Co-located with Variable Energy Resources (VERs)

Author:
Sami Mardini, Director of Product Marketing, EnerVault Corporation, +1 626 318 2646,
smardini@enervault.com

Contributor:
Travis O'Guin, Business Development Analyst LightSail Energy, 510.981.8088 x 127,
toguin@lightsailenergy.com

1. Overview Section

As California moves towards full implementation of the 33 Percent Renewable Energy Portfolio Standard (RPS) by 2020, there is increasing concern about how high penetration rates of inherently variable resources, particularly from wind and solar, may adversely impact system stability. Beyond the fact that utility-scale development of these resources is generally in places far distant from load centers, and often in remote, sometimes environmentally sensitive locations, the operational characteristics of variable renewable energy complicates integration.

An obstacle to achieving higher levels of penetration of utility-scale renewable energy, especially wind and solar, is the variable nature of generation output from these resources. The times of the day when these resources are most productive do not align with the demand curves for utilities, and sudden shifts in weather patterns can cause intermittent output and potentially impacting grid stability. These weather-related variations may be diurnal (i.e., wind blows strongest at night when demand is low), of shorter duration (wind stops and starts abruptly), or even on an instantaneous basis (passing clouds cause solar power intermittency).

2. Use Case Description

This Use Case describes energy storage associated with a hypothetical VER such as a 100 MW wind or solar farm that connects to the grid to deliver energy under a long-term power contract, although a similar situation may apply to any large-scale renewable resource.

The energy storage system is charged by the renewables and delivers energy to the wholesale market at the owner's discretion. The energy storage system provides multiple benefits to both the wind/PV farm owner as well as the grid operator, including: ramp control, time-shifting, reactive power (power conditioning), curtailment avoidance and ancillary services (including regulation).

It is assumed that the resource has successfully connected to the grid under California ISO interconnection rules and possesses CAISO-approved telemetry that allows for remote monitoring of the resource and related factors (i.e., generation output, availability, meteorological data, and circuit-breaker status).

2.1 Objectives

Energy storage offers a way to alleviate output variability and potential instability by: 1) shifting the time when electricity is generated to better match utility demand; 2) balancing renewable generation to provide a more consistent and predictable output level; and 3) providing voltage support. Additionally, use of storage may potentially avoid curtailment of contracted deliveries from non-utility resources because of oversupply situations.

Without the energy storage system, additional ancillary services (i.e. spinning reserve) must be procured by grid operators to compensate for the intermittent nature of wind/PV energy. Additionally, transmission constraints or over production during off-peak hours could cause the VER to be curtailed, wasting hundreds of megawatt-hours of potentially "free" energy.

2.2 Actors

In this Use Case, the storage facility may be owned by 1) the utility, 2) the owner/operator of the VER, 3) a third party that provides backup and reliability under a separate arrangement, or 4) as a joint venture between the developer and the storage system supplier.

Name	*Role description*
Wind Farm Owner/Developer	For VER with co-located storage, developer designs, procures and installs an integrated generation and storage system. Owner operates the system.
Storage Provider	Provides and supervises installation of storage system and integration of controls. Assists developer in storage system sizing and design.
Utility	Determines interconnection and operational requirements for co-located storage. For distributed storage, develops project and operates storage system
Grid Operator	Qualifies project for market participation

2.3 Regulatory Proceedings and Rules that Govern Procurement Policies and Markets for This Use

Agency	*Description*	*Applies to*
CPUC	Renewable Portfolio Standard Bidding	Utility/Third Party
CPUC	Long-term Procurement Proceeding	Utility

CPUC	Resource Adequacy	Utility
CPUC	Rule 21 Interconnection	Third-party Owner
FERC	Order No. 785 Pay for Performance	ISO/RTO, Third-party Owner
CAISO	Renewable Interconnection Study	Utility/Third Party
Other		

2.4 Location

Under most scenarios, the energy storage device is located at the site of the renewable resource, to afford better integration with its operational status. However, given advanced communications technologies, a dedicated storage device does not necessarily need to be co-located with the generation, but may reside at a distant location, at a transmission substation, or in the case of a smaller facility, at a distribution substation.

2.5 Operational Requirements

The expected delivery of generation from this 100 MW wind farm is scheduled in advance under a non-binding day-ahead schedule. However, every hour, a new schedule is set, which governs the expectations for the following 24-hour period. At 2 hours prior to the actual operating hour, a binding hourly schedule takes effect.

