White Paper

The Power of 10

Powering 10MW - 100MW Microgrids and beyond

EXECUTIVE SUMMARY

Power Solutions Division solutions enable MPCs, Engineering, Procurement, Constructors, Investors and Consultants to build fast and cost effectively by simplifying the process for Microgrid development.

Using modular, standard components at scale the Power Solutions Division provides infrastructure to enable professional stakeholders to move forward immediately with realisable, resilient Microgrid technology.

Through decades of experience in design, build, deployment and operation of 10MW gensets Power Solutions Division's Bergen Engines power generation credentials have been established in the field, where clients recognise its build quality, service prowess, and continuous operation.

Bergen 10MW+ Gensets, deployed as modular building blocks are the true grid replacement option for the rapid construction of large scale Microgrids.

Gensets perform equally well for continuous load provision as primary baseload power and coupling and decoupling from the grid. The Power of 10 includes Marelli Motori 10MW alternators and Piller Integrated Power Conditioning Technology.

No other organisation can supply best of breed genset, stabilisation, grid choke, integrated power conditioning technology, alternator and energy storage systems from industry leading manufacturers within the same stable that meet multiple configuration and deployment options for hybrid Microgrids. The combined and integrated solution set are only available from Power Solutions Division.

1. WHY MICROGRID?

The forces driving Microgrid evaluation and adoption go far beyond the existential requirement not to exceed 1.5° C global temperature rise by 2050.

Also in play are the needs to maintain energy security as the energy sector transitions to net zero through the complete re-imaging of supply and transmission which is fundamentally changing how industry, communities and countries source and use electricity.

The transition of the world's energy profile is a combination of mass electrification, a rapid move to dominance by renewables and a shift in the way we consume energy so that waste can be minimised.

By 2050, the 40,000 TWh of electricity used by the planet will need 90% generated from renewable sources including wind, solar and biomass, and nuclear with fossil fuel generation accounting for less than 10%.

For all players across every part of the global energy sector the transition to net zero cannot be met using aging national grid infrastructure.

Every energy intensive industry sector is evaluating its Microgrid options. These includes data centres, manufacturers, transport and process and energy itself.

Private wire alternatives to large scale national grids are being considered both in territories with established grids and mature relationships between generators and DSOs (Distribution Systems Operators) and TSOs (Transmission Systems Operators) and developing economies where grid building based on Microgrids is being established to reach remote, rural and other communities.

WHAT PART WILL MICROGRIDS PLAY?

Microgrids are independent self-accommodated power systems that generate and distribute stored energy across geographic constrained areas.

Put simply Microgrids accelerate the journey to the following key objectives:

Democratisation and Digitalisation of energy
Democratise: Through advanced technology Microgrids play a key role in global innovation by solving the problem of unreliable energy supply. Microgrids effectively diversify the centralized energy grid and create local economic opportunities.

Digitizing the metering and monitoring of power at a Microgrid level deployment uses data from on-site generation combined with real-time energy prices to minimize energy costs.

Energy Transition
Energy Transition: As fossil fuel use becomes obsolete governments and industries are accelerating moves to adopt renewable energy sources such as solar, wind and tidal in response to climate change. Microgrids contribute to renewable energy adoption as their key characteristics are flexibility, resilience, cost effectiveness and stable electrical systems.

Path to Net Zero
Path to Net Zero: Microgrids can function on a combination of renewable and fossil fuels use with a roadmap to phasing out of high carbon emitting power sources to low and no carbon alternatives. Such hybrid electrical solutions consist of renewable energy resources, battery storage and on-site generation.

Energy Independence
Energy Independence: This is a defining characteristic of a Microgrid as its ability to operate independently away from a large utility grid.

Energy Security
Energy Security: Specialised planning and design of the Microgrid energy power supply ends dependency on the main grid and provides protection from power outages.

Ending reliance on imported carbon-based fuel
End reliance on imported carbon-based fuel: Nations still rely heavily on fossil fuels supplied by other countries. With Microgrids and utilising local renewable energy sources this ends the dependence thus accelerating green power adoption.

Ending reliance on local carbon-based fuel
End reliance on local carbon-based fuel: In order to meet sustainability requirements new Microgrids will be designed for any renewable sources that are available locally. A Microgrid is semi-autonomous and locally controls loads and supplies as a backup power system with energy provided by renewable energy sources it provides green power directly in response to immediate demand and for storage use.

Sounds perfect? Not quite. While the use of local prime energy resources is low or zero carbon and avoids high transmission losses often renewable energy cannot be depended upon for its availability.

