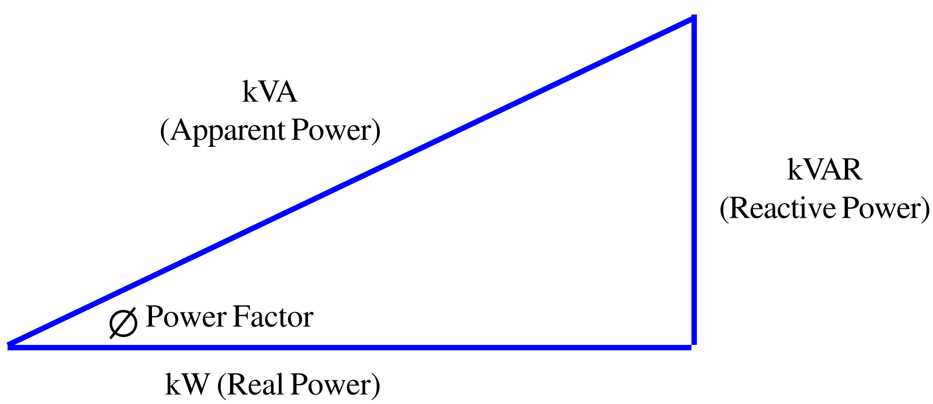
Power Factor



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POWER FACTOR

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Introduction

As energy costs continue to represent an increasing proportion of the overall cost of doing business, energy management has become an important activity. Understanding power factor and how it affects your company's electricity bill can help reduce power costs.

Power Factor gives a reading of overall electricity use efficiency. High power factor indicates that the amount of power doing real work is operating at a high level of efficiency. Conversely, low power factor means poor electricity efficiency which is always costly. Improving power factor can reduce billed peak demand and enhance equipment reliability.

Power factor is not an easy subject to discuss without some knowledge of electricity. The section on Electricity basics provides a refresher of electricity and electrical power components.

Electricity Basics

Electrical energy is consumed by end uses called loads. All alternating current loads are comprised in varying degrees of three components:

- Resistance
- Inductive Reactance
- Capacitive Reactance

Resistance

When electrical energy is consumed in the resistive component, real work is done. Heat is generated or light is emitted

The rate of doing real work is measured in watts. Since a watt is a relatively small quantity, kilowatts (1,000 watts) is most commonly used. The same is true for the other measures.

The product of the applied voltage and the current flowing in the resistive circuit is **real power**. Schematically, real power is represented by an arrow pointing to the right.

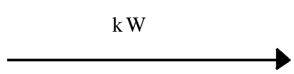


Figure 1a
Arrow Convention Illustrating Real Power

The left to right direction indicates real power. The lenght denotes the amount or magnitude of real power.

Inductive Reactance

When electricity is applied to a pure inductor no real work is done.

No heat or light is generated. Current and voltage are applied to the load. Their product **reactive power**, is measured in kilo-volt-amperes-reactive (kVAR). Examples of inductive loads are transformers, motors and lighting ballasts.

Inductive reactance produces magnetomotive forces, enabling machines to operate. Inductivve reactive power is represented by an upwards arrow.

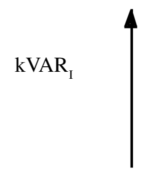


Figure 1b
Arrow Convention Illustrating Inductive Reactive Power

The vertical orientation represents reactive power. The upwards direction indicates inductance. The length denotes the amount or magnitude of kVAR.

Capacitive Reactance

When electricity is applied to a capacitor, no real work is done.

Current and voltage are applied to the load. Their product, **reactive power**, is measured in kVAR. Capacitive reactive power is represented by a downward arrow.

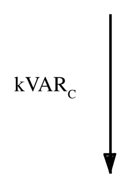


Figure 1c
Arrow Convention Illustrating Capacitive Reactive Power

The vertical orientation represents reactive power. The downwards sense denotes capacitance. The length denotes the amount of magnitude of kVAR.

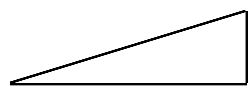
In summary, two kinds of power exist:

1. Real Power (Resistive Power)
2. Reactive Power
   - Inductive
   - Capacitive

Power Triangle

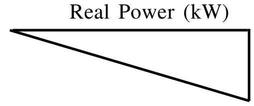
Pure resistance, pure capacitance and pure inductance exist only in theory. All real life loads exhibit varying proportions of these three components. Using arrow conventions and vector addition rules a typical industrial plant's electrical load can be represented by a power triangle. The power triangle describes the quality of power used.

