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UPS Ratings-Not so Apparent

How to Select the Right UPS for Your Application and Why UPS Products Shouldn't be Rated in VA

Introduction

In the highly competitive UPS industry, products are rated in volt-ampere (VA) and are often selected based on the cost per VA of output power. The practice of rating UPS products with the VA specification – sometimes called "computer VA" – began with a now-defunct manufacturer in the 1980s that attempted to gain competitive advantage. Although this practice was readily adopted by the industry, the VA specification doesn't include the effects of harmonic current.

While this approach works well when vendors test their UPS with commonly available computers and provide a table that shows model and backup time, it has significant drawbacks and limitations. Selecting a UPS based on VA does not work well for demanding applications that involve cyclical loads such as starting electric induction motors that are used in applications such as air conditioners, conveyor belts and for gate control. It also doesn't work well for applications that require extended backup time, which place additional demands on a UPS.

This white paper will provide guidance to help a user select the correct UPS product for a demanding application. It will also make the case why the current industry-standard VA specifications are unclear and should be replaced with W (watts). This paper only focuses on the inverter, not the front-end and battery-charging circuits of the UPS.

The Use of UPS Products in Demanding Applications: An Analogy

A UPS can be compared to automobile brakes. Brakes basically convert kinetic energy to heat. The average driver is happy as long as the car stops, not caring about rotor and caliper size. Under typical driving conditions, most people will never experience brake fade. However, if the car is taken to the track and driven hard, it won't take long before the brakes fail from overheating, because few cars are designed with brakes that can take such abuse. Most cars have small brakes that are not up to rigorous performance standards, because they aren't designed for a demanding application such as racing. The same can be said for off-the-shelf UPS products. While the UPS starts motors, rather than the example of brakes stopping cars, they are comparable due to high currents and the heat that is generated.

VA, W, Power Factor and A

The power in an AC circuit consists of three elements:

- Active Power (P) measured in watts (W)
- Apparent Power (S) measured in (VA)
- Reactive Power (Q) measured in VAR

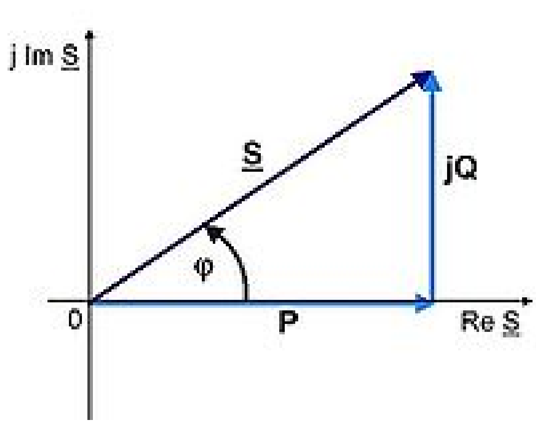

Figure 1: Phasor diagram.

Power factor (also known as displacement power factor) is the cosine of the phase angle φ between the current and voltage sinusoidal waveforms. The power in a circuit that is transformed from electric to non-electric energy, is called real power. The portion of power that is the result of stored energy, which returns to the source over a full line cycle, is known as reactive power.

Apparent power factor (also known as distortion power factor) is real power in W divided by the product of V x I and is typical of the current drawn by a switch-mode power supply that is not power factor corrected. The typical apparent power factor for such a power supply is 0.6 to 0.7. Apparent power factor is neither leading nor lagging, as there is no phase angle to speak of. (Figure 2 on next page.)

