POWER FACTOR

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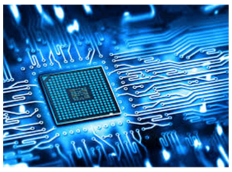

Thank you for your interest in Ziztel - we are a UK based manufacturer of PAGA / MBS and Intercom products. Our systems are mainly designed for use in the Military, Marine, Hazardous Oil, Gas and Petrochemical industries.

Power Factor is often overlooked in the implementation of Public Address and alarm system design. This technical document provides the background to Power Factor and its importance in the provision of an efficient PAGA system.

AC to DC Power Factor Supply Conversion

Power factor is defined as the ratio of ***'real'* power** flowing from the AC mains supply into the PAGA system versus the ***'apparent'* power** in the circuit.

'Real' power is the capacity of the circuit for performing work in a particular time.

'Apparent' power is the product of the current and voltage of the circuit and is always greater than 'real' power unless the load is purely resistive. Power factor is calculated by dividing the 'real' power by the 'apparent' power (Power factor = 1 in a purely resistive circuit). Energy is stored in the central PAGA rack power supply conversion hardware is returned to the source on each cycle of the AC input. Due to the rectification process that converts the AC voltage input to DC voltage in a linear supply the wave shape of the current drawn from the source is distorted and the system Power factor is reduced accordingly. Lowering the power factor results in a corresponding lowering of efficiency and is a direct consequence of the PAGA AC to DC conversion subsystem design, hence a *high* power factor is a desirable parameter in the design of the PAGA power supply hardware.

Background

In a purely resistive AC circuit, voltage and current waveforms are in in phase, changing polarity at the same instant in each cycle. The entire power entering the load is consumed by the PAGA system. Circuits containing purely resistive heating elements (filament lamps, cooking stoves, etc.) have a power factor of 1.0. Circuits containing inductive or capacitive elements (electric motors, transformers, solenoids) have a power factor below 1.0. The conversion of AC main supply to DC required to energise the system amplification inevitably means that reactive components are introduced i.e. the load is no longer resistive. In a linear power supply convertor, the major parts are:

i. The mains transformer, which steps down the AC voltage to a safe level [e.g. $48V_{DC}$] and also provides safety isolation to eliminate electric shock risk.
ii. The reservoir capacitors which filter the rectified waveform to a steady DC level.

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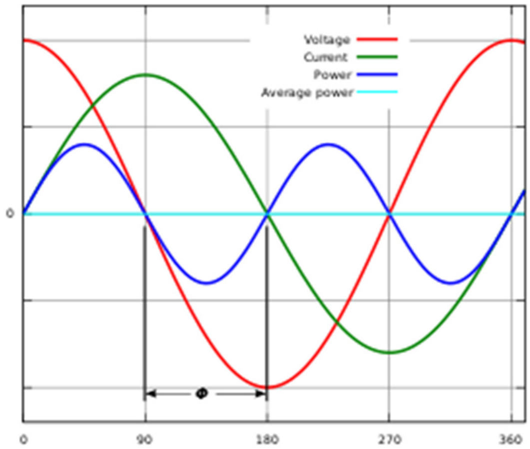
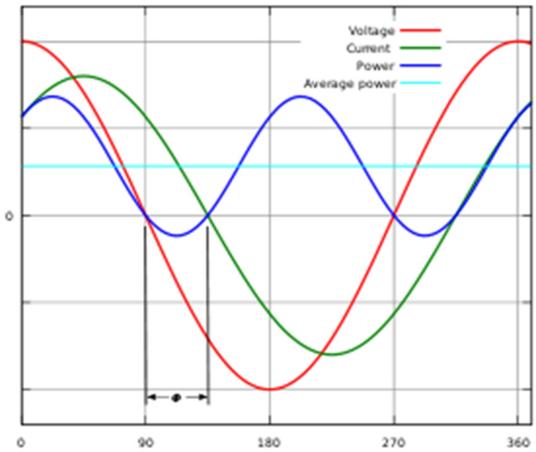
The transformer is highly inductive, and the smoothing filters capacitive. With reactive loads present, i.e. capacitors and inductors, energy stored in the load results in a time difference between the current and voltage waveforms. During each cycle of the AC voltage, extra energy, in addition to any energy consumed in the load, is temporarily stored in the power supply conversion hardware in electric or magnetic fields, and then returned to the AC mains power supply source a fraction of a second later in the cycle. The "ebb and flow" of this nonproductive power increases the current in the AC mains supply feeder. Thus, a circuit with a low power factor will use higher currents to transfer a given quantity of ‘real’ power than a circuit with a high power factor. A linear load does not change the shape of the waveform of the current, but may change the relative timing (phase) between voltage and current.



