Measuring and Expressing the Performance of Energy Storage Systems

Update on and Overview of Revision 2 to the PNNL/SNL Protocol

June 30, 2016

PNNL-SA-118995/SAND2016-6155 PE

Purpose and Expected Outcome

Purpose

Provide an update on enhancements to the *Protocol for Measuring and Expressing Energy Storage System Performance*

Expected Outcome

An understanding of the new metrics, applications and improved format in the protocol leading to increased application and use of the protocol

Background

Problem prior to 2012 - lack of a uniform and repeatable method for determining and expressing system performance

- March 2012 – project initiated under DOE OE ESS Program to involve all interested stakeholders in the development of a protocol/pre-standard for immediate use and as a basis for US and international standards
- November 2012 – first version of the protocol completed (2 applications 7 performance metrics)
- June 2014 – second version completed (added 1 more application and enhanced selected provisions)
- April 2016 – third version completed (added 5 more applications, more metrics and revised format for ease of use)

Protocol Overview

- Describe ESS (boundary and system content) – 4.2
- Identify ESS Application(s) – 4.3
- Specifications and Performance Metrics- 4.4
- Measurements and Determination of Performance Metrics – 4.5
- Reporting of Results – 4.6

Applications Addressed

- Peak shaving
- Frequency regulation
- Islanded microgrids
- Volt/var support NEW
- Power quality NEW
- Frequency control NEW
- PV Smoothing NEW
- PV Firming NEW

- Work for each new application
  - ✓ Describe and define the application
  - ✓ Develop appropriate duty cycle(s)
  - ✓ Confirm which existing metrics are applicable and if necessary adjust them for the application
  - ✓ Identify new metrics that are relevant and needed

General Information and Tech Specs

NEW

Table 4.4.1 General Information and Technical Specifications

Subject	Description
Enclosure Type	A description of the system enclosure, including any enclosure supplied with the system, provided as a part of the site installation and/or comprised of building assemblies associated with the installation.
Equipment Footprint	L x W of system including all ancillary components (sq. ft.).
Height	Equipment height plus safe clearance distances above the equipment (ft.).
Weight	Weight of each individual sub-system (PCS, ESS, accessories, etc.), including maximum shipping weight of largest item that will be transported to the project site (lbs.).
Grid Communication Protocols/Standards	List of communications related protocols and standards with which the ESS is compliant.
General Description of the Energy Storage System	Identification of the energy storage technology type (e.g. battery type, flywheel, etc.) used in the ESS.

Table 4.4.1 added in response to and based on input from EPRI ESIC

General Information and Tech Specs

NEW

Table 4.4.1 (Cont.) General Information and Technical Specifications

Subject	Description
Warranty & Replacement Schedule	Warranty inclusions and exclusions, including replacement schedules and timespan of warranty and any limitations.
Expected Availability of System	Percentage of time that the ESS is in full operation performing application-specific functions taking into account both planned and unplanned down-time.
Rated Continuous Discharge Power	The rate at which the ESS can continuously deliver energy for the entire specified SOC range of the storage device that comprises the ESS.
Rated Apparent Power	The real or reactive power (leading and lagging) that the ESS can provide into the AC grid continuously without exceeding the maximum operating temperature of the ESS.
Rated Continuous Charge Power	The rate at which the ESS can capture energy for the entire SOC range of the storage device that comprises the ESS.

Table 4.4.1 added in response to and based on input from EPRI ESIC

General Information and Tech Specs

Table 4.4.1 (Cont.) General Information and Technical Specifications

NEW

Subject	Description
Rated Continuous AC Current (discharge and charge)	The AC current that the ESS can provide into the grid continuously and can be charged by the grid continuously without exceeding the maximum operating temperature of the ESS.
Output Voltage Range	The range of AC grid voltage under which the ESS will operate in accordance with the ESS specification.
Rated Discharge Energy	The accessible energy that can be provided by the ESS at its AC terminals when discharged at its beginning of life (BOL) and end of life (EOL).
Minimum Charge Time	The minimum amount of time required for the ESS to be charged from minimum SOC to its rated maximum SOC.

Table 4.4.1 added in response to and based on input from EPRI ESIC

Reference Performance

Table 4.4.2 Reference Performance

Subject	Description
Stored Energy Capacity (Section 5.2.1)	The amount of electric or thermal energy capable of being stored by an ESS expressed as the product of rated power of the ESS and the discharge time at rated power.
Round Trip Energy Efficiency (5.2.2)	The useful energy output from an ESS divided by the energy input into the ESS over one duty cycle under normal operating conditions, expressed as a percentage.
Response Time (Section 5.2.3)	The time in seconds it takes an ESS to reach 100 percent of rated power during charge or from an initial measurement taken when the ESS is at rest.
Ramp Rate (Section 5.2.3)	The rate of change of power delivered to or absorbed by an ESS over time expressed in megawatts per second or as a percentage change in rated power over time (percent per second).
NEW **Reactive Power Response Time (Section 5.2.3)**	The time in seconds it takes an ESS to reach 100 percent of rated apparent power during reactive power absorption (inductive) and sourcing (capacitive) from an initial measurement taken when the ESS is at rest.

Table 4.4.2 Applies to ALL ESS regardless of intended application(s)

Reference Performance

Table 4.4.2 (Cont.) Reference Performance

	Subject	Description
NEW	**Reactive Power Ramp Rate (Section 5.2.3)**	The rate of change of reactive power delivered to (inductive) or absorbed by (capacitive) by an ESS over time expressed as MVAr per second or as a percentage change in rated apparent power over time (percent per second).
NEW	**Internal Resistance (Section 5.2.3)**	The resistance to power flow of the ESS during charge and discharge
NEW	**Standby Energy Loss Rate (Section 5.2.4)**	Rate at which an energy storage system loses energy when it is in an activated state but not producing or absorbing energy, including self-discharge rates and energy loss rates attributable to all other system components (i.e. battery management systems (BMS), energy management systems (EMS), and other auxiliary loads required for readiness of operation).
NEW	**Self-discharge Rate (Section 5.2.5)**	Rate at which an energy storage system loses energy when the storage medium is disconnected from all loads, except those required to prohibit it from entering into a state of permanent non-functionality.

Table 4.4.2 Applies to ALL ESS regardless of intended application(s)

Enhancements Related to Reference Performance

- Run reference performance tests ONCE regardless of intended ESS application(s)
- In Rev. 1, the 1st cycle was excluded from cumulative RTE calculation. Included 1st cycle in Rev. 2
- In Rev 1, individual cycle RTE was excluded and it is now included individual RTE
- Added separate equations for the case when auxiliary load is powered by a separate line
- For capacity test the test may begin with charge OR discharge
- Result tables for capacity test specify maximum power and average power during charge and discharge

Duty-cycle Performance

Table 4.4.3(a.) Duty-cycle Performance

Subject	Description
Duty-cycle Round Trip Efficiency DC RTE (Section 5.4.1)	The useful energy output from an ESS divided by the energy input into the ESS over a charge/discharge profile that represents the demands associated with a specific application that is placed on an ESS, expressed as a percentage.
Reference Signal Tracking RST (Section 5.4.2)	The ability of the ESS to respond to a reference signal
State of Charge Excursions SOCX (Section 5.4.3)	The maximum and minimum SOC attained by the ESS during the execution of the duty cycle.
Energy Capacity Stability ECS (Section 5.4.4)	The energy capacity at any point in time as a percent of the initial energy capacity.

