

# **IEEE 1547 Overview**

## **IEEE SCC21 1547 Series of Interconnection Standards**

DOE High-Tech Inverter Workshop  
Codes and Standards Development  
October 13 – 14, 2004

Tom Basso, Dick DeBlasio  
National Renewable Energy Laboratory

# IEEE SCC21 1547 Series of Interconnection Standards

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

Guide for Networks

Guide for Impacts

### P1547.3

Draft Guide for Monitoring, Information Exchange and Control of DR Interconnected with EPS

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

**Guide  
For  
Interconnection  
System  
Certification**

### P1547.2

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

### P1547.1

Draft Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems

DP Specifications and Performance  
(includes modeling)

The above identifies existing IEEE SCC21 standards development projects (1547 series) and activities under discussion by SCC21 Work Group members.



# IEEE P1547.5 Project

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

**Scope.** 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.

**Purpose.** 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.

**Sponsor:** SCC21 - Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage

**Sponsoring Committee Chair:** Dick DeBlasio

**PAR approved** by IEEE September 2004 (project authorization request); ballot to be completed by December 2007.

# Content

## ➤ Background

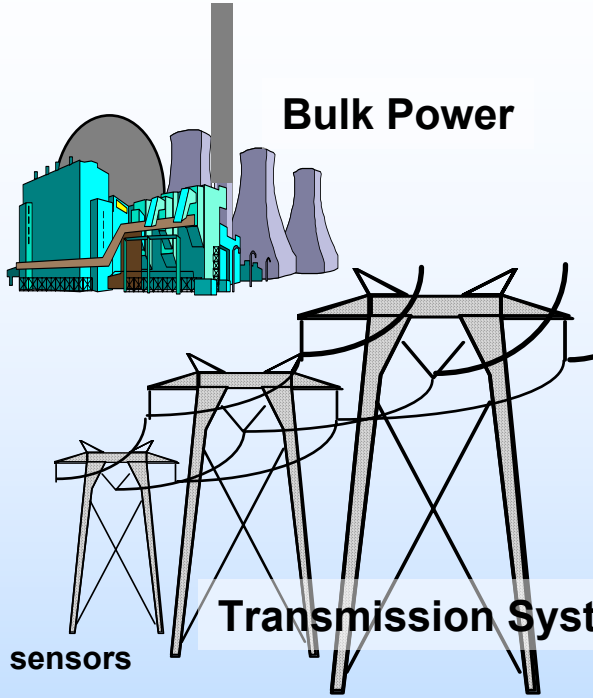
## ➤ IEEE Standards

## ➤ 1547 Series of Standards

- ANSI/IEEE Std 1547 (2003): Standard for interconnection system & interconnection test requirements for interconnecting DR with Electric Power Systems (EPS)
- P1547.1 Standard for interconnection test procedures
- P1547.2 Guide to 1547 standard
- P1547.3 Guide for information exchange for DR interconnected with EPS
- P1547.4 Guide for DR island systems
- P1547.5 Guide for interconnection to transmission grid

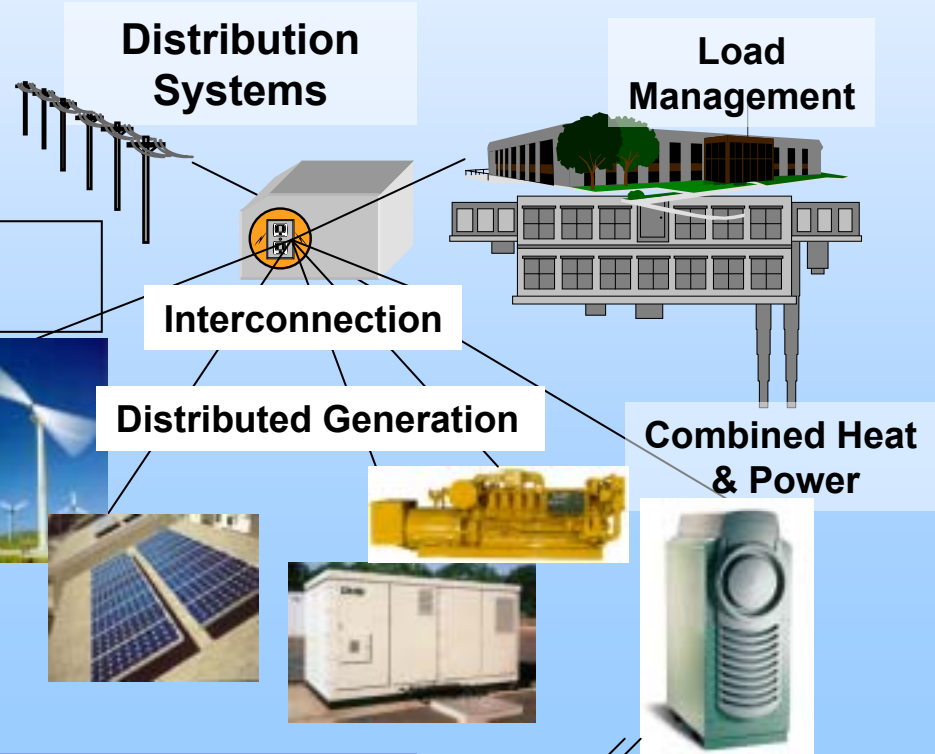
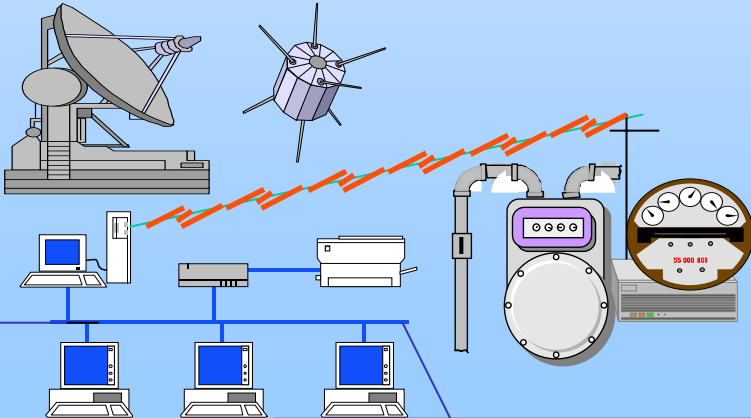


