Distributed Generation, Customer Premise Loads & the Utility Network A Case Study

Revised July, 2008

Richard Ellenbogen, MEE
President, Allied Converters, Inc.
New Rochelle, NY

What is Allied Converters ?

- Small, light manufacturer of Plastic Food Packaging
- 55,000 square foot facility in New Rochelle (Westchester County)
- 80 KW – 90 KW Peak Summer Demand
  - Would be 110 KW without CHP driven chillers

Three sources of Power at Allied Converters

- Utility (Con Ed)
  - As needed
- CHP (Combined Heat & Power)
  - 45 KW maximum electric power output
    - 48 KW – 3 KW of Overhead to operate pumps
  - First grid connected micro-turbine system in the Con Ed service area
- Solar PV (Photo-voltaic)
  - 45 KW AC maximum
  - First commercial solar array in New Rochelle

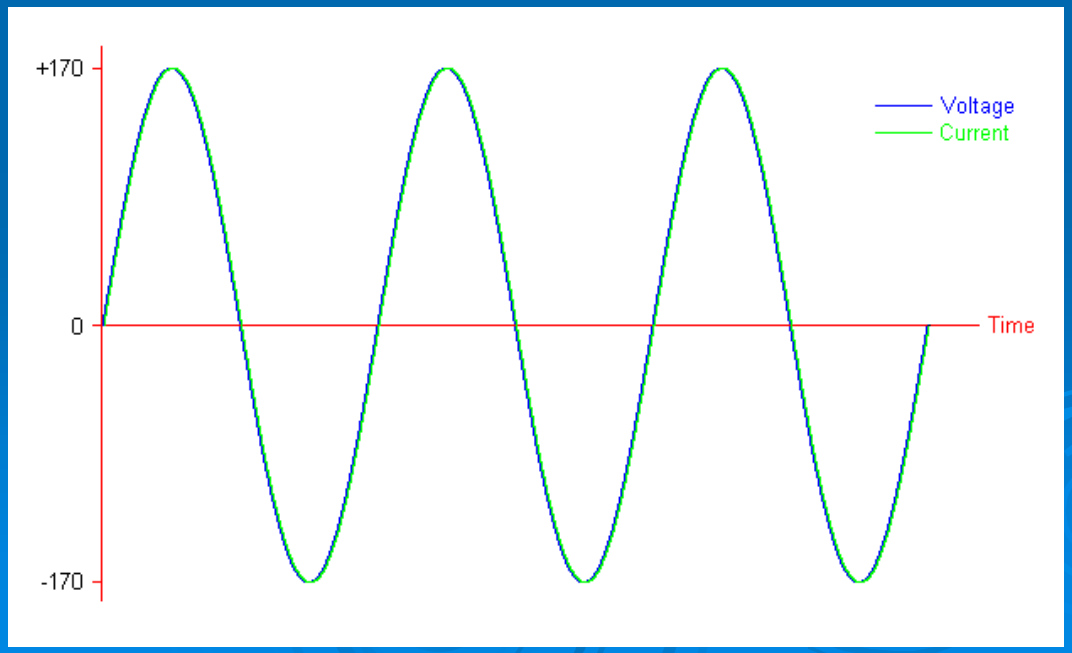
Utility Interconnection

CHP system (Micro-turbines)

Photo-voltaic Solar Array

What are Reactive Power and Power Factor?

- **Power = Current (I) x Voltage (V)**
  - Current & Voltage are in phase (Power Factor =1.0)
  - Devices on System can do maximum amount of work

