



**DER Interconnection and Interoperability
Opportunities and Challenges Introduced with IEEE Std 1547™-2018**

Kevin Chen 4/12/2019



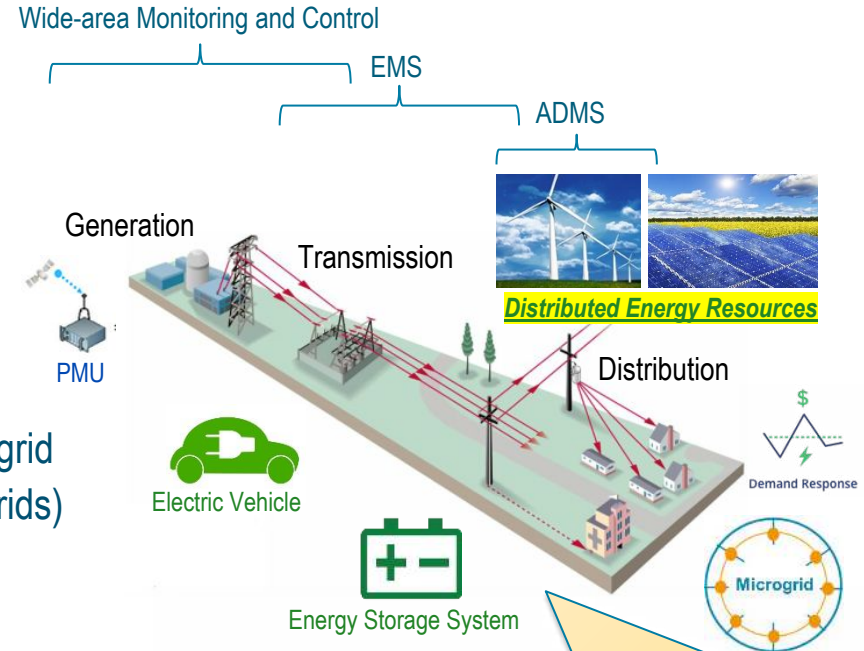
Next Generation Power Systems

- Current Power System

- Carbon Intensive
- Large Generation
- Central Control
- Highly Regulated

- New Challenges in a Modern Grid

- New energy technologies and services
- Increasing penetration of variable renewables in grid
- New communications and controls (e.g. Smart Grids)
- Electrification of transportation
- Integrating distributed energy storage
- A modern grid needs increased system flexibility
- Updated standards – e.g. IEEE 1547-2018 (DER as grid assets)



Questions

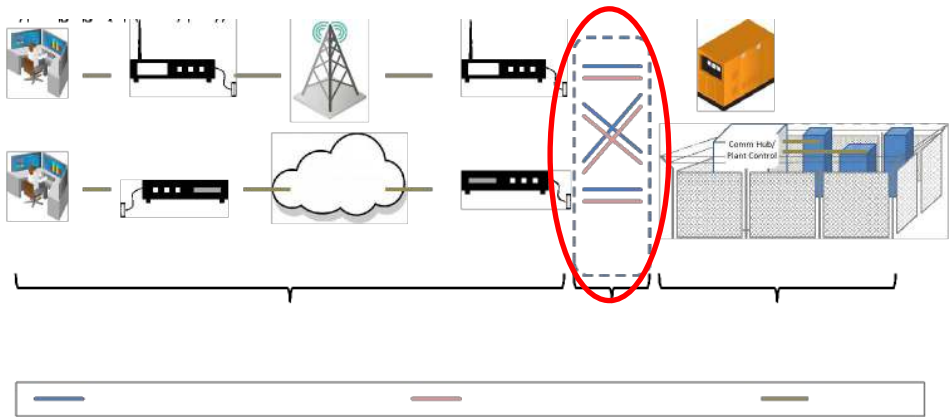
- Will we have 100% renewable resources?
- Will all resources be connected through power electronics?
- What will the load look like?
- Will we still have a grid and transmission lines?
- How will microgrids interact?

- **Title:** *Standard for Interconnection **and Interoperability** of Distributed **Energy** Resources with **Associated** Electric Power Systems **Interfaces***
- **Scope:** *This standard establishes criteria and requirements for interconnection of distributed **energy** resources (DER) with electric power systems (EPS), **and associated interfaces**.*
- **Purpose:** *It provides requirements relevant to the interconnection **and interoperability** performance, operation and testing, and, to safety, maintenance and **security** considerations.*
- **General remarks and limitations:**
 - Applicable to all DERs connected at typical primary or secondary distribution voltage levels.
 - Removed the 10 MVA limit from previous versions.
 - BUT: Not applicable for transmission or networked sub-transmission connected resources.
 - Specifies performance and not design of DER.
 - Specifies capabilities and functions and not utilization of these.
 - It does not address planning, designing, operating, or maintaining the Area EPS with DER.
 - Emergency and standby DER are exempt from certain requirements of this standard.
 - DER with SG units rated 10 MVA and greater shall follow IEEE Std C50.12 or IEEE Std C50.13.

