

Position and discussion paper

Grid-Forming Readiness in Distribution Networks – Medium-Voltage Battery Storage as the Key to Islanding Capability and Resilience

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Call for Action

Grid-forming readiness in distribution networks – prepare now

Regional islanding capability and resilience are gaining in strategic importance as the transformation of the energy system progresses. The ability to operate or restore individual sections of the grid as needed – without compromising on stability – is becoming a crucial requirement for ensuring security of supply in a system increasingly dominated by power electronics.

Large-scale battery systems connected to medium-voltage grids have a key role to play in this context. They are technically capable of supporting grid-forming operation and often provide suitable communication interfaces, besides being long-lived infrastructure assets that will shape the system's future operational flexibility for decades to come.

The transformation of the electrical energy system into a largely inverter-dominated infrastructure is also instigating far-reaching changes in the physical foundations of system stability. Stability, restoration and resilience are increasingly being determined by the technological control properties of power electronics and no longer primarily by rotating masses.

We therefore propose the introduction of grid-forming readiness as a structured availability and classification category. Grid-forming readiness describes a system's ability to provide defined grid-forming capabilities or to activate them with plannable operational input without having to fulfill immediate operational obligations.

Phase 1: Focus on medium-voltage battery storage

During the first phase, the specification should explicitly focus on large-scale battery storage systems connected to medium-voltage grids. This is because

- they are technologically particularly suited to this purpose,
- they are usually accessible using communication technology,
- they have significant system impact at both local and regional levels,
- the implementation of regulatory requirements appears workable.

Subsequent expansion to other technologies and grid levels is possible but should be effected experientially.

Further development of concept – specific steps

1. Updating and prioritization of use cases for grid-forming facilities, including islanded operation, black start capability, support for weak grids, provision of instantaneous reserves and supply of energy reserves in emergency scenarios
2. Introduction of standardized functional classes with a system capable of verifying compliance by performing standardized test procedures
3. Precise definition of "grid-forming readiness" and establishment of verification procedures for technical classes in standards (VDE/DKE, German Commission for Electrical, Electronic & Information Technologies in the VDE) and application rules (VDE/FNN, Forum Network Technology / Network Operation in the VDE).

1. Societal Challenge, Systemic Necessity and Need for Regulation

The transformation of the energy system into one almost entirely dominated by power electronics is a major infrastructural challenge that will have to be faced in the decades to come. The massive increase in renewable energy systems, battery-supported storage and converter-interfaced loads (e.g., electric mobility, heat pumps, industrial drive systems) is fundamentally changing the physical properties of power grids.

In the distribution network in particular, system behavior is shifting from a grid dominated by rotating masses to one whose stability is largely determined by the control systems embedded in power electronics. Frequency and voltage stability, short-circuit power, fault management, post-disturbance recovery and the ability to operate in islanded mode are therefore gaining importance – not only at transmission system level but increasingly also in distribution networks.

Given this situation, there is a growing need for regulatory action and framework development. In the future, distribution network operators will have to be able to operate grids reliably even in unstable conditions, temporarily decouple subnetworks and implement regional resilience concepts. This will give rise to new functional requirements for converter-interfaced resources, particularly for large-scale battery storage systems.

The question is, therefore, not only whether converter-interfaced resources will need to assume grid-forming functions in the future, but also when and under what conditions these capabilities should be available. In the case of long-lived assets such as large battery storage systems, we are seeing the emergence of technical and economic path dependencies that could make later adjustments considerably more expensive or even impossible.

Taking future requirements into account early on in technical design processes – without having to fulfill immediate operational obligations – therefore opens up greater strategic flexibility. The maintenance of grid-forming capabilities can ensure that distribution network operators will be able to respond flexibly to new systemic requirements without having to initiate costly retrofitting programs or deal with regulatory interventions affecting existing infrastructure at short notice. The time-consuming regulation process should therefore be initiated now.

This raises a new question: Are existing terms and regulatory approaches sufficient to adequately describe and categorize this form of forward-looking operational capability, or is there a need for a complementary conceptual category that bridges the gap between current operation and future system responsibility?

