RAP REGULATORY ASSISTANCE PROJECT

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Modernising regulations to prevent blackouts

A non-technical guide

Dominic Scott, Neil Lessem & Alejandro Hernández

Executive summary[1]

Interruptions to our electricity supply happen for a variety of reasons, such as damage to equipment from storms, wildlife or vegetation growth. For the most part, these interruptions are limited in depth and duration. However, if grids are allowed to become unstable, such outages can result in a series of cascading failures leading to large parts of the grid shutting down. This is known as a '**blackout**.'[2]

With proper systems in place to contain disturbances when they hit the grid, blackouts are largely avoidable. We call an energy system that is able to withstand such disturbances 'stable.' As grids modernise, our approach to **stability** must continue to evolve along with the technologies that underpin it. Regulation in turn needs to keep pace with technological advances, ensuring the right solutions are in place when needed.

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[2] Glossary terms appear in bold upon first mention.

This guide explains in non-technical terms the different elements of system stability, the technologies that support stability, and the broad steps for setting up a regulatory regime that enables it. Having such a regime in place is key to unlocking low-cost, low-emissions renewable energy; empowering the electrification of heat and transport; and deploying the mix of new and existing technologies required to keep blackout risk manageable.

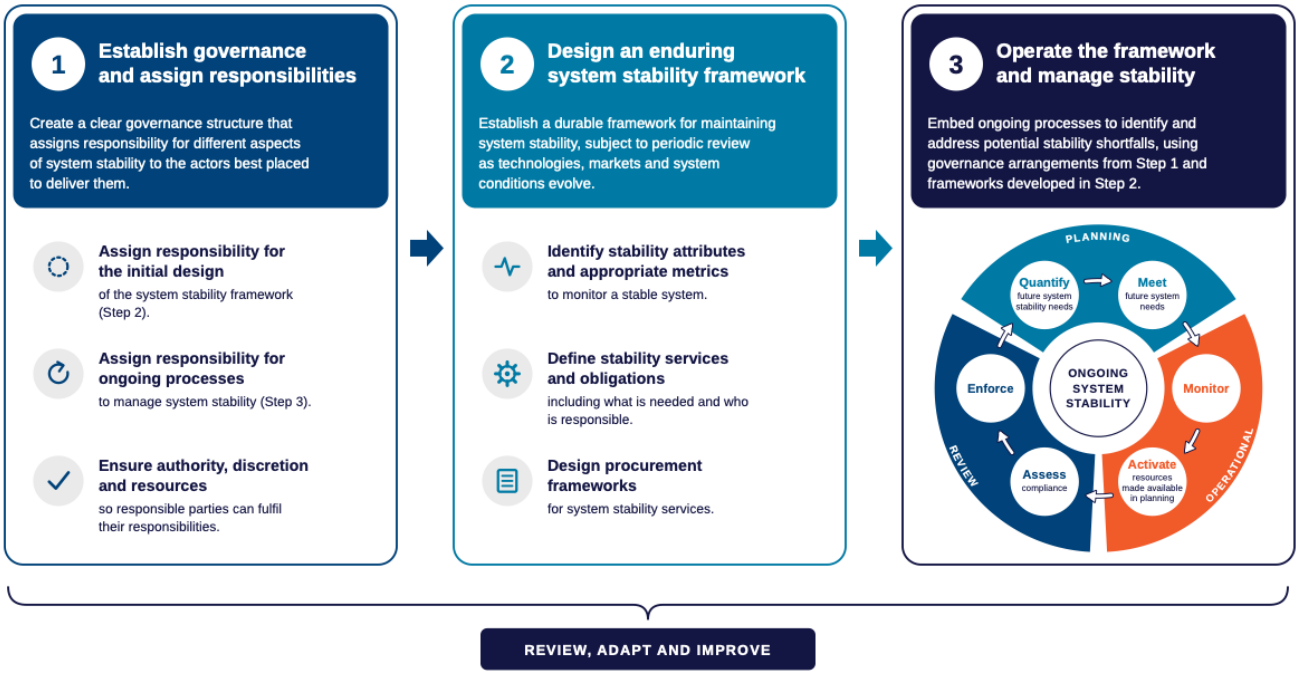
The challenge of maintaining **grid stability** is not new. Historically, many major outages have occurred in the presence of low or negligible shares of renewables – but this has not stopped some news outlets from incorrectly blaming recent outages on growing volumes of renewable resources.

False claims notwithstanding, the risk of large-scale outages remains manageable. The technology exists to ensure stability as we transition to a cleaner, more modern grid. Advancements in power system electronics mean that modern grids can continue to operate securely, even in the absence of older fossil-fuel technology. Alongside this, governance and regulatory reforms are crucial to ensure that decision-makers implement a high-performing set of solutions.

As we modernise power grids, our approach to stability must continue to evolve along with the technologies and regulations that underpin it.

Multiple regions are already meeting the challenges presented by the clean energy transition, and are operating safely with high levels of renewables. These include California, Texas, South Australia, Ireland and the Island of Hawaii. Learning from their successes and failures, we set out three clear steps that policymakers, regulators and **system operators** can take to reduce the risk of large-scale outages as we transition towards a more electrified economy and a cleaner power system, as illustrated in Figure 1 below.

Figure 1. Steps that policymakers and regulators can take to reduce the risk of large-scale outages during the clean energy transition



Implementing these steps, refuting misinformation and ultimately building a lower-cost, lower-emissions grid will require many actors to work together. We hope that this tool makes the subject matter more accessible to a wider audience, unlocks greater participation and expedites necessary reform. The rest of the paper proceeds as follows:

- Section 1 introduces key reliability concepts, presents the different components that make up system stability, and surveys selected technologies that underpin stability.
- Section 2 sets out three clear steps that policymakers, regulators and system operators can take to reduce the risk of large-scale outages as we transition towards a more electrified economy and a cleaner power system.
- Section 3 presents messages that counter the common misinformation and myths that may spread following a blackout. These draw on good practices in the multiple regions that are already operating safely with high levels of renewables.

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1. Understanding system stability

Key concepts in electricity system reliability

Power system **reliability** is the ability of the grid to continuously deliver electricity to customers with an acceptable level of quality. Reliability is founded on the following three simplified concepts:

- **Resource adequacy** means there is enough generation or storage to meet demand. Planning for resource adequacy is carried out years or months ahead of delivery.
- **Operational security** means the grid can withstand regular ('credible') disturbances such as unexpected changes in supply or demand, or the loss of a generator, transmission or distribution line. Planning for operational security takes place in the days, hours, minutes and even seconds ahead of delivery, with some actions such as turning a generator up or down occurring in close to real time.
- **System stability** means the ability of the system to absorb disturbances and unexpected shocks before operators have a chance to react, so that shocks are isolated and handled, rather than causing cascading failures. Stability refers to the effectiveness of a system's dynamic response to a disturbance, within timelines of seconds to milliseconds.

While their precise interpretation may vary across jurisdictions, these concepts often inform regulatory and market functions, roles and responsibilities.

In most grids with sound investment frameworks, the great majority of service interruptions are caused by failures in local distribution networks.[3] These are often caused by weather events, such as through trees falling in high winds, or lightning strikes. Typically, automatic protections will detect any abnormality within milliseconds and disconnect the local network to protect the stability of the greater grid.

Conversely, although it may receive high media and political attention, inadequate generation capacity typically constitutes only a small share of outage time. Moreover, when these rare shortages do occur, they may be by design, reflecting the fact that the costs of building generation capacity to meet every conceivable extreme event would be prohibitively expensive. In such cases, system operators will resort to 'rotational **load** shedding' as a last measure. This is a *controlled* intervention where the system operator sequentially turns off power for groups of customers for limited periods of time, say one hour. Critical loads like hospitals can be protected where configurations and plans allow for it.

Network outages and rotational load shedding are both 'contained' events: although some customers may lose power, the grid operator retains control of the grid. A widespread blackout

[3] The OECD reports that "in four countries that do provide this information – the United States, Japan, Australia and Chile – over 90% of power supply interruptions originate in distribution grids. In the European Union, although comprehensive data for individual outage events is not available, when comparing reliability indicators across voltage levels it is evident that most outages originate in low-voltage grids." International Energy Agency (IEA). *Electricity Grids and Secure Energy Transitions: Enhancing the Foundations of Resilient, Sustainable and Affordable Power Systems.* OECD Publishing, 27 Oct. 2023. https://www.oecd.org/en/publications/electricity-grids-and-secure-energy-transitions_455dd4fb-en.html

(sometimes called a 'system black' event) is different in that the grid operator loses control of the grid or large portions of it, such that it shuts down and needs to be restarted.

These events happen when faults or instabilities, like a wire short-circuiting or a generator breaking down, trigger a chain reaction across the power grid. As built-in safety protections kick in to shield equipment, power plants and appliances from damage, lines, generators or loads are disconnected in rapid succession. Blackouts are rare but they can have devastating consequences, leaving millions of customers without power for hours at a time, often during severe weather.[4]

System stability

This guide focuses on policies and regulatory interventions to embed stability in power systems to limit the risk of blackouts as they undergo modernisation. It is needed because:

- Historical providers of stability capabilities, such as fossil-fuelled generators, are being phased down or completely phased out of energy systems.
- New technologies offer new clean possibilities for embedding stability in power systems.
- Recent events have focused attention on the importance of robust and forward-looking regulation to manage reliability risks during the energy transition.

Stability builds on good practices for ensuring resource adequacy and operational security, and it relies on system attributes and capabilities that act automatically, immediately and in the correct sequence when required. When the electricity system is subject to a disturbance, this stability buys the system operator precious time to marshal operational resources kept in reserve to secure the system. Given that failures can cascade and bring down an entire electricity grid in a matter of seconds, this additional response time is crucial.