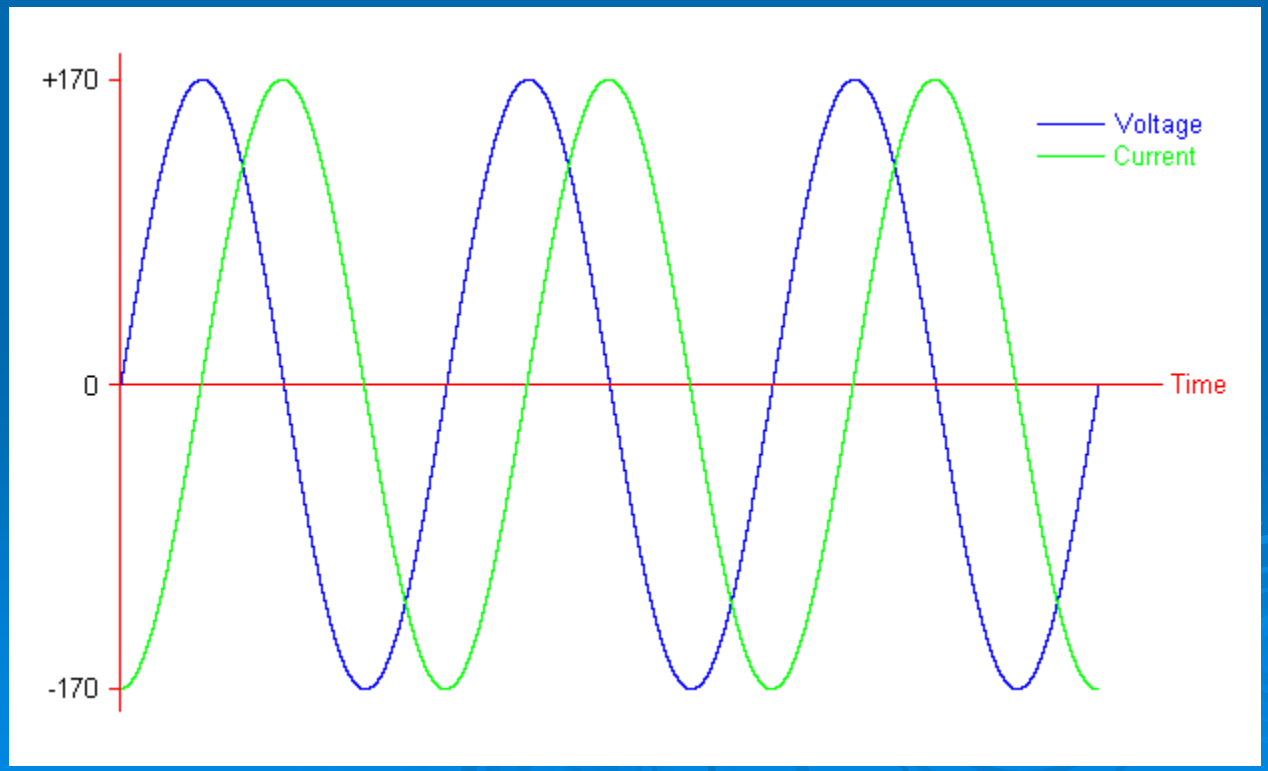


What happens when motors and transformers are introduced into a circuit ?

- Current waveform starts to lag behind the voltage waveform because of the inductance of the magnetic devices.
- In the extreme theoretical case, the waveforms can be 90 degrees out of phase.
- Power drops because voltage is at maximum when current is at 0 and vice versa.
- Power = I x V = 0

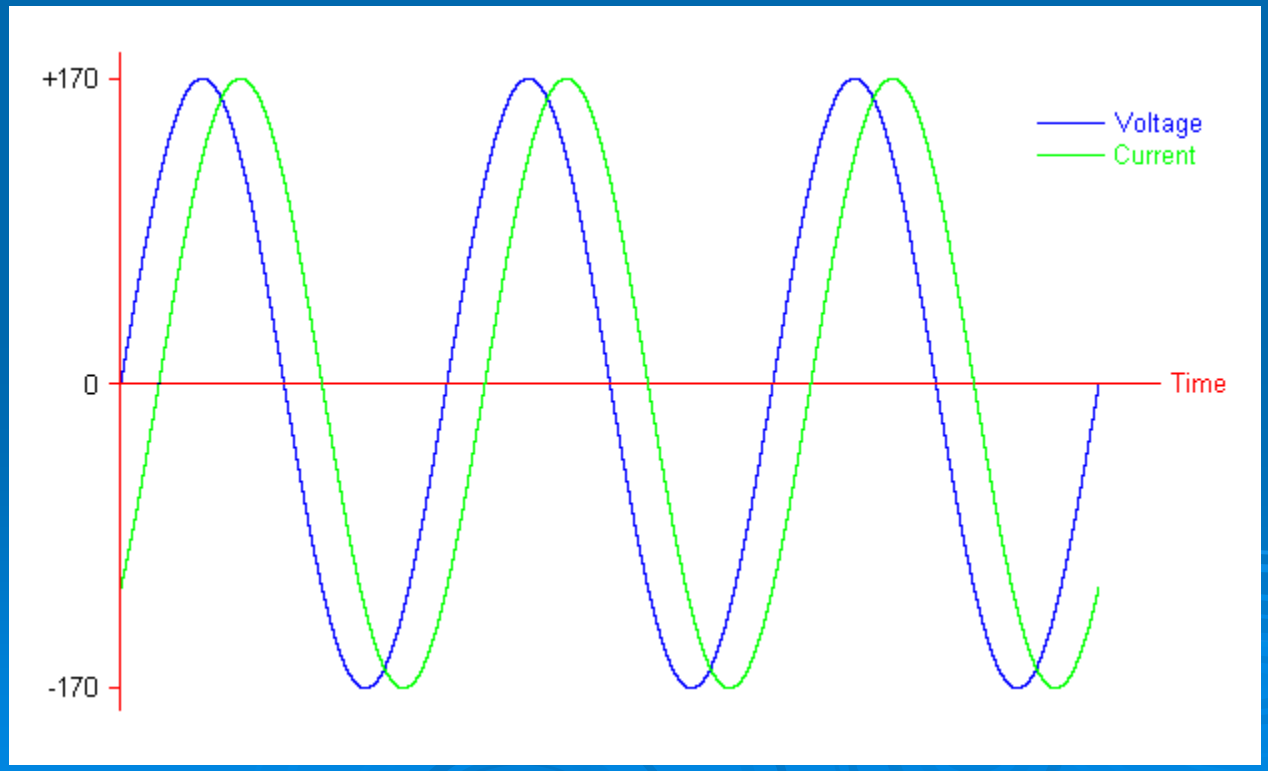
Voltage and Current are 90 degrees out of phase

- Power Factor = 0 No real Power
- System can do no “work”



Voltage and current 45 degrees out of phase

- Power Factor=0.7 (lagging – current lags the voltage)

