Power Factor Correction, LLC

"Bringing The World Back Into Phase, One Step At A Time"

At Load Power Factor Correction
Phase 2: Refrigerated Vending Machines

A Pilot Project to determine the feasibility and economics of small scale "At Load" Power Factor Correction

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New York State Energy Research and Development Authority

NYSERDA New York State Energy Research and Development Authority

1.0 Introduction, Objectives, and Overview of Phase 2 Results

Power Factor is the ratio of the power needed to do the work within customer premises to the power delivered by the utility. A power factor of 1.0 is ideal. Equipment located in customer premises emits reactive power that lowers the power factor. There are devices that can be attached to the loads to raise the power factor and reduce the amount of energy lost as heat on the wires in buildings and on the electrical distribution system.

This paper presents the background information, method, and results from Phase 2 of an eighteen month long pilot project designed to determine the economic feasibility of "At Load" power factor correction in various scenarios as a method for improving efficiency and reducing losses on the electric utility system. "At Load" power factor correction will be analyzed in apartments, residences, commercial and industrial settings. As power factor correction is not a new concept, the project has four objectives. For all phases of the project, our first objective was to measure the power factor in the different environments. This involved creating data bases to simplify handling of the data being collected. Second, we wanted to gain a better understanding of the reactive loads in the different environments. That understanding includes the age of the appliances or equipment discharging the reactive power and the types of installations involved. Our third objective was to correct the power factor in the most cost effective manner possible. Our final objective was to measure the effect of our installation and determine the cost versus benefit of the installations. Benefit is measured in Kilowatt Hours (KWH) saved.

While the results presented for all of the test environments will be similar, they do vary from environment to environment. Also, the volume of data being collected and the timeframe of the data collection at the different sites mandate that we divide the project and reports into four phases. This phase of the project focused on "At Load" power factor correction applied to refrigerated vending machines.

A report issued by Pacific Gas and Electric of California (PG&E) indicated that in 2002 there were three million refrigerated vending machines in the United States[1]. As of 2005, New York State represented 6.4% of the total US population. It would be fair to assume that approximately 6% of the refrigerated vending machines in the United States, or 180,000 machines, are located in New York. That provides a large "market" on which to implement this process. In addition, according to the PG&E document, the design life of the vending machines is ten years so many that are currently in service will be there for many years.

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1 Codes and Standards Enhancement Initiative For PY2004: Title 20 Standards Development, Analysis of Standards Options For Refrigerated Beverage Vending Machines, Prepared for: Gary B. Fernstrom, PG&E, Prepared by: Davis Energy Group - Energy Solutions, May 5, 2004, PP. 2

While much of this documentation will reference the New York Metropolitan Area as the work was done here, it is applicable to other areas of the country as well. Conclusions that we have drawn from the work completed to date are the following:

- The power factor is sufficiently low in refrigerated vending machines that improving it will result in a substantial energy savings throughout the entire utility system, when measured in KWH.

- We can cost effectively improve the power factor for existing refrigerated vending machines

- Standards need to be modified so that new refrigerated vending machines are designed with a high power factor as part of the design criteria.

- Power Factor Correction in this environment does not measurably increase the amount of harmonics.

- Power Factor Correction in this environment will reduce CO_2 emissions by 21,000 tons annually for New York State.

- Power Factor Correction must be load based and must only operate when needed. Excess capacitance connected to the utility system can be as detrimental as excess inductance. Furthermore, in the event of a blackout, the excess capacitance would add extra impedance that would have to be energized, applying extra load to the system during a restart.

2.0 Background

Power Factor is the ratio of the power needed to do the work within customer premises to the power delivered by the utility. The power needed by customer premise equipment to operate is measured in Kilowatts (KW). The amount of power delivered by the utility is measured in Kilovolt Amperes (KVA). KW divided by KVA is the power factor. A power factor of 1.0 is ideal. Appliances and machinery within customer premises discharge reactive power, measured in Kilovolt Amperes Reactive (KVAR). More KVAR present on the utility system results in a lower power factor, and higher currents (I) present on the wires. Because thermal losses on the wires are proportional to the square of the current, a 12 % increase in current will result in a 25% increase in thermal losses related to the increased current. (1.12 x 1.12=1.25). Similarly, a 10% current reduction will result in a 19% drop in thermal losses and provide the corresponding energy savings (0.9 x 0.9 = 0.81). Additional information explaining power factor and the associated energy losses can be found on-line at www.wikipedia.org or on our web site, www.powerfactorcorrectionllc.com .

Historically, utilities have implemented power factor correction at their substations by installing banks of capacitors. The substations are where the utilities reduce the voltage (usually greater than 110,000 volts) from the transmission wires to lower voltages (4,100 volts or 13,000 volts) for distribution throughout the service area. The voltages are further reduced to the range of 208 volts to 480 volts at the transformers on the utility poles or in underground vaults located near the customer premises. The problem with implementing power factor correction at the substations is that the reactive power present on the distribution system, not serviced by those capacitors, is inducing thermal losses. Furthermore, the distribution system with its lower voltages and higher currents already accounts for the majority of the losses on the system. In addition, more thermal losses occur on the customer side of electric meter, within the customer premises. On the Transmission and Distribution System, 50% of the energy lost and almost 75% of the "Accounted For" energy losses occur on the lower voltage Distribution Portion of the system (See Figure 1). Those figures do not include losses from reactive load that occur after the customer meters. While the utility does not bill for reactive power in most cases, excess thermal losses after the meter caused by reactive load would be measured in watts and would be billed. The losses, while relatively small for any single vending machine, when aggregated throughout the New York State are significant.

