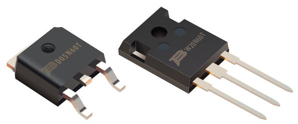
APPLICATION NOTE

IGBTs in Frequency Changing Applications



Bourns® BID Series IGBTs

INTRODUCTION

In power systems, Insulated Gate Bipolar Transistors (IGBTs) are excellent solutions for changing AC power frequency from one voltage and frequency to another. For example, IGBTs are particularly well-suited to change power from 50 Hz to 60 Hz in power equipment rated at only 60 Hz operating in locations where the mains frequency is 50 Hz. This function was previously only available in large, heavy, and expensive motor-generator sets. Solving this functional design challenge by implementing solid-state IGBTs in a frequency changing application has been shown to provide a low cost, lightweight assembly, and high reliability solution.

The purpose of a power frequency conversion apparatus is to allow equipment rated for only one power frequency to operate in locations that are supplied with a different mains frequency. The power frequency conversion will take power from the supplied utility and supply power at the AC frequency needed for the customer's equipment to operate. These frequency converters are commonly found in industrial shops and manufacturing plants for powering industrial robotic operations and enabling repair of various electronic instruments and equipment. Bourns® IGBT devices are ideal for highly reliable and efficient power frequency conversion functions with low loss.

This white paper outlines the many advantages of using IGBTs as the switching elements in the frequency conversion unit. It also highlights how frequency conversion can benefit an Uninterruptible Power Supply (UPS) so it can be designed to be smaller, lighter weight, and more efficient due to reduced power losses and enhanced thermal performance. The result is a simplified circuit design with fewer components to fail, contributing to increased operational reliability and higher Mean Time Between Failure (MTBF) of the completed application while helping to reduce overall Bill of Material (BOM) costs.

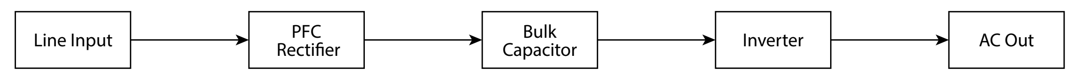


Figure 1. Frequency converter power flow

A frequency converter needs two power stages as shown in Figure 1. The first requirement is for a Power Factor Correction (PFC) rectifier to take power from the available AC mains. The second requirement is for a power inverter to supply power at the desired frequency. This white paper shows the design of one implementation of a frequency converter that supplies 10 kW.

As shown, the PFC rectifier stage supplies the rated power to the bulk storage capacitor as it maintains the harmonic current at a low level. The output inverter takes the power from the 380 VDC on the bulk capacitor and changes it to 240 VAC out at the desired frequency. Note that the PFC rectifier stage will operate on any supplied mains frequency.

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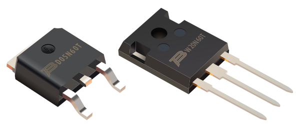

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HOW THE PFC CHANGE AFFECTS AC LINE VOLTAGE

The PFC section takes power from the AC line of 208 to 250 VAC_{rms} at 50 or 60 Hz to charge the bulk capacitor to a nominal 380 VDC as the IGBTs switch from 40 to 80 A. Two IGBTs are used in parallel for each switch to reduce the conduction loss and to withstand the peak current. The controller achieves a near-unity power factor by shaping the AC input line current waveform to correspond to that of the AC input line voltage. The controller for the PFC stage implements average current mode control using inputs from the input AC voltage, input line current, and output DC voltage. This control method maintains low distortion sinusoidal line current, which, in turn, minimizes the input harmonic distortion.

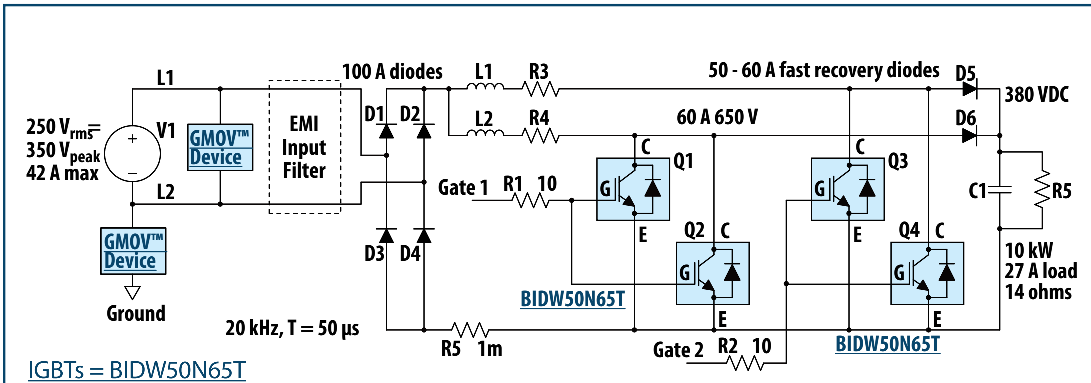

Figure 2. | *10 kW rectifier block diagram showing PFC switching section for an AC line to 380 VDC*

Figure 2 illustrates the PFC switching section for the 10 kW rectifier. It begins with protection from power line surges by using a Bourns® GMOV™ Hybrid Protection Component, has an EMI filter to comply with line harmonic energy requirements, and includes a full wave bridge rectifier. Two chokes (L1 and L2) operate with the IGBT switches (Q1 through Q4) implemented using Bourns® Model BIDW50N65T IGBT to allow current to pass. The load R5 represents the load for the PFC rectifier.

