

IEEE San Diego

**Power & Energy
and
Power Electronics
Societies**

Joint Presentation

**Power Quality and Energy
Savings – *What is Real?***

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Overview

- Need – Everyone wants to save energy!
- People want to believe there is a simple solution
- Electric bills can be confusing
- Power Quality is an “insurance” sell....too difficult
- Energy saving solutions yields a “real” ROI
- Misleading sales methods by unknowing salespeople
 - What claims are real?
 - What claims are false?
 - What should YOU do?

Comments and Questions I get everyday!

I looked at this company's website, and their claim of energy savings of 10% to 20% troubles me. A friend has been asked to consider joining the company and they want to set me up as a distributor – what do you think?

These videos are on the Residential models. We also have commercial and industrial models for: 200, 400, 600 and 800 amp service.

Restaurants, Factories Machine Shops, etc. operate a lot more electrical equipment than a residence, so the savings for these types of businesses are far greater than in a home.

Will our capacitors save homeowners/customers 25% on their electric bill??

XXX claims to do it all - PF correction, harmonic correction, surge protection, capacity release, brown-out protection, etc.

Have you encountered or tested this product?

From this formula [2.4] it results that, for example, by increasing the power factor from 0.7 to 0.9, about 39.5% saving on losses is obtained. Table 2.3 shows the saving on losses obtained by increasing the power factor from an initial $\cos\phi$, to the final value of 0.9 and 0.95.

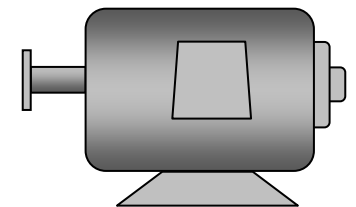
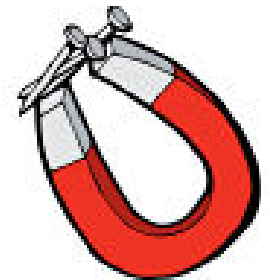
Why can't our company develop a similar product?

Example from FOX News....

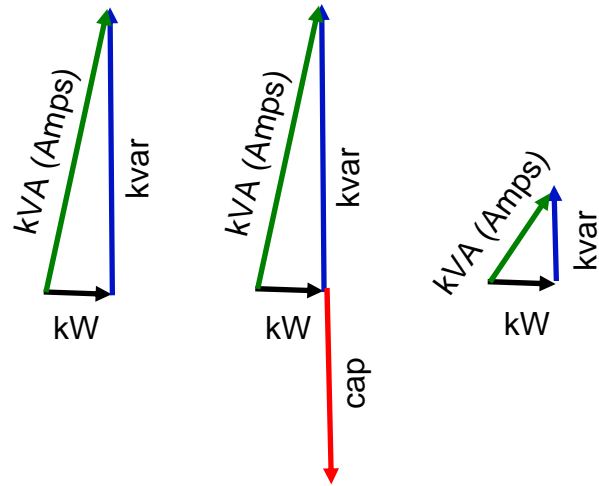


What is a VAR?

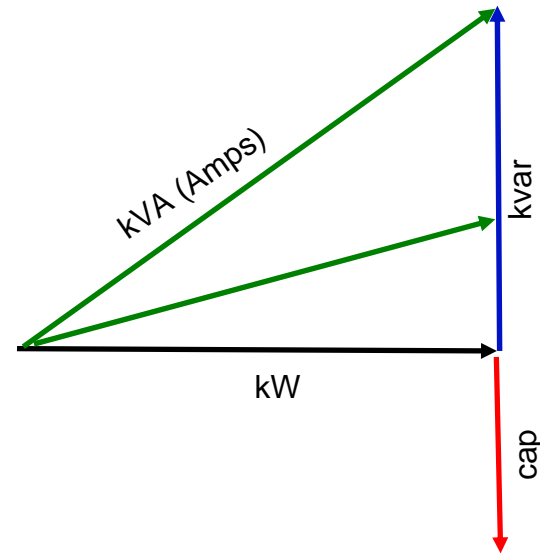
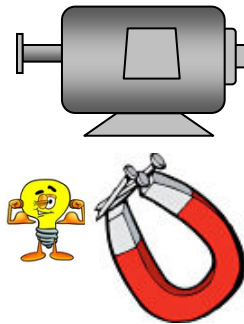
- **Active power**, also called **real power**, is measured in **Watts or kW** and performs **Useful Work**
- Electrical equipment like motors and transformers require **reactive power** create a **Magnetic Field** and allow work to be performed.
- This reactive power is called **volt-amperes-reactive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



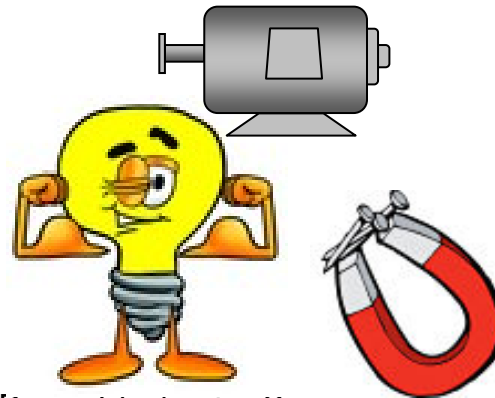
How did they do that???



