WHITE PAPER

Beyond Peak Shaving:

Grid Services as the Next Frontier for DERs

Abstract

The energy landscape is evolving. Global energy demand is accelerating, driven by data center growth, industrial electrification and the rising adoption of electric vehicles. But while consumption increases at an unprecedented rate, grid capacity is struggling to keep up as it's caught between challenging sustainability goals and real-world bottlenecks: aging infrastructure and permitting delays. All these factors mean that increasingly more Distributed Energy Resources (DERs) are deployed on the grid. And while this is a promising and effective solution, the two – being the grid and DERs – must work together to achieve what everybody wants: access to reliable power. This is why it has never been more important to understand what grid code is and why it is essential for DERs to achieve this. Grid ancillary services – which is what grid code enables – ensure that DERs respond rapidly during critical events such as sudden shifts in the grid, imbalances between supply and demand, or even large-scale blackouts by connecting and supplying power when it's needed most.

This paper will explore the types of ancillary services companies can participate in. It will also provide a summary of recent changes in regulatory compliance and technical requirements that you need to fulfil if you want to enable your DERs to participate in frequency reserve and capacity markets. Lastly, it will also explore how, if done correctly, you can not only future proof your entire power solution in the face of changing regulations and increasing risks to grid stability but also maximize the amount of revenue you can generate for your business.

WHAT ARE GRID ANCILLARY SERVICES?

Before we talk benefits, it's important to understand what grid ancillary services are and how they work. In a nutshell, they are support functions that help maintain the stability, reliability, and efficiency of the electricity grid. They balance supply and demand and ensure secure operation in their local grid.

Key types of grid ancillary services include:

- **Frequency reserve:** helps maintain the grid's frequency within acceptable limits by adjusting real power output in response to short-term fluctuations.
- **Voltage support:** maintains voltage levels within required ranges by supplying/absorbing reactive power.
- **Capacity reserve:** available generation capacity that can respond either immediately or within a short time period to sudden changes in demand.
- **Black start capability:** enables parts of the grid to restart independently after a blackout.

Gas and diesel generator sets and Battery Energy Storage Systems (BESS) are common DERs that can partake in these grid ancillary services. Therefore, businesses and communities, especially if they already have assets on-site, can now unlock the potential to use these assets for more than just power production during grid failure. Now, they can be used to participate in grid ancillary services, which provides additional revenue to them and helps stabilize their local grid – essentially a "win-win" situation for all.

OVERVIEW OF GRID ANCILLARY SERVICES

What are the different types of grid ancillary services and how could they apply to your project?

Frequency Reserve

One example of a grid ancillary service is frequency reserve, where grid users can make their DERs available to help stabilise the grid when needed.

There are three main types of frequency reserve, each with different response times and renumeration structures:

- **Frequency Containment Reserve (FCR):** this is the first line of defense, often called "primary reserve." It kicks in automatically when grid frequency moves outside a set range determined by the grid operator. DERs providing FCR adjust their power output up or down and must respond within 30 seconds to help restore balance.
- **Automatic Frequency Restoration Reserve (aFRR):** if the frequency stays outside the required range for more than 30 seconds, aFRR, known as "secondary reserve," is activated. These DERs are automatically instructed by the grid operator to start and must reach their committed capacity within less than 5 minutes.
- **Manual Frequency Restoration Reserve (mFRR):** if the issue lasts longer than 5 minutes, mFRR, known as "tertiary reserve," can be dispatched manually by the grid operator. Once instructed, these DERs must start, synchronize, and deliver their capacity within less than 12.5 minutes.

These reserves work together like layers of protection, ensuring that even when the grid faces sudden changes or prolonged imbalances, there's a structured way to restore stability to the grid.

Voltage Support

Voltage support ancillary services help keep the electricity grid stable by managing voltage levels and ensuring reliable operation. These services include steady-state voltage control, quick reactive power injection, and short-circuit current support. They are usually arranged through regional tenders or market-based mechanisms, where participants agree to provide reactive

power when needed and are compensated based on the amount delivered. Without these services, voltage fluctuations could lead to equipment damage, power quality issues, or even widespread outages, making them essential for a secure and resilient energy system.

Capacity Reserve

Capacity reserve is a backup resource that helps keep the lights on during times of very high demand or unexpected stress on the grid. It consists of generator sets, BESS, or other flexible loads that are held in reserve and can be activated when needed to maintain stability or relieve local grid congestion. These reserves are becoming more important as renewable energy adoption grows, because they provide a safety net when wind or solar output is low. Without capacity reserves, the grid could face shortages during peak demand or extreme conditions, risking outages and reliability issues, therefore making this service vital for a secure energy system.

