Grid Interconnection Standards for Distributed Resources and Microgrids

Dr. Liuchen Chang
University of New Brunswick
Fredericton, NB, Canada
LChang@unb.ca

Dr. Sudip K. Mazumder
University of Illinois
Chicago, IL, USA
Mazumder@uic.edu

UNB 225 YEARS A CELEBRATION OF SPIRIT

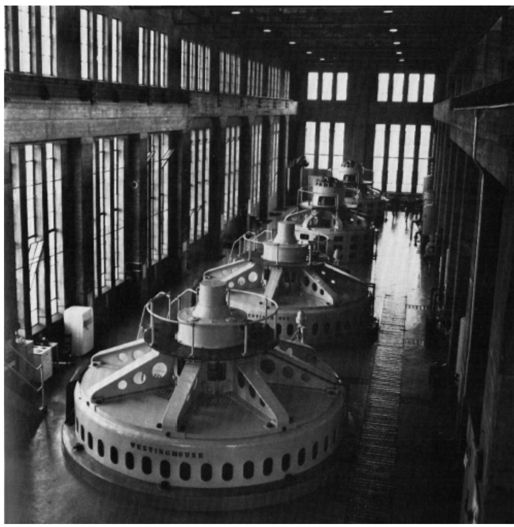
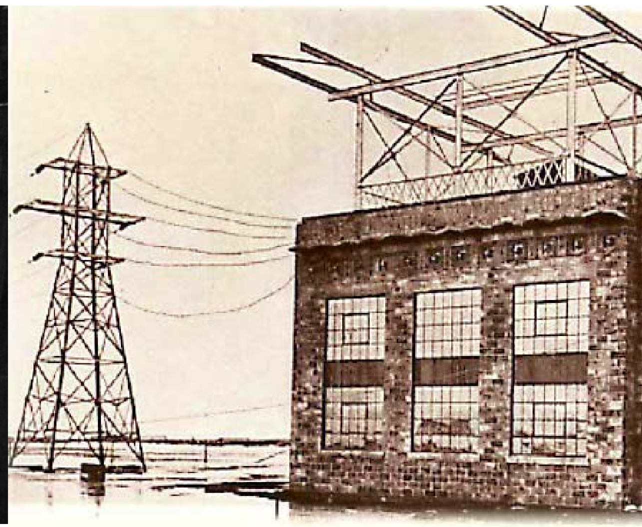
1867

Outline of Presentation

- New developments in power systems
  - Distributed resources & renewable energy
  - Microgrids in a smart grid environment
- Grid interconnection standards for distributed resources
- Grid interconnection standards for microgrids
- Summary

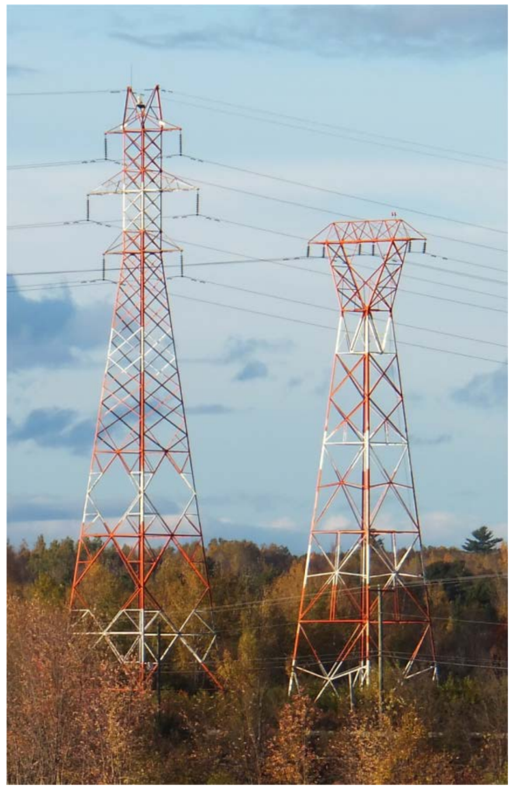
Power Industry – Early Days

- At the beginning of electric power industry 120 years ago, generators were small and services were local
- The Canadian Parliament Building was lit by electric lamps in 1884 – early adopter of new technology


Power Industry – Yesterday

- Larger generators, longer distances and higher voltages - rapid expansion of "electrification"
- Power systems - a sophisticated, reliable, vertically integrated, man-made network

