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Washington Clean Energy Fund: Controller Development Project

Task 1.1 Preliminary Report Outlining Data Needs for Controller Development

December 2015

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U.S. DEPARTMENT OF
ENERGY

Prepared for the U.S. Department of Energy
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Richland, Washington 99352

Executive Summary

The Washington State Clean Energy Fund (CEF) is providing $15 million toward the deployment and demonstration of energy storage in an effort to explore the role storage could play in Washington State and the value it could deliver to Washington State's utilities and to its citizens as consumers and workers. The Washington CEF projects are comprised of five battery systems located at three utilities in Washington State. For the purposes of this project, the storage unit of concern is that deployed by Avista Utilities, a 1 megawatt (MW) / 3.2 megawatt-hour (MWh) UniEnergy Technologies (UET) vanadium-flow battery system in Pullman, Washington.

To maximize the value of the CEF, Washington State has worked with Pacific Northwest National Laboratory (PNNL) to design an assessment framework for the demonstration that is based on a consistent set of use cases and measurements during the demonstrations that does not constrain, but rather enhances the diverse scope of applications for energy storage. This framework, and its application for these demonstration projects, will inform and empower other utilities, storage technology developers, and state regulators to prudently and confidently pursue the deployment of energy storage.

Avista Utilities is further partnering with PNNL to develop a prototype controller for its battery system in an effort to realize the most value from its operation. The controller will utilize similar methods and algorithms from the use case analysis but will develop a system to operate in real-time, defining the battery's operation based on forecasted values and its current state. The controller will also take the uncertainty of forecasted values and the risk tolerance of the operator into account. Avista will work with a third party to create a production-grade version of this prototype based on the development done during this project.

In addition to the direct work of PNNL, Washington State University (WSU) will also contribute to the controller development effort. WSU will develop methods and algorithms that will estimate the effects of the ESS on the local distribution system (e.g., feeder voltage, switched capacitor state). These effects will be used by WSU to further develop a reactive power dispatch algorithm the ESS can use for services on the local feeder such as power factor correction and voltage regulation.

This report presents an overview of the controller development data requirements. To begin the process of developing all of the information required to perform the controller development, PNNL has outlined preliminary data needs in this report. These input data consist of technical and financial value information required to define the most valuable mode of operation for the battery during the optimization period. PNNL will work with Avista Utilities and their contractors to refine this report and transfer the required data using secure systems.

Acronyms and Abbreviations

BSET	Battery Storage Evaluation Tool
CEF	clean energy fund
ESS	energy storage system(s)
MW	megawatt(s)
MWh	megawatt hour(s)
NERC	North American Electric Reliability Corporation
PNNL	Pacific Northwest National Laboratory
PRT	Pattern Recognition Technologies, Inc.
SEL	Schweitzer Energy Laboratories
UET	UniEnergy Technologies
WSU	Washington State University

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1.0 Introduction

Energy storage systems (ESS) have the potential to improve the operating capabilities of the electricity grid. Their ability to store energy and deliver power can increase the flexibility of grid operations while providing the reliability and robustness that will be necessary in the grid of the future – one that will be able to provide for projected increases in demand and the integration of clean energy sources while being economically viable and environmentally sustainable. Energy storage has received a great deal of attention in recent years. Entrepreneurs are working enthusiastically to commercialize a myriad of promising technologies, and venture capitalists and the U.S. Government are investing in this space. The technologies show promise but it remains difficult to evaluate and measure the benefits that ESS could provide.

The Washington State Clean Energy Fund (CEF) is providing $15 million toward the deployment and demonstration of energy storage in an effort to explore the role storage could play in Washington State and the value storage could deliver to Washington State's utilities and to its citizens as consumers and workers. The Washington CEF projects are comprised of five battery systems located at three utilities in Washington State. For the purposes of this project, the storage unit of concern is that deployed by Avista Utilities: a 1 megawatt (MW) / 3.2 megawatt-hour (MWh) UniEnergy Technologies (UET) vanadium-flow battery system in Pullman, Washington.

To maximize the value of the CEF, Washington State has worked with Pacific Northwest National Laboratory (PNNL) to design an assessment framework for the demonstration that is based on a consistent set of use cases and measurements during the demonstrations that does not constrain, but rather enhances the diverse scope of applications for energy storage. This framework, and its application for these demonstration projects, will inform and empower other utilities, storage technology developers, and state regulators to prudently and confidently pursue the deployment of energy storage.

