Whitby Hydro Energy Services Corp.

Power Factor Correction at the Residential Level – Pilot Project

Report to the LDC Tomorrow Fund

September 12, 2005

Executive Summary

In December of 2004 Whitby Hydro applied for funding from the EDA Tomorrow Fund to carry out a pilot project to determine the impact of installing capacitors at residential homes on system capacitance and generation requirements.

The study involved 31 homes within Whitby Hydro's distribution territory. The houses selected were located in a new residential neighbourhood and were consistent in size, age and type of heating.

For the pilot, a bench mark had to be established for the loading of each transformer. The three transformers where metered for a two month period prior to the installation of the capacitors. The information gathered included KW, KVAR, volts and amps. Once the benchmark was established homes fed from two of the transformers where equipped with capacitors providing 3.34 KVAR into there distribution panel. Readings at the transformer continued for an additional two month period after the units were installed in the homes. In addition two homes where equipped with metering devices that allowed the measurement of power factor.

The information gathered allowed analysis to be carried out to determine if the additional capacitance improved power factor at the home as well as at the transformer.

Power Factor at the transformer was the first value to be analysed. KW and KVAR was measured at 15 minute intervals for the pilot period (Appendix G). This information was used to determine monthly power factors and other related billing determinants at the transformer.

The peak Power Factor each month was as follows:

	March (PF)	April (PF)	May (PF)	June (PF)	July (PF)
TX5545 (BM)	96.6	96.1	95.1	92.7	93.0
TX5554	98.4	98.8	99.9	99.1	99.9
TX5547	97.9	98.5	98.3	97.1	95.7

(Note: BM is the bench mark transformer of which capacitance was not added)

During the study it was quickly realized that although the study group was selected for its consistency, variances in ON and OFF-peak Power Factor clearly indicated that there was little or no consistency on how or when motor loads were used. Even though an attempt was made to pick homes with similar characteristics there was enough variance in how and when motor loads where used to cause inconsistency between the transformers. This made it difficult to determine the full effect that the added capacitance had on Power Factor at the transformer. However, based on the fact that KW and KVAR were being measured it was easy to see the impact the added capacitance had on KVAR at the transformer. Also because KVAR is a factor when determining generation requirements, this unit of measurement would allowed us to determine the impact on provincial generation.
The improvements in KVAR was as follows:

	March (KVAR)	April (KVAR)	May (KVAR)	June (KVAR)	July (KVAR)
TX5545(BM)	4.2041	3.3670	3.0253	7.1944	7.5343
TX5554	2.3756	2.3999	-.9916	-4.3036	-4.0268
TX5547	3.1778	2.6754	.9480	3.0449	2.9364

To further verify the impact of the capacitance on power factor two homes where measured. . These homes where fitted with capacitors that would turn on and off on twenty four hour cycles to show day to day comparison on power factor. Typically, the average power factor when the units where off was 87%. When the units were turned on the power factor was over 99%.

To get a real understanding of positive impact power factor correction has on generation costs benefit analysis was carried out to see if such a project would make sense on mass. Four assumptions where used in this analysis:

1. a typical home has a 5kW demand
2. the cost of new generation is about $1,000,000 an MVA
3. a typical homes power factor is improved from 87% to 99% when 3.34 KVAR of capacitance is add
4. the cost of the Power Medix units is $450,000 installed

With an example of 1000 homes each using the above information, the generation requirement would be 5.75MVA (5kW/.87PF x 1000). By installing capacitance at the residential level the requirement of the generator for the 1000 homes would now only be 5.05MVA (5kW/.99PF X 1000) or 700 KVA less.

Therefore the cost to generate 700 KVA would be $700,000 (.700MVA X $1,000,000). The cost to supply and install capacitance at the residential level to free up the same amount of capacitance would be $450,000. The environment and health costs associated with the generation of electricity are also removed making the economics even stronger.

The pilot project showed that the installation of capacitors at the residential level is a viable option in freeing up capacitance within the province is deployed on mass. The savings can also be achieved without having the customer drastically changing their lifestyle.

The following report provides the details and back up information for the analysis.

Introduction

Purpose

The following report outlines the process, procedures and results of a pilot project carried out by Whitby Hydro to determine if providing power factor correction at residential homes frees up capacity at pad mount transformers and therefore reduces load on utility systems. The report also determines whether such applications are feasible at this level.

Scope

The report looks at the application and justification of the process for the pilot. Total costs where also analysed to determine the feasibility of such an application. The report only addresses the resulting impact the pilot had on the customer and the pad-mount transformers. It does not explore system impacts up stream of the transformer other than assumptions of the system impact if implemented on mass throughout the Town.

Background

Whitby Hydro carried out a project to identify the ability to free up system and generation capacity by correcting power factor at the residential level. Theoretically, correcting power factor makes the system, which is generator, distribution and consumer, more efficient. Because kW's are what the load consumes and kVA is what it takes to push the kW's through the system, by improving the power factor the more efficient the system becomes.

