The role of BESS in future power systems

A deep dive on the unique opportunities and challenges of grid inverters and their role in battery energy storage systems

PSC
Specialist Consultants to the Electricity Industry
pscconsulting.com

About the authors

Djino Pirsic
Principal Engineer
Power Network Solutions
PSC Asia Pacific

Hesam Marzooghi
Senior Manager
Power System Studies
PSC Asia Pacific

Amir Mehrtash
Senior Manager
Power System Studies
PSC Asia Pacific

Mohammad Seidaliseifabad
Principal Engineer
Power System Studies
PSC Asia Pacific

Table of contents

Introduction

The make-up and operation of power systems (whether at a grid-level or for smaller islanded systems) are becoming more complex with the increasing penetration of diverse intermittent renewable energy sources.

As the amount of available wind and sunlight can vary, these resources are inherently intermittent, which can make continuous power generation from these sources unreliable. To cover the variability in generation output, a source of energy must be available to offset the imbalance and provide power during low outputs and absorb power during high outputs of such intermittent renewable energy sources.

This trend is leading to significant changes in how electricity is generated and how networks must be managed. In the last ten years, Battery Energy Storage Systems (BESS) have proven to be a technology enabler, allowing greater penetration of intermittent renewable inverter-based resources (IBR) into power systems including islanded grids or micro-grids.

Apart from the inherent intermittency of IBR renewable energy, studies and network operation experience show that the increasing integration of IBRs has been displacing system strength and inertia in the power systems, historically provided by rotating synchronous machines. More advanced BESS utilising grid-forming technology are expected to assist future power systems by providing system strength and virtual inertia.

The ABC of BESS

Here's a comprehensive list of acronyms used throughout this document.

AGL
Australian Gas & Light

ARENA
Australia Renewable Energy Agency

BESS
Battery Energy Storage System

FRV
Fotowatio Renewable Ventures

GaN
Gallium Nitride

GFM
Grid-forming

GFL
Grid-following

IBR
Inverter-based Resources

KESS
Koorangie Energy Storage System

LIB
Lithium-Ion Batteries

LPF
Low-pass Filters

PFR
Primary Frequency Response

PLL
Phase Locked Loop

PSC
Power Synchronisation control

PV
Photo Voltaic

REZ
Renewable Energy Zone

RoCoF
Definition Rate of Change of Frequency

SG
Synchronous Generator

SiC
Silicon Carbine

VSG
Virtual Synchronous

VSM
Virtual Synchronous Machines

WBG
Wide Band Gap

Inverter power electronics developments

In recent years, the continuing market demand across many sectors has driven developments in inverter equipment – particularly power electronics capability and modularisation. Heavy investment and R&D in battery technology have resulted in the faster and significantly more economical deployment of BESS installations. Reports about emerging and superior battery chemistries and capabilities (such as Lithium-sulphur, Lithium-air, Sodium-Ion, molten metal and solid-state batteries) are becoming more frequent. However, equally significant developments have been occurring with inverter power electronics, energy management systems, battery management systems, and how such systems are integrated, housed and installed.

Recent commercial developments of high-power Wide Band Gap (WBG) devices allow the solid-state power switches (the inverter's main semiconductor switching elements) to operate at higher voltages, temperatures and frequencies. Silicon carbide (SiC) and gallium nitride (GaN) power semiconductor substrates (both WBG technologies) have been in commercial development for about ten years and are now being commercialised in next-generation PV and energy storage inverter power modules as well as in electric vehicle applications. WBG technology inverters have benefits such as reduced size and weight of components, ability to operate at higher voltages and temperatures, and achieving > 98% efficiencies, which are 50% better than previous generation inverters and 20% better than the latest silicon semiconductor technology. Figure 1 shows the position of WBG devices in relation to traditional silicon semiconductors in terms of output power and switching frequency.

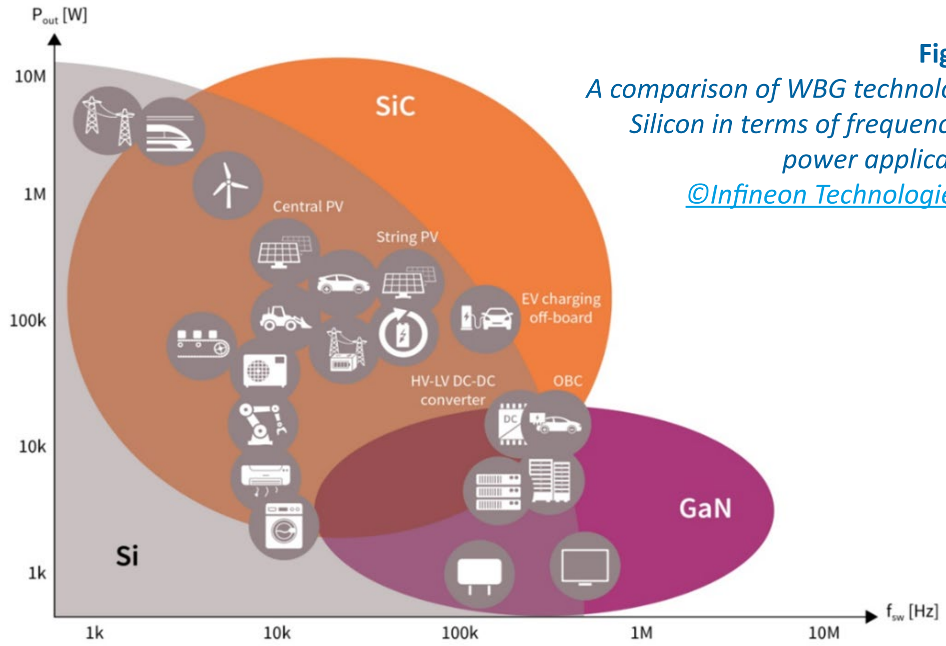


Figure 1
A comparison of WBG technology to Silicon in terms of frequency and power applications. ©Infineon Technologies AG.

