TECHNOLOGIES FOR DIESEL USE REDUCTION IN NON-GRID-CONNECTED COMMUNITIES

FOR WORKSHOP: ENERGY AND CLIMATE TECHNOLOGIES FOR THE ARCTIC

ANCHORAGE, ALASKA

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IEEE STANDARDS COMMITTEE 21

MAY 3, 2024

DISCLAIMER & ACKNOWLEDGMENTS

This presentation conveys the views of the author and is not the formal explanation or position of the IEEE.

Many thanks to the IEEE P1547 Officers and Working Group (WG) members who've contributed their time and effort to develop the 1547 standard and supporting Guides. This presentation uses some content prepared by IEEE P1547 WG members, and is used with permission of IEEE SC21.

PRESENTATION OUTLINE

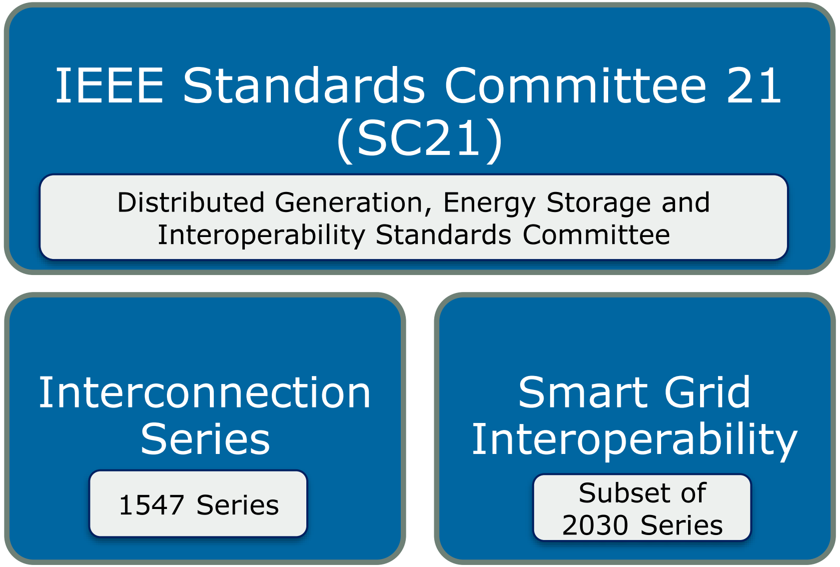
1. **IEEE Standards Facilitating Integration of Clean Grid Technologies**
   - SC21 and Standards Development Process
   - IEEE's Revised 1547 Std for DER Interconnection

2. **BESS Used to Reduce Diesel Use in Non Grid Connected Systems**

IEEE SC21 and Standards Development
IEEE 1547-2018 Introduction

A high-level overview of IEEE Std 1547-2018, i.e. drivers, scope, applicability, and ongoing activities.

