Energy Storage Modules - ESM

Product presentation
Energy Storage Modules

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Why storage?
Energy Storage Modules

Why storage?

Challenges of today’s electrical grid

**Electricity consumption on the rise**
- Electrification of everything – moving towards electricity as the primary source of power
- Economic and population growth will lead to increasing demand for power

**Growth in renewables**
- Governments and industry moving towards solar and wind
- Intermittent generation sources can reduce reliability on the electrical grid
- Instant response is required to maintain grid frequency in microgrids

**Proliferation of smart grid technology**
- Bi-directional flow of power requires additional coordination between power supply and demand

**Coal plant retirements**
- Reducing baseload power capacity from conventional resources
- Limited resources for ancillary services on the utility grid

**Electrification of transportation**
- More users of EVs can increase peak loads placing more strain on the electrical grid
- Increase in high speed rail

**Tax and regulatory incentives**
- Renewable mandates and incentives increasing demand for clean grid technologies
- Potential tax benefits for storage systems (residential, commercial and utility)
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Why storage?

How does energy storage benefit the grid and industry?

Energy storage raises the efficiency of the grid at every level by:

- Providing smooth grid integration of renewable energy by reducing variability
- Storing renewable generation peaks for use during demand peaks
- Flattening demand peaks, thereby reducing stress on grid equipment
- Providing infrastructure support as loads increase with electric vehicle use
- Decreasing or eliminating the power fees related to short time peak loads
- Maintaining generation and demand balance
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Why storage?

Segments

Renewables
- ESM acts as a buffer and smoothen out the renewable generation allowing for seamless grid integration.
- Smoothens the output and controls the ramp rate (MW/min or kW/min) to eliminate rapid voltage and power swings on the electrical grid.
- Aligns wind and solar generation peaks with demand peaks

Smart and microgrid technology
- Balancing fluctuating demand and a changing generation mix, without oversizing equipment.
- Improves the overall efficiency of the energy system by increasing the penetration of wind energy while decreasing the amount of diesel generation

Utility distribution grid
- Flattening demand peaks, thereby reducing stress on grid equipment.
- Allows higher mix of intermittent of renewables into the grid
- Enables grid code compliance
- Prospect of evolving business models. Allows participating in capacity markets as a dispatchable resource.
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Why storage?

Segments

**Industrial loads**
- Demand management meeting the highest peak loads without paying additional power fees
- Improves load factor. Helps control the amount of reactive power flowing through the grid.
- Available back up power for critical loads and equipment

**Residential and small commercial**
- Lowers power charges and cost of energy.
- Supports residential and commercial loads during power outages.
- Serves as a backup power for critical loads (UPS)
- Flattening demand peaks. Stores rooftop Solar generation peaks for use during demand peaks.

**Electrification of transportation**
- Electric vehicles adding a new challenge to already congested distribution networks
- Can provide power from the batteries to reduce the demand on the grid.
- Enables DC fast charging without increasing demand charges.
- More power available for increase in high speed railway lines and for chargers of battery powered trains
Applications
Energy Storage Modules
Applications and benefits

Load leveling
- Load shifting from high peak demand to off-peak period
- Reduces distribution congestion and losses
- Postponement of investments in grid upgrades

Peak shaving
- Flattens demand peaks thereby reducing peak demand charges
- Independency of the grid capacity during peak demand – power available from batteries when you most need it
- Reduce the operational costs

Frequency regulation
- Increases reliable operation of the grid
- Supporting decentralized microgrids
- Reduces the need for additional generation facilities (expensive to operate and maintain)

Capacity firming
- Increases renewable penetration and reliability of the grid
- Supports the frequency and voltage of the grid even when the demand and Solar / Wind generation fluctuates
- Enables grid code compliance

Power quality
- Protects downstream loads against short-duration events
- Reactive power compensation and load factor improvement
- Active harmonics filtration
- Balance the currents between phases

Spinning reserve
- Minimizes the impacts from power outages
- Backup power for critical loads
- Reduces need for generation sources to be online and ready to use (lower O&M costs as well as emissions)
Load leveling

Load leveling involves storing power during periods of light loading on the system and delivering it during periods of high demand. During these periods of high peak demand the Energy Storage Module supplies power, reducing the load on distribution grid and less economical peak-generating facilities. Generation load is shifted from high peak demand to off-peak period.

