Integrating Renewables into the Grid: Applying MW Scale Energy Storage Solutions for Continuous Variability Management

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Introduction

The rapid growth of renewable energy and their large-scale integration pose opportunities and challenges alike. Electricity providers are increasingly faced with the challenge to integrate variable renewable generation with the existing portfolio and the electricity grid. In order to operate reliably and stable, grids need to continuously balance supply and demand – a task complicated by the intermittency of renewable energy, which can cause grid instabilities and power outages. The variability and uncertainty of renewable output are the main hurdles to large-scale integration of renewables and thus to transitioning from a fossil fuel to a renewables biased economy.

Energy storage is now the key to a quick adoption of renewable energy. Energy storage has the ability to control ramp rates of renewables output before presenting it to the grid and to store energy for times of unfavorable weather conditions or peak demand times, making renewables reliable and dispatchable.

Safe, practical, economical and environmentally sound energy storage systems are needed that can operate efficiently in continuous Partial State of Charge (PSoC) use, providing an effective high throughput energy storage mechanism that can do the heavy lifting of variability management.

The energy storage industry is continuously developing new applications that enable large-scale integration of renewable energy at the same time as delivering economic returns. Successful energy storage business cases include:

- Wind and solar smoothing and shifting,
- Diesel efficiency optimization in hybrid energy systems, and
- Grid ancillary services.

MW Scale Energy Storage: Business Cases

Solar Smoothing and Shifting: PNM (NM, USA)

PNM, the leading electric utility company in New Mexico, USA, has integrated an UltraBattery® energy storage technology with a photovoltaic solar energy plant to demonstrate smoothing and shifting of volatile solar power and the ability to use the combination as a dispatchable renewable resource. The project is the first solar storage facility in the USA that is fully integrated into a utility's power grid. It features one of the largest combinations of battery storage and photovoltaic energy in the US.

Increasing levels of renewable energy penetration poses integration challenges for grids. In the case of New Mexico, there were two particular challenges:

- Better manage the misalignment between PV output and utility distribution grid and system peaks
- Better manage intermittency and the volatile ramp rates of renewable energy sources that cause voltage fluctuations

PNM working with Sandia National Laboratories, University of New Mexico and a number of other contractors is applying the energy storage system to achieve several objectives including:

- Peak shaving and elimination of 15% of the feeder peak – benefit defined by avoided industry standard costs of substation and feeder expansion.
- Smoothing of PV ramp rates and minimizing voltage fluctuations – benefit defined by avoided cost of system upgrades that would be installed with high penetration PV.
- Demonstration of dispatchable renewable resource – benefit defined by contrasting the cost of an equivalently dispatched combustion turbine, allocating fuel, Operation and Maintenance and capital to a LCOE (levelized energy cost) comparison and noting an allowance for CO2 emission avoidance.

The energy storage system is currently providing PNM 500 kW of energy smoothing capability (figure 1) and 250kW/1MWh of energy shifting capability (figure 2). Initial test results indicate that targeted objectives are easily being met.

