ENERGY STORAGE CAN ENABLE WIDER DEPLOYMENT OF DISTRIBUTED GENERATION

Troy MILLER
S&C Electric Company – USA
Troy.Miller@sandc.com

Michael EDMONDS
S&C Electric Company – USA
Michael.Edmonds@sandc.com

ABSTRACT

Global adoption of distributed energy storage can enable wider deployment of distributed generation (DG), such as rooftop photovoltaic (PV) and small-scale wind generation systems. Accelerated deployment of grid-tied storage, including battery-based Community Energy Storage (CES) and other innovative systems, can help electric power utilities meet the "20% by 2020" renewable energy use mandates many central governments have enacted. But meeting these mandates also necessitates more widespread deployment of both grid-scale and distributed renewable energy resources. By co-locating distributed storage and DG, electric utilities can realize major benefits, including a significantly improved ability to offset the variability characteristic of renewable output.

INTRODUCTION

Electric power utilities are working diligently to meet the "20% by 2020" [1] renewable energy use mandates enacted by many central governments around the world. This massive undertaking is demanding more widespread deployment of both grid-scale and distributed renewable energy resources. Playing an increasingly critical role in this global initiative are distributed energy storage systems, which help reduce carbon emissions while balancing more dynamic sources and loads on distribution systems.

Adoption of storage systems, from distributed Community Energy Storage (CES) to grid-scale batteries, holds vast potential for enabling broader distribution and deployment of renewable energy resources to complement traditional generation. From rooftop photovoltaic (PV) panels to residential and small-scale commercial wind generation, distributed generation (DG) deployment is expected to grow dramatically within the coming decade due in large part to the benefits of co-location with energy storage devices.

RENEWABLE ENERGY MANDATES

Renewable energy mandates are becoming a strategic focus for electric utilities everywhere, from EMEA and the EU [1] to individual U.S. states, such as California, which is ambitiously mandating 33% renewable energy use by the end of 2020. To help utilities accelerate deployment of the carbon-neutral energy resources needed to serve 20% of their loads in 2020 and beyond, some governments are offering significant subsidies as incentives.

INTERMITTENCY ISSUES

Because output from renewable resources is variable by nature, many utilities are facing new challenges on their distribution systems—challenges they may not be fully prepared to manage. But distributed energy storage systems, particularly when located in close proximity to renewable resources, are uniquely suited to address such challenges, including local and feeder-level voltage swings that occur far too rapidly to allow traditional distribution voltage regulation equipment to respond.

Weak Distribution Networks

When intermittent renewable energy resources comprise a significant amount of overall generation, distribution system problems such as voltage swings are more likely to arise. These disruptions are compounded on "weak distribution networks," which have characteristically high X/R ratios (system reactance to system resistance). Voltage levels on networks with high X/R ratios may not be sufficient to support all loads.

Variability and Voltage Swings

Variable output from solar and other renewable generation produces local voltage swings and contributes to feeder-level voltage swings which occur in a matter of seconds. Traditional distribution voltage regulation equipment does not have a chance to react to such rapidly changing conditions. While designed to handle the typically random occurrences of large loads switching on and off within a network, traditional equipment was not engineered to manage the highly variable output of renewable resources.

Solar power generators and wind turbines are largely synchronized, so all units on a distribution network are affected by variable sunlight and wind. Fluctuating renewable output can cause perceptible feeder-level voltage swings. Such events can temporarily exceed allowable variability limits and have additional noticeable impacts on service to electricity customers.

Distributed energy storage can provide voltage firming capabilities, effectively filling in gaps created by large voltage swings and voltage fluctuations. Co-locating storage systems and renewable resources gives utilities a particularly effective way to manage unwanted voltage changes and improve overall network performance.

Figure 1: This 25-kVA Community Energy Storage unit is part of a large-scale installation serving many homes.

