Open Communication Architecture for Distributed Energy Resources (DER) in Advanced Distribution Automation (ADA)

Presentation for FY04 Peer Review

DOE Electric Distribution Transformation Program

October 28-30, 2003

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EPRI

Electricity Innovation Institute

Outline

- Advanced Distribution Automation Context of Project and of DER Integration in Electric Power Systems
- Presentation Following the DOE Content Guidance
- Questions/Discussion

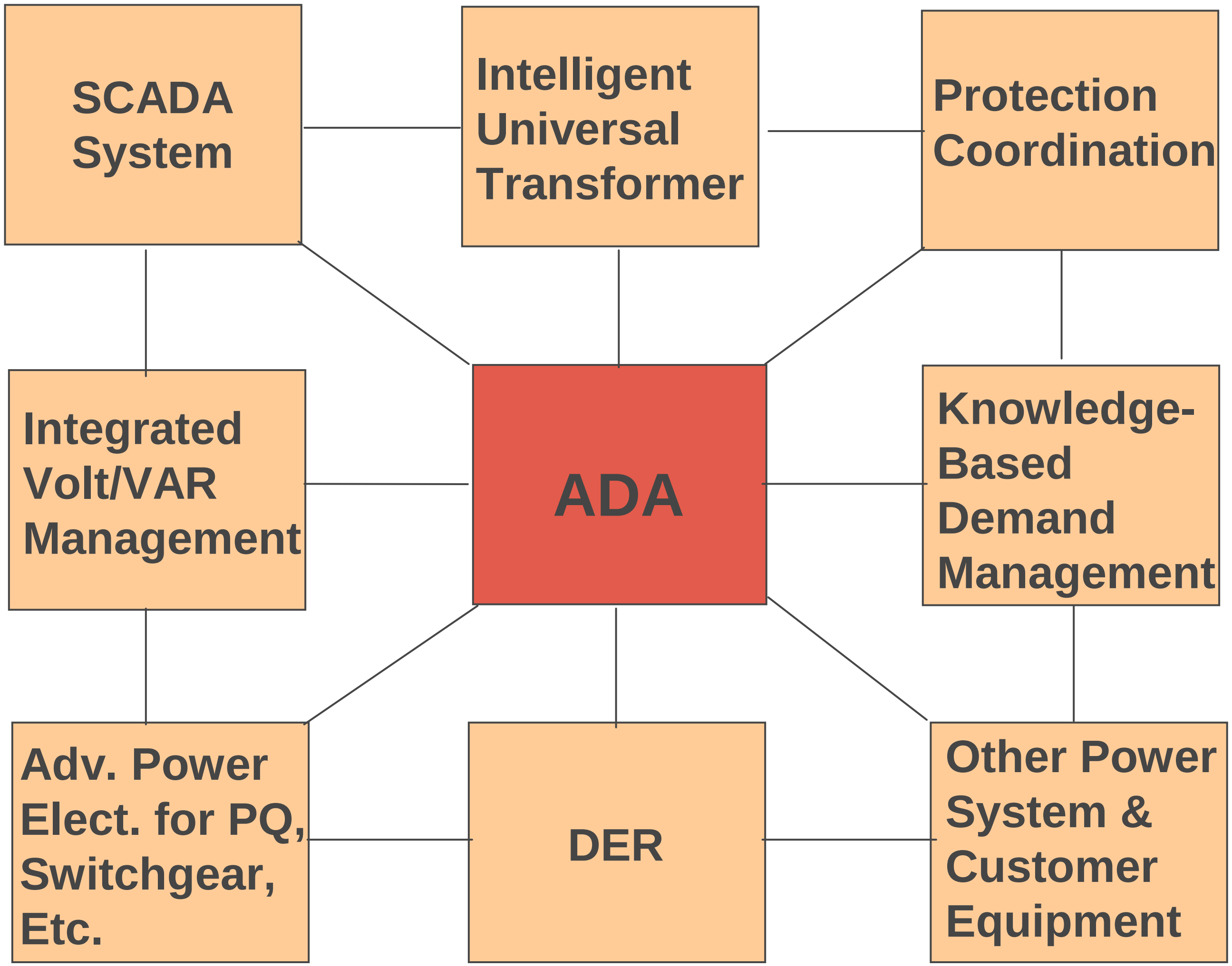
Terminology

- **CEIDS: Consortium for Electric Infrastructure to Support a Digital Society**
- **DER: Distributed energy resources (distributed generation and storage), such as small turbine-generators, photovoltaic systems, fuel cells, battery power systems, etc.**
- **ADA: Advanced distribution automation**
- **DER/ADA Project: Abbreviated name for CEIDS project on Open Communication Architecture for Distributed Energy Resources in ADA**

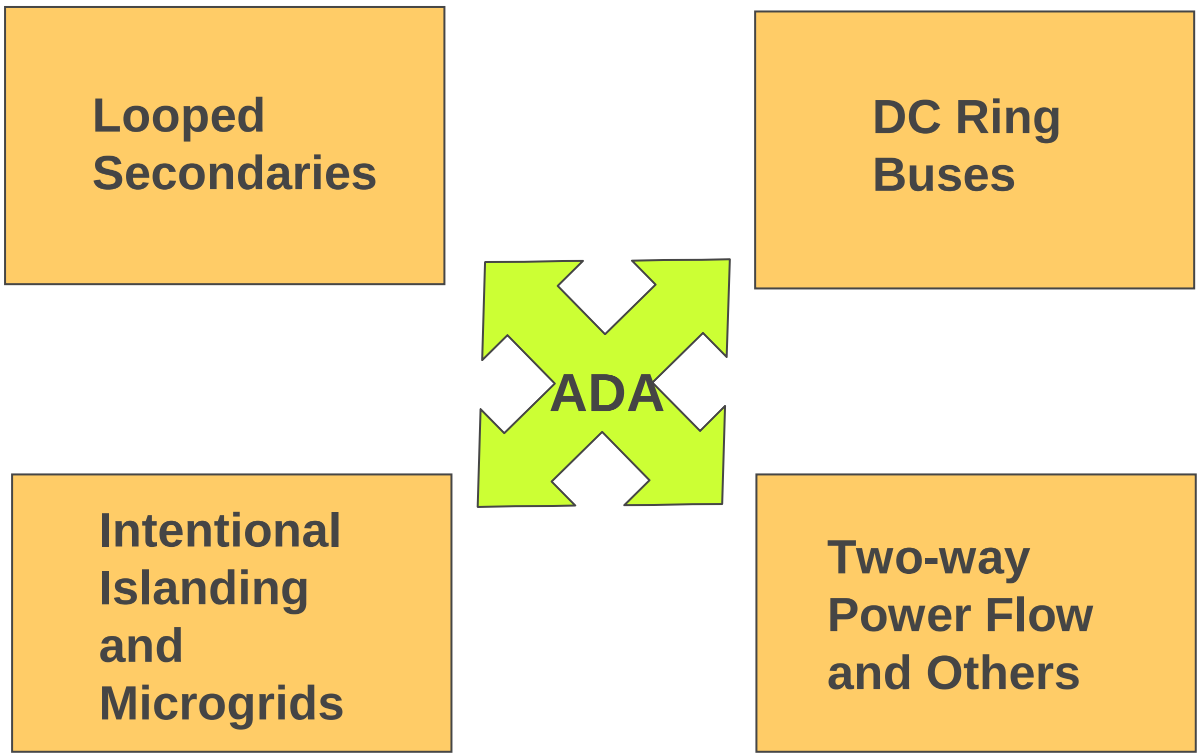
What is Advanced Distribution Automation (ADA)?

- Traditional distribution systems were designed to perform one function—distribute power to end-users
- ADA will transform traditional systems into multifunctional systems that take full advantage of new capabilities in power-electronics, information technology, and simulation
- ADA enables additional customer service options
- ADA captures advances in information technology and distributed computing
- ADA is revolutionary and not just an extension of traditional DA
- But the ADA revolution will happen by evolution