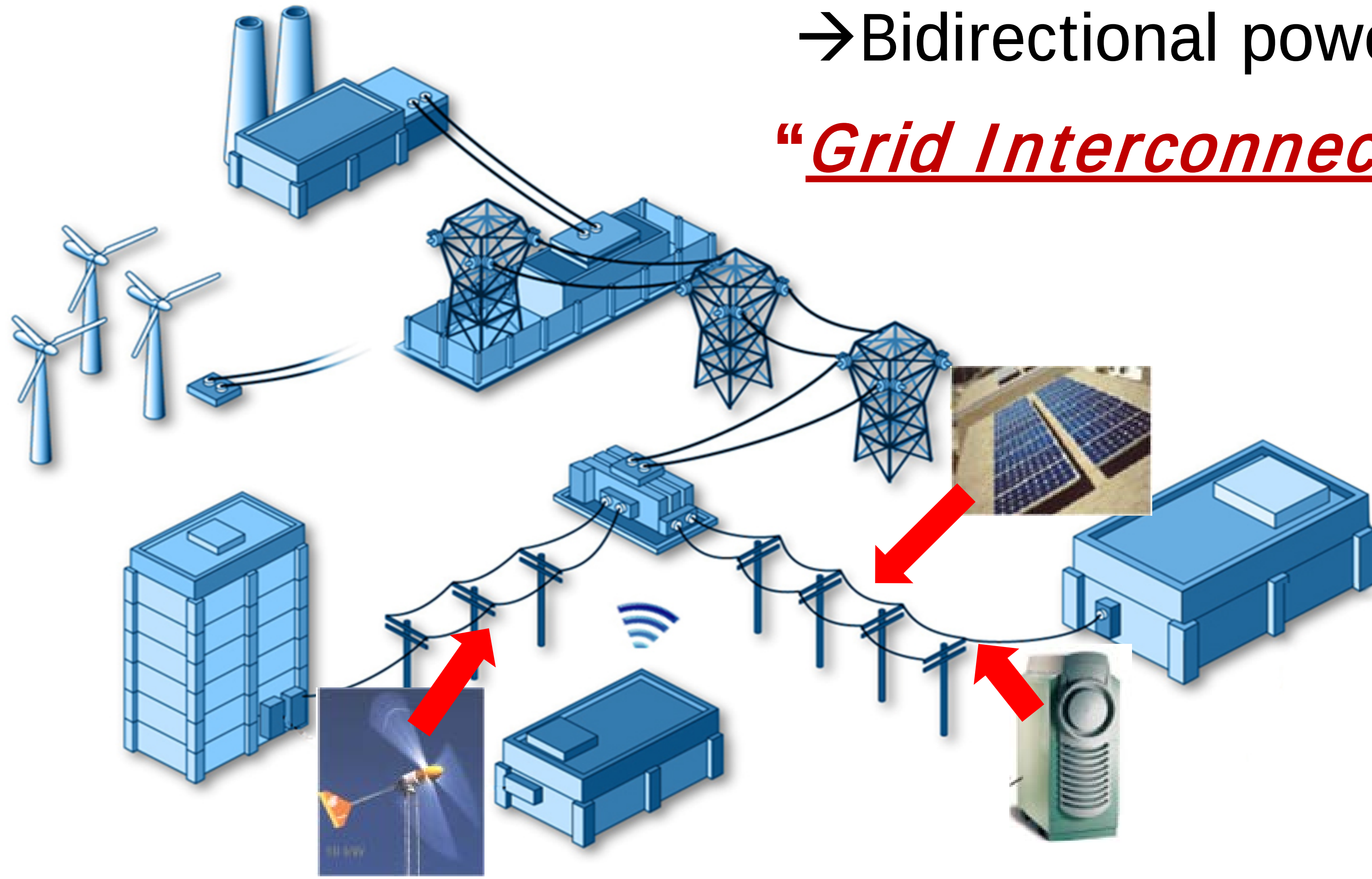


Power Industry in Transition

- Generation, transmission, distribution & consumption
- Integration of renewable energy based DRs
- Vertically integrated network →Mesh network

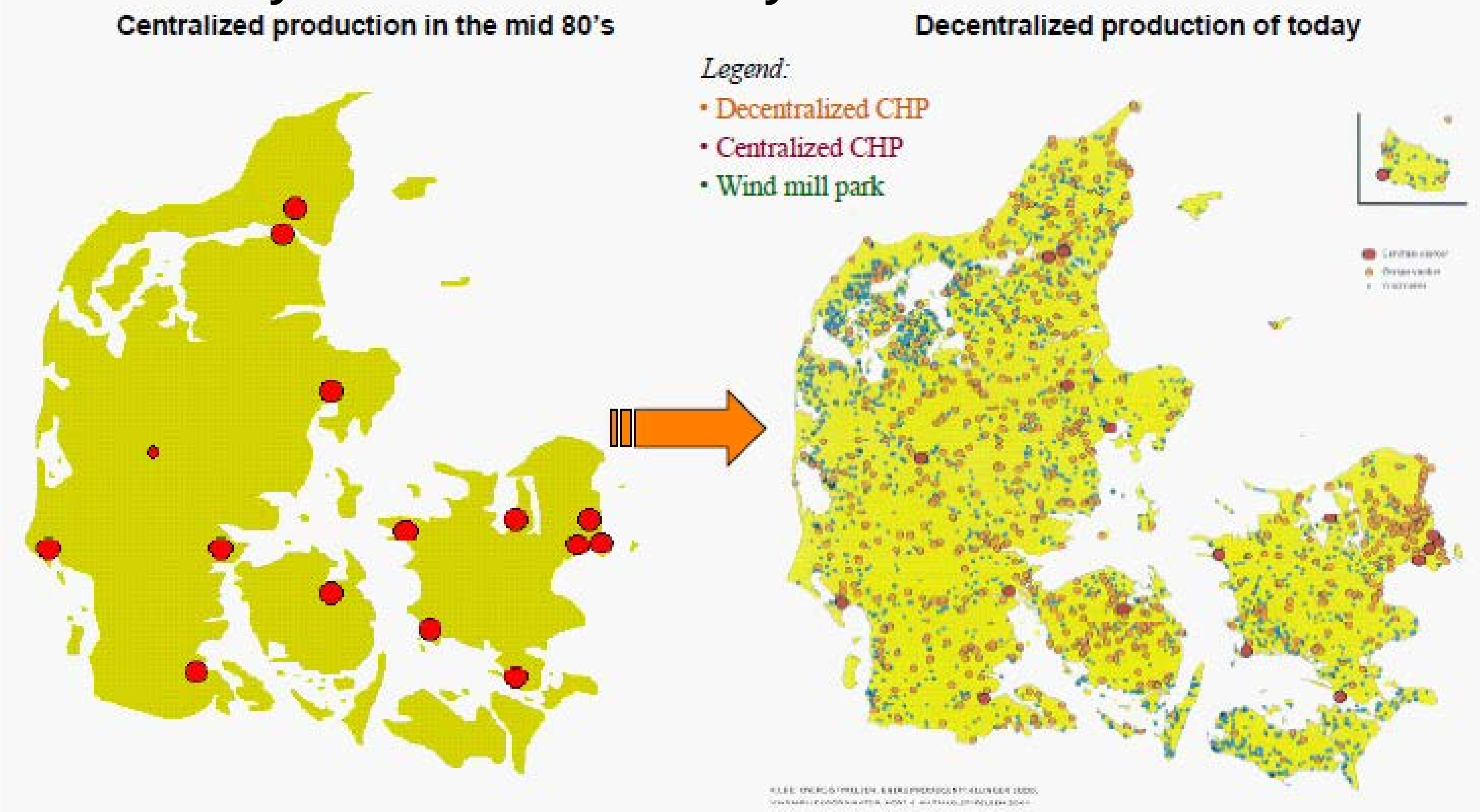
  →Bidirectional power flow

"***Grid Interconnection***"