Benefit

- Postponement of investments in grid upgrades or in new generating capacity
- Reduce T&D congestion
- Renewables time shifting
Peak shaving

Peak shaving is similar to load leveling, but is used for the purpose of reducing peak demand for economy of operation. Peak shaving installations are often owned by the electricity consumer, rather than by the utility. The goal is to avoid demand charges (power fees) and the installation of capacity to supply the peaks of a highly variable load.

Benefit

- Customers can save on their utility bills by reducing peak demand charges
- Utilities can reduce the operational costs meeting peak demand
Frequency regulation

The Energy Storage Module is charged or discharged in response to an increase or decrease, respectively, of grid frequency. This approach to frequency regulation is a particularly attractive option due to its rapid response time and emission-free operation.

Benefit

- Increases reliable operation of the grid
- Reduces the need for additional generation facilities (expensive to operate and maintain)
Energy Storage Modules
Applications and benefits

**Capacity firming**

The variable, intermittent power output from a renewable power plant, such as wind or solar, can be maintained at a committed level for a period of time. The Energy Storage Module smoothens the output and controls the ramp rate (MW/min or kW/min) to eliminate rapid voltage and power swings on the electrical grid.

**Benefit**

- Increases reliability of the grid
- Improves efficiency of the renewable plant
- Enable grid code compliance
Energy Storage Modules
Applications and benefits

Power quality
In power quality applications, an Energy Storage Module helps protect downstream loads against short-duration events that affect the quality of power delivered.

Energy storage with reactive power capability can provide voltage support and respond quickly to voltage control signals.

Benefit
Harmonics mitigation:
- Energy storage as active filter with harmonics compensation up to 50th harmonic. Reduction of THD

Load balancing:
- Balance the currents between phases

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Applications and benefits

**Spinning reserve**

Energy Storage Module can respond within milliseconds and supply power to maintain network continuity while the back-up generator is started and brought online. This enables generators to work at optimum power output, without the need to keep idle capacity for spinning reserves. This eliminates the need to have back-up generators running idle. To provide effective spinning reserve, the ESM is maintained at a level of charge ready to respond to a power outage.

**Benefit**

- Minimizes the impacts from power outages
- Reduces need for generation sources to be online and ready to use (lower O&M costs as well as emissions)
- Acts as a back-up power source – UPS
**Energy Storage Modules**

Applications and benefits

**Benefits from multiple applications**

- Multiple applications can benefit at the same time
- There is always more than one application which will benefit to the user of energy storage. Residential and commercial users can integrate the ESM to the Solar for load leveling, for the frequency and also reduce their power fees during the high consumption hours and fast EV chargers. Having same time the ESM available for the backup power for the critical loads and power outages. Utilities can benefit for the frequency regulation or other possible ancillary services.
- ESM can offer different applications during the different time of the day. Capacity stored in ESM for the renewables ramp rate control can be used as a backup power during the time there is no Sun or for the frequency regulation when the diesel generators are down.
- Commercial payback will increase from the combination of applications and benefits

<table>
<thead>
<tr>
<th>Applications</th>
<th>Industrial, commercial and residential</th>
<th>Renewable integrators</th>
<th>Transmission and distribution operators</th>
<th>Power stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load leveling</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>Peak shaving</td>
<td>✔</td>
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<td>✔</td>
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<tr>
<td>Frequency regulation</td>
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<td>✔</td>
<td>✔</td>
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<tr>
<td>Ramp rate control / Capacity firming</td>
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<td>✔</td>
<td>✔</td>
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<tr>
<td>Power quality</td>
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<td>✔</td>
<td></td>
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<tr>
<td>Spinning reserves / backup power</td>
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<td>✔</td>
<td>✔</td>
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</table>
Portfolio
What is Energy Storage Module

