Ancillary Services – Frequency Response

1. Overview Section

Frequency response is the rapid change in power output that initially stabilizes frequency after an unexpected outage. Without frequency response, a contingency event, such as a sudden generator outage, could rapidly destabilize wide areas of the grid. The amount of measured frequency response in the U.S. has been declining over time.[1] In order to address this decline, NERC may require that Balancing Authorities procure a minimum quantity of frequency response under proposed standard BAL-003-1.[2] If the standard is approved, then a market for frequency response would likely be established.[3]

Traditional rotating generators must maintain unloaded capacity in order to provide frequency response. For example, a 200MW generator operating at 197MW could provide 3MW of frequency response. Renewable generators can also provide frequency response, albeit at significant opportunity cost. This use case describes how an energy storage device could also provide frequency response.

2. Use Case Description

The energy storage device responds to local frequency deviations and injects or withdraws power, as necessary, to prevent frequency runaway and cascading outages.

2.1 Objectives

Any policy or market design should implement a future BAL-003-1 requirement while maximizing reliability and minimizing economic cost. The service should be open to any resource that meets the performance requirements.

Energy storage is a highly responsive, highly configurable resource that can provide frequency response.

2.2 Actors

In this Use Case, the storage facility may be owned by 1) a standalone storage provider, 2) an IPP in conjunction with other generation assets or 3) a vertically integrated utility.

[1] Robert Cummings (NERC), "Frequency Response Trends," Frequency Response Technical Conference, Arlington VA, May 23, 2012

[2] Clyde Loutan, "Frequency Response," CPUC Operational Flexibility Meeting, San Francisco CA, June 4, 2012.

[3] NERC, "Meeting Notes, Project 2007-12 Frequency Response Standard Drafting Team," Carmel IN, June 21-22, 2012.

Name	Role description
Generator Owner	Operates a standalone frequency response resource or a hybrid generator and storage system
Storage Provider	Operates a standalone frequency response resource
Load Serving Entity	Allocated a portion of frequency response procurement costs
Grid Operator	Clears market that procures frequency response capacity
Balancing Authority	Must demonstrate compliance with (proposed) NERC BAL-003-01

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

Agency	Description	Applies to
FERC	Order 693	NERC
NERC	BAL-003 Proposed Standard	Balancing Authority/CAISO
CAISO	Frequency Response Analysis	Utility/Third Party
CPUC	Long-term Procurement Proceeding	Utility
CPUC	Resource Adequacy	Utility

Order 693 directed NERC to "define necessary amount of Frequency Response for reliable operations with methods of obtaining response and measuring that the frequency response is achieved."[4] NERC is considering a BAL-003-1, new reliability standard that would mandate procurement of frequency response. If passed, the CAISO would need to set up a mechanism to procure this service, much like operating reserves.

Note that the market mechanisms for frequency response valuation do not yet exist.

2.4 Location

The energy storage device may be located at any point in the transmission and distribution network.

[4] Terry Bilke, "BAL-003-1 Overview," Frequency Response Technical Conference, Arlington VA, May 23, 2012

2.5 Operational Requirements

The energy storage device must continuously monitor the local frequency, which is nominally 60Hz. When the local frequency dips below a threshold (-0.1Hz/TBD), the energy storage device must deploy its full capacity within 2-5 seconds. Upon recovery above a second threshold (-0.05Hz/TBD), the energy storage system reverts to its standby mode of operation and/or begins a charge cycle.

The frequency response performance requirement necessitates logic and intelligence at the end point. The time required to send measurements sent back to a central dispatch system and instructions to the energy storage unit would introduce too much latency to provide frequency response.[5]

2.6 Applicable Storage Technologies

Any inverter-based energy storage device, including a battery or flywheel, would be ideal resources for this service. These resources, based on digital controls, have the capability to deploy their full capacity well within the time frame (seconds) required for frequency response.

Compressed Air Storage (CAES) may be able to offer a portion of its capacity for frequency response, depending on its governor controls.

Storage Type	*Storage capacity*	*Discharge Characteristics*
Batteries (NaS, Li-Ion)	35 MW/100 MWh	Fast response, medium duration
Compressed Air	100 MW+	
Pumped Storage	100 MW+	

2.7 Non-Storage Options for Addressing this Objective

Among options available to address renewable energy variability are:

- Demand Response resources that shed load during under-frequency conditions
- Generation unloaded capacity or "headroom." This capacity could be located on a traditional thermal generator or a renewable resource.