# Transmission and Distribution System

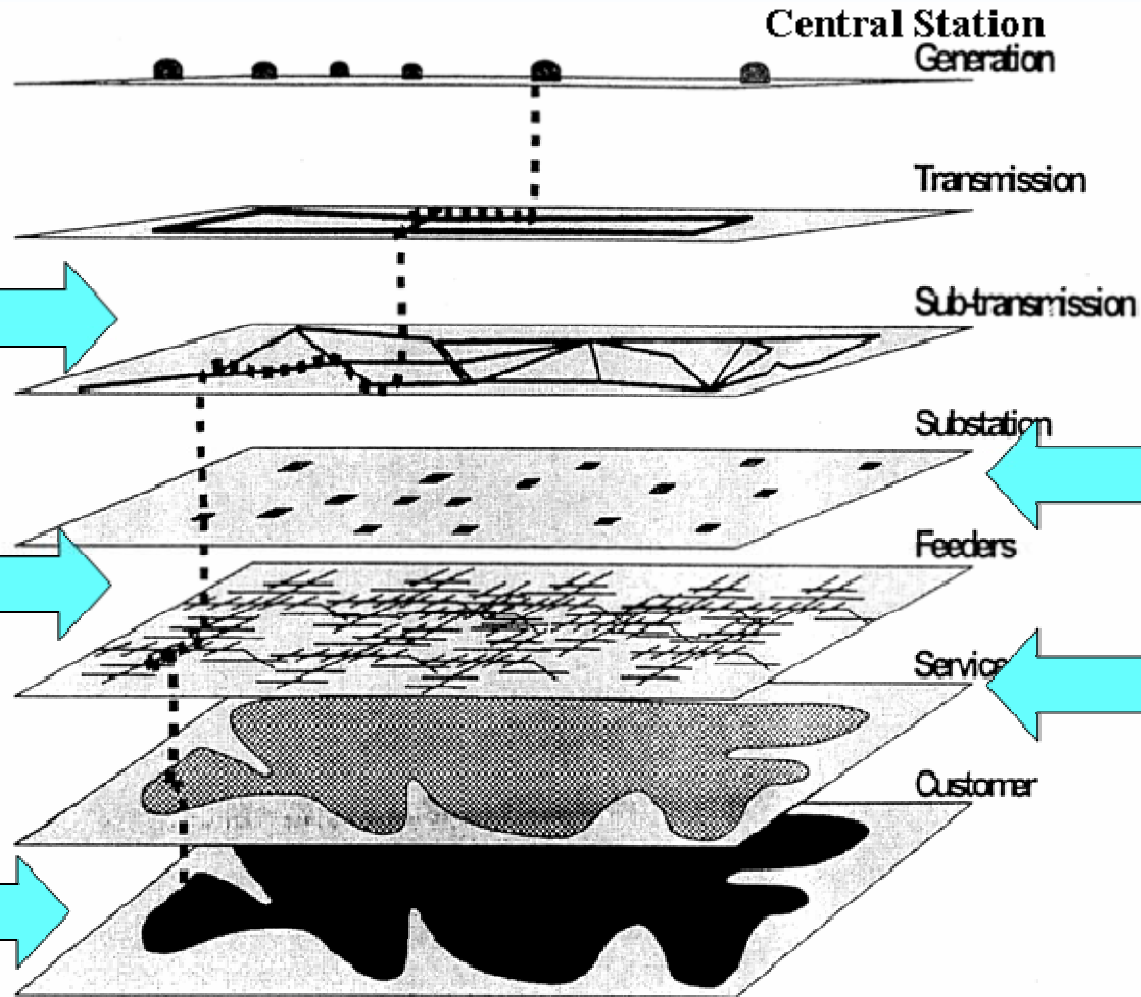


**Substations**

**Communications – Information Flow, Data Management, Monitor & Control**

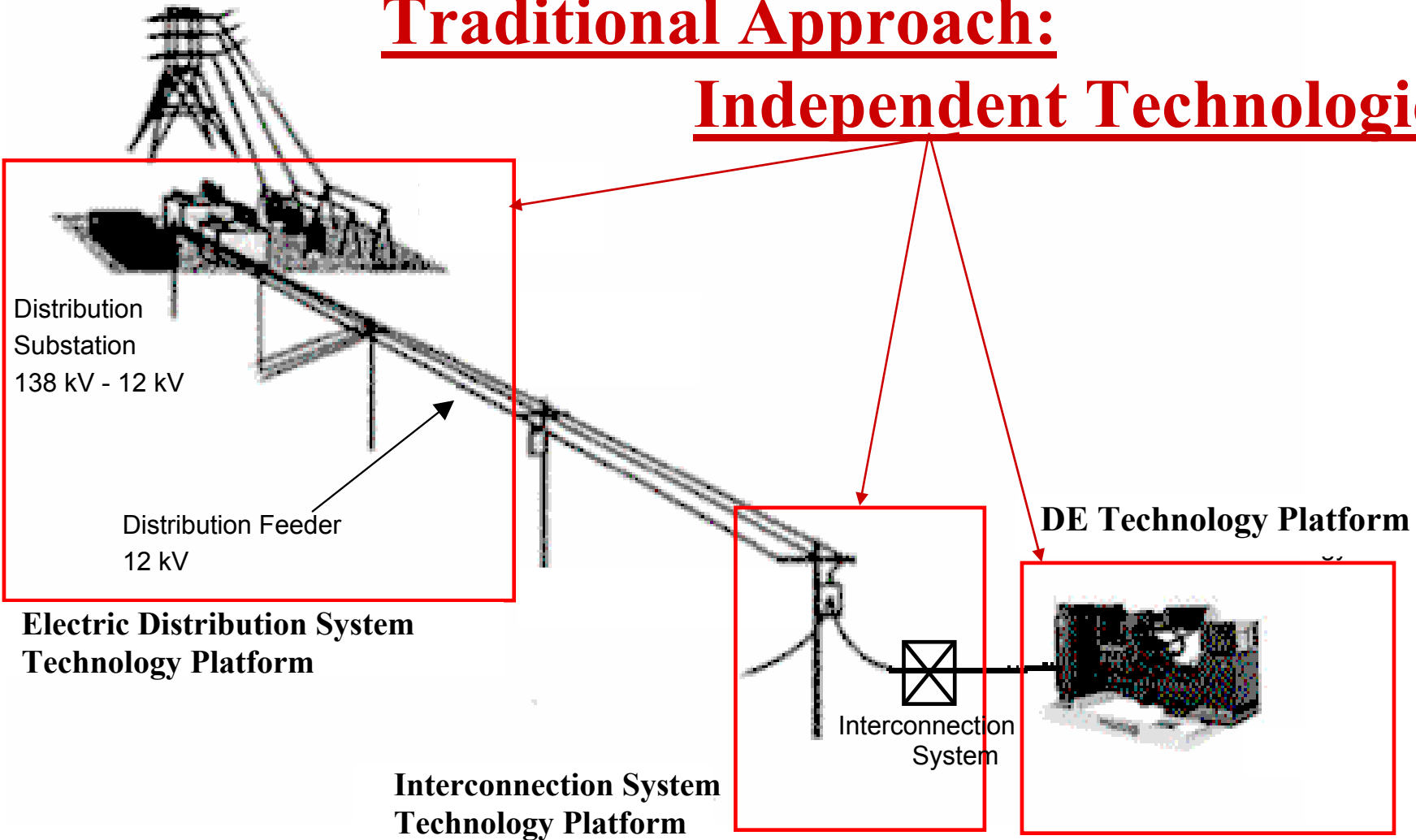


# Interconnecting Power Systems



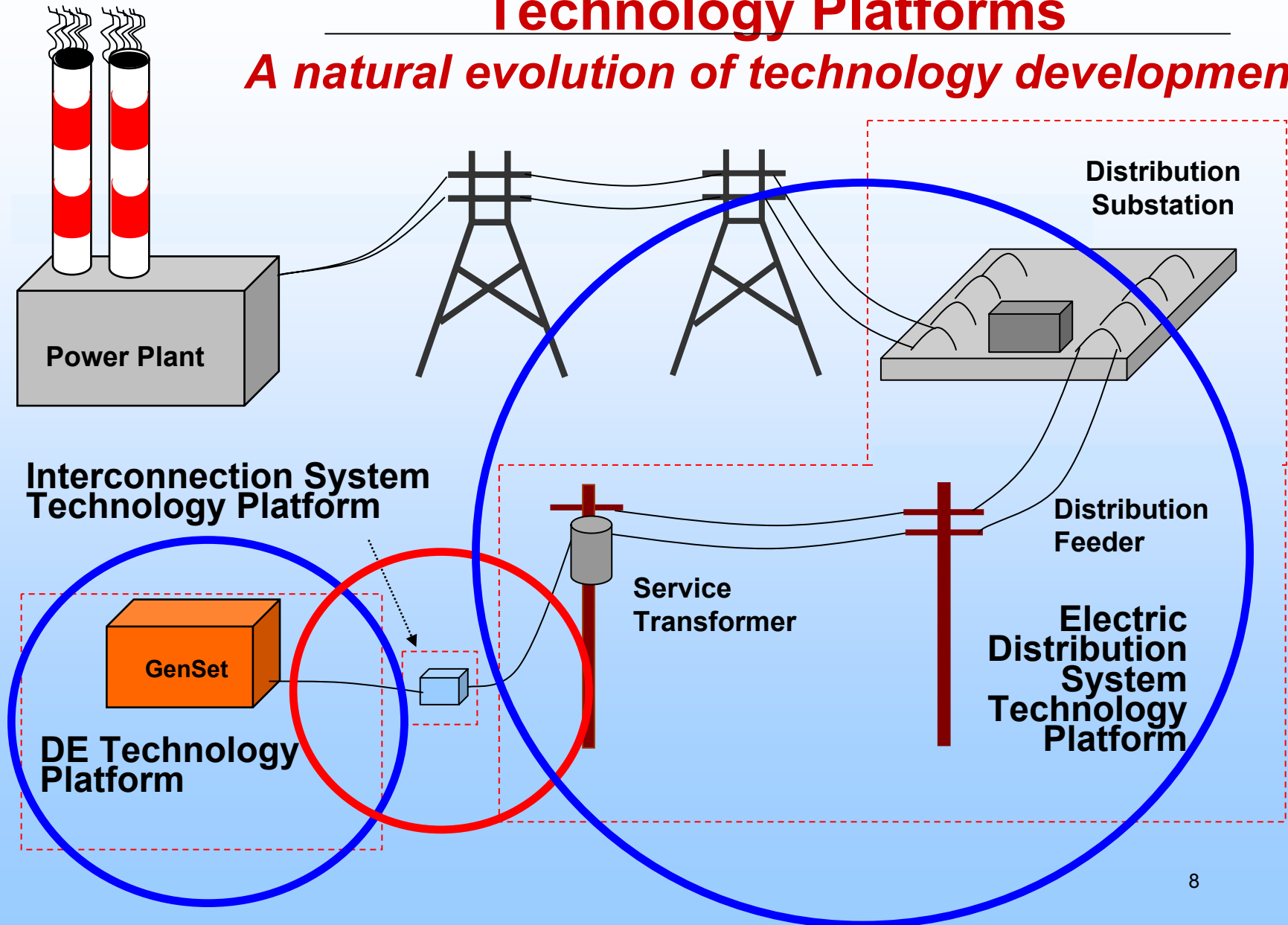
The overall power system is traditionally viewed in terms of 7 layers; each performing its function from central station generation supplying power out to customers.

# Traditional Approach: Independent Technologies



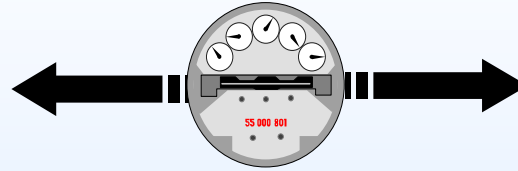
# Technology Platforms

*A natural evolution of technology development*





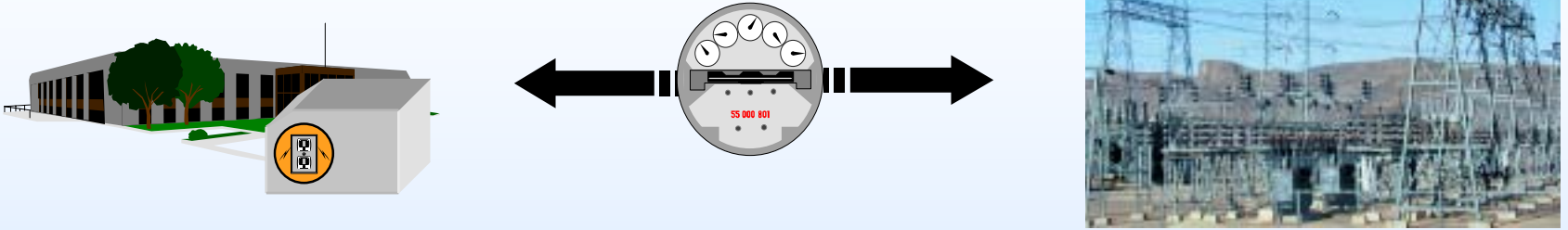
# Standards Benefits



## Standards Development, Validation, and Use

- Safeguards against hazards
- Fosters quality design and manufacture
- Increases competitiveness in industry
- Creates and expands markets
- Facilitates Trade and Commerce
- Assurance is provided when products meet quality standards, then users need not be concerned with further testing or evaluation of the product

# Standards Benefits



## Standards Development, Validation, and Use

- Accelerates engineering advances & implementation, interoperability, and installation
- Assists increased quality and reliability achievement
- Simplifies compliance to needs, permitting, & rules
- Promotes advanced communications; software platforms interchangeability
- Enables enhanced DR systems and grid intelligence
- Lower cost and quicker deployment for projects.

**National consensus standards** established via industry driven partnerships; balanced stakeholder participation.

**Harmonization of national and international standards, codes, and certification/laboratory accreditation**, e.g., International Electro-technical Commission (IEC) dual logo arrangement for IEC to adopt IEEE standards for electronics, telecom, and power generation.

**IEC TC 82 Photovoltaics** – US is Secretariat for IEC/TC82.

**IEC TC 8 *System Aspects of Electrical Energy Supply***:

TC8 facilitates functioning of electricity supply systems – systems encompass T&D networks including interfaces with user installations (generators and consumers).

**IEC Joint Coordinating Group (JCG)** on Distributed Rural Electrification Systems for international stds. development.

# Institute of Electrical and Electronic Engineers - IEEE

- IEEE - international technical professional society
- More than 375,000 members from 150 countries