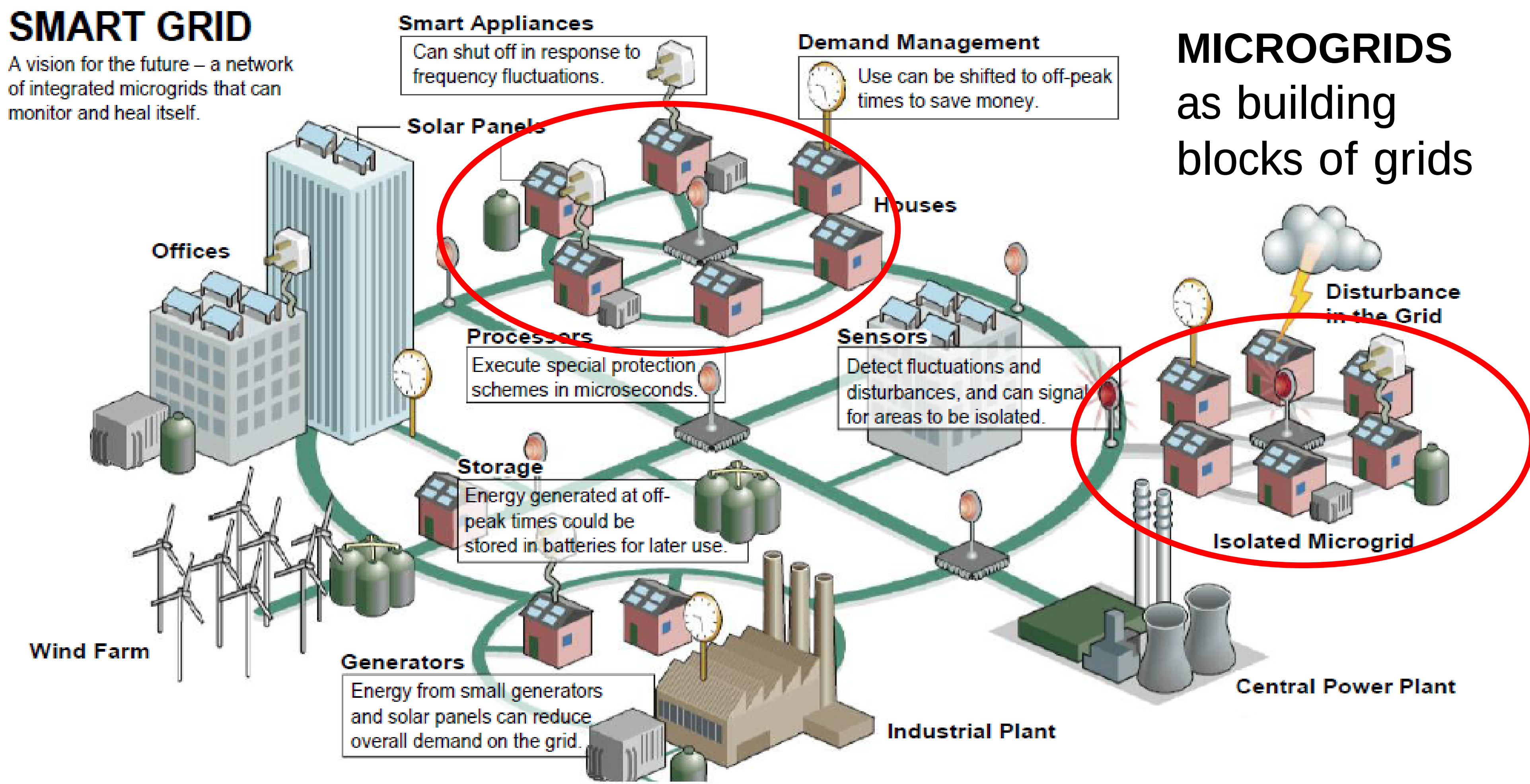
Growth in Distributed Resources

- Distributed generators provides about 45% of electricity in Denmark today



Analogy: large computers <> personal computers

Challenges: Interconnection of Distributed Resources → Standards

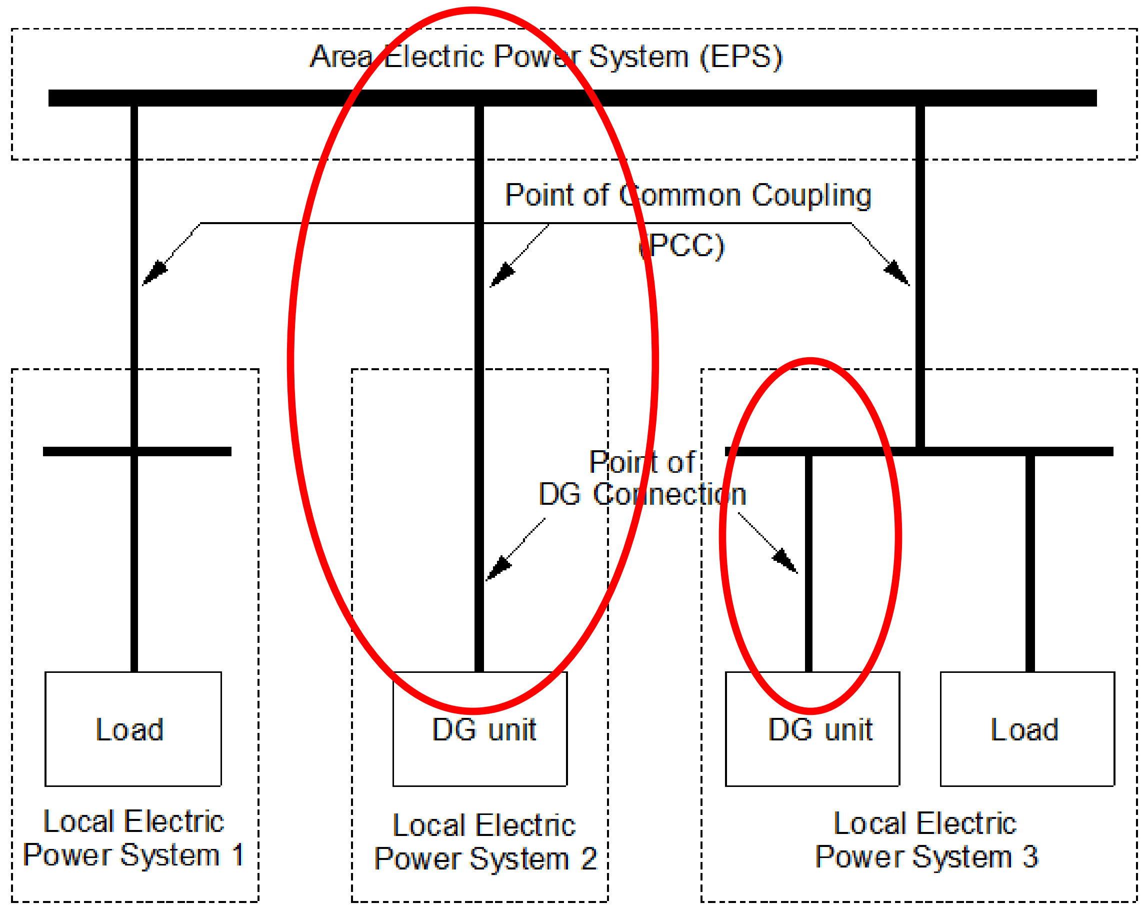


"Upgrading the grid," *Nature, vol. 454, pp. 570-573, 30 July 2008.*

Grid Interconnection Standards for DRs – initiated in late 1990's

(Relevant to power converters for DRs)

