Lesson Learned

Insulator Flashovers Due to Combination of Salt Spray Deposits Followed by Light Rainfall Initiating Loss of Load

Primary Interest Groups
Transmission Operator (TOP)
Transmission Owner (TO)

Problem Statement
Multiple parallel insulators in a bulk power substation that had been exposed to salt spray during a tropical storm flashed over two and a half days later when light rain began to fall. The flash overs were attributable to dry band arcing. Relay misoperations in the presence of the flashover faults resulted in loss of load.

Details
A tropical storm brought high winds of more than 50 miles per hour and moderate rainfall of one-half inch over the course of several hours (see **Figure 1**) by the meteorological data from a nearby weather station.

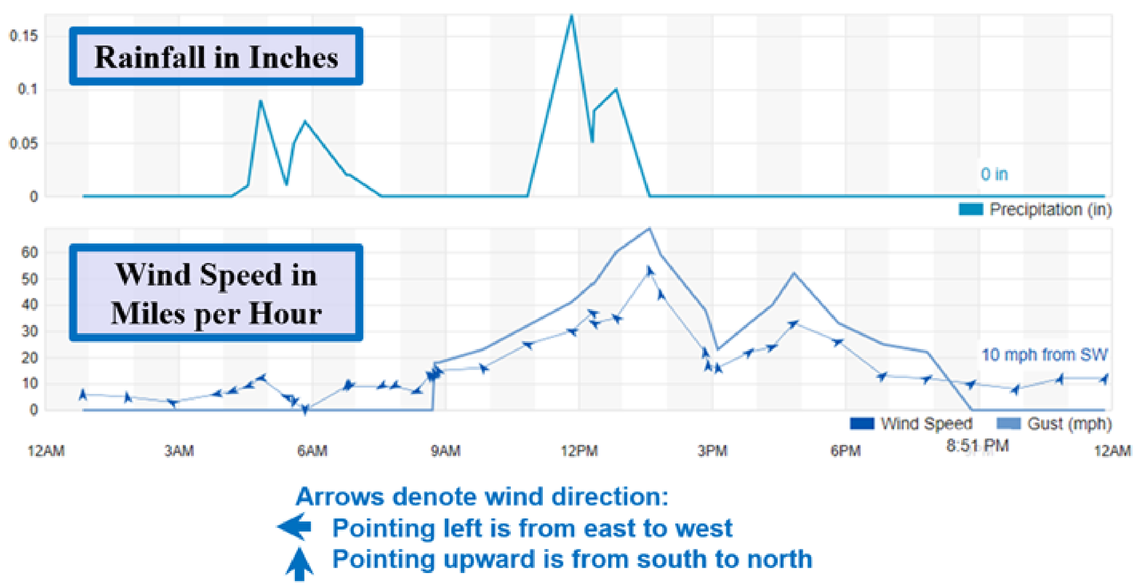

Figure 1: Rainfall, Windspeed, and Wind Direction During Tropical Storm

The rainfall ceased in the early afternoon as the winds were peaking. Around 3:00 p.m., the wind direction shifted. A second period of elevated winds ensued in the absence of any rain, although somewhat lesser than the first. The wind shift coincided with the time of high water in the saltwater channel bordering the substation, about one hour later than the time of the usual astronomical high tide on account of the storm surge. The alignment of wind direction and high water caused airborne salt spray above the churning water in the channel to be carried over the waterfront substation and deposited on surfaces therein, including insulators. Without any further rain to wash the deposits off, a thin, dry salt film remained.

Two and a half days after the storm had passed, the first rainfall arrived. It was a light rainfall in the early morning hours with no appreciable wind. Within minutes after the rain began, four 345 kV insulator columns flashed over on separate bus sections in various locations in the substation. All four flashovers occurred within a time span of only 23 seconds, and all resulted in single-line-to-ground faults on phase C that were cleared properly in normal high-speed fashion by bus differential relaying and circuit breaker tripping. Misoperation of protective relays on other transmission facilities during the faults, however, tripped non-faulted lines connected to the substation, ultimately leading to a loss of load.[1]

All four of the insulator columns that flashed over were double-stack vertical columns supporting 345 kV horizontal swing-arm disconnect switches. One is shown in **Figure 2**.

