# A solution to long duration and high-density battery energy storage

**Words:** Aiden Wicks, Sales Application Engineer, Ingeteam

The gradual retirement of coal-fired power stations across the Australian electricity network is reshaping the way energy systems are planned, built and operated. For decades, coal provided a predictable and continuous supply of electricity, forming the backbone of baseload generation. As these assets are phased out, the challenge is not simply to replace their capacity, but to replicate their reliability while accommodating a rapidly increasing share of renewable energy.

Solar photovoltaic generation in particular has expanded at an extraordinary pace. Its variability, however, introduces new complexities. Electricity supply now peaks during daylight hours, while demand often rises later in the day. This mismatch has made energy storage an essential component of the modern grid. Battery energy storage systems, commonly referred to as BESS, have emerged as a practical solution to capture surplus generation and discharge it when required.

BESS installations are now expected to perform multiple roles simultaneously. They must support grid stability, provide frequency regulation, enable renewable integration and ensure supply reliability. As their importance grows, so too does the need for systems that can operate safely and efficiently at larger scales and higher energy densities.

## The evolution of battery storage technology

Battery technology has progressed rapidly over the past decade. Improvements in chemistry, packaging and thermal management have led to significant increases in energy density. Where utility-scale battery units once offered capacities of around 4 MWh, newer systems can now reach 6.25 MWh or more. This represents a substantial step forward, enabling developers to deploy more storage within a smaller physical footprint.

These advances are not limited to capacity alone. Manufacturers are also improving lifecycle performance, safety characteristics and operational reliability. Thermal management systems have become more sophisticated, allowing batteries to operate within optimal temperature ranges even in harsh environments. System architectures are evolving to better integrate with grid infrastructure and to support increasingly complex operational requirements.

However, higher energy density introduces new engineering challenges. As more energy is concentrated within a single system, the consequences of faults become more severe. Even though failures are rare, the potential for high fault currents during events such as short circuits requires careful consideration. Protection systems must be designed to isolate faults quickly and prevent damage to critical components.

This shift places greater emphasis on system architecture. It is no longer sufficient to simply scale up existing designs. Instead, engineers must rethink how energy storage systems are structured, how faults are managed and how performance can be maintained without compromising safety.

## Limitations of conventional inverter architectures

Traditional BESS installations often rely on a single DC bus inverter architecture. In this configuration, multiple battery racks are connected in parallel to a shared DC bus, which is then linked to the inverter. While this approach has been widely adopted, it presents several limitations when applied to high-density systems.

As the number of connected battery racks increases, so does the complexity of the protection scheme. Fault detection becomes more challenging, and the ability to isolate individual components is reduced. A fault in one part of the system can propagate across the shared bus, potentially affecting the entire installation.

To mitigate these risks, additional protection measures are required. These can include more sophisticated monitoring systems, faster switching devices and enhanced isolation mechanisms. While effective, such measures increase both the cost and complexity of the system.

There are also performance considerations. In large parallel configurations, accurately measuring the instantaneous capacity of the system becomes more difficult. This can lead operators to adopt conservative operating strategies, limiting the usable capacity in order to maintain safety margins. Over time, this reduces the overall efficiency and economic return of the installation.

These challenges highlight the need for alternative approaches that can support higher energy densities without introducing excessive complexity or risk.

## A modular approach to inverter design

In response to these challenges, companies such as Ingeteam have developed new inverter architectures designed specifically for modern BESS applications. One such approach is based on modularity, where the inverter is divided into multiple independent units rather than relying on a single shared DC bus.

In this design, each module operates as a self-contained conversion unit with its own DC and AC connections. Rather than aggregating all battery racks onto a single bus, the system effectively creates several smaller, isolated subsystems within the larger installation. Each module can independently manage power flow, monitor battery performance and respond to grid conditions.

This architecture offers several advantages. By isolating modules from one another, faults can be contained within a single unit rather than affecting the entire system. This improves overall resilience and reduces the risk of cascading failures. It also simplifies protection schemes, as each module can be designed with its own dedicated safety mechanisms.

Operational flexibility is another benefit. Independent modules can be controlled individually, allowing for more precise management of energy flows. This can improve system efficiency and enable more dynamic responses to changing grid conditions. It also facilitates the integration of different battery technologies, as each module can be paired with a specific type of storage system.

## Improving safety and performance

The modular inverter approach addresses many of the safety concerns associated with high-density BESS installations. Reducing the scale of each individual subsystem limits the magnitude of potential fault currents and simplifies isolation strategies. This makes it easier to design systems that comply with stringent safety standards while maintaining high performance.