- Energy Storage Module (ESM) is a packaged solution for storing energy for use at a later time. The product is sized to meet energy demands while optimizing cost.
- The energy is stored in batteries in order to perform demand management, improve the energy quality and to support the integration of renewables into the grid.
- ESM can be connected to the electrical network at Low (<1000 Volts) or Medium Voltage (<40.5 kV).
- ESM unit includes the necessary electrical, protective and monitoring equipment along with the battery system in pre-designed and tested unit.
Energy Storage Modules
Enclosurized ESM

**Product buildup**

**Network**

- **Medium or Low Voltage Equipment (optional)**
- **Isolation Transformer (optional)**
- **Inverter(s)**
- **Batteries**

<table>
<thead>
<tr>
<th>System</th>
<th>Power Range</th>
<th>Duration</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Community Energy Storage (CES) system</strong></td>
<td>25 kW – 300 kW / 30 min – 4 hrs</td>
<td>Enclosurized solution housing batteries, Battery Management System (BMS), inverter, inverter PLC, switchgear</td>
<td></td>
</tr>
<tr>
<td><strong>Distributed Energy Storage (DES) system</strong></td>
<td>200 kW – 2 MW / 15 min – 4 hrs</td>
<td>Enclosurized solution housing batteries, BMS, inverter, inverter PLC, switchgear and transformer</td>
<td></td>
</tr>
<tr>
<td><strong>Grid connection equipment</strong></td>
<td>300 kVA – 3.5 MVA</td>
<td>One enclosure with inverter, inverter PLC, switchgear and transformer</td>
<td></td>
</tr>
<tr>
<td><strong>Battery enclosures</strong></td>
<td>Enclosure solution to house batteries, racks and management systems</td>
<td>HVAC and fire suppression system included</td>
<td></td>
</tr>
</tbody>
</table>
Combination of packages

ESM can be connected to Low Voltage network or to Medium Voltage distribution network.

Smaller scale ESM batteries, inverter and connection equipment is installed into the same enclosure. Medium Voltage connection equipment can be installed into a separate enclosure – into a Compact Secondary Substation (CSS)

- Renewables (PV) or EV fast chargers can be installed to the same LV switchboard inside the CSS

Large scale ESM equipment is spread into separate enclosures. More than 1 battery enclosure can be connected to inverter and Medium Voltage connection equipment enclosure.
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Compact ESM - CESM

High power from minimal layout
- Up to 100 kW from 1 unit
- 65 kWh single rack energy capacity
- Up to 200 kWh with optional extended racks

Modular solution
- Capacity increased by additional battery racks
- More power from several units in parallel

Local and remote monitoring and control
- Easy integration to customer SCADA
- Access from portable devices

Optimized layout
- Ideal for indoor installation
- Can be installed into existing buildings or substations

Target customers
- Renewables – Solar
- Industrial and commercial buildings
- Utilities

CESM can be installed as behind-the-meter storage
- Commercial and industrial customers
- Fastest growing storage market
- Identified customers
- Clear customer benefits
Modularity

Two or more sets of CESM connected in parallel at the AC bus:
- Increase in the power: 100=>200kW
- Increase in the capacity kWh: 65=>130kWh
  - 1 CESM can have from 1 to 3 battery racks, max energy 200kWh
- Operation in Master-Slave configuration
- Inverter + protection according to the ratings of the batteries. No need of retrofitting in case of upgrade
- Communication between the two units needed
Energy Storage Modules
Outdoor enclosure sample packages

Connection at Low Voltage
single enclosure
- Up to 600 kW
- Up to 900 kWh
- LV grid connection and protection equipment included

Single battery enclosure
- Up to 1200 kWh
- DC protection equipment included to be connected to Power conversion and grid connection enclosure

