SPECIAL REPORT FOR SC C2 POWER SYSTEM OPERATION AND CONTROL

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A few words about Session Papers

Session Papers focused 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 .
Session Papers are selected through a two-phase review process – abstracts and full Papers.
Have a look at the Technical Programme which contains the list of selected Papers for the Session, and will help provide an overview of subjects that will be discussed. The Technical Program 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' organized 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.
The Special Reports are available to all on free access – at the end of May - on the CIGRE website, on the Session page.
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 registrations 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 !

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STUDY COMMITTEE C2 POWER SYSTEM OPERATION AND CONTROL

Study Committee C2 focuses on the secure, resilient, and efficient operation of electric power systems amid rapid industry transformation. Its domain covers real-time system operation, operational planning, control center infrastructure, and the human and organizational factors essential for reliable grid management. As power systems become more complex due to decarbonization, digitalization, and increased variability, SC C2 leads global collaboration to develop practical solutions, enhance operational readiness, and integrate emerging technologies such as automation, advanced analytics, and cybersecurity measures. Through its work, the committee supports system operators and industry stakeholders in navigating evolving challenges while strengthening the stability and adaptability of modern power grids. SC C2 has a total of 84 Full Papers Accepted for the 2026 Paris Session.

PS 1 : Advanced decision support, training and skills for control room personnel

- New requirements for personnel skills, procedures and tools
- Digitalization and use of artificial intelligence for enhancing decision support
- Operational procedures, tools and processes for operating grids during extreme events

PS 2 : Maintaining operational reliability through flexibility

- Methods to identify and quantify system services in response to the energy transition
- Operational experience with flexibility services, including demand side response, topology changes, sector coupling and results from pilots

PS 3 : Power system dynamics and control in operations (joint PS with SC C4)

- Operational experience with managing power system stability, including oscillations
- Monitoring and control of power system dynamics in the control room, including wide area systems
- Impact of adverse interactions between power electronics interfaced devices on system operations

PARTICIPATING IN THE 2026 C2 GROUP DISCUSSION MEETING SESSION

You are invited to participate in discussing this Special Report at the SC C2 session held on **Thursday 27 August 2026 starting at 0845 in the Bleue Conference Room at the Palais de Congress de Paris**.
The reporters have compiled up to **25** questions, these are not specifically aimed at the papers' authors, but are synthesised from common issues and trends identified across the papers. This provides the opportunity for a broader response and participation in the discussion session.
We encourage you to share your views or experiences in response to the specific questions in this report. During the Group Discussion Meeting, each prepared contribution will be allocated a time slot of three to four minutes for a presentation.

PROCEDURE FOR CONTRIBUTIONS TO THE GROUP DISCUSSION MEETING

Contributors should upload contributions on the registrations portal – "Contributions to Group Discussion Meetings" section - using your existing account and own credentials before **7th August 2026**, 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.
    - As a consequence, registration to CIGRE Session should be finalized before uploading contribution(s) online.
    - Register now for the Session registrations
    - **Contribution uploading will be open at start of June**.
- Special Reporters will review the prepared contributions (Power point presentation with max **3** slides and a written word file with max 1000 words per contribution).
- A guide for contributors as well as templates and sample pages will be available on the Paris Session webpage. Important notice: No commercial names are to be included in presentation or the written summary (even TSO/DSO names).
- Any recommendations or changes to the contributions will be provided to the contributors by the Special reporters directly on the Registration platform. Contributors are encouraged to visit their account on the registrations portal to see the result of this review.
- All contributors with accepted/finalised contributions will be contacted by the Special reporters, to finalize the presentation and receive the instructions regarding the session.
- Important note:
    - All contributions must be uploaded prior to the Conference in Paris.
    - Last minute changes to the contributions will not be granted.

- During the GDM the Study Committee Chair may call for spontaneous contributions, which will only be verbal with no slides. All attendees are eligible to make such a contribution. Attendees who provide a spontaneous contribution are allowed to deliver a written contribution which will be included in the Session Proceedings. This text is required to be forwarded within a maximum delay of two weeks after the Study Committee GDM Session (**Deadline = Monday 7 September 2026)** to the SC Secretary (Trevor Hines : thines@misoenergy.org).
- It is expected that the questions relevant to the Preferential Subjects will attract many prepared contributions. The number of contributions for each Preferential Subject (PS1, PS2 and PS3) may need to be limited. The selection will be based on relevance, quality and time of submission of the contribution.

- Please note that accepted contributors will be required to attend a short pre-session Contributors meeting with the Special Reporters, SC Chair and SC Secretary on **Tuesday 25 August 2026**. You can meet them **between 0800 and 1200** in **room 311-312** at the Palais des Congrès to finalise presentation arrangements. The purpose of this short meeting is to review the final details of their contribution and to receive the latest instructions (such as schedule).

Study Committee C2 Meetings and Events

Day	Date	Time	Room	Description
Monday	24 August 2026	1040 - 1230	Bordeaux Conference Room	Tutorial : JWG C2/B5.46 Tutorial
Monday	24 August 2026	1400-1800	Grand Amphitheatre	C2/C5 Large Disturbance Workshop
Tuesday	25 August 2026	0800-1200	311-312	C2 Contributors Meeting
Tuesday	25 August 2026	1400-1800	Hall Ternes Room 1	C2 Poster Session
Tuesday	25 August 2026	1600-1800	Room Maillot	C1/C2/C4 Inverter Based Large Loads Workshop
Thursday	27 August 2026	0845-1800	Bleue Conference Room	C2 Group Discussion Meeting

Study Committee C2 Poster Session

Information about poster Sessions together with templates is circulated to authors of accepted Papers by Central Office, and also posted on the Session website.

Authors of SC C2 Session papers are required to present their papers during the **SC C2 Poster Session scheduled on Tuesday 25 August 2026 from 1400-1800** in Halle Ternes Room 1 on level 1. Template and instructions on poster preparation are available on the CIGRE 2026 Session website. Posters will be displayed on digital screens. **Poster presentations must be uploaded on the ConfTool platform from 18th May by 29th June at the latest** for review by the poster session convener. Poster conveners may ask for a final version, incorporating any requested changes, must be uploaded by August **14th**. It should be noted that authors will **not** have the possibility to upload their own file on the day of the Poster Session. If the author(s) cannot attend the Poster Session he/she or the relevant National Committee is requested to send a substitute.

Thank you very much!