Further development of WBG devices is expected to result in higher performance inverters for PV and BESS applications. The advancement for BESS, however, isn't only limited to better power switches. With massive R&D efforts in battery technology and chemistries, their capabilities have improved significantly in the past decade.

Battery developments

Lithium-Ion Batteries (LIB) have seen rapidly increasing development and commercial take-up for both mobile and stationary battery applications. LIB chemistries are quite diverse due to the outcomes of many research and development paths driven by unprecedented demand. Figure 2 compares the most common commercial battery chemistries used for large-scale energy storage in terms of cost, efficiency, thermal stability, maturity and ratings.

There are some viable alternatives to LIBs for energy storage using various technologies. Some capable and well-understood technologies – such as pumped hydro and flywheels – have been commercialised for decades. Still, in comparison, some emerging technologies haven't been widely adopted at this time for large-scale storage and conversion back to electrical power, such as hydrogen gas and sodium-ion batteries. Figure 3 shows the relative capabilities of viable storage methods.

Figure 2
Battery cell performance comparison chart for common batteries used for large-scale energy storage [1].

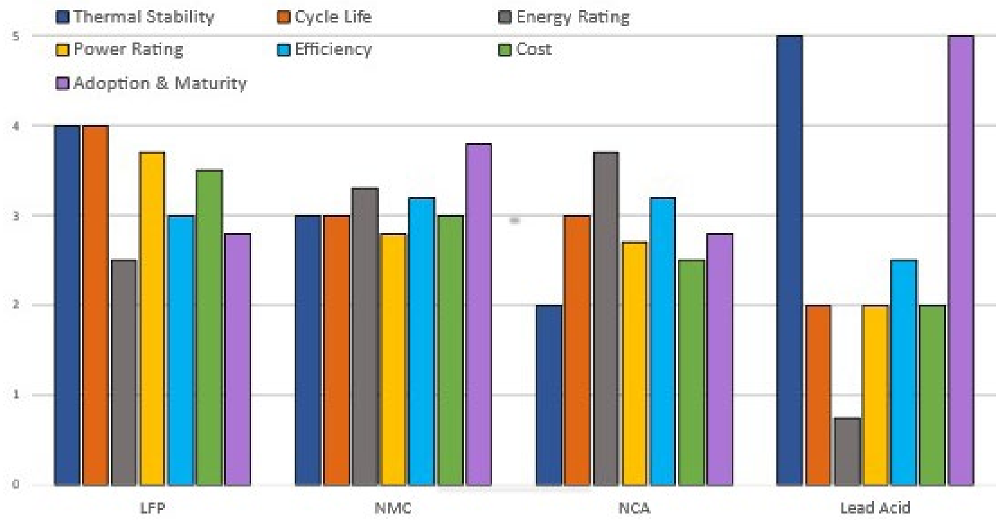
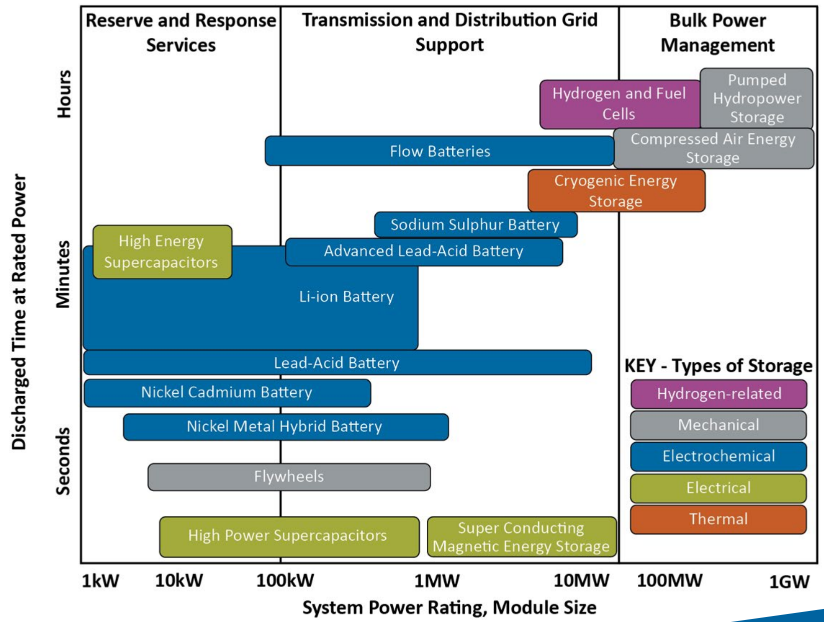


Figure 3
Some viable alternatives for energy storage using various technologies [2, 3].



Grid–following inverters

Most inverters currently installed for IBR renewable generation are of the grid-following type (although grid-forming inverters may become more common – refer to next section). They' are commonly referred to as current source inverters, which require, by design, other generators in the network (usually synchronous generators) to provide a frequency reference and to regulate the network voltage, as shown in Figure 4. The grid-following inverters will synchronise to and "follow" the grid. They essentially feed power into the network (by controlling current) and can support network voltage and power factor to an extent, but they don't regulate the network, and they may shut down if the network voltage or frequency is outside of the inverter's limits.

