# Virtual Conference UPEC 2021

## IEEE Technically Co-sponsored 56th International Universities Power Engineering Conference

***Powering Net Zero Emissions***

Hosted by Teesside University, UK
31 August - 03 September 2021

## PROGRAMME AND SESSIONS BOOKLET

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# Contents

# 1. EXECUTIVE COMMITTEE

- Professor Gianfranco Chicco (UPEC 2020)
- Dr Gobind Pillai (UPEC 2021)
- Dr Oguzhan Ceylan (UPEC 2022)

# 2. LOCAL ORGANISING COMMITTEE

| Name | Role |
|---|---|
| Dr Gobind Pillai | Chair |
| Dr Maher Al-Greer | Co-chair/Programme Chair |
| Dr Gill Lacey | Technical Activities/Publicity Chair |
| Neville Winter | Sponsorship and Public Relations Chair |
| Dr Imran Bashir | Publications Chair |
| Dr Musbahu Muhammad | Finance Chair |

# 3. INTERNATIONAL STEERING COMMITTEE

| Name | Affiliation |
|---|---|
| ▪ Dr Alecksey Anuchin | Moscow Power Engineering Institute (Russia) |
| ▪ Dr Ralf Biernatzki | South Westphalia University of Applied Sciences (Germany) |
| ▪ Professor Graeme M Burt | University of Strathclyde (UK) |
| ▪ Professor Luciane Neves Canha | Federal University of Santa Maria (Brazil) |
| ▪ Dr Oguzhan Ceylan | Kadir Has University (Turkey) |
| ▪ Professor Gianfranco Chicco | Politecnico di Torino (Italy) |
| ▪ Dr Michael Conlon | Dublin Institute of Technology (Ireland) |
| ▪ Dr Mohammed Elgendy | Newcastle University (UK) |
| ▪ Professor Mohamed Emad Farrag | Glasgow Caledonian University (UK) |
| ▪ Dr Chris Gould | Staffordshire University (UK) |
| ▪ Professor Naren Gupta | Edinburgh Napier University (UK) |
| ▪ Professor Manu Haddad | Cardiff University (UK) |
| ▪ Professor Essam Hamdi | Education and Training International (ETI - London) (UK) |
| ▪ Professor Noureddine Harid | Khalifa University of Science and Technology (UAE) |
| ▪ Professor Mattia Marinelli | Technical University of Denmark - DTU (Denmark) |
| ▪ Professor Dan D Micu | Technical University of Cluj-Napoca (Romania) |
| ▪ Professor Naoto Nagaoka | Doshisha University (Japan) |
| ▪ Dr Hassan Nouri | University of the West of England (UK) |
| ▪ Dr Michael O'Donovan | Cork Institute of Technology (Ireland) |
| ▪ Dr Theofilos Papadopoulos | Democritus University of Thrace (Greece) |
| ▪ Professor Grigoris K Papagiannis | Aristotle University of Thessaloniki (Greece) |
| ▪ Dr Gobind G Pillai | Teesside University (UK) |
| ▪ Dr Ioana Pisica | Brunel University (UK) |
| ▪ Professor Radu F Porumb | University Polytechnica of Bucharest (Romania) |
| ▪ Professor Ghanim A Putrus | Northumbria University (UK) |
| ▪ Professor Salman K Salman | Emeritus Professor (Robert Gordon University) (UK) |
| ▪ Professor Gareth A Taylor | Brunel University (UK) |
| ▪ Professor Roberto Turri | University of Padova (Italy) |
| ▪ Dr Yuriy Vagapov | Glyndwr University (UK) |

# 4. UPEC: INTRODUCTION AND HISTORY

The International Universities Power Engineering Conference (UPEC) is one of the most important and oldest established annual Electrical Power Engineering and Education conference. It started in 1966 in the UK.

The first recorded UPEC related event was a power systems academic research community meeting held in 1966 in Newcastle. As an outcome of this meeting, the UPEC series formally began the following year, where it was hosted by the University of Glasgow and a first full set of proceedings was also then published. UPEC was originally established as a university-led conference series and has therefore always been hosted at universities both within and outside the UK. The first time UPEC was hosted outside the UK was in 1994 when it was hosted in Galway, Ireland. Since then, UPEC has become more internationally established and has been held in countries such as Greece, Italy, Germany, Romania, Portugal, Bucharest, and most recently Torino, Italy.

The 56th International Universities Power Engineering Conference, UPEC 2021, is hosted by the Teesside University, United Kingdom.

| UPEC | Year | University | Location | Country |
|---|---|---|---|---|
| **55th** | **2020** | Politecnico di Torino | Torino | Italy |
| **54th** | **2019** | University Politechnica of Bucharest | Bucharest | Romania |
| 53rd | 2018 | Glasgow Caledonian University | Glasgow | Scotland, UK |
| 52nd | 2017 | TEI of Crete | Crete | Greece |
| 51st | 2016 | Coimbra Institute of Engineering | Coimbra | Portugal |
| 50th | 2015 | Staffordshire University | Stoke-on-Trent | England, UK |
| 49th | 2014 | Technical University of Cluj-Napoca | Cluj-Napoca | Romania |
| 48th | 2013 | Dublin Institute of Technology | Dublin | Ireland |
| 47th | 2012 | Brunel University | West London | England, UK |
| 46th | 2011 | South Westphalia University | Soest | Germany |
| 45th | 2010 | Cardiff University | Cardiff | Wales, UK |
| 44th | 2009 | University of Strathclyde | Glasgow | Scotland, UK |
| 43rd | 2008 | University of Padova | Padova | Italy |
| 42nd | 2007 | University of Brighton | West Sussex | England, UK |
| 41st | 2006 | Northumbria University | Newcastle | England, UK |
| 40th | 2005 | University College Cork | Cork | Ireland |
| 39th | 2004 | University of West England | Bristol | England, UK |
| 38th | 2003 | Aristotle University | Thessaloniki | Greece |
| 37th | 2002 | Staffordshire University | Stafford | England, UK |
| 36th | 2001 | University of Wales | Swansea | Wales, UK |

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| 35th | 2000 | Queens University Belfast | Belfast | N. Ireland, UK |
| 34th | 1999 | University of Leicester | Leicester | England, UK |
| 33rd | 1998 | Napier University | Edinburgh | Scotland, UK |
| 32nd | 1997 | University of Manchester | Manchester | England, UK |
| 31st | 1996 | Technological Educational Institute | Iraklion | Greece |
| 30th | 1995 | University of Greenwich | London | England, UK |
| 29th | 1994 | University College Galway | Galway | Ireland |
| 28th | 1993 | Staffordshire University | Stafford | England, UK |
| 27th | 1992 | University of Bath | Bath | England, UK |
| 26th | 1991 | Brighton Polytechnic | Brighton | England, UK |
| 25th | 1990 | The Robert Gordon University | Aberdeen | Scotland, UK |
| 24th | 1989 | Queens University Belfast | Belfast | N. Ireland, UK |
| 23rd | 1988 | Trent Polytechnic | Trent | England, UK |
| 22nd | 1987 | Sunderland Polytechnic | Sunderland | England, UK |
| 21st | 1986 | Imperial College London | London | England, UK |
| 20th | 1985 | Huddersfield Polytechnic | Huddersfield | England, UK |
| 19th | 1984 | University of Dundee | Dundee | Scotland, UK |
| 18th | 1983 | University of Surrey | Surrey | England, UK |
| 17th | 1982 | University of Manchester | Manchester | England, UK |
| 16th | 1981 | University of Sheffield | Sheffield | England, UK |
| 15th | 1980 | University of Leicester | Leicester | England, UK |
| 14th | 1979 | Loughborough University | Leicester | England, UK |
| 13th | 1978 | University of Southampton | Southampton | England, UK |
| 12th | 1977 | Brunel University | West London | England, UK |
| 11th | 1976 | University of Southampton | Southampton | England, UK |
| 10th | 1975 | University of Aston | Birmingham | England, UK |
| 9th | 1974 | University of Cambridge | Cambridge | England, UK |
| 8th | 1973 | University of Bath | Bath | England, UK |
| 7th | 1972 | University of Bradford | Yorkshire | England, UK |
| 6th | 1971 | University of Manchester | Manchester | England, UK |
| 5th | 1970 | University of Swansea | Swansea | Wales, UK |
| 4th | 1969 | University of Nottingham | Nottingham | England, UK |
| 3rd | 1968 | Queen Mary College | London | England, UK |
| 2nd | 1967 | University of Glasgow | Glasgow | Scotland, UK |
| 1st | 1966 | Meeting | Newcastle | England, UK |

# 5. HOSTING INSTITUTION

Teesside University is a public university with its main campus in Middlesbrough, in Northeast England. Originally founded in 1929, Teesside University has a proud history of over 85 years of excellence in education. In recent years, Teesside University has invested £270m on its campus to provide one of the best study environments in the UK. Research and innovation at Teesside focuses on five grand societal challenge themes which make a real and practical difference to the lives of people and the success of business and economies. The five areas address – health and wellbeing; resilient and secure societies; digital and creative economy; sustainable environments; and learning for the 21st century.

The engineering department at Teesside University is composed of 54 academics. It sits within the School of Computing Engineering and Digital Technologies. The electrical power engineering team is relatively new, which started in 2014, with the arrival of the chair of UPEC 2021 Gobind Pillai and Prof Essam Hamdi senior steering committee member of UPEC 2021, who has now retired from Teesside. They joined Neville Winter - a local man, who is the sponsorship chair of UPEC2021, who has seen the group grow to five academics, plus support from Instrumentation and Control lecturers, especially Dr Imran Bashir, our publication chair, a number of PhD students and a few research associates working on externally funded projects.

We host, on campus, an MSc programme in Electrical Power and Energy systems, an MEng in Electrical and Electronics Engineering, a BEng in Electrical and Electronics Engineering and a BEngTech course in Electrical and Electronics Engineering. Via our transnational, online education and college partnership provisions, we host a number BEngTech, HND and HNC courses in electrical engineering.

In terms of research expertise, we mainly focus on Condition Monitoring and Diagnostics; Data Analytics and Artificial Intelligence Applied to Power Systems; Demand Side Management, Flexibility and Demand Response; Distributed Generation; Electric Vehicles and e-Mobility; Energy storage; Energy Efficiency in Buildings; Power electronics; ICT for Future Electricity Grids; Load and Generation Forecasting; Power Engineering Education; Renewable Energy Systems; Smart Grids and Sustainable e-Transition and host a number of EU and UK funding agencies funded projects.

# 6. KEYNOTE SPEAKERS

## 6.1. PROFESSOR TIM GREEN

**BIOGRAPHY:**

Professor Tim Green is Co-Director of the Energy Futures Lab, an institute that promotes and stimulates multi-disciplinary research, education and translation in energy at Imperial College London. His research is in formulating the future form of energy systems to support zero carbon futures and in particular the exploitation of the flexibility of power electronics to achieve high penetrations of variable renewable energy. He has researched Soft-Open-Points for enhanced operation of distribution networks, High Voltage DC for international interconnection and the stability of inverter-dominated grids and microgrids. He is a fellow of the Royal Academy of Engineering and IEEE.

**KEYNOTE: SOLUTIONS FOR STABILITY OF ELECTRICITY GRIDS WITH HIGH PENETRATION OF INVERTER-BASED RESOURCES**

The replacement of electro-mechanical machines by inverter-based resources (IBR) is fundamentally changing the dynamics and stability properties of grids, and further, the growth of small-scale resources raises the curse of dimensionality. How should theories and tools for stability analysis evolve to tackle these new properties and new dimensionality? This talk reviews recent progresses in stability analysis techniques including review of synchronisation across traditional generators, grid-following inverters and grid forming inverters and black-box, grey-box and white-box views of participation of individual IBR in modes of the system. Under pinning this are modelling techniques employing impedance spectrum models and new techniques in order reduction. Together, these methods offer useful advances for simplification and interpretation of complex grids and have been combined into a toolchain for automated stability analysis of large-scale grids.

## 6.2. PROFESSOR JOSEP M. GUERRERO

**BIOGRAPHY:**

Josep M. Guerrero received the B.S. degree in telecommunications engineering, the M.S. degree in electronics engineering, and the Ph.D. degree in power electronics from the Technical University of Catalonia, Barcelona, in 1997, 2000 and 2003, respectively. Since 2011, he has been a Full Professor with the Department of Energy Technology, Aalborg University, Denmark, where he is responsible for the Microgrid Research Program. From 2019, he became a Villum Investigator by The Villum Fonden, which supports the Center for Research on Microgrids (CROM) at Aalborg University. He,Prof. Guerrero, is the founder and Director of the same centre (www.crom.et.aau.dk)

His research interest is oriented to different microgrid frameworks in applications like microgrid clusters, IoT-based and digital twins, maritime microgrids for electrical ships, vessels, ferries and seaports, and space microgrids applied to nanosatellites, lunar bases, and closed ecological systems. Prof. Guerrero is an Associate Editor for a number of IEEE TRANSACTIONS. He has published more than 600 journal papers in the fields of microgrids and renewable energy systems, which are cited more than 60,000 times. During seven consecutive years, from 2014 to 2020, he was awarded by Clarivate Analytics (former Thomson Reuters) as Highly Cited Researcher with 50 highly cited papers.

**KEYNOTE: SPACE MICROGRIDS - NANOSATS, LUNAR BASES AND CLOSED ECOSYSTEMS**

This talk will begin by introducing the control of microgrids, the parallelisms with the human brain and the research for possible sources of inspiration in last frontiers of neuroscience. Then, control in electric power systems of satellites and space platforms will be presented, showing approaches that are extended from terrestrial microgrids and explaining the differences and challenges when it comes to apply them out in the space. Further, multi-microgrid systems will be discussed for moon craters in future lunar manmade bases. Finally, the extension from the hierarchical control of microgrids to bioastronautics in the control of closed ecological systems to support with oxygen, water, and food to the astronauts and creating thus creating new ecosystems for the moon and future mars bases.

## 6.3. CARL ENNIS

**BIOGRAPHY:**

**CHIEF EXECUTIVE OF SIEMENS PLC**

Carl Ennis is Chief Executive of Siemens plc and Siemens Smart Infrastructure. He has worked in the power industry for more than 35 years. He is an engineer first, with a real passion for the breadth of the discipline. Having started his career as an apprentice, he is a keen advocate of the skills and diversity agendas, recognising the need for new and diverse thinking in ever-changing markets.

He has worked for Siemens for over 20 years, having been responsible for a number of the UK businesses, and has also spent 3 years living in Shanghai with responsibilities for the Power Services business across Asia Pacific. He is a Chartered Engineer, a fellow of the IET, sits on the President's Committee of the CBI, is Chair of Net Zero North West, a member of the Board of EngineeringUK, a member of the Government's Build Back Better Business Council, and a Visiting Professor of Practice at Newcastle University.

**KEYNOTE: FROM SOFTWARE TO SAVINGS - USING DIGITALISATION TO UNLOCK ENERGY EFFICIENCY AND SUSTAINABILITY**

Siemens globally supports their broad customer base to improve their productivity and journey towards, sustainably, achieving their net zero targets. However, businesses have many different constraints making every journey different, whether they are an SME or multinational. But thanks to Energy Solutions at Siemens, digital toolchains are providing insight, clarity and data allowing organisations to design tangible roadmaps to net zero. Siemens is collaborating with a number of progressive universities around the UK on digitally enhancing their facilities to sustainably deliver decarbonisation goals and reduce energy costs. One of the key enablers is the use of Siemens industrial software to create digital twins of the facilities and campus, which then incorporate our automated energy management systems to establish the best systems optimisations. As we spend 90% of our lives in buildings, it is important that these designed spaces can be realised for comfort, efficiency and safety, and that can be optimised in real-time to adapt to the conditions - this then has an impact on energy use, occupant density, facility design (storage, efficiency, safety in COVID-19 and heating and cooling).

## 6.4. PROFESSOR PIERLUIGI SIANO

**BIOGRAPHY:**

Pierluigi Siano (M'09-SM'14) received the M.Sc. degree in electronic engineering and the Ph.D. degree in information and electrical engineering from the University of Salerno, Salerno, Italy, in 2001 and 2006, respectively. He is a Professor and Scientific Director of the Smart Grids and Smart Cities Laboratory with the Department of Management & Innovation Systems, University of Salerno. His research activities are centred on demand response, on energy management, on the integration of distributed energy resources in smart grids, on electricity markets and on planning and management of power systems. In these research fields he has co-authored more than 550 articles including more than 300 international journal papers that received in Scopus more than 10,100 citations with an H-index of 49. In 2019 and 2020 he received the award as Highly cited Researcher by ISI Web of Science Group. He has been the Chair of the IES TC on Smart Grids. He is Editor for the Power & Energy Society Section of IEEE Access, IEEE Transactions on Power Systems, IEEE Transactions on Industrial Informatics, IEEE Transactions on Industrial Electronics, IEEE Systems, Open Journal of the IEEE IES, IET Smart Grid and IET Renewable Power Generation

**KEYNOTE: DISTRIBUTED PARALLEL OPTIMIZATION FOR A LARGE-SCALE AGGREGATION OF PROSUMERS**

A novel scalable and privacy-preserving distributed parallel optimization that allows the participation of large-scale aggregation of prosumers with residential PV-battery systems in the market for the ancillary service (ASM) is proposed in this paper. To consider both reserve capacity and reserve energy, day-ahead and real-time stages in the ASM are considered. A method, based on hybrid Variable Neighbourhood Search (VNS) and distributed parallel optimization is designed for the day ahead and real-time optimization. Different distributed optimization methods are compared and designed, and a new distributed optimization method based on Linear Programming (LP) is designed that overcomes previous methods based on integer and Quadratic programming (QP). The proposed LP-based optimization can be easily coded up and implemented on microcontrollers and connected to a designed Internet of Things (IoT) based architecture. Both day-ahead and real-time proposed optimization methods, by allocating the computational effort among local resources, are highly scalable and fulfil the privacy of prosumers.

## 6.5. DR TILO BUEHLER

**BIOGRAPHY:**

**GLOBAL PRODUCT MANAGER OF THE HITACHI ABB POWERGRIDS**

Tilo Buehler is the Global Product Manager of the Hitachi ABB Powergrids Grid Edge Solutions business. He is shaping a product and solutions portfolio for the management of distributed energy resources that find applications in microgrids, large renewable power plants or advanced distribution networks. The Grid Edge Solutions portfolio includes battery energy storage, real time control, energy management, and a cloud based digital service offering. For him it is a fascinating opportunity to support the energy system transformation towards a more sustainable future, implementing innovative concepts to electrify the transport sector, integrate renewables into the power grid and enable novel business models across diverse market segments. Tilo has 15 years of experience with Hitachi ABB PowerGridâ€™s, having worked in diverse roles from applied research to technology management. He holds a PhD in Physics from the University of New South Wales in Australia.

**KEYNOTE: GRID EDGE SOLUTIONS FOR SECTOR COUPLING BETWEEN POWER AND TRANSPORT**

Energy systems are currently undergoing several coincident paradigm shifts. Global megatrends of electrification, digitalization, and decentralization are reshaping how we plan, address, and operationalize for the energy needs of the next generations. Sector coupling, in particular between power and transport as mobility is increasingly powered by batteries, will create new opportunities and require new solutions spanning these sectors.