Preferential Subject 1

Advanced decision support, training and skills for control room personnel

a) New requirements for personnel skills, procedures and tools
b) Digitalization and use of artificial intelligence for enhancing decision support
c) Operational procedures, tools and processes for operating grids during extreme events

The papers show how control-room work is being transformed by high renewable penetration, digitalisation, and increasing system complexity. On the one hand, they highlight new requirements for personnel skills and procedures: operators can no longer rely on “N-1 plus experience” alone but must be trained on integrated steady-state and dynamic simulators,

understand quantitative performance and security indicators, and work within decentralised, TSO–DSO-coordinated optimisation frameworks. Operating procedures move from static manuals to modular, digital artefacts that are tightly linked to EMS/DSA tools and structured training and certification paths.

In parallel, decision support itself is becoming far more digital and AI-enabled. The contributions describe containerised DSA and optimisation frameworks with digital twins, open-source state estimation and PMU data-quality services, probabilistic forecasting of load, PV and congestion, and risk-based security assessment including cascading analysis. AI and ML are used to improve voltage/reactive power control, automate fault diagnosis from oscillography, and provide LLM-based alarm and knowledge-graph assistants—always with attention to validation, explainability, and an appropriate level of automation.

Also, common threads of extreme and highly uncertain conditions and events for operating the grids are discussed. Several papers analyse storms, regional incidents and RES droughts and show how ramping-margin tools, dynamic inertia and security margins, coordinated voltage/reactive power management, and high-resolution wide-area monitoring are embedded into day-to-day processes such as operational teleconferences, critical-grid procedures, and restoration practices. Overall, the body of work paints a consistent picture: advanced decision support, modern training concepts, and evolved operator skills must be designed and implemented together so that control-room teams can safely and efficiently operate low-inertia, high-RES grids in the face of more frequent extremes.

Papers for PS1

C2-10129 – Constraints for real world transmission topology optimization in transmission grids
The paper analyses how Transmission Topology Optimization (TTO) can be used in real power system operations to relieve congestion cost-effectively and identifies that many promising academic solutions fail in practice because they ignore key operational and security constraints. Based on interviews with European TSOs, it compiles a structured set of such constraints (e.g., N-1 security, voltage limits, switching feasibility, coordination with neighbours) to guide the design of practical TTO tools for control room use.

C2-10298 – Enhancing Congestion Forecast for TSOs: a Probabilistic Approach
This paper introduces a probabilistic congestion forecasting (PCF) framework that models nodal power uncertainties with AI, generates correlated scenarios via Gaussian Copula, and uses accelerated AC load flow to obtain congestion probabilities. Compared to deterministic methods, the PCF with dynamic reliability margins significantly reduces missed congestion events for a given false-alarm rate or cuts false alarms for a given security level.

C2-10718 – Advanced decision support for grid operators using high-resolution optical sensing and wide-area synchronized measurements in Puerto Rico
The authors report on a wide-area monitoring system in Puerto Rico using passive optical electric-field sensors sampling up to 1 Msps, providing microsecond-synchronised fault waveforms. The system enables travelling-wave fault location with ~150 m accuracy, pre-fault anomaly detection, harmonics and transient over voltage monitoring and asset-level intelligence, thereby supporting faster and safer operational decisions.

C2-10923 – Integrated Framework for Advanced Voltage Management in High Renewable Penetration Systems: From Reactive Power Coordination to Look-Ahead Optimization
This paper introduces the Reactive Power Coordination System (RPCS), which combines a real-time Security-Constrained Optimal Power Flow (SCOPF) layer with a multi-hour look-ahead optimisation layer to coordinate reactive power devices and inverter-based resources. It demonstrates how this framework reduces voltage violations, limits unnecessary switching and addresses shortcomings observed in events like the Spanish and Chilean blackouts.

C2-10955 – Utilization of Artificial Intelligence for Voltage and Reactive Power Control and Its Operational Results
The paper presents an AI-based voltage and reactive power controller in the Nagano-region grid that uses neural networks and random forests trained offline to recommend optimal control settings online. Operational results show that flexible generator voltage adjustment significantly reduces the number of static capacitors, shunt reactors and tap operations while keeping voltages within target ranges.

C2-11248 – Performance management strategies for power system operation: the application of Overall Equipment Effectiveness (OEE) to the operation of the Italian Transmission System
This paper presents the application of the OEE concept (availability, performance, quality) to transmission system operation, defining OEE-like indicators for voltage regulation, congestion management, frequency/reserves, RES dispatch and flexibility. The paper shows how these metrics highlight process losses and support continuous improvement in operational planning and real-time operation.

C2-11320 – A Multi-Criteria Method for Continuous PMU Data Quality Evaluation
The paper proposes a heuristic, multi-criteria Phasor Measurement Unit (PMU) data quality evaluation that goes beyond IEEE C37.118 quality bits, assessing availability, zero values, noisy frequency, line-down conditions and phase inversion. The method classifies PMUs into reliable, suspect, bad or unavailable, ensuring that only high-quality streams feed Wide Area Monitoring Systems (WAMS) applications and operator dashboards.

C2-11332 – System Operator Training using Simulators in Steady-State and Transient Regimes
This paper presents a training methodology that combines a steady-state operator training simulator (TopSim) with a dynamic simulator (Organon) connected via the GCEN scenario management tool. It enables operators to apply procedures and make decisions in a realistic environment that includes both static and transient system behaviour.

C2-11347 – The Reality of Power System Operation in the Era Where Weather Becomes Fuel: The Fierce Battle of PV Curtailment in Korea's Spring of 2025
The authors show how massive, largely behind-the-meter PV penetration and climate-driven weather volatility create extreme forecasting errors and curtailment challenges in an island-type grid, using South Korea as an example. The Potential Maximum Power Demand Error (PMPDE) metric is introduced for maximum forecasting discrepancy and describe the development of an “Energy-Meteorology” discipline, including advanced solar/wind forecasting and dedicated meteorological support for operators.

C2-11419 – Development of Electricity Demand Forecasting System in Korea Considering the Volatility of Photovoltaic Power Generation
The KPX Weekly Load Forecaster (KWLF) is presented as an automated, web-based system that first predicts total system load and then derives market load, explicitly accounting for non-metered PV. Using four different forecasting methods including AI-based models like eXtreme Gradient Boosting (XGBoost) to achieve high-accuracy for D+10 forecasts.

C2-11665 – Strategic operational management of GB National Energy Transmission System during extreme events: Storm Éowyn
The paper describes how system operators in Great Britain (GB) managed Storm Éowyn, one of the most severe storms in recent years, through proactive adjustments of dynamic response, inertia, reserve requirements and network topology. It highlights the importance of flexible application of Security and Quality of Supply Standard (SQSS), close coordination and simulator-based preparation.

C2-11741 – SIPS – the Unknown Superheroes of the Power System
This paper presents the work performed by the CIGRE Joint Working Group C2/B5.46 "System Integrity Protection Schemes and the (N-1) criterion", gathering knowledge from a wide range of experts from around the globe. The overarching goal of JWG C2/B5.46 is, through knowledge sharing and providing lessons learned, to enable an efficient use of SIPS as one piece of the puzzle in how to best meet the challenges when developing the future sustainable electricity system.

