PROGRAM AT A GLANCE

Time	Tuesday August 30, 2022	
16:00-18:00	Registration	Tutorial: **Optimization in Active Power Distribution Systems: Fundamentals and Applications**, Dr. Sumit Paudyal, Associate Professor, Florida International University, Dr. Anamika Dubey, Associate Professor, Washington State University, Dr. Sukumar Kamalasadan, Profesor, University of North Carolina at Charlotte Kadir Has University **D107** (Online)
18:00-21:00		Registration and Welcome Reception- **Kadir Has University**

Time	Wednesday August 31, 2022.		
09:30-10:15	Registration	Opening Ceremony and Plenary Session: **Electrical and Electronics Engineering Building 1304 Istanbul Technical University**	
10:15-11:00		Plenary Speech I **Changing Modeling and Simulations Needs for Grid Modernization** Prof. Dr. Kevin Tomsovic (IEEE Fellow)– Director of Curent and CTI Chancellor's Professor of Electrical Engineering and Computer Science at University of Tennessee, Knoxville	
11:00-11:30		Coffee Break	
11:30-12:15		Plenary Speech II **The Emergence of Photovoltaics and Its Role in Sustainable Development** Assoc. Prof. Dr. Selcuk Yerci -Vice President of ODTU-GUNAM, Center for Solar Energy Research and Applications and Faculty Member in Electrical and Electronics Engineering at METU	
12:15-12:40		Plenary Speech III **Problems Encountered and Solution Perspectives of a Turkish Distribution Systems Company** Uğur Mutluhan Oruncak, Dicle Elektrik, Chief Technology and Business Development Officer	
12:40-14:00		Lunch	
14:00-15:30		TS-1 Room: Ömer Korzay	TS-2 Room: 1302	TS-3 Room: 1304
15:30-16:00		Coffee Break	
16:00-17:30		TS-4 Room: Ömer Korzay	TS-5 Room: 1302	TS-6 Room: 1304
17:30-18:30	Transport to Baltalimanı for the Cruise		UPEC SC Meeting (Faculty Meeting Room)
19:00-23:00	Cruise tour along Bosphorus and dinner		

Time	Thursday September 1, 2022.			
09:00-09:45	Registration	Plenary Speech IV **The electrical machine air gap, the most expensive real estate in the world** Prof. Alasdair McDonald, Edinburgh University		
09:45-11:15		TS-7 Room: Ömer Korzay	TS-8 Room: 1302	TS-9 Room: 1304
11:15-11:30		Coffee Break		
11:30-13:00		TS-10 Room: Ömer Korzay	TS-11 Room: 1302	TS-12 Room: 1304
13:15-14:00		Lunch		
14:00-15:30		TS-13 Room: Ömer Korzay	TS-14 Room: 1302	TS-15 Room: 1304
15:30-16:00		Coffee Break		
16:00-17:30		TS-16 Room: Ömer Korzay	TS-17 Room: 1302	TS-18 Room: 1304
19:00-23:00	Conference Dinner			

Time	Friday September 2, 2022.			
09:00-10:30	Registration	TS-19 Room: Ömer Korzay	TS-20 Room: 1302	TS-21 Room: 1304
10:30-11:00		Coffee Break		
11:00-12:30		TS-22 Room: Ömer Korzay	TS-23 Room: 1302	TS-24 Room: 1304
12:30-13:00		Free Time		
13:00-13:30		Closing Ceremony		
13:30-14:00		Lunch		

Technical Programme Summary

Wednesday 31 August 2022

14:00-15:30	**Parallel Paper Sessions TS1-TS3**
Session TS1	**Power Systems Operation and Control (1)** **Room: Ömer Korzay**
Session Chair	**Dr Murat Göl (Middle East Technical University)**

31

Detrending and Characterizing System Frequency Oscillations Using an Adapted Zhou Algorithm

Aidan Bowen (Technical University of Denmark); Barry P. Hayes* (University College Cork, MaREI SFI Centre for Energy)

Abstract—Electro-mechanical oscillations between interconnected synchronous generators and oscillations in system frequency are an inherent part of the operation of large power systems. Very Low Frequency (VLF) oscillations are usually classified as oscillations in the 0.01-0.1 Hz range. With the move towards variable renewable energy sources and low-inertia power systems, VLF oscillations are being observed with increasing regularity in many small and island grids. If left undamped, these can present a threat to system stability. However, finding the root cause and source(s) of VLF oscillations is an extremely challenging task for network operators. Recent work has identified a need for improved tools for identifying and characterising VLF oscillations, in order to determine the combination of system conditions that can be used as predictors for VLF events. A suitable small signal model is also required in order to enable verification of the root cause of VLF events and study of mitigation measures. Accordingly, this paper presents a new approach for detrending and characterizing system frequency oscillations using an adapted Zhou algorithm. The paper also describes a method for applying this algorithm for the detection/location of oscillations, and for their detrending and characterization. Finally, an approach for relating detected oscillation events to power system operating conditions for diagnostic purposes is described. The effectiveness of the proposed approach is demonstrated using a single frequency power system model and using system frequency oscillations recorded from the Irish power system.

129

Topological Aspects of Building Synthetic Models for Power Transmission Networks from Public Data

Lorenzo Solida*; Gianfranco Chicco; Ettore Bompard; Tao Huang; Andrea Mazza (Politecnico di Torino); Marco Raffaele Rapizza (Ricerca Sistema Energetico S.p.A.)

Abstract—This paper addresses the preparation of synthetic models for electrical transmission systems, using open (publicly available) data. Starting from information gathered from maps with multiple data such as OpenStreetMap, the nodes and lines are extracted and are used to establish the network topology. An example constructed in an Italian region is shown.

55

Zero-Sequence Based Fault Location in Non-Effectively Earthed Distribution Systems

Mert Bekir Atsever* (Gebze Technical University); Umur Deveci; Seyit Cem Yılmaz (Research and Development Department, BEDAS); Mehmet Hakan Hocaoglu (Istanbul Ticaret University)

Abstract—Earth faults are detected and located by using zero sequence current magnitude in the field. However, distribution networks may have different neutral earthing strategies, generally, preferred by distribution system operators or enforced by regulatory bodies. Different earthing practices create difficulties for earth fault location problems. In addition to this difficulty, heavy underground cable usage increases the capacitive current levels of the system. Circulating capacitive currents during the single line to ground faults may further hinder the effectiveness of earth fault location algorithms. This work presents zero sequence magnitude-based fault location performance on 151-node distribution network considering different earthing methodologies and line types

60

Real-Time Approach of Grid-Parallel Simulation for Automated Distribution Grids

Stephan Ruhe*; Steffen Nicolai; Peter Bretschneider (Fraunhofer IOSB IOSB-AST, Dept. Cognitive Energy Systems); Dirk Westermann (University of Technology Ilmenau)

Abstract— Distribution grids are subject to constant change due to transformations in energy transmission, generation and consumption. Among other reasons, the integration of renewable energy sources (RES) and increasing electromobility make safe and reliable grid operation in conventional structures more difficult. More monitoring devices are increasingly being installed to better track grid conditions and make them available for analysis functions. A powerful grid automation system is becoming a key factor in the operation of distribution grids. Novel automation functions as well as decision support capabilities are required to cope with adverse network conditions and the massive amount of data. Complementing classical monitoring systems, this paper shows an approach and use cases of a real-time simulation (RT) parallel to the grid based on measured data, system identification and state estimation of the real grid. The system extends the monitoring functionalities to an influence reactive system that can reproduce the network operation in a realistic environment. As with hardware-in-the-loop (HiL) simulations, this approach provides a platform for testing and monitoring the automation functions of distribution networks.

14

Discrimination between internal current and external fault in three phase power transformer by Using alienation coefficient

Othman Abdusalam*; Fatih Anayi; Michael Packianather (Wolfson Centre for Magnetics, Cardiff University)

Abstract—Transformers are essential equipment in a power system and require reliable solutions for their protection to ensure smooth operation. This paper proposes a new method based on an alienation coefficient analysis of waveforms to discriminate between external and internal faults that may take place in a three-phase transformer. This method depends on variations in the waveforms of currents which occur due to faults. it depends on the three phase current measurements which can be calculated on the transformer, and thus, does not need extra devices. This method can be used for fault detection and classifying faulty phases. For usage in advanced protection plans, the alienation strategy is appropriate in this field. The new technique was practically applied in the laboratory, and the results were obtained using the MATLAB and LabVIEW software. The proposed technique is quick to such an extent that it can provide conclusions in less than 3ms

* corresponding author

Wednesday 31 August 2022

14:00-15:30	**Parallel Paper Sessions TS1-TS3**
Session TS2	**Analytical Methods and Implementation in Smart Grids (1)** **Room: 1302**
Session Chair	**Dr. Ioana Pisica (Brunel University London)**

48

Stochastic Heuristic Optimization of Machine Learning Estimators for Short-Term Wind Power Forecasting

Athanasios Ioannis Arvanitidis*; Dimitrios Kontogiannis; Georgios Vontzos; Vasileios Laitsos; Dimitrios Bargiotas (University of Thessaly)

Abstract—The continuous fluctuation of wind speed, wind direction and other climatic variables affects the power produced by wind turbines. Accurate short-term wind power prediction models are vital for the power industry to evaluate future energy extraction, increase wind energy penetration and develop cost-effective operations. This research examines short-term wind power forecasting and investigates the effect of sharp, smooth and slow temperature reduction functions on the Simulated Annealing (SA) optimization technique for several prominent prediction models. The regressors under investigation include a Support Vector Machine, a Multi-Layer Perceptron and a Long-Short Term Memory neural network. Their optimization is based on the SA, which is used to specify the hyperparameters of each model in order to enhance the prediction accuracy. The results for each model based on the data of the Greek island of Skyros denote the superiority of the slow temperature reduction function in terms of error metrics and observe that the optimized Multi-Layer Perceptron is the most suitable model for this forecasting task when slow temperature reduction is implemented.

58

Estimating Wind Power Uncertainty using Quantile Smoothing Splines Regression

Ndamulelo Mararakanye*; Bernard Bekker (Stellenbosch University)

Abstract—Forecast errors in wind power forecasting are unavoidable due to the complex nature of weather systems and other influences. As a result, quantifying wind power uncertainty is essential for optimally operating grids with a high share of wind energy. This paper uses the quantile smoothing splines (QSS) regression to estimate conditional quantiles of wind power forecast error for a given wind power forecast. This approach is tested using data from eight wind farms in South Africa and evaluated using reliability, sharpness, resolution, and skill score. The results are compared to that of two commonly used approaches: linear regression and fitting beta distributions in different bins. Despite the slight superiority of QSS regression, this paper finds that the results of QSS regression and fitting beta distributions in different bins are comparable. The benefit of using QSS regression, however, is that it is a nonparametric approach that produces smooth results with no discontinuities, and no need for parameter estimations for each bin, making it easily applicable. System operators can use the estimated quantiles to allocate operating reserves and hence ensure the efficient integration of wind farms into the power grid.

84

One Step Ahead Energy Load Forecasting: A Multi-model Sliding Window Approach

Aristeidis Mystakidis (CERTH, International Hellenic University); Evangelia Ntozi; Konstantinos Afentoulis (CERTH); Paraskevas Koukaras (CERTH, International Hellenic University); Georgios Giannopoulos; Napoleon Bezas; Paschalis A. Gkaidatzis; Dimosthenis Ioannidis (CERTH); Christos Tjortjis (CERTH, International Hellenic University); Dimitrios Tzovaras (CERTH)

Abstract—Emerging Energy Load Forecasting (ELF) methodologies assist Distribution System Operators (DSOs) and Aggregators. Energy imbalance among consumption and generation could also be managed with high prediction accuracy, as well as smart grid applications, like Demand Response (DR) events. This study aims to test several algorithms as a solution for ELF. The proposed methodology utilizes machine/deep learning models for time-series forecasting in the domain of energy consumption. Via result comparison it has been illustrated that Neural Networks (NNs), both artificial NNs such as Multilayer Perceptron (MLP) and Long Short-Term Memory (LSTM) recurrent NNs with Extreme Gradient Boosting (XGBoost) were the more accurate ones among other models, showcasing Mean Absolute Error (MAE), R-squared (R 2), Root Mean Squared Error (RMSE) and Coefficient Variation of Root Mean Squared Error (CVRMSE) values equal to 1.281, 0.98, 2.238 and 0.147, respectively.

152

Using Adaptive Safe Experimentation Dynamics Algorithm for Maximizing Wind Farm Power Production

Mohd Ashraf Ahmad*; Julakha Jahan Jui; Mohd Riduwan Ghazali (Universiti Malaysia Pahang)

Abstract— This research presents a model-free strategy for increasing wind farm power generation based on the Adaptive Safe Experimentation Dynamics Algorithm (ASEDA). The ASEDA method is an improved version of the Safe Experimentation Dynamics (SED) algorithm that modifies the current tuning variable to respond to the changes in the objective function. The convergence accuracy is predicted to be enhanced further by adding the adaptive element to the modified SED equation. The ASEDA-based technique is used to determine the ideal control parameter for each turbine in order to maximize a wind farm's total power generation. A single single-row wind farm prototype with turbulence coupling among turbines is employed to validate the proposed approach. Simulation findings show that the ASEDA-based approach provides more total power generation than the original SED technique.

86

Variable-Length Event Classification using PMU Data with Naïve Bayes

David Foster*; Xueqin (Amy) Liu (Queen's University); Mark Rafferty (Smarter Grid Solutions); David Laverty (Queen's University)

Abstract—Increasing levels of non-synchronous generation prompted by global emissions targets has resulted in power systems with low inertia. This has led to changing system dynamics and evolving trends in system events which are difficult to classify through traditional means. Many countries have invested in Phasor Measurement Units (PMUs) to monitor these systems over large geographical areas which form Wide Area Monitoring Systems. Due to the increased use and improved technology of PMUs this has generated vast quantities of data for system operators to process. Automatic methods for event diagnosis are required due to the complexity of system events, including variable event lengths. This paper demonstrates an approach for the wide area classification of a number of power system events. Event sequencing is used to solve the variability of event lengths. Sequential feature selection is adopted on wide area synchronized frequency, phase angle and voltage measurements to extract the optimal features. Successful event classification is obtained by employing a Naïve Bayes classifier on the features. The reliability of this method is evaluated using simulated case studies and benchmarked against various sequence lengths.

* corresponding author

Wednesday 31 August 2022

14:00-15:30	Parallel Paper Sessions TS1-TS3
Session TS3	HVDC, FACTS, and Power Electronics (1) Room: 1304
Session Chair	Dr. Ozan Keysan (Middle East Technical University)

41

A Basic Phase Shift Full Bridge DC-DC Converter Design and Simulation

Şeyma Küçük*; Erdem Akboy (Yildiz Technical University)

Abstract— Full Bridge (FB) converters are used in the industrial applications such as switch mode power supplies, high voltage power supplies, battery chargers and welding machines etc. FB isolated DC-DC converters provide a safe charging process by providing galvanic isolation between the battery and the mains. Since the efficiency of the battery charger largely depends on the efficiency of the DC-DC converters, DC-DC converters are very important for battery chargers. However, at FB converters, the parasitic oscillations between the parasitic capacitors of the switches and the leakage inductance of the transformer can reach unacceptable levels for switching losses. Therefore, phase-shift method can be used to provide Soft Switching (SS). At this method, the overlapping of the current and voltages of the switches are reduced and so switching losses are decreased. Moreover, current and voltage stresses of power components and Electro Magnetic Interference (EMI) are decreased. It is suitable and preferred for battery chargers in EV technology. In this study, a phase shift FB converter is presented. The design parameters and simulation results are given for input voltage of 385V DC, switching frequency of 50 kHz, and output of 250 W / 48 V.

89

Enhanced Finite Control Set-Model Predictive Control for Three-Phase Split-Source Inverters

Abualkasim Bakeer (Aswan University); Sherif M. Dabour* (Glasgow Caledonian University, Tanta University); I. A. Gowaid (Glasgow Caledonian University); Ahmed A. Aboushady; Mohamed A. Elgenedy; Mohamed Emad Farrag (Glasgow Caledonian University)

Abstract—Three-phase Split-source inverter (SSI) has recently been proposed as an alternative to the three-phase Zsource inverters (ZSI). This paper introduced an improved finite control set-model predictive control (FCS-MPC) algorithm for the SSI. The proposed FCS-MPC algorithm reduces the computational burden by selecting the discharging vector directly according to the current status of the inductor compared to its reference point instead of checking the other states. Moreover, it simplifies the cost function by removing the inductor's current term, and thus no weighting factor is needed inside the cost function. A detailed analysis of the proposed algorithm is presented in this paper. Finally, simulation results based on MATLAB have been introduced to show the viability of the presented research and theoretical study of the FCS-MPC algorithm of the three-phase SSI under different operating conditions

106

Application of a Novel Adaptive Control Approach for the Regulation of Power Converters

Muhammad Ahmed Qureshi*; Salvatore Musumeci (Politecnico di Torino); Francesco Torelli (Politecnico di Bari); Alberto Reatti (University of Florence); Andrea Mazza; Gianfranco Chicco (Politecnico di Torino)

Abstract—In this paper, a novel model-reference adaptive control methodology is proposed for the regulation of two power converter topologies. The main controller objective is the asymptotic tracking of the reference trajectory provided as input. The tracking is achieved through the adaptive mechanism based on Torelli Control Box approach. The control methodology explicitly guarantees convergence and asymptotic stability of the system. The designed controller has been simulated on buck and boost power converters and its performance has been analyzed by subjecting the converters to varying load and voltage conditions. Under all the test conditions, the controller proposed performs better than a backstepping-based controller taken as a benchmark for both converters.