The reliable operation of a power system requires attention to be paid to multiple forms of stability.[5] We highlight three important categories in Figure 1 below:

- **Frequency stability** means keeping the frequency of alternation of the grid current[6] within tight bounds around a given target. In some regions, including Europe, China, India and Africa, this target is 50 hertz.[7] In other regions, such as the United States, South Korea and some of Latin America, it is 60 hertz. Frequency is an indicator of the balance between electricity generation and demand. If it deviates too far from its target, automatic protection systems may disconnect equipment. If not well managed, this can potentially lead to cascading failures and a widespread blackout.

[4] Moreover, global warming, more variable precipitation patterns, rising sea levels and extreme weather events increase the likelihood of climate-driven disruption. International Energy Agency (IEA). (12 April 2021). *Climate Resilience*. https://www.iea.org/reports/climate-resilience

[5] Hatziargyriou, N. et al. (July 2021). Definition and Classification of Power System Stability — Revisited & Extended. *IEEE Transactions on Power Systems* 36, no. 4: 3271–3281. https://ieeexplore.ieee.org/document/9286772/

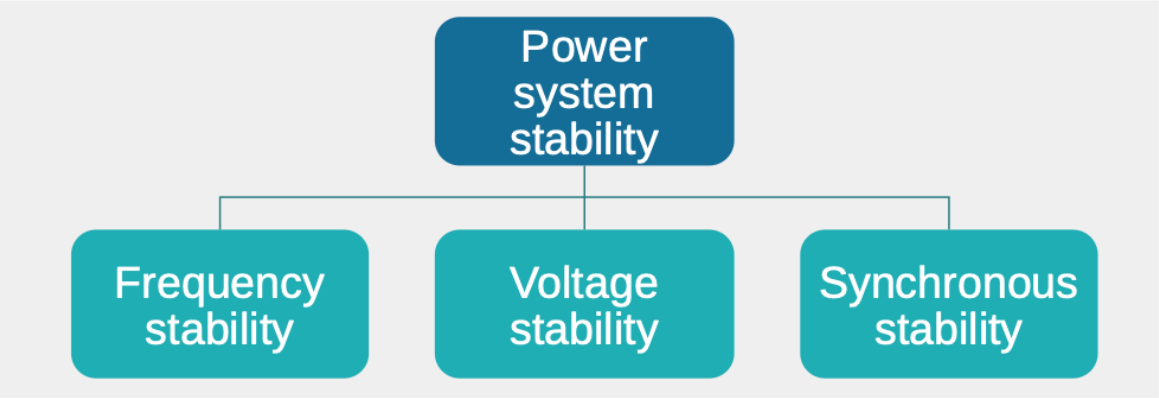
[6] The grid operates on 'alternating current.' See Glossary.

[7] This means the electrical alternating current completes 50 full 'back-and-forth' cycles every second.

- **Voltage stability**: voltage is the electrical pressure that drives the current through the network. Stability requires voltage levels to be kept within specified ranges,[8] and for voltage oscillations to be actively dampened. Undervoltage and overvoltage can prevent equipment from operating correctly and can damage infrastructure. Although voltage is local, voltage oscillations can cascade into systemwide blackouts if they are not sufficiently dampened.

- **Synchronous stability**[9] is the ability of generators to remain in step with one another following a disturbance, without their differences in timing and rotation growing so large that they fall out of step.[10] This helps to avoid large electrical and mechanical stresses and prevents protection systems from disconnecting equipment – which, in extreme cases, can result in widespread system failure.

Figure 1. Key elements of power system stability



Additional forms of stability are expected to become more important with the growing use of power electronic equipment.[11] It is important to note that stability categories can overlap, and a single disturbance may involve more than one of them.

Characteristics and capabilities supporting system stability

Engineers and energy experts often describe the electricity grid as the most complex machine ever made. One reason for this is that conventional synchronous generators – such as those drawing on coal, gas, hydro and nuclear fuels – are electrically coupled through the grid like parts of a single machine. The rotating magnetic fields of these generators remain synchronised with the grid's electrical frequency. The magnetic fields do not all have to rotate at the same

[8] Typically, this is within ±5% to ±10% of the designed, ideal voltage level a system is meant to run on.

[9] This is known technically as 'rotor angle stability,' the angle on a synchronous generator between the rotor's magnetic field and the stator magnetic field.

[10] The synchronisation is not perfectly rigid. Generators can move slightly ahead of or behind one another, and can oscillate relative to one another, but they must remain sufficiently synchronised to continue operating as part of the interconnected system.

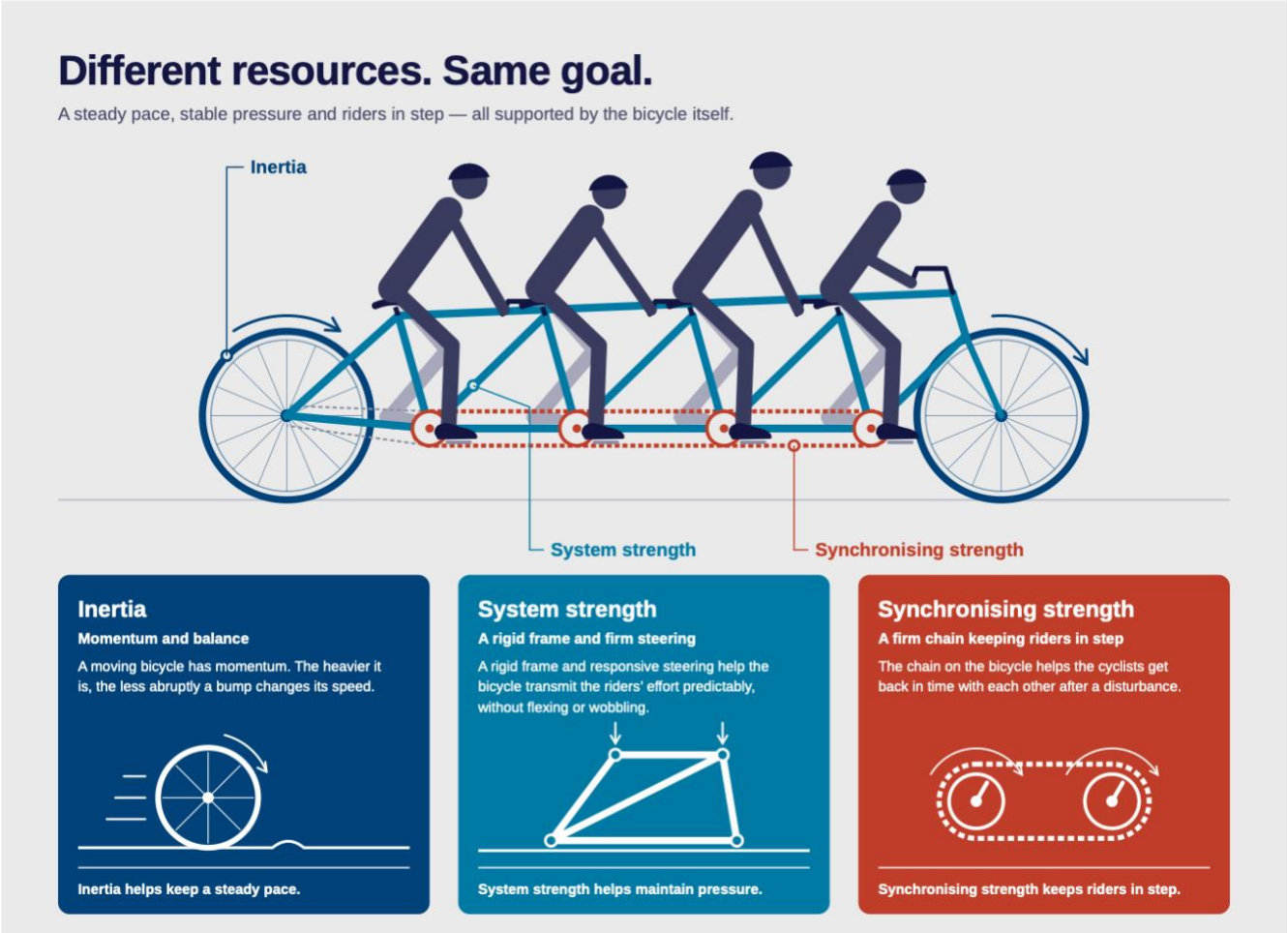
[11] These include preventing resonance and ensuring converter-based stability. As with the other elements of power system stability, these will require regulatory attention.

physical speed: a generator with more magnetic poles rotates more slowly than one with fewer poles, but both produce electricity at the same grid frequency.

This is much like riders on a tandem bicycle. Although the riders may differ in size, strength and ability, the chain they share keeps their pedals moving in a common rhythm – just as synchronous generators remain coupled through the grid's common electrical frequency. When the road becomes steeper or flatter, the riders adjust their effort to keep the bicycle moving at a steady speed. But the bicycle's ability to withstand a sudden bump or change in gradient depends not only on the riders' actions, but also on the characteristics of the bicycle itself – including its momentum, the rigidity of its frame, and how efficiently its chain keeps the riders working together.

Figure 3 uses the bicycle analogy to introduce selected attributes of energy resources that support system stability.

Figure 3: The power system attributes bicycle analogy – like a bicycle, a healthy power system needs certain capabilities to remain stable.



As with the bicycle, maintaining a secure electricity system relies on a combination of operational actions undertaken by the system operator (the rider) and technical stability characteristics embedded within the power system itself (the bicycle). The operator monitors the system, prepares for contingencies, and responds to disturbances in real time. The inherent stability characteristics and capabilities of the power system itself are established through the technical attributes of connected resources and network infrastructure, which are typically specified through **grid codes** and other technical standards. In this paper, we concern ourselves chiefly with those inherent stability characteristics and capabilities of the power system.

Table 1 summarises the principal operational tools and inherent system characteristics associated with the main dimensions of power system stability, based on concepts in Figure 3.