In one scenario, the 100 MW resource initially generates in conformance with the forward schedule, but because of weather conditions, output begins trending downward and quickly falls below full capacity, triggering a shortfall between scheduled output and actual output.

The grid operator may respond by using Automatic Grid Control to remotely control output from other facilities that are able to provide balancing energy (aka regulating power) to maintain grid frequency stability at 60 hertz. However, if the balancing issue persists, the ISO will run out of regulating power, as only a limited number of units can provide it.

The ISO may also dispatch energy from its 5-minute market (aka, Balancing Energy Ex-Post Pricing, or BEEP-stack) which represents a real-time market for ancillary services.

Storage facilities may be participating in this real-time market, and can supply incremental energy in the same manner as traditional generators.

Alternatively, the storage could be directly tied to the VER, and act as a mediating resource without requiring ISO market intervention.

2.6 Applicable Storage Technologies

The potential storage device that appears most applicable to this Use Case is some form of battery, sized to support a portion of the effective capacity of the wind farm – roughly 35 MW. These could be a number of units stacked in a single location, or dispersed but aggregated to act as a single resource.

Commercially viable batteries of this scale include Redox Flow Batteries (RFB), Sodium Sulfur (NAS) and Lithium Ion (Li-Ion). A compressed air storage (CAES) facility could also provide the right combination of response rate and rated power to accommodate VER fluctuations.

In the case of providing longer-term storage solution for a larger set of wind farms on a system wide basis – for example, to store excess wind power generated at night for daytime discharge – it is possible to employ a very large capacity Redox Flow Battery Regenerative Air Energy Storage (RAES), or hydro pumped storage facility that is located distantly, but controlled by a central operator (either the utility or ISO).

Storage Type	*Storage capacity*	*Discharge Characteristics*
Batteries (NaS, Li-Ion)	35 MW/100 MWh	Fast response, medium duration
Batteries (RFB)	10 – 250 MW/ 4 to 8 hrs	Long 100% DOD cycle life. Especially suited for time shifting
Compressed Air (CAES or RAES)	0.5-100+ MW	

2.7 Non-Storage Options for Addressing this Objective

Among options available to address renewable energy variability are:

- A Balancing Energy Market to obtain incremental/decremental energy in real-time;
- Demand Response programs that incentivize end-users to increase or decrease consumption under pre-specified conditions;
- Generation with flexible ramping capacity to match changes in renewables output;
- Various technology upgrades to distribution system, such as static-VAR compensators, and switched capacitor banks to instantaneously adjust to fluctuations in voltage levels cause by abrupt generation variability.

3. Cost/Benefit Analysis

3.1 Direct Benefits

End Use	***Primary/ Secondary***	***Benefits/Comments***
1. Frequency regulation	P	Smaller incremental capacity with faster response and will increase efficiency and reduce maintenance of traditional generators.
2. Spin	S	
3. Ramp	P	Smaller incremental capacity with faster response and will increase efficiency and reduce maintenance of traditional generators.
4. Black start		
5. Real-time energy balancing	P	Smaller incremental capacity with faster response and will increase efficiency and reduce maintenance of traditional generators.
6. Energy arbitrage	P	Benefit enabled by high capacity, time-shift capable storage. Eliminates curtailment.
7. Resource Adequacy		
8. VER[1] / wind ramp/volt support,	P	Smaller incremental capacity with faster response and will increase efficiency and reduce maintenance of traditional generators.
9. VER/ PV shifting, Voltage sag, rapid demand support	P	Benefit enabled by high capacity, time-shift capable storage
10. Supply firming	P	Same as above
11. Peak shaving: load shift	S	Same as above
12. Transmission peak capacity support (deferral)	S	Benefit enabled by distributed high capacity, time-shift capable storage
13. Transmission operation (short duration performance,	S	Same as above

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[1] VER = Variable Energy Resource

inertia, system reliability)		
14. Transmission congestion relief	S	Same as above
15. Distribution peak capacity support (deferral)	S	Same as above
16. Distribution operation (volt/VAR support)	S	Same as above
17. Outage mitigation: microgrid		
18. TOU energy mgt		
19. Power quality		
20. Back-up power		