C2-12108 – Towards Automated Fault Diagnosis in Power Transmission Lines Using AI From Data to Real-Time Decision
This paper describes an AI-assisted framework for automated fault diagnosis in transmission lines using the Stockwell Transform for feature extraction, Principal Component Analysis (PCA) and Rough Set Theory (RST) for dimensionality reduction, and Extreme Gradient Boosting (XGBoost) for classification. It achieves high fault-type classification accuracy and is designed to integrate into a real-time diagnostic application.

C2-12301 – Risk-based probabilistic System Security Assessment: Swissgrid's Approach from Operational Planning to real-time System Operation
The paper presents a risk-based probabilistic security assessment methodology that combines copula-based modelling of power injection uncertainty, Markov-chain-based contingency probabilities and cascading-failure simulation. The approach produces system-level risk indices visualised in a risk plane, enabling risk-based decision making from operational planning to real time.

C2-12310 – OPTESO: An innovative Approach for global OPTimality with limited date Exchange between Transmission and Distribution System Operators
OPTESO (OPTimality with limited data Exchange between System Operators) is an Adaptive Direction Method of Multipliers (ADMM) based coordination scheme that allows TSO and DSOs to solve their own optimal power flow problems and reach a globally consistent solution while exchanging only boundary data. The concept is demonstrated with Swissgrid and DSOs, showing that congestion and voltage issues can be addressed without merging full network models or centralising control.

C2-12353 – Operational Security Challenges in the Western Balkans: Lessons Learned from the 2023 and 2024 Regional Grid Incidents

This paper analyses two major incidents in the Western Balkans (2023 and 2024), identifying structural and procedural vulnerabilities in operational planning and regional coordination. It outlines the resulting improvements in coordinated security analysis, outage planning, daily operational teleconferences and critical-grid-situation procedures.

C2-12459 – Advanced decision support for operation of converter-dominated grids with low inertia utilizing a modular development and testing framework
The paper presents the results of the German project "LI-SA". A modular, containerised DSA framework built around a high-fidelity digital twin (EMT and RMS) for converter-dominated, low-inertia grids. It integrates PMU-based inertia estimation, AI-based anomaly detection and multiple DSA cores via a Kubernetes/Kafka architecture to support online dynamic security assessment and operator decision making.

C2-12535 – Bridging Behind-the-Meter Data Gap: A Nodal Approach to Estimate Embedded Solar Generation in Real-Time
The paper proposes a practical method to estimate embedded (behind-the-meter) PV generation at bulk supply points in real-time using installed Maximum Export Capacity (MEC) data and nearby large-scale PV availability as a proxy. The paper shows that, with an appropriately tuned performance factor, estimates significantly improve over simple jurisdiction-wide scaling and can support EMS and operational decisions without per-customer telemetry.

C2-12538 – aLLarMa - A Large Language Model -based Application for Real Time Operational Data, Alarms, and Network Analysis
aLLarMa is an LLM-based decision support framework that maps natural-language alarm queries to graph database operations using a constrained, template-based GraphRAG pipeline. By bounding the LLM to pre-validated query templates, the system achieves high accuracy and extremely low schema-hallucination rates when navigating a knowledge graph of the network and alarm data.

C2-12550 – Impact and Mitigation of Extreme Weather Events in Ireland
The authors analyse the impact of wind and solar ramps, windstorms and wind and solar droughts on the Irish power system and describe how EirGrid uses ramping-margin tools and operational measures to manage these risks. A detailed case study of Storm Éowyn shows how proactive planning, reserves and network configuration support resilience under extreme weather.

C2-12566 – Open-Source State Estimation in 50Hertz MCCS Project
This paper details the development and deployment of an open-source Weighted Least Squares (WLS) state estimator based on Python-based pandapower library, within 50Hertz's Modular Control Centre System (MCCS). It covers CGMES data import, observability analysis, bad-data detection and benchmarking against a commercial estimator, demonstrating comparable accuracy and operational feasibility.

C2-12600 – A roadmap toward process excellence and digital integration shaping the next generation of Operating Procedures
This paper describes a roadmap to modernise operating procedures, moving from static document-based Operation Procedures Manual (MPOs) to data-driven, dematerialised content integrated with EMS. The roadmap also covers training and certification programmes,

workload distribution and knowledge management to better support real-time teams in a digitalised grid

Clustering for PS1

Papers **10955**, **12108** and **12538** tackle sub-topic b) and present three examples of applications that use digitalization analytics tools and use of artificial intelligence for enhancing digital operator support. Nowadays, these tools are becoming more and more important for control room operators. LLM and neural networks are leading the way, as well as analytics tools that can be embedded in some solutions.

Papers **10298**, **11419** and **12535** tackle sub-topic c) and focus on the great challenge of forecasting with the ongoing penetration of renewable power sources, like PV power plants and rooftop PV panels. Furthermore, the weather volatility as an uncontrollable variable makes the forecasting process very difficult. However, this new reality is seen as an opportunity for engineers to develop smart solutions, as shown in these papers.

Papers **10923**, **12301** and **12459** tackle sub-topic c) and explore some methodological solutions to keep the system security, stability and resilience, especially in high-renewable grids. Some examples are probabilistic risk evaluation, real time voltage management and dynamic assessment for low inertia grids. These cases may enhance operational security, support robust decision-making and efficient operation.

Papers **11347**, **11665**, **12353** and **12550** tackle sub-topic c) and share lessons learned from extreme weather events in South Korea, United Kingdom, western Balkans and Ireland. These events, despite the power grid contingencies, deliver several opportunities for improvements in grid resilience.

Papers **10129**, **11741** and **12310** tackle sub-topic a) and explore the topology optimization, TSO/DSO integration and SIPS. All these solutions are adopted for congestion management and to improve the system security. At the same time, it is demonstrated that these kinds of solutions may reduce the operational costs.

Papers **10718**, **11320** and **12566** tackle sub-topic c) and deal with wide-area monitoring, fault location & asset-centric analytics. These are powerful and necessary tools for all power grids with high renewables sources. PMUs, enhanced state estimator and high-resolution optical sensors are some examples of these tools.

Papers **11248**, **11332** and **12600** tackle sub-topic a) and explore operational training and performance of people who work in the control centers.

Questions for PS1

Q1.01 How far can AI go in grid operation, and where do we need hybrid human-AI workflows to minimize the risk of decision failure or wrong outcomes?
Related to papers: **10955, 12108** and **12538**

Q1.02 How can probabilistic congestion forecasts and TSO–DSO-coordinated OPF (e.g. OPTESO) be integrated into existing operational planning processes without overwhelming operators with scenario complexity?