Take the case of a generator capable of producing 1000 kW into a load of 1000 kW. At unity power factor, 1000 kW = 1000 kVA. At 70% power factor, 1000 kW = 1429 kVA. The generator output would need to be increased by 429 kW to satisfy a 1000 kW load operating at 70% PF. In short improving the power factor at the distribution system and at the load equates to less losses and more efficient use of the energy produced. From the generator's prospective, he is capable of serving more clients from his fixed output.

The project involved the installation of a capacitor unit developed and manufactured by Cos Phi Inc. out of London Ontario. The unit is tied into the residential service panel and provides capacitance and surge suppression. By adding capacitance into the system the power factor for any motor loads (air conditioners, washers, dryers, fans, fridges, and dishwashers) is improved.

Thirty homes were selected for the pilot project. These homes where fed by three 50kVA transformers. Homes from two of the transformers were supplied with Power Medix Units while homes from the third transformer were not be fitted and used as a bench mark.

The dimensions of the units are 12" X8"X4". The small profile makes them easy to install without taking up much physical space in the customers home.

Because the pilot period extended over a number of months, average degree days where collected (Appendix). It was difficult however to determine how weather impacted the results of the pilot and we have put greater emphisis on the comparison between the transformers feeding equipped homes and the transformer feeding the remaining homes.

Initially the pilot was to run for 4 months. Each transformer was fitted with KVA meters and consumption on these transformers was collected for two months prior to the installation of the Power Medix Units. Once the Power Medix Units were installed the measurements at the transformers would be taken for another two months.

Access to customer homes to install the units caused delays in the pilot which required the pilot to be carried on for an additional two months.

Discussion

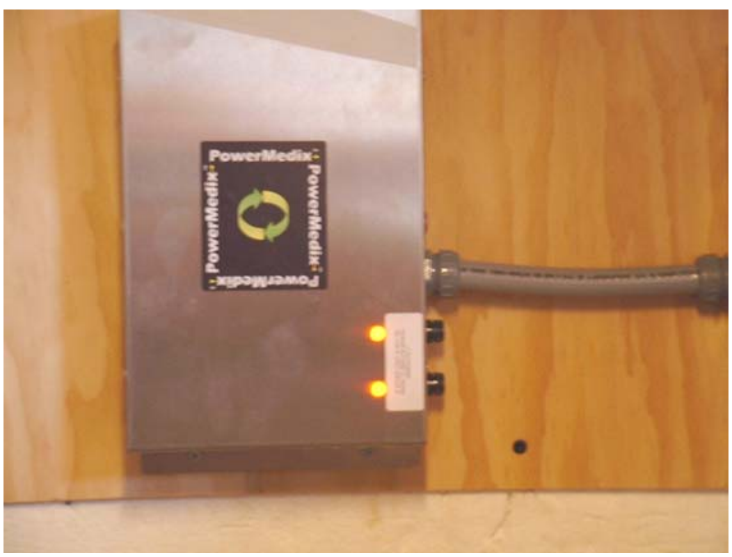
To properly determine the success and benefits of the project a comprehensive detailed pilot project was carried out. Three 50 KVA transformers supplying 31 homes in total were selected in a new residential subdivision. Two of the transformers, TX5545 and TX5547 fed 10 customers each with transformer TX5554 feeding the remaining 11 customers. Appendix A lists the transformers and the associated customers on each transformer.

Although a $10.00 a month incentive was offered to all customers enrolling in the pilot, not all customers participated. Only two customers fed from TX 5545 were interested in participating in the pilot. This transformer was therefore selected as the benchmark site and the homes fed from it were not equipped with PM units. Transformer TX5554 had 9 customers interested in participating in the pilot and 9 homes where fitted with the units. Transformer TX5547 had 8 customers interested in participating in the pilot and 8 homes where fitted with the units. A breakdown of those who did and did not participate is available in Appendix B.

A new subdivision was selected for the pilot so that minimal impact to the home owner would occur. It was assumed that the majority of homes in a new subdivision would not have finished basements allowing easy access to the electrical panel for the installation of the Power Medix unit.

Typical Basement Panel

Installed Unit



The houses selected where in a new residential neighbourhood and where consistent in size, age and type of heating to ensure relative consistency among the usage patterns of each home.

Inventory List per Customer

Part of the pilot was to carry out surveys prior to and after the installation of the units. The first survey provided us with a number of occupants within the house and an inventory of equipment that required motor loads. A copy of the survey can be found in Appendix C.

The surveys allowed us to determine an average number of family members and equipment with motor load. .

The assumed family size and motor loads per house are as follows:

Number of Adults	2.1
Number of Children	1.1
Number of Homes with Central AC	29
Number of Homes with Gas Heating	31
Number of Homes with Refrigerators	31
Number of Homes with Freezers	15
Number of Homes with Washing Machines	31
Number of Homes with Electric Cloths Dryer	25
Number of Homes with Dishwashers	25
Number of Homes with Central Vac	15
Number of Homes with Portable Vac	21 (Note: some of these customers also had central vac)

Customers where also surveyed to assess what other motor loads, such as pumps, power tools, extra refrigerators, pools or hot tubs may be within their homes. A complete inventory list can be found in Appendix D.

These averages where applied to the customers fed from the baseline transformer. This gave us a comparator as to the number of appliances and family members were in each home.