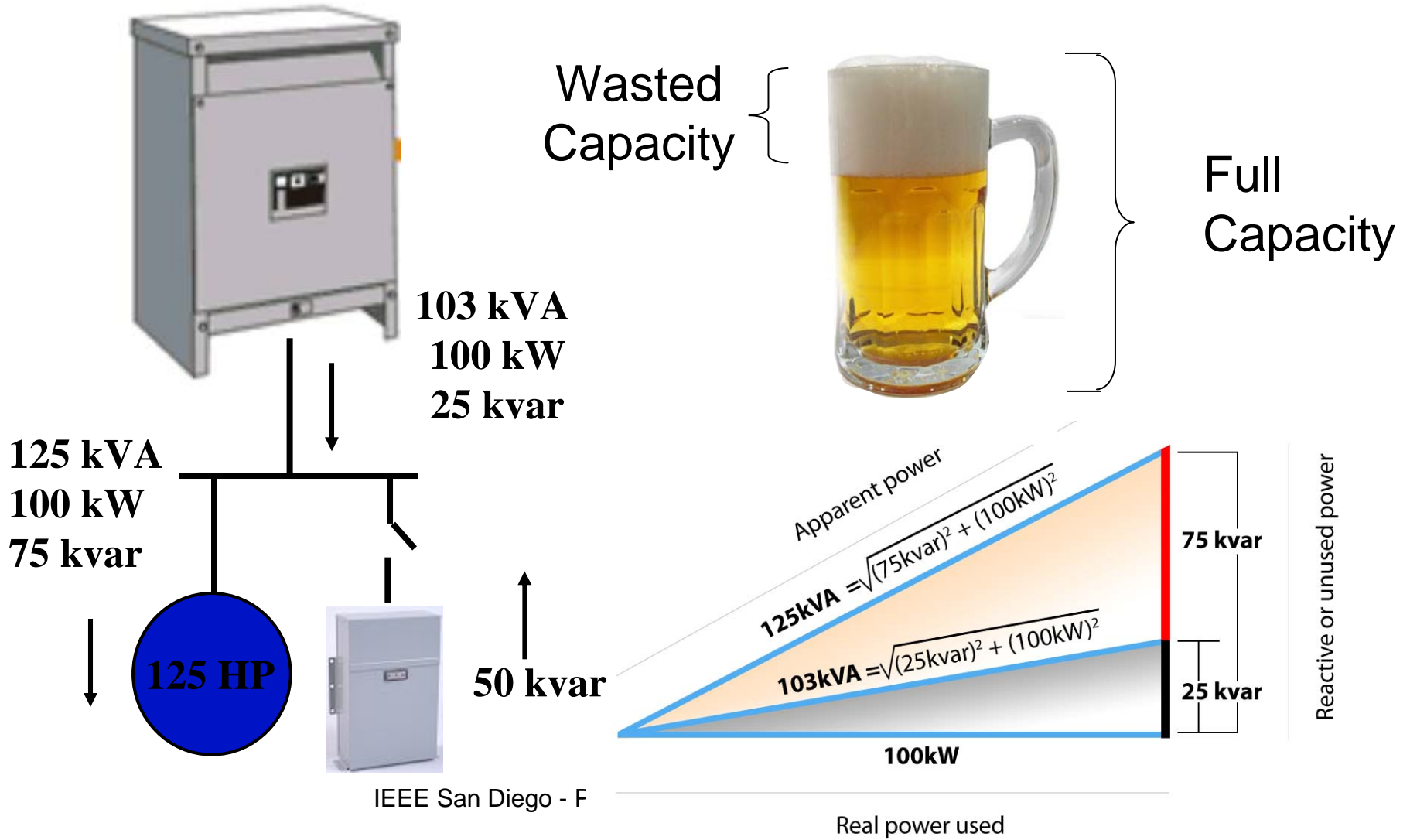
Unloaded Motor



Loaded Motor



No distinction between kVA and kW



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
 - You can save kVA but you are not saving significant kW



EPRI Said It Best....

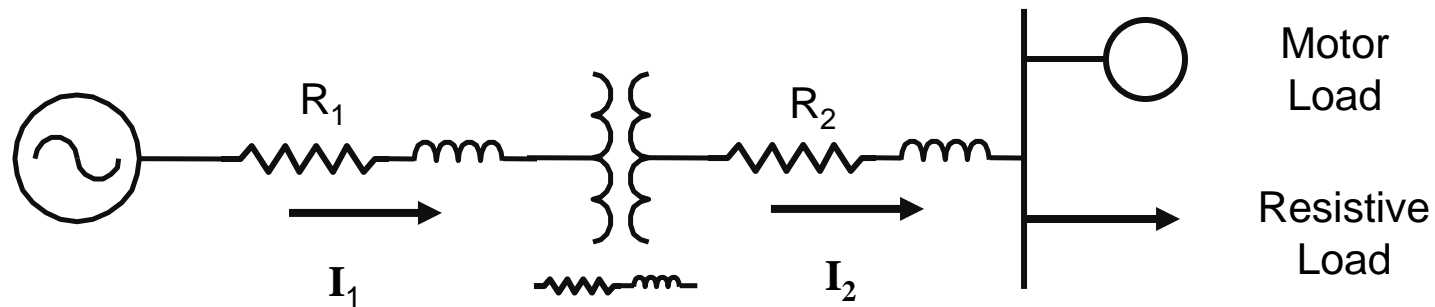
You can only save energy that is
wasted!!!

Energy Savings:

You Can Only Save Energy That Is Wasted

Arshad Mansoor and Roger Dugan (2004)

