Power Quality Agenda

• Impact of poor power quality
• Power disturbances
• Solutions to power disturbances
• The cost of power quality and energy waste
• Tools available to quantify these wastes?
Impact of Poor Power Quality

“Power related problems cost U.S. companies over $26 billion a year”

Frost & Sullivan
What Causes Electrical Disturbances?  80/20 Rule

• The customer!
  - Wiring & grounding errors
  - Load interactions
  - Heavy load start-up
  - Poorly specified power conversion products
    - Incorrect grade and application
    - Incorrect sizing

• Utility power isn’t perfect
  - Power factor correction capacitors
  - Accidents to power lines and power distribution equipment
  - Re-closures, clearing faults
  - Weather
Facility Issues

Every facility / location is different

- Disturbances occur at varying magnitudes and rates
  - Noise
  - Impulse
  - Voltage (sag, swell or brownout)
  - Interruption

- Resources to identify disturbances
  - Power Quality Audit
  - Statistical reports (Loggers, Recorders, Troubleshooters)

Match the protection to the needs of the load!!
Load Sensitivity

All loads are different

- Sensitive to impulses
  - Microprocessors, controllers, process equipment

- Sensitive to voltage sags, swells or brownout
  - Motors, compressors (HVAC), test & measurement equipment, lighting

- Sensitive to power interruption
  - Computer-based control systems, data storage systems, alarm systems, safety equipment

Protect the loads most at risk !!!
ELECTRICAL DISTURBANCES

Transient/Impulse
Surges/Over Voltage
Sag/Under Voltage
Outage/Blackout
Harmonics
Noise
Voltage Sag (Under Voltage)

Definition:
- Temporary drop in RMS voltage, may last for several cycles

Causes:
- Large loads start-up (motors, air conditioner, etc.)
- Utility switching

Effects:
- Hardware crashes, occasional equipment failure, reduce efficiency and life span of electrical equipment particularly motors

Solutions:
- Power Conditioner
- UPS
- DC Power Supplies that meet SEMI F47
Voltage Surge (Swell / Over Voltage)

**Definition:**
- Temporary rise in RMS voltage, may last for several cycles

**Causes:**
- Large loads turning off (motors, air conditioner, etc.)
- Utility shedding loads

**Solutions:**
- Power Conditioner
- UPS with voltage regulation

**Effects:**
- Permanent damage to hardware and other electrical equipment
Brownout

Definition:
• Temporary drop in RMS voltage, may last for several hours

Causes:
• High demand on the utility grid
• Service located at the end of grid

Effects:
• Hardware crashes and occasional equipment failure, reduce efficiency and life span of electrical equipment particularly motors

Solutions:
• Voltage Regulator
Power Interruption (Outage / Blackout)

Definition:
• Sudden loss of AC power

Causes:
• Fuses or circuit breakers opening
• Storms
• Construction accidents

Solutions:
• UPS

Effects:
• Equipment shutdown, data loss, production delays, long process start up cycles and safety issues (loss of lighting, alarms and PA system)
Harmonic Distortion

**Definition:**
- Distortion to the sinewave

**Causes:**
- Switch mode power supplies
- Non-linear loads

**Effects:**
- High neutral current, overheated neutral, overheated transformers, voltage distortion, breaker tripping, loss of system capacity

**Solutions:**
- Ferroresonant Transformers
- Active/Passive filters
- On-Line UPS
- Drive Isolation Transformers
- K-Factor Transformers
Voltage Transient (Impulse / Spike)

**Definition:**
• Narrow, high voltage or current impulse superimposed on the AC waveform

**Causes:**
• Utility grid switching
• Arc welder drawing an arc
• Contactor opening or closing
• Heavy industrial equipment starting
• Lightning

**Effects:**
• Equipment failure or damage, system lock-up, data corruption/loss, and component stress that can lead to breakdown

