Proper Application of Power Factor Capacitors and How They Can Reduce Energy Costs

Learning Objectives

At the end of this web session, you will be able to:

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

Energy Use in Industrial Sector

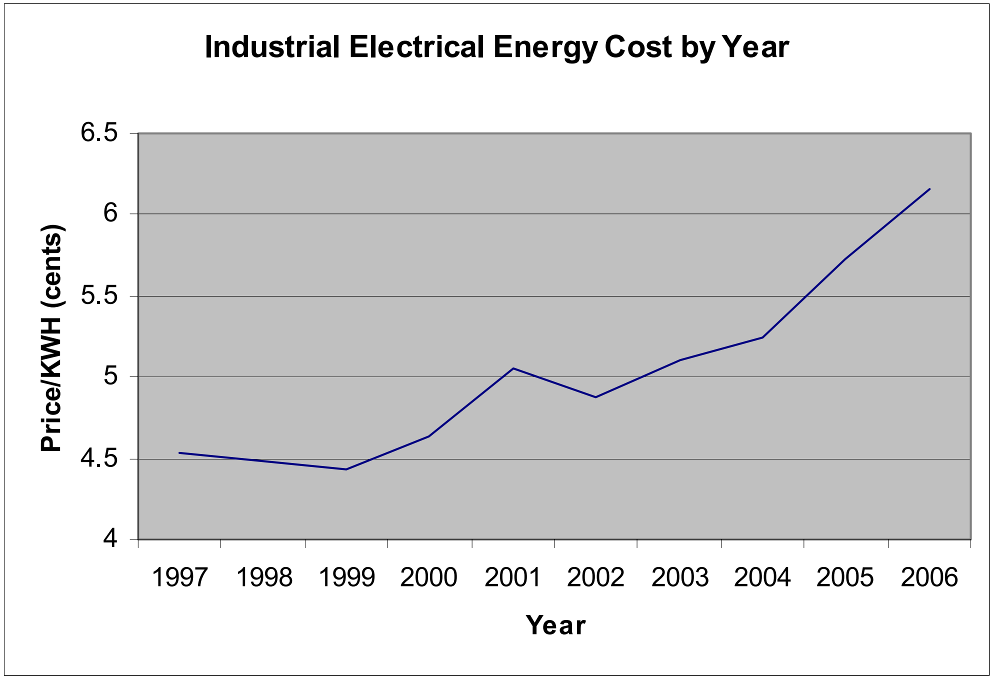
- The cost of petroleum is hitting industrial users
- Natural Gas and Coal are increasing in cost and heavily used in electrical generation

Petroleum	44%
Natural Gas	37%
Coal	9%
Renewable	9%

Source Energy Information Administration

Escalation in Electrical Energy Cost

- Electrical Energy cost has increased nearly 50% over the last 10 years
- The rate of increase has accelerated in the past few years



Source Energy Information Administration

Generation and Distribution Capacity

The U.S. power transmission system is in urgent need of modernization. Growth in electricity demand and investment in new power plants has not been matched by investment in new transmission facilities. Maintenance expenditures have decreased 1% per year since 1992. Existing transmission facilities were not designed for the current level of demand, resulting in an increased number of "bottlenecks," which increase costs to consumers and elevate the risk of blackouts.

-Report Card for America's Infrastructure

Dan Carnovale

- BSEE-Gannon University,
- MSEE-Rensselaer Polytechnic Institute
- MBA-Robert Morris University
- Registered Engineering in PA, CA, and AK
- CEU Certified Instructor for Power System Analysis
- Conducted 100's of PQ investigations for commercial, industrial, and utility customer and applied solutions
- Sr. Member of the IEEE
- Certified Energy Manager, Association of Energy Engineers
- Manager of Eaton's Power Systems Experience Center
- Published several IEEE papers most recently (2008) on Capacitor Applications with Tom Blooming

Where has all the money gone?

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)