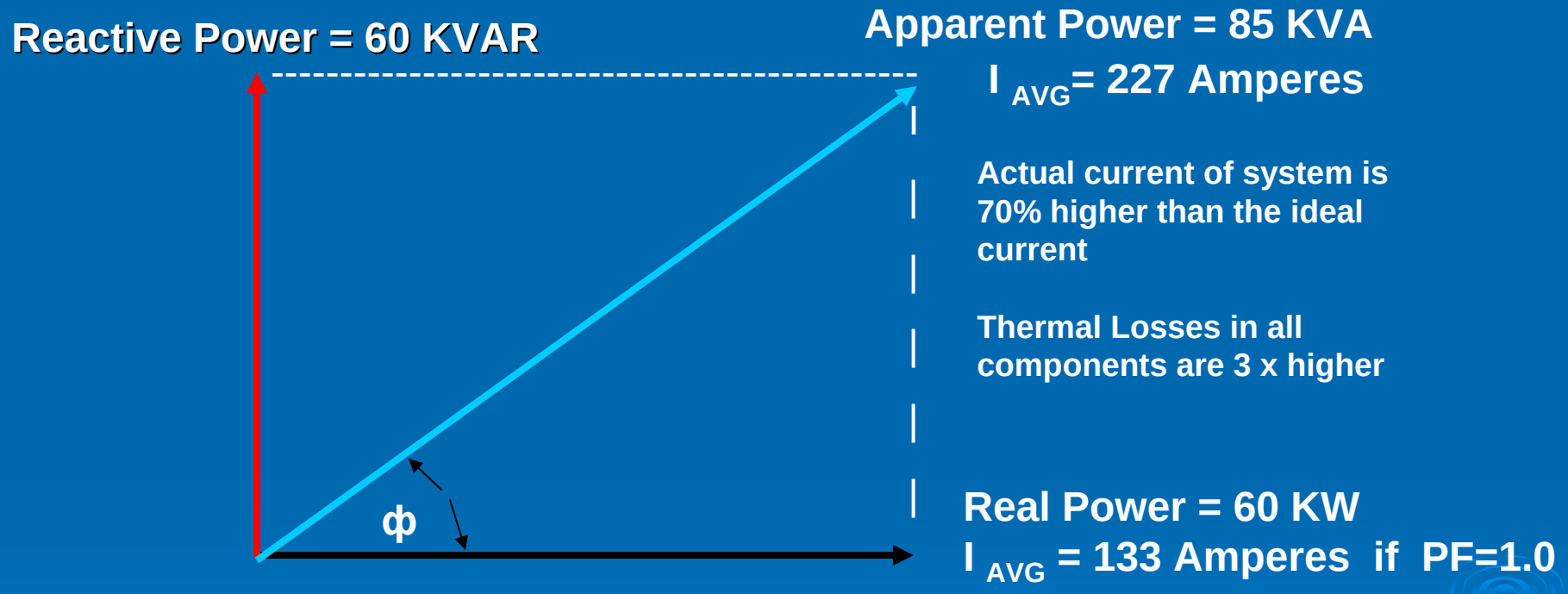


What is the result of the current and voltage being out of phase ?

- Currents rise throughout the system
- As currents rise, the thermal losses in all parts of the system increase. System loses efficiency.
- Power $P = I^2 \times R$ **(R is the resistance of the wires and motors, etc.)**

What is Reactive Power ?

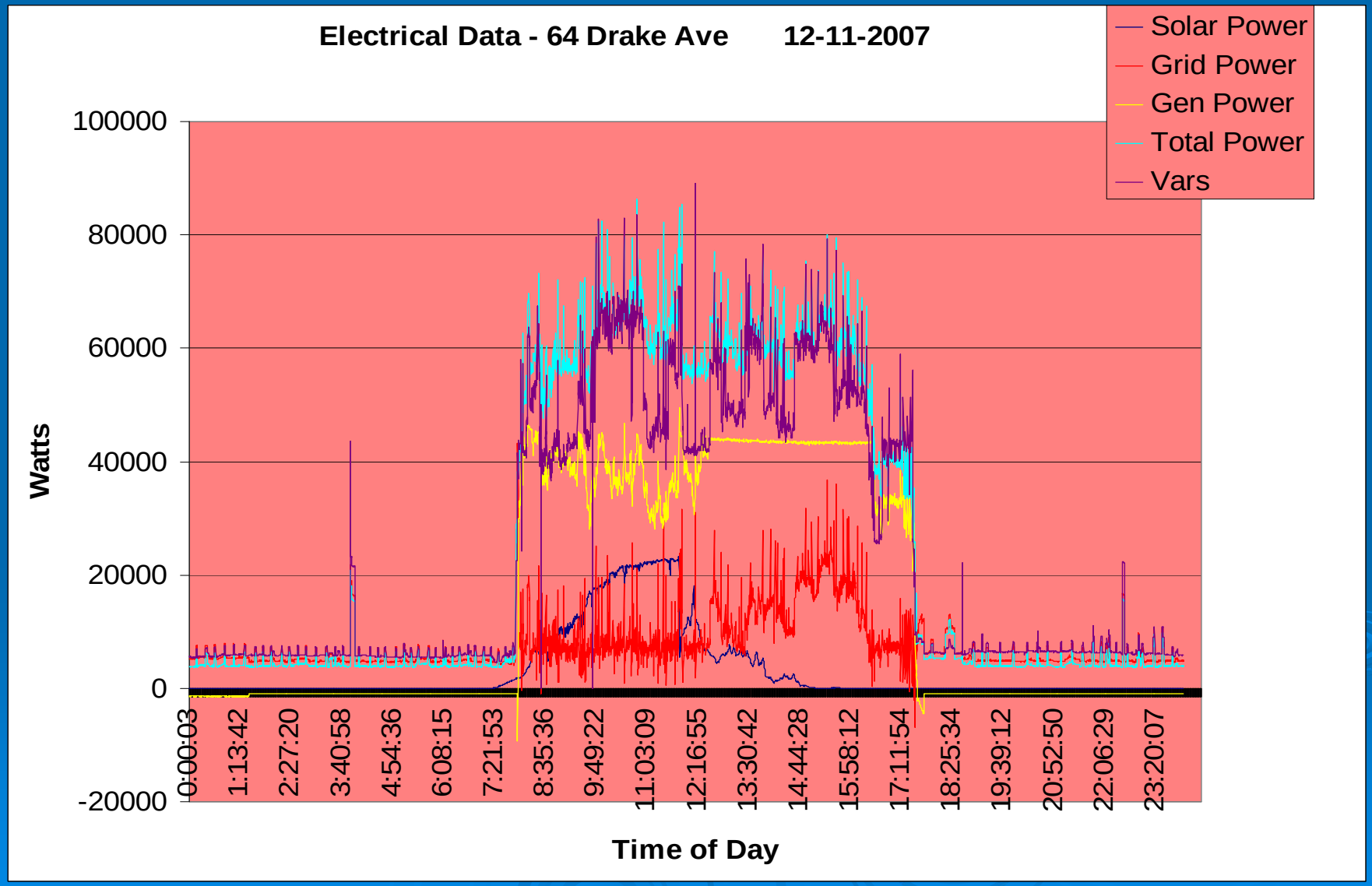
It is the component of Apparent Power that is 90 degrees out of phase with the Real Power.