Figure 1.1. presents an overview of the use cases and applications to be performed and measured/analyzed in coordination with PNNL. "Y" means the service is currently included as part of the use case analysis project. The use-cases are grouped according to their intended target benefits within the electric infrastructure topology (e.g., transmission versus distribution). Although an ESS may be located on the low-voltage side of a substation that provides power to a distribution feeder, a use case that addresses bulk power services could still be provided and would be grouped under the transmission system. Use cases for ESS for applications deep into the distribution circuit would be categorized under the distribution system cases.

Use Case and application as described in PNNL Catalog	Avista	PSE	Sno – MESA1	Sno – MESA2	Sno - Controls Integration
UC1: Energy Shifting					
Energy shifting from peak to off-peak on a daily basis	Y	Y	Y	Y	
System capacity to meet adequacy requirements	Y	Y	Y	Y	
UC2: Provide Grid Flexibility					
Regulation services	Y	Y		Y*	
Load following services	Y	Y		Y*	
Real-world flexibility operation	Y	Y		Y*	
UC3: Improving Distribution Systems Efficiency					
Volt/Var control with local and/or remote information	Y		Y	Y	
Load-shaping service	Y	Y	Y	Y	
Deferment of distribution system upgrade	Y	Y			
UC4: Outage Management of Critical Loads		Y			
UC5: Enhanced Voltage Control					
Volt/Var control with local and/or remote information and during enhanced CVR events	Y				
UC6: Grid-connected and islanded micro-grid operations					
Black Start operation	Y				
Micro-grid operation while grid-connected	Y				
Micro-grid operation in islanded mode	Y				
UC7: Optimal Utilization of Energy Storage	Y	Y			Y

Figure 1.1. Washington CEF Use Case Matrix

Avista Utilities is also partnering with PNNL to develop a prototype controller for its battery system (energy storage plus inverters as an integrated system) in an effort to realize the most value from its operation. The controller will utilize similar methods and algorithms from the use case analysis but will operate in real-time, defining the battery's operation based on forecasted values and its current state. The controller will also take the uncertainty of forecasted values and the risk tolerance of the operator into account. Avista will work with a third party to create a production-grade version of this prototype based on the development done during this project.

The models and testing procedures required to develop the controller for the ESS require financial/economic/price, system and battery-specific data. To begin the process of collecting all of the information required to develop the ESS controller, PNNL and WSU have outlined preliminary data needs in this report. These input data consist of technical and financial value information required to define the most valuable mode of operation for the battery during the up-coming hours of operation. PNNL will work with the Avista and its contractors to refine this report and transfer the required data using secure systems.

2.0 Data Requirements

This report presents an overview of the controller development data requirements. The data required are used in three distinct development efforts:

1. Forecasts – The controller will require forecasts for all input signals in order to determine the optimal operating mode over the optimization period (e.g. twenty-four hours). Some of the required forecasts will be readily available and others will need to be developed.

2. Uncertainty Models – Associated with each forecast will be uncertainty values which will be used by the optimizer in determining the most valuable services to provide. To develop these uncertainty estimates past forecasts will be compared to the actual measured events; both sets of data will be required.

3. Electric System Effects due to ESS – The work being undertaken by Washington State University will require extensive electrical system data, both topology data necessary to build accurate models of the system and time-series data indicating the state of the electrical system. This data will allow WSU to simulate the effects of the ESS on the electrical system and develop reactive control algorithms to be incorporated into the optimization engine.

2.1 Comprehensive Data Requirements

PNNL and WSU models and procedures for developing the ESS controller for Avista requires financial, system and electrical data. Data sharing with Avista has already begun and the data acquisition process, which will continue throughout the battery testing period, is expected to conclude in the Spring of 2017. Data used in the development and operation of the ESS controller will be obtained from both public and private sources, much of which will be specific to Avista, depending on the specific conditions and policies present at Avista. PNNL will work closely with Avista in the coming months to identify and acquire data necessary for the development of the controller.

2.1.1 Price/Value Data

To effectively operate the ESS in a manner to capture the greatest value, the optimization engine in the controller PNNL will develop requires forecasts of the price/value signals for all potential services for the upcoming optimization period. In many cases, the forecast signal must be synthesized and/or calculated from related signals. Price/value information will also be used to form uncertainty estimates of the forecasted signals. Table 2.1 lists the known price/value signals necessary for controller development. Where existing data sets are unavailable to fully evaluate the financial benefits associated with each use case, PNNL and WSU will work with Avista to develop acceptable alternatives. As the control strategy is further developed and refined for each use case, the data requirements defined below will be modified.