Figure 2
Power Triangle Illustrating Inductive Reactive Power



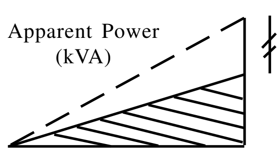
Real Power (Figure 1a) plus Inductive Reactive Power (Figure 1b) results in a power triangle as shown in Figure 2.

Figure 3
Power Triangle Illustrating Capacitive Reactive Power



Real Power (Figure 1a) plus Capacitive Reactive Power (Figure 1c) results in a power triangle as shown in Figure 3.

Figure 4
Effect of Capacitance in Reducing Inductive Load



Inductive reactive loads are usually greater than capacitive loads. When inductive reactive power is greater it can be reduced by adding capacitive reactive power. The power triangle is adjusted as shown in Figure 4.

Apparent Power

Total power is referred to as apparent power. It is the vector sum of real power and reactive power and is measured in kilo-volt-amperes (kVA). The hypotenuse closing the power triangle represents apparent power. (See Figure 4.)

Billed Demand

The maximum rate of electrical consumption or demand charge, measured in kW and the total amount of energy consumed, or energy charge, measured in kWh are calculated each month for billing purpsoes. The demand charges applies to the peak demand at which energy is taken and the energy charge applies to the quality of the electricity consumed during the billing period.

Billed demand is calculated according to the way in which electrical power is used. It is made up of two components:

1. Real Power (Resistive)
2. Reactive Power
   - Inductive
   - Capacitive

Given a fixed maximum rate of real work done (kW) the length of the hypotenuse (kVA) varies depending upon the amount of reactive power (kVAR). Billed demand is based on the peak value of 100 per cent of the kW or 90 per cent of the kVA, whichever is larger. Thus the length of the hypotenuse (kVA) influences the demand portion of the electricity bill.

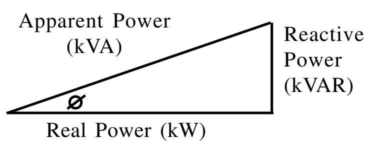
As soon as the kVAR component of the load reaches the point where 90 per cent of the kVA is larger than the total kW, the electrical billing demand charge increases for the same amount of work done.

Although only the power absorbed in the resistive component of a load does real work the principle of supplying power at cost dictates that reactive power components must also be billed.

What is Power Factor?

The relationship between resistive and reactive load components is called **Power Factor**. It is a numerical way of expressing the proportions of real power (kW) and apparent power (kVA). As shown in Figure 5 the power triangle is used to derive the forumla for calculating power factor.

Figure 5
Power Factor
Forumla



Power factor is represented mathematically by the cosine θ of the angle between real power and apparent power.

Formula

$$\text{Power Factor} = \frac{kW}{kVA}$$

If kW and kVA are known, the kVAR, a quantity necessary for billing purposes, can be calculated using the Pythagorean Theorem.

$$kVA^2 = kW^2 + kVAR^2$$

$$kVAR^2 = kVA^2 - kW^2$$

$$kVAR = \sqrt{kVA^2 - kW^2}$$

Measuring Power Factor

The practical way to measure power factor is to simultaneously measure real power (kW) and apparent power (kVA). All demand meters record the maximum average demand (kW), or rate of power used, over a 15 minute period. The standard commercial/industrial meter used by most municipal utilities is a combination demand and energy meter (see Figure 6). The red pointer tracks the power used, averaged over a 15 minute period. As the red pointer rises, it pushes forward the black pointer which records the maximum demand (kW) reached during the month. The maximum demand reading is converted to a true kW or kVA reading by applying the billing multiplier factor. The billing multiplier for your meters is available from your local utility.

Demand measuring meters can accurately discriminate between real power (kW) and apparent power (kVA). When the peak demand is over 50 kW and the power factor is suspected of being less than 90 per cent, both kW and kVA meters are installed (see Figure 7). Meter readings of energy in kWh, power in kW and apparent power in kVA are recorded. The billing multiplier factor is applied to all readings.

Digital Demand Recorders (DDR's) track the maximum average demand in 15 minute intervals on magnetic cassette tapes. The tape is computer read each month and can provide detailed load data. DDR's are commonly used for larger customers (See Figure 8).

With two meters, one reading kVA and the other reading kW, all the information necessary to determine the power factor is available. The bill now reflects a charge for power based on the larger of 100 per cent of kW or 90 per cent of kVA.

