Using Energy Storage to Prepare the Electricity Grid for a Clean, Reliable, Renewable Future

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Abstract

As renewable energy generation like PV and wind become larger proportion of the overall generation fleet in electricity grids around the world, controlling and managing that variable and intermittent generation resource to match with real-time electricity consumption becomes more challenging. NEC Energy Solutions, part of NEC's Smart Energy division, is at the forefront of deploying a new technology on the electricity grid – energy storage – that can provide better and more positive control of renewable energy systems, making future power grids both clean and sustainable, while continuing to provide the reliability and efficiency required by all electricity users.

Keywords

energy storage, electricity storage, power storage, ESS, lithium ion, batteries, renewable integration, PV, wind, grid, reliability, efficiency, GSS, grid storage solution

1. Introduction

Renewable power is an important part of future electricity generation in both major developed countries around the world, as well as developing, rural or remote regions of the world. While renewable power like solar photovoltaic (PV) and wind turbines is clean and reaching the cost effectiveness of traditional fossil fuel thermal generation power plants, it does not come with the same degree of control as a thermal generator does. With traditional coal or gas power plants, increasing or decreasing the rate of fuel supply allows control of output power according to energy consumption needs on the grid. However with wind or PV power plants, the fuel source – sunshine or wind – is not controllable. Thus as the proportion of renewable generation increases in relation to coal, natural gas, or other types of controllable thermal generation, an additional degree of control must be added to the grid to ensure reliability.

2. Energy Storage for Reliable Renewable Grids

Unlike many other commodity markets, the electricity market is unusual in that electricity storage is typically not a core part of the value chain. Supply of electricity must always be equal to the demand for electricity (**Fig. 1**) – if it doesn't, the entire electric grid begins to shut itself down to protect equipment and people from the potential hazards that arise when imbalance occurs. Historically,

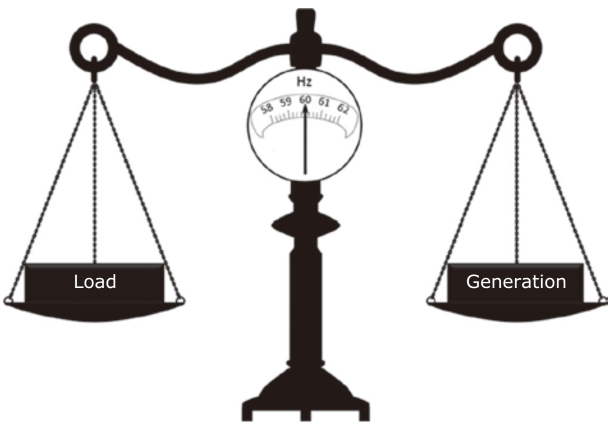


Fig. 1 Schematic image of Generation (Supply)/ Load (Demand) balance in power system.

power plants could increase or decrease their output on demand to accommodate changes in power consumption due to fluctuating loads on the grid, such as lighting or HVAC equipment. As power plants shift away from fossil fuels and more towards renewable generation, the proportion of controllable generation decreases, and installing more renewable generation can cause challenges in the balancing act of electricity supply and demand for the grid system operator, who is typically responsible for maintaining this balance. This is where electricity storage can become an essential tool for the renewable grid.

As changes in the balance between supply and demand – also known as generation and load – of electricity occur due to fluctuations on both sides of the equation, controllable or "dispatchable" resources are brought online to compensate for the fluctuations and restore balance. Ideally, a very rapidly-responding and precise power plant provides this balancing resource to the grid system operator. Using these resources, the system operator commands the balancing resource to increase and decrease its output to match the ever-changing load on the grid.

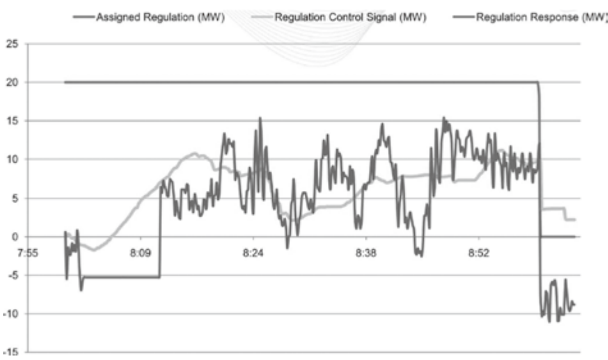
Energy storage, in the form of battery-based electricity storage systems connected to the grid, provides a very rapid and precise response and are one of the most effective tools a system operator can have to maintain balance. NEC Energy Solutions has been providing these types of energy storage systems, known as GSS (Grid Storage Solution), for many years and has demonstrated their effectiveness in many parts of the world (**Photo 1**). In the "PJM" region of the United States, a 32MW lithium ion GSS has been providing a service called frequency regulation since 2011.

