

Transmission Efficiency Initiative: Host Demonstration Project Use of Energy-Efficient Substation Transformers



Power transformer

Project Scope

As part of EPRI's Transmission Efficiency initiative American Electric Power (AEP) is evaluating a possible demonstration project on the use of substation transformers that are more energy-efficient.

The replacement of existing, higher-loss transformers and the use of high-efficiency transformers has been focused mainly on distribution classes, because the effect on system efficiency is more significant there. The Department of Energy's new rule on the Energy Conservation Program for commercial distribution equipment adopts energy conservation standards for liquid-immersed and medium-voltage, dry-type distribution transformers. These standards constitute minimum efficiency levels for transformers manufactured for sale in the United States or imported into the United States on or after 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.

For larger transformers (above a few MVA), the number of units purchased of a given design is limited. Each design series is customized to the customer requirements. Most units are custom-designed to meet individual utility specifications

- Evaluate options to reduce losses with energy efficient substation transformer replacements.
- Monitor before and after energy losses and document the results.
- Benefits include reduced demand, reduced energy losses, and reduced carbon footprint.

that involve significant differences in performance, design, and test requirements, as well as special accessory features, safety factors, and materials. Efficiency is tailored to the loss-evaluation figures specified in the transformer specification defining the unit in order to achieve an optimized total evaluated cost.

When considering transformer replacement, especially for larger, more expensive transformers, loss reduction is not usually a key driver for replacement. However, if a transformer is replaced for other reasons, such as condition, age, or under-capacity, it might be cost-effective to install a transformer with higher efficiency than the existing unit. Very-high-efficiency transformers can be economically justified in some cases while yielding substantial benefits in energy savings, deferred infrastructure, and reduced emissions.

A mathematical relationship exists 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, the initial manufacturing cost should not be the only driver. Other costs, such as transportation, must be considered.

Because large transformers are expensive, it can generally be said that replacing existing transformers with higher-efficiency transformers is economically feasible only if the replacement decision has already been made for other reasons, such as failure (that cannot be repaired), age, or under- or over-capacity.

Usually, the replacement decision and options are determined by a utility's asset management practices. The decision to replace or repair an important asset such as a large transformer is complex. It requires an understanding of corporate risk tolerance, investment strategy, and the prevailing business and regulatory environment. Considerations about the use of higher-efficiency transformers as an option to replace existing units should be embedded into the utility's asset management procedure and practice. The following basic replacement categories can be considered:

- Replacement already decided. In this case, the unit replacement has already been determined for different reasons, such as failure or damage that cannot be repaired or the need for higher capacity. In this situation, the decision is whether to purchase a low-cost, less-efficient transformer or a more expensive, energy-efficient transformer. The total owner cost procedure with emission considerations can be applied for evaluation.
- Failure or trouble unit. The decision in this case is whether to replace the transformer with a new unit with different efficiency or to repair it. The decision is usually an economic one. It involves weighing the increased life span and reduced losses resulting from replacing the existing unit against the cost of repair.

- Early replacement to improve efficiency. The objective in this case is to evaluate the cost effectiveness of replacing an existing transformer with a more efficient unit.

Project Objective

The purpose of this project is to evaluate options to install high-efficiency transformers in AEP's system. The project will document lessons learned during the installation of high-efficiency transformers and will quantify the impact on the lifecycle carbon footprint and system losses.

Project Approach

- EPRI will work with AEP asset management and planning departments to identify opportunities to consider the use of high-efficiency transformers for either replacement of existing units or new substations.
- EPRI will work with AEP and the selected manufacturer to evaluate various design options and the corresponding cost and efficiency implications.
- A comprehensive evaluation will be conducted, including not only price and loss capitalization but also transportation risks, interchangeability, environmental considerations, maintenance, and spare optimization.
- EPRI, by means of a consistent methodology that will be developed as part of this project, will assess the impact of the replacement transformer on demand, energy, and CO₂ savings.

Project Schedule

The schedule of the project tasks is as follows:

1. Identification of possible transformer replacement opportunities. The analysis will be based on the three replacement categories listed earlier.
2. Evaluation of various design options for different levels of efficiency.
3. Comprehensive evaluation of savings and benefits for each different design.
4. Final design, manufacture, and transformer installation.
5. Monitoring of active and reactive power flows on the transformers and selected lines for 12 months in order to evaluate losses and emissions based on the EPRI demonstration protocol.
6. Final project report, December 2011.

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