- “A DER shall have provisions for an interface capable of communicating (local DER communication interface) to support the information exchange requirements specified in this standard for all applicable functions that are supported in the DER.”
- The information to be exchanged falls into the following four categories:
 1. Nameplate Data – As-built characteristics of the DER.
 2. Configuration Information – Each rating in Nameplate Data may have a configuration setting.
 3. Monitoring Information – Latest value measured.
 4. Management information – Information to update functional and mode settings for the DER.

▪ **Management Information Example**

- Volt-var settings
- Voltage, frequency trip settings
- Limit maximum active power
- Cease to energize and trip
- Etc.

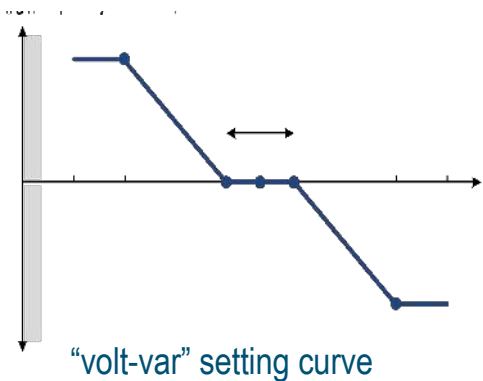


- Two categories of DER for grid support under normal conditions.

Category A

Meets minimum performance capabilities needed for Area EPS voltage regulation.

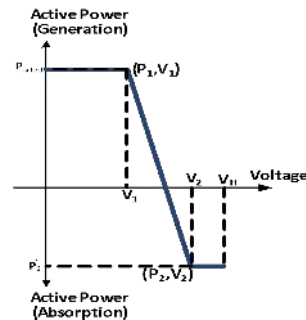
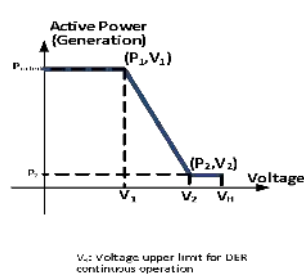
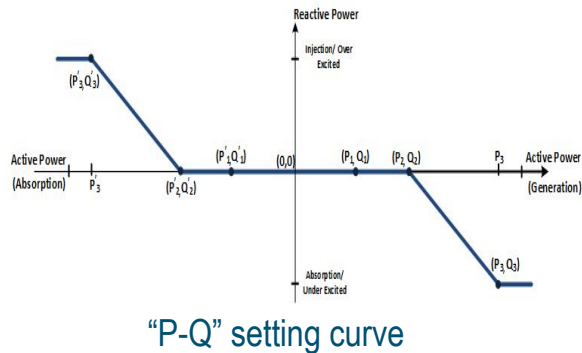
- Constant power factor mode
- Constant reactive power mode
- Voltage-reactive power mode (“volt-var”)



Category B

Meets all requirements in Category A, plus supplemental capabilities for high DER penetration, where the DER power output is subject to frequent large variations.

- Active power-reactive power mode (“P-Q”)
- Voltage-active power mode (“volt-watt”)



- Three categories of DER for grid support under abnormal conditions.

Category I	is based on minimal bulk power system (BPS) reliability needs
Category II	covers all BPS reliability needs and coordinates with the existing BPS reliability standard
Category III	provides the highest disturbance ride-through capabilities

- Driver for new ride-through requirements:
 - Transmission faults can depress distribution voltage over very large areas
 - Sensitive voltage tripping (i.e., 1547-2003) can cause massive loss of DER generation
 - Resulting BPS event may be greatly aggravated
- ***Specific Performance Terminology***
 - Continuous operation, Mandatory operation, Permissive operation
 - Cease to energize: Momentary cessation, Trip
 - Restore output, Return to service

- DER response to abnormal voltages and voltage ride-through requirements – Category III