$$PF = kW / kVA$$

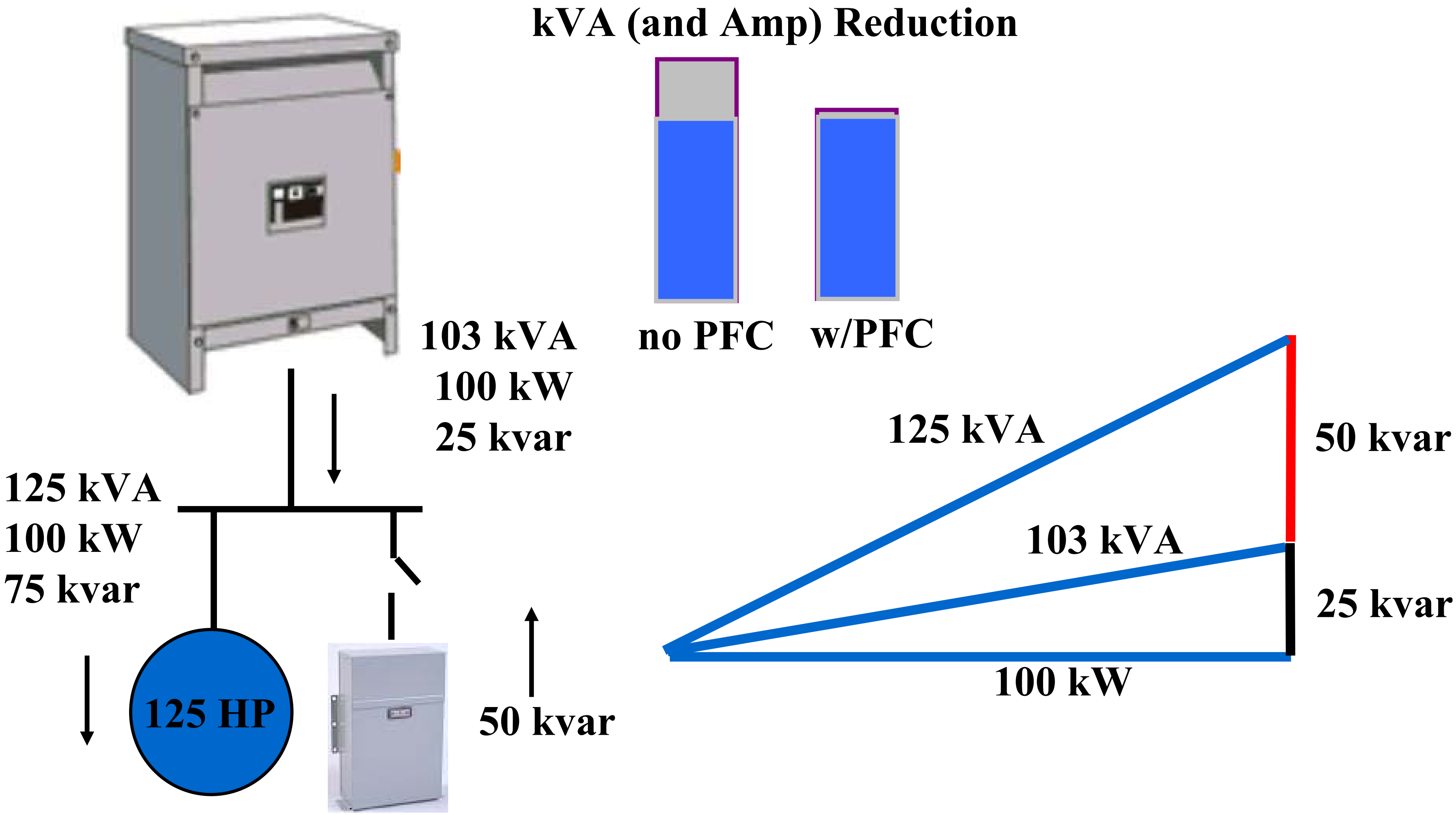
- Poor PF is costly for the utility and for the end user – power system capacity is used, kW losses are increased and voltage at the load is low.
- Utilities often penalize customers for low PF as an incentive to compensate for this inefficiency.

Is the Glass Half Empty or Half Full?

Wasted Capacity

Full Capacity

Example: Improving PF Cont.



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
- Latest 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….

PF Correction and Energy Savings

- Expert/Third party testimonials
- “Technical sign-off”
- Misinformation or half truths – “you are thinking like an engineer – you probably won’t understand”
- Unknowing/Non-technical or passionate salesmen (he believes and so should you!)
- Only the inventor truly understands the “technology”
- Hard to prove/disprove guarantees (buy our stuff and then show us you didn’t save…)
- kVA vs. kW confusion

Why Consider PFC?

PF correction provides many benefits:

- Primary Benefit:
  - Reduced electric utility bill if there is a penalty
    (a typical payback period is less than two 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)

Loads with Low PF

- Air Handling/HVAC
- Pumps
- Elevators
- Compressors
- Computers
- Process Machinery

Typical Uncorrected Power Factor

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

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

Low PF typically results from unloaded or lightly loaded motors

Unloaded motor – PF = .20
Loaded motor – "rated PF" = .85

Power Factor Penalties

- Not possible to cover all penalties
  - Table 3 (Blooming/Carnovale paper) shows some typical methods
- User should determine which type of penalty (if any) the utility is using
  - Then investigate further
  - Sometimes utility uses multiple penalty methods

Power Factor Penalties

- Most penalties are straightforward
  - Easy to calculate and analyze
- Power factor penalty may be “hidden”
  - kVA billing
    - No explicit pf penalty, but you will pay more if you have a low power factor (higher kVA)
  - Utility rebate for maintaining a certain power factor or higher
    - Not a penalty, but functionally equivalent

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Power Factor Penalties

- Usually not practical to correct all the way to unity (1.0) power factor
  - Diminishing benefit per incremental cost
    - May cost more than will be saved in pf penalty reduction, even with kVA billing (1.0 pf target)
    - More long run savings, but lower return on the project
  - Leading power factor concerns, at light load
    - Some utilities bill for leading power factor, too
    - May require switched capacitor bank

Power Factor Penalties

Table I (partial) from "Capacitor Application Issue" paper

http://www.eaton.com/EatonCom/Markets/Electrical/ServicesSupport/Experience/index.htm

