Power for the future

POWERSMITHS

Energy Savings Potential of CSL-3 Transformers and PDU's in Data Centers

Prepared by: Pamela Courtot, BSc. MBA

For: Uptime Institute's Green IT Award

Date:January 2009

Executive Summary

The impact of power conversion losses incurred by stand-alone transformers and transformers integrated into data center PDUs has been largely overlooked. This paper demonstrates the savings potential of upgrading the efficiency of power conversion to meet the United States Department of Energy's Candidate Standard Level Three efficiency.

Step down transformers and PDUs convert high voltage power delivered at the building entrance to lower voltages used by building systems and plug load equipment. All power entering the data center flows through step-down transformers and or power Distribution Units before reaching computing operations equipment. Electricity lost during this process dissipates as heat, which further exacerbates energy use by increasing cooling demand.

Transformers and PDUs are not all equally efficient. While the US DOE has mandated that no transformers sold in the US can operate at less than Candidate Standard Level One (CSL-1) efficiency, the DOE also recognizes that higher efficiency CSL-3 transformers and PDUs reduce losses and offer the lowest overall lifecycle cost.

Measurements taken at the US Postal Services San Mateo data center show that upgrading to CSL-3 efficiency transformers or PDUs can result in substantial economic and environmental savings. These savings are achievable on a retrofit basis and need not be confined only to new facilities. By Installing CSL-3 efficiency transformers/PDUs data centers can realize immediate energy savings and attendant environmental savings related to lowered electricity demand.

Introduction

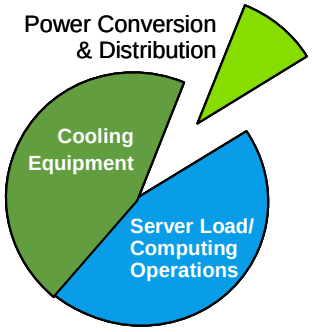
All power entering the data center flows through step-down transformers and or Power Distribution Units (PDUs), prior to reaching computing operations. The combined total of transformer/PDU losses, UPS losses and cooling costs make up a facility's site infrastructure overhead losses. While much attention has been devoted to increasing UPS efficiencies and lowering cooling costs, the impact of improving power conversion efficiency at the transformer/PDU level has been largely over-looked. This study focuses on this neglected area to highlight the energy savings potential of upgrading data center transformers and PDUs to meet US DOE's CSL-3 efficiency.

While the knowledge presented in this study is not new knowledge, the role of power conversion losses at the transformer/PDU is not widely understood. Yet the savings potential is easily measurable and achievable even on a retrofit basis. Furthermore, since transformers and PDU's are the first systems that receive power at the building entrance, all downstream processes magnify the efficiency improvements made at this stage.

Background

Step down transformers and PDUs convert high voltage power delivered at the building entrance to lower voltages used by building systems and plug load equipment. Conversion efficiency of transformers and PDU's is never 100% efficient, because there is an energy cost associated with the conversion process. Power conversion and distribution losses account for more than 10% of total delivered power and more than 20% of wasted power in data centers. For the most part, power lost in the conversion and distribution (C&D) processes is dissipated as heat energy. As such, C&D losses add to the already high cooling demand in data centers. It follows that increasing C&D efficiency yields both direct energy savings and indirect savings attributable to reduced cooling demand.

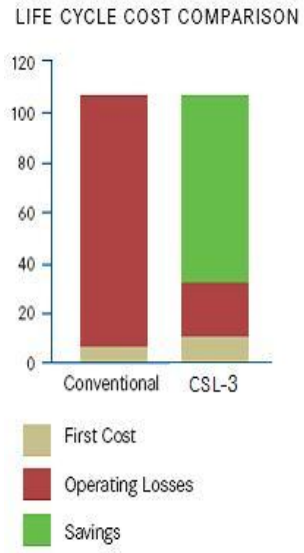
Typical Data Center Energy End Use



Recognizing the role transformers play in the nation's over-all energy consumption, the US Department of Energy studied transformer energy efficiency, defined efficiency standards and established new efficiency standards in 2005. The DOE defined five efficiency standards ranging from CSL-1 to CSL-5. To ensure that transformers sold in the United States meet a minimal efficiency level, EPACT 2005 was put into law. Under this legislation, all transformers must meet CSL-1 efficiency, commonly known as NEMA TP-1 efficiency.

