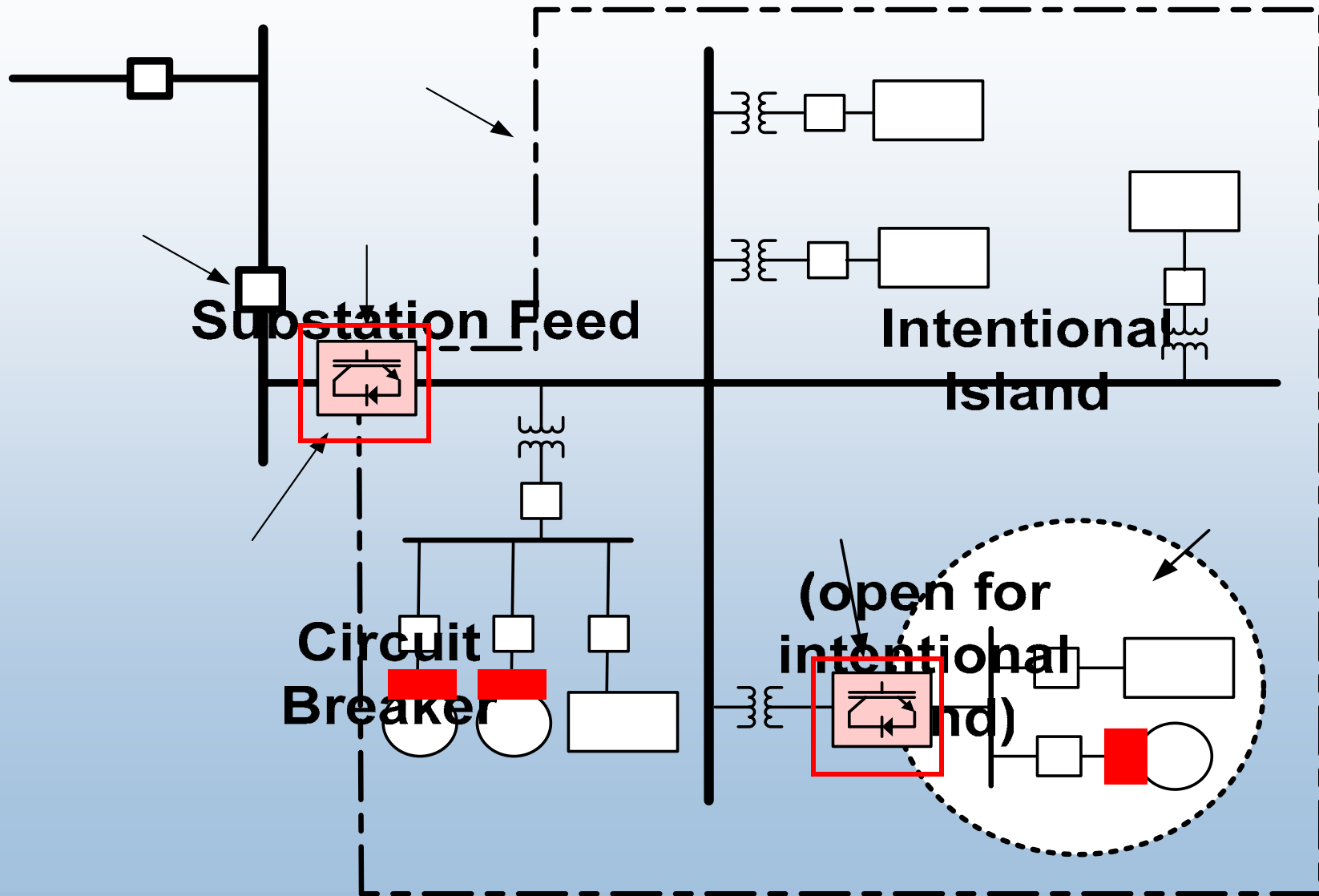


# Microgrids - Hardware Testing and Standards Development

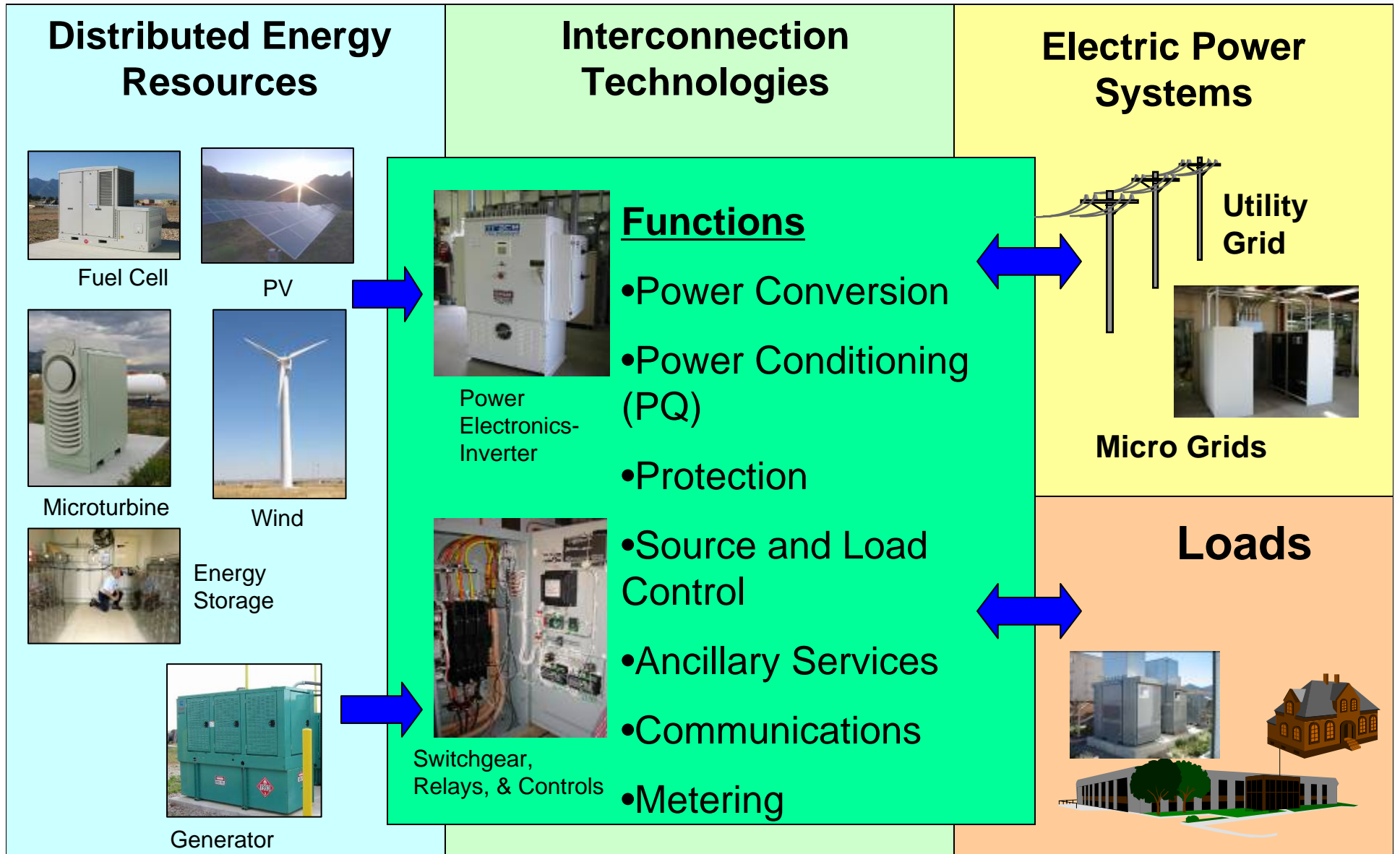
**Ben Kroposki**

**Distributed Energy Systems Integration**  
National Renewable Energy Laboratory

