Power Generation

PowerStore
Renewable microgrid stabilization
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ABB’s microgrids and renewable integration platform provides a modular and scalable solution that integrates renewable power generation into microgrids that previously operated solely on fossil fuel. The key is to design a renewable power plant that can maximize return on investment, while delivering a stable, safe and reliable power supply. ABB’s solution includes grid stabilization technology that enables high penetration of renewable power generation, and distributed control systems that provide intelligent power management and efficient hybrid power plant operation. Our solution achieves 100% peak penetration of renewables in wind/diesel and solar/diesel power systems, maximizing fuel savings and supplying reliable, grid-quality power in remote off-grid locations.

The PowerStore™ is a compact and versatile grid stabilizing generator. Its main purpose is to stabilize power systems against fluctuations in frequency and voltage. Stabilizing the grid needs highly dynamic power injection and absorption for short amount of time, while common energy storage solutions require slower response and discharge over longer time. It combines a 18 MWs low speed flywheel with solid state converters to provide reliable and high-performance grid stabilization.

The PowerStore is able to inject and absorb power up to its nominal power rating and it is available in a range of models from 500 kW to 1.5 MW and can be configured to operate in either a grid support mode for use in multimegawatt grids, or as a virtual generator for use in smaller isolated microgrids.

Main components
The PowerStore consists of:
- Flywheel spinning mass including motor/generator
- AC-DC-AC converter system
- Operator interface
- Container-based building (optional)

Flywheel spinning mass
The PowerStore is a flywheel based technology that provides grid stabilization and uses a pressurized helium environment to reduce frictional losses. The unit has a lifting magnet that holds the weight of the 3,000 kg flywheel during operation, ensuring a long bearing life, reduced losses and low maintenance.

Oversized primary mechanical bearings are also included to hold the weight of the flywheel while it is stationary and below operational speed while catch bearings are installed to provide a fail-safe system.

The design incorporates proven technologies in order to deliver worry free years of operation.

ABB solutions enable the maximum utilization of renewable energy in remote or isolated areas - enabling efficient, reliable and high quality power supply, while minimizing the fuel consumption.
Converter system
The AC-DC-AC converter system hardware is based on customized PCS100 insulated gate bipolar transistor (IGBT) power converters from ABB. Using these proven modules results in a highly reliable design with an installed base of thousands of units worldwide.

The use of back-to-back IGBT converter pairs allows the flywheel to rotate at variable speed enabling the injection and absorption of power. Multiple converter pairs are paralleled to achieve the desired model rating. The PowerStore is able to export and import at maximum power ratings regardless of the state of charge, from 0% to 100% capacity; there is no need to derate the PowerStore for lower state of charge. For example, 100% of power injection until the PowerStore is completely empty, or 100% power absorption until the PowerStore is completely full is possible. This gives the PowerStore its unique fully symmetric power ratings, and the ability to charge with as much power as it can discharge.

The converter modules are configured for redundancy which means that the PowerStore will continue to operate despite the failure of one module.

Operator interface
An operator interface is used to monitor the flywheel and converter components and to provide access to historical data. Historical data recording is provided at two levels: a high resolution (down to 100 ms) recording system for response and performance analysis, and a low resolution (10 minutes) recording system for asset management.

A number of variables are recorded such as:
- PowerStore active and reactive power
- PowerStore state of charge
- Mains 3-phase voltage
- Mains 3-phase current
- Flywheel, container and converter temperatures
- Alarms, status and operation mode
- Next PowerStore service time
- Mains frequency

This data can be exported into a wide range of software, including Microsoft Excel for further analysis. The information is also available to be exported to upper level SCADA systems through a MODBUS/TCP communications interface.

Through the operator web interface the PowerStore can be remotely started and stopped and alarms remotely monitored and reset.

Furthermore, the trending system is capable of displaying multiple types of data at different resolutions simultaneously. The trending package is able to access data from a remote system across a telecommunications path (such as an ordinary modem or a 3G wireless connection) and can display user-defined periods of larger portions of data with ease.

Container building (optional)
The PowerStore can be factory installed into a purpose built 20 or 40 foot shipping container. The container building includes a fan forced cooling system and other necessary building auxiliaries. These units can be transported and installed on site with a minimum of installation work.

PowerStore models
The PowerStore can be configured in three different sizes: 500, 1,000 and 1,500 kW. The energy content of the flywheel remains 18 MWs for all three models (see data sheet for dimensions and ratings).
How it works

PowerStore operation

Charge control

The charge level at which the PowerStore normally operates can be set between full and empty during commissioning.

The normal charge level is set to ensure there is both sufficient energy and headroom to carry out the required grid stabilization. Recharging or discharging back to the idle energy level is controlled by a maximum power level that the PowerStore will consume or generate. The maximum power level can be set as a fixed parameter for charging or discharging or adjusted dynamically by an external power management system during operation (e.g., the external power management system may only want to recharge if renewable power is available).

