A bright future

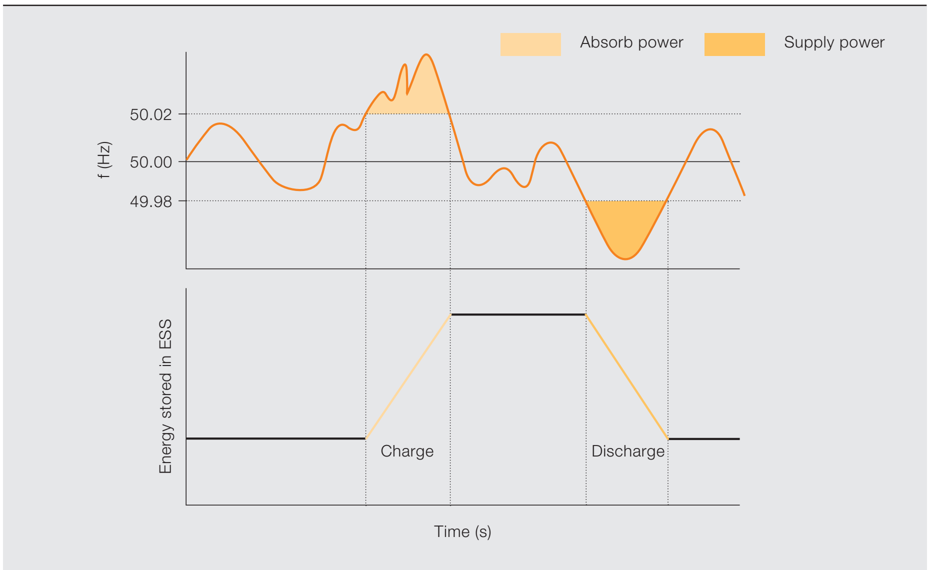
Energy storage transforms the solar paradigm

PAOLO CASINI, DARIO CICIO – The amount of solar radiation that reaches the Earth's surface is more than enough to supply the world's total energy needs. However, matching the intermittent availability of this energy source with demand can present a challenge, especially in the early morning and evening hours when solar energy sources do not produce enough power to meet demand. This challenge can be overcome by energy storage: Coupling solar energy sources with energy storage can eliminate the unpredictable nature of solar power, transforming it into a highly controllable and easily dispatchable source of power. From distributed storage systems to large centralized solutions, ABB has the domain know-how and energy storage solutions needed to enable precise control and connection of solar power installations.

Title picture
The energy the Earth receives from the sun is more than enough to meet the world's power needs. But how can this energy be stored so power needs can be met when the sun is not shining?

Placing energy storage adjacent to the solar PV systems enables precise control over when and how much power will dispatched on to the network.

1 Frequency regulation mode



Strategically placed, local solar power generators not only reduce greenhouse gas emissions, but they also enhance grid reliability and security: Placing smaller, distributed generation sources close to the load makes the grid more resilient against outages and power quality disruptions, which benefits both local utilities and end users. There are economic benefits to be had too if the consumer can generate and consume his own power and thus avoid utility charges.

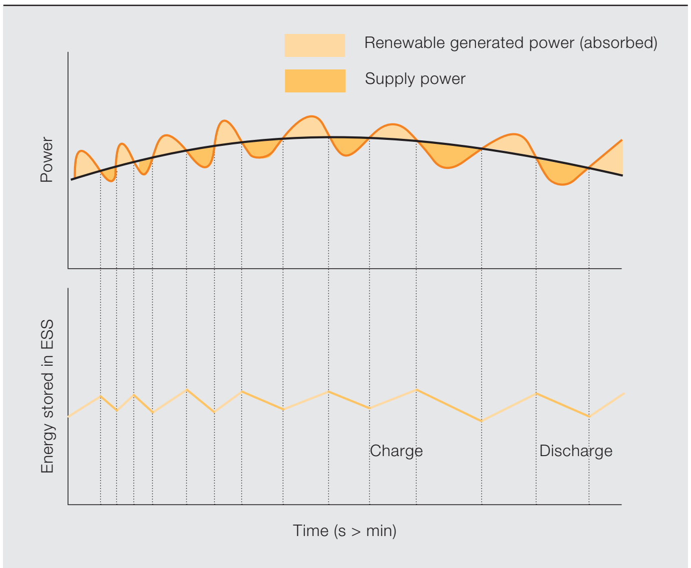
However, in order to fully realize the potential and value of solar power, its intermittent nature must somehow be overcome. One major tool for doing this is the energy storage system (ESS). Placing energy storage adjacent to the solar photovoltaic (PV) systems enables precise control over when and how much power will be dispatched on to the network. Energy storage can also enable smooth power output, which improves power quality for the end users. Further, an ESS allows for more efficient use of the power generated from the distributed solar plants.