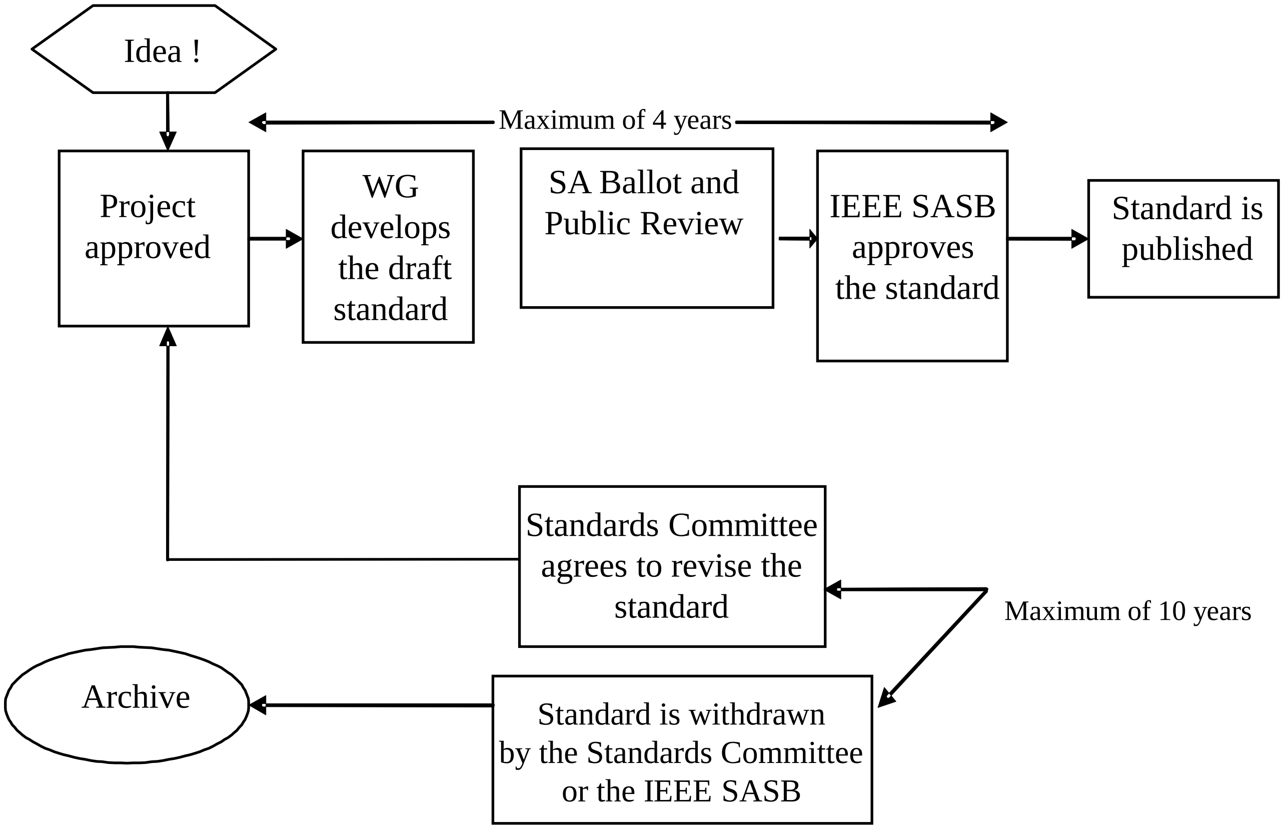
IEEE SC21 OVERVIEW



Scope: *The Committee manages projects for the development of* ***interconnection*** *and* ***interoperability*** *standards for* ***distribution-connected energy resources****, including any kind of distributed generation, energy storage, and demand response. The Committee also reviews proposed IEEE standards in these fields before their submission to the IEEE-SA Standards Board for approval.*

- Developing and maintaining IEEE standards
- Coordinating with other IEEE Societies to jointly develop and maintain standards as needed.
- Periodic reporting to the Standards and Standards Innovation (S&SI) Strategic Management and Delivery Committee (SMDC) of the IEEE-SA Board of Governors (BOG).

