Relectrify BMS+Inverter

Public Report

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Acknowledgements

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What's in this report

- **Section 1** is the executive summary.
- **Section 2** briefly describes the BMS+Inverter project.
- **Section 3** provides an overview of the BMS+Inverter.
- **Section 4** explores the key technical and commercial outcomes of the project.
- **Section 5** summarises the key learnings from the project.

Feedback

Relectrify welcomes further opportunities to share its project learnings to help customers and industry. Your feedback on this report can be sent to info@relectrify.com.

Important notice

1. Executive summary

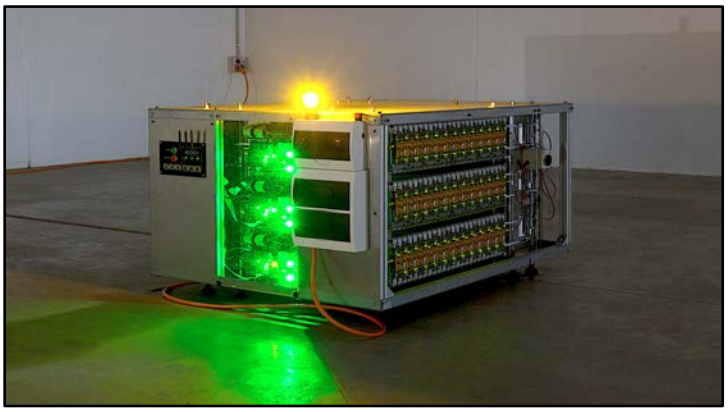
A crucial component of sustainable energy systems are battery solutions for individual homes, businesses, and the larger power grid. Any such installation requires not only a long-lived and cost-effective battery, but also an efficient and cost-effective battery inverter to convert the direct-current battery power into a useful alternating-current (AC) output. The cost of battery inverters today represents a significant hurdle for mass-adoption of battery storage and sustainable energy systems, and a significant uptake opportunity if reduced.

Relectrify is an Australian technology company that develops and supplies advanced battery management systems (BMS). These electronics sit inside the battery system and ensure safe, effective, and long-lived operation of battery systems. Due to the advanced capabilities of its lifetime- and capacity-enhancing BMS, Relectrify identified a unique opportunity to remove the separation between battery and inverter, and effectively co-utilise power electronics components for the benefit of both.

Relectrify's BMS+Inverter is a set of electronics that can be connected to batteries and immediately make these AC-ready without needing an inverter, while unlocking additional battery lifetime. Grid-compliant AC waveforms are created by accurately orchestrating a vast number of individual cell voltage contributions within the battery and is suitable across residential, industrial and grid storage using either new or second-life batteries.

The key takeaways are as follows:

- Relectrify has successfully demonstrated both single-and three-phase prototype BMS+Inverter systems using second-life Nissan Leaf battery modules, in solutions rated up to 60kWh / 20kW.
- Preliminary testing demonstrated a round-cycle combined second-life battery and inverter efficiency in line with market-leading new battery products.
- Harmonics testing achieved power quality levels suitable for grid compliance.
- Relectrify has received notable customer interest in the BMS+Inverter and has secured follow-on demonstration projects on multiple continents.



Three-phase BMS+Inverter prototype using second-life Nissan batteries

2. Project Overview

The ARENA funded BMS-Inverter Hybrid Project aims to combine two central components in battery storage systems – the battery management system and the inverter – into a single solution. The resulting BMS+Inverter ensures the safe and effective operation of the battery and converts the direct current (DC) power from battery cells to mains alternating current (AC) power. This enables substantial cost and performance benefits in battery storage systems using new or second-life battery cells (e.g. from retired electric vehicles).

3.BMS+Inverter Overview

A standard battery inverter is a power electronics unit that takes the direct-current output of the battery and converts this to AC as required by homes and the power grid. These units can either be housed in an entirely separate case to the battery or within the same enclosure as the battery. However, in either scenario, the battery and inverter remain fundamentally distinct and separate electrical systems.

Relectrify's BMS+Inverter is a power electronics device which utilises cell-level battery management systems to provide a very high-efficiency AC output without requiring a battery inverter. Grid-compliant AC waveforms are created by accurately orchestrating a vast number of individual cell voltage contributions within a battery pack.