POWER FACTOR PENALTIES

RATE TYPE	DESCRIPTION OF PF PENALTY	EXAMPLE
kVA (demand) rates	Penalty for < 1.0 pf; generally applied as a $/kVA	Demand = 800 kW; pf=80%; kVA=1000; demand charge = $10/kVA pf penalty = (1000 – 800)*$10 = $2000/month
PF (kVA) adjustment	When the pf is less than X%, the demand may be taken as X% of the measured kVA	When the pf is less than 90%, the demand may be taken as 90% of the measure pf=80%; kVA=1000; demand charge = $10/kVA Billed demand = 0.90*1000 = 900 kW pf penalty = (900 – 1000*0.80)*$10 = $1000/month
PF ratio (kW demand) adjustment	If the pf is < X%, the demand will be adjusted by the following: X%/actual pf * actual demand = adjusted demand.	If the pf is < 85%, the demand will be adjusted by the following: 85%/actual p demand = adjusted demand. Demand = 800 kW; pf=80%; demand charge = $10/kW Adjusted demand = (0.85/0.80)*800=850kW pf penalty = (850-800)*$10 = $500/month
PF magnitude (kW demand)	PF adjustment increases or decreases the net (kW) demand	Where the pf is < 85%, the net demand charges shall be increased 1% for each pf is < 90%; likewise, where the pf is higher than 95%, the demand charges wi

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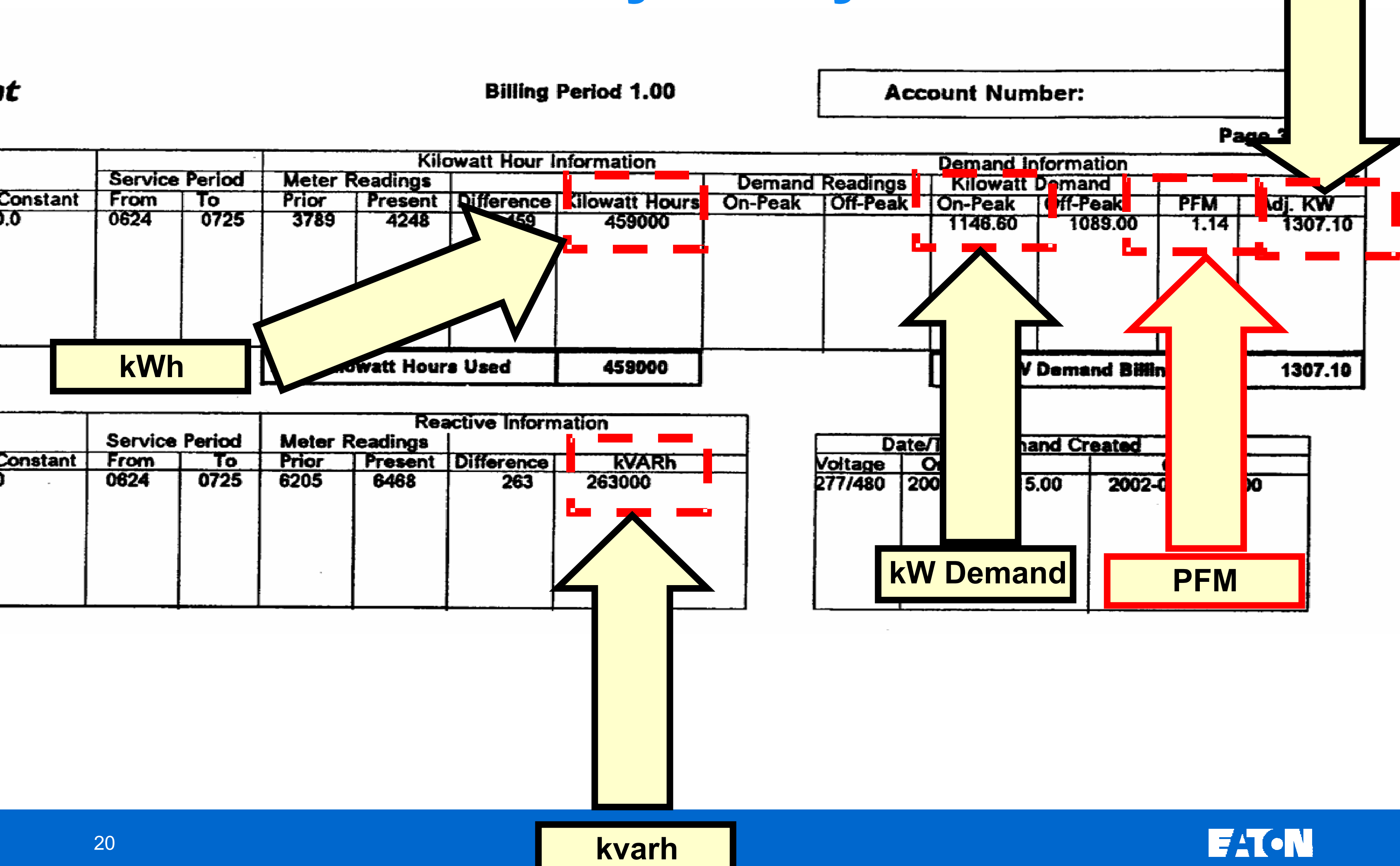
What is *that* on my utility bill?



