## TRANSFORMER LOSSES AND IMPACT ON FIRST COST

BACKGROUND

By DOE mandate, effective January, 2010 all oil-filled distribution transformers manufactured in the U.S. must meet minimum efficiencies, as outlined in Ruling 10 CFR Part 431, Part III. (Reference 1) Many District transformer designs already meet the DOE requirements. Those that do not meet the new ruling will be redesigned (and re-priced) to meet the DOE requirements in the near future.

While the DOE has established a new National standard for transformer efficiency, the District's forecast marginal cost of energy and transformer procurement practices generally drive efficiency levels that exceed the DOE standard. Increased efficiency brings long term value, but it can also have a significant impact on first cost. The higher the cost of commodities, such as copper, steel, insulation material and dielectric fluid, the greater the cost of more efficient transformers.

The District utilizes a total owning cost methodology to determine the low bid supplier(s) for transformers. This approach combines the first cost of the transformer with the lifelong costs that are predicted for the quoted losses, to establish the "total owning cost" (TOC) of a transformer. Transformer losses have two components. "No-load" or constant losses reflect electrical losses incurred when a transformer is energized. "Load-losses" are associated with the electrical loading of a transformer over its life. The load-losses are proportional to the square of the electrical load, which typically follows daily and seasonal cycles. The values established for no-load and load losses are derived from the District's marginal energy costs and the anticipated electrical loading of the transformer over its lifetime. Also captured is the impact of distribution losses on upstream facilities, i.e. additional capacity must be supplied in the transmission system to supply distribution losses, and increased current flow caused by distribution losses results in additional losses in generation and transmission systems.

Because loss values follow marginal cost, and because fuel and renewable generation are forecast to come at increasingly escalated cost, the District's distribution loss formula has increased exponentially in recent years. In 2003, the value of distribution losses was put at $0.93 per load-loss watt, and $3.9 per no-load loss watt. In 2007 those figures had risen to $1.06/W and $5.9/W respectively. Present spot bids for transformers have priced these losses at $2.8/W and $11.4/W, again reflecting high fuel and generation forecasts.

High transformer costs result in greater inventory expense, higher cost of service for District customers and higher system repair and maintenance costs for the District. Provided that energy forecasts are accurate, additional cost for energy efficient designs would be offset by energy savings over the life of the transformer.

In order to quantify the first cost impact of the TOC evaluation I requested the District's Alliance Supplier, Cooper Power Systems, to provide first cost and loss information for four typical transformers used by the District. (See Attachment 1) I asked that they compare transformers that would be built to the new DOE efficiency standard to our presently supplied units, bid award 2007, and also to units designed to minimize total owning costs based upon the escalated 2009 loss values. Coopers' findings are summarized in the attached spreadsheet as Options 1, 2 and 3 respectively.

FINDINGS

For all four units analyzed, moving to minimum DOE compliant designs results in a first cost savings over the present cost of the units. For pole-type and single phase padmount transformer the savings is approximately 2.1%. First cost savings for three phase pad-mount transformers, small and large, is even greater; approximately 6.8%.

With the advent of a new contract utilizing the 2009 loss values, the District's present award methodology would result in even higher unit costs. The pole-type transformer would price 3.5% higher, the single phase pad, 4.7% higher, the 300kVA three phase pad, 3.7% higher, and the 2500kVA pad would price 7.6% higher than the present cost.

Using the 2009 SMUD loss values, the cost difference between DOE efficiency transformers and those selected by SMUD's evaluation, would become quite significant. The 50kVA pole-type unit will be 5.6% higher in price. The 50kVA padmount transformer prices 6.9% higher. The 300kVA pad is 10.6% higher in price. The 2500kVA padmount unit is 14.4% more costly.

To reiterate, actual District costs follow the moving material cost indices, such as copper, steel, and dielectric fluids. At present, many material costs have fallen to relative lows reflecting the recent economy. As material prices rise the first cost differential of DOE and SMUD designs will increase proportionally.

RISK ASSESSMENT

Several factors make it difficult to provide a thorough assessment of risk. Option 1 is based on DOE efficiency levels, without consideration of the value of energy losses. On the other hand, the designs and first costs of transformers identified in Option 2 are based upon material prices in early 2007, while Options 1 and 3 reflect current material prices. Despite these differences, it is interesting to consider the scenario where the present value of lifetime losses is accurately forecast by SMUD's 2009 long-term model.

