IEEE 1547 Interconnection Standards

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Tom Basso* and Mike Coddington
National Renewable Energy Laboratory (NREL)

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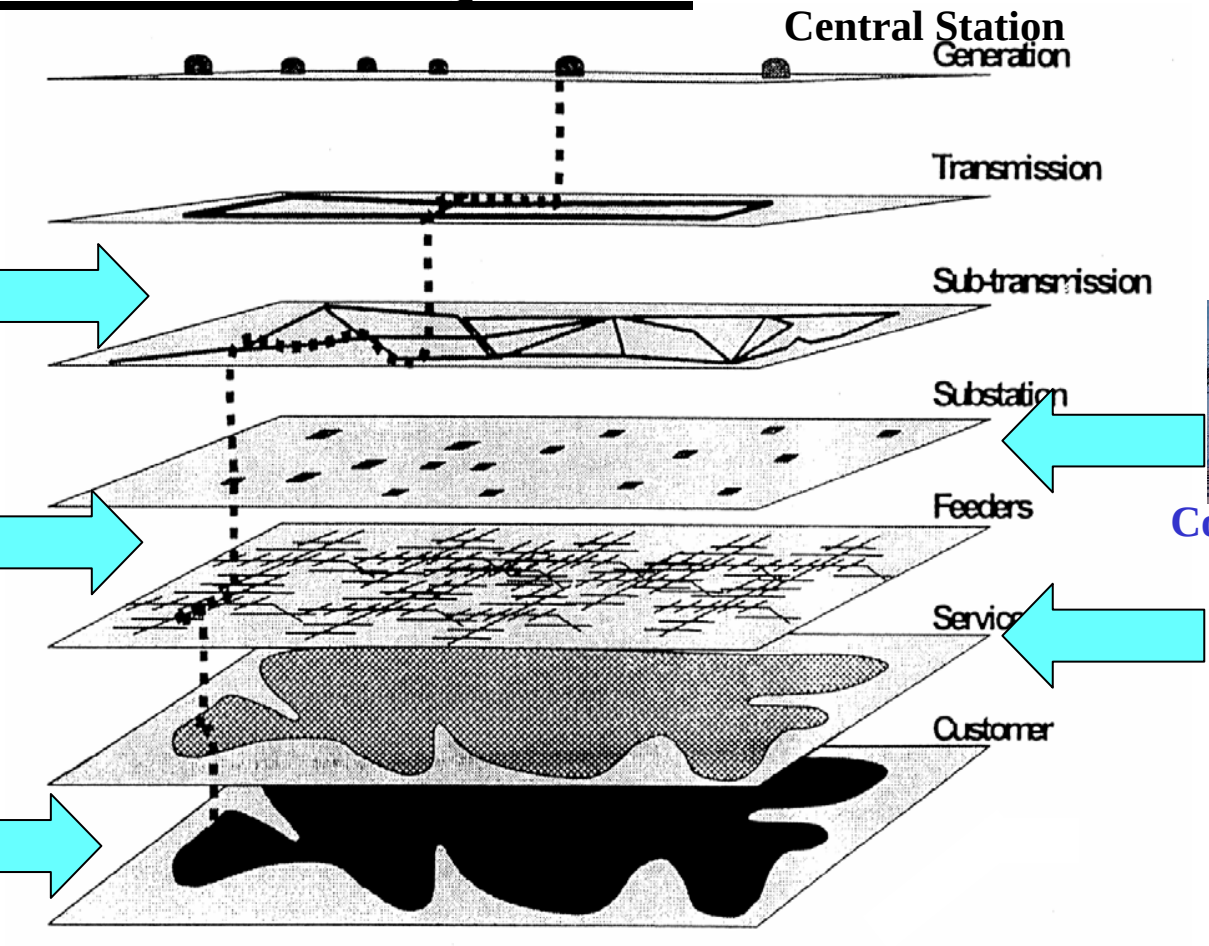
* Secretary IEEE SCC21 & 1547 series;
IEC/TC8 Technical Advisor

EPACT 2005 Cites & Requires IEEE Stds 1547
And Best Practices for Interconnection Implementation
IEEE 1547 Developed By National Team of 444 Professionals