- ***RST does not apply to peak shaving***
- ***DC RTE does not apply to Volt/Var***

Duty-cycle Performance

Table 4.4.3(b.) Duty-cycle Performance – Added Metrics for Volt-var

Subject	Description
∆SOC_Volt-VAr (Section 5.4.5.1)	The difference between the final and initial SOC shall be reported, along with the initial SOC
∆SOC_active standby (Section 5.4.5.1)	The difference between the final and initial SOC at the end of an active standby of same duration as Volt-var duty cycle with auxiliary load turned on, with the initial SOC the same as the value at the start of the Volt-var duty cycle shall be reported.
Wh_discharge (Section 5.4.5.1)	The real energy injected (with and without Volt-var duty cycle)
Wh_charge (Section 5.4.5.1)	The real energy absorbed (with and without Volt-var duty cycle)
Wh_net (Section 5.4.5.1)	The net energy (injected or absorbed) (with and without Volt-var duty cycle)

Duty-cycle Performance

Table 4.4.3(c.) Duty-cycle Performance – Added Metrics for Power Quality and Frequency Control

Subject	Description
Peak Power (Section 5.4.5.2 or Section 5.4.5.3 for Power Quality or Frequency Control Applications Respectively)	The peak power the ESS can provide for a specific duration.

Enhancements Related to Duty-cycle Performance

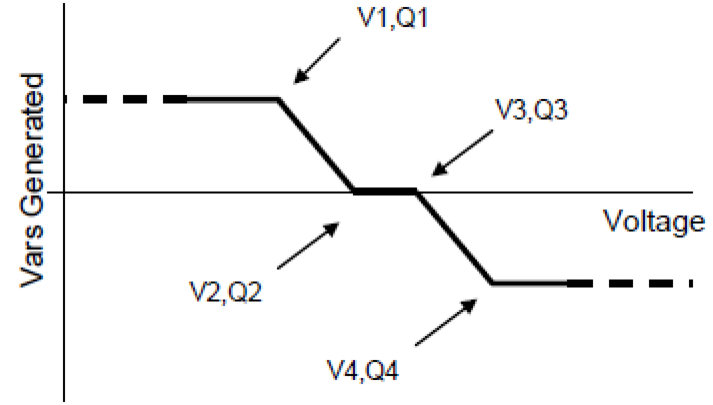
- Run duty-cycle tests in conjunction with reference performance tests
- Use same test set up and data gathering scheme – just run the duty-cycle tests using the duty-cycle for each intended ESS application
- For peak shaving tests the duty cycle may begin with charge OR discharge.
- Result tables for the peak shaving test specify maximum power and average power during charge and discharge
  - For charge, since charge duration is 12 hours, the charge power may taper at some point.
  - For discharge at various powers (6, 4, 2h), the power may taper off towards the end.

Overview of Volt-Var, Power Quality and Frequency Control

- Various var control approaches
  - Unity power factor (PF), Fixed PF, Variable PF, Volt-var
- This work looks at Volt-var
  - During this operation, ESS does ONLY Volt-var
- Available reactive power = rated apparent power
- Absorb reactive power when grid voltage too high
- Source reactive power when grid voltage too low
- Mainly used in distribution grids
  - 120V, 240V residential
  - ~ 5kV commercial
  - 25-50 kV industrial
- Various functions of reactive power needed as f(grid voltage) available (Smart Inverter Working Group, SAND2013-9875, EPRI)

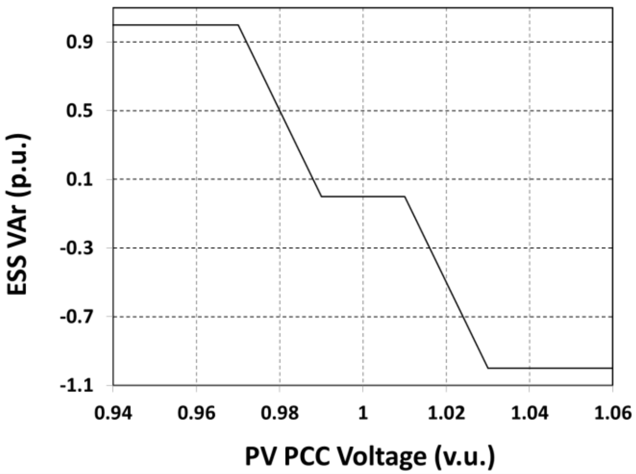
Volt-var

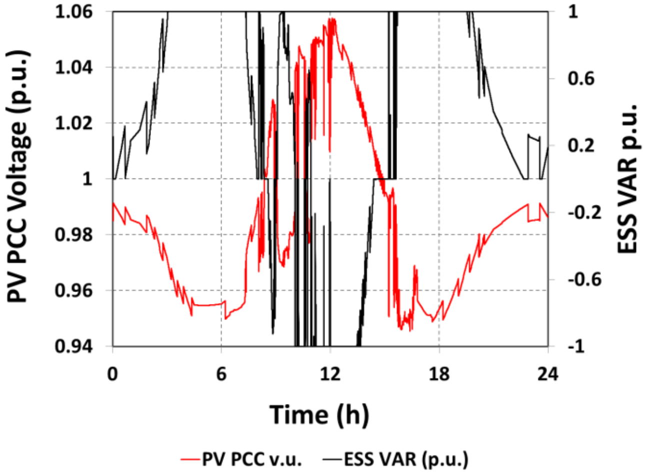
- The reactive power varies as a function of the ESS terminal voltage – this function is a “piecewise linear” between pairs of Qi,Vi, where Qi is ESS reactive power output and Vi is ESS terminal voltage



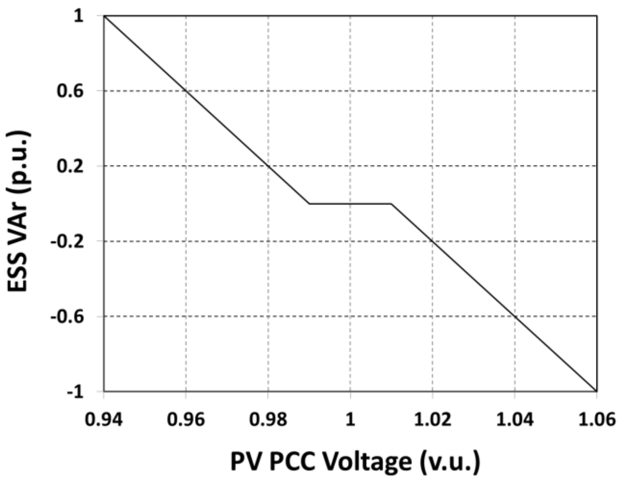
- There is a deadband around the nominal voltage. Q1 and Q4 are 100% of ESS rated power, while V1 is 97% of rated power, and V2 103% of rated power
- While developed for PV inverters, this is easily adapted for ESS - for only Volt-VAr the reactive power is simply equal to ESS rated power
- Repeating this for systems with and without PV is expected to cover the range of Volt-var needs
- Testing the ESS for 24 hours continuously is expected to yield a stressful test to determine reliability

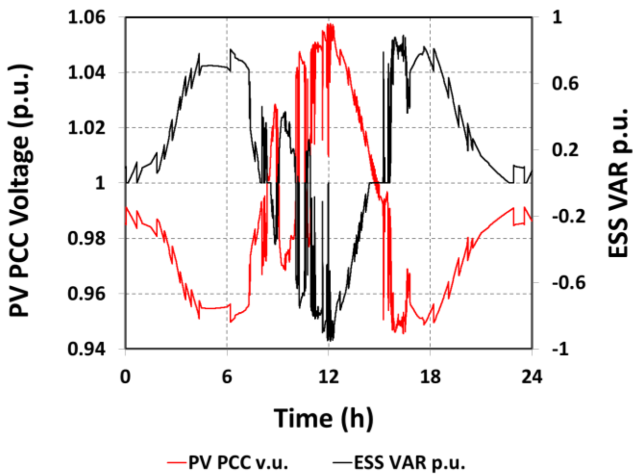
Volt-var Summary ESS Power as f(grid voltage)