PF Correction – Loss Reduction

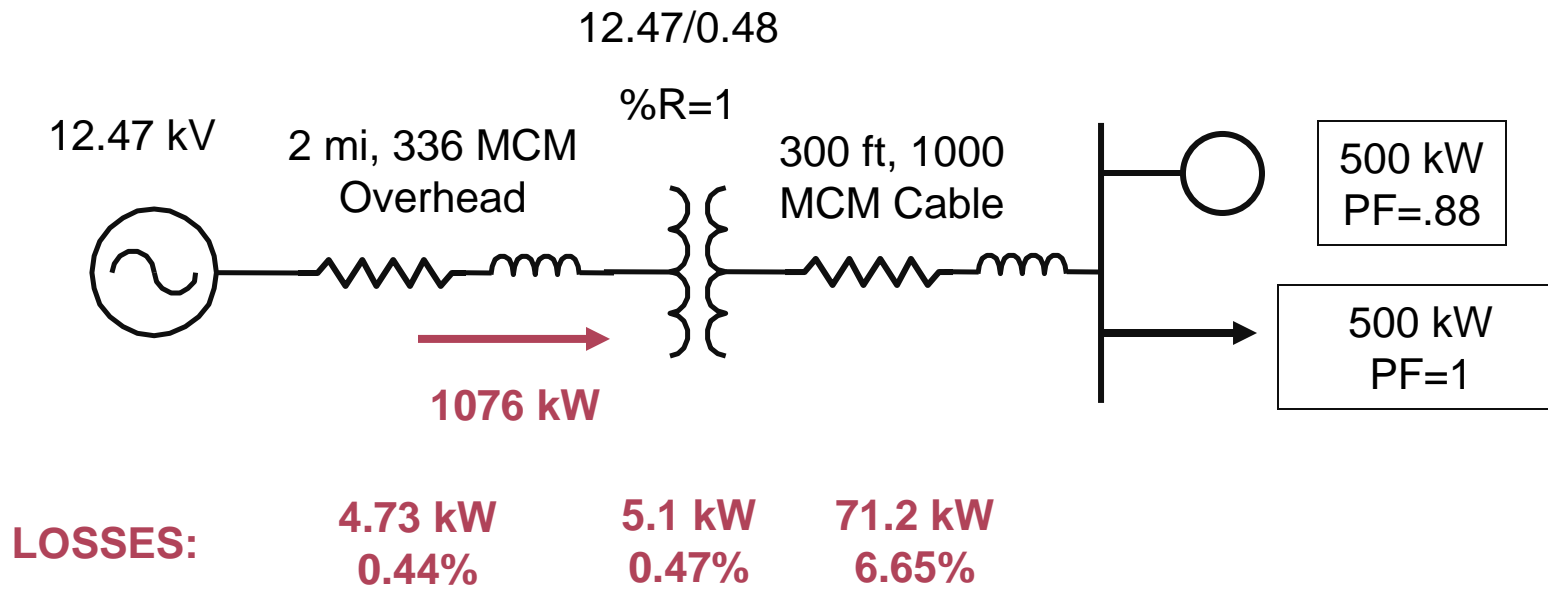


$$P_{\text{LOSSES}} = I_1^2 R_1 + I_2^2 R_2 + (\text{Transf Losses}) + (\text{Load Losses})$$

Delivery Losses

Ex: Con Ed estimated systems losses to customer – approximately 6.8% (May 2010)

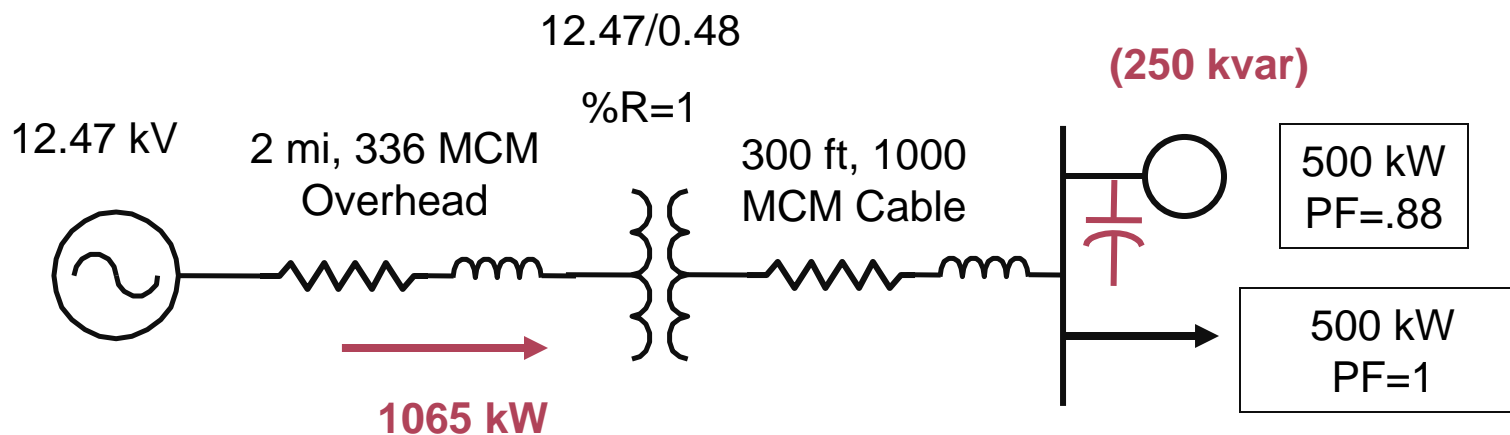
Example – PF Correction Savings



Total Circuit Losses: 81 kW / 8.1%

Source: EPRI

Example, Capacitor at Load



LOSSES:	4.03 kW	4.32 kW	60.6 kW
	0.38%	0.40%	6.23%

Total Circuit Losses: 68.9 kW / 6.89%

End User Loss Savings: 76 kW - 65 kW = 11 kW

This is nearly 15% savings in losses, but net power into load decreases only 11 kW or 1.1% of load