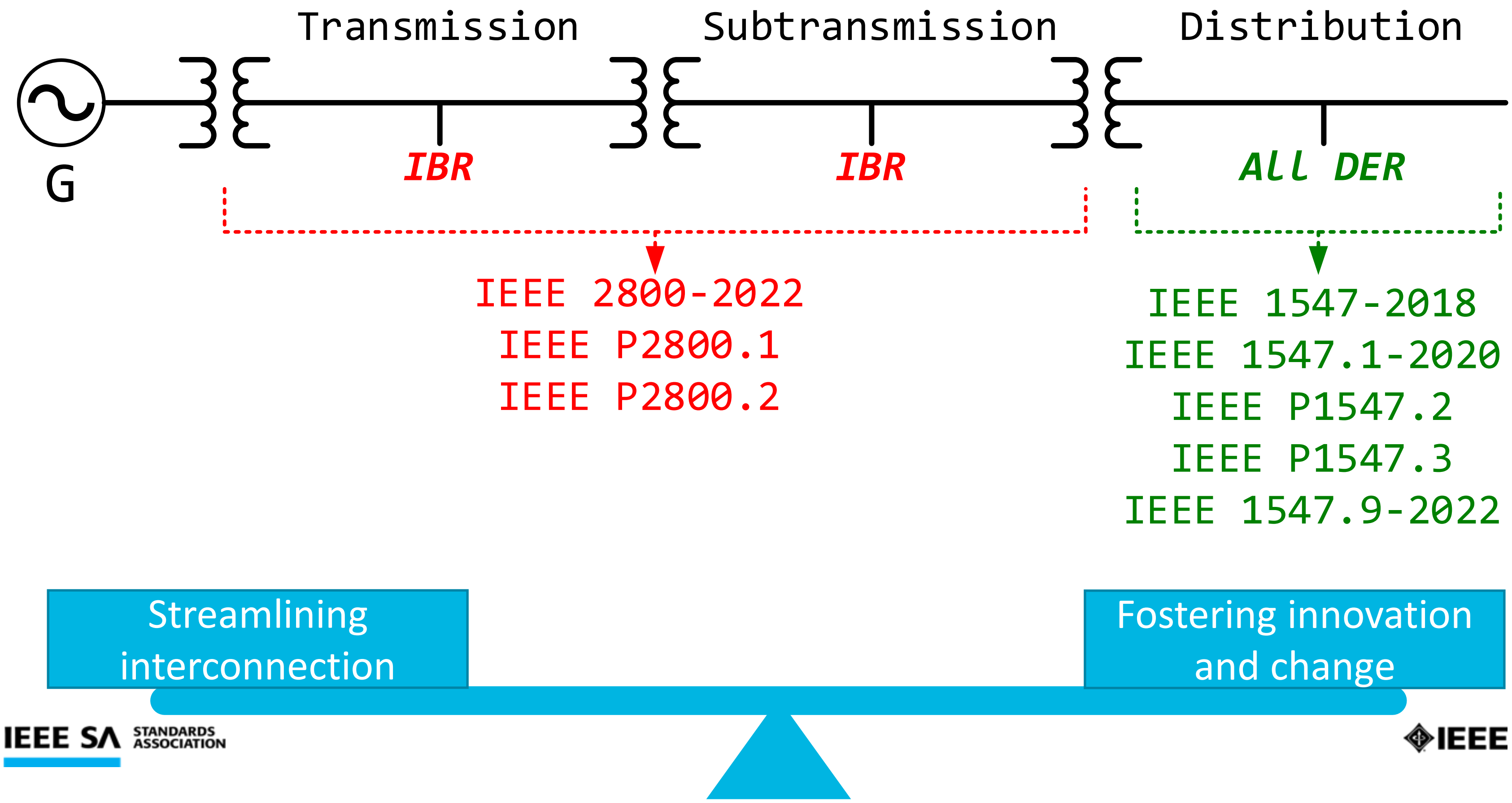
STANDARDS DEVELOPMENT LIFECYCLE



IEEE 1547 INTERCONNECTION STANDARDS *ACTIVE PROJECTS*

- IEEE 1547-2018: Standard for Interconnection
- IEEE P1547: Revision of 1547-2018
- IEEE P1547.1a: Amendment of DER interconnection test and verification requirements
- IEEE P1547.2: Application Guide to IEEE1547
- IEEE P1547.3: Guide for Cybersecurity of DER Interconnected with EPS
- IEEE P1547.4: Islanded Systems (“Microgrids”)
- IEEE 1547.9-2022: Guide for Energy Storage System Interconnection
- IEEE P1547.10: Recommended Practice for DER Gateway Platforms

IEEE STANDARDS APPLICABLE TO INTERCONNECTION, COORDINATING ACROSS T&D



IEEE STD 1547: USES

IEEE Std 1547 is:

- A technical standard—functional requirements for the interconnection itself and interconnection testing
- A single (whole) document of mandatory, uniform, universal requirements that apply at the point of common coupling (PCC) or point of DER connection (PoC)
- Technology neutral—i.e., it does not specify particular equipment or type
- Should be sufficient for most installations

IEEE Std 1547 is not:

- A design handbook
- An application guide (see IEEE Std 1547.2)
- An interconnection agreement
- Prescriptive—i.e., it does not prescribe other important functions and requirements such as cyber-physical security, planning, designing, operating, or maintaining the area EPS with DER

IEEE 1547 SCOPE AND PURPOSE AND IEEE P1547

Title: IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

Scope: This standard establishes criteria and requirements for interconnection of distributed energy resources (DER) with electric power systems (EPS), and associated interfaces.

Purpose: This document provides a uniform standard for the interconnection and interoperability of distributed energy resources (DER) with electric power systems (EPS). It provides requirements relevant to the interconnection and interoperability, operation, testing, safety, maintenance and security considerations.

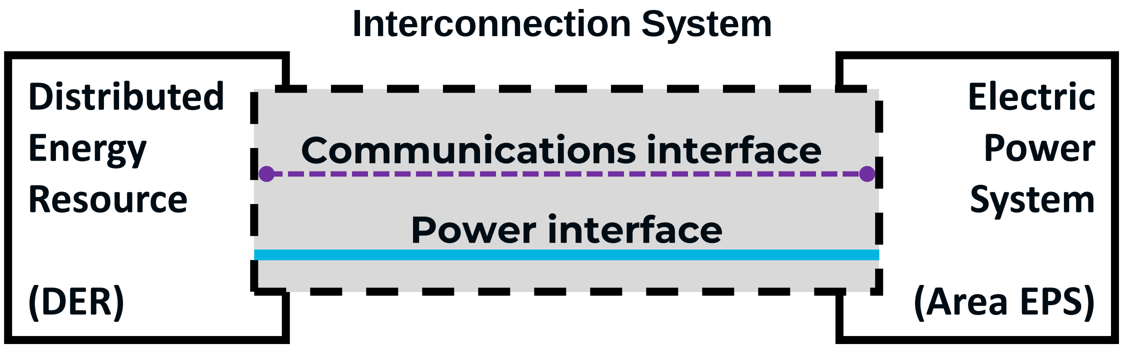


Image based on IEEE Std 1547-2018

Interconnection system: The collection of all interconnection equipment and functions, taken as a group, used to interconnect DER to an area EPS. Note: In addition to the power interface, DER should have a communications interface.

Interface: A logical interconnection from one entity to another that supports one or more data flows implemented with one or more data links.

IEEE STD 1547: INTERCONNECTION EXAMPLE USE IN UNITED STATES

IEEE Std 1547

Interconnection System and Test Requirements

- Voltage Regulation
- Ride-through
- Interoperability
- Islanding
- ….

IEEE Std 1547.1

Conformance Test Procedures

- Utility interactive tests
- Islanding
- Reconnection
- O/U Voltage and Frequency
- Synchronization
- DC injection
- ….