Building PF= .7 ϕ = 45 degrees

Power Factor=cosine ϕ = Real Power / Apparent power

Before Power Factor Correction



What are the effects of a Large amount of Reactive Power and a Low Power Factor on the Utility Network?

- Greater power losses occur in all components caused by higher currents. These losses manifest as heat. ($P=I^2 \times R$)
- Burning wires and cables (Queens-2006)
- Burning transformers
- Increased generation required to compensate for losses
- Wasted Energy
- Increased Greenhouse Gas Emissions from extra power production

Can the problem be fixed ?

- Yes. By adding Power Factor Correction to the service.

What is Power Factor Correction?

- Power Factor Correction re-aligns the voltage and current waveforms so that they are in phase.
- Power Factor Correction Capacitors are sized for each inductive load on the system and wired in parallel with the inductive load.
- They must be wired so that they only operate when the load is energized.

Installation of Power Factor Correction

7.5 KVAR Located at the load

45 KVAR Located at Service Entrance

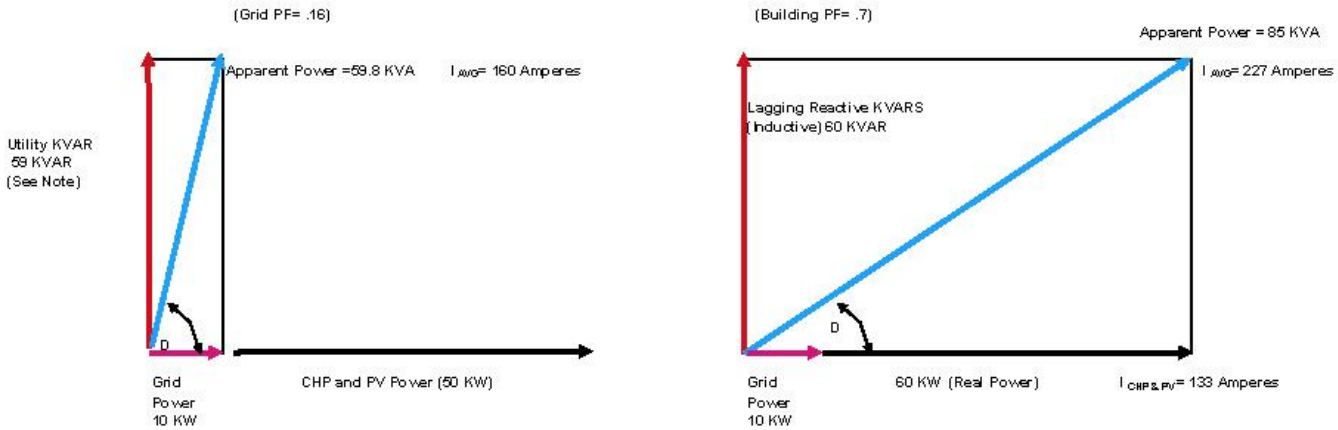
What are the advantages of each type ?

- **At the service entrance – Good for the Utility**
  - **Easier maintenance of Power Factor correction system. Installation is centralized.**
  - **Improves Utility Power Factor.**
    Reduces grid losses by reducing KVAR and the associated KW on the utility network.

What are the advantages of each type ?

- **At the Load** – Good for everyone
  - This is the most effective installation.
  - Improves Utility Power Factor. Even greater reduction of grid losses by reducing KVAR and KW after the meter also. Results in a greater current reduction.
  - Reduces building losses and lowers the utility bill by reducing thermal losses within the customer premise.
  - Reduces thermal degradation of facility electrical devices and associated maintenance.
  - Pays for itself.