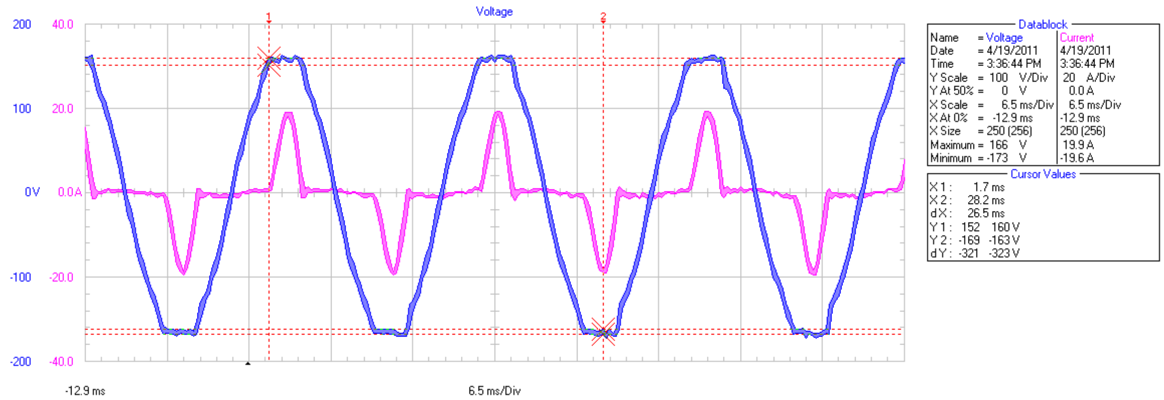

Figure 2: Voltage and current waveforms from switch-mode power supply.

Figure 3 shows the rich harmonic content of a non-power factor corrected power supply. The harmonic current flowing through the inverter of the UPS results in thermal stress on circuit components, which must be accounted for when sizing the UPS.

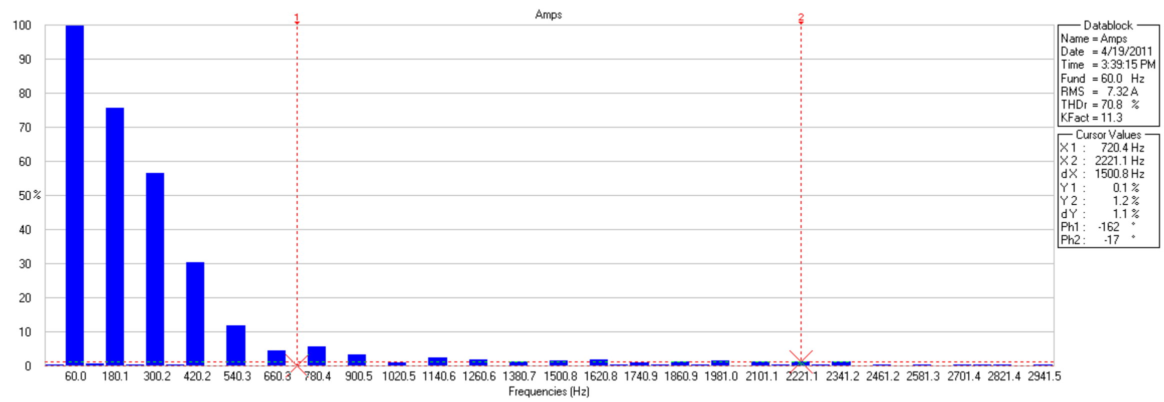

Figure 3: Harmonic distortion from switch-mode power supply.

How the UPS Industry Rates Products

As mentioned earlier, the UPS industry rates most products in VA, which does not include the effects of harmonic current. A hypothetical UPS model might be called XX-1000, leading the prospective customer to assume that the UPS could provide 1 kVA of apparent power to a critical load. However, studying the specifications reveals that the unit is capable of providing only 0.7 kW of real power. The typical specification does not state power factor or maximum continuous current, nor does it allow for harmonic distortion. Without knowing load power factor or maximum current, the user cannot know if the unit will operate at 1 kVA.

For this exact reason, it would be more sensible for the industry to change rating specifications from VA (volt-amperes) to W (watts).

Consider a user with an application that requires 1 kVA of apparent power at an apparent power factor of 0.7, which is typical of computer loads.

