

Controlled Islanding in Distribution Grids

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1. Introduction

This paper presents a joint perspective from E.DSO and T&D Europe on both controlled and intentional islanding in distribution systems, as part of ongoing efforts to align the operational needs of distribution system operators (DSOs) with the development of enabling grid technologies provided by European technology providers.

Distribution networks are evolving rapidly due to the growing penetration of distributed energy resources, particularly power-electronics-based technologies and storage, as well as flexible demand. While these developments create new opportunities to enhance resilience, continuity of supply, and operational flexibility, they also increase system complexity. In this context, the intentional and controlled operation of islands in distribution systems is emerging as a relevant operational option for DSOs under specific conditions, contributing to improved distribution system resilience and more efficient system recovery. Although the technical capability to support controlled islanding has greatly advanced, mainly in certain regions outside Europe and on islands, its deployment in European distribution networks remains constrained by regulatory frameworks, a lack of standardisation for new assets, and by responsibility allocation rules that were designed under the assumption of permanent grid connection and strict anti-islanding principles.

This paper provides a clear, DSO-centric framing of controlled and intentional islanding in distribution systems. It clarifies key concepts, outlines planning and operational objectives and challenges, and highlights areas where existing regulatory and standardisation approaches may hinder the effective use of available technologies. The scope is explicitly limited to distribution networks, with the objective of supporting a common understanding between DSOs, technology providers, and other stakeholders and of guiding future technical and regulatory actions.

2. Understanding the problem

In distribution systems, islanding has traditionally been regarded as an abnormal and undesired operating condition, primarily due to safety concerns and the challenges it poses to system protection and reliability. As a result, the operation and regulation of the distribution network have historically assumed that a permanent connection to the upstream network is necessary, supported by strict anti-island requirements. Moreover, the concept of controlled islanding has not yet been widely adopted by European DSOs, regulators and related authorities. Although the underlying technical principles are relatively easy to implement, embedding this approach into routine operational practice presents significant challenges beyond the research and development phase. Consequently, the primary barrier lies not in technical feasibility but rather in the need for a substantial shift in operational mindset, supported by a new regulatory framework.

The ongoing transformation of distribution systems and customers' perception of electricity as a commodity create an opportunity to exploit distributed energy resources, inverter-based technologies and advanced monitoring and control capabilities that are becoming increasingly integrated into modern distribution networks. It provides a framework for DSOs to introduce and develop the operational capability to manage predefined sections of the distribution system in a controlled islanded mode. Implementing such operational schemes can enhance system resilience and continuity of supply, while simultaneously increasing the overall flexibility of the power system.

Within this context, it becomes essential to clearly distinguish between unintended islanding events, which remain a safety risk and must be avoided, and intentional, controlled forms of islanded operation. The following subsections develop the concepts of controlled, intentional and unintentional islanding in distribution systems. The text also highlights the conceptual and regulatory requirements needed for their deployment particularly regarding planning and operation, safety, and the conditions under which DSOs can enable, supervise, and terminate islanded operation.

2.1 Controlled and intentional islands

In the context of distribution networks, an intentional island refers to a deliberately created and supervised electrical subsystem that is intentionally separated from the upstream transmission or distribution network by the relevant system operator and operated autonomously for a limited period. It is characterised by predefined electrical boundaries and supported by appropriate control, protection and communication systems. Within the intentional island area, local generation, storage and loads are coordinated to maintain an acceptable balance between supply and demand, ensuring voltage and frequency remain within defined operational limits.

On the other hand, the CIGRE definition of microgrids¹ includes a reference to the ability of operating portions of the network in an intentional way: "Microgrids are electricity distribution systems containing loads and distributed energy resources (such as distributed generators, storage devices, or controllable loads) that can be operated in a controlled, coordinated way either while connected to the main power network or while islanded." Although the general concept of a microgrid has a broad meaning, it must be carefully examined where it overlaps with the control of islands within distribution networks permanently connected to the electrical system.

¹ Chris Marnay et al. "Microgrids 1 engineering, economics, & experience". CIGRE Technical Brochure 635, Paris, 2015, last visited September 2026 [eCIGRE Microgrids TB635](#).

Unlike accidental separation events, controlled islands are established following predefined operational criteria and procedures. The intentional separation from the main grid, the operation in islanded mode, and the subsequent reconnection to the power system, are managed under the responsibility of the DSO, based on clearly defined operational objectives (i.e. maintaining supply to critical loads, enhancing system resilience, and supporting system restoration). The process implies a clear allocation of roles and responsibilities during islanded operation.

The ability to transition safely and reliably between grid-connected (grid-parallel) operation and islanded operation, and back again, is an integral part of the concept of controlled islanding. From a functional perspective, a controlled island represents a target operational state of the distribution system, enabled by advanced power electronics, grid-forming capabilities, and enhanced observability. The correct implementation of the necessary tools and procedures requires a thorough consideration of the CAPEX and OPEX implications, and the observance of the most typical regulatory KPIs, such as SAIDI, SAIFI, and other power quality indicators.

In this paper, “intentional islanding” refers to the transition process, while “controlled island operation” refers to the target operational state. The term “controlled islanding” is used in subsequent sections to describe the practical implementation of this capability in distribution systems.

2.2 Unintentional islanding

The situation in which an unintentional islanding occurs is fundamentally distinct from a controlled island operation leading to intentional islanding. The planning and operation processes and the regulatory context which serves as reference, define the applicability of each case for DSOs.