26

Data-Driven Control of DC-DC Power Converters Using Levenberg-Marquardt Backpropagation Algorithm

Kehinde A, Makinde; Maher Al-Greer* (Teesside University)

Abstract—The majority of the controllers are designed around linearized small signal models of switching power converters. These models often encounter shortfalls in capturing the dynamics and underlying behaviours of the switching converters. Hence, in order to comply with the stringent requirement for voltage regulation in many modern applications which are plagued by non-idealities such as load disturbance and varying parameters, the use of adaptive, nonlinear and intelligent controllers becomes pivotal. It is against this backdrop that this paper proposes a data driven control using a four-layered feedforward neural network controller which is able to achieve a near-optimal performance in the output waveforms of a synchronous dc-dc buck converter. The training data for the neural network are extracted from the simulation of the converter using the designed type II compensator in current mode control with load current feedforward, considering wide range of dynamic changes in load current and input voltage. Results clearly show that the proposed ANN controller gives better performance than the conventional Type-II and Type-III compensators.

155

A DC/DC Buck-Boost Converter-Inverter-DC Motor Control based on model-free PID Controller tuning by Adaptive Safe Experimentation Dynamics Algorithm

Mohd Riduwan Ghazali*; Mohd Ashraf Ahmad; Mohd Helmi Suid (Universiti Malaysia Pahang); Mohd Zaidi Mohd Tumari (Universiti Teknikal Malaysia Melaka)

Abstract—Model-free PID control is currently utilized for the examination of a DC/DC Buck-Boost Converter-Inverter-DC motor structure in this study through optimization of the adaptive safe experimentation dynamics (ASED) method. PID controller has been popularized on its uncomplicated construct, convenient employment with limited tuneable parameters, and broad applicability to diverse mechanistic circumstances. Demonstrated nonlinearity, complexity, and high dimensional parameters within MIMO structure of the DC/DC Buck-Boost Converter-InverterDC motor then demand controller with immense precision. The ASED method is hereby adopted as the optimization approach with considerable precision as needed towards fine-tuning the PID controller for its ability to minimize both output of control tracking and energy consumption at reduced processing interval by the exclusion of mathematical modeling in assessing input and output of the system. Traced outcomes regarding voltage of the converter and bidirectional angular velocity are further accounted for performance appraisal of the recommended motor system equipping model-free PID controller following optimization of the ASED approach. A comparison was further operationalized between the proposed ASED approach and its conventional SED-based counterpart. Convergence stability was successively reached by the proposed approach via undertaken simulation with minimization of the specified objective function. Acquired results hereby confirmed smaller values of the objective function and total norm error by the ASED approach towards the precision of operation tracing against the performance of its conventional counterpart.

* corresponding author

Wednesday 31 August 2022

16:00-17:30	Parallel Paper Sessions TS4-TS6
Session TS4	Electric Vehicles and Transport Room: Ömer Korzay
Session Chair	Dr. Alparslan Zehir (Marmara University)

34

Multi-objective Advanced Grey Wolf Optimization Framework for Smart Charging Scheduling of EVs in Distribution Grids

Bahman Ahmadi*; Nataly Banol Arias; Gerwin Hoogsteen; Johann L. Hurink (University of Twente)

Abstract— This paper proposes a multi-objective optimization technique for scheduling the charging of electric vehicles (EVs) in electrical distribution systems (DSs). A multi-objective advanced grey wolf optimization algorithm (MOAGWO) is developed to find the Pareto optimal solutions that minimize the DS's operational costs, energy losses costs, voltage violations, and the energy not supplied to EV users using several scenarios. A 449-node system with 63% penetration of EVs is used to demonstrate the efficiency of the proposed method. The quality of the non-dominated optimal solutions found by MOAGWO are validated via a comparison analysis with other well-known methods such as the multi-objective grey wolf optimizer (MOGWO) and the multiobjective particle swarm optimization (MOPSO) algorithm, based on domination rate, spacing index, hypervolume index, and computational cost measurements. The Pareto solutions indicate that the smart charging coordination found by MOAGWO makes the techno-economic operation of the DS possible while satisfying energy-based goals of the EV users.

23

Overview of Electric Vehicle Interconnected Subsystems

Mostafa Farrag*; Chun Sing Lai; Mohamed Darwish (Brunel University London)

Abstract— This paper examines electric vehicle (EV) subsystems operation and will focus on power management (PM). PM is always concerned with the EVs battery performance, efficiency and lifetime. The battery plays a vital role in the EV's performance, to provide the vehicle driving system with the energy needed for operation. Lithium-ion batteries have emerged as the battery of choice for EV manufacturers due to their high energy density and lightweight as compared to other energy storage. For the safe and dependable functioning of EV batteries, condition assessment of the batteries is significant. This is attained by a battery management system (BMS). In addition to the BMS, the optimal flow of energy between the battery, converters and additional vehicle components should also be regulated. This is called a power management control (PMC), where the vehicle's optimum performance depends heavily on the nature of PMC. Therefore, the design of PMC is critical to reduce energy consumption, increase system efficiency and maximise battery life. This paper presents an overview of EVs battery modelling, technologies and properties. It shows the BMS performance indicator and the benefits of integrating battery and supercapacitor to optimise the energy consumption of EVs.

95

Forecourt Electric Vehicles Charging Hubs – UK and Saudi Research and Education Collaboration

Mohamed Darwish* (Brunel University); Mohamed Rady (King Abdulaziz University); Maysam Abbod (Brunel University); Eydhah Almatrafi (King Abdulaziz University); Chun Sing Lai (Brunel University)

Abstract—This paper covers how a successful model of electric vehicles (EV) forecourts in the UK can be implemented into Kingdom of Saudi Arabia (KSA) for supporting research, knowledge, and innovation in emerging EV technologies. The paper also addresses the challenges of implementation of EV technologies via research, training and curriculum development.

59

Study on the Impact of Aviation Electrification on Voltage Deviation of the GB Transmission System

Bozheng Li*; Zekun Guo; Yuejie Yuan; Xin Zhang (Brunel University)

Abstract—With the increasing demand for clean energy and rapid development of battery technology, there has been a notable trend in developing aviation electrification, particularly for small or regional electric aircraft (EA). Nevertheless, large penetration of EA with high charging power could also influence the stable operation of the upstream grid and even cause severe problems, particularly causing voltage-drop issue. In this paper, the impact on voltage deviation of the Great Britain (GB) electrical power system with the electrification of commercial aviation in the UK is highlighted and analysed. A reduced model of the GB transmission system developed in DigSILENT PowerFactory with 36 zones is modified by incorporating the load curves of the EA charging demand into the model. Quasi-Dynamic simulation is used to obtain 24-hour voltage profiles of each zone. Meanwhile, the Granger causality test is utilised to analyse the voltage profiles obtained from the Quasi-Dynamic simulation and determine the causal effects of the voltage variation between different areas of GB. The results reveal the significant impact of EA charging on the system. When the EA charging demand reached nearly 10000MW at 20:00, the system voltage dropped to 0.826 p.u. The locations of the most influential zones for voltage variation in the system are also illustrated and analysed in this paper.

67

Review of Wireless Charging of EV

Muhammad Salman Sikandar*; Mohamed Darwish (Brunel University) Christos Marouchos (Cyprus University of Technology)

Abstract—Electrified transportation will minimise greenhouse gas emissions while also lowering gasoline prices. To encourage the adoption of electrified transportation, a variety of charging networks must be established in a user-friendly environment. WEVCS (wireless electric vehicle charging systems) could be a viable alternative technology for charging electric vehicles (EVs) without the need for a plug. The work done in the area of wireless power transfer technology for electric vehicles is described in this paper.

* corresponding author

Wednesday 31 August 2022

16:00-17:30	Parallel Paper Sessions TS4-TS6
Session TS5	Renewable Energy Systems (1) Room: 1302
Session Chair	Dr. Ahmed Zobaa (Brunel University, London)

133

PMU based Dynamic Model Calibration of Type-4 Wind Turbine Generators

Etki Acilan*; Fatih Erden (Middle East Technical University); Oguzhan Ustundag; Ersan Bozkurt (Siemens A.S); Murat Gol (Middle East Technical University)

Abstract—Dynamic models of power plants may change during its operation due to physical processes and human error. Inaccurate dynamic power plant models may affect the operation and planning of power systems. Hence, keeping the model updated is crucial. Traditionally, dynamic models of power plants are calibrated by offline staged tests. Recently, PMU based remote calibration techniques are developed in attempt to calibrating the dynamic models remotely and reducing the frequency of offline calibration. This paper presents the implementation of PMU based dynamic model calibration of Type-4 Wind Turbine Generators by using the Ensemble Kalman Filter. The implementation is done by using PSS®E in PythonTM environment and validated by using WSCC-9 Bus System.

103

Characterisation of the Thermoelectric Materials for Energy Harvesting Applications

Iulian Bancuta; Diana Enescu*; Elena Otilia Virjoghe (University Valahia of Targoviste)

Abstract— This paper addresses various aspects concerning the structure and application of thermoelectric devices. The first part deals with the experimental analysis conducted on the materials that form the thermoelements in a thermoelectric device. The paper recalls the main parameters investigated, describes the methods used in the experimental characterisation and shows the results of the experiments. The experimental results are useful for understanding the different characteristics of the materials used in the thermoelements. The successive part presents the results of the simulations carried out by considering the application of the thermoelements studied in the operational framework of an energy harvesting device, in which a temperature difference is converted into an output voltage that can supply an electrical load.

137

Investigation and application of systemic assessment variables and concepts to developed reference districts

Samir Kharboutli* (TU Ilmenau); Cristian Monsalve; Prof. Dr.-Ing. Peter Bretschneider (Fraunhofer IOSB-AST)

Abstract— The focus of the paper is the investigation and application of systemic assessment variables and concepts to developed reference districts. For this purpose, usable variables and concepts are first determined in the context. Then, the electrical energy supply structure of a district is mapped in a time series-based model and extended by different supply variants. For each variant, all evaluation variables are determined. The resulting matrix is used to investigate the applicability, relevance and interdependencies between the evaluation variables.

123

Agrivoltaic System: a Case Study of PV Production and Olive Cultivation in Southern Italy

Alessandro Ciocia* (Politecnico di Torino); Diana Enescu (University Valahia of Targoviste); Angela Amato; Gabriele Malgaroli; Raffaele Polacco (Politecnico di Torino); Fabio Amico (Green-Go S.r.l.); Filippo Spertino (Politecnico di Torino)

Abstract — The double use of the land in the AgriVoltaic (AV) sites allows to "doubly harvest from the sun", increasing the land use exploitation with lower environmental impact. This effect strongly depends on the system configuration for both the PV and agricultural sides. The choice is between a high-density PV module arrangement, with high PV production and low agricultural harvesting, or a highly spaced arrangement with lower PV production. The present work presents a case study in Southern Italy: the simulated PV plant can have two different layouts (rated power of 7.13 MW or 5.68 MW), and each hectare can include the plantation of about 900 Arbequina olive trees.

20

Enhancing photovoltaic hosting capacity in distribution networks by optimal allocation and operation of static var compensators

Bahman Ahmadi* (University of Twente); Oguzhan Ceylan (Marmara University); Aydogan Ozdemir (Istanbul Technical University)

Abstract—This paper presents a novel two-stage optimization approach for the optimal sizing of static var compensators and their operational management to maximize the photovoltaic integration capacity of distribution systems. In the first stage, the optimal locations for fixed size photovoltaic (PV) systems are determined to minimize the sum of total voltage violations. In the second phase, the size of the PV units are resized and the optimal size, number, location, and operating strategy of the SVC units are determined to maximize PV hosting capacity. In both phases, the Marine Predators algorithm is used for the solution optimization equations. The performance of the proposed approach and solution method is validated on modified 33-node and 141- node radial distribution networks. The results are discussed from the point of view of the maximum hosting capacity and compared with the Grey Wolf Optimization and Whale Optimization algorithms in terms of computational performance

* corresponding author

Wednesday 31 August 2022

16:00-17:30	Parallel Paper Sessions TS4-TS6
Session TS6	Smart Grids (1) Room: 1304
Session Chair	Prof. Grigoris Papagiannins (Aristotle University of Thessaloniki)

109

Multiagent Control of DGs in Distribution Network for Active and Reactive Power Management

Omotayo Ilesanmi*; Mohamed E Farrag; Arshad Arshad; Azmy Gowaid (Glasgow Caledonian University)

Abstract — The need for reduction of burning fossil fuels and CO2 emission has led to a change in how electrical power is being generated, transmitted and distributed. This has brought about the introduction of distributed generation units (DGs) mainly renewable energy resources as sources of power generation within the distribution network. With the growing use of distributed generations and energy storage devices across the distribution network, the architecture of the traditional grid faces challenges that threaten its safe and reliable operation. In this paper, the integration of PV and battery storage system is studied. Base models for a PV system and battery storage system were developed. The models were designed to ensure the generation of active and reactive power from the models and a multiagent control which includes a PV management system, battery management system and grid management system was developed to control the interaction between multiple DGs in the distribution network for efficient and reliable operation. Results from this study conducted via simulation show that battery storage systems are playing a big role in power management in the distribution network as they can absorb and produce both active and reactive power.

13

Optimal configuration using renewable technologies for overcome blackouts in Libya power system: Al-Marj city case study

Ali Garada* (Cardiff University); Abdullah Shaher (Cardiff University, Najran University); Saad Alqahtani (Cardiff University, King Khaled University); Liana Cipcigan (Cardiff University)

Abstract—This paper introduces different solutions using renewable energy technologies to overcome the random blackouts that happen in Libya. A case study conducted at Al-Marj city in Libya considering both stand-alone and grid-connected photovoltaic (PV) and wind systems is presented. The analysis of the modelling and simulation results using HOMER Pro software toll shows that the PV system is the economically optimal option comparing with the wind system. The role of solar irradiance and wind speed on the overall output of both sources of energy is highlighted by comparing the cost of energy (COE), with the results revealing that the COE in a stand-alone system for the PV and wind systems is 0.19$/kWh and 0.23$/kWh respectively, and 0.15$/kWh and 0.16$/kWh respectively for the grid-connected case. The results of this study at Al-Marj city can be used to resolve the random blackouts problem occurring in other regions of Libya.

77

Multi-Energy Smart City Urban District Planning with Robust Optimisation

Marco Galici*; Gianni Celli; Emilio Ghiani; Simona Ruggeri; Giuditta Pisano; Fabrizio Pilo (University of Cagliari)

Abstract— Over the years, different energy systems have often been planned and managed independently and not always efficient and 9tilizes9. A paradigm shift towards a holistic, multi-generation approach can achieve more significant benefits by integrating the energy infrastructure for electricity, natural gas and district heating networks and creating energy hubs in the urban districts of future smart cities. In such systems, different energy carriers interact collaboratively. The number of uncertainties in multi-energy hubs requires developing 9tilizes9ion planning methodologies capable of keeping the risk below acceptable values. In this context, the paper proposes a robust linear programming 9tilizes9ion algorithm to solve the energy hub planning problem under uncertainty. The 9tilizes9ion algorithm allows the identification of the optimal energy carriers to meet energy demands and 9tilizes energy costs keeping the risk of failure below the allowable level. Simulation results highlight the benefits of applying the proposed approach considering a multi-energy hub structure in an urban district of the city of Cagliari (Italy).

28

Operational Optimization of an Agricultural Microgrid

Paul D. Brown*; Murat Göl (Middle East Technical University)

Abstract—A demonstration agricultural microgrid containing solar photovoltaic (PV), battery storage system (BSS) and multiple water pumps and reservoirs is presented. A mathematical model of the cost of operating the demonstration microgrid is developed. The mathematical model includes hybrid inverter source switching and BSS charging modes in addition to power balance and interperiod energy and water-level coupling. Electricity pricing and irrigation water use efficiency are allowed to vary by time of day. The mathematical model is formulated as a mixed-integer linear program (MILP), implemented in Python using Pyomo, and optimized using the open-source SCIP solver to plan pumping and water usage. Estimated data for a demonstration system at a farm in Turkey is used to demonstrate the proposed model. Results of the optimization of the demonstration system show intuitive results that are superior to a rule-based initialization. The model may serve as the basis for model predictive control (MPC) or stochastic model predictive control (SMPC).