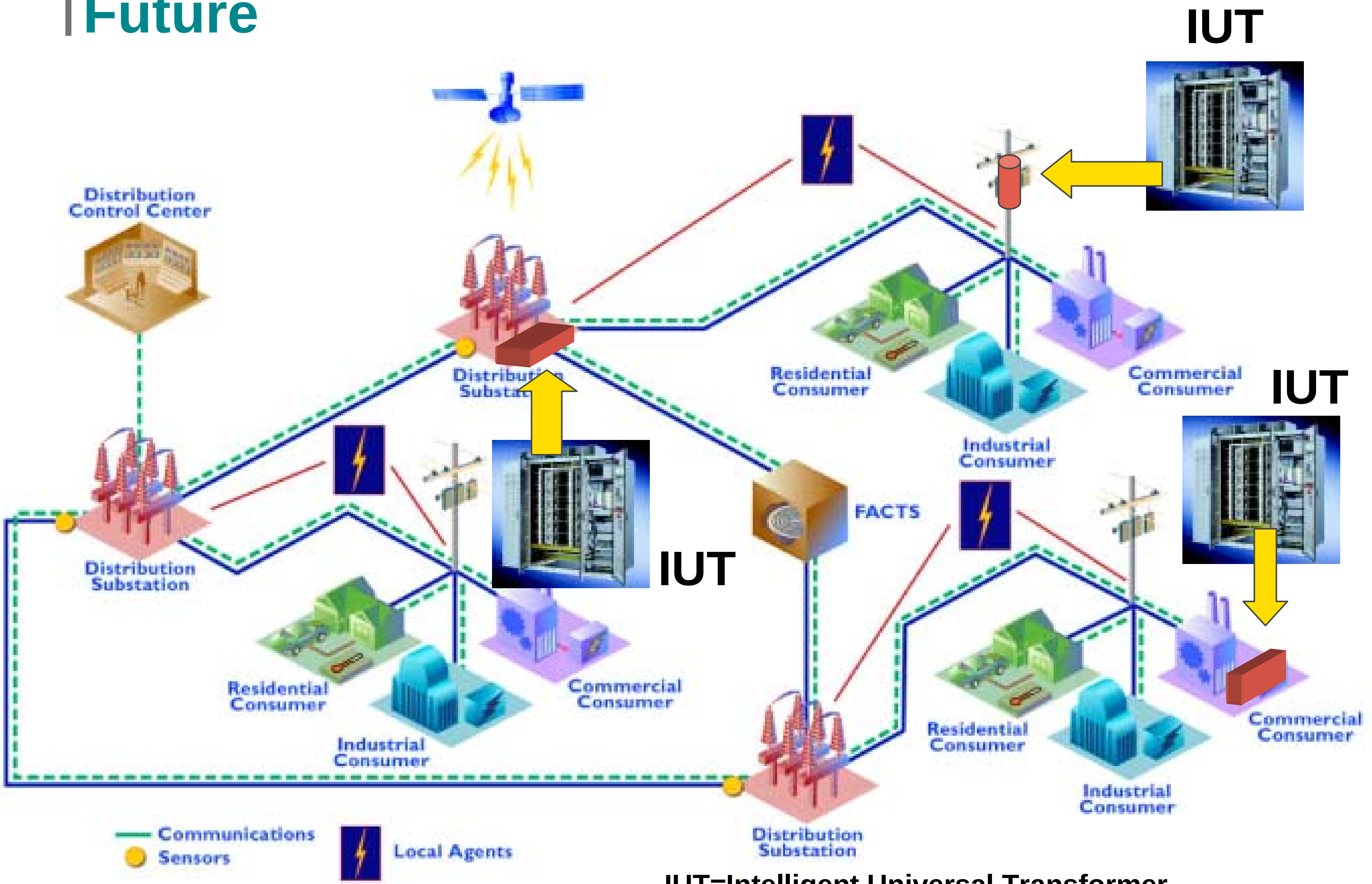
Future distribution system components will be interoperable



Enabling New Electrical System Configuration Concepts



ADA Creates the Distribution System of the Future



IUT=Intelligent Universal Transformer

DER/ADA Project Team

Overall Project Management, Planning, and Lead Responsibility for Standards Working Groups—EPRI/E2I

- **Frank Goodman: Project Manager and PI**
- **Don Von Dollen, Marek Samotyj, Joseph Hughes: CEIDS Program Coordination and Internal Technical Review**
- **Yu-Ting Huang, Logistics and Meeting Support**

Object Model Development, Validation Coordination, and Support for Project Planning

- **Utility Consulting International (Prime Contract to E2I): Frances Cleveland (PI) and Randy Ehlers**
- **Tamarack (Subcontract to UCI): George Schimmel**
- **NettedAutomation (Subcontract to UCI): Karlheinz Schwarz (Germany)**
- **Enernex (Subcontract to UCI): Erich Gunther**

Assessment of ADA Operations with DER

- **Utility Consulting International (Second Prime Contract to E2I), Nokhum Markushevich (PI)**

International Standards Expertise and Liaison

- **William Blair (Consultant to E2I)**

Extended Stakeholder Team and Technical Working Team Have Been Formed

- DER, ADA, and IT Industry Communities
- State and Federal Government Organizations, Including National Laboratories
- Electric Utility Industry
- Universities and Consultants
- CEIDS Steering Committee and CEIDS Project Advisory Group
- All of your organizations are welcome to become involved in the stakeholder team or the technical working team
  - Future plans call for CEIDS teaming with field test hosts
  - These hosts will be teams of vendors/utilities/other stakeholders
  - All possibilities, ranging from new systems to piggybacking on planned or existing systems, are under consideration for the field test phase
- Become involved now and help shape the future phases of the project

Relevance to Problems & Needs-1

- DER has the potential of being a disruptive technology that changes the power supply paradigm and improves the way we do things. This DER/ADA project will:
  – Improve the strategic value of DER in a system context
  – Create the ability to use DER as a valuable resource in ADA
  – Enable interoperability of DER with a variety of other new distribution system and customer equipment
  – Provide improved quality of service to end users (cost, reliability, power quality)

Relevance to Problems & Needs-2

- DER integration is subpart of larger advances in distributed automation
- Changes to electrical system and communication system are needed
- Individual equipment types, such as DER, must be made interoperable with overall infrastructure
- DER/ADA project is currently targeted at one specific part of the architecture, namely the object models for DER devices

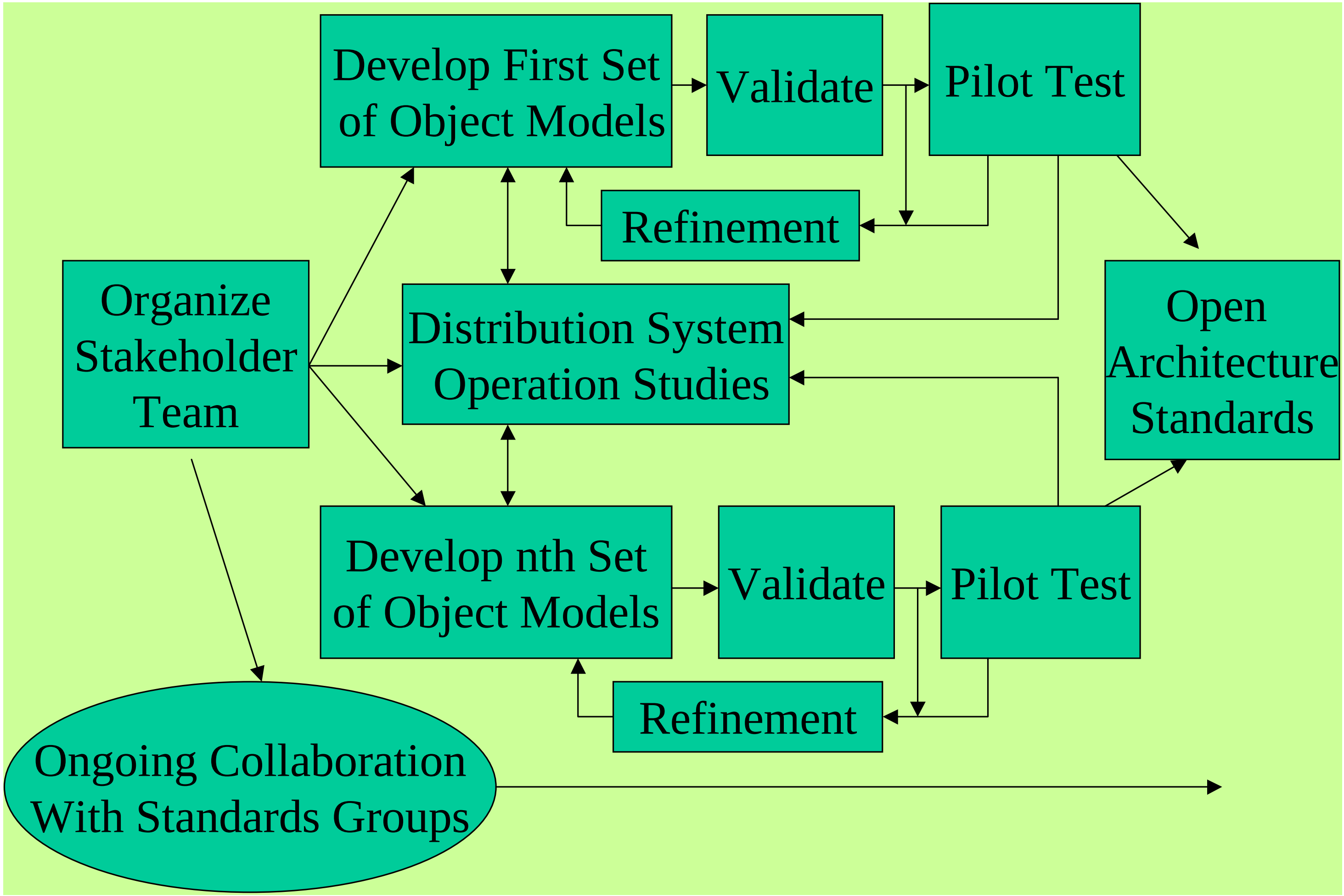
Technical Challenges of Current Practices

- DER use is increasing throughout the world
- DER installers are facing age-old issues: what communications standards and protocols to use for monitoring and controlling DER that is interconnected with electric utility distribution systems?
- Proprietary communication architectures have been used thus far, preventing full system interoperability and ease of integration
- Lack of a standard communication architecture approach increases
  - Technical difficulties
  - Installation costs
  - Maintenance costs

Project Objectives

- Develop, validate and pilot test DER device communication object models that will enable the strategic use of DER in ADA for functions such as
  - Routine energy supply, peaking capacity, voltage regulation, power factor control
  - Emergency power supply, harmonic suppression, and disaster recovery operations (e.g., intentional islanding or "microgrids")
- Promulgate the object models as international industry standards
  - Compatible with IEC 61850 and IEC61970
  - May include extensions to IEC 61850
  - Integrated into the IEEE P1547 series
- Coordinate with other related work, identify gaps, and implement plans for filling the gaps

