University of Idaho
College of Engineering

ECE 528 – Understanding Power Quality

http://www.ece.uidaho.edu/ee/power/ECE528/

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Lecture 22

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Today…

- More on DER Power Quality, and Reliability
  - Operating challenges
  - Islanding
  - Transformer connections
  - DER Protective Relaying

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Performance Categories for DER

- IEEE 1547-2018 describes performance categories for normal operation (A and B) and abnormal operation (I, II, and III).
- Assignment depends on amount of DER on the system, DER technology, etc.

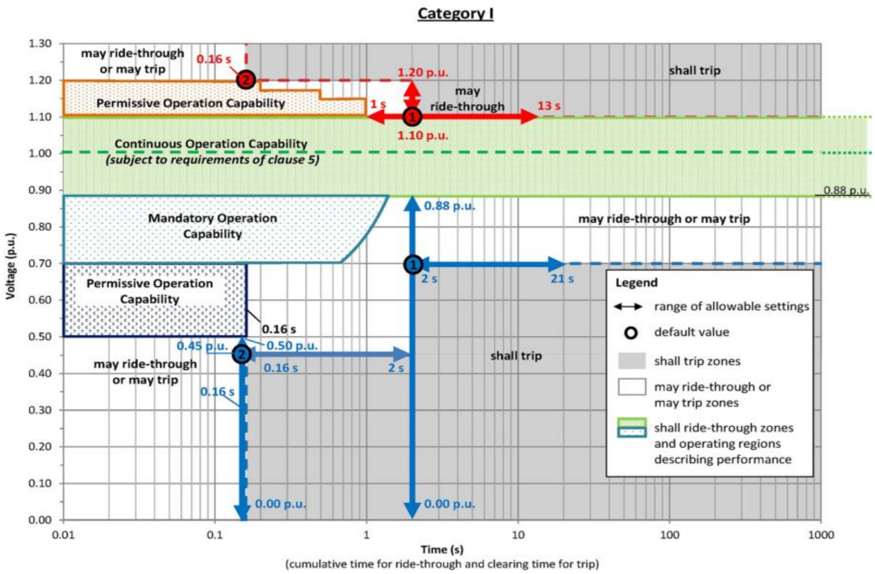
Operating challenges: Reclosing

- Reclosing on rotating generators can damage them
- DER can feed a fault and prevent it from clearing
- Solution – coordinate voltage and clearing time trip settings

Table 11—DER response (shall trip) to abnormal voltages for DER of abnormal operating performance Category I (see Figure H.7)

Shall trip—Category I				
Shall trip function	Default settings[a]		Ranges of allowable settings[b]	
	Voltage (p.u. of nominal voltage)	Clearing time (s)	Voltage (p.u. of nominal voltage)	Clearing time (s)
OV2	1.20	0.16	fixed at 1.20	fixed at 0.16
OV1	1.10	2.0	1.10–1.20	1.0–13.0
UV1	0.70	2.0	0.0–0.88	2.0–21.0
UV2	0.45	0.16	0.0–0.50	0.16–2.0

Operating challenges – Voltage (IEEE 1547 chapter 6)



DER interruption requirements per IEEE-1547

(voltage at the PoC):

PQ issues with DG/DER – Voltage regulation

- Voltage Regulation – previously not allowed, now required per IEEE-1547

"The DER shall provide voltage regulation capability by changes of reactive power."

Table 7—Minimum reactive power injection and absorption capability

Category	Injection capability as % of nameplate apparent power (kVA) rating	Absorption capability as % of nameplate apparent power (kVa) rating
A (at DER rated voltage)	44	25
B (over the full extent of ANSI C84.1 range A)	44	44

PQ issues with DG/DER - Harmonics

- Harmonic current injection is limited by IEEE 519, 1547, and 2800
- How DER may help
  - To the extent that DER increases system capacity at a location, the voltage distortion due to distorted load current there will be lower
- How DER may hurt
  - DER connected through an inverter may inject some harmonic current
  - Switching frequencies may correspond to system resonances

PQ issues with DG/DER – Voltage Sags

- How DER may help
  - Rotating machines, including DER, can help support system voltage during a voltage sag
  - 1547-2018 significantly expanded the ride-through requirements for DER, and shortened the time between “cease to energize” and “restore output” requirements
- How DER may hurt
  - DER may still trip during certain voltage sags. Loss of generation may result in a more severe sag or an interruption.

