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SunSpec Energy Storage Models

SunSpec Alliance Interoperability Specification

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ABSTRACT

The SunSpec Alliance Interoperability Specification suite consists of the following documents:

- SunSpec Technology Overview
- SunSpec Information Model Specification
- SunSpec Information Model Reference Spreadsheet
- Collection of SunSpec Device Category Model Specifications
- SunSpec Plant Extract Document

This document is a member of the collection of Device Category Model Specifications; it covers describes the energy storage models that are being developed by the SunSpec Alliance Energy Storage Workgroup.

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Revision History

Revision	Date	Reason
1	05-28-2014	Initial Draft
2	06-01-2014	Added content related to the 801, 802 and 803 storage models
3	09-23-2014	Incorporated corrections and additions from the working group
4	03-26-2015	Remove data elements to reference in Data Model and Modbus Map Reference Spreadsheet (Note: I left references to specific fields alone in this spec. There are no actual models in the spreadsheet for Storage, so I don't know if the references are correct or should be removed)

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Nomenclature

Abbreviation	Meaning
ESS	Energy Storage System
Evt	Event Bitfield
HMI	Human Machine Interface
PCS	Power Control System
PICS	SunSpec Protocol Information Conformance Statement
RW	Read-Write
SoC	State of Charge
SoH	State of Health

Introduction

This SunSpec Alliance Interoperability Specification describes the data models and Modbus register mappings for storage devices used in stand-alone energy storage systems (ESS). The models in this specification may also be applied to photovoltaic systems with storage subsystems.

The full set of specifications is available for download at http://www.sunspec.org/download. We strongly suggest that you download the latest versions, and note the status of the models you wish to implement, before beginning your implementation.

This specification is not specific to a single storage technology. The base models described herein are designed to support a variety of storage technologies such as lithium-ion batteries, vanadium redox flow batteries, pumped hydro, flywheels, advanced lead-acid batteries, and more. While an initial focus has been placed a small number of popular technologies (lithium-ion and redox flow batteries) it is expected that detailed models for other storage technologies will be added as the specification evolves.

For more information on the different types of energy storage technologies that are used in energy storage systems today, please see the *Energy Storage Technologies* page on the Energy Storage Association web site. You can find the page here: http://energystorage.org/energy-storage/energy-storage-technologies

Storage Data Models and Modbus Maps

This document describes a number of SunSpec models each with an identifier in the 800 series. An attempt has been made to design these models in a modular way so that they may be combined to address a variety of storage devices.

All SunSpec Energy Storage devices must implement the SunSpec Common Model (specification available for download at http://www.sunspec.org/specifications), the Energy Storage Base Model (801), and the End Model. They may optionally implement additional models which provide information and control points for a specific storage technology (e.g. battery storage devices).

All battery devices must implement the Battery Storage Device Model (802). They may optionally implement a model specific to a battery storage technology (e.g. redox flow batteries).

The following top-level data elements are provided to describe each energy storage model:

- **ID** – A well-known value – 8xx that uniquely identifies this model as an energy storage model.
- **Length** – The length of the energy storage model in registers, not including the ID or the length registers.

The various device models are described in detail in the subsequent sections. All storage models, excepting the Energy Storage Base Model, are optional, but if a particular storage model is used, all of the defined registers in that model must be present. Implementations should leave unused or unsupported data points within a storage model set to the "not implemented" value specified in the SunSpec Common Model. For example, the Not Implemented value for a 16-bit signed integer is 0x8000.

Settings are marked in the Comprehensive Data Model and Modbus Map spreadsheet with access RW. It is not required to support writable for all settings. Settings may be read-only if the setting is fixed or not settable via the communication interface. Such limitations shall be specified in the PICS document.

Model Diagrams

Figure 1 illustrates that models that would be implemented by a lithium-ion battery manufacturer who desires to expose a SunSpec-compatible interface to their batteries:

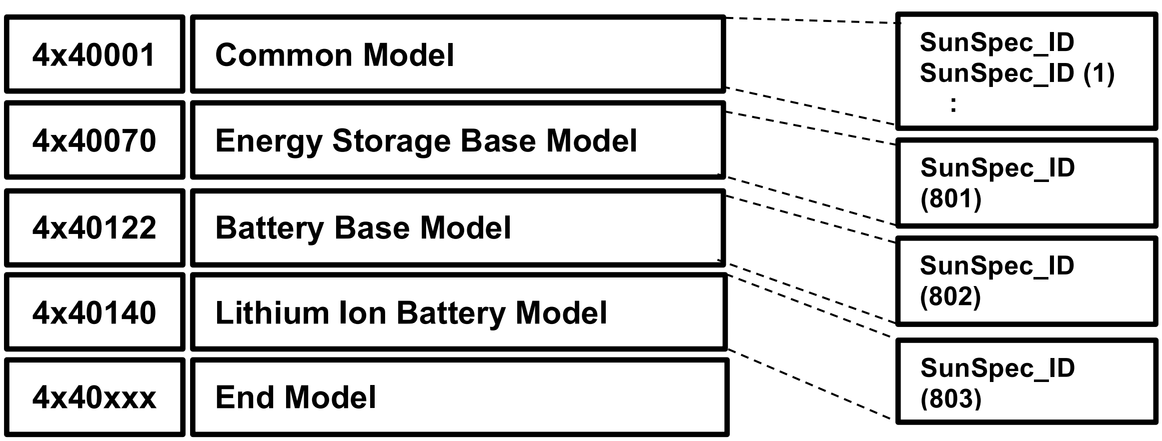

Figure 1: Models Implemented for Lithium-ion Batteries

Figure 2 shows the models that must be implemented by a vanadium redox flow battery. Given that vanadium redox flow is also a battery technology, there is significant overlap with the models shown in Figure 1.

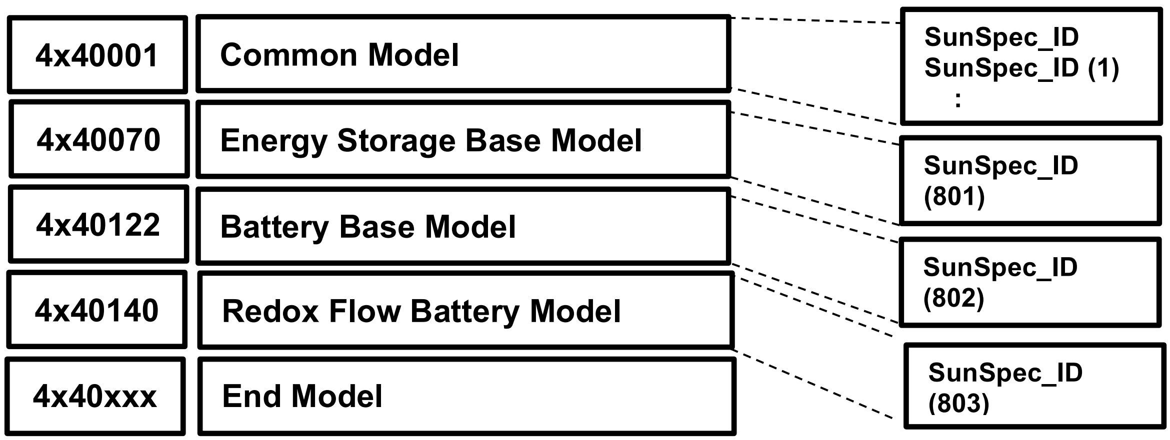

Figure 2: Models Implemented for Vanadium Redox Flow Batteries

Energy Storage Base Model (Model 801)

The Energy Storage Base Model provides nameplate values and other basic information that applies to all types of energy storage devices. Given the variety of devices that are in market today (pumped hydro, compressed air, lithium-ion batteries, flywheels, etc.) the model is fairly simple as it tries to expose attributes that are common to all of these technologies.

Nameplate Values

Nameplate values in the Energy Storage Base Model allow an implementer to express the nameplate energy capacity of the device (WHRtg) in addition to nameplate charge and discharge rates (WMaxChaRate and WMaxDisChaRate).

For storage devices that have a measurable amount of self-discharge (i.e. decay), the DsiChaRte field may be used to expose that quantity to a controller or other master.

State of Charge Management

Since all energy storage devices store a non-zero amount of energy, the Energy Storage Base model contains a number of values related to the state of charge (SoC) of a storage device.

The SoC value in the model expresses the device' state of charge a percentage of nameplate energy capacity (%WHRtg). A fully charged storage device has a state of charge of 100%, while a fully discharged storage device has a state of charge of 0%.

A storage device manufacturer may want to limit a given device to a state of charge range that is less than 0% to 100%. For example, when some battery technologies are used in certain applications, it is not desirable to discharge the batteries to 0% as the lifetime of the batteries may be affected.