When a plant has only one meter installed, other means of gathering the information required to calculate power factor must be adopted. Many capacitor manufacturing companies and electrical contractors conduct power factor surveys. As well, some utilities measure plant power factor.

FIGURE 6
Demand Energy Meter

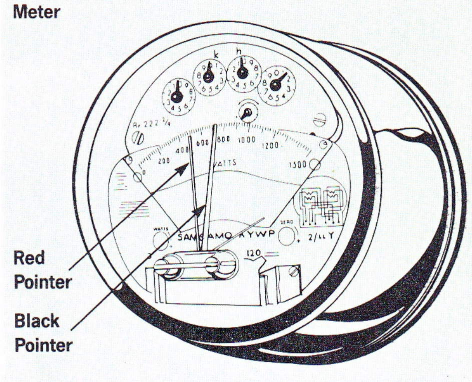


FIGURE 7
kW & kVA Meter

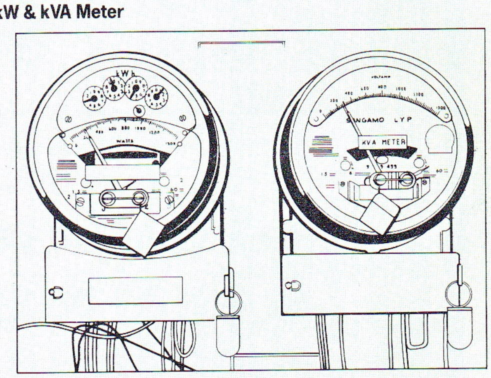
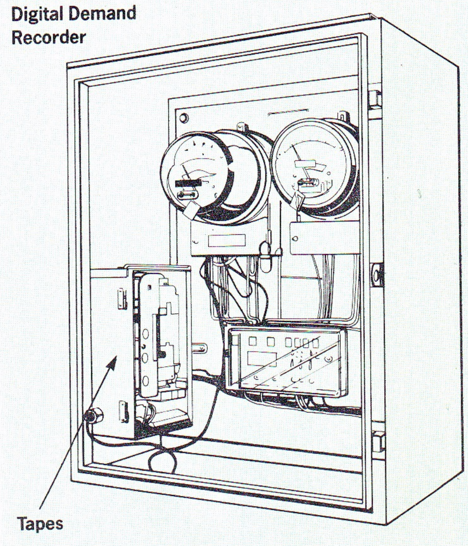


FIGURE 8
Digital Demand Recorder



Poor Power Factor

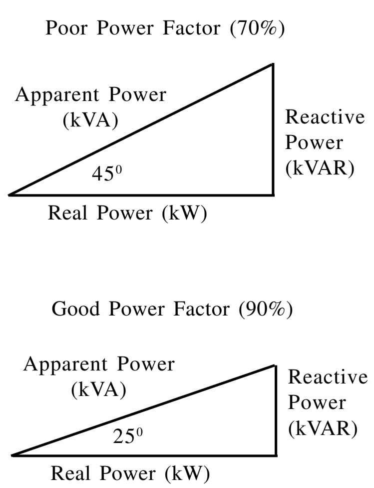
Poor power factor increases billed demand. It costs Ontario industry millions of dollars annually.

In an electrical circuit with poor power factor a large portion of the current does no useful work and is not registered at the energy (kWh) meter. In order for the utility to maintain the equipment necessary to compensate for the increased reactive power (kVAR), billed demand is increased accordingly.

Although reacitve power (kVAR) does no useful work it is necessary to make machinery operate. Most utilities allow a percentage of reactive power to be billed at no additional charge, though this has being phased out over recent years. Poor power factor results in higher than necessary kVAR use and increases electricity costs. Power factor billing charges are levied if the power factor is below 90 per cent. This is sometimes referred to as Power Factor Penalty.

The power triangles shown in Figure 9 demonstrate increased billed demand with poor power factor.

Figure 9
Poor Power Factor vs Good Power Factor



The increased apparent power (kVA) shown in the 70 per cent power factor triangle results in increased billed demand, even though the real power remains the same.

Poor power factor can be caused by equipment design or operating conditions. Motors, transformers, welding machines, induction heating coils and lighting ballasts are major sources.

Lightly loaded induction motors are one of the worst offenders. The factors affecting the power factor of an induction motor are size, speed and load. The larger the motor and the higher the speed, the higher the power factor. The higher the percentage of the rated load, the higher the power factor.

