Energy storage

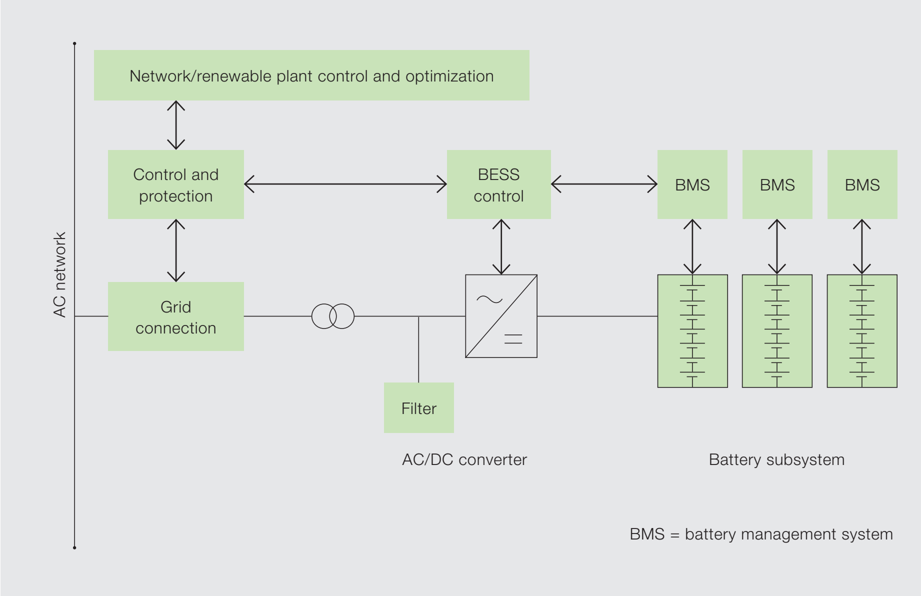
The benefits beyond the integration of renewables

PAT HAYES, JANISSA AREVALO – Many countries are currently in the early stages of a renewable energy revolution. However, as solar- and wind-based generation capacities in electrical power networks soar, operators are finding it increasingly difficult to maintain grid stability and reliability. Two of the principal reasons for this are the short-term variability and low predictability inherent to renewable sources. Energy storage systems can address these issues and thus provide an important contribution to the evolution of the electrical power grid. However, energy storage can do even more than that: Placing energy storage strategically across utility fleets can also offer new ways to enhance the provision and pricing of electrical energy and associated services and provide a way to optimize the entire power system.

Title picture
Strategically placed energy storage systems can transform the business model of enterprises involved in the supply of electrical energy.

The benefits of energy storage span power generation, transmission and distribution – ie, from the generator all the way to the end user.

1 Functional block diagram of a battery energy storage system



Electric energy storage encompasses a broad range of technologies: batteries, flywheels, pumped storage, heat storage and compressed air. Even electric vehicles can be used to store energy. At present, most utilities favor battery energy storage systems (BESSs) as these are easily scalable and can be located almost anywhere.

Regardless of which technology is being used, a complete energy storage system (ESS) – ie, one that can operate in stand-alone mode or be connected to the grid – has four major components: the storage medium, the control system, the power conversion system and the balance of plant (BOP). The design of these components strongly depends on the energy storage application and the power rating required. The storage medium can be based on one of many battery technologies – eg, lithium-ion, sodium-sulfur, nickel-cadmium, lead-acid, or flow batteries. For higher power requirements, several power converter systems can be connected in parallel to provide dynamic control of active and reactive power flow in both directions. Furthermore, monitoring and control systems that allow manual and automatic operation of all components supplement the energy storage system. Communication protocols support remote control and monitoring and may provide load and weather forecasts. In addition to the system components, BOP equipment such as transformers, protection equipment and switchgear are needed to ensure a safe and reliable grid connection and operation of the system [1] → 1.

ABB's Enterprise software builds a link between the energy storage system and the consumer.

