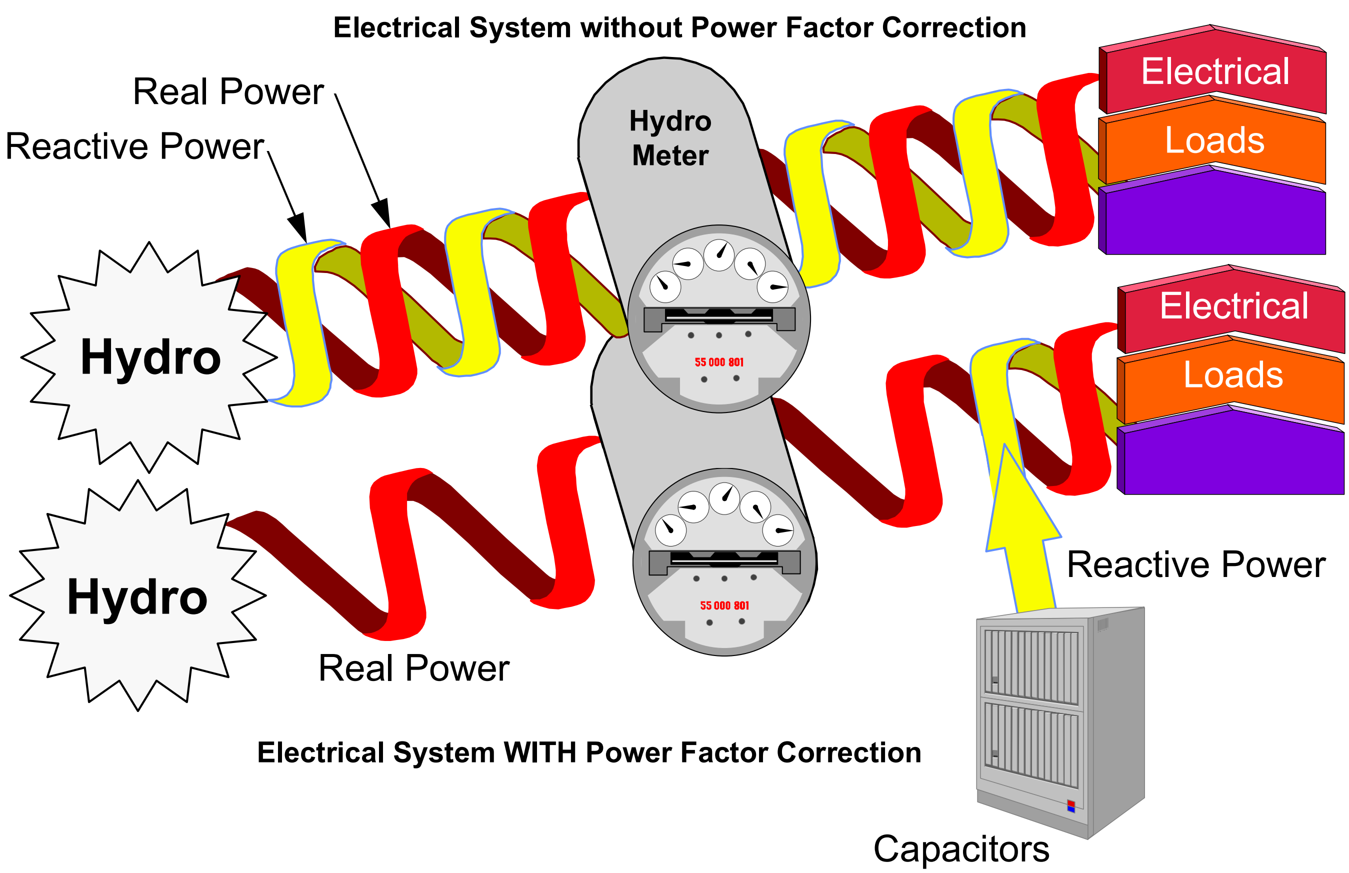
AN INTRODUCTION TO POWER FACTOR

In electrical installations with a low power factor, significant cost savings can be made through the application of power factor correction. These savings are achieved largely due to the way electrical utilities bill their customers.

For a machine to perform work it must be supplied with energy. In the case of electric motors, more electricity must be supplied than actually appears as useful work at the motor shaft. A certain amount of electricity is required just to maintain the necessary magnetic field and does not produce any useful work. This component is known as ***reactive*** (or magnetizing) power. Utility companies will provide a limited amount of reactive power at no cost, however customers with high reactive power loads are charged extra for the reactive component.



DEFINITION FOR POWER FACTOR

Power factor (PF) is the name given to the ratio of the active or usable power measured in kilowatts (KW), to the total power (active and reactive) measured in kilovolt amperes (KVA).

ie: Power Factor = KW / KVA

The total power supplied to inductive equipment is the vector sum of KW and KVA. The Displacement Power Factor is the cosine of the angle between these two quantities.