Compared to a conventional inverter, Relectrify's BMS+Inverter requires neither a transformer nor large passive components for voltage conversion and filtering, switches a much lower voltage, and is capable of actively balancing cells of different capacities.

This results in the following advantages:

- Lower combined cost of BMS and inverter
- Unlocks extra lifetime in new and second-life batteries
- Avoids costly grading and reassembling of second-life batteries
- Unlocks extra capacity in second-life batteries
- Efficiency in line with market leading new battery products
- Low electromagnetic interference
- Improved harmonic control

Relectrify is now engaging with battery manufacturers, integrators and distributors, forming strategic collaborations to bring battery products incorporating Relectrify's BMS+Inverter to market.

For industrial and grid storage between 30 kilowatt-hours (kWh) and 10 megawatt-hours (MWh), installations consist of modular packs including lithium-ion batteries alongside a three-phase BMS+Inverter. At volume, typical 72kWh /25kW nominal modular packs, which integrate the three-phase Relectrify BMS+Inverter, second-life battery modules (e.g. from retired electric vehicle batteries) and racking, are indicatively priced from US$150/kWh. At volume, the three-phase Relectrify BMS+Inverter alone is indicatively priced from US$50/kWh.

For residential and small commercial installations between 8 and 30kWh, installations consist of modular packs including batteries alongside a single- or split-phase BMS+Inverter. At volume, typical 24kWh / 8kW nominal modular single-phase packs are indicatively priced from US$160/kWh. At volume, the single-phase BMS+Inverter alone is indicatively priced from US$55/kWh.

Single- and three-phase BMS+Inverter solutions can be used with both new or second-life lithium-ion batteries. Second-life batteries provide around 2500 cycles per set and can be replaced on-site to increase pack lifetime further.

4. Technical and Commercial Outcomes

Technology Development

Following successful proof-of-concept validation, Relectrify constructed a full-scale single-phase battery and BMS+Inverter prototype. Despite a very first prototype and the battery containing second-life cells, the preliminary efficiency was in line with industry leading battery systems, which achieve bidirectional combined battery and inverter efficiencies around 85-90%[1].

Relectrify subsequently constructed a full-scale three-phase battery and BMS+Inverter prototype. As shown in the photo on the second page of this report, the three-phase BMS+Inverter essentially consists of three Relectrify single-phase systems. It combines 216 modules in the form of nine Nissan Leaf 24-module stacks (same format as removed from the vehicle) into three 72-module phases. This 3-phase prototype battery setup was then connected to the power grid via appropriate grid connection infrastructure.

Testing of this three-phase prototype demonstrated the BMS+Inverter was able to achieve a total harmonic distortion well below the typical grid requirement of 5%, confirming that it is comfortably expected to achieve suitable grid compliance. It also highlighted Relectrify's ability to repurpose battery packs without any need for pre-testing and grading, while unlocking maximum capacity and useful life.

Grid Storage Pilot with American Electric Power

In December 2019, Relectrify successfully installed a full-scale three-phase battery and BMS+Inverter prototype in a grid storage pilot involving American Electric Power (AEP), a leading US power company with over 5 million customers, and Nissan North America. This combined 216 modules in the form of nine Nissan Leaf 24-module stacks with Relectrify's BMS+Inverter.

The pilot was installed at an AEP-owned and -operated site. The battery modules were supplied by Nissan North America with all other battery system components designed and supplied by Relectrify. This 3-phase prototype battery setup was connected into the power grid via appropriate grid connection infrastructure providing a 480Vac three-phase output. Short-term testing has been successfully completed and longer term testing is ongoing.

Commercial Progress

Relectrify is already receiving significant demand for commercial and industrial second-life battery packs using the Relectrify 3-phase BMS+Inverter. This includes:

- Electricity companies seeking 500kWh-5MWh solutions for grid renewables
- Buildings and energy companies seeking 60-300kWh solutions for peak shaving
- Telecoms companies seeking 60-120kWh solutions for on-grid and off-grid telecom towers

