Smart Grid Payback

By **Donald Lamontagne**, *Arizona Public Service Co.*

Marine Maj. Gregory "Pappy" Boyington, World War II fighter pilot and leader of the famed Black Sheep squadron, once said flying is "hours and hours of boredom, sprinkled with a few seconds of sheer terror." The same can be said of transformer monitoring.

In several articles I have written for *T&D World*, I described Arizona Public Service's (APS's) Transformer Oil Analysis and Notification (TOAN) system. Now, I would like to explore the cost-benefit proposition of on-line dissolved gas analysis (DGA).

On July 4, 2004, APS experienced one of the largest substation fires in recent memory at its Westwing Substation. The event caused the loss of five 500-MVA, 525/230-kV single-phase transformers. Westwing has three 1,500-MVA banks of 525/230-kV single-phase transformers and is a major import hub for the Phoenix, Arizona, U.S., area.

Five consecutive phases were destroyed, so two of the banks were unavailable, right during peak loading season. APS was able to procure a spare phase of 400-MVA capacity to partially restore one bank to service within one month, but the other bank was out of service for more than a year, until new transformers could be procured and installed. The following year, the partially restored bank was fully restored with new transformers. Needless to say, this was not only a strain on APS operations, but it was extremely expensive.

As part of the corrective actions for the event, APS decided to install on-line DGA monitors for all 230-kV and above transformers and oil-filled shunt reactors. APS also built a state-of-the-art DGA diagnosis and reporting system.

APS's TOAN system is the first-of-its-kind artificial intelligence platform for on-line DGA. It employs artificial neural networks and fuzzy logic for the diagnosis and severity estimation, and an exception-based notification system to screen out repetitive diagnoses. The artificial neural networks have an accuracy of better than 96%, and the exception based system has an efficiency of more than 99.5%.

APS has one of the largest fleets of on-line DGA monitors, currently more than 190 monitors. These monitors produce a total of more than 400,000 DGA samples per year. The anticipated volume of samples that were going to be produced spurred me to develop the TOAN system, because I knew something had to be created that could automatically separate the samples that were repetitive or not of interest from those that created a few seconds of sheer terror.

The simplest way to think about the cost-benefit analysis for on-line DGA is to compare the cost of monitoring to the replacement cost of the transformers, the collateral damage caused by catastrophic failures and, in some cases (particularly for generator step-up transformers), the cost of the replacement power. In some cases, catastrophic failures can double the cost of the event because of the collateral damage.

The replacement cost of the transformers that TOAN monitors is estimated to be US$750 million. The cost to develop TOAN and install all of the monitors is approximately 1.5% of the replacement cost. Further, replacement power is a consideration for large base-loaded generation and the cost of lost generation can exceed $1 million per day.

In one example at APS, having an on-line monitor in conjunction with TOAN gave plant operators enough confidence to stay on-line for months until the next scheduled outage, rather than take a forced outage for two weeks to replace a transformer. APS realized millions in savings.

In my previous *T&D World* articles, I described some of the analytics within TOAN that are able to detect impending catastrophic failures. To date, APS has detected three of these events and successfully de-energized and replaced those transformers, saving millions in collateral damage.

The most recent case occurred in May 2010. I was speaking at a conference in Sydney, Australia. On my way to the airport, I received an e-mail notification from TOAN that a 525/345-kV, 333-MVA single-phase transformer was actively arcing; the highest single spike of arcing gasses I had seen to date. Because of the time change, I was the only APS person notified by TOAN who was likely awake.

I was able to call the control center to request the transformer be de-energized, but the plane had to take off before I received confirmation. My few seconds of sheer terror actually lasted about 15 hours until I landed in the United States to receive an update. Fortunately, the transformer was successfully de-energized in time. The forensic examination discovered an arc that had already burned through 12 layers of insulating paper. TDW

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