# Microgrids – Improving Grid Reliability



# Grid Integration of DER

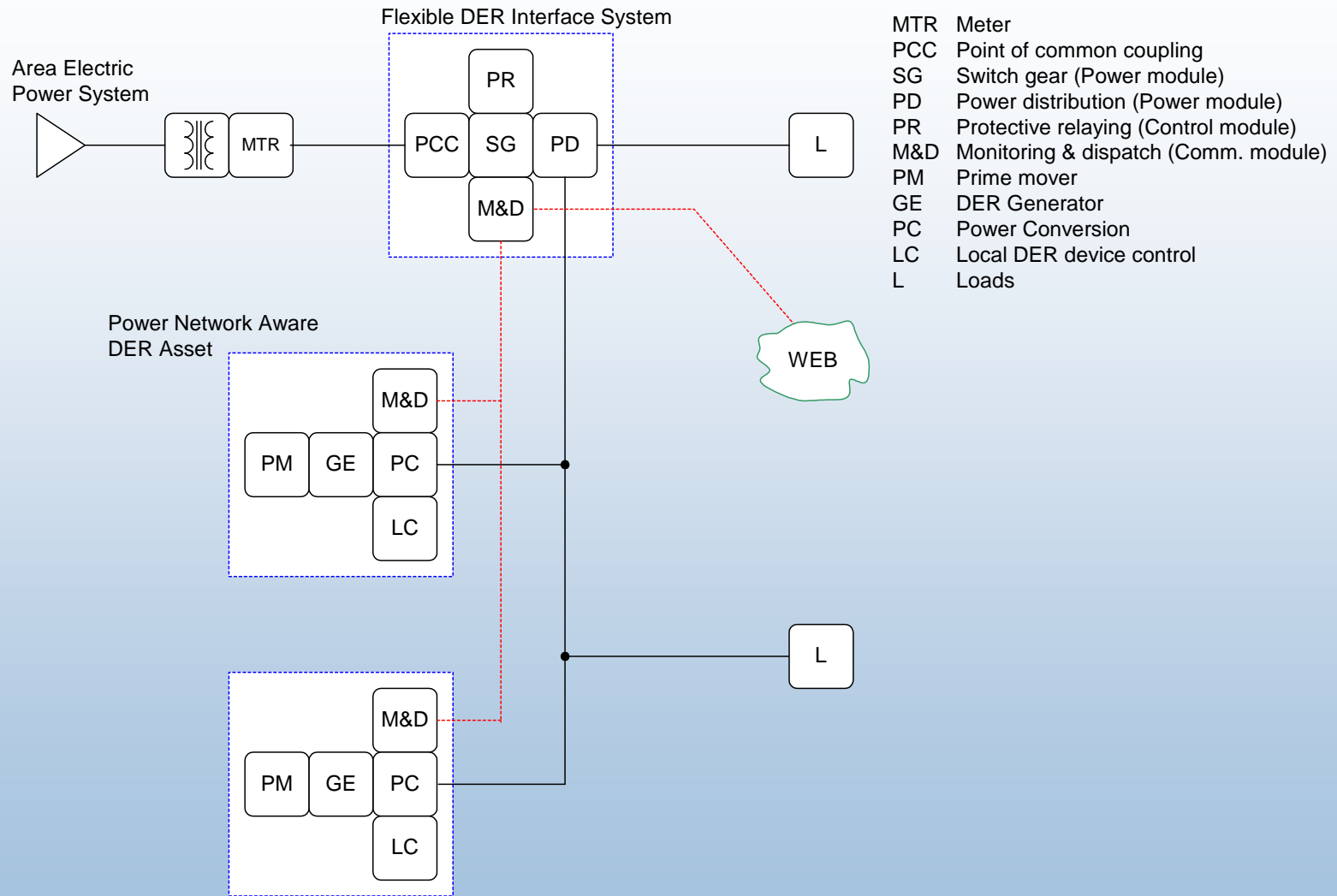


# Development of High-Speed Static Switch for Microgrid Applications

- NREL, Northern Power Systems, and California Energy Commission developed at DER Switch
- Circuit Breaker, SCR, and IGBT hardware with same controller
- Tested CB and controller equipment at Northern and NREL
- SCR based unit installed in CERTS microgrid