Renewables also convert their power through electronic systems that exhibit undesirable behaviour under certain Microgrid scenarios.

Invariably such systems will include an element of combustion engines for dependability in hybrid Microgrids.

As we build our way to net zero a key driver for the adoption of Modular Hybrid Renewable Microgrids is Speed to operation.

Such Microgrid projects can have advantages towards speeding up the energy transition in that access to funding is wider, deployment times are faster, political and regulatory barriers are lower and the configuration flexibility is greater.

2. POWER SOLUTIONS DIVISION APPROACH

The Power Solutions Division approach to Microgrid development is built around scalable modular, 10MW gensets that parallel to 100MW and beyond.

It is a standardised component-based approach that works with all VRERs, with energy storage options and that provides significant advantages over traditional static, inverter and battery deployments.

Bergen Engines Medium-Speed Engines

Bergen Engines is a leading manufacturer of medium speed liquid and gas-fuelled engines and gensets. With high availability and efficiency levels, combined with excellent capability to meet quick and frequent load changes, Bergen's engines combine perfectly with intermittent renewable energy resources that need balancing power.

For Microgrid applications Bergen's largest single genset unit provides 11,8MW of power. These 10MW+ machines can easily be paralleled in modular 'grow as you need' deployments to more than 100MW for large industrial clusters and campus Microgrids for any application in any environment no matter how hostile.

This makes them suitable for every type of Microgrid dedicated deployment, whether islanded or grid integrated.

By providing modular power in 10MW standard chunks using Gensets microgrid developers benefit from fast to deploy primary and back-up power which will accelerate and protect return on value.

Bergen Engines medium speed liquid fuel engines are hydrogen ready and have a clear sustainability road map from diesel to liquid natural gas (LNG) to LNG/hydrogen blend and ultimately to pure hydrogen operation delivering zero carbon, clean, efficient power.

The use of rotating machines in conjunction with batteries provides the stability not always seen with, and which is quite different from, IGBT inverters plus battery.

This technology has immediately available benefits to solve problems when switching between different power sources.

Bergen Engines features include:

- Medium speed Engines provide many advantages for the Microgrid market including high efficiency at long run times which uses less fuel.
- Options for low load continuous running (unique to Bergen) can be applied to Microgrid projects with intermittent RER primary power.
- Hot standby for primary grid loss.
- Through simple paralleling Bergen engines scale to tens and even 100s of MWs.

Genset based primary powered Microgrids at tens of MW scale perfectly filling the gap between traditional large remote turbine power and local power generation for specific applications. They are not restricted to use by large energy outfits but are ideal for many emerging power intensive applications across different sectors (oil and gas, mining, large manufacturing, data centre campuses etc) which will increasingly depend on Microgrid power.

Marelli Motori supply efficient alternators for Microgrid fast start and has developed a new generator series to accompany Bergen Engines' B36:45 engine series.

> Bergen's gensets are hydrogen ready. The company has mapped a natural journey from fossil based liquid fuel to Natural Gas to Natural Gas/H_2 blends to Pure Hydrogen which will provide carbon zero clean, efficient power at scales reaching hundreds of MWs.

Piller – Stabilisation and Storage

Piller is a world-leading producer of power conditioning, stabilisation and grid gate 'choke' technology for mission-critical power applications. For Microgrid power applications, The Power of 10 features Piller Integrated Power Conditioning Technology (IPCT).

IPCT is a frequency stabilisation and voltage support module coupled to the power generation module (or renewables source). The 10MW size comprises 4 x Piller 2.5MW UB-V Series modules electrically coupled to the power module via a single 10MW choke. Conditioned power is then distributed as required up to 10MW per IPCT module.

Under the Power Solutions Division banner Piller solutions for Microgrids provide vital frequency and voltage stabilisation in Microgrids whether integrated or in island mode and grid gate technology that additionally protects against grid outages. IPCT comes in two options. One for island microgrids and one for the grid-connected solution.

Piller Microgrid deployed rotating machines are always available to deliver power to the load while providing vital back up through connected Battery Energy Storage Systems (BESS) or kinetic energy storage.

Piller's focus on frequency and voltage delivers fast response Microgrid stabilisation whatever the nature of the primary energy source, e.g. integrated with existing main grids, directly linked to local RERs, or on site generation.

Whenever the power source changes, for example in speed, in nature or switches from one to another, Piller's stabilisation and conditioning is an autonomous operation that provides fast response.