63

Network-aware operational strategies to provide (flexibility) services from Local Energy Community

Thien-An Nguyen-Huu*; Trung Thai Tran; Phuong H. Nguyen (Eindhoven University of Technology); JG Slootweg (Eindhoven University of Technology, Enexis Netbeheer)

Abstract—This paper proposes the network-aware operational strategies to provide (flexibility) services from Local Energy Community (LEC) by maximizing their profit based on the optimized operation of battery energy storage system (BESS), considering the uncertainty between forecasted and actual load net in LEC. The proposed method takes into account the capacity limitation constrain in the contract between LEC and distribution system operator in order to avoid penalties, and provides insightful data to support LEC in making the decision to join the balancing reserve. Three different case studies, which investigate the hypothetical LEC including 01 BESS (100kW/200kWh) and 55 houses with each installed photovoltaic system, are performed using a mixed-integer linear programming to validate the effectiveness of the proposed method. The results show that, by considering the registered limitation, the benefit is increased up to 30%, compared to the case without the capacity limitation constrain

* corresponding author

Thursday 1 September 2022

09:45-11:15	**Parallel Paper Sessions TS7-TS9**
Session TS7	**Power Systems Simulation and Analysis (1)** **Room: Ömer Korzay**
Session Chair	**Dr. Oğuzhan Ceylan (Marmara University)**

157

Optimal power dispatch of an off-grid renewable energy-based system using linear programming

Oliver Dzobo* (University of Johannesburg)

Abstract – The provision of electricity through renewable energy sources have become the pivot for sustainable development in most remote rural communities. This paper presents the optimal power dispatch of an off-grid hybrid energy system which consists of a solar PV, wind energy and small hydropower system. Linear programming technique is proposed to solve the optimization problem. The objective of the optimization problem is to minimize the cost of electricity taking into account the constraints of the hybrid energy system. A case study for a remote rural community in Zimbabwe is used for this study. The results show that the off-grid renewable energy system is able to supply the load demand of the rural community and it is therefore a feasible solution for energy provision in remote rural communities.

85

Analysis and Simulation of Current-Only Directional Protection Incorporating Simple Communications

Pannita Rajakrom*; Campbell Booth; Qiteng Hong (University of Strathclyde)

Abstract This paper presents a review of a range of novel protection schemes and described a new fault detection method using only current measurements, based upon comparison of pre- and during-fault current angles (and communication of angular shifts between measurement locations when faults are detected). Case studies are also presented to validate the effectiveness of the proposed method. The scheme is suitable for when conventional protection is not suitable for power networks, particularly microgrid with distributed generation units and energy storage leading to bi-directional power flows during normal and fault conditions, and low- and variable fault levels. In such cases, directional relays may be necessary to provide effective protection. However, measuring both voltage and current may be expensive and the scheme highlighted here overcomes such requirements, and it is proposed that 4/5G communications or radio-based communications may provide an effective means of transferring the (low-bandwidth) data when required.

114

VirtualSubstation: An IEC 61850 framework for a Containernet based virtual substation

Dennis Rösch*; Omar Farghaly; Rohan Suri; Pooja Dahane; Steffen Nicolai; Peter Bretschneider (Fraunhofer IOSB IOSB-AST, Dept. Cognitive Energysystems)

Abstract— Our already presented co-simulation, consisting of a real-time power grid simulation and a virtualization of the communication infrastructure, enables a joint and holistic view of the two subsystems. If the IEC 61850 communication standard is used throughout, a substation can be completely described in terms of network technology in their defined substation configuration language (SCL). Our framework presented here enables the automated initialization of the virtual network and its transfer to co-simulation. The complete mapping of different IEC 61850 communication services generates a complete, process relevant database of network traffic. For purpose of our co-simulation approach, with coupling on the process bus, the focus lies on the IEC 61850-8-1 Manufacturing Message Specification (MMS) and Generic Object-Oriented Substation Event (GOOSE) communication and the relations between initialized Intelligent Electronic Devices (IEDs). Based exclusively on IEC 61850 substation configuration descriptions (SCD), the framework enables this implementation of a simplified static communication network using network virtualization. All consisting Access points with underlying IEDs, Logical Devices, Logical Nodes and Data Objects are specified and used to rebuild an existing IEC 61850 communication infrastructure and initialize the relevant communication services. The research shows the possibilities and limitations of the automated generation of the network for use in co-simulation.

42

Design of a Load Frequency Controller based on Artificial Neural Network for Single-Area Power System

Ali Jasim Mohammed* (Directorate General of Education in Amarah Ministry of Education); Sadeq D. Al-Majidi; Mohammed Kh. Al-Nussairi (University of Misan); Maysam F. Abbod; Hamed S. Al-Raweshidy (Brunel University London)

Abstract— A Load Frequency Controller (LFC) is considered an essential part in a single-area Power System Network (PSN) to adjust its frequency level and enhance the output power when the electrical demand is changed rapidly. In this paper, the LFC based on an Artificial Neural Network (ANN) technique is designed for the single-area PSN. The training data of the ANN model are collected from a proposed Simulink test. Then, a MATLAB/Simulink model of the single-area PSN is developed to assess this proposal. The results show that the operation work of the proposed ANN controller is better than a Proportional Integral-Derivative PID controller under the different states of step-change loads in the term of transit state and deviation issues.

119

Accuracy Evaluation of a Linear Method for Active Distribution Network Analysis

Anna Rita Di Fazio; Sara Perna* (Universita di Cassino ` e del Lazio Meridionale); Michele De Santis (Universita Niccol ` o Cusano)

Abstract—The voltage control is a challenging task in active distribution networks, due to the increasing penetration of distributed energy resources (DERs). Voltage regulation devices (VRDs) can suffer the presence of DERs due to reverse power flows along feeders. A previous Jacobian-based method for sensitivity analysis of radial distribution system, for both DERs and VRDs, is extended in terms of accuracy. The present paper analyzes firstly the actions of different types of VRDs together with DERs in a large 237-nodes LV distribution network; then, the effects of sensitivity matrices and initial operating conditions on the linear method (LM) accuracy are evaluated. Numerical results show the great accuracy of the LM.

* corresponding author

Thursday 1 September 2022

09:45-11:15	Parallel Paper Sessions TS7-TS9
Session TS8	Energy Storage Room: 1302
Session Chair	Dr. Radu Porumb (University Politechnica of Bucharest)

65

Dimensioning of Community Energy Storages for Multi-Use Purposes using Households' Storage Requirements

Marcel Böhringer*; AchrafKharrat; Jutta Hanson (Technical University of Darmstadt, Institute of Electrical Power Supply with Integration of Renewable Energy (E5)); David Petermann; Nicole Büchau; Christian Hein (e-netz Südhessen AG); Sebastian Baumann; Christian Preusche (DATAbility GmbH)

Abstract—In this paper, a method is presented to determine community energy storage's size in residential districts. To identify required storage size, different clusters are formed for households' storage requirements. Clusters are differing in generation and load size, as well as using heat pumps and/or electric vehicle charging stations. Maximum installed capacity of photovoltaics plays a relevant role in cluster classification as well. Taking corresponding needs from multi-use operation into account, the model is extended accordingly. It becomes clear that relevant for shared storage sizing are the months in spring and autumn. Major drivers during these months are the use of electric heat pumps as well as installed photovoltaic capacity. In contrast, electric vehicle charging stations generally increases storage shares across all months and all clusters. Using storage shares determined for clusters and characteristics, potential for secondary use is determined on two different bases in a second step of the analysis. Results show that during spring and autumn, storage is mostly used by households. By contrast during summer and winter, up to 85 % is available for other services. Findings are finally determined using an example of residential district in the region of Darmstadt, South Hesse. The proportion of available flexibility is expected to be high, with a maximum of almost 87 % in the month of December.

113

Voltage Fluctations of Battery Storage Systems Providing Fast Frequence Response Services in the UK

Stephen Sommerville*; Professor Gareth A Taylor; Dr Maysam Abbod (Brunel University London, Uxbridge, UK)

Abstract— Within the UK there has been a significant increase in large scale Battery Energy Storage Systems (BESS) that provide services such as Fast Frequency Response (FFR) to National Grid ESO, for the GB system. At present, BESS units are installed by developers at substations with spare capacity, and their size and locations are not being centrally planned, and due to network connection costs, most developers are connecting the BESS units to the distribution network rather than to the transmission network. A concern has been identified that during FFR operation, multiple BESS units in an area would all operate nearly simultaneously, leading to large dynamic power swings in the systems creating problems for voltage Quality of Supply (QoS). This paper examines how the simultaneous operation of multiple BESS units in adjacent substations, can create adverse effects on the distribution system voltage that may not be apparent when considering operation of BESS units individually. The paper develops a simple test network which is representative of two substations on the Distribution Network in the UK; then uses DIgSILENT Powerfactory to examine the system voltage profile for BESS operation for several import-export and export-import cases.

127

Lithium-ion Batteries Capacity Degradation Trajectory Prediction Based on Decomposition Techniques and NARX Algorithm

Ma'd El-Dalahmeh; Imran Bashir*; Maher Al-Greer; Mo'ath El-Dalahmeh (Teesside University Middlesbrough, UK)

Abstract— It is critical to accurately predict the remaining capacity of lithium-ion batteries to guarantee safe, reliable operation with minimal maintenance costs. However, because of the complicated and nonlinear characteristics of the battery's degradation throughout its lifetime, predicting the amount of capacity that will still be available in lithium-ion batteries is a complex process. In addition, the phenomena of capacity regeneration have a significant impact on the accuracy of the remaining capacity projection. For this purpose, the signal decomposition method is becoming a more attractive and promising method for overcoming the difficulty of the capacity regeneration phenomena due to its simplicity and capability to accommodate the nonlinear dynamic behaviour of the lithium ion battery. Therefore, this paper investigates the performance of three signal decomposition techniques: the discrete wavelet transforms, the empirical mode decomposition, and the variational mode decomposition techniques in analysing the capacity regeneration phenomenon. The nonlinear autoregressive neural network algorithm is developed to predict the trajectory of the future capacity of the battery. The performance of the proposed algorithms is analysed by using two datasets from NASA Ames Research centre and the centre for advanced life cycle engineering (CALCE). The comparison results demonstrate that the variational mode decomposition method combined with the nonlinear autoregressive neural network outperforms other methods with 2.385% RMSE and 1.6% MAE.

128

Online Hybrid Prognostic Health Management Prediction Using a Neural Network and Smooth Particle Filter for Lithium-ion Batteries

Mo'ath El-Dalahmeh; Maher Al-Greer; Ma'd El-Dalahmeh; Imran Bashir* (Teesside University Middlesbrough, UK)

Abstract—Accurate real-time prognostic health management (PHM) estimation is essential to lithium-ion battery safety and efficiency. Recent work on developing a framework to predict remaining useful life (RUL) has primarily focused on the traditional empirical degradation model due to its simplicity. Although this model works well under specific operational conditions, for online RUL prediction it may lack the ability to describe capacity degradation, given the variability in decline between cells and others under different operational conditions. As such, this can result in inaccurate RUL prediction. Therefore, this work proposes a hybrid approach to improve the accuracy of online forecasting in the existing framework by integrating data-driven and model-based approaches. The proposed framework utilizes the neural network (NN) to model and track battery degradation trends, and it also degrades the initial values of the degradation model's transactions under different operating conditions. Furthermore, the proposed hybrid framework includes smooth particle filter (SPF) algorithm, which continuously updates the degradation NN model. Lithium-ion battery capacity degradation datasets from the Centre for Advanced Life Cycle Engineering (CALCE) were used to evaluate the proposed paradigm. The results show that the *proposed hybrid framework is more accurate and improves the convergence rate compared to the traditional capacity prognostic framework.*

135

Sustainability Assessment of Flywheel Energy Storage for Grid Applications

Salvatore Cellura*; Andrea Mazza; Ettore F. Bompard; Stefano P. Corgnati (Politecnico di Torino)

Abstract—Flywheel Energy Storage (FES) Systems could be exploited to support energy transition maintaining, at the same time, secure conditions in electricity grids. Among the current remunerated services, they can be deployed for Frequency Containment Reserve (FCR) and automatic Frequency Restoration Reserve (aFRR). However, several aspects have to be addressed, such as environmental impacts of these systems, and the costs. Additionally, since the exploitation of scarce raw materials for the assembling, also risk on supply disruption for these materials has to be taking into account. Main indicators exploited to evaluate Flywheels are the Global Warming Potential, the Cumulative Energy Demand, the Levelized Cost of Storage (LCOS) and the Supply Risk Indicator for Raw Materials. Most impacting components for Cumulative Energy Demand and Global Warming Potential are represented by the steel-based Vacuum Chamber and the Power Conversion System. Investment costs and charging costs are instead major contributors in LCOS, whereas replacement costs have a small contribution on it. The Supply Risk, assessed first for raw materials and then aggregated for the entire FES, is influenced mostly by Natural Graphite and Aluminium. Results on risk are almost not affected by considering the elements contained within the FES instead of raw materials. Finally, the comparison between greenhouse gases emitted during the manufacturing stage of alternative Storage Technologies shows that FES is the highest emitter, due to a low Energy on Power ratio.

* corresponding author

Thursday 1 September 2022

09:45-11:15	Parallel Paper Sessions TS7-TS9
Session TS9	High Voltage Engineering Room: 1304
Session Chair	Prof. Manu Haddad (Cardiff University)

139

On the Optimization of Grounding Design of Rods Covered by Low Resistivity Materials

O. Kherif; S. Robson; A. Haddad* (Advanced High Voltage Engineering Research Centre, Cardiff University); D. Thorpe (Kingsmill Industries (UK) Ltd.)

Abstract—Reducing the grounding resistance using low resistivity materials (LRM) is a widely used technique to improve the grounding system performance, especially under high resistivity conditions. This paper deals with cost-effective design of a typical configuration of grounding systems with LRM coverings. Indeed, two optimization problems are proposed and resolved using particle swarm optimizer (PSO). Considering vertical ground electrodes partially and fully covered by LRM, the first problem consists of obtaining the geometrical configuration that gives the minimum resistance. In the second problem, the objective is devoted to obtain simultaneously an economical and safe grounding design. In both problems, each step is discussed to help generalize the technique for more complex grounding design. It was found that soil treatment using LRM can significantly reduce the grounding resistance by more than 50% compared to the resistance of the same system without LRM coverings. Moreover, the optimal geometrical parameters are sensitive to the variation of the soil resistivity as well as the maximum tolerable limits.

153

The Hydrophobicity Class Identification of Silicone-Rubber Samples using Deep Learning Algorithms

Nesibe Demiroglu; Idris Ozdemir; Halil Ibrahim Uckol; Suat Ilhan* (Istanbul Technical University)

Abstract—This paper presents an approach to classify the hydrophobicity characteristic of silicone rubber (SiR) samples using deep learning algorithms. By deforming the hydrophobicity property of SiR samples using corona discharges, images of water droplets placed on the sample surface were acquired. From the images, the contact angles of the droplets were determined to find the hydrophobicity classes. The generated water droplet image dataset was trained, validated, and tested utilizing AlexNet, VGGNet, and ResNet. The result shows that the modified AlexNet model with an accuracy of 99.36% is a reliable diagnostic method to identify the hydrophobicity qualification of the SiR samples.

18

Impulse Characteristics of Ground Electrodes Over Time (10 Months)

Fazlul Aman; Normiza Mohamad Nor*; Nurul Nadia Ahmad (Multimedia University)

Abstract—One of the parameters to be considered when designing the grounding system is the soil resistivity. The soil resistivity is expectedly to change over time due to changes in water content, soil migration, chemical and fluid composition and temperature in soil. Due to all of these changes, it may affect the relative ground resistance at steady state, RDC and ground potential rise (GPR) values. While many studies have reported that under high impulse currents, ionisation process in soil would occur, with the changes in soil resistivity over time of ten months, responses of ground electrodes under high impulse currents over time would be expectedly to be relatively different. In this work, test results on the soil resistivity, RDC values and responses of ground electrode under high impulse currents over time are presented and discussed.

40

Performance Evaluation of Grounding System of MV/LV Outdoor Compact Substation

Konstantinos D. Merentitis (University of Patras); Emmanouil D. Ellinas; Christos A. Christodoulou* (National Technical University Athens, Greece); Spyridon Christoforos (Hellenic Distribution Network Operator, Grid Operations Department); Eleftheria C. Pyrgioti (University of Patras); Ioannis F. Gonos (National Technical University Athens, Greece)

Abstract—The commitment of many countries worldwide to reduce their carbon footprint in the next few decades, has led to increased penetration of Renewable Energy Sources (RES) into power distribution networks. The connection of those RES to the MV power grid requires the installation of more compact and reliable MV/LV substations that would be easily accessible on the site of the PV Park or Wind Farm. Compact substations consist the preferred option for the connection of RES and LV loads on a power distribution grid since they provide key benefits compared to the conventional overhead substations. However, since they are made of a metal enclosure that is easily accessible, either by qualified personnel either by passers-by, it is necessary to study the adequacy of the grounding system, in order to ensure the reduction of the developed touch and step voltages in case of a short-circuit on the network. In this paper, the efficacy of two grounding grids, under various scenarios, is being evaluated by using the appropriate software tools. Purpose of the present work is to provide comprehensible data on the most common faults of power distribution networks and identify the worst-case scenarios that should be considered during the optimal techno-economic design of grounding grids of MV/LV outdoor compact substations.