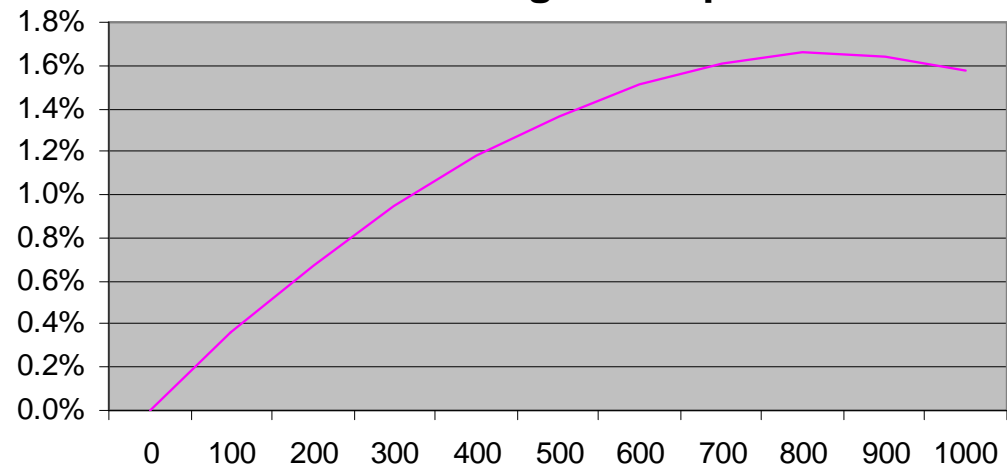
Source: EPRI

Computer Simulation – High Rise Building

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

PF Correction Example

Loss Savings Example

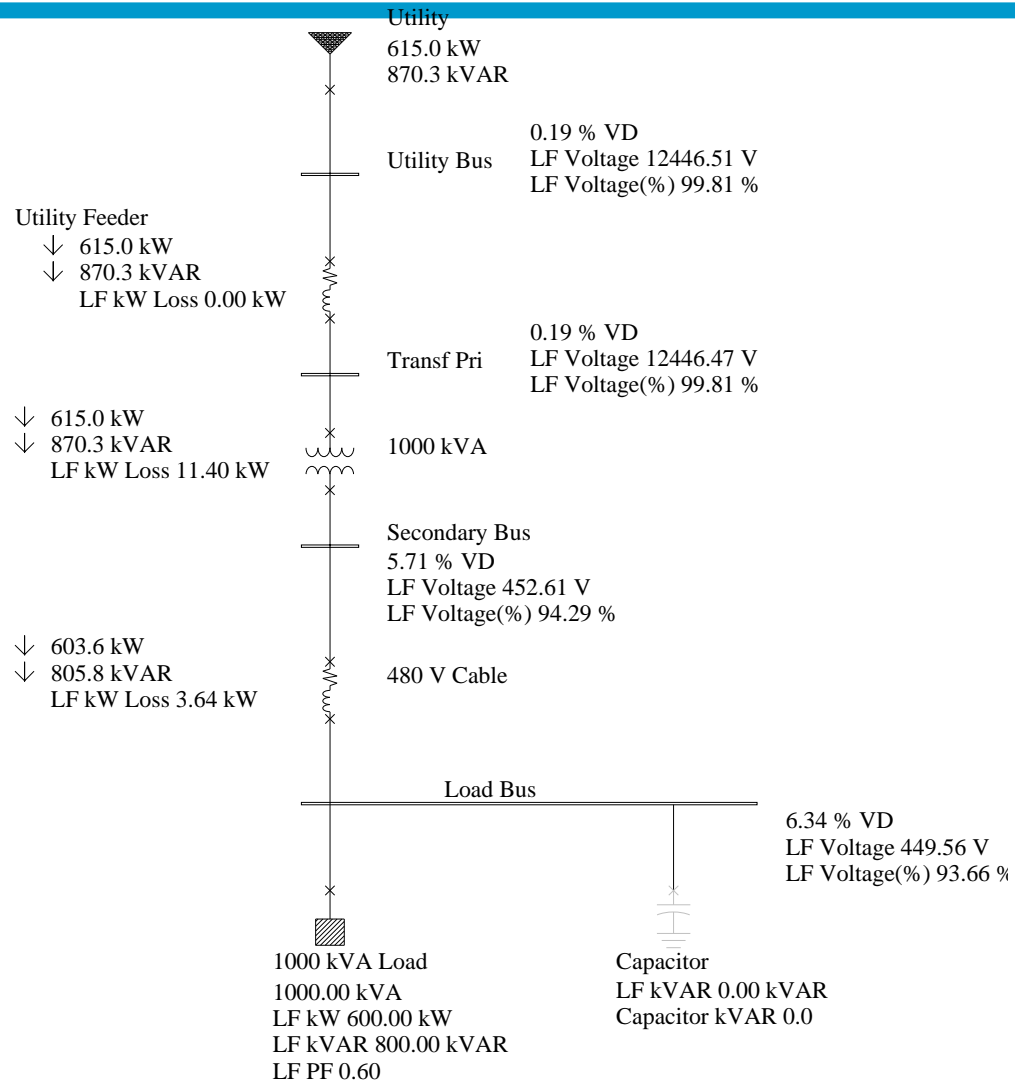


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Losses vs. kvar Added

Computer Simulation – High Rise Building

1000 kVA @ 0.6 PF



PQ Solutions that “Claim” to Save Energy

Category 1: PF correction equipment

- Black/green boxes with capacitors in them
- PF correction capacitors
- Harmonic filters

Category 2: Other PQ Solutions

- Negative sequence current reduction
- Neutral blocking filter
- Surge protection
- Soft starters
- Zig-zag reactors
- Harmonic mitigating transformers (HMT)
- Conservation voltage reduction (CVR) equipment

Energy Savers

A thought....don't you think the government would require these devices if they worked as well as claimed???



....don't be too surprised if you see a new legal directive...

It Happens to the Best of Us....

- 2007 – Eaton Fluid Power Plant
- “Eaton – you know, the old Westinghouse...they love our stuff...they are putting it in all their plants!”
- Applied Three (3) Energy Savers (\$65k)
- Claimed 11-30%
- Actual Savings (Year/Year) – 15%?
 - What?????
 - Actual Savings <1%!
- Three years later the lawyers are finally involved
- Two had failed and were turned off!

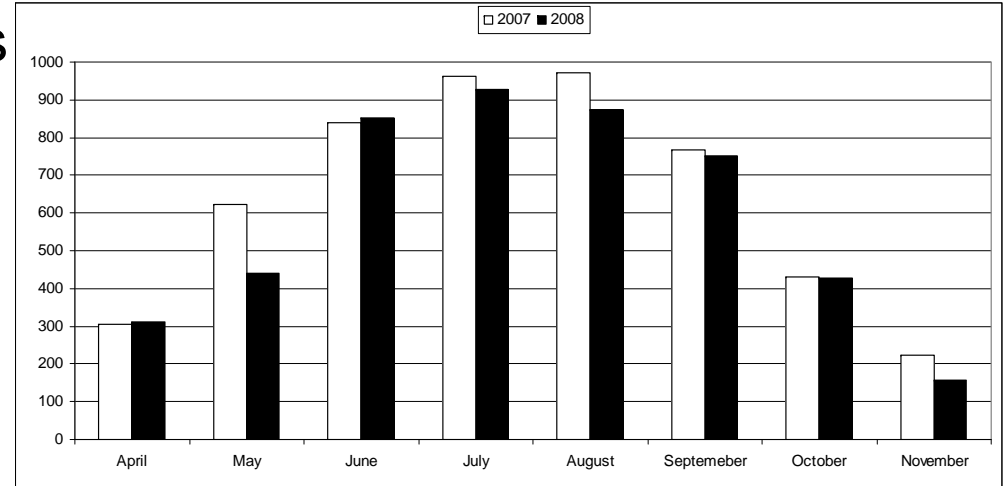


It Happens to the Best of Us....