It is an approach which provides extra levels of stabilisation and power security over standard Microgrid combinations of inverter-based systems and batteries.

3. CHARACTERISTICS OF THE POWER SOLUTIONS DIVISION APPROACH

Power Solutions Division Renewable Hybrid Modular Microgrids technologies is not a turnkey solution. Instead, it is an integrated modular approach which provides significant advantages through Genset/Engine, Alternator, Stabilisation, Conditioning, Storage supplied as a fully integrated set of components or individual elements of Microgrids.

Power Solutions Division's use of rotating machines (gensets and power conditioning technologies) in conjunction with battery or kinetic energy storage is done in a way which is quite different to IGBT inverters plus battery.

Effectively running in 'always on' mode, this technology has immediately available benefits to solve voltage and frequency issues.

For integrated Microgrid mode Piller technology protects against brown outs and instability of main grid supply. It synchronises the Microgrid and main grid providing advantages for planned coupling and decoupling.

Of equal importance in both integrated and island mode this technology also protects and stabilises the power supply when switching between intermittent RER primary sources, when moving from RERs over to battery storage or kinetic ride through and back again.

For Microgrid power quality, fast start responsiveness of the engines is very important to supply the required power in response to load consumption peaks and troughs at times of main grid capacity constraints such as load shedding or peak shaving.

Grid forming advantages

Grid forming: Creating a stable frequency, voltage and amplitude.

Grid forming aids autonomous operation.

By providing constant Short Circuit Ratio (SCR) system strength is increased and system perturbations and disturbances reduced.

Providing SCR strength is easier to achieve with a system such as the Power Solutions Division's that is agnostic to whatever power source the grid is operating on.

It aids fault management in a reliable manner.

The units all have known response times and can interact with each other in a stable manner.

Power Solutions Division technologies inject and absorb power to keep a stable frequency so response when the load changes is consistent and fast.

Building a Microgrid on disparate components from different suppliers – e.g. solar inverters from one partner and batteries from another can present the Microgrid with unknown and unpredictable response speeds to changes.

The Grid Gate that can integrate an engine to the system.

With an engine in the system Microgrids can black start which means if the system is entirely down without grid connection it can be powered up autonomously.

This grid gate acts as a 'choke' between utility and microgrid which offers many possibilities for the subsystem to import or export power and manage output.

4. MICROGRID APPLICATION EXAMPLE – 'CASE STUDY'

Every Microgrid will be different, either in its composition or in its behaviour or both.

However, the issues are characteristically similar.

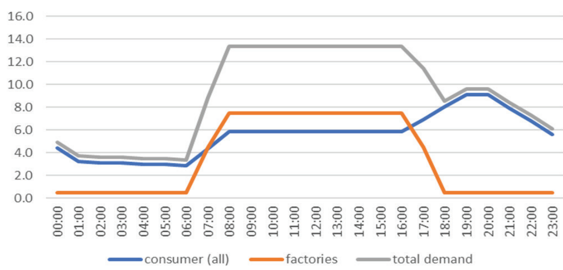
In this theoretical case study, a community Microgrid that could apply to a small town (or island) populated by 10,000-15,000 people is considered.

In this scenario the Microgrid is interconnected to a national grid. However it is intended to run independently of that grid in all but exceptional circumstances.

The inhabitants consume domestic electricity in a fairly typical 24-hour profile with a reasonably steady consumption during the day, peaking in the early evening and falling away during the early hours of the morning (12am-5am).

The industrial zone operates during normal working hours. Together, this presents a wide-varying load profile that the system must cope with.

The weather patterns surrounding the town make it suitable for both solar and wind power generation. The design brief is such that the Microgrid is capable of operation without any renewable energy input or any import from the utility grid.



Power consumption over a typical 24-hour period.

Configuration

Inside the Microgrid network several sources of power exist to supply the various consumers. The demand profile varies significantly according to the time of day and the supply profile can be unpredictable and highly variable depending upon weather conditions.

The system is configured with 10MWp of wind turbines and 6MWp of solar panels which together, constitute the Variable Renewable Energy in the network. Given the variable nature of VRE and the fact that available VRE could even fall to zero, these energy sources are complimented by the addition of 3 x 5.3MW gas generating sets thereby making the system more, although not totally dispatchable.