Related to papers: **10298, 11419** and **12535**

Q1.03 How can the value of improved forecasting (load, PV, wind, congestion) be quantified in terms of avoided redispatch costs, reduced curtailment, and lower risk of near-miss events?
Related to papers: **10298, 11419** and **12535**

Q1.04 How do DSA (Dynamic System Assessment), PRA (Probabilistic Risk Assessment), SCOPF (Security-Constrained Optimal Power Flow) and WAMS (Wide-Area-Measurement-System) complement each other to define and maintain a dynamic "safe region"?
Related to papers: **10923**, **12301** and **12459**

Q1.05 After severe events in power grid, it is usual to increase the budget in power grid reinforcement, planning and strategies, but is it also possible to achieve a high level of resilience without change of budget in these situations?
Related to papers: **11347**, **11665**, **12353** and **12550**

Q1.06 What does a fully integrated congestion management toolbox look like (forecast → topology → redispatch → metrics)?
Related to papers: **10129**, **11741** and **12310**

Q1.07 It is becoming usual for the development of operational advanced tools to use open-source libraries. How much can we trust these kinds of libraries to be used in critical real time solutions?
Related to papers: **10718**, **11320** and **12566**

Q1.08 How do we co-design procedures, training, metrics and tools so that operators can actually use complex analytics under stress?
Related to papers: **11248**, **11332** and **12600**

Preferential Subject 2

Maintaining operational reliability through flexibility

- Methods to identify and quantify system services in response to the energy transition
- Operational experience with flexibility services, including demand side response, topology changes, sector coupling and results from pilots

The papers submitted in PS2 discuss that maintaining operational reliability now depends on identifying, quantifying, and activating flexibility across multiple timescales and technologies. Together, they explore how system operators are adapting adequacy assessment, reserve sizing, congestion management, frequency control, restoration planning, and performance benchmarking to support power systems with higher shares of inverter-based resources, distributed flexibility, and operational uncertainty.

A strong common theme is the shift from static reliability concepts towards more dynamic and operationally useful approaches. Several contributions focus on resource adequacy, reserve requirements, inertia, and transmission capability through probabilistic methods, real-time analytics, and scenario-based assessment. Others show how flexibility services—including BESS, demand response, AGC, nuclear flexibility, and wide-area control—can be

deployed not only to balance the system in normal operation but also to strengthen resilience, restoration capability, and the overall reliability of the grid.

Taken together, the papers cover a broad but coherent picture of how flexibility is becoming central to operational reliability. They demonstrate that reliability is no longer maintained solely through conventional reserves and deterministic rules, but through integrated methods that combine new services, improved visibility, advanced optimisation, and adaptive control strategies. PS2 therefore highlights both the technical innovation and the operational evolution required to keep future power systems secure, resilient, and efficient.

Papers for PS2

C2-10435 presents an Integrated Resource Adequacy Monitoring Suite for load dispatch centers in **India**, combining day-ahead and intraday tools, dashboards, alerts, and performance metrics to support timely corrective actions.

C2-10455 describes an islanding scheme for the load-serving entity that supplies electricity to the large city of Mumbai in **India.** The scheme is designed to island the system through predetermined breaker openings and dynamically balance load and generation within the island using SCADA data at the main control center.

C2-10579 presents a comprehensive simulation-based comparative analysis of the performance and technical capabilities of critical technologies for enhancing grid stability, including Grid-Following (GFL) STATCOM, Grid-Forming (GFM) STATCOM, and synchronous condensers, evaluated in the context of **India's** renewable-rich transmission network. The study provides practical insights for stakeholders navigating the energy transition.

C2-10668 investigates the application of Battery Energy Storage Systems (BESS) for fast frequency response in the power system of **South Africa** and discusses their coordinated operation with governor response and demand response schemes to mitigate frequency overshoot during large disturbances and support frequency stability in low-inertia conditions.

C2-10670 proposes a system-wide operational framework for **South Africa** that co-optimizes flexibility investments with black-start and restoration readiness. The paper argues for a dual-purpose role for flexibility assets such as BESS, gas turbines, hydropower, grid-forming inverters, FACTS devices, and demand response. It also presents a restoration-oriented roadmap triggered by IBR penetration thresholds, highlighting the need for improved visibility, automation, ADMS integration, and decision-support tools.

C2-10850 proposes a probabilistic approach, in place of traditional deterministic security analysis, to generate a D-1 congestion signal that warns BESS operators of potential restrictions so they can optimize market strategies, help prevent congestion, and participate in frequency-control ancillary services in the **French** grid.

C2-10853 presents a methodology built on the **French** system operator's existing flexibility-needs monitoring tool, adapted to the specificities of prospective analyses. Originally designed for short-term operational use, the approach is modified to process the synthetic chronicle outputs generated by its prospective adequacy simulation framework. The core idea is to model each major source of system uncertainty.

C2-10855 describes how an **American** ISO sets dynamic reserves using advanced analytics to manage operational uncertainty. The paper focuses on three key innovations: net uncertainty quantification across different operational timeframes, machine-learning-based net uncertainty forecasting, and the dynamic setting of reserve requirements in MISO's co-optimized energy and ancillary service markets.

C2-11204 contains a detailed description of the hierarchical wide-area automatic frequency and power-flow control system implemented in the **Russian** power system for network-aware, integrated operation across multiple regional control areas using wind and hydro generation sources as controlled plants.

C2-11317 proposes an integrated framework for inertia assessment and provision, combining analyses of real-world low-inertia disturbances, a structured review of inertia assessment methodologies, evaluations of technological solutions for inertia provision, and discussion of ancillary service mechanisms and market design in **Brazil**.

C2-11326 proposes a new approach to the traditional concept of Special Protection Schemes (SPS), incorporating Battery Energy Storage System (BESS) resources and demand response as active control measures for dynamic performance enhancement in the **Brazilian** system.

C2-11335 outlines the operational configurations analyzed and the dynamic security assessment studies conducted by the **Brazilian** System Operator (ONS) to define transmission limits in the region and ensure a secure and reliable supply to the Acre and Rondônia (AC/RO) subsystem during periods of extreme drought. It also presents real-time verified data and the associated risks observed between September and November 2024.

C2-11373 proposes a practical methodology for system-level flexibility assessment using electricity market modelling, load-flow estimation, transfer capability estimation through sensitivity analysis, and machine-learning regression models in the **Finnish** grid.

C2-11434 investigates the evolving system needs associated with decreasing inertia and frequency-dependent load characteristics in the **Nordic** synchronous area. A method is developed to quantify small-disturbance frequency-stability requirements as a function of inertia and load damping, using linear control theory and frequency-domain analysis. Complementary Fast Frequency Control (FFC) measures are then evaluated through analysis of both small and large disturbances.