UL 1741

Interconnection Equipment Safety, Performance Certification

- IEEE 1547.1 Tests
- Protection against risks of injury to persons
- Specific tests for various technologies
- ….

NFPA70 (NEC)

Installation Code

- Article 690 PV Systems
- Article 705: interconnection systems (shall be suitable per intended use per UL 1741)

(NEC info. Based on NEC 2011)

Local interconnection processes and procedures

IEEE STD 1547-2018: DOCUMENT OUTLINE (CLAUSES)

1. **Overview**
2. **Normative references**
3. **Definitions and acronyms**
4. **General specifications and requirements**
5. *[normal grid]* **Reactive power, voltage/power control**
6. **Response to Area EPS abnormal conditions**
7. **Power quality**
8. **Islanding**
9. **Distribution secondary grid and spot networks**
10. **Interoperability**
11. **Test and verification**
12. **Seven new annexes (Informative)**

1.4 GENERAL REMARKS AND LIMITATIONS

- **Applicable to all DER connected at typical primary or secondary distribution voltage levels.**
  - Removed the 10 MVA limit from previous versions.
  - <u>BUT:</u> Not applicable for transmission or networked sub-transmission connected resources.
- **Specifies <u>performance</u> and <u>not design</u> of DER.**
- **Specifies <u>capabilities and functions</u> and <u>not utilization</u> of these.**
- **Does not address planning, designing, operating, or maintaining the Area EPS with DER.**
- **Emergency and standby DER are exempt from certain requirements of this standard.**
  - E.g., voltage and frequency ride-through, interoperability and communications.
- **Gives precedence to synchronous generator (SG) design standards for DER with SG units rated 10 MVA and greater.**
  - E.g., IEEE Std C50.12, IEEE Std C50.13.

1547-2018'S INTEROPERABILITY REQUIREMENTS

LIST OF ELIGIBLE PROTOCOLS

Protocol	Transport	Physical Layer
IEEE Std 2030.5™ (SEP2)	TCP/IP	Ethernet
IEEE Std 1815™ (DNP3)	TCP/IP	Ethernet
SunSpec Modbus	TCP/IP	Ethernet
	N/A	RS-485

1547-2018 REQUIRED DER MANAGEMENT INFORMATION

- Constant power factor mode parameters
- Voltage-Reactive power mode parameters
- Active power-reactive power mode parameters
- Constant reactive power mode parameters
- Voltage-active power mode parameters
- Voltage trip and momentary cessation parameters
- Frequency trip parameters
- Frequency droop parameters
- Enter service parameters
- Cease to energize and trip
- Limit Maximum active power

IEEE 1547-2018 and Energy Storage

IEEE 1547.9 – new'ish guide for applying IEEE 1547 to ES-DER

‘IEEE interconnection and interop 'performance requirements' oriented standards for ES’
‘Communication protocols/telemetry required for interconnection to grid/distribution utilities’

IMPACT OF REVISING 1547-2003 ON ES APPLICATIONS, UPDATES MADE TO 1547-2018 REMOVED OTHERWISE UNINTENDED BARRIERS TO SOME ES APPLICATIONS

Category	Storage "End Use"
ISO/Market	• Frequency regulation • Spin/non-spin/replacement reserves • Ramp • Black start • Real time energy balancing • Energy price arbitrage • Resource adequacy
VER Generation	• Intermittent resource integration: wind (ramp/voltage support) • Intermittent resource integration: photovoltaic (time shift, voltage sag, rapid demand support) • Supply firming
Transmission/ Distribution	• Peak shaving: off-to-on peak energy shifting (operational) • Transmission peak capacity support (upgrade deferral) • Transmission operation (short duration performance, inertia, system reliability) • Transmission congestion relief • Distribution peak capacity support (upgrade deferral) • Distribution operation (Voltage Support/VAR Support) • Outage mitigation: micro-grid
Customer 7	• Time-of-use /demand charge bill management (load shift) • Power quality • Peak shaving (demand response), Back-up power

1547-2003 vs. new CA 21 & 1547Revision

Source (original table): CA PUC, AB2514 workshop 3/25/2013

WHAT’S IN 1547.9?

1547.9 focuses on applying 1547 to energy storage. Examples:

- **ES-specific terminology (e.g., “operational SoC” and “operational capacity”)**
- **Black Start**
- **Clarifying volt-var support modes**
- **Fast Frequency Response**
- **Voltage and Frequency Ride-through Exemptions**
- **ES DERs in Secondary Networks**
- **ES Specific Changes in Interoperability requirements**
- **ES DER’s specific testing requirements**
- **Safety**
- **V2G**

WHAT'S IN 1547.9?

Scope clarification. i.e. 'When is ES in-scope of 1547?'

Any energy storage DER that is "capable of active power export" is in-scope. What does that mean?

capable of exporting active power = any ES DER that is capable of serving load simultaneously with the Area EPS.