Finally, the Microgrid includes a 5MW/10MWh Battery Energy Storage System (BESS) which is a key component performing several functions within the electrical network:

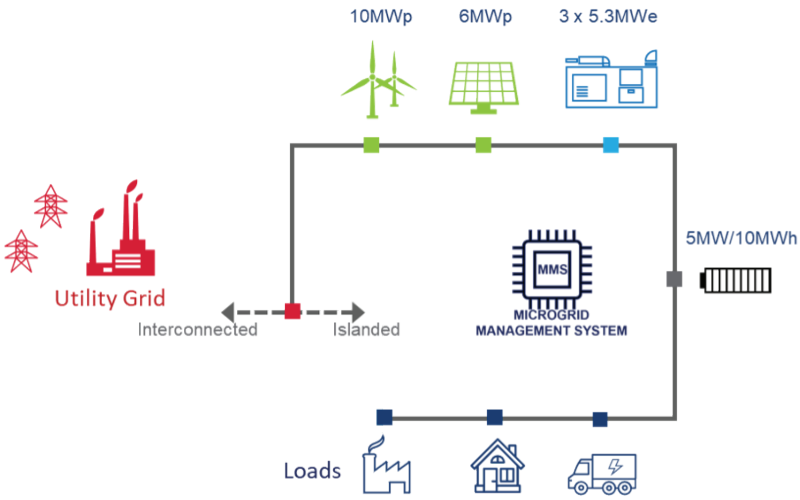
- A storage facility capable of delivering bursts of power to cover small variations in VRE output or to bridge engine failure.
- A store of excess energy when VRE supply exceeds demand. The energy is then ready to contribute when demand exceeds supply.
- A fast-acting manager of active power, necessary to maintain network stability if there is a sudden and significant change in the balance between supply and demand. This would include for example, solar inverter failure or sudden and complete loss of the factory demand.

In this system, the Piller GridStab BESS is employed with its additional features that include natural inertia (used for the control of frequency change) and inherent high Short Circuit Ratio (SCR – used for providing overcurrent to clear system faults quickly).

In this instance, the system is interconnected thereby enabling the capability to export or to import power between the Microgrid and its much larger counterpart.

If a GridGate is used, its internal choke prevents the exchange of short circuit power between the two grids, protecting the micro grid from any macro grid outages and disturbances.

However, the system must also operate satisfactorily with its own inertia when the Microgrid has to operate in island mode for whatever reason.



Every operating state of the hybrid Microgrid creates a unique set of conditions under which the system must perform satisfactorily. To achieve this effectively, the Microgrid must include some form of energy storage and must be capable of recovering from and managing faults.

For economic and performance reasons, engines are almost always part of the energy mix when VRE sources are at play. But these alone are not enough to provide secure and reliable power in such a multi-source network and there needs to be energy storage and power conditioning too. The energy storage helps both the economic and technical characteristics of the hybrid Microgrid and becomes an essential element.

6. CONCLUSION

Power Solutions Division technologies enable all stakeholders from MPCs to consultants to build large scale Microgrids from 10MW to 100MW and beyond, both quickly and cost effectively.

Power Solutions Division's approach is to simplify the process for the constructor, reducing risk for the financier.

The unique integration of Bergen Engines 10MW gensets which combine as grid replacement building blocks, Piller IPCT, Stabilisation and Marelli Alternator technologies presented as a combined or integrated solution is only available from Power Solutions Division.

It allows designers to move confidently towards resilient development for multiple Microgrid modes in every type of application whether industry focused, rural, community, public or private.

APPENDIX

Microgrid Players

MPCs:
Microgrid companies specialize in establishing resilient power systems as the optimal plan is to have Microgrids maintain stability with decentralized low voltage, prevent disturbances and integrate renewable energy sources.

Engineering:
These companies ensure that the Microgrids are designed as resilient power provisional units and assist power intensive industries achieve environmental sustainability governance goals by integrating solutions.

Procurement:
Provide the necessary fuels for Microgrid power generation and design procurement processes enable Microgrid integration with legacy systems or conventional equipment.

Constructors:
Expertise of the electrical utilities construction and project management that partner with electrical utility community members which result in projects being organised, on-budget and successful.

Investors:
By 2030 over $14 billion will be invested into Microgrid technology annually. The success of the Microgrid market will be orchestrated by distributed energy resources (DER) which is attracting investments from energy intensive industries and developers.

Consultants:
Microgrid system modelling on energy conversion, load reduction, storage and generation to calculate the economic value for business management services and contract negotiation.

EPCs:
Deliver specified Microgrid solutions for interactive or completely off main grid in both remote and urban locations. Companies design capabilities that build, commission, operate and maintain Microgrids.