C2-11650 presents a comprehensive evaluation of AGC implementation within the Combined System, assessing operational performance, benchmarking practices against international standards, and identifying opportunities for improvement. The paper underscores the importance of establishing a coordinated roadmap for enhancing AGC performance across the **Gulf** Cooperation Council interconnection.

C2-11732 explores the flexible operation of Boiling Water Reactors (BWRs) for providing frequency control. By evaluating the ability of Forsmark 3 (F3) to provide Frequency Containment Reserve for Normal operation (FCR-N), the paper shows that BWR-type nuclear power plants can be used flexibly. The plant fulfils the requirements set by the **Nordic**

Transmission System Operators (TSOs) and is therefore eligible to enter the ancillary service market for FCR-N capacity.

C2-11917 presents a new method for calculating seasonal power-system reliability in Jordan using hourly generation data to prepare Capacity Outage Probability tables and calculate LOLP, LOLE, and related metrics. This provides a more nuanced view of reliability that changes by season. The impact of renewable generation, with its higher uncertainty of availability, can also be incorporated into the calculations. Results for the **Jordanian** system are presented.

C2-12062 explores the impact of integrating renewable energy sources, such as solar and wind power, into Thailand's electrical power system and its load curve. The paper outlines a multifaceted approach involving energy storage, operational flexibility, advanced forecasting, infrastructure enhancements, and supportive regulatory frameworks to help achieve a sustainable energy future in **Thailand.**

C2-12135 presents a novel real-time optimization framework developed collaboratively by the **Colombian** system and market operator and a local university. The proposed solution introduces a Minimum Market Deviation Security-Constrained Unit Commitment (MMD-SCUC) model, which performs five-minute dispatches aimed at minimizing deviations from the day-ahead schedule while ensuring compliance with operational security constraints. The methodology uses a mixed-integer programming (MIP) approach.

C2-12429 presents a **German** study that investigates the added value of incorporating dynamic capacity—the ability of VSC/HVDC systems to temporarily exceed nominal ratings—into transmission-capacity management operations. Using a 48-hour outage scenario, it demonstrates that the primary benefit derives from algorithmic optimization rather than sustained higher loading, resulting in negligible technical stress to the systems involved. The findings indicate a positive economic and societal impact, although the benefits depend on outage duration, wind conditions, and system configuration.

Clustering for PS2

Papers **C2-10435, C2-10853, C2-10855, and C2-11917** discuss how resource adequacy and reserve planning are becoming more dynamic and uncertainty-aware through integrated monitoring, prospective flexibility assessment, analytics-driven reserve setting, and seasonal reliability evaluation.

Papers **C2-10668, C2-10850, C2-11204, C2-11650, C2-11732, C2-12062**, and **C2-12135** examine how flexibility services and balancing tools are expanding through BESS, AGC, wide-area control, nuclear flexibility, forecasting, and real-time optimization to support reliable operation in increasingly complex power systems.

Papers **C2-10579, C2-11317, C2-11335, C2-11373, C2-11434**, and **C2-12429** highlight how grid stability, inertia, and resilience are being strengthened through new stability technologies, inertia assessment, flexibility evaluation, dynamic security analysis, fast frequency control, and improved transmission optimization.

Papers **C2-10455**, **C2-10670**, and **C2-11326** demonstrate how system protection, restoration, and safety nets are evolving through islanding, restoration-oriented flexibility planning, and the active use of BESS and demand response in protection schemes.

Questions for PS2

Q2.01 How can resource adequacy assessment evolve to balance probabilistic rigour, computational tractability, and the growing uncertainty introduced by renewable generation, distributed resources, and limited historical data?
Related papers: **C2-10435**, **C2-10853**, **C2-10855** and **C2-11917**

Q2.02 What are the most effective criteria for selecting, locating, and valuing flexibility and grid-support technologies such as BESS, STATCOMs, synchronous condensers, and dynamic transmission capacity?
Related papers: **C2-10579**, **C2-10850**, **C2-11373** and **C2-12429**

Q2.03 How should TSOs and ISOs adapt reserve sizing, inertia estimation, and secondary frequency control arrangements to maintain reliability in low-inertia, multi-area, renewable-rich systems?
Related papers: **C2-10668**, **C2-10855**, **C2-11204**, **C2-11317**, **C2-11434**, **C2-11650** and **C2-11732**

Q2.04 Which operational and market mechanisms best encourage flexibility providers—including BESS, demand response, nuclear units, and prosumers—to prioritise essential reliability services while remaining commercially viable?
Related papers: **C2-10668**, **C2-10850**, **C2-10670**, **C2-11732**, **C2-12062** and **C2-12135**

Q2.05 How can system operators improve real-time visibility and secure integration of distributed flexibility resources such as rooftop solar, home batteries, EVs, and heat pumps?
Related papers: **C2-10670**, **C2-11204**, **C2-12062** and **C2-12135**

Q2.06 What design principles should guide the evolution of system safety nets—including protection schemes, islanding strategies, black-start capability, and adaptive under-frequency load shedding—in systems with high shares of inverter-based resources?
Related papers: **C2-10455**, **C2-10670** and **C2-11326**

Q2.07 Which performance metrics and benchmarking frameworks are most useful for assessing flexibility, transmission utilisation, AGC performance, and the operational effectiveness of TSOs and ISOs in evolving power systems?
Related papers: **C2-11373**, **C2-11650**, **C2-12135** and **C2-12429**

Preferential Subject 3

Power system dynamics and control in operations (joint PS with C4)

- Operational experience with managing power system stability, including oscillations
- Monitoring and control of power system dynamics in the control room, including wide area systems
- Impact of adverse interactions between power electronics interfaced devices on system operations

The energy transition implies drastic changes for the actors in the electricity system. The growth of inverter-based connections is accompanied by the gradual decommissioning of conventional generation (i.e. carbon-based) and in general by a change in traditional grid regulation and reserve services, in terms of dynamics, performance, topological location and availability.
The presence of renewable generation also impacts forecasting practices and increasingly influences safety assessments and system operation planning towards a probabilistic approach.
This change also affects the fundamental system characteristics: inertia and short-circuit power. Structural change is accompanied by further elements, such as market demands, which impact operations, and a gradual increase in the extension of networks (i.e., European grid extension), which, for example, changes the dynamic response of natural oscillation modes.
Furthermore, climate change increases the exposure of power systems to severe weather events, such as storms, fires, heavy snowfall, and extreme temperatures (high and low), which challenge both system operation and restoration.
These elements increase the operational relevance of dynamic phenomena, such as voltage instability and inter-area oscillations.
Throughout the world, and particularly in Europe, in recent years there has been an increase in the incidence of instability phenomena which is not accidental but rather suggests that new efforts must be made in the field of power systems and in particular in system operations.
The Control Room therefore increasingly requires advanced network monitoring tools applied to an increasingly complex set of phenomena. Control room operators need to be able to monitor and receive appropriate alarms not only from SCADA/EMS functions but also from wide-area applications, as well as be supported in the decision-making process quickly and effectively.
IBRs, thanks to their extremely rapid control response, also require system monitoring across a wide frequency range. Consequently, even traditional room tools (e.g., DSA) that adopted dynamic RMS models may need to be complemented with e.g. EMT or frequency-domain tools to take inverter dynamics into account. Furthermore, point-of-wave sensors/waveform measurements are becoming increasingly popular on the field side, as they are more suited to intercepting fast dynamics (i.e. the dynamic behavior of data centers and other converter-interfaced loads).