Examples of systems and whether they are in-scope:

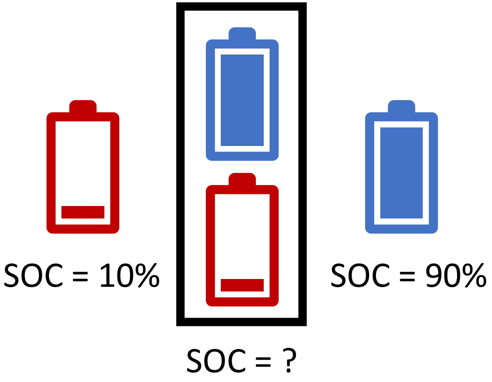
UPS?	PV + ES?	V1G?	V2G?
No	Yes	No	Yes

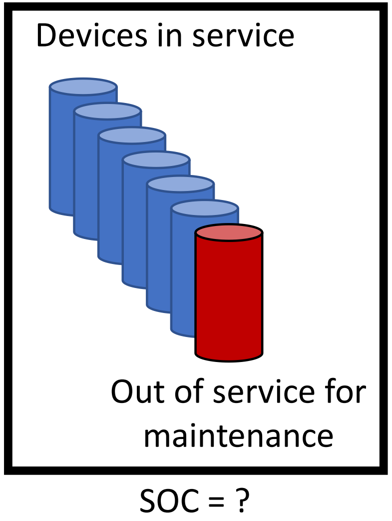
WHAT'S IN 1547.9?

Defines Operational State of Charge. A term used in IEEE 1547-2018.

<u>operational state of charge:</u> the usable energy stored as a proportion of the operational capacity, expressed as a percentage.

<u>operational capacity:</u> the estimated energy that an energy storage system can provide on discharge, subject to operational constraints. Examples of factors influencing operational capacity include rated energy, state of health, discharge rate, temperature, and usable state-of-charge range.





WHAT'S IN 1547.9?

Clarifies volt-var support modes while charging.

It is recommended that ES DER comply with Normal Operating Performance Category B. In Clause 5, 1547.9 clarifies how these extend into the charging region.

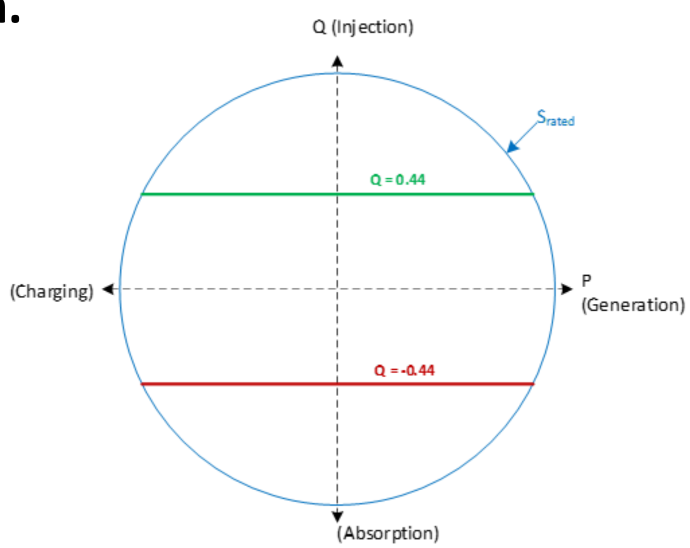


Figure 4—Reactive power capability of ESS

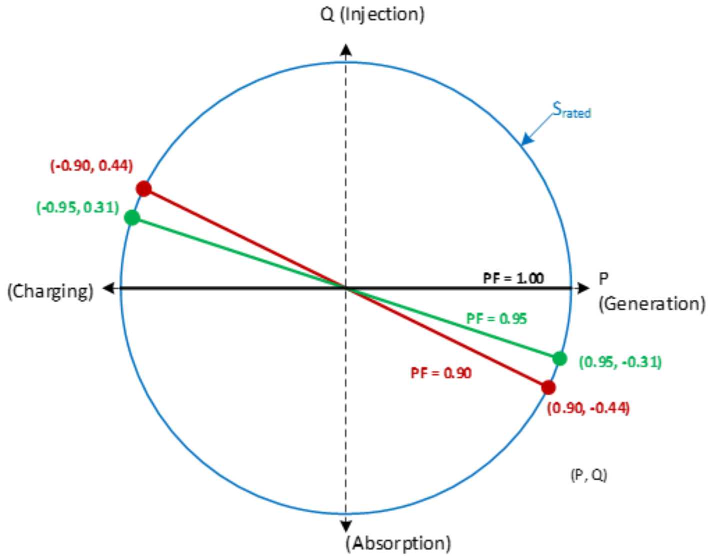


Figure 5—Constant power factor operation of ESS

WHAT'S IN 1547.9?

Interoperability, information exchange, info. models and protocols.

Clause 10 of 1547.9 discusses energy storage-specific changes in the interoperability requirements laid down in the base standard. *Most* of the examples are cases of ES-specific parameters that need to be added to the reporting requirements.

One example is shown at right (ESS-specific additions to Table 29 in 1547-2018).

