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AEP AMERICAN ELECTRIC POWER

Transmission Efficiency Initiative: Host Demonstration Project

Exploring Benchmark Efficiency for Substation Transformers

Power transformer

- Evaluate the impact that efficiency standards for substation transformers might have on transmission system efficiency.
- Evaluate energy, capacity, and CO_2 savings due to high-efficiency transformer standards.
- Benefits include reduced demand, reduced energy losses, and reduced carbon footprint.

Project Scope

As part of EPRI's Transmission Efficiency Initiative, American Electric Power is evaluating a possible collaborative project to assess the implication of setting efficiency standards for large substation transformers.

On October 12, 2007, the United States Department of Energy (DOE) issued the Final Ruling on minimum efficiency for distribution transformers. The Final Ruling sets minimum efficiency standards for liquid-filled and medium-voltage, dry-type transformers up to 2500 kVA, effective January 1, 2010. The standards are intended to achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified and that will result in significant energy savings and emissions reductions. Department of Energy studies showed that the annualized benefits in reduced operating costs are more than twice the increased annualized equipment and installation costs due to the standard.

The loss reduction in a high-efficiency distribution transformer is principally achieved in the no-load losses, because the major improvement is in the core. Therefore, the effect on overall loss reduction is more important in transformers with a relatively low load factor, which is mainly the case in the distribution system. Distribution transformers are also designed in mass quantities, and customization is limited.

For large transformers (above a few MVA), on the other hand, the number of units of a given design are limited, and transformers are usually custom designed for a limited number of purchases. Most units are designed to meet individual utility specifications that involve significant differences in design requirements, features, safety factors, and materials. They are tailored to the loss evaluation figures specified in the transformer specification defining the unit.

A mathematical relationship exits between the transformer MVA rating and its physical size, cost, and efficiency. Losses are affected mainly by the material quality (core steel) and the design (such as magnetic flux control and conductor current density). In general terms, a more efficient transformer will be heavier and have a higher investment cost, because more material and labor or more specialized material is needed to reduce no-load and load losses. This variation is not linear, however. For lower-impedance transformers, the amount of short-circuit forces might affect the amount of copper. Transportation is also a significant issue for large power transformers. The increased weight of higher-efficiency transformers might significantly impact transportation cost (up to 30% of the transformer price). Therefore, in the evaluation of options for more efficient transformers, initial manufacturing cost should not be the only driver. Other costs, such as transportation, as noted above, must be considered.

A widely used technique for purchase evaluations of transformers is the total owner cost (TOC) method. The TOC method consists of determining the capitalized cost of the transformer's losses over its lifetime and weighing that cost with its purchase price. This methodology permits utilities to economically justify paying a higher price for units having lower losses (higher efficiency) and, hence, lower operating costs that result in lower TOC. The customer provides the values of losses, and the manufacturer integrates them into the cost of transformer design, seeking to optimize the total cost. The designer works out the best compromise between initial cost and the cost of losses. The final life cycle cost is then an outcome of the design process, in which the cost of losses is included.

Historically, there has been little standardization in the design and manufacture of substation transformers. Utilities defined loss values according to their needs and business model, resulting in diverse transformer design and characteristics across the industry. Even though large transformers are in general highly efficient, standardization of minimum transformer efficiency and performance might have an important effect on overall transmission system efficiency. There can also be significant differences in losses between competing bid proposals.

Project Approach

- EPRI will work with American Electric Power to define scope, methodology, and expected outcomes. Other project participants will be involved in this phase.
- Transformer manufacturers participating in this project will conduct engineering analyses to evaluate various design options and the corresponding implications in capital cost and efficiency.
- Actual transformer proposals might be used, but data will be presented in a manner that does not reveal proprietary commercial information.
- EPRI, by means of a consistent methodology that will be developed as part of this project, will assess the impact of alternative transformer efficiency standards on demand, energy, and CO_2 savings, as well as TOC.
- A series of workshops with industry and interested stakeholders will be conducted to share experiences, discuss methodology, and study results.

Project Schedule

The schedule of the project tasks is as follows:

1. Conduct an industry survey on current transformer design and specification practice.
2. Develop an evaluation methodology.
3. Manufacturers conduct an engineering study to evaluate the impact of transformer efficiency on cost.
4. Apply the developed methodology to assess the impact of different transformer efficiencies on energy, capacity, and emission savings.
5. Final project report, December 2011.

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