<u>Papers for PS3</u>

C2-12083 – Dynamic Behavior and Instability During the 2025 Chilean Blackout: Causes, Controls, and Systemic Impact.
The paper describes and analyzes the dynamic behavior of the Chilean National Electric System during the February 2025 large-scale blackout thanks to RMS simulations calibrated with SCADA and PMUs recordings. A comparative analysis shows difference

between real behavior and expected response by a system fully compliant to the mandatory requirements.

C2-11950 – Recent ENTSO-E Continental Europe Synchronous Area Extensions for Systems of Ukraine/Moldova (2022) and Systems of Lithuania/Latvia/Estonia (2025) – Continental Europe Perspective.
The authors report about the two latest Continental Europe power system synchronous extensions of Ukraine and Moldova in 2022 and Lithuania, Latvia and Estonia in 2025. The paper describes the challenges faced during the complex process of connecting and extending Continental Europe grid.

C2-11948 – Maximum Loadability Index Adapted for Dynamic Scenarios to Anticipate the Voltage Collapse Events.
The paper proposes adaptation of the Maximum Load Index (MLI) for dynamic scenarios, using real-time complex impedance monitoring to anticipate collapse in response to topological and load variations. A hierarchical approach applied to three test power systems.

C2-10854 – Lessons learnt on the EEAC method for fast contingency screening on RTE use-cases.
The work is focused on transient stability analysis performed in real-time adopting Extended Equal Area Criterion (EEAC) with aim to estimate the system's critical clearing time. The authors illustrate advantages and limitations of the algorithm thanks an open source implementation and comparison with actual RTE's reference time-domain simulation tool.

C2-10342 – Managing South Australia's Power System Under Non-Credible Contingencies with two AC Interconnectors.
The paper describes the construction of a new AC interconnector between South Australia (SA) and New South Wales (NSW) and integration into National Electricity Market taking into account the target to maintain power system resilience for high-impact, low-probability events. The impact of RAS on current defense systems and the effect on IBR integration and new network developments are discussed.

C2- 10745 – Detection and Analysis of Oscillation Events with SCADA-Based Statistical Algorithms.
System oscillations are an increasingly topical issue. Often, sufficient PMU coverage is not available when it is necessary to precisely identify the most active network node during oscillation. Two rigorous algorithms based on inferential statistics are used to analyze the amplitude of oscillations seen in the actual and reactive power measurements aimed at finding the source of oscillations from SCADA data.

C2- 10957 – Frequency Quality Degradation and Measures in Western Japan.
Aim of the paper is analyze the effects of growth of renewable energy sources and, in general, of the IBRs in terms of degradation of frequency quality and decrease of available regulation reserves in Japan grid. Thanks to RMS simulations possible countermeasures are being examined like increasing control reserves, applying ramp commands to tie-line set-points, moderating the ramp rate of frequency converter stations, and implementing a new frequency-control scheme.

C2- 11203 – The Experience of Wide-Area Automatic Centralized Emergency Control

System Coordination in Power Systems of Different Countries to Improve the Power System Stability.
The authors describe the impact of coordination of the United Power System (UPS) of Russia, the UPS of Kazakhstan and Interconnected Power System (IPS) of Siberia - Urals considering the stability issues related to the transmission transits, optimizing the emergency control measures.

C2- 12433 – Online Oscillation Detection based on PMU-Data in the Control System.
The paper describes a modular online system to detect oscillatory phenomena on a wide frequency range (intra area, inter area and potentially IBR oscillations). The mode estimation methods based on ambient power system measurements are the (modified extended) Yule-Walker and the Kalman filter method. Two main European incidents are analyzed thanks to PMUs in the Hungarian and Czech transmission systems to validate the estimations by the algorithms comparing with a benchmark.

C2- 11822 – Early warning of system oscillation events based on precursory signs.
The identification of precursory signs of sub-synchronous oscillation is a strategy proposed for the Great Britain power system. An early warning can be generated thanks to a machine learning based method that processes PMU measurands. The authors discuss also the potential limitations of the PMUs in detection of phenomena associated to IBR.

C2- 11322 – Dynamic Security Assessment of Bulk Transmission Using PMUs.
The paper describes the use of PMU-based voltage angle differences as indicators of inter-regional power transfer behavior, with application to the Brazilian Interconnected Power System. K-Means method is adopted to define dynamically the nodal pairs in each subsystem. The approach offers a complementary alternative to the conventional SCADA monitoring, with added value of dynamic assessments thanks to the PMUs measurands.

C2- 11206 – Monitoring the Power System Operating State using 3D Visualization based on PMU Data.
3D visualization for the Control Room is efficient approach for an intuitive awareness especially during fast transients adopted by System Operator of the United Power System of Russia. The paper describes how some applications like islanding detection of power system segments, power imbalance identification, disturbance source localization and others, can be implemented into the visualization framework.

C2- 10465 – A Study on System behaviour During Different Operating Conditions of Offshore Wind Farm – In Context to the First EHVAC Grid connected Offshore Wind Farm of India.
The paper reports the results of an Indian grid connection study conducted for a 500 MW offshore wind farm, highlighting the main technical challenges related to the energy transition. The study explores both RMS modeling and the main voltage and frequency regulation features, along with compliance with standards.

C2- 12428 – Possible Contributions of MT-DC Systems with Grid-Forming Properties to AC system Stability by Providing Inertia.
The paper investigates alternative solutions to support frequency quality and limit large RoCoF after disturbances proposing a multi-terminal HVDC system with Grid-Forming voltage source converters. The authors demonstrate that proper parameters tuning and adequate control strategy can successfully limit frequency nadir and RoCoF compensating

lack of inertia in the grid.

