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The power factor

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Ronny Schulze, Senior Engineer-Application Engineering at Infineon Technologies explores improving energy efficiency using dual sensor less FOC and active PFC

Improved energy efficiency and reduced system costs are the driving factors in modern motor control designs used in fans, pumps, compressors or geared motors. The implementation of sophisticated motor control concepts with sensor less Field Oriented Control (FOC) and Power Factor Correction (PFC) help to fulfil these demands. To demonstrate the capabilities of these powerful concepts Infineon has built a reference design for the motor control of air conditioners using dual sensor less FOC and active PFC based on its 16-bit microcontroller XE164.

FOC is a method to generate a three phase sinusoidal signal which can easily be controlled in frequency and amplitude in order to minimise the current which means to maximise the efficiency.

With FOC the efficiency of a motor can be improved significantly and raised up to 95%. This has a big impact on power consumption, motor dynamics, heat dissipation and noise. A sensor less FOC (figure 1 below) on BLDC (Brush Less DC motor) or PMSM (Permanent Magnet Synchronous Motors) provides additional cost benefits compared to sensor based motor control.

A BLDC has a permanent magnet rotor and a wound stator. The position of the coils (phases), with respect to the permanent magnet field, are sensed and the current switched electronically (commutated) to the appropriate phases. To sense the rotor position typically Hall Effect sensors are used. But the costs for an encoder or other position sensor can be saved, with sensor less approaches using the back EMF (Electromagnetic Force) of the motor to calculate the rotation angle and rotor position. The back EMF is calculated in the flux estimator, which is based on the voltage model of the system in the two phase reference frame. A single shunt is enough to reconstruct the phase currents.

Active and passive PFC

Most motor control systems use PFC at the first stage of the system to reduce the harmonic content and reactive power, thereby improving the power factor and overall efficiency.

There are two different kinds of power factor correction: passive and active PFC. Linear loads with low power factor (such as induction motors) can be corrected with a passive network of capacitors or inductors. This filter reduces the harmonic current, which means that the non-linear device now looks like a linear load. A passive power factor correction is used for low loads (typically less than 100W) because this filter requires large-value high-current inductors, however, which are bulky, expensive and the power factor at the end is barely acceptable.

Non-linear loads, such as rectifiers or SMPS, distort the current drawn from the system. In such cases, active power factor correction is used to counteract the distortion and raise power factor. An active PFC is a power electronic system that controls the amount of power drawn by a load in order to obtain a power factor as close as possible to unity.

In most applications, the active PFC controls the input current of the load so that the current waveform has the same frequency, phase and shape as the mains voltage with no additional harmonics. Active power factor correctors can be single-stage or multi-stage. This approach is more complex but results in

a really good power factor (0.99). A power converter adapts the used current to the sinusoidal input voltage taken from the power net. This active PFC circuit is typically a boost converter connected after a rectifier, using a capacitor boosted to a voltage level higher than the nominal rectified voltage (typ. 350-400V). In some applications passive and active PFC is combined.

For example, motor drives with passive PFC can achieve power factors of about 0.7-0.75 and with active PFC of 0.98 and more, while a system without any power factor correction has a power factor of only about 0.55-0.65. With active PFC variations of the AC line voltage can be balanced and often the related devices can be adjusted to operate on AC power, about 100V (Japan) to 230V (Europe). A power factor corrected boost converter with continuous mode operation can decrease the total harmonic distortion with simple circuit and easy control method.

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. When being charged it acts as a load and absorbs energy (somewhat like a resistor), when being discharged, it acts as an energy source. The voltage produced during the discharge phase is related to the rate of change of current, and not to the original charging voltage, thus allowing different input and output voltages to the boost converter.