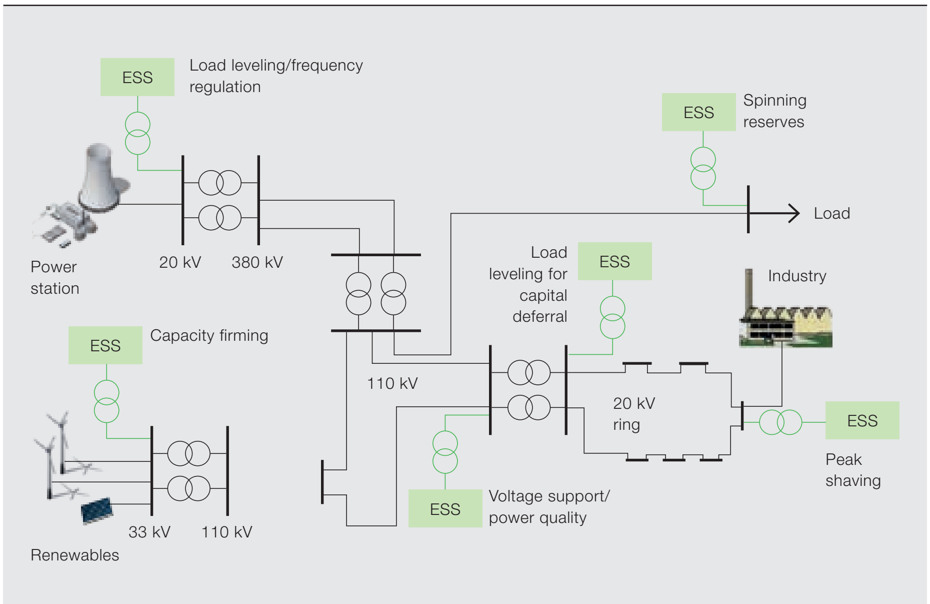
Applications and benefits of energy storage

The benefits of energy storage span power generation, transmission and distribution – ie, from the generator all the way to the end user. Further, modern storage technology and power electronics can support the operation of large, interconnected infrastructure – as well as small, isolated power system setups – across a wide range of applications → 2.

Frequency regulation

Using energy storage to provide ancillary services such as frequency regulation or

2 Main applications of energy storage systems



To provide an effective spinning reserve, the ESS is maintained at a level of charge ready to respond to a generation or transmission outage.

to act as spinning reserves for the electrical grid is proving to be a successful business model that has minimal operation and maintenance costs – with a significantly lower carbon footprint than conventional generation. For frequency regulation applications, the ESS is charged or discharged in response to an increase or decrease, respectively, in grid frequency caused by a sudden misalignment of energy supply and demand. This approach is particularly attractive due to its rapid response time and emission-free operation.

Peak shaving is similar to load leveling, but is for reducing peak demand rather than for economy of power system operation.

Spinning reserve

To provide an effective spinning reserve, the ESS is maintained at a level of charge ready to respond to a generation or transmission outage. The system can respond within milliseconds to supply power to maintain network continuity while the backup 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.

Load leveling

Load leveling usually involves storing power during periods of light loading on the system and delivering it during periods of high demand. During the periods of high demand, the ESS supplies power, reducing the load on less economical peak-generating facilities. Since utilities must design their network according to the peak power usage capacity, having energy storage strategically located next to the load allows for the postponement of investments in grid upgrades or new generating capacity.

