September/October 2008 www.BatteryPowerOnline.com Volume 12, Issue 5

BATTERY POWER PRODUCTS & TECHNOLOGY

Solutions for OEM Design Engineers, Integrators & Specifiers of Power Management Products

Transformer-Free UPS Design: Small Footprint, Big Power

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First appearing at lower power levels, transformer-free uninterruptible power system (UPS) designs have been around for about two decades. A vast majority of designs below 30 kVA are now transformer-free, meaning that the UPS does not contain power line frequency magnetics (transformers or inductors). This transformer-free design trend is moving up in power levels because power line magnetics are both material and labor intensive, though the high frequency power processing needed is technology intensive. Fortunately, advances in technology have matured sufficiently to support improved value to the customer without sacrificing needed reliability.

At higher power levels reaching above 30 kVA and now as high as 1,100 kVA, the challenge is to switch high currents rapidly at high voltages without high losses or excessive peak voltages. Over the last decade, high power insulated gate bipolar transistors (IGBT) have matured enough to allow conversion frequencies of 10 kHz and above without large sacrifices in efficiency at these higher power levels. In addition, some creative control strategies permit further reduction of switching losses to the point where the new transformer-free technology UPS is competitive with the old technology UPS, even when measured in terms of system efficiency.

Considering the basic topology of the legacy and new transformer-free technology UPS powertrain, a phase-controlled rectifier, while efficient and cost effective, produces large harmonic input currents and reduced input power factor that is unacceptable at many sites and incompatible with some generators. Large input inductors and harmonic filters are needed to bring the harmonics down to 5 to 10 percent total harmonic distortion (THD) and power factor (PF) up to >0.99 PF. These components add cost and weight and increase footprint. In addition, they do not hold THD down and PF up over a wide load range. They are typically effective only above 60 percent of full load. At light loads below approximately 40 percent, the input PF can actually become leading and will cause incompatibility with generators. The PF also varies with line voltage but is only specified at nominal line.

The transformer-free design with an IGBT rectifier inherently holds PF up and THD down from 10 to 100 percent load. It is highly compatible with generators and avoids the additional generator over-sizing commonly required with a phase-controlled rectifier. These superior input characteristics are maintained over the input voltage operating range.

There are also battery management advantages of a transformer-free UPS. Note that a half bridge converter can control battery voltage independent of bus voltage and also allows a range of battery voltages (e.g. 192 through 240 cells) to be accommodated. This converter also enables the battery to rest in an open circuit state to avoid continuous ripple current and the accelerated aging (especially at elevated temperatures) resulting from floating at a voltage significantly higher than open circuit voltage. With these additional capabilities, charging techniques can be more effective in extending battery service life.

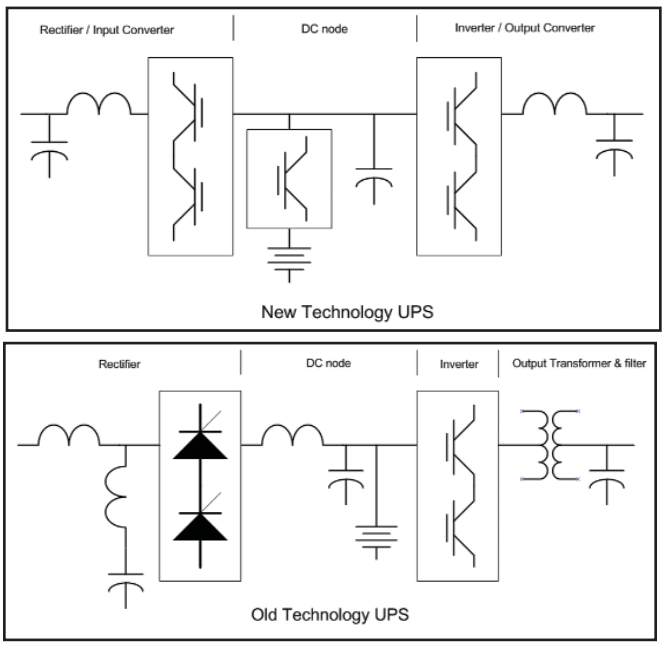

Figure 1. Illustrations of New Versus Old UPS Technology

An example of what is eliminated by using a transformer-free design is shown in Figure 1. The output transformer, input line inductors, DC bus choke, output filter inductors and input harmonic filter inductors are included. Not only is it very heavy, but it is also a significant contributor to the size of the overall unit. The size and obvious weight difference in legacy components versus new transformer-free technology is visually apparent when the units are compared side by side.