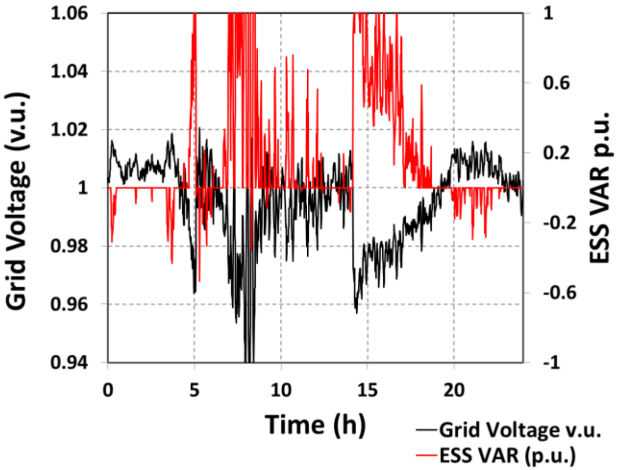
Aggressive case

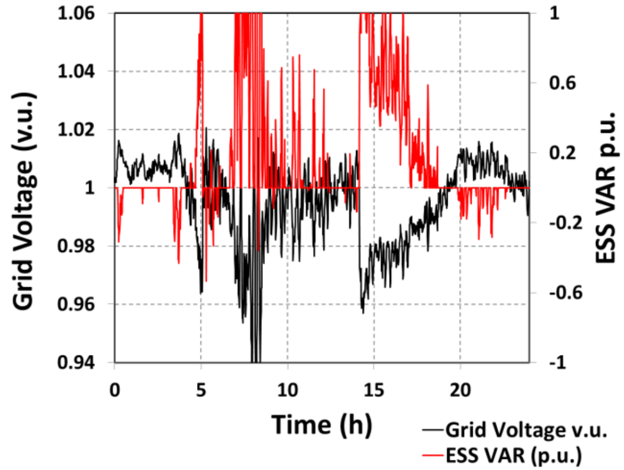


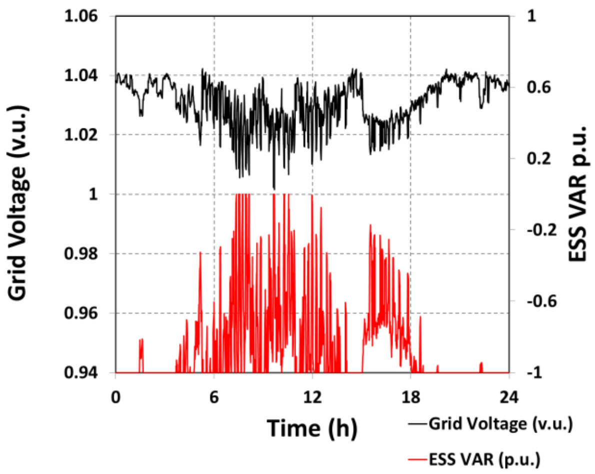


Moderately Aggressive case

Aggressive Volt-var Signal Applied to Grid Lab-D Generated Voltage at 3 Different Feeder Locations







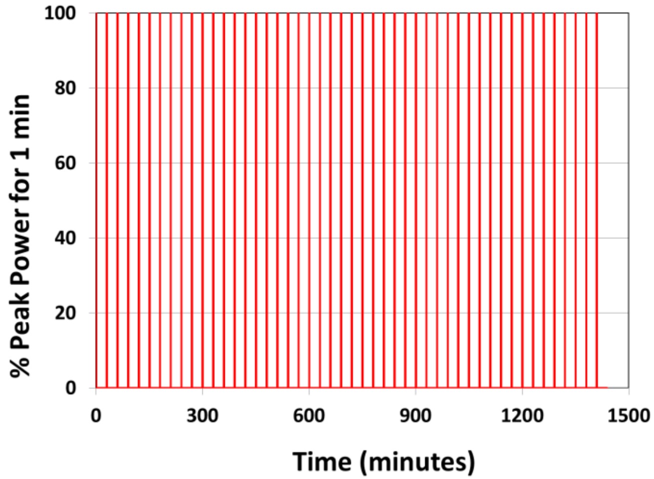
Clockwise from top left:
Distribution grid feeder voltage with
1) deviations above and below the reference voltage
2) deviation mostly less than the reference voltage
3) deviation mostly greater than the reference voltage

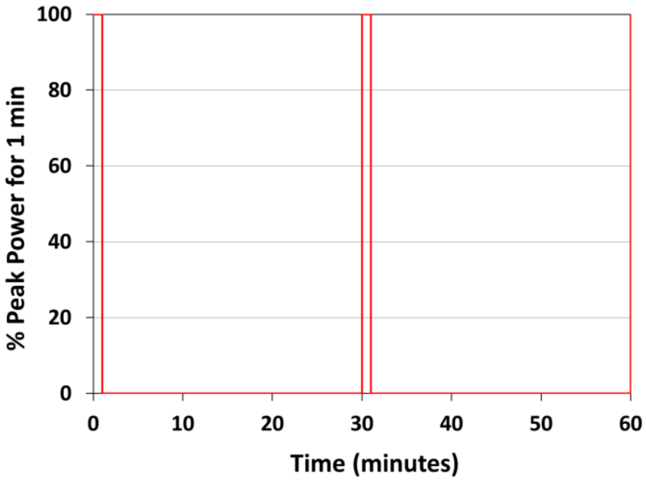
Power Quality

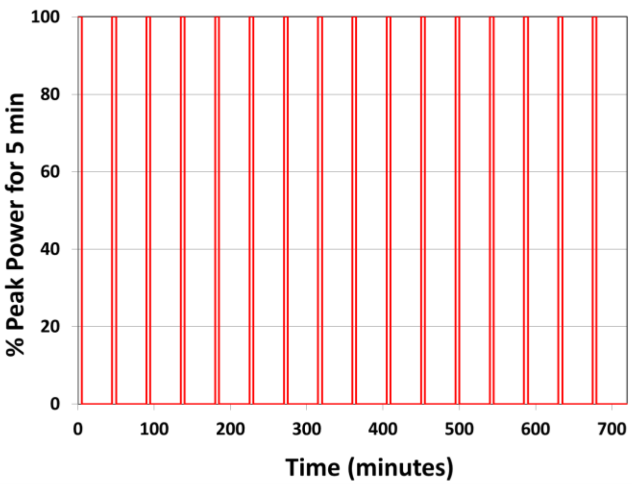
- ESS can mitigate a sag or interruption in voltage that can cause power disturbances that negatively impact power quality (mostly on distribution systems) by injecting real power for up to a few tens of seconds
- This application does not require storage to provide enough power for customers to ride through an outage w/o power loss
- The duty cycle consists of continuous discharge at peak power for 1 min, 5 min and 10 min, where peak power is defined as maximum power for 1 minute, 5 min and 10 min.

