



ANSI WORKSHOP
Standards and Codes for
Electric Drive Vehicles



IEEE SCC21*1547TM Interconnection
and P2030TM Smart Grid Interoperability
Series of Standards

* Standards Coordinating Committee 21

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**National Renewable Energy Laboratory --
Electricity, Resources & Building Systems
Integration Center**

Contents

- Background:

 - IEEE standards and IEEE SCC21

- Interconnection and Smart Grid Interoperability

 - IEEE Series of Standards:

 - IEEE 1547 (Interconnection) and

 - IEEE P2030 (Smart Grid Interoperability)

- Use and Conformance of Standards

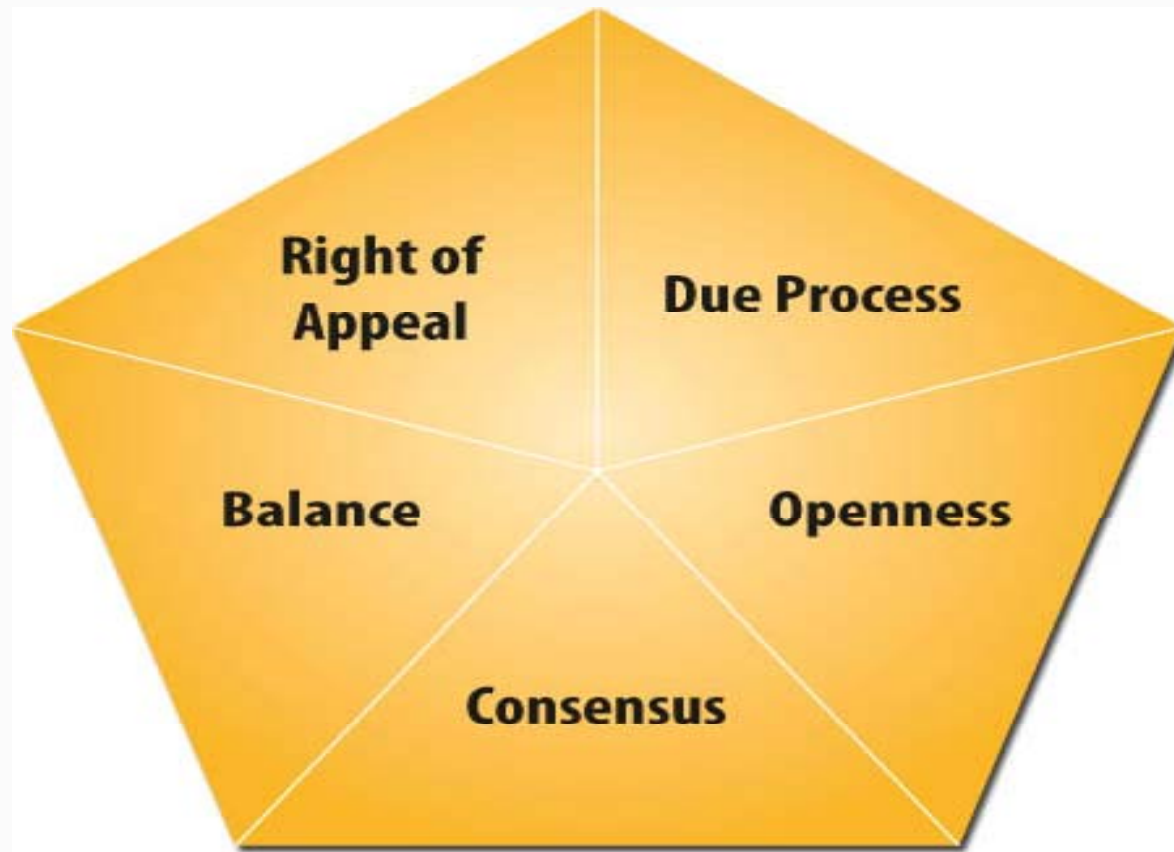
- Reference slides



IEEE Standards Development

Five principles guide standards development

Ensuring integrity and wide acceptance for IEEE standards



IEEE standards follow the standardization principles as stated by the WTO



IEEE SCC21 Fuel Cells, Photovoltaics, Dispersed Generation and Energy Storage

SCC21 Scope/Purpose: SCC21 oversees the development of standards in the areas of fuel cells, photovoltaics (PV), dispersed generation, and energy storage and coordinates efforts in these fields among the various IEEE Societies and other affected organizations to ensure that all standards are consistent and properly reflect the views of all applicable disciplines. IEEE SCC21 reviews all proposed IEEE standards in these fields before their submission to the IEEE-SA Standards Board for approval and coordinates submission to other organizations.

SCC21 Chair: Richard (Dick) DeBlasio (IEEE Board of Governors, Standards Board Liaison to DOE; National Renewable Energy Laboratory [NREL] Chief Engineer and {former} Manager Electricity Program)

SCC21 Vice Chair and Secretary Tom Basso (NREL, Senior Engineer)

IEEE SCC21 Liaison Bill Ash (IEEE)



IEEE SCC21 Standards Development Approach

IEEE SCC21 – sponsors and develops **1547 interconnection and P2030 smart grid interoperability series of standards**, and **Photovoltaic (PV) standards**; NREL provides SCC21 leadership (R. DeBlasio Chair, & T. Basso Vice Chair).

National Consensus Standards – e.g., IEEE/ANSI; IEEE 1547 standards cited in 2005 EPACT Section 1254 *Interconnection*; standards development: industry-driven partnerships, balanced stakeholder participation, open & impartial leadership (e.g., R. DeBlasio, member IEEE Standards Board of Governors & IEEE Standards liaison to DOE);

Harmonization of national and international standards -- IEEE SCC21 and IEC/TC8: International Electro-technical Commission/TC8 *System Aspects of Electrical Energy Supply* -- NREL manages IEC US/Technical Advisory Group/TC8; US/TAG/TC8 Co-Technical Advisors: T. Basso and J. Koepfinger (IEEE Standards Board Emeritus member): e.g., considering an **IEC PAS based on 1547** (IEC *Publically Available Specification*)

NIST *Smart Grid Standards Roadmap & Interoperability Framework* 2007 EISA section 1305; NIST SP-1108; Priority Action Plans (PAPs), e.g., T. Basso PAP7 energy storage interconnection; other PAPs coordinated with SCC21 activities.



