Low Harmonic Variable Frequency Drive

Improves Cost and Energy Efficiency of High-power AC Motors

AC induction motors are the workhorse of the industrial age. They are ubiquitous on a wide range of motor applications including HVAC (Heating Ventilation and Air Conditioning), water pumping and industrial motor drives. Two-thirds of the world's industrial electricity runs electric motors and only 5% of these use variable speed drives, which consume ⅛ the energy of constant speed drives.[1]

AC induction motors are reliable and inexpensive, but are energy inefficient particularly under light loading conditions. An AC induction motor used in an air handling application can consume 10x more electric power than its purchase price over its lifetime, providing an attractive opportunity to reduce lifetime system costs through improved efficiency.

Variable Frequency Drives (VFD) are mature products that enable AC induction motors to operate at variable speed to match light loads and reduce energy requirements by 50% or more. In spite of the dramatic efficiency improvement VFDs are not used universally on large AC induction motors primarily due to technical issues resulting from their generation of high energy harmonics.

Ideal Power Converters (IPC) has developed and patented a VFD (Variable Frequency Drive) motor-control solution for AC induction motors that eliminates the damaging harmonics found in conventional VFD systems. The IPC VFD delivers a utility quality sinusoidal voltage to the motor without these harmonics, resulting in improved system energy and cost efficiency.

IPC has a fully operational 20 horsepower VFD, which has been operating in a field installation since July 2010 with a non-inverter grade AC induction motor. This pilot test was established with the support of Austin Energy and the City of Austin. A photo of the pilot system is shown.

The **major benefits** of IPC's low harmonic VFD include:

- The IPC VFD can reliably use **low cost (non-inverter grade) AC induction motors** since little damaging harmonic energy is created and transferred to the motor. This also enables simple, low cost efficiency upgrades on non-VFD motors as it eliminates the requirement to replace the existing motor with a new more expensive inverter grade motor.

- The IPC VFD is **inherently IEEE 519 compliant eliminating the need for expensive utility filters** to protect the power grid and other equipment. Even in cases where IEEE 519 filters are not required, engineering studies may be required to prove this. Since IPC VFD's are inherently IEEE 519 complaint at the drive, these filters and studies are not required.

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- The IPC VFD is **more energy efficient** than a conventional VFD. Conventional VFD's waste energy in harmonics that must be dissipated in the VFD, motor or utility filter. The IPC VFD does not create these harmonics at the source, eliminating the energy loss.

- Motors using the IPC VFD **operate quietly** like induction motors running directly on utility lines. Both utility line driven motors and IPC VFD controlled motors see a smooth sinusoidal voltage waveform. Motors using conventional VFD's are noisy due to harmonic dissipation in the motors and may require hearing protection by maintenance personnel.

- **System reliability** is improved. Due to lower motor electrical stress, a standard AC motor driven by the IPC VFD will operate more reliably than even an expensive inverter grade motor driven by a conventional VFD. The IPC VFD also eliminates all electrolytic capacitors, the components that normally fatigue and fail in conventional VFD systems.

AC Induction Motor and VFDs

A comparison of AC induction motors driven directly by utility power, a conventional VFD, and IPC's VFD are discussed. In the first example a standard AC induction motor is driven directly by utility power. The motor rotation speed is fixed at a fraction of 60Hz, the utility frequency, depending on the number of poles designed into the motor. The motor runs quietly from sinusoidal utility quality power to deliver air or fluid flow.

The directly driven motor is widely used and inexpensive to purchase, but it produces flow at low efficiency.

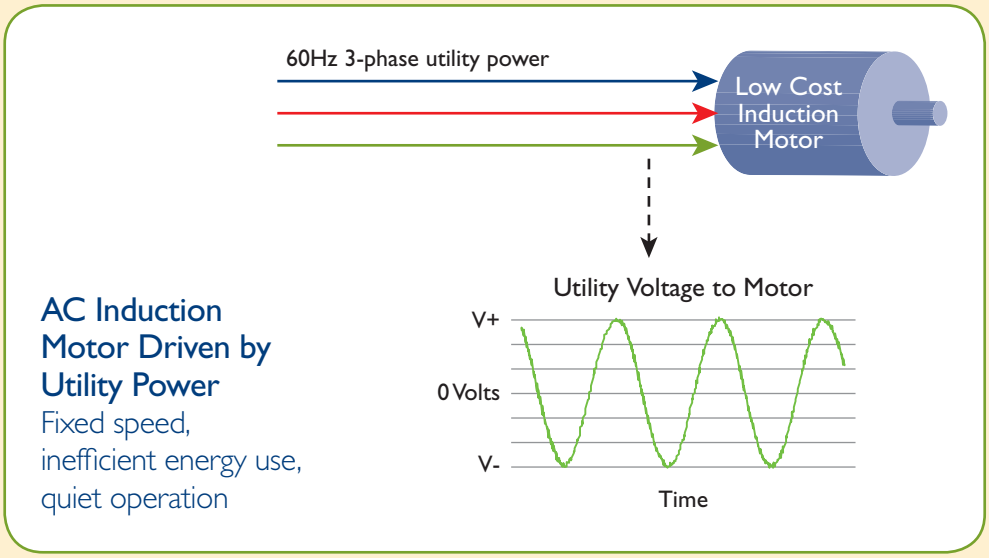
Conventional VFD

The energy efficiency of an AC induction motor and fan or pump combination can be improved by up to 80% by matching the rotational speed and torque of the motor to the loads. Fans and pumps run much more efficiently at reduced speeds on partial loads, so it is highly desirable to run AC motors longer at reduced speed, instead of throttling the fan or pump.

