Texas Reliability Entity
Event Analysis

Event:
April 26, 2011 and May 27, 2011 Events
Category 1a Event

Texas Reliability Entity
August 15, 2011

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Executive Summary

Two separate events occurred in the ERCOT Region on April 26, 2011 and on May 27, 2011. The root cause of these events was due to insulator flashovers, combined with protection system misoperations, which in turn caused the loss of multiple Bulk Electric System (BES) transmission elements and resulted in the loss of numerous industrial loads in the area. This report provides: (1) an overview of the events; (2) the detailed sequence of events; and (3) an analysis of the causal and contributing factors for concerns that arose in this event.

I. Event Overview

Event #1 – April 26, 2011

Transmission Entity A and industrial customers had been experiencing tracking and flashovers of substation insulators for approximately one week prior to the event due to contamination build-up on insulators and lack of rain over the previous two months. At 04:33 on April 26, 2011, there was a fault on the Substation A line terminal in Substation B due to contamination on the insulators. Circuit breaker operations in Substation B, Substation C, and Substation A resulted in loss of power to the Substation C and Substation A and two industrial customers, totaling approximately 97.3 MW of load lost. Power was restored to one industrial customer at 07:25. Power was restored to the other industrial customer at approximately 18:00 after insulators in the Substation A were cleaned of contamination.

The event met the definition of a Category 1a event (loss of three or more bulk power system elements (i.e. generators, transmission lines, and buses)) event under the NERC ERO Event Analysis Process.

Event #2 – May 27, 2011

On May 27, 2011 at 01:48, there was a fault of the Substation B-Substation D 138 kV transmission line on a set of dead-end suspension insulators due to contamination on the insulators. Due to a misoperation of protection system devices at Substation E Switching Station, the event cascaded to include 15 substations, 13,751 distribution customers and 13 industrial customers in the area, totaling approximately 245.8 MW of load lost. Power was restored to all customers by 03:11.

The event met the definition of a Category 1a event (loss of three or more bulk power system elements (i.e. generators, transmission lines, and buses)) event under the NERC ERO Event Analysis Process

II. Sequence of Events

April 26, 2011

- 04:33:36 Fault occurs on the Substation A line terminal of the Substation A to Substation B 138 kV line
  Breakers trip at Substation A and Substation B to clear the fault
  Breakers XXX-1 and XXX-2 trip at Substation A (Line to Substation F).
  This was a Protection System Misoperation.
  Breakers XXX-5 and XXX-6 trip at Substation E (Line to Substation F).
  This was a Protection System Misoperation.
  Breakers XXX-3 and XXX-4 trip at Substation C (Line to Substation B).
  This was a Protection System Misoperation.

  The above operations caused outages to the following elements:
  1) Substation B-Substation A 138 kV line
  2) Substation B-Substation C 138 kV line
  3) Substation A-Substation F 138 kV line
  4) Substation A-Substation C 138 kV line
  5) Substation E-Substation F 138 kV line
  6) Substation A 138 kV bus
  7) Substation F 138 kV bus
  8) Substation C 138 kV bus

- 18:06 Substation B-Substation C 138 kV line 138 kV restored

- 18:43 Substation A-Substation F 138 kV line restored

- 18:43 Substation A-Substation C 138 kV line restored

May 27, 2011

- 01:48:11 Fault occurs on the 138 kV line Substation B to Substation D line
  Breakers trip at Substation B and Substation D to clear the fault
  Breakers XXX-7 and XXX-8 trip at Substation E (Line to Substation G).
  This was a Protection System Misoperation.
  Breakers XXX-5 and XXX-6 trip at Substation E (Line to Substation F).
  This was a Protection System Misoperation.

- 01:49:22 Breakers XXX-9 and XXX-10 trip on overload at Substation H (two 138/69 kV autotransformers). Overload was due to loss of two 138/69kV autotransformers at Substation B from above operations. The Substation H 138/69 kV autotransformer trips cause outages to multiple industrial facilities.

The 138 kV line operations caused outages to the following elements:

1) Substation B-Substation D 138 kV line
2) Substation B-Substation C 138 kV line
3) Substation B-Substation A 138 kV line
4) Substation E-Substation F 138 kV line
5) Substation E-Substation G 138 kV line
6) Substation A-Substation F 138 kV line
7) Substation A-Substation C 138 kV line
8) Substation A 138 kV bus
9) Substation B 138 kV bus (*including two 138/69 kV autotransformers*)
10) Substation F 138 kV bus
11) Substation C 138 kV bus

- 03:03 Substation B-Substation A 138 kV line restored and Substation A-Substation C 138 kV line restored

- 03:05 Substation B-Substation C 138 kV line restored

- 03:11 Substation E-Substation F 138 kV line and Substation F-Substation A 138 kV line restored

- 04:51 Substation E-Substation G 138 kV line restored

- 09:52 Substation B-Substation D 138 kV line restored

III. Analysis of Event

A. April 26, 2011 Event

Transmission Entity A reported the following element outage causes.