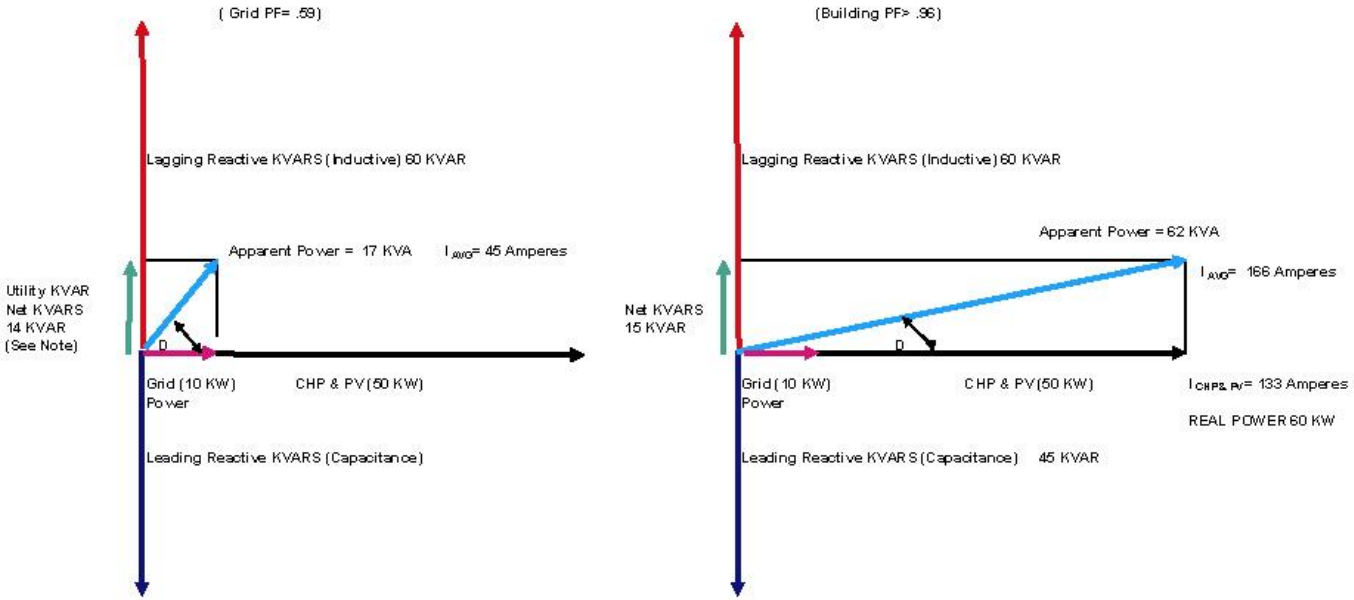
Before Power Factor Correction



I_{AVG} is the average current per phase in the 3 phase system

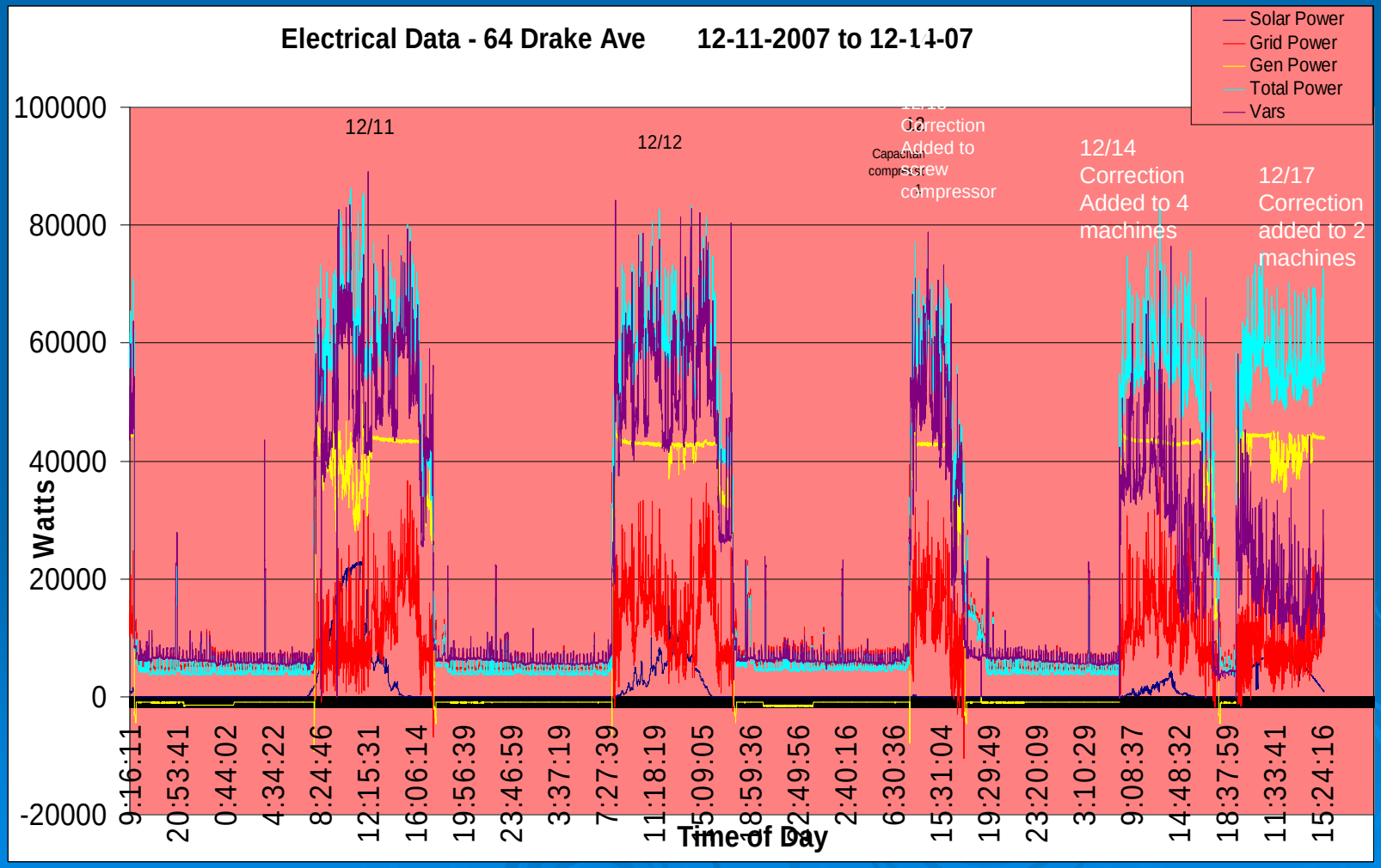
After Power Factor Correction

Capacitance Added

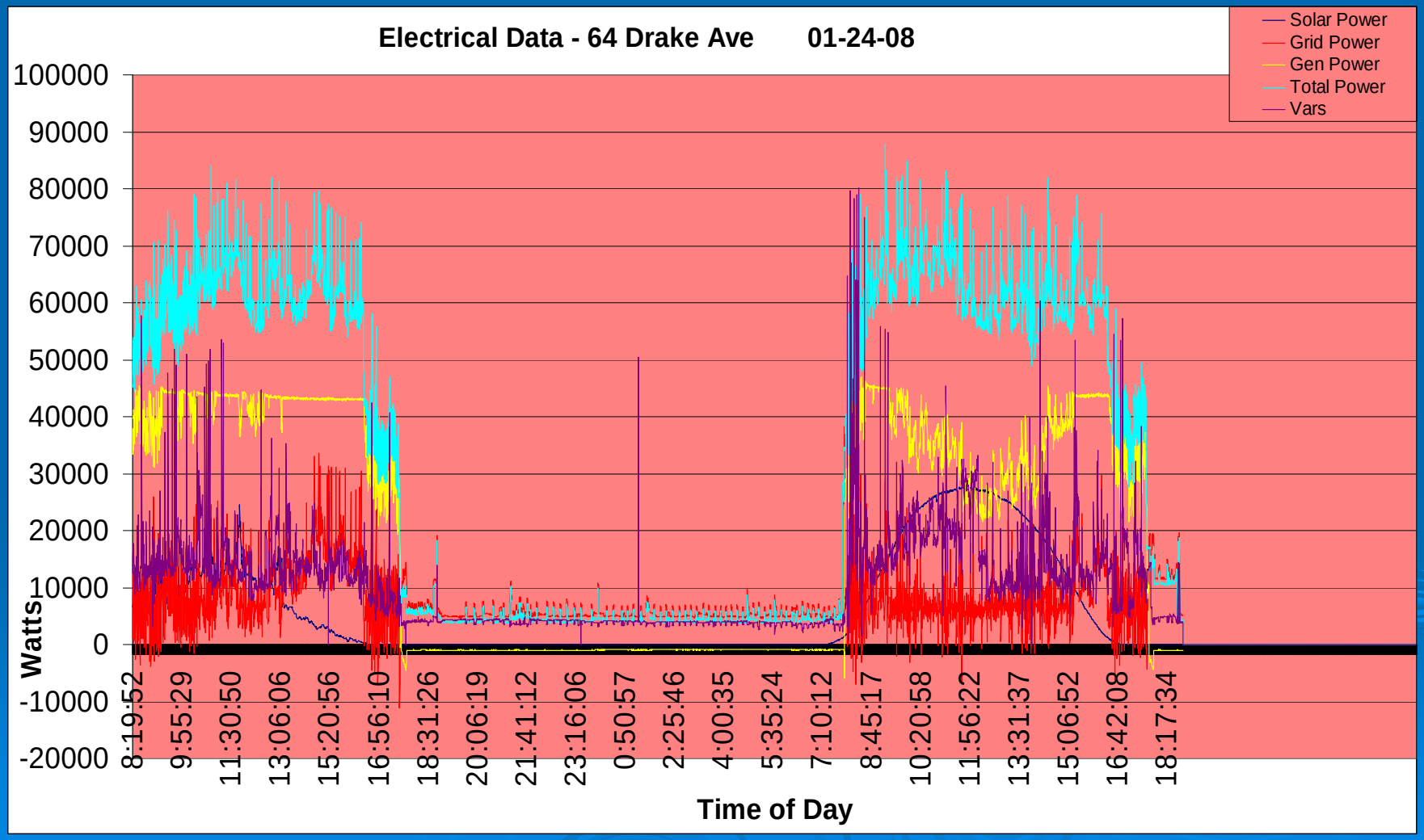


PF=cosine = Real Power (KW) / Apparent Power (KVA)

During Power Factor Correction



After Power Factor Correction



Power Factor Correction Greatly Enhances The Effect of DG

- DG or PF Correction alone only result in a 30% reduction in grid currents
- Used together, they result in an 80% reduction in grid currents
- Resulted in > 5.3% reduction in Customer Premise KW when improving PF from .75 to .95 (New facility with updated wiring to the latest codes)

BEFORE

Utility Current

I_{AVG}=89.4

TIME - 11:27:36 2/4/8

SOURCE	GRID	SOLAR	CAPSTONES
PHASE 1 VOLTS	125.64996	125.57495	125.64996
PHASE 1 AMPS	96.67998	10.42000	117.39997
PHASE 2 VOLTS	125.19996	125.22496	125.24996
PHASE 2 AMPS	99.83997	10.48000	121.31996
PHASE 3 VOLTS	125.27494	125.19996	125.27494
PHASE 3 AMPS	71.59999	7.54000	118.99998
POWER FACTOR	.69750	.86600	.99160
VARS	22649.99218	.00000	.00000
CALCULATED VARS	24717.45703		
KWATTS	24059.99218	3089.99902	44489.99218
FREQUENCY	60.01999	60.02699	60.03099

		Capacitance
TOTAL BUILDING POWER DEMAND	:71639.97656	.00000
TOTAL BUILDING POWER FACTOR	:.94532	10000.00000
TOTAL BUILDING KVARS	:49717.45703	10000.00000
BUILDING KVAR ADJUSTMENT	:25000.00000	5000.00000

