DOE ENERGY STANDARDS FOR DISTRIBUTION TRANSFORMERS

Background

In October 2007, the Department of Energy ("DOE") adopted energy efficiency standards for electrical distribution transformers. In an effort to force the DOE to adopt even higher standards, environmental groups filed a lawsuit against the DOE challenging the rule. In July 2009, the U.S. Court of Appeals for the 9th Circuit approved a settlement agreement allowing the DOE standards to go into effect on January 1, 2010, but also requiring the DOE to re-evaluate the standards, and, if necessary, promulgate new efficiency standards for distribution transformers.

On July 29, 2011, the DOE announced its intent to define new transformer standards through a "negotiated rulemaking" process. To that end, the DOE created a negotiated rulemaking working group of interested stakeholders (the "WG") consisting of transformer manufacturers, steel manufacturers, utilities, and environmental interest groups, to explore higher transformer efficiency levels, and if possible, reach a consensus on new efficiency standards to be included in a proposed rule. The subcommittee has held five meetings since September. The group could not reach consensus regarding liquid-filled distribution transformers and as a result, was dissolved on December 14th, 2011. The DOE has stated that in the event consensus is not reached via the WG, the DOE will be required to issue a Notice of Proposed Rulemaking by February 1, 2012 and propose standards on its own.

This paper is being issued to inform those in a position of influence that the DOE is currently on a path to adopt efficiency standards that will result in more expensive transformers that will not offer sufficient energy savings to justify the investment.

The DOE Efficiency Levels Being Evaluated

Depending on the product class, the DOE has identified either six or seven higher efficiency levels ("ELs") for consideration in developing the proposed standard. These ELs range from the current efficiency level (EL0) that was adopted as a result of the 2007 DOE efficiency standard and the maximum efficiency level that is technologically feasible (EL6 or EL7).

The standard will apply to approximately 95 percent of the transformers manufactured by Cooper Power Systems ("Cooper"). None of the higher ELs, not even EL1, can be economically justified by Cooper nor several other members of the working group. According to the DOE's calculations, adopting EL1 would result in an average price increase of 21% over the base price of a 2010 DOE-compliant transformer, across the various liquid-filled transformer designs considered. For the same designs, the price increase would be 32% to reach EL2, and 42% to reach EL3. For the designs that the DOE evaluated, the cost averaged $21.20 per watt (at 50% load) to move from EL0 to EL1, $32.00 per watt to move from EL0 to EL2, and $41.80 per watt to move from EL0 to EL3. The cost per watt for the 2010 compliant transformers EL0 averaged only $6.63 per watt of losses. The DOE justifies these increased costs with its payback calculations, but Cooper does not consider the calculations to be correct. Cooper's position is based on an independent analysis performed by a recognized industry expert, who obtained actual price quotations and performance data from several transformer manufacturers in deriving his results.

DOE WG Concluded Without Reaching Consensus on Liquid-Filled Distribution Transformers

The final meeting of the DOE working group concluded without the WG reaching consensus on liquid-filled distribution transformers. Three proposals were presented:

- Utilities and conventional grain-oriented core steel companies proposed efficiency levels ranging from EL0 to EL0.5 for the various product classes under consideration. This group's message to the DOE was that the standard currently in effect is a good standard and it should not be changed.
- Transformer manufacturers proposed EL1 for all product classes except EL0 was proposed for single-phase pole-mount transformers. The manufacturers acknowledged the utilities concerns that the EL1 efficiency levels were not economically justified but as an attempt to gain consensus within the group, EL1 efficiency level was proposed.
- The environmental interest groups proposed EL3 for all liquid-filled product types under consideration. They claimed that this efficiency level would allow both silicon steel and amorphous core transformers to participate in the transformer market; however, the DOE's own analysis shows that at EL3, some transformer design configurations are not achievable with conventional core steels. In addition, at current pricing levels, the DOE projects that amorphous core steel will be required for most applications. With only one amorphous core steel supplier serving the US market, and with no material alternatives, steep price escalation is a serious concern.