Unintentional islanding occurs when a portion of the distribution network becomes electrically separated from the main grid without prior notice for disconnection, leading to unplanned operation in islanding mode, and usually seeking a fast reconnection to the wider system. If the distribution network does not have adequate devices (e.g., electrical switches) that disconnect the island and reconnect once the conditions to connect to the upstream grid are met, under this unintentional islanding situation the distributed generation resources continue to energise this portion of the network in an uncontrolled way. This condition poses significant safety risks for personnel, may lead to equipment damage, and undermines the reliability of protection schemes. For these reasons, traditional distribution networks have relied on anti-islanding protection mechanisms designed to rapidly disconnect generation in such situations. A real example of unintentional islanding in distribution networks was described in the experience carried out in Italy².

- Some of the electrical characteristics and operational behaviour that are impacted by the occurrence of unintentional islanding events can be listed below:
- **Low voltage stiffness:** Even small load changes lead to noticeable voltage deviations.
- **Lack of inertia:** Without the masses of the larger power system, the frequency reacts sensitively to any load or feed-in change. Fast control and energy provision are essential.
- **Lower short-circuit power:** Protection concepts must be adapted. Lower short circuit currents change the selectivity of protection devices.
- **Non-linear loads:** Power-electronic devices influence the voltage more strongly. Phenomena such as harmonics and flicker occur more frequently.

² L. D'Orazio, R. Calone and A. Cerretti, "Real Event of Uncontrolled Island on Distribution Network in Italy," 2025 AEIT International Annual Conference (AEIT), Amantea (CS), Italy, 2025, pp. 1-6

- **Power balance and instantaneous reserve:** Surpluses or deficits must be compensated locally, for example through storage or load management.
- **Reactive power behaviour:** Voltage reacts strongly to reactive power changes. Precise, dynamic reactive power management is crucial.

Controlled islanding, by contrast, is a planned and intentional operational mode. It assumes that islanded operation is explicitly allowed, technically enabled, and operationally supervised by the DSO. Instead of preventing island formation, controlled islanding leverages advanced control, protection, and communication concepts to actively manage islanded operation and reconnection to grid-parallel mode in a predictable and safe manner, so the potential eventualities described above are known beforehand and managed accordingly.

Once appropriate operating conditions have been re-established, this part of the network can be reconnected in a controlled manner.

This shift represents a fundamental conceptual change for distribution networks, with important regulatory implications. It requires moving from a paradigm where islanding is always treated as an abnormal and forbidden condition, toward one where intentional islanded operation can be recognized as a legitimate and valuable system capability under defined conditions.

3. Controlled and intentional islanding in distribution networks

Building on the definitions introduced in the previous section, this chapter focuses on how controlled islands can be applied in practice within distribution networks. It outlines the asset management planning and operational objectives pursued by DSOs, the main implementation strategies, the associated business cases and technical challenges, based on experience from pilot projects and field demonstrations. The emphasis is placed on system-level considerations that help align DSO operational needs with technology solutions and their enabling regulatory conditions.

3.1 Operational objectives and requirements

The primary objective of controlled islands in distribution networks should be to enhance resilience and continuity of supply in the presence of upstream disturbances, extreme events, and potentially to address periods of network congestion. By enabling controllable islanded operation, DSOs can maintain electricity supply to critical loads, reduce the impact of widespread outages, and support faster system restoration. Additional objectives may include improving operational flexibility and enabling the effective use of distributed energy resources in increasingly power-electronics-dominated networks.

To achieve these objectives, several key technical and operational requirements must be fulfilled. These include the capability to maintain a local balance between generation, storage, and demand; sufficient voltage and frequency control performance within the island; and adequate observability of network states to support secure operation. Reliable and secure communications infrastructure are needed to coordinate control actions and to support supervision by the DSO. Clear operational processes for island formation, operation, and reconnection are essential. While the execution of islanding actions may rely on fast, locally implemented control functions, the underlying decision logic, settings and operational

criteria are defined ex-ante within a DSO-defined operational framework, including safety responsibilities and coordination with other relevant system actors where applicable.

The main challenge in implementing islanding capacities for regulators, distribution system operators and connected resources is to establish an appropriate framework that sets the conditions and rules under which those safety responsibilities and coordination are ensured. The first step is to be compatible with the European Network Codes, followed by more detailed implementation at national level.

EDSO and GEODE have recently published a paper on revenue regulation that introduces some reflections on the importance of incentives for DSOs in achieving resilience³. Predictable rules give operators the confidence to invest and plan ahead, while a degree of flexibility is essential to accommodate unforeseen developments. Striking this balance supports efficient network evolution and ultimately safeguards the resilience of the grid and the communities that rely on it. The document presents some real-world examples of regulatory developments in this area in some European countries. For example, the regulatory framework in Italy has been shown to improve resilience by supporting measures that prevent or mitigate the impact of emergencies on the electricity grid. The same system also incentivised innovative solutions to strengthen network resilience.

The Spanish Government has just approved a new six-year regulatory framework⁴ in which resilience is recognised for investments to mitigate the effects of extreme weather events and support adaptation to climate change in distribution networks.

Both initiatives could include the formal recognition of the operation of controlled islands in distribution networks as a measure to maintain normal network operation during complicated episodes beyond the use of more traditional methods (for example, the use of generator sets). Naturally, typical regulatory indicators of supply quality, primarily SAIDI and SAIFI, would improve in the face of these events if a favorable framework for controlled islands is implemented.

