ECE 528 – Understanding Power Quality

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

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Lecture 4

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Today… Last Power Quality Fundamentals lecture

- Power quality investigations
- Using the scientific method
- Case studies

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Notes on submitting assignments

- Preliminary drafts:
  - Send your draft and questions via email - easier than Canvas
  - Using Prime? - Send a Prime file – I can open it and experiment
  - Other formats: PDF, XLSX, DOCX
  - If your draft is worth 100% I'll let you know
- Final draft:
  - Submit Prime file and/or other files in Canvas
  - Your grade and feedback will be in Canvas

PQ investigations

- Remember what is needed to create a PQ problem:

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

- Must have all three "inputs"
- Eliminate any one input, and the PQ problem is eliminated
- We can try to be proactive and address common disturbances in advance

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 and more observations
- Refine hypothesis as necessary based on new observations

PQ Investigations: Applying the scientific method

- Don't just measure; test: Normal or abnormal?
  - Know what "normal" is before measuring - Use calculations, nameplate data, nominal values, historical data, other measurements
  - Abnormal measurements can support or refute a hypothesis and change the course of the investigation
- 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
    - Are expectations realistic? i.e. is the equipment really malfunctioning?

A real-world example

- 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
  - Not associated with any activities of the customers

A real-world example continued

- More information from recording
  - Recorded voltage sags when symptoms occurred
  - Two to four per day
  - Not associated with load at monitored location
- Analysis
  - Pre- and Post- sag voltage is different – voltage goes up or down about 2 volts on a 120-volt system.

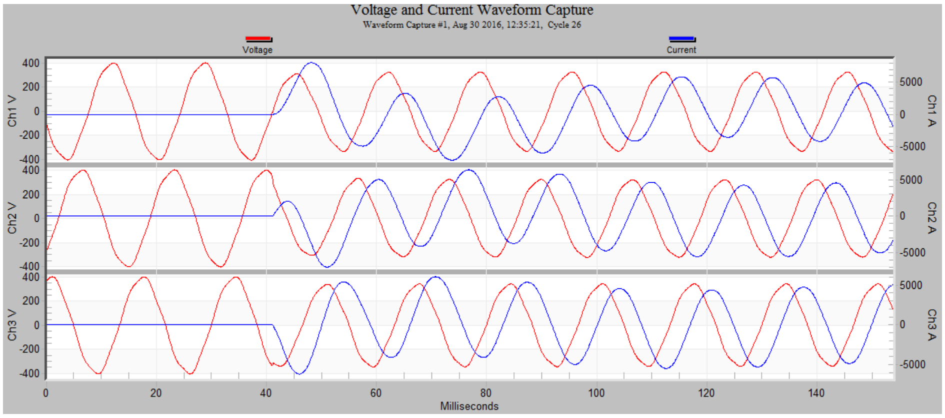
A real-world example continued

- Hypotheses
  - A problem at a capacitor, regulator, or the substation transformer is causing the voltage sag
    - Capacitors, voltage regulators, and substation transformer tap changing can cause step changes in service voltage
- Tests
  - Review capacitor control logs: no correlation
  - Feeder has no regulators
  - Manually step the substation transformer: <u>this reproduced the symptoms</u>
- Results
  - Damaged transformer tap switching mechanism was causing an instantaneous open circuit when changing taps

What can we observe and use in our analysis?

- Voltage and current data (spot measurement, trend, waveforms)
- Calculated parameters –harmonics, power, imbalance, etc.
- Temperature
- Appearance
- Operating characteristics, and response to tests
- Correlation with other events – operating logs
- And more!

A real-world waveform…



Starting a 500hp motor “across the line” with no load connected.

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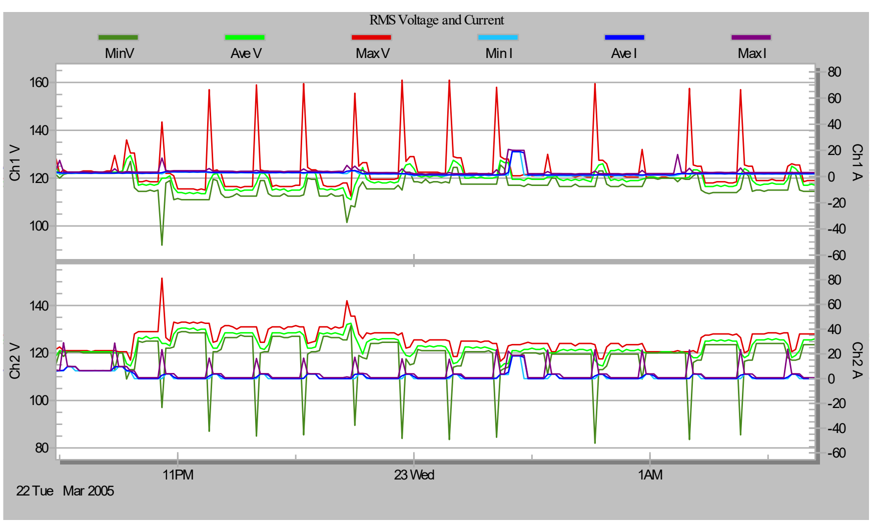
A voltage and current trend, and a problem…



Note the time scale – this is not a waveform.

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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
  - Get accurate and complete description of problem
    - 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

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Deciding where to start…

- Transmission
- Substation
- Feeder
- Service Transformer
- Service Conductors
- Main Panel
- Sub Panel
- Branch circuit
- Equipment

Data from:
Electric company operating logs
Substation SCADA systems
Recloser controllers
Capacitor controllers

Data from:
Measurements and recordings
Direct observations
Customer logs
Equipment logs

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Initial observations and preliminary analysis

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- 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.
  - Voltage across connections should be negligible

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Observations/Hypotheses - Monitoring

- Advantages of monitoring:
  - 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

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 or refine 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.

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.

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.

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.
- If you don't know, say so.
- Ask before speculating and make it clear that you are speculating.

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

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

Example 2: Hot transformer – test hypothesis 2

Normal Transformer

Hot Transformer

Hot Transformer

Example 2: Hot transformer - conclusion

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

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 before blowing fuses
  - Original transformer bank suspected by customer
  - Larger transformer bank installed
  - New motor still would not reach operating speed
  - PQ engineer called

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 ≈ 101hp at 1800RPM

Example 4 – blowing fuses in service disconnect

- Hypothesis 1 -
  - Voltage imbalance causing excessive current imbalance and high current
- 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 with infrared camera

Looking for cause of fuse blowing

Before

After

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

Next time…

- Start Section 2 – Voltage sags and short Interruptions
  - Read FPQ chapters 3 and 4
  - Read PSQ chapter 3