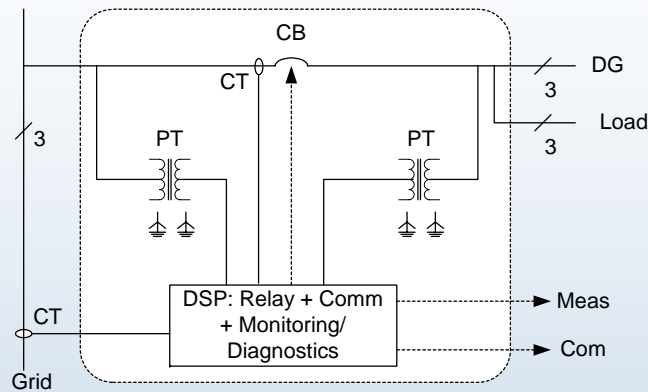


# DER Switch

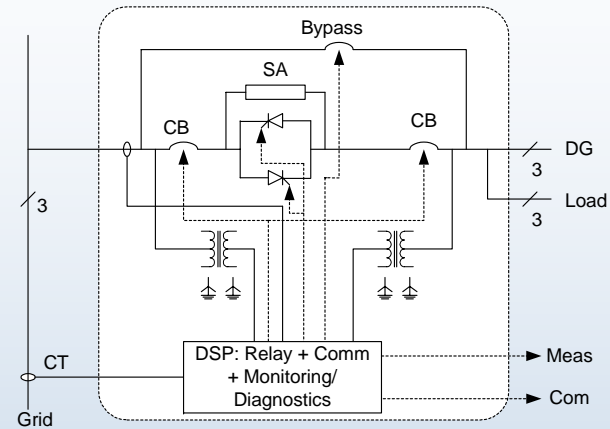


DER Power Network Block Diagram

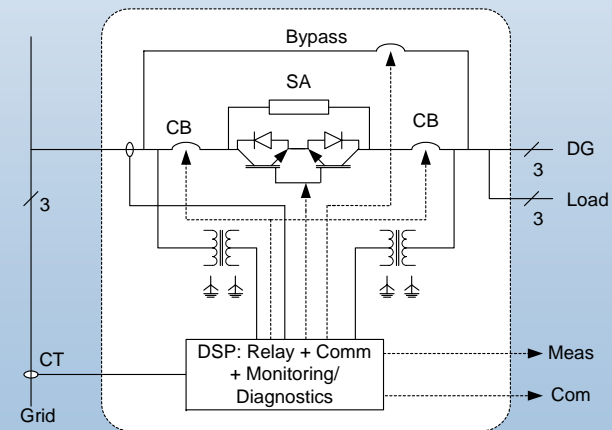
# DER Switch – Possible Configurations



## Circuit Breaker



## SCR



## IGBT

# Testing on DER Switch

## Relay Function Testing

- Undervoltage (27)
- Overvoltage (59)
- Overfrequency (81O)
- Underfrequency (81U)
- Phase sequence (46)
- Instantaneous overcurrent (51)
- Time overcurrent (50)



Omicron CMC 256 – Secondary injection test set

## IEEE 1547 Testing

- Over/undervoltage
- Over/underfrequency
- Synchronization
- Reverse power
- Unintentional islanding.