- IEEE standards
- IEC standards
- Standards of individual countries and utilities



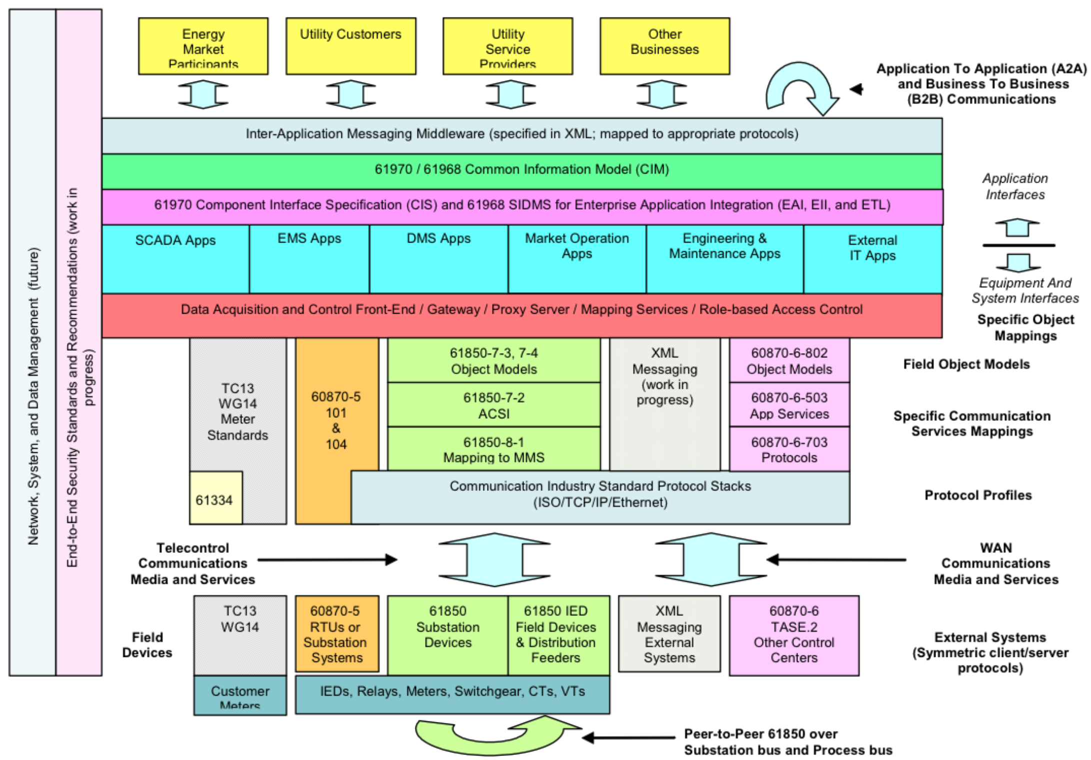
IEEE Standards

- IEEE Standard 929-2000 IEEE Recommended Practice for Utility Interface of Photovoltaic (PV) Systems up to 10 kW
- IEEE Standard 1547-2004 IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems, which laid foundation for:
  - UL1741 Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources
  - CSA 22.2 No. 107.1-01(R2011) General Use Power Supplies
  - CAN/CSA-C22.2 NO. 257-06 (R2011) Interconnecting Inverter-Based Micro-Distributed Resources to Distribution Systems
  - CAN/CSA-C22.3 NO. 9-08 Interconnection of distributed resources and electricity supply systems

IEC TCs on DR Interconnection

- IEC Technical Committees
  - IEC TC8 System Aspects of Electrical Energy Supply
  - IEC TC57 Power Systems Management and Associated Information Exchange
  - TC 82 Solar Photovoltaic Energy Systems
  - TC 22 Power Electronic Systems and Equipment

IEC TC57 Reference Architecture



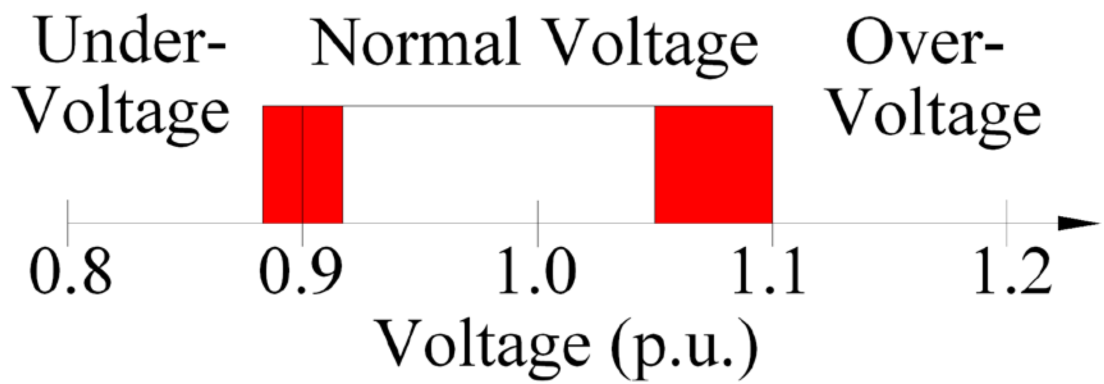
*Notes: 1) Solid colors correlate different parts of protocols within the architecture.
2) Non-solid patterns represent areas that are future work, or work in progress, or related work provided by another IEC TC.