Table 29—Monitoring information [1547]

In Table 29 [1547], the following rows should be added:

Parameter	Description
State of charge	
Temperature [a]	Temperature in degrees Celsius

[a] This temperature can be the overall temperature of the ES DER unit or, for large installations, the temperatures of individual cells and/or other units.

In Table 29 [1547], the following rows should be added if the ES DER has such parameters:

Parameter	Description
Smoke Detection	Smoke has been detected indicating fire
Flame Detection	Flame has been detected indicating fire
Off-Gas Detection	Hydrogen has been detected
Fire Protection System Detection	The fire protection system has activated

In Table 29 [1547], for ES DER the following rows should be changed as shown (**emphasis** added to identify the change):

Parameter	Description
Operational State	Operational state of the DER. The operational state should represent the current state of the DER. The minimum supported states are on and off, but additional states may also be supported. **Include charging and discharging as operational states of the DER.**

IEEE SA STANDARDS ASSOCIATION

THANK YOU!

Please feel free to email me with questions:

meropp@sandia.gov

Chair, P1547.9 Guide for ES-DER Interconnection

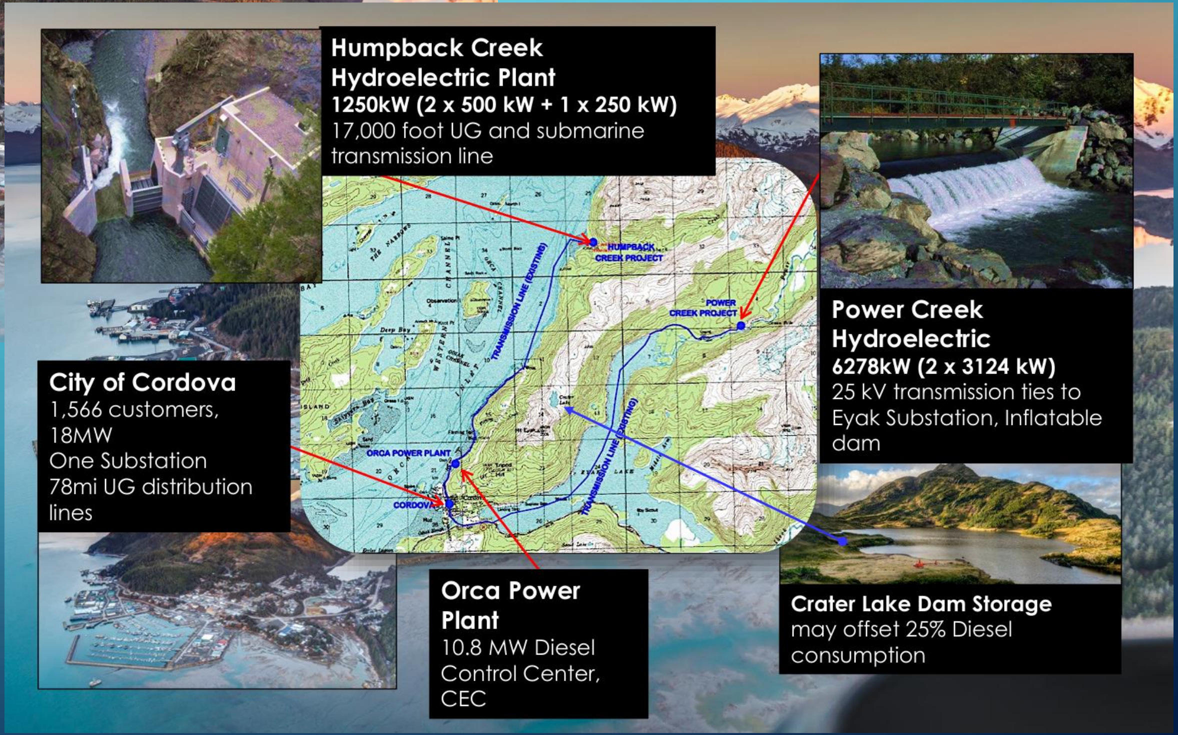
Chair, P1547.4 Guide for MG Interconnection

Special thanks to Dr. Imre Gyuk, DOE – Office of Electricity, Energy Storage Program.

TWO EXAMPLES OF BESS REDUCING DIESEL USE ON NON-BPS-CONNECTED GRIDS

1) CORDOVA ELECTRIC CO-OP BESS
2) SO CAL EDISON CATALINA ISLAND BESS


Cordova Alaska Aerial View


Humpback Creek
Hydroelectric Plant
1250kW (2 x 500 kW + 1 x 250 kW)
17,000 foot UG and submarine transmission line
Power Creek
Hydroelectric
6278kW (2 x 3124 kW)
25 kV transmission ties to Eyak Substation, Inflatable dam
City of Cordova
1,566 customers,
18MW
One Substation
78mi UG distribution lines
Orca Power Plant
10.8 MW Diesel
Control Center,
CEC
Crater Lake Dam Storage
may offset 25% Diesel consumption
HUMPBACK CREEK PROJECT
POWER CREEK PROJECT
ORCA POWER PLANT
CORDOVA
TRANSMISSION LINE (EXISTING)

