Beyond energy shifting: advancing grid-forming energy storage for power system stability and resilience



As renewable generation reshapes electricity systems and artificial intelligence (AI) data centers drive new patterns of power demand, energy storage is taking on a more active role in power system operation. Sineng Electric's next-generation grid-forming technology is designed to support stable operation under demanding grid conditions, extending the role of battery energy storage from energy management to advanced grid support.

As wind and solar generation increase, the generation mix and operating characteristics of power systems are changing. In systems with a declining contribution from synchronous generators, reduced inertia and lower grid strength make maintaining voltage and frequency stability more challenging.

Battery energy storage systems (BESS) can respond rapidly to changing power system conditions. With grid-forming control, a power conversion system (PCS) can establish and regulate voltage and frequency references, helping maintain stable operation rather than relying solely on an existing grid reference.

This capability expands the potential role of energy storage. Beyond shifting electricity from periods of surplus generation to periods of higher demand, grid-forming storage can support frequency response, voltage regulation and stable operation in weak-grid or islanded conditions.

For developers and system operators, the focus is therefore shifting beyond installed megawatts and megawatt-hours toward the grid services a project can deliver and demonstrate under defined operating conditions.

Europe's evolving grid requirements

Across Europe, increasing renewable penetration is driving greater attention to the stability and controllability of inverter-based resources. Grid-forming technology is becoming an important part of the technical discussion as transmission system operators assess how energy storage and other power-electronic resources can contribute to reliable system operation.

In November 2025, the European Network of Transmission System Operators for Electricity (ENTSO-E) published its Phase II technical report on grid-forming (GFM) requirements. The report provides non-binding technical guidance on the GFM requirements set out in the draft amended Network Code on Requirements for Generators (NC RfG 2.0) and is intended to serve as a basis for a future implementation guidance document.

For energy storage projects, this evolving framework highlights the importance of assessing control capabilities alongside capacity, efficiency and commercial value. Grid connection requirements, system studies and project-specific technical specifications remain essential to determining the capabilities a project needs and how they should be validated.

Next-generation grid-forming technology for demanding grid conditions

The value of grid-forming technology becomes particularly evident when the surrounding power system is weak or subject to significant disturbances. Sineng Electric's



next-generation grid-forming technology is designed to address these challenges through short-term overload capability, voltage disturbance response, phase-angle jump response, dynamic voltage regulation, fast frequency regulation, inertia response, damping control, seamless on-grid/off-grid transition and black-start capability.

Its specified capabilities include stable operation under ultra-weak-grid conditions with a short-circuit ratio (SCR) below 1.1. This capability is relevant to projects where limited grid strength can increase the sensitivity of voltage and system stability to interactions between inverter controls and the surrounding power system.

Active frequency and voltage support are delivered through automatic active- and reactive-power control, respectively, with no overshoot or reverse regulation. An adjustable virtual inertia time constant of 0 to 25 seconds helps limit the rate of change of frequency (RoCoF), while damping control helps suppress low-frequency and broadband oscillations.

During large voltage disturbances ranging from 0 to 130% Un, Sineng's energy storage solutions support a system-level short-term overload capability of up to 3 In for 10 seconds (1.5 In per PCS unit). The solutions also support low-voltage, high-voltage and continuous fault ride-through within the specified voltage range, helping maintain stable operation under extreme voltage conditions.

Black-start capability is another important function in suitably configured energy storage systems. A system designed for black start can establish voltage and frequency without relying on an energized external grid.

Its control strategies address key challenges in islanded operation, including multi-unit parallel circulating currents, magnetizing inrush currents and impact load currents, providing a reliable foundation for system restoration and effectively improving grid resilience.

As computing campuses expand toward hundreds of megawatts and the gigawatt scale, increasing power density and dynamic graphics processing unit (GPU) workloads are placing new demands on power infrastructure. Constrained grid connections and the growing role of onsite generation add further complexity.