Table 1. Operational tools and inherent system characteristics underpinning power system stability

Type of stability	What it means	How operators help maintain it (the rider)	What the system itself needs to support it (the bicycle)
Frequency stability	**Pace:** Keeping the system operating close to its target frequency, keeping the 'pace' of the electricity system steady.	Continuously matching electricity generation and demand, supported by **operating reserves** and **fast frequency response** when something unexpected happens.[12]	**Inertia** – is a feature of the system which instantaneously slows changes in frequency following a disturbance, traditionally provided by the stored kinetic energy of synchronously connected machines. New resources like solar PV, wind and batteries can offer inertia-like capabilities.
Voltage stability	**Pressure:** Keeping voltage levels, the network's electrical 'pressure,' within acceptable limits so equipment operates correctly.	Using equipment and resources across the system for voltage control (including by producing or absorbing what is known as '**reactive power**'[13] where needed).	**System strength** – is the inherent robustness of an electrical network at a given location, reflecting its ability to *maintain and control a stable voltage* waveform during normal operations and to resist major voltage fluctuations following a network fault or disturbance. It is primarily determined by the available short-circuit '**fault current**' at that node.[14]
Synchronous stability ('rotor angle stability')	**In step:** Keeping generators operating in synchrony following disturbances such as faults or the loss of equipment.	Managing the operation of the network and generators to avoid excessive stresses, including through generator dispatch, network configuration, transfer limits and rapid fault clearing.	**Synchronising strength** – providing electrical forces that help generators to remain in step. Inertia also helps resist sudden changes in generator speed.

[12] Operating reserves are pre-arranged capability – provided by generation, storage or responsive load – that the system operator can deploy to adjust the supply–demand balance and arrest frequency deviations. Fast frequency response is a particularly rapid, typically automatic form of frequency-responsive reserve that acts within seconds to arrest frequency deviations.

[13] Reactive power is energy that moves back and forth on the grid to help maintain voltage – the electrical 'pressure' needed for power to flow reliably and for equipment to work properly.

[14] Fault current is a sudden, heavy surge of electricity that flows through a circuit when something goes wrong, such as a damaged wire touching a metal frame or a short circuit. A high fault current – provided by generators or storage – is desirable because it forces safety devices like circuit breakers and fuses to react and shut off the power instantly. A system therefore needs enough fault current for reliable protection and adequate system strength, within safety ratings of equipment.

Multiple technologies can contribute to system stability

Stability emerges from the technical capabilities of the system, when they are enabled and available where needed in the network. New technologies expand the range of options available for meeting grid stability needs. While stability has historically been provided by synchronised generators, these do not necessarily need to be part of the future stability mix. Below, we outline a selection of technologies that can contribute different subsets of the required capabilities.[15]

Synchronous generators: Almost all thermal generators – whether coal, gas or nuclear – are rotating synchronous machines. The same is true for hydro generators.[16] System strength and **inertia** are byproducts of synchronous generators, and are thus automatically supplied wherever they run. Because they arrived without being asked for, they were neither measured nor priced. When operated with sufficient spare capacity and fitted with necessary controls, synchronous generators can also adjust their output to provide frequency response.

Inverter-based resources (IBRs): Many of the newer technologies in the electricity system, including wind and solar, connect to the electrical grid via power electronic inverters. These are collectively known as **inverter-based resources**.[17] Inverters convert current from the connected device to the **alternating current** required on the grid, or vice versa (e.g., battery charging).[18] IBRs can be configured to contribute a range of system services, including services that support stability.

Table 2 below presents a selection of IBR technologies along with the primary function of their inverters.[19]

[15] This list is not complete. It could also include flexible load, for example, which can contribute to system stability in a high-variable renewable energy system by acting as very fast frequency response service providers.

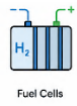
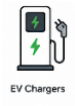
[16] They have an internal magnetic rotor that spins at a precise speed locked to the frequency of the alternating current system and the number of magnetic poles in the machine (the fewer poles it has, the faster it needs to spin).

[17] Wind turbine-generators do rotate like synchronous generators; however, the rotation speed of modern wind turbine-generators varies continuously with wind speed rather than being fixed to a rotational speed compatible with the grid frequency, thus requiring a power electronics-based connection to the grid.

[18] Note that when drawing from the grid, the converter is technically known as a rectifier, rather than inverter. However, in common with much of the literature, we use the term inverter in all cases.

[19] Others include e-statcoms and high-voltage direct current (HVDC) links. E-statcoms are network devices whose only job is to provide stability. The statcom is a high-tech 'shock absorber' that acts within milliseconds to maintain voltage. The 'E' stands for enhanced – through the addition of super-fast energy storage – which can inject real, usable power into the grid for a few seconds to support frequency stability. HVDC transmission wires carry power over long distances or between systems that are not synchronised with each other. Inverters change AC into DC for transmission and then convert it back to AC at the receiving end, allowing the power flowing through the link to be precisely controlled.

Table 2. Selected inverter-based resource technologies and the primary function of their inverters

Technology		Primary function of the inverter
Solar PV		Inverters convert the direct current (DC) generated by the solar PV into alternating current (AC) for the grid.
Wind turbines		Inverters convert the irregular, variable-frequency AC generated by the wind turbine into stable, grid-compliant AC electricity.
Fuel cells		Inverters convert DC from fuel cells into AC for the grid.
Battery energy storage systems (BESS)		Inverters convert DC from batteries into AC for the grid when injecting, and vice versa when charging. Many data centres run off a battery connected to the grid, converting power both into and out of the battery.
EV chargers		Inverters bridge the gap between AC power from the electrical grid and the DC power stored in the electric vehicle (EV) battery. They can be designed to be bidirectional to allow discharge from the EV.

The capabilities of IBRs to provide power system services are continually evolving. Earlier generations of IBRs were predominantly 'grid-following,' providing only a limited range of services. For example, while grid-following inverters can help control voltage under normal conditions, they rely on the power system to provide a voltage and frequency reference because they cannot independently establish these references. As a result, their ability to support the system during severe disturbances is limited, particularly when voltage collapses across a wide area or the grid struggles to maintain stable voltage as conditions change.

Newer IBRs, particularly utility-scale installations, are increasingly being equipped with 'grid-forming' functionality, which allows them to establish and stabilise grid voltage and frequency, including during disturbances. To provide sustained active power[20] following a disturbance, grid-forming IBRs need access to stored energy or available generation. Battery energy storage systems (BESS) are well suited to this role because they can reserve stored energy for use when needed. Wind and solar PV, by comparison, need to curtail output to provide the equivalent reserve themselves. Pairing them with a battery offers an alternative that means the renewable generator is not required to hold back as much output. New utility-scale IBRs, particularly BESS, may have the hardware capability to provide advanced grid-forming services, but software upgrades and new operational procedures may still be necessary.[21]

[20] Active power is the electricity that does the actual work, such as lighting a bulb or turning a motor. It is distinguished from reactive power, which helps control voltage.

[21] Depending on the original design, retrofitting grid-forming capability may also require upgraded electrical components, additional energy reserves, changes to protection systems, and regulatory approval.

Synchronous condensers (syncons): Syncons are large, heavy spinning motors. Like synchronous generators, they spin in lockstep with the grid.[22] Unlike synchronous generators, they are not connected to a turbine or mechanical load and they do not use fuel. Instead, they spin freely to provide grid stability services, without generating sustained active power. Their heavy rotating metal masses provide inertia that helps to slow changes when, for example, a power plant trips offline. Adding a flywheel – an additional heavy spinning mass – to the rotor can increase inertia. Syncons can also help to keep grid voltage stable and support fault detection and clearance. Hydro power generators are often built with a 'clutch' that disengages generation of active power and allows them to run in syncon mode. Some new gas generators are also being built with this capability. This allows them to offer grid stability services without providing energy.

The top half of Table 3 summarises the potential contribution of selected technologies to the system capabilities and characteristics that underpin stability – inertia, **system strength** and synchronising strength. The lower half presents their contribution to key operational capabilities.

Table 1. Characteristics and capabilities for selected technologies

Characteristics and capabilities		Synchronous machines		IBRs (particularly batteries)	
		Generation	Syncons	Grid-following	Grid-forming
System characteristics supporting stability	**Inertia**	Yes	Yes	No (limited and dependent on other resources)	Yes (can provide equivalent response)
	System strength	Yes	Yes	Limited	Yes (though fault current is limited)
	Synchronising strength	Yes	Yes	Limited	Yes
Operational capabilities supporting stability	**Frequency response**	Yes	No (unless paired with energy source and control system like a battery)	Yes	Yes
	Voltage control	Yes	Yes	Yes	Yes

Note: Actual capabilities depend on multiple factors such as equipment design, control settings, operating conditions and the services a resource is configured to provide.

[22] This 2026 video by Transco – *How Do Synchronous Condensers Keep Australia's Power System Stable?* –introduces syncons and their deployment in Australia: https://www.youtube.com/watch?v=IdWaTaNfr10

In many systems, inverter-based renewables are the cheapest option for expanding capacity and replacing ageing thermal generators. As the share of synchronous generation diminishes, it will become challenging to maintain system stability if the resources displacing it are grid-following IBRs and no further stability services are engaged.[23] Fortunately, selective deployment of grid-forming IBRs and syncons can offer the stability capabilities required. Syncons and grid-forming inverters provide complementary capabilities.[24] Syncons offer physical inertia, strong voltage support and high fault current; while grid-forming inverters provide fast, programmable active- and reactive-power responses – and, when paired with storage, sustained frequency support. The appropriate combination depends on the needs and characteristics of the system. This brings us on to how and when the regulatory framework can be amended to unlock these capabilities.

2. What regulators and policymakers can do

Overview – modern grids require modern regulations

Reliability – system stability, operational security, and resource adequacy – depends on the power system as a whole, not on any one technology or set of technologies. Different technologies can provide different services, at different times and in different quantities.

To achieve stability in a modern power system, it is crucial that planning and regulatory frameworks ensure the market delivers the right mix of resources at the least cost. The declining share of traditional sources of system stability and the evolving capabilities of new technologies mean that regulatory frameworks must be modernised to maintain system stability through the clean energy transition. Technological solutions are already commercially available and continue to evolve. Regulators and policymakers have the power to ensure that the right mechanisms are put in place to unlock these solutions and ensure they are available when needed.

