feature

Empowering the Future: Strengthening Renewable Energy Grids with Advanced Storage Systems

Author: **Sebastião Miranda**

As the world rapidly transitions toward cleaner energy, renewable technologies like solar and wind power are gaining increasing importance in how we generate electricity. These energy sources are clean, sustainable, and essential for reducing our reliance on fossil fuels, but come with a challenge: they don't produce a steady flow of power. The sun isn't always shining, and the wind doesn't always blow.

In Malta, photovoltaic (PV) solar panel installations on rooftops account for the largest share of renewable energy generation. The amount of energy produced varies throughout the day, depending on sunlight intensity and other factors that can be harder to predict, such as cloud cover. Meanwhile, electricity consumption also fluctuates as households, factories, and businesses have different energy needs at different times. This creates a problem for electricity grids, which need to balance supply and demand at all times.

Traditionally, electricity grids relied on fossil fuel power plants, such as coal, natural gas, and oil plants. These power plants were designed to be highly flexible, able to increase or decrease their energy output quickly in response to changing demand or renewable energy-generation fluctuations. However, with the growing reliance on renewable energy, the traditional power stations' capacity to manage supply and demand is increasingly under pressure.

In regions like Malta, where PV panel installations are growing rapidly, this challenge is becoming more pronounced. The task now is to maintain a stable, reliable grid while decreasing reliance on fossil-fuel plants and integrating renewable energy sources. The ASPIRE project, carried out by Prof. Reiko Raute, Prof. Cedric Caruana, and Dr Gowthamraj Rajendran from UM's Department of Electrical Engineering, aims to address these issues by integrating smart-controlled battery energy storage systems into the electricity grid.

THE ROLE OF BATTERIES IN STABILISING THE GRID

Batteries can store excess electricity when supply exceeds demand and release it when generation is insufficient. In essence, batteries act as buffers, absorbing and storing energy during periods of excess, and supplying it when there's a shortfall. This ability to store energy for later use is crucial in mitigating the fluctuations that come with renewable energy sources.

In recent years, many residential and commercial PV panel installations have been paired with battery storage systems. These systems, however,

are often set up in 'self-consumption' mode. In this mode, when local solar generation is high, a household or business disconnects from the grid and uses only the energy it generates, storing any excess in the batteries for later use. When local PV generation falls short of meeting demand, the battery is used to supply the remaining power. If both the solar generation and the battery are insufficient, the system reconnects to the main grid to draw power, which generally comes from fossil fuels.

While this self-consumption mode helps alleviate the load on the grid and improves local energy security, it does not contribute directly to stabilising the larger grid or mitigating the broader power quality issues that may arise.

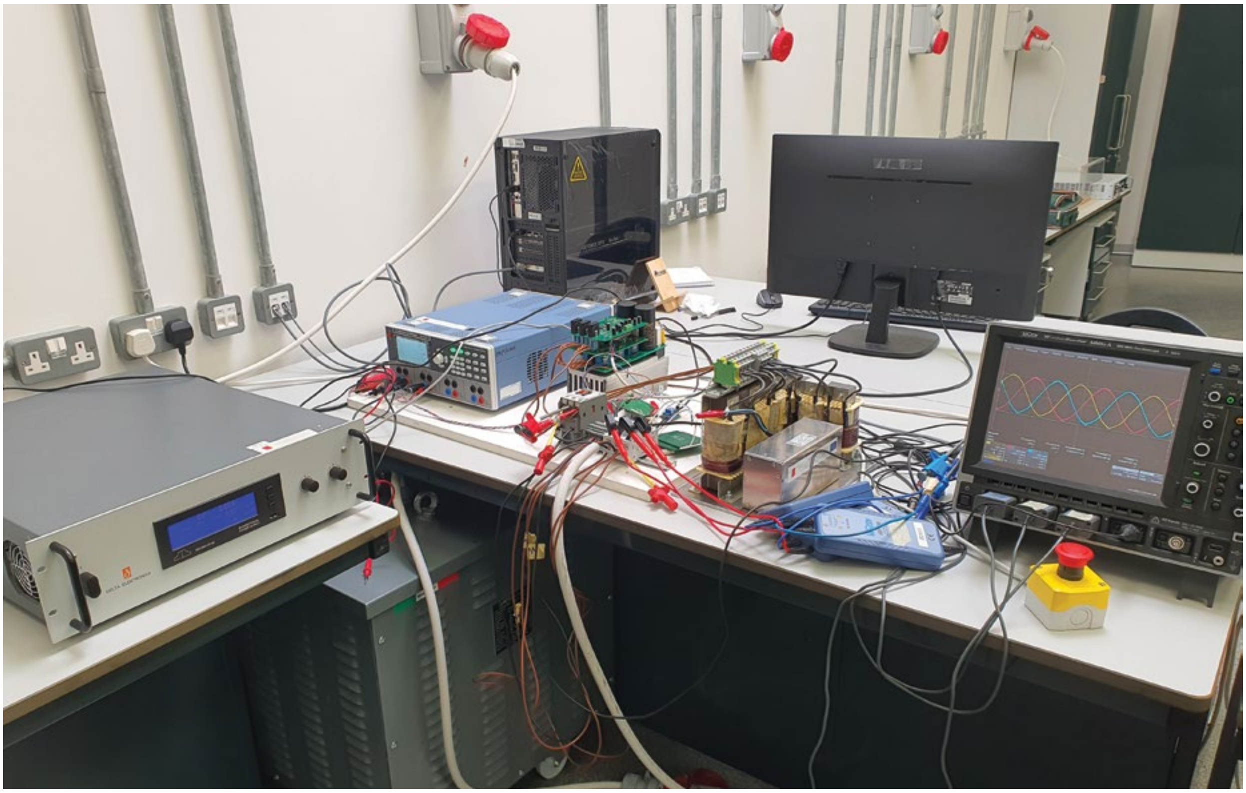
In other words, while these batteries optimise energy use at an individual level, they do not actively participate in balancing the grid as a whole.

