RECLAMATION
Managing Water in the West

U.S. Department of the Interior
Bureau of Reclamation

Alternative Insulating Fluids for Power Transformers

Assessment of the benefits and cautions to using alternate insulating fluids for large power transformers

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With growing environmental and fire protection awareness, insulating fluids for power transformers are evolving. Historically, mineral oil has been used in power transformers and this fluid is the reason for many of the design parameters, testing standards, and operating analysis tools used today. Significant benefits in alternate insulating fluids are causing a shift in the type of insulating fluid used in power transformers. These fluids have different properties which impact the design, manufacturing, and service of power transformers.

Mission Issue

Investigating alternative insulating fluids for power transformers allows Reclamation to assess the effects of these fluids on the Nation's water and water related resources.

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Problem

The backbone of power generation consists of the generator and generator step-up (GSU) power transformer. These assets are of the utmost importance for a generation entity and come with great investment through sophisticated designs, meticulous hand-built manufacturing, in-depth operations testing, and monitoring systems producing trending data that is analyzed to understand the life of these investments. Of these two assets, the power transformer for hydroelectric facilities typically operates in a weathered environment near or directly over a water resource which increases the risk of damage during a failure. Losing this asset unexpectedly may not only be financially detrimental but could also have high impacts to the surrounding environment.

Power transformer design, operation, and maintenance have been well documented and understood for many years. As the industry's GSU power transformer fleet reaches end of life, many utilities are investigating ways to reduce environmental impact and increase energy production, reliability, and safety during the replacement of these transformers. The growing awareness in environmental sustainability, fire protection measures, and optimization of existing space has caused the power transformer to evolve by using different insulating fluid types.

Solution

As the industry's power transformers are replaced, power generating companies will continue to look for ways to reduce environmental impact while increasing fire safety, reliability, and energy production. A growing awareness of the insulating fluid options for power transformers has caused a shift in transformer research, development, and use. More transformers are being designed and installed using an insulating fluid other than mineral oil. This migration will provide more data to further analyze the advantages and disadvantages of alternate insulating fluids.

The research that the Bureau of Reclamation has performed thus far provides sufficient information to justify the use of alternate insulating fluids. Natural ester fluid, synthetic ester fluid, and SF6 gas insulating fluid are viable options when considering a power transformer replacement or attempting to mitigate the risks of the effects of transformer failures.

Natural ester fluid (FR3) power transformer at Glen Canyon Dam.

"By using an alternate insulating fluid, fire safety is increased, possible damage to the environment is reduced, and potential cost saving can be seen over the life of a power transformer."

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More Information

https://www.usbr.gov/research/projects/detail.cfm?id=100

Application and Results

Each project must be analyzed for the best insulating fluid type to use based on existing conditions.

Ester fluids, natural and synthetic, are a viable choice for insulating fluid in power transformers. Both fluids are biodegradable, non-toxic, thermally uprate the cellulose system within the transformer, and greatly improve the fire safety of the transformer. These fluids outperform mineral oil in many ways. Oxidation stability is an issue for natural ester fluid and can be overcome with attention to detail when opening the transformer for inspections/processing and ensuring the conservator on the transformer is always maintained. Pour point is only a concern for cold climates when a transformer is de-energized for several weeks. In most cases Reclamation generator step-up (GSU) transformers stay energized even when the generator is not online, so cold start issues are not as big of a concern. In the case that an ester fluid transformer is installed in one of our cold climate facilities the standard operating procedures may need to be adjusted.

SF6 insulated transformers almost eliminate fire safety and water/soil contamination concerns. This type of insulating fluid is obviously only available during a complete replacement of a transformer. SF6 outperforms mineral oil in many ways but does introduce the concern of future regulations due to its high global warming potential. Research and development is ongoing for an alternate insulating gas for power transformers but currently SF6 is the only available gas for this application.

Future Plans

Reclamation will continue researching these alternate insulating fluids. Next goals are to develop life cycle cost values for installing transformers using each of the insulating fluids. These values will be developed for existing conditions that do not currently have fire protection and containment, have minimal fire protection and containment, and already have fire protection and containment installed.

Currently, Reclamation is installing ten of the world's first 345-kV class, short-circuit tested, power transformers as well as four 230-kV class units at Glen Canyon Dam in Page, Arizona. Over the coming years, Reclamation will gather data on the operation and maintenance for these units. Measures are also being taken to install synthetic ester fluid and SF6 gas insulated transformers at other facilities. The Bureau of Reclamation's power transformer design specifications and Facility Instructions, Standards, and Techniques (FIST) manuals used for maintenance will be updated with findings as we progress through this shift in the industry.

Gas insulated (SF6) power transformer at Osage Power Plant.