Interconnection Standards Development

Tom Basso

National Renewable Energy Laboratory

Electric Distribution Transformation Program

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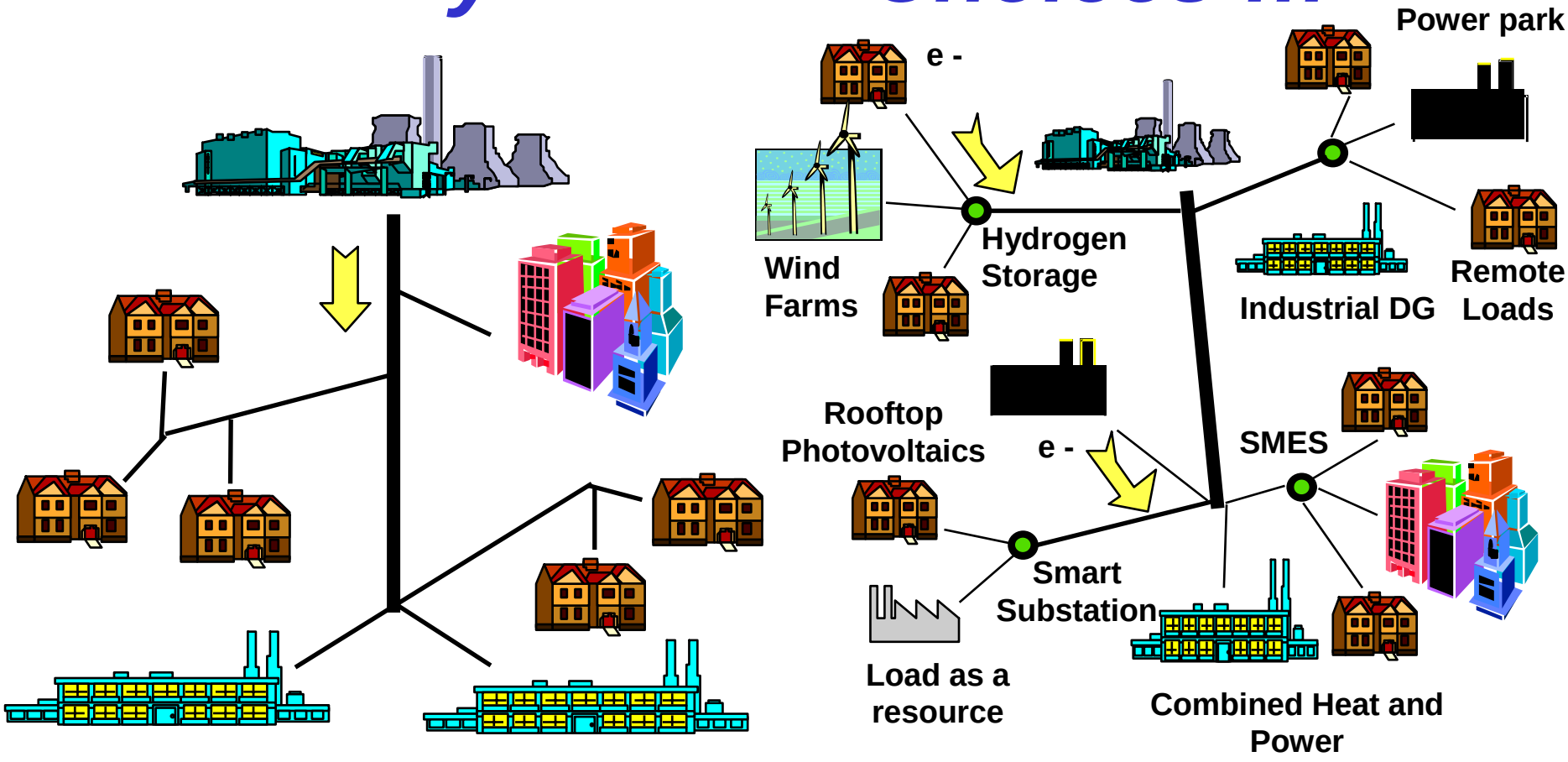
CONTENTS

Summary Remarks

- Standards Are Being Developed and Validated In a Timely, Ongoing and Cohesive Manner.
- Standards Are Promoting Advanced Technology Development That Is Successfully Incorporating Next Generation Standardized Functionalities.
- Standardization Is Enhancing Systems Integration of Sound Distributed Energy Resources With The Grid That Are Contributing To Modernizing Our Electric Infrastructure.

Today's Electricity …

Tomorrow's Choices …



Relevance to Problems & Needs

The ***"Grid 2030" A National Vision For Electricity's Second 100 Years*** document, *Grand Challenges* section states:

> "There is a need to develop and deploy advanced technologies to move the industry from the electro-mechanical to the digital age."

In that section, the *Goals to Achieve The Vision* includes the following goals:

- "plug-and-play protocols for DG/DR by 2010,"
- "DG/DR technologies fully integrated in distributed operations by 2020," and,
- "real-time, two-way flow of information and power."

Relevance to Problems & Needs

The ***National Electric Delivery Technologies Roadmap*** states the following *Grand Technical Challenges* for local distribution systems:

- "Lack of standards for the integration of distributed energy technologies and their interconnection/operation with distribution systems," and
- "Hardware integration - design and acceptance of low cost interconnection equipment"

Further, the Roadmap states the following RD&D needs:

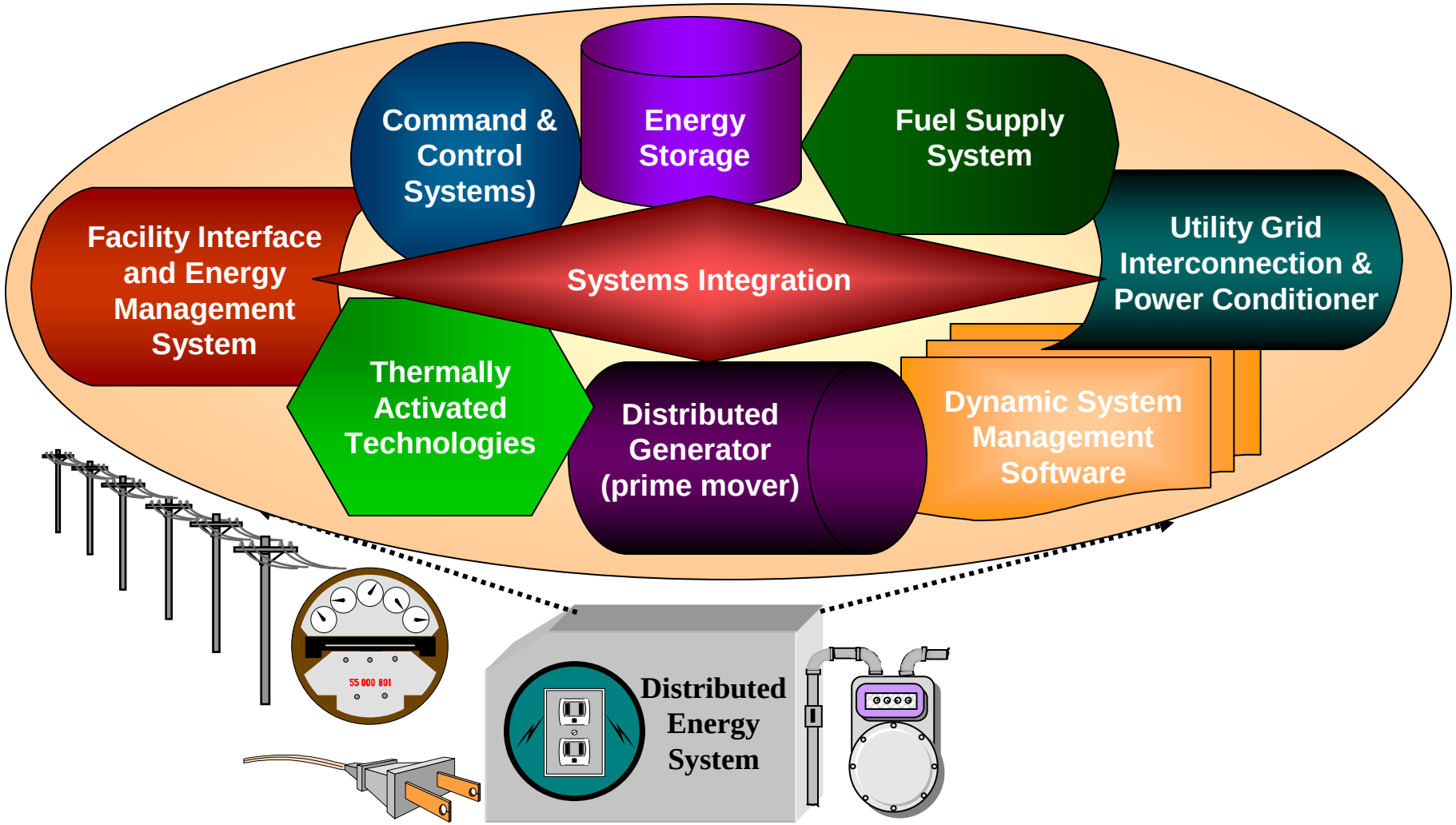
- "End use integration – network interconnection of DR, engineering solutions, develop standards, and demonstrate"
- "standards – need international focus"
- "Communications – facilitate plug & play for customers and DER".

Relevance to Problems & Needs

In relation to the previous two slides (challenges, goals and needs) is the following. There are needs for standardized interconnection and integration requirements and test procedures to facilitate the interconnection and interoperability of DG/DR and electric power systems (EPS). Even though the national consensus based set of requirements for interconnection has been developed with the recent passage of IEEE standard 1547, there still exists needs for the development and standardization of test procedures to meet these requirements, application guides for the requirements, and, guides for the monitoring, information exchange and control of DR; system impacts; EPS distribution networks; islanding; certification and laboratory accreditation; and, specifications and performance designation, including modeling, for modernized electro-technologies. Further, harmonization of international standards, product certification, and laboratory accreditation with US standards and practices are needed to assure an even competitive basis for international trade. International issues and opportunities could also be better addressed, including those associated operating the North American grid with Canada and Mexico.

Technical Challenges of Current Practices

Standards Development and Validation
Technology Standardization and Systems Integration



Technical Challenges of Current Practices

Toward addressing technical challenges, including those identified on previous slides:

"… move .. to the digital age.. "

"Lack of standards … " and,

"Hardware integration…"

This project is pursuing objectives under the following headings

- **Standards Development and Validation**
- **Advanced Technology Development**
- **Systems Integration**

Project Objectives

- **Standards Development and Validation**

  The objectives are to develop and validate national and international standards for interconnection and integration of distributed resources and electric power systems.

- **Advanced Technology Development**

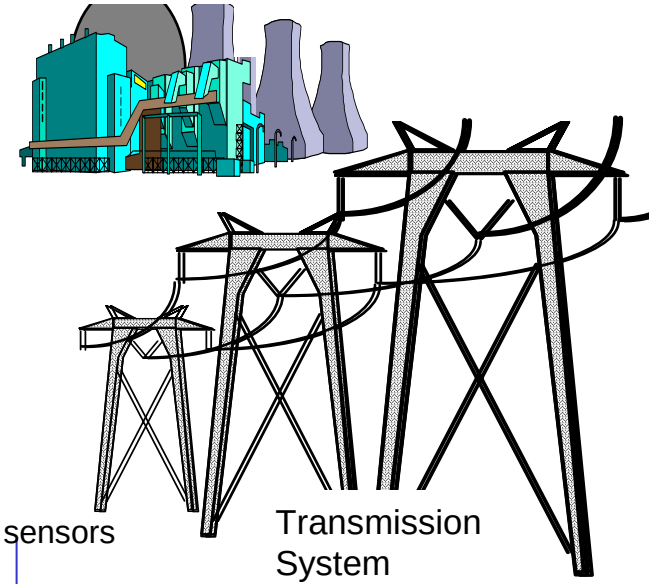
  The objectives are to develop advanced technologies for the interconnection and integration of distributed resources with electric power systems. Those objectives support "developing plug-and-play standards for DG/DR interconnection by 2010" and to have "DG/DR technologies fully integrated into distribution operations by 2020."

- **Systems Integration**

  Standards development is crucial to realize the systems integration objectives to integrate intelligence and control of distributed resources into the distribution system for optimal energy utilization.