What would happen to the UPS if the customer connected a 1 kVA load with a power factor of 0.7? The UPS inverter has to supply 1 kVA x 0.7 for a total real power of 0.7 kW plus harmonics causing 0.714 kVAR of reactive power. Since the UPS is only rated for 0.7 kW, it would overheat fairly quickly since its inverter and inverter transformer are not rated to handle more than 0.7 kW.

This would not be a problem if the UPS is designed with internal batteries to provide backup power for 10 to 20 minutes. However, this becomes a major problem if the customer connects an external battery bank to increase the backup time to several hours, which is often the case with special applications such as security and wireless systems.

Examples of Applications Requiring UPS

Consider the following three different loads for a 1 kVA/0.7 kW UPS:

Heater

These examples show why it would be more effective to rate UPS products in W (watts) instead of VA (volt-amperes).

10 kVA heater is a resistive load with a power factor of 1. Real power is 1 kVA x 1 = 1 kW and no reactive current is returned to the inverter. Therefore, the UPS would not be able to supply the load as it exceeds its rating by 0.3 kW. (Figure 4)

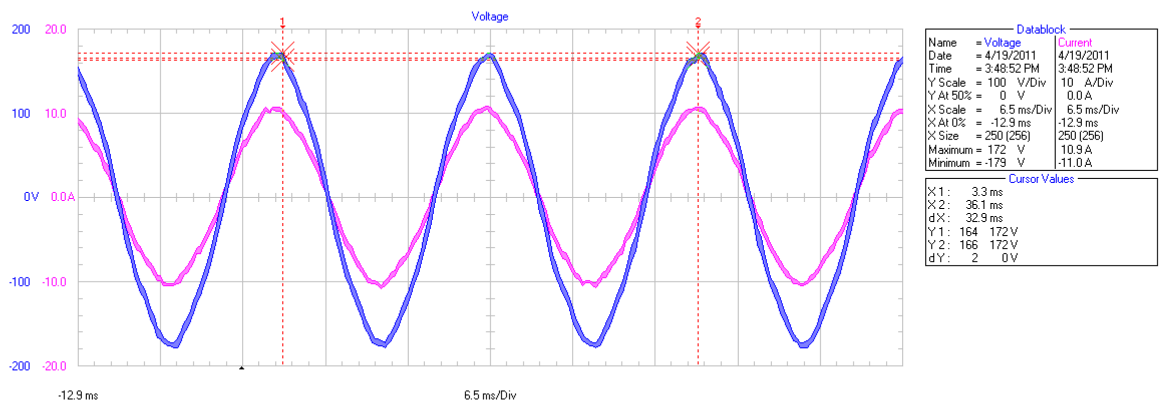

Figure 4: Voltage and current waveforms from resistive load.

Electric Motor

1 kVA electric motor is a resistive/inductive load with a power factor of 0.8. Real power is 1 kVA x 0.8 = 0.8 kW , plus 0.6 kVAR reactive power returned to the inverter. Therefore the UPS would not be able to carry the load

Computer

1 kVA computer is a rectifier/capacitor, non-linear load with a power factor of 0.7. Real power is 1 kVA x 0.7 = 0.7 kW , plus 0.714 kVAR of harmonic distortion current returned to the inverter.

The above three cases demonstrate the inadequacy of the VA rating system. Clearly, all of these cases would require a 1 kW UPS. These examples show why it would be more effective to rate UPS products in W (watts) instead of VA (volt-amperes).

Overload, Starting Current and Basic Inverter Design

For certain applications, it is important to understand how a UPS responds to overload and the starting current of an ac induction motor. These motors are widely used in various industries. Because few UPS specifications state overload specifications clearly, the user typically has to guess.

Most UPS products are designed to shut off the inverter when the internal heat-sink temperature reaches a level that would cause failure. To protect against a short circuit, many UPS products shut down the inverter when excessive current is sensed.