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DER Interconnection

Distributed Energy Resources



Fuel Cell



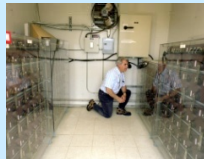
PV



Microturbine



Wind



Energy Storage



PHEV - V2G



Generator

Interconnection Technologies



Inverter



Switchgear, Relays, & Controls

Functions

- Power Conversion
- Power Conditioning
- Power Quality
- Protection
- DER and Load Control
- Ancillary Services
- Communications
- Metering

Electric Power Systems



Utility System



Microgrids

Loads

Local Loads

Load Management



IEEE SCC21 1547 Interconnection Standards

1547- 2008r Standard for Interconnecting Distributed Resources with Electric Power Systems

1547.1 - 2005 Conformance Test Procedures for Equipment Interconnecting DR with EPS

1547.2 - 2008 Application Guide for IEEE 1547 Standard for Interconnection of DR with EPS

1547.3 - 2007 Guide for Monitoring, Information Exchange and Control of DR

Published 1547 Standards

P1547.4 Guide for Design, Operation, & Integration of Distributed Resource Island Systems with EPS (balloted 2010)

P1547.5 Guidelines for Interconnection of EPS >10 MVA to the Power Transmission Grid

P1547.6 Recommended Practice for Interconnecting DR With EPS Distribution Secondary Networks (balloted 2010)

P1547.7 Guide to Conducting Distribution Impact Studies for DR Interconnection

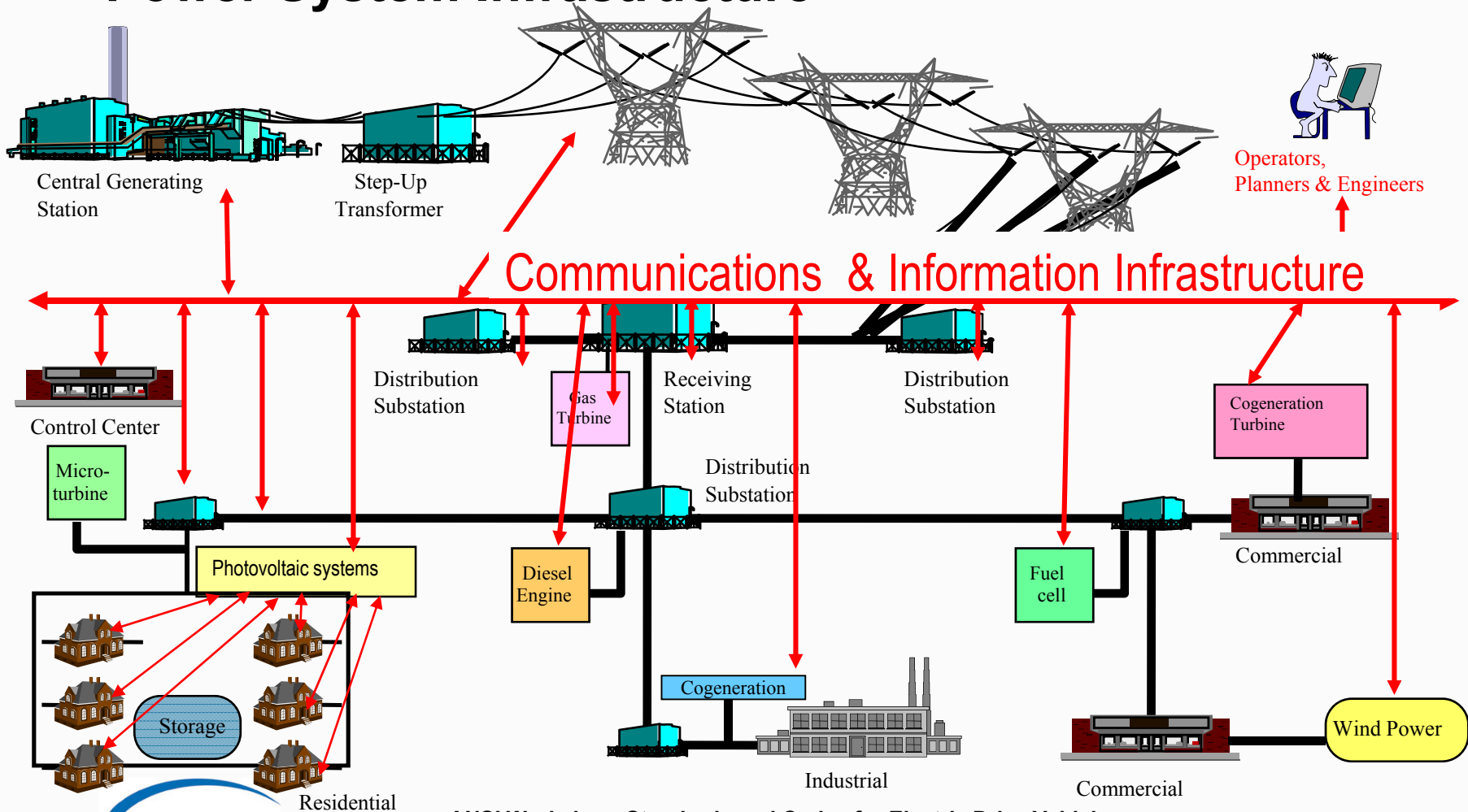
P1547.8 Draft Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Std 1547

Ongoing P1547 Development Projects

<http://grouper.ieee.org/groups/scc21/index.html>

Smart Grid - the Integration: of Power Technologies, and, **Communications & Information Technologies**

Power System Infrastructure



IEEE P2030 Series: Smart Grid Interoperability

- IEEE P2030 Draft Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System and End-Use Applications and Loads
- IEEE P2030.1 Draft Guide for Electric-Sourced Transportation Infrastructure
- IEEE P2030.2 Draft Guide for Energy Storage Systems Interoperability with Electric Power Infrastructure
- IEEE P2030.3 Draft Standard for Test Procedures for Electric Energy Storage Equipment and Systems for Electric Power Systems Applications



<http://grouper.ieee.org/groups/scc21/index.html>



IEEE Std P2030 – Smart Grid Interoperability:

P2030 Draft Guide for Smart Grid Interoperability of Energy Technology & Information Technology Operation with the Electric Power System (EPS) & End-Use Applications & Loads

- Provides guidelines in understanding and defining smart grid interoperability of the EPS with end-use applications and loads
- Focus on integration of energy technology and information and communications technology
- Achieve seamless operation for electric generation, delivery, and end-use benefits to permit two way power flow with communication and control
- Address interconnection and intra-facing frameworks and strategies with design definitions
- Expand knowledge in grid architectural designs and operation to promote a more reliable and flexible electric power system.