Grid-following inverters typically act as a current source on the network and inject real (P) and reactive (Q) power into the network within the inverters' power and stability limits. Grid-following inverters historically used current source DC supplies, where input current is relatively constant (this isn't a strict rule as some modern inverters can act as voltage or current sources with the same hardware). They're rather slow to respond in adjusting their output power, which can be detrimental to network stability. They can be tuned to act faster – however, this can hinder network stability in weak grids.

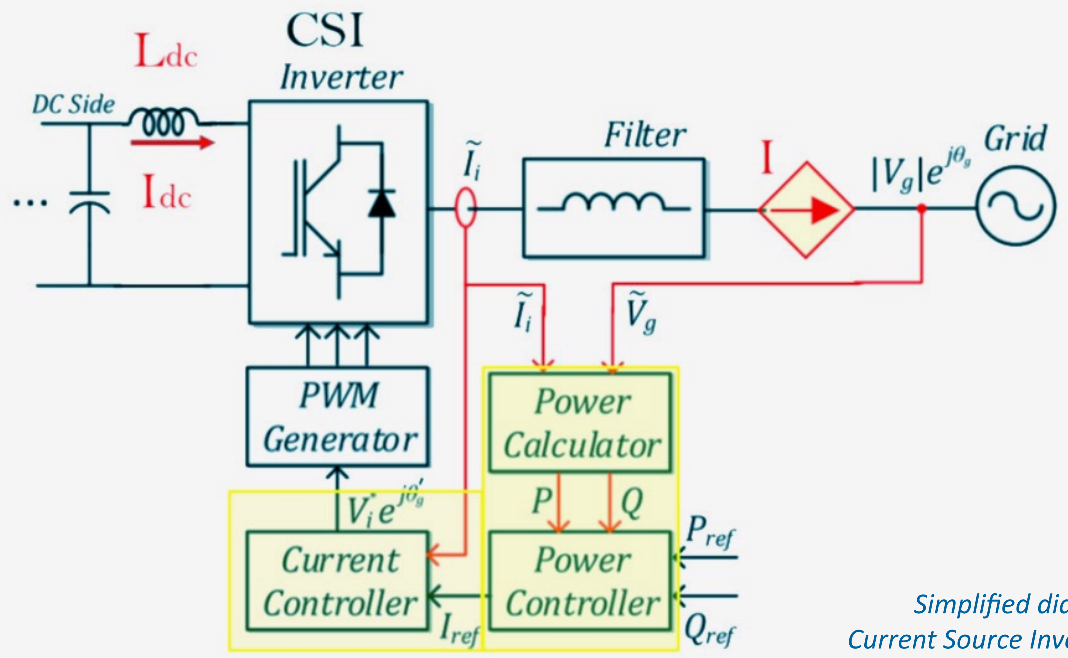


Figure 4 [4]
Simplified diagram of a Current Source Inverter (CSI).

Grid-following inverters can't operate effectively or start without the network voltage and frequency being within normal limits. Their output voltage can vary depending on the load impedance they're connected to, and they can't perform a black start of a network.

From a stability point of view, too many grid-following inverters in any network may lead to lower-than-acceptable network strength, increasing the likelihood of stability problems during network disturbances, which as a result may prevent the addition of more wind and solar farms to the affected parts of the network.

Historically, relatively expensive measures such as installing synchronous condensers (synchronous rotating machines or syncons) have compensated for this problem.

Could grid-forming inverters solve the inertia issue?

Grid-forming inverters (commonly referred to as voltage source inverters) are a class of inverters that can provide their own frequency reference and regulate their output voltage, and even the network voltage if they're sufficiently large, as illustrated in Figure 5.

Grid-forming inverters can provide a source of system strength (with virtual inertia) to stabilize network voltage and frequency, essentially providing the "electronic" equivalent of rotating machine inertia. They can respond almost instantaneously to network disturbance, adjusting their power output without external control to provide a stabilising function to the network by delivering damping and fault ride-through capability.

Grid-forming inverters act like a voltage source on the network. They have internal references for output voltage and frequency, and they output power to maintain a network voltage and frequency (within the inverters' power and stability limits). This is essentially equivalent to grid-connected rotating synchronous generators. Voltage source inverters' control characteristics allow direct control of voltage and frequency. During network contingencies, the inverter will immediately increase or decrease its output power to maintain its terminal voltage and frequency. This is a similar characteristic to grid-connected rotating synchronous generators. Grid-forming inverters have the advantage of rapid response and the ability to perform a black start of a network as long as the load on the network doesn't exceed the inverter's overload capacity.