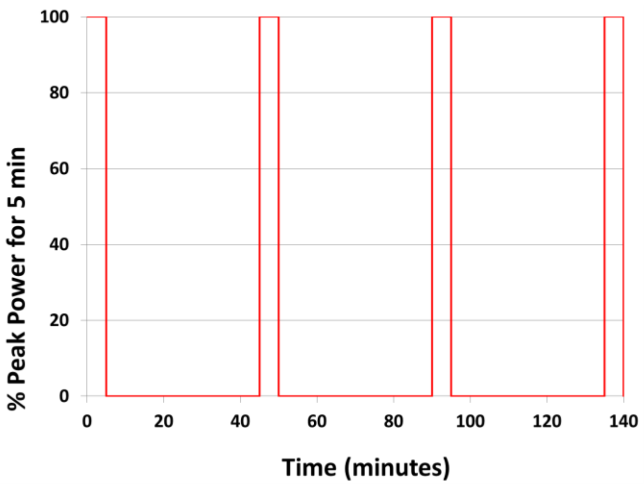
Power Quality Duty-cycle

Left – full duty cycle
Right – zoomed in for clarity





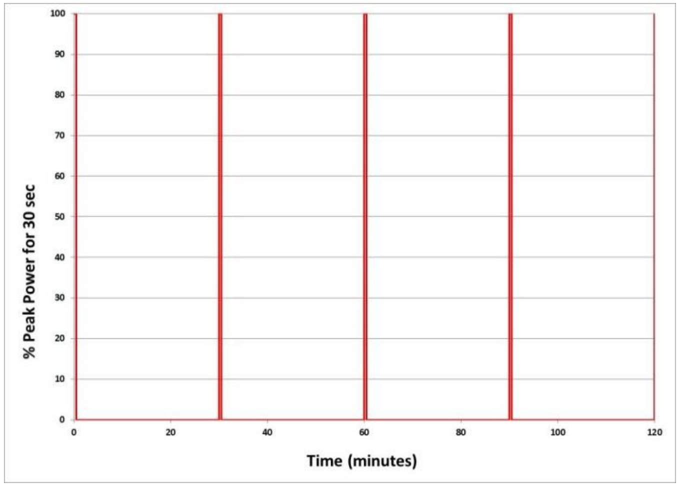


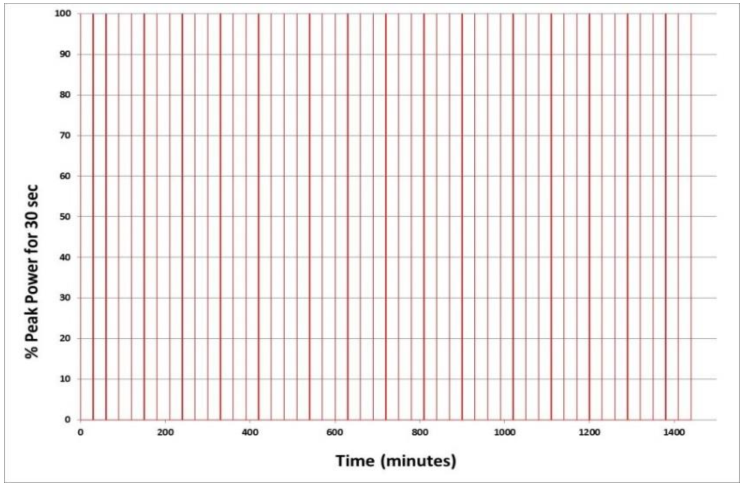


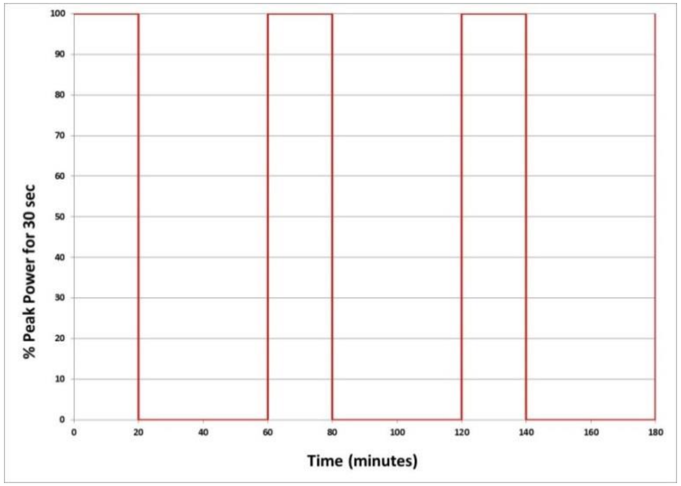
Primary and Secondary Frequency Control

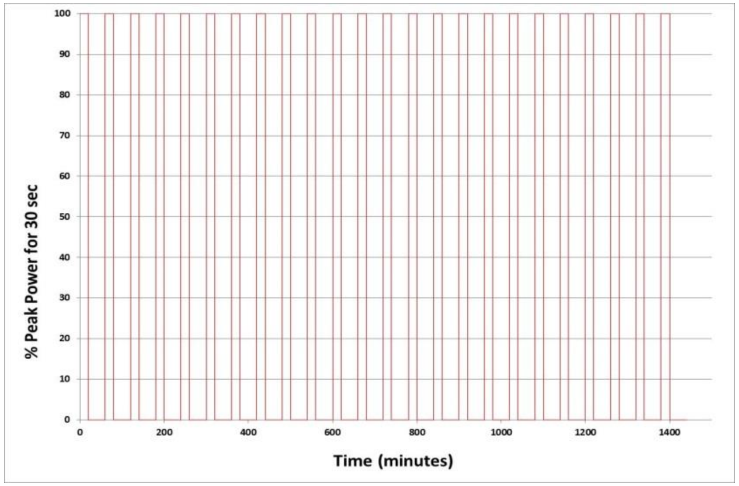
- Sudden loss of load – needs injection of real power for 30 sec (primary frequency control); injection for 20 min (secondary frequency control)
- Duty cycle (charge for sudden loss of lead)
  - Discharge at 30-s peak power for 30 sec (primary frequency control)
  - Discharge at rated power for 20 min (secondary frequency control)