In electricity networks there is a massive concomitant trend towards adding large amounts of renewable and distributed energy resources (DERs) near the edge of the network. In other words, this means more renewables, more battery storage but also more flexible management of loads in the electrical distribution systems. Such a fundamental change in asset portfolios, and new ownership models such as prosumers, requires novel ways of managing the network, leading to the implementation of microgrid and microgrid-like grid edge solutions that locally combine DERs. It also leads to large numbers of these grid edge solutions and other DERs that are aggregated into virtual power plants. Increasingly affordable battery storage and solar generation are key technology drivers, but the benefits of these are unlocked by end-to-end digital solutions integrating real time control with cloud-based asset managing.

# 7. UPEC 2021 SESSIONS AND EVENTS

| *Date and time* | *Session or Event* | *Identifier* |
|---|---|---|
| **Monday August 30, 2021** | | |
| 09:00–11:00 | **Pre-conference Event**<br>Pre-conference Check-in/Training/ Connection testing session (9:00–11:00) | |
| **Tuesday August 31, 2021** | | |
| 8:30–8:55 | ***Conference Welcome***<br>• **General Chair of UPEC 2021 Dr Gobind Pillai and members of the local organising committee Dr Maher Al-Greer, Dr Imran Bashir, Dr Gill Lacey, Neville Winter and Dr Musbahu Muhammad** | |
| 9:00–9:45 | ***Session by Lucas-Nulle***<br>• **Lucas-Nuelle didactic training systems sponsor webinar** | |
| 9:45–10:00 | Break | |
| 10:00–11:30 | ***Plenary Session***<br>• **Keynote 1: - Solutions for Stability of Electricity Grids with High Penetration of Inverter-Based Resources**<br>*Professor Tim Green*<br>The replacement of electro-mechanical machines by inverter-based resources (IBR) is fundamentally changing the dynamics and stability properties of grids, and further, the growth of small-scale resources raises the curse of dimensionality. How should theories and tools for stability analysis evolve to tackle these new properties and new dimensionality? This talk reviews recent progresses in stability analysis techniques including review of synchronisation across traditional generators, grid-following inverters and grid forming inverters and black-box, grey-box and white-box views of participation of individual IBR in modes of the system. Under pinning this are modelling techniques employing impedance spectrum models and new techniques in order reduction. Together, these methods offer useful advances for simplification and interpretation of complex grids and have been combined into a toolchain for automated stability analysis of large-scale grids.<br>• **Keynote 2: - From Software to Savings - Using Digitalisation to Unlock Energy Efficiency and Sustainability**<br>*Carl Ennis*<br>Siemens globally supports their broad customer base to improve their productivity and journey towards, sustainably, achieving their net zero targets. However, businesses have many different constraints making every journey different, whether they are an SME or multinational. But thanks to Energy Solutions at Siemens, digital toolchains are providing insight, clarity and data allowing organisations to design tangible roadmaps to net zero. Siemens is collaborating with a number of progressive universities around the UK on digitally enhancing their facilities to sustainably deliver decarbonisation goals and reduce energy costs. One of the key enablers is the use of Siemens industrial software to create digital twins of the facilities and campus, which then incorporate our automated energy management systems to establish the best | P1 |

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| | systems optimisations. As we spend 90% of our lives in buildings, it is important that these designed spaces can be realised for comfort, efficiency and safety, and that can be optimised in real-time to adapt to the conditions - this then has an impact on energy use, occupant density, facility design (storage, efficiency, safety in COVID-19 and heating and cooling). | |
| 11:30–12:00 | Break | |
| 12:00–12:30 | ***Session: UPEC - S1*** | |
| | **Condition Monitoring and Diagnostics**<br>*Chair: Graeme Burt and M Emad Farrag* | S1 |
| | 31736 | • **State of Health Estimation of Lithium ion Batteries Based on Data-Driven Techniques**<br>*Ma'd El-Dalahmeh, Joseph Lillystone, Maher Al-Greer and Mo'ath El-dalahmeh*<br><br>Accurate prediction of the state of health of lithium-ion batteries is essential to ensure safe and reliable operation with minimum maintenance cost. However, estimates the state of health of lithium-ion battery accurately is a challenge due to the complex and nonlinear characteristics nature of the battery degradation during its lifetime. To this end, data-driven techniques are becoming more attractive promising approach to provide accurate state of health estimation of the lithium-ion battery because of their simplicity and ability to cope with the nonlinearity dynamic behavior of the lithium-ion battery. Therefore, this paper compares the performance of three data-driven algorithms which are nonlinear autoregressive neural network, convolutional neural network, and long short-term memory network in state of health estimation. The performance of the proposed algorithms is analysed by using 16 lithium-ion cells cycled under various operating conditions from NASA Ames Research center. The comparison results demonstrate that the long short-term memory network outperforms the other two methods with maximum root mean square error 0.50 and mean absolute error 0.36. |
| | 35643 | • **Time and Frequency Domain Health Indicators for Capacity Prediction of Lithium-ion Battery**<br>*Ma'd El-Dalahmeh, Prudhvi Thummarapally, Maher Al-Greer and Mo'ath El-dalahmeh*<br><br>Predict the capacity of lithium-ion battery with high accuracy is crucial to the reliability and safety of the system. Due to the complex nature and the nonlinear degradation phenomena of lithium-ion battery, the monitoring of the capacity of the battery is a challenge. This paper proposes a machine learning model based on time and frequency domain health indicator to predict the capacity of lithium-ion battery cycled under different operational conditions. The time and frequency domain health indicators are extracted from the measured voltage and then the extracted features have been fed into extreme learning machine model to predict the capacity. This approach has been tested on 16 lithium-ion batteries cycled at many operational conditions from NASA. The results show that the proposed method capable to track the degradation from the extracted health indicators from both domain (time and frequency) and the extreme learning model can effectively predict the capacity with root mean square error of 1.3%. |
| | 22854 | • **The "Charge Integration Method" to Detect Earth Faults in Compensated Networks**<br>*Erwin Burkhardt, Bastian Zimmer and Frank Jenau*<br><br>The rapid localization of ground faults in compensated overhead line networks at |

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| | | medium-voltage level presents challenges for network operators. Existing fault detection methods cannot be used in overhead line indicators because the high-precision voltage measurement required for this is not possible with state-of-the-art technology. The focus of this paper is the development of an innovative fault direction algorithm for compensated networks. This is realized considering the measurement accuracy of voltage sensors of overhead line indicators. A method for correct statements about the fault direction without knowledge of the zero-sequence voltage working in many scenarios is developed and presented. The new method is successfully validated in simulation networks. At last, the results, advantages and disadvantages of this method are discussed. |
| | 26402 | • **Parameter Estimation of a Ferro-Resonance Damping Circuit using Pseudo-Random Impulse Sequence Perturbations**<br>*Ian P Gerber, Fredrick M Mwaniki and Hendrik Vermeulen*<br><br>A parallel damping arrangement is typically included on the secondary side of a capacitor voltage transformer to improve the measurement accuracy and transient response. The damping arrangement, however, can affect the frequency and transient response of the capacitor voltage transformer. This paper investigates the use of a pseudo-random impulse sequence as a perturbation signal to estimate the model parameters of a passive capacitor voltage transformer damping arrangement. Transfer functions describing the damping arrangement are derived and are used to determine the observability of the circuit. The pseudo-random impulse sequence perturbation signal is applied to the terminals of the damping system, and system responses are recorded and subsequently used to estimate the associated frequency responses. Estimated parameter values, obtained from both the time-domain and frequency-domain responses using the genetic algorithm, are presented. It is shown that the frequency responses obtained using the derived mathematical functions correlate closely with the estimated responses. The damping arrangement parameter values are also shown to be estimated with a high degree of accuracy when more that one transfer function is used in the parameter estimation proced |
| | 26715 | • **Parameter Estimation of a Two-Section Transformer Winding Model using Pseudo-Random Impulse Sequence Perturbation**<br>*Daniel M Banks, Johannes Cornelius Bekker and Hendrik Vermeulen*<br><br>This paper proposes the use of the Pseudo-Random Impulse Sequence as perturbation signal for estimating the parameters of a lumped parameter circuit model commonly used in the wideband modelling of distributed transformer windings. Impedance and voltage ratio transfer functions are derived analytically for the model and the associated frequency responses are determined. These results are used to validate the frequency responses simulated using a Pseudo-Random Impulse Sequence perturbation signal. A constrained Globalsearch optimisation algorithm is used to estimate the model parameters, where the cost function is defined in terms of the frequency responses of various transfer functions. A total of five case studies are investigated. The results show that the proposed method is suitable for estimating the parameters of the target system with a fair degree of accuracy. Inclusion of a midpoint voltage in the parameter estimation process allows for most parameters to be estimated with accuracy of the order of 1%. |
| 12:30–13:00 | ***Session: UPEC – S2*** | |
| | **Distributed Generation**<br>*Chair: Gianfranco Chicco and Grigoris K. Papagiannis* | S2 |

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| 24887 | • **Impact Analysis of PV and PEV integration with a Non-Synthetic European LV Test System**<br>*Marco Bertoncin, Keith Sunderland and Roberto Turri*<br><br>In this paper, the reasons behind the necessity for accurate and reliable test systems for network analysis are addressed, and the almost total absence of representative models for the European LV network is considered. Further, the possibility to exploit non-synthetic electric and geographical data, to build real networks is debated, along with a thorough demonstration of the potential in the work by Koirala et al. to prove the versatility of the tool - which also allows modular implementation of synthetic data - an altered version of the Non-Synthetic European Low Voltage Test System is developed. Distributed photovoltaic (PV) generation and plug-in electric vehicle (PEV) representative loads are integrated in a daily time series power flow analysis for different penetration levels. The results obtained from the stress test comply with the assertions of prior studies, with some exceptions. A moderated PV implementation - up to around 40% of the base energy absorption - is possible for appropriate voltage management, and widely improves the energy conditions, whilst PEV contributions to the load cannot be reduced because of mismatch. Furthermore, the research demonstrates that LV network capability to accommodate PV penetration is inversely proportional to PEV contribution to the load. To facilitate penetration, the implementation of regulation controls within the grid should be evaluated. Finally, concerns regarding power and voltage daily rate of change in the presence of high PV and PEV penetration are raised. |
| 24979 | • **Fault Investigation and Analysis of an Overhead Transmission Line Vibration Damper**<br>*Jason J Noctor, Conor Hickey, Tolulope Mayomi and Paul Young*<br><br>This paper presents the findings from an investigation into the probable cause of damage to vibration dampers found on an existing 110 kV overhead transmission line in the midlands of Ireland. The vibration dampers were positioned on an earthwire and they were found damaged at twelve separate spans along the overhead line. The purpose of this investigation was to establish the main factors which may cause the messenger cable of the vibration damper to deform based on knowledge gained on the characteristics of the overhead line in question, literature review, inspection of the removed dampers and line, and computational analysis. The fatigue characteristics of overhead line conductors, the influence of conductor sag-tension characteristics and conductor wind-induced motions were all factors that have been considered. A fault investigation was designed in two parts. The first part performed by ESB involved modelling the existing line and measuring the vibration response of the line. Part two, conducted by DCU involved performing computational modelling to determine the serviceability of the damaged dampers and to validate the findings of the initial fault investigation. |
| 18894 | • **Over-voltage Problem in Distribution Network with DG: A Review of Mitigation Techniques**<br>*Kehinde Makinde and Gill Lacey*<br><br>The considerable penetration of distributed generation (DG) in the distribution network (DN) invalidates the premises upon which distribution networks are designed. This penetration has resulted in a number of issues in the DN, the leading being voltage rise problem which occurs whenever generation is higher than the demand on the network thereby causing the power to flow in the reverse direction and subsequently leading to overvoltage. Many techniques discussed in the literature to mitigate this issue range from network reconfiguration to active management of |

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| | | the DN. This paper highlights the problem of overvoltage in DN with high penetration of DG and presents a technical overview of approaches to curtail the problem. IPSA software is then employed to model the effects of voltage control in low voltage distribution network. |
| | 28578 | • **Optimal Scheduling of Electric Vehicles for Ancillary Service Provision with Real Driving Data**<br>*Panagiotis Tsagkaroulis, Andreas Thingvad, Mattia Marinelli and Kenta Suzuki*<br><br>Electric Vehicles (EV)s can with the right charger and aggregated in large numbers be considered as a large storage unit. If the chargers have bidirectional power converters, EVs connected to the grid, could provide Vehicle-to-Grid (V2G) ancillary services. The annual earnings from delivering frequency controlled normal operation reserve in Denmark is calculated, based on individual user profiles. The individual earnings are strongly dependant on the driving time, distance and parking time at different locations which determine the availability of each EV to provide ancillary services. The specific user behaviour is based on a set of telematics data acquired from 7,163 Nissan LEAFs in the United States, with information about every driving and charging sessions during one year. The profit of the individual EV, spreads from 51 to 1654 euro/year. A data set of one year of system frequency measurements from the Nordic grid is used to calculate the impact of the service provision on the state of charge. |
| | 24937 | • **Techno-Economic Assessment of Local Control Strategies for PV Inverters in the Dutch LV Networks**<br>*Rocio Revaliente-Revuelta, Tam T. Mai, Hossein Khalilnezhad, Phuong Nguyen and Anne van der Molen*<br><br>The high penetration of solar photovoltaic systems in the low-voltage distribution networks creates the overvoltage problems, causing the decrease in energy yields of existing PVs and hinder new PVs from being connected. Among the available solutions, local control strategies, including active power curtailment and reactive power absorption, for PV inverters based on droop control methods are widely used. In this paper, a comprehensive techno-economic assessment of PV inverters operating with the local control strategies for overvoltage mitigation is provided. The technical part assesses the local control performance with different setting values. The economic part compares the local control with several network planning approaches. A case of study based on real smart meter data and two LV distribution networks from The Netherlands is used. The obtained results show that active power curtailment is an economically viable option to mitigate overvoltage problems, while reactive power absorption help to reduce economic compensation. |
| 13:00–13:30 | ***Session: UPEC – S3*** | |
| | **Electric Vehicles and e-Mobility**<br>*Chair: Graeme Burt and Theofilos Papadopoulos* | S3 |
| | 26021 | • **A Smart Rail and Grid Energy Management System for increased synergy between DC Railway Networks & Electrical Distribution Networks**<br>*Mansoureh Zangiabadi*<br><br>This paper presents results of the H2020 European E-LOBSTER project which is to propose an innovative Railway to Grid (R +G) Management system, combined with advanced power electronics and storage technologies (the smart Soft Open Point and the electric storage developed in the framework of the project). In particular, the R + G management system will be able to make the best use of the available energy on |

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| | both grids by increasing their mutual synergies and increasing the energy efficiency of two networks through electric energy storages and at the same time by creating synergy with charging stations for Electric Vehicles (EV). This paper demonstrates an overview of the state of the art of the proposed smart R+G energy management with simulation results of the main case studies as well as an overview smart mobility through Electric Vehicles, charging stations for EVs, e-mobility in general and its synergies with railways. |
| 28353 | • **Transition to EVs: A Case Study in Scotland**<br>*Kyle Watson, Jack Docherty, Andrew Purvis, Callum Holmes, Imaad Ahmad and Jacqueline Wilkie*<br><br>The research presented in this paper was conducted to evaluate how a transition towards EVs can be achieved given the limitations of an LV distribution network. This paper analyses the implementation of local EV charging stations and how they can utilise renewable sources to provide a clean source of energy for a clean mode of transport. Results showed that the implementation of Solar PV and BESS can reduce usage from the grid by over 30% and facilitate a reduction of 4,170 kg/yr of CO2 emissions related to EV charging. As demand for EVs increases, the LV distribution network will be subject to increased amounts of electrical stress and will have an influence on the stability of distribution transformers. Simulations show that a sharp increase in EVs connected to the grid under a domestic charging regime will result in unstable spikes in demand which will overload the distribution transformer. To help meet the demand of EVs this paper simulates multiple charging strategies that will help control load demand and optimise EV penetration levels in line with distribution network capacities. The studies are based on residential areas in a large city (Glasgow) in Scotland. Findings showed that, in the area investigated, an integration of 1 EV per household was possible under ideal circumstances. |
| 33615 | • **MEMS-based Measurements in Virtual Reality: Set-up an Electric Vehicle**<br>*Michela Longo, Jacopo Andrea Di Antonio, Francesco Ferrise, Andrea Labombarda and Dario Zaninelli*<br><br>The present work is aimed at finding a correspondence between registered consumes for a Battery Electric Vehicle, using a dedicated algorithm, and data available installing a MEMS sensors platform in a scenario which recreates on-road driving conditions. The Virtual Reality (VR) setup is described in its composition together with the placement of MEMS equipment to configurate optimal conditions for driving tests. In specific, the use of SensorTile.box by STMicroelectronics was described in its functioning and for the measurement acquisition chain process. Also, the consumption model is implemented through Unity3D and Matlab software to obtain an estimation of power, State of Charge (SoC) and energy required to perform the simulation path. Afterwards, considering the available literature, it is posed in consideration how the obtained measures from sensors can be useful for a primary characterization of drivers' behavior. Finally, these results for single users are related to the energy requests to determine if and at which level these parameters are also indicators of impact on consumers. |
| 27829 | • **Impact Assessment of Charging of Electric Vehicle on Residential Distribution Network of Bangladesh**<br>*Md. Shadman Abid, Hasan Jamil Apon, Khandaker Adil Morshed and Fahim Abid*<br>This paper presents the impact of electric vehicle (EV) integration on urban residential distribution network in Bangladesh. A probabilistic load flow algorithm has been developed in this study to analyze system parameters for a selected residential feeder of a middle income economic zone in Dhaka, Bangladesh. The algorithm is |

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| | | based on Monte Carlo simulation that considers randomness of EV charging and vehicle mobility patterns to provide a probabilistic load profile for observing the effects of EV integration in distribution grids. Three scenarios of penetration (10%, 20%, and 40%) were considered replacing conventional vehicle fleet. Furthermore, implications of seasonal variation in the impact of electric vehicles on the respective network were investigated. Based on Monte Carlo simulation, an evaluation is presented to analyze aggregated power demand, energy demand, losses, line ampacity violations, voltage security margin violations and average voltage profiles. This study can be used to determine the critical level of EV penetration that does not contravene the grid security margin for a specific urban neighborhood in Bangladesh. |
| | 21660 | • **Optimal power dispatch for EV fast charging microgrid on highways: a storage analysis**<br>*Jordan Passinato Sausen, Alzenira da Rosa Abaide, Cristian Correa, Joelson Lopes da Paixao and Leonardo Nogueira da Silva*<br><br>This paper presents theoretical background and mathematical modeling of an intelligent management system for a microgrid composed of a fast charging station for electric vehicles, local renewable generation (wind and solar) with battery storage. An algorithm is designed to optimize the charging and discharging processes of a battery storage system, treated here together as dis/charging. Tariff signals are considered to determine the optimal power dispatch between battery and grid to reduce operational costs and maximize the utilization of local renewable generation. The overall goal is to use observations regarding the behavior of this system to formulate general principles and then use these same principles to predict future results. |
| 13:30–14:00 | ***Session: UPEC – S4*** | |
| | **Smart Grids and Microgrids**<br>*Chair: Grigoris K. Papagiannis and Radu Porumb* | S4 |
| | 25040 | • **Frequency Stability Considerations of Reciprocating Gas Engine Generators in Microgrids**<br>*Stephen James Sommerville, Gareth A Taylor and Maysam F Abbod*<br><br>This paper considers the suitability of the standard DEGOV diesel generator governor model for use with reciprocating gas engine generators acting as primary frequency control units, within microgrids, due to the reduced capability of gas engines to accept step loads. The paper found that use of the standard DEGOV model would significantly overestimate the gas engines capability to accept step load, and an alternate model was developed using a gain scheduling controller, based on the generators existing loading. This model was found to be effective, but it was identified that the varying values of gain could lead to controller instability and tuning problems, and further investigation work in this area is necessary. |
| | 34985 | • **Voltage Unbalance Mitigation in Low Voltage Distribution Networks using Time Series Three-Phase Optimal Power Flow**<br>*Mohammad Ahmad Al-Ja'afreh and Geev Mokryani*<br><br>Due to high penetration of single-phase Photovoltaic (PV) cells into low voltage (LV) distribution networks, several impacts such as voltage unbalance, voltage rise, power losses, reverse power flow arise which leads to operational constraints violation in the network. In this paper, a time series Three Phase Optimal Power Flow (TPOPF) method is proposed to minimize the voltage unbalance in LV distribution networks with high penetration of residential PVs. TPOPF problem is formulated using the current injection method in which the PVs are modelled via a time-varying PV power |