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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.)

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 You Read These Tariffs?

- Each utility company has rates that vary according to load type and size
- Determine your rate “schedule” type – not always an easy task (Schedule K, GP, etc.)
- Discuss the rate schedule with your utility account representative to see if you pay a PF penalty
- There are too many variations to make generalizations but the following examples give some typical methods

Example One

Power Factor Adjustment

Customers on this schedule should maintain unity power factor as nearly as practical. If the power factor falls below 95% lagging, the customer will take corrective steps to return the power factor to 95% or higher. All customer installations of power factor corrective equipment shall be subject to the approval of the Company. If the average power factor is less than 95% lagging, the billing demand charge will be increased by one percent (1%) for each percent or fraction thereof that the average power factor is less than ninety- five percent (95%) lagging.

Example: Demand = 1000 kW
PF = 87%
Demand Charge = $10/kW
Adjusted Demand = 1000kW + 1000kW X 8% = 1080 kW

Penalty = 95% - 87% = 8% or 8% X 1000kW X $10/kW
= 80 kW X $10/kW
= $800/month or $9600 per year

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Example Two

24. <u>Power Factor Adjustment</u>.

The rate set forth in tariffs subject to a power factor clause are based upon the maintenance by the customer of an average monthly power factor of 85 percent, leading or lagging, as measured by integrating meters. When the average monthly power factor is above or below 85 percent, leading or lagging, the kWh as metered will, for billing purposes, be multiplied by the constant, rounded to the nearest 0.0001, derived from the following formula:

$$\text{Constant} = 0.9510 + \left[0.1275 \left[\frac{\text{RKVAH}}{\text{KWH}} \right]^2 \right]$$

Power Factor	Constant	Penalty
0.5	1.47	47% penalty
0.67	1.24	24% penalty
0.8	1.15	15% penalty
0.85	1.13	13% penalty

Example: Energy Usage = 500,000 kWh; PF = 80%
Energy Charge = $0.10/kWh
Adjusted Energy Usage = 500,000 kWh X 1.15 = 575,000 kWh

Penalty = 75,000 kWh X $0.10/kWh
= $7500/month or $90,000/year

Example Three

DETERMINATION OF DEMAND

The demand will be measured where a customer's monthly use exceeds 1,000 kilowatt-hours or where the demand is known to exceed 5 kilowatts. Individual demand, except in unusual cases, will be determined by measurement of the average kilowatts during the fifteen-minute period of greatest kilowatt-hour use during the billing period. Individual demands which exceed 30 kilowatts will be adjusted for power factor by multiplying by

$$\left\{0.8 + \left[0.6 \frac{\text{Reactive Kilovolt - ampere hours}}{\text{Kilowatt - hours}}\right]\right\},$$

where such multiplier will be not less than 1.00 nor more than 2.00. The Billing Demand will be the sum of the individual demands of each metered service, adjusted for power factor as defined above.

Example: Demand = 1000 kW
PFM = 1.25
Demand Charge = $10/kW
Adjusted Demand = 1000kW X 1.25 = 1250 kW

Penalty = 0.25 X 1000kW X $10/kW
= 250 kW X $10/kW
= $2500/month or $30,000/year

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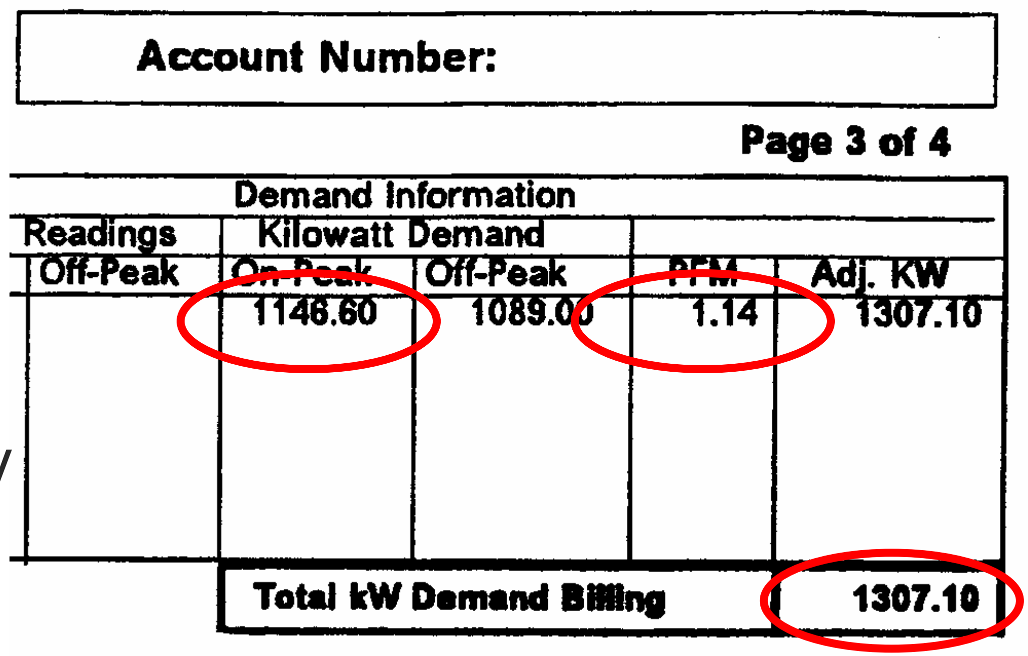
PF Penalty Example