3.1.1 Selection of islandable areas and network readiness

The controlled island operation of a portion of the distribution network cannot be based solely on the availability of generation or storage resources capable of supporting voltage and frequency. The area must be identified in advance by the DSO as a specific network configuration, with defined electrical boundaries, adequate resources, and operating conditions compatible with the expected duration and objectives of the island. The availability of grid-forming resources is an important enabling factor but does not in itself make a network area suitable or authorised for island operation.

The selection of the area should result from a specific technical assessment considering the loads to be supplied and their priority, the availability and location of generation and storage, the active and reactive power balance, operating reserves and available energy. The assessment should also verify the capability to maintain voltage and frequency within acceptable conditions, considering the network topology, thermal and voltage constraints, load variations, transformer energisation and motor starting. Short-circuit conditions, earthing arrangements, protection coordination, network observability and controllability are also necessary elements in determining whether a configuration can be safely operated as an island.

³ “Revenue Regulation for Electricity Distribution System Operators: An exploration of seven European frameworks,” EDSO/GEODE, 2025.

⁴ “BOE-A-2025-27018 Circular 8/2025, de 22 de diciembre, de la Comisión Nacional de los Mercados y la Competencia, por la que se establece la metodología para el cálculo de la retribución de la actividad de distribución de energía eléctrica.”

For each admissible configuration, the points used for separation from the interconnected network and subsequent reconnection must be defined in advance. The island should therefore not be formed or resynchronised through a point selected on an occasional basis during operation. The identified points must be equipped with switching devices suitable for the expected operating currents, short-circuit conditions and required separation and reclosing duties. Where the device must interrupt faults, perform automatic separation or enable controlled reconnection, a circuit breaker with adequate performance must be used; a device intended solely for isolation is not sufficient. Measurements on both sides, synchronisation and synchro-check functions, and the necessary interlocks must also be available at the points of parallel connection.

The controllability of the island also requires an adequate communication and remote-control infrastructure. The DSO must be able to determine the actual network configuration, the status of switching devices, the main electrical quantities and the availability of the resources participating in island operation. The architecture must support coordination between the control centre, network automation systems, local controllers and connected resources, with roles, priorities and responsibilities defined in advance. Fast dynamic control and essential safety functions must remain locally available, while remote control must provide the DSO with overall supervision and control of the operating sequence.

Readiness for island operation must therefore be assessed as a characteristic of the distribution system as a whole, resulting from the integration of network configuration, primary equipment, protection systems, control systems, communications and operating procedures. For each area, the sequences for separation, autonomous operation and reconnection, including the conditions under which the island may be activated, maintained or terminated, must be defined and verified in advance. The technical capabilities of connected resources, including those introduced under the revision of the Network Code on Requirements for Generators, are enabling requirements but do not replace the assessment of network readiness or the DSO's operational authorisation.

3.2 Methods and strategies

Various methods and strategies have been proposed to implement controlled islands in distribution networks. These approaches differ in their degree of centralisation, complexity, and reliance on communication infrastructure. Centralised strategies typically rely on advanced distribution management systems to define island boundaries, coordinate resources, and supervise islanded operation with a marked emphasis on control by the centralised network operator. Distributed strategies place greater emphasis on autonomous local control, often enabled by grid-forming capabilities of inverter-based resources. Hierarchical approaches combine centralised supervision with local control capabilities responsible for fast dynamic responses.

Island boundaries are commonly defined based on network topology and operational criteria such as the availability and location of distributed generation and storage, load criticality, and the feasibility of maintaining acceptable voltage and frequency performance. While different control architectures exist, all approaches aim to ensure stable operation during islanded conditions and smooth transitions between grid-connected and islanded modes. Experience from pilot projects and demonstrations has shown that solutions must be adapted to network characteristics and operational objectives, rather than following a one-size-fits-all approach. This presents an inherent difficulty in deploying global or standardised plans to control the emergence of unwanted islands, requiring thorough studies by the DSOs responsible for managing the network. Experiences of these pilot projects perhaps reflect the

main reason why rules and regulatory developments are still lacking to make island control a common practice. Some of these projects are shown in a later section.

3.3 Main technical challenges

Despite its potential benefits, controlled islanding in distribution networks presents significant technical challenges. One key challenge is adjusting generation and demand at the moment of transition into islanded mode, then maintaining voltage and frequency stability in low-inertia systems dominated by inverter-based resources. Protection coordination becomes more complex due to changing short-circuit levels and power flow directions during islanded operation, with implications for selectivity and sensitivity of protection functions. Ensuring smooth transitions between grid-connected and islanded states - and safe, reliable reconnection - without compromising power quality or equipment integrity remains a critical issue.

In addition, controlled islanding requires secure, reliable, and appropriately performant communication, as well as tight coordination between control, protection, and system dynamics. These interdependencies mean that controlled islanding must be addressed as a holistic system challenge rather than as a set of isolated technical functions. Furthermore, the increasing deployment of grid-forming capabilities may affect islanding behaviour, including the risk of sustaining unintended islands in certain situations, reinforcing the need for clear operating concepts and regulatory clarity.

Another important challenge is interoperability between multiple controlled islands that may contain equipment, controllers, energy management systems, DER inverters, and protection devices from different vendors. While individual components may comply with relevant standards, differences in control philosophies, communication protocols, data models, commissioning practices, and proprietary functionalities can hinder seamless coordination during island formation, operation, and restoration. Achieving reliable interoperability requires not only standardised interfaces but also consistent interpretation of operational states, control commands, measurements, and protection actions across all participating systems.