[5] Hsieh and Johnson, "Frequency Response from Autonomous Battery Energy Storage," CIGRE Grid of the Future, Kansas City MO, October 30, 2012

3. Cost/Benefit Analysis

3.1 Direct Benefits

End Use	*Primary/ Secondary*	*Benefits/Comments*
Frequency Response	P	[Not listed in the original template]
1. Frequency regulation	S	A frequency response-capable resource would also be able to prove frequency regulation, but would not be able to provide both services simultaneously.
2. Spin		
3. Ramp		
4. Black start		
5. Real-time energy balancing		
6. Energy arbitrage		
7. Resource Adequacy	P	If BAL-003-1 passes, then frequency response must be procured in order to demonstrate compliance with NERC reliability rules, and could be considered a component of Resource Adequacy.
8. VER[6] / wind ramp/volt support,	S	A storage resource could be operated to provide voltage support in conjunction with frequency response
9. VER/ PV shifting, Voltage sag, rapid demand support		
10. Supply firming		
11. Peak shaving: load shift		
12. Transmission peak capacity support (deferral)		

[6] VER = Variable Energy Resource

13. Transmission operation (short duration performance, inertia, system reliability)		
14. Transmission congestion relief		
15. Distribution peak capacity support (deferral)		
16. Distribution operation (volt/VAR support)	S	A storage resource could be operated to provide voltage support in conjunction with frequency response
17. Outage mitigation: microgrid		
18. TOU energy mgt		
19. Power quality	S	If located close to load, a frequency response resource would have the effect of correcting frequency-based power quality issues.
20. Back-up power		

3.2 Other Beneficial Attributes

Benefit Stream	*Y/N*	*Assumptions*
Flexibility (Dynamic Operations)	Y	
Reduced Fossil Fuel Use	Y	
Reduced Emissions	Y	
Increased T&D Utilization		
Reduced T&D Investment Risk		
Power Factor Correction		

Optionality		
Other		
Other		

3.2 Analysis of Costs

Cost Type	*Description*
Installation	
O&M	

3.3 Cost-effectiveness Considerations

4. Barriers Analysis and Policy Options

4.1 Barrier Resolution

Barriers Identified	*Y/N*	*Venue for Resolution*
System Need	Y	NERC BAL-003-1 Proposal
Cohesive Regulatory Framework	N	
Evolving Markets	Y	After BAL-003-1 approval, FERC and NAESB (?) for market guidelines
Resource Adequacy Value	Y	After FERC/NAESB Guidelines, determination at CAISO and CPUC on how best to fit this new requirement into California procurement processes
Cost Effectiveness Analysis	N	Ideally, an open market will select the most cost-effective resource, negating the need for analysis
Cost Recovery Policies	Y	Cost for this new resource will need to be allocated
Cost Transparency & Price Signals	N	

Commercial Operating Experience	N	Multi-year commercial operational experience of storage as a frequency response resource already exists.
Interconnection Processes	N	

4.1 Other Considerations

5. Real World Example

5.1 Project Description

AES Gener Los Andes[7]

In 2009, a 12MW, 4MWh BESS was installed in northern Chile in order to offload some of the reserve obligation of a 277MW generation station. The generation station is comprised of two units. Unit 1 (NTO1) has a capacity of 136 MW and unit 2 (NTO2) has a capacity of 141 MW. The BESS consists of eight 1.5MW, 500KWh containerized storage systems, as shown in Figure 1. Each container houses lithium nanophosphate cells arrayed in a modular and hierarchical configuration of packs, trays, racks, and containers, as shown in Figure 2. The containers also house inverters which provide the three phase connection to the low side of a step up transformer.

The BESS responded to approximately 200 contingency events from 2007 to 2012. Gross generator output increased from approximately 253 MW to 267 MW. The typical CPF response increased from approximately 6 MW to nearly 12 MW.

Location	Los Andes, Chile
Operational Status	Online November 2009
Ownership	Owned as part of a hybrid fleet of conventional generators and storage

[7] Hsieh and Johnson, "Frequency Response from Autonomous Battery Energy Storage," CIGRE Grid of the Future, Kansas City MO, October 30, 2012

Primary Benefit Streams	Frequency Response
Secondary Benefits	Increased generator output
Available Cost Information	

Figure 1: View of the BESS installation in Northern Chile

Figure 2: View inside a BESS container

5.2 Outstanding Issues

Description	*Source*
The NERC frequency response requirement is not yet finalized	NERC

5.3 Contact/Reference Materials

6. Conclusion and Recommendations

CPUC and CAISO should incorporate placeholders in future market reforms (such as flexible capacity procurement) to ensure compatibility with frequency response requirements that will likely be approved by NERC.