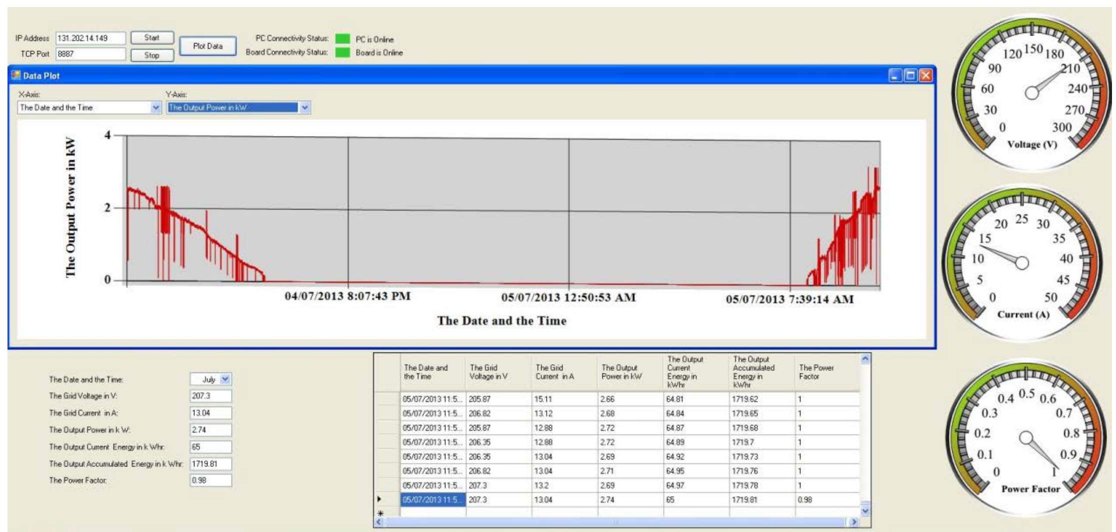
IEC DR Related Standards

- IEC Standards (relevant to DR grid interconnection)
  - IEC 62109 Safety of power converters for use in photovoltaic power systems - Part 1: General requirements & - Part 2: Particular requirements for inverters
  - IEC 62116 Test procedure of islanding prevention measures for utility-interconnected photovoltaic inverters
  - IEC/TR 61850-90-7 Communication Networks and Systems For Power Utility Automation - Part 90-7: Object Models For Power Converters In Distributed Energy Resources (DER) Systems
  - IEC 62477 Safety requirements for power electronic converter systems and equipment - Part 1: General & Part 2: Power electronic converters from 1000 V a.c. or 1500 V d.c. up to 35 kV a.c.
  - IEC 62116 Test procedure of islanding prevention measures for utility-interconnected photovoltaic inverters
  - IEC 61727 Photovoltaic (PV) systems - Characteristics of the utility interface

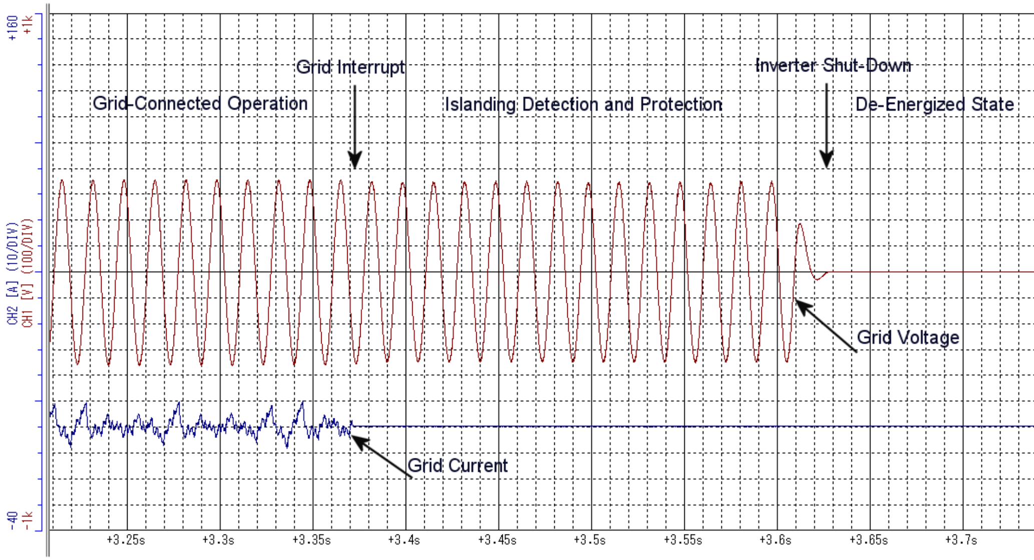
General Interconnection Requirements and Specifications

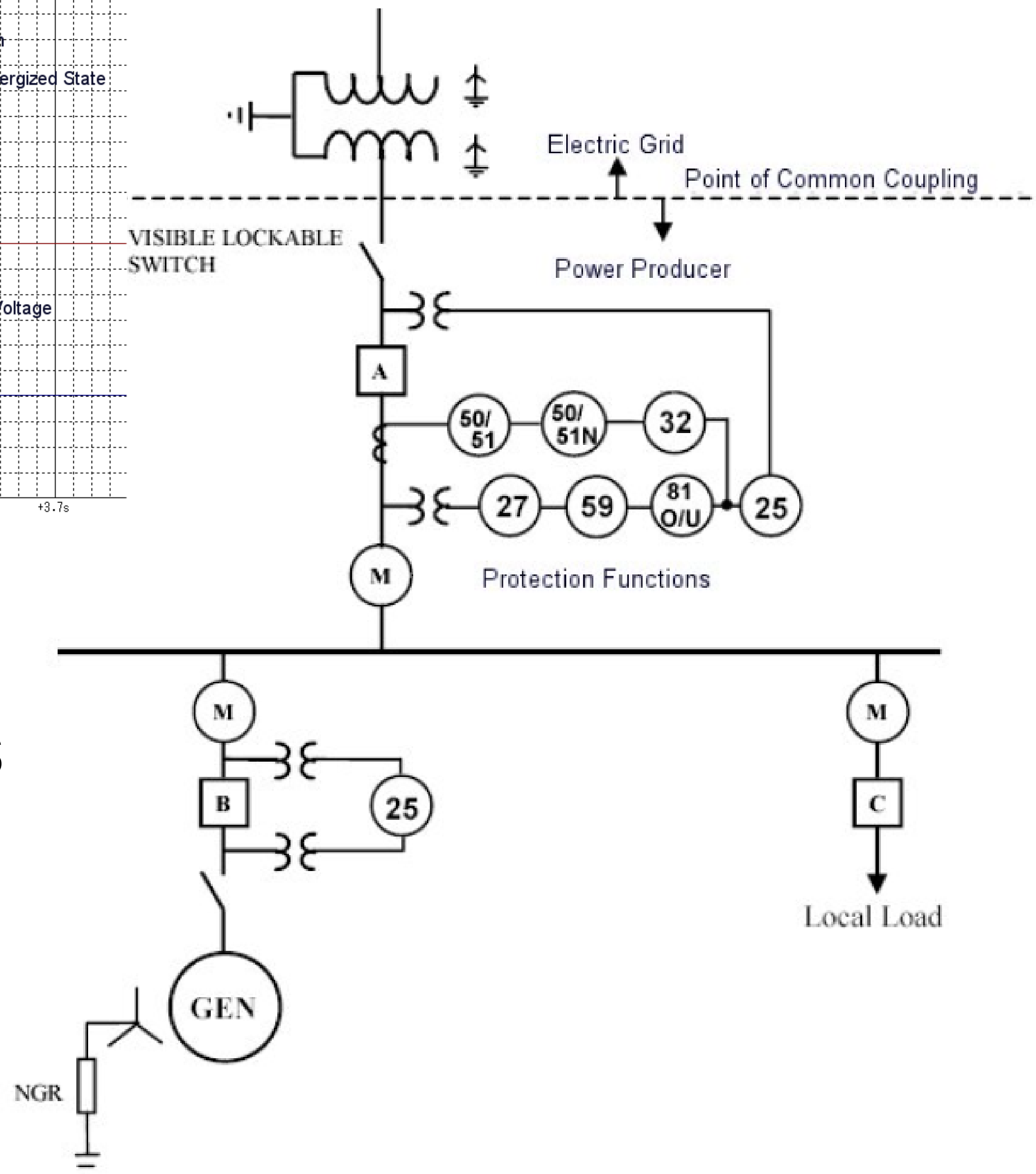
- Voltage regulation
- System frequency
- Synchronization
- Monitoring provisions
- Grounding
- Voltage unbalance
- Immunity