A conventional Variable Frequency Drive (VFD) motor control system is illustrated. A VFD is a power converter system that changes fixed frequency utility AC power to variable frequency power that can drive a motor at variable speed to more efficiently match motor loads. Conventional VFDs use a Pulse Width Modulation (PWM) output that switches thousands of times per second between maximum and minimum voltage. The sharp voltage transitions create high levels of harmonic energy that is produced both on the output to the motor as well as the VFD input from the power grid.

The high energy harmonics will rapidly degrade low cost non-inverter grade AC induction motors. Special inverter grade AC motors have been developed, which include different installation and other material changes to enable these motors to work with PWM inputs with high harmonic energy. Inverter grade AC motors act as both a PWM filter and a motor, and cost significantly more than non-inverter grade AC motors.

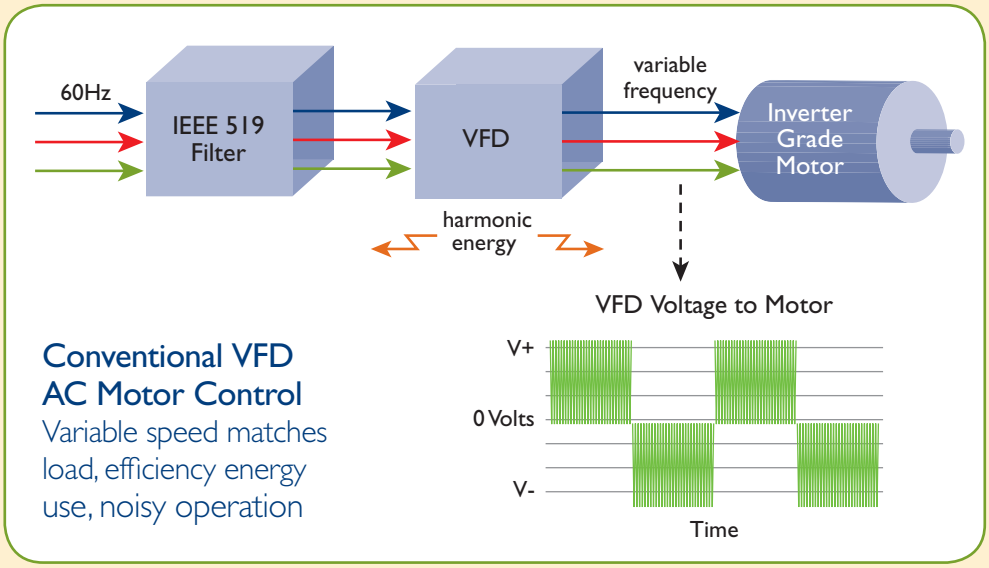
The harmonics are also generated backward to the utility grid. Large VFD motors, such as commercial chillers,



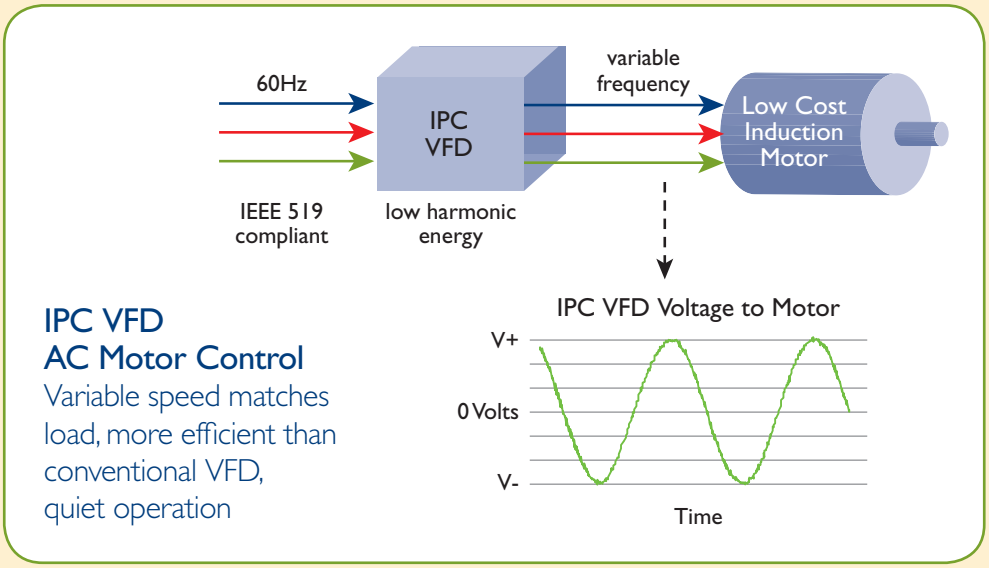
AC Induction Motor Driven by Utility Power
Fixed speed, inefficient energy use, quiet operation

