IGBTs & Digital Power Quality Logic

To achieve the highest degree of UPS efficiency, performance and quality, it is important to have both IGBT inverter modules and components in combination with MGE's advanced Digital Power Quality control logic. The combination utilizes the full benefits of the IGBT, providing users with high efficiency resulting in significant savings in utility costs, superior output performance, and ease of installation and serviceability.

What are IGBTs: IGBTs (Insulated Gate Bi-polar Transistors) are specialized transistors designed to switch a very large amount of current (up 1,000 Amps) with a very small control signal (high gain). Commonly used in thousands of power electronics applications, IGBTs offer many benefits over traditional solid state power control devices such as Bi-polar Transistors and SCRs (Silcon Control Rectifiers) still used on many step wave type UPSs. Among the advantages include: faster response/switching time, higher current carrying capacity, smaller footprint, increased surge tolerance, less support circuitry to control than other devices and above all, higher energy efficiency.

IGBT Advantages

- Lower Switching Losses: The key benefit of the IGBT technology is the minimal power required to switch the transistor on and off. As a result IGBTs provide lower power switching losses and consumes less power overall, thereby providing higher operating efficiencies resulting in annual utility cost savings.
- Smaller Component Size: The IGBT component and associated drive circuitry that makes up the UPS inverter is significantly smaller than on older SCRs and bi-polar transistors inverters. The smaller inverter modules ultimately translate to a smaller overall UPS footprint and easier of serviceability.
- Highly Reliable Components: State-of-the-art manufacturing and packaging make IGBTs highly reliable. The simplified control circuitry used for switching IGBTs requires a extremely low parts count when compared to the controlled circuitry associated with SCR or bipolar transistors, improving the reliability of the inverter and UPS module.
- Faster Switching: A low on state saturation voltage allows IGBTs to switch on and off very rapidly compared to SCR's and Bipolar devices. Slow switching responses cause devices to be less controllable, not meeting the timing requirements necessary to provide superior dynamic responses needed to form a linear power output. While many UPS manufacturers utilizing IGBT's take advantage of the high current density, and reduced support circuitry requirements, MGEs use of IGBTs centers around their fast switching capabilities. By taking full advantage of t he fast switching capabilities, MGE has developed inverters capable of immediately responding to just about any load condition without distorting the output power.

IGBTs Compared to Other Technologies

Characteristic	SCR	Bipolar Trans.	IGBT
PWM Suitability	Poor	Good	Excellent
Parallelability	Complex	easy	Easy
Switching Speed	Very slow	fast	very fast
Shut-off	Very complex	easy	very easy
Drive Circuit	Very simple	complex	Simple
Surge Tolerance	Low	high	very high
Device Cost	Low	high	High

The DPQ/IGBT Technology Combination

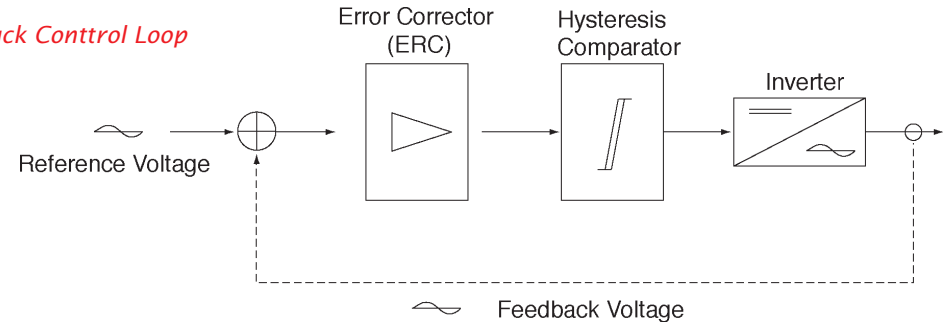
Replacing conventional bi-polar transistors or Silicon Control Rectifier (SCR) inverter components in UPS systems does little more than reduce overall system cost. By themselves, IGBTs provide the UPS with marginally better reliability, but do not truly improve performance. To achieve a meaningful performance improvement, IGBTs must be used with a control logic that takes full advantage of their fast and hard switching characteristics. Using an exclusive Digital Power Quality (DPQ) control logic, MGE utilizes the switching capabilities to provide a UPS that offers superior output performance, industry leading reliability and significant savings in annual utility costs.