Safety & Protection Requirements

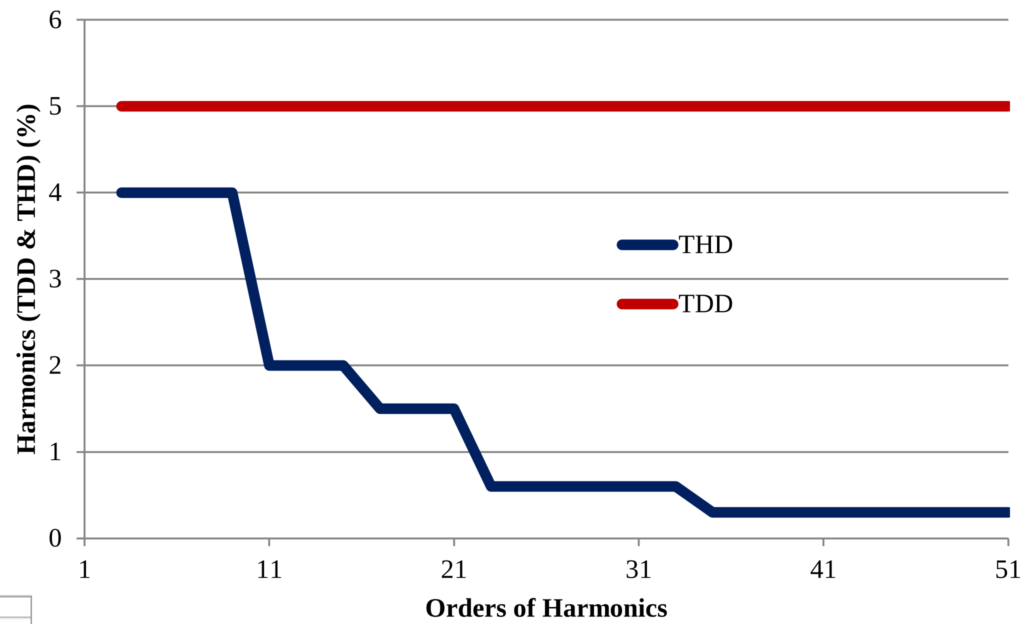


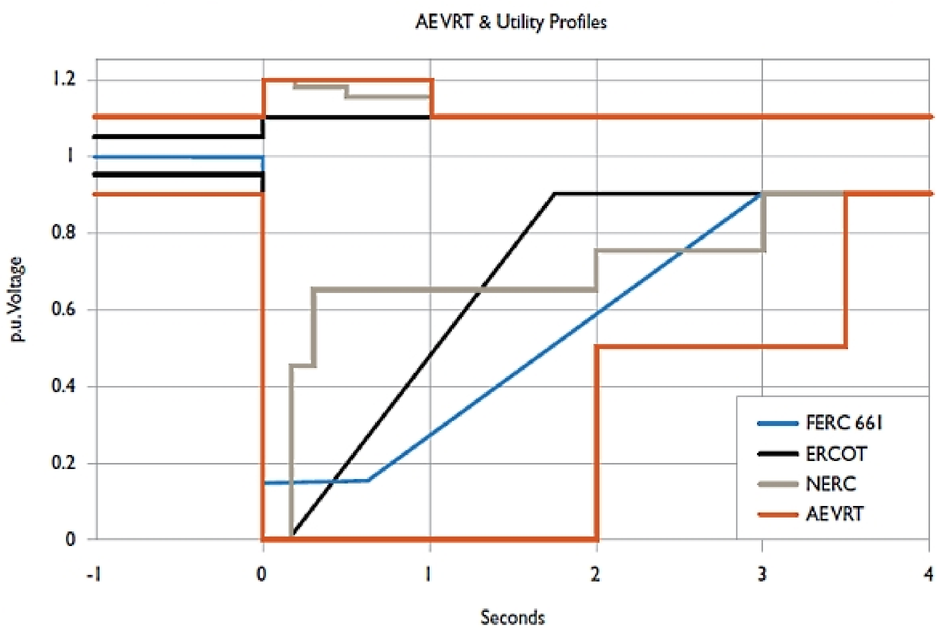


- Voltage disturbances
- Frequency disturbances
- Isolation device
- Disconnect for faults
- Anti-islanding