Upon completion of the pilot a follow up phone survey was carried out to identify any significant changes to the number of appliances and or motorized equipment that may have been added to the home. At the same time we enquired if the customer had noticed any changes or anomalies to the electrical supply when the Power Medix was added. No anomalies where reported however some did report that since the unit was added they did not experience dimming lights due to motors and compressors cycling on and off.

Appliances added included:

One freezer
One hot tub

One Air conditioner
One above ground pool

Meter Readings at the Transformer

For the pilot, a bench mark had to be established for the loading of each transformer. The three transformers where metered for a two month period (March and April) prior to the installation of the capacitors. The information gathered included KW, KVAR, volts and amps.

Seventeen (17) of the target homes were equipped with Power Medix units beginning in May. Delays in getting access to the customer premises required a longer period of time to install the units. All units of participating customers were installed by June 7 and a two month data collection period began. The meters at the transformers continually monitored for the period of the pilot. Two months of data from June 7 to August 7 was collected and used as a comparator to the transformer readings over March and April.

Power Factor at the transformer was the first value to be analysed. KW and KVAR was measured at 15 minute intervals for the pilot period (Appendix G). This information was used to determine monthly power factors and other related billing determinants at the transformer.

The peak Power Factor each month was as follows:

	March (PF)	April (PF)	May (PF)	June (PF)	July (PF)
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Beginning May 11 with completion by June 7 the capacitance added to the system was as follows:

TX5545	3.34 KVAR
TX5554	30.06 KVAR
TX5547	20.04 KVAR

During the study it was quickly realized that although the study group was selected for its consistency, variances in ON and OFF-peak Power Factor clearly indicated that there was little or no consistency on how or when motor loads were used. This made it difficult to determine the full effect that the added capacitance had on Power Factor at the transformer. However, based on the fact that the added capacitance was known, and because we were measuring interval units of power at the transformer, the effect on KVAR would be more noticeable and better represented as a comparator to KW.

The transformers where monitored for three months prior to the installation of the capacitors. Two channels of each transformer where measured and the average KVAR per month was recorded as follows:

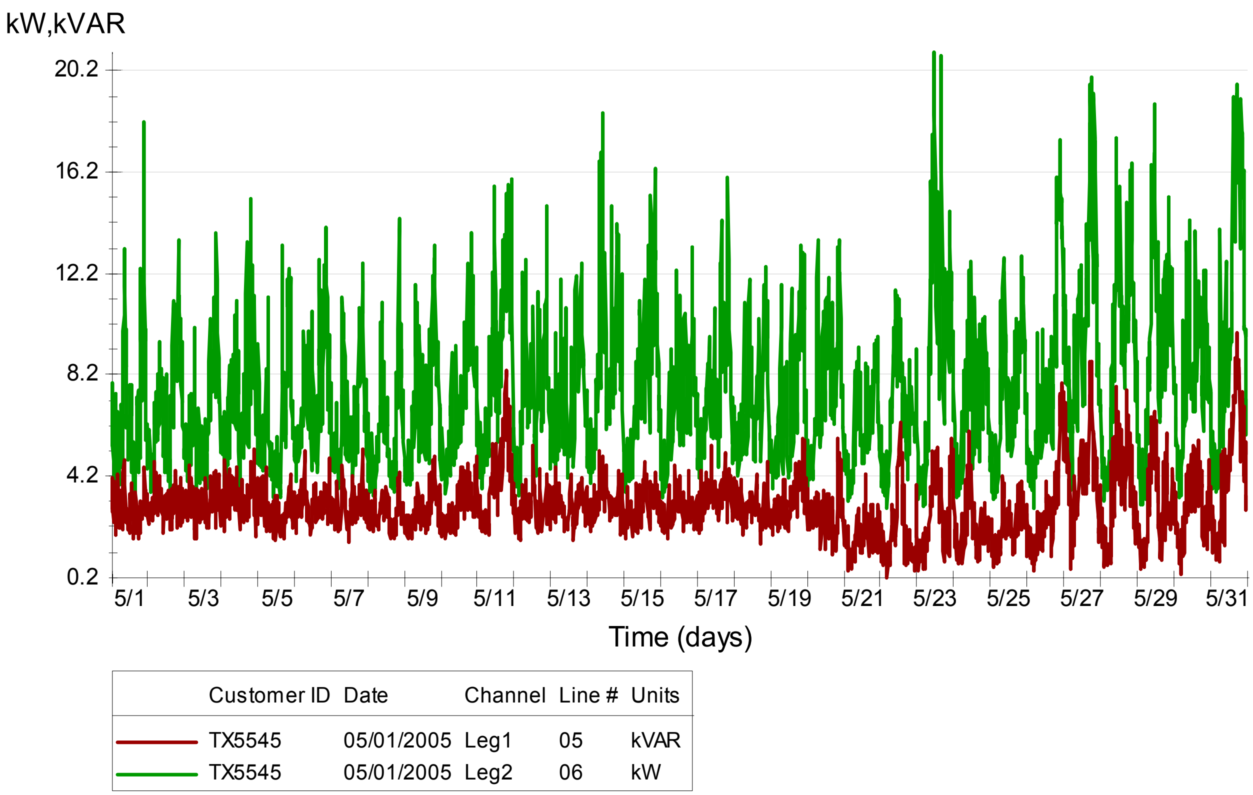
	March	April	May	June	July

	(KVAR)	(KVAR)	(KVAR)	(KVAR)	(KVAR)
TX5545	4.2041	3.3670	3.0253	7.1944	7.5343
TX5554	2.3756	2.3999	-.9916	-4.3036	-4.0268
TX5547	3.1778	2.6754	.9480	3.0449	2.9364