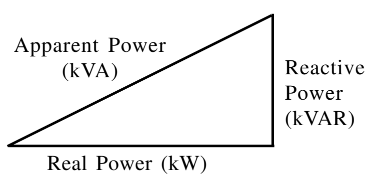
Power Factor Correction

Determining the amount of reactive power (kVAR) required to improve power factor to 90 per cent is called power factor correction.

Reactive power (kVAR) can flow in opposite directions. Lagging kVAR flows in the opposite direction to leading kVAR. Machines that use lagging kVAR are said to be kVAR consumers while machines that use leading kVAR, are said to be kVAR generators. For example, an induction motor which requires kVAR to magnetize its magnetic poles before it can do any work is a kVAR consumer.

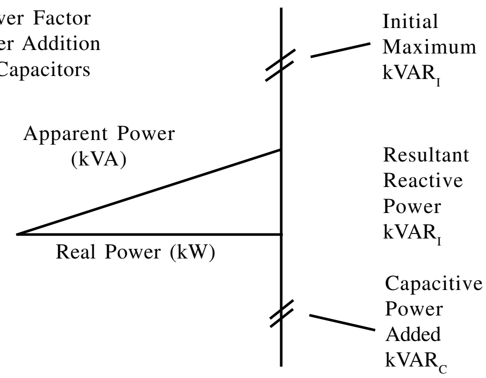
Lagging power factor occurs when the inductive power requirements are greater than the capacitive power requirements. When lagging power factor occurs the current (amps) follows, or lags, the voltage (volts) in magnitude over time. A typical load with lagging power factor is illustrated schematically in Figure 10.

Figure 10
Power Factor
Before Addition
of Capacitors



Lagging power factor can be corrected by connecting capacitors to the system. A capacitor is a device that does no work, uses no power (kW), but produces leading kVAR. The current which flows in a capacitor produces leading power factor. This current flows in the opposite direction to that in inductive equipment or machinery. When the two circuits are combined, capacitance reduces the effect of inductance. Figure 11 demonstrates the effect on power factor after the addition of capacitors.

Figure 11
Power Factor
After Addition
of Capacitors



Calculating the correct amount of capacitance is key to improving power factor. Too little capacitance will not correct a poor power factor. Too much capacitance can cause undesirable effects. A properly determined value of capacitance can nullify inductance and produce unity power factor.

Usually only three-phase loads need power factor correction. In most cases power factor is best corrected at the source, for example at each motor. However, for economic reasons power factor correction usually takes place at the meters.

Power Factor Correction and Power Billing Calculations

The following exercise demonstrates a simple way to determine power factor, how to improve it, and the payback perod for capacitor installation.

$$\frac{kW}{kVA} \times 100\% = P.F.$$

For example, if the watt meter reads 900kW and the volt-ampere meter reads 1125 VA, the true kW and kVA can be obtained by applying the billing multiplier factor to each reading. Using a billing multiplier factor of 2000, the peak demands can be calculated as follows:

$$(900 \times 2000)/1000 = 1800\ kW$$
$$(1125 \times 2000)/1000 = 2250\ kVA$$

The power factor is:

$$\frac{1800\ kW}{2250\ kVA} \times 100\% = 80\%$$

Assuming these are the peak readings for the month, the bill will be based on 80 per cent power factor.

Step 1: Determining Billed Demand
The billed demand is the true kW or 90 per cent of the kVA, whichever is greater.

$$0.90 \times 2250\ kVA = 2025\ kVA$$

Since 2025 kVA is greater than 1800 kW, the billed demand is 2025 kW.

While the peak demand is 1800 kW, the billed demand is 2025 kW. The difference of 225 kW is the power factor penalty. In this instance the power bill shows a higher kW figure than the meter indicated.

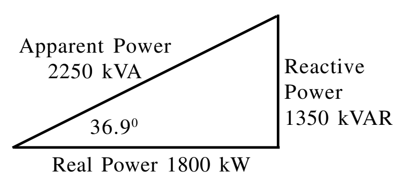
It is not possible to determine whether or not power factor penalty is present if only a kVA meter is installed.

Step 2: Drawing the Power Triangle
Calculate kVAR using the formula:

$$kVAR = \sqrt{kVA^2 - kW^2}$$
$$= \sqrt{2250^2 - 1800^2} = 1350 kVAR$$

The power triangle in Figure 12 represents the following values: 1800 kW; 1350 kVAR; 2250 kVA and 80 per cent power factor (Cos 36.90 = 1800 kW/2250 kVA = 0.8). Thus, the power triangle completely describes the quality of power used.

