Power Factor Correction

Presented by:
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Learning Objectives

- Define power factor (PF)
- Explore other benefits of power factor correction (PFC)
- Identify potential PF charges on your electric utility bill
- Identify solutions available to correct PF
- Summarize how harmonics effect the application of PFC capacitors
- Calculate the financial ROI for PFC
- Determine real savings versus overstated savings
What am I paying for on my bill?

- Energy (kWh)
- Demand (kW)
- PF Charges
- Taxes
What is Power Factor?

- PF is a measure of the efficient use of power or the ratio of Working Power (kW) to Apparent (or Total) Power (kVA)

\[ PF = \frac{kW}{kVA} \]

- Poor PF is costly for the utility and for the end user – power system capacity is used, kW losses are increased and voltage at the load is low.

- Utilities often penalize customers for low PF as an incentive to compensate for this inefficiency.
What is a VAR?

- **Active power**, also called **real power**, is measured in **Watts or kW** and performs **Useful Work**
- Electrical equipment like motors and transformers require **reactive power** create a **Magnetic Field** and allow work to be performed.
- This reactive power is called **volt-amperes-reactive or VAR’s**
- **Reactive power** is measured in **vars or kvars**
- **Total apparent power** is called **volt-amperes** and is measured in **VA or kVA**
Example: Power Factor

\[ 125\text{kVA} = \sqrt{(75\text{kvar})^2 + (100\text{kW})^2} \]
\[ 103\text{kVA} = \sqrt{(25\text{kvar})^2 + (100\text{kW})^2} \]

\[ \text{PF} = 0.80 \]
\[ \text{PF} = 0.97 \]

Real power used

Reactive or unused power

- 75 kvar
- 25 kvar

Apparent power
Power Factor Analogy

• Consider a horse pulling a boat on a canal.

• The boat turns its rudder to stop from running onto the bank.

• The turned rudder creates drag so less of the horse’s power is going toward moving the boat forward.

Source: Con Ed
Somebody has to pay for capacity and losses

- Wasted Capacity (VAR’s)
- Useful Work (Watts)
- Capacity (kVA)
Cost savings due to increased capacity

- Correcting poor power factor can significantly reduce the load on transformers and conductors and allow for facility expansion
  - Transformers are rated by kVA and must be sized accordingly
Example: Improving PF Cont.

- 125 kVA
- 100 kW
- 75 kvar

- 50 kvar

KVA (and Amp) Reduction

- no PFC
- w/PFC

125 kVA = \sqrt{(75\text{kvar})^2 + (100\text{kW})^2}

103 kVA = \sqrt{(25\text{kvar})^2 + (100\text{kW})^2}

Real power used

Reactive or unused power

Apparent power

100 kW

75 kvar

25 kvar
Loads with Low PF

- Air Handling/HVAC
- Pumps
- Elevators
- Compressors
- Computers
- Process Machinery
Typical Uncorrected Power Factor

<table>
<thead>
<tr>
<th>Industry</th>
<th>Percent Uncorrected PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brewery</td>
<td>76-80</td>
</tr>
<tr>
<td>Cement</td>
<td>80-85</td>
</tr>
<tr>
<td>Chemical</td>
<td>65-75</td>
</tr>
<tr>
<td>Coal Mine</td>
<td>65-80</td>
</tr>
<tr>
<td>Clothing</td>
<td>35-60</td>
</tr>
<tr>
<td>Electroplating</td>
<td>65-70</td>
</tr>
<tr>
<td>Foundry</td>
<td>75-80</td>
</tr>
<tr>
<td>Forge</td>
<td>70-80</td>
</tr>
<tr>
<td>Hospital</td>
<td>75-80</td>
</tr>
<tr>
<td>Machine manufacturing</td>
<td>60-65</td>
</tr>
<tr>
<td>Metal working</td>
<td>65-70</td>
</tr>
<tr>
<td>Office building</td>
<td>80-90</td>
</tr>
<tr>
<td>Oil-field pumping</td>
<td>40-60</td>
</tr>
<tr>
<td>Paint manufacturing</td>
<td>55-65</td>
</tr>
<tr>
<td>Plastic</td>
<td>75-80</td>
</tr>
<tr>
<td>Stamping</td>
<td>60-70</td>
</tr>
<tr>
<td>Steelworks</td>
<td>65-80</td>
</tr>
<tr>
<td>Textile</td>
<td>65-75</td>
</tr>
</tbody>
</table>