Interconnection and Integration with the Electric Power System



Wind Energy

Combustion Engines

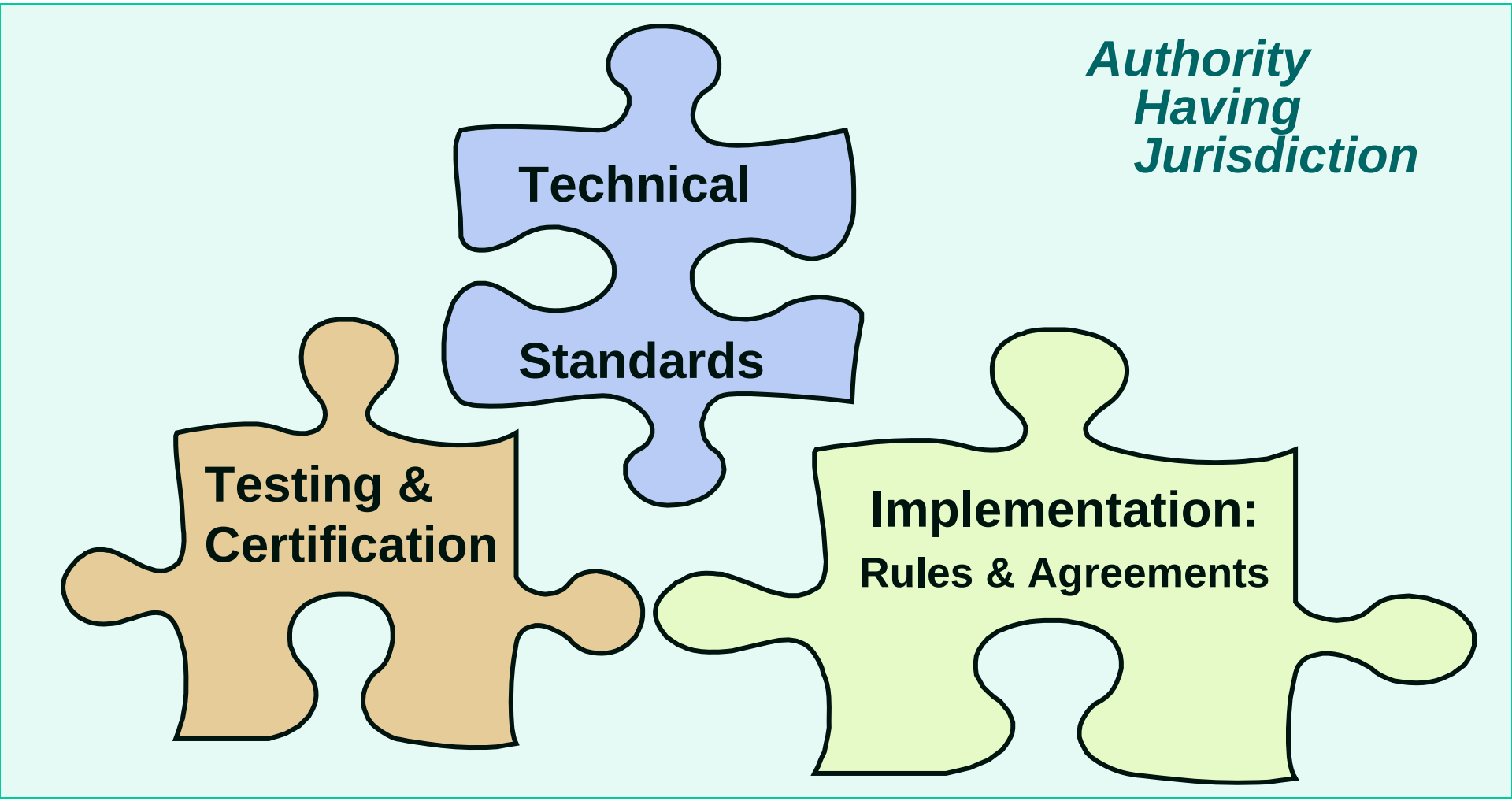
Fuel Cells

MicroTurbines

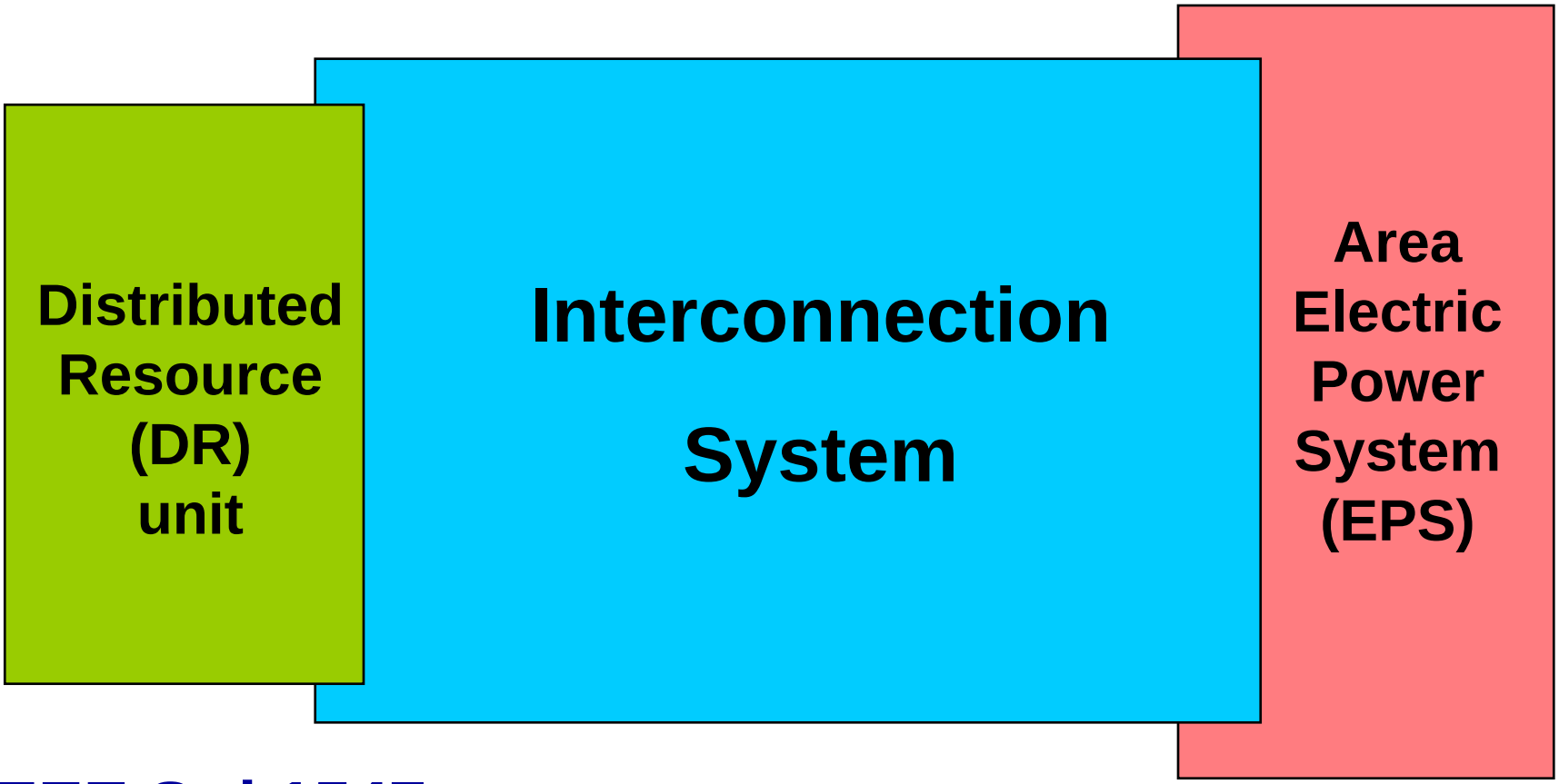
Solar Energy

The overall power system is traditionally viewed in terms of 7 layers; each performing its function from central station generation supplying power out to customers.

Interconnection:
Putting the Pieces Together



Std 1547: Interconnection Is The Focus



IEEE Std 1547: Interconnection requirements and specifications, and, test requirements & specifications

How do the interconnection standards work together?

IEEE 1547
Interconnection System and Test Requirements

- Voltage Regulation
- Grounding
- Disconnects
- Monitoring
- Islanding
- etc.

IEEE 1547.1
Interconnection System Test Procedures

- O/U Voltage