Power Quality Requirements

- Harmonics
- DC current injection
- Flicker
- Power factor



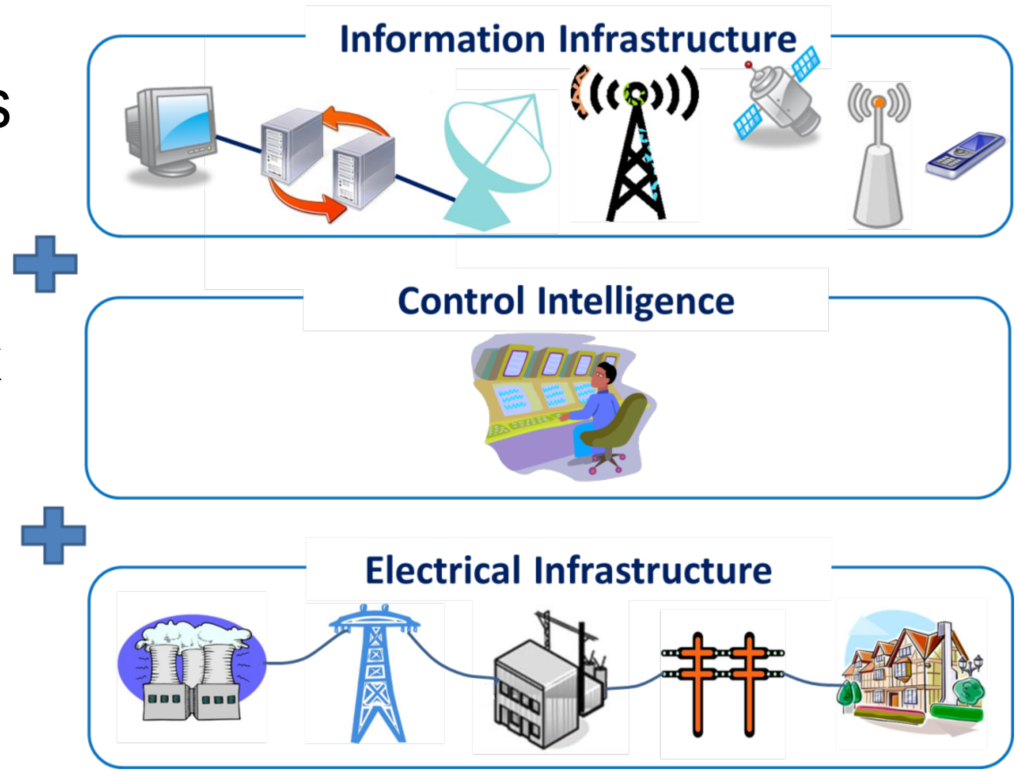


- System support?? LVRT for large scale installations

→ Moving from the unit level to system level

Microgrids

- Transition of power systems from traditional to smart grids
  - Electrical infrastructures + information infrastructures + control intelligence
- Microgrids as building blocks of future grids
  - DRs and loads interconnected to a local distribution network
  - Layers of communication and controls for functionality & services
  - Grid-connected and island operation



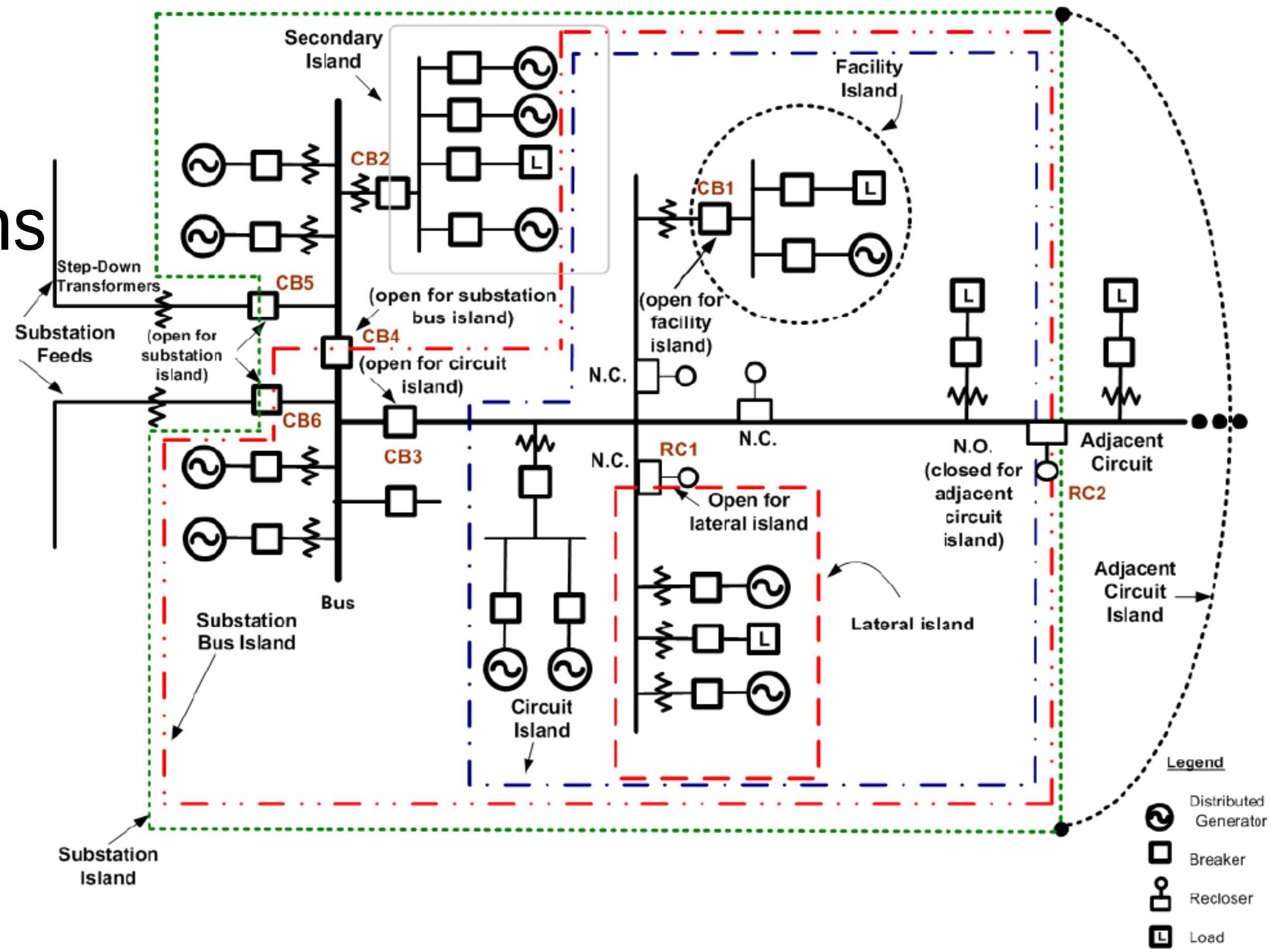
- Microgrid standards are immerging (or lack of standards)

Microgrid Structures-Components

- Distributed resources, including energy storage units
- Communication and (multi-layer) control systems
- Electrical loads
- Switch gears & protection systems
- Grids