IEEE P2030.1 – *Draft Guide for Electric Sourced Transportation Infrastructure*

This document provides guidelines that can be used by utilities, manufacturers, transportation providers, infrastructure developers and end users of electric-sourced vehicles and related support infrastructure in addressing applications for road-based personal and mass transportation. This guide provides a knowledge base addressing terminology, methods, equipment, and planning requirements for such transportation and its impacts on commercial and industrial systems including, for example, generation, transmission, and distribution systems of electrical power. This guide provides a roadmap for users to plan for short, medium, and long-term systems.



P2030.2 Draft Guide for Interoperability of Energy Storage Systems Integrated with the Electric Power Infrastructure

IEEE P2030.2 provides guidelines for discrete and hybrid energy storage systems integrated with the electric power infrastructure, including end-use applications and loads, building upon P2030. The purpose is to provide guidance in understanding and defining technical characteristics of energy storage systems, and, how they may be integrated with and used compatibly as part of the electric power infrastructure. Further, the standard fills the need for guidance relevant to a knowledge base addressing terminology, functional performance, evaluation criteria, operations, testing, and the application of engineering principles for energy storage systems integrated with the electric power infrastructure.



P2030.3 Draft Standard for Test Procedures for Electric Energy Storage Equipment & Systems for EPS Applications

Scope. This standard establishes test procedures of electric energy storage equipment and systems for electric power systems (EPS) applications. It is recognized that electric energy storage equipment or systems can be a single device providing all required functions or an assembly of components, each having limited functions. Components having limited functions shall be tested for those functions in accordance with this standard. Conformance may be established through combination of type, production, and commissioning tests. Additionally, requirements on installation evaluation and periodic tests are included in this standard.



Purpose. Storage equipment and systems that connect to an electric power system (EPS) need to meet the requirements specified in related IEEE standards. Standardized test procedures are necessary to establish and verify compliance with those requirements. These test procedures need to provide both repeatable results, at independent test locations, and have flexibility to accommodate the variety of storage technologies and applications.

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Energy Policy Act (2005) Cites and Requires Consideration of IEEE 1547 Standards and Best Practices for Interconnection.

Energy Independence and Security Act (2007) Established NIST as Lead to Coordinate Framework and Roadmap for Smart Grid Interoperability Standards and Protocols.



Federal 2009 ARRA: Smart Grid projects & DER high penetration.

IEEE 1547 Interconnection Standards Use: Federal, Regional, State and Local Authorities/Jurisdictions

IEEE 1547

Interconnection System and Test Requirements

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

IEEE 1547.1

Interconnection System Testing

- 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

NEC

Article 690 PV Systems;

Article 705: interconnection systems

(shall be suitable per intended use per UL1741)

PJM Interconnection, Inc.

Small Generator

Interconnection Standards

FERC approved

(0-to<10MW and 10-to-20 MW; incorporate 1547 and 1547.1)

* UL 1741 ... for grid connected "... supplements and is to be used in conjunction with 1547 and 1547.1..."

PJM* Interconnect, Inc.

Small Generator Interconnection Standards

Summary Overview (Gen \leq 10 MW, and, 10-20MW)

1547 Std technical requirements

1547 based test requirements

- Design Test (may be pre-certified)
- Production Test
- Installation Evaluation
- Commissioning Test
- Periodic Testing (per PJM tariff requirements)

PJM SCADA option available

Other Requirements

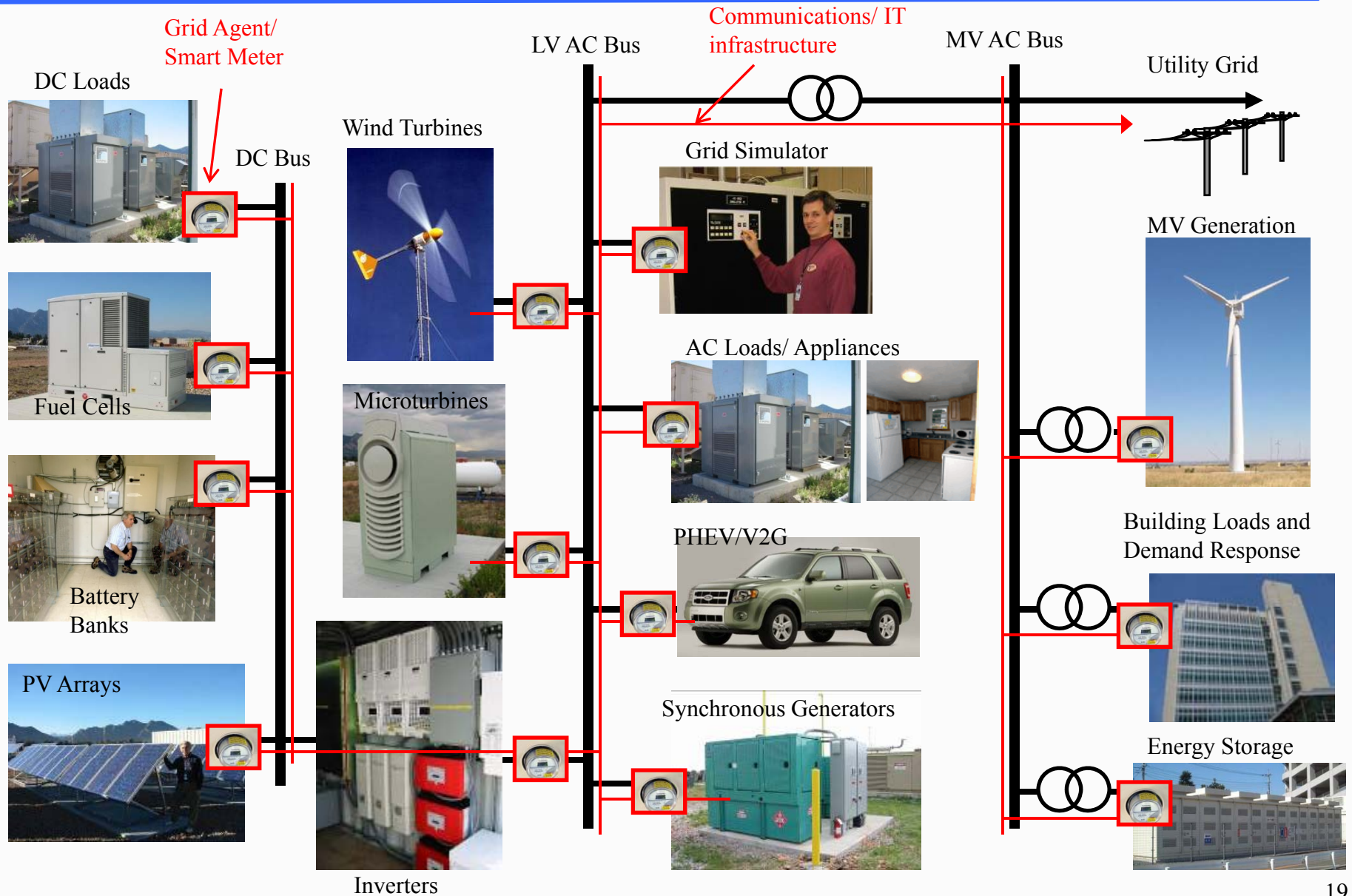
- e.g. PJM EPS owner voltage regulation
- e.g., PJM EPS metering
- e.g. other National / local codes