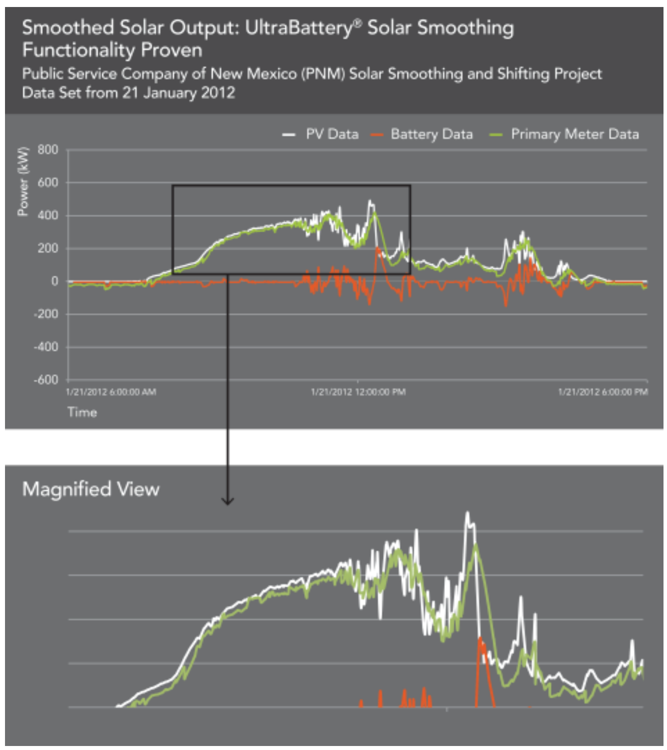

Figure 1 - PNM Smoothed Solar Output: Solar Smoothing Functionality Proven

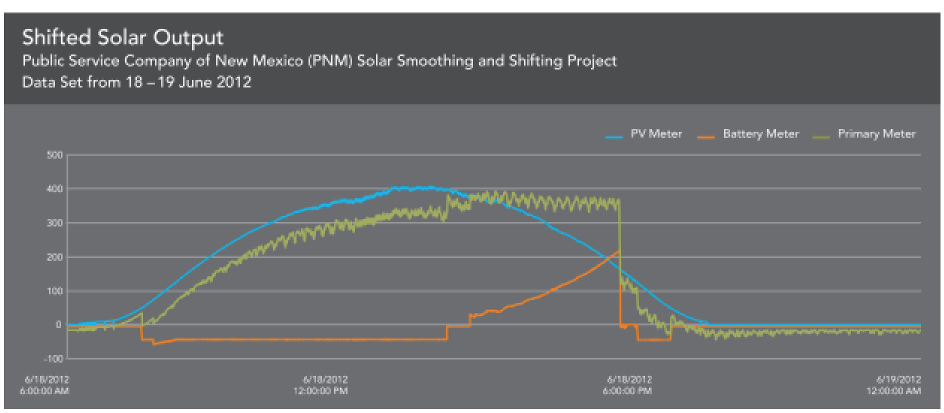

Figure 2 - PNM Shifted Solar Output: Solar Shifting Functionality Proven

Wind Smoothing/Ramp Rate Control: Hampton Wind Farm (NSW, Australia)

Wind energy is clean and has the potential to supply many times the total current global energy production. Although wind energy is reasonably predictable, it is significantly variable. The ramp rate that can be associated with generation of wind energy can create integration challenges for utilities and Independent System Operators/Regional Transmission Organizations (ISOs/RTOs) and limits progress by wind farm developers.

Wind power cannot be controlled. Wind farms exhibit greater uncertainty and variability in their output compared to conventional generation. In power systems, which already manage a large degree of uncertainty due to the need of generation and loads to be equal, demand is constantly matched with generation to maintain system frequency. The variability and uncertainty of wind power further increases uncertainty in the system, effecting its physical operations.

Further challenges with supporting increased penetration of intermittent resources are related to congestion issues in the transmission and distribution system as well as the mismatch between wind availability and prevailing demand. Oftentimes, local networks are constrained, with renewable energy being forced to be curtailed.

An immediate solution to wind integration challenges is to limit the ramp rate of wind output. Project objective is to demonstrate and optimise methods of applying energy storage to constrain the 5 minute ramp rate of renewable output from the Hampton Wind Farm before presenting it to the grid. The impact objective is to achieve higher penetration of wind and renewable energy in grid systems.

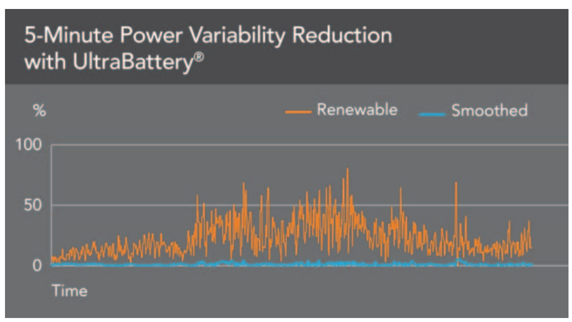

Figure 3 - 5-Minute Ramp Rate Reduction

Ecoult provided and integrated a MW scale smoothing system using UltraBattery® technology. Ecoult has been able to demonstrate the ability to limit the 5 minute ramp rate to 1/10 of the raw output (figure 3) while applying storage with a usable capacity (in kWh's) 1/10 the rated output of the farm (in kW).

Diesel Efficiency Optimization in Hybrid Energy Systems: King Island (Tasmania, Australia)

Most electricity generation on island grids rely heavily on diesel-engine driven generators. The use of diesel generation however involves high diesel costs, inefficiencies in reacting to sudden changes in loads and high CO^2 emissions.

To optimize the efficiency of diesel operation, diesel generation can be paired up with energy storage to minimize the use of diesel. The energy storage system can maintain the output of the generator in efficient bands while buffering the output, i.e. compensating for sudden changes in loads to meet demand. This can be particularly effective in systems with multiple generators where energy storage can be used to avoid the need to start additional generators during short peaks load periods.

Adding renewables to the generation mix can create a very effective Levelized Cost of Electricity and significantly reduce consumption of diesel. Systems can range from single house solutions to small grids that serve thousands of people.

Supported by models that allow combining load power profiles and energy storage profiles to determine efficiencies of various energy storage applications, the business case of applying energy storage to:

1. Reduce diesel fuel consumption,
2. Lower the LCoE and
3. Decrease CO^2 emissions can be demonstrated.

Ecoult is implementing a 3MW energy storage system as part of a full Standalone Power System for the King Island Renewable Energy Integration Project (KIREIP), being developed by Hydro Tasmania on King Island (Australia). The objective of KIREIP is to significantly reduce King Island's reliance on diesel fuel to supply the island's energy needs.