Peak shaving

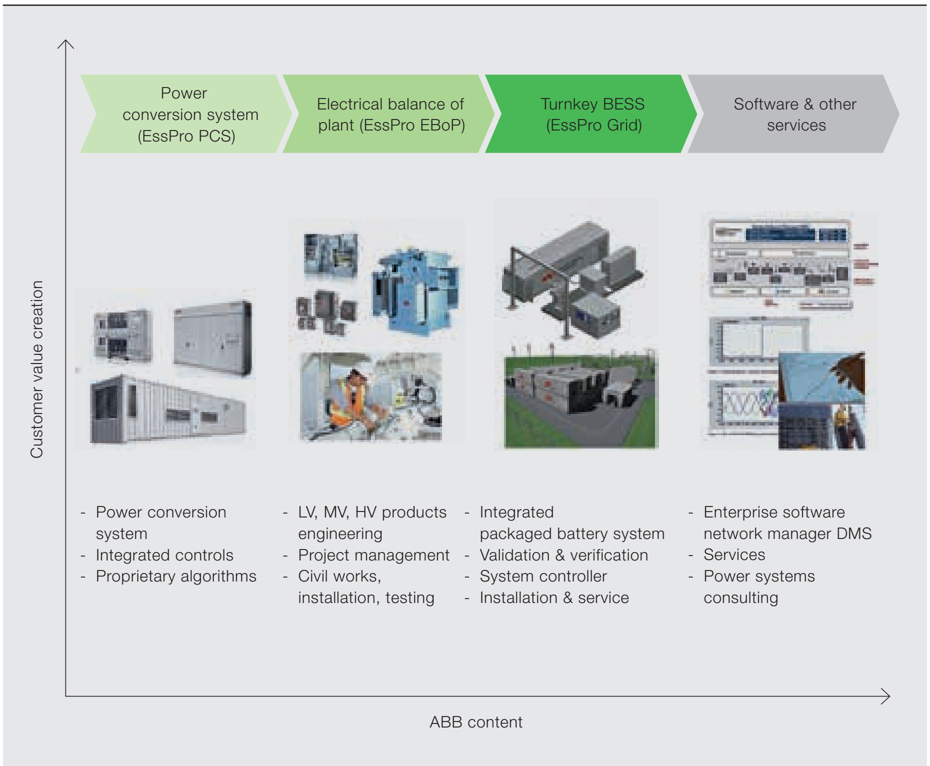
Peak shaving is similar to load leveling but is for reducing peak demand rather than for economy of power system operation. Peak shaving installations are often owned by the electricity consumer rather than by the utility. Commercial and industrial customers benefit from optimized time-of-use energy cost and demand charge management.

Power quality

For power quality applications, an ESS may help to protect downstream loads against short-duration events that affect the quality of the power delivered. For instance, voltage fluctuations due to

For every application, ABB offers optimized energy storage components and complete solutions that help to maintain grid stability and ensure reliable and high-quality energy supplies.

3 ABB's offering: From power conversion systems to integrated solutions



events such as power equipment failure, tree branches falling on the power line or the variability of power output from solar photovoltaic (PV) plants and wind farms, can have adverse impacts on the quality of power delivered to electricity consumers. These power quality issues can lead to brownouts and possibly a complete power interruption. ESSs can provide instantaneous voltage support by injecting or absorbing both active and reactive power. In addition to voltage support, the ESS may serve as an uninterruptible power supply (UPS) that can bridge unplanned disruptions in service, thus further enhancing the quality of power supplied to the energy consumers.

ABB's solutions are available for power requirements ranging from hundreds of kilowatts to tens of megawatts and are ready for connection to medium- or high-voltage grids.

