

Low Harmonic Variable Frequency Drives

Improves Cost and Energy Efficiency of High-power AC Motors

Summary

Ideal Power Converters 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 provides a utility quality sinusoidal voltage to the motor without these harmonics, which present the most significant industry problem of variable frequency control of AC induction motors. The end result is both greater cost and energy efficiency in high-power AC motors in applications such as commercial HVAC chillers, residential HVAC systems, air handlers, municipal water pumping, and industrial motor drives.

Major benefits of the IPC VFD

- The IPC VFD can drive standard, 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 inverter grade motor designed to handle the harmonics from conventional VFD's.
- 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.
- The IPC VFD is more energy efficient than a conventional VFD. Conventional VFD's waste energy in creating 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 run quietly like induction motors running directly on utility lines. Both utility line driven motors and IPC VFD control 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.

IPC has a fully operational 15 horsepower VFD undergoing pilot testing in cooperation with Austin Energy and the City of Austin. A photo of the pilot system is shown in Figure 1.

Figure 1. IPC 15hp VFD System in Pilot Testing



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 below. Figure 2 shows an AC induction motor driven directly by utility power. It operates from utility frequency power, 60Hz, in North America. The rotation speed is fixed at a multiple of 60Hz depending on the number of poles designed into the motor. The motor runs quietly from sinusoidal utility quality power.

This type of motor is widely used and inexpensive to purchase, but it operates at very low efficiency.

**Figure 2. AC Induction Motor Driven by Utility Power
Fixed speed, inefficient energy use, quiet operation**



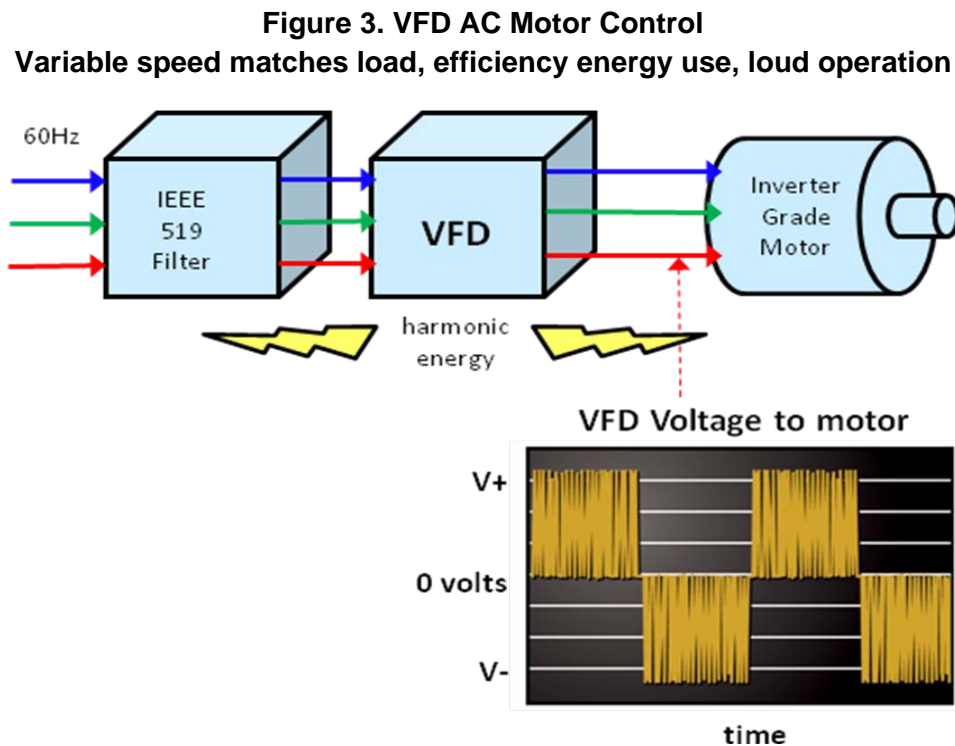
Conventional VFD

The energy efficiency of an AC induction motor 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 partial loads, so it is generally desirable to run AC motors longer at low speed, instead of cycling them between off and full power.

Figure 3 shows a conventional Variable Frequency Drive (VFD) motor control system. A VFD is a power converter system that changes fixed frequency utility AC power to variable frequency power that can drive the motor at variable speed to match loads. Conventional VFD's use a Pulse Width Modulation (PWM) technology that switch rapidly between ground (0 volts) and full voltage (either positive or negative). The resulting sharp voltage transitions and harmonics delivered by the conventional VFD would destroy standard AC induction motors and therefore require more expensive inverter grade motors to be used.

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



IPC VFD

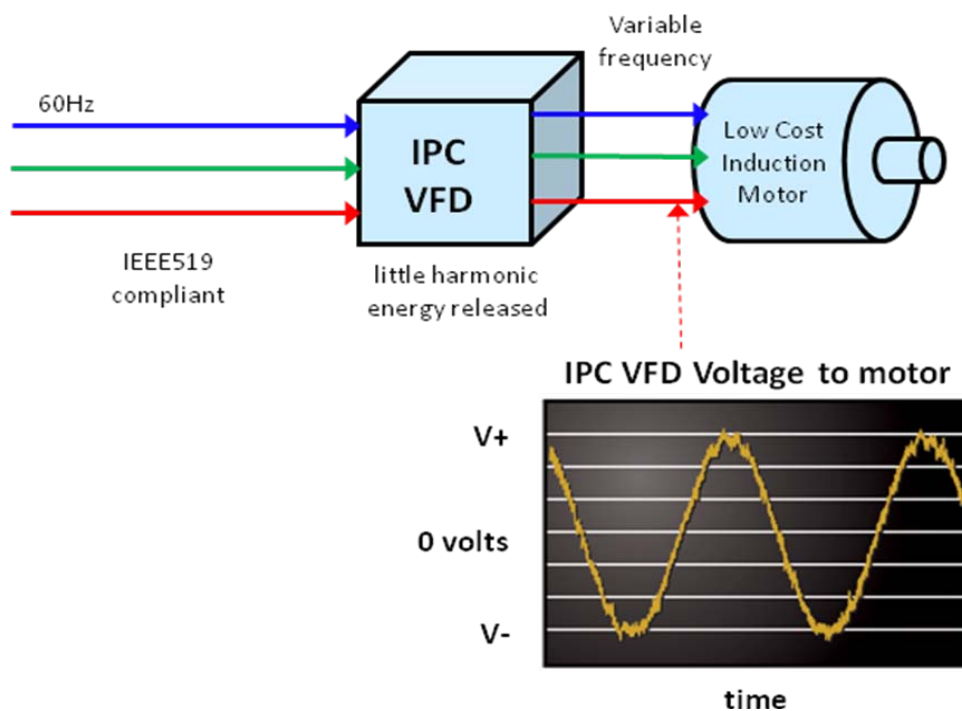
The patented IPC VFD solution does not use Pulse Width Modulation, but instead creates a utility-quality sinusoidal voltage output without additional filters. This also eliminates the damaging harmonics both to the AC induction motor as well as backward to the utility grid.

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.

Figure 4. IPC VFD AC Motor Control
Variable speed matches load, more efficient than conventional VFD, quiet operation



Other Benefits of IPC VFD

1) The IPC VFD can also provide motor voltages above the line voltage (480V, +/-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.

2) 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 relative small film capacitors, the IPC VFD may substantially increase lifetime to 10 years or more.

3) 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.

Conclusion

The paper provides a basic description of VFD technology and how the patented IPC VFD solution offers both improved energy and cost efficiency. IPC VFD's are 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 costs than conventional VFD solutions.