University of Idaho
College of Engineering

ECE 528 – Understanding Power Quality

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

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Lecture 32

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Today…

- HW6 discussion
- Distributed Generation, Power Quality, and Reliability
  - What is it
  - The interested parties
  - Some general, "big picture" issues

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HW 6 information

$$\frac{\sum N_i}{N_T}$$

Customers Affected / Customers Served

- Problem 1
  - SARFI – See PSQ 8.3.2 and Lecture 31
  - SAIFI
    - Defined in IEEE-1366-2012: *IEEE Guide for Electric Power Distribution Reliability Indices* (get a copy)
    - Sustained interruption: Any interruption that lasts more than 5 minutes.
    - Section 3.2 – Sustained interruption indices
    - Section 3.2.1 System average interruption frequency index SAIFI

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HW 6 information

- Problem 2 – Sag scores – see lecture 31 and PSQ section 8.5.3
- Problem 3 – upcoming lectures, PSQ sections 9.5.9. and 9.8.
- Problem 4 – PSQ section 9.6, Sandia Anti-islanding report on website, and upcoming lectures

Definitions

- Distributed Resources (DR)
  - Sources of electric power including generators AND energy storage systems, that are not directly connected to a bulk power transmission system
- Distributed Generation (DG)
  - A subset of DR
  - Electric generators connected to a distribution system through a PCC
- IEEE 1547 – 2003
  - "IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems"

What is it? – Common technologies

- Reciprocating Engine Genset
  - Uses gas engine with synchronous or induction generator
  - Used to produce electrical energy and heat from methane produced in landfills and anaerobic digesters
  - Waste heat can be used for onsite space and water heating, and for heating the digester
  - Methane containing Hydrogen Sulfide is corrosive to metals commonly used in these engines, shortening their life and increasing maintenance requirements.

Common technologies

- Gas turbines
  - Used as "peaking" generators
  - Popular where heat is needed
    - Generating both electrical energy and heat increases efficiency
  - Connected through synchronous generator to the distribution system
  - Microturbines
    - Generally 25kW to a few hundred kW
    - Replacement for reciprocating engine
    - Connected through an inverter to the distribution system

Common technologies

- Fuel cells
  - Expensive, but clean and quiet
    - Can be used indoors
    - Operation is similar to batteries – hydrogen (anode) combines with Oxygen (cathode) in an electrochemical reaction, producing water and electrical energy
  - Popular for remote locations with small, critical loads

Common technologies

- Wind turbines
  - Becoming cost-competitive in some areas
  - May require inverter interface to power system
  - Generally require remote locations away from significant loads
  - Non-dispatchable
  - Requires energy storage for stand-alone operation

Common technologies

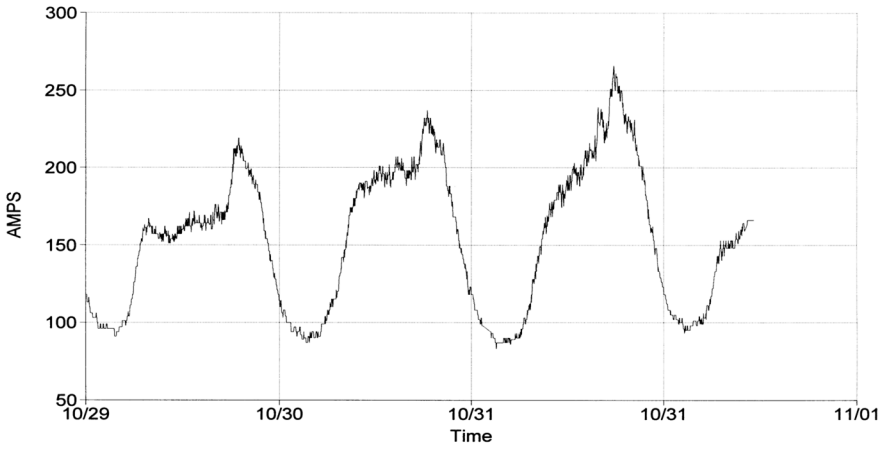
- Photovoltaic – "solar panels"
  - Still expensive
  - Requires inverter interface
  - Requires energy storage for stand-alone operation
  - Non-dispatchable
- Solar-Thermal
  - Produces steam for electric generator