Source: *IEEE Std 141-1993 (IEEE Red Book)*

Low PF typically results from unloaded or lightly loaded motors

Unloaded motor – PF = .1 to .20

Loaded motor – “rated PF” = .85
Demonstration
Why Consider PFC?

PF correction provides many benefits:

• **Primary Benefit:**
  • Reduced electric utility bill if there is a penalty  
    
  (a typical payback 1-5 years)

• **Other Benefits:**
  • Increased system capacity (generators, cables, transformers)
  • Improved voltage regulation
  • Reduced losses in transformers and cables
  • May reduce harmonics on the power system (with harmonic filters)
  • Greening the power system
How Can I Justify PFC Equipment?

- If you know the penalty and you know the cost of the corrective equipment, you can calculate the (ROI)

- So...let’s just **calculate the penalty** – all you have to do is go to the utility company’s website and read the tariff for your rate structure...

- Then we’ll just **calculate the size and cost** of equipment...

*Sounds easy, doesn’t it?*
How do Utility Companies Bill?

• Always measure energy usage in Watt-hours (kWh) – **typical charges are 5¢ -15¢ per kWh**

• For larger customers like hospitals and universities - kW or kVA demand (i.e. - 15 minute demand) **typical charges are $5-$15 per kW or kVA**

• PF penalties may be part of demand charges, separate charges and sometimes kWh charges are affected

• Many times, if a penalty is imposed, a minimum PF is required (i.e. 85%, 95%, etc.)
Con Ed Tariff

$1.10/kvar
@ peak kW demand to maintain 0.95 lagging PF

Step 1 – determine peak kW demand per month
Step 2 – determine kvar demand at same interval
Step 3 – determine kvar at 0.95 PF
Step 4 – determine excessive kvar (i.e. compare step 2 to step 3)
Step 5 – multiply step 4 by $1.10 to determine penalty per month
Con Ed Tariff: Example (estimated)

Billed kvar = measured kvar – (1/3) kw [at peak]

@ 0.95 p.f., kvar ≈ 0.33 *kW

1,800kW @ 0.85 p.f. => 1,115.5 kvar measured
515.5 kvar billed (1,115.5 - 600)

1200kW @ 0.85 p.f. => 743.6 kvar measured
343.6 kvar billed (743.6 - 400)

Source: Con Ed
Con Ed Tariff:  Example

Assuming a 1,800kW peak load for 4 months and 1200kW for 8 months at 0.85 p.f.

1800kW @ 0.85 p.f. => 1115.5 kvar for 4 months, the customer is charged for 515.5 kvar.

1200kW @ 0.85 p.f. => 743.6 kvar for 8 months, the customer is charged for 343.6 kvar.

Assume the installation of 300kvar at a cost of $50/kvar.

- capital cost = $15,000
- avoided kvar charges = $4,724.8 per year
- $3,027 in energy savings annually
- simple payback: $15,000/($4,724.8+$3,027) = **1.9 years**.

Assuming $30/kvar: simple payback = $9,000/$7,751.8 = **1.2 years**

Assuming $70/kvar: simple payback = $21,000/($7,751.8) = **2.7 years**

Assuming $50/kvar, ignoring loss savings: simple payback = $15,000/$4,724.8 = **3.2 years**

Source: Con Ed
How Can I Justify PFC Equipment?

