WHITE PAPER

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LEVERAGE TRANSFORMER TECHNOLOGY TO IMPROVE ENERGY EFFICIENCY AND REDUCE DATA CENTER UTILITY COSTS

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It is no secret that the electrical infrastructure of the United States is aging. Reliability and a renewed focus on energy efficiency means that significant amounts of equipment in the public utility grid will have to be replaced in the years ahead. This reality, as well as other economic and geo-political considerations, led the United States Department of Energy to conduct several studies in the last 15 years on energy-saving components. The idea is that the refurbished infrastructure must be far more efficient than today's model.

Part of the efficiency equation is distribution transformers, which have consistently proven to be problematic. These long-lived components, some 30 years old or more, waste 60-80 billion kWh annually on America's power grid. Implementing improved transformer designs could yield annual energy savings of up to $1 billion. The potential is so dramatic that in 1996, the National Electrical Manufacturing Association (NEMA) published an efficiency standard for dry-type distribution transformers called TP-1-1996. The U.S. Department of Energy quickly adopted this for energy-efficient transformers. However, this standard made specific exclusions for transformers with a K-factor of 4 or above – the type of transformers generally used in data center environments. That means the 1996 legislation had virtually no effect on data centers.

A significant change in direction began on January 1, 2007, when the Energy Policy Act of 2005 went into effect in the United States. This new legislation included an updated standard for dry-type distribution transformers called NEMA TP-1-2002. The revised efficiency standard was designed to cover *all* dry-type distribution transformers and no longer makes exceptions for K-rated transformers. Following the lead of Canada, who enacted a similar law January 1, 2005, based on the C802.2 specification published by the CSA. As a result, the entire North American market – data centers included – will soon have the same energy efficiency requirements for transformers.

The Energy Policy Act of 2005 raises the requirements for transformer energy efficiency.

Three-phase kVA	Standard efficiency level (%)	TP-1-2002 efficiency level (%)
30	96.5	97.5
45	96.6	97.7
75	96.7	98.0
112.5	96.9	98.2
150	97.1	98.3
225	97.3	98.5
300	97.4	98.6

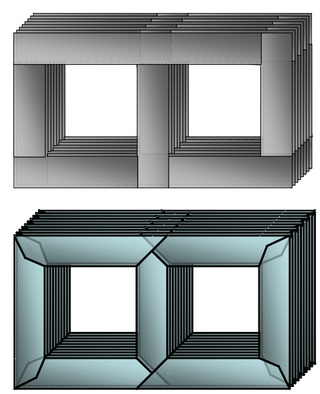
Implementation of the new transformer standard has been complex. Transformer manufacturers have been required to change their business practices, yet clarity for all data center applications has never been issued, nor have penalties for non-compliance. Some system integrators have spent a great deal of time exploiting loopholes in the regulation, which enables them to provide a cheaper transformer and appear to be competitively priced. This is an irresponsible approach that neglects the environment, the economy, and ultimately diminishes the value you would gain in energy savings.

A more thoughtful approach with a critical power system will reveal that the TP-1 regulation is not a bad thing when considered in data center applications. In the long run it can provide dramatic positive return on initial investment.

WHAT MAKES TRANSFORMERS VARY IN EFFICIENCY?

The efficiency of a transformer is primarily affected by the construction of its core. In the core assembly process, thin sheets of electrical steel are stacked together in a lamination pattern. To save on material cost and accelerate production, many manufacturers use low-grade steel and a "butt-stacked" core lamination process, where laminations are interleaved at a 90-degree angle. Unfortunately, this technique creates more electrical reluctance, leading to reduced efficiency.

Figure 1. A butt-stacked core (top) is less efficient than a miter-cut core (bottom).



A more energy-efficient core design is created by modifying the materials and stack design. A higher grade of grain-oriented steel is used, and the lamination sheets are miter-cut at a 45-degree angle and interleaved into the companion stack. These modifications add production cost but yield more efficient flux densities and lower core losses.

WHAT DOES THE ENERGY POLICY ACT OF 2005 MEAN FOR DATA CENTERS?

Legislation dictated that after January 1, 2007, transformers that do not meet the NEMA TP-1-2002 energy efficiency standard or its Canadian equivalent would no longer be available in the U.S. marketplace. However, there were exceptions granted, specifically for transformers used as part of an uninterruptible power system (UPS). One may assume this was meant to cover a transformer within the UPS cabinet itself, but many in the industry believe this exception also covers power distribution units (PDUs). The PDU contains a dry-type isolation transformer and distributes power downstream from the UPS to those fast-growing banks of blade servers, storage devices, and other IT systems.

Since 2007, the Department of Energy has not issued specific clarity on whether or not a PDU is considered part of a UPS system. As a result, considerable debate has ensued within the industry. When you consider the facts, a TP-1 transformer will be more expensive at initial installation; however improved efficiency will quickly return the initial investment and provide ongoing savings to your organization. If the total operating cost of the data center is important to you at all, there is really no debate - a more efficient transformer standard is good news.

In medium to large data centers, energy efficiency is becoming paramount. As you well know, blade servers are consuming three to five times as much power as previous generation equipment in the same footprint. Utility rates have risen three times in the last year alone. Gartner Group studies report that spending on power and cooling exceeded that of I.T. equipment for the first time in 2008. This trend is expected to continue, meaning energy costs will become an even more significant component of every company's operating costs. Never before have data centers been so dense in computing power, so hungry for electrical power, and so difficult to cool.

If you manage a data center – or engineer the architecture for clients who do – you know how critical these issues have become. It is a challenge to provide efficient power protection and distribution for growing loads without generating additional heat.