The Nameplate Max SoC (SoCNpMaxPct) and Nameplate Min SoC (SoCNpMinPct) values in the Energy Storage Base Model can be used to limit the usable state of charge range for a given storage device. These optional values are read-only as they are only intended to be set by the storage device manufacturer.

Should the state of charge on a storage device approach one of the nameplate limits, a warning shall be issued by the device using the event flags on the Event Bitfield (Evt). If the limit is then met or exceeded, an alarm in the same event field shall be issued.

Application constraints on state of charge may be layered on top of any manufacturer constraints. For example, if a given storage device has a nameplate state of charge range between 10% and 90%, it may be desirable to further restrict the state of charge for a given application so that some amount of the energy capacity is held in reserve. The optional Maximum Reserve Percent (MaxRsvPct) and Minimum Reserve Percent (MinRsvPct) settings are provided for this purpose.

Figure 3 illustrates the different values and settings related to state of charge.

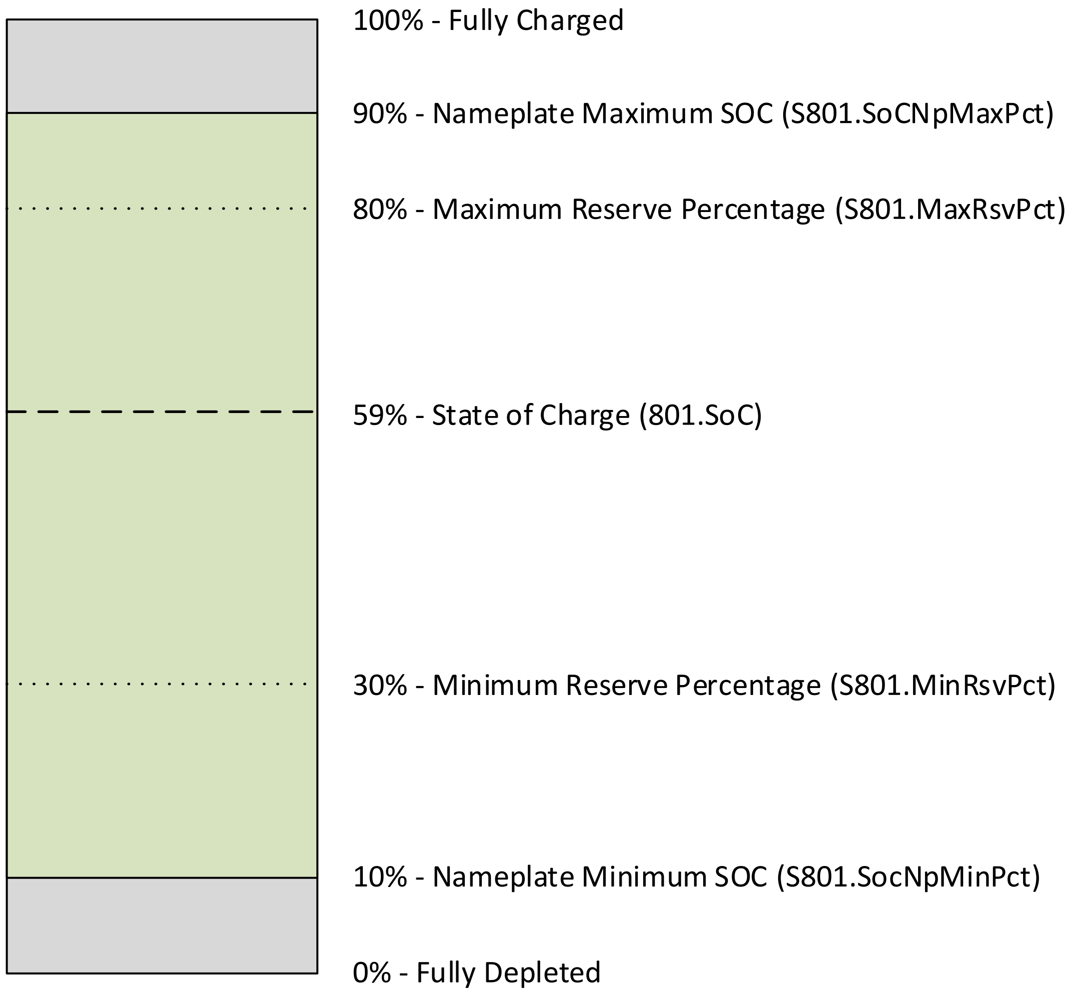

Figure 3: State of Charge

Local vs. Remote Control

When maintenance is being performed on an energy storage device, remote control of the device should be prevented to ensure the safety of the personnel performing the maintenance.