3.2 Other Beneficial Attributes

Benefit Stream	*Y/N*	*Assumptions*
Flexibility (Dynamic Operations)	Y	
Reduced Fossil Fuel Use	Y	Storage improves traditional generation reserves capacity factor and efficiency thus reducing fuel usage
Reduced Emissions	Y	See above + stores and delivers renewable energy
Increased T&D Utilization		
Reduced T&D Investment Risk	Y	When distributed high capacity, time-shift capable storage is used
Power Factor Correction	Y	When distributed storage is used
Optionality		
Safety and Environmental Impact	Y	Highly dependent on storage technology and chemistry
Increased use of renewables to meet RPS goals	Y	Assuming the renewable is curtailed at least some of the time due to congestion, lack of demand or other constraint

3.3 Analysis of Costs

Cost Type	*Description*
Installation	
O&M	

3.4 Cost-effectiveness Considerations

Our analysis has concluded that adding energy storage to a wind farm can increase the IRR of the project substantially. Time shifting wind energy production from off-peak to peak alone can increase revenues by close to 20% (depending on the nature and structure of the PPA).

However, Current PPA structures do not explicitly recognize the value of RE firming or time shifting. Currently, storage used for renewable integration derives economic value almost exclusively from regulation services.

In addition, many utilities have yet to establish smoothing, firming and ramp requirements or standards.

4. Barriers Analysis and Policy Options

4.1 Barrier Resolution

Barriers Identified	*Y/N*	*Venue for Resolution*
System Need	Y	
Cohesive Regulatory Framework	N	
Evolving Markets	Y	
Resource Adequacy Value	N	
Cost Effectiveness Analysis	N	
Cost Recovery Policies	N	
Cost Transparency & Price Signals	N	
Commercial Operating Experience	Y	
Interconnection Processes	N	

4.2 Other Considerations

Smoothing, firming and ramp requirements or standards are needed. These need to be developed by individual utilities and incorporated in RE projects specifications.

5. Real World Example

5.1 Project Description

AES Laurel Mountain Project

This 32 MW integrated battery storage project supports a 98 MW wind farm owned by AES Wind Generation selling regulation services to the PJM Interconnection, by delivering instantaneous response to grid operator requests for power, and balancing generation and demand. The storage also allows the wind facility to control the ramp rate of its generation smoothing out fluctuations in minute to minute output.

The AES Laurel Mountain project consists of 61 GE 1.6 MW wind turbine generators capable of a combined power generation of 97.6 MW combined with 32 MW of A123 Systems energy storage devices (lithium Ion).

Configuration is 16 x 2 MW, with 15 minute discharge capacity.

Location	Laurel Mountain, West Virginia
Operational Status	Online October 2011
Ownership	AES Storage/AES Energy
Primary Benefit Streams	Regulation Services to PJM
Secondary Benefits	Wind Firming
Available Cost Information	Total project cost $239 million; storage component breakout not available

5.2 Outstanding Issues

Description	*Source*
At this point, selling regulations services to grid operator has been more of a benefit than wind firming	AES executive

5.3 Contact/Reference Materials

Praveen Kathpal
praveen.kathpal@aes.com
(703) 682-6690
4300 Wilson Boulevard 11th Floor,
Arlington , Virginia 22203

AES Wind Generation and AES Energy Storage Announce Commercial Operation of Laurel Mountain Wind Facility Combining Energy Storage and Wind Generation; AES news release, Oct. 27, 2011.

6. Conclusion and Recommendations

Is ES commercially ready to meet this use?

Yes, See Section 5

Is ES operationally viable for this use?

Yes, See Section 5

What are the non-conventional benefits of storage in this use?

Refer to section 3.2

Can these benefits be monetized through existing mechanisms?

If not, how should they be valued?

No. A project-specific scoring system for non-monetized benefits should be considered and included in evaluating ES solutions.

Is ES cost-effective for this use?

See section 3. Yes, but higher volumes are needed to improve cost-effectiveness.

What are the most important barriers preventing or slowing deployment of ES in this use?

What policy options should be pursued to address the identified barriers?

Refer to Section 4

Should procurement target or other policies to encourage ES deployment be considered for this use?

Yes. Targets with incentives are needed to accelerate adoption leading to higher volumes that will greatly improve cost-effectiveness.