NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Lessons Learned

Unintended Consequences of Altering Protection System Wiring to Accommodate Failing Equipment

Primary Interest Groups

Substation Maintenance Groups
Substation Design Groups
Transmission Owners (TOs)
Transmission Operators (TOPs)

Problem Statement

Following standard entity practice on discovering a failing capacitor coupled voltage transformer (CCVT), the voltage sensing for the equipment protecting the CCVT line position was jumpered to a CCVT on a nearby line position, but the failing CCVT was left connected to the Bulk Electric System. The applied jumper provided a false indication of good sync voltage across the open breaker, causing the sync-check relays in the reclosing system to close the breakers into a permanent fault multiple times in rapid succession. This in turn caused relay operations at three non-faulted line terminals that were determined to be misoperations.

Details

The TOP received an ancillary alarm for a secondary voltage issue on a CCVT located at a substation. This alarm cleared later in the morning and then the same alarm came back in shortly after noon that same day. Just after noon, a system operator electrician was dispatched to the substation, analyzed the situation, and determined that configuration of the conductor attachment to the CCVT prevented cutting the failing CCVT in the clear that day. To avoid removing a line position from service, operators left a failing CCVT connected to the system, but substation maintenance replaced that line position protection voltage sensing to a source on a nearby line position.

To accommodate the potentially long repair schedule of the CCVT replacement, the decision was made to apply a jumper from a line relay panel protecting a different terminal to the panel with the degraded CCVT reading. This utilized a voltage input from a nearby transmission line as a stopgap measure to maintain protection on the line. A relay technician was called to site and the jumper was applied.

The CCVT failed[1] that same evening, causing a fault. Initially, the line relays cleared the fault that was due to the CCVT failure properly. After this, the reclosing relay should have attempted only one reclose and then locked out due to the faulted equipment. Because of the false indication of a good voltage being utilized from a healthy line terminal, the reclosing system operated continuously through the automatic sync-close circuit.

After the second reclose attempt, a line phase and a ground distance relay on a different terminal operated for unknown reasons. This relay was later tested, and relay setting calculations were reviewed with no root cause found. This operation was classified as a misoperation.

After the fourth reclose at the failed CCVT terminal, a ground overcurrent relay at an upstream substation operated. This was caused by “ratcheting” of the electromechanical disc as it saw fault current with each reclose attempt with very little disc reset time in-between reclose attempts. This operation was also classified as a misoperation.

[1] See previous NERC Lesson Learned LL20200402 “Protracted Fault in a Transmission Substation for a detailed discussion of a CCVT failure.

At this point in the event, several breakers were open, and all sources of infeed were removed between the faulted sub and a second upstream substation. The time-overcurrent relays at this upstream substation were then in-series with the time-overcurrent relays on the faulted terminal. The time-overcurrent settings did not coordinate in this system condition. The relays at this upstream substation tripped and were classified as a misoperation.

In total, the breakers on the faulted terminal reclosed seven times during the event. One of the two ring bus breakers ceased reclosing due to depleted air pressure, and the other became isolated by two of the misoperations previously cited. This event would have ended correctly with a trip-reclose-trip on the faulted terminal if not for the presence of a false sync-check voltage.

Corrective Actions

- The past practice of applying a jumper to compensate for a failing CCVT (to keep a line/bus section in service before until CCVT replacement can be completed) was used to plan for a repair in a safer and more controlled work environment in the next day or two. As a corrective action for this event, the practice of using voltages from an adjacent line or bus to replace those of a faulty CCVT will no longer be used.
- When a voltage alarm is generated for a CCVT and has been confirmed on-site by a system operator electrician, the CCVT and associated protected facility will immediately be taken out of service and remain out until the CCVT is replaced.

Lesson Learned

- The practice of using jumpers from a good CCVT to temporarily replace the voltages of a failing CCVT has been a standard practice at many entities. This practice has allowed for system integrity while planning for the replacement of a failing CCVT as time and resources permitted; however, when CCVTs get to the point that significant voltage error is noticed, the time to failure may be very short.
- Line outage scheduling to replace failing equipment may require a long-term temporary accommodation; this needs thorough consideration. It is difficult to predict the implications of altering protection system wiring in an ad hoc fashion. Taking time to review the design and properly engineer the modification could have avoided some of the problems.
- Equipment that is known to be failing should be removed from service as soon as practicable.

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