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| | profile with active and reactive power control. The proposed method is validated on a real LV distribution feeder. The results show that the reactive power management of the PVs helps mitigate the voltage unbalance significantly. Moreover, the voltage unbalance index reduced significantly compared to the case without voltage unbalance minimisation. |
| 36856 | • **Heuristic Multi-Agent Control for Energy Management of Microgrids with Distributed Energy Sources**<br>*Zunaib Ali, Ghanim Putrus, Mousa Marzband, Mahsa Bagheri Tookanlou, Komal Saleem, Pravat Kumar Ray and Bidyadhar Subudhi*<br><br>The increased integration of distributed Renewable Energy Sources (RESs) and adoption of Electric Vehicles (EVs) require appropriate control and management of energy sources and EV charging. This becomes critical at the distribution system level, especially at a microgrid (MG) level. This control is required not only to mitigate the negative impacts of intermittent generation from RESs but also to make better use of available energy, reduce carbon footprint, maximize the overall profit of microgrid and increase energy autonomy by effective utilization of battery storage. This paper proposes a heuristic multi-agent based decentralized energy management approach for grid-connected MG. The MG comprises of active (controlled) and passive (uncontrolled) electrical loads, a photovoltaic (PV) system, battery energy storage system (BESS) and a charging post for electric vehicles. The proposed approach is aimed at optimizing the use of local energy generation from photovoltaic and smart energy utilization to serve electrical loads and EV as well as maximizing MG profit. The aim of the energy management is to supply local consumption at minimum cost and less dependency on the main grid supply. Utilizing energy available from RESs (PV and BESS), customers satisfaction (fulfilling local demand), considering uncertainty of renewable generation and load consumption and also taking into account technical constraint are the main strengths of the presented framework. Performance of the proposed algorithm is investigated under different operating conditions and its efficacy is verified. |
| 24833 | • **Neural Predictive Control for the Optimization of Smart Grid Flexibility Schedules**<br>*Steven de Jongh, Sina Steinle, Anna Hlawatsch, Felicitas Mueller, Michael Suriyah and Thomas Leibfried*<br><br>Model predictive control (MPC) is a method to formulate the optimal scheduling problem for grid flexibilities in a mathematical manner. The resulting time-constrained optimization problem can be re-solved in each optimization time step using classical optimization methods such as Second Order Cone Programming (SOCP) or Interior Point Methods (IPOPT). When applying MPC in a rolling horizon scheme, the impact of uncertainty in forecasts on the optimal schedule is reduced. While MPC methods promise accurate results for time-constrained grid optimization they are inherently limited by the calculation time needed for large and complex power system models. Learning the optimal control behaviour using function approximation offers the possibility to determine near-optimal control actions with short calculation time. A Neural Predictive Control (NPC) scheme is proposed to learn optimal control policies for linear and nonlinear power systems through imitation. It is demonstrated that this procedure can find near-optimal solutions, while reducing the calculation time by an order of magnitude. The learned controllers are validated using a benchmark smart grid. |
| 27353 | • **Simulation and Monitoring of a Microgrid with Electric Vehicles and Controllable Loads**<br>*Lucian-Ioan Dulău, Dorin Bică and David-Cătălin Urcan* |

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| | | In this paper we present the simulation and monitoring of a microgrid that comprises electric vehicles and controllable loads, considering the season's power output and power demand. The microgrid power is supplied from five generating units: two photovoltaic power plants, two micro-hydro generator and one wind turbine. The microgrid is also supplied from the main power grid, with a certain amount of power. The simulations, performed with CitectSCADA software, give the results for the cases when the electric vehicles are charging or not present in the microgrid. Also, the results emphasis the cases when the controllable loads need to be used. |
| 14:00–14:30 | ***Session: UPEC – S5*** | |
| | **Power System Operations and Control**<br>*Chair: Gianfranco Chicco and Essam Hamdi* | S5 |
| | 33584 | • **Voltage and Frequency Stability Enhancement of Islanded Network**<br>*Hassan Nouri*<br><br>Nowadays, for economic and environmental reasons, power systems usually work close to the limits of stability to make the most of existing networks. However, in such systems, the loss of the main source can cause a severe load mismatch between production and consumption of the load. As a result, the voltage and frequency of the island system exceeds the allowable limit. Due to this fact, voltage and frequency control is essential in the operation mode of the island. This paper investigates the effect of ramp rejecting electric power pre-filter stabilizer (RRPP) on voltage and frequency oscillations of a stand-alone network. It provides a taxonomy of the dynamic behavior of the system in various scenarios: no power system stabilizer (PSS), conventional PSS, and RRPP stabilizer. The accurate model of BESS and wind turbine is incorporated to cope with real conditions. Small signal analysis is used to evaluate and analyze the stability of the understudy network using the proposed method. |
| | 35548 | • **An MILP Approach to Scheduling of Expansion and Maintenance Measures in Electrical Transmission Grids**<br>*Alexander B. Schrief; Miriam Sander; Marco Franken; Albert Moser*<br><br>The increasing share of generation based on renewable energy sources and the resulting need in transport capacities necessitates grid expansion. In order to conduct structural measures on the transmission grid, in many cases the corresponding transmission lines need to be shut down. Measures include grid expansion as well as maintenance, with the completion of expansion measures changing the topology of the grid and allowing additional operational degrees of freedom. This contribution presents a novel approach based on mixed-integer linear programming for scheduling grid expansion and maintenance measures while optimizing grid operation. The method is applied to a synthetic 120-bus test system and the results show that suitable schedules can be obtained. |
| | 27973 | • **Impact of COVID-19 on Power System Load: The case from Oman**<br>*Ammar Suhail Alyafai*<br><br>Due to the COVID-19 pandemic the governments around the world were compelled to reduce business activity and took measures in response to minimize the impact of coronavirus. Under this condition the people lifestyle has been changed due to lockdown restrictions and other measures. Hence the electricity sector significantly affected under circumstance of. Therefore, this study reviews the impact of COVID-19 on power system load in Oman. |

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| | 32217 | • **Design of a Domestic Controlled Voltage Stabilizer**<br>*Ibrahima Gueye; Abdoulaye Kebe; Moustapha Diop*<br><br>This paper aims to design a domestic Controlled Voltage Stabilizer to protect domestic appliances from voltage dips on the electric power distribution. Voltage dips are recurrent and become a concern for both distributors and consumers because on one hand, it can have a negative impact on the proper operation of domestic appliances and other sensitive electronic equipment and, on the other hand, measurement results show that voltage dips can reach 35 to 40 %. Therefore, this work is mainly focused on the design of a single-phase CVS, using control methodologies based on PI controllers that can effectively handle large voltage dips. The proposed controlled voltage stabilizer consists of a fully controlled AC-AC power converter, based on a single-phase boost rectifier connected to a single-phase PWM inverter with control laws. The design and the control laws adopted were carried out taking into account the characteristics of the electric power distribution, as well as the domestic loads. The robustness and effectiveness of the controlled voltage stabilizer are verified by carrying out simulations in the Matlab Simulink environment in various operating cases using real measurements of voltages with different types of electrical loads. Simulation results confirm the effectiveness and robustness of the proposed stabilizer. Furthermore, it enables the protection of domestic appliances by keeping the voltage level stable within a specified range around the nominal value regardless of voltage dips. |
| | 19705 | • **Tractable Iterative Transmission Topology Control Heuristics Based on Node-Breaker Modeling**<br>*Sogol Babaeinejadsarookolaee; Bernard Lesieutre; Christopher DeMarco*<br><br>This paper addresses optimal power flow (OPF) problems that include a broader range of discrete decision variables using detailed node-breaker models of power networks, and it extends some of the existing heuristics to incorporate the node-breaker model. These heuristics can be used standalone or as a pre-screening step to generate a manageably small set of breaker candidates to be considered in a more computationally intensive mixed integer program (MIP) optimization. The computation time and quality of solution for the proposed heuristics here are benchmarked against some of the existing approaches. Numerical case studies demonstrate significant examples in which the methods proposed here yield improved operating points (i.e., lower operating cost), with low computational burden while more accurately representing the broader range of discrete decision variables. |
| 14:30–15:00 | ***Session: UPEC – S6*** | |
| | **Renewable Energy Systems**<br>*Chair: Ghanim Putrus and Hassan NOURI* | S6 |
| | 35471 | • **Phase Angle Difference Analysis Using PMU Data on Grids with Varying Wind Penetration**<br>*Connor Duggan*<br><br>Phase angle differences on a power system are strongly correlated to active power transfer and system topology. The transition from centralized thermal generation to distributed generation is driving phase angle variation in unprecedented ways. In this study, PMU data from three sites across Ireland are studied along with other power system metrics, including system demand and wind generation. Linear regression is used to analyse phase angle variation from power system metrics; the results are used to identify system operating parameters and predict future operating conditions as |

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| | Ireland's wind resource expands. It is demonstrated that anticipated wind expansion may cause phase angle variation across the network that exceeds operational thresholds. The methods of wrangling and joining different power system data sources and the sequential forward selection regression function can be applied to the vast amounts of time series data generated from power system operation. |
| 25045 | • **Comparing Shading With Irradiance Reduction Effects on Solar Cells Electrical Parameters**<br>*Abdulhamid Atia; Fatih Anayi; Gao Min*<br><br>It has been widely accepted in the literature that partial shading of a photovoltaic (PV) solar cell and light irradiance reduction among its whole surface have the same effect on its characteristics and parameters. This paper presents an experimental comparison between those two cases applied to a mono-crystalline silicon (mono-Si) solar cell. Two cases of opaque partial shading were compared with the corresponding irradiance levels on the whole cell surface. The comparison includes the electrical parameters, the current-voltage (I-V) curve and the power-voltage (P-V) curve. The results show that there is no significant difference observed between the two operational cases. Hence, the assumption that partial shading of a single cell is equivalent to irradiance reduction on its surface is valid. |
| 34347 | • **Transient Stability Analysis of Power Systems with the Participation of Wind Parks**<br>*Athanasios Ioannis Arvanitidis; Dimitrios Bargiotas*<br><br>Rising fuel prices, as well as worries about the environmental effects of greenhouse gas emissions, have sparked fresh interest in the generation of electrical energy from renewable sources, including wind power. The behaviour of a 9-bus electrical power system during wind turbine penetration with doubly fed induction generators is investigated in this work. This paper evaluates the electrical grid's ability to sustain transient stability when three-phase solid short circuits occur, as well as the critical cleaning time whether wind turbines are present or not. Finally, the findings of the preceding study are summarized, and the benefits of integrating wind turbines into conventional power systems are assessed. |
| 35124 | • **Hybrid design solution optimized for different types of buildings using renewable energy**<br>*Victorita C. Radulescu; Bogdan Alexandru Radulescu*<br><br>Romania, as part of the EU, is developing new projects based on renewable sources in the supply of electricity for small communities, residential complexes, and isolated areas. This paper presents a hybrid solution for the partial supply of electricity from a residential community with solar potential, in the southeastern part of Romania, with an annual electricity consumption of 1,174 GWh and a peak electric load of 335 MW. At the beginning, some methods of approaching the problem and achieving these objectives are presented. The energy structure of the hybrid system, represented by the structure of the building, the number of windows and walls, used materials, scheme of operation and the consumption of electricity are also taken into account. The energy performance of the investigated buildings was estimated using a numerical simulation, for a residential school with 20 classes on two levels. An estimation of total electricity consumption was made based on existing electrical equipment, lighting, hot water requirements and other non-permanent elements. Some solutions to reduce electricity consumption and peak demand are also briefly mentioned. Finally, an optimization was achieved based on the implementation of the hybrid systems, considering the solar radiation available annually for the selected area of approximately 1500 kWh/m2/year. The results of these analyzes indicate that |

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| | | the implementation of the cost-effectiveness method reduces electricity consumption by 28%, maximum demand by 41%, and CO2 emissions by 28%. |
| 15:00–15:30 | ***Session: UPEC – S7*** | |
| | **HVDC, FACTS and power electronics**<br>*Chair: Essam Hamdi and Alecksey Anuchin* | S7 |
| | 24969 | • **Upgraded Circuit Simulation and Test Circuit Design for Transient Overvoltages in MMC HVDC Links**<br>*Lars Vogelsang; Saskia Düsdieker; Frank Jenau*<br><br>Overvoltages caused by pole to ground faults in High Voltage Direct Current (HVDC) links using Modular Multilevel Converters (MMC) deviate vastly from currently standardized transient test voltages. Previous investigations successfully imitated these transient stresses for a positive polarity, using single stage impulse circuits, and found the spark gap to be crucial for the performance of the circuit as well as for the simulation. Depending on various factors, the overvoltage can also be of negative polarity, which is not currently supported by the simulation model. Consequently, the currently used spark gap model is upgraded to appropriately represent the behavior for transient stresses with negative polarity and is empirically verified in this paper. Furthermore, a circuit design for the laboratory test setup has not yet been presented for arbitrary polarity combinations of DC and transient stress. Therefore, an existing laboratory test setup is adjusted. Measurements are carried out and the results are used to verify a simulation model of the test setup that is upgraded using the spark gap model. |
| | 26031 | • **Comprehensive Mathematical Modeling of Multilevel VSC HVDC Systems for Power System Stability Studies and Controller System Design**<br>*Christoph Hahn; Johannis Porst; Matthias Luther*<br><br>This paper provides a comprehensive approach for mathematical modeling of Multiterminal VSC HVDC systems. The mathematical models are developed in the Laplace Domain as it offers appropriate opportunities regarding implementation in dynamic system analysis tools and the subsequent control design process. Models for the AC and DC side of the MMC as well as for the DC network are determined. The DC network model is based on the concatenation of pi-sections and is easily extendable to Multiterminal systems. Regarding the MMC, a model for the energy storage of the submodules in the converter arms is introduced. This aims in a detailed mathematical HVDC model and applies a connection via the energy storage of submodules within the converter arms. Based on the mathematical modeling, two control strategies are provided. The first strategy controls the active power via a subordinated AC grid controller in the dq-frame and the converter energy via the DC current controller on the DC side. The second strategy controls the converter energy via an AC grid controller and the active power via a DC current controller. |
| | 28307 | • **The Value of Smart Inverter Control in Distribution Energy Management Systems and Virtual Power Plants, and Opportunities for South Africa**<br>*Ria MA Xavier; Bernard Bekker; Justice Chihota*<br><br>The rising penetration of distributed energy resources (DERs) in distribution networks can lead to various technical challenges, including poor power quality and system instability. To mitigate these challenges, distribution network operators and regulators are looking towards the coordinated control of smart inverter-based DERs to support the utility grid and provide additional services. Smart inverters have advanced grid supportive functions that assist the utility in maintaining power quality |

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| | and stability. However, it is not practical for network operators to directly monitor and control each individual inverter and DER. As a result, distribution energy resource management systems (DERMS) and virtual power plants (VPPs) are being tested out in international states with high leading renewable energy penetration, such as Hawaii, Arizona, California and Victoria. DERMS and VPPs can aggregate and optimize the performance of various DERs through smart inverters. This paper investigates the characteristics and benefits of the existing coordinated control techniques of smart inverters as applied in contexts of high DER penetration internationally. The value of smart inverter coordinated control is presented through a literature review and international examples. Based on the review of international practice, recommendations for South Africa are made considering the local context regarding existing infrastructure and grid regulation restrictions, which affect the necessary communications protocol for coordinated control through a DERMS or VPP. The paper finds that VPPs or DERMS in South Africa are feasible, but with the relevant cybersecurity measures and technical regulations update for smart inverter functionality. |
| 24821 | • **A Demand-Response integrated solution for HVAC units in office buildings application**<br>*Dionysios Strongylis; George Isaioglou; Lampros Zyglakis; Paschalis A. Gkaidatzis; Angelina Bintoudi; Athanasios Tryferidis; Konstantinos Arvanitis; Dimitrios Tzovaras*<br><br>Building energy consumption has been declared as an untapped energy source, accounting for 40% of energy consumption worldwide. In this paper, in order to decrease power consumption in an office building aiming at peak reduction a Demand Response solution is proposed integrated in a real building pilot site. Consumption profiling, day-ahead forecasting as long as various feedback techniques were implemented taking into consideration occupant thermal comfort aspects. To make the framework more accurate, various variables have been considered, such as weather forecast, along with environmental conditions (in- and outdoor temperature), occupancy and thermal comfort patterns, space occupancy and current operation of the system. A real-life demonstration of the proposed system was implemented in a commercial building in Thessaloniki Greece, integrating field equipment for real-time monitoring and control of several offices. Preliminary field test results of the working framework are included in this work. |
| 26175 | • **High Frequency ZVS GaN-Inverter with Adaptive Dead Time**<br>*Benedikt Kohlhepp; Thomas Foerster; Thomas Duerbaum*<br><br>This paper presents a zero voltage switching (ZVS) inverter and the corresponding modulation scheme, which uses variable and fixed switching frequency operation during the sinusoidal period to limit the switching frequency range. It is suitable for generating sinusoidal output waveforms and ensuring lossless switching over the entire fundamental period. ZVS requires a sufficiently long dead time during both switches are turned off. Typically, standard modulation schemes apply a fixed dead time. First experiments operate the ZVS inverter with a fixed dead time. Despite achieving lossless switching, unexpected high device temperatures of the Gallium Nitride half-bridge switches occur. The origin of these high temperatures need to be figured out in order to minimize the losses of the power stage. A study shows that significant reverse conduction losses occur during the half-bridge's dead time. Thus, this paper introduces an adaptive dead time method, which shows its effectiveness at an experimental setup by reducing the semiconductor's device case temperature by 10 K. Since the computational effort for this optimal procedure is relatively high, the paper finally presents a simplified, computationally less costly variant that achieves almost the same improvements regarding the device temperatures. |

| 15:30–16:00 | ***Session: UPEC – S8*** | |
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| | **Data Analytics and Artificial Intelligence Applied to Power Systems**<br>*Chair: Theofilos Papadopoulos and Ioana Pisica* | S8 |
| | 27567 | • **Data Driven Solar Forecasting Model for Northern Ireland**<br>*Kellie Cowan; Xueqin Liu*<br><br>Solar forecasting is an increasing problem for power system operators due to its variability from day to day. This inconsistent power generation effects not only load forecasting, but can cause increased network stability problems due to changing system inertia. Ample research has been carried out surrounding wind generation, with several accurate forecast methodologies created and used across the world. However, as the solar industry is only now beginning to take off in Northern Ireland (NI), with its capacity increasing exponentially every year, forecasting methods have not yet been accurately implemented by the System Operator for Northern Ireland (SONI). This report documents the creation of a NI specific photovoltaic (PV) forecasting model, based on meteorological and historic PV generation data, from data collection to testing. It was found that partial least squares out-performed multiple linear regression and therefore was used as the forecast base. A large scale model was created, achieving an average Root Mean Square Error (RMSE) of 11.9MW and MAE of 7.7MW. The forecast also improved accuracy with the addition of temperature, wind speed and cloud cover data. A small scale forecast was also built and up-scaled to its representative capacity on the NI system. The model was tested using NI System Demand data, achieving positive results. |
| | 28293 | • **A Practical Approach to Construct Digital Twin of a Power Grid using Harmonic Spectra**<br>*Hui Cai; Xinya Song*<br><br>The electrical energy system is transforming itself into a sustainable energy supply in response to the decline in fossil fuels. This conversion is driving the expansion of renewable energy facilities such as photovoltaic plants and wind power plants. Except for large hydropower plants and offshore wind farms, the integration of renewable energies takes place predominantly in the medium- and low-voltage distribution networks. This leads to a lack of observability and increasing grid complexity. Consequently, distribution network operators are constantly faced with a challenge in terms of observability. A comprehensive installation of measuring instruments in the medium- and low-voltage networks has proved economically unviable. An alternative approach to network state monitoring within the framework of power grid digital twin (DT) is therefore developed in this paper. The patterns of the electrical energy system are detected and modeled employing an artificial neural network (ANN) in connection with the associated harmonic spectra. Based on this DT model, the active powers of renewable energy facilities are estimated through the measured voltage data. In this regard, this work is first devoted to the modeling of an ANN-based DT estimator. The proposed power state estimation is then validated with the measured data from a field test. The accuracy of the estimation will be investigated according to the different influencing factors. |
| | 34680 | • **Estimation of Inter-Area and Intra-Area Oscillatory Modes Using System Identification Techniques and Clustering Analysis**<br>*Eleftherios O. Kontis; Theofilos A. Papadopoulos; Grigoris K Papagiannis*<br>Inter- and intra-area oscillations are inherent to large-scale power systems. Identification and analysis of these oscillations is vital for evaluating system stability margins and for determining control actions, aiming to enhance system damping levels. In this paper, a two-stage architecture is developed to facilitate identification |