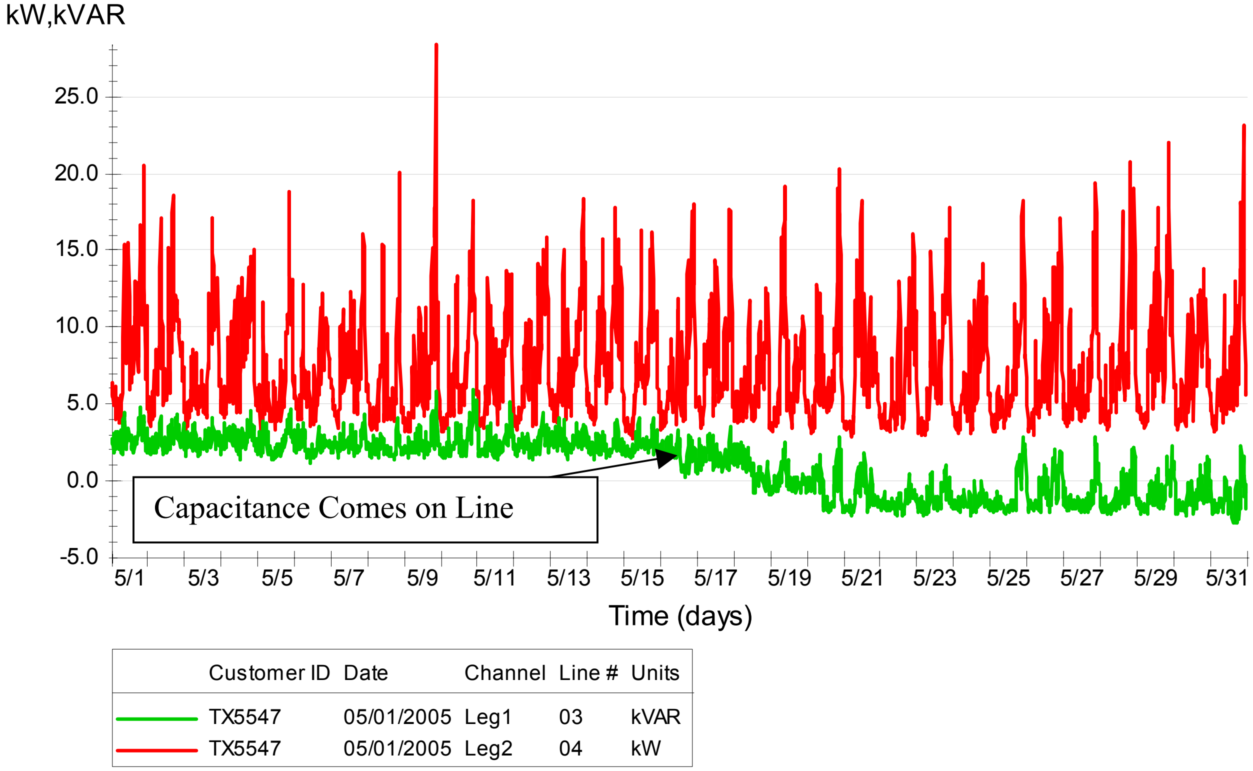
An assessment of the changes that occurred between the three months prior to the installation of the units and the three months after the installation showed that significant change occurred in the KVAR readings of each transformer. This indicates that there may have been an over correction that occurred on Transformer TX5554. This may be due to smaller homes fed from that transformer therefore less air conditioning load or less appliance use.

Visually the impact of the capacitance is clear.

