

## **C6 - ACTIVE DISTRIBUTION SYSTEMS AND DISTRIBUTED ENERGY RESOURCES**

### **SPECIAL REPORT FOR SC C6**

**Barbara HERNDLER**  
(Preferential Subject 1)

**István VOKONY**  
(Preferential Subject 2)

**Ray BROWN**  
(Preferential Subject 3)

#### **Special Reporters**

**Chair SC C6: Kurt DEDEKIND**

**Secretary SC C6: Evert DE HAAN**

### **INTRODUCTION**

The focus of Study Committee (SC) C6 for 2024 revolves around assessing the technological impacts and operational necessities in active distribution systems, as Distributed Energy Resources (DER) become more prevalent, and a significant portion of power generation becomes non-dispatchable. Concurrently, SC C6 evaluates the enabling technologies and innovative approaches necessary for the integration of DER into active distribution networks. Considerations extend to the fields of rural electrification, demand-side integration techniques, and the utilization of storage solutions and electric vehicles as components of DER.

For the upcoming CIGRE Session 2024, SC C6 has defined three Preferential Subjects that mirror the evolving challenges and opportunities within the energy sector:

- PS1: Flexibility Management in Distribution Networks - Explores how distribution systems can adapt to varying supply and demand dynamics to ensure operational efficiency and sustainability.
- PS2: Power Electronic based Solutions for Smart Distribution Systems - Focuses on the application of advanced power electronics to enhance the intelligence and responsiveness of distribution systems.
- PS3: Rural, Islanded and Industrial Electrification Standards, Practices and Technology Options - Addresses the specific challenges and solutions relevant to electrifying rural, isolated, and industrial areas with innovative and sustainable approaches.

A total of 72 papers have been selected for presentation and discussion at the CIGRE Session 2024 - 44 for PS1, 12 for PS2 and 16 for PS3, distributed among the Preferential Subjects to provide a comprehensive view of current research and development efforts. The insights from these papers are crucial for fostering a robust discussion and will form the basis for the questions and dialogues anticipated during the Group Discussion Meeting (GDM). This structured dialogue aims to enhance understanding and promote the development of practical solutions in the field of electric power distribution.

PS1: Barbara Herndler: [Barbara.Herndler@ait.ac.at](mailto:Barbara.Herndler@ait.ac.at)

PS2: Istvan Vokony: [vokonyistvan@gmail.com](mailto:vokonyistvan@gmail.com)

PS3: Ray Brown: [ray\\_brown@ieee.org](mailto:ray_brown@ieee.org)

Briefly unpacking the process that is to be followed, it is necessary to understand how the Paris Conference functions. The following steps will guide your responses to the Special Report that has been compiled for SC C6.

### **Session Papers**

Session Papers focussed on a number of Subjects – referred to as ‘Preferential Subjects’ – selected in advance by the 16 Study Committees of CIGRE and which subsequently formed the basis of the accepted papers in response to the [Call for Papers](#) for the Conference.

The Session Papers for the Conference undergo a two-phase review process – abstracts and full Papers. A reference to the [Technical Programme](#) in the Conference Registration portal will provide you with an overview of the list of selected Papers for the various sessions, and provide you with a perspective overview of the subjects that will be discussed.

### **The Format of the CIGRE Sessions**

At the CIGRE Paris Conference, Session Authors are given the opportunity to present their Paper via a Poster session. The **Poster Session** for SC C6 will be taking place on **Tuesday 27 August 2024 and will be held in Hall Ternes, Level 1 from 08h30 to 12h30.**

Specific days are also dedicated to the ‘Group Discussion Meetings’ (GDMs) that are organised by the respective Study Committees. Four GDMs run concurrently each day from Tuesday to Friday, under the chairmanship of the Study Committee Chair and the assigned Special Reporters for each of the Preferential Subjects. The purpose of the GDM is to create a platform for the discussion of the Session Papers based on the ‘Special Report’ for SC C6. The Special Report summarises the scope of the Session Papers, which then raise several questions and curiosity into real-life experiences, for discussion at the GDM platform.

To allow for fruitful discussions at the GDM, delegates are strongly encouraged to read the applicable Session Papers of interest, before the GDM.

The set of Session Papers is made available for downloading to all registered delegates before the Session via their private account on the [registration portal](#). Papers can also be accessed on the Conference application, whilst in Paris. It is thus encouraged to follow the C6 session news, general program and updates, by visiting the website.

### **Participating in the 2024 Paris session**

You are invited to participate in discussing the topics in this Special Report at the **C6 Group Discussion Meeting on Wednesday 28 August 2024** at the ‘Le Palais des Congrès de Paris’.

The Special Reporters have compiled 34 questions. These are not specifically aimed at the authors of the papers but are synthesised from common issues and trends identified across the papers. This provides the opportunity for a broader response and participation in the GDM.

We encourage you to share your views or experiences *in response to the specific questions* in this report.

#### ***Procedure for contributions.***

1. Contributors should **upload their contribution** on the [registration portal](#) – “Contributions to Group Discussion Meetings” section – using their existing account and own credentials **before 10<sup>th</sup> August 2024, 18.00 CET** for a prior screening and a good organization of the Group Discussion Meeting.

#### **Important points:**

- Access to contribution uploading is given only to duly registered delegates.
- Consequently, **registration to the CIGRE Session** should be finalized before uploading contribution(s) online.
- Uploading of contributions may commence from the start of June 2024.

2. Special Reporters will review the prepared contributions (PowerPoint presentation with maximum 3 slides and a written Word file with maximum 1000 words per contribution). A guide for contributors as well as templates and sample pages will be available on the [Paris Session 2024 webpage](#). Any recommendations or changes to the contributions will be provided to the contributors by the Special Reporters directly on the registration portal between **10<sup>th</sup> of August and 17<sup>th</sup> of August 2024**. Contributors are encouraged to visit their account on the [registration portal](#) to see the result of this review.
3. All contributors with accepted/finalised contributions will be contacted by the Special Reporters of SC C6 by email between **10<sup>th</sup> of August and 17<sup>th</sup> of August 2024**, to finalize the presentation and receive the instructions regarding the session. There will be a limit to the number of contributions for each Preferential Subject (PS1, PS2 and PS3) of SC C6.

There might be the opportunity for spontaneous contributions during the session, which will only be verbal with no slides. Attendees who provide a spontaneous contribution, are encouraged to summarise their contribution as a short, written response for the Proceedings. This text is required to be forwarded within two weeks after the SC C6 Session by **Tuesday, 10 September 2024** to be considered for inclusion into the Conference proceedings.