Technical Approach – Standards Development

Bulk Power



Substation

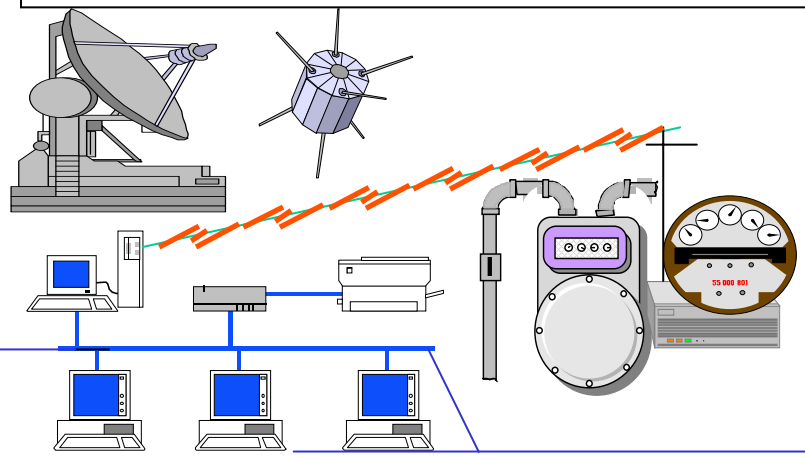
Distribution and Interconnection Systems

1. **Technical Standards**
2. **Advanced Technology**
3. **Systems Integration**

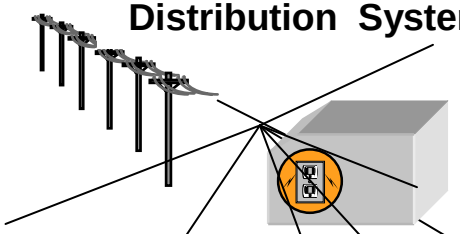
sensors

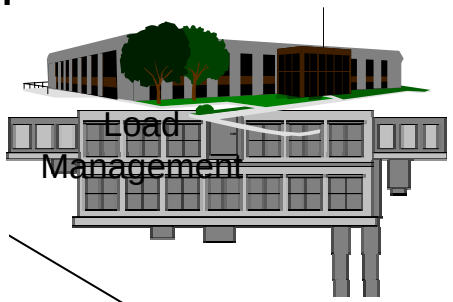
Transmission System

Communications – Information Flow, Data Management, Monitor/Control



Distribution System





Load Management

Interconnection

Distributed Generation

Combined Heat & Power

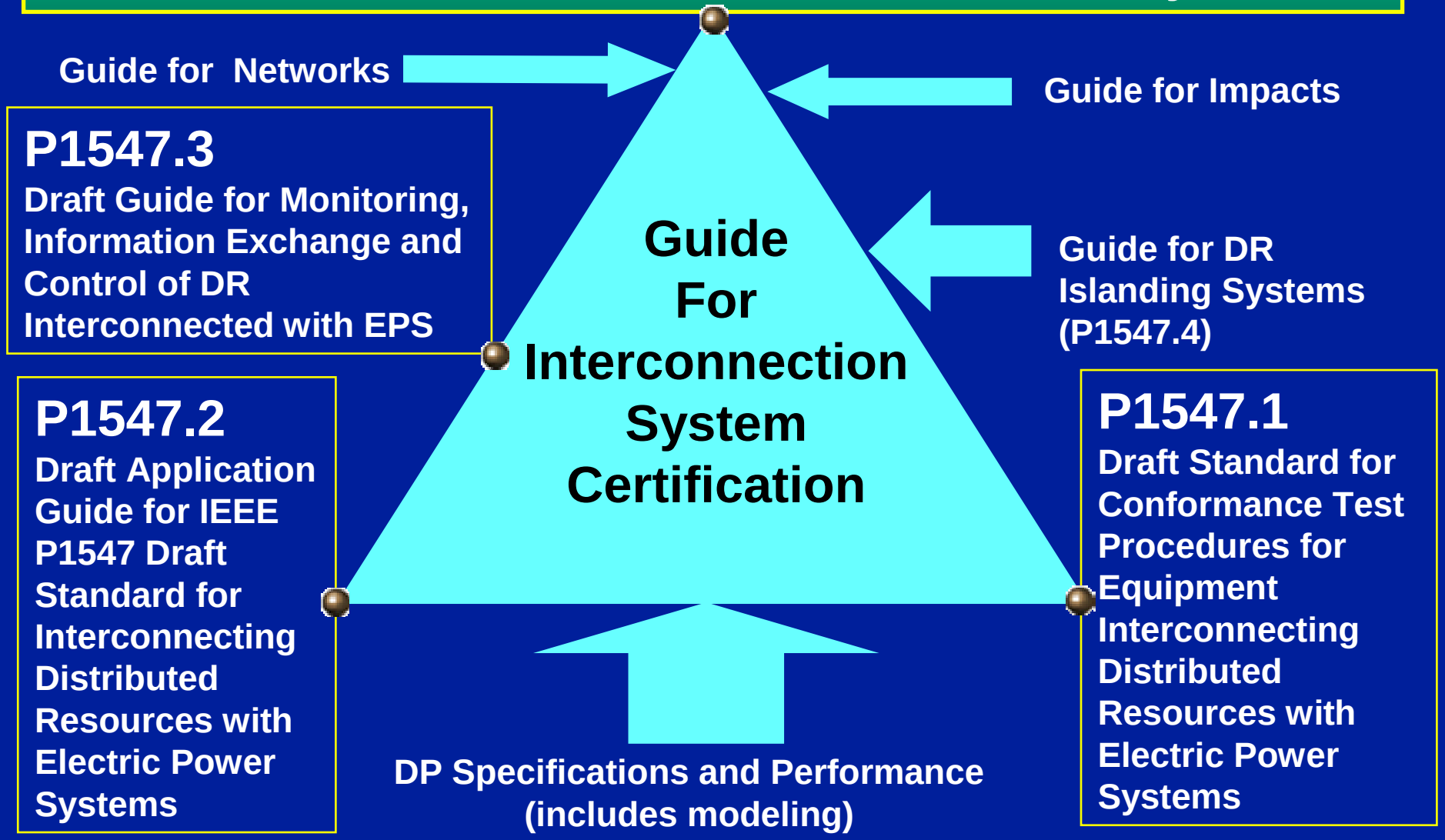
sensors

Technical Approach - **Standards Development and Validation**

- National consensus standards established via industry driven partnerships under IEEE Standards Coordinating Committee 21 (SCC21) ***Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage***; SCC21 also provides liaison activities.
- 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.

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
IEEE Std 1547™ (2003) Standard for Interconnecting Distributed Resources with Electric Power Systems (published June 2003)	• 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.
P1547.1 Draft 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 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.

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.
P1547.3: Draft 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.

Technical Approach - **Standards Development and Validation**

- 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.
- IEEE 1547 members identified additional priority standards needs (see graphic).