The Control Mode value (LocRemCtl) in the Energy Storage Base Model indicates whether or not remote control is allowed. Under normal conditions, this value is 0, which indicates that remote control is allowed. If local maintenance is required, on-site personnel will generally use a device-specific switch or Human Machine Interface (HMI) to put the storage device into local mode, at which point Control Mode will return 1 and all remote commands will be refused. Once the maintenance operation is complete, the same switch or HMI would be used to restore the ability to control the device remotely.

Heartbeats

Many of the storage devices being used today are large, complex systems made up of multiple subcomponents. A lithium-ion battery bank may be made up of multiple strings, each of which is made up of multiple modules, with everything fronted by an intelligent battery management system. Given this complexity, it is often desirable to not only to ensure that a valid communication channel exists, but also that the storage device is functioning at a basic level.

The Distributed Energy Resource Heartbeat value (DERHb) in Model 801 is an unsigned numeric value which is incremented every second on the storage device. Periodically, this value resets to zero and the incrementing process continues (reset periodicity is up to the device manufacturer). A controller or other master can use this changing value to confirm that the energy storage device is healthy and able to provide updated values on demand.

Similarly, the Controller Heartbeat value (ControllerHb) in Model 801 can be used by the storage device to determine if it is properly communicating with the controller. If this value is not updated every second as expected, a storage device may choose to alter its state in some way, for example by entering into a standby or sleeping state.

It is worth noting that the use of these heartbeat values is optional.

Battery Base Model (Model 802)

The Battery Storage Device model provides values and settings that are common to all batteries. This includes lithium-ion batteries, advanced lead-acid batteries, and flow batteries. In general a technology-specific model should be implemented in addition to Model 802 (e.g. Model 803 for lithium-ion batteries) but in cases where no specific support exists today, it is valid to implement Model 802 in isolation.

The battery type enumeration (BatTyp) in the Battery Base Model is used to express the type of battery. The cycle count (CycleCt) and State of Health (SoH) values provide information on how much of the battery's life has been used and on the remaining life of the battery. Note that these health values may not be easy to obtain on all technologies, so they are both listed as optional in the model.

A battery device shall expose battery alarms and warnings may be exposed through the Battery Event 1 Bitfield (Evt1). A wide array of standard alarms and warnings are included in the model, and provisions have been made to allow device-specific or manufacturer-specific alarms to be surfaced as well.

The Battery Base Device model also provides values that express the instantaneous charge and discharge current limits (MaxBatACha and MaxBatADischa, respectively). These values complement the nameplate charge and discharge rates found in model 801, and allow a battery manufacturer to adjust charge and discharge rates as the state of the battery changes. It is expected that battery controllers will monitor these values and ensure that charging and discharging operations fall within the maximums expressed in this model. Failure to do so may damage the battery.

For proper operation, a battery may need to know the current state of the connect power conversion system. The Power Control System (PCS) State setting is used to provide this state information to the battery. A controller or other master should ensure that the current state of the PCS is written to this setting as soon as a PCS state change is detected.

Battery States

While batteries are in many ways passive devices, most provide a limited set of commands (e.g. a lithium-ion battery bank may offer the ability to connect and disconnect the battery strings). A controller or other master may execute one of these commands by using the BSetOperation enumeration.

When a command like connect or disconnect is executed in the battery, the battery will transition from one state to another. The Battery State value in model 802 (BatSt) expresses the current state of the battery. For example, If a controller uses BSetOperation to ask a disconnect battery to connect, a compliant battery will transition from the Disconnected state to the Initializing state, and then from the Initializing state to the Connected state.

It is worth noting that while it is initializing, a battery may wish to perform string balancing and other functions that require the import or export of power. To allow for these operations, a battery may set PCS State Request (BatReqPCSSt) and Battery Power Request (BatReqW) to ask the PCS to charge or discharge power. A controller should monitor these values when a battery is in the Initializing state, and if a power is request, the connected PCS should be instructed to charge or discharge accordingly. Obviously, system operating limits need to be respected in this scenario, so the controller is not required to honor the full magnitude of the battery request.

The state diagram in Figure 4 depicts the various battery states and the decision points that lead from state to state.