Hydro Tasmania is progressively migrating energy generation on the island from 100% dependency on diesel to a solution where 65% of energy consumption will be provided by renewable sources - without any loss of reliability or grid stability and at a price lower than the diesel power alternative. KIREIP will also lower CO^2 emissions by 95 per cent through the use of sustainable clean energy sources, including bio-diesel.

Grid Ancillary Services: Frequency Regulation – PJM (PA, USA)

Supported by funding from the US Department of Energy under the Smart Grid Demonstration Program, East Penn Manufacturing through its subsidiary Ecoult implemented an energy storage system which provides 3 MW of regulation services on the grid of Pennsylvania-New Jersey Interconnection (PJM), the largest of 10 Regional Transmission Organizations/Independent System Operators (RTOs/ISOs) in the US. The system is also used for peak demand management.

With renewable portfolio standards coming into effect, the large scale integration of intermittent wind and solar generation will affect the physical operation of the modern grid, resulting in an increasing need for regulation services.

Regulation Services are necessary to provide fine tuning in real time for the network to match supply and demand and to that end keep a constant frequency. The energy store responds to a signal provided from the market operator, PJM.

Project objective is to demonstrate the outperformance of UltraBattery® based storage solutions in the provision of regulation services. The fast responding UltraBattery® is a hybrid lead-acid energy storage device that contains both an Ultracapacitor and a battery in a common electrolyte.

Energy storage can manage regulation services more efficiently: It is faster, more accurate, cheaper and cleaner than the incumbent gas peaker often used for regulation services. Energy storage is therefore able to displace fossil fuel generation methods in the provision of regulation services and to complement fossil fuel generation in the provision of other ancillary services.

The 3 MW solution is implemented both in a building and in a containerized format to demonstrate flexibility in approach for prospective adopters. It uses four strings of battery cells and connects to the grid from inside the East Penn Manufacturing site in Lyon Station, Pennsylvania.

The project provides continuous frequency regulation services bidding into the open market on PJM. The system is responding to PJM's fast response signal (figure 4).

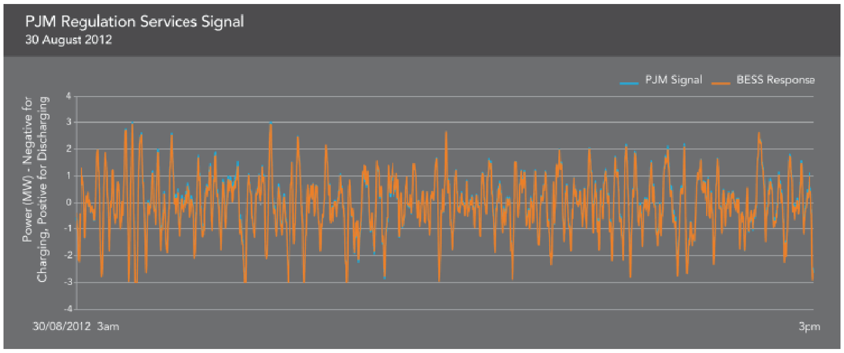

Figure 4 - Frequency Regulation: PJM Regulation Services Signal and Response of Energy Storage System

Dual Purpose Energy Storage – Cloud Storage for the Grid

Further, the increasing deployment of renewable energy generation means there is rapidly growing demand from grid operators around the world for grid ancillary services – services that provide fine tuning in real time for the network to match supply and demand. Electricity supply and demand must be continuously matched perfectly or the stability of the grid suffers. Growth of renewable generation brings with it greater variability in supply. This can occur on the timescale of seconds and minutes. It also increases the complexity of the challenge to match periods of production to load.

A natural solution to the increasing need for short-term variability management is offered by data center and telecom resources, specifically by their largely idle and underutilized backup infrastructure. Energy storage enables data center and telecom infrastructure to effectively balance the discrepancies between supply and demand on the electricity grid, at the same time as delivering 100% reliable UPS service – and an improved economic model for operating the data center power backup services. We call this 'Dual Purpose' energy storage.

Dual purpose energy storage provides continuous variability management for the grid and is simultaneously capable of providing all-times access to a retained capacity of energy to support UPS capability in the case of any grid failure (as shown in figure 5).

