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Pole Mounted EcoSTORE v2

The Transition to Renewables and the Need for Energy Storage

Australia and other regions are on a path to decarbonize their electricity grids by significantly increasing the adoption of renewable energy. Australia now boasts the highest rooftop solar penetration in the world.

To support this shift to intermittent renewables, energy storage is essential at all levels of the electricity network.

This includes large centralized pumped hydro systems, high and medium voltage (HV/MV) connected Battery Energy Storage Systems (BESS), distributed low voltage (LV) BESS, and home energy storage systems.

Among these, LV connected distributed BESS are particularly valuable as they capture the widest range of benefits, as highlighted in ARENA's 'Grid vs Garage' report.

Pole Mounted Battery Energy Storage System

The EcoSTORE v2 is a pole-mounted, low voltage (LV) connected 40kVA/85kWh Battery Energy Storage System (BESS), ideal for community battery or network support applications.

The EcoSTORE provides approximately 2 hours of storage at full output, utilizing Lithium Iron Phosphate (LFP) batteries. LFP batteries are recognized for their higher cycle life, greater temperature tolerance, and lower fire risk compared to the alternative lithium chemistries.

The EcoSTORE ES40-85 comprises two cabinets: one for the batteries and Battery Management System (BMS), and another for the electronics, including the Power Conversion System (PCS), switchgear, customer modem, and other components. The two cabinets are connected via a set of DC power and communication cables.

This capacity is also suitable for pole mounting on both wooden and concrete poles.

Since the PCS in the EcoSTORE v2 is identical to our EcoVAR v2 STATCOM, customers can purchase STATCOM units and later upgrade them to BESS units by adding the battery enclosure and batteries. A pole-mounted BESS offers several advantages over a pad-mounted BESS, including:

- Easier to find an installation location, as no easements are required.
- Less chance of public pushback, as it doesn't occupy sidewalk or park space.
- Lower risk of audible noise issues.
- Equipment is protected from flooding and virtually no earthworks are required.

The 85kWh battery capacity is ideal for 'solar sponge' or energy-shifting applications, where the BESS stores solar energy during the day and releases it during peak evening periods.

ECOJOULE
ENERGY

Common DNA with the EcoVAR STATCOM

The EcoSTORE v2 represents an evolution of EcoJoule's highly successful EcoVAR STATCOM and EcoSTORE v1 products, demonstrating proven performance across diverse installations and environments, from the hot summers of Australia to the cold winters of Northern Europe.

Much of the electronic hardware and real-time control software remains consistent with its predecessor.

This shared technology platform among EcoJoule products ensures that aspects such as operation, control, and mechanical design have been thoroughly validated in grid applications and outdoor pole-mounted environments.

The EcoSTORE v2 utilizes the same EcoVIEW Engineering Access Software. It also offers several advantages over EcoSTORE v1, including:

- The ability to transfer real power between phases to eliminate phase imbalance
- The option to install an EcoVAR and later upgrade to an EcoSTORE
- A simpler and quicker installation process
- Superior active harmonic filtering capability

Functional Highlights

The EcoSTORE v2 integrates all the grid support features of the advanced EcoVAR STATCOM (Static Compensator) with Lithium-ion battery storage.