The inverter output stage of a UPS converts the DC battery voltage to AC. The inverter is a critical part of the UPS. It must be able to handle various types of overload situations including starting an induction motor, which is the most challenging.

The induction motor in Figure 5 has a starting current that is six times higher than the run current. The duration of the starting current is approximately 15 cycles. The duration is longer for larger motors because the magnetic field has to overcome the greater inertia of a larger rotor.

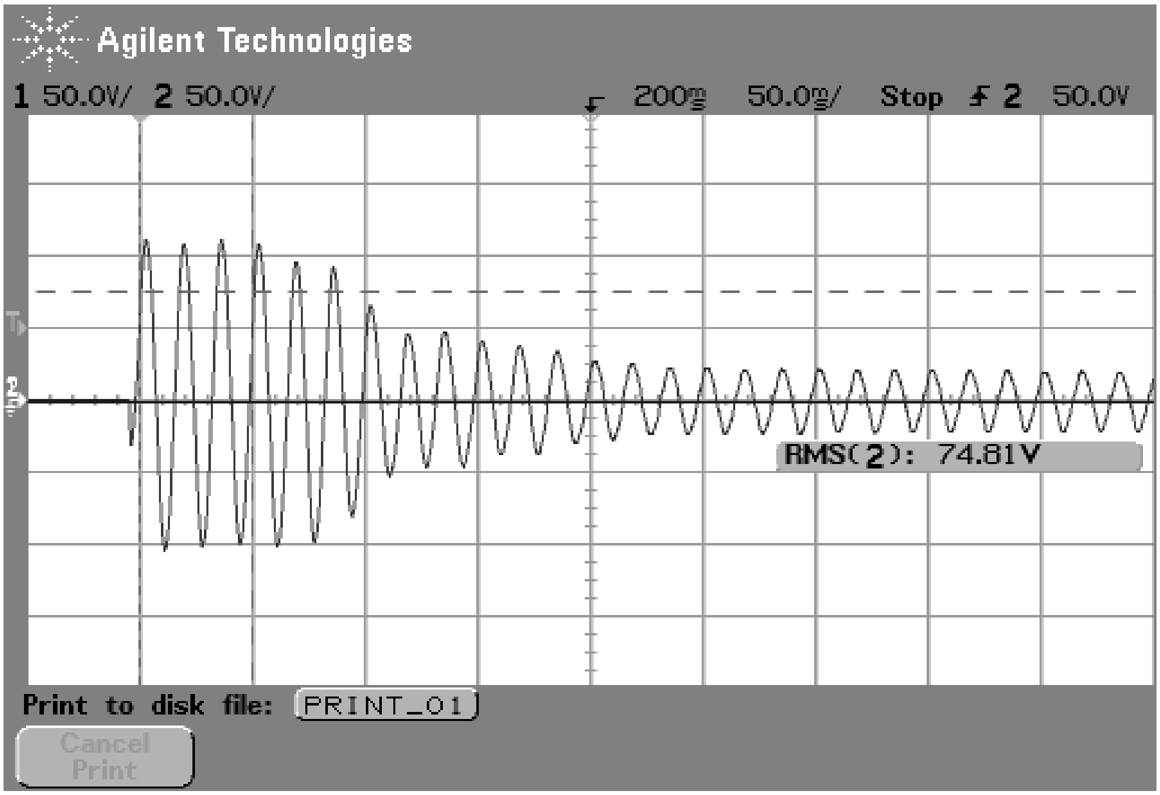

Figure 5: Starting current of air conditioner.

The run current for the air conditioner in Figure 5 is approximately 14.17 A, and the starting current is 85 A.