2. Existing Terms and Their Limits

Current technical and regulatory discourse largely focuses on a binary distinction between “grid-following” and “grid-forming” modes of operation when referring to converter-interfaced resources. While this distinction is technically sound and well established, it only addresses the active operational state of a system.

In Germany, grid-forming properties have been defined and technical specifications developed as part of the work carried out by VDE/FNN. The current FNN guideline *Netzbildende Eigenschaften* (Grid-Forming Capabilities, version 2.1, 2026; this version is currently only available in German) specifies requirements for systems operating in grid-forming mode. These requirements are currently particularly relevant in the context of high-voltage and extra high-voltage networks, but will also gain importance at distribution network level in the future (System Stability Roadmap, milestone plan MS15). The guideline focuses on the active provision of grid-forming functions, for example to maintain voltage and frequency stability and to provide inertia.

At European level, ENTSO-E emphasizes the need for resources with grid-forming capabilities in its ongoing updates to the Network Code Requirements for Generators (RfG) and in accompanying technical reports. International standardization activities such as IEEE standard 2800-2022 and the ongoing project IEEE P2800a also focus on performance requirements for power electronic inverters operated in active grid-forming mode.

Parallel to this, progress is being made at national level with the integration of grid-forming capabilities in the Technical Connection Rules for High-Voltage and Extra High-Voltage (VDE-AR-N 4120 / 4130). Over the course of consultation and assessment processes focusing on system stability, the German Federal Network Agency has made it clear that grid-forming behavior will become an integral technical connection requirement in the future. Until now, the regulatory bodies have paid closer attention to the mandatory active provision of grid-forming functions.

What these terms and regulatory approaches have in common is that they refer either to active operating states or to binding, directly applicable connection requirements. None of the existing definitions explicitly address the structural provision of grid-forming functions that need not be activated immediately. Furthermore, there is no systematic classification for facilities that are already technically prepared or that could be prepared with a reasonable degree of effort without activating these functions during regular operation.

For medium-voltage and low-voltage networks in particular, there are as yet no consistent, systematic specifications regarding the maintenance of grid-forming capabilities. While specific requirements are increasingly being discussed or implemented for high-voltage and extra-high-voltage connections, the question of forward-looking technical preparation within the distribution network remains largely unaddressed from a regulatory perspective.

The result is a conceptual gap between:

- current modes of operation (*grid-following* or *grid-forming*),
- requirements that could potentially become binding in the future
- and the strategic design of technical platforms facilitating the activation of grid-forming functions at a later date.

This gap is particularly relevant in the case of long-lived assets such as large battery storage systems in distribution networks, since their technical design today will shape the system’s operational flexibility tomorrow. A conceptual and regulatory category that systematically records these dimensions of preparedness and time has yet to be established.

3. Objective and Conceptual Gap

The technological rationale for the phase 1 focus outlined in the call for action is explained here.

The implementation of grid-forming readiness should initially be limited to battery storage systems connected to medium-voltage grids. Battery storage systems are not weather-dependent, are capable of supporting bi-directional power flow and are not subject to complex mechanical interactions. They are therefore a technologically suitable starting point that is also manageable in regulatory terms.

The objective of this position and discussion paper is to explicitly address this terminological and conceptual gap. We argue that the current dichotomy of “grid-following” and “grid-forming” is incapable of adequately representing sustainable investment and regulatory decisions in distribution networks.

Large-scale battery storage systems in particular can already be equipped with hardware platforms able to support future grid-forming functions without having to fulfill any obligation to initiate active operation right away. This option has not yet been systematically addressed, either conceptually or in regulatory terms.

4. Introducing and Structuring the Term “Grid-Forming Readiness”

4.1 Objective of the term

The term “grid-forming readiness” was coined to describe a dimension of grid-forming functionality that had not been systematically addressed before: the structural provision of defined functions with no immediate obligation for activation.