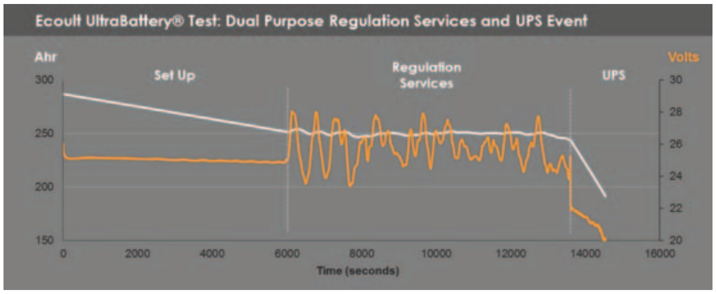

Figure 5 - Ecoult Testing: Dual Purpose Regulation Services and UPS Event

In this scenario, power systems are only used for grid ancillary services when the grid is available and used to supply backup in case the grid fails. This means that both the batteries and the grid connection and power equipment are fully available to each single purpose when needed (figure 6).

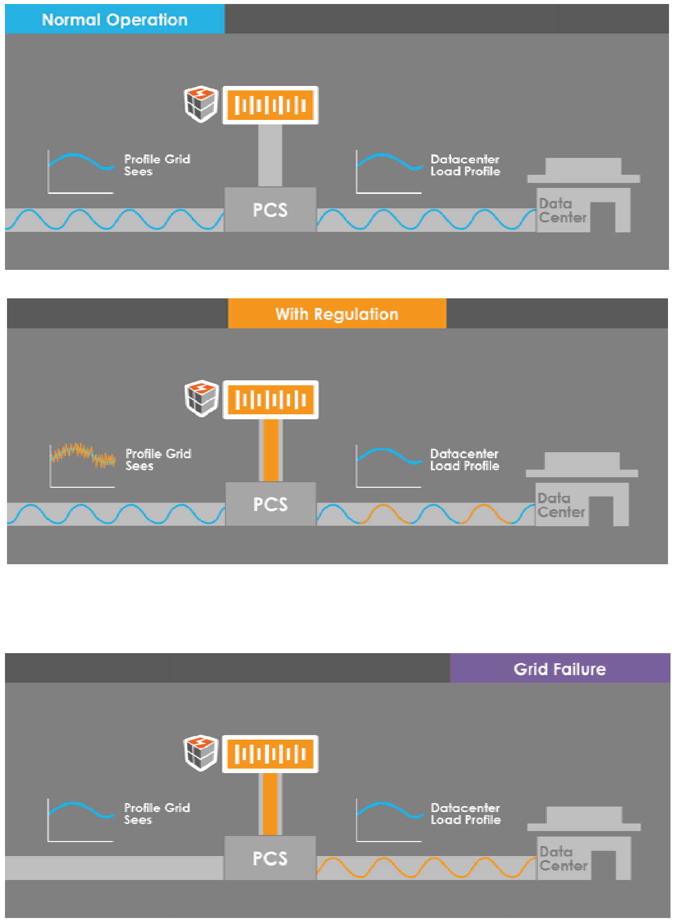

Figure 6 - Dual Purpose Operation of Energy Storage

By meeting two different needs, investment in energy storage technology for data centers becomes 'dual-purposed' as well. The marginal cost for a dual purpose system is approximately 30% of the individual cost of either. This means that a total cost of only 1.3X allows both functions to be delivered from a single installation. The current return on this marginal investment in open markets for ancillary services such as the PJM grid in the USA would deliver a return in excess of 40% (IRR).

Dual purpose energy storage now enables backup resources to be positioned as smart grid assets in support of renewables integration and grid stability while improving the bottom line of data centers and telecom operators.

Developing economies in particular often have an urgent need for improved grid stability and integration of renewable energy sources. At the same time, these markets are experiencing a dramatic increase in data centers required to support booming information technology and telecommunications usage.

Dual purpose energy storage unlocks the opportunity to provide a complete solution for short term variability – in the developed and developing world – by linking up the internet support infrastructure with electricity grid support infrastructure.

Summary

Energy storage has already proven to be the key to large-scale integration of renewable energy sources. Systematic focus on reduction of the cost of each MWh of storage through endurance and longevity of the energy store and use of the value derived from each MWh used through intelligent algorithms, is the path to unlocking business case models with positive returns that will deliver growth in the storage industry and support energy storage in delivering the impact it is capable of.

Economic implementation also requires that platforms be safe, economical, environmentally sound and standardized while delivering flexibility to developers who implement storage to deliver specific business objectives.

Finally, to make its full impact energy storage needs to become ordinary and simple to deploy, maintain, and recycle – an 'ordinary' part of grid design. Lead-acid batteries are the dominant chemical storage method for large-scale storage (primarily used for standby applications) and have a complete ecosystem of safety, manufacture, deployment and recycling in place today. Advanced lead-acid technologies extend lead-acid chemistry beyond standby applications to wherever power variability needs to be controlled. Adding High Rate Partial State of Charge cycling endurance and longevity to a safe, stable, fully recyclable platform offers a path to cost effective and low risk energy storage applications.