It is critical to update regulatory frameworks to maintain system stability through the clean energy transition.

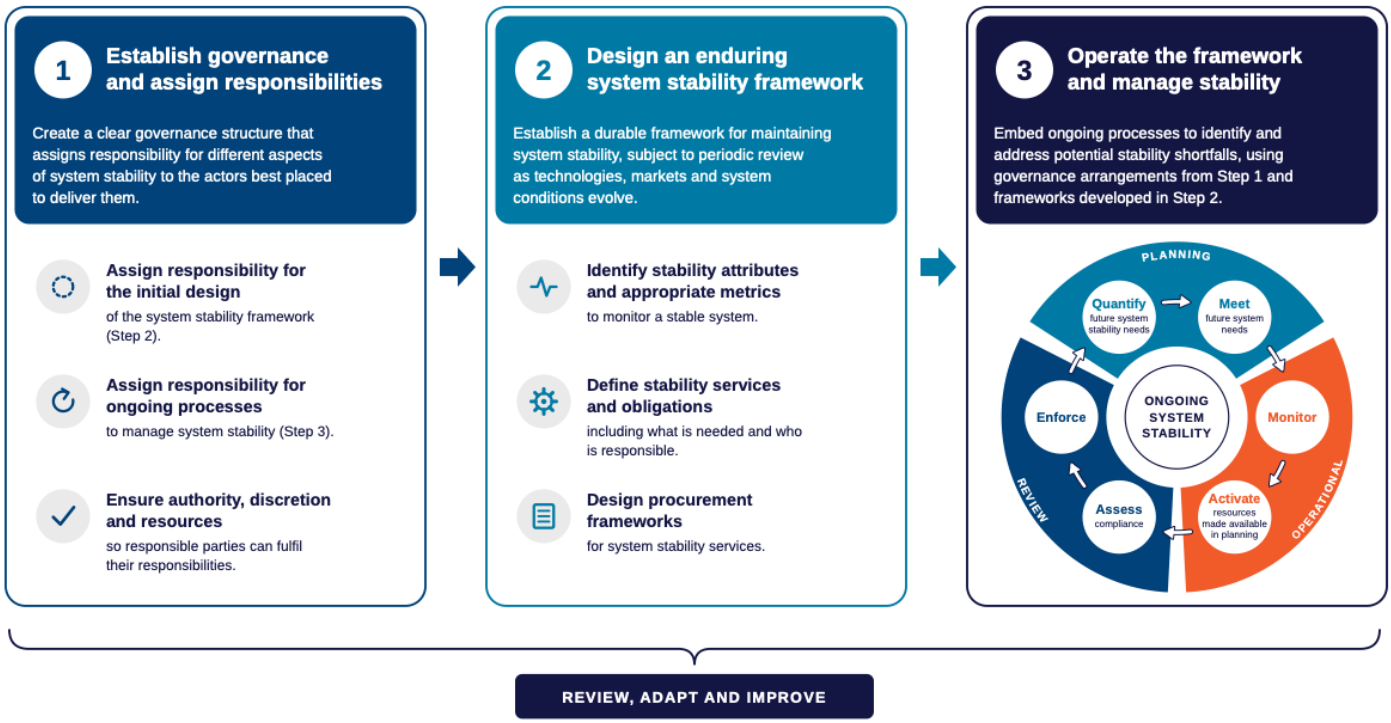
In this section, we present three high-level steps for reducing the risk of large-scale outages, as well as the detailed elements within the three steps, as shown in Figure 4. These steps require cooperation between policymakers, regulators and system operators.

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[23] See, for instance, International Energy Agency. (2024). *Integrating solar and wind: Global experience and emerging challenges.* IEA. https://www.iea.org/reports/integrating-solar-and-wind. Note that power systems based on low-carbon technologies like hydro, nuclear and geothermal can draw on these for traditional services such as physical inertia to underpin stability.

[24] The Australian system operator treats grid-forming BESS as a practical and cost-efficient alternative to conventional system strength remediation (like syncons) for some capabilities like helping meet the 'efficient level of system strength.' For other capabilities, the potential for grid-forming IBRs, notably BESS, to substitute for alternatives like syncons is still being established. See Australian Energy Market Operator (AEMO). (28 November 2025). *Grid Forming BESS Fault Current Contribution Study Scope.* https://www.aemo.com.au/-/media/files/initiatives/engineering-framework/2025/grid-forming-bess-fault-current-contribution-study-scope.pdf

Figure 4. Steps that policymakers and regulators can take to reduce the risk of large-scale outages during the clean energy transition



The checklist in Annex 2 provides a list of activities for the third step – operating the framework and managing stability.

Step 1: System stability governance

The governance structure establishes roles, powers and duties of the regulator(s), the system operator and market participants, and the regulator's oversight of them with respect to system stability. These include the initial design of the system stability framework (Step 2) as well as ongoing system stability processes (Step 3).

System stability is just one aspect of energy sector regulation and market design. Each jurisdiction will have its own pre-existing set of institutions, roles, responsibilities and capabilities which inform the best system stability governance arrangements for that jurisdiction. However, there are some commonalities across jurisdictions with more advanced system stability programmes.

In these leading jurisdictions – which include Australia, Ireland, Great Britain, the U.S. state of Texas, South Africa and New Zealand[25] – responsibilities for the initial design (Step 2) and

[25] We identify these jurisdictions as establishing advanced system stability programmes, noting that each has been proactively monitoring elements of system stability for at least a decade.

ongoing operation (Step 3) of the system stability framework tend to be allocated as shown in Table 4.[26]

Table 2. Allocation of responsibilities in selected jurisdictions

	Regulators	System operators
Responsibility for the initial design of the system stability framework (Step 2)	▪ Set the framework, establish the official regulatory, market, or licensing rules ▪ Define the system stability services to be delivered[27] ▪ Develop procurement mechanisms, including cost recovery	▪ Define system stability needs ▪ Develop proxy metrics of stability ▪ Propose and inform rules: design or draft the framework details
Responsibility for ongoing system stability processes (Step 3)	▪ Formal legal enforcement	▪ Monitoring and needs assessment ▪ Responsibility for meeting needs ▪ Technical compliance monitoring[28]

Finally, effective regulatory governance requires that the legislature and executive give regulators and other institutions the mandate, jurisdiction and resources necessary to carry out their duties. Mandates typically include reliability and value for money, but to unlock clean forms of stability a regulatory mandate to support decarbonisation is helpful.[29]

Step 2: Design a system stability framework

The system stability framework defines what system stability means in practice, how it can be measured, what services can be provided to ensure system stability, and what operators need to do to procure stability. It sets a solid foundation for ongoing system stability processes, such as forecasting stability shortfalls and procuring stability services. Table 5 summarises important questions to steer this process.

[26] Subject to the caveat that lines between roles may blur, and institutions cooperate and work together to varying degrees to share technical and market design expertise and establish workable frameworks.

[27] These services may be established in procurement mechanisms, for instance, or in grid codes, which are typically legally tied to the licensing framework. The services build on system needs and should be technologically neutral.

[28] In some jurisdictions, technical compliance monitoring and responsibility for meeting needs are shared with network owners and service providers. *This does not imply that responsibility for any one element is exclusive to the listed entity*. In practice, system operators depend on network businesses, service providers and market participants for data, modelling, investment and service delivery.

[29] The UK is one of the few jurisdictions where the law gives the regulator the mandate to consider net-zero goals in its regulatory decisions. Gutierrez, E. & Hernández, A. (2025). *Pathways for empowering regulators to advance decarbonisation.* Regulatory Assistance Project (RAP). https://www.raponline.org/knowledge-center/pathways-empowering-regulators-advance-decarbonisation/

Table 5. Guiding questions for developing a system stability framework

Identifying the attributes of a stable power system and any accompanying metrics
▪ Which attributes are needed maintain frequency, voltage and synchronous system stability, and what is the minimum prudent level of each? ▪ How should the attribute be measured, and what metrics should be used? ▪ What geographic are and timeframe should the attribute be measured over?
Defining distinct system stability services
▪ What are the attributes of the service needed to meet stability needs? ▪ How is the service defined and measured? ▪ Given the changing resource mix, what range of options are available to achieve the required functionality?
Designing a system stability procurement framework
▪ How far in advance should the service be procured? ▪ Is the service provided to meet global or local system needs? ▪ Is the delivered service to be procured or an ongoing capability to be embedded (e.g., in grid codes?) ▪ Is the service a complement to, or a substitute for, existing market services? ▪ Will procurement be based on technical and locational service requirements, be technology-neutral and promote competition (lower costs)?

These foundational tasks will require periodic review to ensure they remain fit for purpose as energy systems go through further phases of the clean energy transition. For example, Ireland's transmission system operator EirGrid has planned a future set of reviews of its system inertia requirements as new interconnectors are built and its low-carbon inertia and inertia substitution services programme continues to grow.[30]

Step 3: Embedding ongoing system stability processes

Ongoing processes include detecting system stability shortfalls, procuring services to plug these gaps, and ensuring delivery to avoid blackouts and **rotating interruptions**. Figure 5 presents these ongoing activities at a high level.

[30] EirGrid and SONI. (2025, March). *Operational Policy Roadmap 2025–2035.* https://cms.eirgrid.ie/sites/default/files/publications/EirGrid-SONI-Operational-Policy-Roadmap-2025-2035.pdf

Figure 5. Ongoing processes underpinning system stability



In the following sections we expand on each activity, drawing on case studies. We present a more detailed checklist in Annex 2.

Quantify future stability service needs

Periodic assessment – including through scenario analysis and multi-year projections – is necessary to identify risks and weak areas and to determine the types and extent of stability support required, as well as when and where it will be needed. Analysis must factor in expectations and plausible scenarios of changing load and generation patterns and magnitudes, across time, space and technologies; and it should build on lessons learned from other jurisdictions.