- and Frequency
- Synchronization
- EMI
- Surge Withstand
- DC injection
- Harmonics
- Islanding
- Reconnection

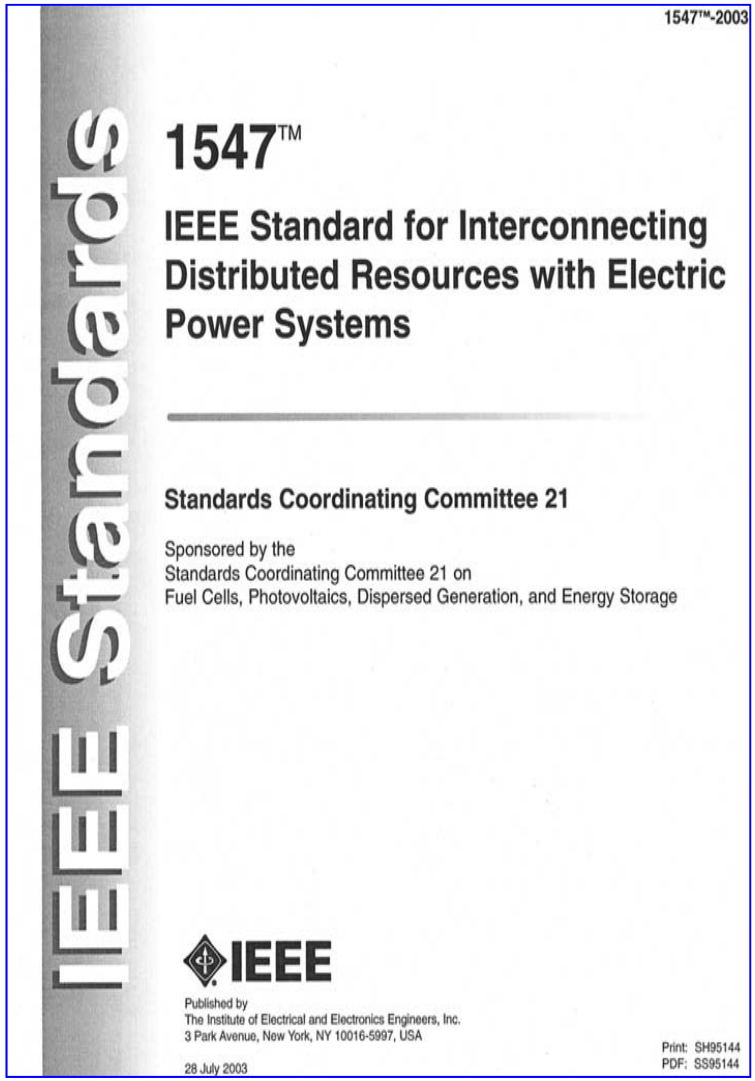
UL 1741*
Interconnection Equipment

- 1547.1 Tests
- Construction
- Protection against risks of injury to persons
- Rating, Marking
- Specific DR Tests for various technologies

Note: NEC (2008 Article 705-xx) requires interconnection systems be suitable per standard UL1741/IEEE 1547 & 1547.1

*** UL 1741 supplements and is to be used in conjunction with 1547 and 1547.1**

American National Standard ANSI/IEEE Std 1547



Contents

IEEE Std 1547.1 Test Procedures …

this standard specifies the type, production, and commissioning tests that shall be performed to demonstrate that interconnection functions and equipment of a distributed resource (DR) conform to IEEE Std 1547.