It is important to compare the components of a traditional legacy UPS to a transformer-free UPS to understand the technology. It is also important to understand the cost-saving benefits of a transformerless UPS design, which will ultimately impact an organization's bottom line.

Space: Floor space in data centers costs on average $600 to $900 per square foot annually; in places like Manhattan, it can cost $1,500 per square foot. One of the top requests from IT and facility managers is to minimize the footprint of power protection products so they can utilize floor space for servers. Though it is not feasible to minimize the size of batteries, removing transformers from a medium to large size UPS can save as much as 60 percent of space. This also reduces the weight of the UPS by up to 50 percent, which can save thousands upfront on shipping costs.

Installation: A transformer-free UPS is smaller and lighter compared to a legacy UPS which can actually simplify the installation process. Companies often overlook the installation process when considering purchasing a UPS, but it is important to consider how the UPS will physically be brought into the building. For example, an elevator may be weight rated for 2,500 lbs. but the UPS module could weigh 3,000 to 5,000 lbs. This oversight could result in unexpected construction costs to widen doorways or even to rent a crane to lift a UPS through a window, simply because the weight of the UPS exceeds the weight limit of the elevator.

Efficiency: A transformerless UPS is energy efficient which ultimately saves on power costs. Although a legacy UPS can claim high efficiency at full load, a vast majority of UPSs are running at a 40 to 50 percent day-to-day operating level. Companies operating at partial-load versus 100 percent capacity can lose 2 to 3 percent efficiency points, a high dollar amount in terms of power costs. But for a transformer-free UPS running at 50 percent load, efficiency is almost the same as it would be at 100 percent capacity. For a large, transformerless 500 kVA UPS, a company can save about $2,000 to $3,000 a year, and at the smaller level, 100 kVA, it can save approximately $1,000 per year. These figures result in real savings considering the average UPS service life is 15 years.

Green: Companies striving to be environmentally-friendly may want to avoid large transformers if possible. Iron and copper, materials are that are expensive (see Figure 2) and non-renewable, make up much of the composition of transformers.

Also, the building process of transformers often involves dipping them in an environmentally hazardous, chemical varnish and baking them in an oven, emitting harmful fumes. While UPS products still contain some copper and iron, the elimination of the transformer significantly decreases the"energy required for production and supports the green nature of the product.

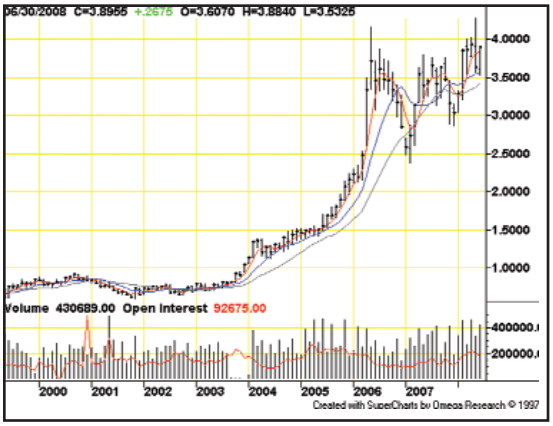

Figure 2. Copper Price Chart

Overall, the new transformer-free topology with small and lightweight filter inductors, high performance IGBTs in both inverter and rectifier, and advanced control strategies can bring improved performance and value to an organization. Compared to legacy UPS topology designs, a transformer-free UPS is typically only 25 percent the weight and occupies 60 percent the footprint. Low input THD (<4.5 percent at full load) and high input power factor (>0.99) are supported down to nearly 10 percent load without the need for an additional input filter. In addition, full load efficiency can reach 94 percent and above. The packaging can be designed so that cooling and wiring do not require side or rear access or clearance. With these new benefits, this technology-intensive design will become the preferred topology.

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