Figure 2: 345 kV Disconnect Switch w/Center-Pivot Horizontal Swing Arms

The single-stack center column supports the swing arm at its pivot point. The double-stack arrangement is visible on the righthand side. One column supports the righthand jaw of the switch assembly while the immediately adjacent column supports the overhead bus work.

The wetting of the insulators during the initial minutes of rainfall caused elevated leakage currents to flow along the insulator surfaces. This is referred to as the critical wetting period. The heat generated from these currents sufficed to burn off the salt film that had been deposited by the tropical storm winds two and a half days prior. This resulted in uneven voltage gradients top-to-bottom along the columns with highly concentrated electric fields in the areas where the film had been burned off. Dry band arcing ensued in these areas. While this in itself is not an uncommon phenomenon, the fact that it was developing simultaneously on two adjacent columns within close proximity, likely at different points of elevation along the columns, significantly increased the probability that the arcing would lead to an overall top-to-bottom flashover. Uneven top-to-bottom voltage gradients on each column resulted in a voltage gradient between or across the two columns at any given height, whereas ideally there should be none. The dry band arcing on one column had the opportunity to cross over and meet up with the dry band arcing on the adjacent column.

Damage to the insulators was minimal due to the arcing being essentially external along the surfaces. As the rainfall progressed, the salt film was washed off the surfaces, allowing the equipment to be restored to service. In fact, most of the transmission facilities and all the load were restored within 33 minutes.

[1] See NERC Lesson Learned LL20210802 "Multiple Faults in Rapid Succession Contribute to Relay Misoperations Leading to Loss of Load"

Corrective Actions

The substation where the faults occurred has been in service for 56 years and has never experienced simultaneous column insulator flashovers. None of the other waterfront substations of similar design in the entity's service territory have experienced this type of problem. Tempered by that long experience, the entity has opted for a measured response. Leakage current detectors are being installed on selected insulator columns so that the phenomenon can be tracked and trended over time during a variety of weather conditions. If any issues are identified, a mitigation plan will be formulated at that time.

Lesson Learned

- During atypical inclement weather conditions where waterfront substation properties are located near bodies of salt water, an unusual combination of strong winds from a particular direction, high tide, and the absence of rain can cause airborne salt spray to be carried over these facilities and deposited on surfaces in significant amounts, leaving a dry film.[2]
- Wetting of that film during subsequent rainfall, even days later, can wreak havoc with the overall dielectric withstand capability of insulator columns. Dry band arcing can develop during the critical wetting period, possibly resulting in flashovers.
- The probability of flashovers is significantly increased where parallel columns are used as arcing on one column can jump across and meet up with arcing on the adjacent column.
- The event described in this Lesson Learned was driven by a more rapid contamination process than generally considered for scheduled insulator cleanings.[3] While regular cleaning and maintaining anti-contamination coatings may remove and slow contaminant accumulation, awareness of conditions that cause rapid conductive contaminant deposition or remote leakage current monitoring and alarming are important tools for prompting actions that can prevent faults like these.

NERC's goal with publishing lessons learned is to provide industry with technical and understandable information that assists them with maintaining the reliability of the bulk power system. NERC is asking entities who have taken action on this lesson learned to respond to the short survey provided in the link below.

Click here for: Lesson Learned Comment Form

For more Information please contact:

NERC – Lessons Learned (via email)

Lesson Learned #:	20210801
Date Published:	August 6, 2021

[2] This phenomena occurs worldwide along salt water coasts, and can be expected along inland salt lakes. See:
"Estimation of atmospheric sea salt dry deposition: Wind speed and particle size dependence"
"Transport, Deposition and Distribution of Marine Aerosols over Southern Sweden during Dry Westerly Storms"
"Measurements and modelling of marine salt transportation and deposition in a tropical region in Brazil"
[3] See previous NERC Lesson Learned "Insulator Coating"

Category: Transmission Facilities

This document is designed to convey lessons learned from NERC's various activities. It is not intended to establish new requirements under NERC's Reliability Standards or to modify the requirements in any existing Reliability Standards. Compliance will continue to be determined based on language in the NERC Reliability Standards as they may be amended from time to time. Implementation of this lesson learned is not a substitute for compliance with requirements in NERC's Reliability Standards.