Has the Tranformer Failed?

Hydro-Québec goes proactive to ensure line worker safety, improve customer satisfaction and increase operational efficiency.

by **Daniel Desrosiers**, *Hydro-Québec*

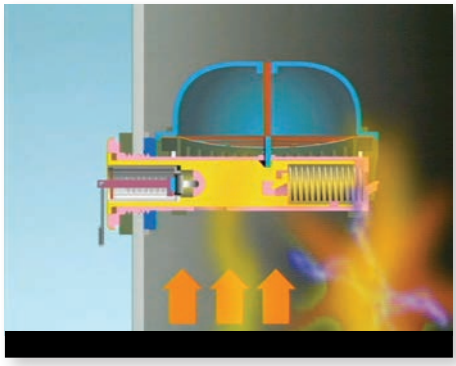
IT'S ALL ABOUT POLE-MOUNTED DISTRIBUTION TRANSFORMERS. Like every other utility, line crews at Hydro-Québec (Montreal, Canada) find reclosing on distribution transformers both potentially dangerous and time consuming. With fuses blown and reclosers open, deciding when to re-fuse a transformer and put it back in service can be difficult. Is it just the fuse, or has the transformer faulted?

The Internal Fault Detector (IFD) from IFD Corp. (Vancouver, Canada) was in development for more than a decade, and represents the result of a collaborative research and development effort involving financial and technical support by the National Research Council, a group of utilities and CEA Technologies Inc. (Montreal). The objectives for the IFD were to improve worker productivity, enhance customer service and increase overall safety associated with transformer failures. More than 45% of all new pole-mounted transformers in Canada are now shipped with an IFD.

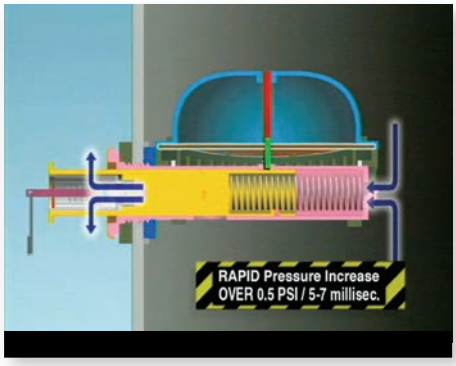
Until recently, there had not been a sound, reliable test—without disconnecting the transformer and applying voltage—to detect faulted pole-mounted transformers. Hydro-Québec now uses IFDs that physically flag faulted pole-mounted transformers.

The IFD has two functions. It incorporates the pressure-relief device (PRD) and provides a visual indication on whether the transformer has faulted internally. The PRD conforms to ANSI's PRD standard, and the sensor inside the IFD detects pressure changes in the airspace above the oil that are caused by internal faults.

The IFD sensor is calibrated to respond only to pressure changes due to faults, not to normal pressure changes due to increased load or rising ambient temperatures. When a fault is detected, an orange indicator, which can be seen from the ground, pops out. The line crew knows immediately that the transformer needs to be replaced. No time is wasted even considering the bad decision to reclose on the transformer. No one is placed in danger, and the utility saves time and money.



Prior to operation, the pressure-detecting membrane and its trigger shaft (red and blue vertical rod) are in the lowered position, locking the indicator (yellow) in place. The large spring on the right side stores the energy to push the indicator out; the small coaxial assembly on the left is the pressure relief device (PRD).



When the membrane reacts to the pressure pulse caused by an internal fault, it moves up, carrying the trigger shaft with it (red and green). This releases the indicator, which is pushed out by the spring. Once this happens, pressure is relieved through the IFD. The blue arrows indicate the flow of gas through the indicator assembly.

Shows a typical distribution pole top with a blown fuse cut-out to the transformer. This transformer is equipped with an IFD that is indicating with the orange flag that the transformer has an internal fault and should be removed from service.

EFFICIENCY

Like all utilities, Hydro-Québec continuously looks for ways to increase efficiency. So, if you consider the time it takes to properly reclose on a potentially dangerous transformer, there is a real operational advantage to using IFDs because they remove the time-consuming decision-making process (return to service or replace) to determine if the transformer is faulted. Our experience has been that only one out of four transformers is usually faulty.

When an IFD has activated, a line worker or scout can call the dispatcher and report that the transformer has faulted, the size of the transformer and the location. Hydro-Québec then sends a replacement team. When the line worker determines the transformer has not faulted, the worker can look to different causes for the fuse operating before starting the process of safely re-energizing, which leads to a faster, safer resolution of the problem. So, in all circumstances where the fuse has operated and an IFD is installed, the line worker saves time.