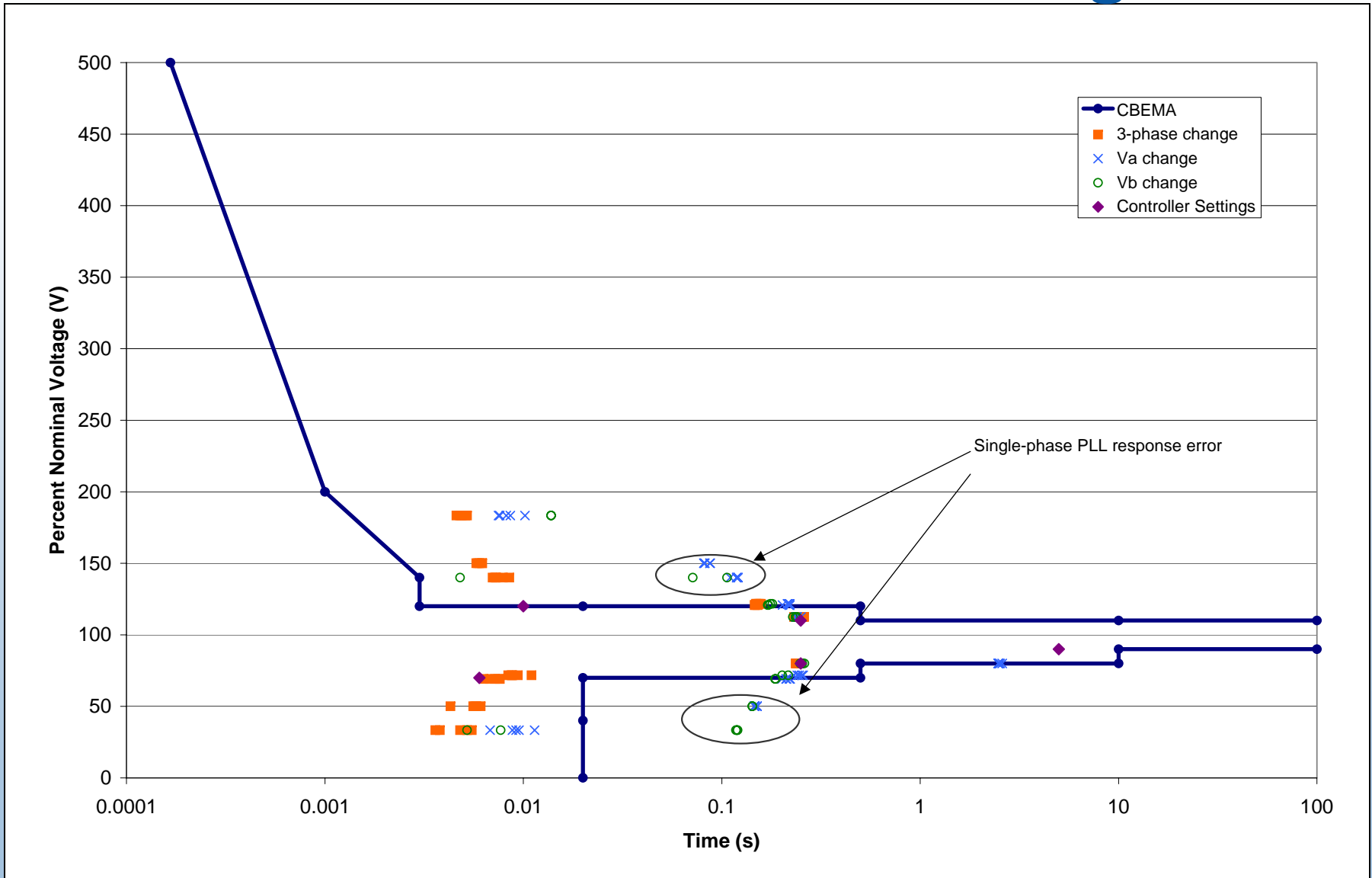
## Power Quality Testing

- CBEMA-ITI curve



Utility Grid Simulators – Primary injection test set

# CBEMA-ITI Curve Testing





# IEEE 1547 Series Standards

**1547-2003** Standard for Interconnecting Distributed Resources with Electric Power Systems

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

## Current Projects

**P1547.2** Application Guide for IEEE 1547 Standard for Interconnecting DR with EPS

**P1547.3** Guide for Monitoring, Information Exchange and Control of DR

**P1547.4** Guide for Design, Operation, and Integration of DR Island Systems with EPS

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

**P1547.6** Recommended Practice for Interconnecting DR With EPS Distribution Secondary Networks

## Future Projects

**DG Specifications and Performance**

**Guide for Interconnection System Certification**

**Guide for Grid/DG Impacts Determination**

**Guide for DR Power Electronics**

**Microgrids**

**Urban distribution networks**

# IEEE P1547.4 (Draft 2)

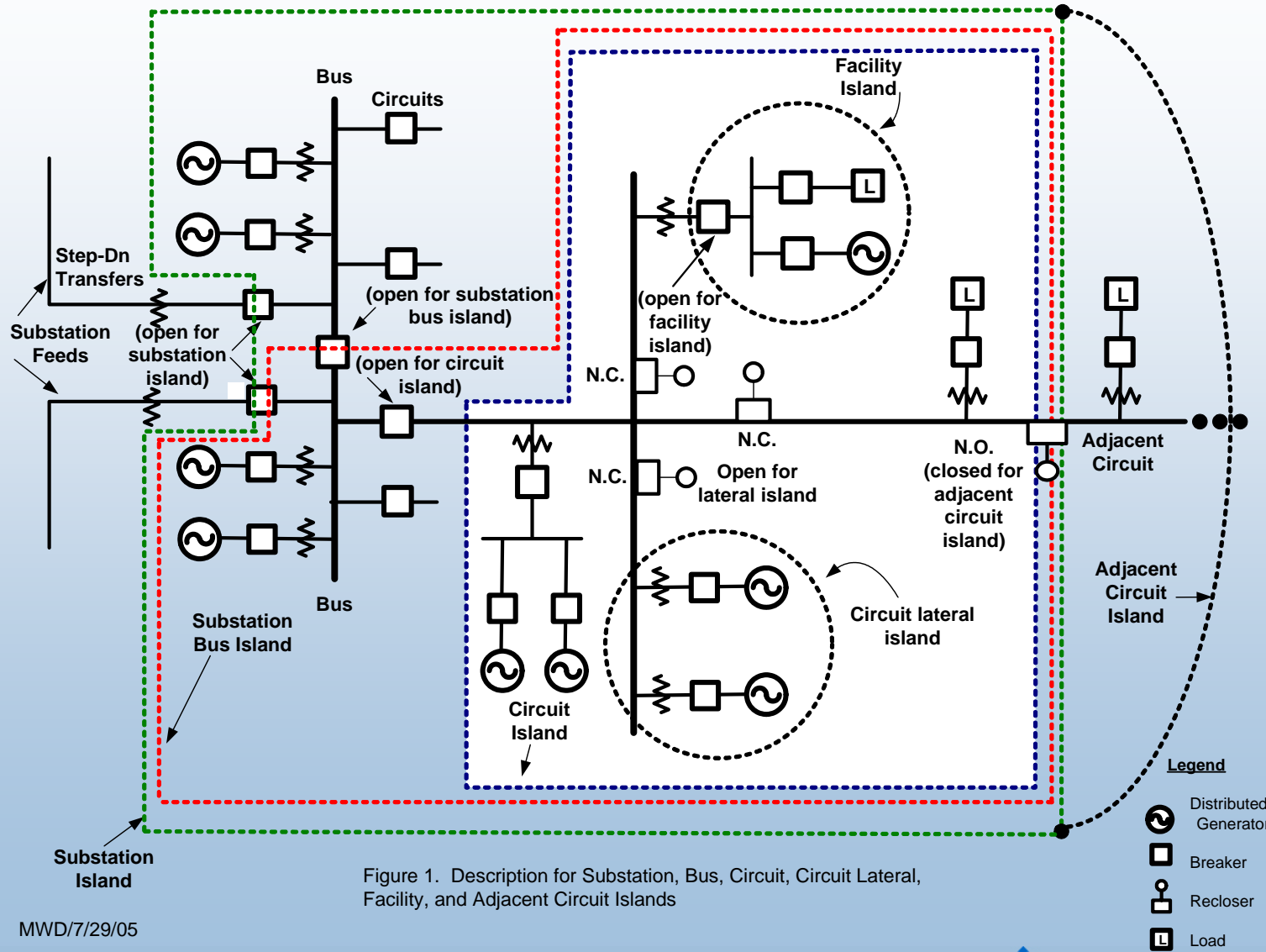