The challenge is no longer limited to securing sufficient power capacity. AI data centers also require rapid responses to load fluctuations, coordinated operation of multiple power sources and reliable power delivery to critical computing equipment.

Meeting these requirements calls for a shift from static power delivery toward dynamic power management.

The objective is not simply to store and release electricity, but to make energy storage an active part of how power is controlled, delivered and sustained.





Beyond renewable integration, grid-forming energy storage is also relevant to the evolving power requirements of AI data centers

Sineng's approach combines high-performance power conversion with battery energy storage and intelligent controls to establish a fast, bidirectional power interface between supply resources and AI computing loads. Within a suitably designed system, Sineng's energy storage solutions can provide several key functions:

- Grid-forming support: establishes voltage and frequency references to support stable operation in weak-grid and islanded conditions, with black-start capability to support power restoration after an outage.
- Load smoothing: responds to GPU load fluctuations within milliseconds, helping reduce their impact on the grid and protect computing loads from external power disturbances.
- Coordinated power supply: coordinates energy storage with onsite generation, allowing storage to manage rapid load fluctuations while generators, such as gas turbines, provide steady power.

Together, these capabilities address four key priorities for AI data centers: speed to power, load smoothing, grid stability and resilience.

For AI data centers, grid-forming technology is therefore not simply an extension of conventional energy storage. It offers a way to coordinate power conversion and stored energy within a more dynamic supply architecture, helping reconcile the demands of high-density computing with the operating requirements of the wider electricity system.

Sineng product portfolio for utility-scale energy storage

In utility-scale energy storage, the choice of PCS influences battery integration, equipment layout, operational flexibility and maintenance requirements. The appropriate configuration depends on factors such as plant capacity, battery arrangement, site conditions and grid connection requirements.

Sineng Electric offers solutions such as the 12.5 MW string PCS medium-voltage (MV) turnkey station and the 13.8 MW central PCS MV turnkey station. Both feature a 40-foot containerized design, integrating PCS equipment with a transformer and a ring main unit (RMU) to simplify medium-voltage integration and onsite installation.

The string PCS enables rack-level management, improving battery utilization and helping manage differences in state of charge between clusters and allowing maintenance to be performed at the module level.

The central PCS consolidates power conversion into larger-capacity units, making it well suited to utility-scale projects designed around large power blocks. It can simplify equipment integration and reduce the number of PCS units required, supporting a streamlined system layout.

Together, these solutions provide flexible options for utility-scale energy storage projects with different system configurations and operational needs.

European project experience: supporting grid flexibility

Sineng Electric has secured more than 5 GW of energy storage projects across Europe. Its portfolio includes the Burgas battery energy storage project in Bulgaria, where Sineng has supplied its advanced central PCS MV turnkey stations for the 150 MW/300 MWh energy storage system. With a total capacity of 602 MWh, the project is the largest operational battery energy storage facility in Eastern Europe. This standalone battery energy storage facility is designed to deliver multiple grid services, including peak shaving, load shifting, frequency containment reserves (FCR) and automatic frequency restoration reserves (aFRR).

These services address different operational needs: energy shifting helps balance supply and demand across time, while frequency reserves support the continuous balancing required to maintain system frequency.

Enabling the next generation of power systems

As electricity systems evolve, energy storage is being asked to do more than shift energy across time. It must increasingly contribute to defined grid services, respond to disturbances and support stable operation across a wider range of operating conditions.

Through next-generation grid-forming technology, advanced PCS solutions and project experience across Europe, Sineng Electric is addressing these changing requirements. The same underlying capabilities are also relevant to emerging applications such as AI data centers, where dynamic loads, constrained power availability and resilience requirements demand more coordinated power management.

Whether supporting renewable integration at grid scale or helping manage the power demands of high-density computing, grid-forming technology provides a common foundation for more flexible and responsive energy systems. The objective is not simply to store and release electricity, but to make energy storage an active part of how power is controlled, delivered and sustained.

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