- 1146 kW load
- $12/kW demand
- PF range 0.86-0.88 lag
- Penalty below 0.95
- PFM (Power Factor Multiplier) increases kW demand for low power factor resulting in penalty
- 1307 kW (billed) -1146 kW (actual) = 161 kW (penalty)
- = $1926 penalty (this bill)



Account Number:

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Demand Information

Readings	Kilowatt Demand			
Off-Peak	On-Peak	Off-Peak	PFM	Adj. KW
	1146.60	1089.00	1.14	1307.10

Total kW Demand Billing 1307.10

PF Penalty Example Cont.

- $2000 power factor penalty per month in the summer.
- .86 lagging to .95 lagging PF to eliminate penalties
- Determined a 300 kvar fixed capacitor was required.
- Payback for a 300 kvar capacitor bank, including installation:

ROI - LESS THAN 5 MONTHS

Example Four (Cost/Benefit)

POWER FACTOR PROVISION

In the case of customers with maximum demands of 150 kilowatts or more, the monthly demand charge shall be **decreased 0.4%** for each whole one per cent by which the monthly average power factor **exceeds 80% lagging** and shall be **increased 0.6%** for each whole one per cent by which the monthly average power factor is **less than 80% lagging**. Customers with maximum demands less than 150 kilowatts shall maintain an average lagging power factor of not less than 80%, and suitable accessory equipment shall be installed by such customers where necessary to avoid a lower power factor.

Example: Demand = 1000 kW
PF = 0.707

Penalty/Opportunity: $1101/month or $13,212/year (includes penalty for < 0.80 PF and opportunity/credit for > 0.80 PF)

PF Calculator

- Eaton Power Factor Correction Tool™ - PF Penalty Page
- Calculator to identify potential PF savings
- Example: $14,592/year based on 6 months of billing

Year	Customer Name	HQ				
2002	MONTHLY ENERGY (kWh)	MONTHLY REACTIVE (kvarh)*	ON-PEAK DEMAND (kW)	PFM	ADJ. DEMAND (kW)	BILLED DEMAND (kW)
JAN					-	-
FEB	370,000	139,000	877	1.03	902.9	902.9
MAR	343,000	136,000	817	1.04	849.9	849.9
APR	406,000	200,000	1,075	1.10	1,182.1	1,182.1
MAY	354,000	187,000	940	1.12	1,052.4	1,052.4
JUN	419,000	242,000	1,121	1.15	1,289.6	1,289.6
JUL	459,000	263,000	1,147	1.14	1,307.1	1,307.1
AUG					-	-
SEP					-	-
OCT					-	-
NOV					-	-
DEC					-	-
Average	391,833	194500	996	1.10	1,097.3	1,097.3
Totals						
Total PF Penalty						

* Enter kWh and kvarh if available (if kvarh is unavailable, leave blank)

Select Service Type: GL - Gen Service Large (> 300 kW) — Rate Structure from page 1 (top rig

Gen, Trans, Dist w/Duquesne — Deregulation option - Duquesne for

Distribution Charges (kW)	$ 1.82	per kW	
Transition Charges (kW)	$ -	per kW	**Note that these values
Tranmission Charges (kW)	$ 0.48	per kW	Therefore, savings is ac
Generation Charges (kW)	$ 9.70	per kW	
Total Cost ($/kW)	$ 12.00	per kW	
Total Months of Data Entered	6	months	
Total PF Penalty/Year	$ 14,592	PF Penalty/Potential Savings Per Ye	
	$ 1,216	Average Potential Savings/Month	

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
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
  - Do not average kW/kVA and pf to do the calculations
    - Can lead to erroneous results
  - Examples shown in the paper

Capacitor Sizing

TABLE 1

EXAMPLE POWER FACTOR CALCULATIONS, USING MONTHLY DATA, .95 PF TARGET

KW	PF	KVAR NEEDED
1200	.78	583.8
1000	.83	343.3
1100	.80	463.4
950	.73	577.2
700	.65	588.3
850	.70	587.8

- Probably choose 600 kvar

Capacitor Sizing

TABLE 2

EXAMPLE POWER FACTOR CALCULATIONS,
USING SUMMARIZED DATA, .95 PF TARGET

MAXIMUM KW	**MINIMUM PF**	**KVAR NEEDED**
1200	.65	1008.5
MAXIMUM KW	**AVERAGE PF**	**KVAR NEEDED**
1200	.75	671.9
AVERAGE KW	**MINIMUM PF**	**KVAR NEEDED**
966.7	.65	812.4
AVERAGE KW	**AVERAGE PF**	**KVAR NEEDED**
966.7	.75	541.3

- Possibly choose 1000 kvar, with most conservative approach!

