C2 - 00

SPECIAL REPORT FOR SC C2 POWER SYSTEM OPERATION AND CONTROL

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1. Introduction

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 available in the Call for Papers. Have a look at the Technical Programme - the list of selected Papers for the Session, and so have an overview of subjects that will be discussed. It is updated as Full Papers review proceeds.

Format of CIGRE Sessions

At CIGRE Sessions authors are given the opportunity to present their Paper during half-day specific meetings – the Poster Sessions. Four days are also dedicated to 'Group Discussion Meetings' organised by Study Committees. Four meetings run simultaneously each day from Tuesday to Friday, under the presidency of the Study Committee Chairs. The purpose of these meetings is the discussion of the Session Papers on the basis of "Special Reports" which incorporate the gist of the Session Papers and raise a number of questions for discussion.
For fruitful discussions delegates are strongly encouraged to read the Papers before the Session.
The set of Session Papers is made available for downloading to all duly registered delegates before the Session through their private account on the registration's portal. Papers are also readable on the Session smartphones application on site in Paris.
Follow our Session latest news and General Programme - by regularly visiting our website.

Study Committee SC C2 Power System Operation and Control

CIGRÉ Study Committee C2 deals with the technical functionalities, structures and competences needed to operate integrated power systems in compliance with the social requirements for security and quality of electricity supply.

The field of activities of SC C2 includes securing the physical integrity of power systems, management of strained systems and capacity shortage situations with controlled risks, restoration strategies, functionalities and reliability of Control Centre and training of System Operators.

SC C2 needs to understand, use and integrate results from studies in other Committees to assure that the technical concepts can be applicable in real time in various contexts and implemented by the System Operators. The SC C2, therefore, embraces a wide range of competence areas and interfaces with other disciplines.

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2. Group Discussion Meeting Session 2024

For the Group Discussion Meeting, SC C2 has invited written contributions to provide discussion materials pertaining to two specified Preferential Subjects. As a result of this invitation a total of 55 papers have been accepted, categorized into the following Preferential Subjects:

Preferential Subject No 1:
Create operational resilience to extreme / unpredictable events (24 papers)
Special Reporter: Vivek Pandey (India)

Preferential Subject No 2:
Changes on system operation and control considering the energy transition (31 papers)
Special Reporter: Ronan Jamieson (United Kingdom)

3. Important Dates

Duly registered delegates who wish to contribute to the SC C2 Group Discussion Meeting should upload their contributions on the registrations portal (https://registrations.cigre.org) no later than **Saturday, 10th August 2024** for a prior screening and good organization of the Group Discussion Meeting.

Important points:

- *Access to contribution uploading is given only to duly registered delegates.*
- *As a consequence, registration to CIGRE Session should be finalized before uploading contribution(s) online.*
- *The set of Session Papers is made available for downloading to all duly registered delegates before the Session through their private account on the registrations portal.*
- *Contributions uploading will be open at start of June.*

A guide for authors and contributors as well as templates and sample pages for posters and contributions will be available on the Paris Session 2024 website - see the top page menu.

Special Reporters Vivek Pandey (vivek.pandey@grid-india.in) and Ronan Jamieson (ronan.jamieson@baringa.com) will review the prepared contributions (PowerPoint presentation with a maximum of 3 slides **and** written version with a maximum of 1000 words). Any recommendations or changes to the contributions will be provided by the Special Reporters directly on the registrations portal. Contributors are encouraged to upload their prepared contributions as early as possible and to regularly visit their account on the registrations portal to see the result of the Special Reporters' review. Contributors who have received requests to change their contributions should make these changes as soon as possible and upload the final versions no later than **Saturday, 17th August 2024**.