Connection at Medium Voltage
single enclosure
- Up to 300 kW
- Up to 300 kWh
- For 12 or 24 kV connection
- Up to 315 kVA transformer

Power conversion and Medium Voltage grid connection enclosure
- Up to 40,5 kV connection
- Up to 2 MVA transformer
- Up to 1200 kVA power conversion system
# Energy Storage Modules

Additional offering from EPMV

<table>
<thead>
<tr>
<th>Commissioning</th>
<th>Training</th>
<th>Remote control</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commissioning</td>
<td>On-site training</td>
<td>Real-time monitoring</td>
<td>Service contract</td>
</tr>
<tr>
<td>Installation supervision</td>
<td>Classroom training</td>
<td>Remote troubleshooting</td>
<td>Extended warranty</td>
</tr>
<tr>
<td>Spare parts</td>
<td></td>
<td>Automatic notifications and alerts</td>
<td></td>
</tr>
</tbody>
</table>
Equipment description
Energy Storage Modules

Equipment description

Inverter technology

- Dynamic power control (P) and reactive power control (Q)
- Harmonic mitigation up to 50th
- Step-less reactive power compensation
- Load balancing in 3 and 4-wire systems
- Islanding mode and black start
- Modularity (several units can be put in parallel) for high-current applications
- Full redundancy and flexibility (master/master configuration and independent DC busses)
- CAN connection to BMS, easy parameterization
- External communication through Modbus

<table>
<thead>
<tr>
<th></th>
<th>323 kW</th>
<th>108 kW</th>
<th>72 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESI-I</td>
<td>ESI-M</td>
<td>ESI-S</td>
<td></td>
</tr>
<tr>
<td>(wall mounted)</td>
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</tbody>
</table>
Energy Storage Modules

Battery system

ABB used only Li-Ion batteries for ESM
- Battery management system - BMS
  - Constant monitoring, system safety and reliability
- Long lifetime, high number of cycles
- Different battery models available for high power and energy applications
- Modular design – capacity can be increased by adding battery racks
  - ESM can be sized to offer needed capacity after certain number of years (EoL capacity)
- Tested in ABB research labs
Safety equipment

ESM includes necessary protective and monitoring equipment for safe operation and reliability:
- HVAC system to provide safe operating conditions to the Li-Ion batteries
- Fire suppression system to avoid any risk of hazardous event to the equipment, operator and people in vicinity
- BMS for continues monitoring of each battery rack, module and cell
- Prevention of possibly dangerous events applying safety interlocking
- Back-up power, UPS, to keep functioning in case of unexpected aux. power shut-down

Real time monitoring and two-way communication between ESM and customer control center to have continues overview of safety features
Energy Storage Modules

Equipment description

Control system

ESM control system allows the product work based on given setpoints, commands from the customer control center, based on signals read from the grid and algorithms installed into the control system.

Control levels:

**Level 1.** System is working based on given set-points, including the time. Reading the signals from the measurement transformers for power quality improvement and harmonics filtration.

**Level 2.** Level 2 includes all functions from Level 1 together with readiness for remote commands to charge and discharge.

**Level 3.** Level 3 would include the algorithms that will let the system to work based on several signals that system owner wants to be followed. Depending on the algorithm the system will choose which application to run, eg renewables smoothing, daily load shifting.
References
Description:
- Power rating: 25 kW
- Energy: 50 kWh, after 5000 cycles
- Used batteries from GM Volt

Application:
- Peak shaving
- Load leveling
- Renewable integration
- Backup power
- Frequency regulation
- Power quality

Benefits:
- Technology investigation into vehicle battery secondary-use through testing and demonstration project.
- Feasibility study of different energy storage applications in small section of distribution grid
  - 10 hours of backup for 5 houses in Michigan - 1 kW per house average
  - Reduction of 25 to 50 kW PV intermittency
  - Enable usage of several 10 kW fast chargers on an existing 25 kW transformer
  - 25 kW support for frequency regulation