Public domain

Energy storage

- Storage offers a way to "bank" generation for emergencies or flatten the daily load profile
- Allows generators to run at maximum efficiency
- Similar to hybrid vehicles, but for the power system
- Can reduce generation and transmission requirements

Typical daily load profile



Energy storage technologies

- SMES – Superconducting Magnetic Energy Storage
- Batteries
- Compressed Air
- Pumped hydro
- Flywheels
- Capacitors
- Heated fluids

The DG / DR / distribution system interface

- Synchronous machine
  - May support "islands"
  - May interfere with protection systems
  - High source impedance changes system response when operating "off grid"
    - Reduced fault current
    - Increased harmonic voltage distortion
    - Increased severity of voltage sags

The DG / DR / distribution system interface

- Induction machine
  - Reduced islanding risk
  - Simpler synchronizing with the power system
  - Often requires capacitors
    - Capacitors may create resonance problems
    - May self-excite if islanded
    - May feed faults and interfere with protection systems

The DG / DR / distribution system interface

- Electronic inverter
  - Harmonics in newer PWM inverters is less of a concern than in older inverters
    - IEEE 519 and IEEE 1547 describe the limits

Individual harmonic order h (odd harmonics)[b]	h < 11	11 ≤ h < 17	17 ≤ h < 23	23 ≤ h < 35	35 ≤ h	Total demand distortion (TDD)
Percent (%)	4.0	2.0	1.5	0.6	0.3	5.0

[a] I = the greater of the Local EPS maximum load current integrated demand (15 or 30 minutes) without the DR unit, or the DR unit rated current capacity (transformed to the PCC when a transformer exists between the DR unit and the PCC).
[b] Even harmonics are limited to 25% of the odd harmonic limits above.

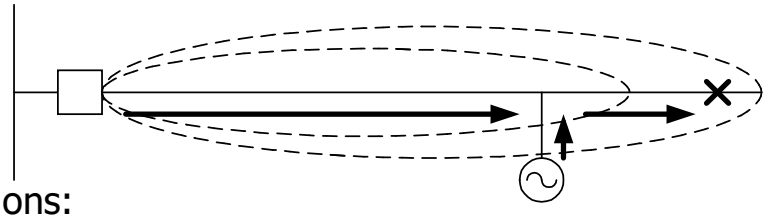
Table from IEEE 1547-2003.

The DG / DR / distribution system interface

- Electronic inverter – continued
  - Islanding is less of an issue
    - Inverter can quickly detect and separate from the system
  - May feed faults - briefly
    - Electronic controls can quickly detect abnormal conditions and disconnect the inverter from the system

Operating conflicts

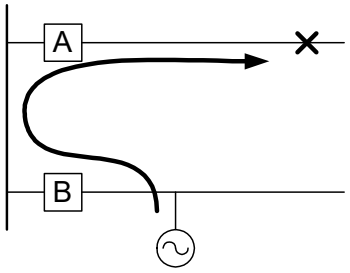
- Interference with relaying
  - Reduction of "reach"



  - Solutions:
    - Adjust relay to increase reach
    - Add recloser to add another protection zone
    - Minimize DG contribution to ground faults

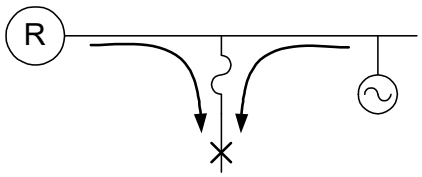
Operating conflicts

- Interfering with relaying
  - sympathetic tripping
    - Issues
      - May make finding faults difficult
      - Increases area affected by fault
    - Solutions
      - Directional relays
      - Changes to circuit breaker settings



Operating conflicts

- Interference with relaying
  - Defeat of fuse saving
    - Issue:
      - Fuse coordinate with recloser fast-trip varies with DG operation
    - Solutions
      - Larger fuses
      - Do without fuse saving
      - Minimize DG contribution to ground faults



Next time…

- More on specific power quality issues
  - Sustained interruptions
  - Voltage regulation
  - Harmonics
  - Voltage sags