NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

# Lesson Learned

## Moisture Intrusion in Hermetically Sealed Metering Current Transformers

**Primary Interest Groups**
Transmission Owners (TOs)
Generator Owners (GOs)

**Problem Statement**
Three hermetically sealed oil-filled metering current transformers (CTs) were placed in service after being in open storage for several years. One failed after five weeks of service; another failed after 10 weeks.

**Details**
In early 2018, three 138 kV metering CTs were retrieved from a utility's long-term storage and tested per the manufacturer's recommendations. The CTs had been stored outdoors, which was within manufacturer's guidelines. The testing included a hi-pot test to 80 kV dc for one minute; a CT ratio, saturation, and polarity test; and a 1 kV insulation test. All testing yielded satisfactory results and the CTs were released to be placed into service as metering CTs.

Oil samples were not taken from the units as the manufacturer's instruction manual advised against it due to the potential to introduce bubbles or contaminants and establish leakage. There were no external signs of oil leakage. The three CTs were subsequently installed on Phases A, B, and C on the 138 kV feeder at the station; secondary connections were made and a primary injection test was successfully performed. The CTs were placed into metering service on the main 138 kV feeder to the utility's system about three months after retrieval from storage.

Approximately five weeks later, the C-phase metering CT experienced a catastrophic failure. The fault interrupted transmission service to the utility's entire service territory. Due to discovery of bullet holes in fence signs and visual observations of potential impact markings on an overhead bus bar, it seemed that foul play could be involved at first. In the overnight hours, crews removed and by-passed the faulted C-phase CT and returned the feeder to service.

Post event, the failed C-phase CT was shipped to an independent test lab for forensic analysis. The two

remaining in-service CTs were scanned with an infrared camera for signs of overheating; no anomalies were observed. Secondary metering data in SCADA was also closely monitored for any abnormal behavior and none was observed.


Ten weeks later, the utility experienced a failure of the A-phase CT while awaiting the results of the forensic analysis. The fault interrupted transmission service to the entire service territory once more. Line crews and engineering responded to the station and removed and by-passed both the faulted A-phase CT and the un-faulted B-phase CT for precautionary reasons.

Analysis of relay data post failure shows no indication of problems prior to the failure. The utility has procured and received replacement metering devices. Oil samples have been taken from both the faulted A-phase and unfaulted B-phase CTs for analysis. The initial inspection of the unfaulted B-phase CT did not revealed any abnormalities in oil level, condition, moisture content, or any other visual causes for concern; however, diagnostic test results from those samples indicated elevated moisture content just above acceptable levels for an in-service component. The A and B CTs were sent to an independent test lab for analysis. The final report from the test lab determined the root cause was that the design allowed moisture to enter the metering CT. The seal design allowed moisture at the rim of the two sections of the tank to be pulled in by internal pressure changes in the otherwise hermetically sealed oil containment caused by the daily cycling of temperature (this is more of an effect in de-energized equipment in open storage – not as much in devices heated by being continuously energized). Over time, this allowed atmospheric moisture to contaminate the CT's kraft paper insulation.

## Corrective Actions

After all three single-phase units were removed from service and bypassed to restore service to the single 138 kV feeder to the utility, Engineering ordered new CT/PT combination units. The newly purchased units were also hermetically sealed; however, the design called for a bolted gasket system. In addition,

the utility has implemented a new program that involves the purchase of spare units at the time of initial purchase and to store the spares in a climate-controlled dry, indoor environment.

## Lesson Learned

Below is a list of lessons learned from this event:

- Electromagnetic CTs may fail without warning and may have with long lead times to purchase replacements. Keep spare units on hand.
- Spare unit storage should ideally be in a temperature/humidity controlled environment.
- Moisture content oil sampling is recommended prior to use if the device was kept in long-term storage. Some manufacturers do not recommend oil sampling by the user. - In those cases, contact the manufacturer, and ship it back to them if necessary to properly perform the sampling.
- Normal hi-pot testing in the field may not indicate a high-moisture content when such a problem is present. The factory test level for this class of CT was 275 kV ac, so an 80 kV dc field test does not stress the insulation enough to reliably find a high moisture condition.
- CT testing (polarity, ratio, and saturation) can provide “perfect-looking” test results despite elevated moisture content. A Doble test (insulation power factor) may provide a better indication of moisture if an original baseline test was performed for comparison later.
- Observing perfect-looking metering data provided no early warning signs or guarantee of avoidance of catastrophic failure.

Other observations are as follows:

- Both encountered failures did not occur during highest load or ambient temperature hours of the day, but occurred at 11:00 p.m., as loads and ambient temperatures were decreasing after daytime levels. This can be a clue when looking into moisture accumulation as a potential cause.
- While catastrophic failure of porcelain components of the CT did not occur in this case, consideration should be given to incorporating shrapnel barriers (e.g., walls) in station designs to protect adjacent equipment. Such barriers may enhance physical security aspects as well.
- Oil-filled CT failures are often not easily isolated nor extinguished, resulting in fires that may burn for hours. Consideration should be given to other metering technology like optical CTs, which are immune to most of the common wire-wound CT failure mechanisms, or high-accuracy breaker bushing CTs.

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