Traditional thinking, as evidenced in articles written as recently as May 2007 [2], assumes that the losses only occur in the wires. Calculations have been done on the losses based on the ohms per foot of a length

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2 "Is Power Factor Correction Justified for the Home", William Rynone, President, Rynone Engineering, Power Electronics Technology, May 2007 http://www.powerelectronics.com

of copper wire. However, in many buildings, especially older buildings, the majority of the losses occur at the junctions. These include screw connections on switches, receptacles, and breaker panels, the metal-metal interface of a switch or of a plug in a receptacle, circuit breakers, and wires in junction boxes connected by wire nuts. As these copper and copper alloy connections age, they oxidize. This oxidation increases resistance and the associated losses.

The result is that any excess current will increase thermal losses within customer premises.

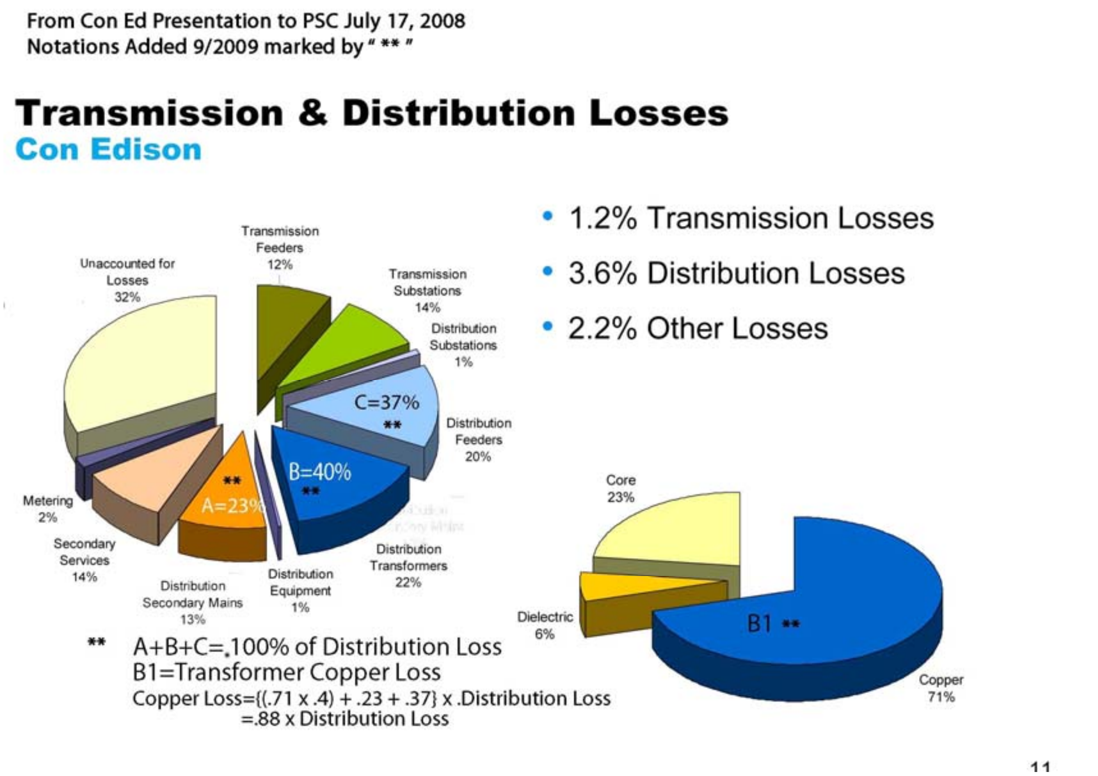

Figure 1: Excerpted from Transmission and distribution Losses. Consolidated Edison. Originally presented July 17, 2008 Percentage Notations added September, 2009.

As many of the buildings in New York are older, the connections will have more oxidation and higher resistances (R). That will result in higher I^2R (thermal) losses at those connections. Any system that can reduce currents in the aging wires and connections will result in an energy savings. As higher operating temperatures in system components causes more rapid aging of those parts, reducing currents and the associated heat will also add longevity to the system and devices attached to it. By reducing the currents at the load, the savings accrue from the load all of the way back to the first substation where power factor correction is traditionally employed. In addition, by increasing the power factor on the distribution system, existing capacitance is freed at the substation to be used to further raise the power factor on the transmission system on hot days when there are increased loads. That would yield additional energy savings on the transmission system.

According to Figure 1, 7 % of the energy that enters the transmission and distribution system is lost before it reaches the customer. The national average is 7.2%. Of that 7.0 %, 3.6% is lost on the distribution system that is not serviced by the utility's capacitors. We are primarily concerned with those losses and the losses after the customer's utility meter. In Figure 1, transformer losses are shown in the pie chart at the lower right. 29% of the losses in the transformer are "no load" losses and are related to eddy currents in the iron core of the transformer and dielectric losses. Those losses are fixed for a given transformer and will not vary with current. The segment marked "B1" represents the copper losses. Those losses occur in the wires of the transformer and will increase with increasing current.

In Figure 1, according to the pie chart on the upper left, on the distribution system 23% of the losses occur in the secondary mains, 37% of the losses occur in the distribution feeders, and 40% of the losses occur in the transformers. 71% of that 40% occurs in the transformer copper, resulting in 28.4% of distribution losses occurring in the transformer windings. The result is that 88% of distribution (thermal) losses, amounting to 3.17% of all energy generated, occurs in the wires of the distribution system that is not serviced by power factor correction. On the 13 Gigawatt Con Ed system, that 3.17% translates to 412 megawatts on a day with peak load. To put that into perspective, the new NYPA (New York Power Authority) combined cycle gas turbine power plant in Queens, N.Y. generates 500 megawatts at peak output.