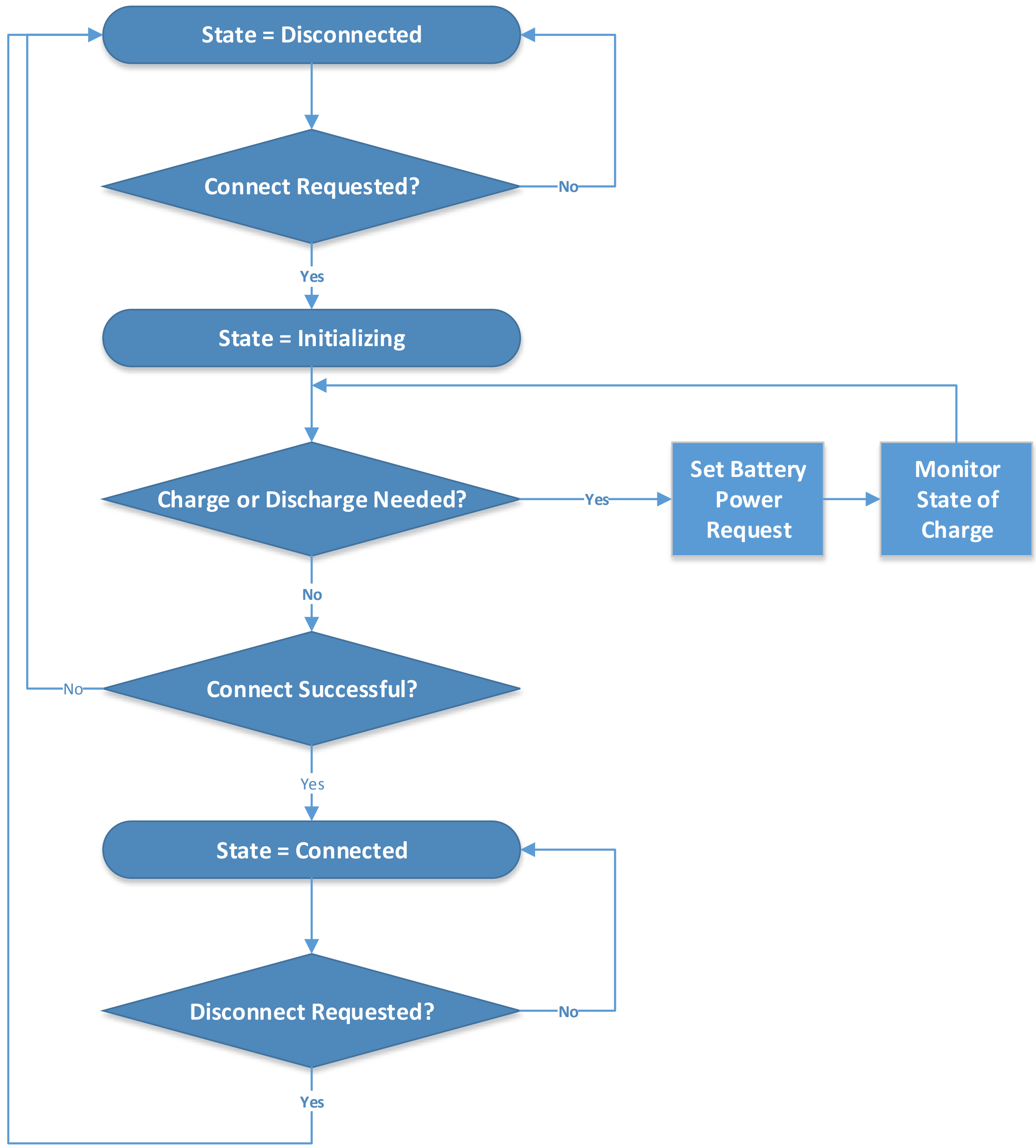

Figure 4: Battery State Diagram

Lithium-Ion Battery Model (Model 803)

Lithium-ion batteries are one of the most popular forms of energy storage. Part of the reason for their popularity is the flexibility of the technology. While a single lithium-ion module may be used in a residential energy storage application, multiple lithium-ion batteries can be connected together to form a grid-scale energy storage device on the utility side of the meter.

The Lithium-ion Battery Model has been developed to expose the unique characteristics of a lithium-ion battery banks.