On **Tuesday 27th August 2024** all experts with prepared contributions need to contact the Chairman, the Secretary and Special Reporters of SC C2 between 13.00 – 15.30 with their final contributions. This previous meeting will take place in Room 234, Level 3 of Palais de Congrès. Please, note that the time available for this meeting is very limited as the SC C2 meeting will also be held in the same afternoon. The **SC C2 Group Discussion Meeting** is scheduled for **Wednesday 28th August 2024**, in the Amphithéâtre Bordeaux, Level 3 of Palais de Congrès, between 8.45 – 18.00.

During the Session the Chairman may call for spontaneous contributions. Attendees who provide a **spontaneous contribution**, are allowed to deliver a text for the Session Proceedings. This text is required to be forwarded within a maximum delay of two weeks after the SC C2 Session (thus by **Wednesday, 11 September 2024**) to the Special Reporters.

It is compulsory for all authors to present the results of their studies during the Poster Session which is scheduled for **Thursday**, **29th August 2024,** between 08.30 – 12.30, Hall Ternes, Level 1 of Palais de Congrès**.** If the author(s) cannot attend the Poster Session the National Committee is requested to send a substitute. Authors have the possibility to post their presentation on ConfTool (https://www.conftool.pro/cigre2024) , so that SC C2 Poster Session Convener, Emil Hillberg (emil.hillberg@ri.se) may check them online and contact the authors directly to inform eventual need of changes and acceptation of their presentation. Authors should upload the first version of their presentation on ConfTool (3 slides in PPTX portrait format 16 :9) from 3rd June 2024 to 31st July 2024. If needed, the presentation may be updated until 16th August 2024.

Preferential Subject 1

Create operational resilience to extreme/unpredictable events

- **Natural phenomena forecasting applied to operation planning studies & real time decision support.**
- **Threats and hazards from other systems that affect supply/demand of electricity.**
- **Lessons learned & best practices to deal with high impact/low probability events on system operation.**

The ongoing energy transition is driving the proliferation of renewable/distributed energy resources in the grid. Digitalization, electrification and emergence of new class of bulk loads (like electrolysers and data centers) is influencing the electrical energy consumption and power flow patterns in the network.

Forecasting of wind speed, solar irradiation, hydro inflows, ambient temperature and other weather events has become critical in the operational and resilience planning on account of growing penetration of weather dependent energy resources.

In addition to the information through conventional SCADA systems, a large number of power system control centers now have access to high-resolution data from Phasor Measurement Units to enhance the situational awareness of the system operators. The information is being effectively used in post dispatch analysis of the power system.

Increasing frequency of extreme weather/geological events are challenging the contemporary transmission infrastructure like never before. Power systems are vulnerable to blackouts due to its inherent characteristics. Reliability risks associated with low inertia, poor short circuit levels, declining system inertia and interactions between electronic controllers has made it imperative for a review of the transmission planning and operation philosophy.

Papers for PS1

C2-10214 presents a suggested post disaster dispatch and energy sales strategy, based on classification of demand users, with diversified resilience and pricing schemes, to reduce the post-disaster electricity shortage.

C2-10439 describes a new approach for development and validation of the 3-dimensional empirical geo electric field model for assessment of local geomagnetically induced current.

C2-10440 proposes a methodology for probabilistic nodal resource adequacy assessment from temporal and locational perspective that yields metrics to value the contribution of generation, transmission, and load during scarcity.

C2-10507 describes the management of the extended right of way, together with a paradigm shift in vegetation management promoting multiple landscape functions valuable for resilience and the environment.

C2-10776 shares a utility case to illustrate diverse mitigation methods for addressing potential resonance over voltages in a network having cables and overhead lines.

C2-10821 reports the updated classification of reference contingencies for assessment of maximum permissible power flow across controlled sections in the Russian power system.

C2-10872 presents an improved solar PV power prediction method that considers the effect of snow cover, temporal change in snow and movement vector of clouds besides solar radiation on Solar PV panels.

C2-10874 present an experience from Japan to highlight the need to improve weather / demand / renewable energy generation forecast. It also emphasises the contribution of energy conservation measures and demand response for ensuring resource adequacy in the journey of transition to green energy future.