Purpose for adopting PJM-wide technical standards based on 1547:

- Limit barriers to interconnection
- Provide transparency
- Allow for pre-certification and other means to expedite interconnection process .

***PJM is a regional transmission organization with over 140 GW load; 165 GW generating capacity**

Example Smart Grid Interconnection and Interoperability Testing (at NREL)



Vehicle-to-Grid (V2G) Electrical Testing (NREL)

- Bidirectional power electronics enable vehicles to both charge from the grid and send power back to the grid
- Possible use of V2G for various DER applications
 - provide power to grid/local loads, regulate voltage and frequency, offer spinning reserves, enable electrical demand management
- NREL is conducting electrical tests on various V2G capable vehicles with the goal to determine unified test protocols – NREL report



V2G Electrical Testing at NREL -- Overview

- Interconnection tests (includes IEEE 1547.1 subset)
 - response to abnormal voltages and frequencies, grid synchronization, unintentional islanding, reconnect, DC injection, harmonics etc.
- Performance tests
 - continuous output power, conversion efficiency
- Advance grid-support tests
 - active power reserve, charging time
- Self-protection tests
 - overload, short circuit, loss of control circuit



Contact Information

- R. DeBlasio* - NREL Chief Engineer, Renewable Electricity and End-Use Systems Directorate; IEEE Board of Governors; Chair IEEE SCC21, 2030, 1547; IEEE Standards Board Liaison to DOE; Standards Board IEEE Smart Grid Standards Contact and Liaison to NIST (em: Dick.Deblasio@nrel.gov voice: 303 275 – 4333)
- **Tom Basso*** - NREL Senior Engineer; B. Kroposki* - NREL Group Manager
Distributed Energy Systems Integration Group
NREL Electricity, Resources and Building Systems Integration Center
(IEEE SCC21 Vice Chair; Secretary P2030, (IEEE Chair P1547.4, & Std 1547.1 reaffirmation
1547, 1547.2, 1547.3, P1547.4, em: Benjamin.Kroposki@nrel.gov
P1547.6, and P1547.7; Co-Chair P1547.8) voice: (303) 275 – 2979
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1617 Cole Blvd. MS-5202 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
 - IEEE Std P2030 Smart Grid Interoperability
 - IEEE Photovoltaic Standards

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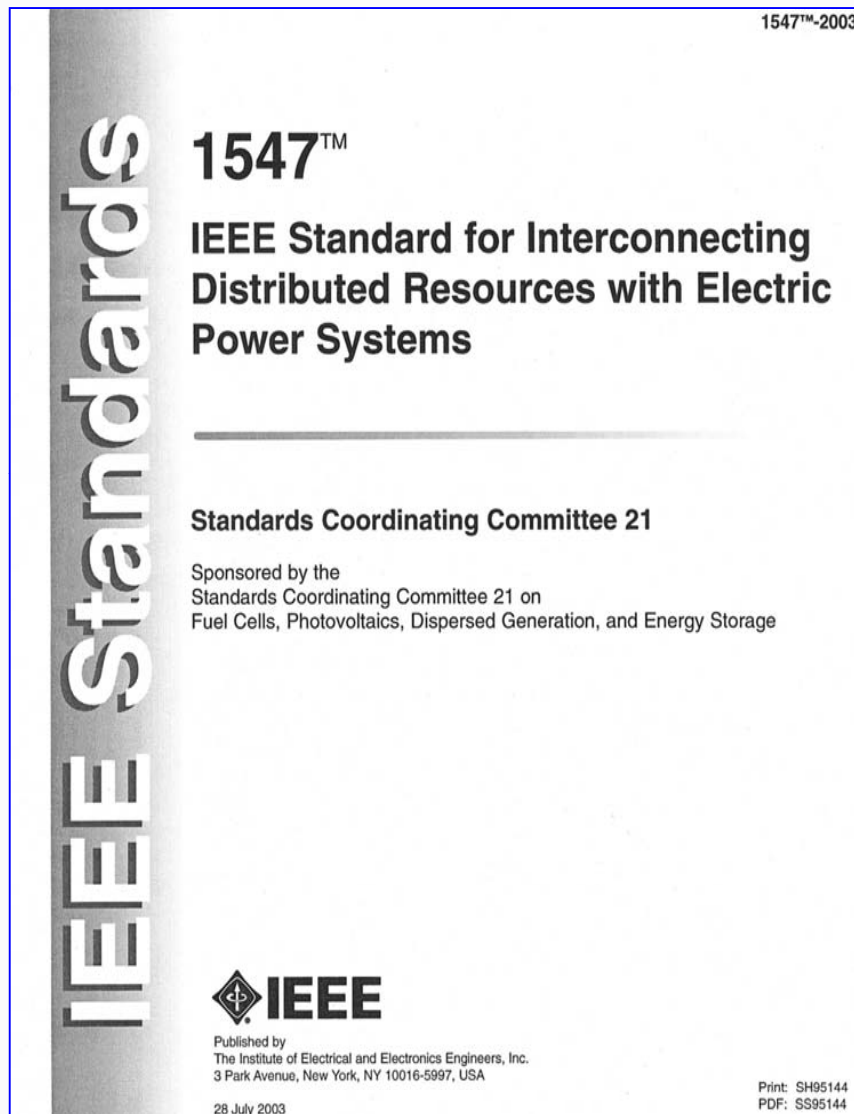
- IEEE P2030 (Smart Grid Interoperability)

➤ Use and Conformance of Standards

➤ Reference slides



ANSI/IEEE Standard 1547



...