It is important to consider that CSL-1/ TP-1 is only the minimal allowable standard, higher efficiency transformers are produced and commercially available. By using higher efficiency transformers all users can reduce electricity losses. Because they are some of the largest consumers of electrical power, data centers have more to gain by specifying higher efficiency level transformers and PDUs with higher efficiency integrated transformers.

Transformer/PDU Cost of Ownership



The ownership cost of a transformer is a combination of the transformers initial purchase price and its operating cost. Because transformers require little maintenance, their operating cost is largely the cost of the power that the transformer wastes to perform its work. Transformers have a very long useful life, normally thirty to forty years. For this reason, their operating cost exceeds their purchase price many times over. The DOE estimates that CSL-3 transformers have the lowest lifecycle cost because their somewhat higher purchase price is more than off-set by their operational savings.

In data centers, higher efficiency transformers yield both direct site infrastructure overhead savings and indirect savings. Direct savings are achieved through lower electricity losses. Indirect savings are achieved as a result of a reduction in heat losses emanating from the transformer. Lower efficiency transformers dissipate more heat than higher conversion efficiency transformers and PDUs; they therefore place a higher burden on data center cooling systems.

Customer Case – US Postal Service Data Center

The United States Postal Service (USPS) has an aggressive mandate to reduce energy consumption by 30% by 2015. Energy saving strategies undertaken at the Agency's five data centers can make a significant contribution to helping USPS meet their conservation goals.

Recognizing the energy savings opportunities of higher efficiency PDUs, Les Kapaun, the US Postal Service's, Manager, Management Support Service Center, replaced all conventional PDUs with Powersmiths Energy Station™ PDUs that meet CSL-3 efficiency levels at their Eagan, MN facility. Plans are underway to upgrade to CSL-3 efficiency PDUs in all of the Service's data centers.

The PDU's at USPS's San Mateo, CA facility are currently being changed out to higher efficiency Powersmiths Energy Station™ CSL-3 units. During the spring of 2008, the conversion process was only partially completed. This provided an excellent opportunity to measure the efficiency of the conventional PDU's still in operation at the facility and compare their losses with those of the newly installed CSL-3 efficiency level PDU's.

For the purpose of this study, electricity input and output measurements were taken on three of the Service's conventional PDUs, and compared with the input, and output measurements on six Energy Station- CSL-3 PDUs installed at the site. Status quo transformers were measured using a Powersmiths Cyberhawk Portable Meter that can measure input and output simultaneously. Measurements of the Energy Station-CSL3 units are recorded automatically, as the Energy Station includes an integrated Cyberhawk Meter.

To calculate total facility savings potential, the average losses of the Energy Station CSL-3 units were subtracted from the average losses of the conventional PDUs. This savings factor was then multiplied over the entire thirty-six unit complement of the San Mateo facility to derive the actual savings potential.

Findings

As expected the Energy Station-CSL-3 PDU's demonstrated substantially lower losses than the conventional PDUs. The average operating efficiency of the conventional PDUs was observed to be 94.6%, compared to an average operating efficiency of 98.4% for the Energy Station PDUs. Aggregated over the entire facility, this 3.8% efficiency improvement will reduce peak power demand by 45.6 kW and lower cooling demand by 13.2 tons annually.

	Conventional PDU	**Powersmiths Energy Station™ CSL-3 PDU**
Range of Operating Losses (kW)	0.619 - 2.593	-.310 – 0.603
Average Operating Losses (kW)	1.768	.0475
Range of Efficiencies	91.1% - 97%	98.1% - 98.5%
Average Efficiency	94.6%	98.4%
Average Cost of Losses per PDU*	$4,440.	$1447.00
Annual Cost of Losses for all 36 PDUs*	$159,840	$ 52,104

** Cost calculations are based on .13 per kWh and include cost savings attributable to reduction in cooling demand.*

To review the measurements taken on all nine PDU's, please refer to Appendix A .

Financial and Environmental Savings

Cost savings attributable to the installation of the CSL-3 efficiency PDUs are about $3000.00 per year per PDU, based on a $.13 per kWh electricity rate. When USPS completes the change out of all thirty-six PDUs at the San Mateo facility, the service will realize more than a $100,000 reduction in electricity costs.

