algorithms.....438*

Hakkı Gülcü (ASELSAN Inc., Turkey); Bunyamin Tamyurek (Gazi University, Turkey)

In this study, a wind turbine design is proposed that complies with the Turkish grid code. The proposed design consists of the control algorithms of the grid connection regulations of the squirrel cage asynchronous generator (SCIG) and full-scale power converter (FSPC) configuration with 5 MW grid output power, which is called type 4 wind turbine (WT). The design studies on the designed 2-level full bridge IGBT modelling is explained step by step under three main parts and a case study is conducted for the grid codes. First of all, the control of energy generation from a 5.15 MW output power SCIG by the rectifier module of the FSPC with the indirect fielddirected control algorithm is explained. In the second part, the energy transferred to the DC busbar with the rectifier modules of FSPC is transferred to the grid with the help of control algorithms created on the inverter according to the grid requirements. Finally, simulation studies of FSPC control algorithms of wind turbines, which will provide solutions to Turkish electrical grid regulations, is carried out.

S18: Real-Time Simulation

Chair: Tao Yang (Northeastern University, China)

9:30 *Analysis of Different Latencies and Time Delays in a Coupled Power-Hardware-In-The-Loop Laboratory.....446*

Timo Wagner (Friedrich-Alexander Universität Erlangen- Nürnberg, Germany); Julian Richter (FAU Erlangen-Nürnberg, Germany); Christian Scheibe (Friedrich-Alexander-Universität Erlangen Nürnberg (FAU) & Siemens AG, Germany); Simon Resch and Gert Mehlmann (Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany); Matthias Luther (University of Erlangen-Nürnberg, Germany)

As the power grid is considered critical infrastructure, new operating equipment and control concepts require multiple levels of extensive testing before integration. Power Hardware-in-the-Loop (PHiL) simulations provide a framework to perform parts of these tests using physical components in simulated power grids. Coupling discretely simulated and physical components, time delays occur at various points, which influence the stability and accuracy of the PHiL simulation. In this work, the time delay of a PHiL simulation in two spatially separated laboratories is analyzed with respect to simulation time step, communication signal travel time and power interface technology. Subsequently, it is discussed under which conditions a reduction of the simulation time step is possible and feasible and how the effect of phase shifting caused by time delay can be compensated in the simulation.

9:50 ***Direct Interfacing of Average-Value Models of VSCs in PSCAD/EMTDC.....452***

Seyyedmilad Ebrahimi (University of British Columbia, Canada); Taleb Vahabzadeh (The University of British Columbia, Canada); Juri Jatskevich (University of British Columbia, Canada)

Voltage-source converters (VSCs) are widely utilized in power systems. Due to their high-frequency switching, discrete detailed models of VSCs are computationally expensive in system-level simulations and their average-value models (AVMs) have proven indispensable for fast/efficient studies. Conventional AVMs of VSCs use dependent current/voltage sources to interface with external circuits. In PSCAD/EMTDC, with non-iterative solutions, the interfacing variables are computed based on the values of the input voltages/currents from the previous time-step. This one-time-step delay can make the results numerically inaccurate/unstable when large time-steps are used in simulations. In this paper, an AVM is developed for VSCs that is interfaced with external circuits directly without delays to allow large time-step. This is done by formulating the VSC AVM formulations as a conductance matrix to be merged into (and solved simultaneously with) the rest of the network nodal equations. The new directly-interfaced AVM of VSCs is verified against the classic dependent-source-based AVM in PSCAD/EMTDC and is demonstrated to allow large time-steps and outperform the existing counterpart in terms of numerical accuracy.

Wednesday, December 7 11:10 - 12:00

Closing Session