	kWh	kW	Excess rKVA	Cost	kW savings over previous year	Cost savings over previous year
N-07	346,811	664.3	198.5	\$28,856.55	4.3%	4.1%
Oct-07	329,366	628.5	150.1	\$27,351.46	3.9%	3.2%
S-07	297,597	571	106.5	\$24,879.59	13.1%	11.5%
Aug-07	312,736	605.02	22.8	\$26,120.39	15.9%	15.4%
J-07	331,227	637.5 ^c	64.1	\$27,100.99	10.5%	10.4%
Jun-07	308,103	616.8		607.99	12.2%	9.2%
M-07	319,200	630	529.7	\$26,920.13	6.3%	5.6%
Apr-07	369,870	643	120.5	\$28,231.73	16.6%	9.5%
M-07	354,678	664		663.34	4.5%	4.5%
Feb-07	400,302	704.4	506.2	\$30,757.42	16.2%	11.7%
J-07	395,049	708.7	533.6	\$30,808.96	-18.0%	-21.5%
Dec-06	357,737	718.6	564.6	\$30,444.10		
N-06	384,850	693.9	546.7	\$30,099.75		
Oct-06	354,128	653.9	455.7	\$28,255.68		
S-06	339,933	656.9	560	\$28,109.33		
Aug-06	382,376	719.2	579.4	\$30,869.79		
J-06	361,292	712.5	558.4	\$30,259.63		
Jun-06	345,645	702.44	508.4	\$29,315.43		
M-06	352,918	672	493.8	\$28,505.66		
Apr-06	337,043	771.2	534.1	\$31,194.23		
M-06	347,956	635.3	468.1	\$27,432.08		
Feb-06	387,728	840.9	527.1	\$34,813.36		
J-06	289,015	600.7	458.5	\$25,364.67		

Year-Over-Year Data Should NOT be Used

- Year-over-year data can be very misleading – you have to account for temperature changes and other variables (consider cooling degree days CDD).
- Usually, only the good months are highlighted
- Residential data is especially difficult to track from year to year
- “Placebo” effect – if you believe you are saving energy, you will!



Source: EPRI

But they showed me how it works...

Demo Cases – What's in that box?

- Motor
- Capacitor
- Meter
- (....maybe a few tricks)



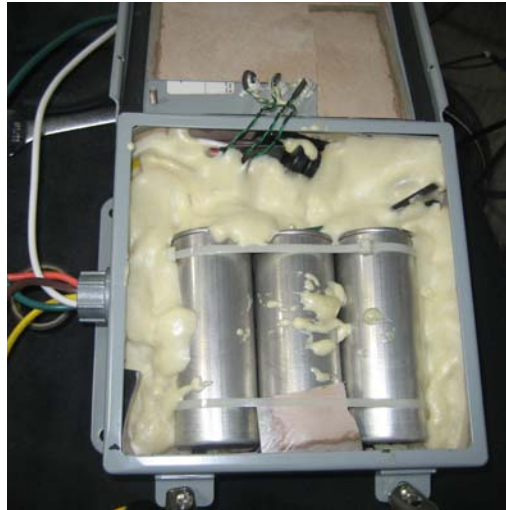
“Look...current reduced from 10 to 5 Amps, that results in 50% energy savings!”



But they showed me how it works...

Electro-magnetic disk meter spins slower with the black box on. It takes 5 hours to make one rotation with the unit on vs. 4 hours with the unit off. Why? **(One rotation on an induction disk meter is about 7.2 WH!)**

Open the “black box” – it’s full of capacitors and MOV’s... If it looks like a duck and swims like a duck and quacks like a duck....



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But they showed me how it works...

They showed me a set of bills from a facility in Alaska and they saved money when the units were on. Why?

We need “transparency” in billing...



Authors' Viewpoint

- We have done the calculations
- We have done the measurements
- We have talked to the vendors
- We simply do not believe the excessive claims
- Can you save significant money with PF correction? Yes, **IF there is a penalty**

How do Capacitors Save Money?

Utility Penalty – If needed for PF penalty

- Typical savings is 5-30% of bill

Capacity Improvement – if needed to improve the capacity of the main transformer

- 0-2% of overall kW savings is typical

Loss Reduction – If needed for kVA or loss reduction

- 1-4% of overall kW is typical with distributed capacitor (some will *claim* more)