Technical Approach



Life-Cycle Project Timeline with Milestones and Budget Estimate, by Fiscal Year (Calendar Year for E2I/CEIDS)

Year	2002	2003	2004	2005	2006	2007	2008	2009
$Million	0.25	0.625	1.5	2	2	1.5	1	0.5
Activity								
Develop Multiyear Plan	■							
Begin Team Development	■							
Obtain CEIDS Review and Approval	■							
Stakeholder Team Development		■	■	■	■			
ADA Operations Studies		■	■	■	■			
Round One Object Model Development		■	■					
Round Two Object Model Development			■	■				
Round Three Object Model Development				■	■			
Develop Object Model Validation Plan		■	■					
Round One Lab Validation and Field Tests			■	■				
Round Two Lab Validation and Field Tests				■	■			
Round Three Lab Validation and Field Tests					■	■		
Develop IEEE Standards	■	■	■	■	■	■	■	
Develop IEC Standards		■	■	■	■	■	■	
Facilitate Standards Adoption				■	■	■	■	■
Annual Updates To Multiyear Plan		■	■	■	■	■	■	■

Notes on Schedule and Budget Estimate

- Schedule and budget shown on prior slide reflect two accelerations from the plan at the start of the year
- Budget estimate shows E2I/CEIDS core program funding; cost sharing from vendor/utility/stakeholder teams will be sought for the validation and field test phases of the program
- Annual budgets are subject to approval by the CEIDS Steering Committee
- Multi-year project plan document is updated annually to reflect results and learning of current year
- A detailed multi-year view of schedule and milestones is updated regularly using Microsoft Project

Two-Year Schedule Detail

	2003				2004			
Quarter	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Activity								
Stakeholder Team Development	■	■	■	■	■	■	■	■
ADA Operations Studies		■	■	■	■	■	■	■
Develop Untested Object Models (2 DER Types)		■	■	■				
Explore Software Validation Options			■	■				
IEEE Standards Development	■	■	■	■	■	■	■	■
IEC Convener Proposal		■	■					

FY03 Progress and Accomplishments-1

- Project accomplishments are ahead of the schedule that was undertaken at start of 2003, due to two accelerations of activity
  - Project team bolstered to get first two object models drafted by end of 2003, rather than mid-2004
  - Validation trials initiated in 2003, to clarify details of validation process sooner
- Standards group activity
  - Convener proposal developed and submitted to IEC and under review at this time; presented at TC-57 plenary session in mid-October (accelerated from 2004, because we were ready to do it ahead of the planned schedule)
  - PI is chairing IEEE P1547.3 working group operations; first document being drafted

FY03 Progress and Accomplishments-2

- Two draft object models near complete
  - Reciprocating engines and fuel cells
  - These were used in current form as a necessary supporting document for the convener proposal to IEC
- First phase of studies of distribution operations with DER near complete—has been beneficial to object model development and to pinpointing other DER/ADA work needs
- Extended teams formed and two workshops held with each
  - Stakeholder team
  - Technical working team

FY03 Progress and Accomplishments-3

- In progress with the goal of completion yet this year:
  - Initial validation process trials to clarify the requirements for the future laboratory validation and field test processes for object models
  - Complete the first two draft object models and supporting basis (use cases, etc.)
  - Update of multi-year project plan, based on learning and results of current year (2003)

Example Results: Close-Up View of Server with Logical Nodes

Logical Device Server

- Communication Protocols
- Communication Services
- Device Applications
- Special Calculations
- Proprietary Database
- Connections to Physical Device

Logical Device Logical Nodes

- LN DRGN
- LN GSYN
- LN DIES
- LN MMSU0
- LN MMSU1
- LN MMSU2

LN DRGN – Data Objects and CDCs

Status Data Objects

SPS: GenSt – Generator On/Off Status

SPS: GenSyn – Synchronized

Measured Value Objects

MV: TotkWh – Total kWh

CTE: TotStarts – Total num of starts

Control Data Objects

DPC: GenCtl – Turn generator on or off

DPC: GenRL – Raise/lower generator

Setpoint Control Objects

ASG: GenOperLev – Generator operating level

ASG: GenPF – Power factor setpoint

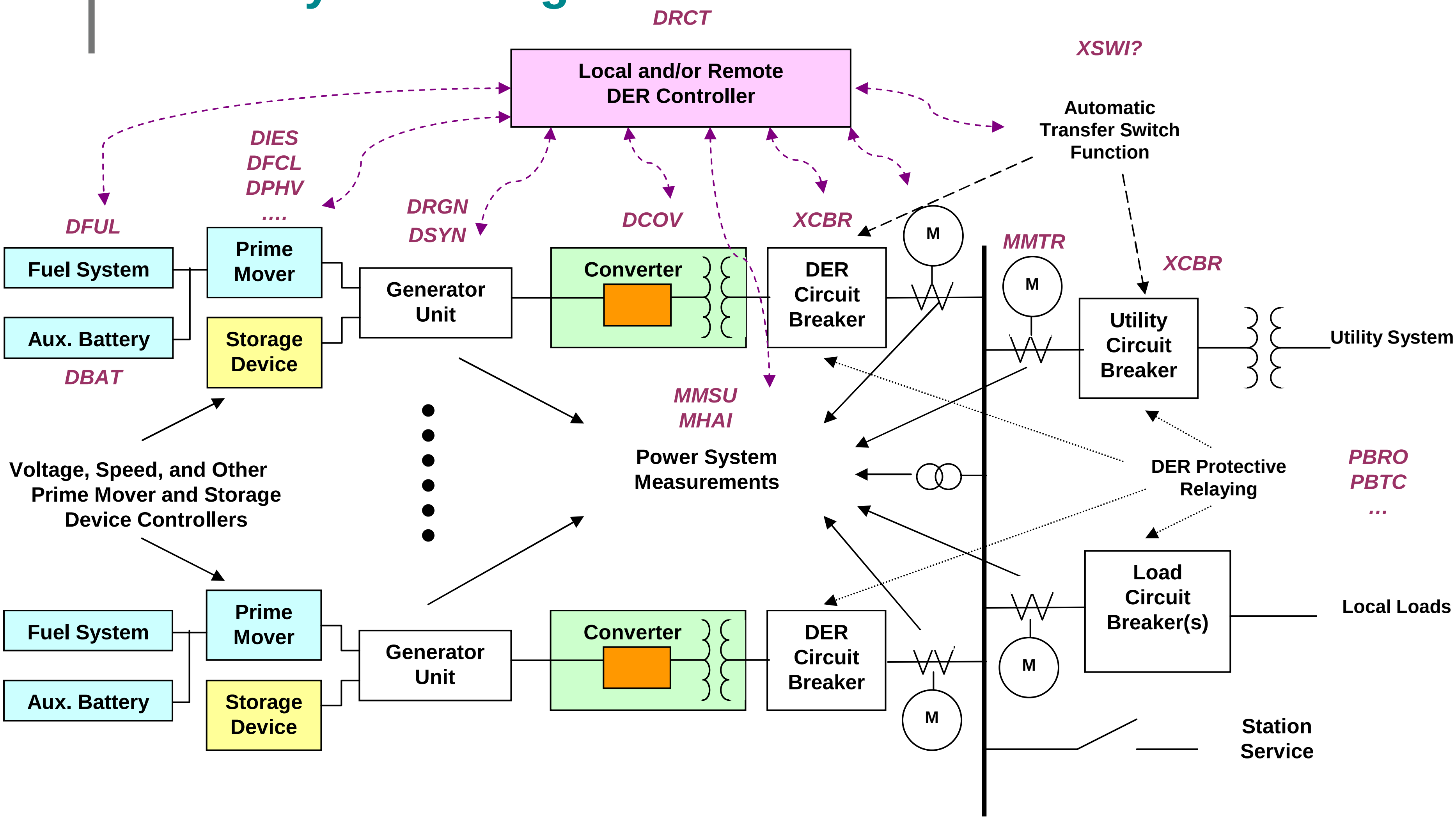
Example Results: List of DER Logical Nodes

(LNs with tan background are new; other LNs already exist in IEC61850)

Logical Node	Description
	DER Device Characteristics
DRCT	*DER Controller*
DRGN{n}	*DER Generator Characteristics and Control (units 0 – n)*
DSYN{n}	*DER Synchronization: GSYN0-n = Generator Unit*
{Multiple LNs} Prime Mover or Storage	*DER Prime Mover or Storage Device Characteristics and Control (e.g. DIES, DFCL). This LN varies, depending upon the DER technology*
DCOV{n}	*DER Converter/Inverter Characteristics: CONV0-n = Converter/Inverter Unit. This LN varies, depending upon the need for a converter/inverter*
DFUL	*Fuel Systems*
DBAT	*Battery Systems*
	Electrical Power System Measurements
MMSU{n}	DER voltage, current, frequency, & var measurements: e.g. MMSU0 = DER Alternator; MMSU1 = local power; MMSU2 = utility power. This LN is similar to MMXU, but contains additional attributes related to statistics
MMXU{n}	DER voltage, current, frequency, & var measurements without statistical information. Alternative to MMSU. (MMXN if single phase)
MHAI{n}	Power System Harmonics (MHAN if single phase)
MMTR{n}	DER Energy Meters: MMTR0 = Total generation; MMTR1 = Net generation; MMTR2 = Transferred to power system; MMTR{m} = submetering