C2-10929 introduces a novel two-stage machine learning-based clustering approach for alarm management which can be applied to real-time as well as port-mortem analysis.

C2-10932 reports the lessons learnt from the three major grid disturbances that occurred in Brazil and proposes measures to enhance operational resilience in power systems having high penetration of inverter-based resources.

C2-10933 presents the case of sharing and lending of electrodes between two or more HVDC bipoles connected to the same AC terminal substation to increase operational flexibility of the grid, while maintaining financial efficiency.

C2-10937 proposes using a neural network for commutation failure pattern recognition and classification. In addition, numerical results are validated via electromagnetic transient simulations.

C2-11051 illustrates the use of Phasor Measurement Units (synchrophasors) data to perform linear state estimation in distribution system.

C2-11252 paper presents the likely impact of inverter-based resources, replacement of synchronous generators with synchronous condensers and Battery Energy Storage System/Fast frequency response on transient stability of AC interconnection of Australia to draw qualitative inferences for technology choices in the ongoing energy transition.

C2-11397 shares a case study on the restoration procedure of a gas power plant after a blackout in Jordan in 2021. It provides insights to improve the resilience of power systems and the recovery of grids via effective preparation planning.

C2-11398 illustrates the actions taken at a distribution control centre for network and load management during inclement weather.

C2-11441 discusses about the zero missing phenomena in the context of offshore wind integration and suggests mitigation measures in the form of network reconfiguration and protection modification.

C2-11483 showcases the efficacy of machine learning and deep learning methodologies for enhancing accuracy of energy demand forecasts.

C2-11564 presents the proactive measures taken for system reliability and resiliency during severe weather events, causing tripping of multiple extra high voltage transmission lines and forced shutdown of generation units in the Indian power system during a super cyclone Biparjoy.

C2-11636 reports PMU measurement-based review of major disturbance events in the electrical grid of Abu Dhabi.

C2-11685 proposes an adapted version of the Prony method for the estimation of interarea oscillation modes for real-time applications. This method is normally used for post-event mode estimation.

C2-11697 shares the operational experience managing exceptionally high demand strategic resource adequacy planning and policy interventions.

C2-11797 illustrates the deterministic methodology used for computation of balancing reserves in Georgian power system to suit its unique geography and interconnection.

C2-11877 proposes co-optimization of multiple distributed resources such as electric vehicles, electric buses, photo voltaic storage bus stations and mobile energy storage systems, to enhance the flexibility of regional power scheduling, improve the speed of post-event power restoration, and broaden the interaction scenarios between distributed resources and the power system.

Preferential subject 1 that invited contributions on the subject "Create operational resilience to extreme / unpredictable events"- is addressed by 24 papers. Sub-topic 1 attracted 4 contributions while sub-topic 2 and 3 attracted 13 and 7 papers respectively.

Novel approaches for mitigating the challenges associated with Solar PV forecasting in snow bound areas and demand/renewable energy forecasting with growing unpredictability of weather systems have been shared. The value of energy conservation methods and demand response in the green energy transition journey has been highlighted. Contributions have highlighted threats to power system reliability due to resource inadequacy, vegetation issues, resonance, contingencies, commutation failure in LCC HVDC, declining percentage of synchronous resources, inter-area oscillations, geomagnetically induced currents, information overload in control centre and availability of physical spares. Innovative solutions have been proposed to mitigate the threats and enhance system resilience to failures.

Deployment of machine learning and pattern recognition techniques for alarm management and commutation failure detection respectively has been demonstrated.

Contributions have reported that the pattern of power flows in the transmission system is changing due to growing penetration of variable resources and a review of prevailing methodology for assessment of available network transfer capability has been recommended. Authors state that the decline of synchronous capacity in the grid is presenting issues such as declining inertia, short circuit capacity and transient instability. The inverter-based resources often interconnect with the main grid through cables which may call for technological solutions for issues like zero missing problem.