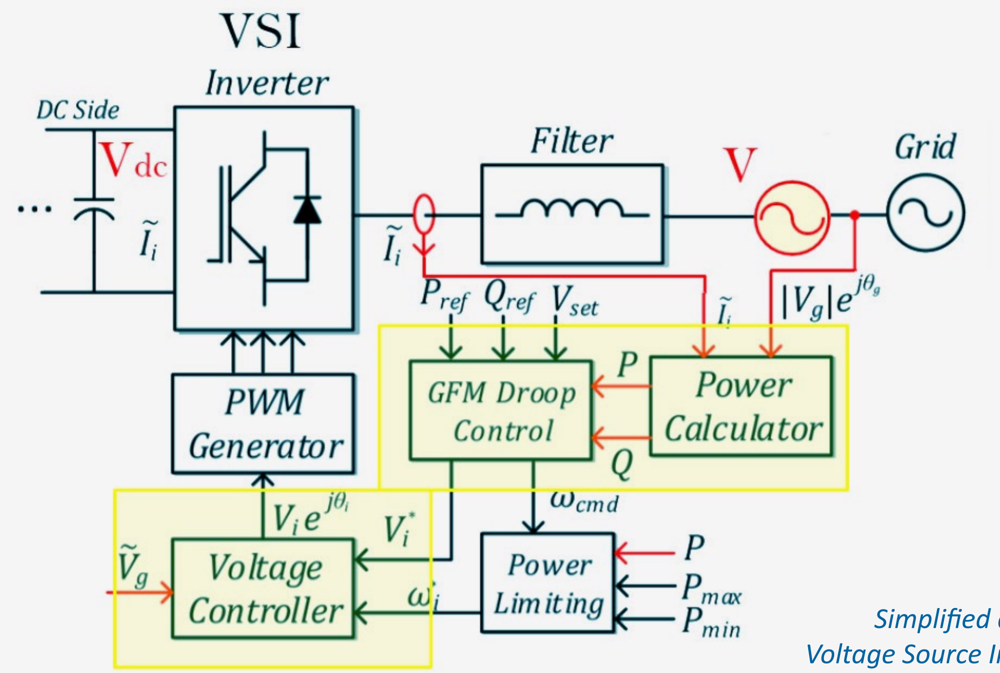


Figure 5 [4]
Simplified diagram of a Voltage Source Inverter (VSI).

Network operators and regulators now understand the useful capabilities of advanced grid-forming inverters. Incorporating the appropriate quantity of grid-following inverters into strategic parts of networks is a top priority to allow greater penetration of IBR and effectively compensate for the diminishing capacity of rotating synchronous generators in future power systems.

Various types of grid-forming inverters are commercialised. Some provide Virtual Synchronous Generator (VSG) capability, which has proven ability for grid stabilisation and has been demonstrated as a complementary and effective alternative to synchronous generators.

Grid-forming BESS: opportunities and challenges

With higher penetration of IBR renewable generation, balancing in power systems isn't the only concern. With higher penetration of IBR renewables and progressive decommissioning of fossil-fuelled Synchronous Generators (SGs), power system dynamics will change in unconventional ways. This is mainly because IBR generation is connected to the grid via power electronics interfaces with different characteristics and limitations than SGs.

Many studies and the experience of network operators are showing that the increasing integration of IBRs is displacing system strength and inertia in the power systems that SGs have historically provided. It's expected that increasing the number of BESS applications using grid-forming (GFM) technology inverters to address system strength and inertia shortcomings developing in power systems will enable higher penetration of IBR renewable generation and less dependence on fossil-fuelled SGs.

Grid-following vs. grid-forming inverters

Presently, IBR renewable generation based on GFL control methodology may not be sufficient to ensure grid stability in future power systems with low system strength. GFM inverter control technology has been considered as a potential solution in recent years. This is mainly due to the features only provided by GFM, compared to GFL, which doesn't offer the same characteristics (or provide them in a limited manner), as summarised in Table 1.

Table 1 [5]

Features of grid-following vs. grid-forming inverters

Inverter Attribute	Grid-Following Control	Grid-Forming Control
Reliance on grid voltage	Relies on well-defined grid voltage, which is assumed to be tightly regulated by other generators, including GFM inverters and synchronous machines.	No reliance on external grid voltage or other generators. Actively maintains internal voltage magnitude and frequency.
Dynamic behaviour	Controls current injected into the grid. Appears to the grid as a constant current source in the transient time frame.	Sets voltage magnitude and frequency/phase. Appears to the grid as a constant voltage source in the transient time frame.
Ability to assist grid stability, a Synthetic Inertia response	Generally not possible, and where implemented, the response speed is limited.	Some GFMs act as a Virtual Synchronous Generator to provide instantaneous synthetic inertial response, adjusting its output power to maintain the local voltage and frequency, equivalent to the response of an SG, at the earliest sign of network frequency disturbance.
Reliance on PLL for synchronisation	Needs PLL or an equivalent fast control for synchronisation.	Doesn't need PLL for tight synchronisation of current controls, but may use a PLL or other mechanism to synchronise overall plant response with the grid.
Ability to provide black start and initiate system restoration	Generally not possible.	Can self-start in the absence of network voltage, thereby supporting network restoration functions. When designed with a sufficient energy buffer and over-current capability, it can also re-start the power system under blackout conditions. Only a few generators on a system need to be black start-capable.
Ability to operate in low grid strength conditions and contribute to system strength	Stable operation range can be enhanced with advanced controls, but is still limited to a minimum level of system strength.	Stable operation range can be achieved without a minimum system strength requirement or at low short circuit ratios (SCR), including operation in an electrically islanded network. However, GFM IBRs won't help to resolve steady-state voltage stability for long-distance high-power transfer.
Field deployment and standards	Has been widely used commercially. Existing standards and standards under development define its behaviour and required functionalities.	Has been deployed in battery storage systems primarily for isolated applications. Limited experience exists in interconnected power systems. Existing standards are yet to define its behaviour and required functionalities well.

Pilot grid-forming projects

The study, "Grid-forming converters. A critical review of pilot projects and demonstrators" [6] summarises some of the major GFM pilot projects in the world. GFM inverters will be increasingly important in network stability and IBR renewable expansion to support decarbonisation in future power systems.

Apart from the mentioned pilot projects [6], which are built and operational, many others are planned for future power systems, particularly in Australia. Those projects have either been approved, are in the pipeline, or are in construction, providing virtual inertia or grid-strengthening services.

