

# Management of Aging Assets

## One Approach to Power Transformers

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Aging power transformers are a key class of assets that utilities must take an active role in managing not only to assure reliability of power supply, but also to minimize risk and to develop responsible capital investment plans. Cooper Power Systems provides a number of tools to enable utilities to manage transformer assets more effectively. Specialty transformer fluid provides the ability to slow down the rate of transformer aging while dramatically reducing the risk of a fire or spill should a transformer fail in service. Surge arresters mitigate the damaging affects of voltage transients and specialty instrumentation and remote monitoring software by Cannon Technologies provides continuous on-line transformer health monitoring capabilities.

### Rising Transformer Demand

Federal Energy Regulatory Commission data indicates that there are in excess of 132,000 power transformers in service in U.S. substations. A number of utilities have reported to the insurance industry that as much as 40 percent of their substation transformer population is already at or beyond their original life expectancy. As a result, the expected rate of failures of these types of transformers are on the rise.

The Energy Bill of 2005 has stimulated significant new utility construction. The demand for transformers in other parts of the world, most notably China and India, has also put a strain on the supply of the specialty steel used in the manufacture of transformers. Many parts of the transformer industry are currently close to capacity. Add to this a large population of aging substation transformers in need of replacement,

and the need for extracting as much service life out of these older transformers comes into sharp focus.

### The FR3 Fluid Asset Management Solution

A long-time supplier of alternative transformer fluids, Cooper Power Systems developed Envirotemp® FR3® fluid in the 1990's. This fluid is an edible-seed oil-based, environmentally friendly, transformer fluid that can be used in place of traditional, petroleum-based mineral oil. When used to retrofill existing transformers, FR3 fluid has been proven to successfully address key concerns with older transformers. Specifically, FR3 fluid can extend transformer life, while mitigating the safety and environmental risks associated with transformer failures.



**Retrofilling an existing transformer with FR3 fluid leads to big savings and has lasting safety and environmental benefits.**

Insulating paper is a major component of a transformer's internal construction. A significant percentage of transformer failures are due to breakdown of the insulating paper. Extensive testing has shown that when filled with FR3 fluid, the paper ages at a much slower rate than one filled with mineral oil. One of the key reasons is that FR3 fluid actually reduces the moisture content of the paper. This has the dual benefit of slowing the aging rate of the paper and increasing the paper's dielectric strength. Both of these attributes combine to increase the life of the transformer.

At the Spring 2006 **IEEE®** Transformer Committee meeting, a paper was presented on a 30-year old, 250 MVA generator step-up transformer. An evaluation of the unit indicated that more than 60 percent of the unit's life was consumed, with a projected theoretical end-of-life in approximately 15 years. Replacing the transformer oil with FR3 fluid, data-based calculations show that in 15 years, 25 percent of the transformer's life would still be remaining. This life-extending property, combined with the fire resistance and biodegradability of FR3 fluid, can reap huge financial benefits. *(See sidebar on page 11.)*

Laboratory testing has shown that FR3 fluid's asset management impact is even more pronounced when the fluid is used in new transformers. Financial modeling of new transformers, using a conservative life extension factor of 2.0 and a discount rate of 15 percent, has demonstrated significant savings. By investing in new FR3 fluid-filled transformers with twice the expected life, a utility can save over \$800 per 50 kVA transformer or \$4,000 per 1 MVA transformer purchased, by deferring the required replacement of these trans-

formers, lowering the risk of fire, reducing the cost in the event of the spill and increasing the reliability of their system. **(Note: Assumptions used in these calculations appear at the end of this article.)**

Another means of taking advantage of FR3 fluid's anti-aging characteristic is to increase the loading of existing transformers. An FR3 fluid retro-filled transformer can typically be loaded 12 to 17 percent more than a mineral oil transformer and have the same expected insulation life. This affords the utility the ability to deliver more power using existing assets, without diminishing the insulation life of those assets. The economic impact is significant as it provides for deferral of purchasing additional transformer capacity to enhance the installed base capacity. FR3 fluid enables utilities to get more out of their transformer assets.