Because PDU's have a long operating life, the long term financial savings of upgrading to CSL-3 transformers are considerable. Over an estimated 32-year lifespan, the thirty-six CSL-3 PDUs installed at the USPS's San Mateo facility will save the USPS $8,878,248.[1]

Savings Metrics

Annual Environmental Savings	
Carbon Dioxide Reduction in Tons	480
Sulphur Dioxide Reduction (kgs.)	3800
Nitrous Oxide Reduction (kgs.)	1630

Operational Cost Savings	
Annual Operating Savings	$107,736
Projected Lifecycle Savings (20yrs)	$3,891,888
Projected Lifecycle Savings (32yrs)	$8,878,248

There are also substantial environmental savings. By lowering electricity losses USPS eliminates the emissions associated with generating electricity. Emission reductions attributed to this lowered electricity demand include elimination of 480 tons of carbon dioxide, 3800 kilograms of sulphur dioxide and 1630 kilograms of nitrous oxides, annually.

Conclusion

In data centers, replacement of conventional transformers and PDU's with higher efficiency models provides substantial quantifiable savings. The US DOE has studied transformer performance and determined that CSL-3 transformers have the lowest lifecycle cost, due to their lower operational costs. Because transformers and PDU's dissipate electricity losses as heat energy, installing higher efficiency units results in direct electricity savings and indirect savings attributable to lower cooling costs. Replacing conventional transformers and PDUs in existing data centers reduces electricity waste, lowers electricity costs and lessens environmental impacts. In new data center, installation of CSL-3 transformers/PDUs is a practical and predictable means of increasing Facility Energy Efficiency. CSL-3 transformers and PDUs provide measurable energy and environmental savings and should be considered along with other energy saving strategies by organizations mandated to "Green Their Data Centers".

[1] Lifecycle savings calculation assumes an annual 3% increase in utility rates.

About Powersmiths International

Powersmiths is a leader in the manufacture of lean and green electrical power distribution systems. Our E-Saver-C3™ transformers and Energy Station™ PDUs meet the United States Department of Energy's Candidate Standard Level 3 efficiency to provide the lowest total lifecycle cost for dry-type transformers and PDUs.

Powersmiths is committed to providing our customers with power distribution products that reduce electricity waste, improve power quality and provide the lowest like cycle cost. In mission critical environments, Powersmiths CSL-3 efficiency transformers and PDUs reduce electricity losses, resulting in direct energy savings and lower cooling costs. By generating electrical savings for our customers, Powersmiths helps build a healthier more sustainable environment. Further information is available at www.powersmiths.com

About the Author

Ms. Courtot works with Powermsiths to publicize and educate the public on the energy savings potential of Powersmiths Technology. She holds a Bachelor of Science Degree from York University and an MBA from the Schulich School of Business.

Appendix A

Measurements taken on six Powersmiths Energy Station™ CSL-3 PDUs

CSL-3 PDU Location #	Model #	KVA Size	Ia Avg	Ib Avg	Ic Avg	%Avg. Load	Van Avg.	Vbn Avg.	Vcn Avg.	Power Factor	I THD % AVG	V THD % AVG	% Eff.	Losses (Kilo-Watts)
1A-11	TT2656-22245	225	122	95	99	16.9%	209	209	209	0.964	12.3%	3.2%	98.5%	0.600
1A-10	TT2656-22244	225	110	113	111	17.8%	209	209	209	0.973	12.5%	3.0%	98.5%	0.603
1G-13	TT2656-22248	150	78	93	77	19.9%	208	208	207	0.955	13.0%	3.2%	98.5%	0.443
1G-12	TT2656-22246	150	72	88	81	19.3%	208	208	207	0.954	14.0%	3.1%	98.5%	0.476
1G-4	TT2656-22247	150	52	67	69	15.0%	209	208	208	0.944	16.0%	3.3%	98.1%	0.419
1G-3	TT2656-22249	150	61	54	45	12.8%	208	208	208	0.948	16.1%	3.2%	98.3%	0.310

Measurements taken on three randomly selected conventional PDUs

Conventional PDU Location #	Model #	KVA Size	Ia Avg.	Ib Avg	Ic Avg	%Avg. Load	Van Avg.	Vbn Avg.	Vcn Avg.	Power Factor	I THD % Avg.	V THD % Avg.	% Eff.	Losses (Kilo-Watts)
PDU 148-4	PPA-125C	125	128	133	177	42.0%	207	206	208	0.91	16.3%	3.2%	95.8%	2.094
PDU 148-2	PPA-125C	125	97	71	106	26.3%	208	208	208	0.81	21.9%	3.1%	91.1%	2.593
PDU 134-1*	?	150	49	59	66	16.8%	208	208	207	0.94	14.2%	2.8%	97.0%	0.619

* Of all the conventional PDU's measured, PDU 134-1 was the oldest being one of the few remaining original PDUs originally installed thirty or forty years ago.