While existing terms such as “grid-forming” or “grid-forming properties” describe the active operational status of a system, grid-forming readiness addresses the question of whether and under which conditions a system is technically prepared to provide defined grid-forming functions in the future.

Grid-forming readiness, therefore, is not an operational mode but rather a structural characteristic of the system’s configuration. It closes the conceptual gap between

- operation exclusively in grid-following mode,
- grid-forming operation with mandatory active operation
- and strategic system preparation.

It opens up the scope for plannable, stepwise system development without creating an immediate regulatory obligation to activate grid-forming functions on a long-term basis.

4.2 Two-level class model: availability level and functional level

A two-level class model is proposed for purposes of conceptual clarification:

Level 1: availability class (time and implementation dimension)

This level describes how readily a system can activate defined grid-forming functions.

Class A – activation-ready

A system is classified as *activation-ready* if:

- all the necessary hardware components are present,
- the grid-forming functions have been implemented and validated,
- it is possible to switch between grid-following and grid-forming operations
- and the system can be activated without structural hardware adjustments.

If necessary, the system can be activated by parameter adjustment or software enabling.

Class R – retrofittable

A system is classified as *retrofittable* if:

- the power electronics are fundamentally suited to this purpose
- but additional hardware adjustments (minor) or functional enhancements (software updates) are necessary,
- which can be achieved with reasonable effort and without replacing the entire system.

Class R signifies planned technical retrofitting capability but not immediate activation. Any subsequent certification and associated testing procedures must also be taken into account.

Power converters are classified using a layer model that allows distinctions to be made between three different layers:

- Hardware layer: power unit, sensors, system protection concepts
- Software layer: control algorithms, switching logic and parameterization capability
- Operation layer: current mode of operation (grid-following, grid-forming)

Level 2: functional classes (scope of grid-forming properties)

The functional class is independent of the availability class and specifies which grid-forming properties can actually be realized.

The following are examples of functional classes:

- **N**: grid-forming operation in an integrated grid system (stabilizing contribution in the coupled grid)
- **I**: islanding capability (stabilization of a defined grid area)
- **S**: black start capability (voltage restoration after a system shutdown)
- **P**: remote parameterization / switchability

A system can for example be classified as “grid-forming-ready A-N,I” if it is activation-ready and meets the specifications for functional classes N and I.

4.3 Relationship with existing grid-forming definition

Grid-forming readiness does not replace any existing operational definition. Instead, it describes an upstream category:

Category	Description
Grid-following	Grid-following behavior
Grid-forming	Active grid-forming operation
Grid-forming readiness	Structural preparation for defined grid-building operation

Grid-forming readiness is therefore a design and investment dimension rather than an operational requirement.

4.4 Activation dimension and test procedures

The following requirements must be defined before a system can be described as grid-forming-ready:

1. Clear specification of the functional classes supported
2. Verifiability by standardized test procedures
3. Documented switching and activation logic
4. Defined interfaces for control and communication

The specific nature of these test requirements is the subject of the standardization proposed in the call for action.

5. System-Level Benefits and Implications for Distribution Network Operators

Based on the two-level class model introduced in section 4, consisting of availability classes (A/R) and functional classes (e.g., N, I, S, P), grid-forming readiness opens up additional scope for systemic solutions in the distribution network.

The core concept is intentionally kept lean. The availability class describes technical activation capability, while the functional classes define the scope of the system's grid-forming properties. Further functions such as islanding capability (I), black start capability (S), synchronizability or parameterizable inertia are not additional independent systems but characteristics of defined functional classes within this model.

5.1 Strategic benefits for distribution network operators

For distribution network operators, grid-forming readiness opens up greater strategic flexibility. Battery storage systems that are already installed can be viewed as potentially activatable system resources with a clearly classified range of functions, even if they regularly operate in grid-following mode.

This allows regional resilience and islanding concepts to be developed step by step, while avoiding the need to make immediate modifications to existing installations and preventing the technical lock-in effects that would occur with a strictly grid-following design.