The challenge becomes even more pronounced in scenarios where several controlled islands exist simultaneously within the same distribution network and may later need to merge during system restoration. In such situations, synchronisation of voltage magnitude, frequency, phase angle, and dynamic control states is required before reconnection can be safely performed. Beyond technical synchronisation, a clear hierarchy of control authority must be established. When two or more islands reconnect, it must be predefined which grid-forming resource, microgrid controller, or system operator assumes the role of the frequency and voltage reference, and how leadership is transferred or coordinated. Without well-defined master-slave, peer-to-peer, or distributed control arrangements, competing control actions may lead to oscillations, instability, degraded power quality, or unsuccessful reconnection attempts.

Furthermore, future distribution systems may contain multiple grid-forming converters capable of independently establishing voltage and frequency. While these capabilities enhance resilience and facilitate islanded operation, they also introduce new interoperability requirements. Grid-forming units from different manufacturers must be capable of stable parallel operation and coordinated power sharing under both normal and contingency conditions. Ensuring predictable behaviour across heterogeneous equipment portfolios remains an open technical and standardisation challenge, particularly as controlled islanding evolves from isolated microgrid applications toward larger, more dynamic multi-microgrid and active distribution network architectures.

3.4 Pilot projects and field demonstrations

This section reviews projects and experiences that have tested the occurrence of controlled islands in distribution networks. Many more examples exist, but those most relevant to the topic of this document have been selected. The purpose is to provide practical information to complement the information described in the previous sections.

Spain

ALOIS Project

The goal of Alois Project (Control and protection systems for island operation of distribution feeders)⁵ was to develop and validate the control and protection systems to ensure the stable island operation of medium-voltage distribution network feeders with the aim of improving the quality and continuity of the electricity service by taking advantage of distributed generation sources. Alois was carried out by the consortium formed by i-DE (Iberdrola Group) and University Pontificia de Comillas of Spain.

The project represents a first step in preparing DSOs to work with primary and secondary systems suitable for island operation. This involved determining the robustness of control structures and protection systems, as well as their stability margins.

As a criterion for selecting the networks for testing, cases were sought in which there had been an accidental islanding event. These networks contained photovoltaic, hydroelectric, or a combination of both sources of generation, and in some cases also batteries connected directly to the distribution network.

The experience showed that if distributed generation is based on synchronous generation, the generators themselves via speed regulation systems can stabilise the frequency. However, even in this case, voltage control was still necessary. The experience showed that existing reactive power modulation acting on voltage control did not achieve the required voltage stabilisation.

If distributed generation is based on photovoltaic generation, stable islanding operation presents significant technical challenges, and maintaining the island under regular supply conditions cannot be guaranteed. The field test on the pilot network resulted in a temporary islanding that shut down due to two external disturbances, so the inverters likely disconnected due to the activation of underfrequency protection. The tests demonstrate the need for a grid-forming control mode. They also highlighted a significant lack of understanding regarding the operation of photovoltaic inverters connected to distribution networks (protection and control configurations). One of the important conclusions was that, if in that portion of the grid a battery inverter was present and could operate in grid-forming mode, the tests showed that the battery inverter was able to stabilise the voltage and frequency of the islanded operation, creating a lasting islanded environment.

The project's most significant outcomes were as follows:

- **Dynamic behaviour of islanded distribution networks:** The dynamic response of islanded networks was analysed in depth thanks to the results generated from the integration of simulation models. Furthermore, online model identification algorithms were developed to provide adaptive modelling based on network conditions.

⁵ [“Sistema de control y protección de ALimentadores reales de media tensión para una Operación en ISla estable y sostenible en el tiempo \(RTC-2017-6296-3\).”](#)

- **Control and protection systems:** The know-how in control schemes and protection systems was implemented for application in real distribution network feeders. In addition, advancements were made in adaptive, flexible, and plug-and-play control and protection technology.
- **Solution scalability:** Following the in-depth analysis of the problem, the developed control structures and protection systems were implemented in selected real distribution network feeders for validation.

These results made a valuable contribution to the next steps described in the following sections, on industry regulation, standards and technological proposals. Probably the biggest obstacle to further work on scaling up results and real implementation is the lack of regulatory incentives for DSOs.

The controlled islanding tests conducted as part of the Spanish CoordiNet⁶ demonstration are equally relevant. They evaluated the DSO's ability to isolate a rural 20 kV radial network in Murcia and maintain autonomous supply during outages or planned maintenance, using a 1.25 MW/2 MWh battery as a grid-forming resource supported by a 1.5 MWp PV plant to extend island duration. The islanded area included 1,179 customers with a peak load of 1.23 MW, and the demo successfully maintained stable island operation for 1.5 hours, delivering 0.012 MWh and supplying a maximum non-transient power of 0.945 MW. The test validated the prequalification and activation procedures as well as information exchange between the DSO and the flexibility provider, although it highlighted the need for improved near-real-time communication to handle potential unexpected events during islanding mode. As controlled islanding is highly site-specific and requires very particular technical attributes, the experience concluded that it is unlikely to become a competitive market product, making bilateral contracting a more realistic approach while underscoring the importance of keeping operational control in the hands of the DSO.

Finland

The LEMENE Microgrid⁷ in Lempäälä, Finland, is an industrial multi-energy system that combines local power generation, battery storage, fuel cells, controllable loads, and a utility grid connection into a resilient and intelligent energy ecosystem. Its primary objectives are to improve energy security, integrate renewable energy sources, reduce energy costs, and generate additional revenue through participation in electricity and reserve markets.