Figure 12
Power Triangle at 80 Per Cent Power Factor



Step 3: Power Factor Correction Worksheet at 80 Per Cent Power Factor

The Power Factor Correction Worksheet (page xx) highlights the potential benefits and monthly cost and savings that can be obtained by improving power factor. It summarizes the demand portion of the power bill and all power factor calculation components.

The following values have been recorded on the worksheet:

Present P.F.	-	80%
kVA	-	2250
kW	-	1800
kVAR	-	1350

These figures are used to calculate the demand charges at 80 per cent power factor using the General Service Rate Structure. The energy consumption charge (kWh) is ignored for this calculation as it is unaffected by the power factor.

Step 4: Total Cost at 80 Per Cent Power Factor

The billed demand is 90 per cent of the kVA.

2250 x 0.90 = 2025 Billed Demand kW

In calculating the demand charge, the first 50 kW are not billed. This eliminates small power users paying demand charges and power factor penalites (This reduction has been phased out in Ontario).

Gross Demand Charge: 2025kW - 50 kW = 1975kW x $3.50/kW = $6,912.50

Transformer allowances are available to customers who own their own transformers. Allowances range in value from $0.45 to $1.40 per kW of billed demand, depending on the utility and the primary supply voltage. In this example the customer is eligible for $0.60 per billed kW allowance.

Transformer allowance:
2025 kW x $0.60 = $1,215.00

Net Demand Charge:
$6,912.50 - $1,215 =$5,697.50

Step 5: Calculating Required kVAR for 90 Per Cent Power Factor

Installing capacitors will raise the power factor to 90 per cent. While there is no change to the kW meter reading, the kVA meter shows a reduction.

The Power Factor Improvement Table is used to determine the kVAR of capacitors required to improve the power factor. The left hand column indicates the existing power factor. The top row of numbers indicates the desired power factor. Accordingly 0.266 x kW will determine the required kVAR of capacitors required to increase the power factor to 90 per cent.

0.266 x 1800 kW = 480 kVAR

Installing 480 kVAR of capacitors will improve power factor to 90 per cent.

Step 6: Power Factor Correction Worksheet at 90 Per Cent Power Factor

Using the Power Factor Correction Worksheet, the new demand charge and the resulting savings can be determined. Improving power factor to 90 per cent reduces total kVAR to:

1350 kVAR - 480 kVAR = 870 kVAR

The kVA is now:

$$\frac{800 \text{ kW}}{0.90 \text{ P.F.}} = 2000 \text{ kVA}$$

The following values have been recorded on the worksheet:

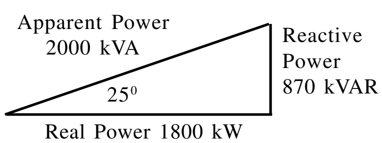
Required P.F.	-	90%
kVA	-	2000
kW	-	1800
kVAR	-	870

Notice the minus sign between the power factor columns on the kVAR line of the worksheet. The difference signifies the capacitive kVAR added.

Step 7: Power Triangle at 90 Per Cent Power Factor

The power triangle in Figure 13 represents the following values: 1800 kW; 870 kVAR; 2000 kVAR; and 90 per cent power factor (Cos 25.8^0 = 1800 kW / 2000 kVA = 0.9). Thus, the power triangle completely describes the quality of power used when the power factor has been improved.

Figure 13
Power Tirangle at 90 Per Cent Power Factor



Step 8: Total Cost at 90 Per Cent Power Factor

The billed demand is now the same as the metered kW reading of 1800 kW.

2000 kVA x 0.90 = 1800 Billed Demand kW
The demand charge is calculated as follows: First 50 kW: No Charge
Gross Demand Charge: 1800 kW - 50 kW = 1750 kW x $3.50/kW = $6,125.00
Transformer Allowance: 1800 kW x $0.60 = $1,080.00
Net Demand Charge: $6,125.00 - $1,080.00 = $5,045.00

Step 9: Improved Power Factor Savings

By maintaining the power factor at 80 per cent the customer in effect pays a power factor penalty of $652.00 each month. Correcting the power factor increases efficiency and reduces energy costs significantly. In this example improving the power factor to 90 per cent realizes substantial monthly savings of $625.00, an 11.45 per cent overall reduction in the monthly power bill. Although the same maximum rate of work as been done with the same peak demand, the customer now benefits from the annual savings of close to $8,000.