**No new contributions will be accepted after 10 August 2024, 18.00 CET.**

The Contributors' meeting for SC C6 is **on Tuesday 27 August 2024 from 08h30 to 10h30**, where the contributor attendance and timing of the program will be checked and finalised. No last-minute changes to the contributions will be accepted at this stage. The venue for this Contributor's meeting will be held in the same venue as the C6 Poster Session, in Hall Ternes, Level 1.

**The contributions received will revolve around the list of question posed by the respective Special Reporters. The summary of the papers and the ensuing list of questions / thoughts to consider, are posed in the section that follows.**

**PREFERENTIAL SUBJECT 1 – Flexibility Management in Distribution Networks**  
**Special Reporter: Barbara Herndler, Austria**

The following main topics are addressed in Preferential Subject 1 (PS1):

- Strategies to ensure uninterrupted power supply, manage DERs, and enhance resilience in distribution networks.
- Integration, optimization, and economic viability of battery energy storage systems (BESS) and renewable energy sources across different regions and sectors, environmental factors, total cost of ownership (TCO) optimization, and overcoming integration barriers.
- Development of innovative energy management and grid optimization solutions, including local ancillary service markets (LASM), energy communities, electric vehicle (EV) integration, flexible resource mobilization, blockchain for peer-to-peer trading, gravity energy storage systems (GESS), and demand response strategies.
- Modernizing grid infrastructure and enhancing flexibility through the integration DERs and demand-side management, covering terminology standardization, DER valuation, congestion management, operational planning for DSOs, EV charging infrastructure, hosting capacity, control strategies, and load forecasting for microgrid design.
- Proactive controls, automated switching, Distributed Energy Resource Management Systems (DERMS), flexibility utilization, energy routers, non-wire alternatives (NWAs), and other advanced technologies.

A total number of 44 papers were received with representation from 24 countries and 4 continents, and where most of the authors came from Europe.

The papers have been grouped into the following subtopics:

- 1. Analysis and Management of Flexibility and Resilience in Distribution Systems**  
Papers 10247, 10473, 10476, 10478, 11131 and 11702
- 2. Innovations in Energy Storage Integration and Utilization**  
Papers 10390, 10480, 10548, 10645, 10987, 11135 and 11563
- 3. Innovations in Local Energy Market Models and Ancillary Services Provision**  
Papers 10244, 10392, 10393, 10394, 10409, 10511, 11342 and 11653
- 4. Advanced Distribution Grid Planning and Management**  
Papers 10472, 10475, 10477, 10551, 10560, 10823, 10984, 10985, 10997, 11000, 11239 and 11293
- 5. Advanced Grid Technologies and Analytics**  
Papers 10474, 10479, 10681, 10690, 11157, 11324, 11360, 11409, 11415, 11417, 11443 and 11452

### **Subtopic 1: Analysis and Management of Flexibility and Resilience in Distribution Systems**

The collection of papers explores various aspects of ensuring uninterrupted power supply, managing distributed energy resources (DERs), and enhancing system resilience in distribution networks. Topics covered include the role of mobile energy storage systems (MESS) in mitigating power outages during extreme disasters, integrating DER-provided services, resilience planning frameworks, and the impact of electric vehicle (EV) adoption on grid reliability. Additionally, practical trials of distributed energy resources for black start capabilities provide valuable insights for real-world application.

**Paper 10247:** The paper discusses the challenges faced by distribution systems in maintaining uninterrupted power supply, particularly in the case of extreme disasters. It highlights the importance of energy storage solutions, particularly mobile energy storage systems (MESS), in mitigating power outages in order to ensure security of supply. The research focuses on optimizing the deployment and operation of MESS to minimize outage times and increase system resilience. A two-stage robust optimization model is proposed and considers the feasibility and uncertainty of photovoltaic output. Simulation results, based on an active distribution network test case demonstrated the effectiveness of the proposed pre-layout strategy for MESS in improving system resilience. The results also provided insights into the use of photovoltaic inverter which can provide support by providing reactive power flexibility.

**Paper 10473:** The paper discusses the potential impact of DER, and the risk factors which are to be managed by DSOs. The paper addresses the risk of failing to serve customers as a primary concern, with consequences including delayed connections and service interruptions. Integrating DER-provided services requires utilities to assess both capacity and energy requirements, unlike traditional planning focused mainly on capacity. The paper offers a comparison between these two methodologies, which can be used to mitigate the risk of interruption. An assessment of contingency management practices, i.e. proactive and corrective is also provided.

**Paper 10476:** This paper takes a high-level look at the issues of reliability and resilience for distribution networks. It discusses the differences and similarities between the two concepts and the fact that reliability has long been a consideration in planning and operating distribution networks but that interest in resilience is more recent. It considers requirements for metrics that can be used for quantifying resilience. It also discusses frameworks for distribution resilience planning.

**Paper 10478:** The paper explores the crucial need for collaboration between the electric utility and transportation sectors to uphold electric power system reliability amidst the increasing adoption of electric vehicles (EVs). It investigates the dynamic behaviour of EV charging loads and their impact on grid reliability, especially during transient stability events like faults. Key points include the rapid EV adoption, categorization of grid reliability impacts, development of EV charging load models, benchmarking, study results on EV load impacts, fault sensing delay effects, and frequency response to grid disturbances. It accentuates the urgency of adopting grid-friendly EV charging behaviours and ongoing sectoral collaboration to address reliability challenges posed by transportation electrification.

**Paper 11131:** This paper presents the results of a very interesting demonstration on a real network in the United Kingdom of the use of distributed energy resources for a blackstart. Tests were carried out in 2023 on two different networks with different characteristics and the paper presents the practical results and lessons learnt from the trials.

**Paper 11702:** This paper addresses the operational challenges of integrating hydroelectric turbines with thermal generation units to provide frequency containment reserve (FCR) and automatic frequency restoration reserve (aFRR) in non-interconnected islands. It details the performance of these systems during testing, highlighting the complexities and potential solutions for managing diverse generation types to enhance grid stability and reliability.

#### **Questions:**

##### Question 1.1.1:

What are the key risk factors associated with integrating distributed energy resources (DERs) into distribution systems? How do traditional planning methodologies differ from approaches that incorporate both capacity and energy requirements when integrating DER-provided services, and what are the implications for mitigating the risk of interruption?

##### Question 1.1.2:

What are the implications of cross-sectoral collaboration between the electric utility and transportation sectors on enhancing grid reliability, and how can regulatory frameworks facilitate effective coordination and communication between these industries?