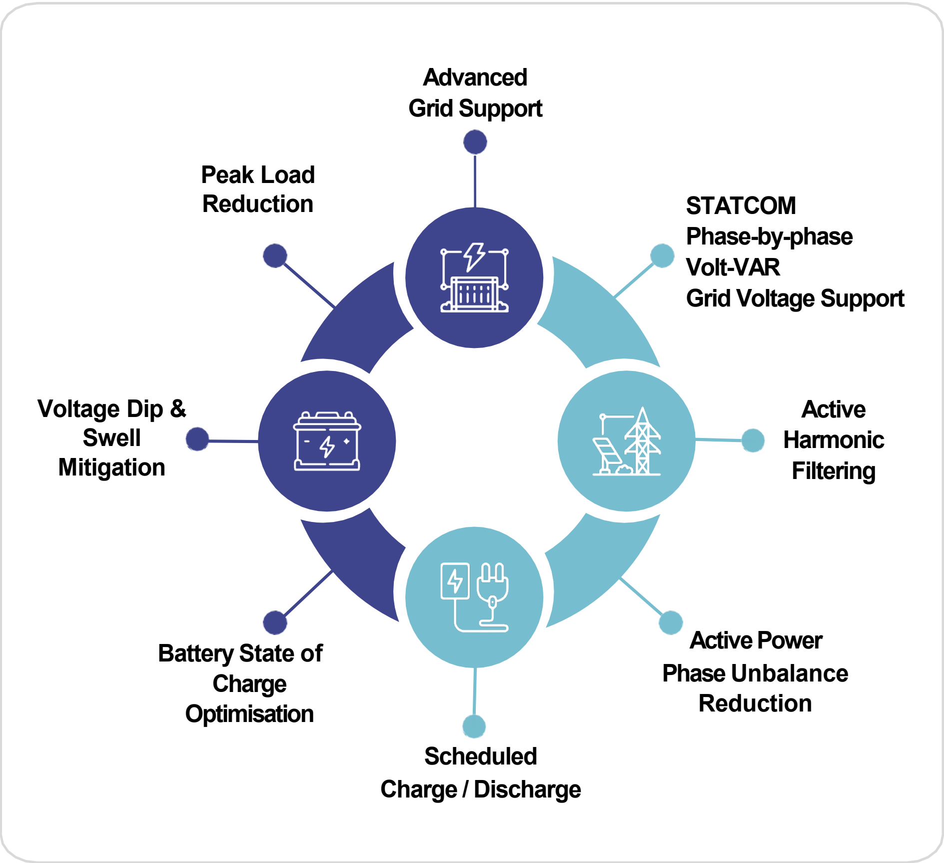
It offers **full four-quadrant** power capability, able to sink or source any combination of active and reactive power up to an apparent power rating of 40kVA. This means it can sink or source up to 40kVAr of reactive power and up to 40kW of active power, operating at any point within the 40kVA PQ capability circle at a maximum **ambient temperature of 50°C**.

The EcoSTORE v2 features a **4-wire** connection (three phases plus neutral), enabling true phase-by-phase operation. It incorporates the **Volt-VAR** capability of the EcoVAR STATCOM and can provide reactive power along a steady-state droop control curve on a per-phase basis. A **Volt-WATT** function can also be enabled with the attached BESS as per AS4777. This improves the performance of grid-tied solar inverters as they are no longer required to perform these functions.

The EcoSTORE features several active power control modes, including **manual control**, **scheduled control** (based on a daily schedule), **remote control** (via a utility server or ADMS), and a unique **Advanced Grid Support** (AGS) mode specifically designed to support weak networks.

Additionally, the EcoSTORE offers a unique (and patent-pending) capability to **transfer active power between phases** without requiring a coupled BESS. This is complemented by phase-by-phase **reactive power control**. Together, these active and reactive controls effectively **eliminate phase imbalance** across a wide range of low-voltage (LV) networks, accommodating various resistance to reactance (R/X) ratios.

These powerful grid support and energy-shifting functions enable the full potential value stack of distributed storage to be captured as well as prolonging the life of existing public infrastructure while ultimately reducing cost to the end consumers.



Advanced Grid Support (AGS)

Advanced Grid Support (AGS) is a sophisticated autonomous control mode developed to support constrained and low inertia low voltage (LV) networks.

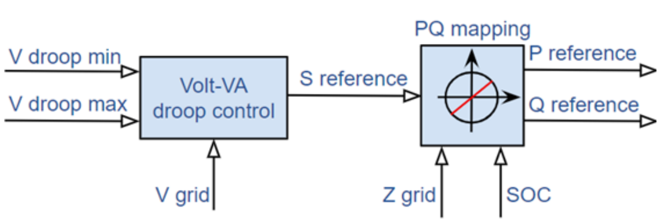
This mode uses both active and reactive power to optimally resolve network voltage issues and manage local network peak load events.

AGS adapts to any LV distribution network configuration by monitoring each phase voltage individually and using grid impedance information. This enables the EcoSTORE to maintain grid voltage within the normal operating range with minimal output power and battery capacity.

The AGS algorithm supplies the optimal amount of active and reactive power for various grid scenarios, including voltage rise/drop, different grid resistance to reactance (R/X) ratios, voltage unbalance, and sudden voltage swell/dip. Additionally, the algorithm optimizes battery utilization, thus improving its lifespan.

The diagram of the AGS algorithm below illustrates its two main components: the Volt-VA droop control (a combination of Volt-var and Volt-Watt) and PQ mapping. The normal operating voltage range is defined by the V droop min and V droop max parameters. The Volt-VA block determines the maximum control effort or apparent power (S) based on the grid voltage.