4.0 Interconnection Technical Specifications and Requirements:

- . General Requirements
- . Response to Area EPS
Abnormal Conditions
- . Power Quality
- . Islanding

5.0 Test Specifications and Requirements:

- . Design Tests
- . Production Tests
- . Interconnection Installation
Evaluation
- . Commissioning Tests
- . Periodic Interconnection
Tests



IEEE 1547

IS:

- A Technical Standard - Functional Requirements
For: the interconnection itself and 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.
- ... Requirements apply at point of common coupling (unless otherwise stated).

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.



IEEE Std 1547.1 (2005)

... *Standard for Conformance Test Procedures* ... 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.

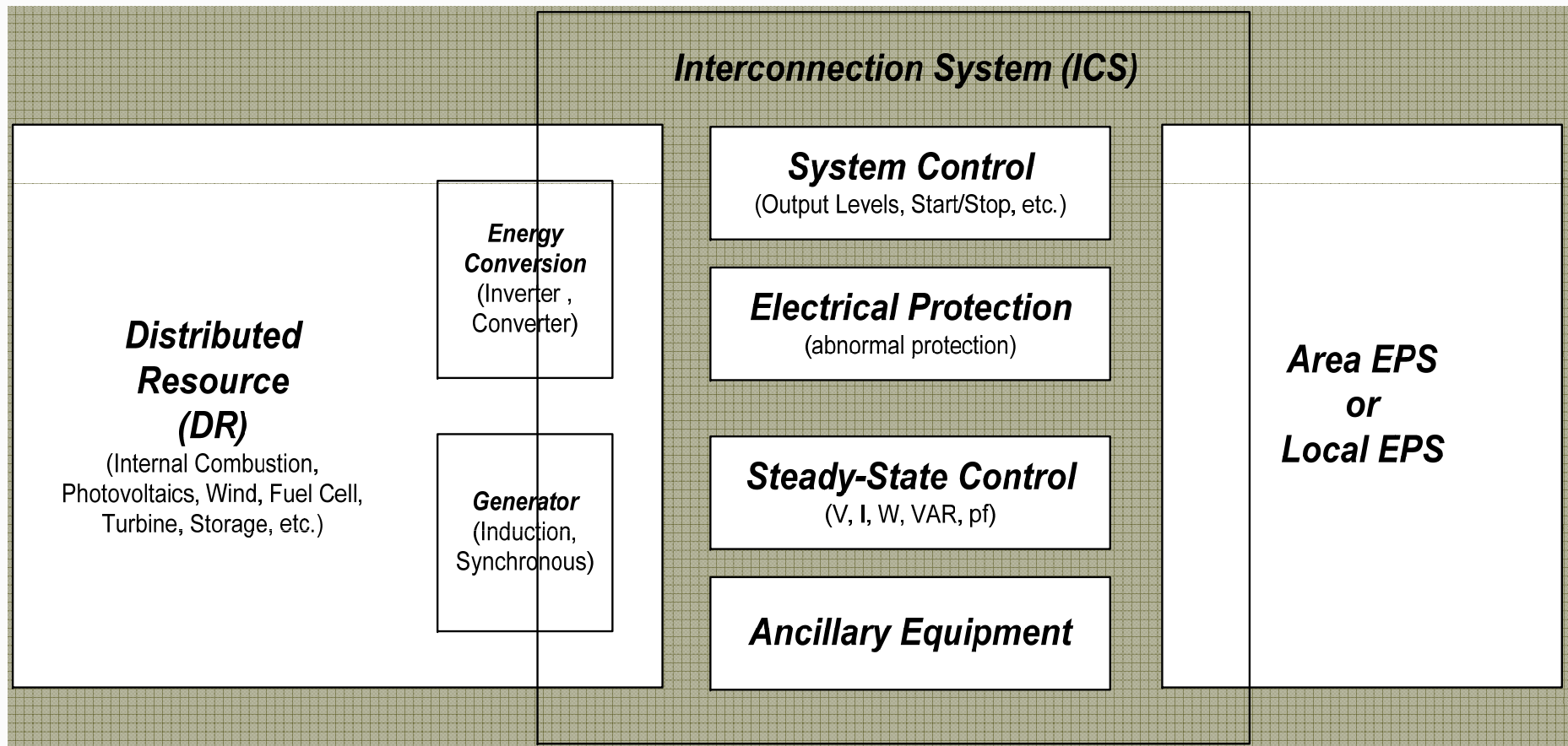


Figure 1. Boundaries between the interconnection system, the EPS and the DR.