Depending on the type of fossil fuel generation being considered, power plant efficiencies can be as low as 25% to 30% for the older coal power plants to 55% for the new combined cycle gas fueled generating plants[3]. The average efficiency of delivered energy to the customer, after factoring in generating losses and

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3 Electric Generation Efficiency, Working Document of the NPC Global Oil & Gas Study, Made Available July 18, 2007, NATIONAL PETROLEUM COUNCIL , POWER GENERATION EFFICIENCY SUBGROUP OF THE DEMAND TASK GROUP OF THE NPC COMMITTEE ON GLOBAL OIL AND GAS

transmission and distribution losses is approximately 33%. Of every three watts of energy consumed at the generating plant, only one watt reaches the customers meter. More energy is lost through inefficiencies after the meter, within the customer premises. Any system that can reduce load, including load caused by distribution losses, will save approximately three times that amount of energy at the generating plant. Associated greenhouse gas production will be reduced proportionally.

Figure 2 shows the average losses in summer versus winter and the seasonal net energy usage. It can be seen that losses during the summer months are 2.2 times higher than during the winter months. The higher summertime electric load results in heating of all components of the transmission and distribution system. In addition, there is less ambient cooling of components as a result of the higher ambient air temperatures. More direct sunlight and more hours of daylight result in a far greater solar load. When all of these factors are combined, the result is that the entire system operates at an elevated temperature. As the temperature of

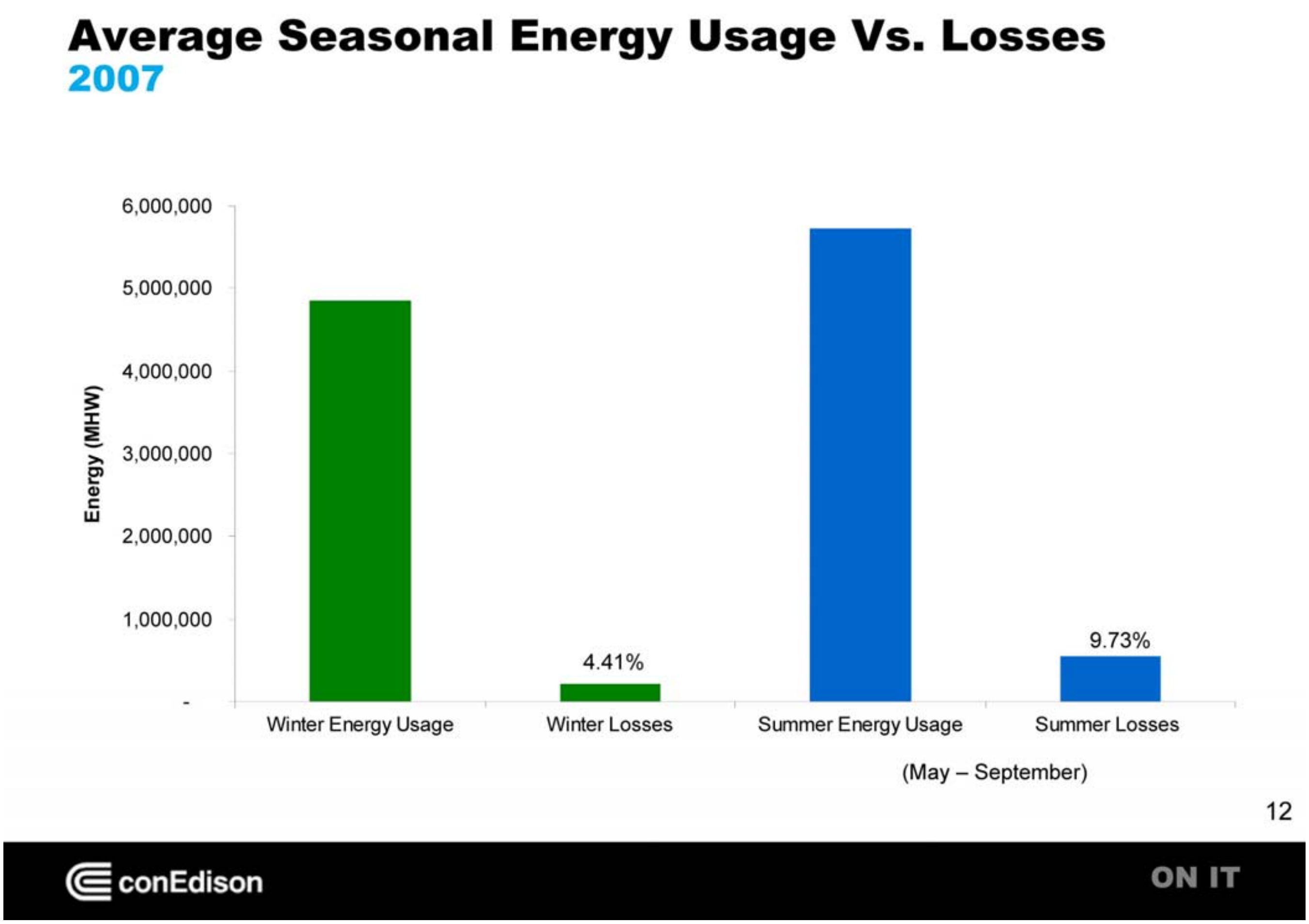


Figure 2: Excerpted from Transmission and distribution Losses. Consolidated Edison. Originally presented July 17, 2008

electrical conductors increases, their resistance increases proportionally. The equation below explains the effect of temperature on the resistance of electrical conductors.[4]

$$R = R_{ref}\,[1 + \alpha(T - T_{ref})]$$

Where,

R = Conductor resistance at temperature "T"

R_{ref} = Conductor resistance at reference temperature T_{ref}, usually 20° C, but sometimes 0° C.