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| | | of power system inter- and intra-area modes. In the first stage, ringdown responses, obtained from individual system buses, are analyzed using the Matrix Pencil (MP) method and modal estimates are derived. Subsequently, modal estimates are forwarded to a control center where they are grouped, analyzed and combined through clustering techniques to extract system properties, i.e., frequencies and damping factors of inter- and intra-area modes. The proposed approach is tested using simulated data, obtained from the Kundur power system, and found to be very accurate. |
| | 27794 | • **A Study of Wind Turbine Parameter Calibration Using Machine Learning Approaches**<br>*Rebecca L McCubbin; Kun Yang; Rui Fan*<br><br>The inertia and damping coefficients of a wind turbine define how the turbine reacts in a transient state. Unfortunately, the values of these coefficients are not always accurately known due to various reasons. This research uses machine learning techniques to determine these coefficients. By perturbing the values of inertia and damping coefficients, thousands of transient events were generated through simulations. The electrical measurements (real and reactive power) of the transient events were used to train a multilayer perceptron (MLP) network to learn the mapping between these time-series data with the corresponding coefficients. A support vector machine (SVM) based regression method was also used to predict the coefficient values using the same input data, and its performance was compared with the MLP approach. While both methods achieved acceptable results, the MLP method outperformed the SVM method by a large margin. A sensitivity analysis was also conducted to evaluate the impact of measurement noises and the size of the training data on the performance of machine learning based wind turbine parameter calibration. |
| 16:00–16:30 | ***Session: UPEC – S9*** | |
| | **Energy storage**<br>*Chair: Radu Porumb and Hassan Nouri* | S9 |
| | 35094 | • **A Techno-Economic Evaluation of Battery Energy Storage Systems co-located with Wind in the Irish Integrated Electricity Market**<br>• *Claudia Sheridan; Michael Conlon*<br><br>As Ireland moves towards decarbonization of electricity, Wind Power Plant Producers (WPP) face novel challenges and prospects. As of October 2018, WPP must partake in the Balancing Marketing where penalties will apply for active power variations. Power Plants in Ireland now also have new opportunities for receiving additional payments from system services. Co-location of BESS with a wind farm can be utilized to absorb additional power where curtailment may have been the only previous option, reduce the risk associated with balancing and offer grid stability as the levels of renewables increase. Using a large-scale Irish wind farm as a case study, the value of co-location of BESS under the existing Irish market regulations was examined. In this study, two separate revenue streams and modes of operation are investigated for one year. The use of BESS for balancing purposes and then for system services payments are considered in turn. The results show that while BESS can offer opportunities for WPP, the correct sizing and representation of degradation of BESS are critical due to the high capital cost of storage. |
| | 34916 | • **Review of Control Algorithms for Reconfigurable Battery Systems with an Industrial Example**<br>*Zoltan Mark Pinter; Mattia Marinelli; Dimitrios Papageorgiou; Gunnar Rohde; Chresten Træholt* |

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| | Battery cells within battery energy storage systems (BESS) do not have homogeneous attributes, and the lowest capacity ones limit the performance and lifetime of the whole pack. Modern battery management systems (BMS) solve this problem with balancing, while providing the required service, and safe operation to the user. Reconfigurable battery systems (RBS) are BESSs that involve a BMS with reconfiguration. Reconfiguration uses feedback to determine the circuit switching logic. This paper presents a structured review of the control algorithms for RBSs. The RBSs are divided into groups according to their control strategies and control implementations. Finding the adequate control strategy requires well-defined objectives and control design. The control implementation focuses on physical and architectural aspects, like the reconfiguration frequency, the balancing operation and the control topology. The considerations and categories are discussed with the advantages, disadvantages and academic examples, and then an innovative industrial BMS is introduced. |
| 34663 | • **Modelling and Development of a Laboratory Scale Superconducting Magnetic Energy Storage (SMES) System**<br>*Stavros P Filippidis; Aggelos Bouhouras; Nikolaos Poulakis; Georgios Christoforidis*<br><br>Superconducting magnetic energy storage systems (SMES) store energy in the form of magnetic field generated by a DC current flowing through a superconducting coil which has been cooled at a low temperature, typically less than 77 K. Therefore, the optimization of the coil and the design of the thermal design are crucial. In this paper the first steps in the development of a laboratory scale SMES are presented. Initially, based on the available material, the geometry of the coil is optimized to store the highest possible amount of energy utilizing Finite Element Methods (FEM). Based on the final geometry, the coil is built and thermally modelled inside a vacuum chamber. An initial experiment is carried out to cool the coil at 70 K and verify the existence of superconductivity. The measurements are carried out using a LabVIEW program. |
| 29994 | • **Impact of Power Smoothing Techniques on the Long-Term Performance of Battery Energy Storage Systems**<br>*Georgios Kryonidis; Angelos Nousdilis; Kalliopi Pippi; Theofilos A. Papadopoulos*<br><br>Power smoothing (PS) techniques are employed to mitigate the network problems caused by the variable output power of non-dispatchable renewable energy sources (RESs). Keystone of these techniques is the use of a battery energy storage system (BESS) acting as an intermediate energy buffer to smooth the RES output power. Scope of this paper is to investigate the impact of the most well-established PS techniques on the long-term performance of BESSs focusing on capacity degradation. To this end, an accurate BESS aging model based on the rainflow cycle-counting algorithm is integrated to the examined PS techniques to estimate the cycle aging of the BESS. Furthermore, a parametric analysis with high-resolution RES measurements is performed to identify the most critical parameters that affect the PS capability and the BESS capacity degradation. |
| 34172 | • **Battery energy storage systems management in a day-ahead market scenario with transactive energy and private aggregators**<br><br>*Luciane Canha; Héricles Eduardo Oliveira Farias; Camilo Rangel; Zeno Luiz Iensen Nadal; Tiago Santana; Leonardo Stringini*<br><br>This paper presents a methodology for battery energy storage systems (BESS) |

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| | | management considering the concept of transactive energy. Transactive energy is defined as the economic and control technique used for energy management that allows the dynamic balance of supply and demand across the electrical system. In a transactive energy market, the consumer can produce energy and inject it into the grid, becoming a prosumer. Also, it is possible to have the presence of private aggregators. Aggregators have large energy production capacity and can negotiate this energy with the grid. The system is composed by two private aggregators, the consumers, and the distribution system operator (DSO). The aggregators are assigned to supply a specific number of consumers defined in the contractual demand with the DSO, and the DSO is responsible for serving the rest of the system. Both aggregators and the DSO have distributed energy resources (DERs), such as energy storage and/or photovoltaic generation. A neural network based on group method of data handling (GMDH) is used for forecasting the grid demand, energy prices and solar generation for the day-ahead operation. The BESS reserve for the day-ahead is optimized based on prediction model. The methodology is validated in a 33-bus distribution network simulated on software OpenDSS. The curve profiles are taken from real data of the Canadian distribution system. |

## Wednesday September 01, 2021

**8:00–8:45**

***Session by Lucas-Nulle***

- **Lucas-Nuelle didactic training systems sponsor webinar**

**8:45–9:00** Break

**9:00–10:30** — *Plenary Session* — P2

- **Keynote 3: Professor Josep M. Guerrero -Space Microgrids - Nanosats, Lunar Bases and Closed Ecosystems**

  *Professor Tim Green*

  This talk will begin by introducing the control of microgrids, the parallelisms with the human brain and the research for possible sources of inspiration in last frontiers of neuroscience. Then, control in electric power systems of satellites and space platforms will be presented, showing approaches that are extended from terrestrial microgrids and explaining the differences and challenges when it comes to apply them out in the space. Further, multi-microgrid systems will be discussed for moon craters in future lunar manmade bases. Finally, the extension from the hierarchical control of microgrids to bioastronautics in the control of closed ecological systems to support with oxygen, water, and food to the astronauts and creating thus creating new ecosystems for the moon and future mars bases.

- **Keynote 4: Professor Pierluigi Siano - Distributed Parallel Optimization for a Large-Scale Aggregation of Prosumers**

  *Carl Ennis*

  A novel scalable and privacy-preserving distributed parallel optimization that allows the participation of large-scale aggregation of prosumers with residential PV-battery systems in the market for the ancillary service (ASM) is proposed in this paper. To consider both reserve capacity and reserve energy, day-ahead and real-time stages in the ASM are considered. A method, based on hybrid Variable Neighbourhood Search (VNS) and distributed parallel optimization is designed for the day ahead and real-time optimization. Different distributed optimization methods are compared and designed, and a new distributed optimization method based on Linear Programming (LP) is designed that overcomes previous methods based on integer and Quadratic programming (QP). The proposed LP-based optimization can be easily coded up and implemented on microcontrollers and connected to a designed Internet of Things (IoT) based architecture. Both day-ahead and real-time proposed optimization methods, by allocating the computational effort among local resources, are highly scalable and fulfil the privacy of prosumers.

**10:30–11:00** — ***Session: UPEC - S10***

**Demand Side Management and Demand Response** — S10

*Chair: Ghanim Putrus and Radu Porumb*

35165 — **Distributed Energy Management Analysis for Microgrids**

*Muhammad Majid Hussain; Waqas Javed; Rizwan Akram; Abdul Razaq; Muhammad Siddique; Tasmiyah Javed*

A key method of reducing energy usage and bills is collaborative demand management of buildings, and smart distribution networks using local renewable energy integrated sources. Emerging technologies such as the IOT (internet of things) can be integrated with grids, allowing bidirectional communication between customers and suppliers, while supporting remote management and monitoring of live energy usage. These systems create opportunities to deal with the distributed

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| | aggregation and control of distributed energy resources (DERs). Investigating how DERs are used at residential level in buildings such as smart houses reveal new possibilities relating to how the demand side can be made more efficient. In the long term, reducing energy demand during on-peak hours is a step towards creating a clean energy future. The primary goal of this paper is to observe and investigate how specific DSM strategies minimize energy consumption while maximizing efficiency with the use of new emerging technologies. A software called ETAP is used to analyse the integration of distributed generation such as renewable energy sources (RES) to utilize local power storage. In short, this is useful in providing flexibility to consumers. A PV system was also tested with an individual domestic load using an energy management system. This test examined how appliance energy usage can be reduced and shows why a management system is required to optimally utilize a PV system. |
| 35528 | • **Capacity Optimisation Framework for Fast Charging Stations Operating under Cold Weather**<br>*I Safak Bayram*<br><br>In this paper, we present a probabilistic capacity planning framework for electric vehicle (EV) fast charging stations that operate under cold weather. Existing literature on charging station modelling assumes that fast charging occurs at the rated capacity. However, recent empirical studies reveal that the actual charging rate depends on the battery and ambient temperatures and substantially reduces under cold weather. The proposed model is based on a multi-class queuing system where EV classes are determined based on temperature-dependent charger rates. The primary goal is to calculate minimum station capacity that can provide a certain level of quality of service (QoS) to each customer class. The performance metric describes the percentage of EVs that need to wait for service or leave the station. Case studies are provided to show the relationship between customer arrival rates, charging power and customer classes, and target QoS levels. The results further illustrate that the proposed framework achieves nearly one-third of capacity savings compared to baseline scenarios. The problems pertinent to temperature effects on EV charging require greater attention as EVs are becoming the main mode of transport in the next decade. |
| 25537 | • **Assessment of Methods to Measure Power System Flexibility: A Review**<br>*Daniello A Mouton; Ndamulelo Mararakanye; Bernard Bekker*<br><br>The addition of variable renewable energy (VRE) plants into the generation portfolio means that the power system has higher volatility, uncertainty, and variability. Therefore, there is an increased need for power system flexibility to account for this influx. Generation expansion planning entails strategizing an optimal long-term expansion plan for building new generation plants that satisfies economic and technical constraints. Concerns associated with VRE integration are evident in the case of the Namibian long-term expansion plan. The Namibian generation expansion plan makes use of two traditional adequacy planning techniques, namely loss of load probability (LOLP) and expected unsupplied energy (EUE), which are used for traditional generation plants where flexibility is already provided for. The problem with LOLP and EUE is that the only condition under which demand will not be met is when the demand exceeds the available capacity. The sole use of these metrics for generation expansion planning may be inadequate. Therefore, there is a need for flexibility assessment methods that can assess the flexibility of the Namibian power system to manage high variability. This paper reviews the different flexibility assessment methods available in literature studies and categorises the methods according to levels of computational complexity and data requirements. This paper finds that each level of flexibility assessment methods makes it possible to answer fundamental flexibility questions. Considering the findings, it is important to conduct |

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| | | all three levels of flexibility assessment methods to optimize flexibility. |
| | 34517 | • **Impact of Demand Side Management Methods on Modern Power Systems**<br>*Vasileios Laitsos; Dimitrios Bargiotas*<br><br>Efficient energy consumption remains an important factor in Europe's ambitious goals for sustainable development and activities related to air quality, global warming and climate change. However, especially during the summer months, southern Europe's electricity generation and distribution grid operates at extremely high loads. In order to meet the growing demand for electricity, a number of solutions for efficient electricity consumption, its production from Renewable Energy Sources (RES) and the implementation of new models for management and control have been taken into account, with some of them have been promoted through regulations at national and European level. This work is an attempt to study a field that forms new ideas about the efficient and economical use of electricity, which is called ''Demand Side Management''. This term consists of advanced activities of planning, implementation and monitoring of power transmission and distribution activities in order to motivate consumers to modify the level and the way of use of the energy consumed. For this reason, an Incentive- Based Demand Response model is implemented, in order to present in practice the way in which consumers communicate with grid administrator how they modify their demand curve in response to grid signals. |
| | 35445 | • **Complex solution to problems of voltage regulation in extended networks of 0.4 kV**<br>*Irina Klavsuts; Dmitry Klavsuts; Alexander Klavsuts; Anastasia Rusina*<br><br>With the transition to the digital economy and digital energy, in particular, there appear a lot of barriers that need to be eliminated as soon as possible. For example, outdated equipment in electric power systems, cybersecurity of facilities, new data transmission protocols, lack of personnel with the necessary "digital" competencies. All this forms the basis of the concept of the Internet of Energy. The article considers the problem of automation of voltage regulation in extended networks of 0.4 kV. The verification of the proposed approach was carried out in the EUROSTAG software package and in the test program. The results showed that the use of the patented devices of Demand Side Management-the normalizers of AC voltage provide automatic voltage maintenance at the implemented facilities, and the creation of a simulation model will allow to unify the production technology with the addition of the functions necessary for the customer. Keywords-demand side management, technological innovation, the normalizer of AC voltage, resource consumption management, machine-to-machine interaction, distributed control system, internet of things. |
| 11:00–11:30 | ***Session: UPEC – S11*** | |
| | **Active Distribution Networks and Virtual Power Plants**<br>*Chair: M Emad Farrag and Naoto NAGAOKA* | S11 |
| | 28095 | • **The Use of Synchronverters for Fast Frequency Response and Automatic Voltage Regulation in Low Inertia Islanded Power Networks**<br>*Jonas B. B. Hansen; Sebastian Østerfelt; Peter Randewijk*<br><br>This paper concerns power system stability challenges for large scale integration of renewable energy sources. Specifically, the focus of this study is based on the Suðuroy power grid on the Faroe Islands, where a 7 MW wind farm - equal to the maximum load for the entire grid - is scheduled for grid integration in 2021. The paper examines whether a synchronverter can help provide grid stability when the grid is solely |

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| | powered by the wind farm by adding virtual inertia to the network. The operation of the synchronverter has been tested in a simulation scenario with a load step using DIgSILENT PowerFactory. The results were compared to a solution with a synchronous condenser (SC) and a battery energy storage system (BESS) with grid following operation, as opposed to the synchronverter that operates as a grid-forming converter. The simulations proved that the synchronverter has the ability to contribute to the grid stability without the typical limitations traditional solutions have. However, the results still require further investigation - both from a practical and an economical consideration - before ultimately determining if it is currently a viable alternative to already existing and typically applied solutions. |
| 24966 | • **Dynamic Behavior of Active Distribution Networks**<br>*Sirkka Porada*<br><br>Due to the increasing penetration of renewable energy sources, which are mainly connected to the distribution grid level, the active and reactive power flows in the distribution grids become more volatile. To avoid costly grid expansions Distribution System Operator uses voltage controlling components, such as on-load tap changing transformers or reactive power controls of grid users connected via inverters to the distribution network, to maintain the given voltage limits. These developments change the dynamic behavior of distribution networks, which affects also the voltage stability in the overlying transmission grid. Therefore, this paper investigates how different reactive power controls of renewable energy sources and sector-coupling consumers as well as different delay times of on-load tap changing transformers affect the dynamic reactive and active power demand and the dynamic voltage response of active distribution networks. For this purpose, dynamic simulations of a representative medium and low voltage network are carried out, which take into account volatile feed-in/demand-profiles for RES and consumers. The resulting vertical reactive and active power flows are discussed within this paper. |
| 25221 | • **Optimizing the turbines distribution in wind farms based on mutual minimization of the wake effect**<br>*Victorita C. Radulescu*<br><br>Romania is considered the country in SE Europe with the second highest wind potential, having a production capacity of over 14 GW. Currently, due to the investments of over 9 billion euros made in wind farms, about 2500 MW are produced from wind, representing about 25% of total domestic energy production. In addition to the existing wind power plants, three other new wind farms will be soon realized. This paper presents a methodology for optimizing the distribution of turbines in a wind farm so as to minimize mutual influence during operation, due to the wake effect. A correlation is created between mast-induced disturbances and turbine nacelles, atmospheric data and the number of rows on which the turbines are implemented. Fluent software is used to model the main vortex for which the computational field is structured in the main wind direction. The vortices formed behind the rotor and nacelle are estimated. The measured and recorded data on the significant air parameters in the future location of the plant, the southern part of Moldova are briefly presented. The numerical model was tested for several types of turbines with a capacity of approximately 2 MW, thus conducting a comparative study. Based on these results, the possible energy to be produced multi-annually was evaluated. A new correction of the turbine distribution was made, by estimating the costs of implementing the wind farm with turbines distributed in two and 100 rows. |
| 27407 | • **Multi-objective Distributed Energy Resource Integration in Radial Distribution Networks** |

