NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Lesson Learned

Substation Flooding Events Highlight Potential Design Deficiencies

Primary Interest Groups
Generator Owners (GO)
Generator Operators (GOP)
Transmission Owners (TO)
Transmission Operators (TOP)

Problem Statement
Heavy rainfall of 5.7 inches of rain and hail over a 2.5 hour period led to the flooding of a basement relay room in the control building at a 230 kV transformer station. This led to unexpected equipment and protection operations during the event that resulted in two 230 kV circuits and six generating units (representing a total of 495 MW) being removed from service over a period of 1 hour and 7 minutes.

Details
There was no actual power system fault during this incident. Due to the flooding in the relay room located in the basement of the transformer station control building, numerous 250 VDC control equipment connections were submerged in approximately 8 inches of water, leading to unexpected equipment and protection operations during the event. In total, 3 breakers had operated on false breaker trip inputs and 2 breakers had operated on false breaker failure inputs. The first breaker failure protection operation resulted in the loss of 1 circuit and 14 minutes later, 2 generating units (connected to the line terminal). Three attempts were subsequently made to restore the circuit to service but all were unsuccessful, and the equipment was considered unavailable as a result of multiple breakers at full duty cycle (breakers that have exceeded the number of reclosing attempts and are required to be inspected before attempting to reclose again).

The second breaker failure protection operation resulted in the loss of one circuit and four generation units (by configuration). The other three independent breaker operations did not result in the loss of any transmission facilities, so a total of two circuits and six generation units (representing a total of 495 MW) were removed from service during this event, which occurred over a period of 1 hour and 7 minutes. There was no load loss as a result of the equipment operations. To secure the system during this event, the RC reduced system operating limits postcontingency, redispatched resources in the area to manage equipment ratings, and coordinated with the neighboring RC to manage intertie transfer capabilities. There were no exceedances of any defined system operating limits during this event.

During the event, staff on site determined that the existing sump pumps were unable to keep up with the volume of water, requiring additional pumps to be installed a few hours later to assist with the effort. The sump pump outlets were also extended to ensure that water drained further away from the building as it was identified that water pumped out was flowing back into the basement through cable trays. Once staff implemented these temporary measures, the water level in the basement began to recede. After the water had been cleared, heaters/dryers were installed to dry out the wet equipment. Alarms started clearing, and

staff began the process of function testing protections, making necessary repairs, and returning equipment to service based on a priority list.

In summary, the TO's own assessment of the event found that the cause of the flooding in the control building basement relay room was a combination of heavy rainfall in a short amount of time and the drainage system from sump pumps being too close to the building. While some of the older vintage terminal racks were in the basement of the station, the critical power system equipment had been relocated above grade due to a previous flooding event. A similar flooding event resulted in LL20150402[1], and the entity had taken action to address the lessons learned from that situation.

Corrective Actions

- During the event, the TO implemented temporary measures by installing more sump pumps and extending sump pump outlets to allow for water to drain further from the building.
- A complete overview of the site drainage system will be performed by the TO to determine a more permanent solution.
- At the system operator's request, the TO will inspect other transmission stations that have been identified to be susceptible to flooding to ensure there are no similar design deficiencies (extent of condition investigation). This will include a review of changes to surrounding properties to ensure that changes there will not impact the flow of water in the area.
- All critical power system equipment at the transmission station involved in this event will be located above grade by 2023 as part of a project to upgrade equipment at the station.

Lesson Learned

As the frequency of adverse weather events increases, preventative actions should be taken by the TO to ensure that their transmission facilities are able to withstand the increased stress on equipment as a result of these adverse weather conditions.

Consider the following ideas for prevention or mitigation of substation flooding:

- TOs should consider an extent of condition review of transmission stations that have been identified to be susceptible to flooding to ensure that precautions are taken.
- TOs should consider an extent of condition review of transmission stations that have not previously been susceptible to flooding to ensure that is still the case.
- TOs should ensure that there are no design deficiencies, such as site drainage systems.
- Ensure that all critical power system equipment at the transmission stations are located above grade where possible.
- Past design criteria may no longer be sufficient. TOs and TOPs should review their criteria and ensure it meets what is needed for today and tomorrow.

[1] LL20150402: Severe Flooding Damages Transformer Substations

- Ensure that a plan is in place to handle rain if sensitive maintenance is occurring. Ensure that drainage is sufficient to move water away from the site and that the system is functional (e.g., pumps work, drains are not clogged).
- Periodic reviews of equipment susceptible to flooding are advisable to determine how water ingress might impact stations.
- Periodic review and examination of all potential water ingress sites are advisable, including cable trays, etc.
- Consider installing a barrier solution as appropriate[2]. Also, see the upcoming lessons learned on System Hardening.

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[2] Example: a potential solution from Duke Energy