ENERGY STORAGE

KIUC case note

EssPro™ PCS to enable solar integration for the island of Kauai

ABB's EssPro PCS, in tandem with a Battery Energy Storage System (BESS), is used to help Hawaii reach its ambitious renewable energy targets by providing grid services such as capacity firming and frequency regulation. ABB's EssPro PCS can enable a BESS to quickly respond to changes in generation levels allowing for a smooth power output onto the grid.

Hawaii's energy goals

Nearly 2500 miles away from the US mainland, Hawaii's remote location and lack of natural resources to produce electricity means the state relies heavily on imports of petroleum and coal. These geographical constraints have resulted in Hawaii having some of the highest electricity cost per kilowatt-hour (kWh) in the United States, nearly triple the amount of the national average. To reduce its dependency on imported fuel, Hawaii is looking to locally produced power from renewables to help meet their growing electric power demand and environmental goals. As a result, Hawaii recently announced an ambitious target of having 100 percent renewable energy generation by 2045.

Energy storage in Kauai

With one of the most ambitious renewable portfolio standards (RPS) in the country, Hawaii's plans of relying 100 percent on renewables does not come without its challenges. Maintaining stability on an island grid with intermittent sources of power requires advanced technology to help compensate for fluctuations in power output.

Kauai Island Utility Co-operative (KIUC), a local utility in Hawaii serving 32,000 accounts, is looking to energy storage to help maintain their system reliability and efficiency as they continue to procure significant amounts of renewables. KIUC has deployed 6 megawatts (MW) / 4.63 megawatt-hour (MWh) lithium-ion battery energy storage systems. ABB's EssPro PCS allows the energy storage system to provide 12 MW of power for a short period of time utilizing the overload capability inherent within the power conversion system. It consists of eight SAFT battery containers and two 20 foot ISO containers housing ABB EssPro Power Converter Systems. Each ISO container houses 3 MW of ABB EssPro PCS converters. The battery system voltage is converted into a 387 VAC, 3-phase, 60 Hertz (Hz). This is fed to the grid via external connection transformers.

Anahola solar array

In the summer of 2015, KIUC completed the construction of a 12 MW solar PV plant in Anahola on the eastern side of the Garden Isle. With a project value of $54 million, this 59,000 panel solar PV plant will generate about 20 percent of electricity for the island. The Anahola solar array will generate energy at a cost of about 12.5 cents per kWh, which is nearly half the cost of electricity generated by imported fossil fuels.

Project highlights	
Location	Island of Kauai, Hawaii
EssPro PCS system rating	6 Megawatts
BESS system rating	6 MW / 4.63 MWh Lithium-ion
Functionality	PV smoothing functionality for solar grid integration and fast responding frequency regulation

Battery Energy Storage System (BESS)

A BESS (Battery Energy Storage System) is comprised of the energy storage medium, the power conversion system, and other ancillary equipment to protect and control the system. It is able to quickly inject and absorb active power to and from the electrical grid. A BESS can help reduce peak demand changes, integrate renewable sources, correct frequency, regulate voltage and provide backup power supply.

BESS functionality

- Load shifting
- Peak shaving
- Frequency regulation
- Spinning reserve
- Capacity firming and ramp support
- Power quality improvement

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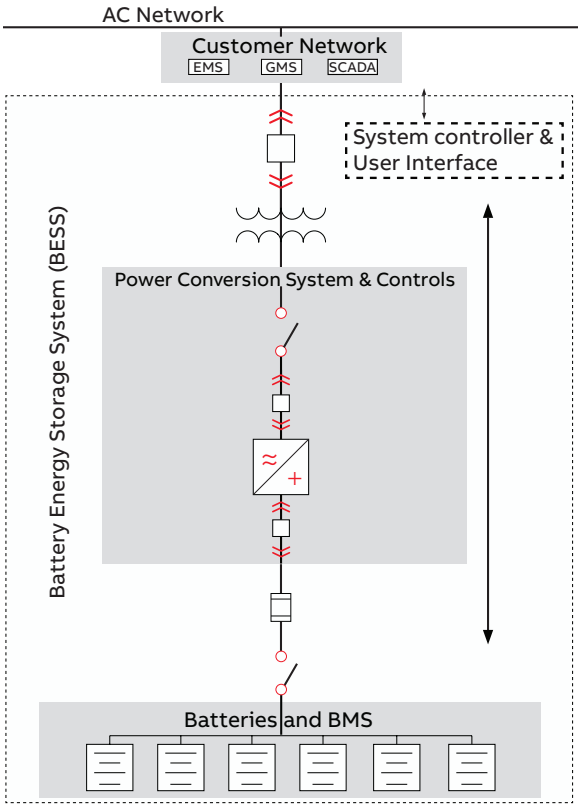
01: Generic single-line diagram