DISTRIBUTED ENERGY STORAGE SYSTEMS

Distributed energy storage is the key to increasing the penetration of renewable energy generation. From residential-scale battery-based Community Energy Storage systems to grid-scale batteries, storage captures excess energy and re-dispatches it precisely when needed. Just as importantly, energy storage helps utilities manage both evolving consumption patterns and dynamic supply.

Community Energy Storage

One of the newest, most innovative storage systems is Community Energy Storage (CES), lithium-ion battery-based storage, which enables utilities to provide reliable local backup power and multi-faceted grid support at the outermost edges of distribution system networks. CES systems are small pad-mounted units, which can be strategically distributed along residential feeders. They are ideally suited to serve neighborhoods and small commercial buildings. One 25-kVA CES unit supplies one to three hours of battery storage for multiple residential or light commercial loads [2].

CES units can be easily co-located with renewable energy resources, including grid-tied rooftop PV panels and small wind turbines. With the growing adoption of small-scale renewable resources and plug-in electric vehicles (EVs), utilities require a more effective way to control voltage on local feeders to sustain service quality. CES offers a unique solution. Utilities can aggregate up to 1,000 grid-tied CES units using a distributed energy management (DEM)

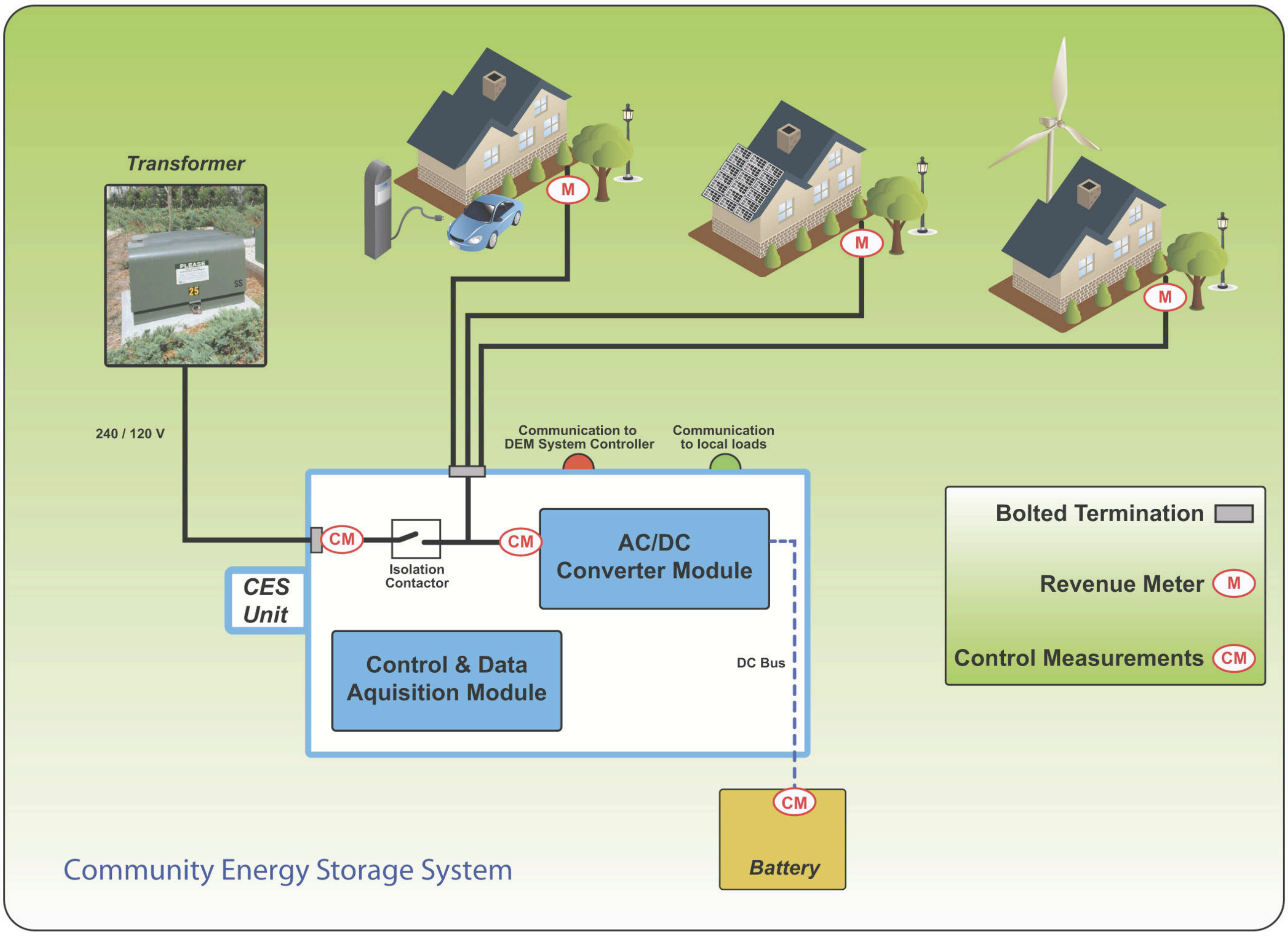

Figure 2: Community Energy Storage (CES) systems buffer co-located residential-scale solar and wind generation and supply reliable backup power during grid outages.

system to enhance local voltage control, integrate and buffer intermittent renewable resources, improve power quality, and better manage peaks due to larger numbers of charging EVs and other loads [2].

CES pushes energy storage out to the grid's edge, while delivering many of the benefits of large-scale storage systems. For example, DEM-controlled CES "fleets" can function collectively as scalable energy storage plants to perform peak shaving and provide asset relief. Utilities can also easily bring CES systems online in increments to defer major distribution system build-outs. CES is an integral part of a more reliable, responsive, and intelligent grid.

Microgrid Systems