PV energy storage helps save even more by making the solar PV plant a reliable source of power when the customer's usage is at its highest. At these times, energy that was stored by the ESS during low demand periods can be used, thus avoiding hefty peak demand charges.

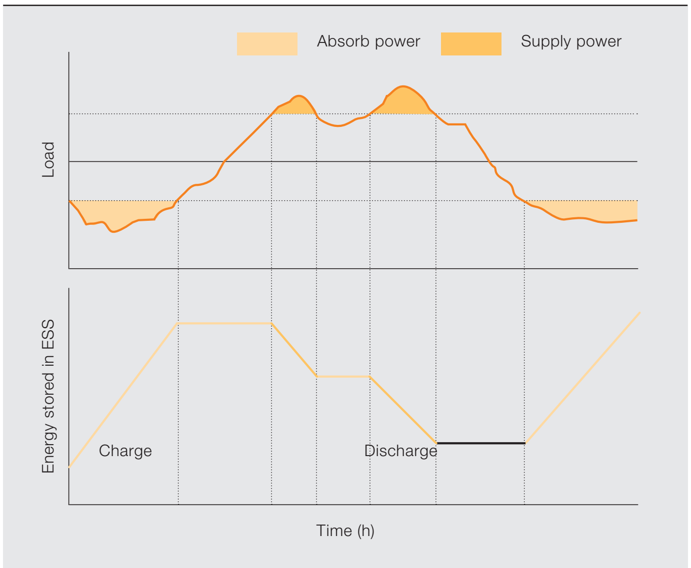
ABB's community storage solutions are designed for all these cases and can be used in applications ranging from 25 kW to multi-megawatts. For example, ABB's integrated energy storage module (ESM) comprises a transformer, low- and medium-voltage switchgear, and automation equipment such as inverters. This unique design provides a quick, simple installation with a high level of safety for the equipment and operators. The choice of

Coupling energy storage with utility-scale solar PV allows the unpredictable and variable solar plant to become an easily controllable resource that can be dispatched to provide second-by-second frequency regulation in real time.

2 Capacity firming mode



3 Load-shifting mode



which lithium-ion battery technology to use in a particular ESM is based on the application's specific requirements.

Utility-scale solar energy

The increasing demand for power sources that emit less carbon and are more sustainable is driving utility-scale solar power generation growth at an unprecedented rate. However, the electrical grid was designed to deliver a planned and stable supply of power from centrally located power sources, via the transmission and distribution lines, to end users. Engineers carefully plan and constantly recalibrate the grid to ensure that power is available where it is needed at the precise moment it is needed. Adding energy sources that are variable, intermittent and distributed throughout the transmission and distribution network requires significant additional control and precision to make sure demand and supply are aligned.

ESS for frequency regulation

System operators often use large-scale generation facilities to not only provide bulk power to the end users, but also to provide the ancillary services needed to maintain the integrity of the electrical grid. One of the more pertinent of these services is real-time frequency regulation. Around the world, the electrical grid needs to operate at either 50 or 60 Hz in order to ensure the facilities and critical equipment used in manufacturing are properly powered. This requires instant and continuous balancing of electricity supply with demand. This is difficult enough to do with traditional, predictable and easily dispatchable generators, but the task becomes extremely complex indeed when solar sources, with their inherent variability, are added to the mix.

Further, as more utility-scale solar plants are brought online and more coal-based plants shut down, the easily controllable resources that provide such grid services become fewer. However, coupling energy storage with utility-scale PV allows the unpredictable and variable solar plant to also become a more easily controllable resource that can be dispatched to provide second-by-second frequency regulation in real time. When used in combination with solar, the ESS is charged or discharged in response to an increase or decrease of grid frequency → 1. This approach to frequency regulation is a particularly attractive option due to its rapid response time and emission-free operation.

ESS for capacity firming and ramping support

In order to maintain the integrity of the electrical grid and ensure power quality, voltage and frequency must constantly be kept at specified levels. However, with utility-scale PV plants, the ability to maintain these levels can be quickly compromised by the passing of clouds, an abrupt change in the weather or a crack in a solar PV panel. These variations can cause rapid fluctuation of the PV power output – resulting in deviations in frequency and voltage. Even a second of cloud coverage can cause the voltage to drop, de-

> By quickly absorbing or injecting power in response to grid control signals, the ESS can ensure that the correct frequency and voltage levels are maintained.