The value for the power factor can theoretically vary between 0/% and 100%, where a value of 100% -- also called unity power factor – delivers all of the power as active power. A value of 0% would mean all the power is supplied as reactive power; no motors would turn and no useful work could be accomplished. Electric utility companies must supply the entire KVA demand. Since a customer only achieves useful work from the KW portion, a high power factor is important. The reactive power used by

electrical equipment like transformers, electric motors, welding units and static converters adds additional load to generators, transmission lines, transformers, switchgear and cables. Reactive power can also cause considerable loss of energy through heat dissipation.

HOW TO IMPROVE THE POWER FACTOR

In order to understand power factor, one must first know the process of energy storage in capacitors and inductive devices. As the voltage in A.C. circuits varies sinusoidally, it alternately passes through zero and starts toward maximum voltage. During this time, the inductive device gives up energy from its electromagnetic field, and the capacitor stores energy in its electrostatic field. As the voltage passes through a maximum point and starts to decrease, the capacitor gives up energy and the inductive device stores energy. Thus, when a capacitor and an inductive' device are installed on the same circuit, there will be an exchange of magnetizing current between them, that is, the leading current taken by the capacitor neutralizes the magnetizing current to the inductive device. The capacitor may be considered to be a KILOVOLTAMP-REACTIVE (KVAR) generator, since it actually supplies magnetizing requirements in the inductive device. The concept of a capacitor as a KiloVoltAmp-Reactive (KVAR) generator is helpful in understanding its use for power factor improvement.

POWER FACTOR CORRECTION: Advantages

There are several advantages in utilizing power factor correction capacitors. These include:

- reduced demand charges
- increased load carrying capabilities in existing circuits
- improved voltage
- reduced power system losses

REDUCED DEMAND CHARGES

Most Utility companies charge for maximum metered demand based on either the highest registered demand in kilowatts (KW meter), or a percentage of the highest registered demand in KVA (KVA meter), whichever is greater. If the power factor is low, the percentage of the measured KVA will be significantly greater than the KW demand. Increasing the power factor will, therefore, lower the demand charge.

INCREASED LOAD CARRYING CAPABILITIES IN EXISTING CIRCUITS

Loads drawing reactive power also demand reactive current. Installing capacitors at the end of existing circuits near the inductive loads reduces the current carried by each circuit. The reduction in current flow resulting from improved power factor may allow the circuit to carry new loads, saving the cost of upgrading the distribution network when extra capacity is required for additional machinery. In addition, the reduced current flow reduces resistive losses in the circuit.

IMPROVED VOLTAGE

A lower power factor causes a higher current flow for a given load. As the line current increases, the voltage drop in the conductor increases, which may result in a lower voltage at the equipment. With an improved power factor, the voltage drop in the conductor is reduced, improving the voltage at the equipment.

REDUCED POWER SYSTEM LOSSES

Although the financial return from conductor loss reduction alone is seldom sufficient to justify the installation of capacitors, it is sometimes an attractive additional benefit; especially in older plants with long feeders or in field pumping operations. System conductor losses are proportional to the current squared and, since the current is reduced in direct proportion to the power factor improvement, the losses are inversely proportional to the square of the power factor.

FIXED VERSUS AUTOMATIC CAPACITORS

What is the difference between fixed and automatic Power Factor Correction Capacitors?

Fixed capacitor banks are “on” at all times, regardless of the load in the facility, while an automatic capacitor bank varies the amount of correction (KVAR) supplied to an electrical system. An automatic capacitor is much more expensive per kVAr (3 to 5 times) than a fixed system.

100 kVAr of fixed capacitors will save as much power factor penalties as a 100 kVAr automatic capacitor.

Generally, when a capacitor is connected to a system there is a reduction in amperage on the system (the lower the power factor the greater the KVA reduction). This reduction in amperage reduces the voltage drop across a transformer, which results in a higher voltage in the system. If 100 kVAr is connected to a 1000 KVA transformer, there is approximately a ¾% voltage rise on the system (if there is no other loads on the system). The more kVAr connected, the higher the voltage rise. This voltage rise is counter acted by the increase of load in the facility. Typically, in the night and on weekends, utility voltage are higher than normal, and facilities that are not normally loaded during these times, could experience a higher than normal voltage rise if too much capacitance is connected to their system.

Based on this, we generally limit fixed capacitors to 10% to 15% fixed kVAr to KVA of transformer size. We would recommend an automatic capacitor bank if the amount of kVAr exceeds 20% of the KVA size of the transformer.

Toronto Hydro Billing Table Penalties to 100% Power Factor

Toronto Hydro demand charges have separate KW and KVA demand charges, therefore, power factor charges are incurred with less than a 100% power factor. The following Hydro Billing Analysis Table indicates the penalties that were paid in power factor penalties in one year, and the amount of capacitance to eliminate these penalties (based on past 12 months history).