Frequency regulation is the name of the balancing service that the grid system operator, PJM, must have as a resource to ensure the matching of electricity generation and load, and can be provided by any resource through an open, organized market structure where eligible providers compete to provide this service, based on both price and performance. Since an overhaul of the frequency regulation market in 2012 based on a regulation change called "FERC Order 755", energy storage systems like NEC Energy Solutions' GSS have been able to provide faster, more precise frequency regulation service to PJM, and in return, earn higher revenues for such service. It is through this increased resource pool of faster, more accurate resources that allows for PJM to actually decrease its procurement costs for frequency regulation service, despite paying more to resources like the NEC Energy Solution GSS installations located throughout the region. The reason it can do this is that with more precise control of power output, PJM can actually procure less total frequency regulation than before, and accomplish the same job of balancing the grid.

As an example, a coal-fired steam generator is allowed to provide frequency regulation service to PJM. However, it is unable to provide very high performance service (**Fig. 2**). Gas-fired combined cycle generators are also allowed to provide frequency regulation, and can perform better (**Fig. 3**). However, an energy storage unit provides almost perfect service (**Fig. 4**). As the resource pool in PJM shifts from poorer performing units to high performing units like energy storage, PJM is able to provide the same balancing service, but use a smaller amount of resources. It is in this way that some resources can actually be paid more than others, but not cause an overall increase in cost to the system or the electricity customers.

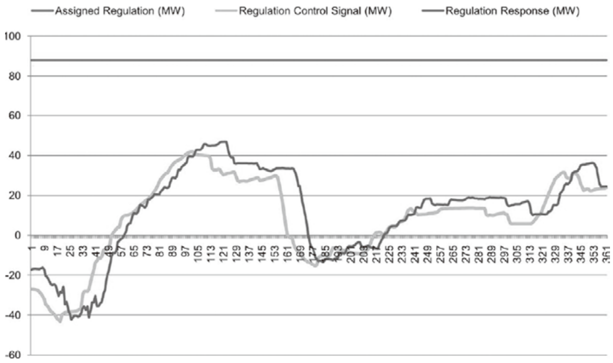
In addition, as clean, sustainable, but variable and intermittent renewable resources like wind and PV become more prevalent on the grid, the need for faster, more precise balancing services is likely to increase. To prepare the future grid for this shift in the overall generation mix, it is crucial for system operators like PJM to develop a more flexible and higher performing pool

Photo 1 32MW GSS for the PJM frequency market in West Virginia, USA.



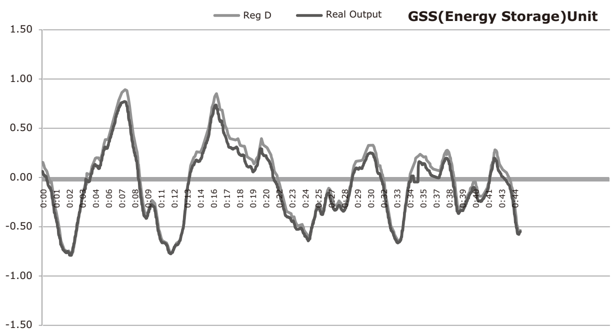
Source: PJM, "RPSTF Performance Metrics Formulas and Examples," August 10, 2011

Fig. 2 Typical response performance using a coal-fired stream generator in the PJM frequency market.



Source: PJM, "RPSTF Performance Metrics Formulas and Examples," August 10, 2011

Fig. 3 Typical response performance using a gas-fired combined cycle generator in the PJM frequency market.



Source: Data from NEC Energy Solutions GSS in actual operation

Fig. 4 Typical response performance using the NEC Energy Solutions GSS in the PJM frequency market.

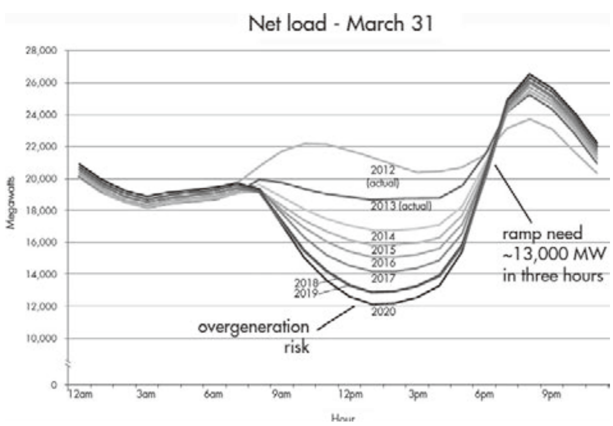
of resources to allow it to more effectively balance the grid in the face of increased renewable generation and a decrease in traditional, controllable thermal generation. This will become true in PJM and in any other grid in the world where controllable generation is increasingly replaced by variable, less controllable generation. Energy storage can perform this key and critical service in support of these future grids.