…

5.0 Type (Design) Tests

- 5.1 Temperature Stability
- 5.2 Response to Abnormal Voltage
- 5.3 Response to Abnormal Frequency
- 5.4 Synchronization
- 5.5 Interconnection Integrity
- 5.6 DC injection
- 5.7 Unintentional Islanding
- 5.8 Reverse Power
- 5.9 Cease to Energize Functionality and Loss of Phase
- 5.10 Reconnect Time
- 5.11 Harmonics
- 5.12 Flicker

6 - Production Tests

7 - Commissioning Tests

- **Verification and Inspections**
- **Field Conducted Type and Production Tests**

UL 1741 Standard (2005)

Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources

- NREL contracted with UL to update 1741 to include all DER interconnections; **for utility interactive equipment; 1741 is to be used in conjunction with IEEE Std 1547 & IEEE Std 1547.1**
- UL 1741 Goes beyond 1547 requirements to include product safety aspects; doesn't incorporate all of 1547
  - Construction, Materials, wiring, component spacing, etc.
  - Protection against risks of injury to persons
  - Output Characteristics and utility compatibility
    (This section includes requirements from IEEE 1547)
  - Rating, Marking
  - Specific DR Tests for various technologies
    (PV, Wind, Microturbine, Fuel Cell, Engine)

Contact Information

- **Dick DeBlasio* Technology Manager**
  NREL Distributed Energy & Electric Reliability (DEER) Program
  Chair IEEE SCC21, 1547; IEEE Standards Board Liaison to DOE
  em: Dick_Deblasio@nrel.gov voice: (303) 275 – 4333

- **Tom Basso* NREL**
  Sec'ty IEEE SCC21 & P1547.2 .3.4.6
  em: thomas_basso@nrel.gov
  voice: (303) 275 - 3753

- **Ben Kroposki* NREL**
  Sec'ty 1547.1 & Chair P1547.4
  em:benjamin_kroposki@nrel.gov
  voice: (303) 275 – 2979

***** NREL DEER Distribution & Interconnection R&D

- **Mike Coddington*** NREL (303) 275-3822 Mike_Coddington@NREL.gov

*** NREL** http://www.nrel.gov
1617 Cole Blvd. MS-1614 Golden, CO 80401-3393

- **IEEE SCC21 -- IEEE Standards Coordinating Committee 21** on Fuel Cells, Photovoltaics, Dispersed Generation, & Energy Storage
http://grouper.ieee.org/groups/scc21/

- **IEEE Std 1547 Series of Interconnection Standards** --
http://grouper.ieee.org/groups/scc21/dr_shared/

IEEE 1547 Definitions

- **Distributed Resource (DR)** – sources of electric power that are not directly connected to a bulk power transmission system
- **Electric Power System (EPS)** – facilities that deliver power to a load
- **Interconnection** – the result of the process of adding a DR unit to an area EPS
- **Interconnection Equipment** – individual or multiple devices used in an interconnection system
- **Interconnection System** – the collection of all interconnection equipment, taken as a group, used to interconnect a DR unit(s) to an area EPS
- **point of common coupling (PCC)** - the point where a Local EPS is connected to an Area EPS.

IEEE 1547 Series Background Slides

IEEE 1547 IS:

- A Technical Standard – Functional Requirements For
  - the interconnection itself
  - the interconnection test
- Technology neutral, e.g., does not specify particular equipment nor type
- A single (whole) document of mandatory, uniform, universal, requirements.
- Should be sufficient for most installations.

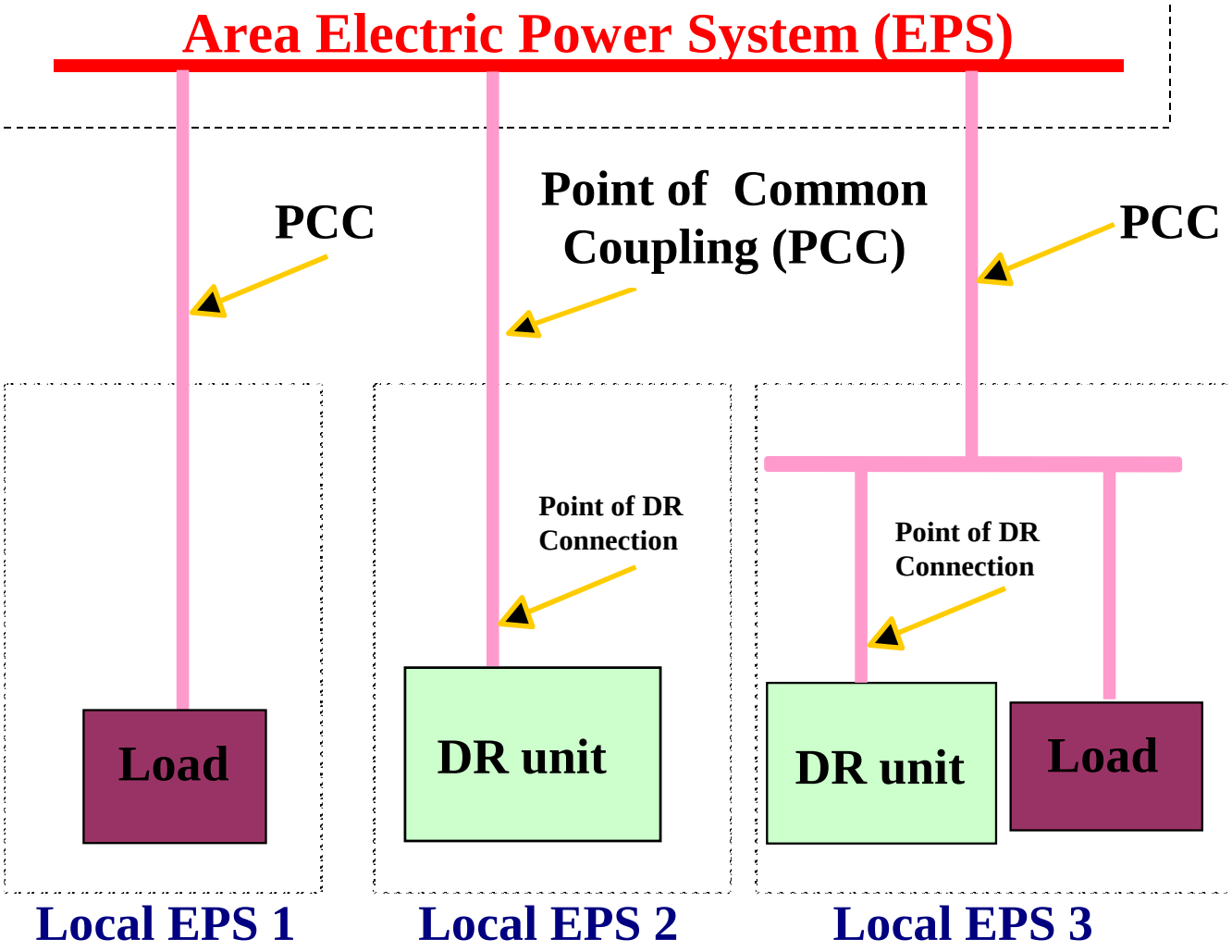
IEEE 1547.1 IS:

Test Procedures Conformance to 1547

IEEE 1547 Is NOT:

- a design handbook
- an application guide
- an interconnection agreement
- prescriptive, e.g., does not address DR self-protection, nor planning, designing, operating, or maintaining the Area EPS.

1547 Interconnection Terms



Note: There can be any number of Local EPSs.

IEEE Std 1547

4.0 INTERCONNECTION TECHNICAL SPECIFICATIONS AND REQUIREMENTS

- 4.1 General Requirements
- 4.2 Response to Area EPS Abnormal Conditions
- 4.3 Power Quality
- 4.4 Islanding

5.0 INTERCONNECTION TEST SPECIFICATIONS AND REQUIREMENTS

- 5.1 Design Test
- 5.2 Production Tests
- 5.3 Interconnection Installation Evaluation
- 5.4 Commissioning Tests
- 5.5 Periodic Interconnection Tests

- **ANNEX A (INFORMATIVE) BIBLIOGRAPHY**

4.0 INTERCONNECTION TECHNICAL SPECIFICATIONS AND REQUIREMENTS

4.1 General Requirements

- Voltage Regulation
- Integration with Area EPS Grounding
- Synchronization
- DR on Secondary Grid and Spot Networks

- Inadvertent Energizing of the Area EPS
- Monitoring Provisions
- Isolation Device
- Interconnect Integrity

4.2 Response to Area EPS Abnormal Conditions

- Area EPS Faults
- Area EPS Reclosing Coordination
- Voltage
- Frequency
- Loss of Synchronism
- Reconnection to Area EPS

4.3 Power Quality

- Limitation of DC Injection
- Limitation of Voltage Flicker Induced by the DR
- Harmonics

4.4 Islanding

- Unintentional Islanding
- Intentional Islanding

5.0 INTERCONNECTION TEST SPECIFICATIONS AND REQUIREMENTS

5.1 Design Test

- Abnormal voltage and frequency
- Synchronization
- Interconnection integrity
- Unintentional islanding
- Limitation of DC injection
- Harmonics

5.2 Production Tests

- Meet requirements of:
  - response to abnormal voltage and frequency
  - synchronization
  - may be performed at the factory or at time of commissioning

5.3 Interconnection Installation Evaluation

- Grounding Integration with area EPS
- Isolation Device
- Monitoring provisions
- Area EPS faults
- Area EPS reclosing coordination

5.4 Commissioning Tests

- Visual Inspection
- Operability test on the isolation device
- Unintentional islanding functionality test
- Cease to energize functionality test

5.5 Periodic Interconnection Tests

- All interconnection-related protective functions and associated batteries

Annex A. Bibliography

IEEE 1547.1 (2005) Std.

IEEE Std 1547.1 *Standard for Conformance Test Procedures …*-- this standard specifies the type, production, and commissioning tests that shall be performed to demonstrate that interconnection functions and equipment of a distributed resource (DR) conform to IEEE Std 1547.

