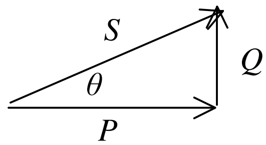
# Power Factor Correction Demo

*Objectives:*

In this demo we will investigate some properties of the power factor and how it affects the system. More specifically we will compare a two AC to DC conversion schemes, one without a power factor correction module and one with one.

*Reasons Behind Power Factor Correction:*

The main reason to drive the power factor to unity from the utility's point of view is to reduce costs. Looking at the power triangle:

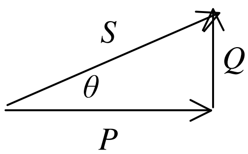



S = Apparent Power
P = Real Power
Q = Reactive Power

In general the utility sells real power to the customer but it must be capable of transmitting the full apparent power. This means that the lines, transformers and all other associated equipment must be sized larger than what the utility is actually selling. This increases the installation and maintenance costs of the whole system. If the power factor were driven to unity meaning the real power is equal to apparent power the utility would be able to supply the same amount of power with a smaller system and thus it would reduce costs.

*Properties of Power Factor:*

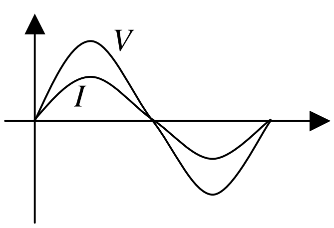
The power factor is defined by the ratio of real power to apparent power as shown below.




$$pf = \frac{P}{S} = \cos(\theta)$$

But the cos(θ) only holds in a harmonic free environment as seen below

In the case below with no delay between the current and voltage waveforms



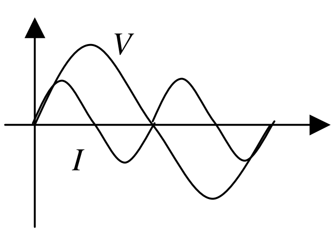

$$P = \frac{1}{T}\int V * I \, \partial t \neq 0 \quad \text{so} \quad pf = \frac{P}{S} \neq 0$$

since $\theta = 0° \Rightarrow P = S \Rightarrow pf = \frac{P}{S} = 1$

$$\theta = 0° \Rightarrow pf = \cos(\theta) = 1$$

so in this case $\frac{P}{S} = 1 = \cos(\theta)$

In this case there is no delay between the current and voltage waveforms but the current waveform has a strong second harmonic




$$P = \frac{1}{T}\int V * I \, \partial t = 0 \quad \text{so} \quad pf = \frac{P}{S} = 0$$

since $\theta = 0° \Rightarrow \cos(\theta) = 1$

so in this case $\frac{P}{S} \neq \cos(\theta)$

So the definition of power factor as the cosine of the power angle does not hold in all cases. The following definition gives a more complete description of the power factor.

$pf = pf_{DISP} * pf_{DIST}$

where:

| | |
|---|---|
| $pf_{DISP} = \cos(\theta)$ | is the power factor due to displacement *($\theta$)* |
| $pf_{DIST}$ | is the power factor due to distortion *(harmonics)* |

When there are no harmonics $pf_{DIST} = 1$ so $pf = pf_{DISP} = \cos(\theta)$

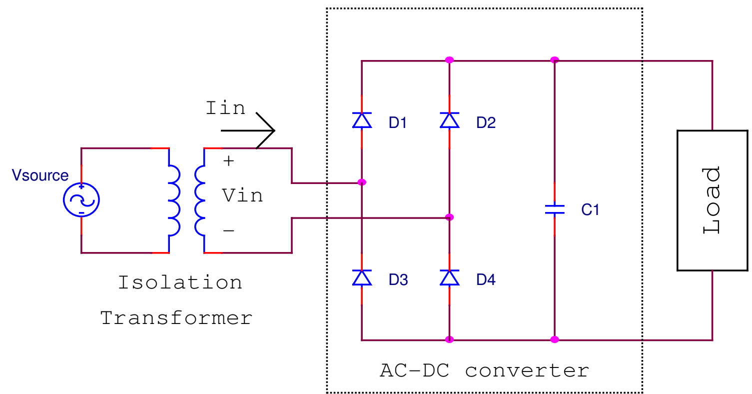
For the case where the current has a strong second harmonic $pf_{DIST} = 0$

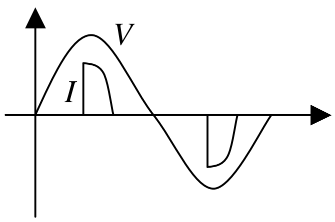
So $pf = pf_{DISP} * pf_{DIST} = 1 * 0 = 0 = \frac{P}{S}$

*Experiment:*

In this procedure we compare two AC to DC power supplies. The first one is a simple computer power supply consisting of a rectifier bridge and a capacitor. The second is the power factor correction module.

*Computer Power Supply:*

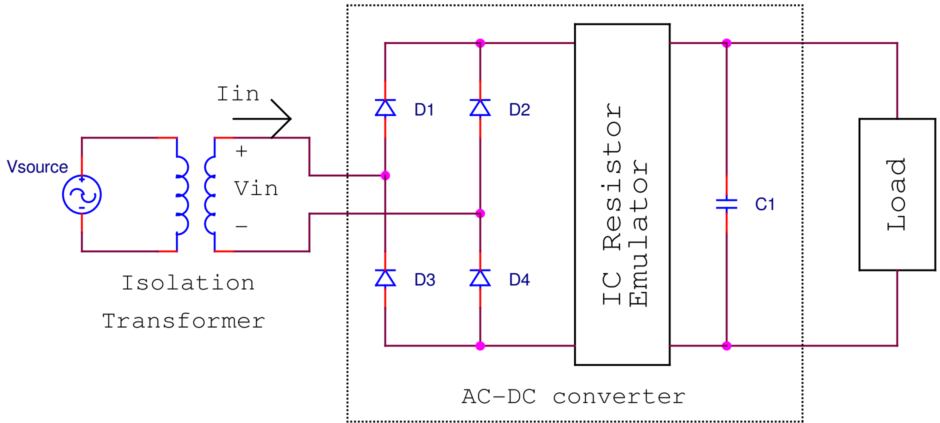


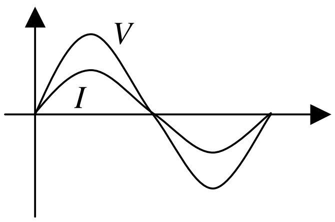




Current harmonics caused by the charging of the capacitor
$\theta = 0^{\circ}$, $pf_{DISP} = 1$, $pf_{DIST} < 1$, $pf < 1$
Produces stable DC output but at a bad Power Factor

- Uses a capacitor to smooth DC output, which also introduces harmonics to line current
- Current harmonics reduce the input power factor
- High efficiency Power conversion (very little power loss from input to output)
- Constant power, as input voltage decreases input current increases and as input voltage increases input current decreases, maintaining constant power on the input and output sides

*Power Factor Correction Module:*




The resistor emulator in effect hides the capacitor from the source side and makes the output look like a resistor to the input.

$\theta = 0^{\circ}$, $pf_{\mathrm{DISP}} = 1$, $pf_{\mathrm{DIST}} = 1$, $pf = 1$

Produces stable DC output with a good Power Factor

- Hides capacitor of previous example to maintain sinusoidal line current
- Fixes power factor problems from first circuit
- Constant power for 85 – 265 V
- High efficiency Power conversion (very little power loss from input to output)