What is a Microgrid?

A Microgrid can be defined as multiple energy sources supplying multiple consumers in a defined geographic area. However, they will operate in a wide variety of scenarios and often multiple modes.

Microgrids consist of standalone local power generators (or access to such), dedicated energy storage (batteries or flywheels or other energy storage types such as CAES or LAES or gravity) and load management control capabilities.

As can be seen from the scenarios, modes and definitions below there are both subtle and significant differences between Microgrids.

Hybrid Microgrids are local, self-sufficient energy networks that are flexible, efficient, and quick to deploy. Often linked directly to renewable energy resources (RER) Hybrid Microgrids use clean power generation while retaining the ability to work inside larger electrical transmission systems.

Different industry sectors have nuanced Microgrid definitions which reflect their requirement and their position within the power sector as customers, and increasingly as customers who are also providers of power.

Today Power Solutions Division is working on a range of projects across different sectors which the end user has defined as a Microgrid application where and the Hybrid Renewable Microgrid approach is applicable.

Microgrid Modes

Islanded:
In an Islanded Microgrid scenario – in normal operation – the Microgrid is not connected to the main power grid. It relies on local power generation, often from RERs with energy storage back up.

Separation means island grids must control voltage and frequency, often while managing energy demand to loads. Challenges identified with Island Microgrids include maintaining stability of voltage and frequency output

Local generation must also be capable of switching from “grid-following mode” to “grid-forming mode.”

These particular grids can operate independently in an island mode or reconnect to a main grid when required.

Integrated:
An integrated Microgrid shares many characteristics of an Islanded Microgrid such as local load, distributed energy resources (DERs) for generation and power storage, distribution management and control, with the ability to operation independently but with the additional interconnection with a large regional or national power grid.

Grid-connected Microgrids physically connected to the main utility grid through a switch mechanism integrated onto the point of common coupling (PCC).

Remote:
Remote, or off-grid Microgrids are isolated from the utility grid. Remote Microgrids are often integrated with battery energy storage systems for backup power and environmental sustainability.

Networked:
Networked Microgrids involve multiple separated DER (distributed energy resources) and 'nested' Microgrids connected to the same utility grid circuit segment that serve communities managed by a supervisory control system.

Blockchain:
Blockchain Microgrid remains a young approach that establishes a market which enables local energy transactions between a specific virtual or physical Microgrid. The technology has the potential for businesses to trade energy directly, bypassing a utility or other central authority.

Microgrid Definitions

1. "A group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A Microgrid can connect and disconnect from the grid to enable it to operate in both grid connected or island mode."

Source: US department of Energy

2. A Microgrid is a closed system of interconnected energy loads and distributed energy resources within a defined boundary and with a single point of coupling to the wider grid and can work disconnected from it. The fact that these systems are made to assure resilience and can work off grid make them appear as single loads that can be regulated by the grid operator according to their needs.

Source: IEEE

3. A Microgrid is a decentralised group of electricity sources and loads that normally operates, connected to and synchronous with the traditional wide area synchronous grid (macrogrid), but is able to disconnect from the interconnected grid and to function autonomously in "island mode" as technical or economic conditions dictate.

Source: Wikipedia

4. A Microgrid is a group of interconnected loads and distributed energy resources that acts as a single controllable entity with respect to the grid. It can connect and disconnect from the grid to operate in grid-connected or island mode.

Microgrids can include distributed energy resources such as generators, storage devices, and controllable loads. Microgrids generally must also include a control strategy to maintain, on an instantaneous basis, real and reactive power balance when the system is islanded and, over a longer time, to determine how to dispatch the resources. The control system must also identify when and how to connect/disconnect from the grid.

Source: NREL

5. "A Microgrid as a distribution network incorporating a variety of possible distributed energy resources that can be optimised and aggregated into a single system. This system can balance loads and generation and run while disconnected from the traditional utility power grid."

Source: Various

Whatever the definition Inside all Microgrid, the 'electrical momentum' is inevitably far less with fewer interconnected sources and the ability to deliver significant overcurrent for fault clearing is much reduced by the substitution (in part or whole) of spinning generation with Variable Renewable Energy Resources (VRERs).

This means that the Microgrid has to be capable of managing faults and changes in network characteristics with a much faster reaction time. Also, that some of the electrical features seen in the larger grids, necessary for secure operation have to be simulated or recreated at Microgrid scale.

This is not straightforward especially in hybrid Microgrids but there are ways to manage this with some solutions being more effective than others.