C2- 10216 – Fast Online Stability Monitoring Trough Identification of Weak Interfaces in Bulk Power Systems.
The authors describe an application that manages fast online stability monitoring through the identification
of weak interfaces in bulk power systems based on SCADA measurements. The software tool has been commissioned at the Control Centre of Interconnected Power System (IPS) of Ukraine, where it is now used as SCADA add-on.

C2- 11307 – Innovative Data Analytics of Low Voltage Frequency Measurements for the Detection of Power System Oscillations
The paper proposes to identify and monitor low voltage oscillations in a wide frequency range, including sub-synchronous resonances, using grid-edge devices installed in the Great Britain power system. The authors discuss the possibility of adopting noise and harmonic removal strategies that outperform conventional filtering techniques.

C2- 12605 – Dynamic Power System Areas Formation for Continuous Inertia Estimation.
A novel method for clustering the power system's nodes into areas to be used for online inertia estimation is proposed by the Authors, with a specific characteristic of cyclic update every 15 minutes, considering grid topology changes and evolution of generation mix. The method also allows a probabilistic prediction of the clustering of nodes associated with the areas.

C2- 11797 – Hybrid Phase Angle Monitoring Using PMU and Power Flow Models.
It is proposed a hybrid approach combining PMU measurements with EMS model results to extend phase angle monitoring and assess model accuracy considering a set of selected Croatian 400 kV corridors. The study shows a good estimation of angles by EMS and integrates the security calculation with a RoCo$\Delta\theta$ indicator showing the quasi-dynamic ramping over the lines.

C2- 11205 – Methods and Techniques for Ensuring the Oscillatory Stability of the Russian Power System.
The Russian Power System is a large and complex grid characterized by extensive intersystem ties between the main generating capacities and power consumers. The goal of the paper is to describe both methods to evaluate the effective level of damping over a range of frequencies (0.05 … 5 Hz) and set of countermeasures aimed to guarantee the system stability.

C2- 10462 – Assessing the Impact of Increasing Non-Synchronous Generation on Frequency Stability in the Indian Power System using Measurement-Based Inertia Estimation.
The paper presents a measurement-based estimation of system inertia for the Indian power system using real disturbance data recorded between January 2022 and September 2024. A method based on swing equation is applied to the inertia calculation and two different approach are proposed for the RoCoF estimation.

C2- 10739 – Operational Experience with Synchro phasor-Based Oscillation Monitoring at RTE France.
The authors report on the operating experience of online Oscillation Monitoring System based on synchrophasor measurements available in Control Room. The system detects and tracks

low-damped modes in real time and issues alarms to operators, enabling timely corrective actions. Some real life examples are showed, as the pre-Iberian black out oscillations of 2025.

C2- 11260 – Electromechanical Oscillation Index for Modern Power Systems.
The paper introduces an Electromechanical Oscillation Index (EMOI) based on synchronized generator frequency measurements. The index is intended to quantify the severity of electromechanical oscillations and support control-room situational awareness, PSS tuning, stability-constrained contingency analysis and other EMS applications.

C2- 11325 – Optimal PMU Allocation for a WAMS-Based EMS in the Brazilian Power Grid.
The paper presents the results of a project for optimal PMU allocation in the Brazilian Interconnected Power System, with the objective of enabling full-system observability and redundancy using synchrophasor measurements. The study also considers complementary deployment criteria, economic evaluation and a staged roadmap for WAMS-based real-time operation.

C2- 12645 – Assessing the Dynamic Stability of the Slovenian Power System.
The paper presents a dynamic security assessment tool for the Slovenian power system, initialized using EMS data. Transient, frequency and small-signal stability are assessed through selected indices such as critical clearing time, frequency extrema, RoCoF, frequency margin and modal damping, with results intended to support operator decision-making.

C2- 11323 – Monitoring Effective Inertia via Ambient Synchronized Phasor Measurements.
The paper proposes a non-intrusive method for continuous effective inertia estimation using PMU measurements and system identification. The method is calibrated using the IEEE 39-bus system and validated with real data from the Brazilian system, showing the ability to track inertia variations.

C2- 10723 – Power System Dynamic State Tracking Under Normal and Disturbance Conditions.
The paper presents a Distributed Quasi-Dynamic State Estimator (DQSE) based on dynamic phasor models and high-resolution substation measurements. The method aims to track the dynamic state of the system once per cycle under both normal and disturbance conditions, including faults, thereby complementing traditional static state estimation.

C2- 12182 – Integrating Battery Energy Storage Systems for Primary Frequency Control: A Practical Implementation and Transformation Outlook from the Colombian Power System.
The paper describes the integration of a BESS with a thermal power plant to provide primary frequency regulation in Colombia. The solution is validated using dynamic modelling and real-time simulation, showing faster response than conventional turbine controls and supporting compliance with national frequency regulation requirements.

C2- 12519 – Research on Short-Term Wind Power Volatility Characteristics Based on High-Order Markov Chain.
The paper proposes a probabilistic method for characterizing short-term wind power volatility using high-order Markov chains, fuzzy clustering and Weibull distributions. The approach is validated using wind turbine data and shows good representation of fluctuation characteristics compared with selected neural-network-based methods.

C2- 10103 – Online Dynamic Security Assessment – A Key to Enhancing Observability and Stability in IBR-Dominated Power Systems.
The paper presents an online DSA approach based on a digital twin that integrates steady-state and dynamic models with real-time SCADA/EMS/WAMS data. The method is intended to assess stability limits and operational boundaries in near-real time, including voltage stability, transient stability, SSR, oscillation source location and inertia/RoCoF estimation.

C2- 12395 – Balancing Cellular Autarky and System Frequency: An Inertia-Conscious Dispatch Concept.
The paper proposes a dispatch concept for low-inertia, inverter-dominated power systems, where frequency-supporting reserves are scheduled in advance. The method considers online inertia estimates and allocates reserve across grid areas to improve RoCoF and frequency nadir after disturbances.

C2- 11331 – Impacts of Electromechanical Oscillations on the Operation of the Itaipu 50 Hz Interconnected Power System.
The paper reports operational experience from the Paraguay-Argentina interconnection involving the Itaipu 50 Hz generators. It discusses observed electromechanical oscillations, the role of PSS and WAMPAC functions, operational impacts such as load shedding and system separation, and the need for real-time modal analysis and remedial actions.

C2- 12311 – Power Transfer Capacity Optimization of a Radial Network Using Battery Energy Storage Systems.
The paper studies the use of a BESS as a grid-booster and remedial action scheme for a radial 220 kV corridor in Chile. The BESS is used to increase transfer capacity by relieving post-contingency overloads and to support frequency stability during unintended islanding, with technical and economic assessment of the proposed solution.