Efficiency is a factor in every element of the data center. Cooling, Uninterruptible Power Supplies and Power Distribution Units all have room for improvement. Functionally, the PDU remains important for several reasons:

- *The transformer within the PDU offers another layer of isolation from the anomalies in utility power*
- *There is computer-grade grounding for sensitive IT equipment downstream*
- *Voltage transformation is provided*
- *Power metering is incorporated*

All of this means that the transformer within the PDU is an essential element in your power system, as well as, a key component of operating costs for two reasons:

- *One – an energy-efficient PDU saves power. Even a slight improvement in transformer efficiency can yield huge savings in utility bills.*
- *Two – an energy-efficient PDU generates less heat. When an inefficient PDU is located on the computer room floor, it generates excessive heat that in turn increases data center cooling costs.*

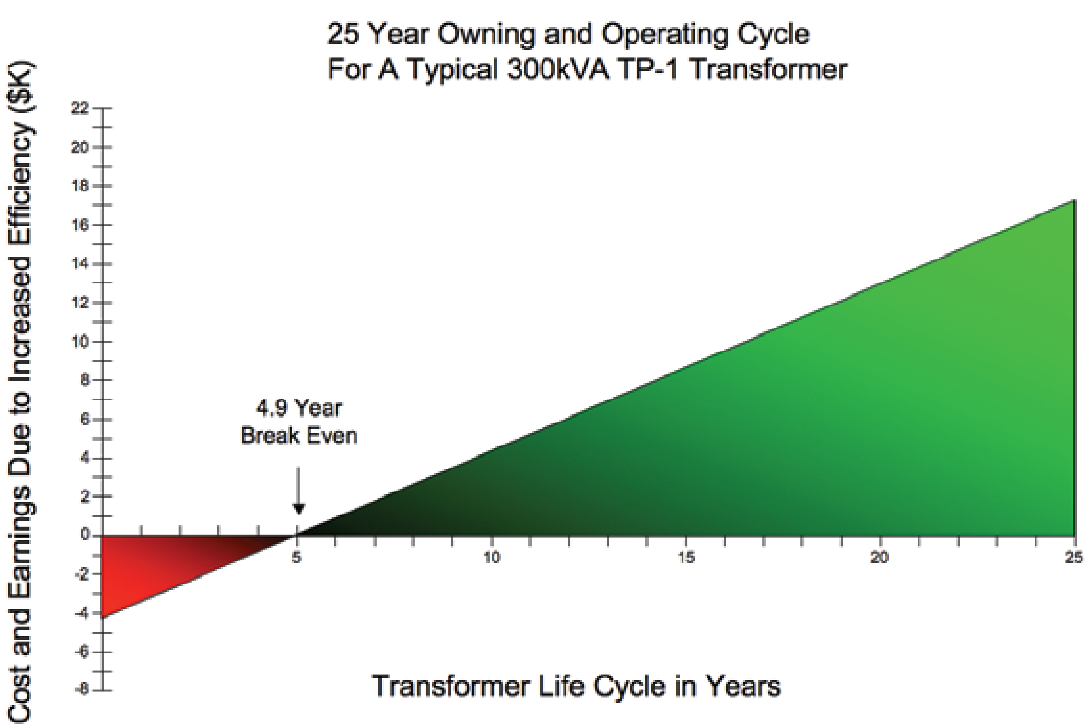
THE BUSINESS CASE

Rest assured an energy-efficient transformer is a worthy investment.

Take this example:

Suppose you buy a new PDU that contains a 300kVA transformer rated K13. An energy-efficient version of this transformer will add approximately $4,200 of extra cost of the PDU, but will operate approximately 1.2% more efficiently. Next, assume your data center is in a major metro area where your utility rates average $.09 per kilowatt hour, the transformer is level loaded at 35%, and cost of capital for your business is 8%. A seemingly small difference in efficiency will prove dramatic over the life of the product. Compared to pre-regulation models that are less efficient, the more efficient PDU can save approximately $800 a year in energy costs. The slightly more expensive, yet more efficient transformer can pay for itself in less than six years, and continues to deliver energy savings throughout the rest of the twenty to thirty year service life of the PDU.

An energy-efficient transformer rapidly pays for itself AND delivers continued operating savings.



EFFICIENCY VARIES AS PDU LOAD LEVELS CHANGE

Transformers have typically been designed to be most efficient at full load, and many manufacturers tout this efficiency as the rating for their unit. Department of Energy studies indicate that a typical distribution transformer in the United States is only loaded at forty percent. Of course this will vary by data center applications, but it is important to remember that your PDU transformer is likely to never be loaded. Due to the dynamic computing environment, data center load variations can easily fluctuate from sixteen to sixty-five percent in the course of a normal day. Transformers are typically oversized to ensure handling of load fluctuation and to withstand any load elevation that may occur due to a partial system outage or maintenance event.

The Energy Policy Act of 2005 addresses this reality. The NEMA TP-1-2002 standard dictates that transformer designs help eliminate low or no-load losses, with efficiency levels at 35% load specifically targeted.

SUMMARY

Electrical demand is driving legislation across North America to improve the efficiency of our aging electrical grid, particularly efficiency designs of distribution transformers. The situation is no different in the data center. Legislation such as the NEMA TP-1-2002 standard has targeted this problem, but the true motivation is derived from business value. If you manage a power distribution system for a data center, you should view transformer design as an opportunity to improve efficiency and reduce overall operating costs. Energy-efficient power distribution equipment will pay for itself in a short period of time – and deliver dramatic savings over the service life of a PDU.