72

Experimental Investigation of the Surface Current on Polluted HVDC Polymer Insulators

Julian Hanusrichter*; Oliver Herms; Frank Jenau (TU Dortmund University)

Abstract—In this work, two configurations of polluted silicone insulators were investigated experimentally for the resulting surface currents when loaded with a positive DC voltage up to 30 kV. The two pollution layers, one drop-like, one continuous, turned out to be visibly different concerning their conductivity, as well as their susceptibility to partial discharges (PD) on the surface when exposed to rising humidity. Furthermore, the importance of long-term studies to observe DC currents without polarization or alternating components was confirmed, in agreement with previous research in this field. Despite the different characteristics of the impurity layers, the selection of different impurity layers emerged as a robust assessment of the insulators' performance, and as a basis for mathematical modeling of further progression of the surface current over time.

117

Technical potential for rooftop solar photovoltaic in Commercial and Residential Areas in Saudi Arabia

Abdullah Shaher* (Cardiff University, Najran University); Saad Alqahtani (Cardiff University King Khalid University); Ali Garada (Centre for Integrated Renewable EnergyGeneration and Supply, Cardiff University); Liana Cipcigan (Cardiff University)

Abstract— The economic and social development of the Kingdom of Saudi Arabia (KSA) has led to a significant increase in its electricity consumption. The KSA is highly dependent on non-renewable sources of energy, but the government has recently formulated a new strategy to encourage an increase in the use of renewable energy sources. The purpose of this plan is to diminish the KSA's reliance on fossil fuels and to reduce the air pollution. Currently, the global cumulative installed capacity of solar photovoltaic (PV) technology is expanding at an exponential rate. For residential and commercial installations, the saturation threshold for distributed PV installations is directly proportional to the availability of the physical roof area. This research assessed how rooftop PV generation in residential and commercial buildings can be used to reduce the electricity import from the national grid. This paper presents the methodology that was used to assess the rooftop PV potential in the residential and commercial areas of Abha city, KSA using real data. The results show that the PV production on the rooftop of a commercial building can meet more than 50% of the building's total electricity consumption. Also, it was found that PV can meet the whole demand of residential buildings and there is surplus energy from the PV generation that could be stored for future use.

* corresponding author

Thursday 1 September 2022

11:30-13:00	Parallel Paper Sessions TS10-TS12
Session TS10	Smart Grids (2) Room: Ömer Korzay
Session Chair	Prof. Hakan Hocaoğlu (Istanbul Commerce University)

51

Dump Load Allocation in Islanded Microgrid with Robust Backward\Forward Sweep and MIDACO

Maen Z. Kreishan*; Ahmed F. Zobaa (Brunel University London)

Abstract—Dump load (DL) allocation in droop-controlled islanded microgrid (DCIMG) is vital to consume excess generation at off-peak hours and provide voltage and frequency (-) support. Furthermore, convergence of load flow (LF) solution is necessary to determine optimal working points of any DCIMG. Proposed in this paper, two LF methods based on the famous backward/forward sweep (BFS): improved special BFS (SBFS-II) and general BFS (GBFS). The former method is based on global voltage variable spread among all distributed generation (DG), while the latter is more general by considering local voltage measurement at each DG. The multi-objective problem of DL allocation in highly penetrated DCIMG to minimize - deviations and power losses was investigated using the two LF methods combined with mixed-integer distributed ant colony optimization (MIDACO). The problem was applied to the IEEE-33 bus system, while solutions were subjected to various convergence tests. Results show SBFS-II and GBFS efficacy in calculation time and accuracy of the solution, respectively, for DL allocation problem in DCIMG.

53

Sequential Volt/Var Controller for PV Smart Inverters in Distribution Systems

F. M. Aboshady* (Brunel University London, Tanta University); Ioana Pisica (Brunel University London); Oguzhan Ceylan (Marmara University); Gareth A. Taylor; Ahmed F. Zobaa (Brunel University London); Aydogan Ozdemir (Istanbul Technical University);

Abstract— Increased photovoltaic (PV) penetration in distribution systems helps improve the system's performance by reducing the active power loss, in addition to the environmental benefits. However, high PV generation during light loading periods results in reverse power flows in the system. In turn, the voltage increases at the nodes located further from the main substation. This paper proposes a reactive power control method to coordinate the participation of different PV smart inverters in solving the overvoltage problem. The proposed control method operates at the lateral level based on the measured voltage at the lateral's end-node (or most downstream PV system). The lateral controller sequentially dispatches power factor commands to the smart inverters. This method maintains the coordination between the PV systems at different operating conditions keeping the reactive power requirement as low as possible. The proposed control method is compared to the volt/var control method from the IEEE standard 1547 and shows an improved performance in terms of reactive power requirement and active power loss.

82

Exploring the Sensitivity of Hosting Capacity Evaluations to Various Simulation Characteristics

Munyaradzi Justice Chihota*; Bernard Bekker (Stellenbosch University)

Abstract-The increasing penetration of distributed energy resources (DERs) and concerns over the associated technical issues have stimulated research towards evaluating the loadability of existing networks with DERs, termed hosting capacity (HC). Various HC methodologies have been proposed and differ in four primary characteristics: (1) the characterization of input characteristics, including stochasticity, variability, and allocation uncertainty, (2) the formulation of the load flow to accommodate identified input uncertainties, (3) characterization and analysis of uncertain impact assessment outputs, and (4) HC quantification and characterization, including the scope of technical parameters considered. This paper investigates the impact of these aspects on the quality of conclusions on feeder HC on distribution networks. An adaptive stochastic framework involving a Monte-Carlo simulation for DER allocation and a probabilistic load flow method is used to solve the HC problem according to the selected simulation characteristics. The analysis is carried out on an LV residential low voltage feeder with electric vehicles. The sensitivity results encourage the development of comprehensive HC formulations and simulations that generate reliable, consistent, and replicable HC solutions and conclusions. The results have significant implications for the optimal regulation of DERs.

97

Establishing a Power Hardware-in-the-Loop Environment with a Smart Energy Complex

Frederik Gielnik*; Johanna Geis-Schroer; Daniela Eser; Samuel Eichhorn; Sina Steinle; Carolin Hirsching; Felicitas Mueller; Michael Suriyah; Thomas Leibfried (Karlsruhe Institute of Technology (KIT), Institute of Electric Energy Systems and High-Voltage Technology (IEH))

Abstract-Improving energy efficiency within existing buildings plays a crucial role in achieving the ambitious goal of future CO2 neutrality. For this reason, this contribution outlines the conversion of an existing, decades-old building into a smart office building. Combining this idea with the integration of future technologies ± power-to-hydrogen and DC microgrids as well as the integration of existing approved facilities such as a switching matrix system ± establishes the concept of a Smart Energy Complex. The setup presented in this contribution allows for both normal operation of the building and power hardware-in the-loop testing at the same time.

94

Smart Grids: Towards an amended Two Point Measuring Hardware Based nontechnical loss detection method for South African municipalities' electricity prepayment residential consumers

Christo Nicholls*; Bernard Bekker; Johan Vermeulen (Stellenbosch University)

Abstract-Energy losses, due to theft, within the South African electricity distribution networks are adding up to millions of kilowatt hours unaccounted for yearly. With many municipal consumers still having electricity meters within the boundary of their property and the energy theft methods becoming more sophisticated, e.g. partially bypassing electricity meters, ghost vending, etc., the conventional Two Point Measuring Hardware Based nontechnical loss detection (NTLD) method can still be implemented as a cost-effective solution within the South African municipal space, but with some amendments. The focus area of this research is on how to amend the conventional Two Point Measuring Hardware Based NTLD method by leveraging on AMI solutions, in conjunction with existing billing and vending systems. This paper presents the hypothesis that if South African municipalities augment their current distribution network with a strategically and temporarily placed AMI solution that is integrated with existing billing and vending systems, it is possible to detect the location of the origin of complex nontechnical losses (NTL) instances. The key findings of the research suggest that by strategically and temporarily utilizing an AMI solution integrated with existing billing and vending systems, the conventional Two Point Measurement Hardware Based NTLD methods can be successfully amended to achieve the desired outcome, despite the existing challenges.

* corresponding author

Thursday 1 September 2022

11:30-13:00	Parallel Paper Sessions TS10-TS12
Session TS11	Renewable Energy Systems (2) Room: 1302
Session Chair	Prof. Michael Conlon (Technological University Dublin)

52

The Effect of Climate Change on Variable Renewable Energy in South Africa: A Trend Analysis

Munyaradzi Keith Mupazviriho*; Amaris Dalton; Bernard Bekker (Stellenbosch University)

Abstract-The advent of climate change (CC) resulting from anthropogenic carbon emissions has resulted in increased adoption of variable renewable energy (VRE) resources in electricity generation as part of emissions mitigation strategies. Consequently, there has been an upsurge in the uptake of solar and wind resources in South Africa. However, as VRE sources depend on meteorological conditions, it is anticipated that VRE sources are likely to be affected by CC. This paper seeks to establish whether there are historic trends in solar and wind resource availability and variability in South Africa that can be attributed to CC. Understanding the shifts in resource potential would aid policy makers and network planners in optimally selecting and siting future VRE generators. A trend analysis was conducted using the ERA5 reanalysis dataset spanning the period from 1951 to 2020. Results indicated that the summer season has shown significant declining trends in solar and wind energy resource. Generally, in areas with good resource potential, less significant changes were observed compared to areas with poorer resource potential, which showed stronger decreasing trends along with increased variability. It is recommended that further analyses be conducted using climate projections to assess future resource shifts and changes to underlying patterns of variability.

74

Modelling Electricity and Heat Supply with Renewable Infeed and Seasonal Storages on a Local Level using Multi-Period Optimal Power Flow

Marcel Böhringer; Manuel Schwenke*; Jutta Hanson (Technical University of Darmstadt, Institute of Electrical Power Supply with Integration of Renewable Energy)

Abstract- In this paper, an optimal power flow model for electricity and heat distribution in district networks is demonstrated. The algorithm is based on the AC power-flow equations and solves problems with a time horizon of up to an entire year with the intention to size and operate generation and storage equipment. The interior-point solver PIPS, that allows to include non-linear and linear constraints and variable bounds is used to solve the problem. To decrease computational effort, an algorithm for time series aggregation is introduced, that allows to maintain the seasonal, as well as the hourly characteristics of the time series while significantly reducing the computation time. Besides the electrical network, a district heating network is modelled. This allows various couplings through generation or storage equipment to be integrated into the model. It could be shown, that, with a joint consideration of electricity and heat in the model, a high self-sufficiency of a district energy system can be achieved while at the same time the costs can be lowered. As a side effect, other operating parameters, such as voltage stability, are significantly improved.

99

Techno-economic Analysis of Deployment of Renewable Energy in Hotel Zone at the West Coast of Myanmar with Limited Grid Access

Gill Lacey; Thet Paing Tun* (Teesside University)

Abstract- Access to the energy grid is a big concern for isolated households and companies, and emergency diesel generators can cause long-term climate and environmental problems. This study investigated the techno-economic feasibility of deploying clean energy sources to support the operation of a hotel zone on Myanmar's west coast with limited connectivity to the primary utility grid (5 hours per day). When utility power is unavailable, hotel owners must rely on diesel generators to provide electricity for visitors. An independent microgrid comprising photovoltaic generators and battery storage is constructed and analysed. The microgrid system to completely supply 100% of the load is not an economically realistic solution due to higher capital expenditures and a more extended carbon payback period of about 20 years due to higher embodied energy. A hybrid diesel generator and PV array covering the partial load demand of 20% was an effective option with lower energy and CO2 payback periods of 8.1 and 4.6 years, respectively.

115

Cost Effectiveness of Standalone Hybrid Power Supplies at Different Locations across Europe

Čedomir Zeljković*; Predrag Mršić; Bojan Erceg; Đorđe Lekić; Nemanja Kitić; Petar Matić (University of Banja Luka)

Abstract-Standalone hybrid systems based on renewable energy sources may represent a convenient and cost effective option for powering isolated consumers located far from the existing grid. In this study the focus is on particular photovoltaic-wind-diesel-battery systems which supply mobile telephony base stations. In the study, both the consumption of telecommunication electronic equipment and the consumption of cooling devices are taken into account. Nine characteristic locations across Europe with different climatic conditions were selected for comparative techno-economic assessment. For each location, a comprehensive simulation and optimization routine was performed, in order to find the optimal system configuration and the minimum amount of total annualized costs. The obtained results are discussed and some conclusions regarding system sizing at different locations are drawn.

122

Impact of the Photovoltaic Array Configuration on its Performance under Partial Shading Conditions

Kamran S. Awan*; Mohammed A. Elgendy; Dehong Huo; Kabita Adhikari (Newcastle University); Hany M. Hasanien (Ain Shams University)

Abstract- Photovoltaic (PV) power generation is playing an important role in meeting global energy needs. PV arrays are made by interconnecting PV modules in several fashions. The most common interconnection schemes to form PV arrays are series, parallel, series-parallel, total cross tied, bridge link, and honeycomb. Depending on PV array configuration, the power harvesting capability of the PV systems may significantly decrease under partial shading conditions. To maximize the energy harvesting capability of PV arrays, it is important to understand the performance of different configurations of PV arrays under partial shading patterns. In this paper, the performance of the PV array configurations is characterized under seven different real-life partial shading scenarios. Thirty PV modules are considered to allow simulation of the different PV array interconnection schemes using Matlab/Simulink. A comparison is made and selection criteria for PV array configuration under different partial shading patterns is suggested, based on simulation results.

*corresponding author

Thursday 1 September 2022

11:30-13:00	Parallel Paper Sessions TS10-TS12
Session TS12	Electrical Services for Buildings Room: 1304
Session Chair	Prof. Mohamed Emad Farrag (Glasgow Caledonian University)

56

A Smart Energy Management System for Elderly Households

Christos L. Athanasiadis; Kalliopi D. Pippi; Theofilos A. Papadopoulos*; Christos Korkas; Christos Tsaknakis; Vasiliki Alexopoulou; Vasileios Nikolaidis; Elias Kosmatopoulos (Democritus University of Thrace)

Abstract-The rapid growth of aging population dictates the necessity of sophisticated monitoring and actuation systems for the smart control and management of elderly households. This paper proposes a state-of-the-art energy management system aiming at increased energy efficiency, lower electricity cost and improved user comfort. The study focuses on a Greek residency with elderly people incorporating controllable and uncontrollable loads, an energy storage system, and photovoltaic generation. A smart home energy management system under the net-metering policy is proposed consisting of three control mechanisms. The reported results offer insights into the optimal residential management practices and evaluate the performance of the proposed control strategy in comparison to other alternative demand response solutions.

130

Monitoring the energy behavior of SMEs before and after Energy Efficiency measures: A case study

Ioanna D. Pasiopoulou; Styliani A. Vomva; Grigoris K. Papagiannis* (Aristotle University); Aggelos S. Bouhouras; Stavros P. Filippidis; Georgios C. Christoforidis (University of Western Macedonia)

Abstract-European Union's target to achieve climate neutrality until 2050, along with the increase in energy costs, boosted the interest on improving energy efficiency (EE) in companies and especially in the small and medium-sized enterprises (SMEs). The SMEmPower Efficiency project, a HORIZON 2020 funded project, aims to address this issue by proposing a holistic approach. This includes also energy checks in real cases, i.e., SMEs. In this paper, a project pilot SME is presented and analyzed based on its real consumption and production measurements. The energy monitoring, targeting and verification (M&T&V) tools are used for the company's energy data before and after the energy check. The adoption of the EE measures is evaluated using the M&V tool and the obtained results are compared to the CUSUM methodology.

46

Improving the Packing Efficiency of Building Integrated Concentrating Photovoltaic Systems through a Novel Hexagonal Concentrator

Lewis Osikibo Tamuno-Ibuomi*; Roberto Ramirez-Iniguez; A Sheila Holmes-Smith; Geraint Bevan (School of Computing, Engineering and Built Environment, Glasgow Caledonian University)

Abstract- Building Integrated Concentrating Photovoltaic systems have the potential of helping to reduce greenhouse gas emissions and global warming as they can be designed not only to generate electricity but also to improve energy efficiency in buildings. These systems can incorporate static low concentration optics and PV cells within double glazed windows, skylights, and double skin facades. This paper addresses the issue of low packing density of solar concentrators used in low concentrating photovoltaic systems and proposes a novel 3-D hexagonal concentrator which offers 89.4% theoretical packing efficiency, which is 16.2% and 21.8% higher than the theoretical packing efficiencies of the circular and elliptical concentrators respectfully, the alternative 3-D concentrators discussed in this study.