##### Question 1.1.3:

The trial used one or two larger generators rather than lots of smaller DER. Would, using many smaller DERs be feasible / cost effective? Black-start events are relatively rare. Is it worth maintaining all the required infrastructure? Can it be put to other uses?

#### **Subtopic 2: Innovations in Energy Storage Integration and Utilization**

The papers explore the integration and optimization of battery energy storage systems (BESS) and renewable energy sources in various contexts. Topics include the economic benefits of BESS integration, environmental factors influencing deployment across different regions, optimization methodologies for placement in distribution networks, and overcoming barriers associated with BESS integration into power grids. Additionally, there's a focus on total cost of ownership (TCO) optimization in specific sectors like data centres and isolated power systems, with studies demonstrating the economic viability and potential revenue streams of BESS deployment.

**Paper 10390:** The paper provides a comprehensive analysis of the potential benefits of integrating renewable energy sources and battery energy storage systems into the supply system of a major inland port on Lake Maggiore, Italy. A detailed technical-economic evaluation, including investment costs, operational expenses, and cost parity analysis is provided. Additionally, the sensitivity analysis on energy prices enhances the robustness of the findings, demonstrating the importance of market dynamics in determining the economic viability of renewable energy integration.

**Paper 10480:** This paper provides a comprehensive analysis of the environmental factors influencing the deployment and financial aspects of BESS across various European countries. It emphasizes the importance of understanding these differences in ancillary service markets to make informed BESS deployment decisions. The proposed environmental analysis provides insights into the impact of various factors such as government investment in power grids, variable renewable energy penetration, energy storage competition, renewable energy demand, and events impacting electricity and ancillary services market prices, allowing for an evaluation/scoring/ranking of evaluated countries. A potential revenue analysis is then presented, to provide insight into NPVs for BESS integration and indicates a correlation between environmental readiness and financial outcomes.

**Paper 10548:** The paper provides a detailed investigation into the potential use and effectiveness of large-scale Portable Energy Storage (PES) systems in electrical distribution networks. The paper recognises the importance of flexible power solutions for addressing challenges in the electrical power grid and investigates the integration of ESS. The authors propose an optimisation methodology to identify the time and location for the placement of the ESS within an exemplary distribution network in the UK.

**Paper 10645:** This paper presents a design methodology for installing a battery energy storage system (BESS) on a geographic island. The study includes a techno-economic analysis, fault-current contribution from the BESS and dynamic studies. The results of some of the studies performed are included in the paper.

**Paper 10987:** The paper focuses on the integration of BESSs into the Norwegian electric power grid to assist in overcoming barriers associated with introducing fast-charging stations for electric vehicles (EVs). A GAP analysis was conducted to assess the current situation, future prospects, and solutions for integrating BESSs into the distribution grid. An assessment of solutions to reduce the gap between current and future scenarios, alongside their advantage and disadvantages is provided. The authors provide emphasis on the interest in utilizing BESS for reducing grid fees, alleviating distribution grid challenges, and increasing the profitability of charging stations in the future.

**Paper 11135:** The paper explores the role of BESS in data centres, focusing on total cost of ownership (TCO) optimization. It introduces optimization methods like two-stage stochastic optimization and Benders' decomposition and presents a German case study demonstrating the economic benefits of BESS integration.

**Paper 11563:** The paper presents an optimal design for integrating Energy Storage Systems (ESS) with Large Scale Solar (LSS) plants in Malaysia to tackle grid stability issues and maximize revenue. The study aims to quantify the true value of ESS by considering revenue streams such as avoided renewable energy curtailment and frequency regulation. Using a Genetic Algorithm (GA) approach, operational strategies are developed based on these revenue streams to ensure optimal ESS dispatch. The proposed approach offers valuable insights into optimizing ESS deployment, with potential implications for informing policies and strategies in other developing countries with similar renewable energy integration goals.

## **Questions:**

### Question 1.2.1:

How do the unique geographical and operational characteristics of major inland ports, such as those in remote areas, influence the potential benefits and challenges of integrating renewable energy sources and battery energy storage systems (BESS)? What advanced control strategies and grid management techniques can be employed to maximize the efficiency and reliability of renewable energy and BESS integration in inland port supply systems, especially during peak demand periods or emergency situations?

### Question 1.2.2:

What are the technical challenges associated with the integration of large-scale Portable Energy Storage (PES) systems into electrical distribution networks, such as grid compatibility, interoperability with existing infrastructure, and safety considerations? How can advanced modelling and simulation techniques be utilized to identify optimal placement and sizing of Energy Storage Systems (ESS) within distribution networks, considering factors such as load profiles, network topology, and voltage stability?

Question 1.2.3:

The addition of the BESS system allows for a reduction in usage of diesel fuel and increased the stability of the system in the example presented. What issues need to be considered to make sure such systems remain stable?

**Subtopic 3: Innovations in Local Energy Market Models and Ancillary Services Provision**

The papers consider various aspects of energy management and grid optimization, addressing emerging challenges and proposing innovative solutions. Topics include the development of local ancillary service markets (LASM) to integrate flexibility services from distributed energy resources (DERs) transparently and efficiently, the role of energy communities in optimizing transaction prices and ancillary services provision, and the challenges posed by the growing adoption of electric vehicles (EVs) in Europe. Additionally, there is a focus on frameworks for the coordinated mobilization of flexible resources in medium and low voltage grids, the integration of blockchain technology for peer-to-peer power trading, and the implementation of gravity energy storage systems (GESS) for providing frequency ancillary services. Furthermore, a demand shift trial conducted in the United Kingdom explores household demand response strategies to reduce curtailment of distributed generation, offering insights into consumer behaviour and load management practices.

**Paper 10244:** This paper explores the application of a large-scale 50 MW/100 MWh energy storage system integrated with grid-forming converters, detailing how such systems can enhance grid stability and flexibility by providing crucial ancillary services and supporting variable renewable energy integration.

**Paper 10392:** The paper proposes a method to model a Local Ancillary Service Market (LASM) for estimating flexibility costs in distribution areas. It responds to directives pushing DSOs to integrate flexibility services from DERs transparently and efficiently, in contrast to traditional planning methods. The methodology employs the use of a linearized Optimal Power Flow in order to obtain the minimised flexibility utilisation costs while ensuring that all technical grid constraints are satisfied. A case study provides insights towards the needs of future market models which would need to rely on accuracy (not only simplicity) in terms of planning.

**Paper 10393:** This paper investigates energy communities and their role in optimizing transaction prices, reactive power management, and ancillary services provision. By analysing real-world data from medium voltage distribution networks, the study assesses the benefits of community participation in energy markets.