Attachment 2, Cost Benefit Ratio (CBR) Analysis, provides a measure of benenfit, assuming the 2009 assessment of the value of transformer losses proves accurate. In Case 1, transformers designed to SMUD's 2009 loss valuation show a benefit as compared to transformers designed to the 2007 loss values. For each transformer design, the cost benefit ratio ranges from 2 to 2.5. In Case 2, transformers designed around SMUD's 2009 loss valuation show a benefit as compared to transformers designed to the DOE Standard. The cost benefit ratio for each transformer ranges from 1.5 to 1.92.

Counter-intuitively, the benefits for Case 2 are less than for Case1. This anomaly reflects the radical change in material supply costs between 2007 and 2009. As a general statement the CBR for both scenarios is relatively low. Many businesses would not invest in projects with cost benefit ratios less than 2.5, especially with a prolonged payback. The payback on transformer losses exceeds twenty years.

## OPTIONS

By maintaining the present loss evaluation methodology, the District will purchase transformers that remain among the most efficient, and highest cost, in the U.S. electric utility industry. In theory, high first costs will be offset by 20-30 years of energy savings, resulting in a lower lifetime owning cost for our customers. However, this prediction is subject to long-term energy and commodity forecasts, which have varied considerably over time. Generally, the more extreme the forecast value of losses, the greater the risk that the District will overpay for transformers. In 2009, the forecast value of losses is approaching four times the 2003 forecast. Lifetime transformer load assessments could drive further errors in the District's TOC calculations. For example, time of use billing, rooftop solar and electric vehicle grid support could reduce peak transformer load, and therefore reduce the future value of losses.

As an alternative to present methods, the District could adopt the DOE efficiency standard for all new transformers. This would put SMUD on level with most other electric utilities and would simplify contract award and monitoring. It could also help to ensure the stability of supply by moving toward industry standard designs. By following the DOE standards, the District would purchase the lowest first cost transformers available. For budgetary consideration, the District could save approximately 4% present cost in the current contract, and 10% in future awards. Assuming a $10 million annual spend for distribution transformers this equates to $400,000 and $1 million annually, which could increase with rising commodity indices.

Because every manufacturer will build to the common U.S. Standard, loss and penalty discussions would be simplified by adopting the industry standard. The DOE stipulates minimum efficiencies for all transformers at 50% load, but does not differentiate the contribution of load and no-load losses. While no transformer will be allowed to exceed the DOE requirements, those that deviate from quoted losses will still need to meet ANSI tolerances.

As another option, the District could maintain its present evaluation methodology, but price the losses on another basis. Loss values could be set at historic levels, and then adjusted consistent with cumulative rate increases rather than long term forecasts. In that case, the District would not adopt the "industry standard design." This would result in ongoing unquantified administrative costs, and potential further adjustments to accommodate any units that do not comply with the new DOE ruling. First cost savings would be less than for DOE compliant designs, but a capital savings could still be realized over the transformer life, assuming rising energy costs.

## CONCLUSION

The District's TOC evaluation methodology results in distribution transformers with high first cost and high overall efficiency. In consideration of recent financial circumstances, and exceptionally high marginal cost forecasts for energy, it is prudent to consider other approaches. It is estimated that first cost savings of $1 million per year or more could be achieved by adopting the DOE Efficiency Ruling 10 CFR Part 431, Part III as the new District requirement. First cost savings would be offset by the cost of higher losses over the life of the transformer. The lifetime equivalent cost of these losses will depend on the actual cost of energy supplied to serve the losses in each transformer over its 20 to 30 year life.

Distribution Standards requests direction from DS Leadership before implementing any change to the long standing evaluation practices. Such a change could impact transformer bid processes this year as well as the existing alliance contract with Cooper Power Systems supplying padmount and pole-type transformers to the District.

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Attachment 1 – Cooper Design Estimates for Typical SMUD Transformers, April 24, 2009. (Spread Sheet)
Attachment 2 – Cost Benefit Ratio Analysis, May 14, 2009. (Spread Sheet)

Reference 1 - Department of Energy, Ruling 10 CFR Part 431, Part III, Energy Conservation Program for Commercial Equipment: Distribution Transformers Energy Conservation Standards; Final Rule, October 12, 2007.