PF Penalty

Loss Savings 0-2%

Green Benefit System/Societal Benefit
# PF Calculator

- Eaton Power Factor Correction Tool™ - PF Penalty Page

- Calculator to identify potential PF savings

- Example: $5366/year

<table>
<thead>
<tr>
<th>Month</th>
<th>Monthly Demand (kW)</th>
<th>Monthly Demand (kvar)</th>
<th>PF</th>
<th>Maximum kvar to avoid penalty</th>
<th>Required kvar compensation</th>
<th>Potential PF Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>JAN</td>
<td>1,200</td>
<td>750</td>
<td>0.848</td>
<td>394</td>
<td>356</td>
<td>$ 391</td>
</tr>
<tr>
<td>FEB</td>
<td>1,200</td>
<td>750</td>
<td>0.848</td>
<td>394</td>
<td>356</td>
<td>$ 391</td>
</tr>
<tr>
<td>MAR</td>
<td>1,200</td>
<td>750</td>
<td>0.848</td>
<td>394</td>
<td>356</td>
<td>$ 391</td>
</tr>
<tr>
<td>APR</td>
<td>1,200</td>
<td>750</td>
<td>0.848</td>
<td>394</td>
<td>356</td>
<td>$ 391</td>
</tr>
<tr>
<td>MAY</td>
<td>1,800</td>
<td>1,100</td>
<td>0.853</td>
<td>592</td>
<td>508</td>
<td>$ 559</td>
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<tr>
<td>JUN</td>
<td>1,800</td>
<td>1,100</td>
<td>0.853</td>
<td>592</td>
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<td>$ 559</td>
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<tr>
<td>JUL</td>
<td>1,800</td>
<td>1,100</td>
<td>0.853</td>
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<td>508</td>
<td>$ 559</td>
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<tr>
<td>AUG</td>
<td>1,800</td>
<td>1,100</td>
<td>0.853</td>
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<tr>
<td>SEP</td>
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<td>750</td>
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<td>$ 391</td>
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<tr>
<td>OCT</td>
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<td>750</td>
<td>0.848</td>
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<td>$ 391</td>
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<tr>
<td>NOV</td>
<td>1,200</td>
<td>750</td>
<td>0.848</td>
<td>394</td>
<td>356</td>
<td>$ 391</td>
</tr>
<tr>
<td>DEC</td>
<td>1,200</td>
<td>750</td>
<td>0.848</td>
<td>394</td>
<td>356</td>
<td>$ 391</td>
</tr>
</tbody>
</table>

Average PF: 0.850

Total PF Penalty: $ 5,366

Select Service Type: Schedule 1 - kvar charge

First Demand Block: $ 1.10 per kvar

Average PF: 0.850

Total Months of Data Entered: 12 months

Total PF Penalty/Year: $ 5,366

Potential Savings Per Year (Enter in B17 of PF Calculator Worksheet)
Next step – select the proper size and type of PFC…

How do you select the correct PFC?

What size of PFC?
What type of PFC?
Where do you install them?
Sizing PFC Equipment

1. Determine the target PF ($> 0.95$ for Con Ed)
2. Determine (tables or software) the size of PFC required
3. Select PFC size to avoid penalty, minimize negative effects (overvoltage, harmonic resonance, losses)
4. Consider installation location to determine low voltage or medium voltage installation, fixed or switched
Capacitor Sizing

“kvar needed” calculation

• Gather past utility bills, if possible
• Do multiple monthly calculations
  • Easy to do many calculations quickly with a spreadsheet
  • Examples shown in the capacitor application paper
  • kvar demand on Con Ed bill will be at peak kW demand (i.e. don’t average kvar levels) – will likely be higher in summer than winter (HVAC loads)
Capacitor Selection

Consideration (after kvar size is chosen)

• Utility penalties (take care of whole penalty?)
• Installed cost and payback of equipment
• Load variability (fixed or switched)
• kW losses (location)
Capacitor Selection

What can cause major problems

- Harmonic resonance
- Switching transients and voltage magnification
- Voltage regulation (especially high voltage)
- Leading PF on generators
- Self excitation of motors
- Load requirements (flicker requirements) – speed of switching device
On November 7, 1940, at approximately 11:00 AM, the Tacoma Narrows suspension bridge collapsed due to wind-induced vibrations...the bridge had only been open for traffic a few months.
Harmonic Resonance