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| | | *Bahman Ahmadi; Soheil Younesi; Oguzhan Ceylan; Aydogan Ozdemir*<br><br>Despite numerous studies on the optimal design and planning of distribution networks (DNs), little attention has been paid to improving the reliability of the distribution systems through optimal operation and planning of distributed generations (DGs) and energy storage systems (ESSs). This paper aims to integrate multi-type DG units and ESSs into the radial DNs to improve network reliability, decrease the losses, and maintain the voltage profiles. System Average Interruption Frequency Index (SAIFI) and Average Energy Not Supplied (AENS) are used as representative reliability indices. Objective functions are formulated and solved by using the slime mould algorithm (SMA). The proposed model's performance is tested on a balanced 33- bus system using the MATLAB environment. Then, the best solution is selected and compared with the base case values. Finally, SMA based solution is compared to those of genetic algorithm and particle swarm algorithm to validate the SMA's performance for finding the near-global solution. |
| 11:30–12:00 | ***Session: UPEC – S12*** | |
| | **HVDC, FACTS and power electronics**<br>*Chair: Theofilos Papadopoulos and Hassan Nouri* | S12 |
| | 33581 | • **Voltage Stability Improvement in Multi-Terminal HVDC grids: A Case Study of Cigré B4 HVDC Test Grid**<br>*Hassan Nouri*<br><br>High voltage direct current (HVDC) breaker is among the essential components of HVDC grids. Currently, DC circuit breakers (DCCBs) of HVDC grids require relatively large DC reactors to limit the rate of increase of fault current. However, DC reactors have destructive effects on the multi-terminal HVDC (MT-HVDC) grid dynamic stability, and in such a system, despite the variety of controllers, the system dynamics are highly sensitive to the operating point. This paper proposes a modification to be applied to the droop control of Multi-terminal HVDC (MT-HVDC) grids for stabilizing the DC voltage and power variations in case of transient events by the introduction of a Dead Band Direct Current Power System Stabilizer (DBDC-PSS). Also, this paper presents the classification of MT-HVDC grid dynamic behavior in different scenarios including without DC-PSS, conventional DC-PSS, and DBDC-PSS. All simulations and analytical studies are conducted on Cigré DCS3 test HVDC grid in MATLAB/Simulink. |
| | 32152 | • **On Systematic DC Fault-Ride-Through of Multi-terminal MMC-HVDC Grids**<br>*Seyed Hassan Ashrafi Niaki*<br><br>Development of Modular Multilevel Converter (MMC) based HVDC grids, as a new generation of Voltage Source Converter (VSC)-HVDC systems, has been considerable through the past decade. Emerging of multi-terminal MMC-HVDC networks makes integration of multiple large-scale sustainable sources and asynchronous power grids quite feasible. However, protection and control of the multi-terminal HVDC grids under fault situations have always been a vital issue. On the other hand, while modern AC grids get benefits of applied Fault-Ride-Through (FRT) operation and capabilities under AC fault conditions, the multi-terminal HVDC grids lack a systematic DC FRT operation. As the multi-terminal HVDC networks are going to become a backbone grid for the future power systems, it is necessary to define grid code requirements and standardizations considering DC FRT regulations. This paper presents potential DC FRT operations and possible profiles from HVDC grid point of view under DC fault conditions. A systematic DC FRT based on voltage against time profile is proposed. Different characteristics of voltage-based DC FRT are investigated in this study and |

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| | results can be applicable to DC grid code definitions and requirements. |
| 26389 | • **Direct Current Analysis of LCC based HVDC System during Fault using DIgSILENT PowerFactory**<br>*Ravikiran Hiremath*<br><br>The performance of the grid connected wind farms (WFs) with HVDC system is attracting much interest. Many WFs employ controllers for converter stations to provide a favourable grid support during fault. This paper aims for the direct current analysis of line commutated current converter (LCC) based HVDC system under 3-phase fault. The paper proposes the DIgSILENT Simulation Language (DSL) oriented voltage dependant current order limiter (VDCOL) and PI controller for the both rectifier and inverter stations. The whole HVDC system is modelled in DIgSILENT PowerFactory software for the better DC current and voltage response under the fault. The stability of this system is analysed with the bode plot. The simulation results under the 3-phase fault indicate the better DC current and voltage behaviour. |
| 31663 | • **Modelling and challenges of integration of large renewable power plants**<br>*Ananya Kuri; Dirk Audring*<br><br>The connection of new large renewable power plants has challenges for optimal integration into a power system. Proper assessment is essential to consider any possible impact, apply countermeasures, and optimize performance. Early cooperation with the transmission system operator is required to align grid operation, plant operation, and specialists' experience from the manufacturer. The transmission system operator needs to gain an accurate steady-state and dynamic model of the converter-based power plant and confirmation that the plant configuration complies with grid codes. The investigations allow the manufacturer to modify or optimize the controllers, assess the impact on the shaft and other components, and perform corrections in protection devices and relay settings. This ensures given performance guarantees and proper operation of the newly commissioned plant. Any possible impact on the power system or the converter interfaced generation (CIG) is assessed, and necessary countermeasures can be applied. The described procedure was successfully applied at several renewable power plant projects of different types, such as hydropower plants, Wind and PV parks, providing communities and countries with efficient and renewable electrical power. The dynamic models developed are optimized, improved, and validated. |
| 34909 | • **Novel DPWM Modulation Scheme for Three-Phase ZVS Inverters**<br>*Benedikt Kohlhepp; Thomas Duerbaum*<br><br>Most inverters driving electrical machines or for grid applications operate under hard switching conditions at fixed frequency. However, the resulting high switching losses from the hard switched operation limit the efficiency. Another approach uses triangular current mode to achieve zero voltage switching of the semiconductors, thus avoiding switching losses. Disadvantageously, this modulation scheme exhibits a huge current ripple especially during the extrema of the sine. To remedy this drawback, this paper studies a discontinuous pulse width modulation scheme by simulation, which avoids switching actions around the sinusoidal maximum and thus, reduces the overall current ripple. In order to be able to use this approach beneficially, the transitions to the intervals with no switching actions should be soft. |

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| | | This attenuates oscillations within the filter and thus provides the intended reduction in rms inductor current. Besides a lower rms current predicted by simulation, also significantly reduced losses of the inductor are to be expected. |
| 12:00–12:30 | ***Session: UPEC – S13*** | |
| | **Power System Protection**<br>*Chair: Essam Hamdi and Naoto Nagaoka* | S13 |
| | 27688 | • **Analysis of a Midpoint Series Compensated Line**<br>*Michael O Donovan; Noel Barry; Joe Connell; Eoin Cowhey*<br><br>Many electrical utilities worldwide are increasingly using series compensation to meet the need to add large amounts of renewable energy resources such as wind and solar to the existing power system network. In series compensated lines, the effective line inductive reactance becomes small due to the capacitive compensation. This can lead to voltage and current inversion and subsynchronous oscillations during disturbances along the series compensated line. For distance relays, special care must be taken for series compensated, and adjacent lines due to the series capacitor bank (SCB) alters the line impedance. This can cause a protection relay to operate for faults beyond its normal reach. A 400 kV series compensated network is modelled using DigSilent Power Factory. Electromagnetic transients (EMT) analysis was performed on distance protection devices on the network. The results presented in this paper show that a series compensated line presents challenges for setting distance relay protection where a three-phase fault can lead to overreach, voltage, or current inversion at different network locations. |
| | 32343 | • **MOSFETs under short circuit conditions for aeronautical applications**<br>*Lydia Niamh Robinson; Ransheng Xu; Sergei Simdyankin; Andrew Gallant; Alton Horsfall*<br><br>The short circuit performance of silicon carbide MOSFETs has been evaluated in a 270 V system designed to mimic the characteristics of a commercial airliner power system. The devices demonstrated the ability to withstand being short-circuited for a period of 8 us before suffering a catastrophic failure when that coincided with the turn-off transient for a 9 µs pulse. At the point of turn off the junction temperature in the transistor is calculated to have risen to approximately 950 C. The withstand period for a transistor held at a case temperature of 150 C was 7 µs, indicating the failure is of a thermal origin and this reduction needs to be addressed for devices operating in high temperature environments, such as those found in aerospace. |
| | 35151 | • **AC and DC Arc Flash Analysis for an Industrial Electrical System Infrastructure and Its Importance**<br>*Jehan Perera; Nkiru Agu; Gobind Pillai; Musbahu Muhammad; Gill Lacey*<br><br>Understanding the amount of incident energy produced by any AC and DC electrical faults using an arc flash hazard study will help abate injuries to operating personnel. This paper presents a case study of an industrial electrical infrastructure including simulation of system modelling and arc flash hazard assessment performed on both the AC and DC components. The power system model of the infrastructure was simulated and analysed using SMK Power Tools software. The system model was fed from 2 sources, the grid and from a battery bank energy storage unit which served as backup power source. The amount of incident energy produced when there is a fault in the system, the severity of the arc flash incident energy when fed from AC grid as |

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| | | well as the high current DC system is evaluated. Ensuing safety measures to be taken to mitigate these arc flash hazards are recommended. |
| | 27884 | • **Fuzzy Logic Based Scheme for Directional Overcurrent Detection and Classification for Transmission Line**<br>*Radhwan Mohammed Saleem Dawood; Maher Al-Greer; Gobind Pillai*<br><br>This paper proposes a fuzzy logic-based scheme to detect the direction of the overcurrent faults (phase-phase) in the transmission lines through polarized voltage. The fault detection is crucial to avoid the overlap action for the protection relays in fault conditions which are led to the maloperation in the transmission grid with unwanted tripping for healthy lines. When the fault occurs, the magnitude of the voltage and the current direction is changed (dip in voltage and rise in current) according to the type of fault in the grid. Three phase voltage and current are measured to generate the inputs for the proposed fuzzy logic-based scheme. The typical IEEE 9- Bus Bars transmission grid has been used to implement the test for the fuzzy scheme using Simulink and Simpower systems toolbox in MATLAB software. The proposed scheme is applied to six-phase to phase faults cases in forward and reverse direction. Results show the effectiveness of the directional fault detection scheme using the fuzzy logic system. |
| | 24739 | • **Optimal Overcurrent Relay Coordination in Distribution Networks**<br>*Mert Bekir Atsever; Ozgur Karacasu; Mehmet Hakan Hocaoglu*<br><br>Over-current relay coordination plays a critical role for effective protection of networks since primary protection is based on over-current detection in distribution systems. Thus, optimal relay coordination must be ensured between relays in faulted condition, providing selectivity and fast operation. Therefore, relay coordination can be designed as an optimization problem with highly constrained equations in such networks. Linear programming, which is simple to be implemented and requires less computation time when compared other optimisation techniques, is widely employed for solving relay coordination problems. To achieve faster and selective protection a number of optimisation algorithms have, also, been customised for the purpose. Water Cycle Algorithm (WCA) is among them and has promising results, already, depicted in the literature. However, capacitive currents may jeopardize traditional optimisation process for earth faults. Thus, in this paper, performance analysis is carried out for earth faults in sample distribution networks constructed with overhead lines and underground cables, separately. The results show that in cabled networks, additional constraints are needed for the optimisation process to provide selectivity. Consequently, optimal relay settings and selective protection are ensured by adding proper constraints into optimisation problem in this paper. |
| 13:00–13:30 | ***Session: UPEC – S14*** | |
| | **Load and Generation Forecasting**<br>*Chair: Gianfranco Chicco and M Emad Farrag* | S14 |
| | 35633 | • **Micro-Genetic Algorithm Embedded Multi-Population Differential Evolution based Neural Network for Short-Term Load Forecasting**<br>*Colin Paul Joy; Gobind Pillai; Kamlesh Mistry; Yingke Chen*<br><br>The load of a power system usually presents a certain range of nonlinear fluctuation with time. Even then, the load characteristics still follow certain rules which can be exploited to optimise and improve the accuracy of computer-based Short-Term Load |

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| | | Forecasting (STLF) models. Therefore, this paper presents a mGA (micro-Genetic Algorithm) embedded multi-population DE (Differential Evolution) to optimise an Artificial Neural Network (ANN) STLF model. Firstly, the mGA embedded multi-population DE is proposed, to improve and balance the global and local search. Then the proposed DE is applied to optimise the weights during the training of the ANN. The overall model's performance is evaluated using publicly available Panama electricity load dataset against four state-of-the-art machine learning algorithms. The evaluation results show that the proposed DE based NN STLF model has higher prediction accuracy compared to the other selected machine learning algorithms. |
| | 35115 | • **A Hybrid Metaheuristics-Based Algorithm for Electricity Load Curves Profiling**<br>*Ioannis Panapakidis; Christos-Alexandros Kechagias; Dimitrios Bargiotas*<br><br>Clustering-based load profiling utilizes unsupervised machine learning algorithms to form homogenous clusters composed by electricity load curves with similar characteristics. Due to the importance of load profiling in modern power systems, a variety of clustering algorithms of different type and complexity has been proposed in the technical literature. Nevertheless, no attention has been placed in the metaheuristics-based clustering. The present paper proposed a novel hybrid algorithm that is composed by two clustering algorithms. A comparison takes place with the most used algorithms of the literature. Experimental results indicate the robustness of the proposed approach to electricity load curves clustering. |
| | 35134 | • **Day-Ahead Natural Gas Demand Forecasting in Hourly Resolution**<br>*Ioannis Panapakidis; Vasileios Polychronidis; Dimitrios Bargiotas*<br><br>Natural Gas (NG) demand forecasting is a research topic that starts to gather the attention of scholars, research institutions, utilities, retailers and other interested parties. Accurate predictions of future needs for NG can aid on the optimal management of NG resources. This manuscript examines the problem of day-ahead Natural Gas (NG) demand forecasting in hourly resolution. Various models of different type are trained and applied using data that correspond to the demand of a large region including urban, sub-urban and industrial loads. A series of scenarios are formed in order to investigate the influence of input selection on the day-ahead forecasting problem. |
| | 15279 | • **Power Output Prediction of Wave Farms Using Fully Connected Networks**<br>*Bhavana Burramukku; Oguzhan Ceylan; Mehdi Neshat*<br>One of the most important factors in the amount of power generated by a wave farm is the Wave Energy Converters (WECs) arrangement along with the usual wave conditions. Therefore, forming an appropriate arrangement of WECs in an array is a significant parameter in maximizing power absorption. This paper focuses on developing a fully connected neural model in order to predict the total power output of a wave farm based on the placement of the converters, derived from the four real wave scenarios on the southern coast of Australia. The applied converter model is a fully submerged three-tether converter called CETO. Data collected from the test sites is used to design a neural model for predicting the wave farm's power output produced. A precise analysis of the WEC placement is investigated to reveal the amount of power generated by the wave farms on the test site. We finally proposed a suitable configuration of a fully connected neural model to forecast the power output with high accuracy. |
| 13:30–14:00 | ***Session: UPEC – S15*** | |

| **Power System Modelling and Analysis**<br>*Chair: Hassan Nouri and Radu Porumb* | S15 |
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| 32470 | • **Development of Excitation System Modelling Approaches for the Nigerian Grid**<br>*Mohamed M Osman; Gareth A Taylor; Barry Rawn; Tochi Nwachukwu*<br><br>The structure of the Nigerian interconnected system, which includes long power lines and a small number of generators, leads to technical challenges to stability of the interconnection. The static models of the Nigerian high voltage system indicate certain system deficiencies and weak points, but records and observations of system collapses suggest that swing instabilities are sometimes part of rapid frequency decline. A dynamic model of system behavior can help determine whether system stability is major limiting factor for system operation, enable better forensic analysis of blackout events, lead to proposals for mitigating measures within the reach of operators. Accurate modelling of generator excitation systems represents a critical first step in the development of robust dynamic models- but validated excitation system parameters are not necessarily available for all generators, for when not all parameters are available, this paper establishes and tests a procedure that is used to select credible parameters. The paper demonstrates how one can build acceptable power system model that supports preliminary benchmarking and validation. |
| 25208 | • **Frequency-dependent Modeling of Generic Honeycomb Networks**<br>*Andrea Kerstin Schaefer; Jutta Hanson; Gerd Balzer*<br><br>Harmonic and resonance analyses demand an appropriate frequency-dependent network model with specific network characteristics. Often these characteristics are not reflected in benchmark network models or a lack of data does not allow a precise network modeling. In this report, a methodology how to set up a simplified generic network model with desired characteristics based on the honeycomb approach is enhanced by frequency-dependent modeling. This includes new modeling approaches for external and downstream networks. Further, the harmonic background distortion is mapped including the zero and negative sequence to consider asymmetries in the network model for detailed harmonic studies. The methodology is demonstrated on an exemplary real transmission grid. The homogeneous network set-up leads to homogeneous busbar impedances and harmonic voltages, so that the impact of changes to the grid can be quantified easily. Consequently, it can be utilized for a large scope of applications such as harmonic studies on the impact of the rising use of underground cables in the transmission grid, or the increasing number of harmonic feed-ins due to the integration of renewable energy sources. |
| 27905 | • **Emulation of Grid-Following Inverters for Impedance-Based Stability Analysis regarding Outer Control Loops**<br>*Carolin Hirsching; Wolf Schulze; Maurizio Zajadatz; Michael Suriyah; Thomas Leibfried*<br><br>With an increasing share of converter based devices in power grids, numerous investigations on the overall system stability have been tackled in recent years to understand their interplay with the existing grid. Here, impedance based studies enable screening studies over a broad frequency range. Whereas interaction studies considering a grid impedance only represent a snapshot of the system, passivity studies enable classification of several sensitivities with respect to the damping behaviour of the considered device. Therefore, a test setup is proposed within this contribution to analyse the frequency-dependent characteristic of a converter at its output terminal up to 10 kHz. Hence, the behaviour of an arbitrary voltage source |