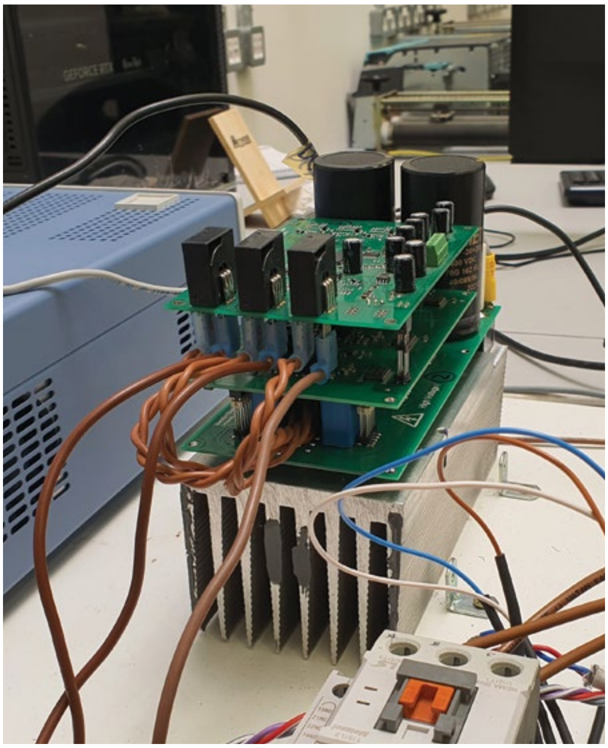
THE VISION FOR GRID-CONNECTED BATTERY SYSTEMS

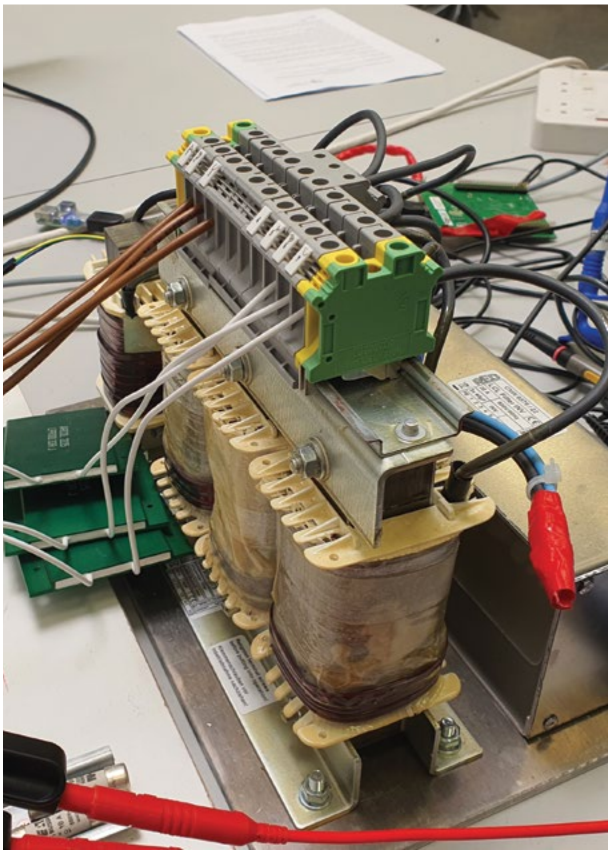
The ASPIRE project envisions a shift in how battery storage systems interact with the grid. Rather than operating in isolation to serve individual houses or businesses, battery systems can be connected to the grid's control mechanisms. In this model, residential and commercial battery storage systems contribute to the stability and reliability of the entire grid's operation. With this approach, batteries can help in several ways:

Balancing Supply and Demand: Batteries can help keep energy supply and demand in balance by storing excess electricity when too much is generated and releasing it to the grid when there is a shortage. By being active elements in the grid's network, each battery now contributes to the overall stability of the grid. This produces a much more stable output, as each battery has an effect beyond its immediate surroundings.

Enhancing Power Quality: Non-linear loads and power electronic devices, like electric car chargers, can cause distortions in the normal flow of electricity in the grid. These fluctuations affect the quality of the power supply and could cause electrical equipment to malfunction. This project shall develop special control algorithms for grid-







Top: Experimental hardware setup in the laboratory
Left: Inverter prototype
Right: Grid connection inductance
Photos courtesy of the ASPIRE Team

Left to right: Prof. Cedric Caruana, Prof. Reiko Raute and Dr Gowthamraj Rajendran
Photo courtesy of the ASPIRE Team

connected battery units that can help smoothen out these variations of the normal electricity flow and ensure the quality of power supplied to customers.

Keeping the Grid's Rhythm Steady: The electricity grid runs on alternating current (AC), meaning that the flow of electricity reverses direction at a steady rhythm. Just as the human heart beats with an approximately stable frequency to keep our body working, the grid must also maintain its frequency as constant as possible to ensure a proper flow of electricity. However, the intermittency of renewable energy generation can suddenly disturb the AC voltage frequency and cause problems. This is where batteries come into play. By adjusting their charge and discharge cycles, batteries can help the grid recover from unwanted frequency disturbances. In other words, they act like a pacemaker, stepping in to regulate energy flow and keep the grid's 'heartbeat' steady.

A network of smart, grid-connected batteries tackles one of the biggest challenges of the energy transition, taking over the balancing functions that are still provided by fossil-fuel power plants.

A NEW ECONOMIC MODEL FOR BATTERY STORAGE

A key innovation of the ASPIRE project is an incentive programme that allows customers to register their battery storage systems with the grid operator and receive financial compensation for the services their batteries provide to the grid. These services would include balancing supply and demand, improving power quality, and supporting the grid in maintaining stable voltage and frequency. This approach could create a new avenue for customers to profit from their battery investments while contributing to the greater good of the energy transition.

Under this model, grid-connected batteries would essentially become participants in a Virtual Grid Support System (VGSS) – a network of distributed energy resources that work together to support the grid. By integrating these resources into a common coordinated system, the grid operator could more easily manage energy fluctuations, reducing the need for fossil-fuel power plants, while ensuring a reliable, stable energy supply.

TOWARDS A FOSSIL-FREE FUTURE: THE ROLE OF ADVANCED STORAGE SYSTEMS

The ASPIRE project is paving the way for the development of advanced battery storage systems that not only store energy but also actively contribute to grid stabilisation. These systems, with smart control features and power-filtering capabilities, will be crucial in building a green electricity grid that can operate without the need for fossil-fuel-powered generation stations.

The ultimate goal is to create a stable, reliable, and sustainable energy grid that can seamlessly integrate increasing levels of renewable energy without compromising on power quality or reliability. By embedding these advanced capabilities directly into battery storage systems, we can help create a more flexible, resilient, and cost-effective power grid.

As renewable energy adoption continues to grow, these innovations will be vital in ensuring that the electricity grid remains robust and capable of supporting the future energy needs of homes, businesses, and entire communities. With these advancements, we move closer to achieving a truly sustainable and resilient energy system – one that operates efficiently, relies on clean energy, and is no longer dependent on fossil fuels.

Project 'Active Support of Decarbonised Weak Power Distribution Networks' (ASPIRE) is financed by Xjenza Malta, through the FUSION: R&I Research Excellence Programme.