Here are some examples:

- A 50 MW / 100 MWh GFM BESS in Broken Hill, New South Wales.
- A 250 MW/250 MWh GFM BESS in Torrens Island, South Australia.
- A 125MW GFM BESS to be built in the Murray Renewable Energy Zone (REZ), Victoria.
- Koorangie Energy Storage System (KESS) in Victoria to increase the renewable hosting capacity of the Murray River REZ by up to 300MW through the provision of system strength to improve network stability.

Australian Renewable Energy Agency (ARENA) backs eight big BESS to bolster the grid. Eight of the largest batteries ever built in Australia will boost grid-forming storage capacity tenfold. They are as follows:

- ***AGL:*** a new 250 MW / 500 MWh battery in Liddell, NSW.
- ***FRV:*** a new 250 MW / 550 MWh battery in Gnarwarre, VIC.
- ***Neoen:*** retrofitting the 300 MW / 450 MWh Victorian Big Battery in Moorabool, VIC, to enable grid- forming capability.
- ***Neoen:*** a new 200 MW / 400 MWh battery in the Western Downs, QLD.
- ***Neoen:*** a new 200 MW / 400 MWh battery in Blyth, SA.
- ***Origin:*** a new 300 MW / 900 MWh battery in Mortlake, VIC.
- ***Risen:*** a new 200 MW / 400 MWh battery in Bungama, SA.
- ***TagEnergy:*** a new 300 MW / 600 MWh battery in Mount Fox QLD.

Grid-forming inverter types

There are various types of GFM inverters proposed in the literature[7, 8, 9, 10, 11], summarised in Figure 6. Virtual Synchronous machines (VSM) and droop-based technologies are the main GFM commercialised and used in modern power systems. Apart from those shown in Figure 1, other GFM control approaches are being developed, such as power synchronisation control (PSC) and synchronverter[6]. The high-level control mechanism behind these GFM inverters is summarised below:

Droop control

"It is the simplest GFM implementation, where the internal frequency is determined by multiplying the difference between the active power reference and the measured active power by a gain, and then obtaining the converter angle integrating the synthesised frequency signal". [6]

Power synchronisation control

"It is a GFM method similar to droop controls, where the converter angle variation is determined by integrating the difference between the reference and the measured active power multiplied by a gain, and then the converter angle is obtained by adding the integral of a reference frequency to the angle variation determined by the power-angle control". [6]

Synchronverter and VSM

"They are GFM schemes which realise the GFM capabilities by a direct emulation of the characteristics of SGs, simply replicating the intrinsic behaviour defined by the swing equation or implementing more complex control schemes to include the replication of the machine electrical dynamics". [6]

Matching control

"In the GFM, the converter pulse-width-modulation signal is controlled to achieve exact matching between the converter in closed-loop and the SG dynamics, while direct power control technique is based on p-q theory and instantaneous power errors of active and reactive power components are kept within a fixed hysteresis band to provide reference values of powers". [6]

It's worth mentioning that there's a lack of synthetic inertia with the droop control GFM, which can lead to a significant frequency deviation and a high rate of change of frequency (RoCoF) when operating with existing SGs. To address this issue, the concept of VSM was proposed by introducing an inertia-emulating term into the basic droop control, as discussed in the study Transient Stability of Voltage-Source Converters with Grid-Forming Control: A Design-Oriented Study[13].

While each of the GFM control mechanisms in Figure 6 has their own advantages (especially when compared to GFL inverters), they're prone to small-signal and transient stability phenomena, which can impact future power systems' stable and secure operation[13]. These challenges are briefly summarised in the next section and necessitate careful GFM technology selection and tuning for different applications.

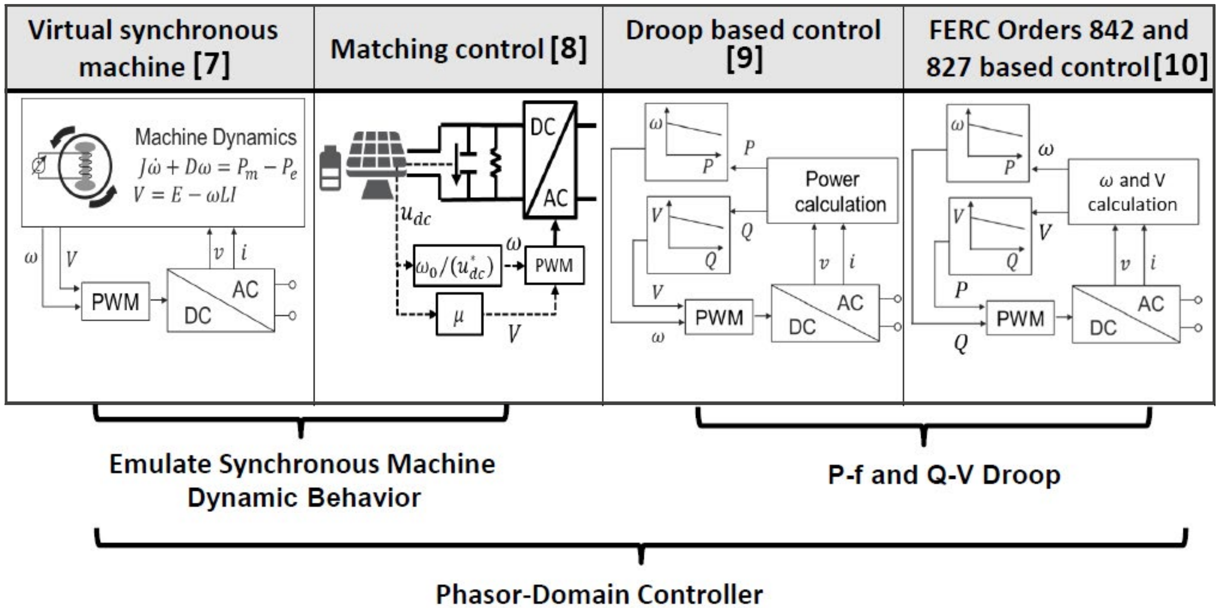


Figure 6 [12]

Several GFM inverter controls from the literature, adapted from [12] (c) 2021 EPRI, used with permission.