**Solutions:**
• SPDs
• SPD/Filter
• Isolation Transformer
• Power Conditioner
Electrical Noise

Definition:
• Low amplitude, low current, high frequency disturbances

Causes:
• Switch mode power supplies, other loads, improper grounding

Effects:
• Perceived software errors, system lock-up

Solutions:
• Isolation Transformer
• Active Tracking Filter
• Power Conditioner
• UPS
**Frequency Variation**

**Definition:**
- Changes to the 60 Hz sine wave

**Causes:**
- Local power generators with poor speed control
- Large load changes on a local generator

**Effects:**
- Permanent damage to hardware and system crashes

**Solutions:**
- UPS

![Frequency Variation Image]
Surge Protective Devices

**Definition:**
- A device which clamps voltage to a safe level during an impulse

**Problems Solved:**
- Impulses and lightening

**Myths:**
- Provides protection from voltage abnormalities (voltage surge)

**Fact:**
- If the RMS voltage goes above the clamping level of the device it will blow input fuses or destroy the device
Signal/Data Line Protection (STC)

**Definition:**
- A device which clamps voltage to a safe level for data and communication lines

**Problems Solved:**
- Impulses and lightning

**Myths:**
- Provides protection from voltage abnormalities

**Fact:**
- No protection from RMS voltage fluctuations
Active Tracking® Filter (STF & STFE)

**Definition:**
- A device which filters high frequency noise (STF) and clamps voltage (STFE)

**Problems Solved:**
- Noise, impulses and lightening

**Myths:**
- Provides protection from voltage abnormalities

**Fact:**
- No protection from RMS voltage fluctuations
**Constant Voltage Transformer (Ferroresonant)**

**Definition:**
- A transformer with inherent voltage regulation due to design

**Problems Solved:**
- Impulses, noise, surges, sags, brownouts and harmonics

**Myths:**
- Provides protection from power interruptions

**Fact:**
- A Constant Voltage Transformer will only ride through a ~3ms power interruption
Drive Isolation & K-Factor Transformers

**Definition:**
- Transformers designed to handle high heat
- Specifically designed for SCR controlled variable speed motor drives

**Problems Solved:**
- Able to handle mechanical stresses, voltage demands, & overheating caused by harmonics.

**Myths:**
- Provides protection on IGBT Drives
- Used when an isolation transformer is requested
- Just a de-rated transformer

**Fact:**
- Typically K-4 Rated

---

Typical Load K-Factors

<table>
<thead>
<tr>
<th>Load</th>
<th>K-Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric discharge lighting</td>
<td>K-4</td>
</tr>
<tr>
<td>UPS with optional input filtering</td>
<td>K-4</td>
</tr>
<tr>
<td>Welders</td>
<td>K-4</td>
</tr>
<tr>
<td>Induction heating equipment</td>
<td>K-4</td>
</tr>
<tr>
<td>PLCs and solid state controls</td>
<td>K-4</td>
</tr>
<tr>
<td>(other than variable speed drives)</td>
<td>K-4</td>
</tr>
<tr>
<td>Telecommunications equipment (e.g., PBX)</td>
<td>K-13</td>
</tr>
<tr>
<td>UPS without input filtering</td>
<td>K-13</td>
</tr>
<tr>
<td>Multwire receptacle circuits in general care areas of health care facilities and classrooms of schools, etc.</td>
<td>K-13</td>
</tr>
<tr>
<td>Multwire receptacle circuits supplying inspection or testing equipment on an assembly or production line</td>
<td>K-13</td>
</tr>
<tr>
<td>Mainframe computer loads</td>
<td>K-20</td>
</tr>
<tr>
<td>Solid state motor drives (variable speed drives)</td>
<td>K-20</td>
</tr>
<tr>
<td>Multwire receptacle circuits in critical care areas and operating/recovery rooms of hospitals</td>
<td>K-20</td>
</tr>
</tbody>
</table>

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Uninterruptible Power Supply (UPS)

**Definition:**
- A device which provides battery back up during a power interruption

**Problems Solved:**
- Power interruptions (limited to the duration of the battery)
- Impulses, noise, surges, sags, brownouts and harmonics (depending on the UPS technology)

**Myths:**
- The $49 UPS from the local computer superstore will cure all power quality problems

**Fact:**
- You get what you pay for, in this case just battery back up during a power interruption
The **Cost** of Power Quality

- How much is the machinery or equipment worth?
- How much is the process worth?
  - 1 second data loss
  - 30 minute delay
  - One hour shutdown
  - ½ day work stoppage
- What is the visibility of a production shutdown to management?