IEEE Std 1547.2 (2008)... Guide to 1547

... Annex A (informative) Interconnection system equipment

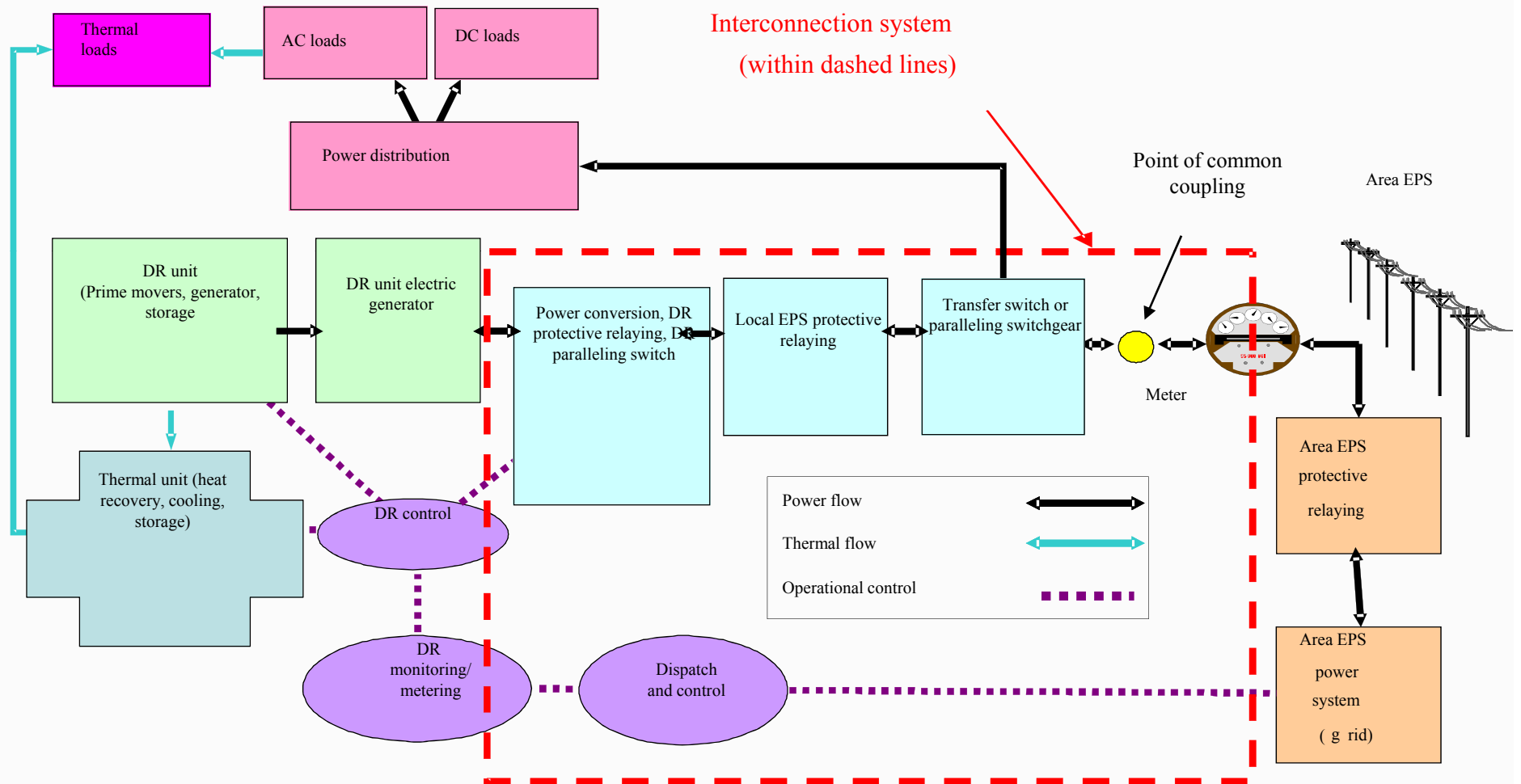


Figure A.1 – Functional diagram of an interconnection system

IEEE Std 1547.3 MIC for DR

... guidelines for MIC (monitoring, information exchange, and control) for DR (distributed resources) interconnected with electric power systems (EPS).

...

4. General information about monitoring, information exchange and control (MIC)

4.1 Interoperability

4.2 Performance

4.3 Open Systems Approach

4.4 Extensibility

4.5 Automatic Configuration Management

4.6 Information Modeling

4.7 Protocols

5. Data exchange guidelines based on 4.1.6 of IEEE Std 1547

6. Business and operation processes

7. Information exchange model

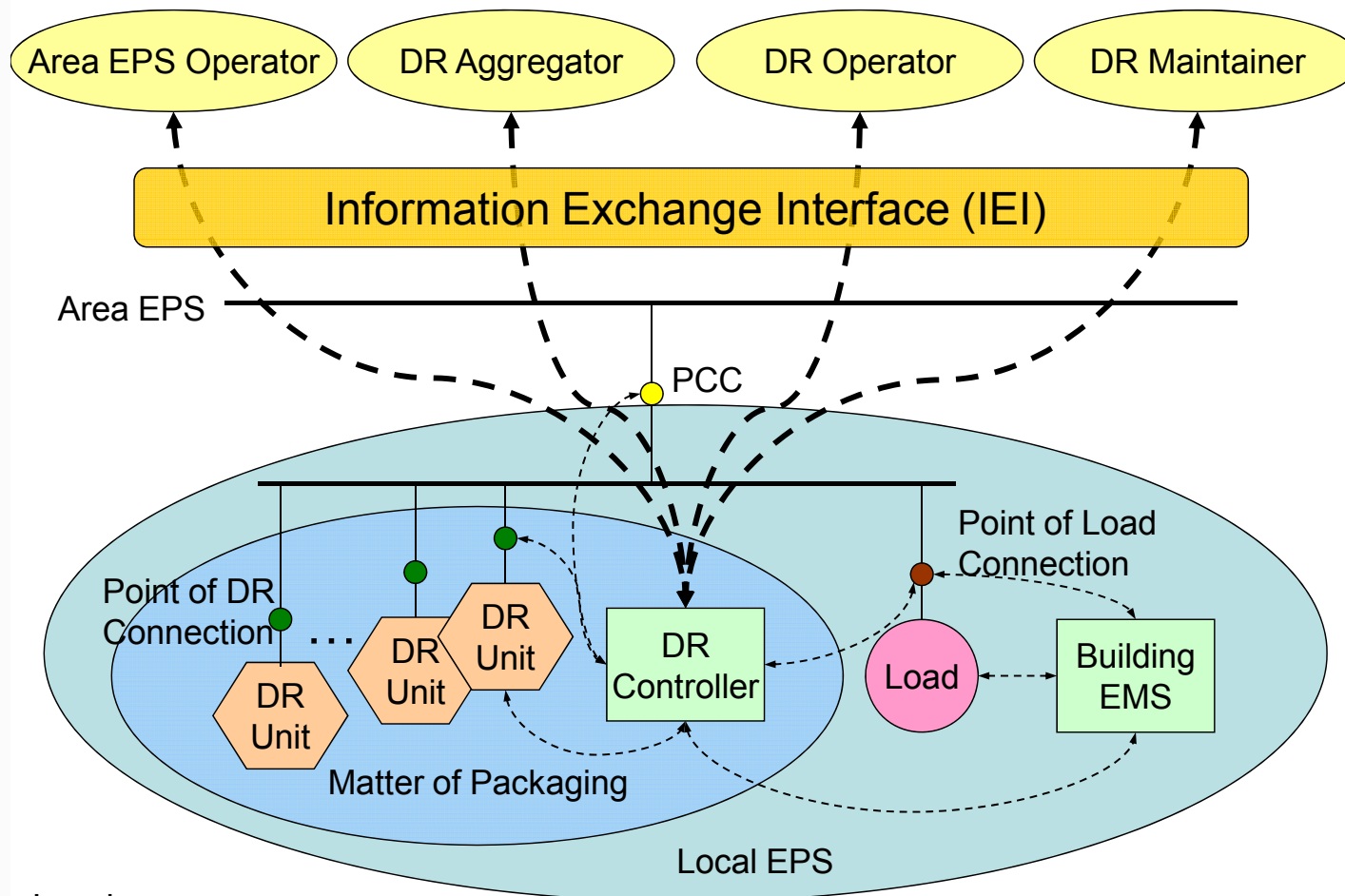
8. Protocol Issues

9. Security guidelines for DR implementation

Annexes (informative)

IEEE Std 1547.3 Guide for MIC for DR

... guidelines for monitoring, information exchange, and control (MIC) for distributed resources (DR) interconnected with electric power systems (EPS).