Figure 1. Description for Substation, Bus, Circuit, Circuit Lateral, Facility, and Adjacent Circuit Islands

MWD/7/29/05

# IEEE P1547.4 (Draft 2)

## **4.0 Electrical System Characteristics**

- 4.1 DR Island System Overview
- 4.2 Characteristics of loads
- 4.3 Characteristics of EPS (Local and Area)
- 4.4 Characteristics of DRs and interconnection systems
- 4.5 Methods of DR voltage regulation and frequency control
- 4.6 Area EPS Fault Clearing
- 4.7 Methods for detecting Islands

## **5.0 Functionality of the DR Island System**

- 5.1 EPS connected (normal parallel operation)
- 5.2 Transition to island mode
- 5.3 Island mode
- 5.4 Reconnection mode

## **6.0 Planning and Engineering of DR Island Systems**

- 6.1 Load Requirements
- 6.2. Electric Power System (EPS) Planning
- 6.3 Systems Studies
- 6.4 Additional Planning Considerations
- 6.5 Testing and Commissioning

## **7.0 Operation and Management of DR Island Systems**

- 7.1 Protection Consideration
- 7.2 Central Dispatch Control Case
- 7.3 Distributed Dispatch Case
- 7.4 Communication and information exchange
- 7.5 Operating the system on a real time basis
- 7.6 Time length of operation