EATON
Powerware

White Paper

Energy efficient transformers reduce data center utility costs

New legislation restricts the type of transformers you can buy, to more expensive models of new design. That's actually good news for your power distribution system.

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The electricity infrastructure in the United States is aging. A significant amount 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.

When the Department of Energy looked closely, distribution transformers proved to be problematic. These long-lived components, some of them 30 years old or more, waste 60-80 billion kWh annually. Better design could yield annual energy savings of up to $1 billion.

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 standard for energy-efficient transformers that are included in the Energy Star program. 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.

That changed on the first day of 2007.

November 14, 2007

1. New legislation now affects the type of transformers used in data centers.

On January 1, 2007, the Energy Policy Act of 2005 went into effect in the United States. This legislation includes an updated standard for dry-type distribution transformers, called NEMA TP-1-2002. The revised efficiency standard is meant to cover *all* dry-type distribution transformers, and no longer makes exception for K-rated transformers. Canada 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, as shown in Table 1.

Table 1. 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**

The new energy law is complex and requires transformer manufacturers to change their business practices. Naturally, some are searching for loopholes so they can 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.

What makes transformers so different in efficiency?

The efficiency of a transformer is greatly 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 a low-grade steel and a "butt-stacked" core lamination process, where laminations are interleaved at a 90-degree angle. Unfortunately, this technique creates more resistance, leading to lower electrical efficiency.

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

A more energy-efficient transformer can be 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 a more efficient conductive flow pattern.

2. What does the Energy Policy Act of 2005 mean for data centers?

After January 1, 2007, you will not be able to buy transformers that do not meet the NEMA TP-1-2002 energy efficiency standard or its Canadian equivalent. This legislation particularly affects the power distribution units (PDUs) that distribute power to those fast-growing banks of blade servers, storage devices and other IT systems.

Replacements for aging transformers in those PDUs, and new transformers to accommodate growth, will undoubtedly be more expensive than their predecessors, due to superior production materials and processes. However, the new transformer standard is very good news, if efficiency is important to you—and it should be.

In fact, energy efficiency is becoming paramount. As you know well, 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. IT spending is expected to continue at seven percent for the next several years (*IDC U.S. Market Watch Survey, Q2 2006*, September 7, 2006). That means energy costs will become an even more significant component of your 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 yet more heat.

Efficiency is a factor in every element of the power system. There has been a lot of attention lately on efficiency in uninterruptible power systems (UPSs) and transient voltage surge suppression (TVSS) equipment. The latest UPSs designed specifically for blade server environments demonstrate efficiency levels of up to 97 percent, which yields tens of thousands of dollars in annual energy savings for even a modest-sized data center.

Yet little attention has been paid to the PDUs that distribute power to IT equipment. PDUs offer another layer of isolation from the anomalies in utility power, plus computer-grade grounding for sensitive IT equipment. PDUs also provide metering and voltage transformation. That means the transformer within the PDU is an essential component in your power system and a key component of operating costs, for two reasons:

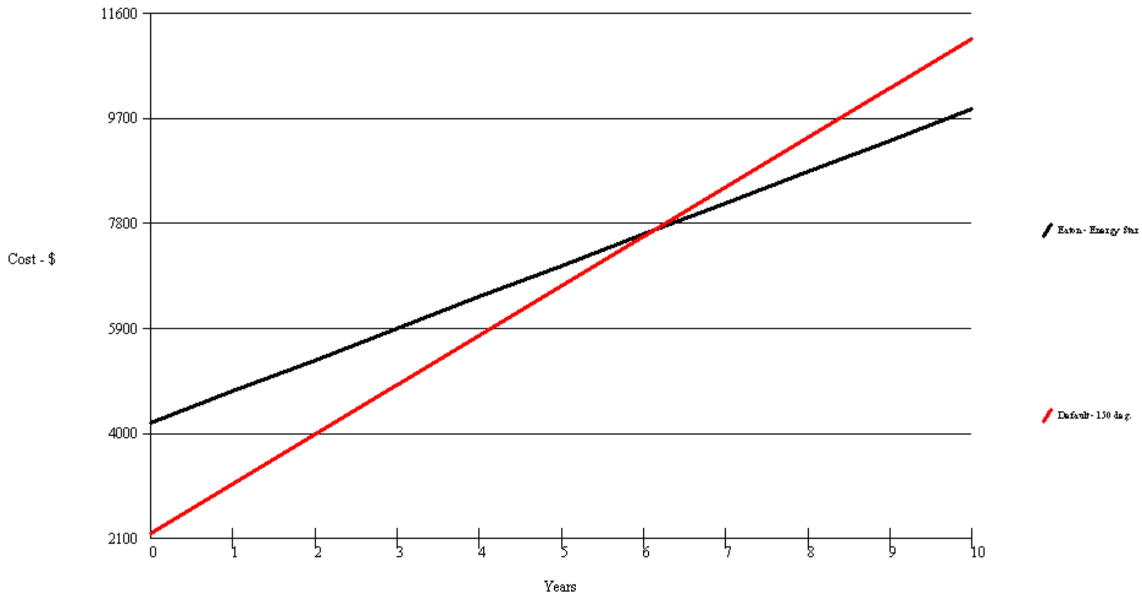
- An energy-efficient PDU saves power. Even a slight improvement in transformer efficiency can yield huge savings in utility bills.
- An energy-efficient PDU generates less heat. When an inefficient PDU is located on the computer room floor, it generates excessive heat that in turn increases data center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