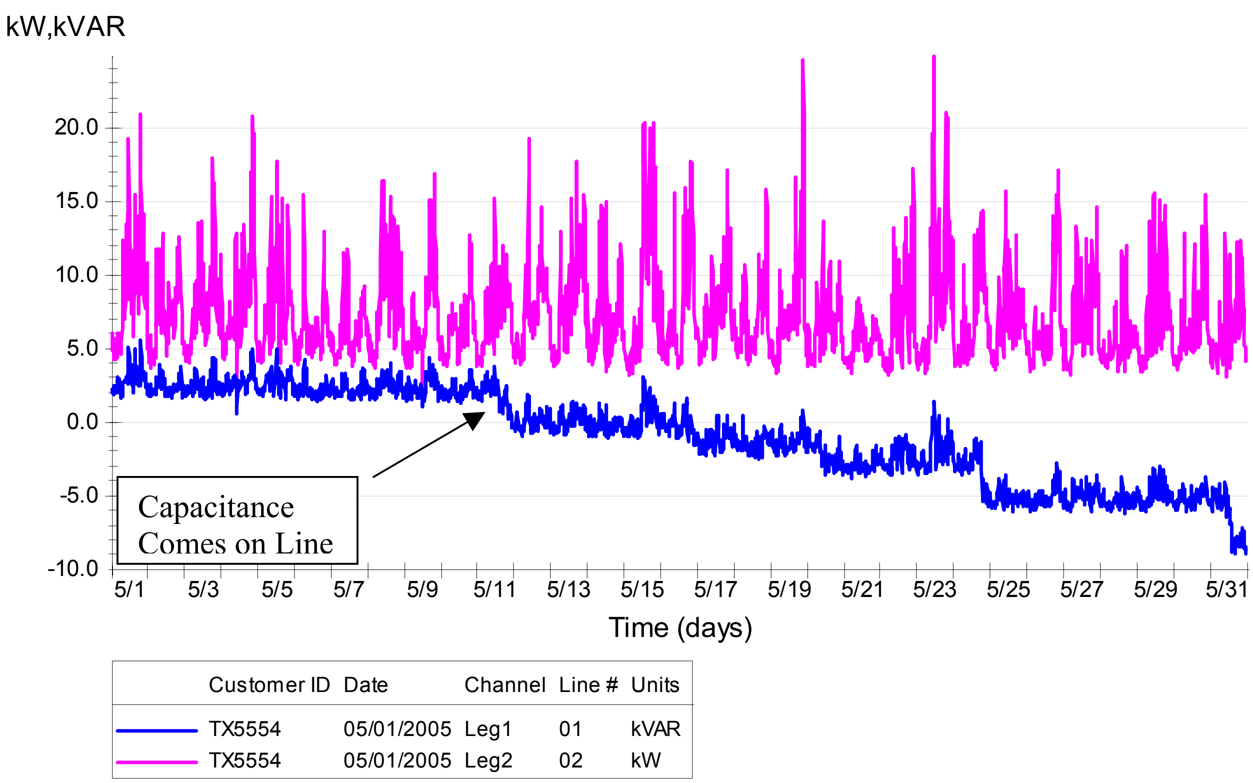
TX 5545 (3.34 KVAR added May 20)



TX5547 (20.04 KVAR added between May16 and June 7)



TX5554 (30.06 KVAR added between May11 and May 31)



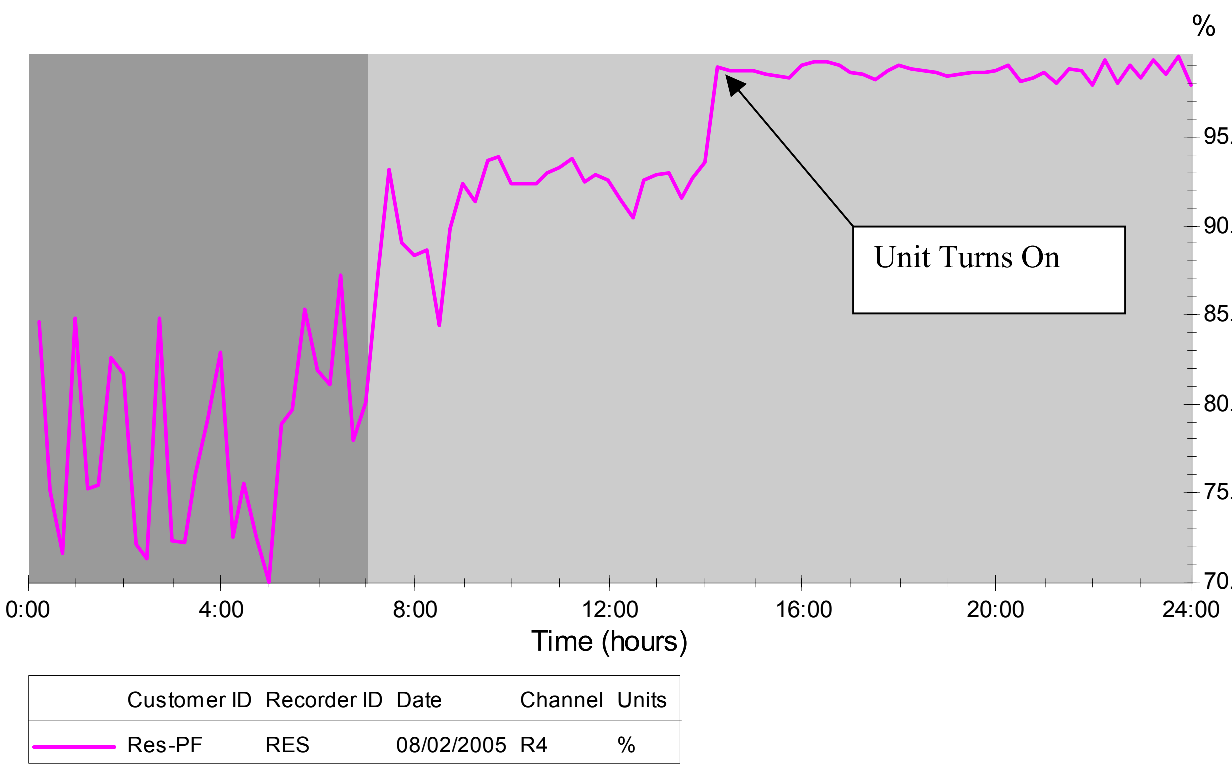
Graphs of all months can be found in appendix ?.

