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College of Engineering

ECE 528 – Understanding Power Quality

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

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Lecture 6

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PQ investigations

- Remember what is needed to create a PQ problem:

Electrical Disturbance + **Path** + **Vulnerable Equipment** = **Power Quality Problem**

- Sometimes the malfunction or failure of some electrical equipment is due to a non-electrical issue; such as a plumbing problem.

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PQ Investigations: The scientific method

- Observe and describe phenomenon
- Form hypothesis (or two or three!) to explain observations
- Make predictions based on hypotheses
- Test predictions with experiments - more observations
- Refine hypothesis as necessary based on new observations

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PQ Investigations: Applying the scientific method

- Know what "normal" is before measuring
  - Use calculations, nameplate data, nominal values, historical data, other measurements
- Don't just measure; test: Normal or abnormal?
  - Abnormal measurements can support or refute a hypothesis
- Other investigation principles:
  - There may be more than one thing to find
  - Beware of assumptions and bias; yours and others'
    - Replacing devices; new equipment can be faulty
    - Data in tables and nameplates may not be correct
    - Are expectations realistic? i.e. is the equipment really malfunctioning?

Example 1:

- Reported problem:
  - Multiple customers on a single distribution feeder reported lights dimming and computers rebooting or switching to UPS.
- More information from discussion with customers:
  - Apparently random, but all customers affected simultaneously
  - Not associated with any activities of the customers

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Example 1 continued

- Recording at multiple locations to refine problem description
  - Recorded short voltage sags when symptoms occurred
  - Two to four per day
  - Not associated with load changes at monitored locations
  - Pre- and Post- sag voltage is different – voltage goes up or down approximately 2 volts on a 120-volt base.

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Example 1 continued

- Hypotheses
  - Capacitors, voltage regulators, and substation transformer tap changing can cause step changes in service voltage
  - A problem at a capacitor, regulator, or the substation transformer is causing the voltage sags
- Tests
  - Review capacitor control logs: no correlation
  - Feeder has no regulators
  - Manually step the substation transformer: reproduced symptoms
- Results:
  - damaged transformer tap switching mechanism caused instantaneous open circuit when changing taps

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Initial observations and preliminary analysis

- Customer observed problem
  - Initial description is usually incomplete
    - "Our computers are rebooting all the time."
    - "We're having power surges."
    - "The factory had another outage yesterday. That's the third one this year."

Initial observations and preliminary analysis

- Gathering more information
  - Goal is to get a problem description that is as accurate and complete as possible
    - When does the problem occur – time, frequency?
    - Does problem correlate with known power system events?
    - What equipment is, and is not, affected?
    - How is the equipment affected?
    - Can the problem be predicted? – How?
    - Can they make the problem happen? – How?
    - Are neighbors experiencing the same problem?
    - What solutions have been tried?
    - What is the impact in dollars, time, etc.?

Initial observations and preliminary analysis

Deciding where to start…

Location	Data sources
Transmission	Electric company operating logs
Substation	Substation SCADA systems
Feeder	Recloser controllers
Service Transformer	Capacitor controllers
Service Conductors	
Main Panel	Measurements and recordings
Sub Panel	Direct observations
Branch circuit	Customer logs
Equipment	Equipment logs

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Initial observations and preliminary analysis

- Visual observations
  - New or temporary equipment?
  - Recent work?
  - Nameplate data on problem equipment
  - Locations of panels and equipment
  - Response during problem
- If suggested by problem description
  - Inspect wiring and panels
  - Control/Protection settings
  - Temperatures/Connections – Infrared?
- Spot measurements of voltage, current, etc.

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Observations/Hypotheses - Monitoring

- Advantages:
  - Accurate disturbance time-stamps
  - Voltage/current data during disturbances
    - May be used to determine direction
  - Document "normal" conditions
- Disadvantages:
  - Requires second trip
  - Collects data unrelated to the problem
  - May require extended recording to catch infrequent problems

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Predictions and Tests - Monitoring

- Keeping a log of events during monitoring is essential
  - Aids in correlating electrical disturbances with equipment malfunctions and may help eliminate some electrical disturbances
- Recorded data often helps form hypotheses and provides data used to test the hypotheses.
- Ideally, tests will clearly confirm or eliminate a hypothesis
  - If switching a certain capacitor is causing the problem, then the capacitor operating logs will correlate with the problem logs.

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Reducing investigation time

- Review system operating logs for correlation with reported issue
- monitor at the service point if possible.
- Install monitors prior to spot measurements
- Use multiple monitors simultaneously.
- Monitor for as short a time as necessary
- Photograph or videotape panels, equipment, etc.