At the core of the solution is the Energy Management System (EMS), based on SICAM Microgrid Control, SICAM SCC, and SICAM A8000. The EMS actively coordinates distributed energy resources in real time, optimises battery operation, manages power exchange with the grid, and supports islanded operation during grid disturbances. It also integrates weather data, electricity prices, production forecasts, and market signals to optimise system performance.

The site includes a mix of generation and storage assets such as CHP units, photovoltaic systems, battery energy storage systems (BESS), fuel cells, and controllable electrical loads. Key functionalities include peak shaving, DER control, reserve monitoring, blackout detection, demand charge management, and participation in ancillary service markets.

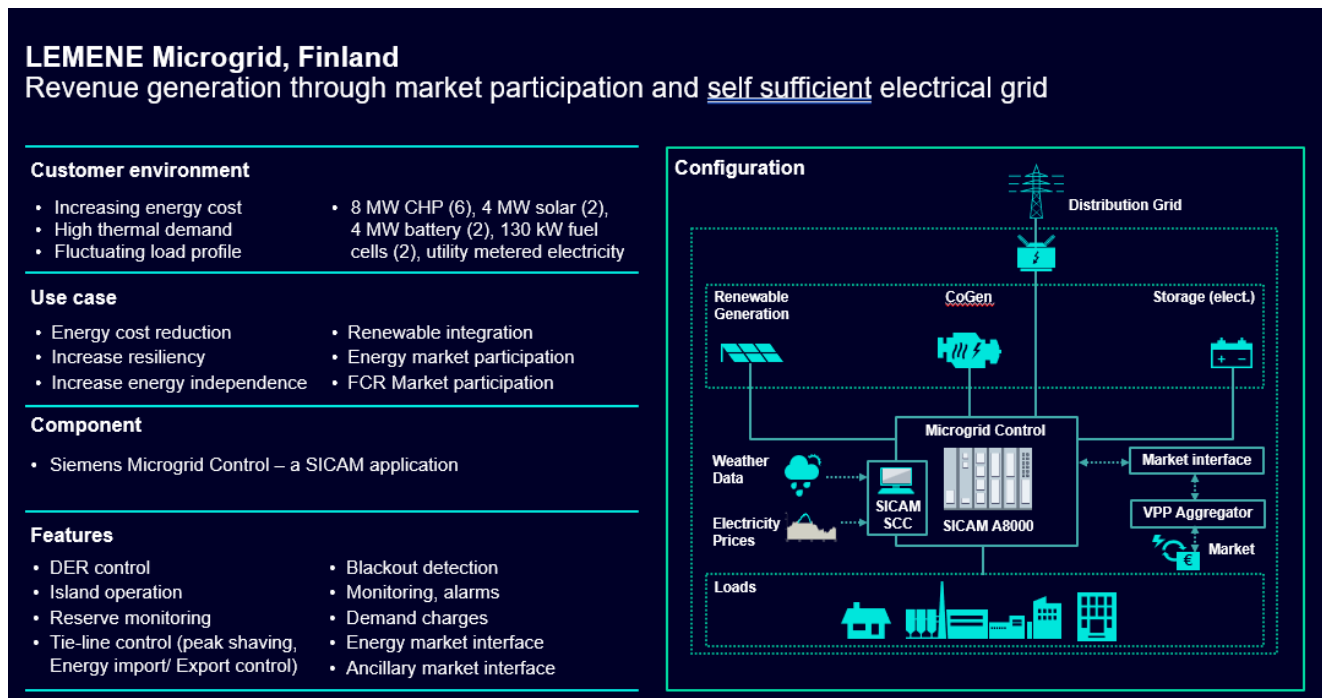
A major differentiator of the project is its integration with external stakeholders, including virtual power plant (VPP) aggregators, the Finnish transmission system operator Fingrid, and weather data providers.

⁶ [Final_Spanish_demo_report_results_and_analysis_of_the_full-scale_demonstration](#), ”.

⁷ “[Video Lemene Microgrid](#),” last visited October 2026.

Through bidirectional interfaces, the microgrid can exchange operational and market data, submit reserve bids, and support real-time reserve activation.

The project demonstrates how renewable integration, resilience, active EMS control, and energy market participation can be combined within a fully operational industrial microgrid. Benefits include increased energy independence, improved power quality and resilience, optimised operating costs, enhanced sustainability, and new revenue streams from flexibility and reserve markets. Technical lifecycle services ensure long-term operation with remote support, security updates, system testing, and a contractual availability target of at least 98%.



Lappeenranta-Lahti University of Technology (LUT) Smart Campus as living laboratory for microgrid and energy-management research is one of Finland's most active microgrid research platforms.

Denmark

Bornholm Island

Bornholm Island is connected to the Nordic power system through a 60kV AC sub-sea interconnector to Sweden during all time of operation. The sub-sea cable was cut several times in the past which created a clear need for local capabilities that can maintain supply during interconnector outages. The Bornholm system operator together with academia has pioneered establishment of a controlled islanding infrastructure on the island in Europe in 2015 in the EcoGrid⁸ project.

For DSOs, this project is particularly interesting because it combines:

- High DER penetration
- Distribution-level islanding
- Utility-scale battery storage

⁸ "CORDIS Fact Sheet," last visited October 2026.