Source, CEC

TIMELINES

- 2007 – CEC System Loads Exceed Hydro Capacity and diesel peaking creates a “valley of death”
- 2012 – CEC partners with ACEP and recognizes the benefits of energy storage to CEC Grid
- 2015-16 ACEP Approaches Dr. Gyuk with CEC use case/opportunity and rich CEC data set
- 2016 Dr. Gyuk initiates phase 1 modelling of CEC energy storage via Sandia Laboratories
- 2017 Modelling and analysis indicates a right-sized, right-located Lithium Ion solution for CEC
- 2018 Dr. Gyuk sponsors phase 2 specification and procurement of BESS
- October 2018 CEC BESS Ordered
- May 2019 BESS arrives on site
- June 2019 BESS Installed
- July 2019 BESS Operational
- November 2019 Fully integrated and automated, saves $10,000 over 2-day Thanksgiving Holiday
- November CEC achieves 94% hydro crushing all previous records
- December 2019 CEC achieves 86% hydro crushing all previous records
- April 2020 CEC goes 100% hydro 3 weeks early and starts automated electric boiler heating
- 2021: Saved 50,000 gallons of diesel directly with BESS, 14,000 gallons indirectly with e-boiler
- 2022: Delivering more hydro, upgraded diesel heat loops to save 25,000 gallons with e-boiler
- 2022: New valves unleashed more hydro; extending heat loops and EV charging with excess hydro

Source, CEC

Pacific Northwest NATIONAL LABORATORY

Cordova Electric Coop Energy Storage Integration (CECESI) Project Objective & Expected Outcomes

- Cordova Electric Cooperative installed a 1MW/1MWh battery energy storage system (BESS) in 2019 with a primary objective of reducing diesel fuel consumption
- To support the BESS's primary objective, the CECESI project will:
  - further improve integration of the BESS into CEC's utility monitoring and controls environment,
  - support CEC's use of recorded operating data to verify the benefits from BESS operation, and
  - inform CEC's continued improvement to the BESS's dispatch algorithms

CEC

Sandia National Laboratories

CECESI 2020 Scope Update, Add Resiliency to Medical Center Load Service

- In 2020, the CECESI project scope was updated
- Addition of a microPMU at the Cordova Community Medical Center with the following goals:
  - Provide additional information on the interrelationships between grid operations and major load operations
  - Expand the CECESI optimization solution
  - Help to further reduce diesel fuel use
  - Explore extending load service reliability through better visibility

Source, PNNL

SCE Catalina Battery Project – May 2008 Update

Charles K. Vartanian, SCE DER

May 5, 2008

Proposed Storage for Emissions Mitigation

- 1 MW 7+ MWh battery to flatten SCE Catalina Island's fossil plant output (Pebbly Beach Generating Station)
- Not a traditional economic or reliability criteria justified T&D project.
- NaS identified as current available credible large-scale technology with best technical fit
  - U.S. Gov's National Renewable Energy Labs (V.P. Gore Panel)
  - SCE EV Staff (timing issue, i.e. possible options emerging on horizon, but 1+ years out)
  - Utility Use/Experience with Large Stationary NaS Is Expanding
    - AEP, TEPCo, active & expanding commercial operation
    - PG&E, EXEL, approved and planned for 2008+
    - SCE, First Energy, HELCO, proposed

Source, SCE

EDISON INTERNATIONAL ENERGIZED

HOME STORIES VIDEOS CONNECT RESOURCES SUBSCRIBE

STORIES / THE GRID

Batteries Help Keep Catalina's Lights On

The workhorse battery energy storage system will soon celebrate five years on the island.

Credit: Ron Hite

By Jude Schneider   August 22, 2017

SUBSCRIBE

Providing electricity to Catalina Island is both a challenge and an opportunity. A challenge because the island is 22 miles from the nearest connection to the mainland's electrical grid. An opportunity because innovation is keeping the lights on, and that innovation can lead to advancements across the grid.

A case in point is Catalina's battery energy storage system. Put into service on Aug. 26, 2012, it is one of the longest-operating battery energy storage systems of its kind in the country, and it has a significant role in powering Catalina.

Source, SCE

December 18, 2015

California Energy Commission
Docket Office, MS-4
Re: Docket No. 15-MISC-05
1516 Ninth Street
Sacramento, CA 95814-5512
docket@energy.ca.gov

Re: Southern California Edison Company's Comments on the California Energy Commission Docket No. 15-MISC-05: Joint Agency Workshop on Bulk Energy Storage

A. Current Operations of the Battery

The 1 MW Na-S battery is currently being used to increase the flexibility of generation serving Catalina's customers as well as to enable Pebbly Beach Generating Station to start up, shutdown, and run the diesel generators at their best pollution control and operating efficiency ranges. Pebbly Beach's diesel generators are equipped with Selective Catalytic Reduction equipment on the exhaust of each engine, resulting in more than 90% reduction of NOx (Nitrous Oxides). To operate effectively, the catalyst requires the exhaust temperature to be 550 degrees F or higher to begin the catalytic reaction.