According to the ground rules established by the DOE at the start of the negotiated rulemaking process, the WG must reach a consensus with 23 of the 25 members in agreement. The failure of the WG to reach a consensus will require the DOE to select new efficiency levels corresponding to those which provide the maximum energy savings that are technologically feasible and economically justified.

Concerns with the Present DOE Life-Cycle Cost and National Impact Analysis

If the transformer efficiency levels are to be increased, the new levels should be supported by irrefutable evidence as to their economic justification and should reflect such practical realities as increased raw materials costs including those stemming from a reduction in viable material options, higher finished transformer prices, capital equipment costs, realistic growth projections for the rebuilt transformer market and its impact on energy savings under each of the proposed efficiency levels, price/performance estimates that are validated against actual price quotations and measured test results as opposed to unchecked price assumptions and unconfirmed theoretical calculations, variation in historical borrowing costs over the time period being considered, accurate transformer loading data as well as future transformer loading practices afforded by smart-grid technologies, reasonable payback periods that take into account the associated investment risks, as well as the impact on rate-payers and US jobs. The analysis prepared by the DOE in support of raising the distribution transformer efficiency levels is currently built upon questionable assumptions and invalidated data. If not adequately addressed, this could result in proposed efficiency standards that save no energy, have payback periods that exceed the useful life of most transformers, or dictate efficiency levels that cannot be met.

- Raw Material Impact: In order to competitively achieve higher efficiency levels, transformer manufacturers will be required to use amorphous core steel. In fact, the DOE's unconstrained supply model predicts greater than 73% of the core steel used to produce liquid-filled distribution transformers at EL1 will be amorphous. At EL2, 99.8% will be amorphous, and above EL2, 100% is projected to be amorphous. While amorphous metal is capable of producing lower core losses, amorphous cores cannot be produced using traditional core manufacturing equipment, but rather they require specialized equipment, processes and handling in order to be used in the construction of distribution transformers. In addition to this, there are currently only two known manufacturers of amorphous core steel in the world; Hitachi Metals in Japan, and its US subsidiary, Metglas, in South Carolina, and ATM in China who is currently not exporting any of its products.

- Capital Equipment Costs: Cooper currently purchases some precut, formed, and annealed amorphous cores for use in single phase transformers; however, the vast majority of its transformers use conventional core steel. The capital investment required to shift production of 95 percent of Cooper's current product sales from conventional core steel to amorphous would be significant – on the order of $1 million per metric ton of core steel; however, despite this large scale capital investment, it would not yield any incremental sales growth. This would simply be the cost to remain in the distribution transformer business. In fact, based on the other factors described throughout this paper, Cooper's sales would likely decline. In addition, Cooper would need to retain its conventional core steel manufacturing equipment in order to produce transformers that fall outside of the scope of the DOE standard, or to produce DOE-compliant transformers should the price of amorphous core steel increase to where it is at or near parity on a price/performance level with conventional steels; however that equipment would be highly under-utilized. While some manufacturers have already invested in amorphous core manufacturing technology and are more receptive to higher efficiency levels, others will be unwilling to make such investments, resulting in loss of US jobs and diminished competition.

- Pricing Leverage Afforded by Diminished Core Steel Options: Requiring transformer manufacturers to use amorphous steel exclusively will provide the few amorphous suppliers with tremendous pricing power. In order to meet EL3, the price of amorphous core steel could double in some cases and still be less expensive than its nearest conventional steel alternative; however, the DOE's life-cycle cost analysis assumes material prices that were established in an environment where conventional core steel was able to keep amorphous prices in check. The lack of suitable core steel alternatives could drive the price of liquid-filled distribution transformers even higher than already predicted by the DOE. This price increase would be passed on to utilities and ultimately to consumers, and the assumed cost savings necessary to justify raising the efficiency levels would be lost.