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Site information

With a population of 65,000 people, the Island of Kauai is the fourth largest inhabited Hawaiian Island and Kauai Island Utility Cooperative (KIUC) is the only provider of electric service. It provides all of the facilities, equipment and personnel required to meet the power generation, transmission, and retail distribution needs of its consumers. KIUC's average load is about 75 MW, which is met by a combination of different generation sources including multiple renewable energy sources. On the sunniest days, 90 percent of Kauai's daytime energy needs are currently met by renewable sources. In order to meet their clean energy targets and provide more cost effective and locally generated power for their residences, KIUC installed a 12 MW solar farm called Anahola Solar array. To ensure that the island grid can maintain system stability and run the PV power plant as efficiently as possible, KIUC decided to look to energy storage to help safely integrate the solar PV plant.

To achieve these objectives, KIUC trusted the power elecronics technology of ABB, and the energy storage technology of SAFT, to be a part of the installation of a new 6 MW energy storage system, which includes battery containers, power electronics, system software and controls. The primary goal of this unit is to respond to sudden changes in frequency within permissible tolerance irrespective of the change in solar farm output. This, in turn, helps KIUC in avoiding the operation of load shedding scheme. This application requires a very fast response from the BESS without losing the synchronization to the grid. The EssPro PCS is a high performance converter capable of responding to the changes in grid frequency within 50 milliseconds (ms). In addition, this converter keeps the battery system synchronized with the grid and can stay operational at a frequency bias of 120 Hz deviation.

Bringing stability to the grid

The battery energy storage system is installed on a small island grid with low Short Circuit Rating. Therefore, it is imperative that proper measures are taken to reduce the impact of the intermittent energy sources being installed on the grid. The EssPro PCS continues to operate in frequency control mode at a high response rate of less than 50 ms. This helps to avoid curtailment of the renewable source, enabling the most efficient use of the solar PV plant and ensuring system reliability for the region.

BESS functionality

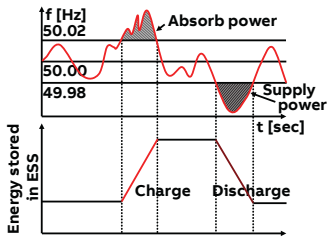
The current EssPro PCS system operates in four different modes. The priority is in the order they are listed:

- Frequency control mode
- Smoothing control mode
- Voltage control mode
- Overload capability of 200%

02: Frequency regulation

03: Capacity firming

04: Voltage regulation



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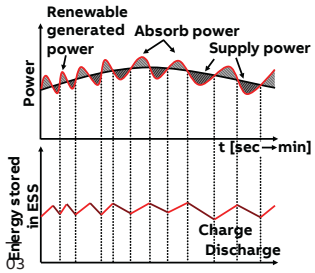

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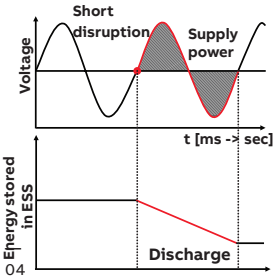