α = Temperature coefficient of resistance for the conductor material.

T = Conductor temperature in degrees Celcius.

T_{ref} = Reference temperature that α is specified at for the conductor material.

For copper α= 0.004041 per degree-C. The result is that a 10 degree-C (18 deg-F) temperature rise will yield a 4% increase in the resistance of a copper conductor. As thermal losses in wires are proportional to the resistance (R), the line losses increase proportionally. Additionally, as the thermal losses increase, the conductor's temperature rises still further and the resistance continues to increase. This process continues until the conductor temperature reaches equilibrium (heat gain from all sources=heat loss to air or surrounding environment) or in the extreme case, the conductor or transformer will overheat and suffer catastrophic failure.

One possible side effect of performing power factor correction could be increased levels of harmonics. Harmonics are waveforms present on the utility system that have a frequency that is a multiple of the system frequency of 60 hertz (hz). (e.g.: 120 hz-2nd harmonic, 180 hz-3rd harmonic, 240 hz-4th harmonic, etc.). The odd numbered harmonics (180 hz, 300 hz, etc.), cannot be used by equipment on the system. They are absorbed into the components on the system and dissipated as heat. For example, harmonics that enter a transformer cause eddy currents in the magnetic core which are released as heat. Sources of harmonics on the utility system include ballasts on fluorescent lighting and switching power supplies on TV's and computers, among others. One goal of the project was to determine if there would be an increase in harmonics after installing power factor correction at the various locations.

By reducing currents only 7%, the associated thermal losses will be reduced by 14%. That reduction will be augmented as the temperatures of the conductors will be lower, resulting in a lower conductor resistance. The goal of this project was to determine the amount of loss reduction achievable through adjusting the power factor of various types of building loads, the associated cost of that process, and to see if there were any undesirable side effects, such as an increase in harmonics.

4 Temperature Coefficient of Resistance: Physics of Conductors, http://www.allaboutcircuits.com/vol_1/chpt_12/6.html

3.0 Implementation

Implementation of the Power Factor Correction for the vending machines was relatively simple and involved the following steps:

1. **Acquiring Funding**: This was provided through a NYSERDA Grant to offset the cost of equipment that would be installed within customer premises

2. **Equipment Measurement** : Upon confirming that we had project funding, we tested various devices to try and find equipment that would lend itself to cost effective Power Factor correction. After measuring the power factor of several refrigerated vending machines, we determined that they were a prime candidate for the project.

3. **Device Design** : While devices for power factor correction are readily available for large facilities, that is not the case for the smaller scale application that we are considering here. Labor and other installation costs have to be kept to a minimum in order to make this process viable. In the past, one of the reasons that small scale power factor correction has not been applied is installation cost. The bulk of that cost is in labor. After applying for the grant and prior to being approved for the grant, we designed and fabricated devices that could be installed by a non-technical person. No electrician is needed. A patent was filed on these devices, called PLIP's®, in November, 2008. PLIP® is an acronym for "Plug In Power Factor Correction". Figure 3 is a photo of a PLIP®. A specialized version of the PLIP® was developed to work with the vending machines. It's physical package is identical to the other versions.

4. **Implementation and Testing** : After receiving approval on the PLIP's® from Underwriters Laboratories, we started installing PLIP's® on various refrigerated vending machines. There are three major manufacturers of these types of machines in the United States and they supply 85% of the machines in use[4]. None of the machines that we tested had a power factor above 0.75 .

4 Codes and Standards Enhancement Initiative For PY2004: Title 20 Standards Development, Analysis of Standards Options For Refrigerated Beverage Vending Machines, Prepared for: Gary B. Fernstrom, PG&E, Prepared by: Davis Energy Group - Energy Solutions, May 5, 2004, PP. 2

Figure 3: The PLIP® Plug In Power factor correction. Power Factor Correction Installation costs are greatly reduced. An unskilled person can install these.

Figure 4: A Dixie-Narco Vending Machine, The waveform for this machine appears in Figure 5.

4.0 <u>Important Facts about Vending Machines that will affect an efficiency program</u>

While learning about the electrical characteristics of vending machines, we also learned a great deal about the market for new and used refrigerated vending machines. This was accomplished by reading the available literature and doing web searches, but also by making phone calls to several vending machine companies and visiting Superior Vending Machine in Mt. Vernon, NY. Among things that were learned are:

1 - The service life for a new refrigerated vending machine is approximately ten years. It can be longer, depending on where it is located and how many times it is refurbished..

2 - A new refrigerated vending machine will cost between $ 3400 and $ 4500, including shipping. As they are expensive, a program to retrofit existing machines will improve efficiency more quickly than a program to replace the machines.

3 - A used, refurbished, refrigerated vending machine will cost between $ 1000 and $ 2300 depending on the bottle capacity, including freight. When the machines are refurbished, they are sold with approximately a four month warranty. The compressors are usually “reworked” but are not usually replaced when the machines are refurbished. That results in vending machines having the compressors with the existing efficiencies remaining in use for an extended period.