This apparent power reference is then mapped into active (P) and reactive (Q) power references according to the network's R/X ratio and the battery state of charge. This provides optimal grid voltage support for various LV distribution networks with different distribution transformer power ratings and conductor types (e.g., overhead lines, aerial bundled, or underground cables).

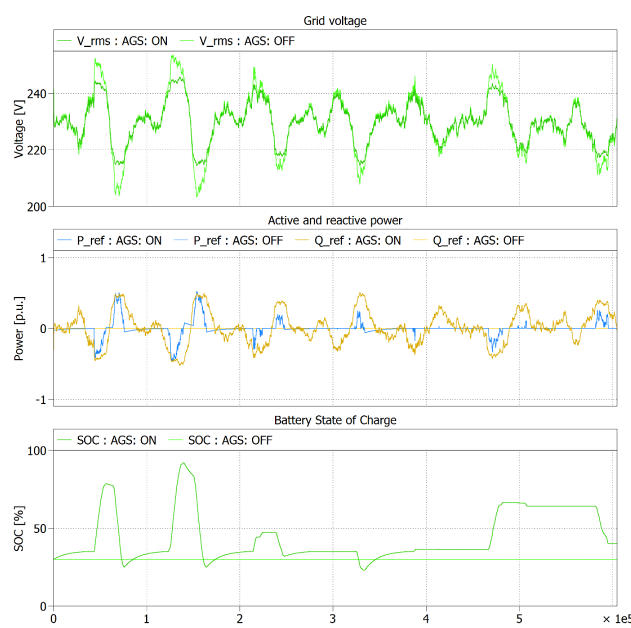


AGS Block Diagram

Users can set different deadbands for active and reactive power to optimize battery energy usage. For instance, a reasonably large active power deadband can be used so that active power (and battery energy) is only employed when the grid voltage deviates significantly from the nominal value. On the other hand, a smaller deadband can be applied to reactive power since it does not consume battery energy.

The AGS algorithm, by considering network impedance, optimizes the ratio of active to reactive power (P/Q) to match the network's R/X ratio. The plots below illustrate examples of the PQ output over a week for a network with an R/X ratio of 3, experiencing variable load and solar profiles.

The AGS significantly improves network voltage while managing the battery state of charge to conserve energy when needed and to charge when required. Given the highly variable nature of loads and generation on LV networks, the distributed autonomous AGS algorithm provides a significant advantage for network support compared to scheduled or centralized control methodologies.



AGS PQ response and impact on voltage

Phase Unbalance Reduction

Software and Firmware Design

The EcoSTORE v2 uses a similar code base to the well-proven EcoVAR V1, with additional functionality for phase balancing control, AGS, energy shifting, and battery management.

Like the EcoVAR, the code can be updated Over-The-Air (OTA), allowing new features to be easily added as they are released, enabling the EcoSTORE v2 to "improve with age."

Additionally, the EcoSTORE v2 supports the same modems and communications methodology as the EcoVAR V1 and uses an extended version of the same EcoVIEW Engineering Access Software.

SECURITY

The EcoVIEW software, along with its evolving fleet management variant, can be hosted on the utility's internal network or externally on a server in a country of choice to mitigate any potential security concerns.

Phase unbalance is becoming a widespread issue with increasing levels of rooftop solar penetration plus the introduction of new loads such as Electric Vehicle charges.

Since most domestic residences have single-phase connections, the introduction of large single-phase generators (e.g., rooftop solar) and new loads (e.g., EV chargers and air conditioners) can exacerbate existing imbalance issues.

Phase unbalance is a dynamic phenomenon, with phase voltage unbalance continually changing throughout the day. This makes it impossible to address through traditional "re-balancing" methods, such as reconnection of consumers.