Use cases of utilization of synchrophasors for linear state estimation, estimation of inter area oscillation modes and for assessment of system stability has been proposed.

Increased vulnerability of power systems to unusually high demand due to extreme weather events such as heat wave have been reported. Case studies highlighting strategic interventions, proactive measures and innovative resource adequacy assessment methodology has been shared.

Several papers have shared their experience with high impact low probability events such as largescale black out, super cyclones, inclement weather. The papers provide insights to enhance resilience of the system by improving system visualization through synchrophasors, better alarm management, linear

state estimation, sharing of assets between multiple transmission/distribution licensees as well as co-optimization of distribution energy resources and storage.

Questions for PS1

Question 1.1:
What are the prevailing challenges in resource adequacy planning (RAP)? Are the existing RAP frameworks robust enough for the evolving operating conditions and vulnerabilities?

Question 1.2:
Do the prevailing mechanisms facilitate availability of sufficient supply to serve short-term requirements? Are the existing regulatory and market mechanisms supportive enough to drive long-term investments in the required resources?

Question 1.3:
What are the lessons learnt from the low probability high impact events experienced in the power system? What strategies are being adopted to enhance power system resilience in future?

Question 1.4
What threats from other systems do you perceive for your power sector? How frequently have they occurred in the past? What is their likelihood in future and what measures are being taken to address them?

Question 1.5
Are the existing control centres equipped to handle the evolving challenges in the power system? What are possible interventions and changes that could be adopted to prevent information overload and strengthen the decision support system?

Question 1.6
What has been the experience of deploying Artificial Intelligence in power systems for areas like asset management, system operational planning, real-time diagnostics, post-dispatch analysis?

Question 1.7
What are the envisaged challenges and possible enablers for harnessing distributed energy resources to enhance system resilience?

Question 1.8
Implementation of WAMS has shown significant value in situational awareness and post-dispatch analysis. What are the future pathways for deploying WAMS in power system operation and control?

P**referential Subject 2**
Changes on system operation and control considering the energy transition

- **Disturbances and system restoration in power systems with a high share of inverter-based resources.**
- **Flexibility and ancillary services for high RES share environments.**
- **Power system operation strategies & operation planning studies considering a high share of RES.**

The amount of change that electrical power systems both at transmission and distribution level are going through has accelerated in the last ten years. These changes are being driven by the need to decarbonize all facets of modern life from transport to home heating, thereby increasing the need for the reliable transportation of clean electrical energy. This energy transition therefore requires changes

to also take place in the operation and control of the associated power systems. Preferential subject 2 is focused on many key aspects in this transition.

The increasing growth of inverter base resources requires system operators and other key players in the industry to develop new approaches to how they plan and restoration systems with an increasing number of disturbances that these power systems are being subjected to. The ability of a power system to be restored utilizing inverter-based technologies requires a detailed understanding of the characteristics of the different technology types and how to deploy them. The simulation of power system restoration has grown in importance, and this has highlighted the importance of accurate models and data.

The reduction in traditional sources of energy and the associated ancillary services (e.g., inertia) they provided means that new sources of ancillary services are required, and the growth of different flexibility services is becoming a key component of these. Awareness, understanding and forecasting the availability of these services is challenging and many new and novel approaches are being trialed by system operators across the planet. Integrating these new services into a power system with a mixture of different energy sources needs new optimization and control techniques.

The growing complexities associated with planning and operating a power system due to an increased number of small energy sources that are embedded deeper into a power system requires new strategies and techniques. These new strategies now need to consider and plan for the probability of system events happening more frequently than in the past. These can range from an increased probability of flooding impacting hydrogeneration to voltage fluctuations due to incorrect protection settings on renewable resources.

The following 31 papers in Preferential Subject 2 seek to increase and share knowledge and learning, demonstrate novel approaches and introduce new strategies for the planning, operating and restoration of power system with a global perspective.