4 ABB's EssPro PCS container and cabinet enclosure configurations

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stabilizing the local network. The sudden drop in voltage and power can also cause deviations in frequency levels, disrupting the overall operating characteristics of the grid. By quickly absorbing or injecting power in response to grid control signals, the ESS can ensure that the correct frequency and voltage levels are maintained → 2. Not only can energy storage provide this capacity firming for the PV system, but it can also make sure that the PV power output increases and decreases at a rate specified by the grid operators to ensure that the PV plant abides by local grid codes.

ESS helps network reliability through load shifting

In areas with a high penetration of solar generation, the local utility network is susceptible to resource adequacy issues when demand and PV generation are out of balance – specifically, in the early morning and evening hours when demand begins to increase but solar sources are not producing enough power to accommodate this demand. This is where energy storage can help the system operator maintain grid integrity through load-shifting capabilities. By coupling solar power with energy storage, the ESS can charge when generation is higher than demand and discharge when demand begins to spike, yet the sun is setting → 3.

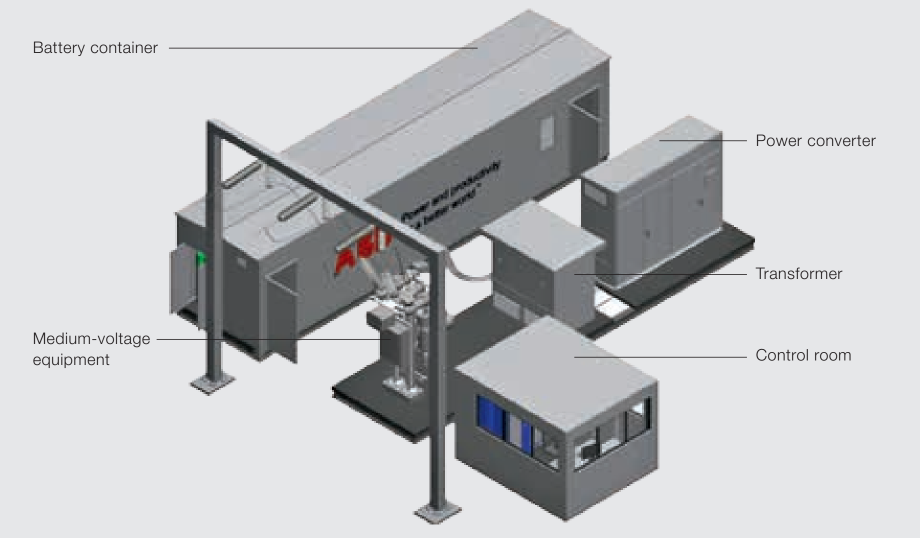
ESS for utility-scale solar performance improvement

Strategically placed ESSs can increase operational performance and grid reliability, and better integrate utility-scale solar generation. From power conversion systems (PCSs) to fully integrated and turnkey battery ESSs, ABB's EssPro™ energy storage solutions help to ensure the high performance of solar plants and to maintain grid reliability and efficiency → 4.

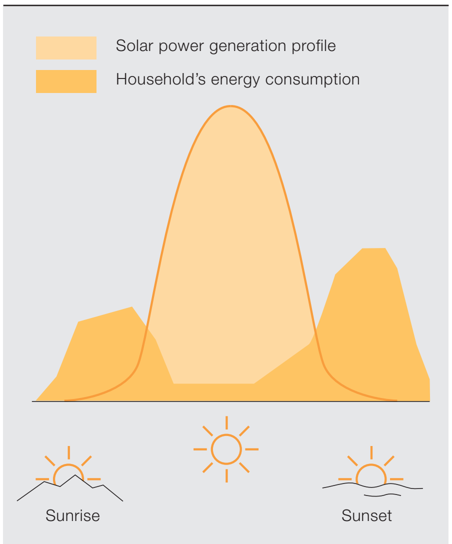
ABB's EssPro PCS links the ESS's battery to the electrical grid and converts the stored energy from DC to AC that is compatible with the utility network. In addition to the conversion technology, the system also provides the controls needed to help maximize the PV plant's operational performance.