The Australian Energy Market Operator (AEMO), for example, publishes an annual ten-year outlook on system stability in its Transition Plan for System Security (TPSS).[31]

[31] Other jurisdictions look many years into the future. For instance, Chile's Robustness Study looks at least five years ahead. Comisión Nacional de Energía (CNE). (2026). *Anexo Técnico: Metodología para el Estudio de Análisis de Robustez del Sistema Eléctrico Nacional* [Technical Appendix: Methodology for the Robustness Analysis Study of the National Electric System]. https://www.cne.cl/wp-content/uploads/2026/02/2026.01.28_AT-Estudio-de-Analisis-de-Robustez_RES45.pdf

To inform this report, AEMO:

- **Models the future power system** under a wide range of operating conditions, including periods of low demand and high renewable output; times when few conventional generators are operating; and situations where a major generator, transmission line or interconnector is unavailable.
- **Simulates disturbances** to assess whether frequency and voltage would remain under control and whether generators and other equipment would continue operating securely.[32]
- **Calculates the minimum amounts of inertia, system strength and voltage support required** in different regions and at important locations on the network.
- **Compares these requirements with the services expected to be available** from existing generators, batteries, synchronous condensers, network equipment and committed projects.
- **Identifies the time and location of any potential future shortfalls** where the expected capability is insufficient to meet minimum system needs.

The plan brings together this assessment of emerging gaps with the required investments and actions already underway to address them.

Meet future stability needs

The future system stability needs identified through these periodic assessments can be met through multiple approaches, including:

- **Obligations on electricity system participants:** Grid codes and other obligations can ensure that generators, storage and other resources provide essential baseline capabilities. In general, obligations are useful when compliance needs to be (near) universal and solutions are low-cost or uniform. They must also be backed by credible enforcement action for non-compliance (this is discussed further below).
- **Contracts for services and markets**: Contracts or markets can be used to procure additional services or support locations where needed. Generally, contracts are most useful when services and the technologies providing them are relatively uniform and the costs are well known. When costs are not known for various reasons, such as many competing or new technologies or locational differences in service needs, market-based solutions may be preferred as a method of cost-discovery. This can take the form of long-term procurement auctions or more dynamic markets. Long-term auctions are good at discovering who is the cheapest provider *on average* over a particular period, whereas markets are good at discovering who is cheapest at a *particular time*. While dynamic markets may help unlock additional value, they may also be more costly to implement than long-term auctions.

[32] An example of such an exercise leading to a change that helped pre-empt a driver of system instability was Germany's '50.2 hertz problem.' This arose because large numbers of solar PV IBRs were configured to disconnect at 50.2 hertz, creating a risk that a frequency excursion could trigger simultaneous loss of substantial generation. Germany addressed this through the 2012 System Stability Ordinance, requiring existing solar PV systems to be retrofitted and new inverters to reduce output progressively rather than disconnect abruptly.

- **Financial incentives:** These can motivate directly – for example, Great Britain's Accelerated Loss of Mains Change Programme[33] provides payments to legacy generators to update protection settings and prevent unnecessary 'nuisance tripping' (e.g., in response to voltage dips).

- **Charges:** In 2021, the Australian energy regulator introduced an arrangement that provides connecting parties with the choice of either paying a charge for using grid system strength services or of opting out by providing their own system strength to remediate their own impact.[34]

- **Other approaches:** These could include non-financial incentives such as expedited network connections or greater network capacity.

Regulatory frameworks should enable any resource capable of providing the required service to participate, and adjustments to existing resources should also be encouraged where helpful. The Chilean framework presents a successful example of this method.[35] Similarly, South Africa explored alternatives to new syncons, such as repurposing conventional plant to be decommissioned. Regulators announced a plan to repurpose two power stations to perform synchronous-condenser functions when the stations are decommissioned, along with the seven new syncons planned for installation. The cost of conversion is expected to be at least half that of new machines. This approach can increase the availability of stability services, encourage innovation and help lower cost.[36]

It is important that requirements focus on the performance and capabilities that are needed, rather than simply on the type or installed capacity of a resource. Clear technical requirements should specify the services resources must be capable of providing, including (where relevant) frequency response, voltage support, fault ride-through, and contributions to system strength. They should also define how resources are expected to perform during both normal operating conditions and disturbances.

Frameworks should look forward in a timely way. The European Network of Transmission System Operators for Electricity's investigation into the multiple interacting factors that contributed to the Iberian blackout of 2025 identified limitations in the voltage-control arrangements applying to renewable generation in Spain. Renewable plants operated under specific requirements that meant they did not provide dynamic support in response to voltage

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[33] National Grid Electricity Distribution. (n.d.). *Accelerated Loss of Mains Change Programme*. https://commercial.nationalgrid.co.uk/our-network/accelerated-loss-of-mains-change-programme-alomcp

[34] Thus, Instead of being paid for providing system strength, they are charged for not providing it – and the grid resources required to cover the gap. Australian Energy Market Commission (AEMC). (21 October 2021). *System Strength: Information Sheet for Final Determination.* https://www.aemc.gov.au/sites/default/files/2021-10/ERC0300%20-%20Information%20sheet%20for%20final%20determination%20%281%29.pdf

[35] The Chilean framework is an example where a jurisdiction requires technological neutrality when identifying the least cost portfolio of new investments to support stability and also requires consideration to changing the configuration of resources already connected and network enforcement. Comisión Nacional de Energía (CNE). (2026). *Anexo Técnico: Estudio de Análisis de Robustez del Sistema Eléctrico Nacional* [Technical Appendix: Methodology for the Robustness Analysis Study of the National Electric System]. https://www.cne.cl/wp-content/uploads/2026/02/2026.01.28_AT-Estudio-de-Analisis-de-Robustez_RES45.pdf

[36] Creamer, T. (8 December 2023). Eskom to Add Synchronous Condensers to Network. *Engineering News*, https://www.engineeringnews.co.za/article/eskom-to-add-synchronous-condensers-to-network-2023-12-08

fluctuations.[37] A revised procedure allowing renewables to participate in voltage control was approved in June 2025, six weeks after the blackout.[38] The proposal had been requested by the system operator in 2020, highlighting the importance of timely regulatory approval and implementation. Given the multiple contributing factors identified by ENTSO-E, it cannot be established that earlier participation would have prevented it from happening. The event nonetheless highlights the importance of designing the regulatory framework to ensure that all technologies capable of providing a stability service can be called upon by the system operator when and where they are needed.

Procurement of services should be sufficiently dynamic to maximise the use of system assets for stability purposes in real time. For example, in Australia, while inertia services are currently contracted for based on long-term contracts, the regulator acknowledges that in the future there may be a material economic trade-off between inertia and frequency control (which are to some extent substitutable) – and in such a case, inertia may need to be co-optimised in dispatch with existing frequency control and energy markets.[39]

Similarly, regulators can ensure that the parties responsible for procuring stability services have incentives to act pre-emptively, while still choosing cost-effective solutions. In Australia, transmission network businesses are generally responsible for addressing system strength and inertia requirements identified by AEMO. However, the framework has exposed them to the risk that expenditure made too early will later be judged unnecessary, while providing little direct reward for anticipatory investment. Combined with lengthy assessment, regulatory approval and procurement processes – and delivery times of around four years for synchronous condensers – this has contributed to concerns that some stability investments may not be available by the time they are needed.

The new procurement framework needs adequate regulatory capability. Regulators may require additional staff, specialist technical expertise and updated assessment methods to evaluate unfamiliar stability technologies and procurement proposals efficiently. Without this increased capability, regulatory scrutiny intended to protect consumers from unnecessary expenditure may itself delay investments needed to maintain system security.

Monitor conditions

Monitoring key stability attributes requires tracking physical inertia or its alternatives, system strength, voltage and frequency stability, and understanding the risks these can pose to stability. The system's response to events, including those not causing outages, must also be assessed. Stability metrics or proxies must be regularly measured and reported.

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[37] European Network of Transmission System Operators for Electricity (ENTSO-E). (20 March 2026). *Final Report on the Grid Incident in Spain and Portugal on 28 April 2025*. https://eepublicdownloads.blob.core.windows.net/public-cdn-container/clean-documents/Publications/2025/iberian-blackout/Final%20Report%20on%20the%20Grid%20Incident%20in%20Spain%20and%20Portugal%20on%2028%20April%202025.pdf

[38] Among other changes, the new version includes a provision allowing renewable installations of 5 MW or more to participate in the voltage control mechanism under the same conditions as conventional plants, with specific penalties for non-compliance.

[39] Australian Energy Market Commission (AEMC). (9 October 2025). Efficient Provision of Inertia. Final determination. https://www.aemc.gov.au/rule-changes/efficient-provision-inertia

Sophisticated techniques may be required, especially as stability needs continue to change over time. When issues are identified, system stability services procured in planning timeframes may need to be enabled in operational time.

In Great Britain, the system operator NESO estimates how much inertia is available by tracking which large generators are running and adding estimates for smaller generators and demand. Newer tools improve the accuracy of that view: one measures changes in frequency and power flows 50 times a second, while a sonar-like system sends small pulses of power through the grid to measure its response.[40]

Tools to measure real-time inertia are a growing area of focus in other jurisdictions too, such as South Africa.[41]

Activate stability services

The system operator can activate in operational timeframes the stability resources it already made available in planning timeframes. For example, when further system stability support is needed, the British NESO can draw on its contracted stability services, including synchronous condensers and grid-forming batteries, and can instruct generators through the balancing mechanism when further support is needed. NESO is working on the development of a short-term stability market.[42]

Assess compliance

Ensuring that resources meet their technical and service delivery obligations is key to ensuring a stable system.

This is particularly important as new technologies and resources enter the system.