- Advances the theory and application of electro-technologies and allied sciences
- Produces over 30% of world's published literature in electrical engineering, computers, and controls
- One of the pre-eminent standards bodies

# IEEE Definitions/Protocols

## IEEE Classification of Standards Documents

**Standards:** documents with mandatory requirements (shall).

**Recommended Practices:** documents in which procedures and positions preferred by the IEEE are presented (should).

**Guides:** documents in which alternative approaches to good practice are suggested but no clear-cut recommendations are made (may).

## IEEE Ballot Consensus

Voter group balanced: each interest group < 50% of total (users, manufacturers, general interest); voter may provide comments, sponsor responds to each negative stating sponsor position on comments, sponsor re-circulates unresolved negatives to allow balloters to change their vote; minimum of 75% affirmation needed to pass to IEEE Standards Board for their approval.

# IEEE Standards Board

- Approves all IEEE standards projects and standards for publication.
- Establishes Standards Coordinating Committees (SCC) that report directly to Board.
- Established new liaison to DOE (R. DeBlasio, Chair SCC21)
- IEEE standards are recognized nationally and worldwide
  - IEEE standards may qualify as American National Standard (ANSI/IEEE status)
  - IEEE and IEC dual logo arrangement



# IEEE Standards Coordinating Committee 21

## SCC21 Fuel Cells, Photovoltaics, Dispersed Generation, & Energy Storage

Scope and Purpose.

SCC21 Oversees the development of standards in the areas of Fuel Cells, Photovoltaics, 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.

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 1547 Development Approach

- **SCC 21 building on long history of DR standards**, e.g., IEEE Std 1001 — Guide for Interfacing dispersed storage and generation with electric utility systems; IEEE Std 929 — Recommended Practice for Utility Interface of PV Systems; IEEE Std 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems; IEEE P1547.x series of interconnection standards
- **National Consensus Standards; Industry Driven**
- **400 SCC21 work group members** (all groups - most with 1547 Series of Interconnection Standards; photovoltaics/energy storage





# 1547 Development Approach

IEEE Std 1547 (Interconnection Standard) -- approved start March 1999; Chair: R. DeBlasio, NREL; over 500 volunteers have worked on developing or balloting the standard.

