NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

Lesson Learned

Air Blast Circuit Breaker Cold Weather Operation

Primary Interest Groups

Transmission Owners (TO)
Transmission Operators (TOP)
Generator Owners (GO)
Generator Operators (GOP)
Reliability Coordinators (RC)

Problem Statement

Cold weather temperatures can drastically challenge the reliability of the Bulk Electric System (BES). This lesson learned focuses on a specific issue for sectionalizing elements in substations. Extreme cold can impede the ability to perform local actions and quick switching of network topology. Restriction of operating maneuvers caused by cold weather also limits scenarios that system operators can perform to overcome emergencies

Details

This substation event took place in very cold and windy location. Local temperatures dropped to -33 F (-36 C) with wind-chill effectively making it -45 F (-42.8 C). Throughout the day, the temperature rose only a few degrees, but winds remained strong. Responding to contingencies and under these conditions in substations is always dangerous and risky.

Earlier in the morning, one air blast circuit breaker automatically locked in the "closed" position because of low pressure protection due to air leaks from the gaskets (see Figure 1). Typically, the air compressor can keep up with slow leaks, but in this extreme cold the leak rate exceeded the compressor's ability to adapt.

The operator tried to isolate the circuit breaker, but one of the phases of adjacent motor-operated disconnect switches did not operate properly because of weather conditions (only two phases opened).

Figure 1: The Failed Air Blast Breaker

This resulted in the opening of several circuit breakers in the substation, the tripping of one circuit, and excessive compressor runtime alarms on the breakers.

The maintenance team worked to isolate the circuit breaker. The intense cold made accessing the disconnect switches for manual operation unwise. The remediation took place the day after with the maintenance teams on location to find the most opportune time to work dependent on the temperature.

Cause

In this case, air leaks occurred from the degradation of the breaker's seals (location marked C-20 in **Figure 2**) mostly due to compression set and hardening that comes with age. The cold temperature causes shrinkage and additional hardness, which is why leakage is more frequently noted in cold weather. (see **Figure 3**).

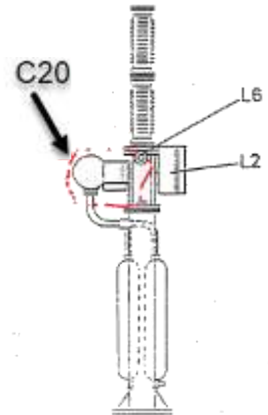

Figure 2: Location of the C-20 Seal

Figure 3: Section of the C-20 Seal that Failed

Observation and Conclusions

The substation in question employed multiple types of circuit breakers: various models of SF_6 circuit breakers and two types of air blast circuit breakers. Both types of transmission-level air blast breakers in this location had been orphaned by their manufacturer.

Air blast breakers comprise 7% of the entity's transmission breakers and are the circuit breakers that seem to tolerate the extreme cold the least in this entity's experience. The entity intends to replace their transmission air blast breakers with SF_6 breakers over time. Due to the extreme cold temperatures in their area, the entity uses heaters, insulated tanks, and mixed gases (SF6/CF4 or SF6/N2) for many of their SF_6 breakers.[1]

The type of air blast breaker that failed in the event described in this lesson learned failed due to the effect of air leaks at their C-20 seals. These air blast breakers are maintained at an internal pressure of 3.1 MPA (450 psi) or 15 MPa (2175 psi). Cold weather was not the only culprit; the seals should have been monitored more frequently and changed earlier during maintenance programs. These breakers were about 36 years

[1] See NERC Lesson Learned LL20201101 Cold Weather Operation of SF6 Circuit Breakers: https://www.nerc.com/pa/rrm/ea/Lessons%20Learned%20Document%20Library/LL20201101_SF6_CB_Operation_during_Cold_Weather.pdf

old and the seals have a mean time between failure of about 20 years. The seals acquire a “set” over time (i.e., the seal elastomer hardens and retains its compressed shape so it does not expand to fill gaps if compression is relaxed.). The entity determined that an inspection frequency of 8 years may be able to detect seal degradation before a failure occurs and allow for a preventive replacement. Durometer measurements taken over the years may be used to track the age-related hardening and can be an input for scheduling predictive-maintenance-based seal replacement. See **Figure 4**.