- Mandatory operation:**

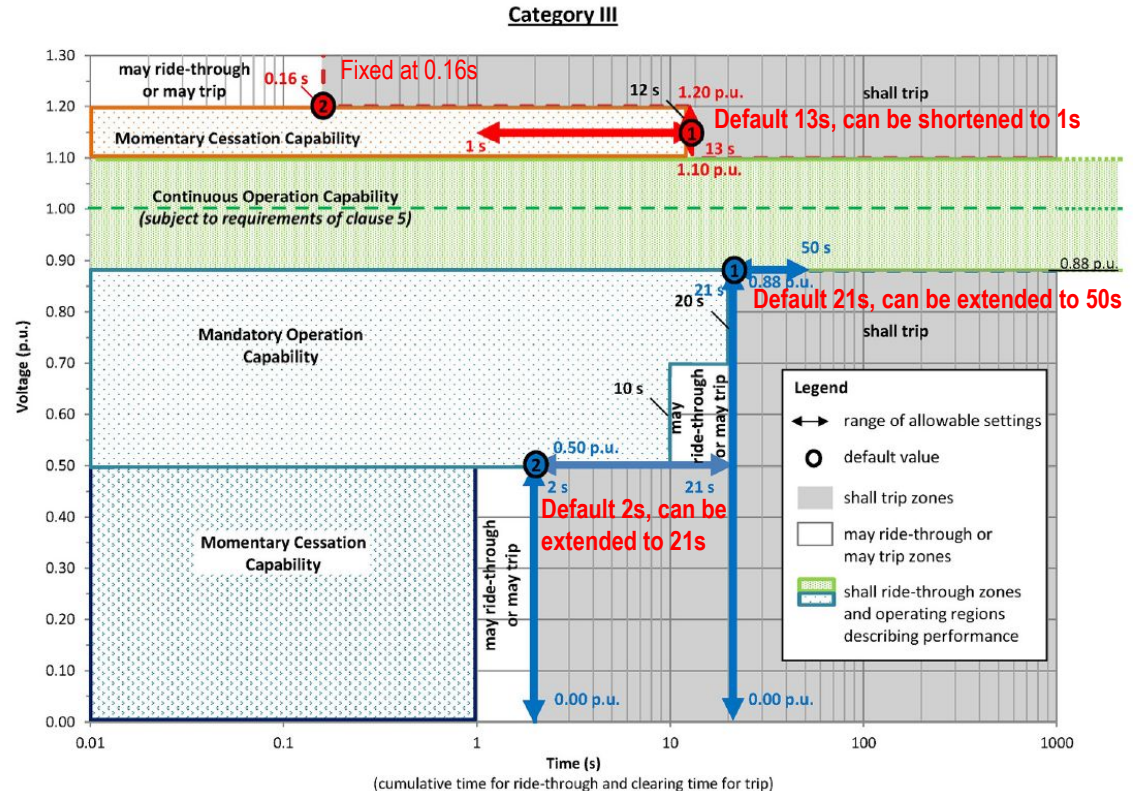
- Continuance of active current and reactive current exchange
- CAT II and III DER shall not reduce its total apparent current below 80% of the pre-disturbance value

- Momentary cessation:**

- Temporarily cease to energize the utility's distribution system
- Capability of immediately restoring output of operation

- Permissive operation:**

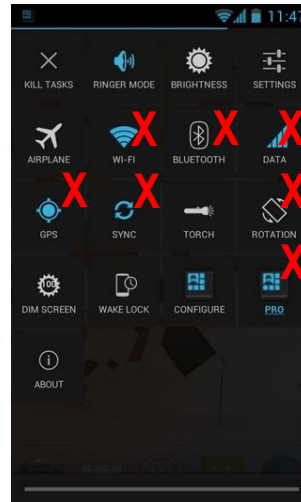
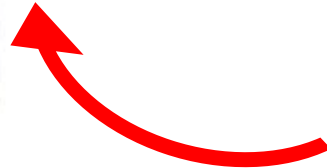
- Either mandatory operation or momentary cessation.



New standards, new capabilities, new functions



all come with a cost



Interoperability and control settings



Today's "smart" DER

- "Good" understanding about it
- "Mature" policy
- "Developed" process
- "Reliably" operated for years