P1547.1 (Test Standard) -- approved start June 2001; Chair: J. Daley, ASCO Power Technologies, Inc., 82 members.

P1547.2 (Guide to Std 1547) -- approved start December 2001; Chair: N. R. Friedman, Resource Dynamics Corporation, 96 members.

P1547.3 (Guide for Monitoring, Information Exchange, and Control) -- approved start June 2002; Chair: F. Goodman, EPRI, 95 members.

P1547.4 (Islanding Systems) – approved start Dec. 2003; Chair: B. Kroposki, NREL (establishing membership).

IEEE/1547 members identified additional priority standards needs (e.g., see 1547 series graphic).

**1547™****IEEE Standard for Interconnecting  
Distributed Resources with Electric  
Power Systems**

---

**Standards Coordinating Committee 21**

Sponsored by the  
Standards Coordinating Committee 21 on  
Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage



Published by  
The Institute of Electrical and Electronics Engineers, Inc.  
3 Park Avenue, New York, NY 10016-5997, USA

28 July 2003

Print: SH95144  
PDF: SS95144



# American National Standard

## ANSI/IEEE 1547 Std

**IEEE Std 1547 (2003) published summer 2003**

**Affirmative IEEE Ballot February 2003**

- Voting Membership
  - 230 members (31% general interest, 4% government, 30% manufacturer/producer, 35% utility/user)
  - 91% affirmatives
- **444 Work Group & Ballot Group Members at time of ballot**
- **Approved by IEEE Standards Board June 12, 2003**
- **American National Standard designation**

**→ ANSI/IEEE Std 1547 - October 20, 2003 ←**



# Some Key 1547 Development Issues

issues not normally addressed as IEEE  
universal, mandatory requirements

- **Federal/State Implementation and Impacts (rules)**
- **Fully Commercialized/Certified Products, After Sale Support, Warranties**
- **Liability (DG vs. grid operators)**
- **Functionality of Interconnection Package (always more to add)**
- **Lower Interconnection System Cost**
- **Cost of EPS Re-Fit (how and who pays)**
- **Operation (which standard and who is in control)**
- **Reliability (operational issues – durability vs. availability)**
- **Misunderstanding/Misapplication (limited experience/knowledge)**
- **User Disagreement (not all utilities and DGs are alike)**

# Some Key 1547 Development Issues

that would benefit from further R&D activities

- Develop improved interconnection technology
- Address field testing vs. type testing
- Interconnection equipment certification
- Evaluate secondary grid and spot networks
- Develop grid/DG monitoring and control
- Understand voltage regulation/stability
- Address grounding/faults
- Establish basis for DG penetration/aggregation
- Develop islanding methods and requirements



# More Key 1547 Development Issues

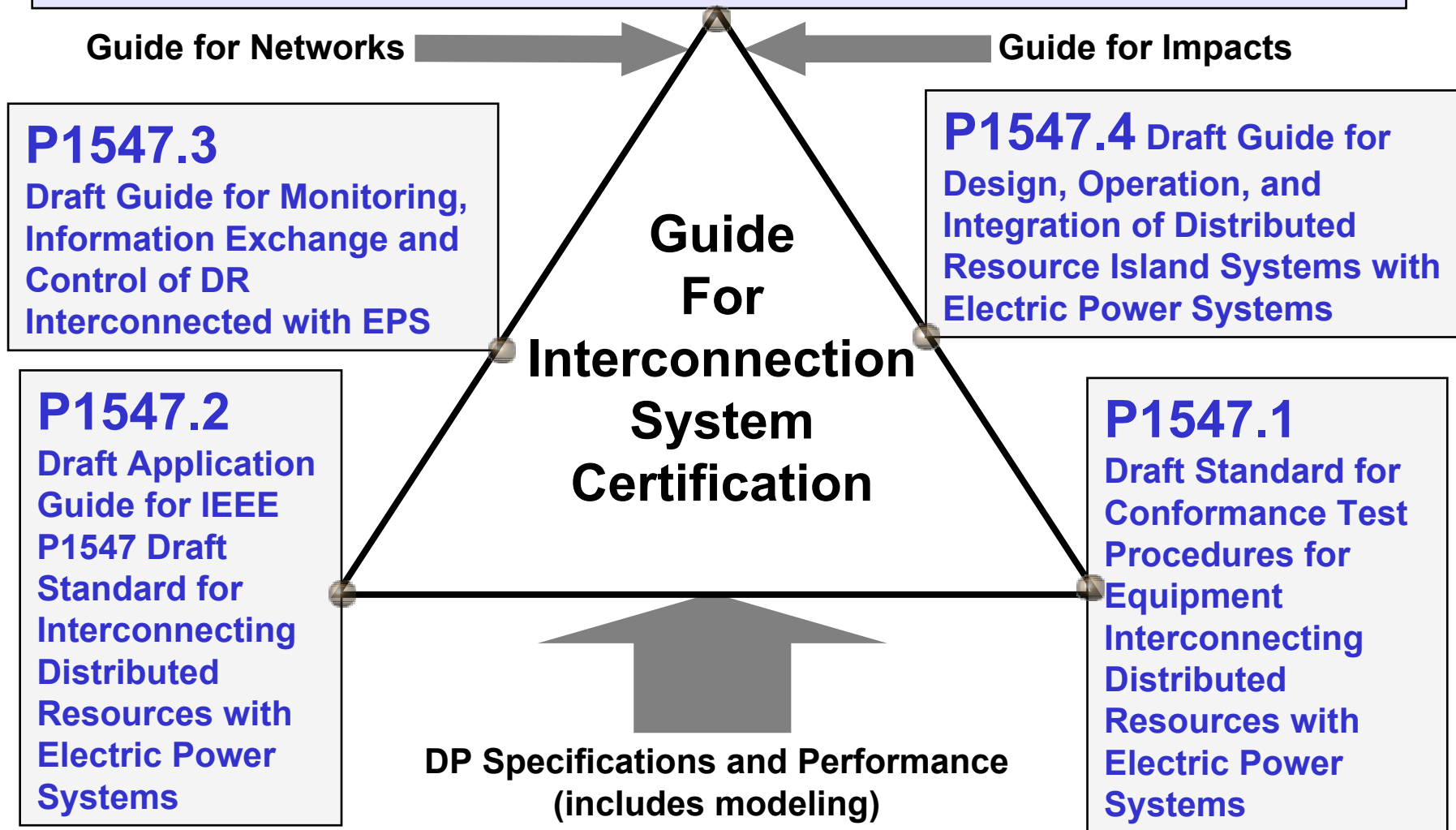
e.g., Grid Modernization, beyond distribution system, DR/interconnection advances: 1547 revision? additions to 1547 series?

## **Research on, and Validation of DR Integration, Advanced EPS/Distribution Operating Concepts:**

- IEEE 1547 covers Unintentional Islanding, Intentional Islanding, Secondary Networks, and Spot Networks.
- Current version of IEEE 1547 minimizes the utilization of distributed resources in the event of system disturbances.
- Research on system integration of DR with all types of EPS/distribution operational concepts to revise IEEE 1547 to maximize the use of DR and realize the potential operational benefits at the transmission and distribution level.

# IEEE SCC21 1547 Series of Interconnection Standards

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



The above identifies existing IEEE SCC21 standards development projects (1547 series) and activities under discussion by SCC21 Work Group members.