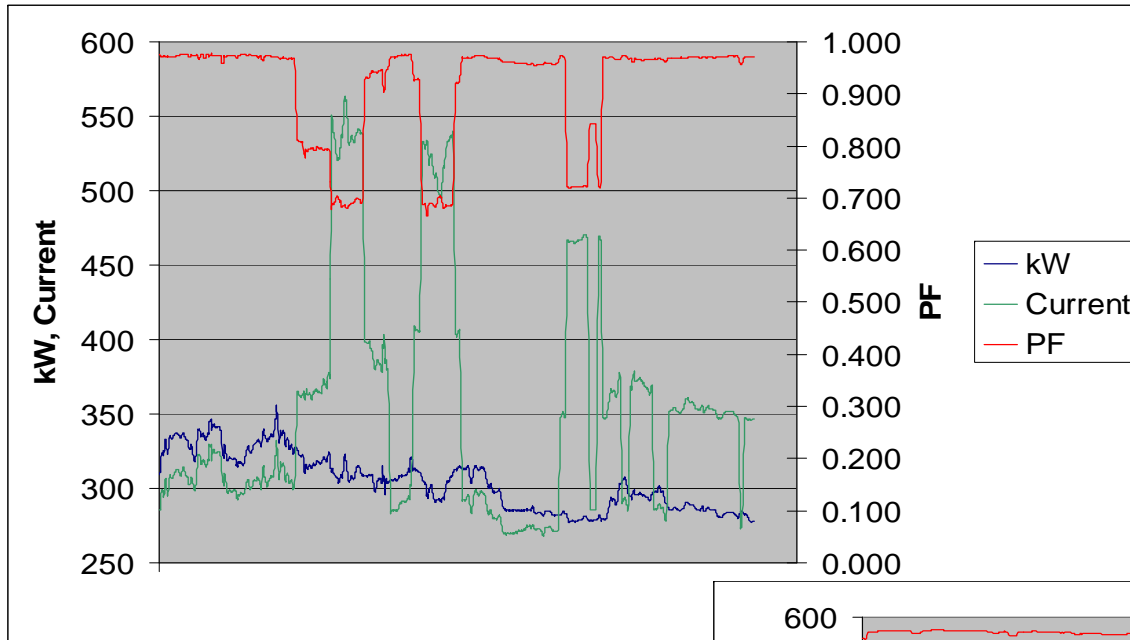
Power Factor Penalties

Table I (partial) from “Capacitor Application Issues” paper

POWER FACTOR PENALTIES

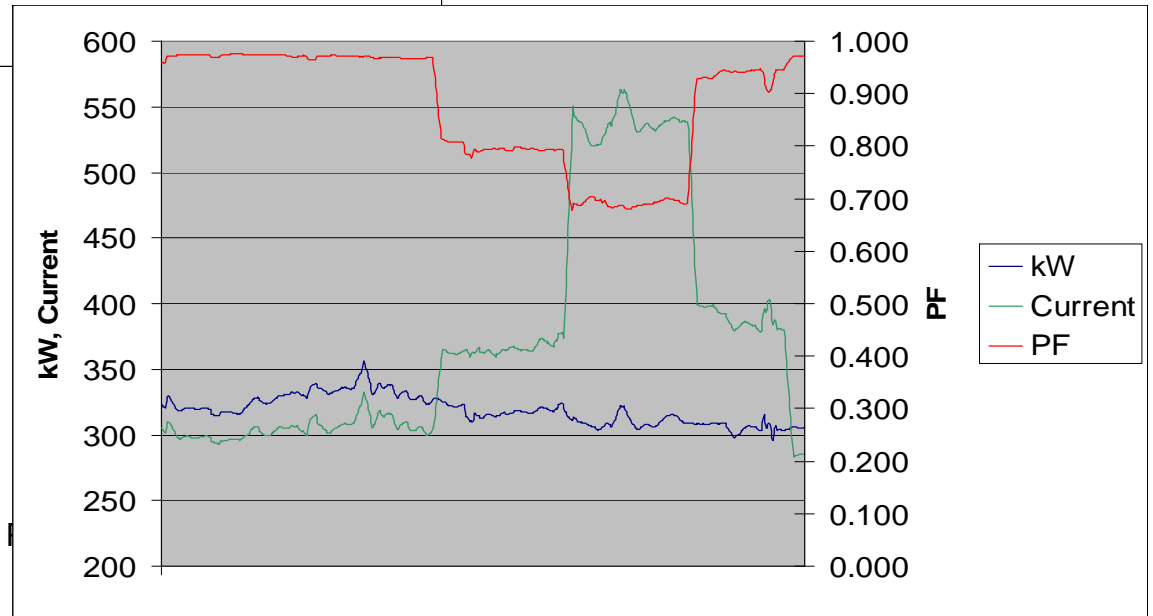
RATE TYPE	DESCRIPTION OF PF PENALTY	EXAMPLE
kVA (demand) rates	Penalty for < 1.0 pf; generally applied as a \$/kVA	Demand = 800 kW; pf=80%; kVA=1000; demand charge = \$10/kVA pf penalty = $(1000 - 800) * \$10 = \$2000/\text{month}$
PF (kVA) adjustment	When the pf is less than X%, the demand may be taken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