Capacitor Selection

Capacitor selection issues (besides size)

- Utility penalties
- Installed cost and payback of equipment
- Load variability
- kW losses
- Voltage regulation
- Load requirements (flicker requirements)
- Generator loading/capacity
- Self excitation of motors
- Harmonic resonance

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

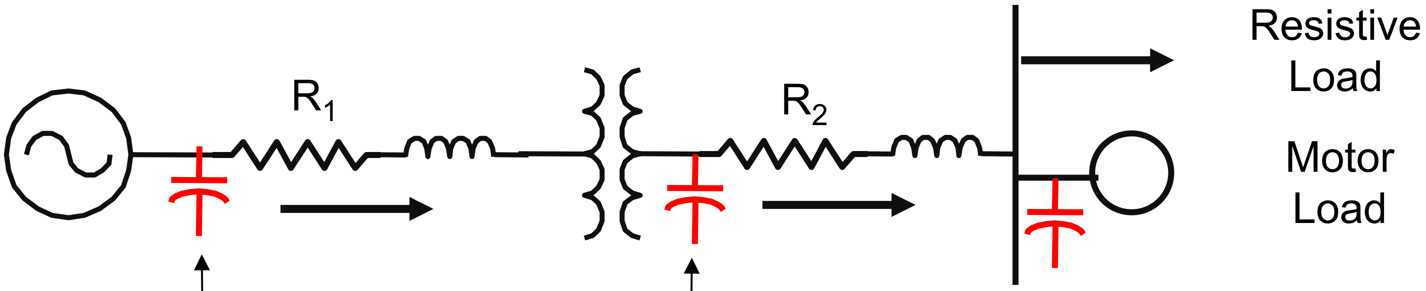
- Apply anywhere downstream of the meter

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 to justify cost to add capacitor

Effect of Location



Place here for line loss reduction and voltage improvement

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

What type of PFC solution?

- Capacitors
- Harmonic Filters (Tuned or De-tuned)
- Active Filters
- LV or MV
- Fixed or Switched (contactor or thyristor)

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

Cost of Power Factor Correction

TABLE 4

INSTALLED COST COMPARISON OF POWER FACTOR CORRECTION EQUIPMENT

TYPE OF CORRECTION	INSTALLED COST, $/KVAR
Fixed (LV – motor applied)	$15
Fixed (LV)	$25
Fixed (MV)	$30
Switched (LV)	$50
Switched (MV)	$50
Static Switched (LV)	$75
Switched Harmonic Filter (LV)	$75
Switched Harmonic Filter (MV)	$60
Active Harmonic Filter (LV)	$150

Power Systems Experience Center

Technical Solution vs. Economic Solution

- Always a tradeoff for PF and harmonic solutions
- What is the right answer?
- Best answer is usually a combination of both

PSEC offers a great opportunity to compare solutions (side-by-side)

- Power Quality Lab
- Industrial/Commercial Power System
- Residential Power System
- Data Center
- Industrial Training Lab

Power Systems Experience Center

Purpose: to demonstrate and test PQ problems and solutions

- Full-scale power system
- Demystify solutions
- "Seeing is Believing"

http://www.eaton.com/EatonCom/Markets/Electrical/ServicesSupport/Experience/index.htm

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

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

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

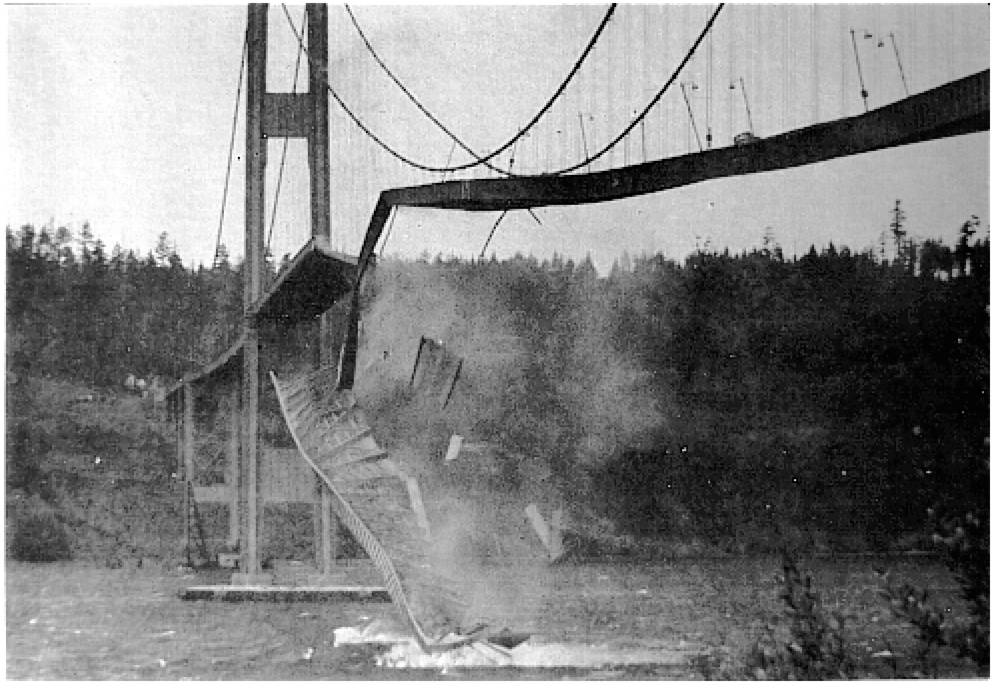
MV Capacitors

- 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.