4 - Refrigerated Vending machines use a 1/4 Horsepower compressor. Frozen food (Ice Cream) dispensing machines use a 1/3 Horsepower compressor. None of the machines that we tested had a power factor above 0.75. The larger vending machines that have more lamps in their display operate with a higher power factor because the compressor is a smaller percentage of the total consumption. However, the compressor discharges the same amount of reactive power (Vars) as the compressors on the machines with the lower power factor and a lower peak consumption. Similar results were seen from all brands of refrigerated vending machines. While Dixie-Narco and Pepsi vending machines are documented in the power consumption graphs, machines from Royal Venders Incorporated and the Vendo Company operated with a similar power factor.

5.0 Data Analysis

Figures 5, 6, and 7 show the before and after graphs from three vending machines that are representative of the various machines that were tested. On all of the machines, it can be seen that at least a 2 ampere reduction was achieved through the implementation of power factor correction. On average, a 2.2 ampere reduction and a 0.26 KVA reduction was achieved per machine. Extrapolated over 180,000 machines in New York State, that corresponds to a 46,800 KVA reduction in coincident peak demand and a 40,600 KVA reduction in continuous load on the distribution system based on an 87% duty cycle for the equipment. 3.6% of energy is lost annually as distribution losses and 88% of that is copper loss, resulting in 3.2% of all losses being distribution copper losses. Applying that to the 40,600 KVA reduction in average demand results in a 1300 KW average reduction in required generation and a 1500 KW reduction in peak generation related to the reduced currents resulting from power factor correction. Using the figure of a 1300 KW average power reduction yields a net annual savings of 11,388,000 KWH annually in reduced losses on the distribution system. However, in addition to savings on the utility's distribution system there will also be significant savings on the customer's side of the meter within the customer premises. This will occur because of reduced heating within the premise's wiring that is manifested as KWH on the utility bill. Measurements that we have taken at industrial locations indicated that raising the power factor from .7 to .96 can reduce KWH loss by as much as 5% to 7% within customer premises. A lower initial power factor will yield more dramatic KW savings resulting from power factor correction. The power factor of refrigerated vending machines is sufficiently bad that large KW reductions can be achieved through correction.

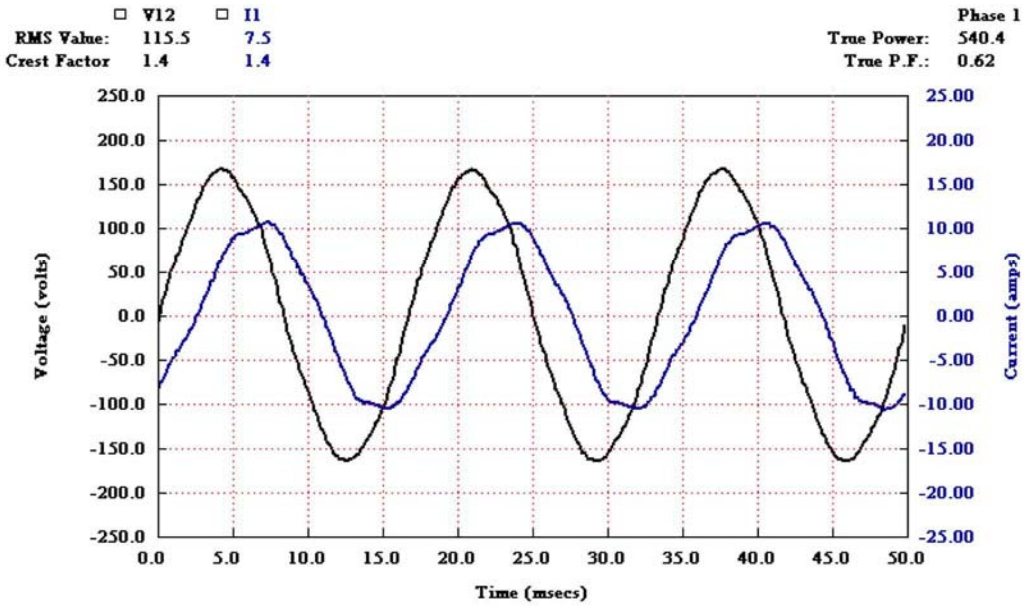
To test this concept we used a 120 Volt motor that operated at 4.65 amperes, within the current range of a refrigerated vending machine. We plugged it in to several receptacles throughout a five year old building, wired during 2004 to the electrical code being used at that time. As the building is relatively new, oxidation levels on the electrical components will be at a minimum. The building has approximately a 5000 square foot footprint and a 400 amp service that was only delivering approximately 18 amps per phase at the time of the tests. The receptacles were connected by approximately fifty feet of #12 wire to 15 amp circuit breakers in a sub panel. (50 feet of #12 copper wire will have a resistance of approximately 0.1 ohms.) That was in turn wired to a 200 amp circuit breaker in a main panel near the building service entrance. Because of the low building current at the time of the tests and the large size of the service relative to the 4.65 amp motor current, nearly all of the voltage drop would have occurred at the circuit breakers, within the 12 gauge wire, and the receptacle-plug interface. A 1.4 volt drop at a 4.68 amp current indicates a circuit resistance of approximately 0.3 ohms. For the Dixie-Narco machine, the waveform for which is shown in figure 6, the I^2R line losses within the building before correction, with an 8.4 amp current and a 0.3 ohm circuit resistance, would be 21.17 watts (8.4 x 8.4 x 0.3). After correction, with the current at 6.3 amperes, the line losses would be 11.9 watts (6.3 x 6.3 x 0.3) . The correction would yield a reduction of 9.27 watts on a circuit with a resistance of .3 ohms. In an older building, with increased levels of oxidation on the wire interfaces, the resistance and associated thermal losses could be considerably higher. Furthermore, refrigerated vending machines are primarily located in commercial buildings that could have much larger footprints than 5000 square feet. That would make the circuit lengths longer than fifty feet and increase the circuit resistance. While the after meter line loss savings for some machines may be less than 9 watts, the average age of the building stock in New York is also considerably older than five years. That would result in higher circuit resistances than the 0.3 ohms that we measured. Considering the variables of circuit length, circuit age, and the different machine capacities, the 9.27 watts is a reasonable average for after meter line losses, as they relate to refrigerated vending machines.