- Reduced Reliability: Where rate increases are intolerable, Utilities will be forced to either buy rebuilt transformers or simply replace fewer aging units in order to manage their transformer budgets. Neither of these options is particularly attractive, as each one is likely to reduce the reliability of the US electrical grid, and call US energy security into question.

- Increased Transformer Rebuilding Activity: Half of all pole mount transformers are bought to replace existing units which have either failed or reached the end of their useful life. As the cost of new transformers increases, more and more Utilities are expected to explore purchasing rebuilt transformers as a means of managing their transformer spend. What makes this option even more enticing is that used, rebuilt and refurbished distribution transformers are currently exempt from the DOE efficiency standard. So as the cost and hence the price of new transformers skyrockets, the cost of rebuilt transformers should remain largely unchanged.

Furthermore, the transformer core can typically be reused in a rebuilt transformer, and thus transformer rebuilders would be fairly immune to any price fluctuations in the core steel market brought about by the introduction of higher efficiency standards. Reusing the core from a transformer that has reached the end of its useful life though would yield a significantly lower efficiency. The factors driving this are threefold. First, the efficiency standard that went into effect January 1, 2010 reduced base transformer losses by approximately 30% from pre-2010 levels. So at this point, the majority of eligible transformers would be older, more inefficient units to begin with. Second is the fact that iron losses in transformer cores have been reduced by more than 50% over the last 50 years, so add that to the 30% reduction in losses that occurred from 2009 to 2010. And lastly, because distribution transformers built prior to 2000 were primarily built with copper coils. Starting in 2000, the price of copper increased much faster than aluminum and therefore, aluminum is now the primary conductor material in distribution transformers. However, since the conductivity of aluminum is lower than the conductivity of copper, replacing copper coils with aluminum coils of the same size will yield an even lower efficiency than that old transformer had when it was new.

The mechanism within the DOE's life-cycle cost and national impact analyses by which they explain that they are able to account for this is by adjusting the quantity of new units shipped; however, it is arguable whether their shipments estimates reflect a realistic vision of the future should these standards take effect. For instance, as the purchase price of new transformers increases, so should the market share for rebuilt transformers; however, no such adjustment was made, even at levels where new transformers would cost 50% more. In addition, their energy savings predictions only consider old transformers that are replaced with new highly efficient ones, and not old transformers that are rebuilt and result in a less efficient unit than was previously on the system.

In short, the exemption for used, rebuilt and refurbished transformers will provide an economic incentive to rebuild transformers. As a result, Cooper expects this market to increase under the proposed efficiency guidelines and this will serve to decrease the energy savings sought by these regulations and projected by the DOE analysis.

- The Foundation upon Which the DOE Analysis was Built: The efficiency levels and the transformer prices associated with achieving those efficiency levels were based on theoretical transformer designs that were created by non-industry consultants using off-the-shelf transformer design software that had not been calibrated. In order for manufacturers to use predicted efficiencies to rate their transformers, they must validate their predictions using actual test data for multiple models of various configurations. To Cooper's knowledge, the DOE did not build or contract to have a single unit of their design built to confirm their predictions. Furthermore, to Cooper's knowledge, and despite subcommittee member requests, the DOE did not obtain any price quotations from manufacturers to confirm that their pricing assumptions were correct. Cooper's independent consultant obtained price and performance data from actual transformer manufacturers to derive an economic model that did not support increasing the efficiency levels at all. In addition, the DOE's analysis was only performed on one or two "representative" designs for each product type and the results would then be scaled across all kVA ratings and voltage configurations without confirming whether those designs are even buildable at the higher efficiency levels proposed. For instance, the environmental advocates initially sought adopting EL4 for all liquid-filled distribution transformers and cited that both conventional core steels and amorphous could compete at EL4, but even the DOE's design data returned no valid designs with conventional core steel at EL4 for the single-phase pad design line.