Grid-forming inverter limitations and challenges

While benefiting from the SG-like features, GFM inverters are prone to suffer from stability problems during grid disturbances. Consequently, substantial research efforts have been devoted to this issue, focusing mainly on small-signal and transient stability, as discussed [13].

The PSC and the basic droop control GFM can retain a stable operation as long as there are equilibrium points (stable operating conditions) due to their non-inertial transient responses [13].

Conversely, the droop control with low-pass filters (LPFs) and the VSM control GFM can be destabilised even if the equilibrium points exist, due to the lack of damping on their inertial transient responses [13]. This is because the inertial GFM control schemes, i.e., the droop control with LPFs and the VSM control, are a second-order system, hence have dramatically different transient behaviours compared with the non-inertial ones. The overshoot in the response of such control approaches (i.e., second-order system) is shown in Figure 7-(b), where this can be reduced by tuning parameters. There's a further conflict between the frequency and transient stability of the virtual inertia for VSM control GFM technologies [13]. This necessitates careful tuning inertia and damping to ensure both frequency and transient stability criteria can be provided with VSM control GFM inverters.

The last point to note here is that these discussions are based on assuming GFMs don't hit their current limits (maximum safe inverter output current) during stability phenomena. If the maximum current limit of the inverter is reached, the performance of GFM can further deteriorate. Researchers are enhancing the control mechanisms to address the shortcomings [13].

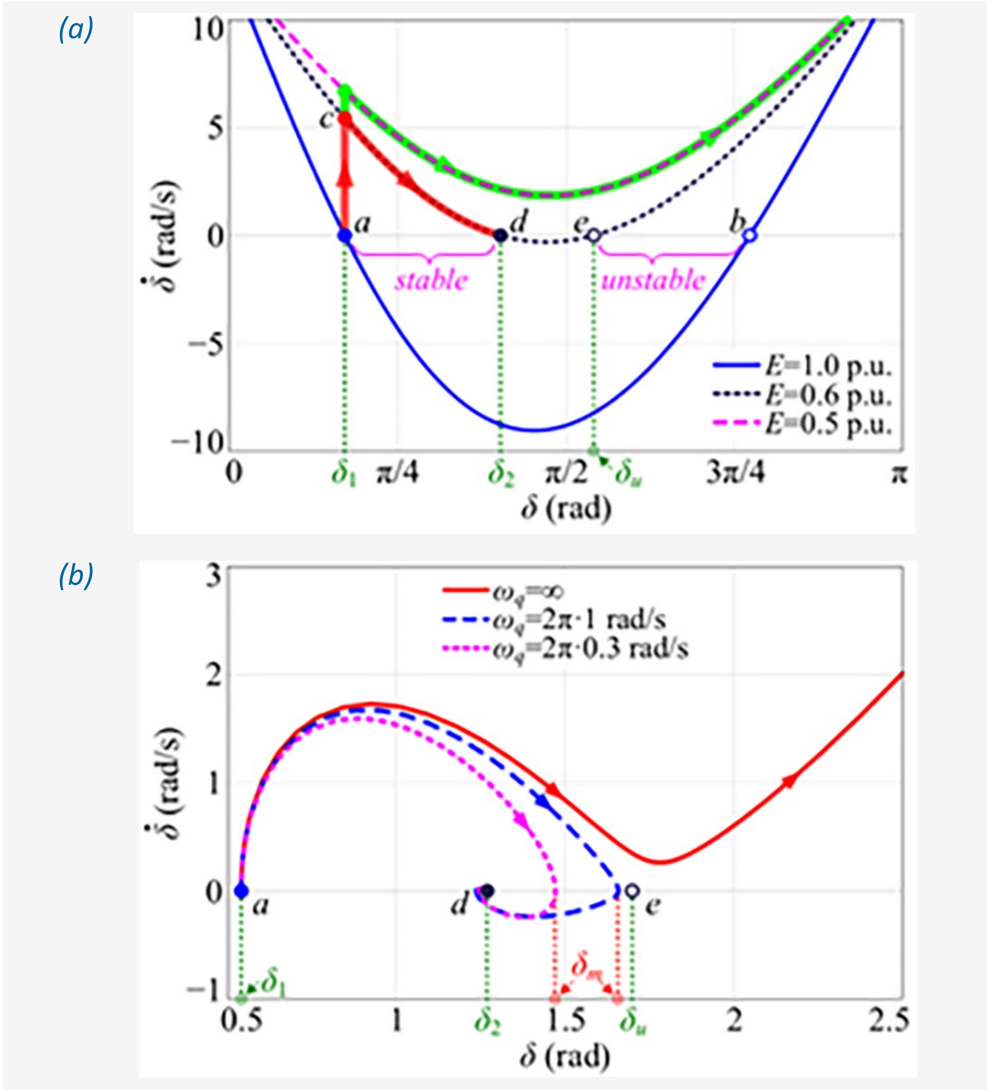


Figure 7 [13]

Transient stability of (a) non-Inertial grid-forming control (e.g. PSC and basic droop control), and (b) Inertial grid-forming control- An LPF in both active and reactive loop [13].