136

Hybrid Energy System Analysis for a Swimming Pool Complex using HOMER Pro

Timea Farkas*; Paula Unguresan; Mihaela Cretu; Denisa Stet; Levente Czumbil; Andrei Ceclan; Claudia Muresan (Energy Transition Research Center, Technical University of Cluj-Napoca); Alexis Polycarpou (Frederick University); Dan D. Micu (Energy Transition Research Center, Technical University of Cluj-Napoca)

Abstract-The paper investigates hybrid energy systems that could be applied in case of a swimming pool complex in order to reduce exploitation costs and increase renewable energy usage. The presented approach starts with the assessment of the chosen building at the level of energy consumption, and utility costs, along with two proposed system configurations: one proposed by the RE-COGNITION innovation project, and one proposed by the authors based on the market solutions. The mentioned cases represent two hybrid energy systems using conventional sources, renewable energy, and highly efficient cogeneration units. The two proposed system configurations are simulated using the HOMER Pro program which allows a wide analysis along with techno-economic indicators of the different scenarios. Results and comparisons are presented to highlight the feasibility of the two proposed cases.

73

Modeling a Domestic All-Electric Air-Water Heat-Pump System for Discrete-Time Simulations

Gijs Verhoeven; Bart van der Holst; Sjoerd C. Doumen* (Eindhoven University of Technology)

Abstract- Heat pumps are expected to significantly affect future distribution grids, necessitating their inclusion in future distribution grid research. This research will include discrete time simulations, which will require time-step adaptable and detailed models of heat pumps. These models exist, but often with simplified heat demands and constant or inflexible coefficients of performance, making them less accurate. In this work, a heat pump model is developed for discrete-time simulations with varying weather conditions, operating set-points, and an accurate coefficient of performance. The model produces realistic yearly heat demands, coefficients of performance, and power consumption.

*corresponding author

Thursday 1 September 2022

14:00-15:30	Parallel Paper Sessions TS13-TS15
Session TS13	Electric Vehicles and Transport (2) Room: Ömer Korzay
Session Chair	Prof. Mohamed Darwish

68

Optimizing EV cluster contribution for vehicle-to-grid(V2G) frequency regulation

Erbo Wu* (Zhengzhou University); Krzysztof Jakubiak (Cardiff University); Yaoqiang Wang (Zhengzhou University); Jun Liang (Cardiff University)

Abstract-When electric vehicles (EVs) are integrated into the grid for frequency regulation, the energy stored the EVs would be released excessively without a proper schedule. The system cannot appropriately utilize the energy of the generator and EVs. Many studies only focus on frequency stability but ignore the output of EV cluster. Based on this, this paper proposes a control strategy (Fuzzy-PI) that uses fuzzy control to generate a variable coefficient, which is multiplied with the PI control signal as the control signal for the EV cluster. The coefficient can increase or decrease the EV output power depending on the variation of the frequency deviation. In order to contribute an appropriate number of EVs, this paper optimizes the ratio parameter of EVs invested in V2G with the goal of reducing EV cluster output and improving frequency stability. The private cars, buses and taxis are considered for integrating into an EV cluster to participate in the grid auxiliary frequency regulation. A single-area system model for the participation of EV cluster in the micro-grid frequency regulation is established. Finally, by the comparative study of simulation algorithms, the results demonstrate the superiority of EV cluster participation in frequency regulation, as well as the effectiveness of the proposed Fuzzy-PI control and optimization strategy.

163

Electric Vehicle Charging Station Management with Flexibility Potential Estimation Oriented to Energy Transaction

Aérton P. Medeiros*; Luciane N. Canha; Vinícius J. Garcia (UFSM); Rodrigo M. de Azevedo (IFSul); Rodrigo B. dos Santos (COPEL-DIS)

Abstract- The present work aims to address the growing interest in the subject of flexibility. For this, the study estimates flexibility potential available in an electric vehicle charging station (EVCS) to service public recharges, which serves scheduled and unscheduled recharges. The considered EVCS operates with the existence of photovoltaic generation and battery energy storage system (BESS). In the case study, the flexibility potential available for each of the 24 hours of EVCS operation is presented, estimated according to the methodology presented, considering the management of the EVCS operation performed in real time with 1 minute discretization.

150

Electric Bus Demand Management through Unidirectional Smart Charging

Nicolae Darii*; Roberto Turri (University of Padova); Keith Sunderland (Technological University Dublin)

Abstract- This paper addresses the challenge of the charging control of Electric Busses (EBs) and implications on network demand. Present literature has already confirmed the possibility to do this type of service and its benefits, but the solutions proposed require a complex communication infrastructure. Moreover, the Distribution Network (DN) must be ready to an increased prevalence for reverse power flow manifest by mainstreaming of EVs. In this context, the paper proposes a transitional solution to host the EBs until the required communication infrastructure is mature enough. The Smart Charging (SC) method proposed here relies instead on the Day-Ahead Energy Market to forecast the network working conditions. The method also facilitates distributed photovoltaic (PV) production so that network demand reference is based on net demand. The algorithm focuses on load-levelling or peak shaving as the primary objective, in the optimisation of individual charger current per vehicle and per time step to realise an overall charging strategy for the charging station. The strategy seeks to control fleet charging by managing how individual vehicle charging is interchangeable based on an 80% vehicle state-of-charge objective. The algorithm achieves a scheduling capability for the EBs that transit through the Charging Station (CS) through optimum load-levelling/peakshaving based on the size of the fleet.

154

Wind Based Charging via Autonomously Controlled EV Chargers under Grid Constraints

Simone Striani*; Kristian Sevdari; Mattia Marinelli (Technical University of Denmark); Vasileios Lampropoulos (Nordic RCC, Energinet); Yuki Kobayashi; Kenta Suzuki (EV System Laboratory, Nissan Motor Co., Ltd.)

Abstract-Smart charging has a strong potential to mitigate the challenges in security of supply caused by the increasing reliance on renewable energy sources (RESs) and electric vehicles (EVs). This paper describes the performances of an autonomous distributed control for coordinating the charge of four parking lots as part of a virtual power plant. The virtual power plant consists of a wind farm and four parking lots located in different areas of the grid and connected to two different feeders. The control architecture is applied to a 24-hour simulation with input data from a wind park, the loading data of two feeders, and user behavior from 68 EVs. The objectives of the architecture are: maximization of the wind power usage to charge the EVs; minimization of feeders overloading; minimization of energy imported from the grid; assurance of sufficient charging fulfillment; wind power variability mitigation. Under simulated conditions, the control architecture keeps the feeder loading below 80% by reducing the power allowance to the parking lot during peak demand. Nonetheless the four parking lots guarantee an energy charged of 10.7 kWh for all EVs starting the charging session with less than 60% state of charge (SOC). The total energy produced by the wind power plant is 4.36 MWh, of which 1.34 MWh is used to charge EVs. The remaining 3.07 MWh is exported to the grid, and only 92 kWh is imported from the grid for charging. Further investigation is needed regarding the wind power variability mitigation, as its reduction is only marginal under simulated conditions.

156

Battery Buffered EV Fast Chargers on Bornholm: Charging Patterns and Grid Integration

Aidan Bowen*; Jan Engelhardt; Tatiana Gabderakhmanova; Mattia Marinelli (Technical University of Denmark); Gunnar Rohde (Danish Center for Energy Storage)

Abstract-The widespread adoption of electric vehicles (EVs) is a vital step in the reduction of emissions within the transport sector. However, the development of public fast charging infrastructure and the proper modeling of EV charging behaviours is required to enable this adoption. This paper presents charging data and patterns observed at a battery buffered fast charging DC microgrid on the Danish island of Bornholm. The charging sessions observed at this single site tend to be shorter with lower total energy transfer compared to studies with a wider scope. An atypical uptake of charges with higher than average energy transfer late in the evening is also observed. A simulation based study using this charging data to examine the effectiveness of the battery buffers at facilitating EV fast charging at reduced grid capacities is then presented. This study shows that the Bornholm DC microgrid would have been able to supply all observed EV charging at a reduced grid capacity of 11 kW, enabling such a system to provide EV fast charging at a much wider range of locations.

*corresponding author

Thursday 1 September 2022

14:00-15:30	**Parallel Paper Sessions TS13-TS15**
Session TS14	**Analytical Methods and Implementation In Smart Grids (2)** **Room: 1302**
Session Chair	**Prof. Hasan Dağ (Kadir Has University)**

112

On the Reliability of Static Load Models for the Modeling of Active Distribution Networks under Steady-State Conditions

Ioanna D. Pasiopoulou*; Eleftherios O. Kontis; Ioannis A. Angelis (Aristotle University of Thessaloniki); Theofilos A. Papadopoulos (Democritus University of Thrace); Grigoris K. Papagiannis (Aristotle University of Thessaloniki)

Abstract-Robust and well-established distribution network (DN) equivalent models have been used by system operators. Nevertheless, the advent of distributed energy resources (DERs) has changed the nature and the characteristics of the DNs triggering the need for updating the existing models. This study deals with the reliability of the exponential and polynomial static load models on active DN (ADN) modeling under steady-state conditions. The accuracy of the examined models is evaluated under specific load types and DERs penetration level. The conducted analysis reveals the high impact of the DER penetration level on the model accuracy and its parameters. Results indicate that the ZIP model presents higher accuracy compared to the exponential. However, both models fail to accurately capture the steady-state behavior of ADNs in case frequency and voltage controls are applied to the DER units.

120

A Novel Blockchain Based Approach to Exchanging Information and Data in Power Systems

Mubashar Amjad*; Gareth Taylor; Chun Sing Lai; Zhengwen Huang; Maozhen Li (Brunel University London, UK)

Abstract- Exchanging information and data using cloud computing in power systems is now becoming common practice. However, there are still many challenges such as data security, interoperability, and scalability that need to be considered. In this paper, the authors have exploited blockchain technology by integrating it with Hadoop to enhance interoperability concerning power system operators at both transmission and distribution levels. A blockchain based approach is developed to exchange information and data within power systems. This approach enables users to exchange information and data without losing ownership or control of the data. The proposed approach provides the solutions to three important issues: scalability, data ownership, and interoperability. The case studies as presented in this paper evaluate the effectiveness of the proposed novel approach for enhancing information and data exchange. The paper specifically evaluates enhanced performance with regard to scalability, latency, and computational time.

43

Analytical-Numerical Dataset Analysis and Sensors Architecture Review for Vehicle Dynamics Application

Andrea Di Martino; Michela Longo*; Dario Zaninelli (Politecnico di Milano)

Abstract-Modern vehicles are nowadays largely equipped with sensors sampling several physical quantities in order to monitor the status of on-board subsystems and more in general give all the information needed on the vehicle dynamics to Electronic Control Units (ECUs). Sensors mounted are featured by different nature as far as the working principles and its techniques of fabrication are concerned. However, it can happen that the actual sensor architecture is not sufficiently robust to prompt the correct behaviour of the vehicle itself. If some physical quantities are not adequately monitored by dedicated sensors, the sampled dataset can be incomplete or not correlated with the real vehicle dynamics. In order to provide for the lack of sensors, it is important to consider both the analysis of the problem via numerical and a review of the whole sensor architecture. This paper aims to analyse the dataset sampled by on-board sensors of the vehicle to evaluate the odometry and estimate the physical quantities not monitored because of the absence of such sensors through a numerical model of the vehicle. The numerical model adopted is fitted and tuned on real tests performed. The information recovered contributes to define the dataset with more accuracy. Furthermore, a schematization of an optimal sensors architecture for vehicle dynamics application is provided to reduce the lack of information on the odometry, considering a frequent critical condition due to the interference given by the weather.

22

Data Fusion and State Estimation Using Belief Propagation in Gas Distribution Networks

Goekhan Demirel* (IAI, Karlsruhe Institute of Technology); Steven de Jongh; Felicitas Mueller; Thomas Leibfried (IEH, Karlsruhe Institute of Technology);

Abstract-This paper proposes a solution to the state estimation problem in gas networks using the distributed belief propagation (BP) algorithm. Power system identification applications require precise and robust state estimators as well as various sensor information. Compared to augmenting the power system with a very large number of sensors, a limited number of sensors and probabilistic graphical models can be used to infer the system state and reduce hardware investments. A novel BP algorithm propagates the pressure quantities at nodes in the gas network based on pressure manometer signals and applies a correction based on the information of neighboring nodes in the fusion step by using additional supporting sensors. Finally, the data fusion algorithm is demonstrated for a 14-node gas distribution network based on real data. This paper presents a novel algorithm aimed at tackling the traditional weighted least squares method to validate the developed novel approach in order to highlight the advantage of the distributed inference algorithm over traditional methods.

71

Wavelet Transform based Differential Protection for MVDC Distribution Network

Yaxi Li* (Zhengzhou University); Vageesh Mohan (Cardiff University); Songfang Jiang; Yaoqiang Wang (Zhengzhou University); Jun Liang (Cardiff University)

Abstract -A short-circuit fault on the DC side in a MVDC distribution network can cause the rapid drop of inter electrode voltage and the large overcurrent, which will have a serious impact on reliable power supply and cause severe damage to voltage source converters. Requirements of fast and accurate detection and isolation techniques against such DC faults presents a challenge. In this paper, a current differential protection scheme based on the wavelet transform is used to identify the faults. Fault currents are decomposed in order to identify the fault area. A corresponding model is built based on PSCAD/EMTDC, the effectiveness of the proposed protection scheme and the effects of transition resistance and noise are verified, the operation time also meets the requirement of protection scheme for rapidity.

*corresponding author

Thursday 1 September 2022

14:00-15:30	Parallel Paper Sessions TS13-TS15
Session TS15	Protection Systems Room: 1304
Session Chair	Dr. Suat İlhan (Istanbul Technical University)

160

Improved Coordinated Protection Scheme for DFIG Based Wind Turbines

Arshad Arshad* (Glasgow Caledonian University); Wahab Ali Shah (Namal University)

Abstract- Doubly Fed Induction Generator (DFIG) is one of the most commonly used wind turbines generating system in the world. This is mainly due to its improved performance as compared to other wind turbine generating systems. DFIG wind turbines has the convenience of variable speed operation, reactive power support and low converter losses. This paper proposed an enhanced protection scheme consisting of DC chopper and crowbar. The crowbar protection protects rotor windings during grid faults while DC chopper protects DC link capacitor from overcharging. The coordinated protection scheme is implemented in MATLAB/SIMULINK under various grid faults conditions. The effect of fault location (turbine terminal, transmission line, grid) and recurring faults is also investigated. It was found out that the proposed protection system can bound the DC link voltage and rotor current between allowable limits at short circuit conditions.

81

Emulations of Overvoltage and Overcurrent Relays In Transmission Lines

H. Amreiz*; A. Janbey (London College UCK); M. Darwish (Brunel University)

Abstract- An “Over Voltage Relay” is one of the protective relays which operates when the voltage exceeds a preset value. In a typical application the over voltage relay is used for over voltage protection, which is connected to a potential transformer, and calibrated to operate at or above a specific voltage level. An "Under Voltage Relay" and an "Over Current Relay" are also protective relays which operate when the voltage is reduced, or the current is increased below or above a preset value. In a typical application these relays are connected to potential transformers, and calibrated to operate at, above or below a specific voltage or current levels. The emulator used in paper simulated experiments of all three types of relays mentioned above. The transmission line emulator used in this paper is an HVAC transmission line of length of 180 km. The transmission line of the emulator can be used as a 3- phase transmission line of 180 km length or as a single-phase transmission line of 540 km long. This transmission line in the emulator is divided into 6 π sections and each π section is 30 km long. The line inductance of the transmission line of the emulator is examined for every 30 km and the line capacitance is examined for every 15 km. The line parameters of the emulator (RLC) for the 400kV transmission line are: 0.02978 Ω/km, 1.06 mH/km and 0.0146 μF/km, respectively.

121

An Evaluation of Extending an Existing Substation Automation System using IEC 61850

Michael O Donovan* (Munster Technological University); Aidan Heffernan; Seamus Keena (Electricity Supply Board); Noel Barry (Munster Technological University)

Abstract-Substation Automation Systems are commonly used to control, protect and monitor substations in a power system. Many existing substation automation systems use proprietary protocols, which are no longer supported. Therefore, expensive and complex solutions are often required when automation equipment fails or reaches the end of life (15/20 years), or a substation extension is required. Older proprietary-based protocols in substation automation systems are being updated and replaced by introducing the IEC 61850 standard series. IEC 61850 brings significant changes to how Intelligent Electronic Devices used for protection are to be tested. The introduction of non-traditional relay signals resulted in the need for new tools and processes regarding commissioning, testing and maintenance. This paper provides an overview of existing proprietary protocols and outlines the IEC 61850 standard. The challenges in testing IEC 61850 protection equipment are investigated. Finally, a power utility approach for extending existing legacy substation automation systems is demonstrated in a lab-based trial. The comparison illustrated the many benefits of installing and extending substations using IEC 61850 rather than reengineering the proprietary systems.

131

Time Characteristic Curve Based Earth Fault Relay Selectivity Assessment for Optimal Overcurrent Relay Coordination in Distribution Networks

Mert Bekir Atsever* (Gebze Technical University); Mehmet Hakan Hocaoglu (Istanbul Ticaret University)

Abstract-Coordination of overcurrent relays has been handled with optimization techniques. Time and pick up settings are optimized by using three-phase fault magnitudes. Generally, Standard Inverse Characteristic (SIC) has been used for three phase fault protection settings. However, single line to earth fault is the most common fault types in distribution networks. Definite Time Characteristic (DTC) is, widely, used for coordination of earth fault relays. Topology type, neutral earthing resistance and capacitive currents of underground cables may cause selectivity issues when DTC is used for the coordination. In this work, time characteristic curve (TCC) based earth fault relay selectivity assessment carried out on distribution network. Different earthing resistance and TCC are taken into account during optimization processes. Results show that both DTC and SIC have issues in terms of operating time and selective protection.