# Current SCC21 Interconnection Projects

Title	Scope & Purpose
<p>IEEE Std 1547<sup>TM</sup> (2003) <u>Standard</u> for Interconnecting Distributed Resources with Electric Power Systems (published June 2003)</p>	<ul style="list-style-type: none"><li>• This <u>Standard</u> establishes criteria and requirements for interconnection of distributed resources (DR) with electric power systems (EPS).</li><li>• 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.</li></ul>
<p>P1547.1 Draft <u>Standard</u> for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems</p>	<ul style="list-style-type: none"><li>• 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.</li><li>• Interconnection equipment that connects distributed resources (DR) to an electric power system (EPS) must meet the requirements specified in IEEE Standard P1547. 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.</li></ul>



# Current SCC21 Interconnection Projects

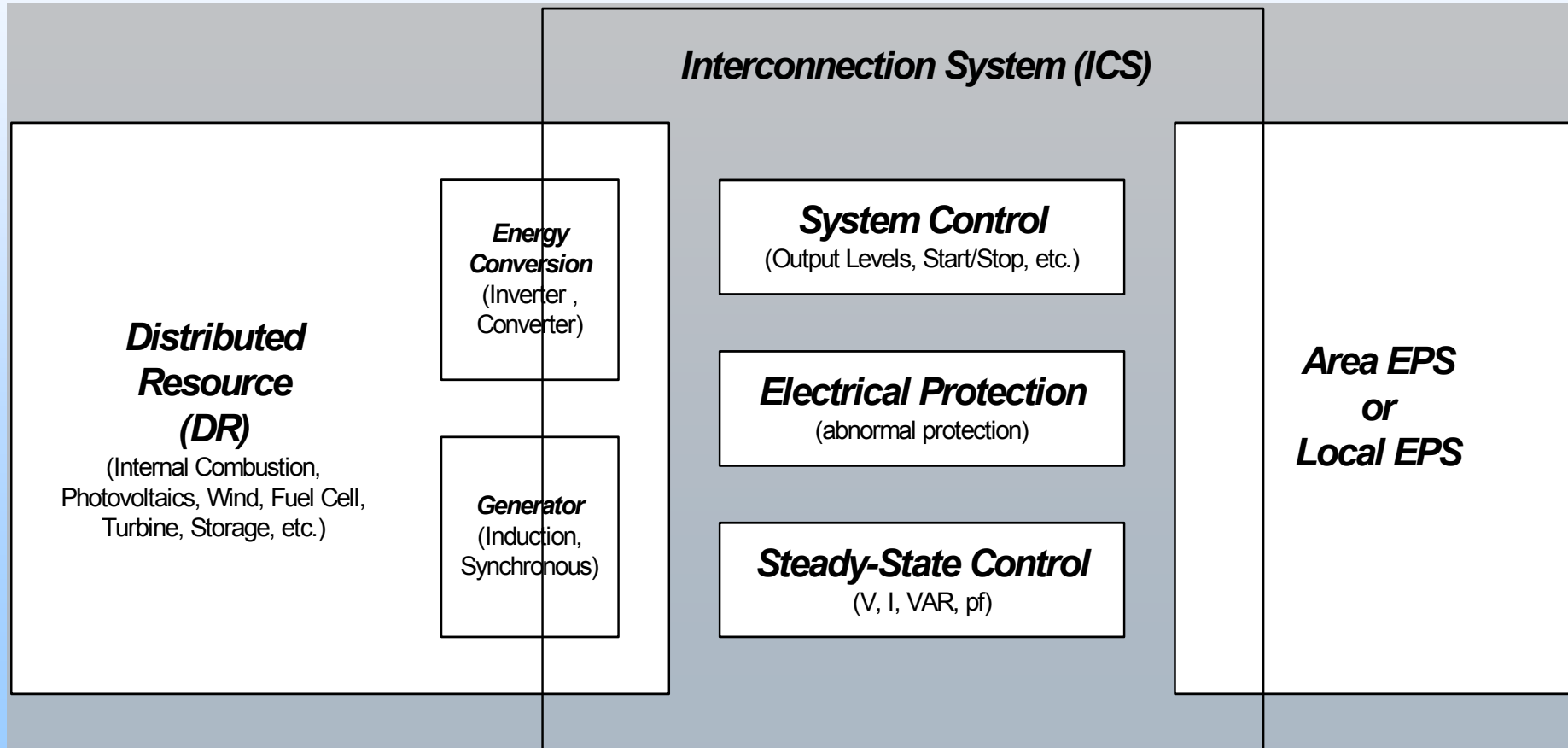
Title	Scope and Purpose
P1547.2 <sup>TM</sup> Draft Application <u>Guide</u> for IEEE Standard 1547 for Interconnecting Distributed Resources with Electric Power Systems	<ul style="list-style-type: none"><li>• This <u>Guide</u> provides technical background and application details to support the understanding of IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems.</li><li>• 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.</li></ul>
P1547.3 <sup>TM</sup> Draft <u>Guide</u> for Monitoring, Information Exchange and Control of Distributed Resources Interconnected with Electric Power Systems	<ul style="list-style-type: none"><li>• This document provides guidelines for monitoring, information exchange, and control for distributed resources (DR) interconnected with electric power systems (EPS).</li><li>• 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.</li></ul>

# Current SCC21 Interconnection Projects

<b>Title</b>	<b>Scope and Purpose</b>
P1547.4 <sup>TM</sup> Draft <u>Guide</u> for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems	<ul style="list-style-type: none"><li>• 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.</li><li>• 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.</li></ul>

# P1547.1 Draft

**IEEE P1547.1 test standard for 1547 (plan to ballot in fall 2004) -- 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. Definition of the installation and its content. (P1547.1 Draft 4 4/04)**

# P1547.2 Draft

IEEE P1547.2 *application guide to 1547* (ballot originally planned for 12/04 – delayed) -- 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.

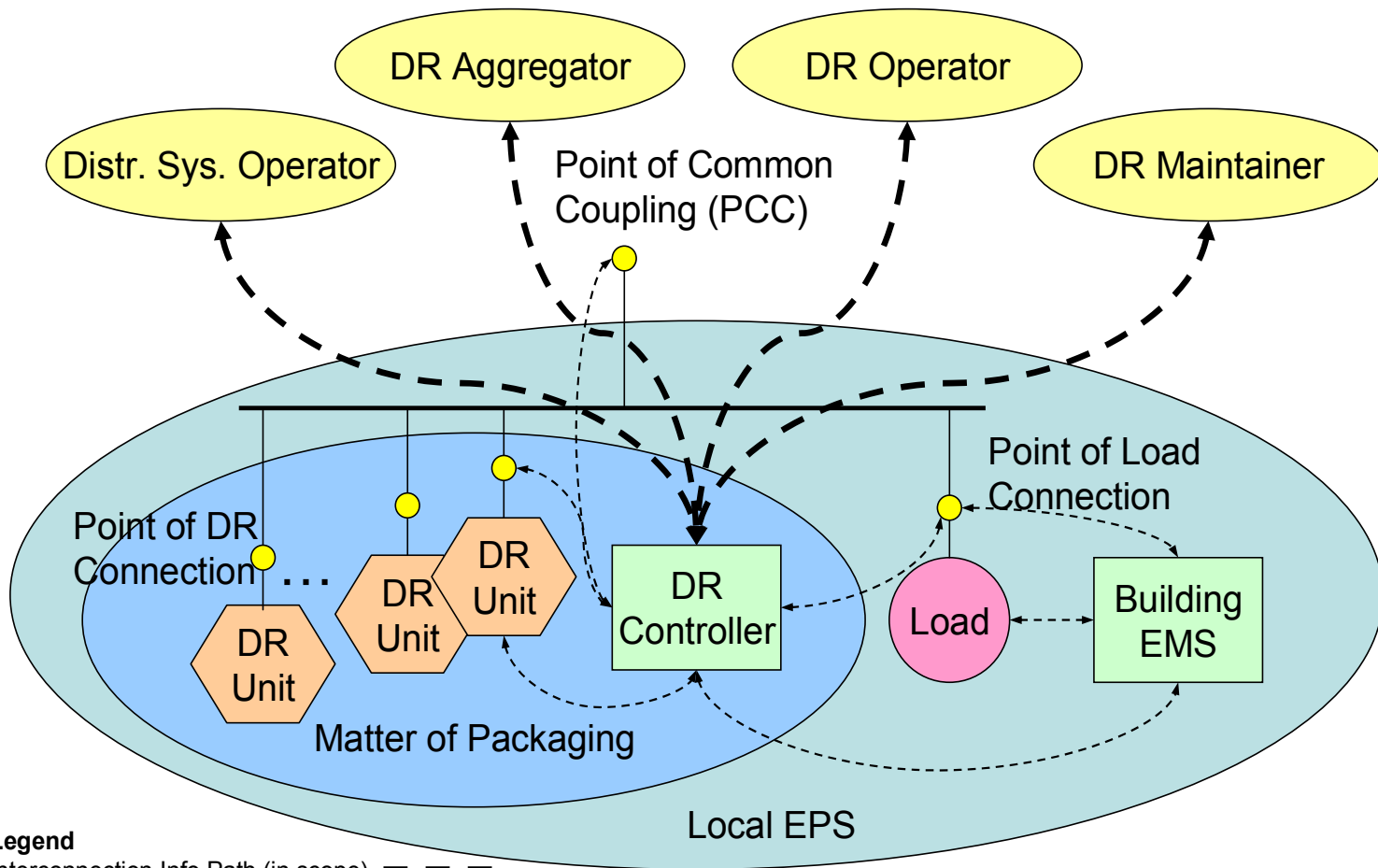
Example of an alternate approach to 1547 requirements.