The “Self Correcting” Problem

- Blown Fuses
- Failed Capacitors
- Damaged Transformer

Harmonics = Wind (Excites Resonance)
Harmonic Resonance - Solutions

1. **Change the method** of kvar compensation (harmonic filter, active filter, etc.)
2. **Change the size** of the capacitor bank to over-compensate or under-compensate for the required kvar and live with the ramifications (i.e. overvoltage or PF compensation).
Eaton Power Factor Correction Tool™ - Resonance

Step 1
- Bus Voltage: 480
- Existing Load: 1150 kvar
- Target PF: 0.95
- Required kvar: 211 kvar

Enter Quantities in Blue
Quantities in Orange are Calculated

Step 2
- Select CapFilter Size: 200 kvar
- Estimated Installed Cost for:
  - Fixed Cap and Breaker: $5,000
  - Switched Cap and Breaker: $10,000
  - Fixed Harmonic Filter and Breaker: $11,000
  - Switched Harmonic Filter and Breaker: $15,000
- Actual Total Equipment Cost: $6,000

- Estimated Payback:
  - 5 Months for Fixed Cap and Breaker
  - 10 Months for Switched Cap and Breaker
  - 11 Months for Fixed Harmonic Filter and Breaker
  - 15 Months for Switched Harmonic Filter and Breaker

Step 3
- Transformer kVA: 1500
- Transformer %Z: 5.75
- Bus Voltage: 480
- Load Reduction (kVA) with Addition of Selected Capacitor Bank: 6%
- Actual Corrected PF: 0.95
- Maximum % bus voltage rise at this bus - no load with the full capacitor: 0.77%
- 1150 kW
- 589 kvar
- Breaker or Fuse Size @ 135% Rating: 325 Amp
- Typical Breaker or Fuse Size or Setting @ 135% Rating for Selected Capacitor Bank: 400 Amp

Check Harmonics

Note: For more information or assistance in using this tool, please contact the Power Quality Hotline at (800) 809-2772 Option 1, Sub-option 2.
Capacitor Switching Transients

**Figure 8. Voltage Magnification Circuit**
Capacitor Switching Transients

**Figure 9. Utility Capacitor Energized With LV Capacitor Energized: Voltage Magnification at 480 V Bus**

**Figure 10. Utility Capacitor Energized Without LV Capacitor Energized: No Voltage Magnification**
Applying PF Capacitors

Where to apply?

• When applied close to the load (i.e. motor) transformer and cable losses are reduced
• Lower installation cost when applied in a central location
• Commonly applied at the utility metering point

So, what is the right answer?

• Depends on the application, budget, physical space and preference of the customer
Capacitor Placement – Physical Location

**Utility Penalty** – If needed for PF penalty

- Apply anywhere downstream of the meter

**Capacity Improvement** – if needed to improve the capacity of a transformer or cable, it must be placed downstream of the component

**Loss Reduction** – If needed for kVA or loss reduction

- Apply at or near the loads for $I^2R$ loss reduction
- 1-2% of overall kW is possible with distributed capacitor (some may claim more)
- Payback is generally 10 years or more (Typically not enough alone to justify cost to add capacitor)
PF Correction – Loss Reduction

Place here for utility PF penalty

Place here for utility PF penalty
(utility owned transformer)

or

Place here to reduce losses in transformer or free capacity

Place here for line loss reduction and voltage improvement

Resistive Load

Motor Load
Example – PF Correction Savings

12.47 kV

2 mi, 336 MCM Overhead

%R=1

300 ft, 1000 MCM Cable

12.47/0.48

500 kW

PF=.88

500 kW

PF=1

1076 kW

LOSSES:

4.73 kW  5.1 kW  71.2 kW
0.44%  0.47%  6.65%

Total Circuit Losses:  81 kW / 8.1%

Source: EPRI
Example, Capacitor at Load

\[
\begin{align*}
12.47/0.48 & \\
12.47 \text{ kV} & \\
2 \text{ mi, 336 MCM Overhead} & \\
300 \text{ ft, 1000 MCM Cable} & \\
(250 \text{ kvar}) & \\
1065 \text{ kW} & \\
500 \text{ kW} & \\
PF=0.88 & \\
500 \text{ kW} & \\
PF=1 & \\
\end{align*}
\]

\[
\begin{align*}
\text{LOSSES:} & \\
4.03 \text{ kW} & 4.32 \text{ kW} & 60.6 \text{ kW} & \\
0.38\% & 0.40\% & 6.23\% & \\
\text{Total Circuit Losses:} & 68.9 \text{ kW / 6.89\%} & \\
\text{End User Loss Savings:} & 76 \text{ kW} - 65 \text{ kW} = 11 \text{ kW} & \\
\text{This is nearly 15\% savings in losses, but net power into load decreases only 11 kW or 1.1\% of load} & \\
\end{align*}
\]

Source: EPRI
## Computer Simulation – Loss Savings

<table>
<thead>
<tr>
<th>PF</th>
<th>kW</th>
<th>kvar</th>
<th>kvar added</th>
<th>% kW Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.58</td>
<td>615</td>
<td>870</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>0.62</td>
<td>612.8</td>
<td>771</td>
<td>100</td>
<td>0.4%</td>
</tr>
<tr>
<td>0.67</td>
<td>610.9</td>
<td>671</td>
<td>200</td>
<td>0.7%</td>
</tr>
<tr>
<td>0.73</td>
<td>609.2</td>
<td>568.8</td>
<td>300</td>
<td>0.9%</td>
</tr>
<tr>
<td>0.79</td>
<td>607.7</td>
<td>466</td>
<td>400</td>
<td>1.2%</td>
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<tr>
<td>0.86</td>
<td>606.6</td>
<td>361</td>
<td>500</td>
<td>1.4%</td>
</tr>
<tr>
<td>0.92</td>
<td>605.7</td>
<td>255</td>
<td>600</td>
<td>1.5%</td>
</tr>
<tr>
<td>0.97</td>
<td>605.1</td>
<td>147</td>
<td>700</td>
<td>1.6%</td>
</tr>
<tr>
<td>1.00</td>
<td>604.8</td>
<td>38</td>
<td>800</td>
<td>1.7%</td>
</tr>
<tr>
<td>0.99</td>
<td>604.9</td>
<td>-72</td>
<td>900</td>
<td>1.6%</td>
</tr>
<tr>
<td>0.96</td>
<td>605.3</td>
<td>-184</td>
<td>1000</td>
<td>1.6%</td>
</tr>
</tbody>
</table>

### Losses vs. kvar Added

![Graph showing % Loss Improvement vs. kW kvar and kW](image_url)
What type of PFC solution?

- Capacitors (standard/harmonically hardened)
- Harmonic Filters (Tuned or De-tuned)
- Active Filters
- LV or MV
- Fixed or Switched (contactor or thyristor)
- Active harmonic filter (PF and harmonic control)
## Estimated Cost of Power Factor Correction

**INSTALLED COST COMPARISON OF POWER FACTOR CORRECTION EQUIPMENT**

<table>
<thead>
<tr>
<th>Type of Correction</th>
<th>Installed Cost, $/kvar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed (LV – motor applied)</td>
<td>$15</td>
</tr>
<tr>
<td>Fixed (LV)</td>
<td>$25</td>
</tr>
<tr>
<td>Fixed (MV)</td>
<td>$30</td>
</tr>
<tr>
<td>Switched (LV)</td>
<td>$50</td>
</tr>
<tr>
<td>Switched (MV)</td>
<td>$50</td>
</tr>
<tr>
<td>Static Switched (LV)</td>
<td>$75</td>
</tr>
<tr>
<td>Switched Harmonic Filter (LV)</td>
<td>$75</td>
</tr>
<tr>
<td>Switched Harmonic Filter (MV)</td>
<td>$60</td>
</tr>
<tr>
<td>Active Harmonic Filter (LV)</td>
<td>$150</td>
</tr>
</tbody>
</table>
What else should be included?