- Reserve-power responsibility

This makes Bornholm one of the few real-world European examples where a battery is being deployed explicitly to support both:

- Grid-forming/resilience functions during islanded operation
- Market-based flexibility services during normal operation

In the meantime, a 30 MW BESS installation is operated in grid-forming (GFM) mode⁹ to strengthen security of supply, facilitate the integration of renewable energy sources, and provide balancing and ancillary services under normal operating conditions. The installation is designed to support grid-forming operation and can act as an emergency power source in the event of a loss of the interconnection. In case of an island blackout the BESS will support with black-start services until the island's energy is fully recovered by the thermal power plant. A 10 MW BESS expansion is under construction. This demonstrates how battery storage can simultaneously support system resilience, controlled island operation, and flexibility services, illustrating the growing role of grid-forming resources as enabling technologies for future distribution-network islanding strategies.

"If the submarine cable fails, the battery at Hasle could quickly connect and supply the island while boilers at the local power plant heat up." - Claus Møller, Commercial director, EWII Group



Source: Hitachi Energy

Other projects

There are many other projects that have tried to solve the problem of separated portions of the grid working with inverter-based generation. For example, the project "Massive InteGRATion of power Electronic devices (MIGRATE)"¹⁰ project developed the technical basis for demonstrating that justifies the viability of intentional islanding in networks with high penetration of DER and power electronics (grid forming), a key condition for future distribution systems. Whereas MIGRATE takes the transmission system perspective, the microgrid pilot case in Latvia is a local demonstrator. It is run by DSO Sadales tīkls and aims to demonstrate autonomous microgrid operation by integrating a diverse generation mix comprising a run-of-river hydroelectric plant, solar photovoltaic plant, and a BESS equipped with GFM inverters. Deployed across three secondary substations, the primary objective is to test a dual use case logic for normal grid operations and upstream network outages, fast grid following to grid forming (GFL-to-GFM) transitions, and black-start capabilities, ensuring uninterrupted power supply to customers for extended durations both in winter and summer conditions - targeting at least a week of continuous islanded operation.

⁹ "EWII har sat strøm til Danmarks største batteri," EWII press release, last visited October 2026.

¹⁰ "Migrate, the Massive Integration of Power Electronic Devices," H2020 MIGRATE, archived by Arquivo.pt, last visited October 2026.

Australia

Another interesting project describes the progress in a different geographical area. The ESCRI Dalrymple project developed in South Australia describes one of the world's most advanced demonstration of grid-forming battery energy storage supporting controlled island operation. The project deployed a 30 MW/8MWh battery energy storage system at the end of a radial network supplying local communities and connected renewable generation. The installation was specifically designed to maintain continuity of supply following upstream network disturbances by seamlessly transitioning between grid-connected and islanded operation. During islanded operation, the battery acts as the voltage and frequency reference for the local system, coordinating with a nearby wind farm and distributed photovoltaic generation while maintaining system stability and power quality. The project also demonstrated black-start capability, rapid restoration of local distribution feeders, and the ability to reconnect safely to the wider power system. Beyond the resilience benefits achieved for local customers, the experience highlighted the broader role that grid-forming resources can play in supporting system strength, renewable integration, and operational flexibility, illustrating how controlled islanding can evolve from a pilot concept into a practical operational tool for future power systems. The project included the development of a first-of-its-kind commercial model to support the provision of regulated reliability and security services by a Network Service Provider ElectraNet alongside competitive market services by retailer AGL, challenging perceived limitations to network ownership of battery energy storage technologies navigating the market registration, licensing and connection processes for the first time, paving the way for others to follow – a very transparent approach assisted AEMO in developing registration procedures for utility-scale battery technology largest autonomous regional micro-grid development to date, co-optimised for both grid-connected and islanded operation with 100% renewables, allowing seamless transition between the two operating modes (for both planned and unplanned islanding)".

A link could potentially be established between the above experiences and the work conducted by IAEW Institute of RWTH Aachen University, which in a different study on the Impact of Grid-Forming Converters on Unintended Islanding of Distribution Grids, found evidence that an increased risk of unintended islanding in medium and low voltage grids comprising grid forming converters can be expected. Integration of grid forming converters into the distribution grids requires alternative techniques for reliable detection and shutdown of unintended islanded grids. Communication-based approaches are reliable alternative from a technical perspective. This might require additional costs due to individual connection of grid forming units.

The Kythnos microgrid, established in 2001 as the first renewable powered community microgrid (low voltage microgrid), continues to serve as living laboratory. One of Europe's pioneering microgrids and remains a benchmark for controlled islanding.

4. Regulatory frameworks and standards

This section summarises how controlled islanding is addressed, directly or indirectly, in regulatory frameworks, international standards and technical guidelines.

4.1 European regulation

This review of the European regulatory developments, emphasising the diversity of approaches and also reflecting on the frequent lack of explicit provisions for controlled islanding needs to be analysed from a practical perspective. It serves to address typical regulatory barriers, such as safety responsibilities, quality-of-supply requirements, and the role of the distribution system operator during islanded operation.

- Network Code on Electricity Emergency and Restoration. Regulation (EU) 2017/2196.¹¹

The Network Code on Electricity Emergency and Restoration. Regulation (NC ER) sets the basis for incorporating the island operation for the purposes of safeguarding operational security, preventing the propagation or deterioration of an incident to avoid a widespread disturbance and the blackout state as well to allowing for the efficient and rapid restoration of the electricity system from the emergency or blackout states.

In this context, it is established that each TSO should prepare a proposal for restoration service providers, which includes the target geographical distribution of power sources with black start and island operation capabilities. Development under this grid code is therefore very limited and does not take into account the specific needs for maintaining islands controlled by Dispatch Service Operators (DSOs). A future revision of the grid code is expected, which should include provisions in this regard.