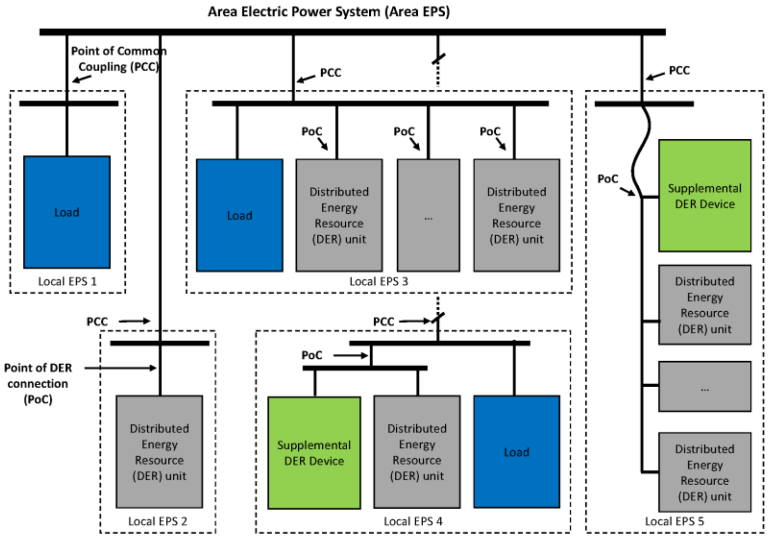
PQ issues with DER - Sustained interruptions

- How DER may help
  - Individual customers can run on DER during the interruption if the DER is designed for intentional "islanding"
  - Portable DER can be used for critical loads during planned outages
- How DER may hurt
  - If the utility relies on DER for base capacity and the DER becomes unavailable, load shedding may be required
  - A trip/close that trips the DER but not the load may result in longer voltage sags or undervoltage.

Islanding

- 1547: "A condition in which a portion of an Area Electrical Power System (EPS) is energized solely by one or more Local EPSs through the associated PCCs while that portion of the Area EPS is electrically separated from the rest of the Area EPS on all phases to which the DER is connected."
- Islands may be intentional or unintentional

Area EPS, Local EPS, PCC, Poc



From
IEEE Std.1547-2003

Issues with unintentional islands for the area EPS

- Safety
  - DER could energize a portion of an Area EPS thought to be de-energized, placing line workers and the public at risk
- Power Quality
  - Voltage regulation and distortion in an island may be significantly poorer than they were prior to the formation of the island
- Reliability
  - Islands may increase the time required to restore normal system operation following a fault

Issues with unintentional islands for the DER

- Protective devices on the area EPS (reclosers, substation circuit breakers, etc.) are normally designed to protect radial systems
- The synchronism of any downstream DER is not checked when they reclose
- Reclosing on out-of-phase rotating generators or inverters could damage them
- The DER protection and control system must incorporate appropriate protection – DER must protect itself

Preventing unintentional islands

- Load/generation imbalance
  - Relies on an intentional and significant difference between the DER output and the local load
  - When an island forms, the mismatch between the DER and the load will quickly cause detectable voltage and/or frequency variations

Island detection difficulties

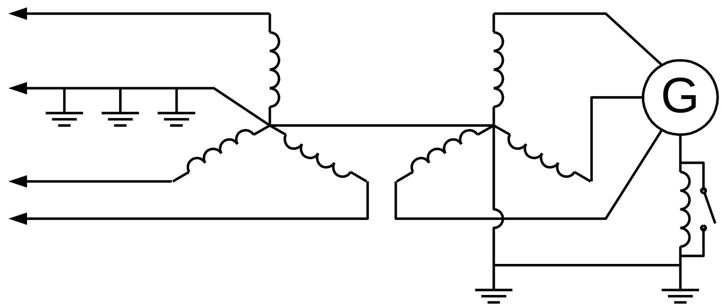
- It may not be possible to ensure that there is always a significant load/DER imbalance
- Multiple DER units may act together to support an island (destabilizing signal should still work here)
  - Multiple DER units in an area are common where some natural resource makes DER attractive
- In these cases, it may be necessary to use "transfer trip" controls – a remote trip signal to simultaneously trip multiple DERs

DER transformer connections and power quality

- The transformer configuration used to connect the DER to the distribution system can have a significant impact on power quality and reliability
- There are several options:
  - Grounded wye-wye
  - Delta-wye
  - Delta-delta or ungrounded wye-delta
  - Grounded wye-delta
    - Note: All connections are in system-generator order