**Paper 10394:** The paper discusses the growing adoption of Electric Vehicles (EVs) in Europe, with a focus on Italy, and the challenges it poses to the electricity grid, particularly in managing recharging operations. The paper highlights the potential and challenges of flexibility application. Additionally, it addresses the importance of smart management of EV charging profiles to mitigate grid issues and create opportunities. The authors introduce the use of the CIR-RO model, as a solution to manage EV charging and provide flexibility to the grid.

**Paper 10409:** This paper summarises a demand shift trial conducted by SP Energy Networks (a distribution system operator) and Octopus Energy (a retailer) in the United Kingdom. The goal was to increase household demand to reduce curtailment of distributed generation. 8692 domestic customers were enrolled in the trial, representing a total load of 10.6 MW. Six trials of two hours each were

conducted in 2022. Three trials were conducted from 7:30 pm to 9:30 pm on weekday evenings and three from 5:30 am to 7:30 am on weekend mornings. Average response across the trials was an increase of 1.7 MW per event (186 W per customer) with a maximum of 2.84 MW (327 W per customer).

**Paper 10511:** The paper presents a detailed framework for the coordinated mobilisation of flexible resources in both Medium Voltage (MV) and Low Voltage (LV) grids as developed within the E-Universal project. The development of predictive management operation tools which include the MV Flexibility Scheduling Tool (MV FST), and the Data-driven Voltage Control (DdVC) Tool is presented. Based on the approach of a Coordinated Management Framework, the activation of flexible resources within the MV and LV networks can be facilitated to avoid causing further network violations and maximize the use of available flexibility. The concept is implemented and validated within a representative pilot demonstration in Portugal.

**Paper 11342:** The paper explores the integration of blockchain technology in the energy sector, particularly focusing on peer-to-peer (P2P) power trading and its implications for renewable energy adoption and grid management. It introduces blockchain as a secure, decentralized transaction technology enabling smart contract execution in P2P networks. It details pilot projects in India demonstrating P2P trading of rooftop solar energy using blockchain, emphasizing technical viability and business models. The paper highlights blockchain's potential to decentralize energy trading, enhance transparency, and drive renewable energy adoption in the energy sector.

**Paper 11653:** The paper provides a comprehensive analysis of implementing a Gravity Energy Storage System (GESS) in DIgSILENT PowerFactory to assess its capability to provide frequency ancillary services on the UK electrical grid. It introduces GESS as a storage technology utilizing gravity's potential energy, offering scalability, long-duration storage, and cost-effectiveness compared to other alternatives. The methodology involves modelling GESS characteristics and conducting simulations to validate its performance in meeting service requirements. The paper presents GESS's potential as a viable solution for grid stability and ancillary service provision, highlighting the need for ongoing improvements.

### **Questions:**

#### Question 1.3.1:

How does the linearized Optimal Power Flow (OPF) methodology ensure the minimization of flexibility utilization costs while satisfying all technical grid constraints, and what are the computational challenges associated with its implementation? What insights does the provided case study offer regarding the accuracy and complexity trade-offs in future market models, and how can these insights inform the development of more robust and efficient planning frameworks for distribution grids?

#### Question 1.3.2:

What technical innovations are being explored to incentivize active participation of energy communities in optimizing transaction prices, and how do these innovations impact grid stability and reliability?

#### Question 1.3.3:

Is demand shifting seen as useful to help reduce DER curtailment?

### **Subtopic 4: Advanced Distribution Grid Planning and Management**

The papers within this subtopic explore various aspects of modernizing grid infrastructure and enhancing grid flexibility through the integration of distributed energy resources (DERs) and demand-side management strategies. They address terminology standardization to facilitate dialogue among stakeholders, propose methodologies for valuing DER components, and discuss the potential benefits of demand-side flexibility in distribution planning. Furthermore, they delve into congestion management in distribution grids, operational planning frameworks for distribution system operators (DSOs), and the integration of flexibility resources into distribution networks. Additionally, the deployment of electric vehicle (EV) charging stations along transportation corridors is considered, alongside methodologies for



optimizing their development and assessing economic feasibility. The papers also include concepts which investigate the remaining hosting capacity for DER integration in low voltage networks, control strategies to increase EV charging capacity, and the use of load forecasting for optimal off-grid microgrid design.

**Paper 10472:** The paper proposes new terminology to portray various system conditions and discusses the increasing interest of distribution utilities in procuring flexibility services from distributed energy resources (DER) to optimize grid operating costs. It aims to clarify the terminology used to categorize and describe system conditions triggering DER-provided flexibility services, facilitating discussions among utilities, DER owners, service providers, and regulators. The proposed terminology includes three main conditions: normal, alternate, and emergency. The paper provides insights into the opportunities for DER-provided flexibility services in each condition and emphasizes the need for clear terminology to support effective dialogue and service development in the distribution domain.

**Paper 10475:** The paper discusses the value of DER components in the context of modernizing the grid infrastructure. It highlights various frameworks for evaluating DER benefits, including energy cost savings, emissions reductions, and customer choice. Approaches for DER valuation, such as locational net benefit analysis and ComEd's (energy supplier) framework, are explored, focusing on capacity, outage support, line loss reduction, and voltage support. The paper proposes a methodology to quantify the value of DER technologies in supporting grid services.

**Paper 10477:** The paper discusses the expected rise in electricity demand due to electrification and the potential benefits of demand-side flexibility at the distribution level. It highlights current gaps in integrating demand flexibility into distribution planning and proposes a methodology for evaluation. Survey results show varying levels of consideration for demand-side assets among utilities. The paper acknowledges the importance of addressing challenges such as limited visibility into customer technology adoption and lack of coordination between planning and customer programs. A methodology for the modelling of demand flexibility is proposed and validated by means of a case study. It concludes by emphasising the need for increased collaboration and development of new operational capabilities to effectively integrate demand flexibility into distribution planning.

**Paper 10551:** This paper considers how much additional DER can be accommodated in a low voltage network by calculating the remaining hosting capacity after considering existing DER and loads. It uses two different types of low flow simulations to calculate the remaining hosting capacity, using data from three networks in the Netherlands. The two methods show broadly similar results.

**Paper 10560:** This paper examines the investigation of congestion management strategies by Liander, a Dutch DSO, focusing on mitigating grid congestion by examining possible congestion management products. The paper discusses the regulatory framework for congestion management, highlighting its application to current-based congestion at primary substations and challenges at MV and LV grid levels. The paper also evaluates the effectiveness of various congestion management products, identifies risks, and proposes a risk-based approach for optimizing grid usage and societal benefits.