Logical Node	Description
	Circuit Breakers
XCBR{n}	DER Circuit Breakers: XCBR0 = Load Breaker; XCBR1 = Common Coupling Breaker; XCBR2 = Interface Point Breaker; XCBR3-n = DER Generator Unit Breakers
	Protection Function
PBRO{n}	DER Protective Relaying base logical node: for PUVR, POVR, PTOC, PDPR, PFRQ
PBTC{n}	DER Protective Relaying timing logical node: for PUVR, POVR, PTOC
RREC{n}	Reclosing relay for circuit breakers
PRCF{n}	*DER Rate of Change of Frequency Relaying*
Pxxx {n}	*Other protection functions (TBD)*
	Automatic Transfer Switch
ATSC{n}	DER Automatic Transfer Switch Characteristics
SWIT{n}	DER Automatic Transfer Switch (ATS) status
SDRV{n}	DER ATS Control
AUTO{n}	DER ATS Automatic Control Logic
FIND{n}	DER ATS Fault Indicator
	Administrative Function
DMIB{n}	SNMP Management Information Base for DER Installations

Example Results: DER Logical Nodes Imposed on Power System Diagram



Prime Mover = Microturbines, Fuel Cells, Photovoltaic Systems, Wind Turbines, Reciprocating Engines, Combustion Turbines

Storage Device = Superconducting Magnetic Energy Storage, Battery, Pumped Hydro, Flywheels, Micro-flywheels

Converter = DC to AC, frequency conversion, voltage level conversion

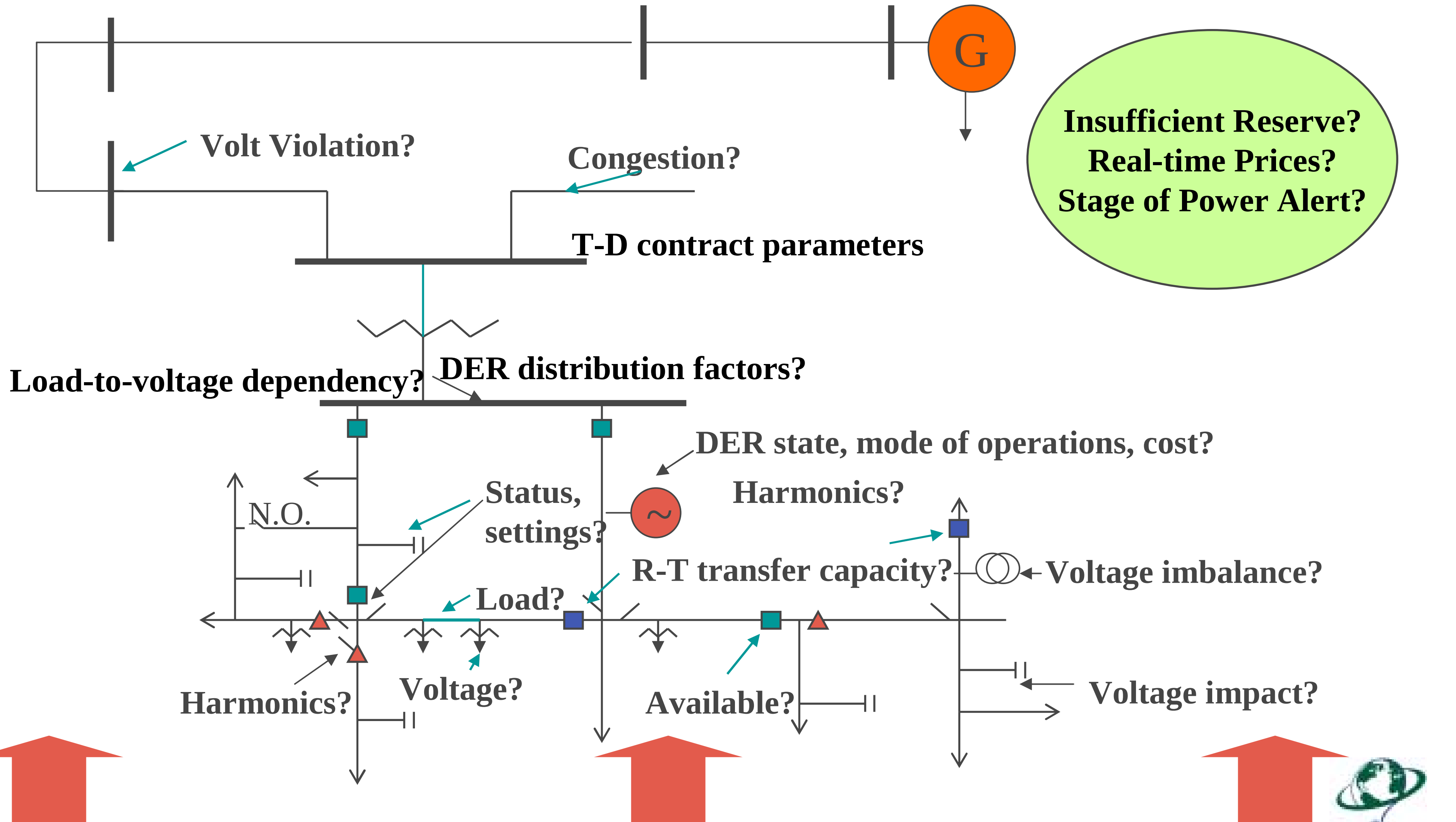
Tasks from Studies of ADA Operations with DER to Determine the Impacts on Object Models (Phase 1, 2003)

- Task 1: Define the DER-Related Changes in Distribution Operation Functions and Processes under Normal Operating Conditions
- Task 2: Define the Needed DER-Related Changes in the Applications Controlling Distribution Systems under Normal Operating Conditions
- Task 3: Define the Resulting Requirements for Processes and Object Models for Normal Operating Conditions

Example Results from Operations Studies: Operating Conditions to Consider

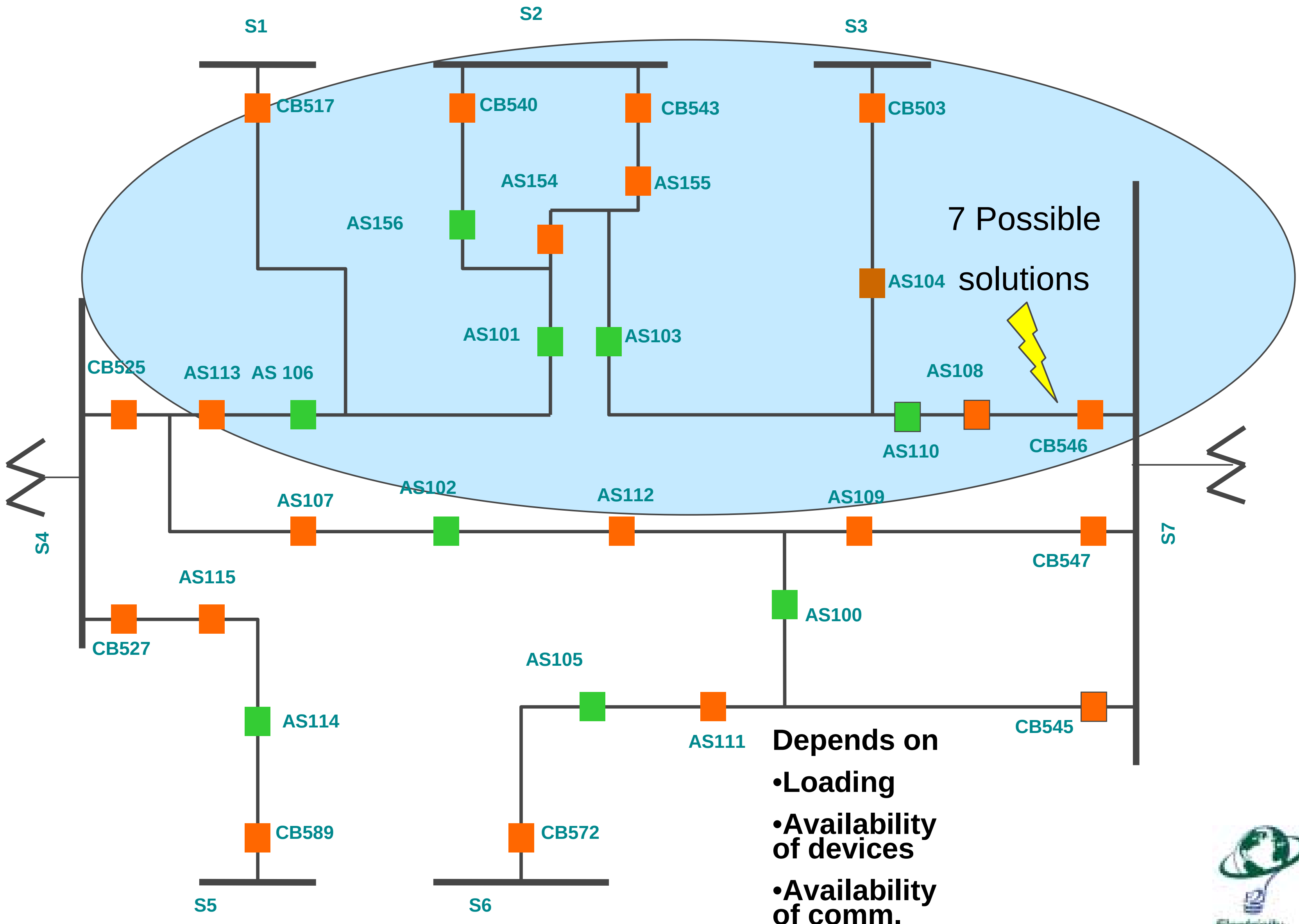
- Normal steady-state conditions
- Post-fault steady-state conditions
- External disturbances (bulk power system disturbances, other same-bus feeder disturbances)
- Disturbances in proximity of DER (de-energization and faults in the same feeder)

Results from Operations Studies: What Do We Need to Know to Optimally Control Distribution Operations with DER?