The state-of-the-art DER

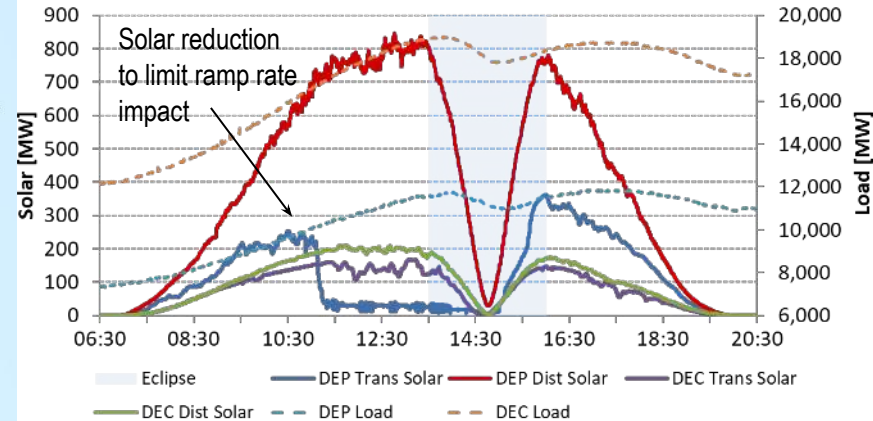
- Need better understanding
- Need updated policy
- Need new process
- Need new infrastructure
- Need people

Duke Energy Example – Interoperability

- DER power curtailment under emergency
 - Currently available options: (1) Open recloser, on/off control; (2) Contact customer ahead of time.
 - Possible future options: real-time control of DER maximum output, enforce ramp rate limit.
 - Prerequisites: ADMS, communication infrastructure; cyber security; regulatory policies, etc.
 - Other considerations: existing “not-so-smart” DER in the system.
- Solar Eclipse – August 21, 2017

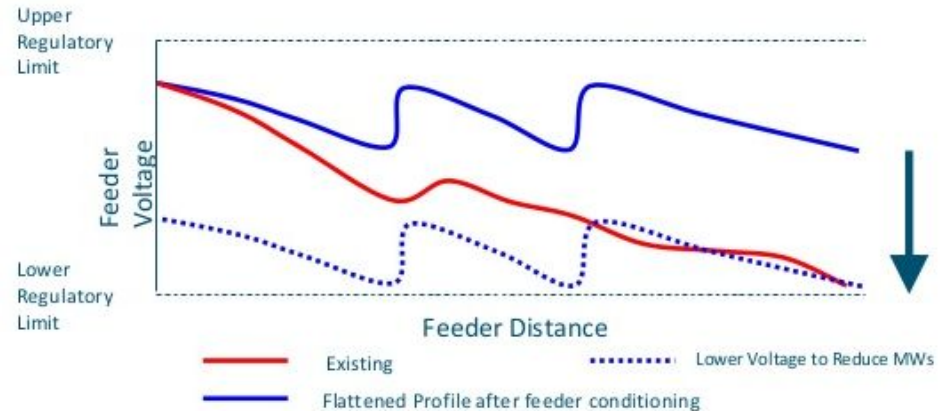


Duke Energy Solar Profiles (DEC & DEP)



Duke Energy Example – Voltage Regulation

- Duke Energy Progress (DEP) spent six years and implemented the Distribution System Demand Response (DSDR) in 2014.
- It was built around the well-known utility industry concept of Conservation Voltage Reduction (CVR); and is one of the Volt/VAR Optimization (VVO) modes in the ADMS.
 - 2,541 new line voltage regulators
 - 611 new line capacitor banks
 - 1,539 new MV sensors
 - 5,444 line phase changes to help improve load balancing
 - 204 mi of new overhead conductor
 - 13,000 LV system upgrades (customer transformers, secondary conductor, services, etc.).



Duke Energy Example – Voltage Regulation

- Challenges to both the utility and the DER customer:
 - DER may limit the switching flexibility of the distribution system, and negatively impact the measured effectiveness the DSDR.
 - Large DER commonly reverse flow on the feeder, resulting in voltage rise. Some projects cannot pass system impact study.
- Current policy:
 - Elimination of non-unity power factor. ²⁰¹⁵
 - Restrict location of utility-scale DER to the first regulated zone of distribution circuits. ²⁰¹⁷
- Opportunities:
 - IEEE 1547 – 2018 makes new DER capable of voltage regulation as grid support function.
- Challenges / other considerations:
 - Impacts to energy production (which in turn has contractual impacts)
 - Additional protection & control requirements
 - Utility-to-customer control interface requirements, etc.