**Paper 10823:** This paper studies how to increase the capacity for EV charging via different control strategies. A simulation model of the urban electric charging infrastructure was obtained, which enabled simulating both the charging behaviour of EVs and the electrical operation of EV charging stations. Algorithms for direct EV charging control were developed.

**Paper 10984:** The study proposes a comprehensive operational planning framework for DSOs, aiming to bridge the gap in current DSO planning practices across different time horizons, which include long-term planning, operational planning (including mid-term and short-term), and real-time operation. The authors propose numerous changes to the existing process such as the inclusion of increased interaction

between processes, incorporation of new technological opportunities, and adoption of operational measures like flexibility activation mechanisms, thereby proposing an operational planning framework.

**Paper 10985:** The paper addresses the integration of flexibility resources in distribution networks, where it is emphasised that the classification and characterisation of flexibility resources are essential for modelling and planning purposes. The paper provides insight into traditional grid planning, which is focused on passive measures, and acknowledges that active measures like flexibility are increasingly considered to defer grid reinforcement. The paper references a proposed framework for grid planning based on previous work, and experience from the implementation within pilot projects, are presented and show inspirational results. Key outcomes highlight that there are still many challenges for utilising flexibility which include technical, regulatory, and economic aspects.

**Paper 10997:** This paper discusses the deployment of DC charging stations for electric vehicles (EVs) along the TEN-T corridor with a focus on Slovenian and Austrian integration. The author emphasis that various factors need to be considered for the feasible integration of EV chargers within the network. This includes location consideration and available grid connection. In this regard, the author proposes a methodology which aims to optimise the development of EV infrastructure based on factors including grid connection feasibility, time, environmental conditions, existing infrastructure, and urban planning. A cost benefit analysis is provided, to assess the feasibility from an economic perspective, based on tailed cost breakdowns were provided, including grid connection fees, equipment costs, and other associated expenses.

**Paper 11000:** This paper considers the use of load forecasting to assist with the optimal design of off-grid microgrids, primarily for sizing of generation. Load forecasting is performed by employing a support vector regression (SVR) method, where annual load growth is incorporated into the forecast. Case study simulations are used to compare the results of the proposed method to that of just using historical data.

**Paper 11239:** In preparation for the Olympic Games in 2032, Brisbane is implementing a project to create a transport system for the future. To ensure optimal charging of this high-capacity electric metro system, an advanced Energy Management System (EMS) is designed to automate the smart charging of the transportation fleet. In a grid that is faced with increasing constraints, the EMS will play a crucial role to optimise the dispatch of these resources. This paper demonstrates how the EMS manages to balance the requirements for charging, transit schedule requirements, applicable electricity tariffs and grid supply limitations.

**Paper 11293:** This paper presents a case study on alleviating congestion in distribution networks with flexibility provided by DER. It estimates electricity demand and amount of DER (PV and EVs) in 2050 based on modelling of DER penetration scenarios.

### **Questions:**

#### Question 1.4.1:

How does the proposed terminology for categorizing system conditions triggering DER-provided flexibility services accommodate the dynamic and evolving nature of distribution grid operations, and what technical considerations are involved in its implementation across diverse utility landscapes? Do you think reaching a consensus on the proposed terminology is feasible in the near future. How do we achieve this?

#### Question 1.4.2:

Load estimation is clearly an essential part of designing a microgrid. Has the use of advanced modelling been able to produce substantive savings in the cost of building and/or operating microgrids?

#### Question 1.4.3:

Some implementations of using the flexibility provided by DER to delay or eliminate the need for capital expenditure to upgrade electricity infrastructure require the control of equipment owned by the customer, such as EVs. (How) should the customer be compensated for this? At what point is it no longer viable to use such flexibility and it is necessary to upgrade the network?

### **Subtopic 5: Advanced Grid Technologies and Analytics**

The papers collectively consider the various challenges and opportunities in modernizing grid infrastructure to accommodate the increasing integration of distributed energy resources and renewable energy sources. They propose architectures and systems for distribution operations, focusing on proactive controls, automated switching, and Distributed Energy Resource Management Systems (DERMS). Furthermore, they discuss the efforts of utility companies modernizing grid infrastructure, particularly through projects which include Fault Location, Isolation, and Service Restoration (FLISR) system implementation. Additionally, the papers explore methods for integrating RES and DERs while considering flexibility utilization and network expansion requirements, highlighting the potential of energy routers and non-wire alternatives (NWAs). Moreover, additional topics such as redundant local active network management (LANM), solar thermal heating, and the use of metering data for LV planning and system operation are also considered, providing insights and case studies to demonstrate their effectiveness and implications for grid modernization.

**Paper 10474:** The paper explores the aspects related to distribution operations to accommodate the growing integration of DER into the grid. The paper proposes an architecture paradigm for distribution operations adaptable for different utility companies. It discusses operational coordination of DER, emphasizing proactive controls with automated switching and the role of Distributed Energy Resource Management Systems (DERMS). Interoperability, communication networks, and cybersecurity are highlighted as essential elements for effective DER operational coordination. Furthermore, the paper provides insight towards grid services at both the bulk power system (BPS) and distribution system levels, including energy provision, capacity management, voltage regulation, and resiliency services. The paper emphasises that successful implementation of DERMS requires a multidisciplinary approach involving stakeholders from business, technology, and regulatory domains.

**Paper 10479:** The paper provides a comprehensive overview of Pacific Gas and Electric (PG&E) and its efforts in modernizing its grid infrastructure, particularly focusing on a Fault Location, Isolation, and Service Restoration (FLISR) system. An introduction and overview of the company provides context to the development of the paper. Herewith, a project which aimed to consolidate its distribution operational technology platforms into a single Advanced Distribution Management System (ADMS) is presented. Various testing strategies were employed, including Simulator, Hardware-In-Loop, and Injection-Based Hardware-In-Loop (HIL) testing. The results indicated that HIL testing approach provided confidence in the transition to the ADMS-based FLISR system. Lessons learned from testing will improve future phases of the ADMS project and enhance the utility's testing strategies.

**Paper 10681:** This paper provides an in-depth comparison of using solar thermal for heating versus using electricity generated by PV systems. It discusses the different technologies, such as plate, evacuated tube and parabolic trough collectors. It evaluates the financial returns for the two different systems.