Black Start Capability

Black start capability is a service that helps bring the power system back online after a major outage. It relies on generator sets or other resources that can start up on their own and energize part of the grid, creating a small "island" that can gradually reconnect other equipment and loads. This service is arranged through contracts that set expectations for quick start-up, reliability in tough conditions, and coordination with restoration plans. Black start capability is essential for system resilience, ensuring that even in severe outages, the grid can be restarted safely and efficiently, minimizing downtime and economic impact.

IMPORTANCE OF GRID CODES

To enable participation in the grid ancillary services mentioned above and therefore access additional revenue streams, it is essential that the DERs connecting to the grid meet the relevant grid code standards. Grid codes define the required technical capabilities, operation, and performance expectations and therefore guide how DERs are designed, built, and tested, making it easier to deploy them across different regions.

At Caterpillar, our generator sets provide reliability, flexibility, and fulfil the technical requirements necessary for participating in grid ancillary services.

WHAT IS A GRID CODE?

A grid code is a set of requirements defined by the Transmission System Operator (TSO) or Distribution System Operator (DSO) that DERs and power generating facilities must fulfil to gain permission to connect to the electricity grid. Typically, grid codes will define requirements in three main areas:

1. Technical – the requirements defining the functionality and capability that DERs and power generating facilities must provide to support the grid.
2. Operational – requirements defining when a distributed energy resource can be connected/synchronised, and how it must perform during certain conditions such as faults, islanding, and black starts.
3. Procedural – requirements defining the processes relating to grid connection approval, compliance testing and documentation, and other aspects such as simulation modelling.

Many countries have multiple grid codes which are applicable to the different voltage levels within the electrical grid.

In addition to grid codes, several technical standards have been published which define requirements for DERs connecting to the grid. Commonly referenced standards in this area include:

- EN 50549-2:2019+A1:2023; "Requirements for generating plants to be connected in parallel with distribution networks. Connection to a MV distribution network. Generating plants up to and including Type B"
- IEC TS 62786-1:2023; "DERs connection with the grid. Part 1: General requirements"
- IEEE 1547:2018; "IEEE Standard for Interconnection and Interoperability of DERs with Associated Electric Power Systems Interfaces"

Grid codes often refer to national or international standards, but they may also include extra requirements specific to the local TSO or DSO area. Because electricity grids differ in size and how they are connected, there is no universal approach, so it is crucial to identify the exact grid codes or standards that apply to each project. Additionally, proving compliance can vary: some operators need official certification from an accredited provider, while others accept on-site testing or a manufacturer's declaration.

WHAT ARE THE BENEFITS OF GRID CODE COMPLIANT PRODUCT?

Grid code compliance is an entry-level requirement for all applications where DERs or a power generating facility will be connected to the grid for continuous operation to provide grid ancillary services. By purchasing grid code compliant or certified equipment, customers can have:

- Greater confidence that the grid connection will be approved without lengthy delays due to clarifications or expensive compliance testing
- Enable potential future extended use of their assets to provide grid services
- Comply with the required standards for power generation
- Have the benefits of on-site power generation

WHY GAS GENERATOR SETS ARE A SMART CHOICE FOR GRID SUPPORT

Many customers who want to partake in grid ancillary services, and therefore comply with grid code, find that choosing gas generator sets as their DER of choice brings multiple benefits compared to other options. They offer:

Speed: Depending on gas generator set type, the engine can start up in less than 5 minutes, which is essential for responding to rapid demand fluctuations and participating in frequency reserve.

Scalability: You can configure one or multiple gas generator sets to match your load profile, then adjust as demand evolves, while benefitting from high efficiency over a wide range of power outputs and increased reliability.

Quick deployment: Gas generator sets are available in a standardized container design, which facilitates transport, site installation and commissioning, and re-deployment.

CONCLUSION

DERs are no longer just backup or supplementary power sources. Today, they are central to grid stability and flexibility. What makes them exciting is their ability to allow customers – such as businesses and communities – to access and benefit from ancillary services like frequency regulation, voltage support, and reserve capacity. By participating in these grid ancillary services, customers can earn both capacity and energy payments, creating new revenue streams beyond traditional power generation and support their local grid.

Grid codes define the technical, operational, and procedural requirements for connecting distributed energy resources to the grid. Compliance with grid code ensures reliable performance during grid disturbances and is essential to participate in grid ancillary services. Grid code compliance also helps streamline grid connection approvals which enhances customer value and supports long-term strategic planning.

WHERE TO FIND MORE INFORMATION?

In most cases the TSO or DSO will publish the applicable grid code requirements on their website, as well as any relevant information on compliance testing and certification.

Caterpillar offers a range of grid code compliant products, including gas generator sets and energy storage solutions. A key enabler of grid code compliance is the DER controller. The Cat® Energy Control System (ECS 200) provides all the functionality required to be compliant with many of the major grid codes worldwide. For more information visit http://cat.com/utilities.

If you are unsure about where to start, contact your local Cat dealer who can put you in touch with the experts who can advise on which grid code and requirements are applicable.

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