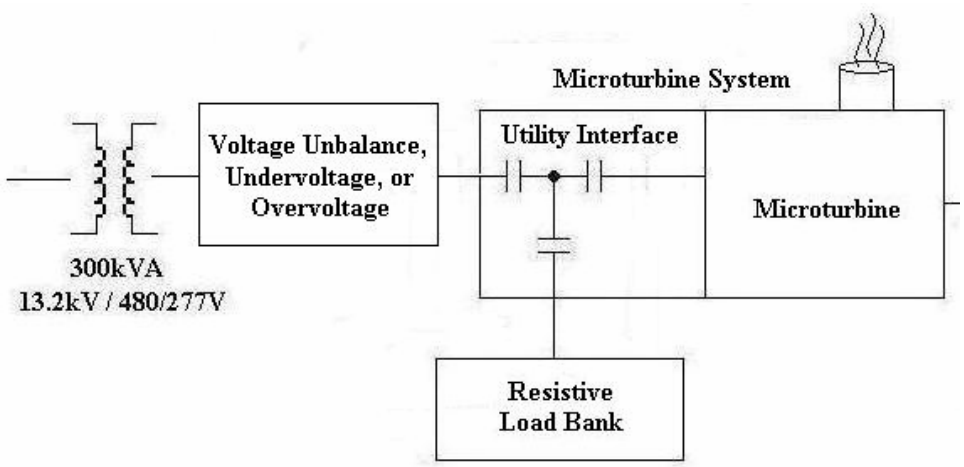
Technical Approach - Standards Development and Validation

- IEEE ballot consensus: voter group must be balanced (each interest group < 50% of total: users, manufacturers, general interest); voter may provide comments, draft sponsor responds to each negative stating sponsor position on comments, sponsor recirculates unresolved negatives to allow balloters to change their vote; minimum of 75% affirmation needed to pass to IEEE Standards Board for their approval.
- NREL manages the US Technical Advisory Group for IEC Technical Committee 8 (US/TAG/TC8) *System Aspects of Electrical Energy Supply*. TC8 standards facilitate functioning of electricity supply systems – systems encompass T&D networks including interfaces with user installations (generators and consumers). The main system aspects include: electrical system reliability, connection practices, operation, network responsibility, metering, data exchange and balancing, communication, characteristics of energy supply, and, terminology. Membership for US/TAG/TC8 must have balanced representation of interest categories, e.g., each group <50%. Additionally, NREL leads the IEC Joint Coordinating Group (JCG) on Distributed Renewable Energy Systems for international standards development.

Technical Approach – Standards Development

UL – Development of a UL Standard for Distributed Generation

Underwriters Laboratories Inc. (UL) is developing a standard for testing distributed generation equipment for safety and performance based on IEEE 1547 requirements.



EPRI-PEAC – Certification Model Program and Interconnection Agreement Tools

EPRI-PEAC is developing the proposed organization, procedures, plans, and labeling for distributed resource equipment certification and test-laboratory accreditation, as well as establishing tools supporting interconnection agreements. These will help establish a common benchmark ensuring a certified product has been manufactured and type-tested to well-established standards.

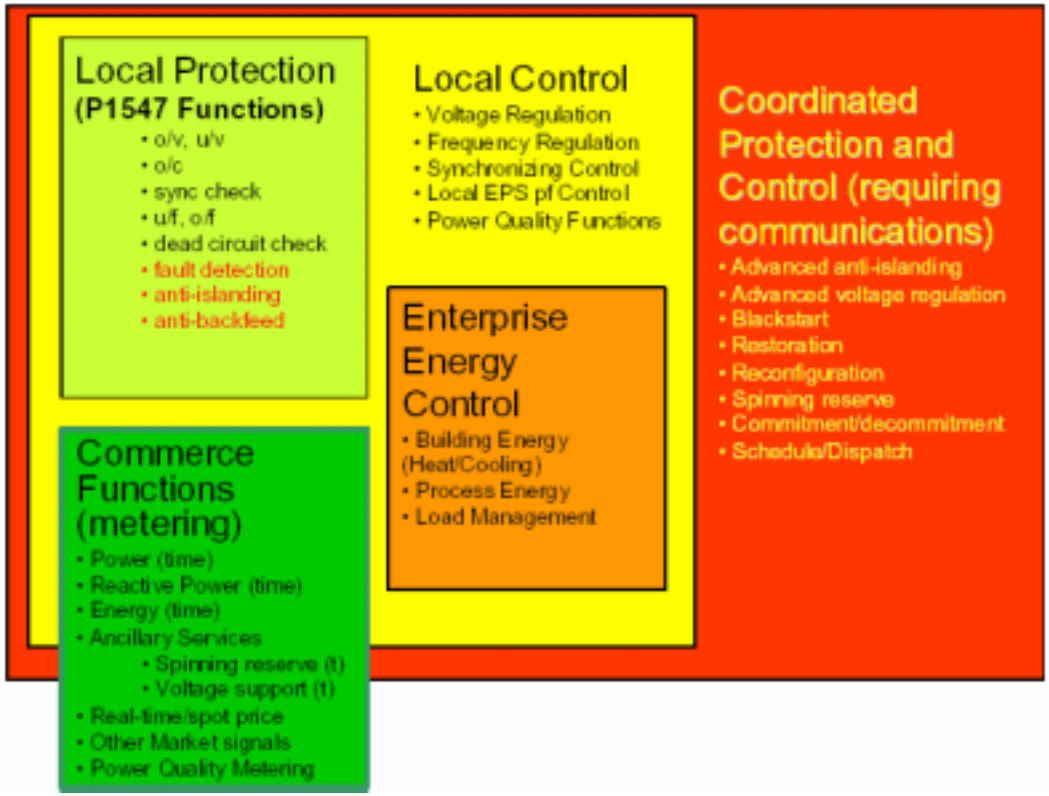
Certification Labeling Provides a Mark of Conformance