Step 10: Determining Payback

In Step 5 the required kVAR of capacitors needed to improve the power factor to 90 per cent was calculated at 480 kVAR. Using 1987 estimated rates of $25 per kVAR, the cost for installing 480 kVAR of capacitors is $12,000. Annual savings of almost $8,000 generate a payback period of approximately18 months.

Power Factor Correction Worksheet

Supply Authority Your Hydro	Customer ABC Company		
	Date October 1987		
Rate Designation 1800	Present P.F. 80%	Required P.F. 90%	
MEASURED DEMANDS			
kVA	2250	2000	
kW	1800	1800	
kVAR	1350	- 870	= 480
Billed kW = kVA x 0.9	2025	1800	

DEMAND CHARGE:	$	$	$
First 50 kW @ no charge Next 4950 kW @ $3.50/kW	0 $6,912.50	0 $6,125.00	
Total	$6,912.50	$6,125.00	
Less, Transformer Allowance @ $0.60/Billed kW	$1,215.00	$1,080.00	Monthly Saving
NET CHARGE	$5,697.50	- $5,045.00	$652.00

ESTIMATED COST OF CORRECTION	$12,000.00
PAYBACK PERIOD (MONTHS)	18

Table 1 - Power Factor Improvement

Desired Power Factor in Per Cent

Current Power Factor	80	81	82	83	84	85	86	87	88	89	91	90	92	93	94	95	96	97	98	99	100
50	0.982	1.008	1.034	1.060	1.086	1.112	1.139	1.165	1.192	1.220	1.276	1.248	1.306	1.337	1.369	1.403	1.442	1.481	1.529	1.590	1.732
51	.937	.962	.989	1.015	1.041	1.067	1.094	1.120	1.147	1.175	1.231	1.203	1.261	1.292	1.324	1.358	1.395	1.436	1.484	1.544	1.687
52	.893	.919	.945	.971	.997	1.023	1.050	1.076	1.103	1.131	1.187	1.159	1.217	1.248	1.280	1.314	1.351	1.392	1.440	1.500	1.643
53	.850	.876	.902	.928	.954	.980	1.007	1.033	1.060	1.088	1.144	1.116	1.174	1.205	1.237	1.271	1.308	1.349	1.397	1.457	1.600
54	.809	.835	.861	.887	.913	.939	.966	.992	1.019	1.047	1.103	1.075	1.133	1.164	1.196	1.230	1.267	1.308	1.356	1.416	1.559
55	.769	.795	.821	.847	.873	.899	.926	.952	.979	1.007	1.063	1.035	1.090	1.124	1.156	1.190	1.228	1.268	1.316	1.377	1.519
56	.730	.756	.782	.808	.834	.860	.887	.913	.940	.968	1.024	.996	1.051	1.085	1.117	1.151	1.189	1.229	1.277	1.338	1.480
57	.692	.718	.744	.770	.796	.822	.849	.875	.902	.930	.986	.958	1.013	1.047	1.079	1.113	1.151	1.191	1.239	1.300	1.442
58	.655	.681	.707	.733	.759	.785	.812	.838	.865	.893	.949	.921	.976	1.010	1.042	1.076	1.114	1.154	1.202	1.263	1.405
59	.618	.644	.670	.696	.722	.748	.775	.801	.828	.856	.912	.884	.939	.973	1.005	1.039	1.077	1.117	1.165	1.226	1.368
60	.584	.610	.636	.662	.688	.714	.741	.767	.794	.822	.878	.850	.905	.939	.971	1.005	1.043	1.083	1.131	1.192	1.334
61	.549	.575	.601	.627	.653	.679	.706	.732	.759	.787	843	.815	.870	.904	936	.970	1.008	1.048	1.096	1.157	1.299
62	.515	.541	.567	.593	.619	.645	.672	.698	.725	.753	.809	.781	.836	.870	.902	.936	.974	1.014	1.062	1.123	1.265
63	.483	.509	.535	.561	.587	.613	.640	.666	.693	.721	.777	.749	.804	.838	.870	.904	.942	.982	1.030	1.091	1.233
64	.450	.476	.502	.528	.554	.580	.607	.633	.660	.688	.744	.716	.771	.805	.837	.871	.909	.949	.997	1.058	1.200
65	.419	.445	.471	.497	.523	.549	.576	.602	.629	.657	.713	.685	.740	.774	.806	.840	.878	.918	.966	1.027	1.169
66	.388	.414	.440	.466	.492	.518	.545	.571	.598	.626	.682	.654	.709	.743	.775	.809	.847	.887	.935	.996	1.138
67	.358	.384	.410	.436	.462	.488	.515	.541	.568	.596	.652	.624	.679	.713	.745	.779	.817	.857	.905	.966	1.108
68	.329	.355	.381	.407	.433	.459	.486	.512	.539	.567	.623	.595	.650	.684	.716	.750	.788	.828	.876	.937	1.079