3. More Efficient Renewable Power

In addition to being more difficult to control, a grid relying more on renewable power derived from sunshine and wind will not always produce electricity exactly when it is needed. This constraint can limit the efficiency in the form of constraining the output of the renewable resource. This constraint is demonstrated by the California Independent System Operator (CAISO) in a study showing how increased renewable generation in the form of PV solar can cause over-generation during the day, and then as the sun goes down, force a massive increase in power output of all remaining non-PV generating resources of over three hours (**Fig .5**). This can be difficult for generators to accomplish due to the necessity of running power plants at near economic minimums or even shut off during the day, and then forcing them to rapidly increase their output over a few hours in the evening. Traditional power plants like coal or natural gas fired thermal generators not only wear out more quickly under these circumstances than if they ran at the same output level all the time, but also produce more carbon emissions under rapidly ramping conditions. The increase in cost and emissions is fundamentally opposed to a key motivation for installing renewable generation like wind or solar, which seek to both reduce pollution and enable lower cost of electricity by taking advantage of free fuel (sunshine and wind). Yet achieving this vision, while maintaining the reliability and efficiency of today's electric grid, requires power plants to operate under these very sub-optimal conditions.

Unlike traditional thermal power plants, battery-based electricity storage systems can easily accommodate changes in power output to provide the flexibility the grid needs to accommodate more renewable generation. For instance, during the day, the electricity storage system cannot only run at zero, but also absorb all the overgeneration risk by charging up the batteries, while in the evening, the electricity storage system can provide the increase in power output by discharging.

NEC Energy Solutions' GSS is able to ramp very rapidly, with outputs from zero to 100% within 250 milliseconds or faster, with no penalty on wear rate, no emissions, and of course no fuel consumption. It can provide increased reliability and efficiency for more renewable



Source: California ISO : Flexible Resources to Help Renewables - Fast Facts, 2013.10

Fig. 5 California's "duck curve" (the overgeneration risk on certain days of the year with increased PV solar generation over the next several years).

Photo 2 11 MW, 4.4 MWh GSS for stabilizing of wind farm power output in Maui, Hawaii, USA.

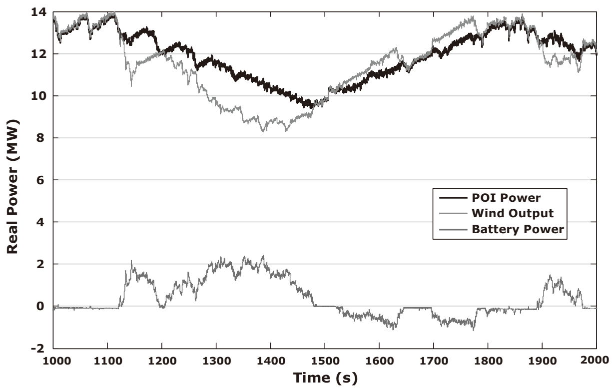


Fig. 6 The example of stabilizing the power output of the wind farm using the GSS in Maui.

grids. For example, NEC Energy Solutions has deployed 11MW GSS in conjunction with a wind farm located in Maui, Hawaii (**Photo 2**). This GSS stabilizes the power output of the wind farm, boosting it if the wind dies down too quickly, or absorbing it if the wind speeds up too quickly (**Fig. 6**). This energy storage installation allows the system operator and electric utility Maui Electric Company to manage the grid more effectively.

4. Conclusion

We have covered only a few of the different applications for energy storage on the grid, all of which enable grid system operators to better manage and control the flow of electricity. NEC Energy Solutions has been working on these and many other projects around the world using its GSS grid storage solution. These GSS installations are helping to stabilize and increase the reliability and efficiency of electric grids by giving operators the ability to move electricity in time, using a resource that can be deployed in any location on the grid from under 100kW to over 100MW in scale. Deployed in the transmission system, distribution system, or even at customer sites at what is called "behind-the-meter", energy storage in the form of the GSS is having a real impact on electric power reliability today, running not in demonstration projects, pilot projects, or proof-of-concept, but in commercial revenue service, 24 hours a day, seven days a week.

As the electric power grid undergoes transformation from fossil fuel generators to more renewable and sustainable sources like wind or PV, it must also prepare itself to accommodate the increasing variability of these types of generation, previously unknown. Energy storage will become a key part of tomorrow's grid, and with it, an improvement in not just reliability and efficiency, but also in environmental friendliness, providing society a more sustainable, clean electricity supply.

Reference

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2) California ISO : Flexible Resources to Help Renewables - Fast Facts, 2013.10
https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

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