and

- Standards/Guide



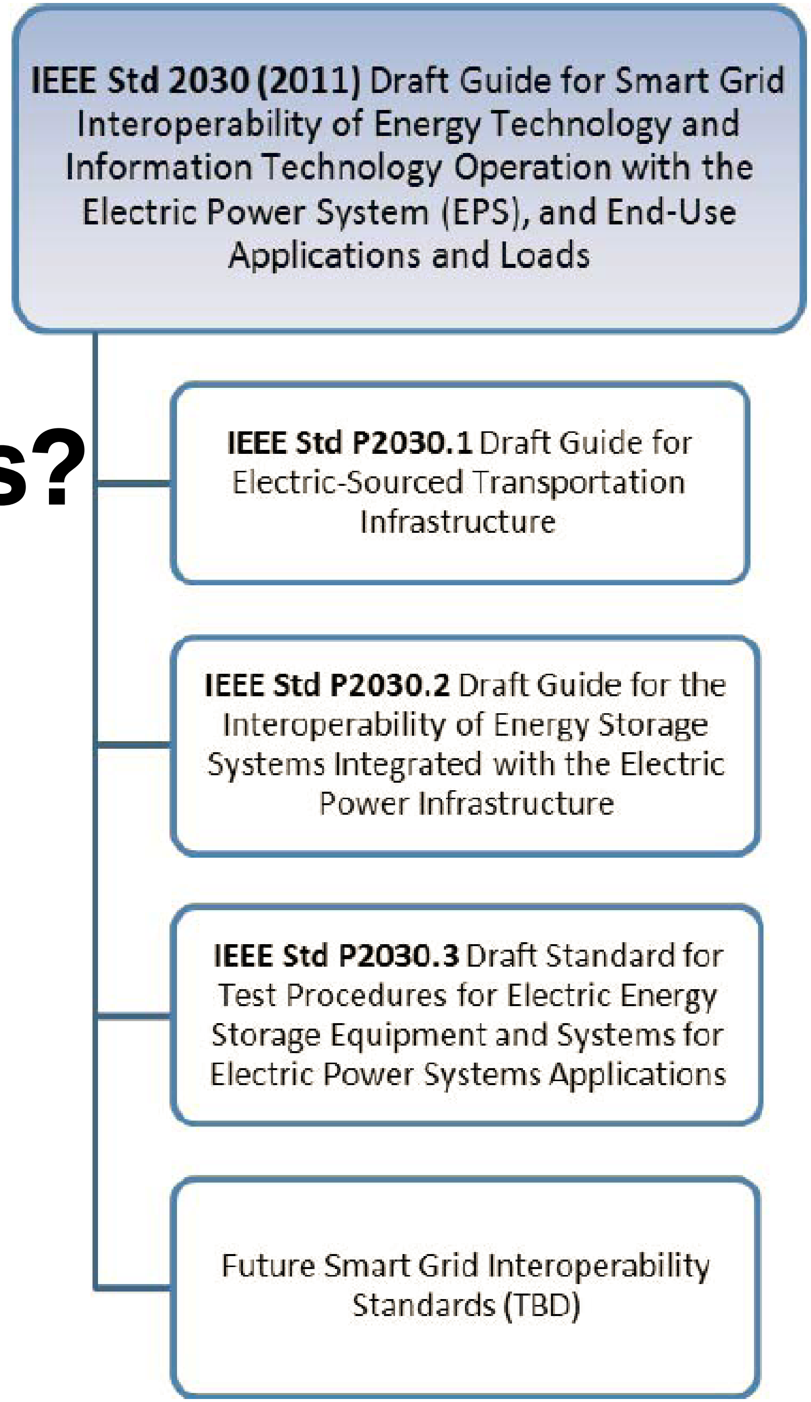
Microgrid Standards

- IEEE Standard 1547.4-2011 Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems

- IEC 61850 Communication Networks and Systems For Power Utility Automation
- IEEE 2030 Smart Grid Interoperability Series
- IEEE P1547.8 Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE 1547
- Along with other DR interconnection standards

Microgrid Standards?

- More comprehensive standards are being developed in the smart grid areas
- Maybe there is no need for more specific standards for microgrids???



Microgrid Integration Guide

- With IEEE Standard 1547.4 as a base

Grid-Connected Operation

Compliant with IEEE 1547 / IEC61850 etc. wrt control, protection/integration, information exchange and load/energy management

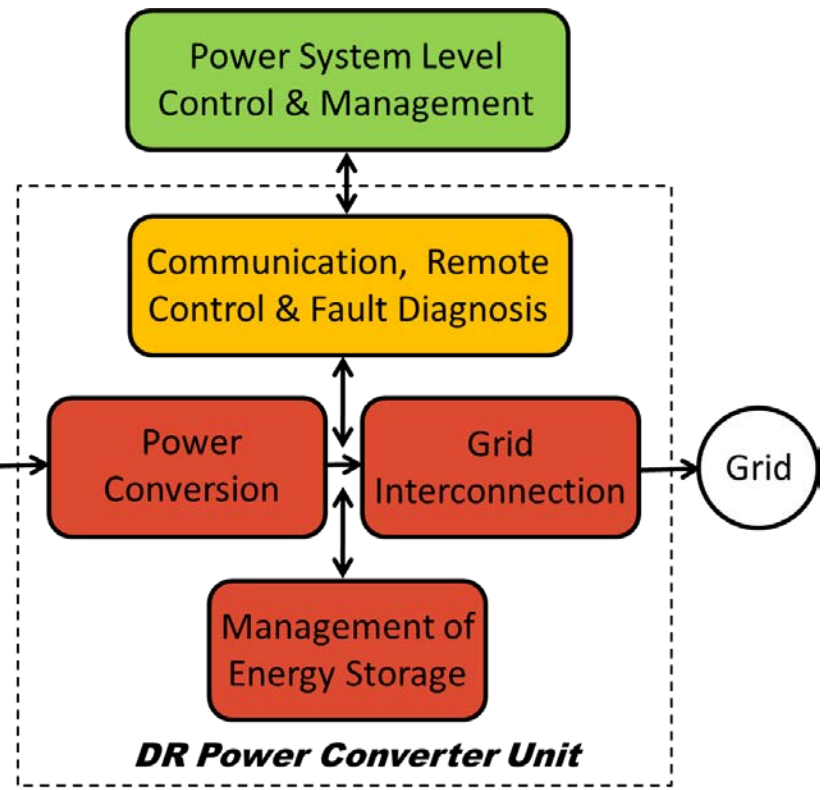
Seamless transfer – minimum impact to customers and grids. Synchronization

Island (Standalone) Operation

Compliant with power system specs wrt Frequency and voltage range and stability, reserve margin, protection, information exchange, and load/energy management

Power Converters for Modern Power Systems

- Traditional functions of power converters: power conversion, interconnection and protection, resource management (MPPT) and control, monitoring
- Extended functions of power converters: power system support, dispatch and energy management, information exchange, transition between standalone & grid-connected operation
- Opportunity→new standards



System Ready Power Converters?

- Need for Development of a Guide??

- Expanding functions of DR power converters
- Growing applications of microgrids, distributed resources and demand response services
- Interests in developing "IEEE guide for system interactive power converters" (inter-operability)
  - Basic and advanced functions of DR power converters
  - Control hierarchy
  - Information exchange
  - Transition between grid-connected and island modes
  - Forecast, dispatch and energy management
- →Forming a working group?

Summary

- Power systems in transition:
  - Increasing penetration of distributed resources
  - Structural change to a mesh-networked smart grid
- Interconnection standards:
  - Rather mature for DRs in grid-connected operation
  - Under-developed for microgrids, smart grids
- Opportunities for power electronics professionals to develop a guide for system interactive power converters in the new grid environment

Thank you very much!