Frequency Control Duty-cycle



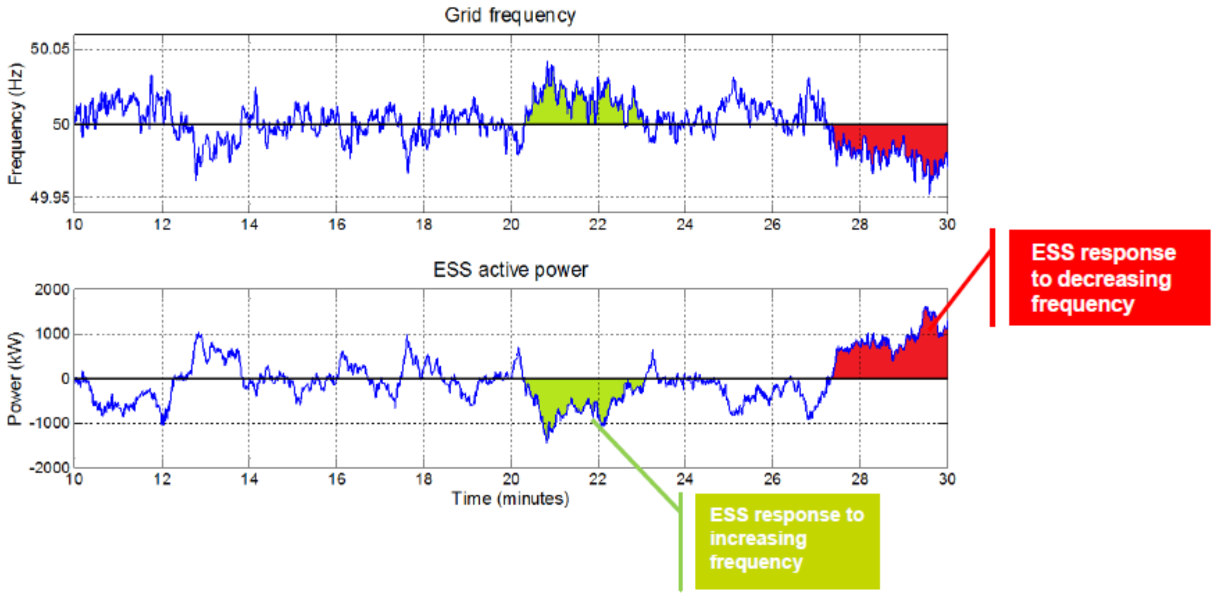


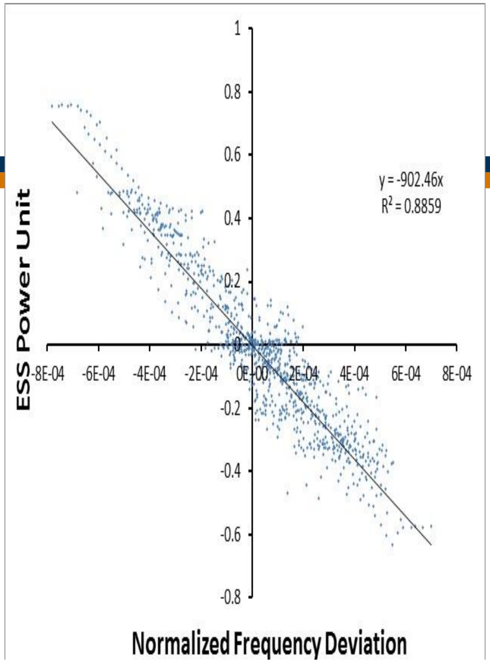


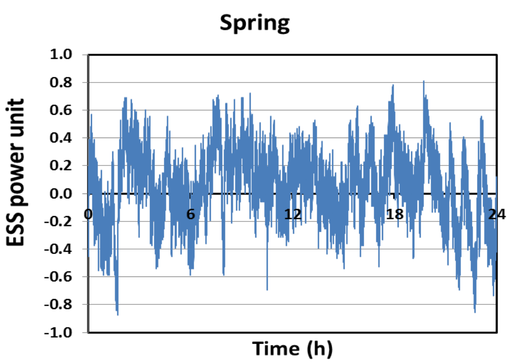


Dynamic Frequency Control – Additional Duty Cycles

EXAMPLE: PRIMARY FREQUENCY CONTROL







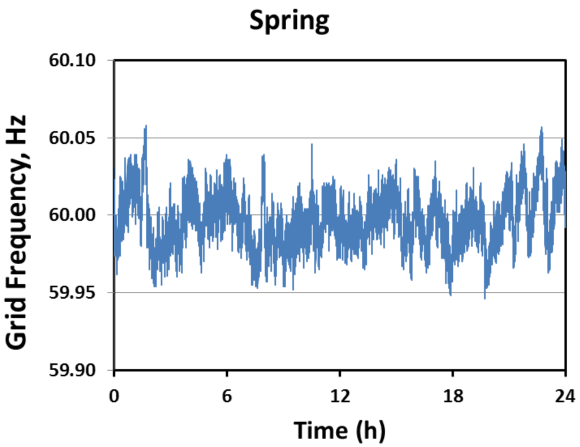
FIELD TESTS: May 2015 to May 2016

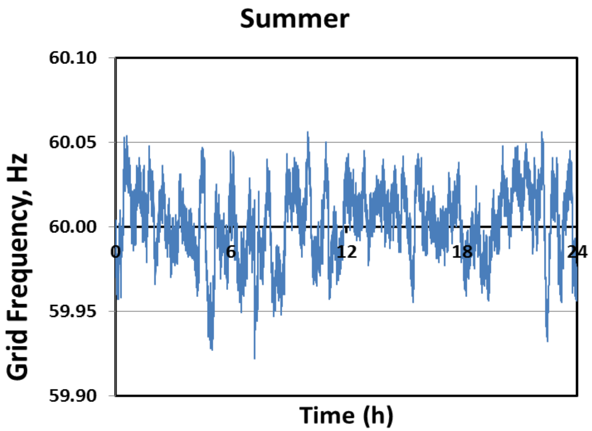
GOAL: analyze impacts of seasonal variations of wind generation and load on the operation of the storage system (benefits, grid constraints, etc.)

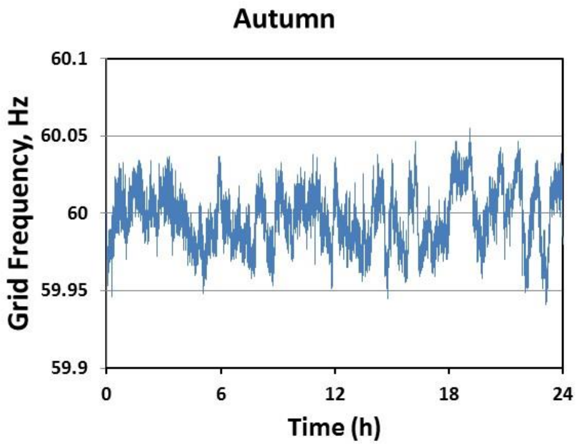
Bruno Prestat (EDF), Chair EPRI-ESIC WG4 Grid Integration. July 10, 2015 presentation
Didier Colin et al ERDF/SAFT/Schneider Electric and others – Venteea 2 MW 1.3 MWh battery system. Lyon France 15-18 June 2015

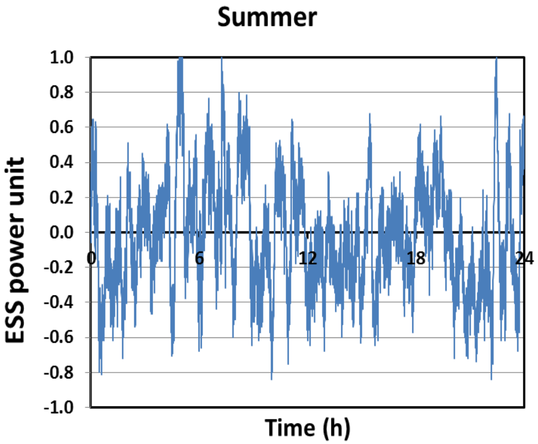
Applied the response signal to a US grid for Spring season