Grounded wye-wye transformer connection

- Most common transformer connection in the US



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Grounded wye-wye transformer connection

- Advantages:
  - Standard utility transformer – replacements available if needed
  - No voltage phase shift – simpler relaying and fault detection
  - Ferroresonance is not much of an issue

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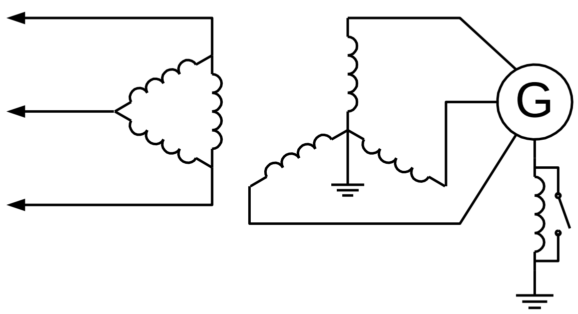
Grounded wye-wye transformer connection

- Disadvantages:
  - DER can feed any type of primary system fault
  - Passes zero-sequence currents
- Solutions:
  - A reactor in the neutral will limit the DER contribution to a ground fault and will also reduce zero-sequence current flow between the DER and the distribution system

Delta-wye transformer connection

- Second most common transformer connection in US
- Most common transformer connection in Europe



Delta-wye transformer connection

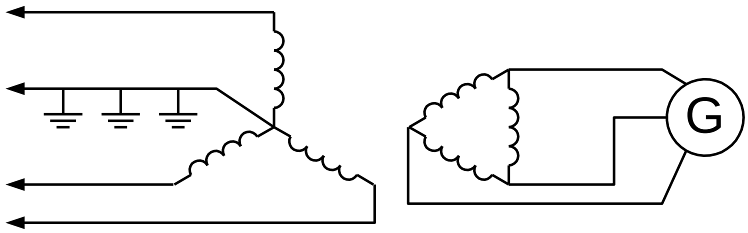
- Advantages:
  - Low DER contribution to ground faults
  - Zero sequence harmonics from the DER are blocked
  - Primary single line-to-ground faults do not have as severe an impact on the secondary voltages

Delta-wye transformer connection

- Disadvantages:
  - May be difficult for generator protection to detect single line-to-ground faults on primary system
  - Triplen harmonics from DER may circulate in low-impedance secondary neutral
  - Possible ferroresonance and the need for three-phase switches on the primary side of the transformer

Grounded wye-delta transformer connection

- Usual connection for substation transformers and central station generators



Grounded wye-delta transformer connection

- Advantages:
  - Primary system faults are easily detected by the generator's interconnection protection system
  - Blocks triplen harmonics from the generator
  - Protection scheme is standardized based on utility-owned generator protection systems

Grounded wye-delta transformer connection

- Disadvantages:
  - Acts as a source for ground fault current (See PSQ fig 9.30)
  - May interfere with existing protection systems
    - May cause sympathetic tripping of other feeders during ground faults
    - May make fuse saving impossible
  - Transformer may overheat due to zero-sequence currents

Protective relaying for distributed generation

- Purpose of protective relaying
  - Protect the generator
    - Detect abnormal operation
    - Block unsynchronized paralleling
  - Prevent unintentional islands
    - Detect primary system faults
    - Detect conditions indicating islanding

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Protective relaying for distributed generation

- Small generators
  - Over/under voltage
  - Over/under frequency
- Large generators – same as above, plus…
  - Over/under current
  - Negative sequence voltage and current
  - Synchronizing
  - Many other relays may be used depending on the generator and the particular installation

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DER relay example:

- Single device incorporates:
  - Undervoltage
  - Overvoltage
  - Under/over frequency
  - Negative sequence voltage
  - Directional power
  - Synchronism check

From Schweitzer Engineering Laboratories, SEL-547

Next time…

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- Introduction to Industrial Control Systems
  - Download and read:

1. Siemens STEP-training: Control Components

http://www.sitrain.us/step/pdfs/control_components.pdf

Read through page 18 – skim the rest

2. Siemens STEP-training: PLCs

http://www.sitrain.us/step/pdfs/plcs.pdf

Read: 1-6, 12-15, 41-45 – skim the rest

Links are also on PQ links page of class website