According to Florida Power and Light (FPL) Electric Service Standards, IX. MOTORS, CONTROLLERS AND AIR CONDITIONERS
http://www.fpl.com/doingbusiness/builder/pdf/Ess9MotorContAC.pdf

“The current required to start a motor is much greater than that required to operate it at full load after it has reached rated speed. If not controlled, this starting current may cause severe voltage fluctuations, not only on the wiring of the Customer using the motor, but also on other Customers' wiring. The more frequently the motor is started, the more objectionable these voltage fluctuations become."

FPL is clearly worried about motors connected to its distribution network, which underscores how difficult it would be for an inverter to handle a motor load.

Let's take a look at how two different inverters handle the task of starting the air conditioner shown in Figure 5. The first inverter's current is shown in Figure 6 and its voltage is shown in Figure 7. The first inverter is rated at 2 kVA and is designed to handle motor starting. The second inverter's current and voltage are shown in Figure 8.

The second inverter is rated at 2.5 kVA and is also designed to handle motor starting. These oscilloscope shots show a clear and significant difference.

Inverter 1

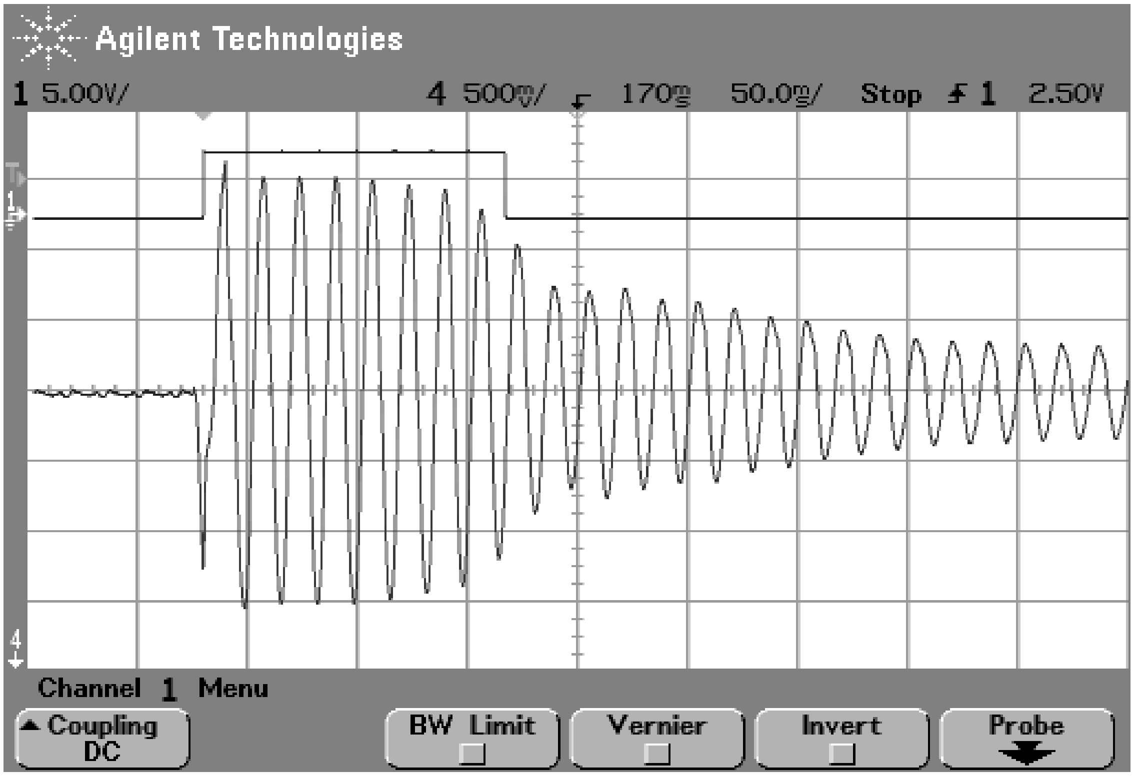

Figure 6: Air conditioner starting current supplied by Inverter 1.

