University of Idaho
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# ECE 528 – Understanding Power Quality

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

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Lecture 34





## Today…

- DG/DR Power Quality, and Reliability
  - Islanding
  - Transformer connections
  - DG Protective Relaying

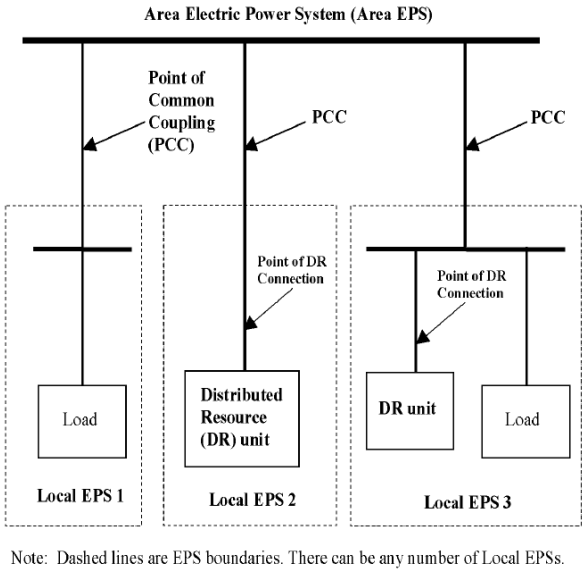
In today's lecture notes, "1547" refers to IEEE Standard 1547-2003.

Some information for today's lecture came from "Development and testing of an Approach to Anti-Islanding in Utility-Interconnected Photovoltaic Systems" Sandia Report SAND 2000-1939, August 2000. Available at: http://www.osti.gov/scitech/servlets/purl/759506

(From the citation page, scroll down and find the "View Full Text" pdf link.)

# 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."
- Islands may be intentional or unintentional




Note: Dashed lines are EPS boundaries. There can be any number of Local EPSs.

From IEEE Std.1547-2003





# Issues with unintentional islands for the area EPS

- Safety
  - DG 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 DG

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





# Issues with unintentional islands

- 1547 Synchronization limits

| DR Aggregate Size (kVA) | Frequency difference Hz | % Voltage difference | Phase angle difference (degrees) |
|---|---|---|---|
| 0-500 | 0.3 | 10 | 20 |
| >500-1,500 | 0.2 | 5 | 15 |
| >1,500-10,000 | 0.1 | 3 | 10 |

The area EPS protective devices don't monitor these parameters

## Preventing unintentional islands

- The Sandia destabilizing signal in inverters
  - Inverter controls raise a rising frequency or lower a dropping frequency
  - The power system frequency normally fluctuates very slightly, and acts to correct the inverter frequency
  - Without the large power system to correct the frequency, the destabilizing signal in the inverter controls quickly drives the frequency to an over- or under-frequency condition, and frequency relays trip the inverter





## Preventing unintentional islands

- Load/generation imbalance
  - Relies on an intentional and significant difference between the DG output and the local load
  - DG is operated at constant power factor or constant reactive power, and not permitted to regulate voltage
  - When an island forms, the mismatch between the DG 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/DG imbalance
- Multiple DG units may act together to support an island (destabilizing signal should still work here)
  - Multiple DG units in an area are common where some natural resource makes DG attractive
- In these cases, it may be necessary to use "transfer trip" controls – a remote trip signal to simultaneously trip multiple DGs



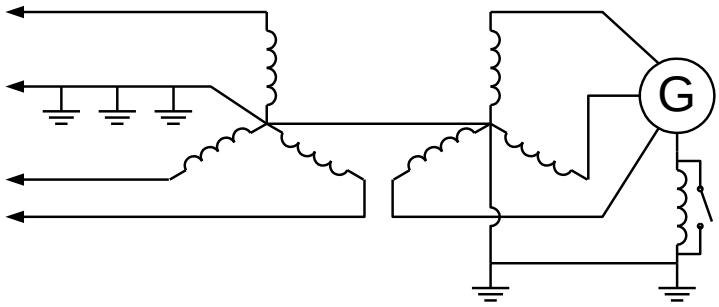


## DG transformer connections and power quality

- The transformer configuration used to connect the DG 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





## 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

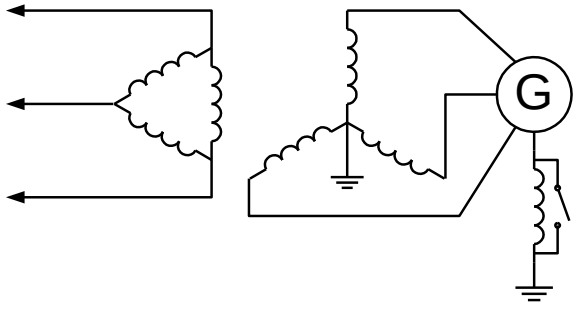
## Grounded wye-wye transformer connection

- Disadvantages:
  - DG can feed any type of primary system fault
  - Passes zero-sequence currents
- Solutions:
  - A reactor in the neutral will limit the DG contribution to a ground fault and will also reduce zero-sequence current flow between the DG 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 DG contribution to ground faults
  - Zero sequence harmonics from the DG are blocked
  - Primary single line-to-ground faults do not have as severe an impact on the secondary voltages

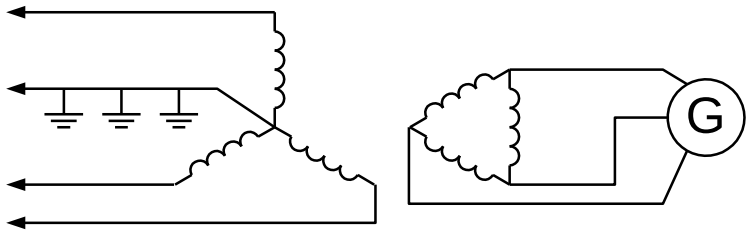




## Delta-wye transformer connection

- Disadvantages:
  - May be difficult for generator protection to detect single line-to-ground faults on primary system
  - Triplen harmonics from DG 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

## 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





## DG 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…

- 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: 1-16, 34-51, skim the rest**

Links are also on PQ links page of class website