146

Implementation of Second Earthwire on L6 400 kV Transmission Line

Padoan Federico*; Manu Haddad; Maurizio Albano; Stephen Robson (Advanced High Voltage Engineering Research Centre, Cardiff University); Guo Dongsheng; Christopher Land; Neil Loftus (National Grid London, UK)

Abstract-The Earthwire is an important device to shield the transmission line from lightnings and to exchange information among the substations. OPGWs (Optical ground wires) are widely used for these purposes. Technical operations on the line impose a temporary implementation of a second earthwire between the two circuits. In this paper a study is undertook to understand the possible variations in the electric and magnetic field distribution and the induced currents due to the installation in a trial site of the second OPGW. In order to ensure reliabilty to the simulation, a comparison of three different calculation techniques has been conducted, and a boundary element Method has been then implemented in COMSOL Multiphysics to study a 3D configuration of the line and quantify the electric field around the pylons. To estimate the induced currents, the software ATP-EMTP has been used simulating the conditions with and without the second earthwire. Good agreement has been reached between the different numerical techniques for the field calculation, and a high value of induced current has been found on the ground wires in the case of the implementation of a second one. A measurement system has been built in Cardiff University to measure in June and August 2022 the induced current values and validate the numerical models.

*corresponding author

Thursday 1 September 2022

16:00-17:30	Parallel Paper Sessions TS16-TS18
Session TS16	Power Systems Operations and Control (2) Room: Ömer Korzay
Session Chair	Dr. Theofilos Papadopoulos (Democritus University of Thrace)

35

Characteristics of a mixed 100-km EHV transmission line with shunt compensation for various topologies

Nils Pfeifer*; Mustafa Kizilcay; Pawel Malick (University of Siegen)

Abstract- With the current power grid reinforcement, cable sections are increasingly required due to the densely populated regions and the acceptance of residents. This results in a mixed transmission line with overhead and cable sections. Due to the higher capacitance of cables, there is a larger charging current which can be reduced by shunt compensations. This complete setup with overhead lines, cable sections and shunt compensations are analyzed on a 100-km long 400-kV transmission line in order to gain general knowledge about the operation of a mixed line. The studies have been carried out using EMTP-ATP for certain steady-state cases and EMTP-RV for transients.

44

Combined Transmission and Distribution Test System for Small-Signal Stability Analysis: Initial Results

Theofilos A. Papadopoulos*; Georgios A. Barzegkar-Ntovom (Democritus University of Thrace); Eleftherios O. Kontis (Aristotle University of Thessaloniki); Evangelos A. Koukouliantas (Democritus University of Thrace)

Abstract-In modern power systems is recommended to study the overall system with detailed understanding of the largescale generation, the wider transmission network, the distributed renewable energy sources and the flexible loads. Therefore, detailed simulation models are required. In this paper, a combined transmission and distribution network synthetic model is developed to investigate the dynamic performance of the overall power system and analyse the interactions between its constituent parts. Conventional and modern power system configurations are considered. The small-signal stability of the power system is investigated by means of eigenvalue analysis and by applying the Matrix Pencil algorithm to identify the dominant modes contained in the dynamic responses.

78

Impact of the PLL Time Constant in Converter Control on the Dynamic Frequency Support

Anna Pfendler*; Martin Coumont; Jutta Hanson (Technical University of Darmstadt)

Abstract-The use of a phase-locked loop in grid-forming converter control is controversially discussed, as it implies a time delay to the converter's response to grid disturbances. In literature, slowing down the PLL dynamics to create a retarded measured voltage and current phasor is discussed to virtually resemble synchronous generators' inherent inertia. In this case study, the influence of the PLL time constant is investigated in a simple medium-voltage testbench with the standard cascaded control and the direct voltage control concept. The frequency, active power, direct and quadrature current of the converter based generator are evaluated for different PLL time constants following an active power mismatch. The results show that slowing down the PLL has a small impact on the current and power infeed of both control concepts. However, results of the standard cascaded and the direct voltage control are similar and a general advantage of the slower PLL cannot be concluded in this case study.

134

Voltage Control of Unbalanced Distribution Systems with Penetration of Renewable Sources: A Gradient-Based Optimization Approach

Ramin Ebadi*; Hande Şenyüz; Fathy Aboshady; Oguzhan Ceylan; Ioana Pisica; Aydogan Ozdemir

Abstract-The penetration of distributed energy resources (DERs), including renewable energy sources (RES), into electric power systems has led to several challenges for the system operators. Despite various economic and environmental benefits offered by RES, the issue of voltage rise due to active power injection from RES is still an open problem. On the other hand, voltage decrease due to high load in distribution systems is another challenge faced by operators. In this study, we investigated the problem of over-voltage and under-voltage in the operation of unbalanced 3-phase distribution systems with penetration of RES. Moreover, We utilize derivative-based Exterior Penalty Function (EPF) optimization to solve the voltage deviation problem. The results of the tests conducted on a modified IEEE 13 Bus Test System have confirmed that the use of the tap changer voltage regulators and reactive power from PVs connected close to inverters can effectively contribute to the voltage control problem.

161

Whale Optimization Algorithm Based Optimal Operation of Power Distribution Systems

Olzhas Baimakhanov *; Almaz Saukhimov (Almaty University of Power Engineering and Telecommunications); Oguzhan Ceylan (Marmara University)

Abstract-This paper solves the optimal operation problem of distribution systems using renewable energy sources and voltage regulators. The developed model makes use of Whale Optimization Algorithm based optimization. We apply the proposed optimization model to a modified low voltage distribution system of Almaty, Kazakhstan. Three different cases were simulated. The cases considered are medium load level with medium PV power output, high load level with medium PV output, and high load level and low PV power outputs. The simulation results show that the proposed algorithm is able lower the active power losses.

*corresponding author

Thursday 1 September 2022

16:00-17:30	Parallel Paper Sessions TS16-TS18
Session TS17	Smart Grids (3) Room: 1302
Session Chair	Prof. Gianfranco Chicco (Polytechnic of Turin)

108

Determining Node Importance in Graph-Based Modelling of Cyber-Physical Power Systems

Al Hussein Dabashi*; Dongmeng Qiu; Gareth Taylor; Xin Zhang (Brunel University London)

Abstract-Electrical power systems have evolved into cyber physical power systems (CPPS). The increasing interdependence between electrical power systems and cyber systems has introduced new sources of failure as well as causing additional security concerns. Therefore, it is vital to study the increasing level of interdependency using a whole system approach. Whilst power systems and cyber systems have well-matured models and simulation tools in their own regard, adequate whole system analysis tools are yet to be established. After evaluating the whole system challenges of CPPS modelling, this paper introduces a novel index for determining cyber node importance in a graph-based CPPS model. The proposed cyber node importance index (CNII) considers cascading failure, betweenness centrality and the time delay of the shortest paths, which provides a more accurate representation of power systems. To demonstrate the applicability of this approach, the UK's British Telecom 21st Century Network (BT 21CN) was linked with the GB Transmission System Reduced Model (GB TSRM). Experimental results show the improved accuracy and utility of this method as well as the applicability of analysing cyber contingencies in graph-based CPPS models.

116

Utilizing PV-Battery Systems and Shiftable Loads for Minimizing Grid Losses and Prosumer Cost: A Comparative Assessment

Nikolaos S. Kelepouris; Angelos I. Nousdilis* ; Aggelos S. Bouhouras; Georgios C. Christoforidis (University of Western Macedonia)

Abstract- This paper presents two Optimization Schemes (OS) formulated under respective objective functions aiming to exploit the Photovoltaic and Battery Energy Storage Systems (BESS) in installations with Demand Side Management. The first one is locally applied within the prosumer installation to minimize electricity cost, while the second one is centrally applied by the Distribution System Operator or an aggregator, to minimize the power losses of the Distribution Network (DN). To achieve those goals, the OS schedule the charging and discharging time slots for the BESS and manage the time allocation of flexible appliances. Both OSs are examined on a DN with prosumers, using measured consumption patterns of actual residential appliances. The optimization schemes use a Particle Swarm Optimization variant. The results highlight the conflict of interests between the different objectives.

141

Stochastic Model Predictive Control for Microgrids Based on Monte Carlo Simulations

Mustafa Erdem Sezgin*; Soheil Pouraltafi-Kheljan; Mehmet Beyarslan; Murat Gol (Middle East Technical University)

Abstract—Distributed renewable generation can be harmonized with the utility grid in flexible structures called microgrids. However, the use of renewables has its drawbacks, such as intermittency and generation uncertainty. Smart controllers can be used to solve such problems and operate the microgrids seamlessly. Accurate forecasts of the generation and demand can be beneficial for optimum operation. Unfortunately, such accurate forecasts may not be available in many cases due to the lack of measurements, the uncertainty of weather conditions, and the human factor. Although renewable sources can be predicted with the state of the art weather forecast methods, there is still uncertainty in their forecasts. Moreover, electric vehicles' charging time and duration has a probabilistic nature. A stochastic model predictive control methodology is proposed in this work to cope with such scenarios. Throughout the manuscript, the methodology and the corresponding simulation results are presented.

145

Comparison of Non-Communication based DC Load Shedding Scheme

Abdulrahman Babagana*; Taimur Zaman; Yljon Seferi; Mazheruddin Syed; Graeme Burt (University of Strathclyde)

Abstract-Whenever the total power that can be provided by the distributed energy resources (DERs) is less than the total power demand of the loads, the DC bus voltages start to fall which could lead to power collapse. This paper investigates and compares the performances of the existing non-communication based (decentralized) load shedding schemes in a direct current (DC) microgrid to protect the integrity of the microgrid under a large disturbance. The simulation is carried out in a Matlab environment with various forms of load and distributed energy resources on an IEEE 37 AC Node converted to DC. The findings show that the conventional load shedding scheme could expose critical loads to substantial and lengthy voltage sags. Voltage sags and over-shedding of load could be resolved using combined load shedding scheme. The adaptive schemes minimise the duration and magnitude of voltage drop by utilizing the rate of change of voltage (ROCOV) to achieve a more reliable assessment of the microgrid operating conditions and determine the appropriate load shedding voltage thresholds and time delays. All the schemes could not achieve an optimal load shedding, this work therefore leads to the need for more advanced load shedding schemes that can shed load optimally for future DC microgrids.

143

Adaptive Multiagent Primary Secondary Control for Accurate Synchronized Charge-Discharge Scenarios of Battery Distributed Energy Storage Systems in DC Autonomous Microgrid

Mudhafar Al-Saadi; Maher Al-Greer* (Teesside University)

Abstract- The inaccurate synchronization of the charge discharge scenarios for battery distributed energy storage systems under a decentralized multiagent-based primary secondary control in a DC-autonomous microgrid is a crucial control drawback. Specifically, under a sudden load variation or an excessive load fluctuation. Which, in turn, negatively affects the optimization and stabilization of the control process. Furthermore, exacerbates the batteries' health and reduces their prolonged life. The second concern that the DC microgrid faces under the specific control is the possibility of malfunctioning or downtime in one of the energy storage agents, which defects the stability and balance of the load sharing. These result in reduced system performance, and a violated renewable energy sustainability and penetration. This paper proposes an accurate synchronization technique through the adaptation of the average voltage consensus, and the introduction of a new droop-correction-based the multiagent neighbor-to-neighbor communication. A digital real-time comparison of the multiagent input of each energy storage agent is introduced, and the feature of plug and play is attained. Simulation results prove the success in attaining an accurate synchronization of the charge-discharge scenarios and enhanced balance of output voltage. Furthermore, the independency of operation from the number of the energy storage agents.

144

The potential for swarm electrification as a flexible tool for last-mile energy access

Stephen Sheridan*; Keith Sunderland; Jane Courtney (Technical University Dublin)

Abstract-Swarm Electrification (SE) is gaining considerable attention as an exciting tool to provide last-mile electrification at the lowest possible cost. A swarm grid is similar to a micro-grid, but rather than a planned network, it is assembled in an ad-hoc fashion, simply connecting available equipment via a controller, and expanding the grid as more resources become available. This allows the owners of small solar home systems (SHSs) to sell excess energy and enables others to gain an electrical connection without investing in their own system. Creating an income for the prosumer and helping others to get on the electrification ladder. This paper provides the first review specific to SE, giving an overview of the current state of the technology. A search was performed using the following terms: Swarm electrification, bottom-up electrification, organic microgrids, ad-hoc microgrids, pico-grids, nano grids, mesh grids and P2P energy trading. This yielded 91 publications that implicitly mentioned swarm electrification or described an ad-hoc grid with P2P energy trading. Of these, 48 were selected for this review as they were deemed to represent the key aspects of SE. The main topics within the literature are identified discussed, and the key challenges are noted. It is recommended that further research be performed in the areas of optimisation, stability and reliability with a view to scaling up these grids to support small industrial devices.

*corresponding author

Thursday 1 September 2022

16:00-17:30	Parallel Paper Sessions TS16-TS18
Session TS18	Electrical Machines and Drives Room: 1304
Session Chair	Prof. Graeme Burt (University of Strathclyde)

69

A Direct Synthesis based Sliding Mode Control of a Nonlinear Continuous Stirred Tank Reactor

Mohammad Atif Siddiqui* (Integral University); Mohammad Nishat Anwar (National Institute of technology, Patna); Ahmad Faiz Minai; Akhlaque Ahmad Khan; Mohammad Naseem; Abdul Jabbar (Integral University)

Abstract- This work proposes a sliding mode controller (SMCL) design approach based on direct synthesis method for non-linear continuous stirred tank reactor (NCSTR). The SMCL parameters are derived based on (i) NCSTR model obtained by performing the closed loop test on the nonlinear differential equations of the NCSTR, (ii) direct synthesis approach and (iii) grasshopper optimization scheme. The performance of the suggested approach is assessed by performing the simulation on the nonlinear differential equation of the NCSTR. The results indicate that the suggested approach delivers satisfactory performance under nominal and noisy conditions with minimal efforts by the controller.

45

The Application of Slotless Skewed Windings to a Rim Driven Fan for Aircraft Electrical Propulsion (AEP)

Antoine Saulin; Robert Cameron Bolam; Jhon Paul C. Roque; Yuriy Vagapov* (Glyndwr University)

Abstract-This paper investigates the slotless winding characteristics of motors intended for aircraft electrical propulsion (AEP), together with a preliminary design study of a winding model derived from a Faulhaber configuration. Geometrical relationships and magnetic requirements driving the design, such as the width of each phase coil side, the skew angle, and the winding arrangement, are analysed. Finally, electromagnetic (EM) simulations were conducted to study the electromagnetic performance of the Faulhaber model and the influence of the stator conductor skewness. Upon analysis of the results, it is found that the skew angle should remain low to assure efficiency, while it should also be great enough to satisfy the geometric and magnetic requirements. In conclusion, the paper proposes a hybrid slotless winding configuration based on the Faulhaber structure, which is a trade-off between efficiency and end-winding length for a motor powering a rim driven fan.

98

Torque-Speed Characteristics for Electrically Powered Rim Driven Fans and Thrust Comparison with a Small Conventional Fan Jet Engine

Robert Cameron Bolam; Jhon Paul C. Roque; Yuriy Vagapov*; Richard J. Day (Glyndwr University)

Abstract-The aim of this paper is to provide a method of estimating torque versus speed characteristics of single and dual-stage electrically powered Rim Driven Fans which are intended for aircraft propulsion. The methodology is based on the well-known Euler equation which considers the change in angular momentum of the air as it passes through the fan rotors. A derivation of the useful and versatile Specific Work parameter (Y) is provided along with its important relationship with the fan Work Co-efficient (ψ) and an explanation of the relevance of the Fan Flow Co-efficient (ϕ) in determining the flow of air through the RDF device. An equation is derived which relates the fan torque to its rotational speed and a specimen calculation of a 200 mm inlet diameter RDF has been provided. Electrical performance graphs, generated with Motor-CAD LAB software, are included to illustrate an example of a suitably optimised RDF motor circuit. Finally, a thrust performance comparison is made between a theoretical dual-stage RDF and a commercially available fan-jet engine. It is demonstrated that the dual-stage RDF technology could offer a viable solution to power high-speed medium and large commercial transport aircraft, making them particularly suited to distributed thrust system architectures and blendedwing-body aircraft designs.