SAFETY

Hydro-Québec has an objective of zero accidents. The utility also has some of the strongest safety-oriented policies in the utility industry. The decision to use the IFD is one of the many policies that address this objective. When you try to increase the efficiency of your process, you have to maintain, if not increase, the safety level.

Before including the IFD in its transformer specification, Hydro-Québec toured the manufacturing facility. IFDs are manufactured with stringent quality control, and each IFD is tested in the lab before being shipped. Therefore, it is highly unlikely an IFD device would give a false negative. Even so, mechanical failures are possible. To be on the safe side, IFD Corp. recommends that transformers where the IFD has not operated be reclosed following each utility's standard safety procedures.

CUSTOMER SATISFACTION

Customer service is important to Hydro-Québec. By making diagnoses faster and improving the efficiency of trouble crews, utilities can reduce the system average interruption duration index. Restoration is quicker because time is not spent restoring what is faulty. All the information is rapidly being sent to the dispatcher, who then decides how many transformers to send and how many work crews to assign.

Hydro-Québec is considering launching a public-awareness campaign to let customers know about IFDs. The company would ask the public to check for an IFD on their transformers and, if they do see the orange indicator of an IFD, to let Hydro-Québec know so it can make a no-light call. It would be easier for Hydro-Québec to know which kind of crew it has to send on the trouble call, which means faster restoration and increased customer satisfaction.

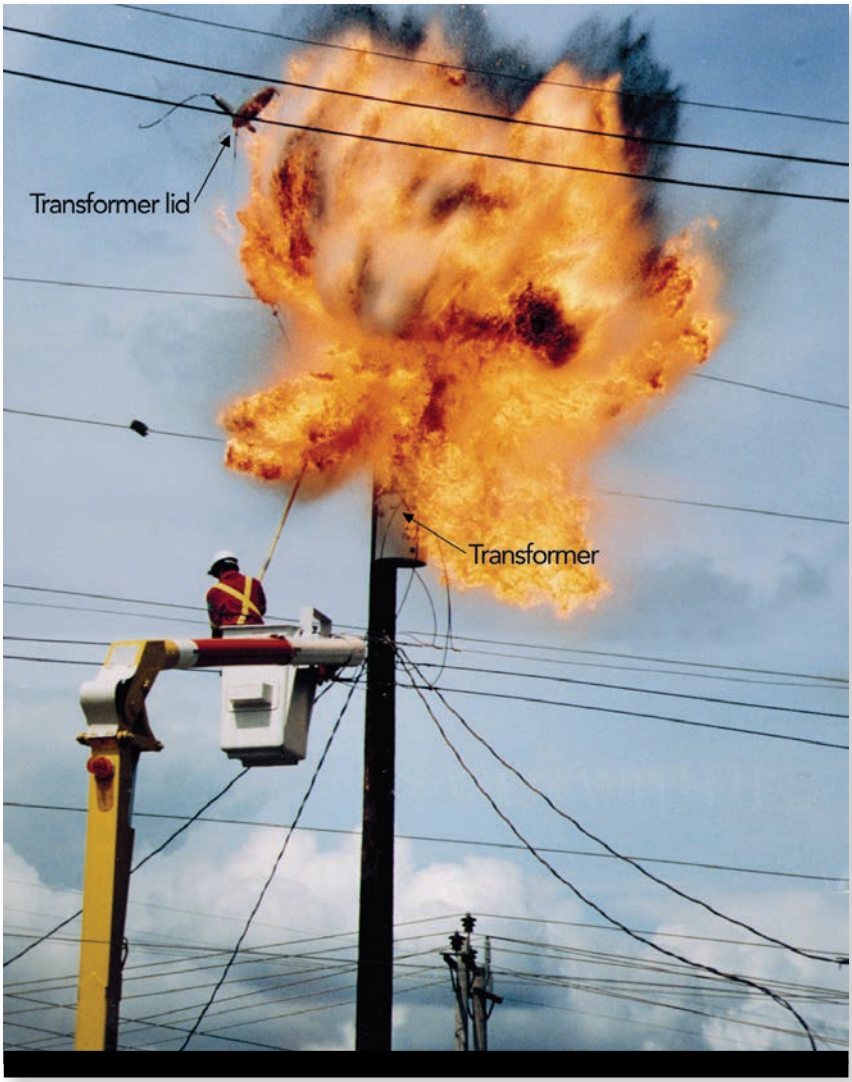
WEATHER IMPACT

Like every other utility, Hydro-Québec finds dealing with outages, especially major storm outages, challenging—particularly if there have been many lightning strikes. In a severe lightning storm, literally thousands of fuses can operate in a limited geographic area in a period of only a few hours. This puts