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| | | converter with an arbitrary controller implementation is replicated by a converter emulation setup. Utilizing the introduced test setup, the impedance characteristic related to different controller structures and operation points are received and evaluated. |
| | 28146 | • **Vector fitting algorithms for impedance modelling of converter based systems**<br>*Viswaja Yellisetti; Matthias Quester*<br><br>This paper investigates Vector Fitting (VF) algorithm variants for frequency-domain impedance modelling of converters in different control modes. The VF variants are obtained by varying the error norm used for minimizing the error between approximated fitting function and the measurement data. Consequently, in addition to the L2 norm minimized in the standard VF, L1 and H2 norms are minimized and their fitting accuracy is compared. Furthermore, a comparison of accuracy is also carried out by minimizing these three norms in the modified standard VF known as Relaxed Vector Fitting (RVF). The results show that an additional degree of freedom introduced in RVF leads to higher accuracy fitting compared to standard VF. The accuracies of VF between the three norms differ only marginally. Minimizing the H2 norm results in high accuracy, but it requires pre-defined measurement frequency points, which can lead to an impractical definition of input data. L1 norm minimization results in large deviations at a few measurement points due to an additional weighting factor introduced in the error minimization function. Moreover, RVF minimizing L2 norm shows the highest VF accuracy. |
| | 33797 | • **Calculation and validation of sector-shaped conductor cable parameters in LV distribution systems**<br>*Le Thi Minh Trang; Hassan Nouri; Simon Le Blond*<br><br>The exact determination of faults in underground power distribution networks requires accurate cable parameter data. Accuracy depends on how the cable parameters have been derived, which in turn is a function of the core shape. This paper schematically highlights an approximate transformation of the sector-shape core into a circular shape that is needed for simulation. Then the available multi-core circular shape cable expressions are elaborated for calculation of the cable impedance and admittance matrices. The computed parameters of the four sector-shaped conductor cable are verified against those obtained in PSCAD-EMTDC and EMTP-RV simulation software, as well as with those provided by the manufacturer that comply with the BS7870. The results show that the presented cable parameter calculation method is robust and reliable. |
| 14:00–14:30 | ***Session: UPEC – S16*** | |
| | **Continuity of Supply, Reliability and Resilience**<br>*Chair: Ghanim Putrus and Alecksey Anuchin* | S16 |
| | 35063 | • **Improving the Operational Reliability of Wind Farms with Vehicle-to-Grid**<br>*Zu Han; Christopher Challen; Spyros Skarvelis-Kazakos*<br><br>This paper investigates the integration of a wind farm with electric vehicles capable of Vehicle-to-Grid operation, and the impact of this integration on the reliability of the energy supply to the load. The operational reliability of wind farms was considered, in order to predict the outage probability. The operational reliability model was implemented on a small power system, and a case study analysis was undertaken of the influence of Vehicle-to-Grid in the event of an outage at the wind farm. Several reliability indices were calculated for the case study. Results show a significant improvement of the system's reliability by the presence of Vehicle-to-Grid |

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| | functionality, since it is able to compensate for the power lost during a wind farm outage. |
| 37149 | • **Sensitivity Analysis of Transmission Assets: Special Case Transformers Aging**<br>*Arshad Syed Anwar; Mohamed Farrag; Jim Baird*<br><br>The paper describes initial research undertaken, exploring the impact of demand and other environmental factors on the power transmission network. How these factors lead to a determined probability of failure is currently determined through a set of complex equations. Demand, or loading, is expected to be the principal factor on the expected life of transmission assets such as transformers. The long-term aim of the research is to understand the likely impact of electrification of vehicles, the associated increased demand on the network, leading to the prospect of a deterioration of the network assets. This initial research suggests that transformer ageing is highly sensitive not only to the average and maximum demand in the network but also to other environment factors. Recommendations from this research will help power transmission companies to more effectively manage their assets through a more robust understanding of the ageing of assets as a consequence of Governmental policy shifts on electric vehicle uptake. |
| 35519 | • **New Design of UHF Microstrip Patch Antenna for Partial Discharge Detection on Power Transformer**<br>*Jean Pierre Uwiringiyimana; Suwarno Suwarno; Umar Khayam*<br><br>Partial discharge (PD) activity in high-voltage power equipment is a warning sign of insulation degradation that subsequently leads to the aging and breakdown of the power equipment. For the reliable and safe operation of high voltage power equipment, a PD diagnostic technique needs to be performed to assess and monitor closely the insulation condition. This paper presents a new type of UHF microstrip patch antenna with ultra-wideband frequency that can assist the UHF PD monitoring system to detect PD on high voltage equipment such as power transformers. This antenna was designed and simulated using CST Microwave Studio software. After design and simulation, the antenna was fabricated on a printed circuit board with FR4-epoxy substrate having a thickness of 1.6mm and dielectric permittivity of 4.4. The radiating patch and ground plane of this antenna are made of copper whose thickness is 0.035. The designed microstrip patch antenna was implemented to detect partial discharge on the transformer tank model. Based on the measurement results of the antenna characteristic parameters by using the Vector Network Analyzer, it is seen that the designed antenna has an operating frequency range of 1.2GHz-4.5GHz, and a bandwidth of 3.3GHz. Based on PD measurement results, the new design of the microstrip patch antenna has a high sensitivity in detecting the PD signals caused by insulation defects inside the transformer tank. The ultra-wideband frequency response of this antenna makes it a suitable and promising sensor for PD detection and PD recognition on high voltage equipment such as power transformers. |
| 28026 | • **Optimization of the Reliability of Power Systems through Allocation**<br>*Lucian-Ioan Dulău; Dorin Bică*<br><br>The reliability of power systems is an important and actual study domain. This paper presents the optimization of the reliability of a power system through allocation. We consider two cases: a degree of security imposed on the bus and the maximization of bus reliability if limited funds for the security of power supply are available. Different values are considered for the degree of security in the power supply, respectively funds available. The bus load is supplied from the power system, respectively from two power sources. The results give the optimal reliability of a power system, namely |

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| | | the reliability of the power sources. |
| | 34003 | • **Real-Time Electromechanical Mode Identification through Energy-sorted Matrix Pencil Method**<br>*Rahul Rane; Abhishek Pandey; Faruk Kazi*<br><br>Large areas of modern power systems are interconnected for improved power pooling, resulting in higher system inertia. On the other hand, it provides the capability of long-distance transmission of power. Thus, increasing the potential of tie-lines to run at near-maximum capacity. The probability of inter-area oscillations between two areas increases as tie lines are operated closer to full capacity, and this is particularly prevalent near high load density areas. Inter-area stability analysis is becoming more difficult as the current power system becomes more interconnected. This paper implements the energy-sorted Matrix Pencil Method (MPM) on a real-time simulation testbed to perform an online estimation of Low-Frequency Electromechanical Oscillations (LFEOs) present in a power system that is complex and highly interconnected and also implements an oscillation detection method on Phasor Measurement Units (PMUs) data to ensure that energy-sorted MPM is be applied to the relevant data type. As a result, the estimation of modal parameters can be utilized further with confidence and promptly. The proposed process is evaluated on a Klein-Rogers-Kundur test case, and the outcome of the simulation is presented which justifies the effectiveness of energy-sorted MPM in real-time LEFOs. |
| 14:30–15:00 | ***Session: UPEC – S17*** | |
| | **Environmental Impacts and Targets High Voltage Engineering**<br>*Chair: Theofilos Papadopoulo and Radu Porumb* | S17 |
| | 24800 | • **Geomagnetically induced currents: A measurement based inverse determination of earth impedances**<br>*Philipp Schachinger; Dennis Albert; Herwig Renner*<br><br>Geomagnetically induced currents (GIC) can lead to serious disturbances in transmission grids. Arising problems range from high noise levels and reactive power consumption of transformers up to transformer outages and regional blackouts. To mitigate GICs effectively, simulation is an important aspect. However, incomplete electrical grid data in combination with discrete earth layer models lead to differences between measurement and simulation. In this article, we describe an inverse calculation method of the complex earth impedance, based on transformer neutral point measurements. We show that the resulting model leads to higher simulation accuracy. This calculation method may be used especially when earth layer data is missing or inaccurate. |
| | 35127 | • **Power Quality Impact of Distributed Energy Resources in Low Voltage Distribution Grids**<br>*Jone Ugarte Valdivielso; Abel Thomas; Jayakrishnan Pillai; Sanjay K Chaudhary*<br><br>The amount of power electronic-based distributed energy resource connected to low voltage grids is increasing at a fast rate. These interfaces can create power quality issues and consequently, affect the system's equipment and the quality of supply. In this study, the focus is on analysing the harmonic distortion impact of photovoltaic connected through a two-level voltage source inverter with a pulse-width modulation control and electric vehicle connected by a six-pulse rectifier in an existing low voltage grid. The converters are modelled by their Norton equivalent. Moreover, passive filtering is used to mitigate the high amount of harmonic distortion that the selected converters inject into the grid. The results show that the increase in photovoltaic and |

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| | electric vehicle penetration increases the harmonic distortion at the point of coupling and that the photovoltaics act as an active filter by filtering out the electric vehicle harmonics. |
| 22574 | • **Development of a New Method and a Discharge Indicator for the Evaluation of Isolating Gases**<br>*Philipp Huber; Kerstin Friebe; Frank Jenau*<br><br>As part of the design and dimensioning of systems for high-voltage applications such as high-voltage laboratories, transformer stations or converter halls, it is necessary to minimize the distances for reasons of cost optimization between voltagecarrying components and the ground electrodes. In this case, the insulating medium is atmospheric air. To avoid electrical breakdowns or so-called flashovers, the air clearances have to be designed adequately. Conventional air clearance calculation is based on empirically determined equations with correction factors for climatic conditions and used geometries. Here, the breakdown voltage, which leads to an electrical arc, is considered particulary. However, before electrical breakdowns occur, phenomena such as Townsend, Streamer and Leader discharge occur. Therefore, this publication attempts to investigate the forerunners of an electrical breakdown from high-voltage-carrying components with the help of electrical discharge mechanisms. Using the high-voltage direct current test center at the chair of High Voltage Engineering (TU Dortmund University) as motivation, the ignition criteria of a direct current source to a grounded wall is examined, in order to optimize the spacing respectively verify the new method as presented. |
| 24817 | • **Harmonic Emission Limit Allocation Using VDE AR-N 4130: Application and Adaptation [...]**<br>*Nico Schütte; Alexander Neufeld; Lutz Hofmann; Robert Dommerque; Mohammad Nazemi*<br><br>Increased installation of power cables and the intensified roll-out of power electronic equipment in the extra high voltage level pose challenges for network operators to assess network perturbations and power quality issues. In order to regulate harmonic levels in electric networks, grid operators are required to assign harmonic emission limits to the grid connection users. This ensures the compliance with the compatibility levels of the transmission grid. In this paper, the allocation procedure of harmonic current limits according to the novel German application rule VDE AR-N 4130 is compared with the approach from technical guideline IEC TR 61000-3-6. Key differences between both approaches are detected and presented on the basis of a case study. A restrictive component formulated in IEC method is elaborated, which is decisive for the differences occurring. Based on this finding, an adaptation of the allocation principle according to VDE is proposed. This adaptation enhances the allocation of comparable harmonic current emission limits. |
| 33208 | • **Impact and Sensitivities of Low-Frequency Resonances Caused by EHV Cables**<br>*Andrea Kerstin Schaefer; Jutta Hanson; Gerd Balzer*<br><br>The demand for extra-high voltage cables in the transmission grid is growing in the wake of the energy transition and growing need for expansion of transmission lines. The challenge regarding the resonance behavior is that the capacitive cable characteristics lead to a shift of the network resonances to lower frequencies. Parallel resonances amplify the harmonic voltage, which can pose a danger to network elements and is critical for switching operations at low frequencies. The likelihood for stimulating parallel resonances increases at lower frequencies, especially for typical transmission network harmonics such as the 5 th and 7 th harmonic fed in by |

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| | | distribution networks. Therefore, the focus in this report lies on the low frequency parallel resonances. In order to determine to which busbar a cable can be connected without amplifying critical harmonic voltages, it is important to know at which frequencies parallel cabling resonances occur and how the different network components affect the cabling resonances. In this report, a sensitivity study on cabling resonances is carried out. The correlations are shown on the example of a honeycomb network reflecting a real 380 kV network. This honeycomb network allows general investigations and statements. The results show that especially the distance to the cable and the cabling degree have a high impact on the resonance behavior while the busbar characteristics have a lower impact. |
| 15:00–15:30 | ***Session: UPEC – S18*** | |
| | **Continuity of Supply, Reliability and Resilience**<br>*Chair: Graeme Burt and Noureddine Harid* | S18 |
| | 36847 | • **A study of Qatar's Network Reliability During the Forthcoming FIFA 2022 World Cup**<br>*Almaha Al-Jassim; David (zhiwei) Gao*<br><br>The effect of increased load, due to the use of eight air-conditioned football stadiums during the forthcoming FIFA 2022 world cup, on Qatar's electricity network is investigated with the aid of PowerWorld simulator. The bowl areas of the stadiums currently under construction are estimated according to their seating capacity, and their air-conditioning loads are calculated using the air-conditioning requirement for a Qatari villa as a reference. Data regarding Qatar's electricity network are compiled with the aid of three publicly available sources. Power flow studies and contingency analyses are performed with and without the stadiums' load. An arbitrary correction factor is introduced to account for the uncertain nature of air-conditioning in open environment as well as cooling of other facilities. Results indicate that the addition of the stadiums' load introduces supply security violations. These are identified and appropriate remedial actions are devised and implemented. |
| | 25311 | • **Operating Reserve Dimensioning Methodologies for Renewable Energy Aligned Power Systems**<br>*Leigh Bongers; Ndamulelo Mararakanye; Bernard Bekker*<br><br>Over the last decade there has been a significant transformation in the electricity generation sector across the world, with the aim of reducing the environmental impact of electricity generation. Variable renewable energy (VRE) sources such as wind and solar photovoltaic have proven to be particularly popular in mitigating these environmental impacts. Increasing the penetration of VRE in the electricity generation mix will increase generation variability and uncertainty and can potentially introduce various technical challenges regarding the reliability of the power system network. Generation and demand must be in balance at all times for network reliability and operating reserves exist on the network to ensure system reliability during periods of imbalance. The risk exists that current "traditional" operating reserve dimensioning methodologies do not efficiently account for the increase in system imbalance variability and uncertainty as a result of increased VRE generation. This paper reviews the challenges associated with high VRE penetration networks and the caveats of current, "traditional" reserve dimensioning methodologies. Emerging, state-of-the-art methodologies in literature and in practice are reviewed to form a basis for future considerations in development of reserve dimensioning methodologies. The paper finds that transmission system operators (TSOs) of modern power systems with high VRE penetration in general are increasingly using probabilistic methodologies to dynamically dimension reserve requirements economically while reliably ensuring system adequacy. |

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| | 33022 | • **Unsupervised NILM Implementation Using Odd Harmonic Currents**<br>*Petros G Papageorgiou; Paschalis Gkaidatzis; Georgios Christoforidis; Aggelos Bouhouras*<br><br>In this paper, an unsupervised non-intrusive load monitoring approach is proposed in order to encounter the disaggregation problem for Non-Intrusive Load Monitoring (NILM) methodologies, using odd harmonic current amplitudes. The problem has been contemplated as a multi-class multi-label one and for the combinations examined the number of appliances operating simultaneously varies between from one to up to three appliances. K-means has been utilized to cluster the different combinations, using additionally the elbow technique, in order to obtain the most suitable number of clusters that should be created. The results indicate that the proposed technique performs efficient load identification even with few samples at the training stage especially under the consideration of the third and fifth odd harmonic currents. |
| | 27399 | • **The Arithmetic Optimization Algorithm for Optimal Energy Resource Planning**<br>*Bahman Ahmadi; Soheil Younesi; Oguzhan Ceylan; Aydogan Ozdemir*<br><br>This study presents a new formulation regarding optimal placement and sizing of multi-type distributed generations (DGs) and energy storage systems (ESSs) to enhance the reliability of a radial distribution system and to reduce the line losses employing Arithmetic Optimization Algorithm (AOA) method. The model determines the number of DGs and ESSs automatically, and is designed to minimize the losses and the reliability indices such as Customer Average Interruption Duration Index (CAIDI). The performance of the algorithm is tested on 69-bus radial distribution system. The objective functions corresponding to optimal type, location, and size of distributed energy resources are compared to the base-case values. Finally, a comparative performance analysis of the proposed algorithm is performed in terms of reliability indices and power losses with Particle Swarm Optimization (PSO) and Grey Wolf Optimizer (GWO). |
| | 35202 | • **Improving Power Transformers Maintenance with Data Science**<br>*Samuel Lessinger; Rodrigo Figueiredo; Lúcio Rene Prade; Alzenira Abaide*<br><br>The continuous expansion of the electrical power system demands increasingly strict operating standards in terms of safety and availability. In this scenario, the maintenance of power transformers becomes essential for the safe and efficient operation of the entire system. Operating data must be analyzed to verify the correct functioning of the transformer. This work applies a data science methodology in a real transformer to extract operating thermal profiles and commutations Taps characteristic. This analysis helps in decisions about predictive maintenance planning. |
| 15:00–16:00 | ***Speed networking session*** | |
| 16:00–16:30 | ***Time for networking*** | |

| Thursday September 02, 2021 | | |
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| 8:00–8:45 | ***Session by Lucas-Nulle***<br>• **Lucas-Nuelle didactic training systems sponsor webinar** | |
| 8:45–9:00 | Break | |
| 9:00–9:45 | ***Plenary Session***<br>• **Keynote 5: Dr Tilo Buehler Grid Edge Solutions for Sector Coupling Between Power and Transport**<br>*Tilo Buehler*<br>This Energy systems are currently undergoing several coincident paradigm shifts. Global megatrends of electrification, digitalization, and decentralization are reshaping how we plan, address, and operationalize for the energy needs of the next generations. Sector coupling, in particular between power and transport as mobility is increasingly powered by batteries, will create new opportunities and require new solutions spanning these sectors. In electricity networks there is a massive concomitant trend towards adding large amounts of renewable and distributed energy resources (DERs) near the edge of the network. In other words, this means more renewables, more battery storage but also more flexible management of loads in the electrical distribution systems. Such a fundamental change in asset portfolios, and new ownership models such as prosumers, requires novel ways of managing the network, leading to the implementation of microgrid and microgrid-like grid edge solutions that locally combine DERs. It also leads to large numbers of these grid edge solutions and other DERs that are aggregated into virtual power plants. Increasingly affordable battery storage and solar generation are key technology drivers, but the benefits of these are unlocked by end-to-end digital solutions integrating real time control with cloud-based asset managing. The electrification of the transport sector emphasizes the need for reliable, flexible, and resilient electricity supply. In my presentation I want to highlight how automation and storage play a key role in successful sector coupling, illustrated by smart charging concepts for commercial electric bus and fleet depots. The combination of intelligent energy management solutions for charging in depots together with battery energy storage can contribute towards reducing peak demand charges, avoiding overload conditions for the grid interface and also allow for integration of local renewable generation or the provision of network services. | P3 |
| 9:45–10:00 | Break | |
| 10:00–10:30 | ***Session: UPEC - S19*** | |
| | **Power System Optimisation and Planning**<br>*Chair: Naoto Nagaoka and Alecksey Anuchin* | S19 |
| | 14872 | • **Mechanical Switching Pattern of Hybrid Dynamic Reactive Power Compensation in Wind Farm Power Plants**<br>*Seyed Alireza Mousavi Mirkalaei*<br>Dynamic Reactive Power Compensation (DRC) plants are amongst the most expensive equipment on Wind Farm Power Stations (WFPS) which are essential for fulfilling Grid Codes requirements. Wind Turbine Generators (WTG), STATCOMs and SVCs are some of widespread solutions (technology) for this application. Hybrid DRC is an alternative solution which is gradually accepted by Transmission System (TS) operators and Grid Codes (GC) all around the world. Hybrid DRCs are usually combinations of power electronic devices like SVCs, STATCOMs, Inverters and some Mechanically Switched Reactors/Capacitors (MSR/MSC). Statistical understanding of the mechanical switching |