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



# P1547.3 Draft

**P1547.3 (ballot planned 6/05) - guide to information exchange, monitoring and control for DR: alternate approaches – e.g., guidance for power industry communications/specific cases of DR interconnection situations.**



**Legend**

- Interconnection Info Path (in scope) - - - - -
- Local Info Path (out of scope) ·····
- Electric Path (out of scope) ———

# P1547.4 Draft

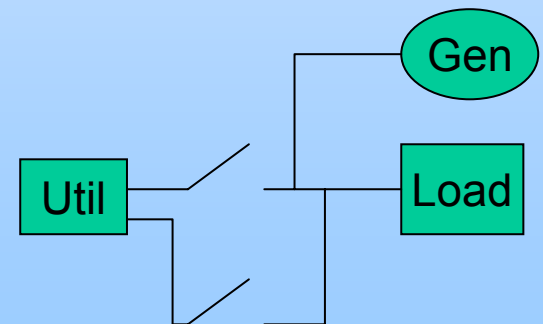
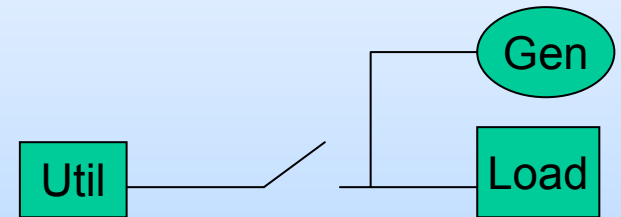
-- Work Group Inaugural Meeting Aug 5-6, 2004 --

## Background: Operating Concepts for the Distribution System

- Radial Distribution System: The most common type of connection between utility and load. Power only flows from utility to load.
- Microgrid or Intentional Island: Aggregation of loads and sources capable of operating either in parallel with or to end users. Depending on configuration, power flows only within microgrid or can export power to utility.

Independent from a larger electric grid, while providing continuous power.

- Networked Distribution System w/ 2-way power flow: Distribution in which the secondaries of the distribution transformers are connected in a grid, typically energized at the customers' utilization voltage, to serve multiple loads.



# UL 1741 Standard

- NREL has a contract with UL to update 1741 to include all DR interconnections.
- Goes beyond 1547 Requirements to include product safety aspects
  - 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)



# How do these standards work together ?

## NREL Interconnection Pre-Certification Approach

### IEEE 1547

#### Interconnection System 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

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





# Draft Implementation: e.g., PJM Small Generator (2MW and less) Interconnection Standard

## Summary Overview (work in progress)

### 1547 based Test Requirements

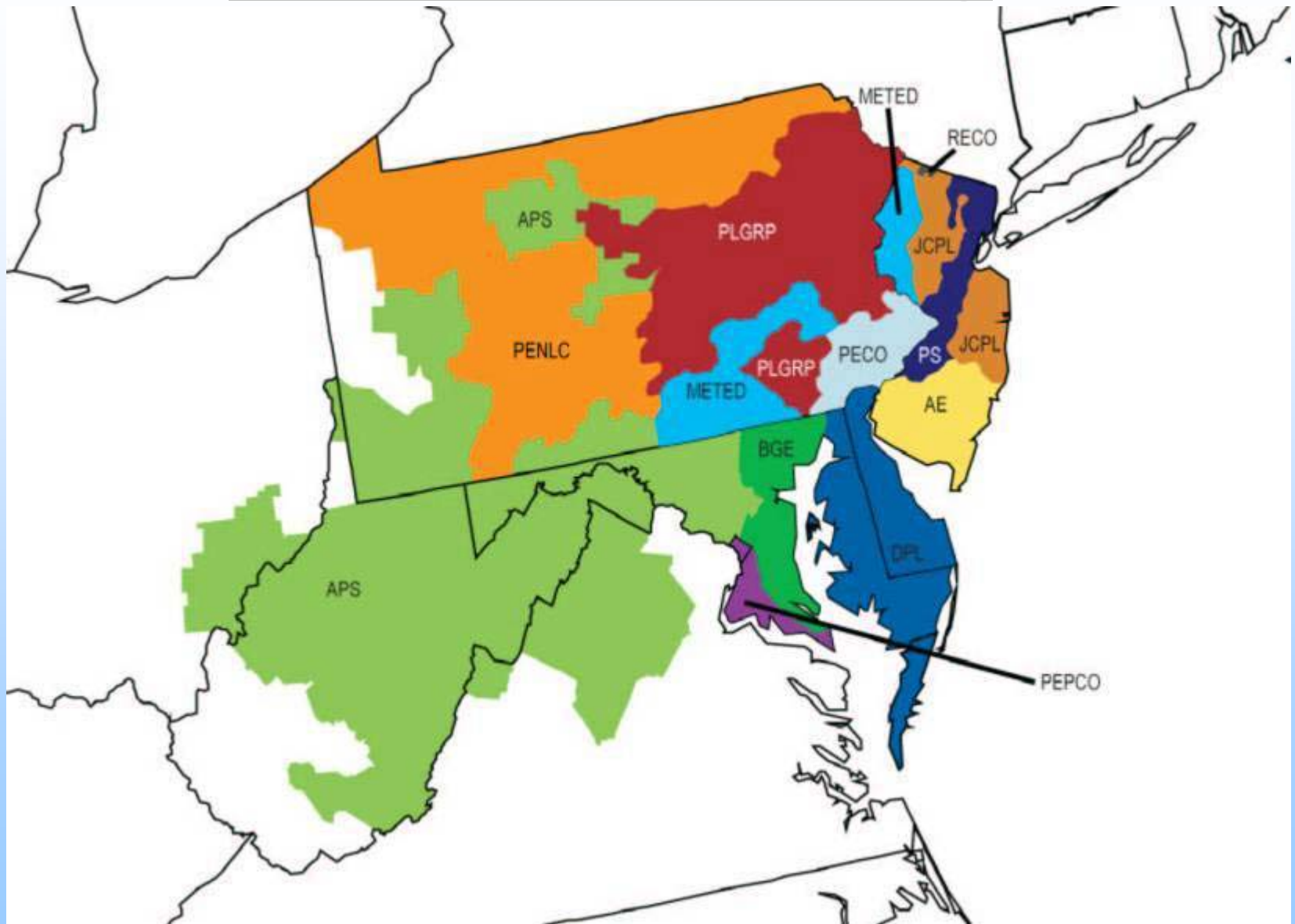
- Design Test (**may be pre-certified**)
- Production Test
- Installation Evaluation
- Commissioning Test
- Periodic Testing (per PJM tariff requirements)