3. Does an energy-efficient transformer really make <u>that</u> much difference?

Yes, it does. For example, suppose you buy a new PDU that contains a 75kVA transformer rated K13. The energy-efficient transformer adds about $2,200 to the cost of the PDU, compared to pre-regulation models that are less efficient, but the more efficient PDU can save over $300 a year in energy costs. (Depending on load scenario, cost per kWh and energy demand).

That means the higher-priced transformer can pay for itself in as little as six years, and continues to deliver energy savings throughout the rest of its 20 to 30-year service life.

Figure 2. The more energy-efficient transformer rapidly pays for itself, and then delivers continued savings.



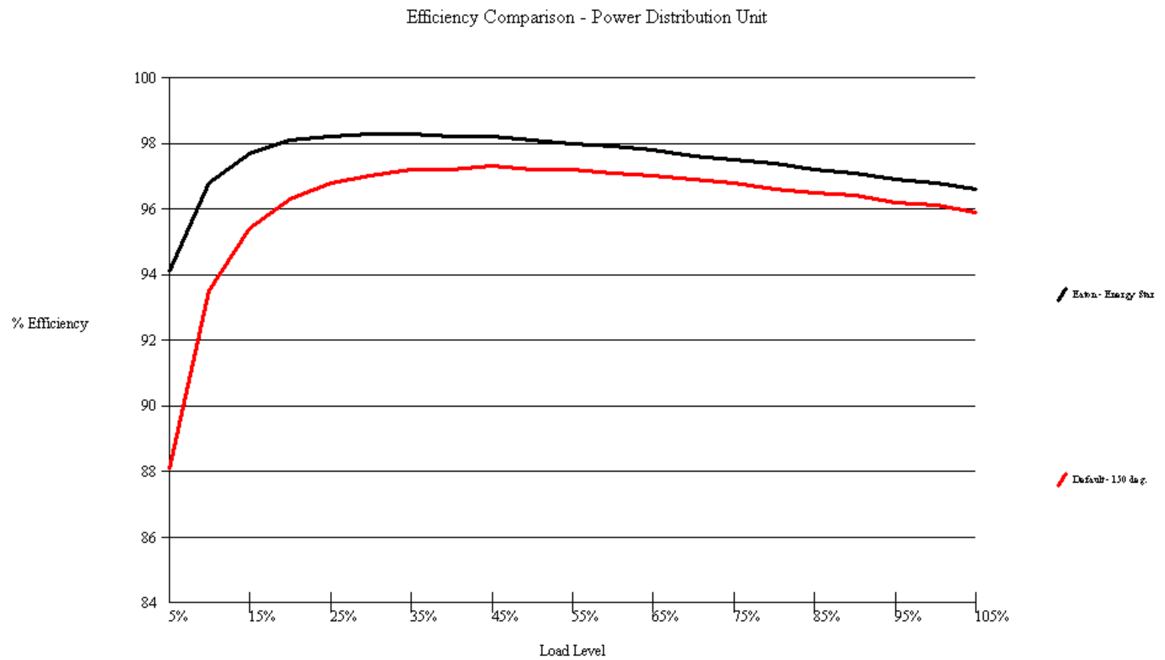
4. Efficiency varies as PDU load levels change.