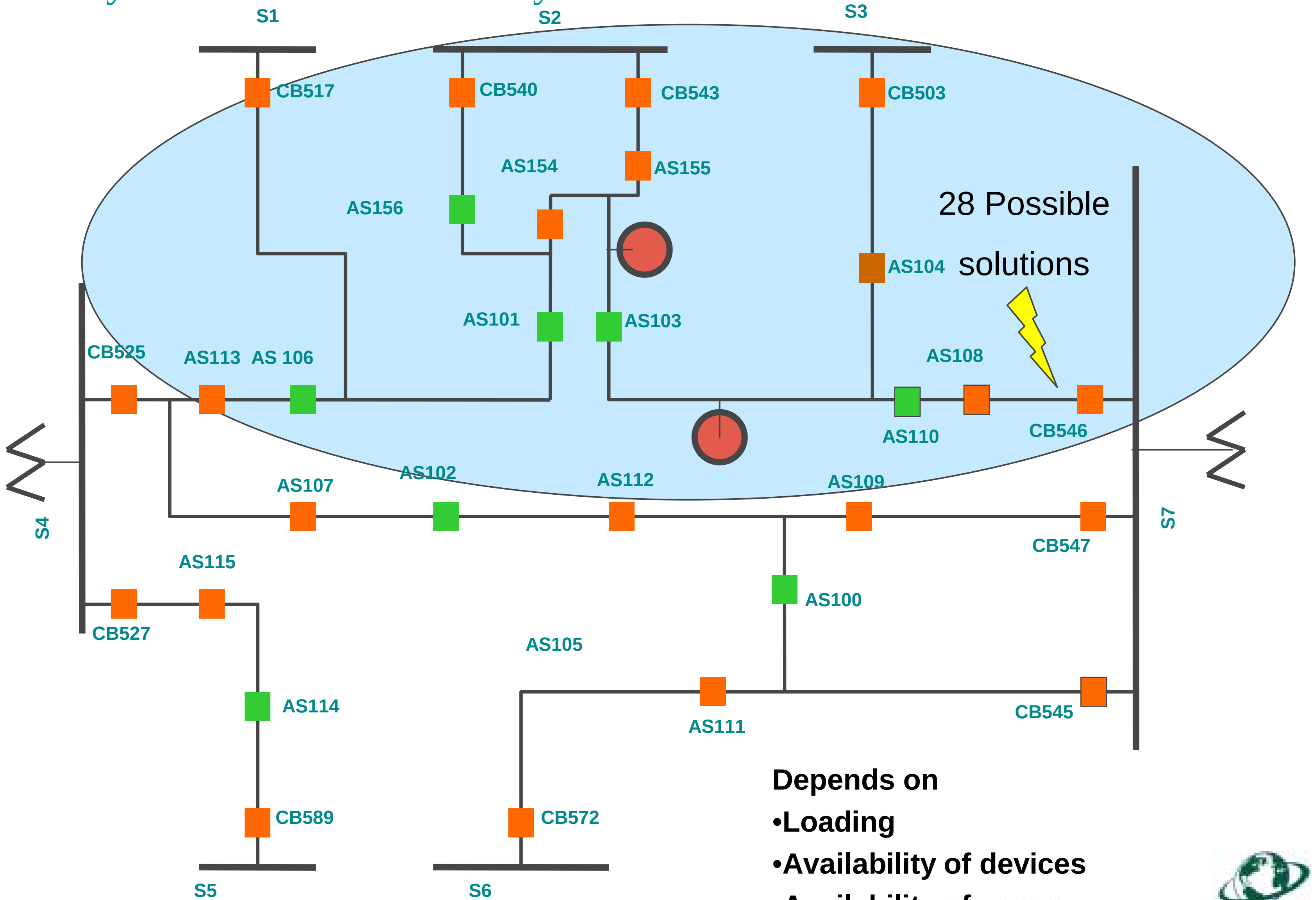
Distribution and Transmission Facility Parameters and Customer Data

Results from Operations Studies: Contingency analysis w/o DER - Remotely Controlled Devices Only



Depends on
- **Loading**
- **Availability of devices**
- **Availability of comm.**

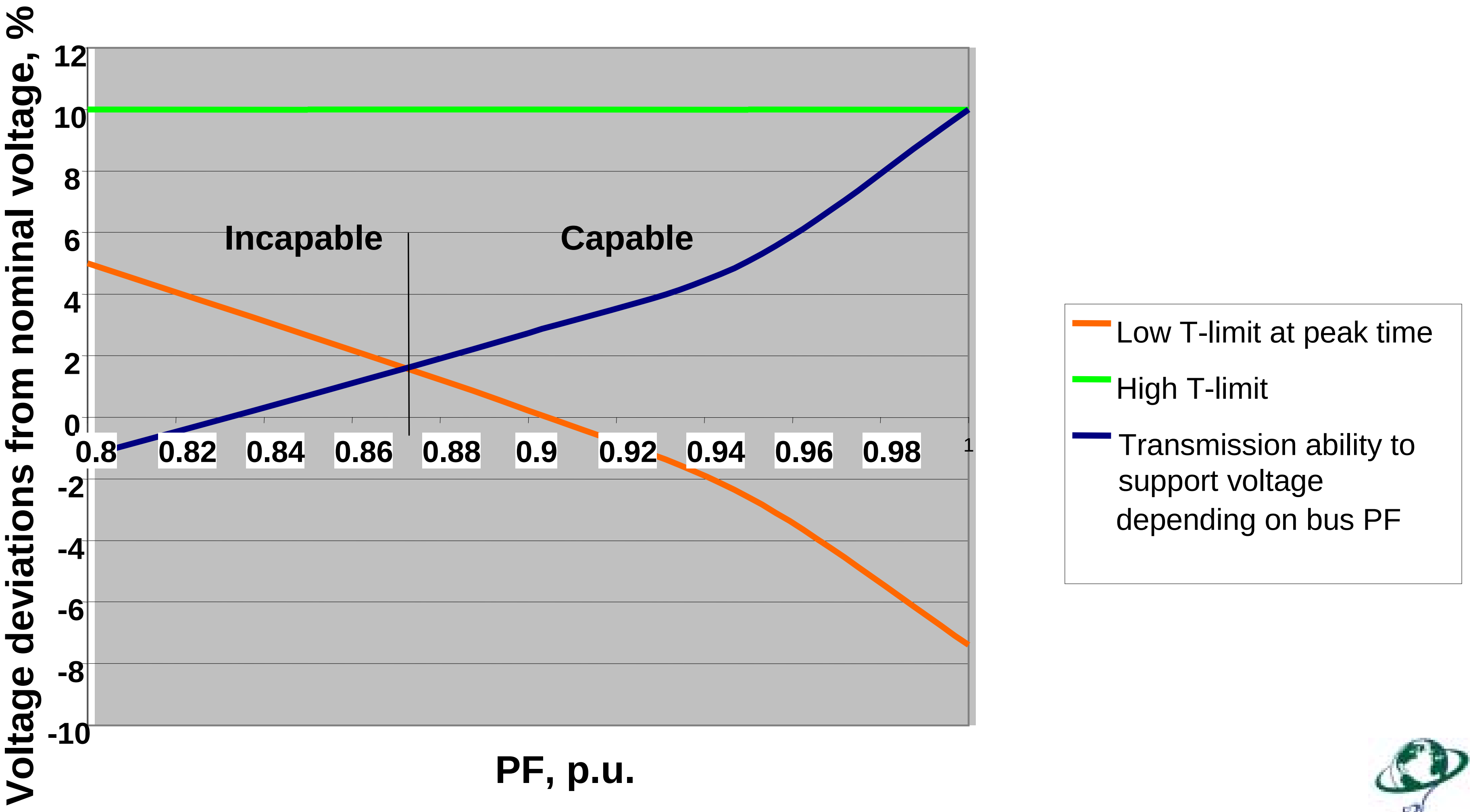
Results from Operations Studies: Contingency analysis with DER - Remotely Controlled Devices Only