Technical Approach -- **Standards Development**

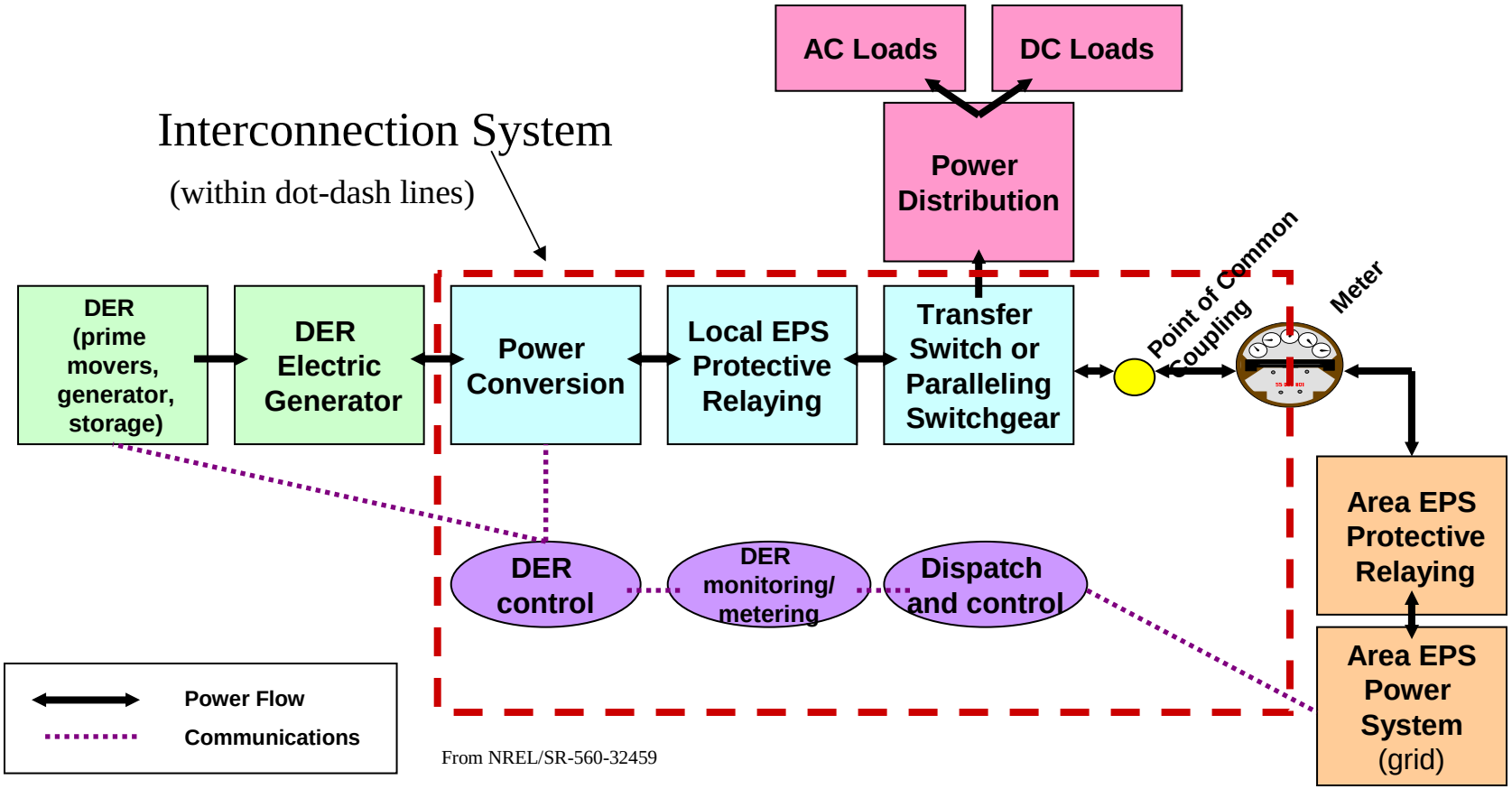
Resource Dynamics Corporation is providing technical support and facilitation to help ensure that the IEEE P1547.2 *application guide* is successfully developed and implemented in a timely manner. IEEE P1547.2 is a "guide" offering alternate approaches – e.g., practical applications guidance, tips, techniques and rules of thumb for applying IEEE 1547 to specific interconnection situations on specific utility distribution feeders. Industry has identified this as a critically important practical companion standard to 1547.

Example of an alternate approach to 1547 requirements.

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



Technical Approach – Advanced Technology Development

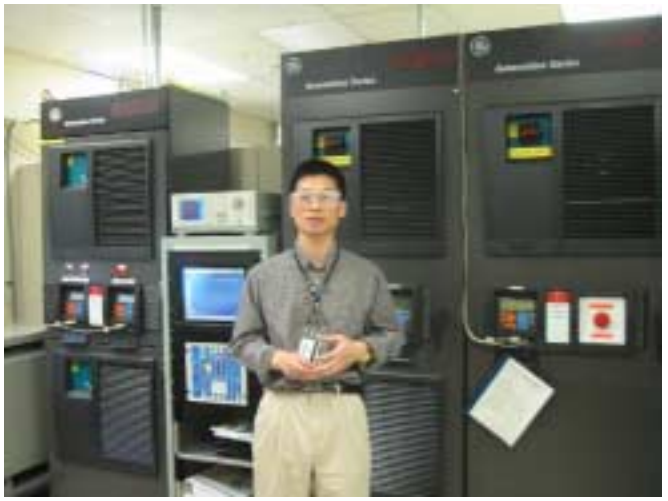


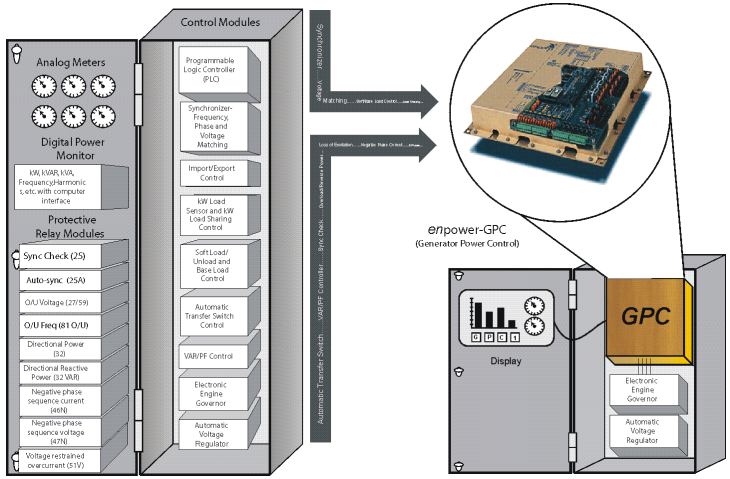
One focus area is development of advanced modular plug-and play interconnection systems for interconnection and systems integration. The interconnection system (within the dotted line) is designed to handle the power between and serve as the communication and control gateway among the DER, the Area EPS and the customer loads. Workshops with industry provided a forum for furthering this activity and several manufacturers are working on developing and validating standardized, advanced, universal interconnection technologies.

Technical Approach – **Advanced Technology Development**

General Electric Global Research and Development is developing standard-compliant DG/Grid interconnect to overcome interconnection barriers, to allow reliable system operation, and to achieve full value of DG.

GTI/ Encorp -The Gas Technology Institute (GTI) and Encorp are developing and demonstrating cost-effective plug-and-play distributed power grid interconnection products, software, and communication solutions applicable to improving the economics of a broad range of distributed power systems, including existing, emerging, and renewable power generation technologies. The subcontract is providing enhanced features and capabilities of distributed power products for integrating, interacting, and providing optional benefits to the electric power system and advanced building energy management systems.