Papers for PS2

C2- 10219 proposes an approximate optimal operation strategy to assist wind power in AGC tracking via a hybrid energy storage system and seeks to obtain an approximate optimal solution quickly, thereby presenting a strategy.

C2- 10276 presents research that concludes that radial distribution networks with tie-switches are better in terms of technical and economic feasibility than ring distribution networks after considering the fault-repair condition as a comparison in the study.

C2- 10282 presents a new voltage control law and an improved Secondary Voltage Regulator (SVR). This new control structure aims to reduce the non-minimum phase behaviour and enables a faster overall response in voltage regulation. This paper assesses the benefits of operating the system with this enhanced SVR.

C2- 10379 introduces innovative indicators which are proven to be able to identify critical operating scenarios and quantify the risk of power system instability. The continuous rise of new instability phenomena that were atypical in the past (such as inter-area oscillations or combinations of different types of instability) leads to the need to strengthen the indices.

C2- 10446 presents key findings across multiple large-scale disturbances and widespread data collection of the existing solar photovoltaic (PV) fleet. Previous work has identified significant inverter-based resources performance deficiencies that are not being captured in planning, or operational models or studies that could pose a serious risk to system reliability.

C2- 10448 introduces the field implementation and testing of the measurement-based adaptive Wide Area Damping Control (WADC). This is providing system operators with a novel automated wide-area monitoring protection and control (WAMPAC) tool that mitigates natural oscillations and enhances secure operation of power grids.

C2- 10508 presents the outcome of streamlined TSO-DSO coordination, facilitating resource-efficient reactive power compensation adaptable to new load/generation scenarios, crucial with the increasing Distributed Energy Resources (DER) integration. Optimizing local reactive power compensation helped reduce losses in high voltage network by 3,6 GWh/year and decreased reactive power interface penalties by 22%.

C2- 10528 presents a tool that generates topological strategies for congestion management that are a significant improvement compared to both the situation in which no topological remedial actions are applied and the known operator strategies. The tool offers a simple user interface which is developed in interaction with operators to satisfy their cognitive needs.

C2- 10553 introduces the initial research phase used to guide investigation into potential improvements to existing frequency defence measures to enable a more robust response to contingency events and reduce the risk of cascading disconnections and blackouts in the future power system.

C2- 10593 aims to assess the impact of two types of operational modes for special protection schemes, namely event-based protection, and response-based protection. The importance of communication infrastructure, its streamlining and the necessary devices will be considered. It also presents a steady-state analysis and dynamic simulations in order to check the impact of protection schemes from the transient stability point of view.

C2- 10596 proposes a new approach based on a novel genetic algorithm for the optimisation of the voltage profile and active power losses in an arbitrary distribution network by using the strategic arrangement of voltage regulation devices. Also, a comparative analysis with available techniques from the literature is made in terms of the quality of obtained results.

C2- 10640 introduces a sandbox for voltage control involving 6 generation control centers (GCC) which aggregated 42 generators based in a large majority of generation technologies. Real-time following of voltage and reactive setpoints for both conventional and renewable generation has been successfully verified during the sandbox. Moreover, the concept of zonal reactive capacity markets was proved to be viable although more complexity is needed in its design to solve various price formation and competitive issues.

C2- 10675 presents an investigation of the impact of power system inertia erosion on a power grid is studied and mitigation measures are proposed. The study also analyses the effects of Demand Response (DR) and Battery Energy Storage Systems (BESS) on critical inertia. The findings suggest that with proper planning and implementation of fast frequency response services, the power system can maintain stability and reliability amid increasing variable renewable energy penetration.

C2- 10686 presents the results from a research project and proposes visualisation concepts for strengthening situational awareness, addresses solutions to estimate data accuracy to provide enhanced trust in phasor measurement unit (PMU) based systems and presents a case study for assessment of low damped wide-area oscillations as an integrated part in addressing the dynamic state of the power system.