Brazil offers an example demonstrating the importance of compliance. Following a blackout in 2023, investigations found that wind and solar plants' voltage control and dynamic reactive power support underperformed relative to their owners' models. This motivated the Brazilian system operator to move away from accepting agent-submitted models to requiring field-validated dynamic models and enforcing more realistic representations in planning and operations, a direct tightening of the technical compliance regime for IBRs.[43]

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[40] See, for example, National Energy System Operator (NESO). (11 December 2020). '*Sonar of the power grid': new inertia measurement tools planned for Great Britain's electricity system*. https://www.neso.energy/news/sonar-power-grid-new-inertia-measurement-tools-planned-great-britains-electricity-system; and International Energy Agency (IEA). (11 March 2020). *Introduction to System Integration of Renewables: Market and System Operation.* IEA. https://www.iea.org/reports/introduction-to-system-integration-of-renewables/market-and-system-operation

[41] System operator Eskom is collaborating with partners to identify tools and methods to help it ensure inertia adequacy in a system with increased deployment of inverter-based resources, as well as approaches that can better integrate inertia considerations into dispatch decisions. The collaborative development of an open-source tool for real-time inertia will provide Eskom with accessible tools to assess system stability. Global PST Consortium. (n.d). *South Africa.* https://globalpst.org/where-we-work/south-africa/

[42] National Energy System Operator (NESO). (n.d.). *Short-term stability market*. https://www.neso.energy/industry-information/balancing-services/stability-market/short-term-stability-market

[43] Operador Nacional do Sistema Elétrico (ONS). (2025, May). *RT DGL-ONS 0189/2025: Diagnóstico e Perspectiva da Evolução dos Cortes de Geração no* [Brasil Analysis and Outlook on the Trend of Generation Outages in Brazil]. https://www.ons.org.br/AcervoDigitalDocumentosEPublicacoes/RT%20DGL-ONS%200189-2025%20-%20GT%20Curtailment%20rev1.pdf

Comprehensive monitoring approaches may helpfully include the following measures:[44]

- Random tests, including simulations under stress conditions
- Performance reviews during events not leading to outages
- Examination of settings, including who controls them – the owner, the original equipment manufacturer (OEM), the aggregator or the system operator – and whether they can be changed remotely
- Scrutiny of manufacturer limitations and control-mode details

Designing compliance into the installation process in Australia

Australia provides an example of designing compliance into the equipment installation process. AEMO found significant non-compliance with mandatory connection settings.[45] They also found that some distributed inverters were difficult to configure correctly: the required settings could be buried in complex menus, while older settings remained readily accessible.[46] This created a risk that installers would select an incorrect but easier-to-access setting.

Australia subsequently introduced a technical standard for inverter settings, with an 'Australia A' default setting mandated for inverters connecting to the mainland national electricity market.[47] AEMO found that linking the standard to the default produced very high compliance with the required disturbance ride-through characteristics.[48]

Enforce obligations

Enforcement and the threat of penalties are important drivers of compliance. To be effective,the consequences of non-compliance must be clear and proportionate.

In the years following the South Australian blackout of 2016, the Australian Energy Regulator took a few windfarm operators to court over excessively sensitive protection mechanisms. In the court proceedings, two operators acknowledged that they had not gained prior written approval before applying their particular low-voltage ride-through system settings to their generating units.

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44 Porter, K. (16 June 2026). Maintaining Grid Stability in a Wind and Solar World. *Watt-Logic*. https://watt-logic.com/2026/06/16/maintaining-grid-stability-in-a-wind-and-solar-world/

45 Australian Energy Market Operator (AEMO). (n.d.). *AS/NZS 4777.2 – Inverter Requirements Standard*. https://www.aemo.com.au/initiatives/major-programs/nem-distributed-energy-resources-der-program/standards-and-connections/as-nzs-4777-2-inverter-requirements-standard

46 Australian Energy Market Operator (AEMO). (2023, April). *Compliance of Distributed Energy Resources With Technical Settings.* https://www.aemo.com.au/-/media/files/initiatives/der/2023/compliance-of-der-with-technical-settings.pdf

47 Australian Energy Market Operator (AEMO). (n.d.). *AS/NZS 4777.2 – Inverter Requirements Standard*. https://www.aemo.com.au/initiatives/major-programs/nem-distributed-energy-resources-der-program/standards-and-connections/as-nzs-4777-2-inverter-requirements-standard

48 Australian Energy Market Operator (AEMO). (2024, March). *OEM Compliance Report 2023.* March 2024. https://www.aemo.com.au/-/media/files/initiatives/engineering-framework/2024/oem_compliance_report_2023.pdf

In subsequent court actions four wind farm operators were ordered to pay a total of AUS$6.15 million in penalties by the Federal Court for breaching the National Electricity Rules.[49]

3. Communications after a blackout

As discussed above, the technological solutions to maintain system stability exist as we transition away from fossil-fuelled generation. As regulators and system operators take steps to modernise their frameworks and systems, it is also important that everyone has access to the best information available to prevent the spread of misconceptions. To serve the public interest and safeguard trust, leaders, public authorities, and clean energy practitioners alike can draw on the following guidance to counter misinformation during major outages.

Before misinformation spreads: The narrative after a blackout and *before* event-specific misinformation proliferates can be shaped with the following proactive lines:

- **Blackouts typically result from *multiple* interacting factors**, often including major natural hazards such as storms and floods, alongside shortcomings in the planning, regulation, monitoring and procurement of the capabilities needed to maintain system stability.
- **It typically takes weeks or months to identify with confidence the causes of blackouts.** We therefore need to wait for authorities to complete their investigations before drawing conclusions.
- **Interim information vacuums are often filled with unverified theories that subsequent investigations disprove.**
- **Investigations often ultimately point to outdated grid codes, gaps in monitoring and compliance, and other regulatory issues.**

After misinformation spreads: High-level lines to draw on once misinformation is circulating in the media include:

- **A grid with a high share of renewable energy resources can be just as reliable as any other grid.** Renewables do not inherently cause blackouts.
- **Many grids operate safely with high levels of renewables**, including South Australia, Texas, Hawaii and Ireland.[50]

[49] Australian Energy Regulator. (28 June 2022). *AGL to pay $3.5 million in penalties for breaching energy rules* [press release]. https://www.aer.gov.au/news/articles/news-releases/agl-pay-35-million-penalties-breaching-energy-rules

[50] Note: Texas suffered a severe outage in 2021. This hinged on major failures of fossil-fuel generation and upstream gas supply during extreme weather. In South Australia, incorrect inverter settings contributed to the loss of wind generation (stimulating 'nuisance tripping') following faults during the extreme weather event of 2016. Both cases illustrate the importance of appropriate system planning, technical requirements and compliance. These events are described in more detail below.

- **Large-scale outages can occur in any power system**, and they long predate the modern generation mix.[51]
- **Grids no longer need to rely on fossil-fuelled generators to provide the services required for stability**, thanks to modern power-system technologies.
- **Wind, solar, batteries and synchronous condensers can provide fast frequency, voltage and other services** to support the grid when appropriately specified, configured and operated.
- **Blackouts typically result from a complex interaction of circumstances and events.** Blackouts are usually caused by extreme weather or other natural hazard, human error or technical failure, all of which contribute to failures of generation, transmission or fuel-supply infrastructure. This is often a result of regulatory shortcomings, including in system planning, technical requirements, operational practices and compliance.
- **Regulations must evolve with the power system.** Governments, regulators and system operators have the tools to plan for changing system needs, to set appropriate technical requirements, and to ensure that the capabilities needed to maintain stability are available and delivered.

In the sections that follow, we present four common myths that emerge following major outages, with examples and responses to counter them.

[51] This survey of reliability events suggests their prevalence over 2010 to the present is no greater than the period from 1990 to 2009, when variable renewables were largely entirely absent from electricity systems. It notes that "interruptions to supply in well-established systems have not been 'caused' by the variability of renewables – and happen in systems with different sources of energy." See slides 27 and 36 of Bell, K., & Mancarella, P. (2026) *Reliability and resilience in a renewables-dominated power system*. Universities of Strathclyde and Melbourne. https://pure.strath.ac.uk/ws/portalfiles/portal/343671875/Reliability_and_resilience_in_a_renewables_dominated_power_system_-_v0.2-PM.pdf

Myth 1 – Renewables cause blackouts

The 'renewables cause blackouts' myth was propagated during the Texas outage of February 2021,[52] *while the crisis was still unfolding*, when Fox News[53] displayed banners as presented in Figure 6.[54]

Figure 6. Fox News banners during the Texas outage, as presented by CNN



However, the system operator ERCOT was quick to establish the key contributor to the Texas outage.[55] Thermal generation, predominantly gas and coal-fired, failed, largely because of its reliance on natural gas infrastructure that was far more vulnerable to severe winter weather than either the system operator or the regulator anticipated, exposing regulatory shortcomings. Equipment freeze-ups at the plants themselves were also a major issue. Although most of the wind fleet was also frozen, its low output was expected and built in to the system operator's plans.

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[52] For more details on the outages cited in this section, see Hogan, M. & Scott, D. (22 September 2026). *Power outage rapid response toolkit: 2026 update*. Regulatory Assistance Project (RAP). https://www.raponline.org/knowledge-center/power-outage-rapid-response-toolkit

[53] See for example Fox News (16 February 2021). *Texas winter storm freezes wind turbines, causes blackouts* [video]. https://www.foxnews.com/video/6232641136001; and for an overview see CNN. (21 February 2021). *As Texas went dark, Fox News blamed windmills* [video]. https://edition.cnn.com/2021/02/21/media/fox-news-texas-weather-wind

[54] CNN. Fox News and the Texas Weather: How the Network Covered the Winter Storm. February 21, 2021. https://edition.cnn.com/2021/02/21/media/fox-news-texas-weather-wind. Other banners included 'Frozen Wind Turbines Cause Blackouts in Texas,' 'Green Energy Failure,' 'Green Energy Disaster,' 'Winter Storm Shuts Down Renewable Energy in Texas' and 'Winter Storm Cripples Texas' Green Energy Grid.'