Protection

The PowerStore has a number of protection systems in place including but not limited to:

- Mains overvoltage
- Flywheel and converter overtemperature
- Flywheel overspeed
- Flywheel over/undercharging
- Converter overcurrent

The PowerStore automatically adjusts its rating in the event the converter system detects a temperature overload. This ensures ongoing operation even during high temperatures.

Backup power supply

In the event of a mains failure (black station) the flywheel will slowly spin down until standstill. While it is spinning down it provides power to keep the control and operator interfaces alive to monitor the controlled shutdown process. No external UPS backup is required.

PowerStore operating modes and applications

The PowerStore can be configured according to the special requirements of each site. It is able to operate in either Grid Support Mode (GSM) for large networks or Virtual Generator Mode (VGM) for isolated microgrids.

The value of the PowerStore can be increased further through the introduction of the Microgrid Controller (MGC600) - the control system especially designed to match the needs of microgrids - which can enable additional features, including:

- Spinning reserve reduction (generator overload support)
- Renewable Only Mode
Grid support mode
The PowerStore supports the grid by providing three support functions:
- Frequency support
- Voltage support
- Disturbance feed-forward

Frequency support reduces the disturbance in grid frequency by injecting active power based on the grid’s frequency deviation from nominal. If the grid frequency is below nominal then power is injected into the grid, while power is absorbed from the grid if the frequency is above nominal; the magnitude of the injected power is a function of the size of the deviation. A zone or dead-band has been included to allow for a variety of primary grid frequency controllers; the dead-band size and position is adjustable.

Voltage support is a method of reducing grid voltage disturbance similar to that of a STATCOM. The PowerStore voltage support function implements a form of reactive droop control. Capacitive VArS (volt-ampere reactive) are injected into the grid if the voltage is lower than desired and inductive VArS if the grid voltage is higher.

Changes to the average or nominal system frequency or voltage are allowed to occur to accommodate operation in voltage and/or frequency droop and allow for the presence of a time correction system.

The disturbance feed-forward function reduces system disturbances, both in voltage and frequency, by injecting real and reactive power proactively based on fluctuating load or renewable energy source measurements. In essence this function counteracts the effects of a disturbance before it affects the grid frequency and voltage.

The above grid support functions are parameter-adjustable to allow for optimization of the system and tuning to the particular application and power system dynamics.

Virtual generator mode – Renewable Only Mode
In Virtual Generator Mode (VGM) the PowerStore operates as a generator and is especially suited to small isolated grids with a large amount of renewable energy connected. In this mode of operation the PowerStore is capable of operating as the only generator on the grid.

For both modes in GSM or VGM in case of loss of plant within a power system (e.g., a generator has tripped offline) usually a step in the system load appears which results in a large frequency deviation. Such changes can cause load shedding of consumer feeders. The PowerStore is capable of compensating for this step load by discharging up to its nominal power rating with a fast response. After the PowerStore has picked up the load and discharged its energy into the power system it gradually reduces its power output to pass the load back to the power system. In this event the PowerStore acts like a shock absorber to dampen the step load impact on the system’s frequency and voltage.

In the above case a power management system coordinating the schedule of generation plant needs to call replacement capacity to ensure the PowerStore can pass the additional load back to the generators. For this purpose the PowerStore provides an interface that allows other controllers to monitor its status.

PowerStore works like an electrical noise filter to smooth power fluctuations and also has the ability to minimize the impact from loss of plant through the shock absorber, making PowerStore the ideal technology to manage the start of large loads, smoothing renewable energy fluctuations, or support system stability after a reclosing event.

Spinning reserve reduction
Isolated power systems require the provision of spinning reserve to allow for the sudden increase in load or the sudden loss of generation plant. Spinning reserve is usually provided by conventional generators such as diesel or gas-fuelled reciprocating engines. As a result generators are not operated at their rated power output where the fuel efficiency is usually the highest. The PowerStore is able to provide the spinning reserve for the power system and allow generation plant to operate closer to their rated power output.

Generator overload support
The PowerStore can prevent the diesel/heavy fuel oil (HFO)/gas generators from going into overload by monitoring their power output. This measurement can be provided by the ABB’s microgrid controllers or a third party upper level control system.

In case the charge level of the PowerStore falls below a set parameter, the supervising power management system schedules additional generating capacity to start.
Fault ride through
The PowerStore is able to ride through faults, providing grid stability in case of a loss of a generator or large system disturbance.

The PowerStore is capable of providing real and reactive power to support the system
- When the system voltage is depressed
- During a fast rate of system frequency change
- During an instantaneous voltage phase shift

The above events usually occur during line faults within the distribution system. The PowerStore has been designed to ride through those distribution faults, provide system stability and support the system recovery after the fault has been cleared. The PowerStore remains connected to the network during line faults.