- Breaker/Fused Disconnect
- Installation Costs (labor, cables, shutdown required?, etc)

These are very important to understand the “total cost” – this could easily triple the cost of the project for low voltage applications.
Applying PF Capacitors

Special NYC considerations

• If applied at main service
  • 6 circuit tap rule
  • NYC Advisory Board if modifying incoming service

• Applied on 208 V network system
  • 130-180kA of available fault current!
  • Excessive 3\textsuperscript{rd} harmonics on 120/208 V service
Fixed capacitor banks

Advantages
- Simplest to install
- Lowest cost per kVAR
- Longest life, least maintenance (no moving parts)

When to Use
- Facility load is relatively constant – 24/7/365
- Few anticipated changes to plant system and loads

Considerations
- Possibility of “overcorrecting” (utilities really don’t like that) if load fluctuates
- Overvoltage can occur if load drops
LV Fixed Capacitor Banks

- Designed for industrial and commercial power systems
- var Range: 1 kvar to 400 kvar
- 208 Volts through 600 Volts AC
- Must be harmonic free environment
Individually mounted capacitors

Advantages
- Auto-regulating, comes on and off with load
- Capacitor matched with load – reduces concern of overcorrection
- Relatively small in size – easy to locate, no additional distribution equipment required

When to Use
- Facility load fluctuates
- Many anticipated changes to plant system and loads

Considerations
- Higher installation cost – each capacitor must be individually installed
- Higher cost per kVA than a single large fixed bank
  - i.e. 1 – 100kVAR bank is less expensive than 10 – 10kVAR individual units
- Need to adjust motor overloads to compensate for lower currents
Automatically switched capacitor banks

Advantages
- Single installation
- System is monitored and brings in and out individual capacitors as required

When to Use
- When ultimate system flexibility is required
- When future or final facility load is unknown or expected to change

Considerations
- Highest purchase expense compared to fixed and individual capacitors
- Some maintenance required for contactors switching capacitors
- Consider how many steps are desired
LV Switched (Automatic) PFC Capacitors Banks

- Automatically sense changes in load
- Automatic Controller
- Steps of 50 kvar standard

Smaller wall mounted units are available, and can be a real cost savings
LV Harmonic Filtering Equipment

- Provides similar PF correction (as caps)
- Avoid harmonic capacitor interaction problems
- “Filter” harmonics to reduce voltage and current distortion
MV Capacitors

- **Pole Mounted**
  - These banks have exposed live parts and are typically supported on a wood power pole.

- **Rack Mounted**
  - These banks have exposed live parts and are supported on a steel structure. These banks are usually located in fenced-in substations.

- **Metal Enclosed or Pad Mounted**
  - These banks are typically enclosed in a steel enclosure and are usually located within a fenced-in substation or switchgear room.
Medium Voltage Metal Enclosed Bank

- Inrush Reactors
- Vacuum Switches
- Fuses

1500 kvar + 1500 kvar
Careful!!! PF Correction and Energy Savings

- Well known benefit: kW Loss Reduction (real savings)
- Problem: Overstated
- Reality: 1-4% overall savings typical
- Claim: 11-30% savings
- Selling technique: sell to unknowing residential and commercial customers with little or no knowledge of kW vs. kVA (look…current reduced from 10 to 5 Amps, that results in 50% energy savings!)
- Open the “black box” – it’s full of capacitors… If it looks like a duck and swims like a duck and quacks like a duck….
It Happens to the Best of Us….

- 2007 – Eaton Fluid Power Plant
- Applied Three (3) Energy Savers ($65k)
- Claimed 11-30%
- Actual Savings (Year/Year) – 15%?
  - What?????? (Plant lighting was changed to energy efficient lighting three months prior to application of Energy Saver!)
- Actual Savings <1%!
It Happens to the Best of Us….