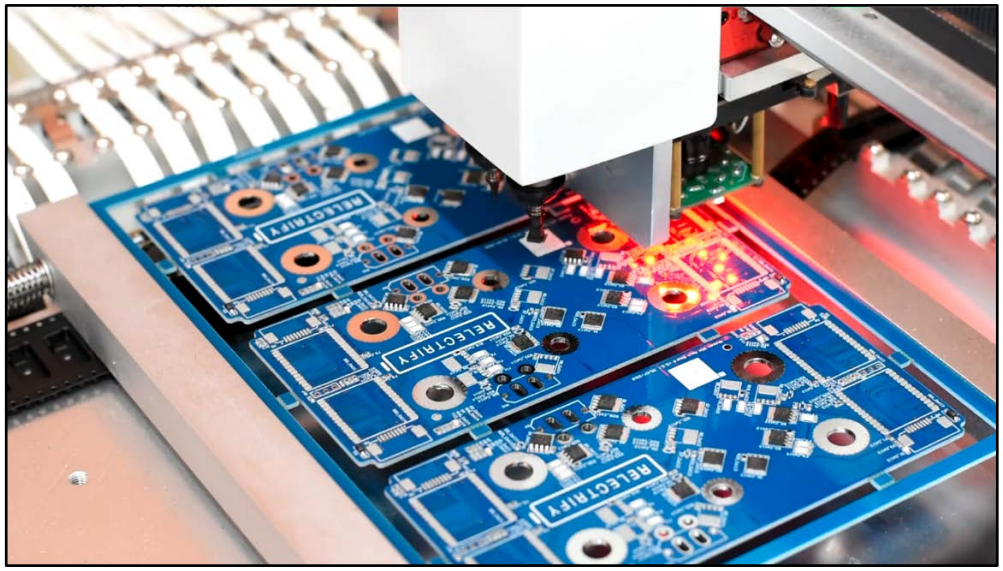
[1] See e.g. page 15 and page 27 of the following Australia battery test centre report: http://batterytestcentre.com.au/wp-content/uploads/2017/07/Battery-Testing-Report-6-June-2019.pdf

- EV charger manufacturers seeking 60-300kWh solutions for peak shaving

To realise these opportunities, Relectrify is presently engaged in discussions with a range of leading battery storage and inverter manufacturers which Relectrify has identified as suitably positioned to bring fully built battery units to market. These manufacturers typically possess deep technical and productisation experience, supply chain and assembly and sales capability to mass-product solutions, and a global marketing and sales team to achieve volume product uptake. From Relectrify's perspective, the targeted commercial outcome is the market introduction of customer residential, commercial and utility storage products using a technically mature version of the Relectrify BMS+Inverter.

From an integration perspective, Relectrify's BMS+Inverter technology will need to be certified for volume commercial deployments. In-depth discussions with a leading global certifications organisation have helped to highlight minor aspects of Relectrify's BMS+Inverter design that may need to be adjusted to ease the certification process. Relectrify is presently considering the optimal time to obtain certain certifications, which will need to be incorporated into the prioritisation of Relectrify's rapidly growing project pipeline.

The pilot involving AEP and Nissan North America and subsequent public launch of the BMS+Inverter in late January 2020 is catalysing Relectrify's commercial pipeline. Additional deployments have already been secured on multiple continents and Relectrify is progressing commercial discussions with some of the world's largest battery pack and inverter manufacturers it views as strong commercial customers and collaborators.



Automated assembly of Relectrify BMS electronics

5. Key Learnings

In undertaking the BMS+Inverter Project, the following key learnings and lessons were made and these are provided by Relectrify as guidance to benefit future renewable energy projects.

Category	Issue	Learning	Knowledge gap
Deployment	BMS+Inverter Printed Circuit Boards ('PCB') were damaged in transit to customer	Understood the pressure points in the PCB design and made changes to reduce the risk of damage in future deployments. Also improved packing methods.	Further testing on improved package with different transportation methods
Design	Temperature rose above the optimal range with a full enclosure after several days.	We used acrylic panels instead of steel ones for better display. However, it was less thermally conductive and prevented the effectiveness of the passive cooling design. We redesigned the enclosure to improve cooling and added fans with active control to make sure that the cells will always run within the optimal condition	Long term testing is required to validate the new design.
Manufacturing/ Commercial	Air freight costs are expensive	Future deployments should ideally be planned well in advance (with mature/stable product) to be able to use sea freight and/or manufacture in-country to avoid these costs/delays/customs etc.	Establish a contract manufacturer in a country where we expect to deploy systems of quantity (>5), place orders, verify quality and then proceed. Investigate logistics of sea freight incl packaging, lead-times etc.