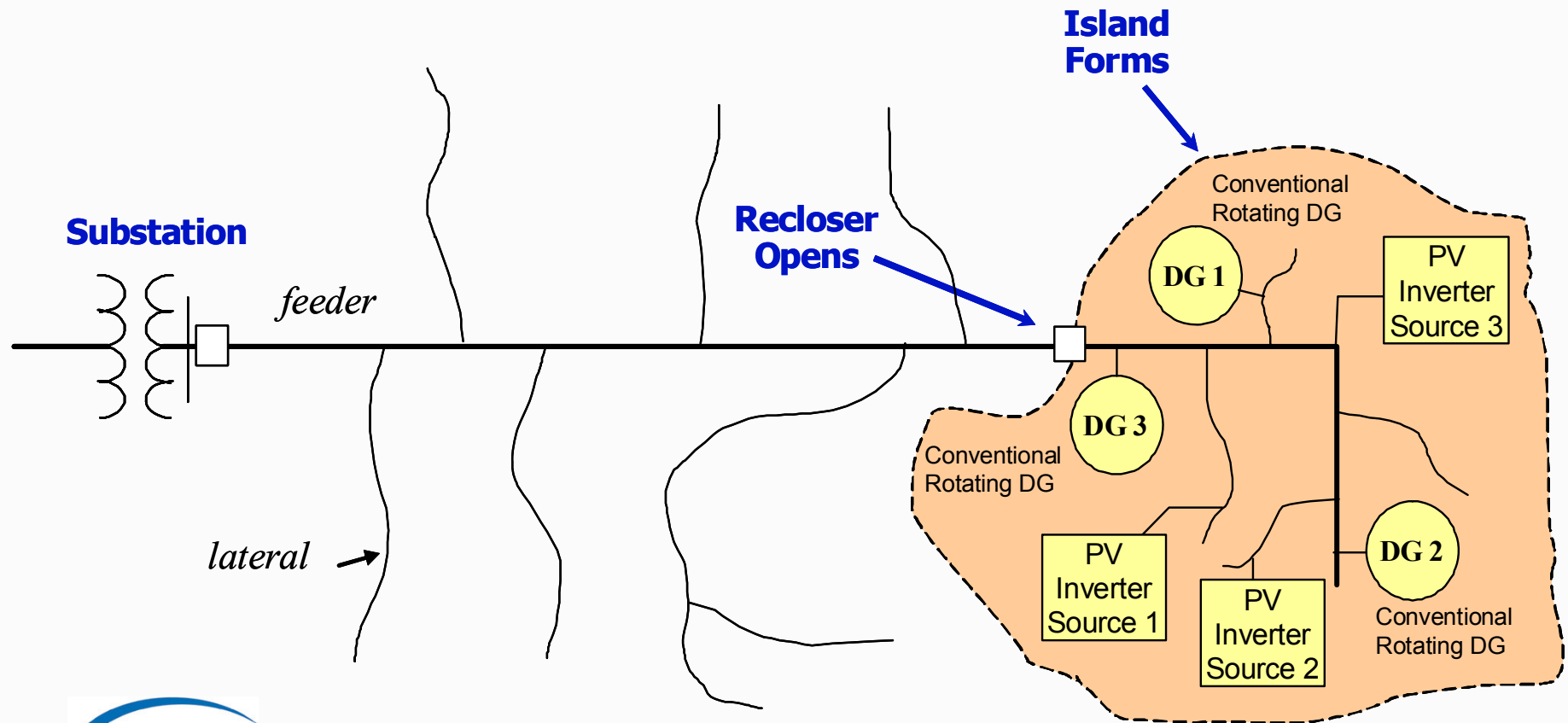
1547.3 Figure 1
Reference
diagram for
information
exchange.

Legend

- Interconnection Info Path (focus of this guide) - - - - -
- Local Info Path (not addressed in this guide) ······
- Electric Path (not addressed in this guide) _____

P1547.4 (Planned DER Islands) IEEE ballot: Apr-May 2010

E.g., DER (generation and energy storage) technologies are integrated with all others including the grid technologies to form Micro-grids (planned islands; includes – load management, voltage & VAR control, active participation, etc.)