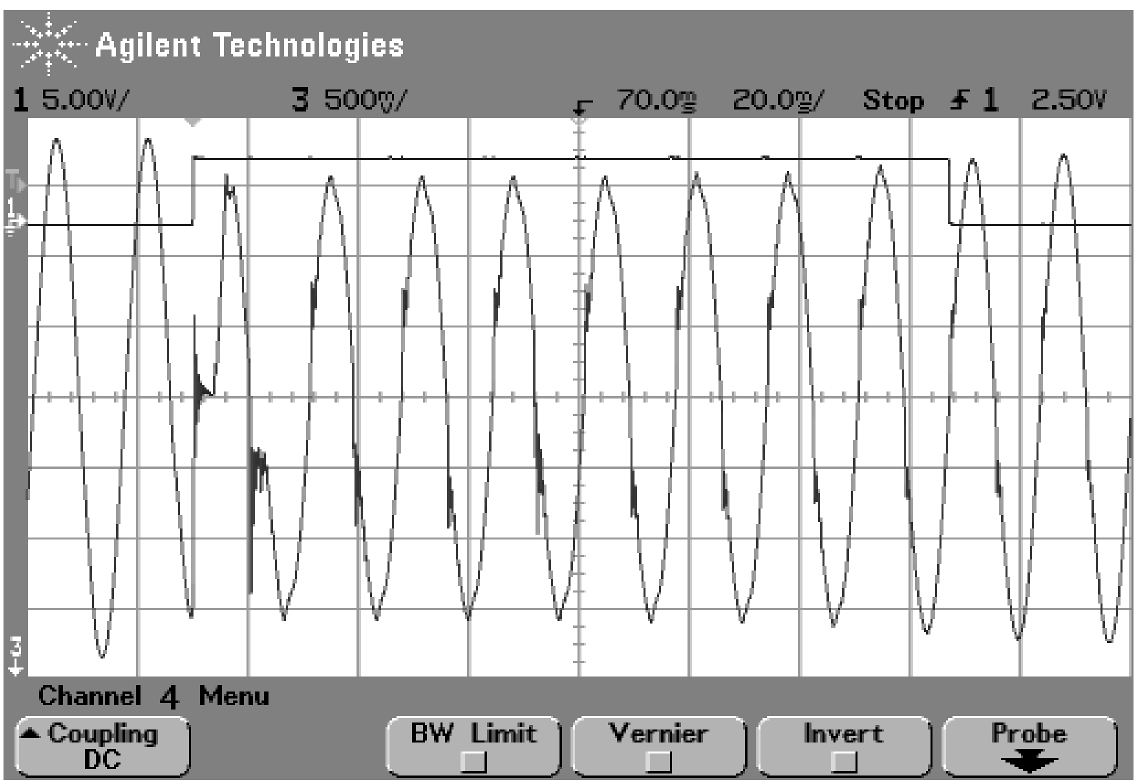

Figure 7: Air conditioner voltage supplied by Inverter 1.

