ISON

System Operator Priorities

December 2024

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Version control

Version	Release date	Changes
1	20/12/2024	First release

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Overview

The International System Operator Network (ISON) brings together six system operators to align on shared priorities to help transition to high renewable power systems. AEMO, CAISO, EirGrid, ERCOT, Energinet and National ESO are the founding members of ISON.

These System Operators (SOs) have a shared ambition to accelerate the transition to renewable energy. The energy transformation continues at pace, and there is an increasing need for, and benefit from, collaborating with a broad range of stakeholders. While SOs have unique systems, regulatory regimes and markets, there are common challenges and opportunities to accelerate the integration and operation of renewable generation – particularly variable, inverter-connected, decentralised generation – across transmission and distribution systems.

The remit of SOs is to maintain the reliability and security of power systems while navigating major changes in how the power system operates and performs. The objective of this System Operator Priorities report is to highlight a set of key priorities SOs are working together to address as they navigate the transition, and to encourage engagement from a broad range of industry stakeholders including academics, research institutes, manufacturers, vendors and other stakeholders. The key priorities addressed in this report relate to six topics – inverter performance, modelling tools, control room tools, planning, system restoration and system services.

ISON would like to acknowledge contributors to the precursor of this document, the G-PST Research Agenda[1].

A separately published appendix includes a detailed list of SO priority questions across short-, medium- and longer-term time horizons.

ISON welcomes engagement on this report and associated appendix, and encourages those working on related areas to share their expertise.

[1] See https://globalpst.org/wp-content/uploads/042921G-PST-Research-Agenda-Master-Document-FINAL_updated.pdf.

Summary of priorities

Table 1 summarises the SO priorities across all six topics.

Table 1 Summary of System Operator priorities

No.	Priority	Details	Topic
2025_01	IBR capabilities	What inverter capabilities (which may include grid forming [GFM]) are required to operate a 100% inverter-based resources (IBR) power system in future? How should technical performance and compliance requirements be specified in grid codes to ensure stability?	Inverter performance
2025_02	Performance standards for power electronic-based loads	What performance standards are appropriate for loads, in particular power electronic-based load types such as electric vehicle (EV) chargers, hydrogen electrolysers and data centres, to ensure they can be successfully and reliably integrated into the system without adverse impact to power system operations, considering their susceptibility to voltage and frequency fluctuations and the impact on system security? What power system model requirements are appropriate?	Inverter performance
2025_03	Stability modelling	What methods and tools are needed for off-line and on-line analysis and detection of instabilities including oscillations? What thresholds are appropriate for planning and operational studies?	Modelling tools
2025_04	Operational capability	What real-time operational capabilities are required for power systems with high levels of variable, inverter-connected generation across transmission and distribution networks, with few or no synchronous machines?	Control room of the future
2025_05	Visualisation capabilities for decision-making	What visualisation capabilities are needed to enable operators to effectively and efficiently interpret relevant information and make operational decisions (in the context of the vast increase in number of connections and data, alarms, new phenomena such as oscillations)?	Control room of the future
2025_06	Forecasting and management of high VRE grid	How do control rooms more optimally address uncertainties in weather conditions that impact loads and renewable energy output and rate of change (ramps)? How can probabilistic forecasting techniques be better incorporated into real-time operations? What operational forecasting capabilities are required in the context of a variable renewable energy (VRE)-dominated grid? What tools and mechanisms are needed to manage an increasing mix of renewables (including battery energy storage) and evaluate and manage short-term resource adequacy/capacity/reserve requirements hours to days ahead?	Control room of the future
2025_07	DER monitoring and control	Based upon the relevant SO control architectures, roles and responsibilities, how can system operators most effectively manage distributed energy resources (DER), including for resource adequacy, contingencies and minimum load management in the control room?	Control room of the future
2025_08	Planning for operability / integrated planning	What tools, methodologies and metrics are appropriate for SOs to plan for operability and resilience (integrated planning approach for longer-term planning), accounting for emerging power system phenomenon and system needs? What tools, methodologies and metrics are required to evaluate resource adequacy in the context of a high IBR/VRE power system? What scenarios do system operators need to consider, including methods for development of future models 5+ years out, including assumptions?	Planning
2025_09	IBR/VRE-based system restart	What capabilities including study tools, monitoring systems, and processes are needed by SOs to black start power systems with high levels of transmission- and distribution-connected IBR/VRE, potential for multiple islands during the restoration process, and very few (or no) synchronous generators?	System restoration
2025_10	System strength	What capabilities are needed to ensure adequate system strength stability when operating a power system with few (or no) synchronous generators?	System services
2025_11	DER system architecture	What core functions, capabilities and roles will system operators, transmission businesses, distribution businesses and DER aggregators need to enable whole-system models of visibility, data exchange, control and operational coordination?	System services