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

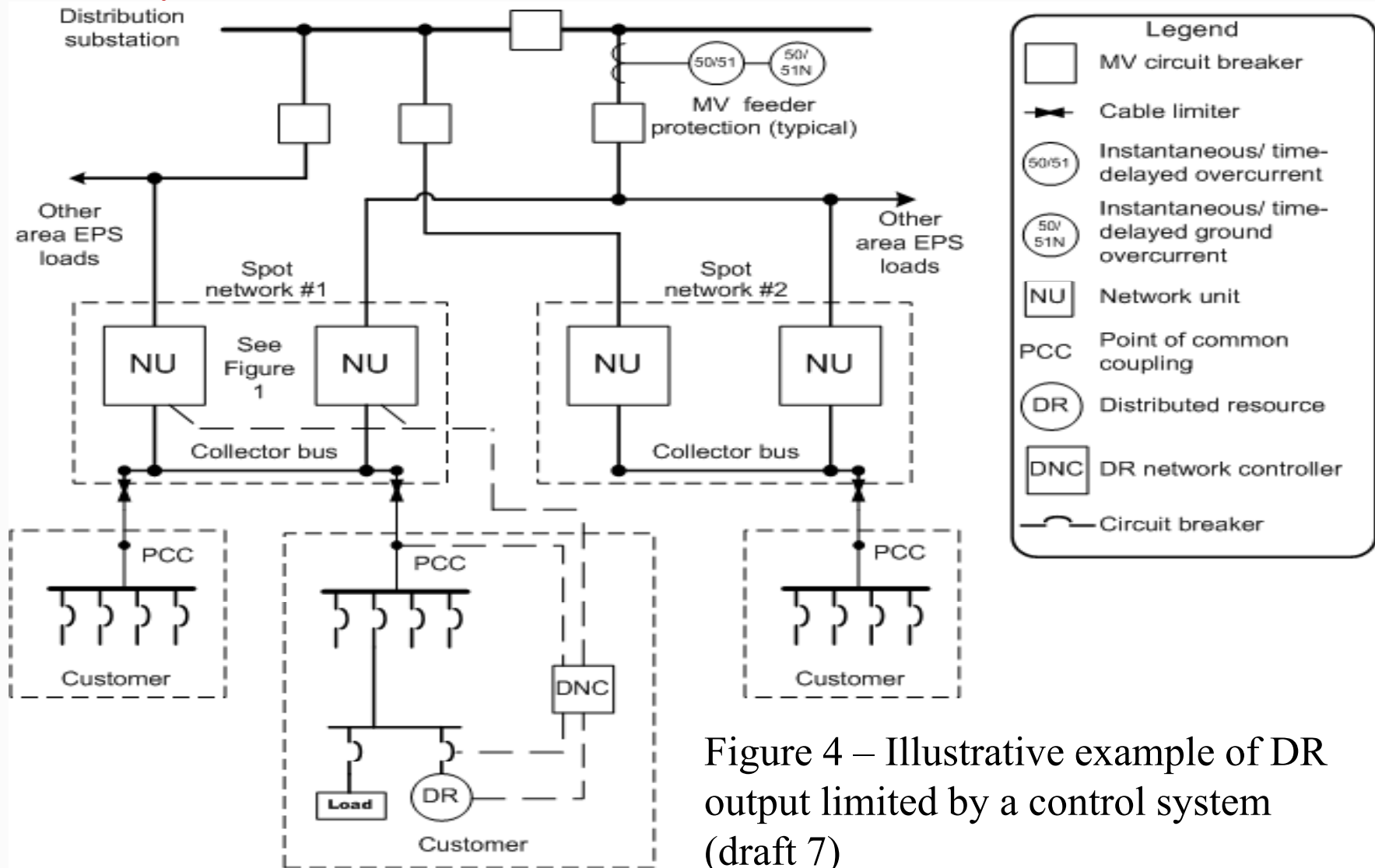


Figure 4 – Illustrative example of DR output limited by a control system (draft 7)

P1547.7 Guide to Conducting Impact Studies

- Describes criteria, scope, and extent for engineering studies of the impact of DR on distribution system.
- Methodology for performing engineering studies.
- Study scope and extent described as functions of identifiable characteristics of:
 - the distributed resource,
 - the area electric power system, and
 - the interconnection.
- Criteria described for determining the necessity of impact mitigation.
- Guide allows a described methodology for:
 - When impact studies are appropriate,
 - What data is required,
 - How studies are performed, and
 - How the study results are evaluated.

P1547.8 Draft Recommended Practice to Extend Use of 1547

Need for P1547.8 is to address industry driven recommendations and NIST smart grid standards framework recommendations (e.g., NIST priority action plans).

Example considerations include: voltage ride thru; volt-ampere reactive support; grid support; two-way communications and control; advanced/interactive grid-DR operations; high-penetration/multiple interconnections; interactive inverters; energy storage; electric vehicles; etc.

Current SCC21 Interconnection Standards

Title	Scope & Purpose
IEEE Std 1547™ (2003, 2008 reaffirmed) <u>Standard for Interconnecting Distributed Resources with Electric Power Systems</u>	<ul style="list-style-type: none"> • This <u>Standard</u> 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) <u>Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems</u>	<ul style="list-style-type: none"> • This <u>Standard</u> 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 Standards

Title	Scope and Purpose
IEEE Std 1547.2 TM (2008) <u>Application Guide</u> for IEEE Standard 1547 for Interconnecting Distributed Resources with Electric Power Systems	<ul style="list-style-type: none"> • This <u>Guide</u> 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 TM (2007) <u>Guide</u> for Monitoring, Information Exchange and Control of Distributed Resources Interconnected with Electric Power Systems	<ul style="list-style-type: none"> • 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
<p>P1547.4 Draft <u>Guide</u> for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems</p>	<ul style="list-style-type: none"> • 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
<p>P1547.5 Draft <u>Technical Guidelines</u> for Interconnection of Electric Power Sources Greater Than 10 MVA to the Power Transmission Grid</p>	<ul style="list-style-type: none"> • 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.
<p>P1547.6 Draft <u>Recommended Practice</u> for Interconnecting Distributed Resources With Electric Power Systems Distribution Secondary Networks</p>	<ul style="list-style-type: none"> • 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.

Current SCC21 Interconnection Projects

Title. Scope and Purpose
<p><u>P1547.7TM Draft Guide to Conducting Distribution Impact Studies for Distributed Resource Interconnection</u></p> <ul style="list-style-type: none"><li>• Scope. This guide describes criteria, scope, and extent for engineering studies of the impact on area electric power systems of a distributed resource or aggregate distributed resource interconnected to an area electric power distribution system.<li>• Purpose. The creation of IEEE Std 1547 “Standard for Interconnecting Distributed Resources with Electric Power Systems” has led to the increased adoption of distributed resources (DR) throughout distribution systems. This document describes a methodology for performing engineering studies of the potential impact of a distributed resource interconnected to an area electric power distribution system. Study scope and extent are described as functions of identifiable characteristics of the distributed resource, the area electric power system, and the interconnection. Criteria are described for determining the necessity of impact mitigation. <p>Establishment of this guide allows distributed resource owners, interconnection contractors, area electric distribution power system owners and operators, and regulatory bodies to have a described methodology for when distribution system impact studies are appropriate, what data is required, how they are performed, and how the study results are evaluated. In the absence of such guidelines, the necessity and extent of DR interconnection impact studies has been widely and inconsistently defined and applied.</p>

Current SCC21 Interconnection Projects

Title. Scope and Purpose

P1547.8TM Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Standard 1547

- Scope. This recommended practice applies to the requirements set forth in IEEE Std 1547 and provides recommended methods that may expand the usefulness and utilization of IEEE Std 1547 through the identification of innovative designs, processes, and operational procedures.
- Purpose. The purpose of the methods and procedures provided in this recommended practice is to provide more flexibility in determining the design and processes used in expanding the implementation strategies used for interconnecting distributed resources with electric power systems. Further, based on IEEE Std 1547 requirements, the purpose of this recommended practice is to provide the knowledge base, experience, and opportunities for greater utilization of the interconnection and its applications.