### 1547 based Technical Requirements

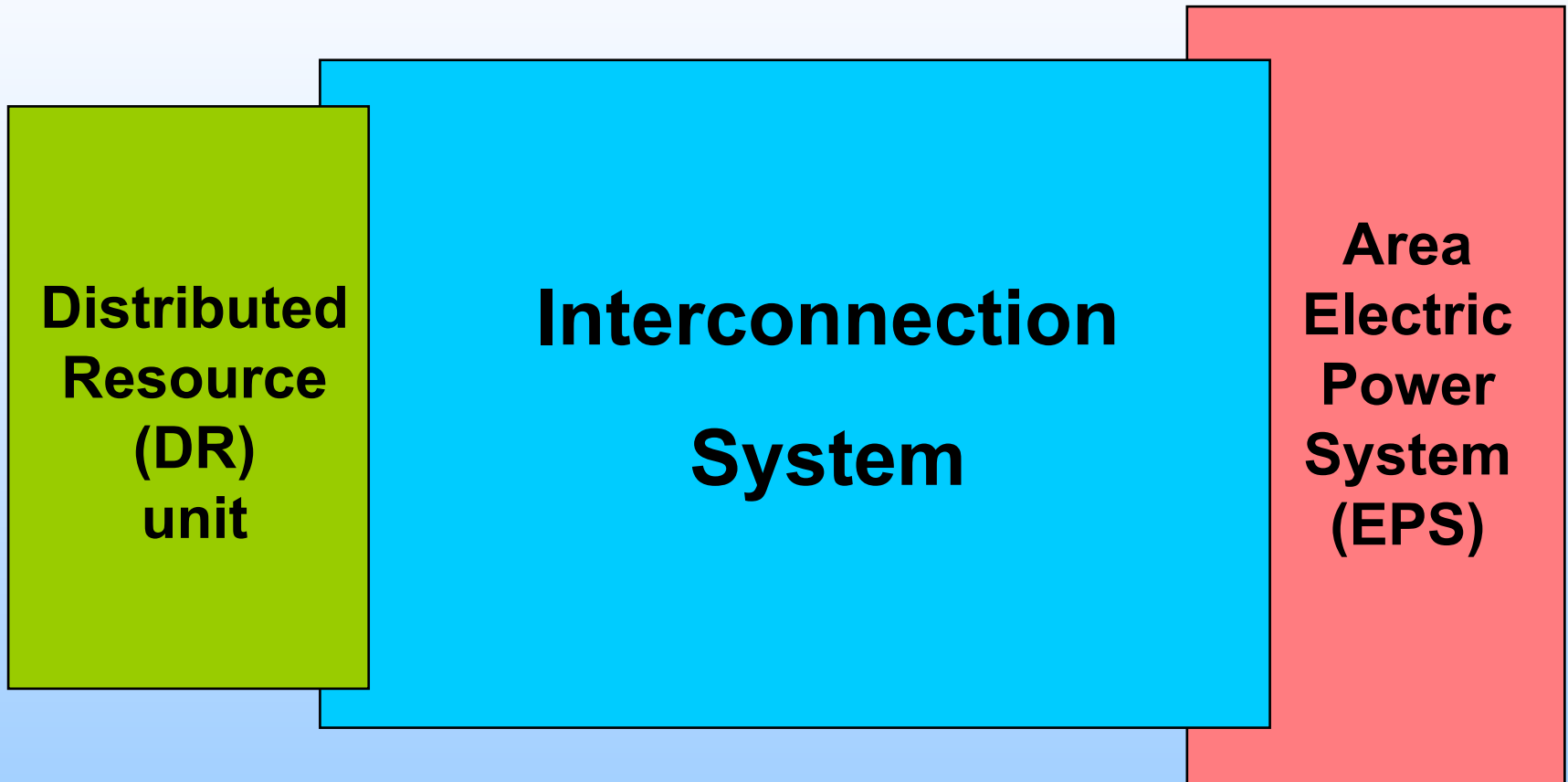
### Other Requirements

- e.g. PJM / EPS metering
- e.g. National / local codes

# PJM Business Territory



# 1547: Interconnection Is The Focus



# IEEE Std 1547 Contents

## **INTRODUCTION**

### **1.0 OVERVIEW**

### **2.0 REFERENCES**

### **3.0 DEFINITIONS**

### **4.0 INTERCONNECTION TECHNICAL SPECIFICATIONS AND REQUIREMENTS**

### **5.0 INTERCONNECTION TEST SPECIFICATIONS AND REQUIREMENTS**

### **Annex A : Bibliography**

# IEEE 1547 Table of Contents

## **INTRODUCTION**

### **1.0 OVERVIEW**

**1.1 Scope**

**1.2 Purpose – Uniform standard requirements**

**1.3 Limitations – 10 MVA or less**

### **2.0 REFERENCES**

### **3.0 DEFINITIONS**

**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**

**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.

# DR Interconnection

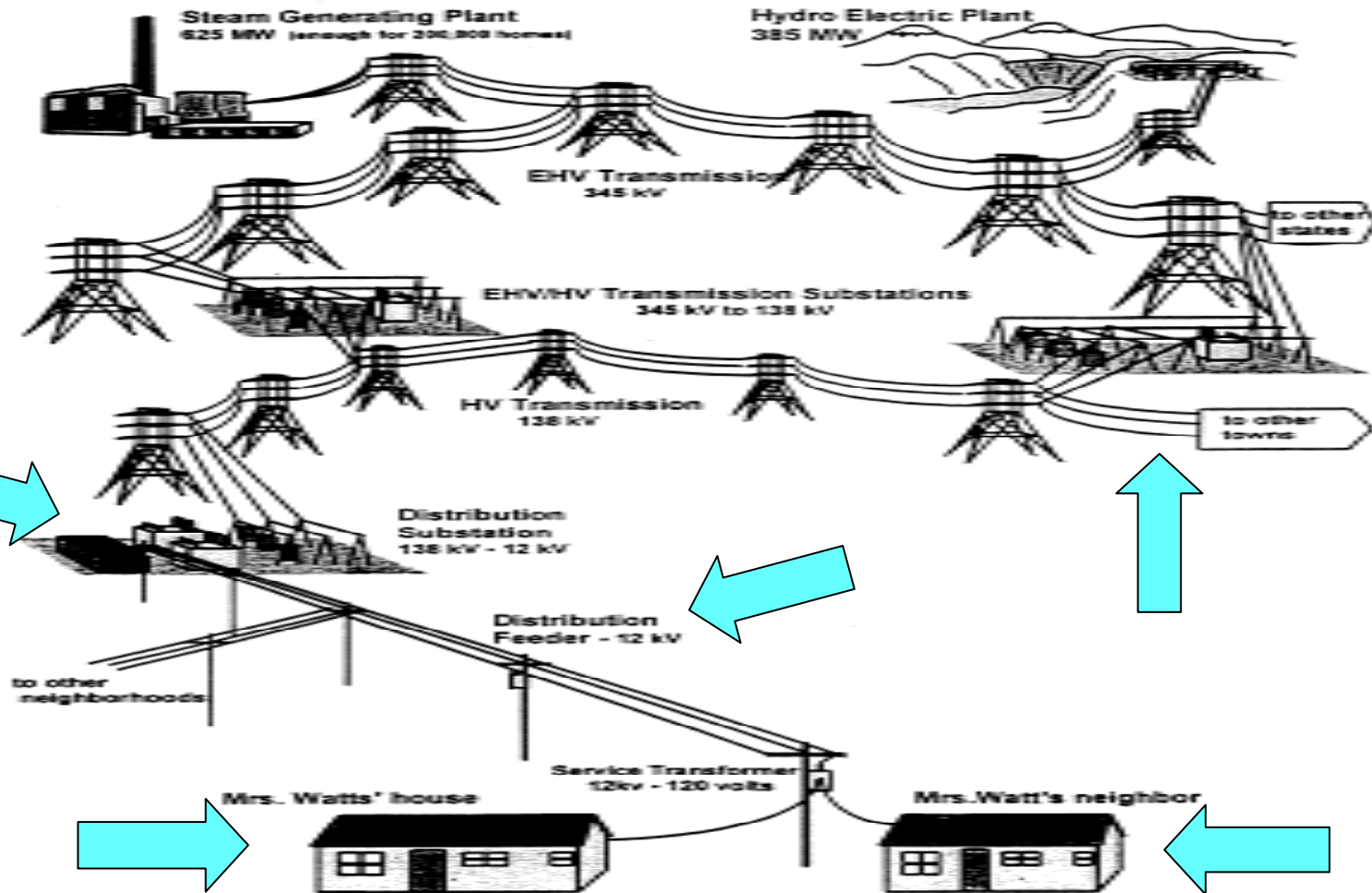


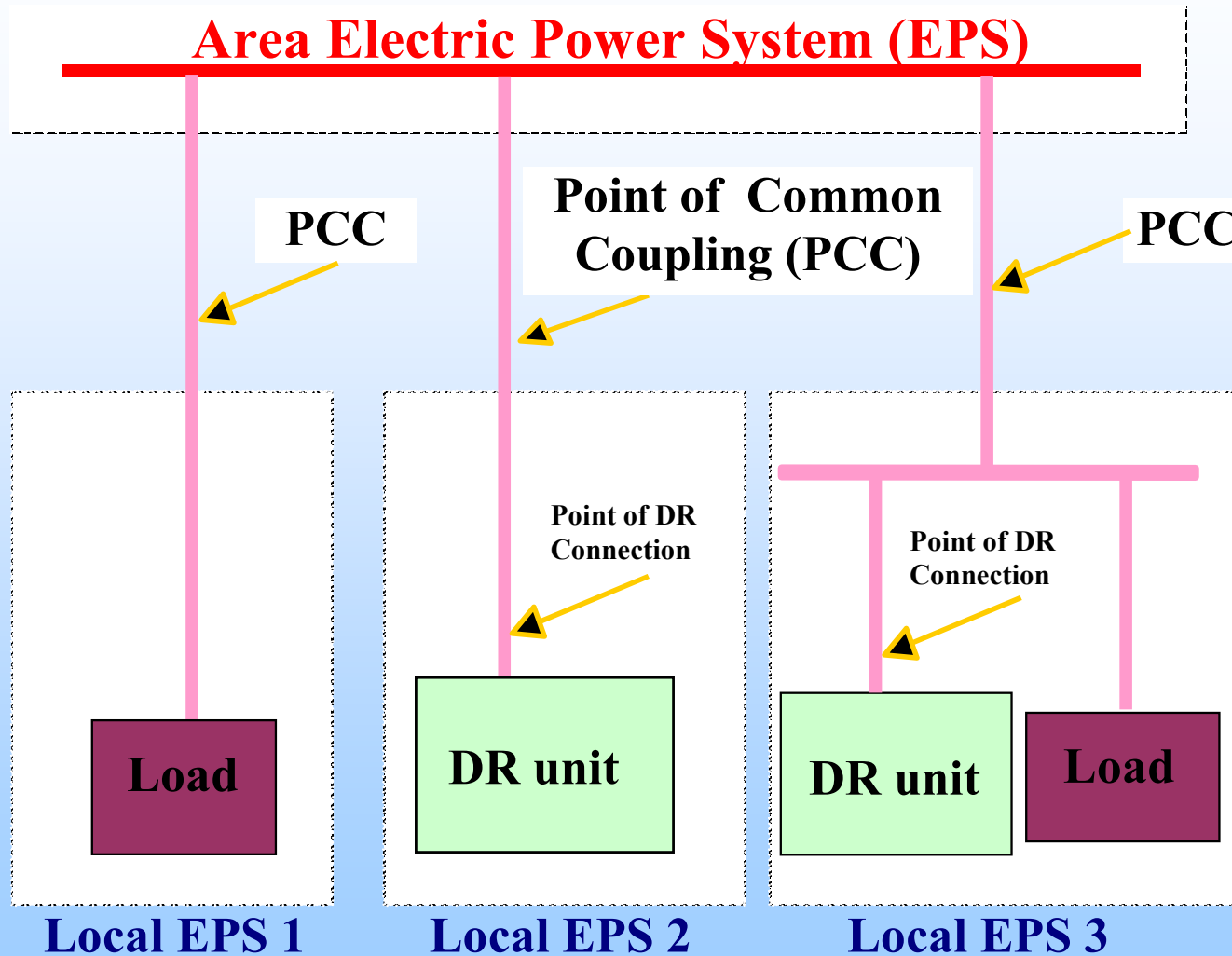
Figure 7.8 A power system consists of several levels: generation, extra high voltage (EHV) transmission, high voltage (HV) transmission, distribution, and utilization.



# IEEE 1547 Definitions

- **Distributed generator (DG)** –electric generation facilities connected to an Area EPS through a PCC; a subset of DR.
- **Distributed resources (DR)** – sources of electric power that are not directly connected to a bulk power transmission system. DR includes both generator and energy storage technologies.
- **Electric power system (EPS)** – facilities that deliver power to a load.
- **Area EPS** – an EPS that serves local EPSs.
