Technical Note

Power Factor Correction

Most people associate electricity and energy with kilowatts (kW). In fact, however, kW only makes up a part of the overall energy usage in a home, commercial building or an industrial manufacturing plant. In the world of 'AC' power, there are actually three types of power:

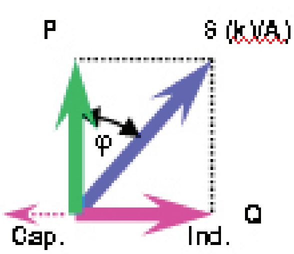
- *Apparent Power (measured in Volt-Amps)*
- *Real Power (measured in Watts)*
- *Reactive Power (measured in VARs)*

Apparent Power is the easiest to measure and calculate. It is simply the product of the single-phase rms Voltage and rms Current.

Formula 1:

Apparent Power (S) = $V_{rms} \times I_{rms}$

The relationship between Apparent Power (S) and the other two is influenced by what is called Power Factor (PF). The PF is directly correlated to the magnitude of real and reactive power being consumed. The following graphs illustrate two definitions of power factor. Figure 1 is called the vector-sum definition. The power factor is calculated as the cosine of the angle between the Real Power and Apparent Power. It can also be determined by dividing the Real Power by the Apparent Power.

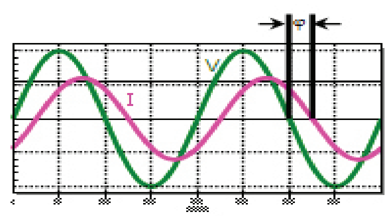


Formula 2:

$$PowerFactor = Cos(\phi) = \frac{P(kW)}{S(kVA)}$$

Figure 2 represents the AC waveforms of voltage and current. The waveform definition also calculates the power factor as the cosine of the angle, however this time the angle is the difference between zero-crossing positions of each waveform on the x-axis.

FIGURE 2



To calculate Real Power, multiply the Power Factor times the Apparent Power.

Formula 3:

Real Power (P) = S x PF = $V_{rms} \times I_{rms} \times PF$

Reactive Power (Q) is used by loads such as motors that require more than purely real power to operate. The relationship between Apparent Power, Real Power and Reactive Power can most easily be described using the Pythagorean Theorem. The Real and Reactive Power vectors form the right angle of a triangle, and the Apparent Power vector, then is the resultant sum of those two vectors, the hypotenuse.

Formula 4:

$S^2 = P^2 + Q^2$

As a result, every electrical utility actually generates Apparent Power and not just Real Power. The power factor can in many ways be considered a measure of the efficiency of an electrical system, or as a measure of the customer's electrical utilization of plant and equipment. Because of this, most utilities throughout the world charge customers for power factor and reactive power in a variety of ways.

UTILITY BILLING SCENARIOS:

- *kVA Billing – straight charges for all apparent power consumed*
- *kVAr Billing – additional charges for reactive power*
- *Power Factor Penalty – charges based on the customer's actual power factor*
- *Adjusted kW Demand – the real power demand is adjusted by a formula and is based on the customer's actual power factor*

In This Document

Read about:

- The difference between apparent, real and reactive power
- Utility PF billing
- Calculating energy parameters using power equations
- Examples of power factor correction

POWER FACTOR CALCULATION EXAMPLES

EXAMPLE #1: Customer 1 wants to increase his power factor to 0.95 to avoid paying power factor penalties that are being charged by the electrical utility. Calculate how much reactive power compensation / power factor correction they need to install to raise the power factor to 0.95. (Values are rounded)

KNOWN ELECTRICAL PARAMETERS

Phase-to-Phase Voltage	480 Volts
Existing Power Factor	0.80 Lagging
Current Apparent Power	1000 kVA

Step 1: Calculate Real Power:

P = S x PF

(1000 kVA) x (0.80) = 800 kW

Step 2: Calculate Current Reactive Power:

$S^2 = P^2 + Q^2$

$(1,000)^2 = (800)^2 + (Q)^2$

$(1,000)^2 - (800)^2 = (Q)^2$

SQRT $\{(1,000)^2 - (800)^2\} = Q$

Qcurrent = 600 kVAr

Step 3: Calculate New Apparent Power @ New PF:

P = S x PF

800kW = S x (0.95)

S = {(800kW)/(0.95)}

S = 842 kVA

Step 4: Calculate New Reactive Power @ New PF:

$S^2 = P^2 + Q^2$

$(842)^2 = (800)^2 + (Q)^2$

$(842)^2 - (800)^2 = (Q)^2$

SQRT $\{(842)^2 - (800)^2\} = Q$

Q_{new} = 260 kVAr

Step 5: Calculate Reactive Power Compensation / Power Factor Correction Needed:

$Q_{current} - Q_{new} = Q_{required}$

600 kVAr – 260 kVAr = $Q_{required}$

$Q_{required}$ = 340 kVAr

POWER FACTOR CORRECTION REFERENCE GUIDE

How to use this chart: Find original power factor in the top row. Find new power factor desired in far left-hand column of the chart. Multiply the kW load by the number in the row and column where they intersect to determine the amount of reactive power compensation / power factor correction is needed. Repeat the exercise in Example #1 to re-calculate the required power factor correction they need and see if it works!

Desired Power Factor	Current Power Factor										
	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.925	0.95	0.975	0.98
1.000	1.333	1.169	1.020	0.882	0.750	0.620	0.484	0.411	0.329	0.228	0.203
0.975	1.105	0.941	0.792	0.654	0.522	0.392	0.256	0.183	0.101	0.000	
0.950	1.005	0.840	0.692	0.553	0.421	0.291	0.156	0.082	0.000		
0.925	0.923	0.758	0.609	0.471	0.339	0.209	0.074	0.000			
0.900	0.849	0.685	0.536	0.398	0.266	0.135	0.000				
0.850	0.714	0.549	0.400	0.262	0.130	0.000					
0.800	0.583	0.419	0.270	0.132	0.000						

SMT-0008-02E

International
Elspec Ltd.
P.O. Box 3019
4 HaShoham St., Zone 23
Caesarea Industrial Park
38900, Israel
Tel: +972-4-6272-470
Fax: +972-4-6272-465
email: info@elspec-ltd.com

North America
Elspec North America, Inc.
500 West South Street
Freeport, IL 61032
USA
Tel: +1-815-266-4210
Fax: +1-815-266-8910
email: info@elspecna.com

Europe
Elspec Portugal Lda.
Zona Industrial 1a Fase
4900-231 Chafe
Viana do Castelo
Portugal
Tel: +315-258-351-920
Fax: +315-258-351-607
email: info@elspecportugal.com