- Network Code on Requirements for Grid Connection of Generators. Regulation (EU) 2016/631.¹²

The Network Code on Requirements for Grid Connection of Generators (NC RfG) is particularly relevant because it represents the main interface between the generators connecting to the network and the system operators operating it. As stated in the NC RfG, common requirements for generators must contribute to maintaining, preserving and restoring system security in order to facilitate proper functioning of the internal electricity market, including in certain occasion the mitigation of risks, such as local islanding.

The NC RfG definition of island operation is the following (Art. 2.41):

‘Island operation’ means the independent operation of a whole network or part of a network that is isolated after being disconnected from the interconnected system, having at least one power-generating module or HVDC system supplying power to this network and controlling the frequency and voltage”.

Nevertheless, the capability to take part in island operation for power-generating modules is only required for those of Type C and D when required by the relevant system operator in coordination with the TSO (Art. 22.4 (b)). Considering that the threshold between Type B and C generators is established at above 1 MW for continental Europe (1.5 MW for the Nordics, 0.5 MW for the Baltics, and 0.1 MW for Ireland and Northern Ireland), this implies that most of the generators connected to the distribution network are not currently required to integrate islanding functionalities.

¹¹ ["Commission Regulation \(EU\) 2017/2196 of 24 November 2017 establishing a network code on electricity emergency and restoration."](#)

¹² ["Commission Regulation \(EU\) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators."](#)

From another perspective, the proposed new version of the NC RfG (known as RfG 2.0) considers the possibility of island operation of power park modules with grid-forming capabilities (Art. 29) regardless of their category (as established in the national roadmap). For this purpose, the NC establishes the need to nationally develop roadmaps which, among others, shall include an analysis of the risk of local network island operation in cases of high penetration of grid forming power park modules. The reason is the practical evidence that the integration of grid-forming capabilities in certain environments could lead to unintentional islanding.

In conclusion, it can be said that as it pertains to the NC RfG, power-generating modules of Type C and D are required to be able to operate in island mode under the mandate of the relevant DSO. Type A and B power-generating modules are not required to integrate these functionalities; moreover, their grid-forming capabilities should be assessed in a way that does not contribute to the existence of unintentional islanding.

It is also interesting to consider the regulatory perspective on the role of supply reliability. In this sense, the Eurelectric paper entitled “Reliability: The Coming Storm - Building electricity resilience to extreme weather”¹³, identifies the concept of reliability as a key factor in achieving success in the electrification ambition. Reliability can be measured using two KPIs: the System Average Interruption Duration Index (SAIDI), helps quantify power system reliability by measuring the total amount of time that an average customer experiences service interruption during the measurement period, typically a year. Similarly, the System Average Interruption Frequency Index (SAIFI), measures the number of interruptions an average customer experiences during the measurement period. Typically, Major Event Days, such as storms, are excluded from reliability calculations as they constitute “force majeure”, however, there is no a single accepted standard for interpreting what constitutes a Major Event Day.

If the regulatory framework allowed to maintain controlled islands of network alive when there is disruption upstream, regardless of whether they constitute force majeure or not, network reliability could be improved and, consequently, customers’ perception of network reliability would also improve. The consequence: there is an incentive for DSOs to seek alternative methods of managing the network in these situations.

4.2 International regulation

The ESCRI Dalrymple regulatory model is a dual-use battery framework in which ElectraNet owns the BESS for regulated network reliability services while AGL operates its competitive market functions, creating one of Australia’s first successful examples of sharing battery value between regulated transmission services and merchant electricity market revenues.

Under Australia's National Electricity Market (NEM) framework, transmission network service providers (TNSPs) such as ElectraNet are generally prohibited from owning generation assets because this could distort competition. Batteries, however, can provide both:

1. Regulated network services (reliability, system security, islanding support)
2. Competitive market services (energy trading, FCAS, arbitrage)

¹³ ["The Coming Storm - Building Electricity Resilience to Extreme Weather,"](#) Eurelectric.

This created a regulatory grey area when the project was conceived.

The ESCRI Regulatory Model

The project^{14, 15} introduced a shared-use model with functional separation between regulated and market activities:

Regulated Function (ElectraNet)

ElectraNet owns the battery and uses part of its capability to provide network support services, including:

- Reliability support for the lower Yorke Peninsula¹⁶
- Network contingency support
- Voltage and system security services
- Operation of an autonomous renewable microgrid when the transmission line is disconnected

These services are treated as regulated transmission services because they improve network reliability and defer traditional network investments.

Market Function (AGL)

AGL was contracted to utilise the battery's remaining capacity for competitive market activities, including:

- Frequency Control Ancillary Services (FCAS)
- Energy arbitrage
- Wholesale market participation

AGL receives market revenues while ensuring reserved capacity remains available for ElectraNet's network obligations.

The project required approval under Australia's ring-fencing framework¹⁷, which aims to prevent regulated network businesses from gaining unfair advantages in competitive markets.

The solution was to:

- Separate network and market functions contractually.
- Reserve battery capacity for regulated services.
- Allow a third-party market participant (AGL) to operate the commercial component.
- Demonstrate that the battery was the most efficient non-network solution for reliability needs.

This became a precedent for later battery projects across Australia.

¹⁴ S. Cherevatskiy et al., "Grid Forming Energy Storage System Addresses Challenges of Grids with High Penetration of Renewables (A Case Study)," Proceedings of CIGRE Session 2020, Paris, 2020, available at eCIGRE: [Technical Publications on Electric Power Systems](#).