Table 2.1. Financial Data Requirements

Item	Required Information
Energy Price	Historical forecasted (from PRT) and actual (from Avista) hourly prices for 2011-2015.
Mid-C Flexibility Price	Historical Mid-C flexibility adder price for 2011-2015. Indication of times when flexibility was not available from Mid-C.
ADDS Weekly Marginal Cost of Energy	Historical hourly marginal cost of energy as computed by ADDS for 2011-2015.

2.1.2 System Data

Some of the forecast signals used by the optimization engine are derived from electrical system conditions that can be served through the operation of the ESS. For example, low power factor on a the feeder where the ESS is located can be improved through reactive power output, reducing losses on the feeder. Table 2.2 presents an initial list of system data requirements necessary for the development of forecasts for the services the ESS will provide and the corresponding uncertainty estimates. As the control strategy is further developed and refined for each use case, the data requirements defined below will be modified.

Table 2.2. Electricity System Data Requirements

Item	Required Information
Feeder Load Forecast	Historical 24-hour forecasted and actual feeder loads from 2011 - 2015
System Load Forecast	Historical hourly forecasted and actual system load values from 2011 - 2015
Flexibility Forecast	Historical hourly forecasts of frequency regulation, load-following, and "real-world" (such as those caused by wind turbine ramps) requirements from 2011 – 2015.
Power Factor Loss Estimates	Estimates of the amount of loss reduction possible from the ESS due to its power factor correction service based on studies of the two feeders attached to the ESS.
Reactive Power	Historical hourly reactive power forecasts and actual reactive power requirements for the feeders on which the ESS is installed from 2011 -2015.
Upgrade Deferral Limits	Critical power level for any piece of equipment on the feeder that is a candidate for upgrade deferral due to ESS unloading.
Feeder Topology	For the two feeders attached to the ESS, feeder topology and structure such as line lengths, distance between conductors, phase configuration, height above ground, and connected node list.
Time-Series ESS Data	Operational data from both feeders attached to the ESS sampled at one minute from 2011-2015. Parameters of interest are ESS real and reactive power, voltage and current, ambient temperature, state-of-charge for the battery, ESS auxiliary power (pumps, etc),
Time-Series Feeder Data	Operational data from both feeders attached to the ESS sampled at one minute from 2011-2015. Parameters of interest are customer real and reactive power flows, voltage, and current.
Voltage Regulator Configuration	For the two feeders attached to the ESS, information on the equipment attached to the feeders such as regulator type and configuration and forward voltage settings for each phase.
Capacitor Bank Configuration	For the two feeders attached to the ESS, information on the capacitor banks attached to the feeders such as capacitor bank locations, connection types, connected phases, metering phases, kVAr of each phase, potential transformer (PT) ratio, current transformer (CT) ratio, and voltage rating.

2.2 Price/Value Forecast and Uncertainty Development Procedures – Energy Arbitrage

In an effort to better define the data requirements for controller development, PNNL and WSU are working with Avista to better understand the needs of their system and how the ESS can play a role in the services it will provide. As an example of this, the process of developing forecast and uncertainty estimates for energy arbitrage is considered

In the case of energy arbitrage, Avista has contracted with an external vendor, PRT to provide energy forecasts. These forecasts are generated every hour and list the hourly energy prices for the upcoming two weeks.

To prepare an uncertainty estimate for this forecast, the actual energy price data set needs to be formed. Avista records the price of every energy transaction; in the hours where a transaction takes place, the average of these prices could be used as the actual price. For hours where no energy transactions take place, the price is calculated by Powerdex based on all the transactions at the Mid-C hub and is called the Mid-C Hourly Index.

Based on the hourly forecasted and actual prices, the error in the forecast can be calculated and a mathematical model of the error can be formed. This model may take into account a wide variety of inputs such as the time of day, the month, the number of hours into the future being forecast, or even the forecast amount. The process of developing the uncertainty model seeks not necessarily to remove the error from the estimates but rather provide a structure for the error to allow it be usefully represented to the optimization engine.

3.0 Concluding Comments

The development of the ESS controller architecture, its operating plan, the input signals necessary to run effectively, and the uncertainty estimates associated with each of these signals are still in progress. The data requirements listed in this document are preliminary and based on the current state of the controller development. As the specific functionality of the controller is refined, additional specific data are likely to be needed and new methodologies of developing uncertainty estimates will take place. The use case analysis taking place as a part of CRADA 352 will also help refine the controller operation methodology and will influence the data it require

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