Abbreviations

Abbreviation	Term	Abbreviation	Term
AI	artificial intelligence	IBR	inverter-based resources
BESS	battery energy storage system	IS	information system
CROF	Control Room of the Future	ISON	International System Operator Network
DC	direct current	IT	information technology
DER	distributed energy resources	ML	machine learning
DPV	distributed photovoltaic	MW	megawatt(s)
DSO	Distribution System Operator	OEM	original equipment manufacturer
EMT	electromagnetic transient	PEID	Power Electronic Interfaced Device
EV	electric vehicle	PMU	Phasor Measurement Unit
GET	grid-enhancing technology	PV	photovoltaic
GFL	grid-following	RE	renewable energy
GFM	grid-forming	RMS	Root Mean Squared
HDVC	high-voltage direct current	RT	real time
HIL	hardware-in-the-loop	SO	System Operator
HILP	high impact low probability	TSO	Transmission System Operator
HVDC	high voltage direct current	VPP	virtual power plant
IP	intellectual property	VRE	variable renewable energy

1. Inverter performance

This section sets out priorities relating to the effective integration and operation of inverter-based resources (IBR) and power electronic-based loads.

The objective of this priority area is to help identify the optimal design characteristics needed to maximise the potential of IBR to support secure and reliable power system operation in power systems with up to 100% instantaneous operation of IBR, for a range of generation and load technology portfolios. The priority area encompasses:

- Technical standards and settings.
- Mandated technical capabilities (including advanced inverter capabilities and grid forming).
- Operation and service provision.
- Economic factors (design, cost of service provision).

Table 2 Inverter performance

No.	Priority	Details
2025_01	IBR capabilities	What inverter capabilities (which may include GFM) are required to operate a 100% IBR power system in future? How should technical performance and compliance requirements be specified in grid codes to ensure stability?
2025_02	Performance standards for power electronic-based loads	What performance standards are appropriate for loads, in particular power electronic-based load types such as EV chargers, hydrogen electrolysers and data centres to ensure they can be successfully and reliably integrated into the system without adverse impact to power system operations, considering their susceptibility to voltage and frequency fluctuations and the impact on system security? What power system model requirements are appropriate?

In addition to the above priority areas, other areas of SO interest relate to:

- Inverter tuning – design of inverter control systems to reduce undesired performance.
- Frequency performance – establishment of standard IBR frequency response behaviour to respond to system incidents and maintain a reliable power system.
- Protection schemes in IBR-dominated grids – adapt protection schemes to unique characteristics of IBR dominated systems.

2. Modelling tools

This section sets out priorities relating to power system data, models, modelling tools and simulation methods.

The objective of this priority area is to define offline and online power system modelling capabilities needed by system operators to evaluate stability and meet relevant technical standards for power systems with areas of the power system dominated by IBR and characterised by low system strength.

Table 3 Modelling tools

No.	Priority	Details
2025_03	Stability modelling	What methods and tools are needed for off-line and on-line analysis and detection of instabilities including oscillations? What thresholds are appropriate for planning and operational studies?

In addition to the above, other areas of SO interest relate to:

- Methodologies and processes for studies – development of techniques to maximise simulation performance, improving speed and accuracy for system studies.
- Control room tools for power system phenomenon and developments – creation of tools to analyse system performance, technical limits, high impedance areas, grid-forming (GFM) and grid-following (GFL) device performance, system inertia, frequency control, voltage collapse and reactive power control.
- Inverter-based technology models – establishment of requirements to validate models of inverter-based technology, such as variable renewable energy (VRE), distributed energy resources (DER) and inverter-based loads.

3. Control room of the future

This section sets out priorities relating to operational and control room capabilities, with a view to leveraging new technologies.

The objectives of this priority area are two-fold:

- Define the suite of control room tools needed to operate a power system with very high levels of VRE and IBR across transmission and distribution networks.
- Identify new capabilities, technologies and visualisation methods that can be integrated into the SO control room environment to improve operational decision-making and reduce operational risks.