During the initial subcommittee meetings, several members voiced concerns about adopting an efficiency level that would preclude manufacturers from being able to compete on a price/performance basis using "M3" grade conventional core steel. The subcommittee members were receptive to this and no members voiced opposition. In an effort to identify the efficiency level where amorphous and M3 achieve price/performance parity, subcommittee members used the DOE's design data and plotted the lowest cost design for each material at each proposed efficiency level and found the point where they crossed. That turned out to be EL0.6 for single-phase pads, EL0 for single-phase poles, EL1.1 for small three-phase pads and EL0 for large three-phase pads. Despite the fact that no committee members were requesting it, the DOE revised their core steel pricing assumptions prior to the last meeting in Washington DC, to reflect what they cited as 2011 prices. They revised M3 from \$1.88/lb to \$1.30/lb, a 31% reduction, yet they only changed the price of finished amorphous cores from \$2.38/lb to \$2.20, an 8% reduction. Both core steel manufacturers and transformer manufacturers alike indicated that the M3 pricing was approximately 20% too low, but the DOE stood by their numbers despite never having purchased any actual core steel. The effect of this unsolicited price change request was that when plotted, the crossover point between amorphous and M3 core steel supported moving to an efficiency level that was approximately 1 efficiency level higher than previously supported by their data.

- Conservative Borrowing Cost Assumptions: The DOE used cost of money hurdle rates (3% and 7%) that are substantially lower than those used in industry or than is reflected over 30-year historical periods.

- Transformer Life: The analysis considers a transformer's average life expectancy to be 30 years, extending out to 60 years. This varies significantly from the 20.6 year life expectancy required under IEEE standards to which transformers are designed. On top of that, the analysis does not consider the increased cost associated with historically shorter life spans for amorphous core transformers. The life expectancy was based on data for transformers constructed of conventional core steels.

- Loading Assumptions: Amorphous core transformers are able to save relatively small amounts of energy during periods of low loading, mainly at night, but during peak loading conditions, or anytime loading levels exceed 50%, conventional core transformers are more efficient, sometimes significantly more efficient, coinciding with when the cost of energy is highest. However, the DOE's economic analysis did not assign different weights to base watts versus peak load watts; rather it simply valued all watts according to the cost per watt of constructing a new power plant.

For two cost-optimized transformers having the same efficiency at 50% load and at the DOE reference temperatures, the peak efficiency for the conventional steel transformer will be at approximately 50% load; however, the amorphous core transformer's peak efficiency will be at a much lower loading level, approximately 30% load. Despite the fact that DOE's testing standard defines the loading level for calculating transformer efficiency to be 50%, the DOE's analysis generated in support of this efficiency evaluation used average loading levels that were between 25%-30% for single-phase transformers and approximately 40% loading level for three-phase transformers. The DOE cited that their loading data came from data collected from approximately 10,000 meters of undisclosed location. Cooper obtained loading information from several Utilities that suggest that current loading levels are significantly higher, and their data emanated from millions of meters. Another large Utility, serving in excess of 5 million customers explained that they are using data collected from smart meters to allow them to select the smallest kVA size transformer that has the capability to handle the expected peak load (capability is greater than nameplate, IEEE standards cite up to 300% for short durations) and meets the voltage and flicker requirements (along with any service and any secondary cables). This results in an average annual loading level of about 50% for single-phase transformers; however, they indicated that six of their other rate classes that have annual load factors that are above 75%. Those rate classes tend to be the larger loads, stemming from a single customer on a single large transformer. Their comment regarding these loading levels was, "For the larger transformers, DOE's evaluation at 50% is way too low." Essentially, they are loading their transformers as heavily as they can which is a stark contrast to the loading levels used in the DOE analysis.

The results of Cooper's analysis show that for two cost-optimized, 25kVA single-phase pole mount transformers that have the same efficiency at 50% load and at the DOE reference temperatures, when the loading drops to 30%, the amorphous core transformer will save 27 watts compared to a conventional steel core transformer. This is because the core losses, which are fixed and do not vary with loading level are 43 watts less for the amorphous core design. However, at 100% load, the amorphous core transformer will actually consume a whopping 128 watts more than a conventional steel core transformer. As load increases, the total losses increase roughly by the square of the loading factor. Therefore, if the DOE's efficiency levels and loading requirements drive the industry to exclusively adopt amorphous core transformers, but Utilities use smart-grid data to more heavily load their transformers to maximize their assets, the amorphous core transformers may actually consume an exponentially greater amount of energy than the DOE's life-cycle cost and national impact analysis predict.