TRANSFORMER FAILURE DATA

CEA Technologies Inc. analyzed how pole-mounted transformer tanks actually fail in service. Their report documents that of a population of more than 400,000 units, there were approximately 20,000 (5% of population) fuse operations per year. In these fuse operations, a total of 4000 units (1% of total population) failed per year. About one in 270 of the failed unit operations was explosive in nature. Or, there are about 15 explosive failed unit reclose operations annually. The population was in eastern Canada and the researchers expect that in areas with greater lightning activity, the percentage of failed units would be greater.

There are more than 50 million distribution transformers in service in North America. And, applying the CEA Technologies Inc. findings about failure incidence to this larger population, one would expect between 1100 and 1800 explosive transformer reclosings annually without IFD applications or if no checks or precautions were taken.



This is the possible result of reclosing on a transformer with an internal fault. This photo was staged at a utility test lab with a mannequin, not a line worker, and the reclose onto the line voltage was done remotely.

A typical shot of a line worker reclosing a refused cut-out. Without an IFD there is no way to know the consequences of this action.

tremendous pressure on the linemen who are working to restore power. As transformers fail in these areas, they are being replaced by units with IFDs. So, units with IFDs are finding their way into the areas they are most needed. Annually, Hydro-Québec replaces 3000 faulty transformers, which has been the average over the last 10 years.

HARD NUMBERS

Hydro-Québec has more than 3.3 million customers and about 550,000 pole-mounted transformers. Each year, the utility installs between 10,000 and 12,000 new units—all of which have IFDs installed by the transformer manufacturer.

Hydro-Québec's line workers would like a higher penetration rate, but this is not possible yet. The most efficient method for getting IFDs onto a system is through the installation of new transformers (either through new construction or the replacement of existing units). It is possible to retrofit a unit with an IFD, but the costs associated with removing the transformer from the pole to do so are currently too high to make it cost effective. On the other hand, the cost to have an IFD installed in a transformer already in the shop is relatively low.

Since Hydro-Québec has been specifying IFDs in all new pole-mounted transformers for three years, total penetration is about 12%. Nevertheless, even with this fractional penetration, the company is seeing results.

THE RIGHT DECISION

After using the IFD for three years, Hydro-Québec wanted to assess the financial impact of introducing the IFD on pole-mounted transformers. To do this evaluation, Hydro-Québec first looked into events influenced by the presence of IFDs in transformers.

Experts were consulted to establish the impact of having, or not having, IFDs in transformers. These experts used reliability data, frequency and duration of events to build the business model for a single year of purchase of transformers equipped with IFDs. Finally, they built cash-flow models based on the impact of their data analysis.

The data showed that, typically, replacing a transformer requires:

- Four hours for a two-linemen team if they can use their equipment, such as a boom truck
- Six hours for a five-linemen team if the transformer is situated in a back-lot location.

In the case where there is no evident cause for the fuse operation, testing or inspection is required before re-energizing the transformer. These experts estimated that 70% of the time having an IFD-equipped transformer, diagnostic, testing and inspection prior to closing the fuse, can be reduced by 30 minutes to 1 hour.

When calculating the net present value of having certain transformer populations equipped with IFDs, the following hypotheses were used:

- Additional cost of the IFD: US$40
- Transformer life expectancy: 30 years

- Transformer's fuses operation rate: 3.8% (spread evenly over the life of the transformer)
- Annual purchase: 10,000 transformers
- Hourly linemen team rate: $232
- No dollar value for incident/accident reduction
- No dollar value for positive reliability impact (downtime reduction).

The resulting business case showed that on a 30-year planning horizon, the net present value for an additional dollar spent toward IFD installation in pole-mounted distribution transformers is estimated at $1.55. Additionally, in the long term, Hydro-Québec expects the IFD to provide better diagnostic information that should prevent non-required replacements of transformers (300 units per year estimated).

Furthermore, no dollar value was attributed to downtime reduction for customers and lower risks for linemen since these issues are strategic in nature.

From this data, the conclusion is that including IFDs in transformers is not only a good risk-reduction practice, but also produces an excellent return on the initial investment. More strategically, the IFD represents another small step on the journey to a distribution system where, more and more, information is used to improve customer service and the effective utilization and safety of valuable resources. TDW

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