Field Tests

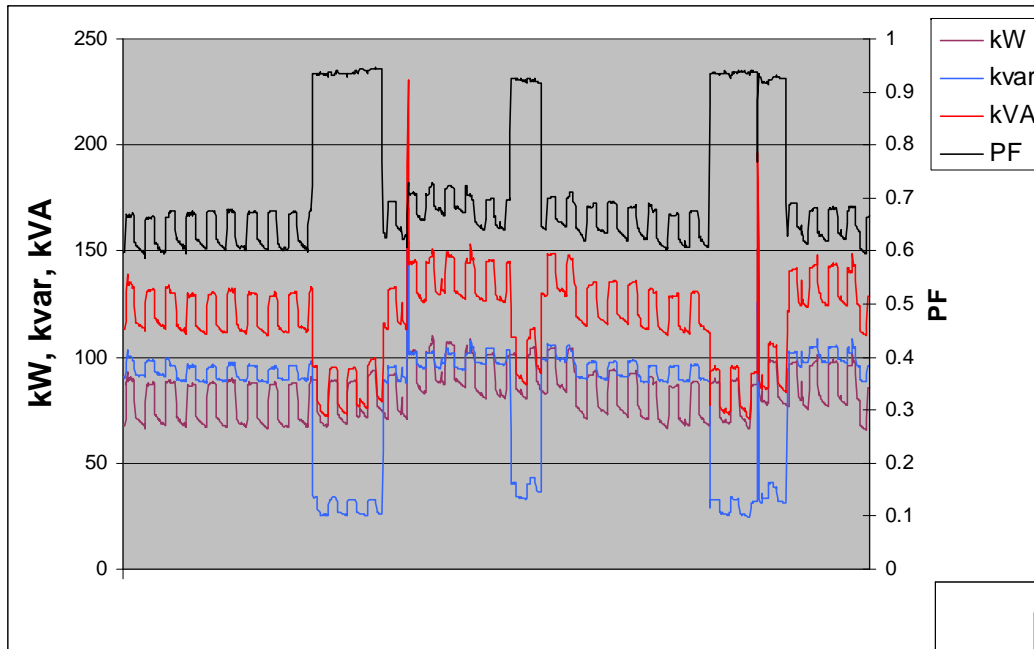


Trend Data During Test

Trend Data Zoom

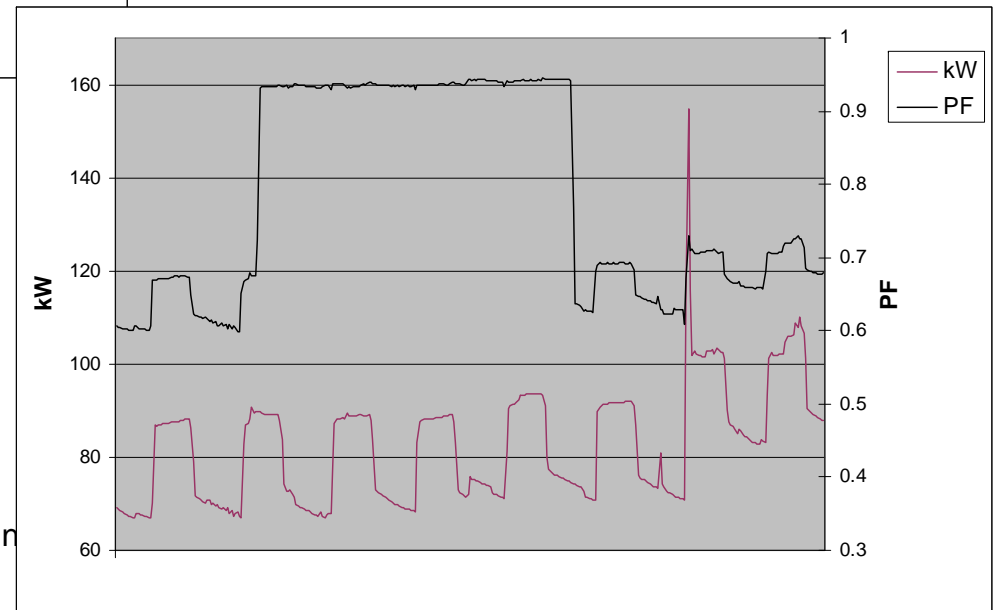


Field Tests



Load with Cycling Air Compressor

Zoom of Load with Cycling Air Compressor



Confusion Created by Sales

Hard Savings	Soft Savings
Reduced kWh	Lengthens equipment life
Reduced kW	Protects sensitive electronic equipment
Improved PF	Reduces maintenance
Reduction in equipment losses (cables, transformers, motors, etc.)	Protects environment
Reduced taxes	Less HVAC required
	Space savings
	Improves safety
	Reduces greenhouse gases

Confusion Created by Sales

- Expert/Third party testimonials and/or “**Technical sign-off**” (usually engineer signs off then the sales person goes to the controller or finance person with the paper)
- Unknowing/Non-technical or **passionate salesmen** (he believes and so should you!)
- **Patented** technology
- Only the **inventor** truly understands the “technology”
- Hard to prove/disprove **guarantees** (buy our stuff and then show us you didn't save...)
- Sell to unknowing residential and commercial customers with little or no knowledge of kW vs. kVA (**current is reduced so “power is reduced**)

Confusion Created by Sales

Confusing Percentages

- Transformer 97% Efficient
- New Transformer 97.8% Efficient
- Either 0.8% Improvement or 27% Reduction in Losses

Faulty/Questionable M&V

- Inferences/overgeneralizations from “similar” measurements
- Comparison to customer with PF penalty
- Revenue grade metering
- CT inaccuracies/phase shifts
- Lack of practical demonstration method
- Too long/short measurement length

Interesting Quotes

What genuinely makes this product different and thus sets it apart from most other devices on the market is built in line noise filtering, "LNF". This **LNF circuit helps to balance out the distortion in the wave cycle** which causes KVAR's in the harmonic balance associate with inductive loads.

(Interpretation: Can you say "flux capacitor"?)

Achieved savings derived from using both MOV, TVSS and line filter capacitance together in one unit maximizes the energy savings feature in real time operations, with results **showing anywhere from 5% - 20% or more in monthly electrical savings possible.**

(Interpretation: I can almost guarantee it might work....)

Highly sophisticated band-pass filter....blocks out harmonics, power spikes and surges....clean up your power...increase your power factor, reduces KVAR, amp draw and most importantly kWH usage...remember, you are billed for kWH....reducing your **kWH reduces your electric bills.**

(Interpretation: Always hints of truth...does everything but wash your car)

Interesting Quotes

Utility companies hate our product because it takes money out of their pockets. They don't like when customers save money on their bills.

(Actually: yes, they do and they would love to pay you to save them from building new gen plants)

How do you get 30% savings on a typical power system – **well, if you save 2% on every motor and you have 15 motors, there you go....**

(Must be that "new math" – I guess I really don't understand per unit math after all....)

The **inventor** will call you to talk to you about the product

(I'm still waiting by the phone....)

Interesting Quotes

You have to install our product – it works over time. **You can't just turn it on and off and expect it to show a difference.**

These capacitors are “**different**” – they aren't just regular capacitors....
(opened the box and what do you know....)

You **can't just install one capacitor** – you have to “optimize the system” by placing them in many locations.

Q: How does 18 AWG wire in a demo box translate up to 500 MCM in a plant?

A: **It just does....**

Interesting Reference Quotes

Our KWH was reduced by approximately 15-18%....Amperage was reduced by 22% and the KWH was reduced by about the same....**I'm not an electrician**, so cannot explain exactly how they work, but testing has shown us they do.

This also gave (us) the opportunity to participate in something that is **positive for the environment** and good for the country we live in.

My Favorite Personal Slams (on me)

You are **thinking too much like an engineer** – you will probably never understand this product.

OK smart guy, **how many classes** did your professors talk about PF correction in college – 2, maybe 3 and does that make you an expert on this stuff?

Eaton doesn't like us because we have a patent on the “technology” and you can't sell it.

....what doesn't kill you makes you stronger!

Favorite HELP Line Calls

"I just started working for a company that makes energy saving devices...sometimes our product saves energy and sometimes it doesn't – can you help me explain to our customers why that is the case????"

I want to sell some black box energy savings devices and I want to be conscientious about what I'm selling. I've set up a W-H meter and did some testing. Why would my meter spin slower with the unit on if it doesn't save real kW?

(Finally, a valid question!)