Table 4 Control room of the future

No.	Priority	Details
2025_04	Operational capability	What real-time operational capabilities are required for power systems with high levels of variable, inverter-connected generation across transmission and distribution networks, with few or no synchronous machines?
2025_05	Visualisation capabilities for decision-making	What visualisation capabilities are needed to enable operators to effectively and efficiently interpret relevant information and make operational decisions (in the context of the vast increase in number of connections and data, alarms, new phenomena such as oscillations)?
2025_06	Forecasting and management of high VRE grid	How do control rooms more optimally address uncertainties in weather conditions that impact loads and renewable energy output and rate of change (ramps)? How can probabilistic forecasting techniques be better incorporated into real-time operations? What operational forecasting capabilities are required in the context of a VRE-dominated grid? What tools and mechanisms are needed to manage an increasing mix of renewables (including battery energy storage) and evaluate and manage short-term resource adequacy/capacity/reserve requirements hours to days ahead?
2025_07	DER monitoring and control	Based on the relevant SO control architectures, roles and responsibilities, how can SOs most effectively manage DER, including for resource adequacy, contingencies and minimum load management in the control room?

In addition to the above priority areas, other areas of SO interest relate to:

- Capabilities needed to ensure real-time situational awareness of the state of the power system.
- How system operators can best employ grid-enhancing technology (GET), virtual power plants (VPPs) and grid topology to optimise the operation of a power system.
- Digital architecture required to support control room operations.
- Effective monitoring and control of DER for a given system architecture.
- Leveraging big data, artificial intelligence (AI) and machine learning (ML) for operational insights.
- Cybersecurity and cyber protection of the control room, and in-bound and out-bound communications.

4. Planning

This section sets out priorities relating to power system planning, particularly with regard to resource adequacy, and considering the future technical and operational needs to maintain both reliable and secure systems.

The objective of this priority area is to define the metrics, methods and tools needed for long-term planning, resource adequacy and assessment of resilience for a power system with a VRE instantaneous penetration of up to 100%.

Table 5 Planning

No.	Priority	Details
2025_08	Planning for operability/ integrated planning	What tools, methodologies and metrics are appropriate for SOs to plan for operability and resilience (integrated planning approach for longer-term planning), accounting for emerging power system phenomenon and system needs? What tools, methodologies and metrics are required to evaluate resource adequacy in the context of a high IBR/VRE power system? What scenarios do system operators need to consider, including methods for development of future models 5+ years out, including assumptions?

In addition to the above, other areas of SO interest relate to:

- Resource adequacy/capacity planning – long-term studies into resource adequacy of future power systems, including probabilistic forecasting of inverter-based and battery technologies.
- System risks – planning for a resilient system taking into account environmental conditions and system/market costs.

5. System restoration

This section sets out priorities relating to system restoration and black start.

The objectives of this priority area are to:

- Explore how system restart standards and procedures should evolve as power systems move from large, centralised synchronous generators to dispersed VRE and, ultimately 100% IBR penetrations.
- Determine what technical capabilities are needed to restart a power system with 100% transmission- and distribution-connected IBR generation.

Table 6 Restoration and black start

No.	Priority	Details
2025_09	IBR/VRE-based system restart	What capabilities including study tools, monitoring systems, and processes are needed by system operators to black start power systems with high levels of transmission- and distribution-connected IBR/VRE, potential for multiple islands during the restoration process, and very few (or no) synchronous generators?

In addition to the above, development of procedures to restart specific infrastructure, such as feeders with DER, and identification of equipment that may assist with restoration of future energy systems are of interest.

6. System services

This section sets out priorities relating to the effective integration and operation of IBR.

The objectives of this priority area are to:

- Define and quantify services required by a system with 0% synchronous, constant fuel generators, considering how they can be procured and dispatched over a range of timeframes to effectively operate gigawatt-scale power systems with very high levels of VRE and IBR.
- Define the structural arrangements and market design to enhance the capability of legacy power systems to enable secure and efficient operation with up to 100% instantaneous supply from centralised and distributed renewables (including up to 100% penetration of DER).
- Define operational and modelling requirements for 100% instantaneous penetration of DER.

Table 7 Services, architecture and DER

No.	Priority	Details
2025_10	System strength	What capabilities are needed to ensure adequate system strength stability when operating a power system with few (or no) synchronous generators?
2025_11	DER system architecture	What core functions, capabilities and roles will system operators, transmission businesses, distribution businesses and DER aggregators need to enable whole-system models of visibility, data exchange, control and operational coordination?

In addition to the above priority areas, other areas of SO interest relate to:

- Ability for IBR to provide system services – identification of system services that can be provided in a cost effective manner by IBR plants, offshore wind, high voltage direct current (HVDC) and DER.
- Wholesale market design – development of market structures and incentives to enable the energy transition.