C2- 10688 presents innovative measures to operate a stable power system with increase renewable generation. **S**trategies include deriving measures such as raising frequency maintenance standards, utilizing low-frequency load shedding resources, and reducing the number of substation where low-

voltage occur during fault by separating bus to ensure frequency stability. To secure transient stability, operational strategies including automatic reclosing, special protection system (SPS), power generation constraints have been devised.

C2- 10748 presents the first step towards automation and optimization of outage scheduling. The technical and non-technical constraints for the scheduler optimizer are derived from real outage planning business cases and programmed using multi-objective Mixed Integer Linear Programming (MILP). The structure of the outage scheduler platform is followed by the validation of the scheduler for the already planned outage requests of 2023 in a year-ahead outage planning process.

C2- 10875 proposes a multi-purpose cooperative control method of battery energy storage system for use in power systems, in which the system frequency control is used as a basic control, and the system stabilization control and voltage control can be selected as secondary controls. In this study, a small-scale analog and a large-scale analog simulators were used for verification studies.

C2- 10876 develops a model to estimate the electricity and fuel demand in distribution networks based on the open data such as the Grid-Square Statistics of national census and other open data. The proposed model calculates not only the future electricity demand but also fuel demand by assuming various factors such as the change in population, the future improvement of energy efficiency, the ratio of electrification.

C2- 10927 presents simulation results of real cases of disturbances in a power system with the occurrence of load-generation imbalances, underfrequency, and over frequency phenomena, to compare the performance of the electrical network with and without the operation of frequency controls by wind farms. The results of the simulations and operational measurements after events show the benefits for the Power System with wind turbines with underfrequency and overfrequency control.

C2- 10972 presents improved situational awareness design considerations and examples of wide area monitoring, protection and control applications developed. The main message from this work is that close collaboration and coordination among power system operators in the different parts of the grid – between TSOs and between TSOs and DSOs – are essential to achieve full utilization and benefit from a wide area monitoring system.

C2- 11170 delves into the interaction between grid forming and grid supporting inverters within an islanded grid context. Employing a comprehensive grid model that incorporates grid forming as a voltage source and gris supporting as a current source, the study conducts a sensitivity analysis to evaluate the impact of active and reactive power increases on the Rate of Change of Frequency (ROCOF) and voltage deviation.

C2- 11182 explores the implementation of an alternative isochronous control method, allowing effective power sharing between thermal units and hybrid stations, that allows effective contribution of storage facilities to active power-frequency regulation. Minimizing changes in existing controllers enhances the applicability of the proposed method, while allowing for real-time coordination of thermal units and hybrid stations, located far apart from each other.

C2- 11185 presents the advanced functionalities designed for managing wind parks that are integrated into the recently developed SCADA-EMS. For the SCADA-EMS to automatically manage wind parks effectively, an algorithm has been developed that takes into consideration the limitations and constraints imposed by the dispatched thermal units, the load fluctuations and the intermittency inherent of wind parks.

C2- 11396 examines two balancing options for the meshed offshore grid operator. To evaluate the two balancing options, a benefit analysis based on a generation dispatch optimisation simulation to

determine the generation and flows is used. The two balancing options are modelled in the generation dispatch simulation.

C2- 11557 aims through detailed analyses and proposed solutions, to enhance the reliability and adaptability of power systems amid the evolving renewable energy (RE) landscape. It stresses the need for precise grid management strategies to tackle these challenges effectively. This paper also examines operational, maintenance, and control challenges arising from RE integration.

C2- 11574 serves as a case study of the though process, strategies, challenges faced, and improvements made when developing and deploying a machine learning based solar generation forecasting model to perform short term day ahead forecasting with weather forecast data as the input to provide insights of solar generation behaviour ahead of time.

C2- 11660 explores two concepts for frequency control and power balancing. The first concept fixes the frequency in all asynchronous islanded AC networks, second concept varies frequency in all asynchronous connected AC islands. Both concepts were validated using targeted electromagnetic transients (EMT) simulation studies, in which various system components and associated controllers were reasonably modelled.