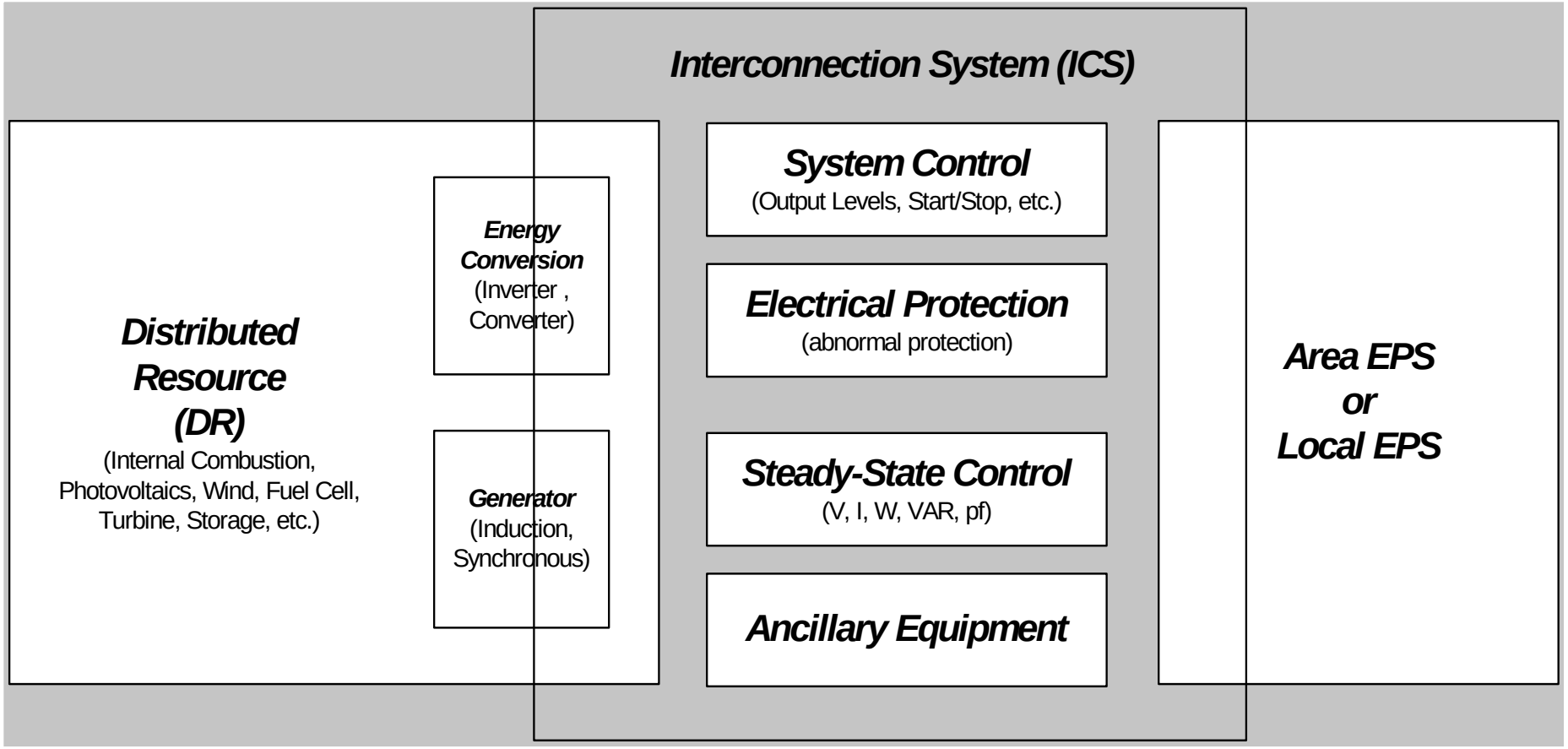


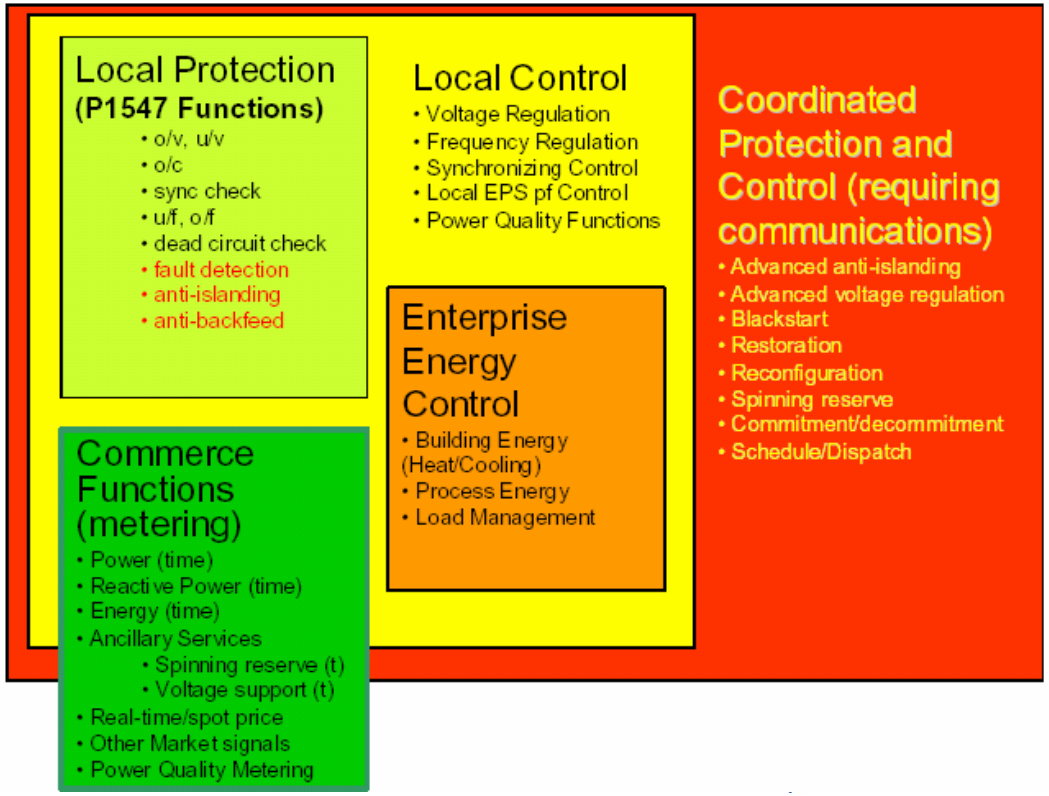
Figure 1. Boundaries between the interconnection system, the electric power system and the distributed resource (IEEE Std 1547.1)

P1547.2 Ballot Targeted Feb/Mar. 2008

IEEE P1547.2 *application guide* to 1547 (ballot targeted Feb/Mar 2008). "guide" offers alternate approaches – e.g., practical applications guidance, tips, techniques and rules of thumb for applying IEEE 1547 to specific interconnection situations on specific utility distribution feeders. Industry identified this as critically important practical companion to 1547.