From a performance perspective, the ability to monitor and control each module independently allows for a more accurate assessment of system capacity. This can reduce the need for conservative operating margins and enable greater utilisation of the available storage. Over time, this translates into improved efficiency and better economic outcomes for project developers.

The modular design also supports redundancy. If one module requires

maintenance or experiences a fault, the remaining modules can continue to operate. This ensures that the system remains partially functional rather than shutting down. For large-scale installations, this level of resilience is particularly valuable.

### Reducing footprint and infrastructure requirements

Another important consideration for utility-scale projects is physical footprint. Land availability, site layout and infrastructure costs all play a significant role in determining project feasibility. High-density systems can reduce the amount of space required, but only if the associated power conversion equipment is similarly optimised.

Modern inverter designs have achieved significant reductions in size while increasing capacity. For example, systems with power ratings exceeding 9 MVA can now be deployed with a footprint more than 30 per cent smaller than earlier generations. This has direct implications for the balance of plant costs, including civil works, cabling and installation.

A smaller footprint also simplifies site design. Fewer components and shorter cable runs can reduce construction time and improve overall project efficiency. In regions where land is constrained or expensive, these benefits can be decisive.

### Advances in thermal management

Thermal management remains a critical aspect of BESS performance. Batteries and power electronics must operate within specific temperature ranges to maintain efficiency and longevity. In large-scale installations, managing heat effectively can be challenging, particularly in climates characterised by high ambient temperatures.

Liquid cooling has emerged as a preferred solution for many modern systems. Circulating coolant through key components provides more consistent temperature control than air cooling. This helps to maintain stable operating conditions and reduces the risk of thermal degradation.

Centralised cooling systems offer additional advantages. By consolidating cooling circuits into a single unit, they can reduce maintenance requirements and improve system reliability. Higher ingress protection ratings can also be achieved, protecting equipment from dust and moisture. This is particularly important in environments where conditions are harsh or variable.

Lower acoustic emissions are another benefit. As energy storage projects are increasingly located near populated areas, noise reduction has become an important consideration. Quieter systems are more likely to gain community acceptance and meet regulatory requirements.

### Supporting long-term system evolution

Battery systems degrade over time, leading to gradual reductions in storage capacity. To address this, many projects incorporate augmentation strategies, where additional battery capacity is added to the system's lifetime. This allows operators to maintain performance levels and extend the operational life of the installation.

Modular inverter architectures are well-suited to this approach. Additional battery units can be integrated into existing modules or new modules can be added as required. This can often be achieved without significant modifications to the overall system, reducing both cost and downtime.

This flexibility also allows developers to respond to changes in technology and market conditions. As new battery chemistries become available, they can be incorporated into the system without replacing existing infrastructure. This helps to future-proof investments and ensures that projects remain competitive over time.

### A changing landscape for energy storage

The transition to renewable energy is fundamentally altering the structure of electricity systems. As variable generation becomes more dominant, the role of energy storage will continue to expand. BESS installations are no longer supplementary assets. They are becoming central to grid operation and planning.

To meet these demands, technology must continue to evolve. Higher energy densities, improved safety and greater operational flexibility will all be required. Systems must also remain economically viable and adaptable to changing conditions.

Innovations in inverter design, particularly those based on modular architectures, represent an important step forward. By addressing the limitations of traditional approaches, they enable more efficient and resilient energy storage solutions.

### Conclusion

The challenges associated with long-duration and high-density battery energy storage are complex, but not insurmountable. Advances in technology are providing new tools to address these issues, from improved battery chemistries to more sophisticated system architectures.

Modular inverter designs offer a compelling solution. By enhancing safety, improving performance and enabling greater flexibility, they align well with the evolving needs of the energy sector. As the deployment of BESS continues to accelerate, such innovations will play a role in supporting the transition to a more sustainable and reliable electricity system.

In this context, companies like Ingeteam are contributing to the development of solutions that address both current challenges and future requirements. Their work reflects a broader industry effort to rethink how energy storage systems are designed and deployed.

Ultimately, the success of the energy transition will depend on the ability to integrate renewable generation with reliable storage. By continuing to refine and improve these technologies, the industry can ensure that the shift away from traditional baseload generation does not come at the expense of stability or performance.

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**About the author**

Aiden Wicks is a member of Ingeteam Australia's Sales Application Team and has been a trusted technical voice in the Australian renewable energy industry for two years.

He has a wealth of knowledge on the applications of inverter power systems and the future of renewable-lead energy grids including grid forming inverters and long duration battery energy storage applications.