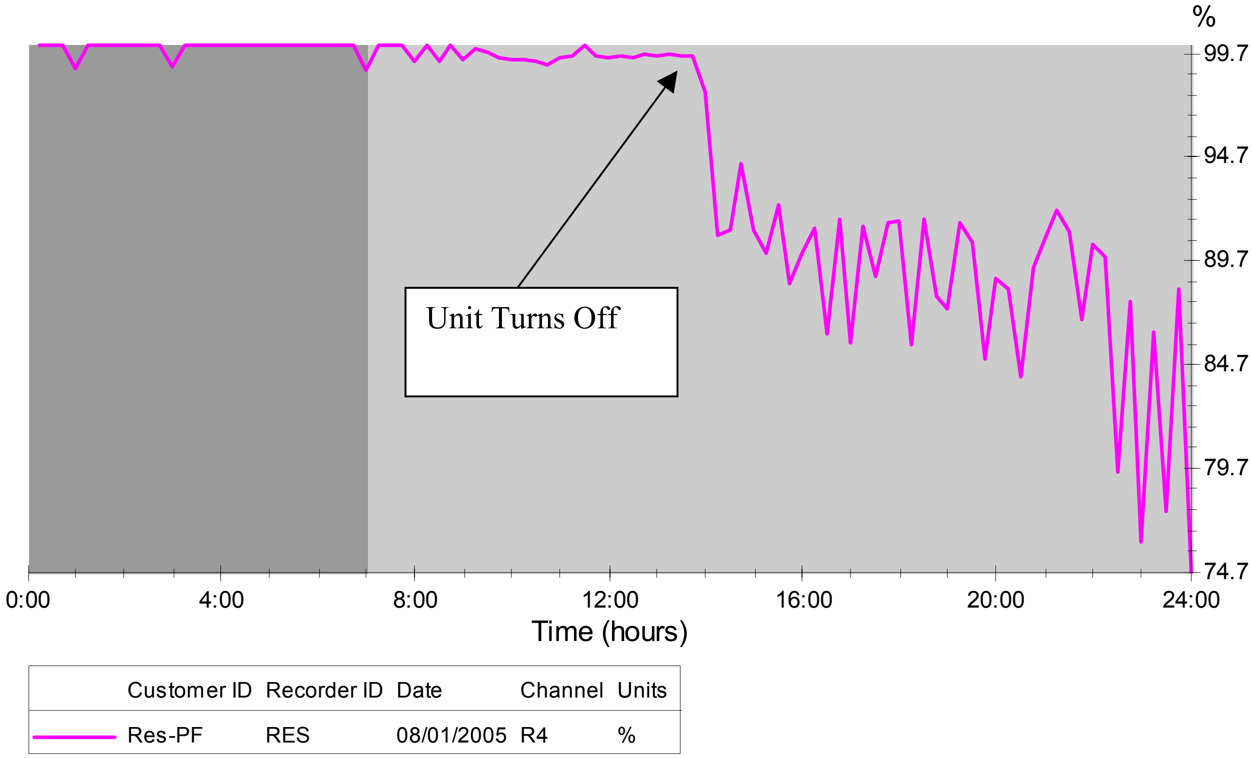
Clearly the addition of capacitance into the system reduced the KVAR readings at the transformer. It was noted, however, that the amount of KVAR added was not equivalent to the the KVAR reduction at the transformer. It was determined that this was the result of loads switching on and off at different times. The results indicate that the installation of the Power Medix units has had a positive impact on the transformer requirements. Our results showed that TX5554 experienced a significant reduction on the loading of the transformer. Further investigation which involved field verification and analysis of the meters showed no indication of faulty data collection. Regardless of this anomaly, TX5547, which was fitted with the Power Medix equipment, showed significant decreases in VAR readings as opposed to TX5545 which was not fitted with the units and showed substantial increases in VAR's during the summer months.

Meter Reads at House (Alternate Analysis)

To further support the pilot project two homes where retrofitted with Power Medix units along with KVA meters and timers. The units would run for a twenty-four hour period and then turn off for 24 hours.