Based on the 425 watt average power consumption of the vending machines listed in the PG&E paper, 180,000 machines would consume 76,500 KW. A 2.2% reduction in customer premise losses, less than half of what we have previously measured at industrial locations, would yield a reduction of 1669 KW in required generation for losses incurred within customer premises. A 9.27 watt savings per machine on 180,000 machines would yield the same 1669 KW savings. The annual energy savings would be 14,620,440 KWH annually.

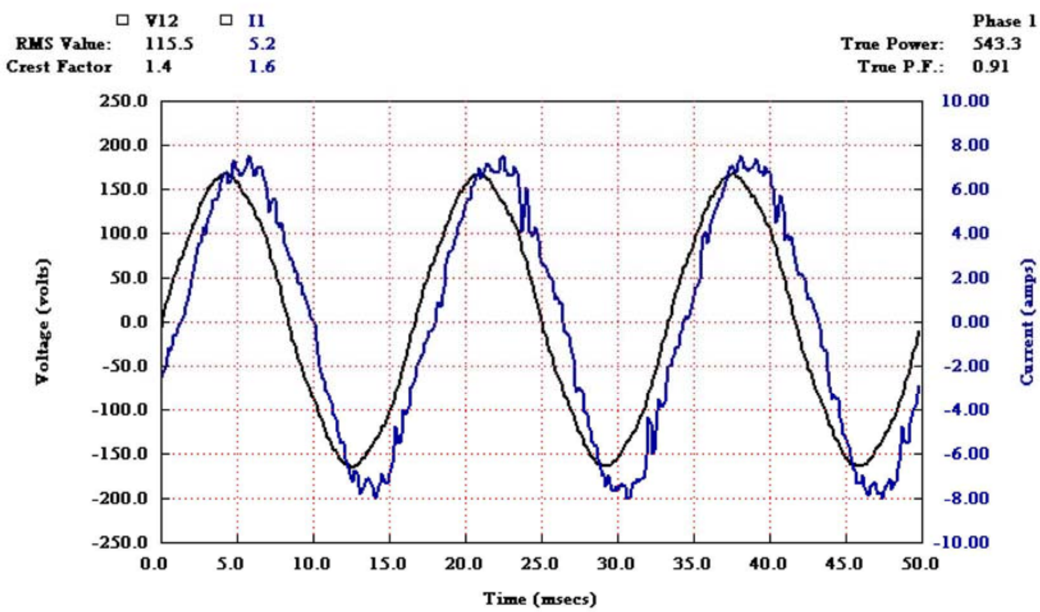
Based on efficiency improvements achieved on both the distribution system and within the customer premises as a result of "At Load" Power Factor Correction, the total savings for New York State are:

- 3,170 KW Reduction in required generation
- Minimally, a 26,008,440 annual reduction in KWH that includes 11,388,000 KWH on the utility's distribution system and 14,620,440 KWH within the customer premises

In addition, our measurements indicated that the Power Factor Correction may raise the Total Harmonic Distortion of the current waveform by approximately 1%. At such a low level, the minimal increase in harmonics does not contribute a negative effect on the system.