  = *Lost Performance, Productivity, Data*

  *This leads to lost $$$MONEY$$$*
Poor Power Quality = Energy Waste

Identifying and quantifying energy waste
### Power Quality Measurement Solutions

<table>
<thead>
<tr>
<th>Maintenance</th>
<th>Electric Utility</th>
<th>Field Service</th>
<th>Electrical Contractors / Installers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Troubleshooters</td>
<td>PQ Loggers</td>
<td>Troubleshooters</td>
<td>Power Logger</td>
</tr>
<tr>
<td>Energy Logger</td>
<td>Recorders</td>
<td>Basic Recorder</td>
<td>PQ Clamp</td>
</tr>
</tbody>
</table>
How is energy waste manifested?

**Electrical**
- Power consumption
- Power distortion
- Overheating

**Mechanical**
- Excessive vibration, friction
- Overheating
- Excessive sound
Focus on three building systems

Three-phase electrical distribution (Mains)

Production process systems
- Mechanical loads
- Flow: Air compression, steam

Electrical subsystem
- Utility billing
- Electrical distribution infrastructure

Building Infrastructure
- Ventilation, heating, cooling
- Building envelope
- Lighting

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How can energy waste be quantified?

• Electrical
  – kWh
  – Harmonics
  – Unbalance
  – Power Factor
  – Peak demand
  – Anomalies

• Mechanical
  – Vibration
  – Temperature

• Building Infrastructure
  - Environmental losses
  - Roof leaks
Tools for identifying and quantifying waste

Fluke 435-II, 1730, & 1738 Power & Energy Logger

Fluke TiX & Ti Series Thermal Imagers:

Fluke 810 Vibration Tester
What is electrical energy?

Power, kW (True Power)
Rate at which ac energy is expended. Watts measure the energy required to do actual work, such as running a motor.

Demand, kVA (Apparent Power)
Total voltage and current required from the utility, regardless of its efficiency or whether it does actual work.

Power factor, PF
When a circuit operates at 100% efficiency, demand = power. When power is less than demand, the difference, kW/kVA, is power factor. PF below .95 is inefficient.

Harmonics and unbalance
Other causes of inefficient power usage

→ To measure power the way the utility bills for it, a power measurement accounting for volts, amps, watts, and PF is necessary.

→ To increase efficiency, harmonics and unbalance should be also be assessed.
Fluke 1730 Series, & 435-II Power logger capabilities for identifying energy waste

- Energy assessments
  - Quantify energy consumption before and after improvements to justify energy saving devices
- Monitor maximum power demand
- Energy waste logger functions:
  - kWh
  - Harmonics
  - Unbalance
  - Power Factor
  - Peak demand

Easy to use, powerful and complete

- Charge the battery, load the software: ready to go
- View graphs, generate reports with Power Log software
- 600 V CAT III rated.
Diagnostic and troubleshooting capabilities

- Troubleshoot real-time:
  Analyze trends using cursors and zoom tools. Automatically trend kWh, Harmonics, Unbalance, Power Factor, Peak demand

- Logger:
  Configure for any test condition with memory for up to 600 parameters at user defined interval

- System-monitor:
  Ten power quality parameters on one screen according to EN50160 power quality standard

- Automatic transient mode:
  Capture 200 kHz waveform data on all phases simultaneously up to 6 kV

- PowerWave data capture:
  Capture fast half-cycle RMS data and waveforms to characterize electrical system dynamics (generator start-ups, UPS switching)

- Waveform capture:
  Capture 120 cycles (60 Hz) of each event that is detected in all modes, without set-up.
Fluke 1730 Series