69	.299	.325	.351	.377	.403	.429	.456	.482	.509	.537	.593	.565	.620	.654	.866	.720	.758	.798	.840	.907	1.049
70	.270	.296	.322	.348	.374	.400	.427	.453	.480	.508	.564	.536	.591	.625	.657	.691	.729	.769	.811	.878	1.020
71	.242	.268	.294	.320	.346	.372	.399	.425	.452	.480	.536	.508	.563	.597	.629	.663	.701	.741	.783	.850	.992
72	.213	.239	.265	.291	.317	.343	.370	.396	.423	.451	.507	.479	.534	.568	.600	.634	.672	.712	.754	.821	.963
73	.186	.212	.238	.264	.290	.316	.343	.369	.396	.424	.480	.452	.507	.541	.573	.607	.645	.685	.727	.794	.936
74	.159	.185	.211	.237	.263	.289	.316	.342	.369	.397	.453	.425	.480	.514	.546	.580	.618	.658	.700	.767	.909
75	.132	.158	.184	.210	.236	.262	.289	.315	.342	.370	.426	.398	.453	.487	.519	.553	.591	.631	.673	.740	.882
76	.105	.131	.157	.183	.209	235	.262	.288	.315	.343	.399	.371	.426	.460	.492	.526	.564	.604	.652	.713	.855
77	.079	.105	.131	.157	.183	.209	.236	.262	.289	.317	.373	.345	.400	.434	.466	.500	.538	.578	.620	.687	.829
78	.053	.079	.105	.131	.157	.183	.210	.236	.263	.291	.347	.319	.374	.408	.440	.474	.512	.552	.594	.661	.803
79	.026	.052	.078	.104	.130	.156	.183	.209	.236	.264	.320	.292	.347	.381	.413	.447	.485	.525	.567	.634	.776
80	.000	.026	.052	.078	.104	.130	.157	.183	.210	.238	.294	.266	.321	.355	.387	.421	.459	.499	.541	.608	.750
81	-	.000	.026	.052	.078	.104	.131	.157	.184	.212	.268	.240	.295	.329	.361	.395	.433	.473	.515	.582	.724
82	-	-	.000	.026	.052	.078	.105	.131	.158	.186	.242	.214	.269	.303	.335	.369	.407	.447	.489	.556	.698
83	-	-	-	.000	.026	.052	.079	.105	.132	.160	.216	.188	.243	.277	.309	.343	.381	.421	.463	.530	.672
84	-	-	-	-	.000	.026	.053	.079	.106	.134	.190	.162	.217	.251	.283	.317	.355	.395	.437	.504	.645
85	-	-	-	-	-	.000	.027	.053	.080	.108	.164	.136	.191	.225	.257	.291	.329	.369	.417	.478	.620
86	-	-	-	-	-	-	-	.026	.053	.081	.137	.109	.167	.198	.230	.265	.301	.343	.390	.451	.593
87	-	-	-	-	-	-	-	-	.027	.055	.111	.082	.141	.172	.204	.238	.275	.317	.364	.425	.567
88	-	-	-	-	-	-	-	-	-	.028	.084	.056	.114	.145	.177	.211	.248	.290	.337	.398	.540
89	-	-	-	-	-	-	-	-	-	-	.056	.028	.086	.117	.149	.183	.220	.262	.309	.370	.512
90	-	-	-	-	-	-	-	-	-	-	.028	-	.058	.089	.121	.155	.192	.234	.281	.342	.484
91	-	-	-	-	-	-	-	-	-	-	-	-	.030	.061	.093	.127	.164	.206	.253	.314	.456
92	-	-	-	-	-	-	-	-	-	-	-	-	-	.031	.063	.097	.134	.176	.223	.284	.426
93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.032	.066	.103	.145	.192	.253	.395
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.034	.071	.113	.160	.221	.363
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.037	.079	.126	.187	.328
96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.042	.089	.150	.292
97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.047	.108	.251
98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.061	.203
99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.142

Improving System Reliability

Correcting power factor by installing capacitors reduces billed demand. Assuming that the voltage remains unchanged by the introduction of capacitors, the reduction in kVA will result in a decrease in current (amperes). Reducing current helps to increase electrical equipment reliability by optimizing and not overloading existing systems.