Favorite Redemption Line

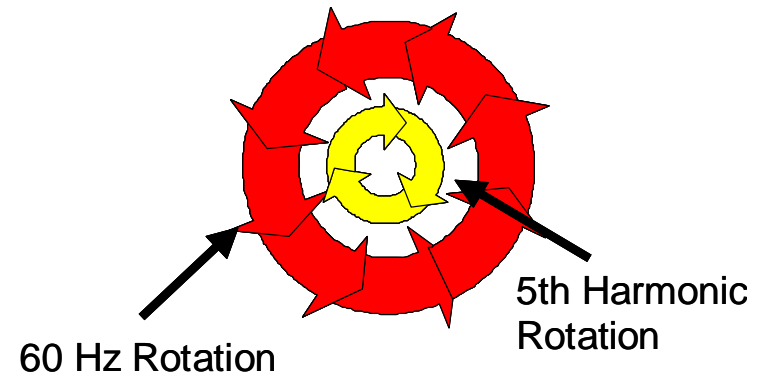
...salesman that sold the product but came to understand the truth....

“I can't believe we sold you this bucket of \$%#*^!

Other PQ Solutions that “Save” Energy

Products that Reduce Negative Sequence Currents in Motors

- **Description:** Voltage unbalance or negative sequence voltage harmonics make motor resist 60 Hz rotation
- **Claim:** > 10% savings?
- **Reality:** MG-1 describes voltage/current unbalance but losses are typically < 2%



Other PQ Solutions that “Save” Energy

(Balancing) Zig-Zag Reactors

- **Description:** Balance voltages, cancel harmonics, improve PF
- **Claim:** > Up to 20% savings?
- **Reality:** I^2R savings, possible harmonic savings, possible PF savings, possible voltage unbalance savings – total less than 3% typically

Other PQ Solutions that “Save” Energy

Surge Suppressors

- **Description:** TVSS/SPD typical equipment
- **Claim:** Transients waste energy and surge protection equipment removes transients
- **Reality:** Impossible and unbelievable! FTC warning = 0.00000%
- From EPRI = typical load may yield 0.044 Wh/yr from many severe transients/year
“....you can only save energy that is wasted...”

Other PQ Solutions that “Save” Energy

Harmonic Mitigating Transformers

- **Description:** Phase shifting transformers
- **Claim:** Up to 20%
- **Reality:** Actual savings is from energy efficient transformer changes (2-4%) plus < 4% from harmonic reduction is typical

Other PQ Solutions that “Save” Energy

Neutral Blocking Filter

- **Description:** 3rd harmonic blocking filter
- **Claim:** Up to 8%
- **Reality:** Possible to get up to 8% but more typical is 1-4% depending on load mix

Other PQ Solutions that “Save” Energy

Soft Starter

- **Description:** Power electronic motor starter
- **Claim:** Reduce kW demand
- **Reality:** 2-10 seconds of starting current will not significantly reduce 15 min billing demand. In addition, inrush current is primarily reactive (kvar, not kW). Savings = 0%.

Other PQ Solutions that “Save” Energy

Conservation Voltage Reduction (CVR)

- **Description:** Reduce voltage to loads by 5-10%
- **Claim:** Reduce kW demand, usage up to 13%
- **Reality:** Depends on load mix – constant impedance loads will reduce kW but could increase load cycles (heating loads, for example). Constant HP (motor) loads could increase current and increase I^2R losses. Typical <2% for aggregate systems could be more for specific individual loads.

Table 2 – Summary Table

- Description
- Primary PQ Benefit
- Stated EM Savings or Other Benefit(s)
- Realistic EM Savings
- Reasons for Discrepancies

Description	Primary PQ Benefit	Stated EM Savings and Other Benefits	Realistic EM Savings	Reason for Discrepancy
Products to address negative sequence currents	Negative Sequence Current reduction	<ul style="list-style-type: none"> • Eliminates “reverse” rotation action on motors yielding higher efficiency • kW and kWh savings (usually > 10%) • Reduces heating • Prevents premature damage 	<ul style="list-style-type: none"> • kW and kWh savings (usually < 2 %) 	<ul style="list-style-type: none"> • Hard to measure and disprove stated claims. • Easier to stretch the truth based on “some” savings.
Products to address unbalanced voltages	Negative Sequence Current reduction	<ul style="list-style-type: none"> • Eliminates “reverse” rotation action on motors yielding higher efficiency • kW and kWh savings (usually > 10%) 	<ul style="list-style-type: none"> • kW and kWh savings (usually < 2 %) • May actually increase kW usage in some cases 	<ul style="list-style-type: none"> • Hard to measure and disprove stated claims. • Easier to stretch the truth based on “some” savings.

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Power Systems Experience Center (Power Quality Lab)

– Purpose

- To demonstrate and Test PQ Problems and Solutions
- Power Quality solutions, especially harmonic and PF, are difficult to understand
- Demystify solutions – mis-information and confusion regarding PQ and energy savings



– Sample Equipment (Harmonic and PF Related)

- | | | |
|---------------------|-----------------------------|-----------------------------------|
| • PF Caps | • Passive Filters | • 3 rd Harmonic Filter |
| • HMT's | • Active Rectifier (UPS) | • 18 Pulse Drives |
| • Active Filters | • Reactors | • Load Banks/Drives |
| • Broadband Filters | • > 300 480W Power Supplies | • 30 HP, 75 HP, 300 HP Motors |

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Summary

Is it a good idea to buy PQ solutions?

- Yes – for PQ and reliability reasons

Do PQ solutions save energy?

- Sometimes but not as much as many will claim

Does PF Correction equipment save significant money on the utility bill?

- Yes, if there is a penalty

References

Reference Papers and Presentations:

1. Carnovale/Hronek, “Power Quality Solutions and Energy Savings” (World Energy Engineering Congress – 2008)
2. “The Truth Behind PQ Solutions and Energy Savings”, EC&M April 2010
3. Blooming/Carnovale – “Capacitor Application Issues” (IEEE IAS – 2006)
4. EPRI – “Energy Savings: You Can Only Save Energy That Is Wasted”
5. EPRI – “Strategies for Evaluating Black Box Technologies”

Latest Related Work

- Friends and Enemies
- New products/partners for Eaton and our friends (IBEW, etc.)
- Papers, articles, measurements
- Demos in Power Systems Experience Center
- Sharing info with EPRI

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Joint Presentation

Thank You!

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**Eaton Corporation
Power Systems Experience Center
(www.eaton.com/experience)**

If you want to contribute to this series of technical presentations, please contact Nick Abi-Samra, Chair, San Diego Power & Energy and Power Electronics Societies.

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