The DOE claimed to have insufficient data to support higher loading levels; however, Cooper was able to obtain information that would support higher loading levels in a matter of days. Considering the impact that the loading assumptions have on the outcome of the DOE's analysis, they need to invest more effort in collecting accurate information regarding future loading practices throughout the industry and on more than 10,000 meters.

In addition to low loading levels, the DOE assumed essentially zero load growth over the next 30 years, despite game-changing technology like electric and hybrid-electric vehicles that could have a significant impact on the loading of the US electrical system. As load increases, conventional steel core transformers become the more efficient choice; however this may not be an option under the stringent efficiency levels proposed by the DOE. These factors could completely reverse the energy savings estimates or at a minimum, significantly extend the payback periods to a point that exceeds the life expectancy of the transformers themselves.

- Payback Periods: Raising the efficiency levels to EL1 projects payback periods that are between 9.1 and 17.4 years, while the payback periods for raising the efficiency levels to EL3 are between 5.0 and 22.4 years, using the 2010 DOE efficiency levels as their baseline, combined with an assortment of assumptions that appear biased toward supporting raising the efficiency levels. The previous analysis that was generated in support of the 2007 efficiency standard projected payback periods ranging from 7.4 to 15.6 years. Cooper expects payback periods will be much longer than the DOE projects under any of the proposed efficiency levels and when coupled with the payback in going from a pre-2010, may exceed the average life expectancy of a transformer.

- Impact on US Jobs: Requiring amorphous core transformers will require a large investment on the part of many US transformer manufacturers, with some opting not to make the investment, job losses are predicted at the transformer manufacturers as well as at US conventional core steel producers and suppliers. At a point in time when US jobs are critical, increasing the efficiency requirements on distribution transformers will have a detrimental effect!

Conclusion

Cooper supports higher energy efficiency levels if they allow manufacturers to compete on a price/performance basis using both conventional and amorphous core transformers and if and only if the higher efficiency levels are economically justified. Raising energy efficiency levels to the point where transformer manufacturers are precluded from using conventional steel cores would be unjustifiable from an economic standpoint, and would far outweigh the potential energy savings.

Furthermore, the DOE's economic justification for raising the efficiency levels on liquid-filled distribution transformers is highly speculative and built upon assumptions that have not been afforded due diligence. The assumptions that provide the foundation for the energy and economic savings projected do not accurately reflect the future state of the US electrical grid as communicated by those in the driver's seat. The three factors that could significantly swing the economics are:

- Materials pricing and the associated potential for price escalation brought about by economically forcing all transformers to use amorphous core steel, coupled with a severely limited supply base,
- Loading factor assumptions and the fact that transformers constructed from conventional core steel are more efficient at higher loading levels, and
- The 3%/7% money hurdle rates.

The most significant factors that hurt Cooper's business are:

- The need to completely retool core manufacturing while simultaneously idling a significant portion of existing production capacity,
- The need to requalify new designs built with amorphous cores,
- Develop new manufacturing processes in order to build amorphous core transformers, and retrain affected production personnel,

- The need to invest up to $40 million only to realize a reduction in sales, and
- The fact that higher efficiency standards provide an economic incentive to customers to purchase refurbished transformers, which will further decrease Cooper’s sales.

Raising transformer efficiency requirements to the point where amorphous is the only game in town will unnecessarily burden consumers with higher utility rates, and reduce the reliability of the US electrical grid by prolonging transformer replacements and spurring growth in the refurbished transformer industry. Furthermore, it will drive conventional core steel manufacturers and transformer manufacturers who are unwilling to make the steep investments in retooling their factories out of business, costing thousands of US jobs at a time when they are needed most.