The following example demonstrates how approaching 90 per cent power factor reduces the current drawn.

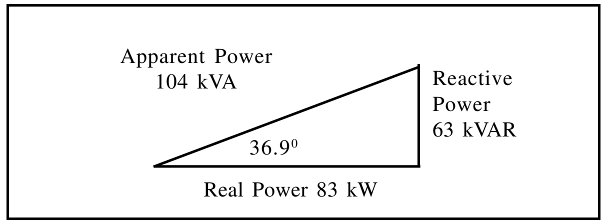
The nameplate on a 100 hp, 3-phase motor indicates that it draws 100 amps at 100 volts at full load. The kW input can be calculated using the formula

$$kW = \frac{hp \times 0.746}{\%\ efficiency}$$

For a 3-phase motor of 90 per cent efficiency, the input is 83kW. The kVA required can be calculated using the following forumula:

kVA	$= \sqrt{3}$ x kilo-volts x amps
kVA input	$= \sqrt{3}$ x 0.600 kV x 100 amps = 104 kVA
Power Factor	= 83 kW / 104 kVA = 80%
kVAR	$= \sqrt{(104^2 - 83^2)}$ = 63 kVAR

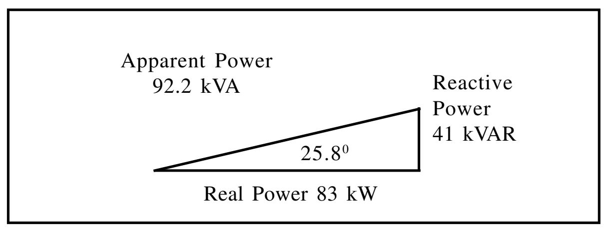
The power triangle for this load is:



The Power Factor Improvement Table is used to determine the kVAR of capacitors required to increase the power factor to 90 per cent.

$$0.266 \times 83\ KW = 22\ kVAR$$

If capacitors producing 22 leading kVAR are added, the lagging 63 kVAR drawn by the motor would be reduced to 41 kVAR. The power triangle for this load at 90 per cent power factor is:



At 600 volts, 92.2 kVA results in a draw of only 89 amps.

$$\sqrt{3} \times 0.600\ kV \times 89\ amps = 92.2\ kVA$$

Adding capacitors to the motor has decreased the current drawn from 100 amps to 89 amps, a reduction of 11 per cent.

Capacitor Installation Pointers

Contactors
When capacitors are installed at the inductive load side of the switchgear, contactors supplying machinery may need to be upgraded.

Fuses
Non-renewable or HRC type fuses are recommended. They are less likely to heat up than renewable fuses.

Harmonics
Capacitors installed either in series or parallel to inductive loads can create tank circuits. Unstable resonances within the tank circuits can cause stress to connected equipment and voltage variations within the plant.

Harmonics generated by solid state rectification can blow protective fuses. Harmonic voltages and currents can create low impedance circuits when capacitors have been added.

Location
The preferred location for capacitors is in the switch room, on the load side of the meter. There is less likelihood of capacitos being accidentally disconnected in this location. As well, there is often unused space and adequate wire size available.

Maintenance
While capacitors require little maintenance, they should be accessible for inspection of fuses and terminals. Capacitors should be frequently checked with a clamp-on ammeter to be sure they are operating.

Operation
Once capacitors are installed they must be left on continuously. If a capacitor is left off for only 15 minutes during the load period, it may as well not have been installed for the entire month.

Switching
Manual switching is preferred. The capacitors should be left on at all times when a load is running, unless, for example, there is excessive voltage during light load periods.

Wiring
Since capacitors have 100 per cent load factor, all wiring should be maximum copper cross-section. All switches should be of extra heavy duty construction.

SAFETY

Capacitors can store extremely large voltages, even when not connected or in use. Extreme caution must be exercised when handling them. Always insist that experienced personnel and licensed contractors install electrical equipment.

All electrical equipment installations must be inspected by the Electrical Safety Authority (ESA)

For more information on Power Factor, Harmonics, Energy Management visit

www.cosphi.com

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