AFTER

Utility Current

I_{AVG}=73.3

down 18%

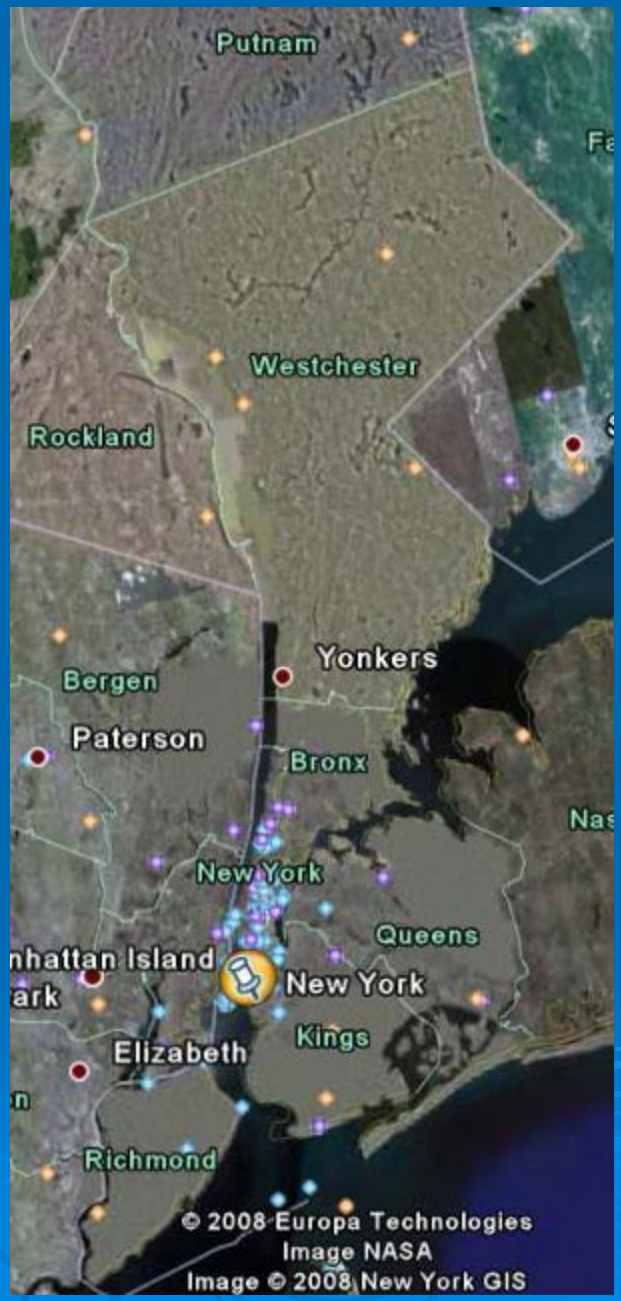
7% Reduction in Building Current

TIME - 11:30:23 2/4/8

SOURCE	GRID	SOLAR	CAPSTONES
PHASE 1 VOLTS	125.67495	125.69999	125.77497
PHASE 1 AMPS	86.83997	10.22000	117.51997
PHASE 2 VOLTS	125.37496	125.47496	125.39994
PHASE 2 AMPS	86.39998	10.30000	120.11997
PHASE 3 VOLTS	125.59994	125.62496	125.57495
PHASE 3 AMPS	46.75999	7.14000	118.79997
POWER FACTOR	.86740	.86390	.99190
VARS	3989.99902	.00000	.00000
CALCULATED VARS	14111.33789		
KWATTS	24599.99609	2999.99951	44399.98437
FREQUENCY	60.01198	59.96500	60.01599

		Capacitance
TOTAL BUILDING POWER DEMAND	:71999.96875	20000.00000
TOTAL BUILDING POWER FACTOR	:.98133	10000.00000
TOTAL BUILDING KVARS	: 59111.33593	10000.00000
BUILDING KVAR ADJUSTMENT	:45000.00000	5000.00000

The Bigger Picture



Increase in Electric Load

- Increase in Air Conditioning Load
  - 56% of Residences had Air Conditioning in 1978
  - 77% had Air Conditioning in 2001 (Source: NY Times August 2, 2006)
- Every Desktop computer has a 200 - 300 watt power supply that is a relatively large source of reactive power
- Widespread use of Metal Halide and other transformer based lighting w/ “poor” PF
- The new CFL’s that are replacing incandescent bulbs, while reducing KW load are increasing KVAR load. The effect on apparent power is not as great as on the real power. Some have a PF=.54 and 125% harmonic distortion.

Apply Power Factor Correction Across the Entire Service Area

- Precedent set with water distribution
- Backflow Preventers are required to prevent Customer Premise “contaminants” from entering utility’s distribution network
- Apply concept to Electric Distribution

Results of Network Wide Power Factor Correction

- Enhanced Results from DG and DG Investments
- Improved Service - Fewer Network Failures
- Improved Energy Efficiency - Fewer Losses within the system (Transmission & Customer Premise)
- Lower Energy Costs resulting from Higher Energy Efficiency & Reduced Maintenance
- More Capacity Available on Existing Network
- Reduction of Greenhouse Gas Emissions

Can Network Wide Power Factor Correction be Applied Cost Effectively to Smaller Businesses and Residences

- A study Done in Whitby, Ontario in a Residential Subdivision during 2005 documented large potential savings
- Our analysis of a residence indicates that a home w/ two Air Conditioning Compressors could be corrected with three PF devices for approximately $ 600 in equipment, plus 3 hours labor. (Using available commercial devices)
- Pilot Project Proposed for New Rochelle. Awaiting approval of NYSERDA Funding. Will Involve 80 to 100 homes. Con Ed has agreed to provide $ 10,000 worth of labor and engineering to assist this project. New Rochelle has waived permit fees and the final inspection fees have been reduced by 40%. We are presently working on getting UL approval for a less expensive device for residences to further reduce costs.
- Possible Use of Smart Grid Technology to offer the Utility the ability to monitor and control Power Factor on the secondary of each pole transformer

WINDOW AIR CONDITIONER

17.2% Reduction in current

12% reduction in real power

30% reduction in related I^2R losses on the transmission lines

500 AC Units in One Apartment Complex

80-100 KVA Reduction in utility load

COST

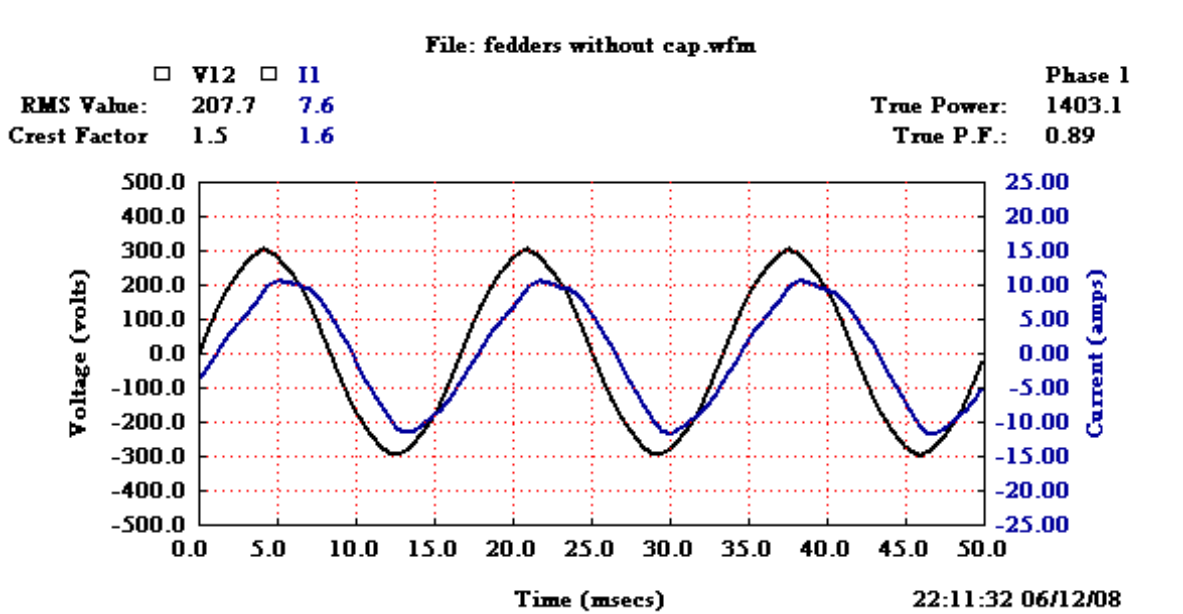
Approx. $ 75,000 initially, $ 35,000 in mass production
($ 450 - $ 900/KW)
No Fuel Cost