References
CES in North America, installed 2013
**References**

**CESM in Norwey, installed 2017**

**Description:**
- Power rating: 45 kW, power can be increased
- Energy: 130 kWh

**Application:**
- Peak shaving
- Power quality
- Back-up power
- Islanding

**Benefits:**
- Improved power quality at the end of the power line, where consumption was fluctuating depending on a season and day of the week
- Avoiding power outages by balancing load and incoming capacity
- Investment deferral. Installing Energy Storage Module allowed customer to postpone the investment into the new power line and the transformer
- Available back-up power during incoming line failures
References
DES in Sweden, installed 2013

Description:
- Power rating: 75 kW
- Energy: 110 kWh

Application:
- Peak shaving
- Load shifting
- Power quality
- Wind power integration
- EV charging

Benefits:
- Main transformer working in better conditions. No overloaded is needed
- Reduced consumer’s power fee with reduction in the transformer losses
  - Load shifting from high peak demand to off-peak period with high reduction in the transformer losses
  - Peak shaving in order to improve the power factor of the utility transformer
- Reactive compensation (cos fi=0.99) and harmonic mitigation independent from the status of the batteries
- Integrating wind to distribution network
  - Frequency and voltage regulation; spinning reserve
Description:
- Power rating: 260 kVA
- Energy: 62.5 kWh

Application:
- Renewable integration
- Frequency regulation (while diesel is off)
- Power quality
- Back-up power
- Islanding

Benefits:
- ESM improves the overall efficiency of the energy system by increasing the penetration of wind energy while decreasing the amount of diesel generation.
  - Reduced energy (inc freight) costs and dependency on fossil fuels
  - Higher penetration of installed Wind
  - Smart hybrid microgrid
- Provides smooth grid integration of renewable energy by reducing variability
- Flattens demand peaks, thereby reducing stress on existing grid equipment (eg DG)
- ESM also supports the frequency and voltage of the microgrid even when the demand and wind generation fluctuates

References
DES in North America, installed 2014
Description:
- Power rating: 1 MW
- Energy: 250 kWh

Application:
- Peak shaving
- Frequency regulation
- EV charging
- PV integration, capacity firming
- Islanding

Benefits:
- ESM is installed to grid connected facility with integrated solar panels and electric vehicle charging stations
- Increasing the penetration of solar energy and integration of renewables to the distribution grid via capacity firming, frequency and voltage regulation
- Enabling fast charging for multiple electric vehicles via peak shaving and energy stored in batteries
- Including advanced control algorithms - forecasting to enhance operational efficiency
Description:
- Power ratings: 27 MW - 15 minutes / 46 MW - 5 minutes
- Ni-Cd batteries

Application:
- Spinning reserve, back-up power
- Power quality
- Frequency regulation

Benefits:
- Backup power in the event of power plant outage or transmission line equipment failure
- Improved reliability of electricity services
- Emergency power source to feed energy to the grid until backup generation can come online
  - 15 minutes power boost to get generators online, leading to 90 percent reduction of power blackouts due to grid faults
- Seamless switch from power line to battery and back to power line goes unnoticed by users
- ESM operation at temperatures as low as -52°C
Takeaway
Conclusion
Energy storage raises the efficiency at every level of the grid by:

- Maintaining the balance between generation and demand
- Providing smooth grid integration of renewable energy by reducing variability
- Storing renewable generation peaks for use during demand peaks
- Provides stored energy for minutes up to several hours, when electric power is most needed or most valuable for the network
- Raising power quality with better voltage and frequency regulation as well as minimum interruptions
- Flattening demand peaks, thereby reducing stress on grid equipment
- Providing a reliable source of energy to communities
- Providing infrastructure support as loads increase with electric vehicle use
- Energy Storage Modules make the grid smarter by giving the option to use the electrical power when it has the biggest impact in the network's performance