[55] By 18 February 2021, three days into the event, ERCOT issued a statement showing 62% of generation capacity forced off the system by extreme weather was thermal. Electric Reliability Council of Texas (ERCOT). (18 February 2021). *Grid operator continues to restore power* [press release]. https://www.ercot.com/news/release?id=c851460b-4e51-3363-8d69-94bb7e9a0090

The following lines may be useful to provide better information to the public in similar situations:

- **Beware of quick assessments**.
    - Experts need time to unpack the causes of events. This can range from just hours or days to many months.
    - Investigations often find that causes of outages are complex and dependent on multiple factors.
- **In the past, calls to blame renewables have not stood up to subsequent scrutiny**.
    - In recent outage events in Texas, South Australia and Iberia, such claims have been shown to be incorrect.[56]
    - Systems are designed to be stable and able to cope with a wide range of contingencies, so the technical causes of outages tend to be multi-factored.
- **Analyses of historic events often ultimately point to deficiencies in regulation.**
    - In many cases, the chief reason for a blackout is found to be regulatory failures. In Texas, there were gaps related to gas grid regulation, while in South Australia and Iberia the regulation of technical settings of power resources was inadequate.
    - While it is perhaps unsurprising that regulations do not always keep up with the pace of technological change, good practice toolkits[57] are available to help guide regulation and operation to meet the needs of modern power systems.
- **Reliable facts and fact-checks can be shared as they become available.**
    - Authoritative sources typically include the system operator and the energy regulator. It may be helpful to encourage these voices to provide information and counter misinformation, especially in the immediate aftermath of an outage.
    - Share exposés of bias among news outlets. For example, just days after the start of the Texas 2021 blackout, Business Insider published its fact-checks of Fox News' claims, dispelling the notion that frozen wind turbines were an important contributor.[58]

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[56] Hogan, M., & Scott, D. (22 September 2026). *Power outage rapid response toolkit: Update 2026*. Regulatory Assistance Project (RAP). https://www.raponline.org/knowledge-center/power-outage-rapid-response-toolkit/

[57] See also, for example, Kritzinger, K., Dusolt, A., & Spire, É. (27 November 2024). *Power System Stability: Ensuring System Stability with a Rising Share of Variable Renewable Energy.* Agora Energiewende. https://www.agora-energiewende.org/publications/power-system-stability; and Beyer, D., Cantre, J., Chen, T., Gupta, E., Kotwis, S., Lillis, G., Sherwood, J., & Singh, K. (2026). *Procuring Grid Flexibility: A Global Guide for Decision Makers to Increase Power System Reliability and Affordability in the Context of Rapid Technological Change*. RMI. https://rmi.org/app/uploads/dlm_uploads/2026/09/rmi-august-2026-geapp-bess-report-part-1.pdf

[58] Business Insider. (21 February 2021). *FACT CHECK: Fox News aired bizarre and wildly misleading claims about Texas' blackouts that pin blame on renewables and climate policies*. https://www.businessinsider.com/fact-check-fox-personalities-make-false-claims-about-texas-blackouts-2021-2

Myth 2 – A high-renewables grid will always be vulnerable to blackouts

This misconception asserts that renewables weaken the grid and make it harder to maintain stability, and thus 'the higher the share of renewables, the greater the vulnerability.' It is often employed after a blackout to imply that the growth of renewables is the likely cause and to push back against further expansion.

For example, some news outlets repeated the 'vulnerable renewables grid' message at the time of the Iberian blackout in April 2025. Specifically, they suggested that wind and solar may have contributed to the blackout by making it harder to maintain grid stability, because these renewable sources provide no physical inertia.[59] For example:

- The Telegraph's article *Net zero blamed for Europe's biggest power cut*[60] argued that a "reliance on net zero energy left Spain and Portugal vulnerable to the mass blackouts engulfing the region." The article suggested that high shares of wind and solar leave system operators with less time to react to disturbances that can lead to cascading failures. The outlet published the article 28 April 2025, the day of the blackout itself.

- The same lines were aired in The Irish Sun[61] on the same day, which noted that "unlike fossil fuels, renewables do not generate 'inertia' – the stabilising energy needed to absorb shocks in the grid." These talking points were then picked up in other media.[62]

- In an article titled *How Spain's Success in Renewable Energy May Have Left It Vulnerable,*[63] published on the day after the blackout, The New York Times focused on the possible role of renewables and inertia, with prominent quotes from experts asserting that "When you have more renewables on the grid then your grid is more sensitive for these kind of disturbances."

In reality, authoritative analysis by the Expert Panel of the European Network of Transmission System Operators (ENTSO-E), which took a year to conclude, did not find inertia levels playing a determining factor in the event. It identifyied rather a combination of interacting technical and operational factors.[64] The investigation did not identify a need to reverse or slow the transition away from fossil generation. Its recommendations instead point to the need to ensure that the capabilities required for system stability remain available as the generation mix changes. These

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59 See earlier section on *Characteristics and capabilities supporting system stability*.

60 The Telegraph. (28 April 2025). *Net zero blamed for Europe's biggest power cut*. https://www.telegraph.co.uk/business/2025/04/28/blackout-risk-made-worse-by-net-zero/

61 The Sun (Ireland). (29 April 2025). *Net zero, cyber attack or freak weather? Urgent probe after Spain & Portugal left in chaos by Europe's biggest blackout*. https://www.thesun.ie/news/15125748/net-zero-cyber-attack-weather-cause-spain-portugal-blackout/

62 UNILAD Tech. (28 April 2025). *Spain and Portugal could be without power for up to a week as mass outage causes complete chaos*. https://www.uniladtech.com/news/tech-news/spain-portugal-power-outage-756825-20250428

63 The New York Times. (29 April 2025). *How Spain's success in renewable energy may have left it vulnerable*. https://www.nytimes.com/2025/04/29/business/spain-renewable-energy-power-grid.html

64 European Network of Transmission System Operators for Electricity (ENTSO-E). (20 March 2026). *Grid incident in Spain and Portugal on 28 April 2025.* https://www.entsoe.eu/publications/blackout/28-april-2025-iberian-blackout/

capabilities can increasingly be provided by a range of technologies, including appropriately configured renewable and storage resources, grid-forming inverters and syncons. ENTSO-E characterises the solutions as already technically feasible and highlights the need for regulatory frameworks to evolve accordingly.

Proactive responses to prevent the spread of misinformation include the following:

- **Beware of quick assessments.**
    - Experience shows that premature speculation about the causes has generally been inaccurate (see examples above).
- **The technology is there.**
    - Solar PV and wind – and other clean technologies like batteries and syncons – can in fact contribute inertia-like and other capabilities to support grid stability if suitably enabled by regulation (see Section 2. What regulators and policymakers can do).[65]
    - Furthermore, experience shows that a single technology is almost never solely at fault – the power system is designed to be stable and to cope with a wide range of contingencies.
- **Good regulation is key**.
    - The regulatory framework must keep pace with technological change.
    - It is crucial that regulatory frameworks ensure compliance with grid codes and support system operators in unlocking the full capabilities of all technologies to contribute to system stability – including renewables, batteries and syncons – in a timely and forward-looking fashion.
- **There are already many reliable renewables-based systems around the world**.
    - In the last decade, several power systems have operated reliably with instances or sustained periods of very high shares of variable renewable energy, including in South Australia, Hawaii and Ireland.[66]

[65] van Stiphout, A., Kritzinger, K., Naem, H., & Pescia, D. (18 June 2025). *Power system stability in the age of renewable energy Recommendations in the context of the Iberian blackout.* Agora Energiewende. https://www.agora-energiewende.org/fileadmin/Projekte/2023/2023-32_EU_System_stability/A-EW_The_Iberian_Blackout_recommendations.pdf

[66] See p9 of van Stiphout, A., Kritzinger, K., Naem, H., & Pescia, D. (18 June 2025). *Power system stability in the age of renewable energy Recommendations in the context of the Iberian blackout.* Agora Energiewende. https://www.agora-energiewende.org/fileadmin/Projekte/2023/2023-32_EU_System_stability/A-EW_The_Iberian_Blackout_recommendations.pdf

Myth 3 – The excessive speed at which the energy transition is advancing is a security risk

An example of this narrative is ABC's article of 29 September 2016, which claims *SA storms: Rushing to renewable energy targets puts sector's reputation at risk*, linking this to the South Australia blackout of 2016.[67] In this article, the political editor states that "Renewables are the future but, today, they present serious engineering problems. To deny that is to deny the science. Those problems can be sorted in time, but rushing to a target to parade green credentials exposes the electricity network to a serious security risk and, in the long run, risks permanent reputational damage to the renewable energy cause. The grid is being transformed, and that transformation needs to be managed sensibly, or the entire nation might go to black."

The reality was that the blackout was largely attributable to regulatory issues like technical non-compliance, alongside the precipitating event of extreme weather.

The following points are important to inform the public:

- **Agile regulators can accommodate the pace of the clean energy transition required to meet decarbonisation targets.**
    - To do so, it is important that regulators adopt a forward-looking approach that anticipates the coming phases of the clean energy transition and unlocks in a timely way the necessary capabilities and services.
    - Regulation is needed to enable new technologies – such as grid-forming inverters and other relative newcomers to the stability toolkit – through updated procedures and standards.
- **Regulatory delay brings risk.**
    - Sluggish regulation may undermine reliability or slow the pace of the energy transition.
    - The 2025 Iberian blackout, ultimately driven by voltage control failure, exposed how regulatory limits prevented renewables from supporting the grid. Although a harmonised framework for renewable participation was approved just six weeks later, the incident highlights the danger of regulations lagging behind the clean energy transition.
- **Regulators with sufficient resources and a proper mandate play an important role in ensuring power system stability.**
    - Regulators will need specific capacities, for instance, power system engineering experts on staff. Policymakers can ensure that regulators have sufficient resources overall, as well as independence.

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[67] Uhlmann, C. (29 September 2016). *SA Storms: Rushing to Renewable Energy Targets Puts Sector's Reputation at Risk*. ABC News. https://www.abc.net.au/news/2016-09-29/rushing-to-renewables-risks-sectors-reputation%3A-uhlmann/7888290

- Policymakers have the ability to ensure that regulators are mandated to support decarbonisation alongside security. This remit can expressly focus regulatory attention on unlocking the growing capabilities of new, clean, stability-supporting technologies. In doing so, it is critical to ensure that procedures and standards evolve in parallel so the system remains safe.