Capacity firming

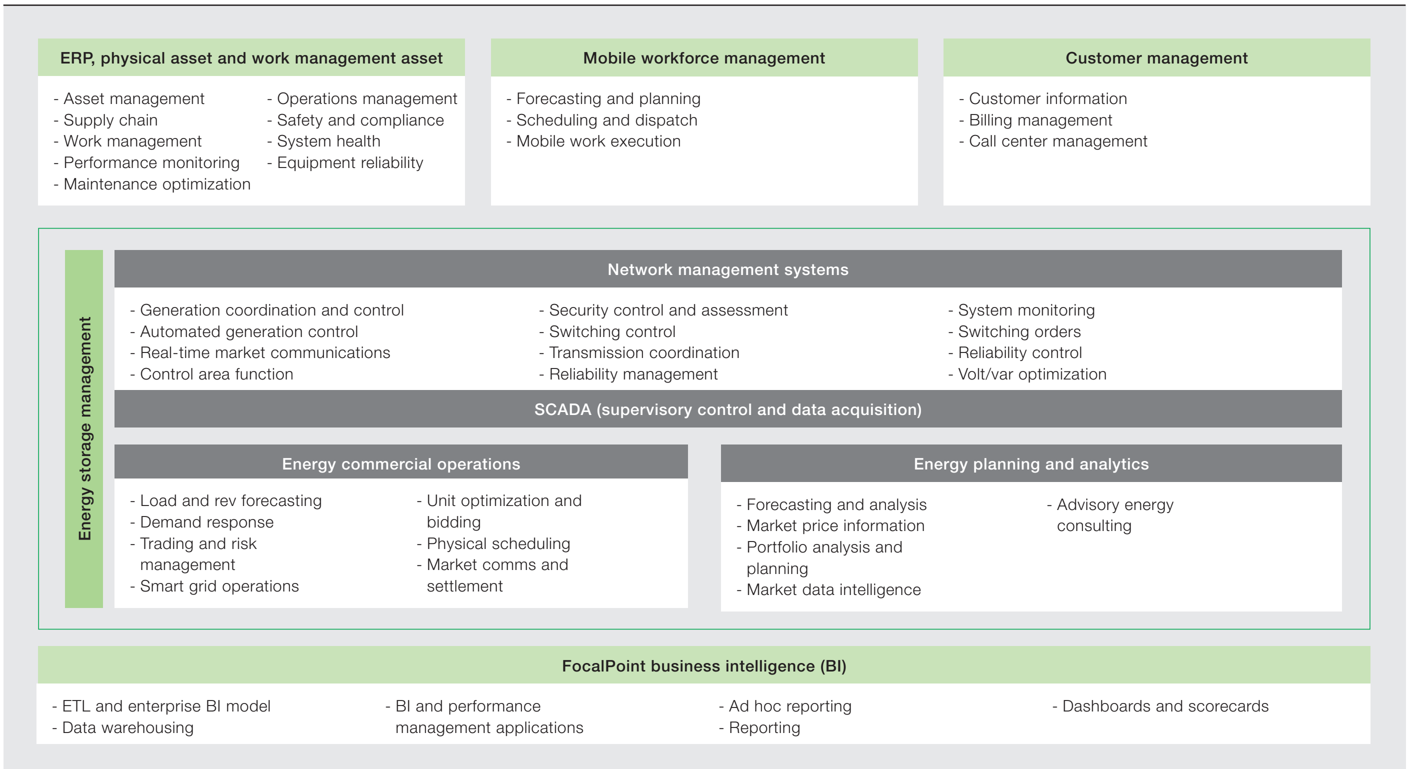
Maintaining the variable, intermittent power output from a renewable power plant at a committed (firm) level for a period is called capacity firming. The ESS smooths the output and controls the ramp rate (MW/min) to eliminate rapid voltage and power swings on the electrical grid.

For every application, ABB offers optimized energy storage components and complete solutions that help to maintain grid stability and ensure reliable and high-quality energy supplies. ABB's solutions are available for power requirements ranging from hundreds of kilowatts to tens of megawatts and are ready for connection to medium- or high-voltage grids [2] → 3. For example, ABB's EssPro™ Grid system features include dynamic active and reactive power control, active filtering of harmonics, islanding mode and black start capability. Furthermore, the implemented advanced control algorithms ensure compliance with the utilities' standards through in-depth knowledge of grid codes.

Taking a strategic approach

To realize these benefits, energy storage has to be an integral part of utility net-

4 Enterprise software solution map



works, not an isolated component to meet an immediate local need. Adding energy storage is more complicated than simply buying the hardware, connecting it to the grid and normalizing the voltage. Utilities need to look beyond the tactical or local level and take a holistic – or strategic – view of both the physical and financial components of energy storage.

The first step should be to develop a long-term resource plan to meet the utility's portfolio goals, independent of the particular energy storage technology at the outset. This enables the utility to determine how best to dispatch stored energy based on energy-price forecasts and, critically, how to provide electricity at the lowest cost.

Utilities that operate distribution grids need first to identify the weak points on the networks where energy storage can help to enhance system reliability and then determine the optimal point of common connection for it. ABB has a long experience in performing grid studies and can support the process for an optimized BESS design in relation to the technical and economic aspects.

Furthermore, grid operators are required to make decisions based on the performance of their network. These decisions are based on electricity price predictions and the use of those prices to forecast how often their energy storage facilities will run and how profitable they will be over a particular period. This requires additional inputs involving forecasts based on weather, forecasted load, grid knowledge, and system lifetime and lifecycle costs. By considering all of these key elements, the energy storage system can facilitate operational efficiency and enhance grid reliability.