5.2 Operational feasibility

Communication and control systems must be appropriately interconnected to enable the activation of grid-forming functions at a later date. Many medium-voltage battery storage systems already have this connectivity, but this is not generally the case with low-voltage systems. This confirms that the decision to prioritize medium-voltage battery storage during the initial implementation phase was the right one.

5.3 Technical advantages

As converter-interfaced resources become more dominant, functions that until now have been implicitly provided by rotating masses are gaining importance: inertia, angle and phase stability, defined short-circuit and fault behavior and the stabilization of weak grids.

Grid-forming readiness establishes the structural basis for these functions to be activated as needed without having to keep them in continuous operation. As described in section 4, a clear distinction must be made between islanding capability and black start capability. These functions involve different verification and operation processes and must be classified separately.

5.4 Laying the foundations for future system services

Grid-forming readiness deliberately separates technical feasibility from subsequent regulatory or market structures. This makes it possible to lay the technical groundwork for future system services – such as time-limited grid stability contributions or resilience-related services – without preempting regulatory requirements.

Overall, grid-forming readiness opens up additional scope for the further development of the energy system by linking present-day investments with future adaptability.

6. Additional Stakeholder Perspectives

6.1 System developers and operators

For battery storage system developers and operators, grid-forming readiness is mainly a matter of investment security and future viability. Maintaining the availability of corresponding technical options increases the system's long-term value without giving rise to additional operational obligations that must be met right away. At the same time, there is a concern that readiness could implicitly create future obligations. This uncertainty confirms the need for clear regulatory definitions and communication of the concept.

6.2 Manufacturer perspectives (power converter and system manufacturers)

From the perspective of converter and system manufacturers, grid-forming readiness is in essence technically feasible and largely already achievable today. Platforms currently maintained by major European manufacturers usually have sufficient computing power, sensor technology and control architecture to support operating modes based on voltage sources, switching logic capable of switching between grid-following and grid-forming mode, and software-based enhancements throughout the system's lifecycle. In most cases, grid-forming readiness does not require any major redevelopment of the power electronics but rather a forward-looking software architecture, parameterization capability and update capacity.

At the same time, it should be noted that the provision of grid-forming readiness is not cost-neutral for manufacturers. Additional outlay for development, validation and documentation is incurred in particular from maintaining functions that are not actively used, securing upgrade paths and the need to anticipate various future deployment scenarios. Without clear signals from network operators, regulatory bodies or the market, there is therefore a risk that manufacturers will only provide these capabilities on a project-specific basis, if at all.

For grid-forming readiness to become widely available, three framework conditions are decisive from the manufacturer's perspective: Firstly, there must be a clear conceptual distinction between active operating

requirements in order to limit liability and warranty risks. Secondly, it must be clearly understood from a regulatory perspective that readiness should initially be defined as an optional capability and quality attribute that does not suggest an immediate operational obligation. Thirdly, there must be reliable prospects for later use, such as prioritized grid connections, project-related requirements and remunerated services.

The introduction of clearly defined availability and functional classes reduces special project-specific requirements and creates a standardized development framework. A uniform definition of grid-forming readiness in line with the model described in section 4 facilitates economies of scale in the areas of development, validation and certification.

In these conditions, grid-forming readiness can become a distinguishing characteristic for manufacturers, demonstrating their prioritization of system competence, software quality and integration capability over unit costs. European and national manufacturers with outstanding engineering and grid code expertise are particularly well placed to reap the benefits of this.

6.3 Transmission system operators

In the medium to long term, transmission system operators stand to benefit from local grid-forming resources in the distribution network, since these can facilitate system restoration and reduce cascade effects.

Grid-forming readiness in distribution networks is becoming increasingly important for transmission system operators, especially in the context of system stability and system restoration. The progressive decline in rotating masses and advancing decentralization of essential functions are making transmission systems more dependent on stable, locally effective references in downstream networks. When integrated into the distribution network, battery storage systems with grid-forming capabilities can make a significant contribution by providing voltage and frequency references, limiting cascade effects in the event of disturbances and supporting step-by-step restoration after large-scale outages.