Grid Frequency Data from a Utility for 4 Seasons

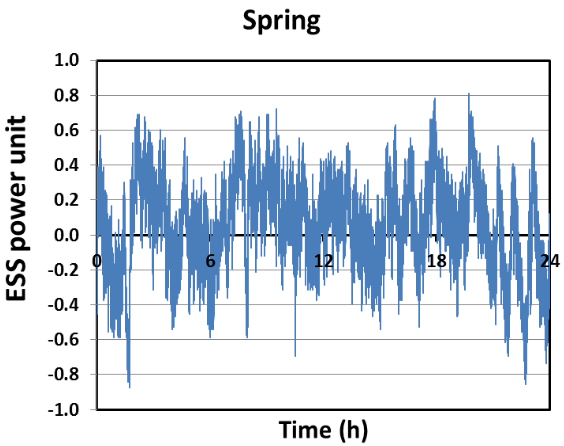


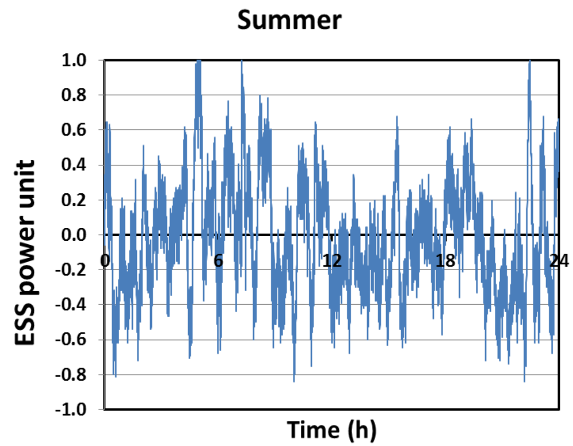


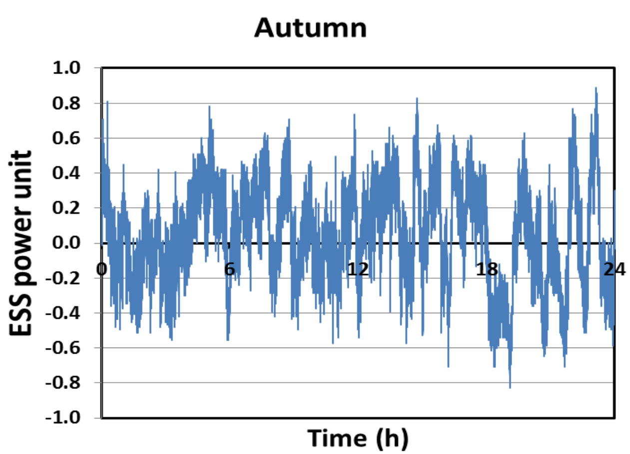


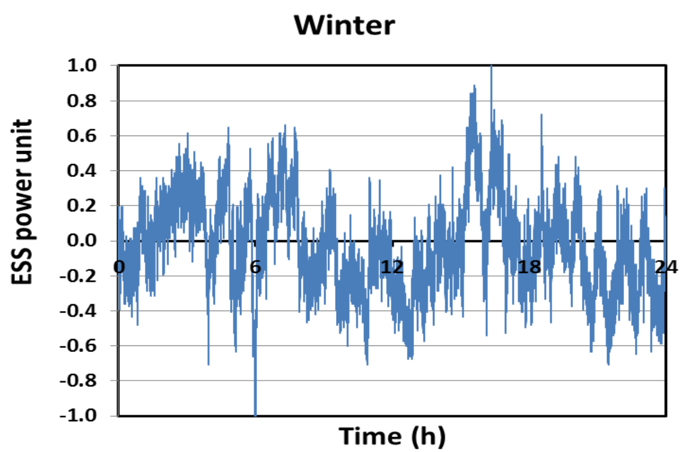


Duty Cycle (dynamic frequency control) for BESS from Grid Frequency Data





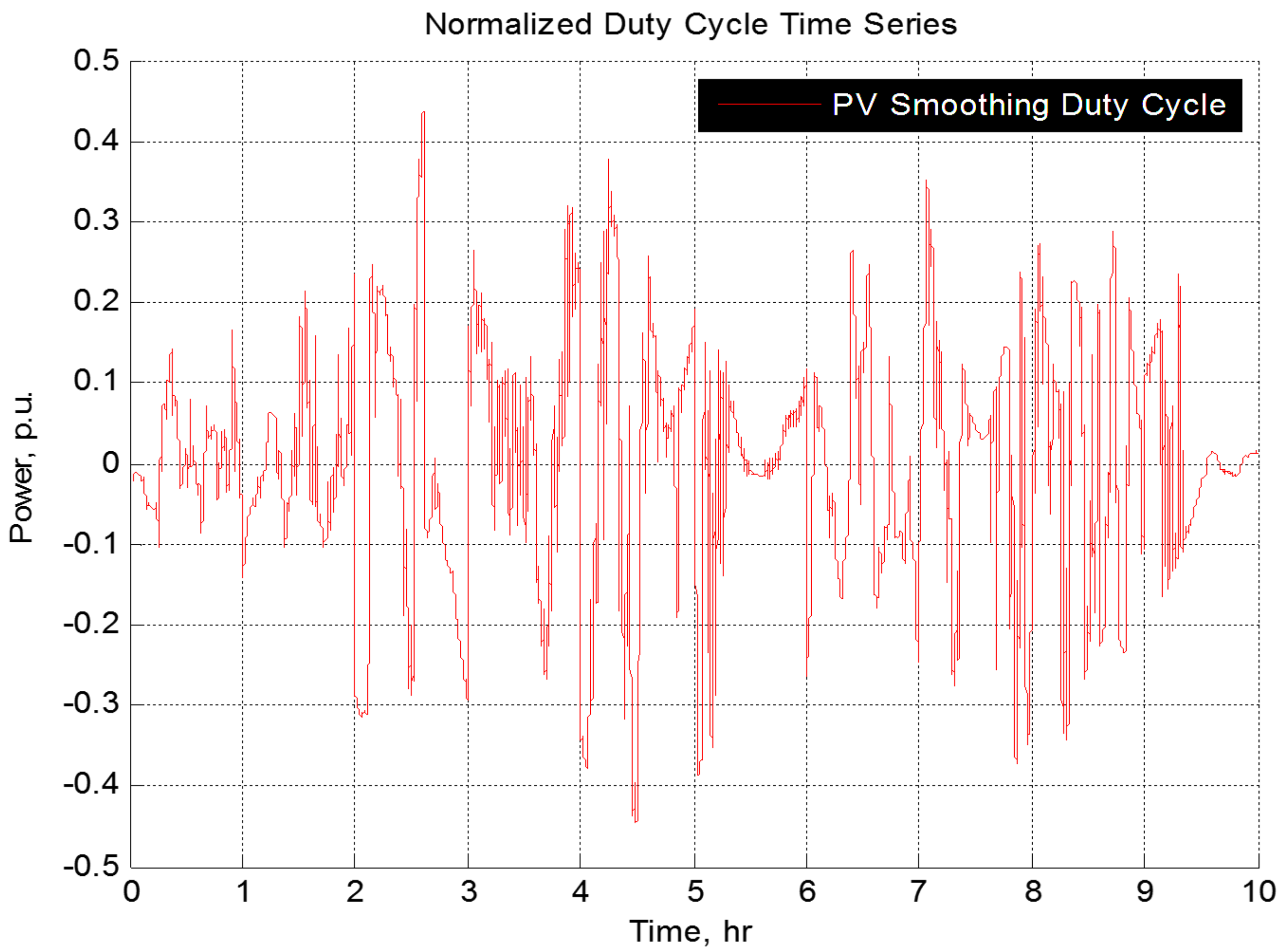




PV Smoothing

- ESS mitigates the rapid fluctuations in PV power output that occur during periods with transient shadows on the PV array by adding power to or subtracting power from the PV system output to smooth out the high frequency components of the PV power
- Reference performance metrics apply as they are ‘blind’ as to application and duty-cycle
- Duty-cycle performance metrics (Table 4.4.3(a.)) apply with tests for each run using the PV smoothing duty cycle

PV Smoothing Duty-Cycle



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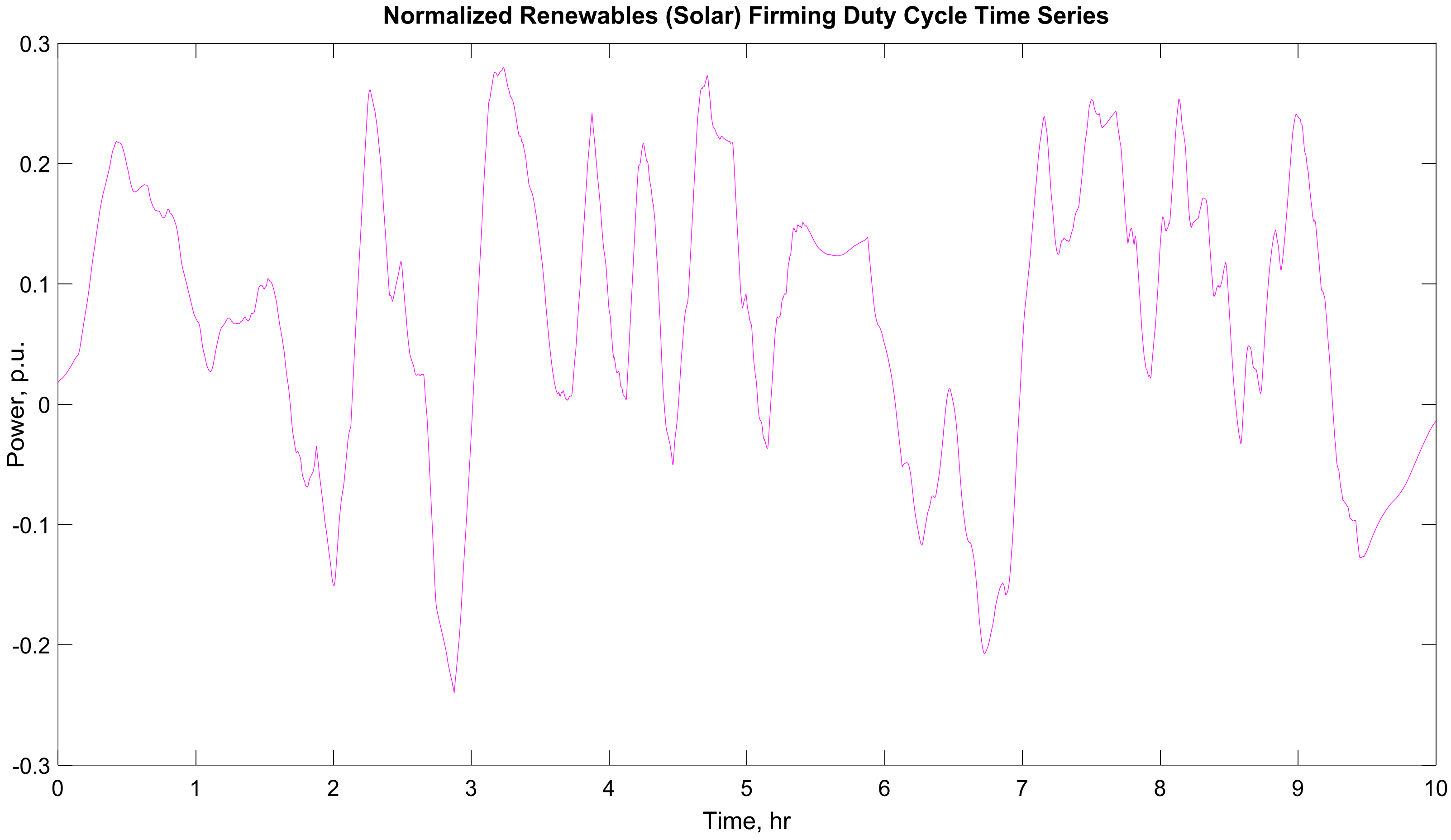
Renewables (solar) Firming