Myth 4 – Reliable grids must retain large amounts of fossil fuels or nuclear generation

This narrative is the other side of the coin of Myth 2 – that renewables leave grids inherently vulnerable to instability, and that, therefore, only fossil fuels can provide stability.

An opinion piece published in The Telegraph on 18 June 2025, titled *Spain's power cut shows the risks of gas-free Britain*,[68] argued that the Iberian blackout highlighted the risks of replacing conventional generation with renewables. The piece stated that too few gas and nuclear plants were online to balance the grid and suggested that a shortage of inertia contributed to the blackout. It warned that reducing conventional generation could leave the British system more vulnerable to instability.

We note two points here. First, the services that underpin a reliable and stable power system, however, are not exclusively provided by fossil-fuel or nuclear generators. What matters is whether the system has access to the services it needs, and whether those services are properly planned, procured and delivered. Second, the ENTSO-E investigation identified multiple interacting factors behind the Iberian blackout, with shortcomings in voltage and reactive-power control at the core. It did not identify insufficient inertia as the root cause, nor did it characterise the incident simply as a shortage of balancing energy.

To provide the public with clear, high-quality information, the following key insights can guide communication efforts:

- **Power systems do not inherently require fossil-fuel or nuclear plants to be stable. Clean energy technologies can increasingly provide many of the stability services traditionally associated with fossil generation:**

    - Wind, solar, batteries and other inverter-based resources can provide a range of frequency, voltage and other grid-support services if the regulator and system operator unlock these capabilities. These can include grid-forming capability.

    - Other technologies like synchronous condensers (syncons) can provide inertia and voltage-support capabilities without burning any fossil fuels.

[68] The Telegraph. (18 June 2025). *Spain's power cut shows the risks of gas-free Britain*. https://www.telegraph.co.uk/business/2025/06/18/gas-free-britain-not-just-fantasy-downright-foolish/

- **A clean grid can therefore be a reliable grid.**
    - South Australia is aiming to be the first gigawatt-scale 100% net renewable electricity generation grid by 2027.
- **Planning ahead for the changing needs of the system is essential.**
    - As conventional generation retires and inverter-based resources – wind, solar PV, batteries, EV chargers and the like – take on a larger share of the generation mix, regulators and system operators need to identify the stability services that will be required and ensure that sufficient capability is made available to fulfil them.
    - Appropriate tools include technical requirements, charges, markets and procurement mechanisms, network investment and system planning.

Annex 1. Quick-start guide to countering misinformation

Table 6. Common power system myths - and responses that debunk them

Myth	Example	Framing	Response
1. Renewables cause blackouts	**Texas, 2021** – Fox News: 'Frozen Wind Turbines Cause Blackouts in Texas'; 'Green Energy Failure'	Wind was blamed while the blackout was still unfolding. In reality, the key contributor was the failure of thermal generation, particularly gas infrastructure and plant freeze-ups.	Beware of quick assessments. 'Renewables-to-blame' narratives tend not to stand up to subsequent scrutiny. Potential deficiencies in regulation should be investigated.
2. Renewables weaken the grid and make it vulnerable to blackouts	**Iberia, 2025** – The Telegraph: 'Net zero blamed for Europe's biggest power cut'; similar coverage in The Irish Sun	Wind and solar were framed as making the system less stable because they provide little physical inertia.	Beware of quick assessments. The technology is there. Good regulation is the key. There are many reliable renewables-based systems.
3. The energy transition is happening too quickly and is compromising security	**South Australia, 2016** – ABC: 'Rushing to renewable energy targets puts sector's reputation at risk'	The rapid growth of renewables was described as creating unacceptable engineering and security risks.	Agile regulators can accommodate the necessary pace of the clean energy transition. Regulatory delay poses risk. Regulators with sufficient resources and a proper mandate play an important role in ensuring power system stability.
4. Reliable grids must retain large amounts of fossil-fuel or nuclear generation	**Iberia, 2025** – *The Telegraph*: 'Spain's power cut shows the risks of gas-free Britain'	Conventional generation is necessary to avoid unacceptable risks to system stability.	Clean energy technologies can provide the stability services traditionally associated with conventional generation. There is no fundamental reason why a system must keep fossil-fuel or nuclear plants generating electricity on stability service grounds. A clean grid can therefore be a reliable grid. Planning ahead for the changing needs of the system is essential.

Annex 2. Checklist of ongoing activities for grid stability

Table 7 presents a checklist of activities to support grid stability. The reader can use it to identify both the activities that apply to the stage of development of the power system under consideration and those that remain outstanding – and to drive activity.

Table 7. Checklist of activities to support grid stability

Quantify future stability service needs	
Determine stability service needs through system assessments	Use periodic studies including multi-year future projections to identify risks and weak areas, and to understand how much stability support is needed, where and when.
	Base requirements on evidence from scenario analysis and system studies.
	Update assessments as the system evolves.
	Draw on lessons from other jurisdictions.
Meet future stability needs	
Secure essential stability services through a mix of mechanisms and have clear technical performance requirements	Procure services and capabilities using a technology-neutral and inclusive approach.
	Combine grid-code obligations for baseline capabilities with markets, charges, or contracts for additional or location-specific needs.
	Define how resources must respond during normal and disturbed conditions.
	Cover capabilities such as frequency response, voltage support, fault ride-through and system-strength contribution.
	Focus on performance, not simply installed capacity.
Invest in advanced physical and digital infrastructure for monitoring and control	Update planning and operating practices, including deeper integration between the transmission and distribution levels.
	Invest in new interconnection capacity.
	Update operational guidelines to deal with increasing cross-border risks.
Monitor conditions	
Explicitly monitor key stability attributes	Track relevant stability conditions such as physical inertia or its alternatives, system strength and voltage stability, and the system's response to events (including those not causing outages).
	Measure and report stability metrics or proxies regularly.
Activate stability services	
Enable stability services	Call on stability services as needed and as specified in the system needs planning timeframe.

Assess compliance	
Verify that resources can deliver what they are meant to provide	Monitor delivery against obligations.
	Require testing, model validation and performance verification.
	Use factory and site acceptance tests, together with disturbance performance tests.
	Ensure models and settings are validated against real-world performance.
Enforce obligations	
Monitor actual performance and enforce compliance	Check compliance with technical and contractual obligations.
	Ensure there are clear consequences for non-compliance – enforcement and the threat of penalties for non-compliance are important drivers of compliance.
	Review and adapt rules as the system and technologies evolve.

Glossary and acronyms

- **AEMO** – Australian Energy Market Operator.
- **Alternating current** – the grid operates on a current which periodically reverses direction and changes its magnitude continuously with time.
- **BESS** – battery energy storage system.
- **Blackout** – total collapse of the grid.
- **ENTSO-E** – European Network of Transmission System Operators for Electricity.
- **ERCOT** – Electric Reliability Council of Texas.
- **EV** – Electric vehicle.
- **Fast frequency response** – a particularly rapid, typically automatic form of frequency-responsive reserve that acts within seconds to arrest frequency deviations.
- **Fault current** – a sudden, heavy surge of electricity that flows through a circuit when something goes wrong, such as a damaged wire touching a metal frame or a short circuit. A high fault current – provided by generators or storage – forces safety devices like circuit breakers and fuses to react and shut off the power instantly.
- **Frequency** – reflects how frequently the direction of current alternates on the grid. Most things connected to the grid are designed to operate safely based on a defined expected range of system frequency.
- **Grid codes** – specifications set by system operators, with the approval of regulators, for devices to connect to the grid. The purpose of the codes is to preserve safe and reliable system operation.
- **Grid stability** – the maintenance of system frequency and voltage within narrowly prescribed ranges, essential to preventing damage to equipment connected to the grid.
- **Inertia** – a service that slows the rate of decline in system frequency following a sudden disruption. Inertia has traditionally been supplied by the rotating mass of synchronous generators and large motors connected to the grid. Increasingly, very-fast-responding storage devices or inverter-based resources can provide inertia-like services to react to imbalances.
- **Inverter-based resources (IBRs)** – resources that do not rotate, or that rotate at a frequency incompatible with the grid and must therefore be connected via solid-state electronic devices called inverters.
- **Load** – the amount of electricity being used – or demanded – at a given moment by homes, businesses, factories and other consumers. Load is the ‘demand’ placed on the power grid.
- **NESO** – National Energy System Operator [Great Britain]

- **Operating reserves** – pre-arranged capability – provided by generation, storage or responsive load – that the system operator can deploy to adjust the supply–demand balance and arrest frequency deviations.
- **Operational security** – ensuring that the grid can withstand regular ('credible') disturbances such as unexpected changes in supply or demand; the loss of a generator, transmission or distribution line; or a large load.
- **PV** – Photovoltaic.
- **Reactive power** – the power 'lost' to end users due to the extent to which the alternation of current is pushed out of sync with the alternation of voltage. It is used as a tool to control voltage.
- **Reliability** – reflects the extent of interruption to services. A prudent level of reliability trades off the expected cost of being without electricity against the cost of reducing expected interruptions.
- **Rotating/rolling service interruption** – when the system operator selectively orders groups of customers to be sequentially interrupted for limited periods of time, in order to protect designated critical loads and ensure the operability of the grid.
- **Stability** – the ability of the system to maintain a steady and reliable supply of electricity when something unexpected happens, such as a power plant suddenly disconnecting or a fault occurring on the grid.
- **Synchronous machines** – rotating machines (synchronous generators and syncons) that operate in step with the frequency of the grid's alternating current.
- **System operator** – ensures that demand and supply are balanced and that grid stability is maintained in real time.
- **System strength** – the inherent robustness of an electrical network at a given location, reflecting its ability to maintain and control a stable voltage waveform during normal operations and to resist major voltage fluctuations following a network fault or disturbance.
- **TPSS** – Transition Plan for System Security [Australia].
- **Voltage** – the electrical pressure that drives current through the network.





Regulatory Assistance Project (RAP)®
Belgium · China · Germany · India · United States

info@raponline.org
raponline.org

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