Storage is essential to microgrid systems, which are self-sustaining "energy islands" that provide reliable power when grid service is disrupted, cost-prohibitive, or undependable. Microgrids can facilitate renewable resource integration and utilization. University campuses, military bases, correctional facilities, and other isolated locations are ideal for microgrids since they place an imperative on maintaining highly secure, reliable power around the clock.

Recently, an advanced large-scale microgrid system was deployed at the largest correctional facility in the U.S. This sophisticated microgrid is capable of operating indefinitely without connecting to the local utility grid. It co-locates renewable energy generation (solar and wind) and energy storage on the site. The microgrid employs a 2-MW/4-MWh lithium-ion battery and 2-MW power control system [3], which manages charging and discharging of the battery to meet the facility's changing energy needs. The system also stores excess renewable energy for later use, smoothes variable power output, and dispatches power when demand outpaces renewable generation. Other successful microgrids rely on lead-acid and even sodium-nickel chloride (NaNiCl) battery systems for energy storage and dispatch.

Grid-Tied Storage

Battery technologies appear to hold the most potential for dependable, economical, grid-tied energy storage. While sodium-sulfur (NaS) batteries supplied the first grid-scale storage, more advanced and innovative technologies are taking precedence, such as lithium-ion, flow batteries, sodium-nickel chloride, advanced lead-acid, and ultra-batteries [4]. Most of these batteries can integrate renewable resources with the grid and help manage intermittency.

Another noteworthy innovation is grid-connected thermal energy storage, a system that leverages HVAC systems nightly to generate and store energy in the form of ice or cold water for use the next day during peak demand periods [4]. Utilities can easily control thermal systems and scale them for residential and commercial sites.

Flywheel energy storage and bulk energy storage, including compressed air energy storage (CAES) and pumped hydroelectric storage, are also viable grid-scale storage solutions that can work with renewable resources. Large-scale battery plants and flywheel plants also play key roles, though they provide centralized versus distributed storage.