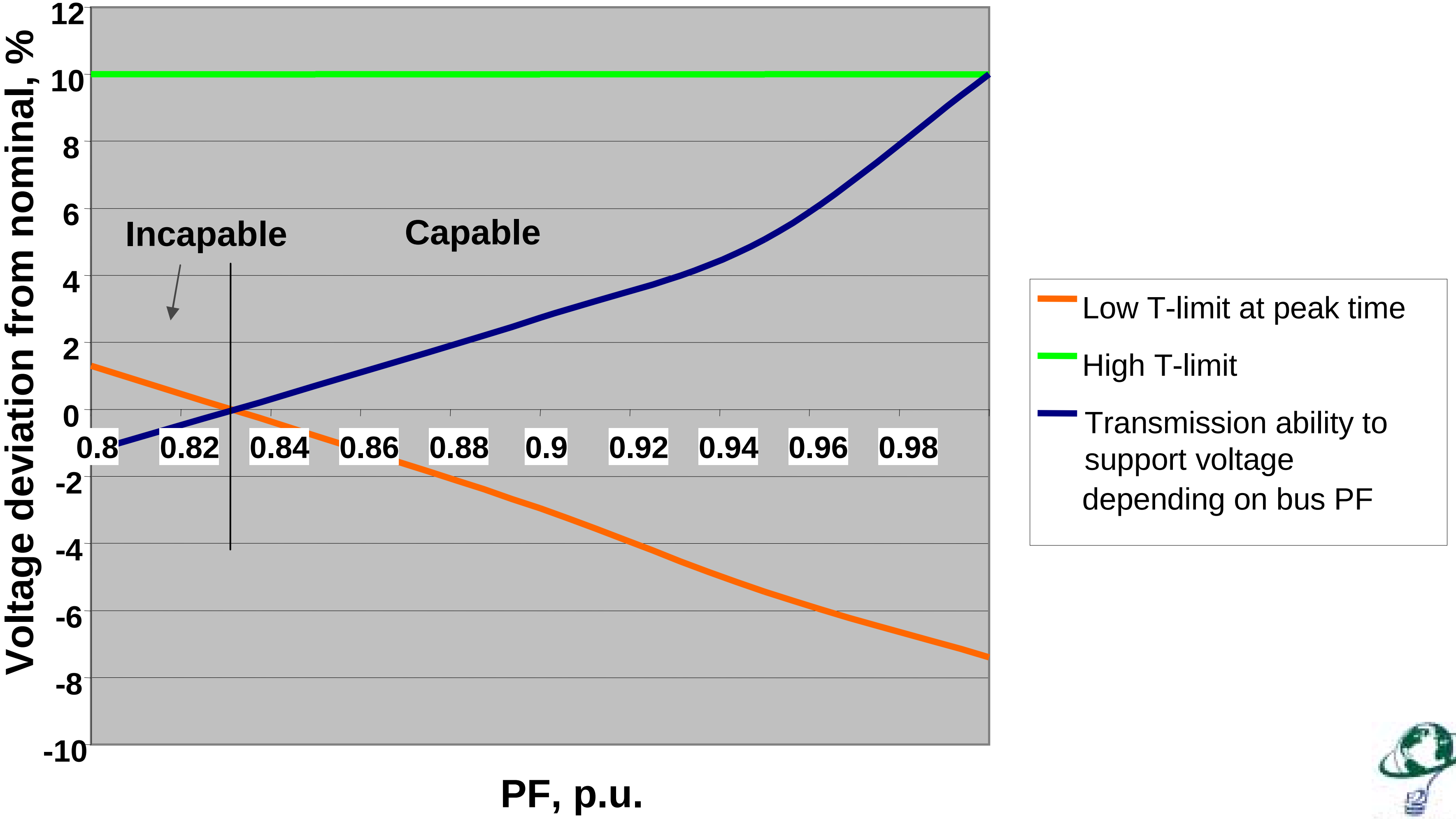
28 Possible solutions

Depends on
- **Loading**
- **Availability of devices**
- **Availability of comm.**
- **State of DER**

Results from Operations Studies: Distribution requirements and transmission capability to support voltage at the high-voltage bus with DER OFF

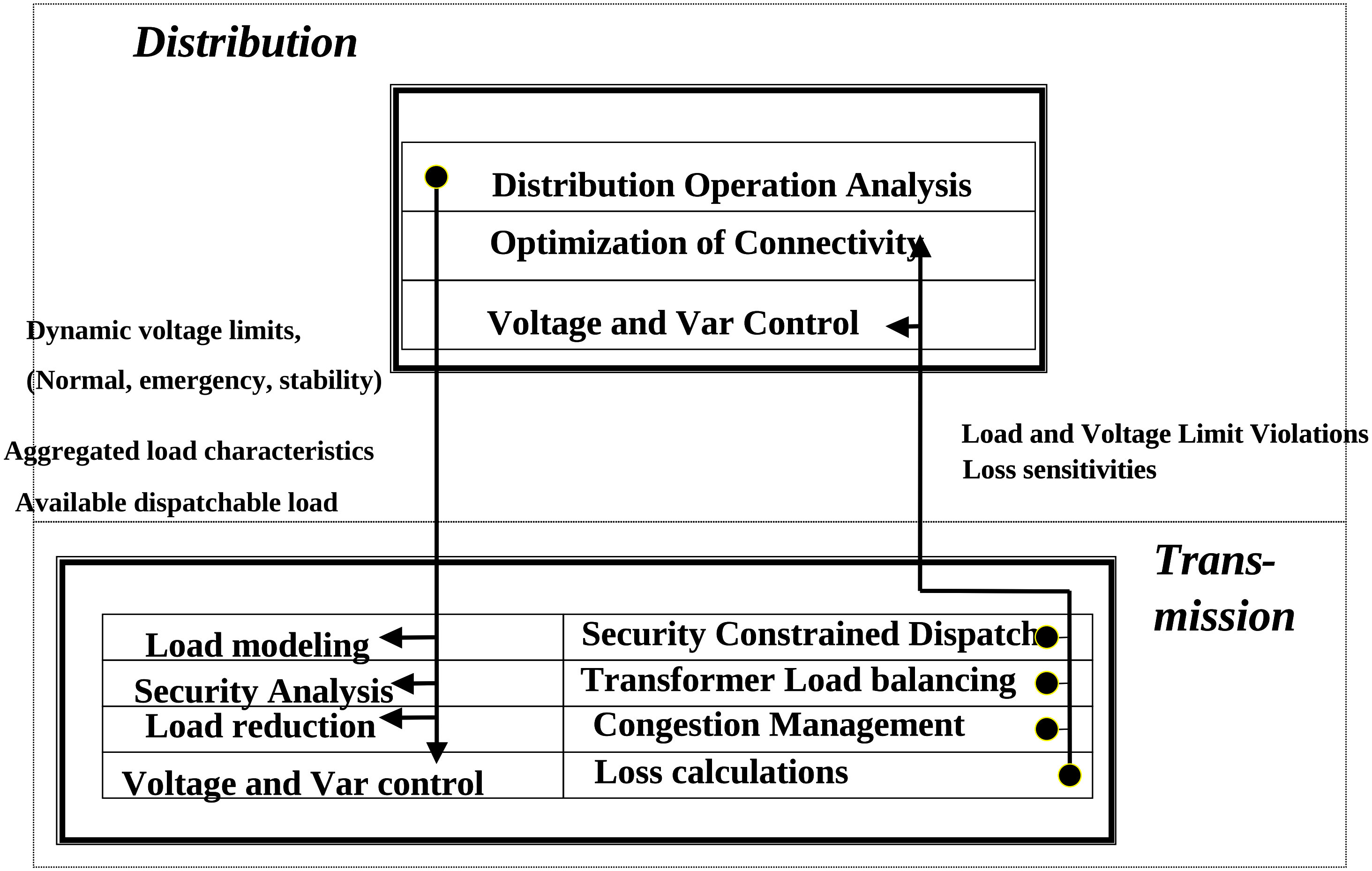


Results from Operations Studies: Distribution requirements and transmission capability to support voltage at the high-voltage bus, with DER ON



Results from Operations Studies: Coordination of distribution operations with bulk power system operations

INFORMATION FLOW BETWEEN DISTRIBUTION AND TRANSMISISON PROCESSES



Planned Activities for FY04

- Define and establish object model laboratory validation process, using draft reciprocating engine generator and fuel cell object models
- Establish the necessary facilities and capabilities for laboratory validation testing
- Organize stakeholder teams to participate with cost sharing in first round of field tests that will follow starting in 2005
- Continue to develop the relationships with the IEC and IEEE standards groups
- Draft next two object models (tentatively photovoltaics and microturbines)
- Conduct additional studies of ADA operations with DER to aid in object modeling
- Build and strengthen the stakeholder participation in the project

Brief Summary of Out-Year Activities-1

- **2005**
  - **Field tests for DER with object models from first round (reciprocating engines and fuel cells)**
  - **Laboratory validation of object models from second round (tentatively photovoltaics and microturbines)**
  - **Begin development of third round of object models**
- **2006**
  - **Field tests for DER with object models from second round**
  - **Laboratory validation of object models from third round**
  - **Promulgate first-round models as standards**
  - **Implement standards adoption plan**
- **2007**
  - **Field tests for DER with object models from third round**
  - **Promulgate second-round models as standards**
  - **Continue standards adoption activities**