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| | operation is critical to assess whether Hybrid DRC is a cost-effective solution. Conditions and numbers of operations for Circuit Breakers (CB) are limited and they need maintenance and replacement accordingly. This paper studies a real WFPS conditions and reviews mechanical switching statistics. It also reviews Hybrid DRC in comparison with conventional STATCOM. The studies outcomes give clear understanding of statistics together with advantages/disadvantages of one special case, then the high-level understanding in some ways can be generalized. Keywords- Hybrid STATCOM, Hybrid SVC, Grid Code, Wind Farm, Mechanical Switched Reactor. |
| 20414 | • **Fuzzy PID with filtered derivative mode based load frequency control of two-area power system**<br>*Mokhtar Shouran; Fatih Anayi; Michael Packianather*<br><br>This work proposes a design of Fuzzy Proportional Integral Derivative with Filtered derivative mode (Fuzzy PIDF) having six parameters for Load Frequency Control (LFC) of a two-area interconnected power system. In order to obtain the optimal values of the proposed structure parameters, the Bees Algorithm (BA), Teaching Learning Based Optimization (TLBO), and Particle Swarm Optimization (PSO) are used to accomplish this task. A step Load Perturbation (SLP) of 0.2 pu is applied in area 1 to investigate the dynamic performance of the system with the proposed controller. The supremacy of Fuzzy PIDF is proven by comparing the results with those of previous studies for the same power system. The robustness of the proposed controller is also evidenced against a wide range of parametric variation of the investigated system. |
| 28154 | • **Modular Controller Design applied to Network Reduction Suited for Offline and Online Simulation**<br>*Moraish Sukumaran; Ananya Kuri; Gert Mehlmann; Matthias Luther*<br><br>The integration of renewables has caused dynamic network reduction to gain grounds in both offline and online applications. This paper proposes a new multifunctional and modular automatic voltage regulator (AVR) and governor (GOV) model that may be used as equivalent controllers for any reduced-order power system model. The idea stemmed from the structure preservation technique and applied to mathematical models. The simplified exciter system (SEXS) and the TGOV1 (GovSteam0) were used as base models. Modifications were made to their control structure to enable the emulation of a wide range of controller responses. The control development and parameter optimization of the new modular simplified AVR (MSimAVR) and the modular simplified GOV (MSimGOV) were performed in DIgSILENT PowerFactory using particle swarm optimization (PSO), respectively. Validation of the MSimAVR and MSimGOV responses was performed by benchmarking them against other standard controller types and displayed encouraging results. The newly developed controllers were implemented, optimized, and tested on a coherency-based dynamic reduced model of the New England 68-bus test network for the intended usage. Additionally, the new controllers also demonstrated good robustness and versatility when tested in the reduced network under different fault scenarios. |
| 23977 | • **An Adaptive Control Strategy for Dynamic Response of an Autonomous DC system**<br>*Farshid Norouzi*<br><br>The dynamic behaviour - steady-state and transient - of the DC Microgrids during power disturbance can affect the system's general performance. A hybrid combination of energy storage devices with slow frequency response, like a Fuel Cell, and with a fast dynamic response, like a Super-Capacitor, provides an improved dynamic response to stabilise DC bus voltage. However, control parameters should be designed based on the preferences of the system. This paper proposes a fuzzy-based controller to |

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| | | determine the Virtual Capacitor Droop controller to achieve the desired transient response. The proposed dynamic control method is validated through MATLAB/Simulink. |
| | 28324 | • **New Solution for Optimizing the Operation of the Bottom Coil boiler to Increase Heat exchange**<br>*Victorita C. Radulescu*<br><br>Sometimes steam injection is used to extract oil, especially when it has a high viscosity, as it is the case in the oil scaffolding of Suplacu de Barcau, Bihor County, Romania. The paper presents an improved solution for the bottom coil boiler of the furnace to improve heat exchange. This method can also be used at installations from old buildings that have classic boilers in the basement, with low efficiency and high fuel consumption, compared to the European standards. This model of boiler was tested for heating a three-room house, measuring the temperature at some key points of the boiler and house. At the oil scaffolding, the recovery boiler produces part of the steam necessary for the technological extraction process, being integrated in a cogeneration power plant. Firstly, it is presented the mathematical model, associated with certain technical specifications of the fuel, air, and flue gases. The implemented changes lead to the maximization of the operating time and yields, even if the supplying agent is inadequate prepared and the assembly and operating conditions are deficient. By calculating the total heat transfer coefficient and validating the overall thermal balance, it proves to be a better solution for this type of boiler. The mathematical model is well structured, because the differences between the values calculated by numerical modeling and measured in the specific nodes are below 4.2%. Finally, due to the proposed modification in the bottom coil the efficiency of this boiler increased by about 7.1%. |
| 10:30–11:00 | ***Session: UPEC – S20*** | |
| | **Power System Economics and Electricity Markets**<br>*Chair: Mohammed Elgendy and M Emad Farrag* | S20 |
| | 24486 | • **Optimal scheduling of electric vehicle charging and discharging in a smart parking-lot**<br>*Seyed Ashkan Nejati; Benjamin Vui Ping Chong; Mahyar Alinejad; Shahriar Abbasi*<br><br>With large penetration and uncontrolled charging and discharging of Electric Vehicles (EVs) due to rapid increasing demand for clean energy, the upstream grid may face many technical issues such as energy security and reliability risk. Therefore, it is essential to carry out smart scheduling for charging and discharging of EVs. In this paper, a residential parking-lot scheme using 200 EVs as an example is developed to schedule the charging and discharging of EVs which is based on the initial and final value of the State Of Charge (SOC) of all EVs requested by the owner one day in advance, and the information the expected arrival and departure time to the parking-lot. However, errors most probably exist in this scheme where owners' requests cannot be met because of random behaviours of the other EV owners which will require the imposition of penalty. An optimisation problem is formulated to maximise the Smart Parking-Lot (SPL) profit considering random behaviours EV owners and the penalty imposed. In this paper, the aim is achieved by defining some random behaviours and penalty flexibility. The related optimising problem is solved by using the Particle Swarm Optimisation (PSO) algorithm. The effectiveness of the proposed method is verified through four different scenarios; in the first scenario, some random behaviours of EV owners are considered. In the last three scenarios, some flexibilities in penalising of the EV owners have been considered. The simulation results of all scenarios are compared and used to demonstrate the features of the proposed scheduling method. |

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| | 27762 | • **Whole Life Costing of Off-Grid Power Supplies for Rail Level Crossing Safety Systems**<br>*Arrmeila Jeyanathan; Samuel Chew; Donald Stevenson; Liana Cipcigan*<br><br>In a collaborative project between Network Rail and Cardiff University, a comparative whole life cost analysis on two off-grid power supply solutions to power an Overlay Miniature Signal Light at an unprotected crossing was completed. Following a methodology closely aligned with Network Rail standards and BS EN 60300, a renewable off-grid power supply was designed in order to be compared with the non-renewable solution currently on trial on UK infrastructure. The whole life cost analysis was performed using HOMER Pro software where parametric cost estimating was used to populate the cost breakdown structure of each system. The new solution was developed from conducting a feasibility study on a case study location. Simulation results show that the new renewable solution demonstrates a positive investment after a 20-year lifetime where the net present values of the proposed and base system were £8,207 and -£27,523.27 respectively. A roll out scenario of installation across 4,794 crossings was also done where the proposed solution showed to have a lower total whole life cost. Both solutions were modelled for the case study location Coedmawr Farm 2 Level Crossing in Carmarthenshire, Wales where an unprotecting crossing is situated. |
| | 35087 | • **Analysing Trading Trends in Continuous Intraday Electricity Markets**<br>*Priyanka Shinde; Iasonas Kouveliotis-Lysikatos; Mikael Amelin*<br><br>The intraday electricity market provides the possibility to trade closer to real-time, aiming at assisting the market participants in improving their market position, based on their updated forecasts. The growing popularity of the intraday markets coupled with the single intraday coupling (SIDC) project in Europe drives certain trends and trading behaviours, that are analysed in this paper. Further, we present different approaches to transform the price data of the historical trades into price time series. The price time series obtained is then leveraged to derive insights on the correlation of the prices in the day-ahead and intraday market; wind power and hydropower generation, and demand time series. |
| | 35274 | • **Educational and Training Program to Increase SME's Energy Efficiency Skills**<br>*Denisa Stet; Levente Czumbil; Andrei Ceclan; Stefan Cirstea; Alexandru Muresan; Dacian Jurj; Claudia Muresan; Farkas Timea; Laura Darabant; Mihaela Creetu; Grigoris K Papagiannis; Dan Micu*<br><br>A series of training courses were developed through EU founding programs focusing on the presentation of energy efficiency measures, in strong relation with energy surveys and technical data in order to quantify the best energy saving possibilities for SMEs, and by using financial tools, to prove the cost effectiveness of them. The uniqueness of the whole training program is proved by the application of the knowledge, on demo pilot sites or directly on trainee's company. The paper provides evidence especially regarding the designing and implementation of an energy efficiency training program in Romania. The aim of the course is the increasing of skills and competencies for the energy professionals within SMEs. |
| 11:00–11:30 | ***Session: UPEC – S21*** | |
| | **Automation Sustainable e-Transition**<br>*Chair: Graeme Burt and Grigoris K. Papagiannis* | S21 |
| | 27775 | • **Analysis and Experiential Verification of Power Loss in Joint Area of Laminated Transformer Core** |

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| | *Yevgeniy Kalinin; Alexander Chivenkov; Yuriy Vagapov; Alecksey Anuchin*<br><br>This paper discusses the processes of power loss development in the joint area of the laminated transformer core due to eddy currents produced by the normal magnetic flux. Normal magnetic flux is directed in perpendicular to the plane of the laminations and the dominating factor in the power loss formation in the joint area. The analytical approach was verified by a set of tests where two experimental setups have been employed to investigate power loss in the laminations under various conditions. The tests provided data on the power loss produced by the normal flux in relation to the lamination width and lamination overlap length. It was shown that the power loss in the joint area significantly depends on the lamination width and is independent of lamination overlap. |
| 27785 | • **Review of Low Aspect Ratio Blade Dynamics for Electrical Axial Fans and Compressors**<br>*Jhon Roque; Robert Bolam; Yuriy Vagapov; Shafiul Monir; Alecksey Anuchin*<br><br>The quest for lighter and shorter propulsion systems has led to the reduction of axial compressor and fan blade chord-lengths. Theoretical and experimental results show that the geometrical aspect-ratio criterion significantly affects the overall performance of axial flow compressors and fans. In conducting this review, it was found that the experimental results differ from one literature source to another. Highlighting that the way in which blade aspect ratio affects the performance of axial flow compressors and fans is still not fully understood. Nonetheless, the reviewed literature has still proven valuable for compressor and fan design. This paper focuses on creating a review of the available literature relating to how low aspect ratio blades may affect the performance of electrical axial compressors and fans. |
| 34059 | • **Impacts of Electric Vehicle Charging under Cold Weather on Power Networks**<br>*I Safak Bayram*<br><br>Deep decarbonisation of the transportation requires widespread adoption of electric vehicles (EVs). Currently, the dominant energy storage technology for EVs is lithium based batteries which are designed to work under mild ambient temperatures (e.g. 21 Celsius). However, most cities with high EV penetration experience cold winter months when the performance of EVs is significantly degraded. In this paper, we present an impact assessment of cold weather EV charging on the power networks by reviewing existing literature on empirical studies related to battery performance, EV driving range, and charger characteristics. Two potential issues are identified. First, charging EVs at low temperatures significantly increases distribution network harmonics, hence limits the number of EVs that can be charged at the same time. Second, more frequent charging of EVs increases demand from the grid. To quantify this, a Monte Carlo based simulation is developed for the case of UK and results show that nearly 450 MW of extra generation is needed to cushion impacts of cold weather charging of 11 million vehicles. The problems pertinent to temperature effects on EV charging require greater attention as EVs are becoming the main mode of transport in the next decade. |
| 35406 | • **Barriers and solutions for EVs Integration in the Distribution Grid**<br>*Simone Striani; Kristian Sevdari; Lisa Calearo; Peter Andersen; Mattia Marinelli*<br><br>The mass penetration of electric vehicles (EVs) could develop grid stability problems due to the increase of peak loads created by coincident charging factors. Smart charging is the control of the EV charging loads and has long been identified as a potential solution. Smart charging could also contribute to grid stability by mitigating the intermittent nature of renewable energy generation. This paper describes the |

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| | | current status of EV flexibility services at the distribution level. The analysis of the smart charging status is done considering the technological, economic and regulatory frameworks, and presenting what the different barriers of each of these aspects are. Additionally, the paper introduces the ACDC project (Autonomously Controlled Distributed Charger), which aims at developing an EV clustering method based on distributed smart charging control logic for flexibility services. For divulgation purposes, the scheduled test case scenario of the parking lot at the Technical University of Denmark is described. The paper concludes on some of the most relevant actions to overcome the most imminent barriers and to push further the roll-out of EV charging infrastructure towards the target EV penetration planned by policymakers. |
| | 32315 | • **An Analytic Hierarchy Process (AHP) Framework for Feature Evaluation of Smart Electricity Meters in India**<br>*Krishna Priya S; Gobind Pillai; Santanu Bandyopadhyay; Tracey Crosbie; Arnab Jana; Dana Abi Ghanem*<br><br>This paper presents as methodology for assessing the smartness required of an electricity meter from the perspective of affordable, inclusive, and sustainable electricity access in the Global South. The multicriteria decision making tool Analytic Hierarchy Process (AHP) is utilised for developing a framework for assessing smartness. The framework relies on input from experts to assign specific weights to various criteria contributing to smartness. As an example, a select few meters available in India are evaluated based on their smartness score and affordable costs, and the insights obtained are discussed. It is shown that utilisation of the developed framework provides a new means for selecting smart meters cost effectively without compromising on sustainability. |
| 11:30–12:00 | ***Session: UPEC – S22*** | |
| | **Smart Grids and Microgrids**<br>*Chair: Mattia Marinelli and Naoto Nagaoka* | S22 |
| | 32344 | • **Assessment of Roof-Top Photovoltaic Installations on the Total Harmonic Distortion of Low Voltage Distribution Networks.**<br>*Maysam F Abbod; Sadeq D. Al-Majidi; Mohammed Kh. Al-Nussairi; Jabbar Raheem Rashed*<br><br>The connections of roof-top photovoltaic (PV) systems with low voltage distribution networks have been raised dramatically in the last years due to decreasing in the capital cost and investing in the operating cost. However, the power generation of this source is variable owing to the solar irradiance dependency. This variation in the PV generation can cause a Total Harmonic Distortion (THD) into the low voltage distribution network. In this paper, the effect of roof-top PV system installations on the total harmonic distortion is assessed under different weather conditions. Regarding this, the voltage and current of an on-grid PV system composited at the roof-top of Brunel university London campus are measured and analysed for sunny and cloudy days. Furthermore, this installed PV system is developed based on MATLAB/Simulink. The results prove that the solar irradiance of the surround PV system has a significant impact on the THD-current when compared with the THD-voltage. |
| | 35572 | • **Analysis of the Performance of G3 Power Line Communication Synchronisation**<br>*Stephen Robson*<br><br>The new generation of narrowband Power Line Communication (PLC) standards, notably PRIME and G3-PLC, take different approaches to time synchronisation. This paper presents a detailed performance analysis of G3-PLC's novel approach, with a |

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| | focus on the performance in the AWGN noise channel. The paper goes on to suggest modifications to the algorithm to enable better performance on the hostile power line channel. The methodology used is based on bespoke models of the synchronisation algorithms, coded in the MATLAB programming language, providing scope for probabilistic studies under different conditions. |
| 37328 | • **Peer-to-peer energy transactioning -a DSO-centric proposal**<br>*Steven P Deacon; Gareth A Taylor; Ioana Pisica*<br><br>As the penetration of distributed energy resources in low voltage distribution systems continue, the risk that their integration presents to the smooth operation of power networks continues to rise. This is because, unlike traditional generation, renewable resources are unpredictable and generally attached to less flexible parts of the power transmission network. The solution is to encourage customers to make decisions in their usage of the power distribution network that ultimately helps keep the system stable and allow further distributed energy resources to be integrated into the network. In this context, a new peer-to-peer energy trading market is proposed, which offers prosumers an incentive to reduce trades between peers with high Impedance between them. These are usually peers located furthest from one another; this helps reduce line losses and congestion on the network. The market designed marketplace uses topology and impedance identification methods to calculate a fee reduction for each trade completed on the market. In addition, the market will use a continuous double auction clearing method to pair buyers and sellers efficiently while allowing them the opportunity to maximize the benefits they receive from taking part in the peer-to-peer market. Finally, power flow tracing is proposed to allow participants to see how their power flows through the network. The designed flow tracing graph will allow them the satisfaction of knowing that the power is being sent to/received from their trade partner, giving increased confidence in the peer-to-peer market. |
| 35555 | • **Application of Artificial Dynamics to Represent Non-isolated Single-Input Multiple-Output DC-DC Converters with Averaged Models**<br>*Muhammad Qureshi; Francesco Torelli; Andrea Mazza; Gianfranco Chicco*<br><br>This paper presents for the first time the application of a method based on the transformation of the differential algebraic equations of non-isolated Single-Input Multiple Output (SIMO) DC-DC converters into a set of ordinary differential equations, by using artificial dynamics whose asymptotic convergence to the solution is guaranteed by the satisfaction of the relevant Lyapunov conditions. The mathematical formulation is simpler than in other formulations applied in the literature to study non-isolated SIMO DC-DC converters, and encompasses the use of sensitivity functions. The results show that the proposed solution represents in a fully accurate way the dynamics of the averaged models of Zeta Buck-Boost and Ćuk Boost Combination converters. |
| 35716 | • **Review of Operational Challenges and Solutions for DER Integration with Distribution Networks**<br>*Akhtar Hussain Javed*<br><br>Traditionally, distribution networks were designed for unidirectional flow of electricity, but due to integration of distributed energy resources there is bidirectional flow of power in the system. This bidirectional flow of power has given rise to new challenges in the distribution network. These challenges include voltage variations, fairness issue, protection problems and power system stability. Grid operators also require that all converters connecting these distributed energy resources with distribution network should have the fault ride through capabilities for system reliability. In this paper a summary of these challenges occurring due to integration of distributed energy |

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| | | resources in distribution network is described. Also, a review about the solutions for these challenges available in literature is presented. |
| 12:00–12:30 | ***Session: UPEC – S23*** | |
| | **Power System Modelling and Analysis**<br>*Chair: Grigoris K. Papagiannis and Radu Porumb* | S23 |
| | 28310 | • **Analysis of zero-mode inrush current characteristics of converter transformers**<br>*Zhichang Liu; Xin Yin; Yuanlin Pan; Wei Xi; Xianggen Yin; Binyan Liu*<br><br>In recent years, there have been situations in which the zero-sequence protection of the transformer has been incorrectly operated due to the converter transformer energizing or fault recovery. For converter transformers, maloperation may also occur. However, there is almost no theoretical research on the zero-mode inrush currents of converter transformers. This paper studies the characteristics of the zero-mode inrush currents of the converter transformers, including the relationship between the amplitude and attenuation characteristics of the zero-mode inrush currents of converter transformers, and their relationship with the system resistance, remanence, and closing angle. First, based on the T-type equivalent circuit of the transformer, the equivalent circuit of the zero-mode inrush current of each transformer is obtained. On this basis, the amplitude relationship of the zero-mode inrush currents of different converter transformers is obtained: the zero-mode inrush current of the energizing pole YY transformer becomes larger than the YD transformer, the energized pole YD becomes greater than the YY transformer, and the YY transformer zero-mode inrush current rises from 0. It is also analyzed that the sympathetic interaction will make the attenuation of the converter transformer zero-mode inrush current slower. The system resistance mainly affects the initial attenuation speed, and the later attenuation speed is mainly determined by the converter transformer leakage reactance. Finally, PSCAD modeling and simulation are carried out to verify the accuracy of the theoretical analysis. |
| | 35459 | • **Modelling Stability Improvement In Kazakhstan's Power System By Using Battery Energy Storage**<br>*Ansar Berdygozhin; Dauren Akhmetbayev; David Campos-Gaona*<br><br>Kazakhstan is going to increase the share of RES up to 10% until 2030 and up to 50% until 2050. The current share of RES is 3% and BESSs are not used. This paper analyzes the simplified national power grid and the ability of BESS participation in frequency regulation in accident loss of generation on one of the stations. The results show that BESS only is not enough to keep frequency in desirable restrictions. |
| | 35695 | • **Load Flow Analysis of the Nigerian Transmission Grid Using DIgSILENT PowerFactory**<br>*Omowumi Olasunkanmi; Zhida Deng; Grazia Todeschini*<br><br>The subject of this work is the development of a load flow model for the Nigerian 330 kV transmission system. The model has been developed in DIgSILENT PowerFactory based on data provided by the Nigerian Electricity system operator (NESO). Two scenarios (summer and winter) were considered: for each scenario, load data, generator data, and transmission line parameters were used as inputs to the model. The voltage profiles resulting from the load flow were compared with the original data, and some discrepancies were found. Assumptions and modifications were made to achieve load flow results that were closer to the system data. The results show that in summer and winter, power generated was 4804.10 MW and 4394.41 MW, respectively. The bus voltages were within the voltage magnitude of 0.85 pu and 1.05 pu, according to the local grid code. The model documented in this paper will be used |