Instantaneous and average power calculated from AC voltage and current with a zero power factor ($\varphi = 90$, $\cos\varphi = 0$).

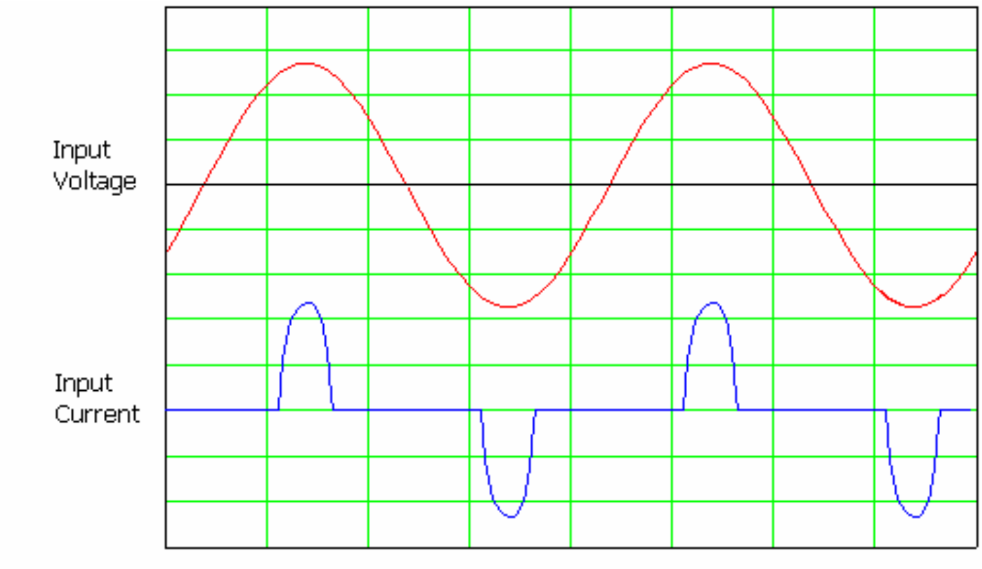
The blue line shows all the power is stored temporarily in the load during the first quarter cycle and returned to the mains supply during the second quarter cycle, so no ‘real’ power is consumed.



Instantaneous and average power calculated from AC voltage and current with a lagging power factor ($\varphi = 45$, $\cos\varphi = 0.71$).

The blue line shows some of the power is returned to the grid during the part of the cycle labelled φ.

In a standard linear power supply, i.e. a classic bridge rectifier full wave supply, the power factor is rarely greater than about 0.7, this is mainly due to the nonlinear current flow into the power unit caused by the way the bridge rectifier 'tops up' the smoothing/reservoir capacitors, i.e. the bridge rectifier only conducts during periods when the capacitor voltage falls below the terminal output voltage of the rectifier.



During times when the system is in quiescent and power demand is small the diode bridge connects the capacitor to the AC source when the voltage is near the peak, resulting in an abridged sinusoidal shaped current wave with current only flowing for about 1 to 2ms every half cycle. Although the current is nominally in phase with the voltage the distorted nature of the current waveform creates potential problems for the AC voltage supply.

To deal with this type of nonlinear load the term "'apparent' power factor" has evolved. The inclusion of the word "apparent" implies a nonlinear load and hence a non-sinusoidal current. This is still expressed in the same way as a 'real' power factor, as follows:

'Apparent' Power Factor = 'Real' Power / (RMS Voltage x RMS Current)

It is possible to apply correction to this basic linear approach and this is done by placing an inductor in series with the capacitor filters and an electronic switch. Since change in voltage cannot occur instantaneously due to the inductor then the peaks present in the basic design are removed.