CO-LOCATING STORAGE AND DG

Distributed energy storage systems enable more widespread deployment of distributed generation, such as rooftop PVs and wind turbines (hundreds of kWs) for residential and small commercial sites. When co-located, storage and DG have the potential to deliver a number of important benefits to utility distribution systems and their customers. The core benefits of co-location include improved load factor, stabilized voltage, improved voltage profile, mitigated reverse current flow, and minimized power losses.

Load Factor Improvement

Improvement of the utility load factor (average load divided by peak load for a specific time period) can be achieved by time-shifting real power using distributed energy storage systems. Batteries and other storage devices can store excess energy generated off-peak by co-located renewable resources and re-dispatch that power later (time shifting).

Load factor improvement is very similar to load levelling or peak load shaving. The time profiles of loads and renewable generation are impacted together. Effective load levelling depends on the analysis of feeder-specific performance data coupled with accurate demand forecasting methods. The incorporation of renewable generation modelling and irradiance forecasting will help enhance this function for utilities. Load levelling also positively impacts the voltage profile along the distribution network, reducing power losses and enabling improved use of capacity.

Voltage Stabilization

Stabilization of distribution system voltage is achieved by minimizing the rate of change of apparent power (volt-amperes). This method uses distributed energy storage as a fast-acting, short-term resource that allows time for traditional voltage regulation equipment (including switched capacitors) to respond as steady state resources on the distribution controller. Each distributed storage unit can estimate and regulate voltage on the source side of its distribution transformer by modifying its flow of real power (watts). The energy storage unit can also regulate local, load-side voltage using reactive power compensation.

Voltage Profile Improvement

Utilities can improve the voltage profile by co-locating renewable resources and distributed energy storage systems. When storage is co-located with renewable resources at distribution load points, less power needs to be supplied by traditional generation. Utilities no longer need to rely on distant traditional generation plants, which are much slower to respond than local storage, to attempt to push voltage levels back up at the far edges of the distribution system.

By leveraging local battery storage, which reacts more swiftly, utilities can ensure that voltage drops are less severe and less likely to impact service.

Reverse Current Flow Mitigation

When energy storage is co-located with PV panels, it can prevent reverse current flow caused by excess generation during outages. Storage reliably mitigates reverse current flow by quickly consuming real power to charge its own battery. By consuming any excess power generated, battery storage prevents energizing the transformer's load side, thereby avoiding equipment damage and other potential safety problems.

Power Loss Minimization

Distributed energy storage systems, such as Community Energy Storage, located close to loads and renewable resources, can give utilities the control needed to reduce outages that would otherwise impact service at the grid's edge. Storage can mitigate these outages by warehousing power at or near distribution system load points. By improving distribution line efficiencies and reducing power outages, storage helps utilities strengthen the grid for more reliable service.

SUMMARY

Energy storage systems hold tremendous potential for enabling electric utilities to deploy distributed renewable generation, including rooftop PV panels and small wind turbines, on a much broader scale. As utilities gear up to meet the "20% by 2020" renewable energy use mandates enacted by central governments worldwide, they are adopting and deploying more grid-scale and distributed renewable energy resources. Utilities and governments are also recognizing the far-reaching benefits of co-locating distributed energy storage and distributed renewable generation. In the next decade and beyond, well-established and emerging energy storage technologies will be pivotal in realizing the shared global vision of more carbon-neutral, reliable, efficient, and intelligent electric power grids.

REFERENCES

[1] Stephen Jones, 2012, "Integrating Grid Technologies for a Low-Carbon Economy," *Pan European Networks: Government.* August issue 03, 172.

[2] Mike Edmonds, Troy Miller, 2012, "Distributed Energy Storage: Adapting the Grid to Changing Consumption Patterns", *NEMA electroindustry.* June issue, 22-24.

[3] Brad Roberts, 2013, "Substation Scale and Community Energy Storage," *IEEE Smart Grid Newsletter* (online). January issue.

[4] Bradford P. Roberts, 2012, "Energy Storage Solutions: Barriers and Breakthroughs to a Smarter Grid", *Public Utilities Fortnightly.* May issue, 46-57.