C2- 12629 – Comparative Study of Model Order Reduction Criteria for Interaction Studies in Converter-Dominated Power Systems with Cable Networks and Partial Black-Box Subsystems.
The paper compares model order reduction methods for converter-dominated AC/DC systems, including cable networks and partial black-box subsystems. The study evaluates how different reduction methods preserve interaction-relevant dynamics, eigenvalue trajectories and root-locus behaviour, with the aim of enabling more efficient interaction studies.

C2- 10958 – Development of Cross-Border Load Frequency Control for the Japanese Power System.
The paper presents a cross-border load frequency control scheme planned for implementation in Japan. The proposed method coordinates secondary control reserve activation across TSO control areas, improving frequency recovery and reducing activation costs under both normal operating conditions and generator outage scenarios.

C2- 11481 – Instantaneous Energy Dynamics of Wideband Oscillations in Inverter-Dominated Power Systems Based on Port-Hamiltonian Energy Model.
The paper proposes a port-Hamiltonian energy-based modelling framework for analysing wideband oscillations in inverter-dominated systems. The method characterizes storage, dissipation, and exchange of energy across electrical and control subsystems to identify dominant oscillation sources and subsystems.

C2- 12632 – A Preliminary Exploration of Standardized Modular Modeling Methodology for Renewable Generation Suitable for Power System Security and Stability Analysis.
The paper proposes a standardized modular modelling methodology for renewable generation, moving from "model-follows-device" toward a "model-leads-device" approach. Using PV generation as an example, the paper describes model classification, functional modules, parameter identification and validation for EMT simulation and small-signal stability analysis.

C2- 12520 – Dynamic Multi-Parameter Coordination for Enhanced Efficiency and Grid Responsiveness in High-Temperature Power-to-Gas Systems.
The paper presents a dynamic control strategy for high-temperature power-to-gas systems, coordinating electrolysis current, stack temperature and feedstock flow rates. The proposed maximum production point tracking strategy enables fast power tracking while improving efficiency, loading capability and hydrogen production under AGC-type commands.

C2- 11686 – Optimal Restoration of the Power System in Case of Black Start Using Genetic Algorithm.
The paper proposes a genetic-algorithm-based method for optimal black-start restoration following a partial or complete blackout. Applied to the IEEE 39-bus system, the method optimizes system partitioning and sequencing of black-start and non-black-start units.

C2- 10812 – Deployment and operational experience of an adaptive wide-area damping controller at the Italian power grid to mitigate Continental Europe north-south mode oscillations.
The paper presents Terna's operational experience with an adaptive Wide-Area Damping Controller designed to improve damping of inter-area oscillations in the Continental European system. The controller uses PMU-based monitoring and selected controllable resources to provide supplementary damping action, and the paper discusses implementation, testing and operational lessons from a TSO perspective.

C2- 11123 – Practical implementation and Operational Experience of Machine Learning Surrogate Model for Real-Time Dynamic Stability Assessment of the Italian Power System.
The paper presents the practical implementation of machine-learning surrogate models for real-time dynamic stability assessment in the Italian power system. The models are trained on offline dynamic simulations and used to rapidly classify operating conditions according to stability risk, reducing the computational burden of large-scale time-domain simulations and supporting control-room decision-making.

C2- 11124 – Offset-Free Model Predictive Control for Secondary Voltage Regulation: Field Validation on the Italian Transmission Network.
The paper reports field experience with a Model Predictive Control approach for secondary voltage regulation in the Italian transmission system. The proposed control scheme coordinates reactive power resources to improve voltage control performance and demonstrates how advanced control methods can support system operation.

C2- 11125 – Wide-area damping control schemes with grid-forming as actuators.
The paper investigates the use of grid-forming converters as actuators for wide-area damping control. A wide-area control concept is proposed where converter controls contribute to damping of inter-area oscillations, illustrating the potential role of grid-forming resources as active stability-supporting devices in future power systems.

Questions for PS3

Q3.01 What are the lessons learnt from the large disturbances and BO over the last recent years ? How do they translate into operational requirements/processes? Furthermore, to what degree does the actual response/behaviour of the system and connected plants match grid code prescriptions and expected behaviour? What countermeasures and actions can be taken at systemic level to minimize this mismatch?

Q3.02 How can advanced control-room tools detect emerging voltage instability early enough to support preventive or corrective action, and what indicators are most useful to operators? What is the state of the art in centralized and local voltage-control schemes, including the role of STATCOMs, synchronous condensers, BESS and renewable reactive-power control? How should reactive reserve needs and dynamic voltage-control capability be assessed in operation?

Q3.03 What WAMS, SCADA, PMU or waveform-based tools are used to detect, classify and locate oscillations in real time, and how can operators distinguish natural modes, forced oscillations or converter-driven oscillations and take correct remedial action? For converter-driven oscillations and wideband phenomena, where are synchrophasors sufficient, and where are waveform or point-on-wave measurements required?

Q3.04 As converter-driven dynamics increasingly affect system operation, for which operational decisions are RMS/phasor-domain models still sufficient, and when are EMT simulation, frequency-domain methods, etc., required? How can these approaches be combined into practical operational workflows?

Q3.05 What new dynamic load behaviors, including data centres, flexible industrial loads and power-to-gas, are relevant for system stability, and how should they be represented in operational assessment? What opportunities and challenges are offered by power-to-gas and other flexible demand technology?

Q3.06 The growing complexity of the system means there's an opportunity to introduce WAPC and WAPS. What's your experience with this? What indicators are needed for remedial actions ? Is automatic mitigation feasible ? What validation, level of robustness, training, etc., are needed before WAPC and such functions can move from advisory support to automatic remedial action?

Q3.07 IBR growth implies a gradual decrease of system inertia short circuit power. What are the detection and estimation techniques and tools adopted by the Control Rooms ? As inertia becomes time-varying and partly converter-dependent, what should control rooms monitor: synchronous inertia, effective inertia, or some other form of frequency-security index? What are the criteria adopted to define a minimum inertia target for the Control Room ? What is your experience about real time algorithms and methods to estimate inertia ? For example from SCADA, PMUs ? How to consider loads contribution ?

Q3.08 How can advanced screening and AI/ML support real-time dynamic security assessment while maintaining traceability, validation and operator trust?

Q3.09 How can advanced monitoring and control techniques support rapid system restart? What are the potential roles of inverter-based resources in restoration, including possible benefits of grid forming capabilities?

Q3.10 How resilient are PMU/WAMS-based monitoring and control applications to GNSS/GPS loss, jamming or communication failures, and how should operators maintain situational awareness and system security when time-synchronised measurements are degraded or unavailable? When advanced monitoring tools provide uncertain, conflicting or degraded results, how should this uncertainty be presented to operators, and when should the system shift to conservative operating limits?