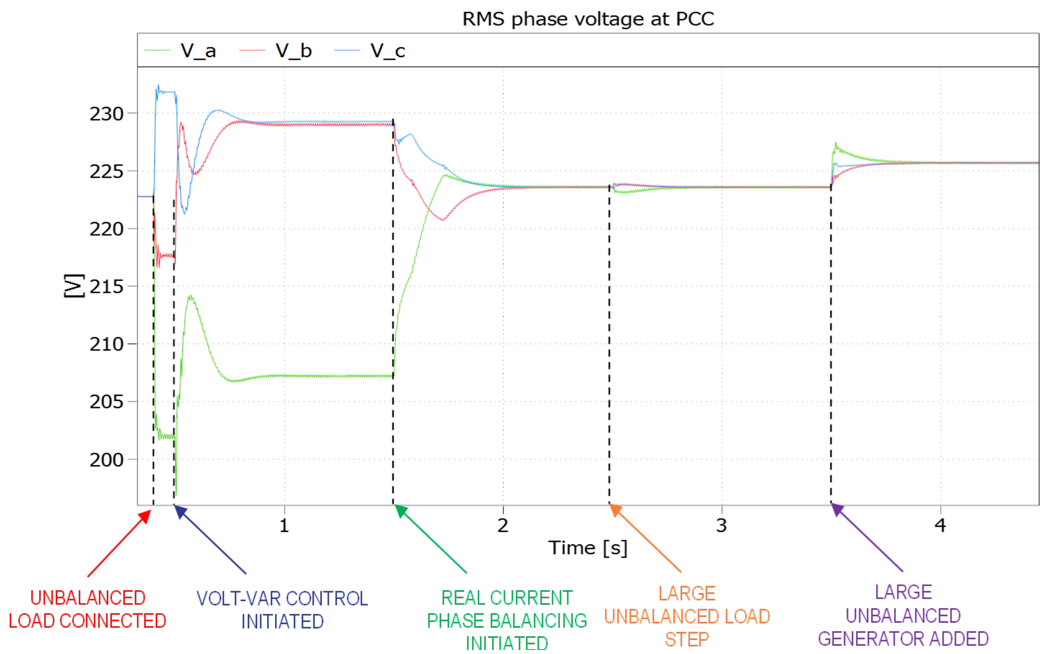
Modern STATCOMs, like the EcoJoule EcoVAR V1, can inject reactive power on a per-phase basis to effectively address phase unbalance, particularly on networks with high reactance. However, on weaker, highly resistive networks (high R/X ratio), reactive power alone is insufficient to effectively address unbalance.

EcoJoule has developed a unique (patented) methodology to transfer active power between phases in the EcoVAR and EcoSTORE v2. This approach is extremely effective at resolving phase unbalance across all networks, including those with high R/X ratios.

The plot below shows the response on a network with a source impedance R/X = 3. Volt-VAR control is initiated at around 0.5 seconds and is able to reduce the unbalance by several volts.

The real current balancing algorithm is initiated at 1.5 seconds, and it can be seen to eliminate all voltage unbalance and the PCC.

With the phase balancing algorithm active, unbalanced load and generation steps have little impact on the actively balanced system.



Mechanical Design

The EcoSTORE v2 is housed as two IP56 rated powder coated stainless steel enclosures.

Like the EcoSTORE v1, the EcoSTORE v2 utilizes a "double skin" design for thermal management. The electronics and batteries are enclosed inside separate inner cabinets and heatshields are placed over the unit to prevent direct solar radiation on the electronics and battery enclosures. This serves several purposes:

1. **Minimises the internal cabinet temperatures**, prolonging the life of the electronics and batteries.
2. **Enables optimum thermal design** that uses temperature-controlled fans, eliminating the need for air-conditioning systems. Air-conditioning systems drastically reduce the round-trip efficiency of Battery Energy Storage Systems (BESS), require frequent maintenance, and produce high levels of acoustic noise, making them unsuitable for outdoor pole-mounted enclosures.
3. **Minimizes the operation and speed of the temperature-controlled variable speed fans** to:
    a. Prolong the life of the fans (30-year design life).
    b. Minimise the audible noise of the product.

The temperature-controlled variable speed fans have been selected not only for their flow rate and life expectancy characteristics, but also for their low audible output.

