POWER QUALITY

Is it real?

Prat Nagu, E.I.T.
CTC Engineering, Inc.
Ann Arbor, MI
Why should we care?

- Computer Lockouts (20%)
- Light flickering (22%)
- Electronic failures (18%)
- Power factor correction system failures (17%)
- Failures in high load switching (16%)
- Neutral conductor overheating (12%)
- Unexpected breaker operation (11%)
- Power meters inaccurate readings (6%)

And of course excess losses and downtime...
Typical PQ Issues

- (a) Transient
- (b) Sag
- (c) Swell
- (d) Undervoltage
- (e) Momentary interruption
- (f) Long term interruption
- Steady state voltage distortion
- (h) Flicker
- (i) Noise
Chicken or the egg?

- Loads distort current waveforms
- In turn causes voltage distortion
  - System Impedance
  - Amount of distorted current
## Sources of PQ problems

### Utility
- Lightning
- Power Factor Correction
- Faults
- Switching

### End User
- Individual Loads
  - Lighting loads
  - Elevators
  - Coolers
- UPS
- VFD
- Battery Chargers
- Large Motors during start up
- Electronic Light Dimmers
- Electronic Light Ballasts

- Arcing Equipment
  - Welding
  - Steel manufacturing
- Medical Equipment
  - MRI, X-Ray, etc.
- Office equipment and Computers
- Switch Mode Power Supply (SMPS)
- Improper Electrical System Design
- Wiring
Waveform Distortion

- Effect of a simple residential light dimmer on current waves

https://www.youtube.com/watch?v=puxQTRj2TRl

https://www.youtube.com/watch?v=yEPoxiO-H68

- Now think about the number of residential/commercial loads and the number of electronics loads that disrupt the waveforms
<table>
<thead>
<tr>
<th>PQ Problems</th>
<th>Major Sources</th>
<th>Solutions</th>
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<td>The Utility</td>
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<tr>
<td>Interruptions</td>
<td>The Utility</td>
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<td>Voltage variations</td>
<td>Load changing</td>
<td>Synchronous loads</td>
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<td>Fast PF correction</td>
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<tr>
<td>Voltage flicker</td>
<td>Load change (welding)</td>
<td>Fast PF correction</td>
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<tr>
<td>Voltage dip</td>
<td>Motor and heavy load start up</td>
<td>Motor Starters</td>
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<td>VFD</td>
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<tr>
<td></td>
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<td>Fast PF correction</td>
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<tr>
<td>Over voltage</td>
<td>Over PF compensation</td>
<td>Fast PF correction</td>
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<td>Start up or Switching</td>
<td>Controlled switches</td>
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<tr>
<td>Unbalance</td>
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<td>Non linear loads</td>
<td>Active passive filters</td>
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<td>Resonance</td>
<td>Detuned capacitors</td>
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<td></td>
<td>Improved VFD operation</td>
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</table>
Harmonics
Harmonics

Fourier Analysis
THD or TDD?

\[ IHD_n = \frac{I_n}{I_1} \times 100\% \]

\[ THD_I = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \ldots + I_n^2}}{I_1} \times 100\% \]

\[ TDD_I = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \ldots + I_n^2}}{I_L} \times 100\% \]

For limits and standards, please visit CTC booth!!!
Expected Harmonics in VFDs

What order of harmonics to expect from your VFD?

- $H = np \pm 1$
  - E.g.: 6 pulse VFD: 5, 7, 11, 13, 17, 19...

- Generally magnitude decreases as order increases

- Expected harmonics:
  - SMPS: 3, 5, 7, 9, 11, 13...
  - Fluorescent lights: 3, 5, 7, 9, 11, 13...
  - Arcing devices: 2, 3, 4, 5, 7...
  - Transformer energization: 2, 3, 4
If you cannot **measure it**, you cannot **manage it**
## Case Study – Steel Plants

<table>
<thead>
<tr>
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<th>Industry A</th>
<th>Industry B</th>
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<tr>
<td>Trafo Rating</td>
<td>5 MVA</td>
<td>5 MVA</td>
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<tr>
<td>Demand</td>
<td>3.5 MVA</td>
<td>4.9 MVA</td>
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<tr>
<td>%THDv</td>
<td>3.3 – 4.7</td>
<td>2.9-5.6</td>
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<td>%THDi</td>
<td>24.9</td>
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## Case Study – Steel Plants

### Table

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<th>Timestamp</th>
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<th>Phase B</th>
<th>Phase C</th>
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</table>

### Diagram

- Harmonics Trend
- THD % V
- Timestamp: 10/11/2017
- CTC Engineering, Inc.
Triplen Harmonics

- They add up and return as neutral current
Triplen Harmonics

Neutral Conductor
Economic impact

- Oversizing of equipment
- Losses through inefficiencies
- PF penalties
- Inconsistent meter reading
- Cost associated with downtime due to
  - Equipment failure
  - Frequent repairs/maintenance
- Cost for adding harmonic filters
If you cannot **measure it**, you cannot **manage it**
Monitoring Options

• Temporary

Power Recordings
Monitoring Options

• Wireless - New
Wireless & Online PQ Monitor

• CTC’s latest R&D project

• Striking Features:
  o Plug and Play
  o Wireless communication
  o Cyber secure
  o Elegant, User friendly, ‘Anywhere’ HMI
  o Monetization and Prediction
  o Multi-node monitor
  o All-in-one Power Quality Monitor

• Application:
  o Utilities
  o Municipalities
  o Industrial Substation
  o Power Plants
  o Manufacturing facilities
  o Process Industries - WWTP
  o Hospitals
  o Universities

• Prototypes are already out!

To find out more stop by at CTC Booth!
Thank you!

Visit our booth, we are here till tomorrow

www.ctcengineer.com