Grid-forming readiness is particularly attractive from the TSO's perspective because it does not require immediate operational integration or centralized control. Instead, it provides the technical conditions necessary to draw on prepared local resources should extraordinary events such as blackouts, system splitting or critical stability situations occur. In time, therefore, grid-forming readiness will help relieve the load on the transmission system without changing the existing distribution of tasks between the transmission and distribution networks or creating new coordination obligations during normal operation.

6.4 Policy

From a policy perspective, the main question is how the energy system can remain resilient and maintain its security of supply in the long term while utilizing an infrastructure that is largely dominated by power electronics. Grid-forming readiness addresses this issue without giving rise to additional obligatory regulations in the short term. This approach provides scope for the proportionate, step-by-step development of the regulatory framework while preventing overregulation and eliminating the need for cost-intensive retrofitting programs later on. Particularly relevant in terms of policy is the character of readiness as a no-regret option that safeguards present-day investments while preserving future flexibility.

From the perspective of industrial policy, grid-forming readiness can help ensure that quality and system competence are prioritized over unit costs. The maintenance of grid-forming capabilities – especially in the form of software-based upgrade and parameterization pathways – benefits manufacturers with solid expertise in control systems, integration and network coding. This approach can structurally strengthen the competitive position of European and national power manufacturers as long as readiness is defined not as a binary obligation but as a differentiated quality attribute. At the same time, the approach remains technology-neutral and avoids barriers to market entry since neither specific implementations nor proprietary solutions are prescribed. However, it is crucial that grid-forming readiness is not reduced to the fulfillment of items on a formal checklist. Otherwise, there would be a risk of short-term cost optimization again prevailing over long-term system

and integration expertise. Properly implemented, readiness can therefore contribute to strategic autonomy and resilience both systemically and in terms of industrial policy.

The task for policymakers is therefore to enable the creation of a regulatory framework in which such maintenance capabilities can be made visible and assessable and put to use over time.

6.5 German Federal Network Agency (regulatory and supervisory perspectives)

For the Federal Network Agency, grid-forming readiness is primarily a transparency and option category rather than a new system service. A clear distinction from remunerated services and mandatory connection requirements is crucial. Readiness can initially be declared with no immediate cost effects such as those associated with grid fees or market mechanisms. This ensures that freedom from discrimination is preserved and allows for targeted regulation later on.

6.6 VDE|FNN and VDE|DKE (need for technical regulation)

A formal definition of grid-forming readiness requires the standardization of availability and functional classes as well as appropriate test procedures. This is the only way to prevent the term from being used inconsistently or in a marketing-driven manner.

It is crucial that grid-forming readiness is not understood as a new operating requirement but as a description of a technical system attribute. The concept can serve as a structuring element allowing preparations to be made to meet future requirements without preempting existing testing and compliance frameworks. Possible forms of verification range from manufacturer or operator declarations to project-specific technical assessments.

7. Funding Questions and Outlook

The introduction of grid-forming readiness inevitably raises the question of funding. The maintenance of appropriate technical options is not cost-neutral, especially where the design, dimensions and software architecture of battery storage systems are concerned. If grid-forming readiness were to become an element of grid codes or connection regulations in the future, these costs would be incurred by the system operator directly without any immediate benefit.

One alternative would be to initially treat grid-forming readiness not as a mandatory requirement but as a qualifying attribute. Bonus or prioritization criteria during the grid connection process could for example be considered for systems that can demonstrate the maintenance of grid-forming capabilities. This could create incentives without immediately passing on costs.

In the long term, grid-forming readiness opens up the opportunity to develop new, remunerated system services. These specifically include the contractually agreed provision of energy for islanded operation or the provision of grid-forming functions in cases of need. The structure of such models – for example as bilateral agreements between distribution network operators, transmission system operators and system operators – is a separate topic that requires special regulatory and economic analysis.

Grid-forming readiness should therefore be understood as a preparatory element that severs the association between technical feasibility, regulatory development and economic models, thus facilitating an experiential, step-by-step development of the system. Inaction also creates costs.

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