Unfortunately, the inductor is costly and physically nearly as large as the transformer it is operating in conjunction with; both factors due to the operating frequency of the mains supply input either 50Hz/60Hz fundamentally.

In more recent times a more effective solution is the use of switch mode power supplies which operate at a high frequency. This reduces the size and costs of magnetics dramatically and enable the practical realisation of high power factor with reasonable size and cost.

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Switch-on Surge

In power supplies that use large reactive components – example the mains transformer, there is risk of very large inrush currents at the point of switch on. The peak of the in rush can be present for several cycles before decaying to the normal operating current. **Inrush current** refers to the maximum, instantaneous input current drawn by an electrical device when first turned on. When a transformer is first energized a transient current up to 10 to 50 times larger than the rated transformer current can flow for several cycles.

One of the consequences of a toroidal transformers' superior magnetic properties is that the transformer "remembers" what polarity the primary AC line voltage had immediately before the power was last shut off and consequently the core is magnetised accordingly. Whenever the line input voltage has the *same polarity* as the applied AC voltage when the transformer next is turned on, the core will saturate for part of a half-cycle, and a high in-rush current will flow in the primary of the transformer. Toroidal transformers (1.5KVA and higher) can have up to 80 times larger inrush than conventional transformers, because the remnant magnetism is nearly as high as the saturation magnetism at the "knee" of the hysteresis loop.

Eliminating switch-on surge in-rush is a very tricky design job as the requirements for fail safety conflict with fail safe design philosophy as applied elsewhere on the system. If the surge arresting circuitry is not carefully designed a latent fire hazard will result. By using switch mode technology, the large transformer necessitated by direct AC line frequency operation [e.g. 50Hz/60Hz] is eliminated and replaced by wound components and cores that are designed to operate at much higher frequencies thereby enabling:

i. Tiny physical foot print.
ii. Elimination of core saturation.

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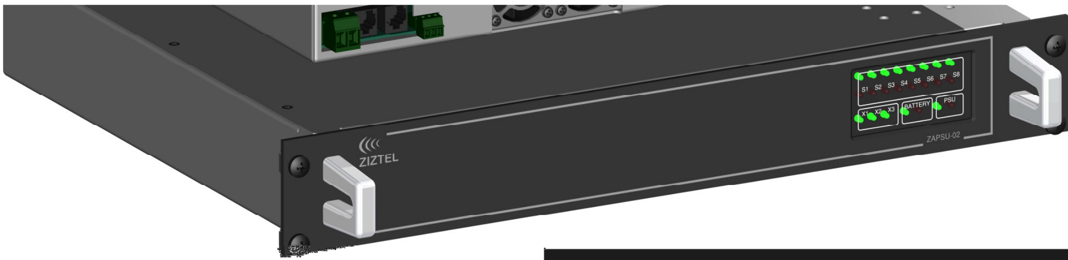
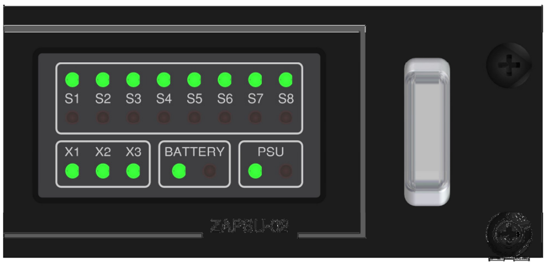
Ziztel ZAPSU-01 power unit shown. This unit takes linear power supply design to its ultimate progression. There are 5x PSU units housed in a 1U 19-inch case to energise 4x on line and 1x standby 350 Watt amplifier modules with staged switch on to eliminate surge.





Ziztel ZAPSU-02 design pioneers the use of switch mode digital technology to remove the detrimental factors present in standard linear designs. The result is:

i. *A high power factor – 0.9 being normal.*
ii. *Light weight – approximately 10% the weight of an equivalent linear unit.*
iii. *Elimination of in rush spikes.*

ZAPSU-02 switch mode power unit shown, this features 9x PSU outlets capable of powering 8x on line amplifiers and 1x hot standby.

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