Inverter 2

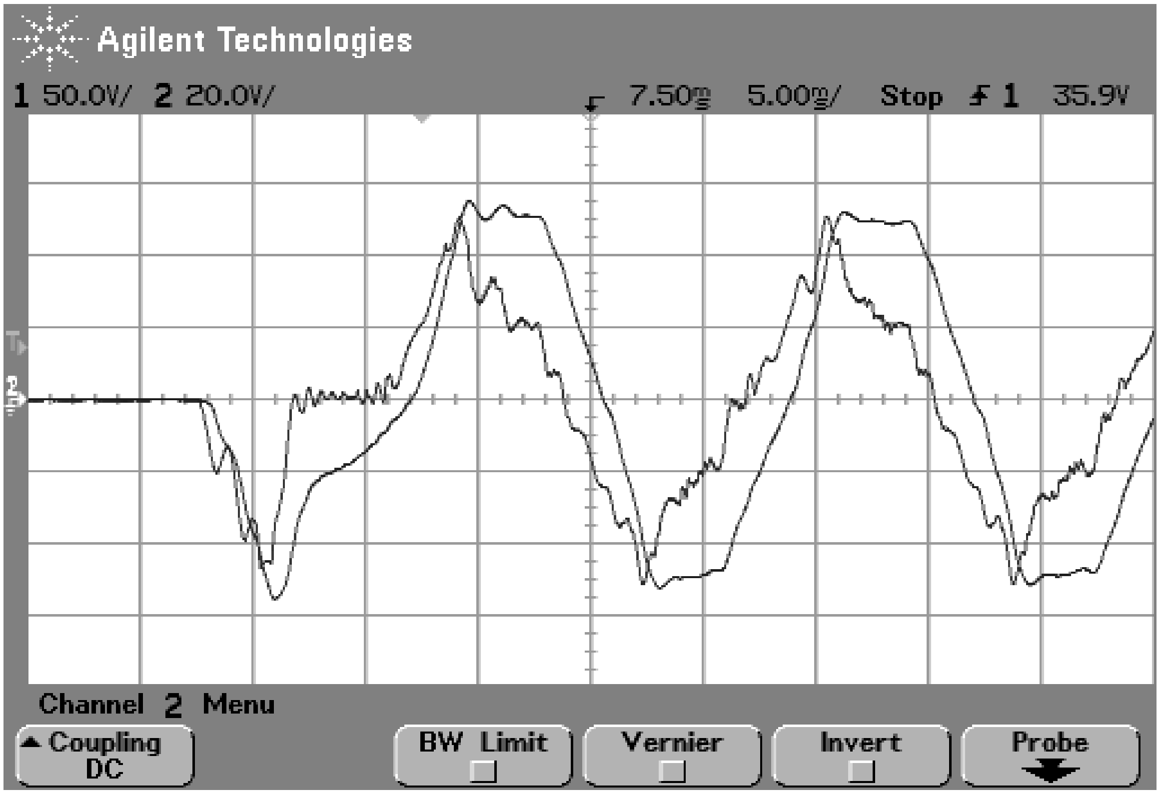

Figure 8: Air conditioner current and voltage waveforms from Inverter 2.

It can be seen that Inverter 1 starts the motor with smooth current limitation and mild voltage distortion. Inverter 2 exhibits severely distorted current and voltage waveforms and had trouble starting the motor. It is noteworthy that Inverter 1 is rated at 2000 VA while Inverter 2 is rated at 2500 VA. Inverter 2 is clearly inadequate for the purposes of starting this air conditioner.

How an Inverter Converts DC to AC

An inverter converts DC to AC by switching a transistor bridge to create PWM pulses that form a sinusoidal wave. The motor current has to pass through the transistors in the bridge and the transformer. The transistors must be able to handle the much higher starting current without junction breakdown and the transformer and the transistors must be able to handle the continuous motor current without overheating.

A microcontroller controls the bridge and the other inverter functions. The controller must be programmed to deal with a number of situations. The microcontroller is the brain of the inverter. Old inverters were designed with hardwired logic and didn't involve programming. Modern inverters use microcontrollers that execute assembly language instructions. Programming the microcontroller is a highly difficult task that constitutes 70% of the end product – and is what sets a quality UPS inverter apart from the rest. In other words, you don't see what you get.