- ESS provides energy to supplement renewable (solar) generation such that the combination of the stored energy and the renewable generation produces steady power output over a desired time window.
- Reference performance metrics apply as they are ‘blind’ as to application and duty-cycle
- Duty-cycle performance metrics (Table 4.4.3(a.)) apply with tests for each run using the Renewables (solar) Firming duty cycle

Renewables (solar) Firming Duty-Cycle



Summary

- ✓ Revision 1 has been used as a basis for US and International (IEC) standards and is being applied by proponents and users of ESS
- ✓ Revision 2 was released April 2016
- ✓ Revision 2 adds key information and technical specifications, new applications, new metrics and significant formatting and use enhancements
- ✓ All proponents and users of ESS benefit when performance can be measured and expressed with confidence in a uniform, comparable and consistent manner

Acknowledgement

Dr. Imre Gyuk, DOE-Office of Electricity Delivery and Energy Reliability

U.S. DEPARTMENT OF ENERGY

All the participants of the working groups

Thanks

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To participate in future protocol efforts contact
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July 2016 PNNL-25540 / SAND2016-6668 O

Measuring Energy Storage System Performance: A Government/ Industry - Developed Protocol

June 30, 2016 WEBINAR QUESTIONS AND ANSWERS

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Funded by the Energy Storage Systems Program of the U.S. Department of Energy
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Measuring Energy Storage System Performance: A Government/ Industry - Developed Protocol

June 30, 2016 WEBINAR
QUESTIONS AND ANSWERS

July 2016

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Prepared for
U.S. Department of Energy, Contract DE-AC05-76RL01830

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Abstract

This document augments a webinar hosted by the Clean Energy States Alliance (CESA) and conducted by PNNL and Sandia on June 30, 2016 on the above subject (PNNL-SA-118995/SAND2016-6155 PE) in providing questions asked during or after the webinar and answers to those questions as well as comments attendees provided during the webinar.

Contents

1.0 Questions Regarding the Protocol[1] and Data:

How can an energy storage system/battery defer a distribution substation upgrade? It seems like if a circuit is at or near capacity, the battery would not be able to charge itself, because the circuit is highly loaded.

Note that the battery energy storage system (BESS) does not have to charge itself when the circuit is at capacity. In fact, it is being prepared for just such an event, by charging when the circuit load is below capacity, so that it can deliver power to the circuit during times when the demand on the circuit is at or above the capacity of the circuit.

This protocol already has a peak shaving application which addressed substation upgrade deferral. Peak shaving is also used to avoid incurring a penalty for exceeding an upper limit of power consumption. The protocol peak shaving duty cycle consists of charging the BESS in 12 hours, followed by discharge at 2, 4 and 6 hours. This covers the wide range of peak shaving durations experienced in the real world. PNNL has just finished work on this application with a utility using a multi MWH BESS system rated at hundreds of kilowatts. The BESS simply came online to discharge when the power exceeded a fixed amount. This power level was based on historic load data for weekdays and weekends.

If an energy storage system (ESS) is used in a smoothing application, particularly at the head of a feeder, the voltage profile will be more stable (less variable) at the head of the feeder. This stabilized voltage profile can lead to a reduced need for load tap changes (LTCs) at the substation. See the IEEE PVSC paper by Matthew Reno, et al (2016):

Is this developed independent of electrochemistry?

Yes the protocol is "blind" to the electrochemistry used in the ESS. By including any stakeholders who wanted to participate in development of the protocol PNNL and Sandia worked hard to ensure in practice the document is agnostic to the electrochemistry under consideration, and doesn't favor any particular technology.

What do you see as the priority for R&D to support this protocol?

Battery state of health and aging properties are a key area of research that needs to be studied. While there are limited studies on cycle life and calendar life on individual cells, this has not been translated into modules and systems. It is especially important for battery users in making decisions about costs and operation and maintenance (O&M) needs over a battery lifetime. It is also just as important for battery manufacturers to understand in the creation of warranties for battery users. Insurance companies who underwrite these warranty policies also need this information. This area will be challenging to address, especially since no vendor would want to

[1] Use of the term protocol in this document and the webinar refers to the *"Protocol for Measuring and Expressing the Performance of Energy Storage Systems"* (PNNL 22010 Revision 2/SAND2016-3078R)

invest in a large battery system simply to study the effect of various environmental and operating parameters on the life of the battery system. This is where DOE sponsored grid storage projects come in – as data are gathered pursuant to those projects the impact of operating parameters on the battery state of health can be studied. PNNL is doing some of this work as part of the BESS grid integration projects with various utilities using MW/MWh level BESS.

Are there any guidelines on how to measure ramp rates in the protocol?

Yes. Section 5.2.3 of the protocol covers both response time (RT) and ramp rate (RR) measurements and then how to use the results in determining the resultant values. Section 6.2 provides details for how the resultant values for RT and RR are to be reported.

How will this activity be aligned with the duty cycles that are being developed under the ARPA-E CHARGES program hosted at UC San Diego and NY Best?

The ARPA-E CHARGES program is tasked to develop duty cycles for grid storage to test novel battery chemistries and designs developed in the ARPA-E program. UC San Diego has a large microgrid with a 42 MW peak load, which has a variety of assets including solar fired gas turbines, steam turbines, chilled water storage, fuel cells, PVs and energy storage. UCSD and DNV GL will develop test protocols for cells and modules based on various load profiles and duty cycles. The suite of applications developed in this protocol addresses several applications for grid storage, including Microgrids. UCSD and DNV GL can use some of this work for their testing purposes.

Is there any relationship between the protocol and the ESIC created ESS test procedures?

The Energy Storage Integration Council (ESIC) Energy Storage Performance working group, operating under the Electric Power Research Institute, used the DOE-OE Protocol as a starting point, and used several of the metrics and duty cycles contained within the protocol. While the DOE-OE sponsored work developing the protocol was restricted to ESS performance test procedures, the ESIC team also focused on identifying grid applications to be addressed, grid integration of storage and communications aspects of storage. While the DOE-OE effort also identified the need to address several of these applications based on input from stakeholders, having the ESIC effort serve as a feedback loop to identify any missing application(s) was very useful. For instance, the ESIC performance working group had several useful suggestions that have been incorporated in this latest version of the protocol, including a whole section of ESS Technical Specifications and the dynamic frequency control.

Will PV smoothing and firming apply to wind power uses?