¹⁵ ElectraNet Pty Limited, "[ESCRI-SA Battery Energy Storage Final Knowledge Sharing Report](#)" - Australia, March 2021, last accessed October 2026, ESCRI-SA Final Report 2021.

¹⁶ "[Boosting Energy Reliability On Lower Yorke Peninsula](#)," Hitachi Global.

¹⁷ "[Time to Understand 'Ring-fencing'](#)," Compliance Quarter.

The "stacked revenue" approach improved project economics while ensuring compliance with Australian energy regulation.

The ESCRI-SA project demonstrated:

- A network utility can economically justify battery ownership.
- Battery storage can simultaneously provide regulated and market services.
- Ring-fencing rules can accommodate storage through functional separation.
- BESS can replace or defer traditional network reinforcement investments.
- Large-scale batteries can support renewable islanded operation and system security.

Beyond the commercial structure, the project demonstrated that utility-scale battery storage can support autonomous renewable microgrid operation and controlled islanding while simultaneously providing regulated reliability services and competitive market services. This experience offers valuable insights for future regulatory frameworks seeking to promote resilience-oriented investments in distribution and transmission networks.

5. The way forward

Distribution networks require key developments to enable wider adoption of controlled islanding in distribution networks. They are mainly technological advances such as grid-forming inverters, energy storage, and adaptive protection, as well as operational enablers including advanced distribution management systems and improved observability. The need for regulatory evolution and large-scale demonstrations —going beyond pilot projects — should also be explored so that controlled islanding capabilities become one tool within a broad set of preparedness resources.

One possibility for initiating a new line of collaboration, but outside the scope of this work, would be for T&D Europe and E.DSO to engage in dialogue with relevant stakeholders who work on preparedness of society for extreme weather events or sabotage and other attacks.

Distribution System Operators have crisis teams and crisis plans in place. This new study could introduce the latest technological concepts and support the review and extension of existing plans. The focus would be on prioritising critical areas where controlled islanding could add value. The details of that potential study would require a preliminary analysis of the critical sectors and the magnitude of the risks, as well as a preliminary investigation into the most exposed areas and the availability of resources.

6. Conclusions and next steps

The transformation of European distribution networks, driven by the increasing penetration of distributed energy resources, storage systems, power-electronics-based technologies and flexible demand, is creating new opportunities to enhance resilience and continuity of supply. In this context, controlled islanding is emerging as a relevant operational capability that can enable DSOs to maintain service to customers during upstream disturbances, support restoration processes, and improve the overall flexibility of electricity systems.

The experiences reviewed in this paper demonstrate that controlled island operation is technically feasible and potentially valuable for improving system-recovery processes. Advances in grid-forming technologies, battery energy storage systems, digital monitoring, communications and control architectures have significantly increased the ability of distribution networks to operate safely and reliably in temporary islanded conditions. Pilot projects and field demonstrations have already shown that controlled islanding can contribute to maintaining supply to critical loads, improving resilience against extreme events, and supporting the integration of renewable energy resources.

However, the deployment of controlled islanding at scale remains limited. The main barriers are no longer purely technical. Regulatory frameworks, operational responsibilities, incentive schemes, interoperability requirements and standardisation gaps continue to restrict wider implementation. Existing regulations and grid codes were largely developed under the assumption that islanding should be avoided, whereas future distribution systems may increasingly benefit from the capability to intentionally and safely operate portions of the network independently when justified by system needs.

Controlled islanding should therefore be considered as one element within a broader resilience toolbox available to DSOs. It is not a universal solution and will not be appropriate for every network segment. Its application should be based on a clear assessment of local conditions, including the availability of distributed generation and storage, the criticality of connected loads, exposure to extreme events, and the level of network observability and controllability. In many situations, controlled islanding may complement other resilience measures such as network reinforcement, automation, flexibility services, mobile generation, and emergency preparedness plans.

To unlock the full potential of controlled islanding in European distribution networks, several next steps should be prioritised:

- Develop a clearer regulatory framework defining the roles, responsibilities and operational conditions associated with controlled island operation in distribution networks.
- Support the inclusion of distribution-level islanding use cases in future revisions of European network codes and related implementation guidelines.
- Accelerate standardisation activities addressing interoperability, communications, protection systems, data models and integration of grid-forming resources.
- Promote large-scale demonstration projects involving DSOs, manufacturers, research organisations and public authorities, moving beyond isolated pilot installations towards operational deployment.
- Establish common methodologies to assess resilience benefits and quantify the contribution of controlled islanding to quality-of-supply indicators and preparedness objectives.

- Continue research on protection concepts, island detection, multi-island coordination, reconnection procedures and the interaction between grid-forming resources and distribution network operation.
- Strengthen cooperation between the electricity sector and other critical infrastructures, including water, telecommunications, transport, healthcare and public authorities, to identify areas where controlled islanding could provide the greatest societal value during major disturbances.

E.DSO and T&D Europe are well positioned to facilitate this dialogue and contribute to building a common understanding among stakeholders. Continued collaboration between DSOs, technology providers, regulators, standardisation bodies and research institutions will be essential to transform controlled islanding from a promising technical capability into a practical and scalable operational tool for resilient European distribution networks.

Controlled islanding should no longer be viewed solely as an exceptional operating condition, but as a strategic capability that, when properly enabled and regulated, can contribute significantly to the resilience, flexibility and sustainability of the future European electricity system.

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