140

Application of the Impulse Response of Transformer Winding for Detection of Internal Turn-to-Turn Short Circuits

Mozon Shadid* (Khalifa University, UAE); Noureddine Harid (APEC Research Centre, Khalifa University, UAE); Braham Barkat (Khalifa University, UAE); Ashwin Manjunath (APEC Research Centre, Khalifa University, UAE)

Abstract-Several techniques are currently used to monitor internal defects in power transformers. These are very useful for reducing failure rates and extending the service life of transformers. One of the most sensitive techniques is the frequency response analysis method that injects a swept frequency ac signal into the transformer winding and analyses differences between the measured output signal and a benchmark reference signal. This paper applies the impulse voltage method for the diagnosis of turn-to-turn short circuit faults inside a transformer winding. The input signals are a set of impulse voltages of different shapes instead of the standard ac signals of variable frequency. The merits of this method compared with the standard swept frequency method are a shorter time for testing and for signal analysis. The output results are processed to produce a frequency response plot of the winding. Measurement results on a small test transformer show that the plots are closely similar to those obtained using the swept frequency method. In this initial study, impulse voltages are used to emulate the naturally occurring transients in power systems such as switching events and tap changer operations. The sensitivity of the method is verified by applying statistical techniques to interpret the measured frequency response in different frequency bands.

111

Power Modulation and Phase Switching Testing of Smart Charger and Electric Vehicle Pairs

Kristian Sevdari*; Simone Striani; Peter Bach Andersen; Mattia Marinelli (Technical University of Denmark (DTU))

Abstract-De-coupling transport sector from the use of petroleum is giving way to the rise of electric mobility. As compromising the user's comfort is not an option managing the power system becomes a tall challenge, especially during peak hours. Thus, having a smart connection to the power system, such as an electric vehicle (EV) smart charger, is considered part of the solution. This paper focuses on assessing the capabilities of smart chargers in the context of helping the electrical network without compromising the user's comfort. By using a Tesla Model S P85, Renault Zoe, and Nissan LEAF, the paper first evaluates differently controlled (centralized and distributed) smart chargers against the IEC 61851 standard. Second, it tests smart features such as peak-shaving, valley-filling, and phase balancing. Being representatives of the state-of-the-art, both chargers exceed standard requirements and offer new grid service possibilities. However, the bottleneck for providing faster grid services remains the EV on-board charger. The results from this article can help to better simulate the dynamic charging behaviors of EVs.

*corresponding author

Friday 2 September 2022

09:00-10:30	Parallel Paper Sessions TS19-TS21
Session TS19	Electricity Markets Room: Ömer Korzay
Session Chair	Dr. Alexis Polycapou (Frederick University)

29

How will Heat Pumps affect Electricity Load Profiles for Buildings in Ireland? Empirical data used to model possible financial impacts facing consumers

Mr. Michael McDonald* (Technological University of Dublin)

Abstract—The current geopolitical situation is certainly challenging the colossal transition to Zero carbon Economy. In fact, in the coming years, the electricity sector will have to find new innovative ways to meet the ever increasing need for energy without the over reliance on fossil fuels and their country of origin. Over the next decade, oil and gas boilers will not be permitted in new buildings in Ireland, in line with the Irish Building Regulations, Technical Guidance Document L – Conservation of Fuel and Energy 2021. This is a major shift in traditional building services methodology and heat technology. In line with the European Union Green Deal, member states are developing and updating policies in an effort to foster this energy transition. The main areas of focus are the three pillars of energy and the associated carbon emissions; electricity, transport and heat. This paper aims to examine energy bills, electricity and gas, for a domestic family premises over a 24 month period. This data will allow the author to build a demand load profile model for the energy consumption and thus, forecast the transition to the electrification of building services. Today, the readily available solution on offer for industry are heat pumps (HP) which will allow the fuel source to move away from a carbon heavy source to a cleaner electricity source. This paradigm shift in thermal demand technology, to a decarbonised electricity source may place a large burden on the national electricity grid during peak demand times. Given the acute energy crisis being currently witnessed throughout Europe, this paper highlights the potential increased electricity bills that consumers might face while shifting to heat pumps. This paper's main findings are that without Demand Side Management (DSM) tools and smart services, such as smart meters and Time-of-Use (ToU) tariffs, consumers could face increased winter energy bills in the region of 184%.

61

Risk-Averse Decentralized Optimal Scheduling of a Virtual Energy Hub Plant Equipped with Multi Energy Conversion Facilities in Energy Markets

Amin Mansour Saatloo*; Manthila Wijesooriya Mudiyanselag (Northumbria University); Mohammad Amin Mirzaei (University of Tabriz); Abbas Mehrabi; Mousa Marzband; Nauman Aslam (Northumbria University);

Abstract—Distributed multi-energy systems, in addition to their advantages, pose significant challenges to future energy networks. One of these challenges is how these systems participate in energy markets. To overcome this issue, this paper introduces a virtual energy hub plant (VEHP) comprised of multiple energy hubs (EHs) to participate in the energy market in a cost-effective manner. Each EH is equipped with multiple distributed energy resources (DERs) in order to supply electrical, heating and cooling loads. Moreover, an integrated demand response (IDR) program and vehicle-to-grid (V2G) capable electric vehicles (EVs) are taken into consideration to enhance the flexibility to EHs. The manager of the VEHP participates in the existing dayahead markets on behalf of EHs after collecting their bids. Since EHs are independent entities, a hybrid model of mobile edge computing system and analytical target cascading theory (MECATC) is proposed to preserve data privacy of EHs. Further, to tackle the uncertainty of renewables, a robust optimization method is applied. Obtained results corroborated the proposed scheduling is efficient and could increase the VEHP's profit about 21.4% in light of using flexible technologies

100

Bidding Strategy of a Microgrid in Joint Energy and Reserve Markets: An IGDT-Based Approach

Mojtaba Mohseni; Ali Sedaghatkerdar; Mahdi Mohseni (Shiraz University of Technology); Ehsan Heydarian-Forushani (Qom University of Technology); Sitki Guner* (Eskişehir Technical University); Aydogan Ozdemir (Istanbul Technical University)

Abstract— The increasing penetration rate of distributed energy resources (DERs) influences the operation process of power systems and also results in lots of challenges. One of the major challenges is to scheduling of such sources, and one of the most applicable approaches is to operate them in the form of micro-grids (MGs). Thus, the decision-making framework of the power systems' operation problems, in the emergence of MGs, has encountered a decentralized form instead of centralized one. Based on this change, the operation problem as well as the bidding strategy of the MGs participating in joint energy and reserve markets need new optimization approaches. Moreover, the control of uncertain parameters in the decisionmaking of MG operators (MGOs) should be molded through new mathematical Techniques. In this paper, the model of a grid-connected MG's operation problem is proposed so that the MGO implements the demand response programs (DRPs), and deals with the uncertainties of the reserve deployment probability and the renewable energy sources (RESs). To achieve this aim, an information gap decision theory (IGDT)- based approach is applied with the purpose of controlling the risk-based decision-making of the MGO. Lastly, the validation of the model is investigated by employing it on a test modified 15-bus MG and the results reveal the difference between the decisions of the risk-averse and risk-taker MGO.

118

Benefits and Threat of Business Models in the German Electrical Systems

Cristian Monsalve*; Tilo Hirsch; Steffen Nicolai; Peter Bretschneider (Fraunhofer IOSB-AST)

Abstract—This paper presents several key aspects and results as part of the research project "Evaluation of novel Business Models (BMs) in the electrical supply" financed by the German Ministry of Economy and Energy (BMWi). This paper focuses on presenting some of the results from the technical and economical evaluation of the German electrical infrastructure when multiple BMs are implemented by multiple actors of the whole energy system. The motivation of this paper is to demonstrate the contribution of implementing some BMs to the sustainability and controllability of the energy distribution system by assessing some technical indicators such as changes in peak load and availability of load shifting potential in Germany and determining the effects of these BMs.

125

The impact assessment of an energy efficiency focused course implementation in electrical engineering undergraduate students curricula

Claudia Mureșan*; Laura Dărăbant; Denisa Șteț; Ștefan Cîrstea; Levente Czumbil; Andrei Ceclan; Timea Farkas (Technical University of Cluj-Napoca); Alexis Polycarpou (Frederick University); Dan D. Micu (Technical University of Cluj-Napoca)

Abstract—The global energy situation highlights the critical need for sustainability-focused education and raising awareness for environmental issues among the younger generation. In the same context, the increased demand for well-trained energy professionals is often emphasized as a key factor for a smooth and efficient energy transition. Despite this, there is a limited number of studies in the literature presenting examples of good practice in sustainability and energy efficiency implementation in higher education curricula. This study aims to fill this gap in the framework of an impact assessment survey concerning the implementation of a dedicated optional course in sustainability and energy efficiency field for undergraduate electrical engineering students. The results of the survey show that together with a better understanding of specific concepts, improvements in concern, willingness and behavior associated with sustainability and energy efficiency concepts have been reported by students, after they attended the proposed course during the semester.

* corresponding author

Friday 2 September 2022

09:00-10:30	Parallel Paper Sessions TS19-TS21
Session TS20	Power Quality Room: 1302
Session Chair	Prof. Engin Karatepe (Ege University)

93

An Analysis of Power Quality Improvement by Reactive Power Compensation Devices

Farzana Hossin; Gill Lacey; Rafiqul I. Chowdhury* (Teesside University)

Abstract— Providing continuous high-quality power is an important aspect of a power system. This, however, requires the use of compensation devices due to the nonlinear load condition and dynamic nature of the power system to avoid invalidating the legal limit standard set by a country's supply regulation. Keeping the power and voltage level within the given statutory limit can be achieved by injecting or absorbing reactive power by using reactive power compensation (RPC) devices. Flexible AC Transmission Systems (FACTS) also play a key role in enhancing power quality. This paper discusses simulation models developed in IPSA and ETAP software to simulate the power quality improvement of a selection of devices and conducts a performance analysis

147

Applying and comparing the general power theory compensation for unbalance and harmonics

Hilary Chisepo*; C. Trevor Gaunt; Pitambar Jankee (University of Cape Town)

Abstract— The general power theory (GPT) was formulated to provide metering and optimal compensation solutions for practical power delivery systems with unbalance, harmonic distortion, and dc components. Despite the availability of a detailed derivation and description of the GPT, there is still some uncertainty about how to apply it a) in measurement and b) to control a compensator. This paper summarizes the implementation of the GPT and demonstrates its compensation in a power system with equipment generating distortion and unbalance. A model of the physical behavior of a variable speed drive (VSD) and an unbalanced load was developed in MATLAB/Simulink in conjunction with the GPT's approach to measurement and compensation. The application of the GPT and the results of the modeling indicate that it is possible to achieve optimum compensation for power delivery loss, distortion, and unbalance. A comparison of the novel GPT approach with conventional pq theory showed the GPT's better loss reduction and general capability.

164

A Survey of Microgrid Operation Influence on Power Quality

Vlăduț-Andrei Ion; Andrei Tudose; Eda-Elif Gemil; Nicolae Anton; Mădălina Arhip-Calin; George Serițan (University Politehnica of Bucharest)

Abstract—The continuous development of distributed generation and renewable energy resources has a significant impact on microgrids today. This paper summarizes the main concept of a microgrid, the status of the literature, ongoing developments, and the relevant standards. This paper has covered the aspects of a generical microgrid system, its control and development for the improvement of power quality. The outputs of hydrogen-based studies on microgrids are designed to aid in the future development of secure, reliable, and stable real-life networks with greater penetration of renewable energy sources.

165

A Survey of VPP Influence on Power Quality

Eda-Elif Gemil; Mădălina Arhip-Călin; Vlăduț-Andrei Ion; Cristian Gorea; Radu Porumb; Nicolae Anton (University Politehnica of Bucharest)

Abstract—This article is a survey of the power quality problems that can occur in power systems, in the context of rising integration of the renewable energy systems, as well as the energy storage systems. By aggregating the production, consume and storage process into a Virtual Power Plant (VPP), some of the many effects of the problems of power quality could be minimized, with the appropriate management plan.

166

An overview of PMU-based Electrical Power Systems modelling for Power Quality enchancement

Nicolae Anton; Eda-Elif Gemil; Constantin Bulac; Bogdan Dobrin; Mihai Sănduleac; Vlăduț-Andrei Ion (University POLITEHNICA of Bucharest)

Abstract—The increasingly important use of renewable energy resources within the electricity networks has changed the paradigm of electrical power system operation. This shift is enforced by the ever-present power electronic devices, which are used both at generation side, as well as on the consumption side, cluttering the normal operation, and issuing new threats from power quality point of view. However, the new technology involved in the advanced metering systems, such as Phasor Measurement Units (PMUs), is helping both transmission and distribution operators to efficiently manage the electrical system, by correctly identify the upcoming threats for a priori calculations, as well as the causes which may have led to faults, for a posteriori evaluation. This paper deals with the widespread use of PMU-based advanced metering systems.

* corresponding author

Friday 2 September 2022

09:00-10:30	Parallel Paper Sessions TS19-TS21
Session TS21	HVDC, FACTS, and Power Electronics (2) Room: 1304
Session Chair	Dr. Yuri Vagapov (Wrexham Glynwr University)

50

A Six-Phase Interleaved Buck-Boost Converter using Adaptive Delta Modulation Control loop for Renewable Energy Applications

Farag S. Alargt* (The Centre for Solar Energy Research and Studies); Ahmed S. Ashur (University of Tripoli); Ahmad H. Kharaz (University of Derby)

Abstract— The design and simulation of a six-phase interleaved buck-boost DC/DC converter are detailed in this paper. An adaptive delta modulation control loop strategy has been employed. This strategy has not been previously applied to interleaved buck-boost converters. The converter provides an output voltage of 48 V and 10KW output power which conforms to the requirements of the 24/48V scheme used in the Small-Scale Renewable Energy Systems (SRES) and similar applications. The design, simulation and analysis of the buck-boost converter power system in the multi-phase interleaved scheme are presented. This converter is designed to operate in a Discontinuous Conduction Mode (DCM). The effect of the design parameters variation on the performance capabilities of the converter is described. Simulation results are presented to demonstrate the advantages of the presented control technique and the converter scheme. All the normal advantages associated with interleaving, such as higher efficiency and reduced input/output ripples for current and voltage, are also achieved in the converter. The results show that the output voltage is stable and remains within the desired specified values for a range of input voltage variations.

142

Impact of recovery and sympathetic inrush phenomena on VSC HVDC systems

Michael Richter*; Gert Mehlmann; Matthias Luther (Friedrich-Alexander-Universitat Erlangen-Nürnberg)

Abstract—The converter transformer of a VSC HVDC station can be driven into saturation caused by external grid events as short-circuits or the energization of nearby transformers. These effects are classified as inrush phenomena and named recovery inrush and sympathetic inrush, respectively. In this paper, a thorough study on different influencing factors on the inrush magnitude and its impact on the operation of the HVDC system is analyzed based on electromagnetic transient analysis using an average based EMT MMC HVDC model. As important parameters for the analysis of the recovery inrush the short-circuit ratio, the time point of fault inception and the fault duration, the fault distance and the fault resistance are selected. The impact of these parameters on the inrush intensity and the transients of the transformer and converter currents as well as active and reactive powers during the inrush events are analyzed and worst-case scenarios evaluated. By evaluation of internal converter signals, it is checked whether the converter is able to maintain stability for different inrush intensities.

149

Performance Analysis of Grid Forming Converters for a Didactic Smart Grid System

Macit Tozak; Sezai Taskin (Manisa Celal Bayar University); Ibrahim Sengor (University College Cork, Izmir Katip Celebi University)

Abstract— Grid forming control for inverter-dominated power systems of the future is crucial as it enables more renewable penetration and provides enhanced stability. In this paper, a power system that consists of both Synchronous Machines (SM) and Grid Forming Controlled PV system is modeled and simulated in MATLAB®/ Simulink®. Moreover, the real parameters of laboratory pieces of equipment in Manisa Celal Bayar University Smart Grid Laboratory (MCBU-SGLab) are used throughout the study. In addition, various Grid Forming Converter control methods such as droop control, matching control, and dispatchable virtual oscillator control are compared in terms of frequency stability under different conditions.

30

Current Balancing Circuit Design for Parallel LED Strings in QDOT High Bright TV with Dual- Transformer LLC Resonant Topology

Melisa Ersoy*; Gokturk Poyrazoglu (Ozyegin University)

Abstract—New LED technologies demand slim designs with increased backlight power. When the parallel-connected LED strings are driven by multiple transformers, the magnetic coupling difference and the LED string voltage difference cause backlight current mismatch problem. This imbalance causes the line with low voltage to draw more current hence to create heat spots on the backlight causing reduced lifetime. This problem is observed as backlight fluctuation at the end-user side. In this study, a cost-effective balancing circuit is simulated and implemented for eight parallel-connected LED strings using two transformers in an LLC half-bridge resonant topology while meeting the power demand in a relatively slim design. For the 145W backlight power, the current mismatch was 57.59% when there was an 8% deviation in transformer leakage inductance and a 10% variation between LED string voltages. The temperature difference between the strings was measured as 31.8℃ taken at room temperature with the open back cover. With the balancing circuit, the LED current difference being reduced to 9.99%. When the string voltages are the same, the maximum deviation in the current is measured as 2.59%.