To support today's loads and operate effectively in hard switching applications, UPS inverters must include both IGBT inverters and fast switching logic. When IGBT technology for UPS devices is combined with MGE's advanced Digital Power Quality control logic circuitry, the results are the highest quality output voltage and the highest efficiency possible.

Digital Power Quality Control Logic

DPQ Logic Real-time Feedback System: At the heart of a MGE UPS is Digital Power Quality (DPQ) control logic. Using a real time feedback control loop, the Digital Power Quality control logic constantly monitors the output voltage and waveform, comparing it to a perfect reference sine wave [see figure 1]. The DPQ control logic manages the switching frequency of the PWM inverter to match the output of the UPS to this reference sine wave for the lowest possible output voltage distortion as well as optimizes the switching to wave match load demand, achieving the highest efficiency. The DPQ logic with the feedback control loop used in MGE UPSs are composed of five key components: Pulse Width Modulated (PWM) IGBT Inverter, voltage reference signal, feedback control circuitry, the error corrector value, and hysteresis comparitor.

Figure 1 Feedback Conttrol Loop

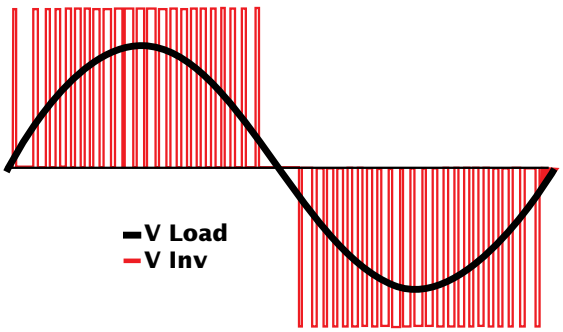


Pulse Width Modulated IGBT Inverter (PWM)

The UPS inverter to uses Pulse Width Modulation or PWM technology to generate the output waveform. In simple terms PWM breaks the output waveform into many highly controlled pulses, which when put together make a very fine resolution output waveform. Each pulse is highly regulated as to duration (frequency), amplitude & many other factors. By having total control over the shape of each pulse, the inverter can control the output waveform to instantly respond to load changes and still form a perfect sine wave, eliminating output distortion.

PWM provides a far superior response to dynamic loads over IGBT UPSs using step wave outputs whose resolution may not be fine enough to generate the required enough output voltage when exposed to heavy step load changes. PWM technology also optimizes efficiency by matching the load pattern in fine detail on non-linear (electronic) loads.

Figure 2 Pulse Width Modulation Output



PWM technology allows MGE UPSs to limit output distortion to under 3.5% on a 100% step load (0-100% of capacity instantly), even when powering non-linear loads.

Voltage Reference Signal: The voltage reference signal is a pure sine wave generated by the control logic to match the frequency and voltage of the UPS output voltage. This signal is compared to the output waveform of the UPS in the feedback control circuitry. The inverter switches as needed to match the output sine wave to the pure reference sine wave.

Feedback Control Circuitry: The feedback control loop constantly compares the waveform of the UPS output to the voltage reference signal. Transistor switching occurs when the output voltage crosses over the upper or lower hysteresis limits around the reference signal [see figure 3]. When the value of the output voltage crosses over the lower hysteresis limit, the positive inverter transistor turns on. This increases the output voltage until it crosses the upper threshold, at which point the negative transistor turns on and the positive turns off and the cycle repeats itself. In this way, the inverter voltage closely follows the reference voltage. While phase control feedback loops are a classical control technique, MGE has optimized the switching performance to load demand via a proprietary control algorithm, the Error Corrector (ERC)/Hysterisis Comparitor/ DPQ algorithm.

Error Corrector (ERC)/Hysterisis Comparitor/ DPQ Algorithm: The ERC value is composed of a proportional and derivative correction factor that is created from the difference between the output voltage and the reference voltage. This value is compared to a hysterisis level that results in transistor switching. By adjusting the levels of correction in the ERC circuit via a proprietary control algorithm, the amount of transistor switching is increased or decreased. This, subsequently, has a direct relationship to the inverter switching voltage regulation and efficiency.