Source, SCE

December 18, 2015

This exhaust temperature is generally not achieved when the units are operated below 70% of maximum power. Thus, in order to ensure constant NOx reduction treatment is maintained, the units must be operated at least at 70% of maximum output. As discussed below, operation of the Na-S battery allows for higher loading of the engines to maintain the emissions reduction.

As load increases, SCE must start additional units to serve the incremental load. Without the battery, it would be a challenge to operate the diesel fleet such that all units operate above the 70% threshold; at certain times, especially during morning and evening ramps, it would be necessary to run a unit below 70% power in order to balance supply and demand. For example, when incremental load requires starting up a new unit, that unit may need to operate at low power until load further increases.

The battery provides a solution to this problem: Pebbly Beach uses the battery as a load source to increase the net power demand of the system. This allows an engine that is coming on-line to go immediately into its upper power range, maintaining the supply and demand balance while allowing the catalytic reduction to begin immediately. As the island load further increases, the battery charging mode is reduced as the net output of Pebbly Beach follows the load ramping up. The process is reversed when Island net load is lessening: an engine can be taken out of service while running at high power by having the battery pick up its output upon shutdown. This avoids the need to ramp down the generator to low power to follow down the load, which would result in increased NOx emissions. Finally, the battery may also be used as a conventional peaking resource. The battery can either avoid the need to start another diesel unit, or can delay the start of the diesel unit.

Source, SCE

ESTIMATED ANNUAL DIESEL USE REDUCTION VIA BESS OPTIMIZATION, GENERIC CASE

Daily Average Load : 2,000kW On-Peak, 1,000kW Off-Peak. N-1 (Unit loss mitigation) Operating Requirement

W/OUT 1000 kW BESS

	MW	% Load	Off Peak Hours	Gal/hr	Gallons
UNIT 1	1,000	50	8	36	291
UNIT 2	1,000	50	8	36	291
UNIT 3	1,000	-			-
			Mid Peak Hours		
UNIT 1	1,000	75	10	71	711
UNIT 2	1,000	75	10	52	521
UNIT 3	1,000	-	-		-
			On Peak Hours		
UNIT 1	1,000	Full	6	71	427
UNIT 2	1,000	50	6	52	313
UNIT 3	1,000	50	6	36	218
					2,772 Gallons per day
					1,011,780 Gallons per year

Generator Size (kW)	¼ Load (gal/hr)	½ Load (gal/hr)	¾ Load (gal/hr)	Full Load (gal/hr)
20	0.6	0.9	1.3	1.6
30	1.3	1.8	2.4	2.9
40	1.6	2.3	3.2	4.0
60	1.8	2.9	3.8	4.8
75	2.4	3.4	4.6	6.1
100	2.6	4.1	5.8	7.4
125	3.1	5.0	7.1	9.1
135	3.3	5.4	7.6	9.8
150	3.6	5.9	8.4	10.9
175	4.1	6.8	9.7	12.7
200	4.7	7.7	11.0	14.4
230	5.3	8.8	12.5	16.6
250	5.7	9.5	13.6	18.0
300	6.8	11.3	16.1	21.5
350	7.9	13.1	18.7	25.1
400	8.9	14.9	21.3	28.6
500	11.0	18.5	26.4	35.7
600	13.2	22.0	31.5	42.8
750	16.3	27.4	39.3	53.4
1000	21.6	36.4	52.1	71.1

WITH 1000 kW BESS

	MW	% Load	Off Peak Hours	Gal/hr	Gallons
UNIT 1	1,000	Full	8	71	569
UNIT 2	1,000	Full	8	71	569
UNIT 3	1,000	-	-	-	-
			Mid Peak Hours		
UNIT 1	1,000	75	10	52	521
UNIT 2	1,000	75	10	52	521
UNIT 3	1,000	-	-	-	-
			On Peak Hours		
UNIT 1	1,000	Full	6	71	427
UNIT 2	1,000	-	-	-	-
UNIT 3	1,000	-	-	-	-
					2,606 Gallons per day
					951,263 Gallons per year
					(60,517) Gallons reduced per year

REFERENCES AND ADDITIONAL INFORMATION

https://standards.ieee.org/standard/1547-2018.html

Fuel-Consumption-Chart-Diesel-Generators.pdf (cliffordpower.com)

Batteries Help Keep Catalina's Lights On | Energized by Edison

BESS System on Hybrid Microgrid Powers Remote Alaskan Community (powermag.com)

4_PNNL-IPS-Cordova-Vartanian-July202_Charlie_Vartaniann2_lores.pdf (alaskarenewableenergy.org)

https://www.sandia.gov/ess-ssl/

Thank You! **Charlie.Vartanian@ieee.org**