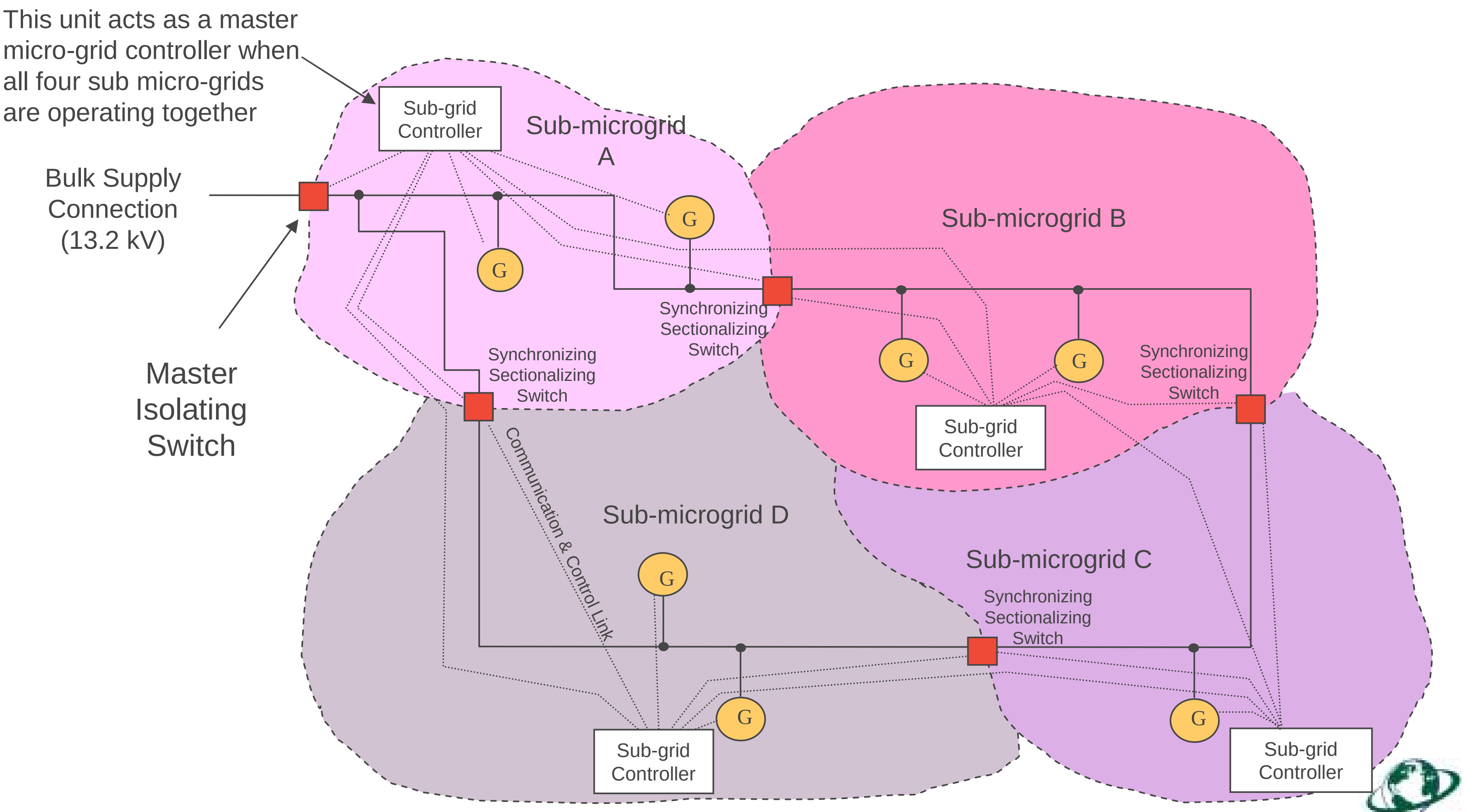
Brief Summary of Out-Year Activities-2

- 2008
  - Promulgate third-round models as standards
  - Continue standards adoption activities
- 2009
  - Complete standards adoption activities
- 2005-2009
  - Selectively initiate other ADA electrical and communication architecture work as may be identified by the current work of DER/ADA Project, by EPRI's ADA requirements definition project, or elsewhere
    - Coordinate new activities with work elsewhere
    - Initiation of such activities is dependent on CEIDS board approval if the work is to be done under CEIDS and EPRI approval if work is to be done under EPRI

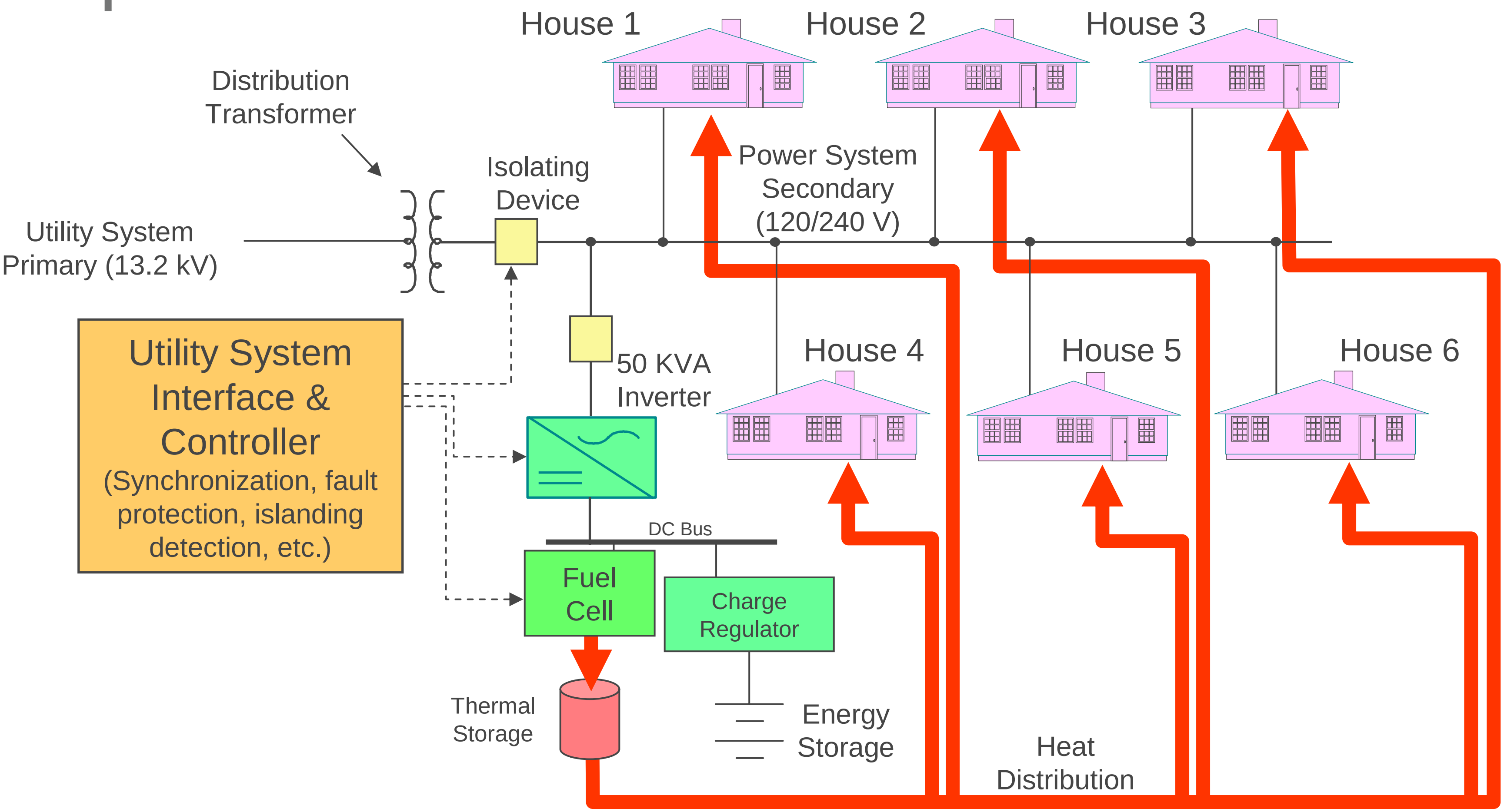
Impacts and Benefits

- Provide one international standard that would define the communication and control interfaces for all DER devices
- Simplify DER implementation
- Encourage and facilitate more widespread use of DER and ADA
- Increase the value of DER functionality (capabilities) in utility distribution system operations
- Reduce DER installation and maintenance costs
- Improve reliability and economics of power system operations
- Enable new system-level ADA options

Example of New ADA Option: Adaptable Microgrid – breaks apart into multiple regions



Impacts and Benefits: Another Example



Interactions and Collaborations

- Stakeholder team formed—two workshops conducted in March and September
  - Seek broad stakeholder input to overall strategic direction of project
  - Establish interest in object model implementations and field testing
- Technical working team formed—two workshops conducted in April and September
  - Get broad technical expert review of the work
  - Get technical inputs to help perform the tasks
- All interested parties should let me know if they want to be involved in these teams
- The two teams above include broad representation from vendor, utility, government, and other stakeholder communities

Interactions and Collaborations: New Work Item Proposal (Convener Proposal) Submitted for IEC Working Group Under TC-57

- Working Group Title: "Communications Systems for Distributed Energy Resources (DER)"
  - Provide one international standard that would define the communication and control interfaces for all DER devices
  - Simplify DER implementation from a technical standpoint
  - Reduce installation and maintenance costs
  - Enable new system-level ADA options, such as microgrids
  - Integrate communications for DER in ADA with the principal body of international standards for utility communication architecture (IEC 61850, IEC 61970, and extensions)
- Ongoing direct participation in IEC TC-57 to follow, with PI as the new working group convener