may therefore require IEEE 519 complaint filters to protect the power grid from its harmonic energy. IEEE 519 filters can weigh and cost more than the VFD controller. For many applications IEEE 519 filters may not be required, but an expensive engineering evaluation may be required to determine this. The harmonics also create radio frequency emissions that can generate control problems in facilities with large VFD's.

VFD's used with inverter grade motors also operate loudly. This is a side effect of the motors dissipating the damaging VFD harmonic energy.



Conventional VFD AC Motor Control
Variable speed matches load, efficiency energy use, noisy operation



IPC VFD AC Motor Control
Variable speed matches load, more efficient than conventional VFD, quiet operation

IPC VFD

The patented IPC VFD solution does not use Pulse Width Modulation, but instead directly creates a utility-quality sinusoidal voltage output without additional filters. This also eliminates the damaging harmonics both to the AC induction motor as well as backward to the utility grid.

A standard AC induction motor requires a sinusoidal voltage input and therefore can be used with the IPC VFD. The IPC VFD may be particularly attractive for upgrading existing non-VFD motors systems to higher efficiency VFD without the added expense of replacing the motor with an inverter grade motor. Also unlike conventional VFD solutions, the motors controlled by the IPC VFD run quietly, similar to motors running utility power.

The IPC VFD eliminates the damaging harmonics from conventional VFD's at the source and is inherently IEEE 519 compliant. This eliminates the need for expensive IEEE 519 filters and harmonic studies. Radio Frequency Interference is also eliminated.

Since no energy is lost in creating powerful harmonics, the IPC VFD is more energy efficient than conventional VFD's.

Other Benefits of IPC's VFD

- The IPC VFD can also provide motor voltages above the line voltage (460V, +/-10%), which maintains optimum motor efficiency during low utility voltage conditions. In addition, the IPC VFD is more stable than a conventional VFD as it will not drop out from input voltage sags.

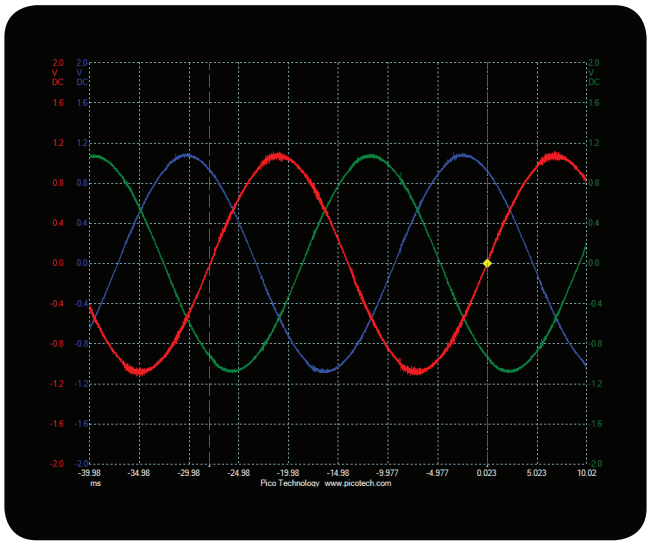
- VFD systems often have relative short lifetimes of only a few years, largely due to the use of electrolytic capacitors. By eliminating all electrolytic capacitors, and using only more reliable film capacitors, the IPC VFD may substantially increase lifetime to 10 years or more.

- The IPC VFD is inherently hardened against input voltage transients, as it's switch topology allows it to survive input voltage transients up to 1800 volts, or about 50% more than what a conventional VFD can handle.

- Since the IPC VFD delivers utility-quality sinusoidal output to the motor, there is increased installation flexibility by allowing long motor runs between the IPC VFD and the non-inverter grade motor. Conventional VFDs must be located very close to the inverter grade motor.

IPC VFD Output Signal

The following screen capture shows the actual output voltage waveforms of the IPC VFD running at 38Hz. All 3 phases are shown. The system delivers utility quality sinusoidal output directly to a non-inverter grade AC induction motor.



Conclusion

IPC's VFD pilot test demonstrates that its low harmonic VFD can directly control standard non-inverter grade motors. This low harmonic VFD technology is particularly attractive for retrofitting existing large non-inverter grade motors such as commercial chillers to obtain the energy-efficiency benefits of variable frequency control at much lower upgrade costs than conventional VFD solutions.

REFERENCES

1. Semiconductor Industry Association "Doing More with Less"