Technical Approach – **Systems Integration**

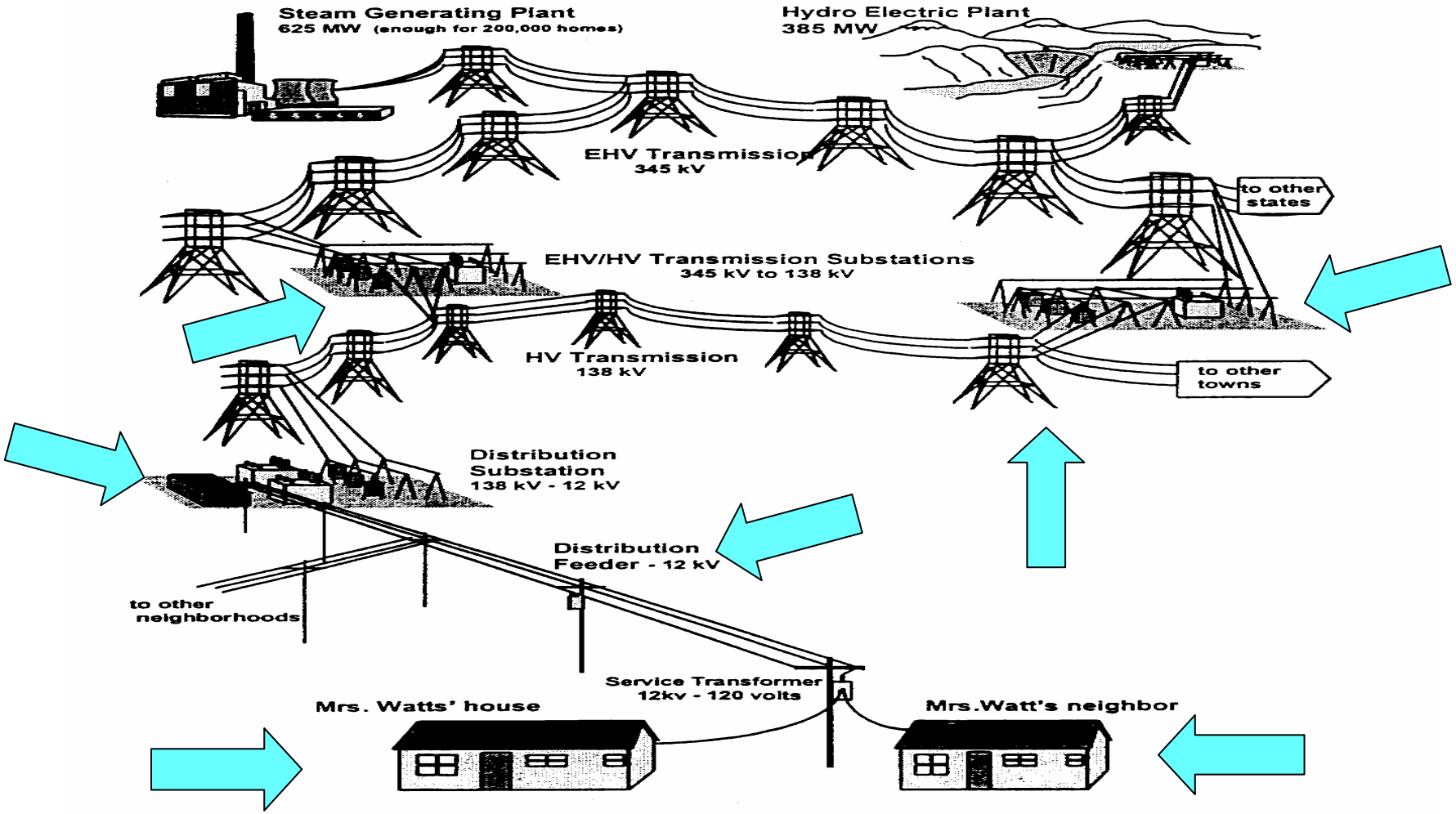
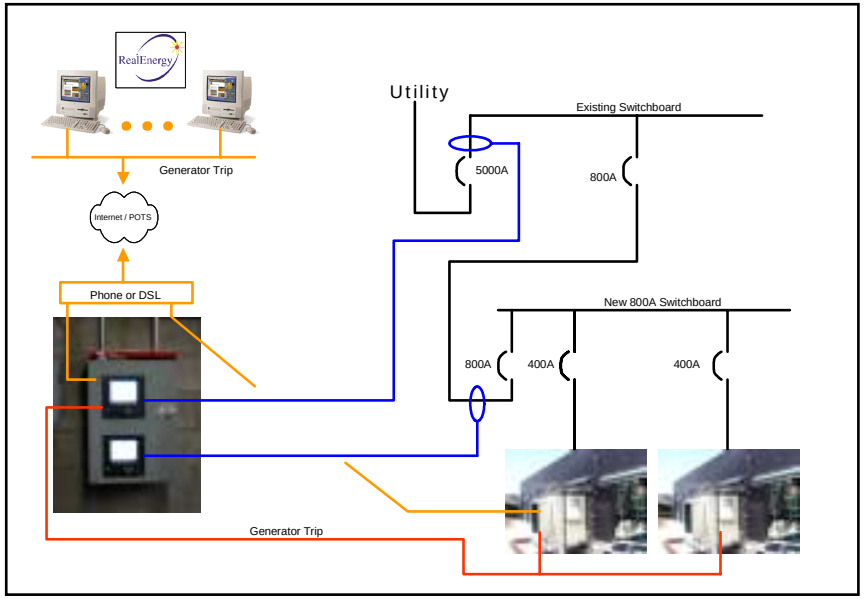


Figure 7.8 A power system consists of several levels: generation, extra high voltage (EHV) transmission, high voltage (HV) transmission, distribution, and utilization.

Technical Approach – Systems Integration

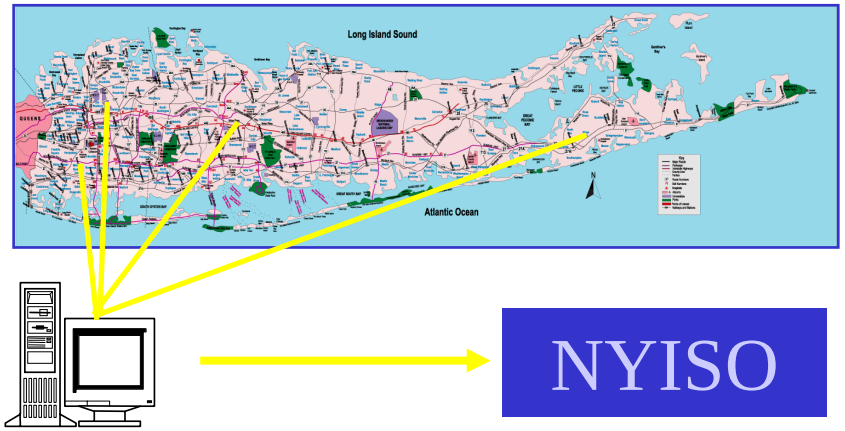
RealEnergy — Development of an Enterprise-Wide DG Management System

RealEnergy is addressing the integration and management of distributed power technologies in a virtual utility structure interconnected to the grid. The system balances system integration, communications, metering, billing, monitoring, alarming, and control with equipment run-time allocations, thermal and electric storage requirements, power flows, and the real-time valuation of grid services.