Transformers have typically been designed to be most efficient at full load, and many manufacturers tout the efficiency at full load as the rating for their unit. But your PDU transformer will never be fully loaded. Data centers are "non-linear" environments, where the load can easily fluctuate from 16 to 65 percent in the course of a normal day. A typical distribution transformer is only loaded at 35 percent, according to Department of Energy studies.

How efficient is your PDU going to be, at real-world load levels, rather than theoretical maximums?
The Energy Policy Act of 2005 addresses this reality. The NEMA TP-1-2002 standard dictates that transformers be designed to be more efficient at 35-percent loading.

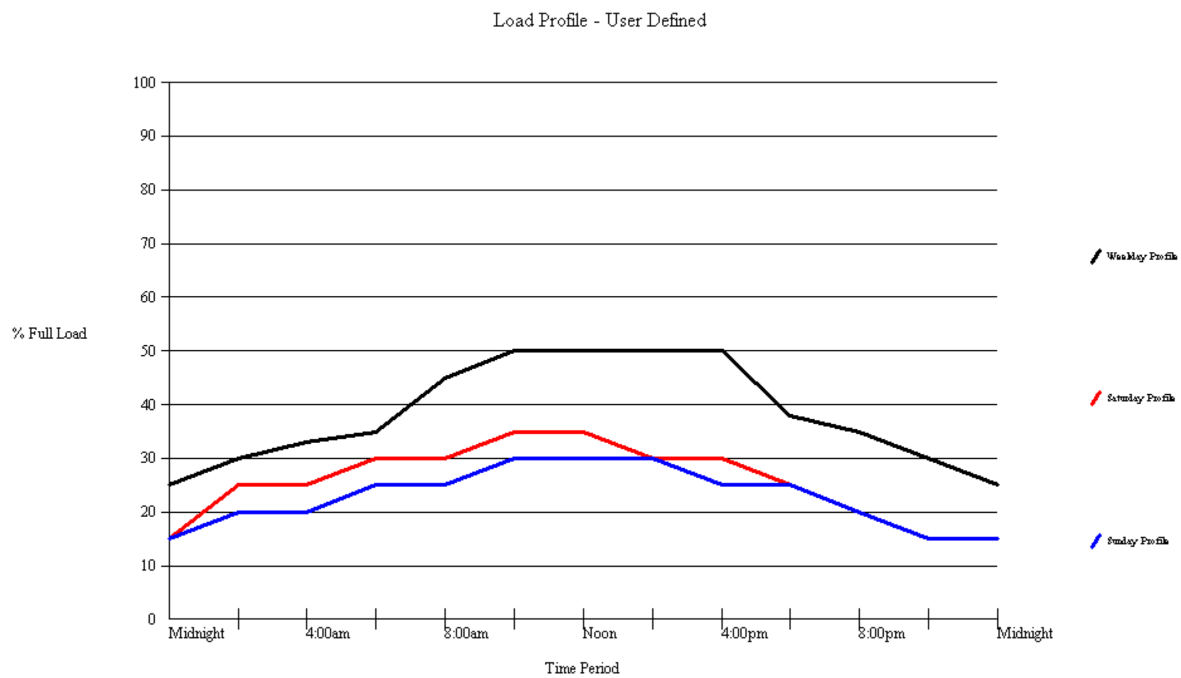
Let's revisit our example from earlier, looking at relative efficiency over different load levels. Figure 3 shows that the more efficient transformer outperforms its older counterpart at all load levels, but the gain is actually greatest when the transformer is loaded at less than 45 percent. That means the most dramatic savings will be achieved under typical operating conditions.

Figure 3. New, energy-efficient transformers provide the greatest advantage under real-world load levels.



For purposes of this case study, we assumed that power consumption would be greatest during weekday working hours, averaging to 35 percent, as shown in Figure 4.

Figure 4. This transformer load profile would be typical for an office environment with computer equipment.



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5. Summary

Electrical demand is driving legislation across North America to improve the efficiency of distribution transformers. Transformers that do not meet the NEMA TP-1-2002 standard for energy efficiency cannot be sold in the United States after January 1, 2007.

If you manage a power distribution system for a data center, you should view this legislation as an opportunity, rather than as a cost burden. 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.

Additional Resources

U.S. Department of Energy

http://www.eere.energy.gov/buildings/appliance_standards/commercial/distribution_transformers.html

Energy Star Transformer Program

http://www.energystar.gov/index.cfm?c=ci_transformers.pr_ci_transformers

NEMA Transformer Data

http://www.nema.org/prod/pwr/trans/