36

Current Ripple Evaluation of Space Vector Modulated Five-Phase Split-Source Inverters

Sherif M. Dabour* (Glasgow Caledonian University, Tanta University); Ahmed A. Aboushady; Mohamed. A. Elgenedy; I. A. Gowaid; Mohamed Emad Farrag (Glasgow Caledonian University)

Abstract—Split-source inverters (SSIs) have recently gained much attention as single-stage boost inverters due to their advantages compared with their other counterparts, such as the Z-source inverters (ZSIs). This paper extends the topology of the basic SSI to multiphase systems. It focuses on a five-phase topology as an application to a five-phase drive system. The power circuit and operating principles of the analyzed topology are introduced. Moreover, a modified space vector modulation (MSVM) scheme is developed to eliminate the low-frequency ripples in the input current. In addition, detailed analysis and graphical evaluations of input and output current ripples are presented. Finally, simulation results based on PLECS have been conducted to show the viability of the presented analysis and theoretical study of the five-phase SSI.

* corresponding author

Friday 2 September 2022

11:00-12:30	Parallel Paper Sessions TS22-TS24
Session TS22	Analytical Methods and Implementation In Smart Grids (3) Room: Ömer Korzay
Session Chair	Dr. Sıtkı Güner (Eskisehir Technical University)

102

A Voting-Based Machine Learning Strategy to Detect False Data Injection Attack in Cyber-Physical Power Systems

Amirreza Jafari*; Hakan Ergun; Dirk Van Hertem (KU Leuven/EnergyVille)

Abstract— Integrating the information and communications technology (ICT) infrastructures with the physical layer of the electrical grid puts the power system at the risk of a wide range of cyber intrusions. Cyber-physical power systems (CPPS) require effective and applicable prevention, detection, and mitigation strategies to defend the system against malicious attacks. In this process, precise attack detection is one of the vital phases. This paper designs a novel voting-based detection tool to identify cyber intrusions in the system. In the considered cyber-attack, the attacker attempts to inject a wide range of false data into the phasor measurement units (PMU) to simulate false short circuit conditions in the system. The proposed detection strategy utilizes several machine learning (ML) algorithms like ensemble learning, discriminant analysis, naive bayes, feedforward neural network (FNN), recurrent neural network (RNN), k-nearest neighbors (KNN) classification, support vector machine (SVM), and decision tree. The voting-based technique calculates the average output based on the performance of the detectors and can recognize FDI attacks from real short circuit faults. Training features are selected optimally among several mechanical and electrical features of the system with maximum relevancy and minimum redundancy (MRMR) method. The simulations on the IEEE 39 bus test system illustrate the performance of the proposed detection tool for each type of short circuit fault.

126

Medium-term forecasting of active power curtailment from MV/LV transformer loadings with an increasing capacity of PV panels

George Rouwhorst* (Eindhoven University of Technology); Anuradha Tomar (Netaji Subhas University of Technology); Phuong H. Nguyen (Eindhoven University of Technology); Han Slootweg (Eindhoven University of Technology, Enexis Netbeheer)

Abstract—Driven by the energy transition, the electricity generated by photovoltaic panels connected by customers behindthe-meter is annually increasing. This is expected to lead to congestion of medium to low voltage (MV/LV) transformers because the related capacity is unable to be reinforced fast enough to accommodate all these PV panels. Based on medium-term load forecasts of an MV/LV transformer with an annual increasing capacity of installed PV panels behind-the-meter, active power curtailment (APC) necessary to prevent congestion and related compensation costs to owners of these PV panels is forecasted. First, a month-ahead load forecast of the studied MV/LV transformer with an annual increasing capacity of installed PV panels behind-the-meter is performed multiple times based on weather conditions measured during the same month but in previous years. Second, each of these month-ahead load forecasts is used to forecast the related APC and compensation costs. Subsequently, the distribution in forecasted APC and compensation costs due to annual variation of weather conditions over a month is analyzed. In addition, APC duration curves are calculated for all these forecasts to analyze the distribution of the amount and duration of alternative solutions, such as demand-side management to reduce necessary APC and the local mismatch between supply and demand.

39

Synthesis and Characterization of Multi-level Pseudo-Random Sequences as Excitation Signals for System Identification

Zandile Moyo*; Fredrick Mukundi Mwaniki; Ian Paul Gerber (Stellenbosch University)

Abstract—Identifying the frequency characteristics of systems prone to noise and non-linear distortions, such as grid-connected components, requires careful consideration of the excitation signal. For instance, to obtain the linear behaviour of such a system, the effects of the non-linear distortions should be reduced in the system identification procedure. This paper discusses the synthesis and suitability of multi-level pseudo-random sequences for system identification in the presence of harmonic distortion. Three different methods of synthesising multi-level pseudo-random sequences are presented and the properties of the resulting signals are discussed. It is shown that the design of these sequences can be optimised such that certain harmonics are suppressed. This is beneficial for minimizing, detecting or separating the effects of nonlinear distortions in an identification experiment. A method that uses a field programmable gate array is developed to generate controllable multi-level pseudo-random sequences. A frequency response estimation of an equivalent circuit model of a lithium-ion battery is conducted to demonstrate the use of multi-level signals in system identification. It is shown that the estimation corresponds well with the analytical response.

159

Small signal stability research on integrating Wind Power Plant – An Almaty Region Example

Aigerim Aman*; Anur Bektimirov (Almaty University of Power Engineering and Telecommunications named after Gumarbek Daukeev); Nassipkul Dyussembekova (FH Westküste University of Applied Sciences); Azamat Ilyasov; Almaz Saukhimov; Alexandr Gunin (Almaty University of Power Engineering and Telecommunications named after Gumarbek Daukeev)

Abstract — The paper presents the results of Wind Power Plant (WPP) influence during its integration to the electrical grid of 110 kV and higher, as well as the help of Power System Stabilizer (PSS) to the power system. Providing stability is the most important aspect in the electric power industry, especially when renewable energy sources (RES), in particular WPPs are integrated. When integrating a large amount of RES into the power system, there are challenges for the System Operator associated with generation instability and undamped low-frequency oscillations (LFO). The aim of this work is to study the impact of WPPs integration into traditional power system considering the standards and requirements and the use of PSS in the power system to prevent LFO during WPP integration. The object of the study is an installed WPP in the Almaty region with a capacity of 60 MW. WPP with DFIG type connection to the grid. Rotor-angle stability, small signal stability, voltage stability of the electrical system during the integration of the WPP was carried out. It should be noted that when integrating WPPs into electrical networks without revising the existing PSS at traditional power plants, the oscillatory stability of the power system may decrease.

101

The Impacts of The Temperature-Humidity Fluctuations in Substations and Practical Experimental Applications

Ilker Dursun (Sakarya University); Hulya Akinc (Enerjisa); Sıtkı Guner* (Eskişehir Technical University); Aydogan Ozdemir (Istanbul Technical University)

Abstract— Substations are the most critical components of power grids. A failure in a substation may cause power outages for thousands of households and workplaces. That's why it is crucial to operating substations under proper conditions. Temperature and humidity directly affect the electrical equipment's lifecycle, performance, and efficiency. They lead to many failures and power outages. This paper presents the humidity-temperature relation inside and outside environments of substations. It also covers the causes and impacts of humidity inside the substations, environmental factors, and mitigating methods of these factors. Besides, some experimental studies are handled such as indoor-outdoor temperature and humidity measurements, basic construction improvements to prevent water ingress and excessive ventilation, and installation of a dehumidifier device. The importance of continuous measurement and controlling of the substation's indoor environments are proved. Besides, it is presented that the humidity problem can be overcome by avoiding sudden temperature & humidity fluctuations and controlling the indoor climate conditions continuously.

* corresponding author

Friday 2 September 2022

11:00-12:30	**Parallel Paper Sessions TS22-TS24**
Session TS23	**Renewable Energy Systems (3)** **Room: 1302**
Session Chair	**Dr. Maysom Abbod (Brunel University, London)**

33

Minimize the Customer Outage for improved Reliability in Distribution System with Photovoltaic Distributed Generation

Nattachote Rugthaicharoencheep*; Papon Ngamprasert; Natchapol Ruangsap; Nawin Rodrueang (Rajamangala University of Technology Phra Nakhon)

Abstract— This paper presents minimize the customer outage for improved reliability in distribution system with photovoltaic distributed generation. The objective functions to be minimize the customer outage cost. The problem is to reliability improvement of distribution system with distributed generations. The technique employed to solve the outage cost by Tabu search algorithm. An application of the Tabu search algorithm to test system for the case study is a radial distribution system with Roy Billinton Test System (RBTS) bus 2. Numerical results from the tests demonstrate that the optimal placement of distributed generators can be used to promote the reliability of the distribution system.

138

Frequency Stability in Renewable-Rich Modern Power Systems, Saudi Grid Case Study

Saad Alqahtani* (King Khalid University, Cardiff University); Abdullah Shaher (Najran University, Cardiff University); Ali Garada; Liana Cipcigan (Cardiff University)

Abstract— The transition toward a zero-carbon society is the driving force for pushing traditional power systems to dramatically increase the share of Renewable Energy Sources (RESs). The high penetration of RESs in modern power systems would lead to a reduction in system inertia as they are indirectly connected to the grid using power converters. This reduction in the rotational inertia associated with synchronous generation might result in deteriorated frequency response following a power disturbance. This paper investigates the impact of high penetration of inverter-fed generation technologies on the Kingdom of Saudi Arabia (KSA) grid. The impact of RESs has been studied through the simulation of four case studies of the future KSA power system using MATLAB/Simulink simulation software. The model was tested after the integration of various penetration levels of RESs into the grid. The simulation results showed that high penetration of RESs would lead to a severe effect on the frequency response. The importance of Battery Energy Storage Systems (BESSs) for compensating the reduction in the system inertia has been addressed. The results showed the aggregated BESSs effectiveness for improving the stability of the system frequency.

21

Stability of Series Capacitor Compensated Thermal Power System with FSWTGs under Strong Wind Gust

Fawzi A.Rahman AL-Jowder*

Abstract —This paper studies the effect of a strong wind gust on the stability of a series capacitor compensated thermal power system with Fixed Speed Wind Turbine Generators (FSWTGs). The IEEE first benchmark model (IEEE-FBM) for Subsynchronous Resonance (SSR) studies has been adopted and modified to perform the study. The influence of the strong wind gust on the stability of the system is investigated at different degrees of series compensation and power rating of the FSWTGs. Time domain simulations using PSCAD are employed to perform the study. Simulation results showed that strong wind gusts can cause instability in the system.

32

Frequency and Voltage Compliance Capability of Grid-Forming Wind Turbines in Offshore Wind Farms in Weak Grids with a Power Imbalance

Benjamin Vilmann* (Tech. University of Denmark); Jesper Hjerrild (Ørsted Wind Power A/S); Peter Jan Randewijk (Energinet Systemansvar A/S); Ashraf Khalil (Tech. University of Denmark)

Abstract—Grid-forming wind turbines are a promising technology for weak grids with a high penetration of converter-based power sources. The droop control, the synchronverter, and the virtual synchronous machine grid-forming control topologies are benchmarked by voltage and frequency stability performance from a frequency disturbance under different grid conditions (by varying short-circuit ratio, X/R ratio, and the inertia). The wind turbines are modelled in an offshore wind farm application and the frequency disturbance are scaled to 5% of the installed capacity. The study have shown that the virtual synchronous machine performs best regarding frequency and voltage compliance in weak grids under a frequency disturbance. DC-link modelling is essential for dynamic simulations of grid-forming converters, as grid perturbations can drain the link for energy.

104

Multi-Objective Optimization Framework for Integration of Distributed Energy Resources in Smart Communities

Bahman Ahmadi*; Aditya Pappu; Gerwin Hoogsteen; Johann L. Hurink (University of Twente)

Abstract—This paper studies a multi-objective optimization problem on the allocation problem of photovoltaic (PV) and battery energy storage systems (BESSs) in a community, whereby the aim is to find Pareto optimal solutions according to two different set of objective functions. These objective functions are minimizing the dependency of the whole community or each household on the national grid and minimizing the investment, operation, and maintenance costs of PV and BESS units. A Parallel Multi-Objective Multi-Verse Optimization (PMOMVO) algorithm is developed to obtain the Pareto optimal solutions for the problems. The optimization framework is used to determine all Pareto front solutions in a real community and the results are compared to the base case scenario of the community. The Pareto solutions show that by small investment in the BESS units, community can be less dependent on the national grid even with less PV panels installed in the community.

24

Influence of Strong Wind Gust on Transient Stability of Power System with FSWTGs

Fawzi A.Rahman AL-Jowder*

Abstract —This paper studies the influence of a strong gust wind on the transient stability of a power system with Fixed Speed Wind Turbine Generators (FSWTGs). The IEEE first benchmark model (IEEE-FBM) for Subsynchronous Resonance (SSR) studies has been adopted and modified to perform the study. The influence of wind gust duration and magnitude on transient stability of the system is investigated using Equal Area Criterion and time domain simulations. The influence of the pitch angle controller of FSWTGs is also studied. Simulation results showed that the system under strong wind gusts with higher magnitude and shorter duration becomes unstable. In addition, it shows that including the model of pitch angle controller in FSWTGs modelling improves the transient stability of the system.

* corresponding author

Friday 2 September 2022

11:00-12:30	**Parallel Paper Sessions TS22-TS24**
Session TS24	**Power Systems Simulation and Analysis (2)** **Room: 1304**
Session Chair	**Dr. Gobind Pillai (Technical University)**

124

Improved Situational Awareness for Power Distribution Systems Based on WLAV Estimator and Direct Load Flow Solution

Kemal Parlaktuna* (Middle East Technical University); Erk Dursun; Mustafa Cihan Cinalioglu (Siemens); Murat Gol (Middle East Technical University);

Abstract—With high renewable penetration, increasing popularity of electrical vehicles and rapid growth of electrical system especially in urban areas, modern distribution power systems are becoming more complex. Having situational awareness of the system is crucial for system operator both to have knowledge on the current state of the system and where to improve infrastructure. In this paper an application of a situational awareness tool for an active distribution power system is discussed. Improvements on the information gathered about the system with situational awareness tool are given as well.

132

Issues of Capacitive Reactive Power Flow in Electricity Networks

Akhtar Hussain Javed; Phuong H. Nguyen; Johan Morren* (Eindhoven University of Technology); J.G. (Han) Slootweg; Sharmistha Battacharyya (Enexis Netbeheer)

Abstract—Due to changes in power networks and increased use of power electronics-based devices as consumer loads, utilities are now facing a problem of capacitive (reverse) reactive power flow in electricity networks. In this paper, the field measurement data from Dutch distribution system operator (DSO) and transmission system operator (TSO) is presented which clearly shows the flow of capacitive reactive power occurring in electricity networks. Moreover, the historical data illustrates that there is decline of imported reactive power from transmission system to distribution system over the years. Furthermore, in this paper a case study for a modified CIGRE low voltage (LV) distribution network in DIgSILENT PowerFactory is done where first the capacitive reactive power situation is simulated using loads with capacitive power factor and then a solution based on smart inverter function is proposed to minimize the capacitive reactive power exchange between LV and medium voltage (MV) network. In this way, by controlling smart inverters available in distribution network we can manage the amount of reactive power flow in the LV network and at the transmission distribution system boundaries.

49

The SMEmPower Monitoring, Targeting and Verification Tool

Stavros P. Filippidis; Nikolaos Kelepouris; Aggelos S. Bouhouras*; Georgios C. Christoforidi (University of Western Macedonia); Styliani A. Vomva; Ioanna D. Pasiopoulou; Grigoris K. Papagiannis (Aristotle University)

Abstract— This paper presents the methodology and the implementation of the monitoring and targeting (M&T) and monitoring and verification (M&V) tools that were developed in the context of the SMEmPower Efficiency Horizon 2020 project. The tools were built to allow energy managers and energy experts of Small and Medium Enterprises (SMEs) to store and organize energy consumption and production measurements, identify increased energy readings, create scenarios of reduced energy consumption, and finally verify the efficiency of energy conservation measures. The tools were used during the three training rounds that were organized in eight countries by the SMEmPower Efficiency project partners. More specifically, they have been applied for the practical action of the trainees in order to perform energy evaluations or actualization of energy audits in pilot sites under real consumption and production data.

75

Comparison of Transient Frequency Estimation Methods for Evaluating the Frequency Gradient in Active Distribution Grids

Anna Pfendler; Rafael Steppan*; Jutta Hanson (Technical University of Darmstadt)

Abstract— In the interconnected power system, frequency control and stability are of vital importance and an indicator of the system-wide active power balance. The shutdown of conventional power plants leads to faster frequency changes and a steeper frequency gradient due to the reduced system inertia. For this reason, the importance of electrical frequency estimation methods is increasing, among others as an input variable for the control of converter-based generation plants. The aim of this work is to implement, compare and analyze the robustness of different frequency estimation methods in time domain simulations. The Phase-Locked Loop, the Zero-Crossing method and the Recursive-Gauss-Newton method are implemented as real-time methods in a simple testbench in Matlab/Simulink. The parameters of the methods are tuned for a reference case and compared to the rotational frequency of a connected synchronous generator. With the tuned parameters, the maximum deviation between frequency estimation and the synchronous generator frequency can be limited to 15 mHz. The Zero-Crossing method shows the best robustness when changing the magnitude of the active power imbalance. In addition, the sensitive parameters of the frequency estimation methods behave approximately linear to the magnitude of the active power imbalance, so that a simple implementation can be designed for simulations.

* corresponding author