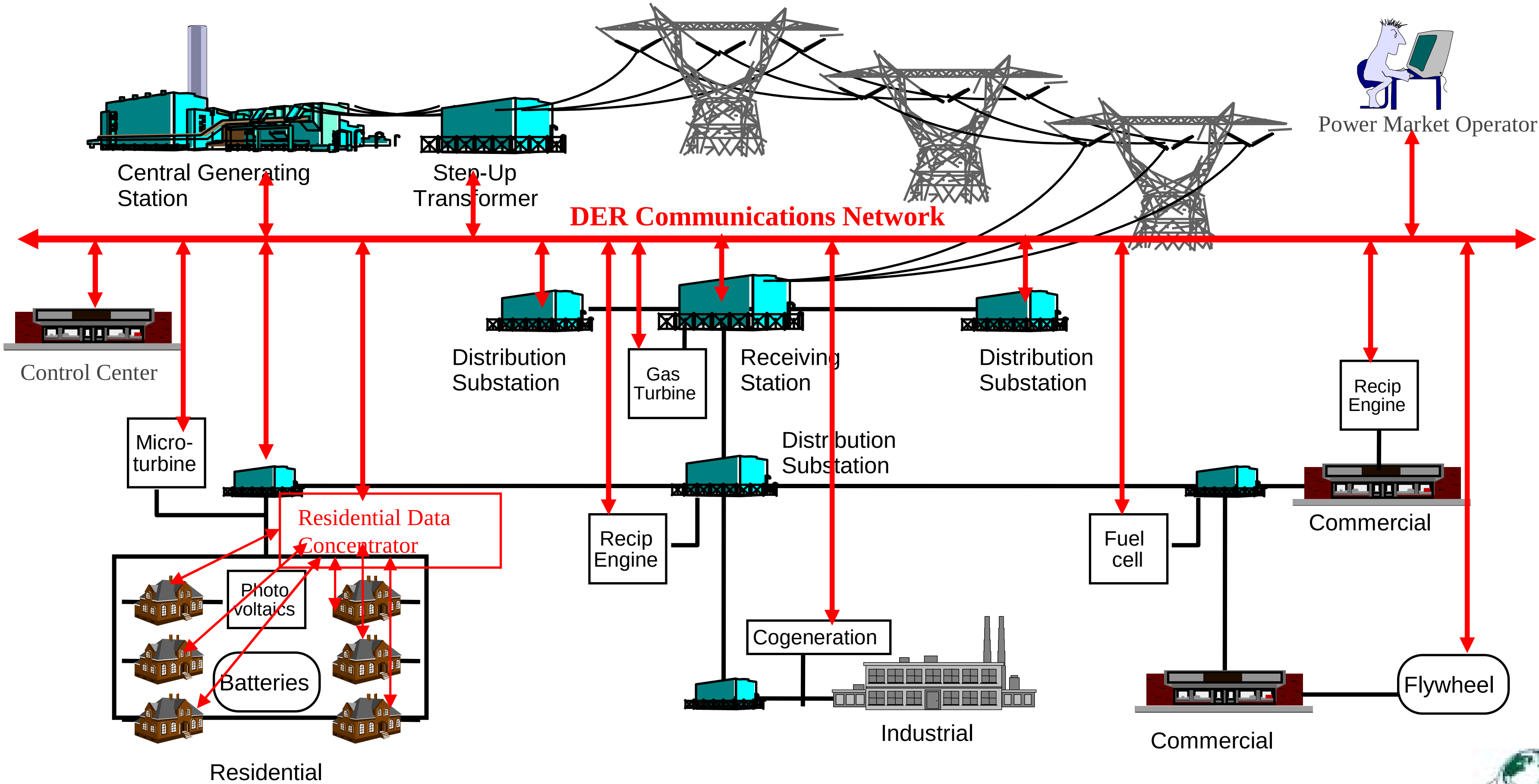
Other Interactions and Collaborations

- Collaboration/coordination with other IEC TCs will be necessary as a part of the work of the new TC
  - TC88—Wind turbines
  - TC82—Photovoltaic technologies
  - TC105—Fuel cell technologies
- Collaboration with related EPRI and E2I programs, existing and planned, will be maintained
- Continue PI's role as Chair of IEEE P1547.3 and other involvement in the P1547 series of standards under IEEE SCC21, including serving as a member of SCC21
- Goal is to achieve an international standard document that is jointly published by IEC and IEEE

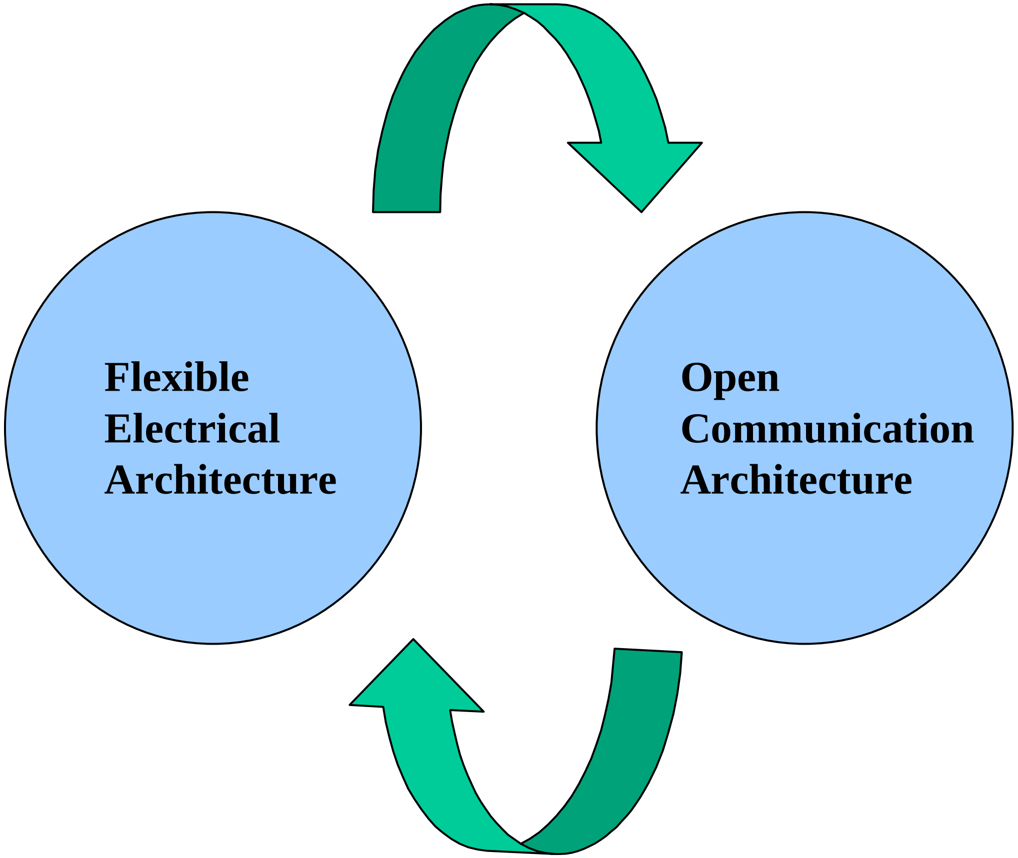
Interactions and Collaborations: Maintain Working Relationship with Utility Communications Architecture International Users Group

- Develop new DER communications protocols, services, and templates that would be proposed to IEC for standardization
- Provide conformance testing of new DER protocols in vendor products
- Provide a forum for utilities and vendors to discuss and resolve technical problems and issues regarding implementation and operations
- Provide tutorials for utilities, vendors, and consultants to learn about DER communication, protocols, and services
- Lay groundwork for adoption of the DER communication standards

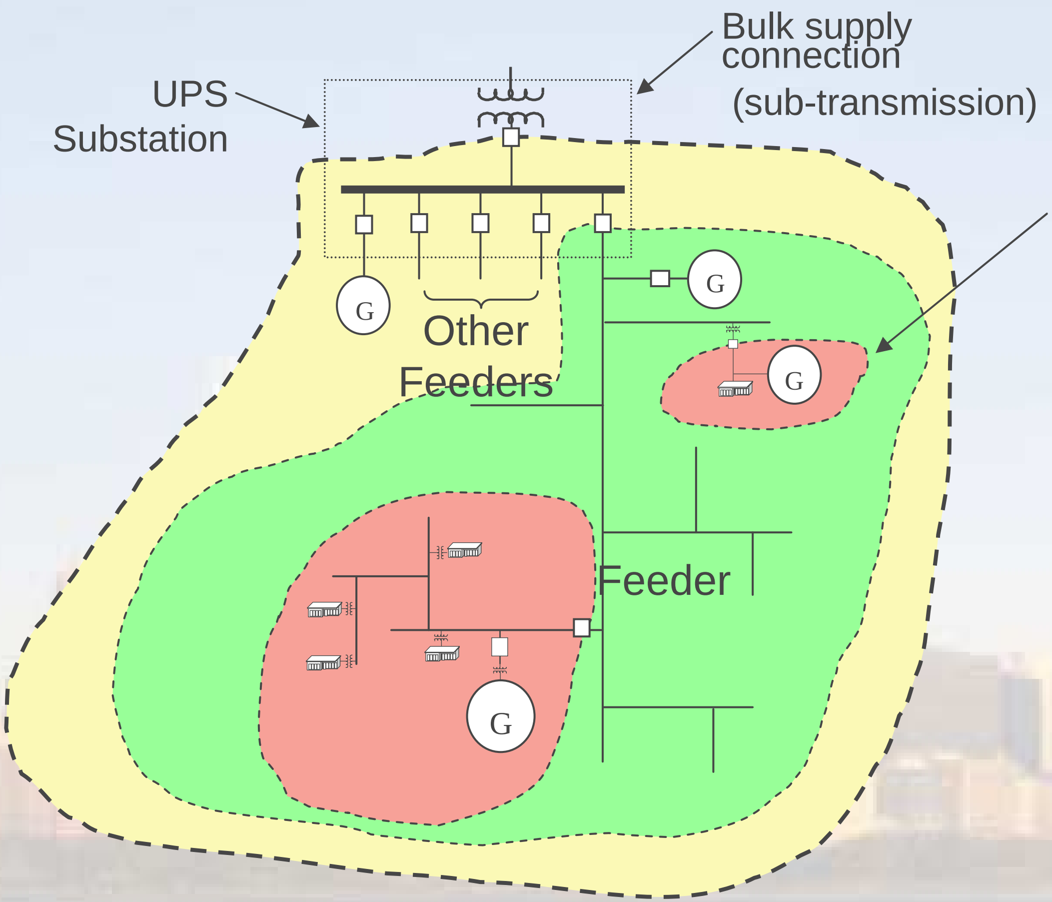
Recap: DER Interoperability in ADA



Synergy of This and Other Projects: Empowering the Power System



Questions/Discussion



ADA Enables True Full Integration of DER

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