Additional services an advanced BESS can provide

Many network operators globally are experiencing ever greater penetration of IBRs as energy generation transitions to sustainable energy sources. As the reliance on conventional SG declines, this leads to significant transformations and developments in generating technology and where it is located. The vast majority of IBR is presently connected through GFL inverters, but this will also need to change to overcome new challenges in maintaining network stability and security, which we have come to expect.

The historical reliance on carbon-fueled SGs for network stability will need to be replaced by a similar dependence on advanced GFM inverter BESS installations which will continue to improve in their capabilities, cost and constructability.

At PSC, our engineers support clients from all parts of the energy sector to enable them to execute their energy decarbonisation strategies, maintain network security and assist with the compliance and connection process for advanced IBRs.

The following pages identify the main services where BESS technology provides benefits for energy generators and network operators. Developers of BESS projects don't rely on just one capability as that may limit the optimum utilisation of the batteries and inverter hardware and may not be economically viable. Developers commonly maximise value by appropriately selecting and sizing BESS and inverter technology and value-stacking multiple services that the BESS and inverters can provide to the network.

Arbitrage

Definition

Purchasing low-cost off-peak energy and selling it during periods of high prices.

Applications

- Reducing renewable energy curtailment (which often occurs when there is an excess of renewable energy generation capacity that can't be consumed or stored).
- Load-leveling (storing energy during low demand and delivering it during high demand).

Firm capacity (or peaking capacity)

Definition

Provide reliable capacity to meet peak system demand.

Applications

- To reliably meet demand during the highest-demand periods in a given year or the peak demand. Peaking generation capacity.
- Pairing renewable IBR resources with BESS to coincide with peak demand.
- GFM inverter BESS has been successfully used to replace hydrocarbon-fuelled gas turbines and diesel power generators employed for spinning reserve or peaking capacity.
- BESS can provide fault ride-ride through capability in hybrid generation systems where there is the likelihood of spinning machine failure or delay in machine re-start time.

Operating reserves and ancillary services

Including

- Primary frequency response.
- Synthetic inertia or virtual synchronous generator response.
- Voltage and power factor regulation.
- Contingency spinning reserve.
- Replacement/supplemental.
- Ramping/load following.

Applications

- To ensure grid stability and reliability.
- BESS can rapidly charge or discharge in a fraction of a second, faster than conventional thermal plants.
- Short-term reliability services such as Primary Frequency Response (PFR) and Regulation.
- Longer-duration services, such as load-following and ramping services to ensure supply meets demand.

Transmission and distribution upgrade deferrals

Definition

Reduce peak loading on transmission and distribution systems.

Applications

- Deferral of expensive distribution infrastructure upgrade costs such as those that occur with transformers and conductors (even extending to generator augmentation).
- Better utilisation of transmission and distribution infrastructure which must be sized to meet peak demand which may only occur over a few hours of the year.
- Mobile BESS installations can be relocated to new areas when no longer needed in the original location.

Black start

Definition

Generation brought online to start a system after a system-wide failure (blackout).

Applications

- Appropriate generators must be started through an on-site source of electricity, such as a diesel generator.
- Not all forms of generation are suitable for black start application. GFM inverter BESS are capable of supporting black start services.
- An on-site BESS can also provide this service, avoiding fuel costs and emissions from conventional black-start generators.

Conclusion

Battery energy storage systems (BESS) are essential in today's energy mix. They enable energy to be stored and then released to provide various services to the grid, such as backup power, peak shaving, frequency regulation, voltage support and grid stabilisation.

Grid inverters play a crucial role in BESS because they enable the bidirectional flow of electricity between the batteries and the grid. The difference between grid forming and grid following inverters is mainly in how they synchronise with the existing grid frequency and voltage. More advanced BESS utilising grid-forming technology will assist future power systems by providing system strength and virtual inertia.

While BESS does have some advantages, such as its ability to enhance power system flexibility and enable high levels of renewable energy integration, they have some drawbacks when compared to other storage solutions, including high initial cost, limited energy capacity and duration, and a finite lifetime and degradation.

To choose the right BESS, it is important to consider cost, efficiency, and reliability to maximise value by selecting and sizing technology to take advantage of multiple services.

Need help?

PSC engineers have a thorough understanding of the available BESS technologies to advise on such matters as the pros and cons of competing inverter technologies and various battery chemistries, as well as being able to quantify the effects of varying levels of BESS integration capability offered by vendors on the cost of balance of plant and the overall round-trip efficiency of BESS installations. Please contact us to learn more about how our services can help with your BESS-related projects.

CONTACT US

Sources

1. PSC internal – Battery Technology – Overview of rechargeable batteries for grid-scale applications.

   Lithium-Ion Battery Chemistries by John T. Warner, Elsevier Publications, 2019, ISBN: 978-0-12-814778-8.

   Battery University, Types of Lithium-ion Batteries.

   Batteries for Electric Cars – Challenges, Opportunities and the Outlook for 2020. The Boston Consulting Group, January 1, 2010.

2. DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA, SANDIA REPORT SAND2013-5131 Unlimited Release July 2013. Abbas A. Akhil, Georgianne Huff, Aileen B. Currier, Benjamin C. Kaun, Dan M. Rastler, Stella Bingqing Chen, Andrew L. Cotter, Dale T. Bradshaw, and William D. Gauntlett. Sandia National Laboratories Albuquerque, New Mexico.

3. "Energy Systems and Storage Lab," Centre for Renewable Energy Systems Technology (CREST) Loughborough University, 2017.