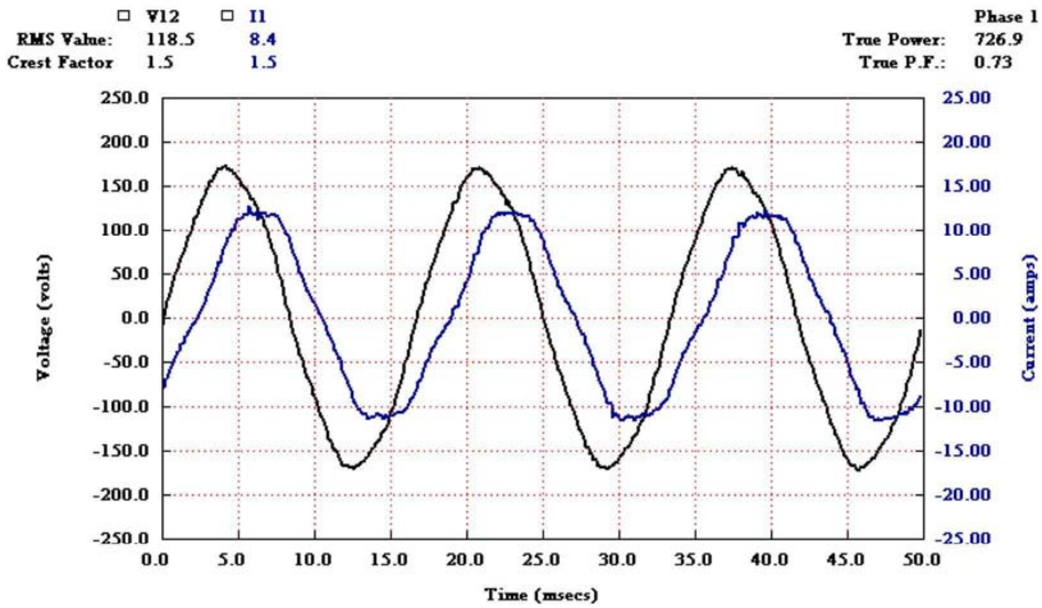


Before Correction - Power Factor =.62, Current=7.5 Amperes

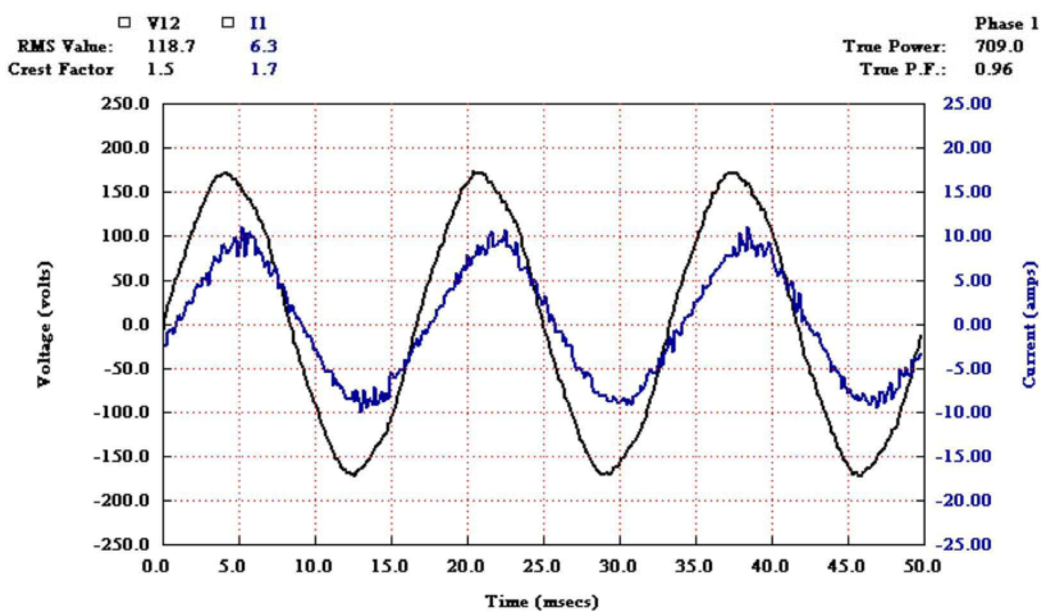


After Correction - Power Factor = .91, Current =5.2 Amperes
31% Current Reduction, 51% reduction in associated line losses

Figure 5: Before and after waveforms from a Dixie-Narco vending machine. A 2.3 ampere (31%) current reduction was achieved through the use of power factor correction.