Terminology

Battery manufacturers have different terms for the components that make up a lithium-ion battery energy storage system. This specification and the associated model use the following terms:

Term	Definition
Cell	A single energy or charge-storing unit
Module	A single enclosed unit consisting of a set of cells
String	Set of battery modules connected in series
Bank	Set of battery strings connected in parallel

Monitoring Information

Many of the values exposed on the Lithium-Ion Battery Model provide data which is useful in monitoring the health of the battery. Given the importance of maintaining consistent voltage levels throughout the battery bank, the Maximum Cell Voltage (BMaxCellVol) and Minimum Cell Voltage (BMinCellVol) values return the maximum and minimum voltages for all cells in the bank. Similarly, given the importance of operating lithium-ion batteries at the right temperature, the Maximum Module Temperature (BMaxModTmp) and Minimum Module Temperature (BMinModTmp) return the maximum and minimum temperatures for all modules in the bank.

To help operators determine where these minimum and maximum values were measured, a lithium-ion battery may expose location information through the optional Maximum Cell Voltage Location (BMaxCellVolLoc), Minimum Cell Voltage Location (BMinCellVolLoc), Maximum Module Temperature Location (BMaxModTempLoc) and Minimum Module Temperature Location (BMinModTempLoc) registers. In each of these unsigned 16-bit registers the first byte indicates the zero-based string number, while the second byte identifies the zero-based module number within that string.

In addition to providing temperature and voltage data, Model 803 also exposes information on the DC current measured by the battery system. Total DC Current (BTotDCCur) reports the DC current flowing to or from the battery, while Maximum String Current (BMaxStrCur) and Minimum String Current (BMinStrCur) provide the maximum and minimum measured currents for each string.

Battery String Repeating Block

As mentioned above in the Terminology section, a lithium-ion battery bank is made up of one or more battery strings. Accordingly, it is quite often necessary to monitor and control the individual strings in the bank. Model 803 includes a SunSpec repeating block which is repeated once for every string in the bank. Using the Model Size field (i.e. the second uint16 register in the model) it is possible to calculate the total number of strings in the repeating block.

Each string exposes a set of values that are similar to those that exist in the fixed block. For example, State of Charge (StrSoC), State of Health (StrSoH), Maximum Cell Voltage (StrMaxCellVol), Minimum Cell Voltage (StrMinCellVol), Maximum Module Temperature (StrMaxModTemp), and Minimum Module Temperature (StrMinModTemp) are all repeated at the string level. These values are represented in the same way that they are represented at the bank level.

A small number of string-specific values are also included in the repeating block. Module Count (StrModCt) provides a count on the number of battery modules in the string. Connection Failure Reason (StrConFail) is used to indicate why a given string failed to connect when the battery bank was last asked to connect. And the Enable/Disable String (StrSetEna) setting allows a given string to be enabled or disabled by a controller or other master. A disabled string will not attempt to connect the next time that the battery is asked to connect. This provides a convenient mechanism to performance maintenance on a given string, while continuing to use the rest of the battery bank.

Redox Flow Battery Device Model (Model 804)

The Redox Flow Battery Device Model (S 804) provides monitoring and control values related to redox flow batteries. This model is currently under development. The Energy Storage Working Group has engaged redox flow battery manufacturers and is actively evolving the specification.

The S 804 model will support multiple redox flow technologies including vanadium redox flow batteries and zinc bromide batteries. As other redox flow battery technologies become commercially viable, the Energy Storage Working Group will make efforts to ensure that these technologies are covered by the S 804 model.

ISSUE: Aside from vanadium redox flow batteries, which seem to have some momentum in the industry, the other redox flow technologies may be more experimental. Should they be scratched from the list above?

ISSUE: Is "Redox Flow Battery Device Model" the right level of scoping? Should we open this up so that it attempts to cover all flow batteries? Note that ESA groups flow batteries together: http://energystorage.org/energy-storage/storage-technology-comparisons/flow-batteries.

About the SunSpec Alliance

The SunSpec Alliance is a trade alliance of developers, manufacturers, and service providers, together pursuing information standards for the distributed energy industry. SunSpec standards address most operational aspects of PV and other distributed energy power plants on the smart grid—including residential, commercial, and utility-scale systems—thus reducing cost, promoting innovation, and accelerating industry growth.

Over 60 organizations are members of the SunSpec Alliance, including global leaders from Asia, Europe, and North America. Membership is open to corporations, non-profits, and individuals. For more information about the SunSpec Alliance, or to download SunSpec specifications at no charge, please visit www.sunspec.org.

References

Energy Storage Association. "Energy Storage Technologies". www.energystorage.org. http://energystorage.org/energy-storage/energy-storage-technologies (accessed October 1, 2014).

IEC 61850 Basic Communication Structure - Distributed Energy Resources Logical Nodes, IEC 61850-7-420, Edition 1.0