An additional advantage that FR3 fluid offers is the mitigation of oil fires associated with failed transformers due to the fluid's very high ignition temperature. According to industry research, 6 to 8 percent of petroleum-based mineral oil substation transformer failures result in a fire. When a fire occurs at a substation, financial losses are inevitable. Not only do these fires destroy the affected transformer, but they also have the potential to damage or destroy surrounding assets, including other transformers. In 2004, a fire that started in one transformer at a utility in Arizona propagated and destroyed four nearby transformers, costing the utility millions of dollars in equipment replacement, repairs, clean up and lost revenue. The fire history of FR3 fluid is impeccable, with no fires reported in the tens of thousands of FR3 fluid-filled transformers in service.

This reduced fire risk not only brings safety and peace of mind, but also economic returns. One utility estimates that their transformer insurance premiums were reduced by \$60,000 annually by retro-filling their units with FR3 fluid. For self-insured utilities, the reduced fire risk can permit decreasing the levels of funds set aside for contingency budgets, freeing up capital to invest in profit-making investments.

*(Continued on page 12.)*



## How One Utility Saved Assets with FR3 Fluid

A large investor-owned utility with service territories in the Midwest performed a safety audit at one of their coal-fired generating stations. They determined that the 200 MVA, 161 kV Generator Step-Up (GSU) Power Transformer, with an 865 kW Static Excitation Transformer, 14 MVA Main Auxiliary Transformer, and 11 MVA Reserve Auxiliary Transformer were too close to the main station facility to meet new safety requirements. The need for the retrofit benefited the utility by extending asset life and addressing safety requirements for this equipment, which was located too close to the main station building. Traditional external fire protection methods were not attractive due to their expense, on-going maintenance costs and ability to only limit or contain a fire, not prevent one. In addition, since the GSU was on the banks of a river, switching to an environmentally preferable, vegetable oil-based dielectric like FR3 fluid was also a significant benefit.

Cooper Power Systems Envirotemp® FR3® (FR3) fluid is approved by FM Global®, as well as Classified by UL® for fire-sensitive installations. FM Global has recognized the fire safety benefits of fire-resistant (or "less-flammable" per the NESC) fluids in distribution and small power transformers for more than 20 years. The FM Global Loss Prevention Data 5-4 (May 2003) also allow the use of approved fire-resistant insulating liquid as a fire safeguard for transformers containing up to 10,000 gallons of fluid, as close as five feet from a fire-resistant or non-combustible structure, without additional fire protection. No fire walls, enclosures or sprinkler systems are required. A retrofit with FR3 fluid replacing mineral oil could be done during a routine shutdown

and leaving the transformers in place. By choosing FR3 fluid as a replacement for the existing mineral oil, the utility not only met FM Global safety requirements, but integrated fire prevention into the transformer itself. The FR3 fluid retrofit saved the utility money immediately compared to the installation of a deluge system. In addition, due to FR3 fluid's ability to extend the thermal life of cellulose insulating paper, the expected life of the retrofilled transformers is at least doubled by the utility's calculations based on **IEEE Standard C57™** insulation life standards. In the case of the 200 MVA GSU originally installed in the 1950's, the estimated remaining life has doubled, deferring a replacement purchase at least five years.

When the utility analyzed the net present value (NPV) of the cash flows for retrofitting versus installing a deluge system, they projected an NPV benefit of \$490,000. Key components of the analysis included a lower cost of retrofit than to install a deluge system, lower fire liability and insurance costs, lower environmental liability and lower maintenance costs. The largest economic benefit came from the deferral of replacement of the transformer. Because of the asset life extension, this Investor Owned Utility's accounting practices allowed the retrofit cost to be treated as a capital investment that could be depreciated, not a period expense. The same economic model also projected a positive return on investment after only two years. This utility sees benefit to retrofitting their generating station transformers, located close to buildings, to take advantage of the fire safety, environmental exposure and asset life extension benefits of FR3 fluid.

