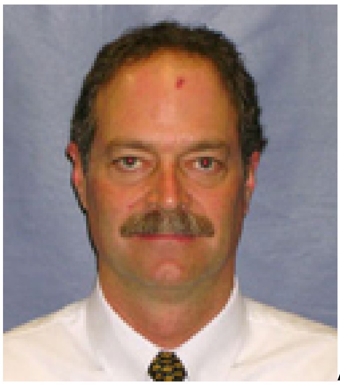
Variable Speed Technology Improves Power Factor, Boosts Grid Reliability

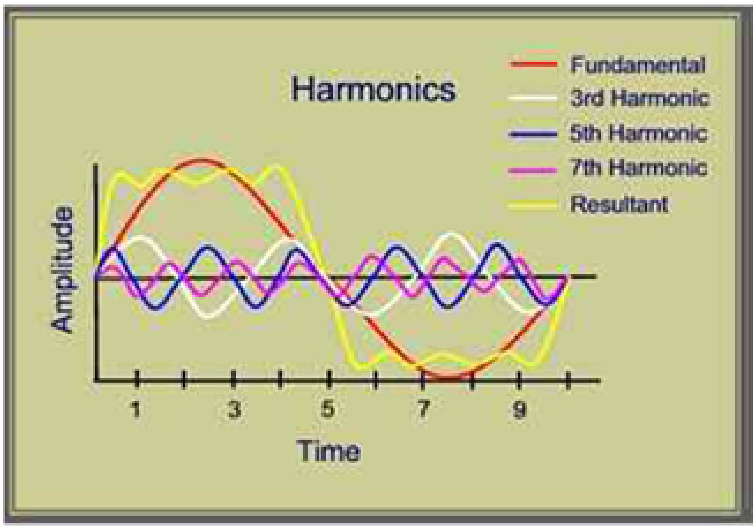
Dan Schillinger, Business Development – Variable Speed, Danfoss VLT Drives



Air conditioning is responsible for approximately 20 percent of the total U.S. annual electricity consumption*. The introduction of variable speed drive (VSD) technology to residential air-conditioning and heat pump systems presents an opportunity for significant energy savings due to efficient part load operation, but also facilitates the improvement of power quality on the grid. Power quality, often represented by power factor, is important as a measure of how hard the utility must work to delivery electricity.

To understand the impact of power factor on the power grid we must first define the two types of loads that draw power: linear and non-linear. Linear loads, such as AC motors, draw a sinusoidal current from the grid which is proportional to the voltage but not necessarily in phase. Power consumed by the linear AC motor flows continuously while the load is energized. Non-linear loads draw current that is not in a sinusoidal wave form due to the power being consumed in pulses. A non-linear load, like those in PC power supplies and VSDs, continuously switches line power on and off to regulate power delivered to the energized device. Because the non-linear load consumes power in pulses, harmonic ripples can feed back upstream through the power grid transmission lines. These harmonic disturbances create transmission losses since the grid, as a result, must work harder to push useful current past this distortion to the device.

Power factor is a ratio of real power -- what is used by the device -- to apparent power -- load present in the circuit. Power factor (real power/apparent power) is a dimensionless number between 0 and 1. Apparent power is the product of current and voltage in a circuit while real power is the measure how much useful work is produced in the circuit. A linear, pure resistive load will have a power factor of 1 versus an induction motor with a typical range of 0.70 up to 0.90. A VSD can have a power factor as low as 0.60 if not corrected. Left uncorrected, harmonics created by a VSD increase apparent power at a higher proportion than real power. Fortunately, however, methods exist to suppress harmonics in order to increase VSD power factor.



Caption: Fundamental (or 1st harmonic) current contribution at mains frequency (60Hz).
3rd: current at 180Hz
5th: current at 300Hz
7th: current at 420Hz
The current is decreasing with the higher order of harmonics.

Power factor correction (PFC) is common for applications involving VSDs. Typical harmonic suppression methods for PFC are AC line reactors, DC inductors and Active Power Factor Correction. When AC line reactors are used, a large choke or coil is installed in the power line to the drive. The reactance of the choke dampens the harmonic currents, smoothing the distortion being fed back into the power grid. DC inductors, alternatively, require the installation of two smaller chokes in the intermediate circuit (DC-link) of the drive to smooth the distortion. Both AC line reactors and DC inductors are passive correction methods where the larger the coil, the greater the correction impact. Larger coils, most typically copper in makeup, add cost, size and weight and, though simple, may not be the most cost effective option. AC inductors also have one significant disadvantage in that they borrow voltage from the motor, thus decreasing efficiency.

Active PFC, a more sophisticated and versatile method for suppressing harmonics, requires a smaller inductor on the supply side of the drive be energized with a dedicated set of fast switching transistors. By working together, the inductor and transistors shape the current to be very close to sinusoidal, minimizing harmonics generated by the non-linear VSD load. Active PFC is managed by a control circuit which, depending on the speed and load condition of the drive, can be switched off in instances of low harmonic currents. Active PFC solutions require less copper, reducing size, weight and costs while providing power factors up to 0.98.

Other benefits of active PFC include:
• Boosts the immediate circuit voltage whenever necessary which improves operating capabilities at low supply voltages.
• Increases voltage within the AC inductor, reducing current and stress throughout the entire chain of VSD power components while minimizing costs.
• The higher DC-link voltage reduces motor current and losses.
• The PFC can be switched on and off as desired for best system efficiency.

With active PFC in mind, variable speed technology presents HVAC OEMs with versatile solutions, especially as the United States and industry move to create a smarter power grid. Focusing on improving power distribution by increasing power factor of the grid can encourage new standards for power grid cleanliness. For electric utilities, this equates to fewer losses and improved reliability of service. For homeowners, this means more efficient equipment with the possibility of local utility, state and/or federal incentive programs for equipment that provides even better levels of home comfort.

*Source: Department of Energy