**Paper 10690:** This paper provides insights into providing for the integration of RES and DERs with the consideration for aspects related to flexibility utilisation and network expansion requirements. The paper focuses and compares the possibilities of energy routers and non-wire alternatives (NWA). In this regard, a grid connected system with NWA ESS is connected to the AC networks through multi-terminal ports. Operationally, the use of Energy Routers (ER) can dynamically adjust power flows to balance supply and demand, utilizing binary variables to control charging and discharging operations of ESS. Linearized capacity constraints ensure optimal utilization of inverters while maintaining system

stability. The approach is further evaluated via a case study to demonstrate the effectiveness and compares various scenarios with local ESS, NWA ESS, and ERs. The results highlight ER's potential to enhance distribution system efficiency, improve renewable energy hosting capacity, and facilitate local energy supply.

**Paper 11157:** This paper presents a novel scheme for redundant local active network management (LANM) designed to minimize the curtailment of DERs in the event of failures in the central active network management system (CANM). The paper considers flexibility management concepts where LANM is used to address communication failures by providing alternative curtailment instructions to DERs. The developed concepts employ deterministic logic and machine learning algorithms to manage DERs. Factory tests are demonstrated to provide insight into how LANM can respond to constraint violations and extreme network events by curbing or releasing DERs power output.

**Paper 11324:** This study presents a Distributed Energy Management System (DERMS) designed to manage solar power and storage to enhance grid flexibility and reliability. The system demonstrates its capability to mitigate grid constraints by operating Distributed Energy Resources (DER) within the hosting capacity limits of the feeder, while also minimizing energy productivity losses for DER owners, ensuring efficient and reliable grid operation under diverse conditions.

**Paper 11360:** The paper addresses the challenges encountered by DSOs in managing low-voltage networks, particularly amidst increasing electrification and distributed renewables. It advocates for enhancing network intelligence through hardware and software components to meet evolving customer needs. The authors focus on developing a low-voltage state estimation algorithm to facilitate real-time monitoring, outage management, and targeted dispatch. By strategically installing measuring instruments in secondary substation areas and conducting pilot studies, the results demonstrate the effectiveness of measurement sensors in providing real-time data and identifying network asymmetry issues. Furthermore, it evaluates the performance of the developed state estimation algorithm, highlighting significant improvements in accuracy through the integration of voltage and current measurements.

**Paper 11409:** The Kopernikus projects aim to transform Germany's energy system through large-scale initiatives involving stakeholders from academia, industry, and civil society. This paper summarizes advancements in two projects focused on developing new energy network structures and exploring the flexibilities within distribution grids, particularly through the application of low and medium voltage direct current (LVDC and MVDC) technologies.

**Paper 11415:** This paper explores the revision of photovoltaic (PV) regulatory connection rules in Jordan's low voltage distribution feeders using smart meter data. It highlights the inadequacies of the existing 15% threshold for PV installation, proposing a redefinition based on detailed Monte Carlo power-flow simulations that consider the real-time operational data from smart meters to better manage voltage levels and increase PV hosting capacity.

**Paper 11417:** This paper presents two case studies on the use of metering data for LV planning and system operation, including dealing with overloaded distribution transformers and overloaded LV feeders. The paper includes results from actual installations in Palestine.

**Paper 11443:** This paper compares various dimension reduction techniques for effectively clustering household load profiles using k-means clustering. By extracting common statistical features and latent variables, the research assessed the ability to group load profiles with similar behaviours. Using typical weeks (summer, winter, and transition periods) as inputs improved both calculation speed and clustering robustness by mitigating the dominance of unique profiles. The results indicated that latent variables,

especially five principal components applied to typical weeks, outperformed common statistical features, providing more stable and reliable clustering.

**Paper 11452:** This paper examines the utilization of distribution transformers to enhance grid flexibility and observability. It discusses the integration of multiple data sources, including smart meters and sensor networks, to monitor transformer health and load characteristics more accurately, facilitating better operational decisions.

### **Questions:**

#### Question 1.5.1:

How do the results from Simulator, Hardware-In-Loop, and Injection-Based Hardware-In-Loop (HIL) testing strategies inform the development and deployment of Fault Location, Isolation, and Service Restoration (FLISR) systems, and what are the technical considerations in scaling up these testing methodologies for large-scale grid modernization projects?

#### Question 1.5.2:

What real-world deployment strategies and validation methodologies are proposed to test the performance and reliability of local active network management (LANM) systems in mitigating the curtailment of DERs during communication failures or extreme network events, and what are the key performance metrics used to evaluate system effectiveness?

#### Question 1.5.3:

Solar thermal can reduce electricity demand but is not actually part of the electricity system. How can it be appropriately modelled for the planning of electricity networks?

## **PREFERENTIAL SUBJECT 2 – Power Electronic based Solutions for Smart Distribution Systems**

### **Special Reporter: Istvan Vokony, Hungary**

PS2 received and evaluated to present 12 papers. Authors came from 11 different countries and four continents.

Papers in the subtopic were grouped as follows:

- 1. Grid Systems and Converters**  
Papers 10115, 10248, 10481, 10625, 10822 and 11297
- 2. Renewable Energy Integration and Management**  
Papers 10753 and 11804
- 3. Energy Distribution and Control Systems**  
Papers 10823, 11295, 11414 and 11479

These groupings align the papers with their overarching focus on grid systems and technology, renewable energy management, and specialized distribution and control systems within the broader context of electric power systems.

### **Subtopic 1: Grid Systems and Converters**

The integration of advanced grid systems and converters plays a pivotal role in enhancing the resilience, flexibility, and efficiency of modern power networks, particularly with the rising penetration of inverter-based resources (IBRs) like renewable energy systems. The reviewed papers discuss various aspects and technologies including highly resonant wireless charging for electric vehicles, large-scale energy storage systems, hybrid networking with grid-forming and grid-following converters, and innovative solutions for black-start operations and system reliability enhancement.

**Paper 10115:** This paper discusses the classification of highly resonant wireless charging techniques tailored for light electric vehicles (EVs) and similar applications, emphasizing their potential to simplify

the charging process and increase the adoption of EVs by eliminating the need for cable connections.

**Paper 10248:** The study proposes a hybrid networking scheme that combines grid-forming and grid-following converters to enhance the resilience and flexibility of active distribution systems, potentially transforming how power distribution networks operate and respond to disruptions.

**Paper 10481:** This paper focuses on the capability of grid-forming converters to perform black-start operations under unbalanced conditions using a generalized three-phase droop control, which could be critical in restoring power in the event of a complete system blackout.

**Paper 10625:** This paper discusses the implementation of a Soft Open Point (SOP) using voltage source converters to enhance the operational flexibility, reliability, and hosting capacity of the distribution system by enabling better management of power flows and voltage profiles.