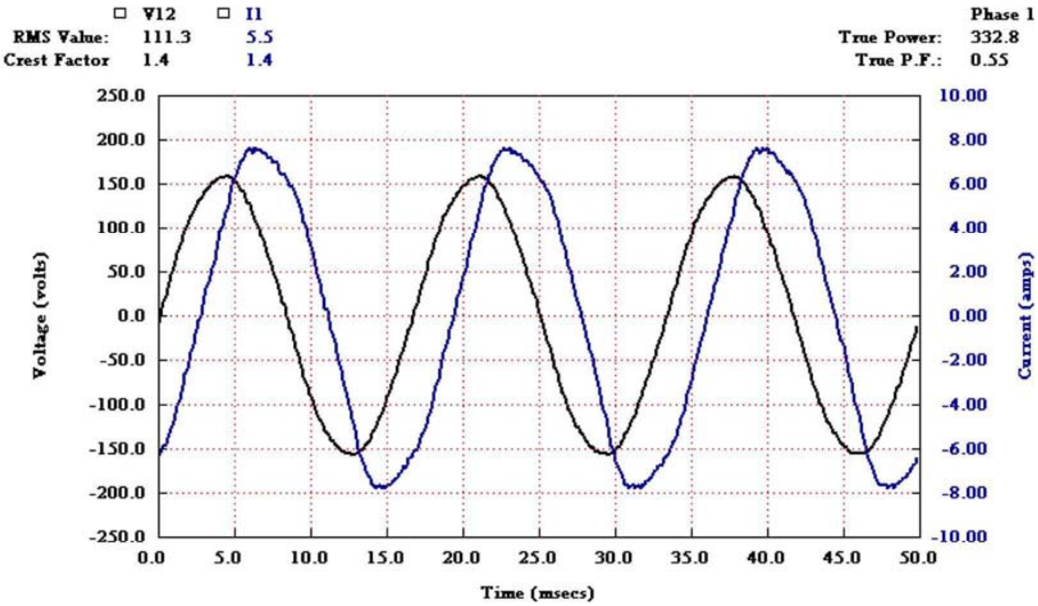


Before Correction - Power Factor = .73, Current=8.4 Amperes

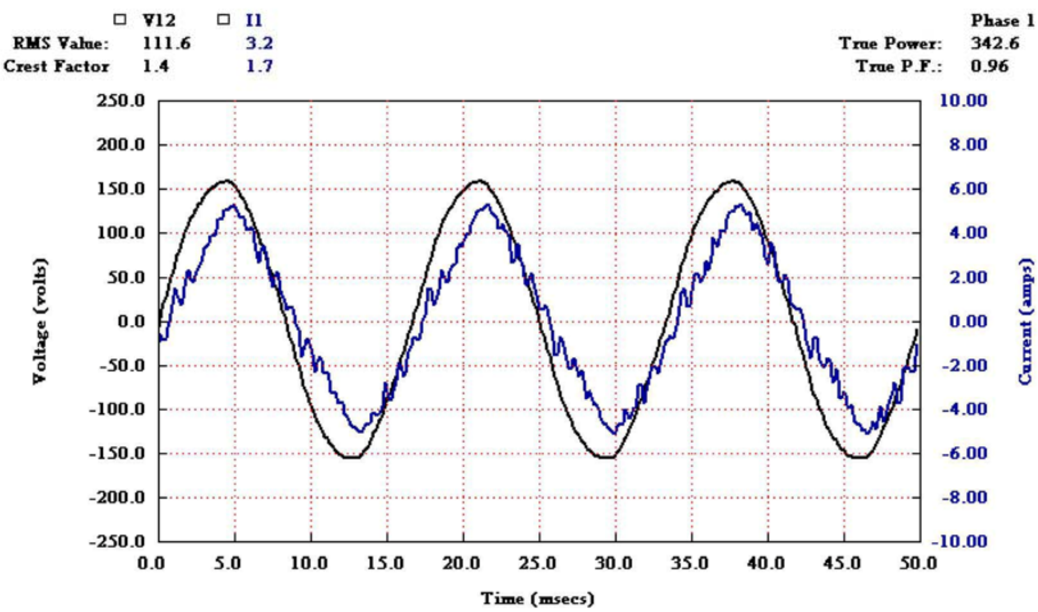


After Correction - Power Factor=.96, Current=6.3 Amperes
25% Current Reduction , 43% Reduction in associated line losses

Figure 6: Before and after waveforms from a Dixie-Narco vending machine. A 2.1 ampere (25%) current reduction was achieved through the use of power factor correction.



Before Correction - Power Factor =0.55, Current = 5.5 Amperes



After Correction - Power Factor =0.96, Current =3.2Amperes
42% current reduction , 66% reduction in associated line losses

Figure 7: Before and after waveforms from a Pepsi® High Visibility vending machine. A 2.3 ampere (42%) current reduction was achieved through the use of power factor correction.

6.0 Cost Benefit Analysis

We will be making the following assumptions in performing the financial analysis based on figures for the Con Ed service area :

- $2000 per KW to construct generation
- 13$/ KVAR to install capacitance at the substation[5]
- $ 70 cost for a PLIP®. This is higher than what the cost will be if it is mass produced.
- 180,000 PLIP® ‘s will contain approximately 100,000 KVAR of capacitance.
- 26,008,440 annual reduction in KWH that includes 11,388,000 KWH on the utility’s distribution system and 14,620,440 KWH within the customer premises
- 3,170 KW Reduction in necessary generation
- $ .05/KWH wholesale electricity price, $ .20/KWH retail electricity price

Using the figures above, the cost for 180,000 PLIP®‘s would be $ 12,600,000 and the savings are as follows:

One time cost offsets

• Reduced generation (3170 KW @ $ 2000/KW)	$6,340,000
• Reduced cost of Capacitance at the substation	$1,300,000
	$7,640,000

Annual cost offsets

• Reduced annual consumption (wholesale price)	$1,300,422

Based on a $ 12,600,000 project cost, the Return on Investment (ROI) would be 3.8 years if the utility implemented the program. The figures above do not factor in reduced costs for reduced maintenance of the system because of reduced load, both within customer premises and on the utility’s portion of the system. While the reduction at each location is fairly small, these machines are very prevalent and reducing their combined effect on certain areas of the system could be the difference in portions of the system surviving a day of very high load.

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5 New York Independent System Operator (NYISO), Benefits of Adding Capacitors to the Electric System , February 27, 2008, PP.14

In addition to savings on the utility system, the savings to the customer would be as follows:

(14,620,440 KWH x $.20)/180,000 machines = $ 15.84 per machine/year.

If the utility customers purchased the devices, the Return on Investment (ROI) to improve the power factor on a vending machine would be approximately four years on a machine with a lifespan of ten years or more.

In addition to the short ROI for the equipment there are environmental benefits, as well. On average, every KWH of electric generation in the United States results in 1.5 pounds of CO_2 emissions. The 26,008,440 annual reduction in KWH in New York State would result in a minimum reduction of over 19,500 tons of CO_2 emissions annually. Those reductions cannot be achieved with capacitance installed at the substation.

If the standards for these machines were tightened to mandate a high power factor, the cost of a $ 4000 machine would increase by approximately $20. However, as the numbers above indicate, that amount would be recouped by the customer in approximately one year.

7.0 Conclusions

Based on our measurements and results obtained measuring the electrical characteristics of refrigerated vending machines, we have come to the following conclusions:

- The power factor is sufficiently low in refrigerated vending machines that improving it will result in a substantial energy savings throughout the entire utility system, when measured in KWH.
- We can cost effectively improve the power factor for existing refrigerated vending machines
- Power Factor Correction in this environment does not measurably increase the amount of harmonics.
- Power Factor Correction in this environment will reduce CO_2 emissions by a minimum of 19,500 tons annually for New York State.

- Power Factor Correction must be load based and must only operate when needed. Excess capacitance connected to the utility system can be as detrimental as excess inductance. Furthermore, in the event of a blackout, the excess capacitance would add extra impedance that would have to be energized, applying extra load to the system during a restart.

- Standards need to be modified so that new refrigerated vending machines are designed with a high power factor as part of the design criteria.

While the last item on the list will increase the price of the equipment, the accrued savings on energy will more than offset the additional cost.

8.0 Acknowledgements

This project has been partially funded through a grant from the New York State Energy Research and Development Authority (NYSERDA).

Peter Plotkin of Superior Vending Machine in Mt. Vernon, NY permitted measurement of several vending machines at his facility and provided information that confirmed that the results that have been presented in this document are not an aberration, and are in fact typical of vending machines presently in use.

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