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Accurate conclusions

- Avoid speculation
- Take steps to avoid bias
- Discuss preliminary conclusions with other engineers, technicians, the customer, etc.
- Test preliminary conclusions and recommendations:
  - Use models, etc. to try recommendations on a small scale.
  - Avoid "shotgun" approach – make one change at a time.

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Communicating results

- Talk with the customer at their level of understanding
- Engineers tend to write, but face-to-face meetings are often more effective.
- Help the customer follow the process
  - From problem report, to hypotheses, tests, analysis, and conclusions so that the customer can reach the same conclusions on their own.
- Understand and acknowledge the impact of your conclusions on the customer.

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Example 2: Hot transformer

- Reported problem:
  - High temperature alarms on substation transformer
- More information from discussion with customers:
  - Occurs during peak use times, but load doesn't appear to exceed transformer ratings

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Example 2: Hot transformer continued

- Hypothesis 1 (from customer)
  - Harmonic currents are causing excessive heating
- Test the hypothesis – record current with PQ analyzer
  - Very minimal current distortion
- New hypothesis
  - Cooling problem

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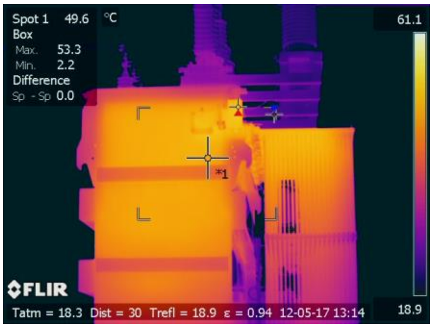
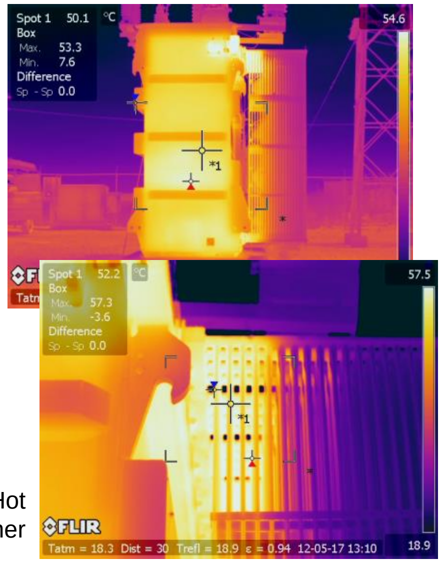
Example 2: Hot transformer – test hypothesis 2



Normal Transformer



Hot Transformer

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Example 2: Hot transformer - conclusion

- Hypotheses 2 confirmed
  - Cooling problem
    - Oil was not circulating through the cooling fins
    - Also, fans mounted to blow against the prevailing winds
  - Not really a power quality problem, but we didn't know that until investigating
  - Finding the true problem is more useful than not finding a power quality problem.

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Example 3 – motor will not reach operating speed

- Reported problem
  - 30Hp pump motor failed following rebuild of pump
  - Replacement (same horsepower) would draw high current and not accelerate to operating speed
  - Original transformer suspected by customer
  - Larger transformer installed
  - New motor still would not reach operating speed
  - PQ engineer called

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Example 3 - Forming and testing hypotheses

- Hypothesis 1 - Voltage problem
  - Recorded voltage and current at 1-cycle intervals during attempted start
  - voltage sag was not excessive
  - Starting current continued to rise as if load was larger than 30hp
- Hypothesis 2 – pump problem
  - Check specifications on rebuilt pump for lift, pressure, flow-rate and speed based on installation – Pump matched installation
- Hypothesis 3 – motor specification/compatibility
  - Check nameplate - New motor: 1800RPM, old motor: 1200RPM
  - Horsepower for pump varies with the cube of the speed
  - 30hp at 1200RPM $\approx$ 101hp at 1800RPM

Example 4 – blowing fuses

- Hypothesis 1 -
  - Voltage imbalance causing excessive current imbalance
- Test hypothesis 1:
  - Measured current was normal and balanced
- Hypothesis 2
  - fuse is thermal element – Something is causing excessive heat at one fuse
- Test hypothesis 2:
  - Look for other heat sources

Looking for cause of fuse blowing

Before

After

Loose connections can result in enough additional heating for fuses to melt.

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Next time…

- Start sags and interruptions
  - Read FPQ chapters 3 and 4
  - Read PSQ chapter 3