**Paper 10822:** This paper outlines the development of an adaptive control system for converter-interfaced generation units, simulating the dynamics of traditional synchronous generators to improve grid stability and integration of renewable energy sources.

**Paper 11297:** The paper presents the challenges and development strategies of grid-forming inverters designed to support high penetration of variable renewable energy sources, focusing on providing virtual inertia to stabilize the grid in the absence of traditional power generation methods.

These advancements underline a strategic shift towards more decentralized and resilient grid architectures capable of supporting diverse energy sources and dynamic load conditions.

### **Questions:**

#### Question 2.1.1:

How can grid-forming converters be optimized to handle synchronization and stability in grids with high levels of renewable penetration without traditional baseload generation?

#### Question 2.1.2:

What are the challenges to scaling highly resonant wireless charging systems for wider applications, including public and commercial transportation sectors?

#### Question 2.1.3:

How can the technical and regulatory challenges of integrating large-scale energy storage and advanced converter technologies into existing grid infrastructures be effectively addressed?

#### Question 2.1.4:

As technologies like soft open points become more common, what innovative approaches can be taken to further enhance grid flexibility and reliability while minimizing environmental impacts?

### **Subtopic 2: Renewable Energy Integration and Management**

The integration of distributed energy resources (DERs), particularly photovoltaic (PV) systems, into distribution networks is increasingly vital for achieving grid flexibility and managing the transition towards renewable energy sources. This collection of papers presents a comprehensive look at the challenges and solutions associated with integrating and managing DERs to enhance grid reliability and optimize renewable energy use.

**Paper 10753:** This paper discusses the development and application of a semiconductor circuit-breaker based on Reverse Blocking Integrated Gate-Commutated Thyristor (RB-IGCT). It highlights the device's efficiency in protecting Low Voltage Direct Current (LVDC) microgrids from overcurrent conditions, which are increasingly prevalent due to the integration of renewable energy sources and the growing complexity of electrical networks.

**Paper 11804:** Addressing the challenge of voltage rise in utility-scale solar PV-based microgrids, this paper discusses various strategies to suppress voltage increases that can compromise grid integrity. It includes techniques such as dynamic voltage regulation and the integration of advanced grid support technologies, aimed at maintaining stable and reliable operation of microgrids with high levels of solar PV penetration.

These summaries provide an overview of the innovations and challenges discussed in each paper within the broader context of enhancing energy distribution and control systems for modern power grids.

### **Questions:**

#### Question 2.2.1:

What technological advancements are necessary to enhance the reliability of power grids with high DER penetration, particularly concerning real-time data analytics and control systems?

#### Question 2.2.2:

How can utilities balance the benefits of DERs for consumers and the overall needs of the grid, particularly in contexts where grid stability might conflict with consumer energy generation goals?

### **Subtopic 3: Energy Distribution and Control Systems**

The collection of papers regarding energy distribution and control systems reflects the ongoing evolution and challenges in managing energy systems with a high penetration of renewable energy sources (RES), enhanced control technologies, and the integration of electric vehicles (EVs). These studies reveal intricate aspects of power-flow management, voltage control, frequency regulation, and fault management within diverse and rapidly transforming power systems.

**Paper 10823:** This paper discusses the development of an advanced control system for managing electric vehicle (EV) charging at substations to balance load and reduce peak demand impacts. The system utilizes dynamic pricing to encourage off-peak charging, integrating real-time data and predictive analytics to optimize the charging schedules and enhance grid stability.

**Paper 11295:** The paper evaluates the impact of dynamic pricing on the timing of EV charging and its subsequent effects on voltage variations within distribution lines. It highlights the challenges and potential of dynamic pricing to mitigate nighttime voltage drops and daytime voltage rises associated with photovoltaic generation, based on customer response rates to price incentives.

**Paper 11414:** This study explores the use of Volt-Var techniques for voltage control in distribution networks equipped with smart inverters, focusing on a case study in Jordan. It assesses the effectiveness of these techniques in maintaining voltage stability and improving power quality in networks with high penetrations of distributed energy resources.

**Paper 11479:** The paper presents the development of average models for fault analysis in DC microgrids, focusing on the characteristics of current-controlled converters. It explores the implications of these models for designing more effective protection systems that can handle fault conditions without excessive hardware requirements.

### **Questions:**

#### Question 2.3.1:

How can grid systems efficiently integrate and manage the varying load dynamics introduced by large-scale EV charging, considering the potential stress on local distribution transformers and voltage regulation systems?

Question 2.3.2:

How can dynamic pricing effectively be implemented to encourage beneficial EV charging behaviours without leading to new peak demand problems, and what role does customer behaviour play in this context?

Question 2.3.3:

What are the implications of high renewable penetration in non-interconnected islands for system stability and reliability, and how can these systems ensure adequate frequency and voltage control?

Question 2.3.4:

In the context of integrating hybrid AC/DC systems, what are the technical and regulatory barriers, and how might these systems evolve to support the future energy landscape?

**PREFERENTIAL SUBJECT 3 – Rural, Islanded and Industrial Electrification Standards, Practices and Technology Options**  
**Special Reporter: Ray Brown, Australia**

PS3 received and evaluated to present 16 papers. Authors came from 8 different countries and five continents.

Papers in the sub-topics were grouped as follows:

- 1. Off-grid and island DER applications including appropriate resilience measures**  
Papers 10683, 11300, 11416, 11431, 11737 and 11772.
- 2. Microgrid and multi-microgrid installations**  
Papers 10482, 10682, 11299, 11411, 11542 and 11775
- 3. Protection Issues in Distribution Systems with High Levels of DER**  
Papers 10861, 10966, 11413 and 11774

Applications highlighting the interface between technical and non-technical aspects for rural electrification.

**Subtopic 1: Off-grid and island DER applications including appropriate resilience measures.**

Large numbers of people across the world remain without access to electricity, often in rural and remote areas. The following papers look at this issue from several aspects, such as load estimation, sizing of BESS and PV systems, the level of reliability required, community engagement and the type of payment arrangements used to finance the required infrastructure.

**Paper 10683** presents the steps undertaken in a feasibility study for the electrification of a small rural community located 70 km from the nearest existing electricity network. It examines, the technical, economic and community aspects of developing a PV and BESS based isolated power system.

**Paper 11300** discusses a calculation tool developed to determine the capacity of generators and storage for off-grid systems in Japan. The output of the tool is compared with data from two actual installations with PV and BESSs to check the tool's performance.

**Paper 11416** provides a study of a microgrid using BESS and PV systems and implementing energy conservation strategies. The case study uses data from residential loads at four different times of the year. The output of the study is the energy storage capacity of the BESS.