4. IEEE Lasseter et al, "Grid-Forming Inverters: A Critical Asset for the Power Grid," IEEE, 2020.

5. H. S. o. I.-B. G. T. F. 2022., "Grid-Forming Technology in Energy Systems Integration," Reston, VA: Energy Systems Integration Group, EGIS, 2022.

6. R. Musca, A. Vasile and G. Zizzo, "Grid-forming converters. A critical review of pilot projects and demonstrators," Renewable and Sustainable Energy Reviews, vol. 165, 2022.

7. J. Liu, Y. Miura, H. Bevrani and T. Ise, "Enhanced Virtual Synchronous Generator Control for Parallel Inverters in Microgrids," EEE Transactions on Smart Grid, vol. 8, no. 5, pp. 2268-2277, 2017.

8. Arghir and F. Dörfler, "The Electronic Realization of Synchronous Machines: Model Matching, Angle Tracking, and Energy Shaping Techniques," IEEE Transactions on Power Electronics, vol. 35, no. 5, pp. 4398-4410, 2020.

9. J. Liu, Y. Miura and T. Ise, "Comparison of Dynamic Characteristics Between Virtual Synchronous Generator and Droop Control in Inverter-Based," IEEE Transactions on Power Electronics, vol. 31, no. 5, pp. 3600-3611, 2016.

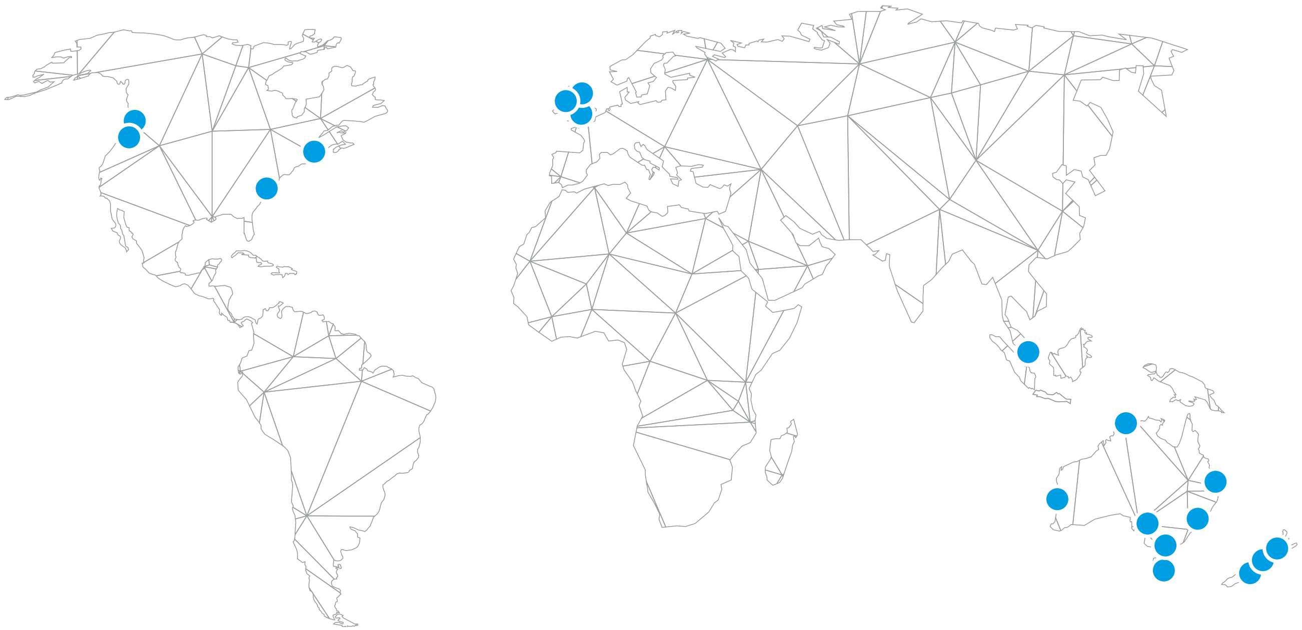
10. D. Ramasubramanian, W. Baker and E. Farantatos, "Operation of an All Inverter Bulk Power System with Conventional Grid Following Controls," CIGRE Science & Engineering, vol. 18, pp. 62-76, 2020.

11. G. Seo, M. Colombino, I. Subotic, B. Johnson, D. Groß and F. Dörfler, "Dispatchable Virtual Oscillator Control for Decentralized Inverter-dominated Power Systems: Analysis and Experiments," in IEEE Applied Power Electronics Conference and Exposition (APEC), Anaheim, CA, USA, 2019.

12. EPRI, "Grid Forming Inverters: EPRI Tutorial. EPRI," Palo Alto, CA: 2021. 3002021722, 2021.

13. D. Pan, X. Wang, F. Liu and R. Shi, "Transient Stability of Voltage-Source Converters with Grid-Forming Control: A Design-Oriented Study," IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 8, no. 2, pp. 1019 – 1033, 2020.

18 locations for a worldwide presence



At PSC, we're helping power a more sustainable world. Our global team of electricity experts has been tackling the thorniest problems for some of the most prominent industry players for over 25 years. By empowering people to make a difference and do the right thing, we help our clients and employees innovate and thrive in a rapidly changing industry.

pscconsulting.com

Specialist Consultants to the Electricity Industry

pscconsulting.com

New Zealand
Wellington
+64 4 232 7680

Australia
Fortitude Valley, QLD
+61 1300 933 632

North America
Kirkland, WA
+1 425 822 8489

Europe
Newcastle, UK
+44 7967 228 064

Asia
Singapore
+65 (800) 616 3283