MV Bank

1500 kvar + 1500 kvar

Harmonic Resonance



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**.

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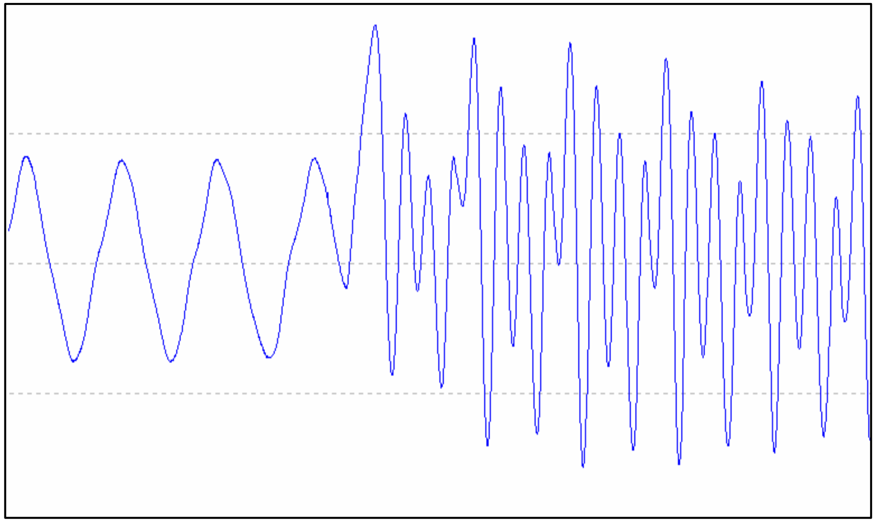
Harmonic Resonance

The "Self Correcting" Problem

- Blown Fuses
- Failed Capacitors
- Damaged Transformer



Harmonics = Wind (Excites Resonance)

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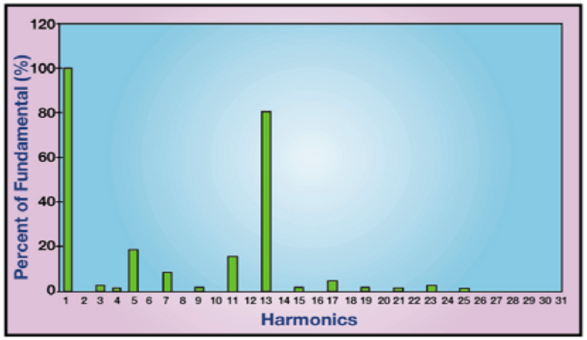
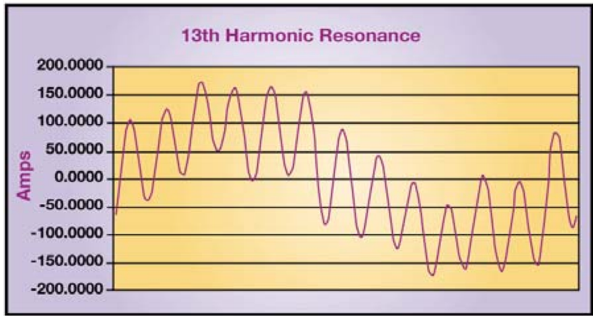
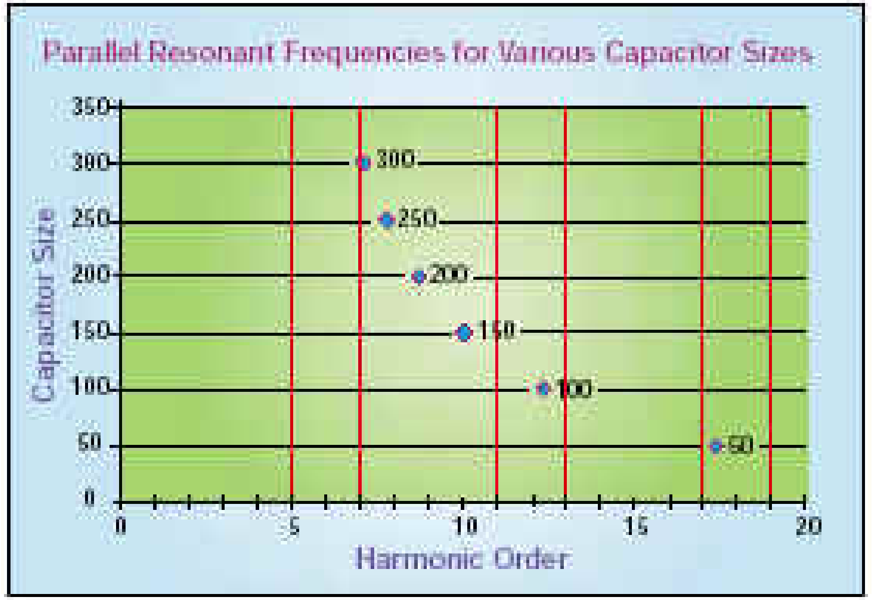
Harmonic Resonance - Solutions