The smoothing and firming applications for wind are similar in principle to those of PV, which are covered in the protocol, but the duty cycles for performance testing of PV and wind are different. This version of the protocol does not address wind smoothing and wind firming, but these applications will likely be a high priority for any new revision of the protocol. Since wind power sources are usually located at the transmission level, they are typically larger in size than

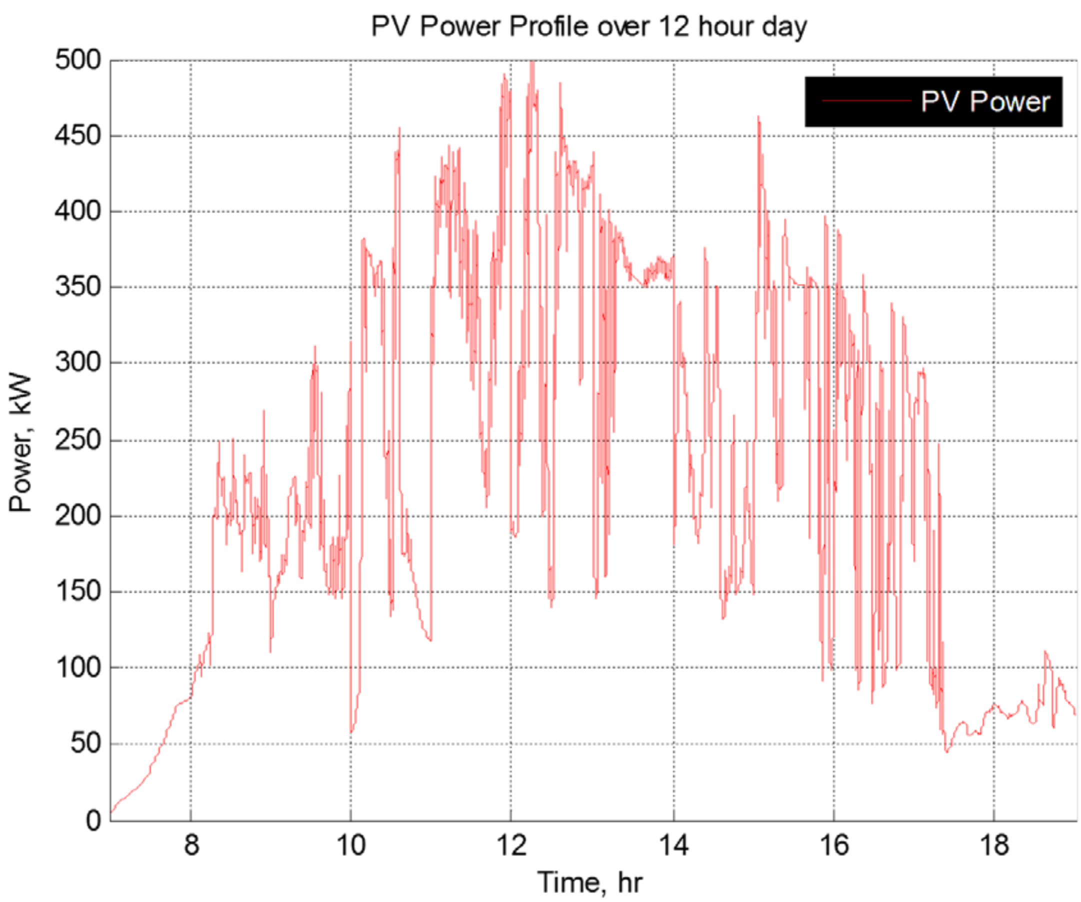
PV power sources, but less in number. As a result, high resolution data (one second granularity) for wind power plant output is more difficult to obtain for a public document such as the protocol. However, given enough interest, wind applications for ESS will be pursued in the next revision.

Is the protocol only being applied to solar? How about Wind?

For solar photovoltaic resources yes. For wind resources, not yet. Wind applications (smoothing and firming) will be considered during a future revision of the protocol.

In the information presented during the webinar on Renewable (Solar) firming duty cycle, what does the output of the solar generation looks like with solar firming?

A one-day time-series plot of the PV power output used in the solar firming application is shown in the figure below. This power profile was created from multiple days of PV data obtained (by permission) from the Public Service Company of New Mexico Prosperity Energy Storage Site.



If this graph is derived from 10 different hours of data, how were sharp jumps between hours addressed?

Simple linear interpolation (first order smoothing) over a few sampling instants (5 – 10 seconds) was performed to prevent excessively large jumps between spliced-together hours. In most cases, this was not needed since the jumps were small and small jumps are realistic in PV smoothing applications.

Is the protocol agnostic to battery capacity size? (i.e., some criteria apply only to systems above 100 kWh and others applied to systems below 10 kWh?)

Yes. There is no capacity size distinction in the protocol.

Is this the final revision of the protocol?

No. This activity was started in early 2012 because there was no guidance on measuring and reporting ESS performance. Without such guidance (standardization) presentation of any performance information was non-uniform, unreliable and not comparable. During the initial establishment of the working group to develop the protocol it was noted that the scope of activity as to technology, metrics, applications, duty cycles, etc. was so large to attempt to cover everything in the time allocated (6 months to get the first version completed) the decision was made to address the scope of activity 'a slice at a time'. That has been done and will continue to be done to address additional gaps, advances in ESS technology, new metrics or applications that need to be addressed and to address input from users of the document. Given the goal was to develop a credible document that could be used until formal standards were completed and recognizing that US and international standards developers are drafting formal standards based in total or in part on the protocol it is likely at some point in the future the work being done will be re-directed to more directly support those standards efforts (i.e. similar to some of the ESS safety work where involvement by PNNL and Sandia is to help update existing standards and model codes).

Can you list a few energy storage system vendors/manufacturer names that participated with your group in developing the standard?

Yes. The Foreword to the 2012 Protocol provides a list of the participants. Any interested party was then, and continues to be, invited and encouraged to participate in this activity since its inception in March 2012. That document is available here.

Regarding PV smoothing, what would the system performance look like for small batteries which are embedded on each PV panel assuming there are supporting electronics on each panel allowing embedded battery on each panel?

The performance is expected to be similar to a situation where an energy storage system is separate from the PV system and is used to smooth or firm it.

The system performance for small batteries embedded on each PV panel will be similar to a single separate battery storage system, provided that there is a similar smoothing algorithm for each of the small batteries. As the question states, this assumes that there are supporting electronics on each panel for these batteries. The only difference would be that of scale. But, since the PV smoothing duty cycle is given in normalized form, it should be readily applicable.

What is the minimum recommended performance level for an energy storage system?

The protocol does not provide a baseline or benchmark associated with what is or is not acceptable ESS performance. It would be expected that those adopting and applying the protocol, which addresses the issue of comparability and uniformity in performance measurement and expression, would establish acceptable values for the metrics covered in the protocol.

2.0 Questions regarding resources and links:

Where can I find revision #2 of the protocol?

You can find Protocol revision #2 on the ESS publications page or navigate to it through Sandia.gov/ess.

Will the presentation material be available for review after the webinar?

Slides and a recording of this webinar have been posted on the CESA website at http://www.cesa.org/webinars/measuring-energy-storage-system-performance/?date=2016-06-30.

A summary of the content presented in this webinar is also available.

Where can I submit typos, drafting commentary and other small editing comments on the protocol?

Suggested changes, indicating the page, section, etc. and showing the change in strikeout (current text to be deleted) and underline (of new text to be added) can be directed to Pam Cole of PNNL at pam.cole@pnnl.gov. To become active in any of the DOE OE ESS activities related to the protocol or ESS safety email energystorage@sandia.gov for more information. For more information please see the Sandia website for activities within the DOE ESS program, or see the list of DOE OE ESS publications.

Can details of the Sandia hosted URL featuring the documents be emailed to the list server roster?

Please see: http://www.sandia.gov/ess/sandia-national-laboratories-publications/

Where can the reference tables for the duty cycles be downloaded?

The reference tables for Microgrids, volt-var, power quality and frequency control applications are appended as excel spreadsheets in the pdf version of the protocol. They have not been linked separately.

Frequency regulation: http://www.sandia.gov/ess/publications/SAND2013-7315P.xlsx

PV Smoothing: http://www.sandia.gov/ess/publications/SAND2016-2543R.xlsx

PV Firming: http://www.sandia.gov/ess/publications/SAND2016-2544R.xlsx

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