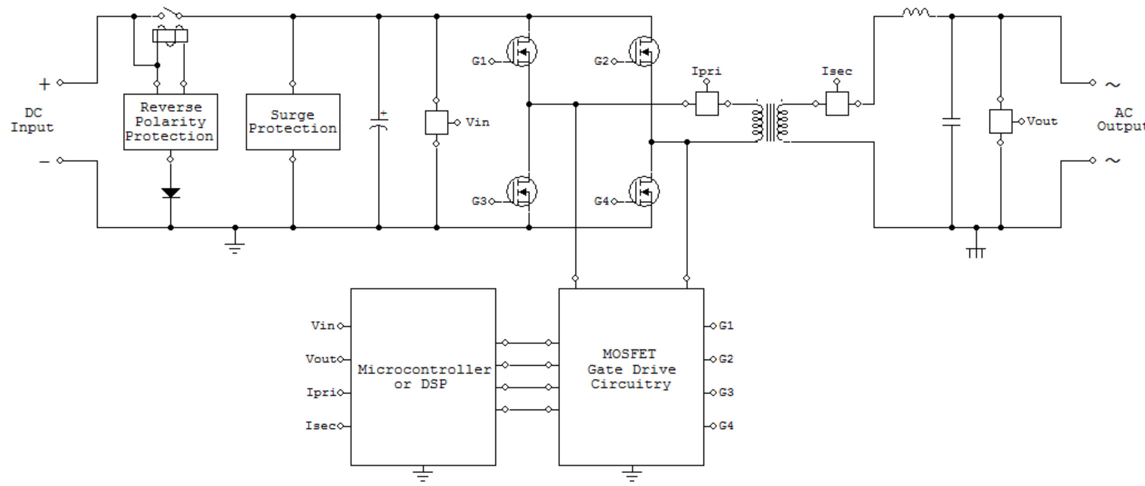

Figure 9: Typical inverter block diagram.

The microcontroller performs many different calculations to ensure that the power transistors Q1, 2, 3 and 4 in the bridge receive the correct drive signals. The drive signal calculations are based on the primary and secondary transformer current, the DC input voltage, as well as the difference between the desired and measured output voltage.

Extended Backup and Thermal Considerations – Why Off-the-Shelf UPS Products Fail

While using off-the-shelf UPS products for extended backup may seem attractive because of the low price and easy availability, they have severe limitations, especially when used for demanding applications. Low-cost UPS products come with an internal battery bank, which typically provides 5 to 10 minutes of backup at full load. These products are safety listed based on the temperature the internal components will reach after 5 to 10 minutes at full load, assuming an ambient temperature of 40°C. The temperature rating sounds impressive but is meaningless for continuous duty. The maximum backup time of 5 to 10 minutes allows the manufacturer to reduce the size of internal components such as transformers, power transistors and heat-sinks. While this saves money, it is guaranteed to fail in applications that need extended backup.

It takes several hours for a transformer to reach maximum operating temperature. A UPS designed for 5 to 10 minutes of backup typically uses a transformer that is one-half the size of a transformer designed for continuous duty. With copper and steel prices at an all-time high, it is unlikely that most manufacturers will reengineer the typical UPS to handle demanding applications.

Heat-sinks designed for short duty can be much smaller than those required for continuous duty. Power transistors are rated for the lowest possible current.

UPS products designed for extended backup at high ambient temperatures require much larger components in order to survive. If you are unclear about a product's specifications, multiply the standard UPS rating by a factor of three to gain a better idea of what is required.

Conclusions

1. The standard industry VA (volt-amperes) specification should be replaced with W (watts).
2. Applications involving motor loads need a UPS designed to handle extended starting currents.
3. Standard UPS products are not designed for continuous duty at elevated temperatures.
4. You get what you pay for – in short, avoid off-the-shelf low-cost UPS for continuous applications.

Users are advised to take such factors into consideration before deciding on a UPS.

About the Authors

This article was coauthored by Peter Nystrom and Jason Marckx of TSi Power Corporation. Peter Nystrom is the president of TSi Power and has been in the power conversion industry for over 30 years. Jason Marckx is the chief engineer of TSi Power and has 10 years of power converter design experience.

TSi Power specializes in designing DC–AC power inverters and UPS products for demanding applications in the wireless, security and industrial markets. TSi Power Corporation, www.tsipower.com, is based in Antigo, Wisconsin. Peter and Jason can be reached at: peter@tsipower.com and Jason@tsipower.com

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