Maximizing performance

Once this strategic analysis is completed, the utility will be in a position to determine the optimal storage technology and its size for each application. To get the maximum benefit from its investment in energy storage, a utility has to employ it as efficiently as possible – and for the greatest return at any given time. This requires software capable of monitoring and controlling more than just a single energy storage facility – the software has to enable grid operators to visualize their entire network.

ABB's Enterprise software builds a link between the energy storage system and the consumer. It can map distributed energy resources on the grid while also employing advanced algorithms to analyze weather forecasts and projected load

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

ABB's EssPro Grid system features include dynamic active and reactive power control, active filtering of harmonics, islanding mode and black start capability.

5 1 MW/15 min EssPro Grid BESS at EKZ in Dietikon, Switzerland

profiles to help utilities optimize the energy storage system's charging and discharging schedules ➔ 4. This not only enhances operational efficiency but also provides immediate access to those who need to use energy storage resources.

Improved power storage and grid stabilization

In 2012, together with EKZ – one of Switzerland's largest energy distribution companies – ABB commissioned the largest battery energy storage project of its kind in Switzerland ➔ 5. To enable additional power to be provided to the grid on demand, ABB supplied and installed a lithium-ion battery BESS that can provide 1 MW for 15 minutes. The storage facility is integrated into EKZ's power distribution network and is being evaluated for balancing peak loads, handling intermittent power supply and optimizing the grid. In island mode, it can power a complete office building. The BESS enables reactive power control and it can serve as a primary regulatory reserve for the transmission network. Significant experience has also been gained with the integration of a solar PV plant and electric vehicle charging stations.

A BESS to support solar power integration on Kauai Island

As a cluster of islands situated thousands of miles from the mainland, the state of Hawaii in the United States needs to import nearly all the fuel used to generate electricity. This leads to high energy costs. As a result, the state is embracing renewable energy sources with the intention of these meeting its entire energy needs by 2040. Kauai Island Utility Cooperative (KIUC) – a local not-for-profit utility in Hawaii serving 32,000 customers – is looking to BESS technology to help maintain its system reliability and efficiency as it continues to procure significant amounts of renewables.

As electricity systems becomemore complex, the importance of BESSs along the entire power value chain will further increase.

6 ABB's EssPro PCS c600

6a Indoor package

6b Outdoor package

As part of a new 12 MW solar energy park under construction in Anahola, KIUC deployed a 6 MW/4.63 MWh lithium-ion BESS consisting of eight battery containers supplied by SAFT (a leading producer of advanced batteries) and two containers housing an ABB 6 MW power conversion system. The main purpose of the BESS is to regulate the distribution voltage on the AC bus to prevent undervoltage and overvoltage conditions; serve as a spinning reserve to provide instant backup power supply in the event of unplanned outages; and help maintain frequency levels during the loss of generation or a sudden increase in demand.

Energy storage to support wind power integration in Canada

In 2013, the Cowessess First Nation installed an 800 kW Enercon wind turbine along with a 400 kW/744 kWh lithium-ion battery storage system and an ABB EssPro power conversion system on tribal land in Saskatchewan, Canada. Along with smoothing out the ebbs and flows of power from the wind turbine, the storage system also reliably dispatches power at times of peak demand.

On a windy day, the Cowessess system can dispatch 1 MW of electricity for a full hour – 800 kW from the wind turbine and 200 kW from the batteries. In addition, the system can be employed to firm the turbine's output for extended periods. The project verified that the system is compliant with anti-islanding standards when the grid was absent and the wind turbine was still in production. The system was also used in coordination with the Sask Powers utility's demand response programs and proved to be a valid technology for this application.

ABB's turnkey BESSs provide an essential contribution to the enhancement of system flexibility that is needed to accommodate significant amounts of renewable energy on the grid and to optimize power generation management around the world → 6. As electricity systems evolve and become even more complex, the importance of BESSs along the entire power value chain will further increase.

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[2] P. Casini, D. Cicio, "A bright future: Energy storage transforms the solar paradigm," *ABB Review* 2/2015, pp. 27–32.