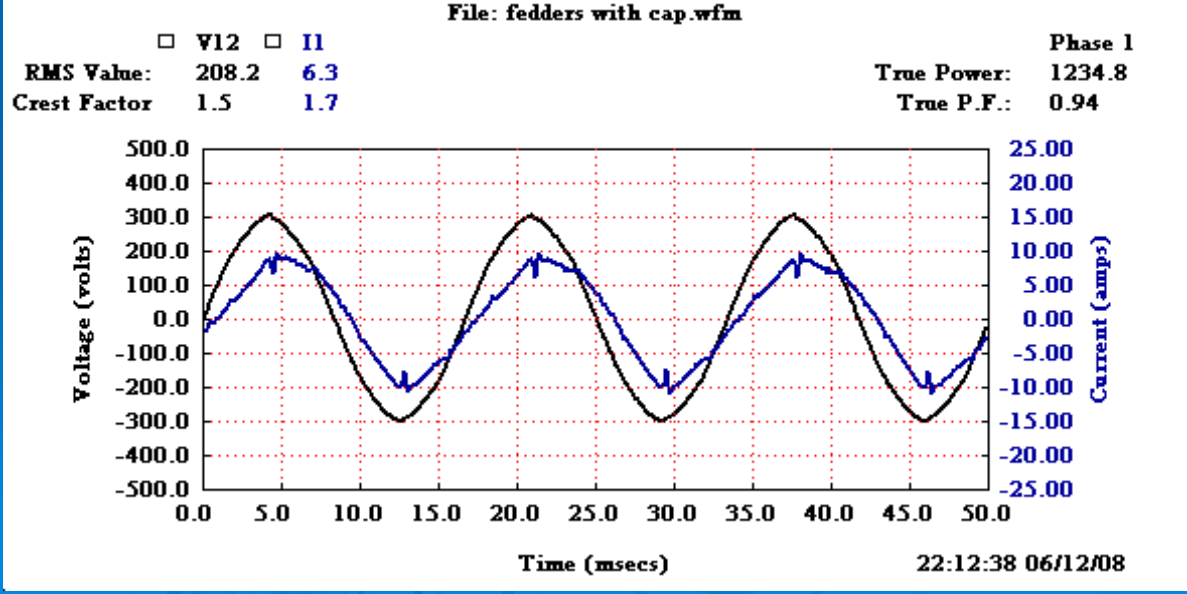
SAVINGS

$ 160,000 for equivalent power plant construction ($ 1600/KW) Will Use
$ 15,000 fuel in 2 months

1200 MCF Natural Gas

25 Tons CO2 Emissions





Potential Energy Savings Resulting from Network Wide Power Factor Correction (Con Ed Service Area)

- Reduce Transmission Losses by 125 Megawatts (MW)
- Reduce Customer Premise Losses by 4% (500 Megawatts)
- Reduce Energy Usage by 1600 MW (40% Generation efficiency, 92% Distribution Efficiency)
- Reduce Natural Gas Consumption by 53,000 Therms per Hour (3 million to 5 million Cubic Feet per Hour)
  - 27 billion to 45 billion cubic feet of natural gas annually
- Reduce Annual CO_2 Emissions by 700,000 tons

$$ Savings Resulting from Network Wide Power Factor Correction

- Reduced Cost of Equipment because of fewer failures
- Lower residual costs related to power failures
  (e.g. Spoiled Food, Lost Business, etc.)
- Reduced Labor Costs - Labor can be used to improve the network instead of maintaining the status quo.
- Eliminates need for Large Power Plant Construction
- Lower customer electric bills
- $ Save 550 million of Fuel Annually (at $ 12.00 per 1000 CF)

Environment needed to achieve Network Wide Power Factor Correction

- **Regulatory Support -**
  - KVAR charges commensurate with their actual cost
  - Modification of Electrical Codes to Require High PF
  - Requirements that new equipment has PF correction installed at the factory (e.g. Air Conditioning)
- **Financial Support -**
  - NYSERDA Smart Loans to defer cost over time. This will allow the real savings to pay for the debt and minimize resistance to the project from the customer side.
- **Utility Support -**
  - Staff and data will be needed to provide feedback on the condition of the utility network where correction is being implemented and to confirm that the installation is working

Logistics

- Personnel
- Structured, Simplified Program
- Equipment
- Centralized Engineering Support
- Centralized Oversight and Database

Conclusions

- DG can help to greatly reduce demand on the utility network and reduce transmission losses
- Power Factor Correction must be included in all high PF, inverter based DG installations and depending on the size of the DG plant, in the surrounding area as well
- Power Factor Correction in all customer premises will improve energy efficiency and service while reducing costs and pollution
- Power Factor Correction is both economically and logistically feasible
- Power Factor Correction is an environmental necessity