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| | | as a baseline for reliability and stability studies. This research aims to identify potential reinforcements to the 330 kV Nigerian transmission system to meet future electricity demand. |
| | 35604 | • **An Evaluation of Graph Algorithms for the Wind Farm Cable Layout Problem under Electrical Aspects**<br>*Sascha Gritzbach; Huseyin Cakmak; Pascal Mehnert; Torsten Ueckerdt; Veit Hagenmeyer*<br><br>The task of the Wind Farm Cable Layout Problem is to design a cable system between turbines and substations such that all turbine output can be transmitted to the substations. This problem can be modelled with different levels of complexity. While a higher level of complexity yields solutions that can be implemented in a real-world setting more readily, problem instances also become more difficult to solve or even remain intractable. More simplistic models are easier to solve but their usability could be inhibited. One such more simplistic model for installation cost minimization contains a network flow and a suitable minimum-cost flow algorithm provides good cable layouts on instances with up to 500 turbines within tens of seconds. The question remains whether those cable layouts are suitable for electrical implementation as well. We propose a workflow to evaluate the cable layouts generated from such algorithms under electrical aspects. This workflow converts the output of cable layout optimization algorithms to power flow models. The power flow models are simulated using the simulation framework eASiMOV. The evaluation of the power flow simulations under electrical metrics shows that output from the minimum-cost flow algorithm and from an approach solving a Mixed-Integer Linear Program perform very well under electrical aspects on a vast majority of input instances. For the remaining minority we are able to identify structures in the solutions that result in a worse performance. These observations can be used by the algorithm engineers as possible directions for future improvements. |
| | 35026 | • **Soft Transformer Energization: Ramping Time Estimation Method for Inrush Current Mitigation**<br>*Abdulrahman Alassi; Khaled Ahmed; Agusti Egea-Alvarez; Colin E.T. Foote*<br><br>Uncontrolled transformer energization is known to cause high magnitude inrush currents that can reach up to 10 times transformer rating. Several techniques are proposed in literature to mitigate this issue, including soft transformer energization using a voltage ramp. This technique is regaining more traction with the increased use of converters-based generation. Defining the required voltage ramping time for effective inrush current mitigation is important to avoid fast ramps that can still cause large inrush currents. This paper proposes a model-based ramping time estimation technique that can be used to identify the minimum-adequate voltage ramp time for a given set of constraints, transformer model and network configuration. Key ramping time influencing factors are defined as: residual flux, source to energized core effective impedance and control, in addition to core saturation characteristics. The proposed method considers multiple simulation steps to identify the minimum required ramping time. Simulation case study is presented for a voltage source energization of a 53 MVA three-phase delta-wye transformer, demonstrating the technique capability of determining appropriate ramping times for effective inrush current mitigation. Sensitivity analysis are also carried out to illustrate the impact of varying key parameters such as the transformer core saturation characteristics on the results. |
| 13:30–13:30 | ***Session: UPEC – S24*** | |
| | **Renewable Energy Systems**<br>*Chair: Mattia Marinelli and Hassan Nouri* | S24 |

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| 25035 | • **Techno-Economic Analysis of a Commercial Factory's Renewable Energy System Replacement Alternatives**<br>*Jake H Stott; Gobind Pillai; Neville Winter*<br><br>Renewables typically have a finite life expectancy of around 20 to 30 years. An existing wind energy system for a large commercial factory in the rural area of Barnard Castle, United Kingdom (UK) is nearing the end of its usable life. The existing system is operating at 8 % load factor, providing only 5 % of the site annual load. A techno-economic assessment of three renewable energy proposals will ensure the site's energy strategy is successful. Three proposals were examined, to continue with the current system until failure, to overhaul the current system and prolong its usable life, or to replace the wind turbines with a rooftop photovoltaic (PV) system. The Net Present Value, Payback Period, Levelised Cost of Electricity and the equivalent Carbon Dioxide emissions were compared for each alternative. The photovoltaic system was the unanimous choice. The Analytical Hierarchy Process was used to systematically select the most appropriate PV module technology for the proposed system, based on the most important factors. Seven different PV module variants were selected and given weighted ratings to determine the most suitable model, the outcome of this was the SunPower SPR-MAX2 360 model. This decision was verified by the Consistency Ratio which indicated an informed decision had been made. |
| 34593 | • **High Gain DC-DC Multilevel Boost Converter to Enable Transformerless Grid Connection for Renewable Energy**<br>*Abdulrahman Essa Alsafrani; Mason Parker; Mahmoud Shahbazi; Alton Horsfall*<br><br>The solid state transformer (SST) is a new technology that will result in the replacement of traditional line frequency transformers in applications demanding high-power density and greater level of control. This paper describes a new form of boost converter to support the development of SST to enable the grid connection of renewable energy sources, such as wave energy and photovoltaics. SST contains the initial low voltage AC-DC converter, a high gain transformer based DC-DC converter, and the output high voltage DC-AC converter. A transformerless DC-DC Multilevel Boost Converter (MBC) is proposed, which combines the traditional boost converter with switched capacitor topology to realise a high voltage gain with only one driven switch and passive components. The main advantages of the proposed converter are the ability to realise high voltage gain without the need for an extreme (>80%) duty cycle, resulting in low voltage stress on the switching device and the creation of three self-balanced voltage levels at the output. The simulation results of the proposed topology are compared to the experimental results to validate the analyses. Thus, a 1 kW prototype MBC converter operating at 75 kHz is reported that resulted in a voltage gain of 10, with an experimental efficiency of 92.4% at a duty cycle of 71%, which compares favourably with the simulated efficiency of 94.5% under the same operating conditions. |
| 35032 | • **Modified Grid-forming Converter Control for Black-Start and Grid-Synchronization Applications**<br>*Abdulrahman Alassi; Khaled Ahmed; Agusti Egea-Alvarez; Colin E.T. Foote*<br><br>The increasing grid integration of converter-based generation and distributed resources is necessitating a review to the classical synchronous generators dominant network models, and to equip converters with the necessary control capabilities such as inertia emulation and black-start to carry on the required ancillary services provision. This paper proposes a modified grid-forming converter control technique based on virtual synchronous machine (VSM). The modified controller uses a ramping voltage reference to achieve soft transformer energization and eliminate high-magnitude inrush current that can traditionally exceed converters rating. Grid- |

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| | | synchronizing functionality is added to the VSM controller to achieve smooth transition from black-start to grid-connected mode while maintaining grid-forming operation. This is achieved by gradually adjusting the power loop reference through a dedicated synchronizing controller, which is disconnected once grid-connection is achieved. A MATLAB/ Simulink case study is presented to illustrate the controller performance with a 40 MVA simulated converter. The results demonstrate successful black-start sequence execution, starting by soft transformer energization, followed by a block load pickup and grid-synchronization. The sequence is achieved with minimal transformer inrush current, and with seamless transition to the grid-connected operating mode. |
| | 27376 | • **Design and Modified Radial Flux Synchronous Generator Using V-Shaped Permanent Magnet Method**<br>*Elsa Mariana Munawaroh I; Sutedjo Sutedjo; Endro Wahjono*<br><br>Indonesia has the potential for low-speed wind energy which can be used as an energy source for electricity generation. Permanent Magnet Synchronous Generator (PMSG) is a technology used for applications in wind turbines. Permanent Magnet Generators based on the direction of the flux are categorized into two groups, namely radial flux and axial flux. PMSG technology with radial flux direction has been developed with various geometric variations used to overcome common problems in generator performance, one of which is by modifying the modeling of the stator iron core and rotor. Therefore, it is necessary to develop low-speed PMSG with radial flux direction. In this paper, a design and simulation will be carried out using the umbrella field method on the stator design and the V-Shaped Magnet Neodymium (NdFeB) model in the rotor design based on specifications to obtain performance values when the engine is operating. The generator is designed to get a voltage of 140 volts and 200 watts of power at a speed of 750 RPM. The design and simulation process was carried out using Finite Element Method (FEM) based software. |
| 13:30–14:00 | ***Session: UPEC – S25*** | |
| | **Condition Monitoring and Diagnostics**<br>*Chair: M Emad Farrag and Alecksey Anuchin* | S25 |
| | 29953 | • **Power Quality Event Classification in Distribution Grids Using Machine Learning**<br>*Thet Paing Tun; Gobind Pillai*<br><br>With the penetration of non-linear loads, renewables and distributed generation with power electronic converters, solutions for maintaining good power quality have become a major concern for the stakeholders of electrical power systems. In this paper, a machine learning based model for power quality event classification is developed and tested. 16 categories of the most commonly occurring power quality events are classified by means of wavelet transform and select machine learning based methods to evaluate the best performing machine learning model. The outcome of classifications and effectiveness of machine learning methods is evaluated using the 'Classification Learners' application in MATLAB. The selected machine learning model is implemented in Simulink for test distribution grid circuits. The results obtained from simulation showed acceptable accuracy and performance and demonstrated the efficiency of the model in different operating conditions. |
| | 35726 | • **Generation of synthetic datasets for transformer's dissolved gas analysis using Monte-Carlo Simulation**<br>*Eaby Kollonoor Babu; Imran Bashir, IB; Gobind Pillai; Kiran Jyothi*<br><br>The fault diagnosis in power transformers is carried out using Dissolved Gas Analysis (DGA). Although DGA does provide key information for fault detection, but the method |

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| | is inherently complex. Several methods have been developed for DGA, but still possess challenges in accurately detecting the fault. A method has been developed to generate synthetic data using Monte-Carlo simulation. The generated synthetic data is feed into DGA excel tool to investigate the accuracy of fault detection. The synthetic data generator further integrated with machine learning to obtain an automated and improved DGA tool for fault diagnoses in power transformer. |
| 24186 | • **Novel Hybrid Invasive weed optimization and Machine Learning Approach for Fault Detection**<br>*Alasmer Ibrahim; Fatih Anayi; Michael Packianather; Osama Al-Omari*<br><br>Fault diagnosis of anomalies in induction motors is essential to ensure industry safety. This paper presents a new hybrid Invasive Weed Optimization and Machine Learning approach for fault diagnosis in an induction motor. The vibration signal provides a lot of information about the motor's operating condition. Therefore, the vibration signal of the motor was chosen to investigate the fault diagnosis. Two identical 400-V, 50-Hz, 4-pole 0.75 HP induction motors were under healthy, mechanical, and electrical faults tested in a laboratory with different loadings. A hybrid model was developed using the vibration signal, the Invasive Weed Optimization algorithm (IWO), and machine learning classifiers. Some statistical features were extracted from the signal using Discrete Wavelet Transform (DWT). The invasive weed optimization algorithm (IWO) was utilized to reduce the number of the extracted features and select the most suitable ones. Then, three classification algorithms namely k-Nearest Neighbor neural network (KNN), Support Vector Machine (SVM), and Random Forest (RF), were trained using k-fold cross-validation and tested to predict the true class. The advantage of combining these techniques is to reduce the training time and increase the average accuracy of the model. The performance of the proposed fault diagnosis model was evaluated by measuring the Specificity, Accuracy, Precision, Recall, and F1_score. The experimental results prove that the proposed model has achieved more than 99.90% of accuracy. Furthermore, the other evaluation parameters also show the same representation of performance. The hybrid model has proved successfully it's robust for diagnosing the faults under different load conditions. |
| 35644 | • **A Real-Time Prioritization Approach Applied for System Identification Request Coordination in Multi-Rail Power Conversion Architecture**<br>*Jin Xu; Matthew Armstrong; Maher Al-Greer*<br><br>To rank System Identification (SI) requests of multi-rail power converters based on system variation severity in real time, this paper presents a ranking approach which dynamically updates priorities in hard-real-time. By comparing quantitated application importance and severities of system variations of rails, their ranks can be acquired. Besides, a window time is set aside in SI processes, only during which higher priority requests may interrupt SI processes of lower priority rails so that estimation opportunities can be provided to both high and low priority rails in rush hours. The paper also proposed to save intermediate iteration results, acquired from interrupted SI processes, for being continuously used once the processes recover to save computational cost. For validation, this technique is applied for a five-rail power conversion architecture. The proposed workflow also shows high flexibility as all variables included in this approach are user-defined to match individual requirements. |
| 40045 | • **Enhanced Modeling and Experimental Verification of a ThermoElectric Refrigerator Unit Considering the Door Opening Effect**<br>*Cesar Diaz-Londono; Diana Enescu; Andrea Mazza; Fredy Ruiz; Gianfranco Chicco*<br><br>This paper introduces some novel aspects concerning the circuit-based modelling of |

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| | | ThermoElectric Refrigerators (TERs) used for the purpose of time-domain simulations. Starting from a previously published model, some enhancements have been introduced to represent with more details the point at which the temperature is monitored inside the TER compartment, and in particular to take into account the effects of door opening with different duration and in different conditions. The novel circuit model has been validated through experiments carried out on a real TER. In particular, a small-size TER has been used for the experiments. The advantages to consider a small-size unit is that the temperature variations following door opening are large and the identification of the suitable model and parameters becomes more challenging. The results show that the door opening effect can lead to a significant temperature transient, that can continue for a long term (hours) especially when more thermal loads are located in the TER compartment after door opening. |
| 14:00–14:30 | ***Session: UPEC – S26*** | |
| | **Electric Vehicles and e-Mobility**<br>*Chair: Graeme Burt and Radu Porumb* | S26 |
| | 35735 | • **Optimisation of locally connected renewables for high power EV charging station**<br>*Benjamin Aaron Hunter; Gill Lacey; Huda Dawood*<br><br>All over the world, renewable energy technologies which need power electronics-based inverters in their designs are becoming more and more popular, thus detailed analysis to test the operational efficiency is required. This paper utilizes a new adaptive Multi-verse Optimization (MVO) Algorithm combined with novelty search method to solve harmonic elimination problem in multilevel inverters. We compare the obtained numerical simulations to those obtained by using the grey wolf optimization and standard MVO algorithm. The numerical simulations are performed on 7, 11, and 15 level inverters with different modulation indexes. From the simulation results, we observe that adaptive novelty search Multi-verse Optimization(MVO) based approach was able to obtain less total harmonic distortion for different modulation indexes |
| | 15200 | • **Optimization of Multilevel Inverters Using Novelty-driven Multi-verse Optimization Algorithm**<br>*Oguzhan Ceylan; Mehdi Neshat; Seyedali Mirjalili*<br><br>Constantly increasing uptake of Electric Vehicles (EVs) necessitates a rapidly growing and evolving network of charging stations, including rapid charging systems which attempt to make up for the issue of slow charging. Rapid charging systems, however, can be difficult to implement in larger scale due to the heavy energy supply capacity required and the disruptive nature of the load that they place on the electrical network. This paper examines some of the potential benefits that can be seen by incorporating a Battery Electrical Storage System and directly connected Renewable Energy Systems into EV Rapid charger installations, as well as some of the ways that energy may be managed in such a system |
| | 35228 | • **Ev Fast Charging Microgrid On Highways: A Hierarchical Analysis For Choosing The Installation Site**<br>*Joelson Lopes da Paixao; Alzenira da Rosa Abaide; Jordan Passinato Sausen; Leonardo Nogueira da Silva*<br><br>This paper presents the development of a methodology to evaluate candidates places for installation an EV fast charging microgrid (EVFCM), composed by charging station, electrical grid connection, photovoltaic carport and a small wind generation. The methodology proposed focus on evaluating pre-defined points over eleven different criteria, such as: vehicle flux, proximity of medium voltage grid, availability of wind and |

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| | | solar generation, and socioeconomical data from place and population. The overall goal is to classify hierarchically this points to find the best options places to install the EVFCM. The case study is applied in the east of the state of Rio Grande do Sul, and the predefined points are sitting along important highways that connect Brazil to Uruguay. |
| | 35494 | • **Proposal of a load curve modeling applied to Highway EV Fast Charging Stations**<br>*Leonardo Nogueira da Silva; Alzenira da Rosa Abaide; Jordan Passinato Sausen; Joelson Lopes da Paixao; Cristian Correa*<br><br>One of the greatest challenges of EV penetration is to ensure conditions of large distances travel, mainly by the battery range capabilities and the impact of charging events in the total travel time. For these reasons, it is fundamental to develop fast-charging station (FCS) infrastructures applied to highways. The decrease in charging times implies an increase in charging power. Moreover, the load curve shape of FCS is highly impacted by user's patterns, with a stochastic behavior. Many studies are being developed to evaluate the impact of FCS on Power Systems, based on the EV penetration increase. By the innovative technology and a small sampling of these applications yet, the development of tools to generate FCS scenarios is important. This paper shows a proposal of FCS load curve modeling, based in a mixed process of a deterministic model, to estimate the traffic and the FCS operation, and a stochastic model, based on a Monte Carlo simulation, to determine aspects as charging time length and FCS entry rate. The model was applied in a case study, based on a Brazilian highway. The load curves obtained indicate compatibility between scenarios and inputs, and the fast saturation of a static FCS infrastructure by the increase of EV market share. |
| | 35613 | • **Transient Analysis of Vehicle-to-Grid Systems Incorporating Plug-in Electric Vehicles**<br>*Olapade O Olagbemi; Pablo Gomez; Richard T. Meyer*<br><br>Vehicle-to-grid (V2G) systems are being considered as complementary sources for peak shaving and load levelling on traditional power grids. However, the harmonics and transients associated with this technology may threaten utility grid power quality, stability and equipment reliability. In this study, the transient behavior of a V2G system under varying grid and vehicle load conditions is examined using a test system. Bidirectional converter transient behavior is simulated to predict the relationship between V2G load variations and associated transients. Potential applications of this test system include the prediction of grid conditions that could lead to equipment failure, and the design and evaluation of equipment protection for V2G systems. |
| 14:30–15:00 | Break | |
| 15:00–15:30 | ***Speed networking*** | |
| 15:30–16:00 | Break | |
| 16:00–16:30 | ***Time for networking*** | |

| Friday September 03, 2021 | |
|---|---|
| 9:00–9:45 | ***Session by Lucas-Nulle***<br>• **Lucas-Nuelle didactic training systems sponsor webinar** |
| 9:45–13:00 | Break |
| 10:30–12:00 | ***Final event, awards, handover to UPEC 2022 and closing*** |

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