NYSERDA and Electrotek — Aggregation of DER Generators in Response to Area Capacity Shortages

One of the potentially exciting uses of DER involves the aggregation of DER (including emergency generation) owned by individual market participants to address area-wide power emergencies. NYSERDA and Electrotek are demonstrating the aggregation of dispatchable backup generators by adding controls to make them immediately dispatchable from a single control point when required to provide spinning reserve, interruptible load, and peak power to the utility grid or to an independent system operator.

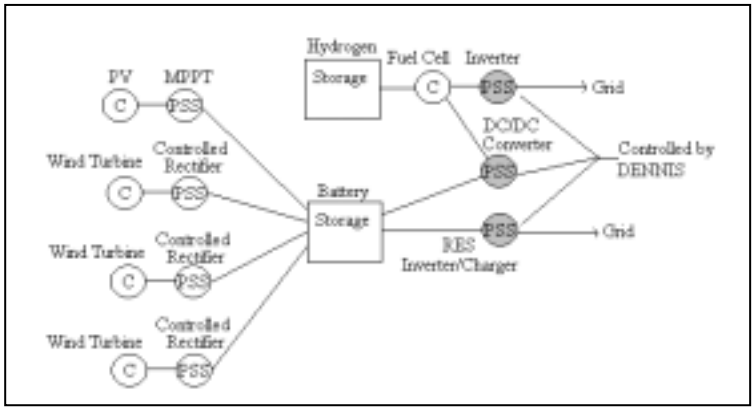


System Aggregation Center

Technical Approach – Systems Integration

Orion — Distributed Energy Neural Network Integration System (DENNIS)

Orion is developing a household controller module and will demonstrate the ability of a group of these household controllers to operate through an intelligent neighborhood controller to provide a smart, efficient, and economical solution for aggregating a community of small distributed generators into a virtual single large generator capable of selling power or other services to a utility or ISO.



NiSource — Utility System Integration Issues and Integration of DER into Building Control Systems

A leading proponent of utility use of distributed generation, NiSource will work with subsidiary utilities to identify the system integration and implementation issues for distributed generation for use with small industrial customers and to develop and test potential solutions to these issues.

FY03 Progress and Accomplishments

- Completed and published IEEE Std 1547 – 444 work group (WG) and ballot group members (230 balloters).
- Established P1547.1 Draft 2
- Established P1547.2 Initial Draft
- Established P1547.3 Initial Draft
- Managed and conducted two co-located meetings for each P1547.1, P1547.2, and P1547.3 work groups.
- Organized and held 15 virtual meetings (PC-teleconference) for P1547.2 and P1547.3
- Performed as Chair, Vice Chair, and Secretary for every P1547 series of standards work groups.
- Managed ballot for IEEE P1547, wrote various ballot reports, oversaw IEEE Standards Board approval and final editing.
- Participated in numerous meetings/conferences on DG/DR, interconnection and IEEE 1547 series of standards.

FY03 Progress and Accomplishments

- Represented IEEE 1547 at various states and other jurisdictional meetings considering interconnection.
- Completed numerous reports (see publications)
- Established US/TAG/TC 8 initial membership and liaisons.
- Continued as Chair for IEC Joint Coordinating Group for Distributed Renewable Energy Systems; have lead to establish draft on distributed resources interconnection practices, including renewable-hybrid systems and village or mini-grids.
- Participated in numerous planning and implementation workshops and meetings on interconnection and systems integration.
- Established standards development inputs to various programs.

FY03 Progress and Accomplishments - Publications

Standards Development

- EEE Std 1547 (2003) Standard for Interconnecting Distributed Resources With Electric Power Systems http://standards.ieee.org/
- PRI PEAC, Inc. - Key, T.S.; Sitzlar, H.E.; Geist, T.D. "Fast Response, Load-Matching Hybrid Fuel Cell: Final Technical Progress Report." NREL/SR-560-32743. Golden, Colorado: National Renewable Energy Laboratory. June 2003.
- REL - Basso, T.S. and DeBlasio, R. "IEEE P1547 Series of Standards for Interconnection: Preprint for IEEE Power Engineering Society Transmission and Distribution 2003 Conference and Exhibition" NREL/CP-560-34003. Golden, Colorado: National Renewable Energy Laboratory. May 2003.
- REL - Basso, T.; DeBlasio, R. “IEEE 1547 Series of Standards: Interconnection Issues.” NREL Report No. 34882. September 2003.

FY03 Progress and Accomplishments - Publications

Advanced Technology Development

- GE - “DG Power Quality, Protection and Reliability Case Studies Report”, NREL/SR-560-34635, August 2003
- GE - “Reliable, Low Cost Distributed Generator/Utility System Interconnect: 2001 Annual Report” NREL/SR-560-34634, August 2003
- GTI/Encorp. - Liss, W.; Dybel, M. "Development of Innovative Distributed Power Interconnection and Control Systems, Annual Report: December 2000-December 2001." Work performed by the Gas Technology Institute, Des Plaines, IL, and Encorp Inc., Windsor, CO. Golden, CO: National Renewable Energy Laboratory. November 2002.

FY03 Progress and Accomplishments - Publications

Systems Integration

- NYSERDA and Electrotek – "Aggregation of Distributed Generation Assets in New York State." NREL/SR-560-34779. Golden, CO: National Renewable Energy Laboratory. September 2003.
- RealEnergy. "Development, Demonstration, and Field Testing of Enterprise-Wide Distributed Generation Energy Management System: Phase 1 Report." NREL/SR-560-33581. Golden, CO: National Renewable Energy Laboratory. April 2003.
- Orion Corp. - Regan, T.; Sinnock, H.; Davis, A. "Distributed Energy Neural Network Integration System: Year One Final Report." NREL/SR-560-34216. Golden, Colorado: National Renewable Energy Laboratory. June 2003.