The lower propensity of fires associated with seed-oil-filled gear is also recognized by FM Global, one of the world's largest commercial and industrial property insurers. FM Global specifies significantly larger clearances between mineral oil-filled equipment and nearby buildings than is necessary for electrical equipment using high ignition temperature, seed-oil, dielectric fluids, such as FR3 fluid. The FM Global minimum clearance for mineral oil is calculated from the edge of the oil containment structure to the nearest equipment or building. Even more advantageous for FR3 fluid, the measurement is from the transformer itself to the nearest equipment or building. This can result in clearance reduction for FR3 fluid to just five feet compared to 60 feet or more for mineral oil installations. These lower clearances require less real estate allowing better utilization of real property. Installing electrical equipment closer to the loads also reduces the length of expensive bus work. Typically expensive to install and maintain deluge systems are not required for FR3 fluid power transformers, including GSUs. These benefits combined yield significant financial benefits.

A key distinction between mineral oil and seed oils is their biodegradability. Unlike mineral oil, FR3 fluid is 100 percent readily biodegradable, non-toxic, and essentially decomposes into H<sub>2</sub>O and CO<sub>2</sub> in 21 days. It is produced from seed oil and a small quantity of food-grade performance-enhancing additives. Consequently, costs associated with spill prevention and spill remediation can be much lower for FR3 fluid than for petroleum-based or synthetic fluids. While the likelihood of a transformer fluid spill in a given year may seem small, approximately 14,000 fluid spills are reported in the U.S. each year. The costs of these spills can be substantial, particularly for large power transformers, which may contain over 10,000 gallons of fluid. Spilling large amounts of mineral oil can cost a utility several hundred thousand dollars. The site may have to be excavated, remediated, and the contaminated soil properly disposed of.

## Benefits of Proactive Management

Proactive management of aging transformer assets is a necessary step that every utility must take. The benefits are numerous and the cost savings are easy to quantify. Whether it be reduced fire and oil spill risk, reduced insurance premiums or deferred investment. The intangible benefits from avoiding negative public relations events are also a factor to consider to make your balance sheet and your environmental profile greener, while making your competitors green with envy! ■

## Assumptions

*Assumptions for both 50 kVA and 1 MVA: 20 year expected life of the mineral oil transformer, 35 percent Corporate Tax Rate, 15 percent Discount Rate (or Cost of Capital), 10 percent End-of-Life Equipment Salvage Value, 1 percent Real Inflation Rate of Equipment, \$4 per gallon for mineral oil, \$8 per gallon for FR3 fluid, 0.05 percent of FR3 fluid-filled transformer and installation cost allocation into contingency budget and 0.50 percent of mineral oil transformer and installation cost allocation into contingency budget.*

*Assumptions specific to 50 kVA: 40 gallons of fluid, \$2250 mineral oil transformer cost, \$2500 EF transformer cost, installation costs of \$3000 for both fluids, fire-wall costs for \$2000 for both fluids, no deluge system installed, \$10 reduction in insurance premiums per year for FR3 fluid due to lower fire risk, \$500/hr cost of downtime for both fluids, 4 hours of downtime in the event of a fire for both fluids, 4 hours of downtime in the event of a spill for both fluids, \$5000 cost of a fire for both fluids, \$1000 cost of spill remediation for FR3 fluid, \$5000 cost of spill remediation for mineral oil, 0.0000 annual fire frequency for FR3 fluid, 0.00040 annual fire frequency for mineral oil, 0.0040 annual spill frequency for FR3 fluid and mineral oil, \$350 cost per service interruption for both fluids.*

*Assumptions specific to 1 MVA: 350 gallons of fluid, \$18,000 mineral oil transformer cost, \$20,000 FR3 fluid-filled transformer cost, installation costs of \$5000 for both fluids, firewall costs for \$5000 for both fluids, deluge system costs of \$5000 for both fluids, \$25 reduction in insurance premiums per year for FR3 fluid due to lower fire risk, \$1000 in reduced bus work for FR3 fluid, \$5000/hr cost of downtime for both fluids, 24 hours of downtime in the event of a fire for both fluids, 24 hours of downtime in the event of a spill for both fluids, \$10,000 cost of a fire for both fluids, \$5000 cost of spill remediation for FR3 fluid, \$25,000 cost of spill remediation for mineral oil, 0.0000 annual fire frequency for FR3 fluid, 0.00040 annual fire frequency for mineral oil, 0.0040 annual spill frequency for FR3 fluid and mineral oil, \$7000 cost per service interruption for both fluids.*