C2- 11693 presents and discuss the application of the Monte Carlo simulation-based tool used for short term operation planning for flooding scenarios. At presented time, the official inflow forecast did not show a flooding scenario which would be considered worrisome. The Monte Carlo simulation-based tool, however, indicated a relatively high probability that the upcoming event could be far more severe.

C2- 11811 proposes a hybrid model that integrates cloud motion forecasting into a single artificial neural networks (ANN) framework to enhance intra-hour PV power generation forecasting for one hour ahead at half-hourly resolution. The technique of convolutional long short-term memory (ConvLSTM) was utilized to extract cloud shielding effects from satellite imagery.

C2- 11835 presents analysis that confirmed that by applying decentralized flexible under-frequency load shedding systems solutions to medium voltage feeders significantly improved the central region's system response. This was then verified in both simulations and in practice.

C2- 11872 shares experiences with the new challenges and solutions faced by power system operations as a consequence of the current trends in the energy transition and the resulting high share of Renewable Energy Sources (RES) and Inverter-Based Resources (IBRs). It also highlights the need for appropriate monitoring tools to provide fast and reliable situational awareness for operators to monitor and assess the real-time state of the power grid.

Questions for PS2

Subtopic 1 (PS2-1) – Disturbances and system restoration in power systems with a high share of inverter-based resources is directly addressed in 7 papers.

Question 2.1:
With an increasing amount of energy connecting at a lower level in power system, how will TSO and DSO communicate the challenge of restoration to these non-traditional providers?

Question 2.2:
How does the increasing amount of inverter-based resources pose a risk or an opportunity for accelerated restoration?

Question 2.3:
How does the System Operator ensure that sufficient inverter-based resource testing (especially for disturbance) takes place considering the scale and pace of renewable growth?

Question 2.4:
What is the biggest unsolved challenge facing system restoration due to the growth of inverter-based resources?

Question 2.5:
How does the investment in Resilience bridge a gap in restoration plans?

Question 2.6:
What part does the modelling of consumer/market behavior play in restoration modelling and planning?

Question 2.7:
What is the limit to the amount of inverter-based resources that can be allowed to connect to a power system so that it can be confident that system restoration can take place in a meaningful timescale?

Subtopic 2 (PS2-2) – Flexibility and ancillary services for high RES share environments is directly addressed in 9 papers.

Question 2.8:
How should flexibility be developed in high RES environments, mandated or market driven?

Question 2.9:
Which ancillary service is least likely to be delivered by RES and why?

Question 2.10:
How do you model the efficient operation of flexibility if it is all connected at lower voltages?

Question 2.11:
What percentage of future demand will be flexible?

Question 2.12:
How do you ensure sufficient ancillary services from RES replace the traditional sources in the energy transition?

Question 2.13:
How do you model flexibility within traditional power system studies?

Subtopic 3 (PS2-3) – Power system operation strategies & operation planning studies considering a high share of RES is directly addressed in 16 papers.

Question 2.14:
What aspect of system operation will be impacted most by a high share of RES and why?

Question 2.15:
How will power system studies be capable of modelling the increasing number of variables with a higher share of RES?

Question 2.16:
With the increasing amount of HVDC on power systems, how will operational studies need to change to enable them to model the rapidly changing power flows due to RES changing production/demand?

Question 2.17:
The System Operator is required to operate a secure power system. How do they balance growth of RES with increasing complexity due to variability within these systems or it is just a question of increased measurement/observability?

Question 2.18:
What value are system studies providing system operations if the assumptions used are largely based on historic data (largely consisting of traditional energy sources)?

Question 2.19:
How deep do system studies now need to go to ensure that power systems are secure if the majority of RES is connected at a local level?

Question 2.20:
What is the biggest risk to operational strategies that is not being considered?