The other type of air blast breaker at this location had a different temperature-related failure mechanism: grout failure. These air blast breakers are maintained at an internal pressure of 3.5 MPA (35 bar [508 psi]) and were 34 years old on average. Typical grout failure begins with a combination of a less-than-adequate waterproof coating for the grout and many freeze/thaw cycles. Coatings decay over time, so this is usually a periodic inspection and maintenance issue. Liquid water gets into tiny crevices or cracks in unsealed grout. When the water freezes, it expands about 4% and expands the crack. After many cycles, the cracks can be a source of leakage and can eventually become a structural issue. If the grout is holding a bushing with no other adequate restraint/mechanical capture in place, the internal air pressure (500 psi in this case) may launch the bushing like a rocket, flinging large and heavy objects and shrapnel that can harm personnel or damage equipment.

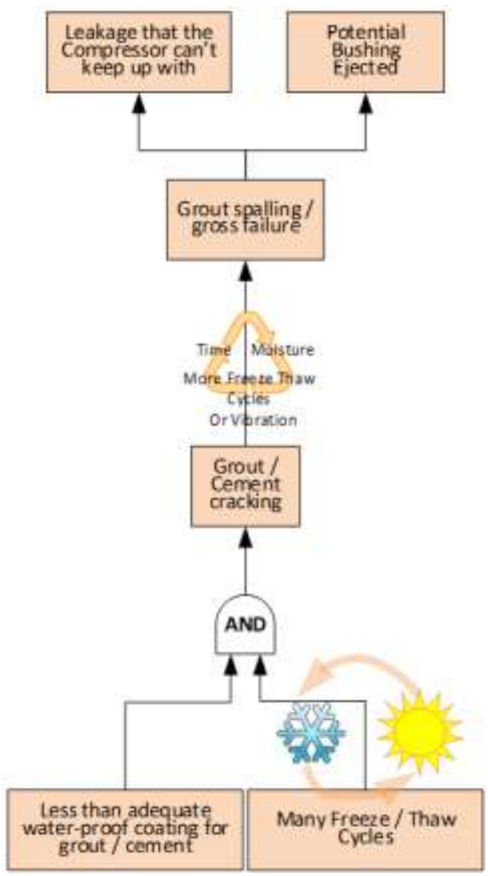

Figure 4: Air Blast Breaker Grout Failure Mechanism

Corrective Actions

A regular maintenance program to prevent issues for the air blast breakers includes the following:

- **Predictive Inspection:** This maintenance for air blast breakers is meant to detect issues that concern resistance, the appearance of corrosion or mechanical damage, silicone seals, and the position of drip washers. This should occur every 8 years.

- **Complete Inspection:** One module per breaker is inspected. The main contacts and sub-assemblies (blow-off and control valves as well as the C-20 valve and its spherical reservoir) are tested and drive shaft pins are replaced. This maintenance should occur every 1,000 operations.

Lesson Learned

- Scheduled condition monitoring should be used to keep track of seal or gasket degradation as a potential cause of air leakage. Extreme cold temperatures reduce the effectiveness of the seals due to loss of elasticity during operations. Long term compression of gaskets also makes them less effective.
- Maintenance and inspection practices for air blast circuit breakers need to include condition checks and grout and coating replacements as needed.
- Advancing maintenance programs to replace seals and gaskets earlier than specified in the manufacturer's manual should be considered.
- Small air leaks cause unnecessary cycling and wear on compressors, resulting in additional maintenance needs (e.g., oil changes, belt/motor/piston replacement).
- The complexity and number of required components in an air blast breaker introduces additional failure modes and mechanisms not seen in similar capability SF6 breakers. They have additional maintenance needs as well. The general age of these devices and the difficulty in obtaining service and parts from the vendors adds to the cost of maintaining them. Entities may find that a cost benefit analysis favors their replacement with something else.

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