<table>
<thead>
<tr>
<th></th>
<th>kWh</th>
<th>kW</th>
<th>Excess rKVA</th>
<th>Cost</th>
<th>kW savings over previous year</th>
<th>Cost savings over previous year</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-07</td>
<td>346,811</td>
<td>664.3</td>
<td>198.5</td>
<td>$28,856.55</td>
<td>4.3%</td>
<td>4.1%</td>
</tr>
<tr>
<td>Oct-07</td>
<td>329,366</td>
<td>628.5</td>
<td>150.1</td>
<td>$27,351.46</td>
<td>3.9%</td>
<td>3.2%</td>
</tr>
<tr>
<td>S-07</td>
<td>297,597</td>
<td>571</td>
<td>106.5</td>
<td>$24,879.59</td>
<td>13.1%</td>
<td>11.5%</td>
</tr>
<tr>
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<td>312,736</td>
<td>605.02</td>
<td>22.8</td>
<td>$26,120.39</td>
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<td>15.4%</td>
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<tr>
<td>J-07</td>
<td>331,227</td>
<td>637.5</td>
<td>64.1</td>
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<td>10.5%</td>
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<td>308,103</td>
<td>616.2</td>
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<tr>
<td>M-07</td>
<td>319,200</td>
<td>630</td>
<td>529.7</td>
<td>$26,920.13</td>
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<td>5.6%</td>
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<tr>
<td>Apr-07</td>
<td>369,870</td>
<td>643</td>
<td>231.73</td>
<td>$30,757.42</td>
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<td>9.5%</td>
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<tr>
<td>M-06</td>
<td>354,678</td>
<td>604</td>
<td>693.94</td>
<td>$30,099.75</td>
<td>-18.0%</td>
<td>-21.5%</td>
</tr>
<tr>
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<td>400,302</td>
<td>704.4</td>
<td>506.2</td>
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<td>16.2%</td>
<td>11.7%</td>
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<tr>
<td>J-07</td>
<td>395,049</td>
<td>708.7</td>
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</tr>
<tr>
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<td>718.6</td>
<td>564.6</td>
<td>$30,444.10</td>
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<tr>
<td>N-06</td>
<td>384,850</td>
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<td>546.7</td>
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<tr>
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<td>354,128</td>
<td>653.9</td>
<td>455.7</td>
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<tr>
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<td>560</td>
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<tr>
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<tr>
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<td>771.2</td>
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<tr>
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<td>347,956</td>
<td>635.3</td>
<td>468.1</td>
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<tr>
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<td>387,728</td>
<td>840.9</td>
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<tr>
<td>J-06</td>
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<td>458.5</td>
<td>$25,364.67</td>
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</tr>
</tbody>
</table>
Power Systems Experience Center

Purpose: to demonstrate and test PQ problems and solutions
- Full-scale power system
- Demystify solutions
- “Seeing is Believing”
- Technical vs. Economic Solutions

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Equipment (PF/Harmonic Related)
- Fixed capacitors
- Switched capacitors
- Static switched capacitor
- Broadband Filters
- Passive (Fixed) Filters
- Passive (Switched) Filters
- Active Filters
- Reactors
- 3rd Harmonic Filter
- HMT Transformers
- K-Rated Transformers
- Phase shifting transformers
Learning Objectives

- Define power factor (PF)
- Explore other benefits of power factor correction (PFC)
- Identify potential PF charges on your electric utility bill
- Identify solutions available to correct PF
- Summarize how harmonics effect the application of PFC capacitors
- Calculate the financial ROI for PFC
- Determine real savings versus overstated savings
What should you do?

Step 1: Gather 12 months of utility bills.
Step 2: Examine the bills and evaluate the need for PF correction based on your PF.
Step 3: Discuss your penalty with your Con Ed rep.
Step 4: Size the corrective equipment.
Step 5: Determine the type of PF equipment.
Step 6: Calculate your ROI.
Step 7: Install the PF equipment and start saving!

…. Eaton is here to HELP!
Reference Information

Reference Papers and Presentations:
2. Carnovale/Hronek, “Power Quality Solutions and Energy Savings” (AEE Magazine, EC&M)
4. PFC Calculator Link
   http://www1.eatonelectrical.com/calculators/PowerFactorROI/index.html

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Thank You!

Questions?