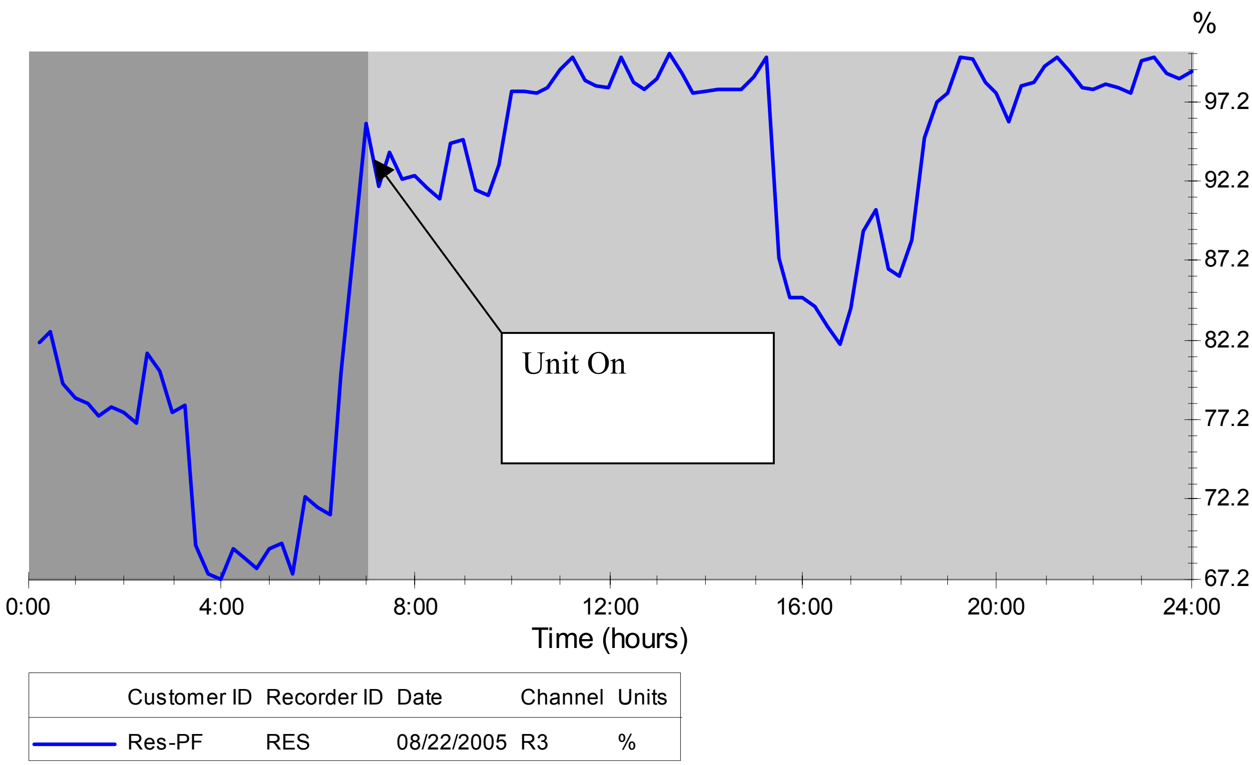
Test site 1 represented a typical home. The Power Medix turns on at approximately 2pm and runs for 24 hours at which time it stays off for 24 hours. The graph below shows the impact on Power Factor when the unit is on and when it is off.