Example of an alternate approach to 1547 requirements.

(Graphic From "Universal Interconnection Technology (UIT) Workshop Proceedings" NREL/BK-560-32865.)



IEEE Std 1547.3 (May 2007)

1547.3 Guide to monitoring, information exchange, and control (MIC) for DR: MIC qualities (interoperability, etc.); technical and business operations; stakeholder transactions; alternative approaches – e.g., MIC use cases for DR applications.

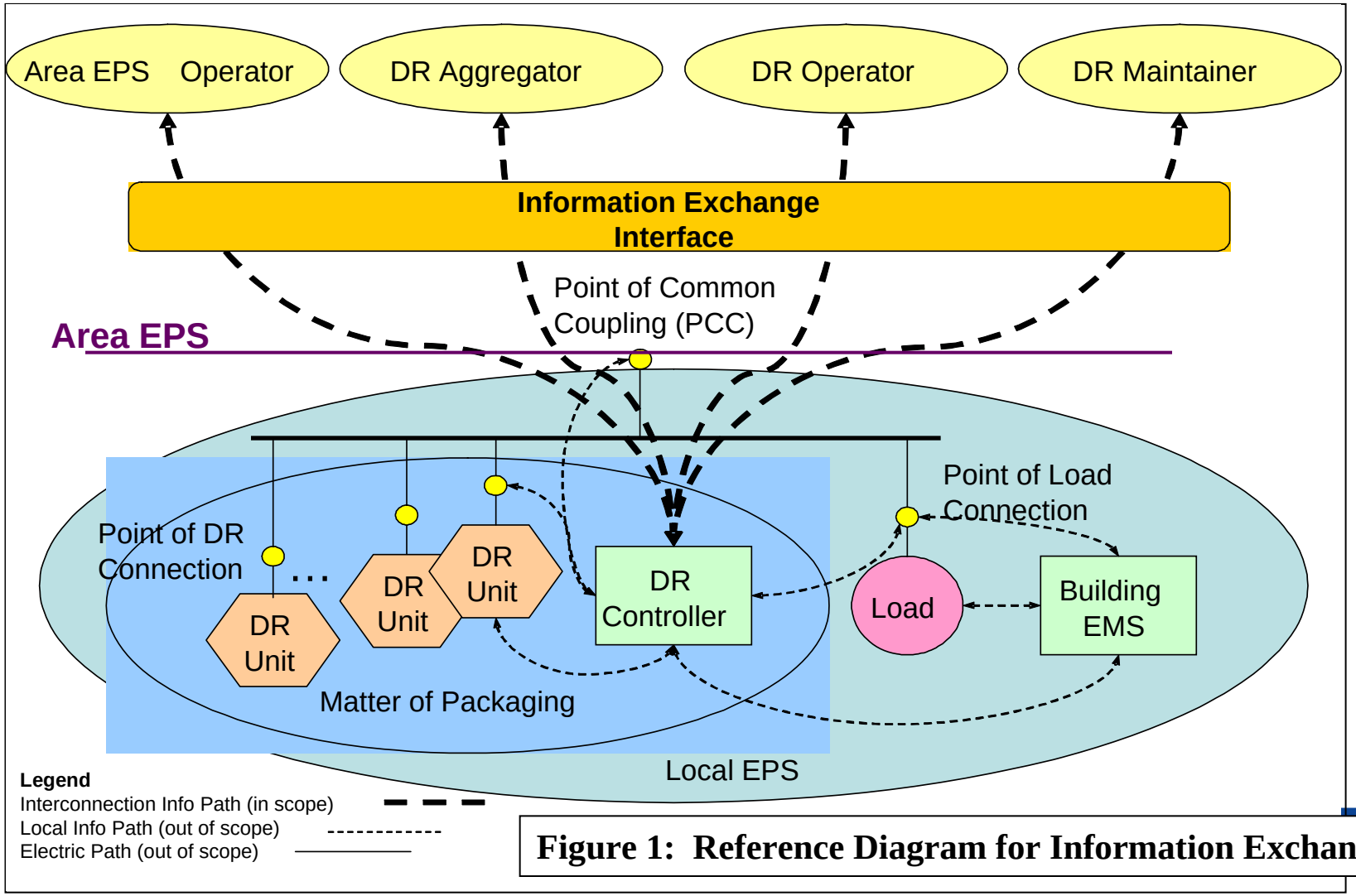


Figure 1: Reference Diagram for Information Exchange

American National Standards
ANSI/IEEE 1547 Series of Standards

IEEE Std 1547 (2003) – Requirements

Affirmative IEEE Ballot February 2003

- Voting Membership
  - 230 members (31% general interest, 4% government, 30% manufacturer/producer, 35% utility/user)
- 444 Work Group & Ballot Group Members at ballot