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







Eaton Power Factor Correction Tool™ - Resonance

Step 1

Bus Voltage	480	
Existing Load	1150	kW
	0.89	PF
Target PF	0.95	
Required kvar	211	kvar

Enter Quantities in Blue

Quantities in Orange are Calculated

Instructions

Step 1: Calculate required capacitance.

Step 2: Select a standard capacitor or harmonic filter size (refer to price list for standard sizes) and penalty per year to calculate return on investment (ROI).

Step 3: Input system data and calculate potential overvoltage, harmonic resonance, kva reduction, and breaker or fuse size

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

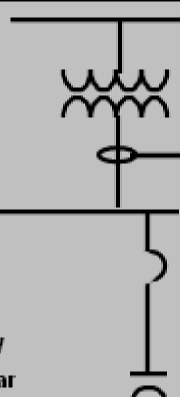
Step 2

Select Cap/Filter Size	200	kvar
Penalty per Year	$ 12,000	

Estimated Installed Cost for		Estimated Payback
Fixed Cap and Breaker	$ 5,000	5 Months
Switched Cap and Breaker	$ 10,000	10 Months
Fixed Harmonic Filter and Breaker	$ 11,000	11 Months
Switched Harmonic Filter and Breaker	$ 15,000	15 Months
Actual Total Equipment Cost	$ 6,000	6 Months

Step 3

Transformer kVA	1500
Transformer %Z	5.75
Bus Voltage	480
Maximum % bus voltage rise at this bus - no load with the full capacitor	0.77%



6%		Load Reduction (kVA) with Addition of Selected Capacitor Bank
0.95		Actual Corrected PF
325	Amp	Breaker or Fuse Size @ 135% Rating
400	Amp	Typical Breaker or Fuse Size or Setting @ 135% Rating for Selected Capacitor Bank
11.42		Estimated Parallel Resonant Harmonic Order (Based on Selected Capacitor)

Load: 1150 kW, 589 kvar

Check Harmonics

Note: For estimating harmonic resonance, check every STEP of a multi-step capacitor bank

University Example – kVA Rates

Billing Rate Code : 009 (Schedule K) — Rate Schedule

KWH USAGE : 4,681,343.00 — kWh Energy

LOAD FACTOR : 82%

KVA DEMAND : 10,502.60 — kVA Demand

Power Factor : 0.73 (@ 10,502.59 KVA) — Power Factor

Bill Calculation Results

	Billing Units	Charge Rate	Revenue
Demand			
First Demand Block	1,000.0	8.349000	$8,349.00
Second Demand Block	9,502.6	7.006000	$66,575.22
Total Demand Charge	10,502.6		$74,924.22
Energy Charge	4,681,343.0	0.023280	$108,981.67
Total of Base Rate Charges			$183,905.89

[redacted]

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University Example – kVA Rates

- 7,700 kW (10,500 kVA) Typical Peak Demand
- 0.73 PF
- $200k/Month Bill
- $20k/Month Penalty - $240k/year Penalty
- Solution: Combination of LV and MV Fixed and Switched Capacitors
- Payback (ROI) < 18 Months
- ***Leasing Option:*** Positive Cash Flow Month 1

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Learning Objectives

Now that you have completed this web session, you should be able to:

- Define power factor (PF)
- Identify potential PF charges on your electric utility bill
- Identify solutions available to correct PF
- Explore other benefits of power factor correction (PFC)
- 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 look for obvious indications of a potential penalty (look for words like "adjusted demand", "PF multiplier", kVA demand, kvarh charges, kvar demand charges). **Eaton is here to help!**
- Step 3: Call your utility account representative and ask if you pay a PF penalty.

  If they say *Yes, d*etermine your ROI for correcting the PF penalty.

  If they say *No,* there may still be a penalty, look for things like kVA charges, and other indications that you pay a penalty.
- Step 4: Size the corrective equipment using tables or tools.
- Step 5: Calculate your ROI

Wrap-up and Questions

Questions?

Reference Papers and Presentations:

1. Blooming/Carnovale – "Capacitor Application Issues" (IEEE IAS)
2. Carnovale/Mueller, "Power Quality Solutions and Energy Savings" (PQ Conference – 2005)
3. EPRI – "Energy Savings: You Can Only Save Energy That Is Wasted"
4. EPRI – "Strategies for Evaluating Black Box Technologies"
5. PFC Calculator Link
   http://www1.eatonelectrical.com/calculators/PowerFactorROI/index.html

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http://www.eaton.com/EatonCom/Markets/Electrical/ServicesSupport/Experience/index.htm