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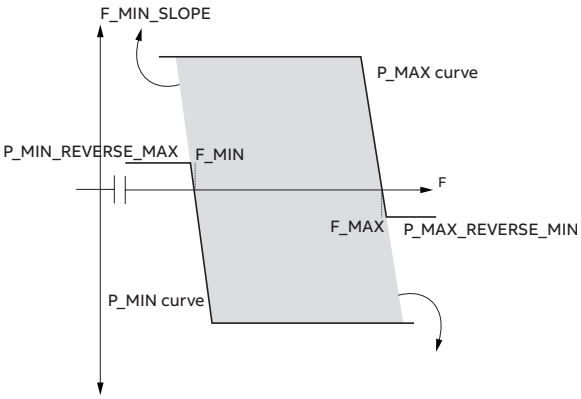
05: Frequency envelope control

Frequency envelope control

From figure 5, it can be observed that the frequency envelope control logic is used and the BESS output is based on frequency limits and power output slopes which form this envelope. This logic allows the user to determine when the BESS shall react to change in frequency. It also ensures that adequate power is available to perform frequency control when needed. Within the dead band, the BESS is free to perform other functions such as smoothing for the PV farm or maintaining the battery State of Charge (SOC). As mentioned earlier, this is only limited by the charge and discharge limits set within the controller. These limits ensure that the BESS has enough power/energy to respond to the sudden frequency excursions as the frequency exceeds the specified dead band limits.



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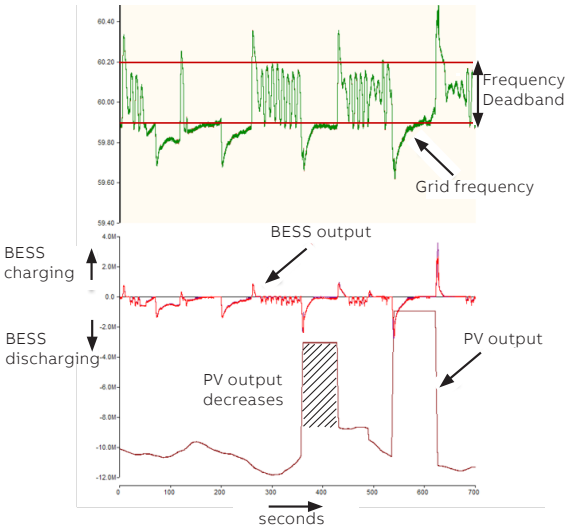
For optimum operation of the battery and State of Charge management, charge/discharge limits take priority over all the modes mentioned above. As long as the battery charge/discharge is within limits, the battery shall operate in the modes specified above based on the requirement. Predominantly, the BESS installed on KIUC's island works in frequency control mode.

Field data analysis

Figure 6 shows the BESS and PV power output on the lower graph and system frequency on the top graph, over the total recorded duration. It can be seen that when the frequency goes outside the dead band, the EssPro PCS responds accordingly. For a frequency over the maximum dead band limit, EssPro PCS proprietary software communicates to the BESS to begin charging and to then discharge when the frequency falls below the minimum dead band limit. The response of the BESS is based on the frequency control logic and is adjusted to bring the frequency within dead band as soon as possible. Such changes in frequency can be due to a sudden loss in load or due to irregular PV farm output.



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06 Recorded field data of two units of EssPro PCS sized at 3MW each. The output of these units is overlapped in the graph above.

Event	Time of event (s)	BESS response time (ms)	Event description
1	6.5	23	Over frequency
2	120.5	20	Over frequency
3	260	49	Over frequency
4	428	30	Over frequency, 5.6 MW increase in PV output
5	535	20	Under frequency, 9.6 MW drop in PV output
6	621	23	Over frequency, 10.2 MW increases in PV output

Continuously improving plant performance

The EssPro PCS unit, while operating in autonomous mode, has been constantly monitoring the grid conditions and responding to the frequency drops and overshoots to keep them within their set limits. Regulating grid frequency eliminates the need to either curtail the PV farm output or activate a load shedding scheme.

Available in system sizes ranging from 100 kW to 50 MW, ABB's EssPro PCS and its advanced controls maximizes the performance of the energy storage system and enables a variety of grid applications.

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07 Due to its modularity and compact design, the 3MW power conversion system is easily transportable

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