Year	Month	Peak KVA Demand	Peak KW Demand	Actual Power Factor	Power Factor Penalty	KVAR Req'd
2009	Jan	1069	883	82.6%	$1,004	602
2009	Feb	993	836	84.2%	$847	536
2009	Mar	973	812	83.4%	$871	537
2009	Apr	1008	843	83.6%	$891	553
2009	May	1005	841	83.8%	$881	549
2009	Jun	1119	947	84.6%	$928	596
2009	Jul	1102	918	83.3%	$993	610
2009	Aug	1053	887	84.3%	$895	567
2009	Sep	1063	882	83.0%	$974	592
2009	Oct	1063	882	83.0%	$974	592
2009	Nov	1046	881	84.2%	$894	565
2009	Dec	1048	861	82.1%	$1,012	598

Maximum amount of KVAR required to eliminate the penalties. $11,164
At 100 % Power Factor 610 KVAR

Based on the past years usage and indicated on the billing analysis, a total of 610 kVAr would recover $11,164 in annual penalties. Generally, targeting a power factor of 95% to 97% provides the best payback. The following table shows the results if 350 kVAr were added to the system recovering $9,308 in power factor charges.

Year	Month	KVA	KW	Actual P.F.	P.F. Penalty	KVAR Installed
2009	Jan	918.6	883.2	96.15%	$191	350
2009	Feb	856.5	836.2	97.62%	$110	350
2009	Mar	833.3	812.2	97.46%	$114	350
2009	Apr	866.9	842.9	97.23%	$130	350
2009	May	864.6	841.4	97.32%	$125	350
2009	Jun	978.4	947.0	96.79%	$170	350
2009	Jul	954.2	918.2	96.23%	$194	350
2009	Aug	913.2	887.0	97.14%	$141	350
2009	Sep	914.9	882.2	96.43%	$176	350
2009	Oct	914.9	882.2	96.43%	$176	350
2009	Nov	906.7	880.8	97.15%	$140	350
2009	Dec	895.7	860.6	96.09%	$189	350

350 KVAR WOULD HAVE REDUCED ANNUAL PENALTIES TO $1,857
THEREFORE SAVING $9,308

Depending on the availability of existing breakers/disconnects and harmonic distortion, the cost per kVAr installed ranges from $50 to $90 per kVAr.

Enersource Billing Table Penalties to 90% Power Factor

The following Hydro Billing Analysis Table indicates the penalties that were paid in power factor penalties in one year, and the amount of capacitance to eliminate these penalties (based on past 12 months history). Notice in the tables the different demand for each month. The amount of kVAr of capacitance required to eliminate the monthly power factor penalty varies from month to month. This range sometimes generates a better pay-back if less than the maximum kVAr is installed. For example, if 250 kVAr is purchased, a 90% power factor would have been achieved for 7 months, and the 5 other months would have a reduced penalty. Therefore, the payback is sometimes better if less than a minimum power factor of 90% is targeted.

Year	Month	KVA	KW	Billing Demand .9 of KVA	Actual P.F.	P.F. Penalty	KVAR Req'd
2007	Jan	555	368	499	66.4%	$1,078	236
2006	Feb	544	374	490	68.8%	$949	214
2005	Mar	500	348	450	69.6%	$839	190
2005	Apr	601	408	541	68.0%	$1,087	243
2005	May	572	385	515	67.2%	$1,074	238
2005	Jun	606	407	546	67.2%	$1,138	252
2005	Jul	594	399	534	67.2%	$1,114	246
2005	Aug	636	433	572	68.0%	$1,152	257
2005	Sep	648	435	583	67.2%	$1,216	269
2005	Oct	590	392	531	66.4%	$1,146	251
2005	Nov	628	422	565	67.2%	$1,178	261
2005	Dec	553	367	498	66.4%	$1,075	236
						$13,045	

To Ensure 90 % PF Each Month, use 269 KVAR

Based on the past years usage and indicated on the billing analysis, a minimum of 269 kVAr is required to maintain a 90% power factor. The kVAr requirements range from 190 to 269 kVAr per month over a year. The following table shows the results if 250 kVAr were added to the system recovering $12,914 in power factor charges.

Year	Month	KVA	KW	Billing Demand .9 of KVA	Actual P.F.	P.F. Penalty	KVAR Instl'd
2007	Jan	403.6	368.4	368.4	91.28%	$0	250
2006	Feb	401.4	374.3	374.3	93.26%	$0	250
2005	Mar	364.7	348.0	348.0	95.43%	$0	250
2005	Apr	450.6	408.4	408.4	90.64%	$0	250
2005	May	422.1	384.6	384.6	91.12%	$0	250
2005	Jun	453.4	407.4	408.1	89.85%	$5	250
2005	Jul	441.7	398.9	398.9	90.32%	$0	250
2005	Aug	483.6	432.5	435.3	89.43%	$23	250
2005	Sep	492.2	435.3	443.0	88.44%	$63	250
2005	Oct	435.8	391.7	392.2	89.88%	$4	250
2005	Nov	473.4	421.8	426.1	89.11%	$35	250
2005	Dec	402.2	367.4	367.4	91.34%	$0	250

250 KVAR WOULD HAVE REDUCED ANNUAL PENALTIES TO $130
THEREFORE SAVING $12,914

Depending on the availability of existing breakers/disconnects and harmonic distortion, the cost per kVAr installed ranges from $50 to $90 per kVAr.