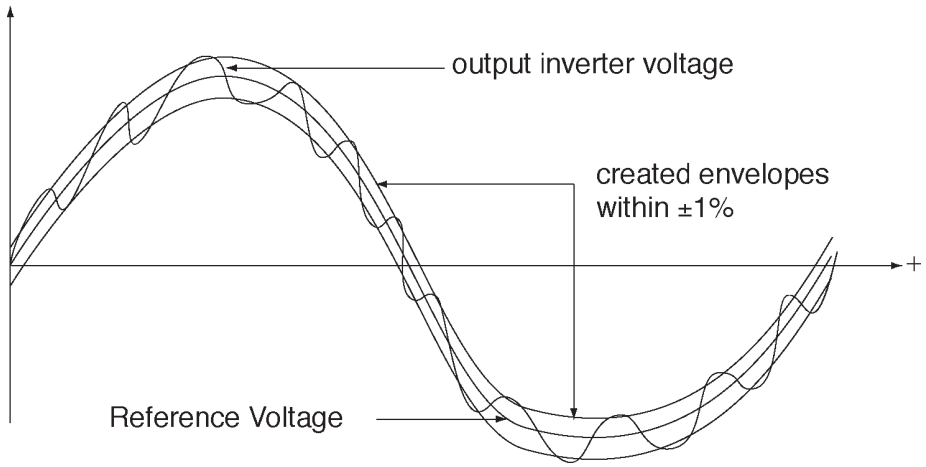


Figure 3 Correction and Hysterisis

Able to adapt to rapidly changing system load conditions, the PWM IGBT inverter combined with DPQ logic can handle harsh load conditions found today's electronic (non-linear loads). The result is superior output voltage quality and maximum operating efficiency. Under step load or non-linear load conditions, DPQ control logic switches the PWM inverter at higher speeds for fast response with low distortion to provide instantaneous load correction. Under less severe load conditions, DPQ slows the PWM inverter frequency for high efficiency operation. DPQ logic optimizes the inverter's switching performance to match load demand via a proprietary control algorithm. In this way, switching is kept constantly at the lowest possible frequency to keep losses at a minimum and to maximize efficiency. The DPQ control logic controls the switching rate to meet the demands of the load as rapidly as possible & provides tight voltage regulation for critical loads without the penalty of low efficiency. The DPQ/IGBT combination endows MGE Uninterruptible Power Supplies with a superior set of

Efficiency

- *High efficiency.* The DPQ/IGBT combination provides MGE UPSs with an efficiency rating as high as 95%. Typically one to three percentage points higher than competitive UPS devices, this extremely high efficiency rating can equate to utility cost savings of ten of thousands of dollars annually.

Superior Output Performance

- *100% Step Loads:* MGE UPSs can operate in a 100% step load condition with barely any voltage distortion. This allows MGE UPSs to be used isolated redundant configurations for the highest system reliability of any configuration available.
- 100% Non-Linear Loads with High Crest Factors: MGE UPSs can handle 100% non-linear, dynamic loads with crest factors as high as 3:1 and maintain the output voltage distortion to less than 3.5% THD.

Compact Design

- *Small UPS footprint.* MGE UPS footprints are among the smallest in their class. The small footprint is a direct result of the significantly reduced size of the inverter modules. The smaller UPS footprint makes system installation much easier and requires less space in computer or electrical room environments.
- Smaller Inverter Module. The compact size of the IGBT components and the control circuitry in the module make the inverter module smaller and easier for field engineers to install.

Ease of Serviceability

- *Low MTTR.* The inverter's compact size provides the unit with a very low mean time to repair (MTTR). The newer design IGBT module can be replaced in minutes.

High Reliability

- *Low Parts Count.* The low parts count of both the IGBT component and the control logic circuitry that drives the IGBT component on and off helps account for the device's high reliability and high mean time between failures (MTBF). The design life of products from MGE UPS is greater than 20 years.