**Paper 11431** discusses how to predict future load and generation profiles of households. The profiles are modelled via a bottom-up approach considering energy-efficient building retrofits and the expansion of distributed energy resources such as photovoltaics, heat pumps and energy storage systems.

**Paper 11737** discusses microgrids and mini-grids with a focus on community engagement in rural and remote areas. Case studies from South Africa are presented.



**Paper 11772** describes a scheme for the provision of electricity supply to remote communities. The scheme typically comprises PV systems, each coupled with a relatively small BESS. The billing arrangement adopted is interesting in that it uses a pre-paid time (availability) component and a post-paid energy component.

### **Questions:**

#### Question 3.1.1:

Even in very sunny regions well suited to the use of PV systems there will be cloudy days when the energy generated is not sufficient to meet demand. In one of the projects the isolated system was sized for five consecutive days of low PV generation whereas in another project even a single cloudy day would cause a shortfall of electricity. What factors determine how much storage is provided for isolated power systems to cater for poor solar conditions or whether to install diesel generating sets or similar?

#### Question 3.1.2:

Community engagement is crucial to the success of isolated power systems. What strategies have been found to be most successful? What are unexpected problems that have arisen in rural electrification schemes from a mismatch with community expectations?

#### Question 3.1.3:

Financing of rural electrification schemes can be a major issue. Have schemes other than billing based on simple energy consumption been found to be effective?

### **Subtopic 2: Microgrid and multi-microgrid installations**

Microgrids, particularly those utilising renewable energy sources and using batteries for energy storage, are finding increasing application in distribution grids. The reason for their use may be a desire to increase reliability and resilience or may be to avoid or reduce the costs of a conventional network upgrade to supply a load. The following papers look at several aspects of planning and operating microgrids.

**Paper 10482** describes a microgrid that was, at the time of writing, under construction by a utility in the United States to serve as a research centre and test bed. The microgrid serves one of the utility's facilities and will comprise a 1 MW/4 MWh BESS and 1.2 MW PV system. The paper includes details on the sizing of an earthing transformer used in the plant.

**Paper 10682** examines interconnected microgrids and an associated nested energy management system. It compares the proposed EMS with conventional centralized; decentralized; and hybrid energy management strategies.

**Paper 11299** describes a practical demonstration of a microgrid on a small island, to show the functionality of a PV and battery-based system, including actual practical testing of disconnection from the main grid. The system uses a voltage ramp to "soft start" the system when in islanded mode.

**Paper 11411** presents an analysis of whether to use an extremely large microgrid to supply a new city with a load of the order of 500 MW or whether to provide supply by building new 400 kV transmission lines to connect to the national grid. The microgrid would comprise 400 MW of PV and 600 MWh of BESS.

**Paper 11542** proposes a method of system restoration (black-start) for a microgrid or section of a distribution system, using grid-forming inverters supplied from renewable energy sources. It uses mainly modelling, with some laboratory simulation with real time digital simulators and hardware in the loop.

**Paper 11775** provides an overview of the energy sector in Columbia and a general discussion of the use of microgrids.

## **Questions:**

### Question 3.2.1:

Restricting microgrids (or distributed generation more generally) to zero power export is disadvantageous for the microgrid (financial loss), the connecting network (loss of flexibility) and the community more generally (loss of energy from low-carbon generation). What valid factors dictate a no-export policy for microgrids and what means can be used to militate such issues?

### Question 3.2.2:

It would obviously be desirable for a microgrid to be able to change very quickly from grid-tied to islanded mode in the event of the loss of the grid supply, with the best outcome being where the interruption duration was so short that it was imperceptible to the end users. What has been the experience with microgrid systems in this regard? Has it proven possible to have a very fast change to islanded mode or has it been necessary to include a defined interruption time (of perhaps a few seconds) to disconnect from the grid and change to islanded mode?

### Question 3.2.3:

Do grid-forming inverters have the capability to pick-up the step load on re-energising a segment of the network, including transformer inrush currents? For example, would it typically be necessary to re-energise at considerably reduced voltage and then ramp the voltage back up to nominal once initial inrush currents had died away?

### Question 3.2.4:

Is the use of microgrids where supply from the network is either not feasible or too costly becoming more common or is it restricted to niche applications? Is cost the main determining factor in cases where microgrids are used instead of augmenting the supply network or are technical factors also involved? Can any general statements be made as to when the installation of a microgrid is likely to be the best option?

## **Subtopic 3: Protection Issues in Distribution Systems with High Levels of DER**

While issues of protection in distribution systems with high levels of penetration of DER may not be as difficult as was anticipated 10 or 15 years ago, it is still necessary to take them into account. In addition, new methods for dealing with existing issues are being developed and protection systems for DC medium voltage systems are still evolving. The following papers consider a range of protection issues applicable to modern distribution systems.

**Paper 10861** introduces an algorithm for single-phase-to-earth faults in medium voltage multi-terminal DC networks using symmetrical monopole technology and high impedance neutral-grounding.

**Paper 10966** presents a theoretical study of detection of open (broken) conductor faults on medium voltage overhead lines and presents a method of detecting such conditions. The method uses phasor measurement units installed at the protective devices (switchgear) and at the ends of the lines. Results are presented from a simulation of the method.

**Paper 11413** presents a scheme for protecting lines in microgrids, and in distribution systems more generally, using a centralised protection system. The scheme takes information from micro-phasor measurements units installed at each node of the network and communicates it back to a control centre to calculate tripping commands.

**Paper 11774** discusses a study of protection requirements for microgrids. It makes use of software models of the system and an emulator in a university laboratory.

## **Questions:**

### Question 3.3.1:

What practical approaches have been adopted in the field to deal with the protection issues in distribution systems caused by the increased penetration of distributed energy resources?

### Question 3.3.2:

Have the use of phasor measurement units (PMUs) or micro phasor measurement units ( $\mu$ PMUs) found practical application in solving protection issues in distribution networks?

*Study Committee C6 sincerely appreciates the efforts from the 18 reviewers and our Special Reporters for the detailed reviews that were undertaken for all the C6 related papers for the Paris Conference. This to a large extent has contributed to allowing us to filter through this Special Report, with a request that the questions that are posed, will stimulate further thoughts and innovative ideas from our authors and parties interested in our list of C6 related topics.*

*Study Committee C6 looks forward to many contributions from across the globe and it is hoped that the questions posed in this Special Report will stimulate much debate at our Group Discussion Meeting in Paris on 28 August 2024.*