- **Local EPS** – an EPS entirely within a single premises or a group of premises.
- **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 the Area EPS.
- **Pont of DR connection** – the point where a DR unit is electrically connected in an EPS.

# 1547 Interconnection Terms



Note: There can be any number of Local EPSs.

# 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

## 4.0 Interconnection Technical Specifications and Requirements (cont'd)

### 4.2 Response to Area EPS Abnormal Conditions

- Area EPS Faults
- AREA EPS Reclosing Coordination
- Voltage

- Frequency
- Loss of Synchronism
- Reconnection to Area EPS

## 4.0 Interconnection Technical Specifications and Requirements (end)

### 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**





# Contact Information

- **Dick DeBlasio, Technology Manager**  
NREL Distributed Energy & Electric Reliability (DEER) Program  
Chair IEEE SCC21, 1547; IEEE Standards Board Liaison to DOE  
email: [ddeblasi@tcplink.nrel.gov](mailto:ddeblasi@tcplink.nrel.gov) voice: (303) 275 – 4333
  - **Tom Basso\*, NREL**  
Sec'ty IEEE SCC21 & P1547.2 .3. 4  
email: [thomas\\_basso@nrel.gov](mailto:thomas_basso@nrel.gov)  
voice: (303) 275 - 3753
  - **Ben Kroposki\*, NREL**  
Sec'ty P1547.1 & Chair P1547.4  
email: [ben\\_kroposki@nrel.gov](mailto:ben_kroposki@nrel.gov)  
voice: (303) 275 – 2979
- \* NREL DEER Distribution & Interconnection R&D
- **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™ (2003) Standard for Interconnecting Distributed  
Resources with Electric Power Systems --**  
[http://grouper.ieee.org/groups/scc21/dr\\_shared/](http://grouper.ieee.org/groups/scc21/dr_shared/)