FY03 Progress and Accomplishments - Publications

General Publications

- NREL/SR-560-32459 *Distributed Energy Resources Interconnection Systems: Technology Review and Research*
- NREL/BK-560-32865 *Universal Interconnection Technology Workshop Proceedings*

Planned Activities for FY04

- Complete the certification/accreditation final draft plan and interconnection agreement handbook.
- Complete the P1547.1 Draft 3 and the development tests for it.
- Complete the P1547.2 Drafts 1 and 2 including feedback-review cycles.
- Complete the P1547.3 Drafts 1 and 2 including feedback-review cycles.
- Complete the UL 1741 final version to include all utility interconnection equipment.
- Establish new IEEE standards projects, e.g., P1547.4 DR islanding systems.

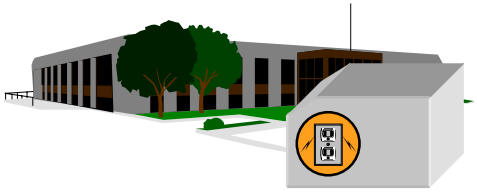
Planned Activities for FY04

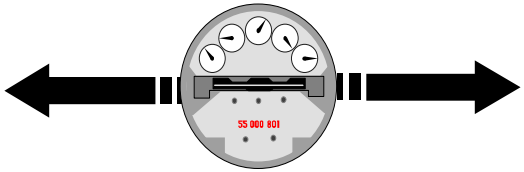
- Define for future release, a competitive procurement for systems integration of advanced distributed control technologies.
- Report on developing the innovative distributed power grid interconnection and control system; complete the interim advanced prototype (GTI/Encorp).
- Complete the interim advanced prototype for universal interconnect (GE).
- Final report on Development of an Enterprise-Wide DG Management System (RealEnergy).
- Final report on Aggregation of DER Generators in Response to Area Capacity Shortages (NYSERDA/Electrotek).
- Final report on Distributed Energy Neural Network Integration System (Orion, Corp.).

Summary of Out-year Activities

- Complete the ballots for IEEE standards: P1547.1, P1547.2, P1547.3 and P1547.4
- Publish the model certification and lab accreditation plan
- Establish the interconnection agreement handbook and tools
- Develop coordinated national and international standards and codes revisions or new documents encompassing priority needs
- Complete the near term universal interconnection hardware development
- Develop additional advanced distribution system hardware, e.g., to allow two-way power flow on network systems, and advanced protective equipment for distribution systems

Impacts and Benefits





Standards Development and Validation

- 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

Impacts and Benefits -- **Standards Development & Validation**

- IEEE Std 1547 standard will have a significant effect on how the energy industry does business in the future and will influence the way the electrical distribution system will operate — with distributed generators and two-way flow of electric energy. This national standard may be used in federal legislation and rulemaking and state PUC deliberations and by more than 3,000 utilities in formulating technical requirements for interconnection agreements.
- US/TAG/TC 8 provides the venue for US interests in establishing IEC standards to facilitate world commerce by removing technical barriers to trade leading to new markets and economic growth. Put simply, a component or system manufactured to IEC standards and manufactured in country A can be sold and used in countries B through Z.

Impacts and Benefits **Standards Development & Validation**

- Throughout the US uniform adoption of IEEE 1547 interconnection standards can lead to eliminating barriers posed by project-specific interconnection requirements. The uniform implementation of consensus standards, local codes and permitting processes will allow more open and cost effective competition in the electricity markets without compromising reliability, protection, environmental values, health, and safety. Various states have cited 1547 in their rules, and FERC, NARUC, and other jurisdictions (e.g., PJM) are looking at 1547 as a mainstay of their technical requirements.
- Harmonized national and international standards will improve global industrial efficiency and help further world trade. Harmonization provides a uniform framework for economies of design, greater product/service quality and interoperability, and better production and delivery efficiency. Certification/lab accreditation at the national level ensures a certified product has been manufactured and type-tested to well-established standards. The end-user is assured the product meets quality standards and need not be concerned with redundant testing or evaluation of the product.

Impacts and Benefits

Advanced Technology Standardization and Systems Integration

- Facilitates standardized designs, engineering implementation, interoperability, and installation – lower cost.
- Simplifies conformance assessment (to standards, permitting, and rules)
- Assists increased system quality and reliability achievement
- Promotes advanced communication and software platforms
- Enables enhanced grid intelligence

Impacts and Benefits

Advanced Technology Development. The current high cost and complexity of interconnecting DR will greatly benefit from development of standardized advanced interconnection equipment. A universal interconnection platform will allow increased compatibility and flexibility with various DR, while reducing overall interconnection costs.

Systems Integration. Standards development and standardized technologies will enable more effective technology development, systems integration, and operations for distributed sensing, intelligence and control technologies that are considered vital for the large-scale deployment of DR to achieve optimal energy utilization. As identified in the National Electric Delivery Technologies Roadmap, distributed sensing and control technologies are essential to expand DG applications, and will improve reliability, increase affordability and enhance security.

Interactions & Collaborations – include the following.

- ANSI
- ASCO Power Technologies
- California Energy Commission
- CEIDS DER/ADA
- DTE Energy
- DUA
- EEI
- EGSA
- Electrotek Concepts
- EPRI PEAC
- EPRI (Palo Alto, CA)
- Encorp, Inc.
- FERC
- GTI
- General Electric
- IEC
- IEEE
- NARUC
- NEMA
- NiSource
- NRECA
- Northern Power Systems
- NYSERDA
- Orion
- PG&E
- PJM
- PNNL
- RealEnergy
- RDC
- UL
- University of Wisconsin
- Xantrex
- (others)

Budgets

Standards Development and Validation

	FY03 ($K)	FY04 ($K)	FY05 ($K)	FY06 ($K)	FY07 ($K)
In-House	516	510	656	739	813
Subcontract	389	331	500	550	605

Advanced Technology Development

	FY03 ($K)	FY04 ($K)	FY05 ($K)	FY06 ($K)	FY07 ($K)
In-House	356	348	467	514	565
Subcontract	274	817	2,000	2,200	2,420

Systems Integration

	FY03 ($K)	FY04 ($K)	FY05 ($K)	FY06 ($K)	FY07 ($K)
In-House	236	236	293	323	355
Subcontract	147	259	1,000	1,100	1,210

Contact Information:

National Renewable Energy Laboratory

1617 Cole Blvd. MS1614, Golden, CO 80401-3393

- Dick DeBlasio — Phone 303-275-4333 – Email deblasid@tcplink.nrel.gov
- Tom Basso — Phone 303-275-3753 – Email thomas_basso@nrel.gov
- Ben Kroposki — Phone 303-275-2979 – Email ben_kroposki@nrel.gov
- Gary Nakarado — Phone 303-275-3719 – Email gary_nakarado@nrel.gov
- Holly Thomas — Phone 303-275-3755 – Email holly_thomas@.nrel.gov