ABB's EssPro Grid integrated, turnkey ESSs are available for power requirements ranging from hundreds of kilowatts to tens of megawatts and are

5 Example of a 1 MW, 15-minute layout of ABB's EssPro Grid



6 Residential PV demand and supply match poorly.



ready for connection to medium- or high-voltage grids → 5. Based on ABB's broad experience in electrical utility grids and in-depth knowledge of battery technologies, the EssPro Grid combines advanced controls and algorithms with the storage technology best suited for the application to maximize the performance of the ESS.

Residential-scale solar energy storage

The record growth experienced by the solar market worldwide since 2004 was initiated by the introduction of the feed-in tariff (FIT) scheme in Germany. For years, the FIT ensured remuneration for every solar kWh injected into the grid at a tariff substantially higher than the retail electricity price – without the necessity of a match between what was injected and the actual demand of the household, either in terms of energy balance or in terms of power equivalence at any given time. But this landscape is now changing, driven by the increased penetration of distributed generation further exacerbating associated grid instability issues; the approaching parity of self-generation costs and retail energy costs; and the diminution of incentives.

The new solar energy keywords are self-consumption (the consumption by the household of locally produced solar energy) and self-sufficiency (the capability to autonomously meet the energy demand of the household). To achieve these two aims, the misalignment between the daily solar power profile and the household demand must be overcome → 6. This is achieved by the addition of an energy storage capability to the traditional PV system.

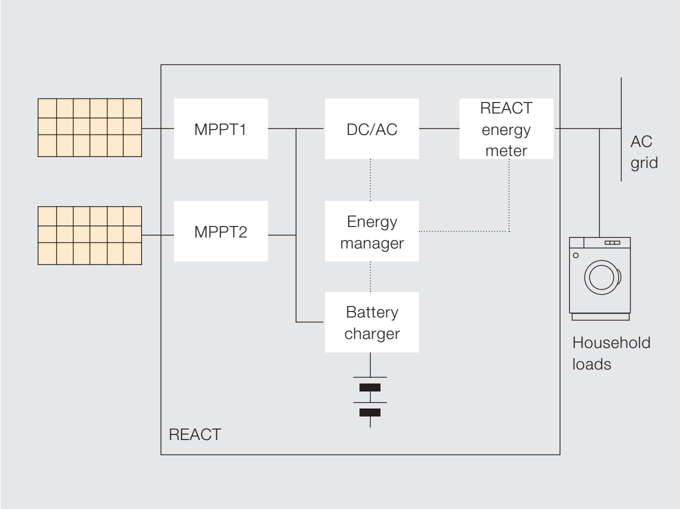
REACT

Practicality and cost make electrochemical batteries the best way to store excess solar energy. But the unplanned addition of batteries to a PV plant – even if it could bring self-sufficiency – would most likely result in a very doubtful financial return. An economically sustainable residential PV/storage solution is, instead, the result of a compromise between the size of the installed battery bank and the levels of self-consumption and self-sufficiency the household can achieve with the addition of a tailored energy management strategy.

> The misalignment between the daily solar power profile and the household demand is overcome by the addition of an energy storage capability to the traditional PV system.

7 ABB's REACT has battery storage in the left compartment and electronics in the right.

8 A typical REACT layout: A dedicated energy meter delivers real-time feedback on self-consumption and self-sufficiency.



ABB's residential energy storage system REACT (renewable energy accumulator and conversion technology) → 7 is designed to realize this trade-off in the best possible way. A REACT system comprises a grid-tied PV inverter (up to 5 kW) fed from a DC link – to which the maximum power point tracking (MPPT) trackers (connected to the PV array) and a bidirectional battery charger are connected → 8. Though its integrated DC-link architecture is the best cost solution for new installations, it can also be used to retrofit existing PV plants as an AC-link battery charger by simply not connecting the PV array to its input.

The energy storage section of a REACT system is made of lithium-ion batteries with a modular architecture that allows the system to expand from its native 2 kWh up to 6 kWh (field upgradable). An onboard load management system allows interaction with selected loads/appliances, thus boosting the energy independence of the household by up to 60 percent in the basic system configuration.

The choice of lithium-ion batteries is driven by their favorable expected cost profile in coming years, size/capacity performance, charge/discharge power rating, efficiency and longevity (more than twice that of other current technologies).

The future is bright

The addition of an energy storage capability to a PV installation, no matter what size, helps overcome the intermittent nature of solar power and brings it into line with more traditional energy sources in terms of dispatchability, stability, controllability, etc. The continued development of storage technology is essential to speed the journey toward self-consumption, self-sufficiency and the flawless integration of solar sources into electrical power grids worldwide.

> The new solar energy keywords are self-consumption and self-sufficiency.

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