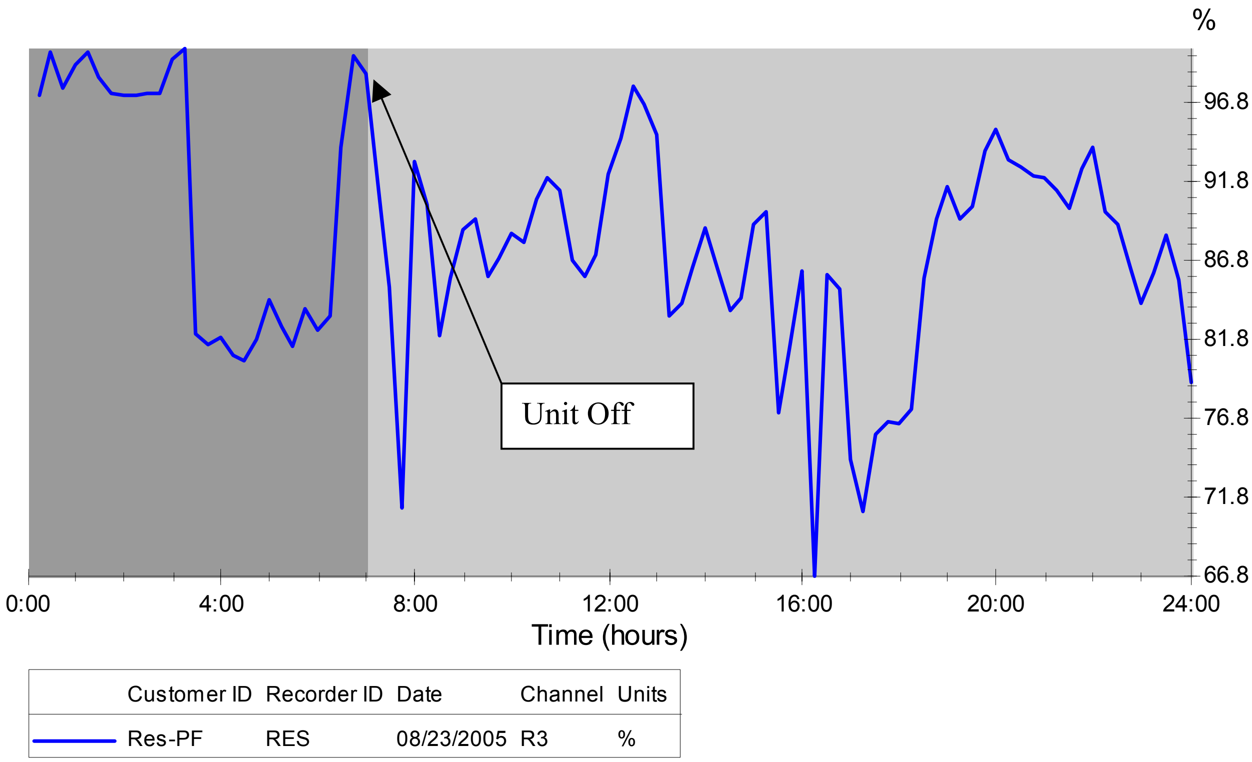




As shown the power factor achieves almost 100% when the unit is on. When off, power factor fluctuates between 70 and 90%.

Measurements where also taken at a home that had a ground source heat pump. The unit turned on at 7 am and ran for 24 hours at which time it would shut off and stay off for a 24 hour period.





Significant loads are apparent in the above example but the power factor is improved during periods that the unit is on compared to periods when the unit is off.

Full data on the actual home measurements can be found in Appendix

Cost Benefit Analysis

The reductions in KVAR translate into a reduction in generation requirements and reduction in the amount of capacity required in the system. Improving system capacity results in less wear and tear on the system. It is difficult, however, to determine exactly what the savings are.

The cost of the units was $491.00/each. These units included surge suppression for cable, phone and satellite. The cost without this feature is approximately $300.00 and is the value we used to calculate savings. Installation costs including material and inspection was $150.00 per unit.

There are a number of ways to estimate what the savings are when correcting power factor at the residential level. For industrial customers, adding capacitance reduces utility penalties and frees up capacity within their system, often reducing the need for new or larger transformers. Although there are no billing incentives to the end use residential customer by correcting power factor the benefits of free capacitance to the utility is similar to that of the industrial customer.

By preventing overloading of a transformer we extend the life expectancy of it, however, residential pad mount transformers are not typically overloaded, however the improved capacitance on a transformer allows for the connection of additional residential units. The problem is that the number of units connected to a transformer is typically determined by space on the buss or a function of the subdivision planning process.

The real benefit of adding capacitance is that it improves the efficiency of the current provincial generation and transmission system. In the case of a typical home power factor went from 87% to 99% on average. Assuming each home uses 5 KW the KVA at a home is reduced from 5.75 KVA to 5.05 KVA. This means that the reactive power of KVAR of a generator is reduced from 2.83 KVAR to 0.708 KVAR or by 2.12 KVAR.

With an example of 1000 homes each using 5KW and not fitted with capacitance, the generation requirement would be 5 MW. The KVA requirement would there fore be 5.75MVA. By installing capacitance at the residential level the requirement of the generator for the 1000 homes would now only be 5.05MVA or 700 KVA less.

A ball park figure for building new generation is $1,000,000 per MVA. Therefore the cost to generate 700 KVA would be $700,000. The cost to supply and install capacitance at the residential level would be $450,000 to free up the same amount of capacitance.

The installation of the units therefore makes economical sense as a method of reducing the requirement of generation in the province.

Another advantage to this conservation application is the environmental and health benefits. Improving efficiency of existing generation and displacing the requirement for the addition of new generation have significant advantage in offsetting the environment and health costs associated with generation in the province. Although a firm number can not be put on the cost of generation from a heath and environmental prospective, the following from Ministry of Healt gives an idea of the associated costs.

Health and Environmental Costs

Ontario’s coal-fired plants are the largest industrial source of greenhouse gas emissions, sulphur dioxide (SO2) and oxides of nitrogen (NOx) in the province. Greenhouse gas emissions are subject to the Kyoto treaty on climate change, while SO2 and NOx are contributors to smog.

	Scenario			
	1 Status Quo	**2 All Gas**	**3 Refurbished Nuclear/ Gas**	**4 Emission Reducing Technology**
Financial Costs	**$ 985 a**	**$ 2,076**	**$ 1,529**	**$ 1,367**
Health Damages	**$3,020**	**$388**	**$365**	**$1,079**
Environmental Damages	**$371**	**$141**	**$48**	**$356**
Total Cost of Generation	**$4,377**	**$2,605**	**$1,942**	**$2,802**

a: All values are expressed as annualised costs/damages in 2004$ Millions.

The study found a relationship between increased air pollution due to coal-fired electricity generation and up to 668 premature deaths, 928 hospital admissions, 1,100 emergency room visits and 333,600 minor illnesses annually. These health costs amount to $3 billion annually.

In addition to the health costs are economic damages due to environmental effects. The cost of greenhouse gas control and carbon sequestration from coal-fired emissions is $371 million annually.

Conclusions

The results of the pilot indicated that the addition of capacitance at the residential home reduces the demand requirements at the transformer. Further assumptions indicate that installation of the units on mass will reduce the generation requirements throughout the province.

There are a number of other social costs associated with building generation that are difficult to put a price to such as:

- environmental impacts of construction
- emissions
- fuel costs

Recommendations

We recommend that the findings of this pilot be shared with government officials as a viable means to help address the supply and transmission issues within the province.