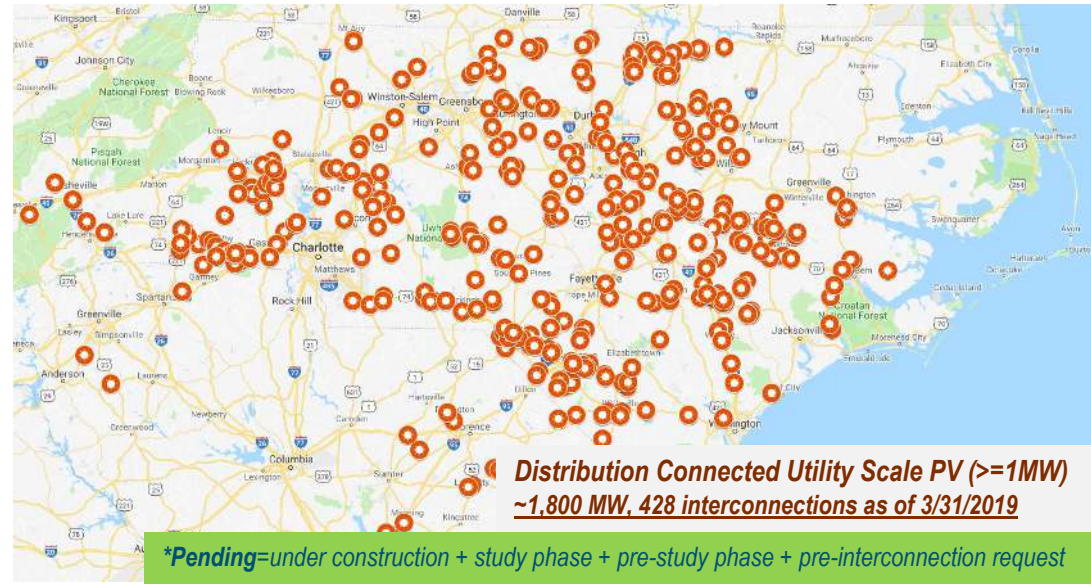
Duke Energy Example – Ride Through

- The need for ride-through is strongly driven by NERC power system (BPS) reliability needs
- Blue Cut Fire Disturbance, 8/16/2016
 - PV resources impacted – 1,178 MW
 - Mitigate erroneous frequency tripping
 - Recovery from momentary cessation
- Canyon 2 Fire Disturbance, 10/9/2017
 - PV resources impacted – 937 MW
 - No frequency-related tripping
 - Mitigation of momentary cessation
 - Mitigation of voltage-related tripping
- Angeles Forest Disturbance, 4/20/2018
- Palmdale Roost Disturbance, 5/11/2018
 - Both were very similar to the 2017 Canyon 2 Fire event
 - **Loss of distribution-connected inverter-based resources**

The image shows a screenshot of a NERC alert report. The header includes the NERC logo and the text 'RELIABILITY | ACCOUNTABILITY'. The main title is '1,200 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report'. Below the title, it specifies 'Southern California 8/16/2016 Event' and 'June 2017'. The report includes an 'Industry Recommendation' section with the text: 'Loss of Solar Resources during Transmission Disturbances due to Inverter Settings II'. There is also a section for 'Initial Distribution' dated June 20, 2017, and a 'Status' section indicating 'Acknowledgement Required by Midnight Eastern on June 27, 2017' and 'Reporting Required by Midnight Eastern on August 31, 2017'. The footer contains the NERC contact information: '3353 Peachtree Road NE, Suite 600, North Tower, Atlanta, GA 30326, 404-446-2560 | www.nerc.com'.

Duke Energy Example – Ride Through

- Solar in Carolinas (Duke Energy Service Area)
 - NC jumps to second place for solar energy. (>3 GW connected, >6.6 GW pending)
 - SC has huge potential to grow. (~6 GW pending)
- Most transmission connected PV followed the NERC alerts and recommendation.
- Can the system afford losing distribution connected solar?
- Possible options:
 - Relax trip settings
 - Require ride-through
- Challenges:
 - Existing DER without ride-through
 - Existing protection and control
 - Modeling and study methodology
 - Universal requirements or case by case?



*Pending=under construction + study phase + pre-study phase + pre-interconnection request

- ***“The changes were happening YESTERDAY!”***
 - Increasing DER penetration was a major driver for revising IEEE 1547.
- ***“What we thought was the future is here NOW!”***
 - IEEE 1547 – 2018 specifies performance, capabilities, and functions of DER.
- ***“The ‘Grid’ is becoming a huge control problem!”***
 - Interaction of controls, system protection, and behavior of new and existing loads and resources will make or break reliability.
 - Current analysis tools are inadequate to study the potential controls interactions.
- ***“The Grid of the Future will ONLY be as Smart as we make it!”***
 - Utilities need to integrate the utilization of the smart functions of DER into the planning, designing, operating, and maintaining the system with DER.
 - All changes come with cost.
 - Any plan must be efficient and economical.