- Optimized layout with specialized touch screen makes navigation easy – even with gloves
- Powered from the measured voltage line or regular power cord
  - up to 500V AC (from 90V) for line measurement
- Supplied as standard with 1,500A flexible current probes
  - optimized for easy installation in tight panels
  - self powered and automatically recognized
- Flat three phase voltage measurement lead set
  - eliminates tangles, simplifies connection
- Battery and AC powered
  - battery rides through power outages or powers the instrument when not connected
The Fluke Energy Loss Calculator

Identify, quantify and monetize comprehensive energy losses, including harmonics, unbalance, power factor and cabling.

- Useful kilowatts (power) available
- Reactive (unusable) power
- Power associated to unbalance
- Power associated to harmonics
- Neutral current
- Total cost of wasted kilowatt hours per year

Cable length and diameter are factored in to the wastes above.
Start with electrical measurements

**Loads: Lighting, computers**

- **Load #1 50 kVA**
- **Load #2 100 kVA**

**Motor #1**

**Transformer**

**Sub-panel #1.1**

**Sub-panel #1.2**

**480 V panel**

**Main Service Entrance**

**Capacitor**

**Disconnect**

**Starter**

**Motor #2**

**Detect waste**

**Switchgear/Capacitor bank**

- **Switchgear/Alt energy source**

**277/480 Panel or load**

**Unit** | **Measurements** | **Objective**
--- | --- | ---
Main switchgear | KW, PF, unbalance, harmonics | Compare usage to bill, evaluate level of waste
Switchgear/Capacitor bank | PF | Verify efficiency of PF mediation
Switchgear/Alt energy source | KW, inverter efficiency, temperature | Verify power contributed and inverter efficiency
277/480 Panel or load | KW, PF, unbalance, harmonics, temperature | Evaluate level of waste and ROI for mitigation or changes to loads or schedules

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Current harmonics generated by motor drives, unbalance voltages and currents or an inadequate cabling sizing may result in an increment of energy losses along the cables that feed the motor drive, in the form of more heat that can damage the installation and increase the electricity bill.
Follow-up with a thermal scan

<table>
<thead>
<tr>
<th>Unit</th>
<th>Measurements</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main switchgear</td>
<td>KW, PF, unbalance, harmonics</td>
<td>Compare usage to bill, evaluate level of waste</td>
</tr>
<tr>
<td>Switchgear/Capacitor bank</td>
<td>PF</td>
<td>Verify efficiency of PF mediation</td>
</tr>
<tr>
<td>Switchgear/Alt energy source</td>
<td>KW, inverter efficiency, temperature</td>
<td>Verify power contributed and inverter efficiency</td>
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<td>Evaluate level of waste and ROI for mitigation or changes to loads or schedules</td>
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## Electro-mechanical measurements

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical</td>
<td>Vibration, temperature</td>
</tr>
<tr>
<td>Electrical</td>
<td>Voltage unbalance, current unbalance, power factor</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Grounding, connections, insulation resistance</td>
</tr>
</tbody>
</table>
Electro-mechanical loads

- Insulation resistance
- And Unbalance
- Temp
- Temp and Vibration
- PQ
Maintenance team safety comes first

- Measurements from a safe distance – stay outside of the arc blast zone.
- Gather inspection data away from dangerous moving machinery and reduce the risk of injury by moving heavy machines to get the right measurements.
- Wireless measurement transfer reduces error and eliminates mundane data collection so your team can focus on the real work.
- Data is stamped with time and date, removing uncertainty with data collection.
- Baseline, historical and current inspection data is all in one place.
Fluke Connect → Collaboration Across All Tiers

Over 20 Connected Tools And More Coming…

- Capture & Save Measurements
- Add Voice or Text Notes
- Create Trend Lines
- Share Live with Team Members
- Escalate Issues to Managers
- Generate Work Order Requests
- Send Data to 3rd Parties
- Measure From a Safe Distance

Could better tools influence better work practices? and better collaboration? and better maintenance culture?
Thank You!

Time for lunch