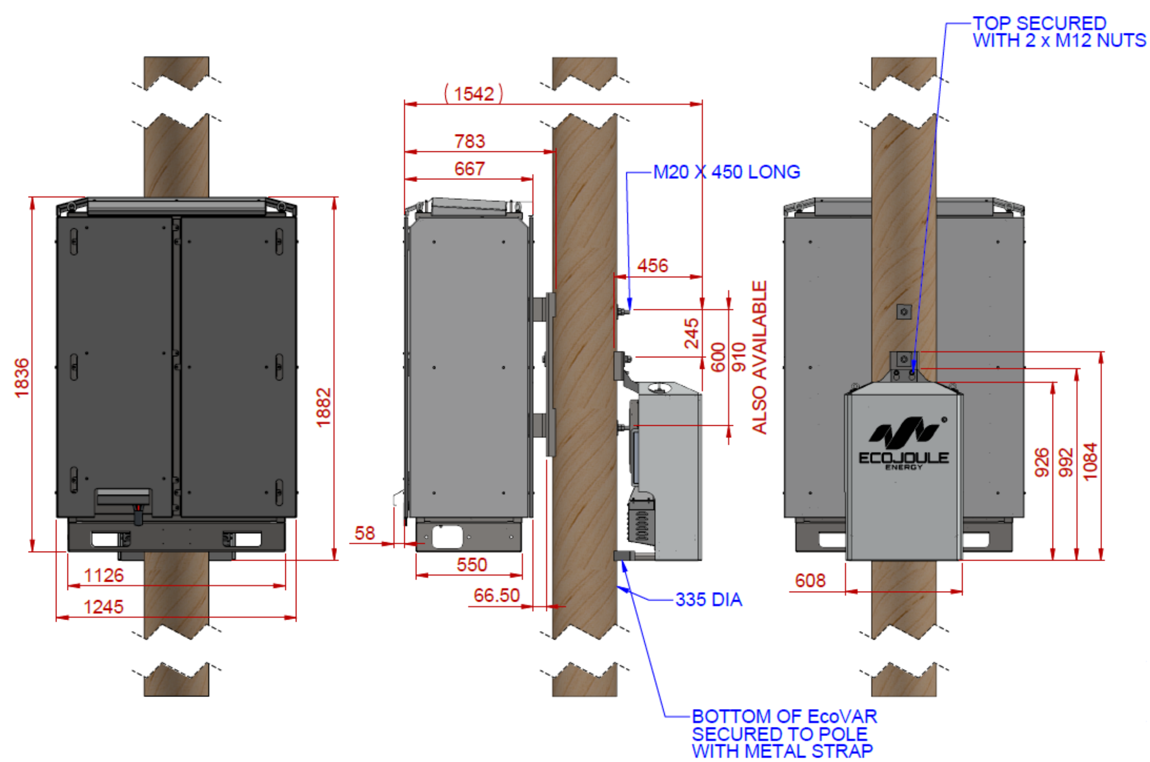
The EcoSTORE v2 has been designed to minimize the need to open doors and access the inside of the enclosure.

Electrical connection to the product is facilitated through Amphenol plug-in connectors, which do not require internal access.

Utility modems are typically installed at the EcoJoule factory and tested remotely by our utility customers before dispatch.

Light periodic external maintenance may be required on a site dependent assessment. The fan cassette can be accessed externally if required.

Battery mounting to the pole can be achieved using through-pole coach bolts or pole straps.



Mechanical dimensions (in mm)

Technical Specifications

Specification	Value
Steady state Operating Voltage Range	180 - 260V (L-N)
Continuous Rating @ 50 °C	40kVA
Rated Current @ 50 °C	63A
Active Power @ 50 °C	-40kW to 40kW
Reactive Power @ 50 °C	-40kVAr to 40kVAr
Nominal frequency	50Hz
Installed Battery Energy Capacity (BOL)	86.4kWh
Battery Chemistry	LFP
Battery Cycle life (90% DOD, 25°C average)	4,000
Minimum battery calendar life	15 years
Ambient temperature	-15°C to 50°C
Maximum Solar Loading	1100 W/m^2
Cooling	Temperature controlled variable speed fans
Power Electronics Efficiency	>98.5%
Current Harmonics	<4% THD at full load
Output switching frequency	16kHz
Audible noise	<40dBA at 10m
Communications	Ethernet interface to Cellular Modem, DNP3 & Modbus protocol supported
Anti-islanding	Active and Passive as per AS/NZS 4777.2:2020
Voltage dip support	Voltage dips to 130V supported via injection of maximum reactive power
Enclosure	Powder-coated 304 Stainless Steel, “surf-mist” colour
Mechanical Protection	IP56
Mounting	Pole mounted via coach bolts
Weight	Battery cabinet: Approx. 1000kg EcoVAR cabinet: Approx. 85kg
Standards	Designed to: AS/NZS 4777.2:2020, AS/NZS 5139:2019, AS/NZS 62477.1:2016, IEC 62619:2017 AS/NZS 61000.3.12, AS/NZS 60529:2004

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