The Gate 1 and Gate 2 controls are timed so they pass current when the line voltage is available to supply it. The gates are enabled by calculating when the AC line is capable of delivering current to the load and using the Pulse Width Modulation (PWM) technique will regulate the voltage on the bulk storage capacitor C1. Current is taken from the line in phase with the voltage, thus providing a phase-corrected load on the line. The basic IGBT active period is calculated from a constant frequency, typically around 20 kHz.

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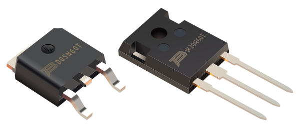

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DC TO AC INVERTER 10 KW

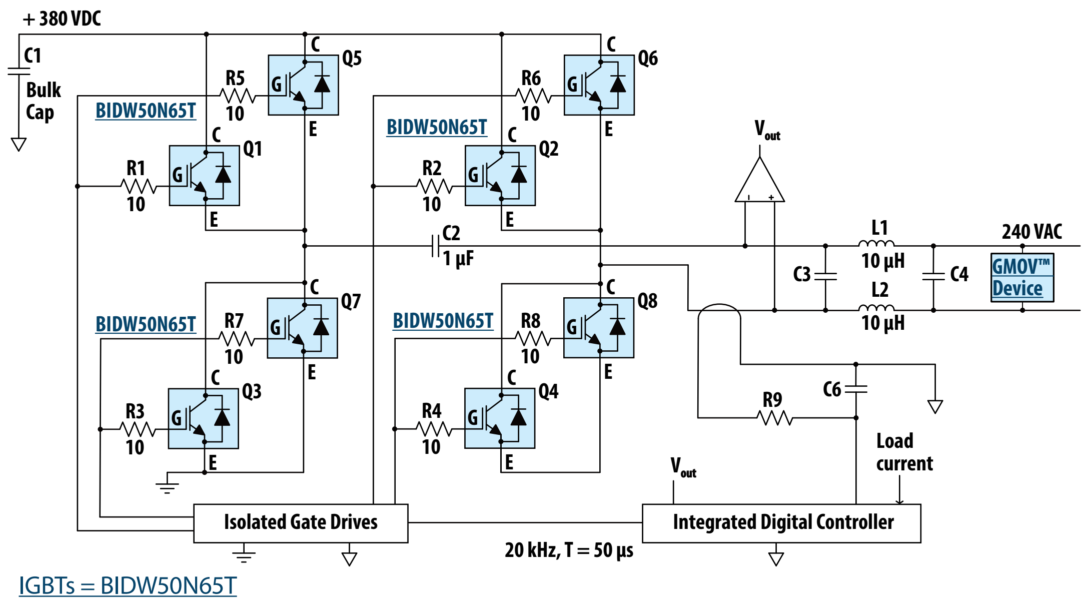
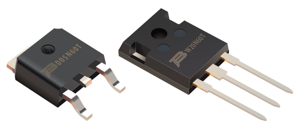


Figure 3. | *Inverter from 380 VDC to 240 VAC$_{rms}$ at the desired frequency, 50 Hz to 60 Hz*

Figure 3 shows a full-bridge direct drive inverter that is used to switch from 380 VDC to 240 VAC output. The integrated digital controller uses the synthesized AC voltage and current waveforms to control the gate drives for the H-bridge switches. The switching phases are calculated from the internally-calculated power frequency waveform and referenced to an internal 20 kHz clock. Frequency stability and a narrow tolerance of the resultant AC waveform frequency is provided by the stable frequency control.



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CONCLUSION

Using appropriately-rated IGBTs in the PFC rectifier that supplies power to a DC to AC inverter yields an instrument that provides a power line frequency changing function. These instruments are useful for varied power frequency conversion applications such as the following:

- Converting AC mains frequency from the commercial supply to a frequency needed for equipment used in a local plant
- Implementing a Variable Frequency Drive (VFD) for pump and fan motor variable speed control
- Providing the needed power frequency for webcam, video, and other entertainment equipment in countries other than where it was designed for

Employing IGBTs to perform as switches and rectifiers, together with various diodes and magnetic components, makes versatile power frequency changing units that are lightweight and efficient. Taking this approach to design next-generation digital control circuits helps streamline the control and tuning of the gate controls in the conversion circuits so that the highest efficiency is achieved. Bourns® Model BID Series IGBTs offer the advanced features necessary to allow the circuits to function with minimized high frequency noise and also to help reduce the number of components required to facilitate lower total BOM costs. Combined with the ease of driving the gates the same way as MOSFETs, utilizing Bourns® Model IGBTs makes designing the complete frequency changing application circuit a relatively straightforward process with high efficiency.

See the Bourns website for complete specifications and other application information.

ADDITIONAL RESOURCES

- Product Page: Bourns® Discrete IGBTs
- Technical Library: Bourns Discrete IGBTs
- Product Page: Bourns® GMOV™ Hybrid Protection Component
- White Paper: Understanding IGBT Data Sheet Parameters
- White Paper: Achieving Fast IGBT Reverse Recovery Loss
- White Paper: Measuring IGBT Conduction Loss to Maximize Efficiency
- White Paper: Bourns® IGBT vs MOSFET - Determining the Most Efficient Power Switching Solution

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