Power management system
The PowerStore is able to interface to external power management systems to receive power and reactive power set points that are independent of the voltage and frequency fluctuations of the connected grid.

The PowerStore comes with a dedicated interface to the control system from ABB. This allows the PowerStore to interact with the whole power system not only based on electrical fluctuations but also on communication to other equipment like wind turbine generators or solar power plants.

Typical use cases/applications
- Isolated grids with high renewable energy input
- The virtual generator mode provides additional inertia to the network to reduce frequency and voltage disturbances at high renewable penetration levels and power quality
- The virtual generator mode allows the network to run without diesel generators
- Power systems with huge periodical scheduled loads that cause instabilities
- The PowerStore is able to supply nearly limitless short period, high power cycling without detrimental effect on its life-span
- Reactive power balancing
- The PowerStore is able to inject and absorb reactive power independently of the real power behaviour
- General smoothing of load and generation fluctuations
- 100% renewable energy microgrids
- Stabilization
- Management of power flow
- Frequency master
- Larger grid stabilization
- End of grid support applications

Frequency variations and PowerStore power output in a high penetration wind diesel system
## Specifications

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
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<tbody>
<tr>
<td>Design life</td>
<td>20 years</td>
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<tr>
<td>Nominal supply voltage</td>
<td>3 ph, 380 - 440 Vac</td>
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<tr>
<td>Supply frequency</td>
<td>50/60 Hz</td>
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<tr>
<td>Max. mains voltage</td>
<td>480 Vac</td>
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<tr>
<td>Aux. AC supply</td>
<td>3 ph + N, 380 - 480 Vac, 50/60 Hz, 50 A</td>
</tr>
<tr>
<td>Under-voltage fault ride through</td>
<td>Yes</td>
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<tr>
<td>Output short circuit protection</td>
<td>Yes</td>
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<tr>
<td>Fault current available</td>
<td>Yes</td>
</tr>
<tr>
<td>Paralleling of units</td>
<td>Yes</td>
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<tr>
<td>Unbalanced current</td>
<td>Optional</td>
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## Technical Data

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
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<tbody>
<tr>
<td>Nominal kVA rating</td>
<td>See table below</td>
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<tr>
<td>Overload kVA rating</td>
<td>150% for 30 sec</td>
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<tr>
<td></td>
<td>175% for 2 sec</td>
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<tr>
<td></td>
<td>200% for 2 sec (75% pre-load)</td>
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<tr>
<td>Nominal kW rating</td>
<td>See table below (max. 1,500 kW)</td>
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<tr>
<td>Nominal kVAR rating</td>
<td>See table below</td>
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<tr>
<td>(Power factor from 0 leading to 0 lagging is possible)</td>
<td></td>
</tr>
<tr>
<td>Nominal current unbalance</td>
<td>100 A/phase</td>
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<tr>
<td>Flywheel energy stored (@3,600 rpm)</td>
<td>18 MWs</td>
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<tr>
<td>Estimated discharge/charge time @100 kW</td>
<td>150 s</td>
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<tr>
<td>Estimated discharge/charge time @500 kW</td>
<td>30 s</td>
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<tr>
<td>Estimated discharge/charge time @1,000 kW</td>
<td>18 s</td>
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<tr>
<td>Estimated discharge/charge time @1,500 kW</td>
<td>12 s</td>
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<td>Flywheel operating speed range</td>
<td>1,800 – 3,600 rpm</td>
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<td>Minimum power to maintain SOC</td>
<td>15 kW</td>
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<tr>
<td>Flywheel power losses</td>
<td>12 kW</td>
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<tr>
<td>Power conversion efficiency charge or discharge</td>
<td>&gt; 90%</td>
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<td>Min. charging power spin-up</td>
<td>35 kW</td>
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<tr>
<td>Nominal DC-link voltage</td>
<td>750 VDC</td>
</tr>
<tr>
<td>Altitude above sea level</td>
<td>&lt; 1,000 m without derating</td>
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</tbody>
</table>

## Communication

**Supported protocols**  
Modbus TCP/IP

## Model

<table>
<thead>
<tr>
<th>Model</th>
<th>Nominal Rating (+/-kVA)</th>
<th>Building size (optional)</th>
<th>Approximate weight (incl. building)</th>
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<tbody>
<tr>
<td></td>
<td>@440 VAC</td>
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<td>Tonnes</td>
</tr>
<tr>
<td>PS04</td>
<td>458</td>
<td>20 ft</td>
<td>11.47</td>
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<tr>
<td>PS08</td>
<td>915</td>
<td>40 ft</td>
<td>11.96</td>
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<td>PS12</td>
<td>1,372</td>
<td>40 ft</td>
<td>14.19</td>
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