American National Standard designation ANSI/IEEE Std 1547 - October 20, 2003

IEEE Std 1547.1 (2005) – Test Procedures

Affirmative IEEE Ballot February 2005 - published July 2005

- Voting Membership 118 members

IEEE Std 1547.3 (2007) – DR MIC*

Affirmative IEEE Ballot May 2007 - published Nov 2007

* monitoring, information exchange and control

IEEE SCC21 1547 Series of Interconnection Standards

IEEE Std 1547™ (2003) Standard for Interconnecting Distributed Resources with Electric Power Systems

P1547.6 Draft Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks

Guide for Impacts

P1547.4 Draft Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems

IEEE Std 1547.3 (2007) Guide for Monitoring, Information Exchange and Control of DR Interconnected with EPS

Guide For Interconnection System Certification

IEEE Std 1547.1™ (2005) Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems

P1547.2 Draft Application Guide for IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems

P1547.5 Draft Technical Guidelines for Interconnection of Electric Power Sources Greater Than 10 MVA to the Power Transmission Grid

DP Specifications & Performance (includes modeling)

(publication year in parentheses; P1547.X are under development; other topics are under consideration by SCC21 work group members)

Current SCC21 Interconnection Projects

Title	Scope & Purpose
IEEE Std 1547™ (2003) Standard for Interconnecting Distributed Resources with Electric Power Systems	• This Standard establishes criteria and requirements for interconnection of distributed resources (DR) with electric power systems (EPS). • This document provides a uniform standard for interconnection of distributed resources with electric power systems. It provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection.
IEEE Std 1547.1 (2005) Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems	• This Standard specifies the type, production, and commissioning tests that shall be performed to demonstrate that interconnection functions and equipment of a distributed resource (DR) conform to IEEE Std 1547. • Interconnection equipment that connects distributed resources (DR) to an electric power system (EPS) must meet the requirements specified in IEEE Standard 1547. Standardized test procedures are necessary to establish and verify compliance with those requirements. These test procedures must provide both repeatable results, independent of test location, and flexibility to accommodate a variety of DR technologies.

Current SCC21 Interconnection Projects

Title	Scope and Purpose
P1547.2 ™ Draft Application Guide for IEEE Standard 1547 for Interconnecting Distributed Resources with Electric Power Systems	• This Guide provides technical background and application details to support the understanding of IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems. • This document facilitates the use of IEEE 1547 by characterizing the various forms of distributed resource technologies and the associated interconnection issues. Additionally, the background and rationale of the technical requirements are discussed in terms of the operation of the distributed resource interconnection with the electric power system. Presented in the document are technical descriptions and schematics, applications guidance and interconnection examples to enhance the use of IEEE 1547.
IEEE Std 1547.3 ™ (2007) Guide for Monitoring, Information Exchange and Control of Distributed Resources Interconnected with Electric Power Systems	• This document provides guidelines for monitoring, information exchange, and control for distributed resources (DR) interconnected with electric power systems (EPS). • This document facilitates the interoperability of one or more distributed resources interconnected with electric power systems. It describes functionality, parameters and methodologies for monitoring, information exchange and control for the interconnected distributed resources with, or associated with, electric power systems. Distributed resources include systems in the areas of fuel cells, photovoltaics, wind turbines, microturbines, other distributed generators, and, distributed energy storage systems.

Current SCC21 Interconnection Projects

Title	Scope and Purpose
P1547.4 ™ Draft Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems	• This document provides alternative approaches and good practices for the design, operation, and integration of distributed resource (DR) island systems with electric power systems (EPS). This includes the ability to separate from and reconnect to part of the area EPS while providing power to the islanded local EPSs. This guide includes the distributed resources, interconnection systems, and participating electric power systems. • This guide is intended to be used by EPS designers, operators, system integrators, and equipment manufacturers. The document is intended to provide an introduction, overview and address engineering concerns of DR island systems. It is relevant to the design, operation, and integration of DR island systems. Implementation of this guide will expand the benefits of using DR by targeting improved electric power system reliability and build upon the interconnection requirements of IEEE 1547.

Current SCC21 Interconnection Projects

Title	Scope and Purpose
P1547.5 Draft Technical Guidelines for Interconnection of Electric Power Sources Greater Than 10 MVA to the Power Transmission Grid	• This document provides guidelines regarding the technical requirements, including design, construction, commissioning acceptance testing and maintenance /performance requirements, for interconnecting dispatchable electric power sources with a capacity of more than 10 MVA to a bulk power transmission grid. • The purpose of this project is to provide technical information and guidance to all parties involved in the interconnection of dispatchable electric power sources to a transmission grid about the various considerations needed to be evaluated for establishing acceptable parameters such that the interconnection is technically correct.
P1547.6 Draft Recommended Practice for Interconnecting Distributed Resources With Electric Power Systems Distribution Secondary Networks	• This standard builds upon IEEE Standard 1547 for the interconnection of distributed resources (DR) to distribution secondary network systems. This standard establishes recommended criteria, requirements and tests, and provides guidance for interconnection of distribution secondary network system types of area electric power systems (Area EPS) with distributed resources (DR) providing electric power generation in local electric power systems (Local EPS). • This standard focuses on the technical issues associated with the interconnection of Area EPS distribution secondary networks with a Local EPS having DR generation. The standard provides recommendations relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. In this standard consideration is given to the needs of the Local EPS to be able to provide enhanced service to the DR owner loads as well as to other loads served by the network. Equally, the standard addresses the technical concerns and issues of the Area EPS. Further, this standard identifies communication and control recommendations and provides guidance on considerations that will have to be addressed for such DR interconnections.