1. It was determined that the initial fault occurred on the Substation A to Substation B 138 kV line. REL 352 relays at each end of the line saw the fault and operated. After analyzing fault data it appears that the Substation B end of the line operated slower than expected, approximately 22 cycles. The Substation A end operated in 4.5 cycles as expected.

2. There was a protection system misoperation on the Substation A to Substation E 138 kV line.

   The protection system for this line includes the following:

- Primary relay is SEL 311L line differential using a direct fiber connection.
- Backup relay is SEL 421 POTT scheme using a direct fiber connection. The SEL 421 also has non-pilot direction ground overcurrent and mho impedance elements.

The backup SEL 421 relay at Substation E saw a fault on the system in the forward direction. At this point, the relay transmitted a permissive trip signal to the SEL 421 backup relay at Substation A. After about 20 cycles, the relay from Substation A transmitted a permissive trip signal back to Substation E. When the Substation E relay acknowledged the permissive trip, breakers XXX-5 and XXX-6 opened. This operation also caused breakers XXX-2 and XXX-1 at Substation A (138 kV line to Substation F) to open. There was no operation on the primary relaying (SEL 311L) on either end. The SEL 421 relay at Substation A contained a Weak Infeed Logic setting that permitted the remote end (SEL 421 at Substation E) for rapid tripping on internal faults. The relay at Substation A saw that the fault was in the reverse direction and transmitted a block signal to the Substation E terminal. This Weak Infeed Logic setting interfered with the scheme and halted the transmittal of the block signal from Substation A to Substation E. This was determined after reviewing the fault data records for each of the relays at the Substation A and Substation E terminals.

The last protection coordination study was performed in 2003 due to generator installation at an industrial facility and addition of Substation E. The last relay maintenance and calibration was performed in April 2003.

3. There was a protection system misoperation on the Substation B to Substation C 138 kV line.

The protection system for this line includes the following:

- Primary relay is ABB REL 356 line differential using a direct fiber connection.
- Backup relay is SEL 421 POTT scheme using a direct fiber connection. The SEL 421 also has non-pilot direction ground overcurrent and mho impedance elements. The 421 on this line also had a blocking scheme that would block ground time overcurrent elements for out of section faults.

The backup SEL 421 relay detected a fault in the forward direction at the Substation C terminal and showed to commence a trip output. The trip output initiated by this relay caused breakers XXX-3 and XXX-4 to open at Substation C. The primary REL 356 relays did not operate at either end. When the fault transpired between the Substation B and Substation A 138 kV line, the Substation C SEL 421 relay detected the fault in its forward direction. The SEL 421 relay at Substation B detected that same fault in the reverse direction and initiated a blocking signal to the Substation C SEL 421 relay. After further analysis, it was pointed out that the 51S1T torque control setting initiated

(approximately 8 cycles). Once the blocking 50G3 signal from the Substation B relay de-asserted, it then completed the Substation C relay's trip circuit logic, therefore initiating a trip output and opening breakers XXX-3 and XXX-4 at Substation C. It appears that the blocking signal terminated before the permissive trip dropped out.

This condition apparently arose in or after 2006. This scheme has been disabled. The last protection coordination study was performed in 2006 due to addition of Substation C. The last relay maintenance and calibration was performed in December 2005.

All other breakers involved operated as per design during this event. No personnel injuries or other equipment damage were identified.

B. May 27, 2011 Event

Transmission Entity A reported the following element outage causes.

1. There was a failure of an insulator on the Substation B to Substation D 138 kV transmission line due to contamination and tracking over the insulator. Circuit breakers at Substation B and Substation D operated and isolated the fault as designed.

2. There were two protection system misoperations at the Substation E. The Substation E circuit breaker operations in conjunction with the Substation D circuit breaker operations isolated the Substation F, Substation A, Substation C and Substation B Substations from the 138 kV system. There are two 138-69 kV auto-transformers at the Substation B Substation. The isolated substations remained energized from the 69 kV system. This resulted in overloading the auto-transformers at the Substation H Substation. Approximately one minute after the event started overcurrent relays at Substation H, and then tripped the 138 kV circuit breakers for the auto-transformers resulting in a complete outage to the 69 kV system and Substation F, Substation A and Substation C substations.

3. The Substation E to Substation G 138 kV line opening was a misoperation due to a low set instantaneous ground overcurrent element. This open-ended the Substation E-Substation G line but resulted in no customer outages. The condition apparently arose when additional generation was installed at an industrial facility in the area in 2008. The last protection coordination study was performed in 2003 due to Generator installation and addition of Substation E substation. The last relay maintenance and calibration was performed in April 2003.

The protection system for this line includes the following:

- Primary relay is SEL 311L line differential using a direct fiber connection.
- Backup relay is SEL 421 POTT scheme using a direct fiber connection. The SEL 421 also has non-pilot direction ground overcurrent and mho impedance elements.

4. The Substation E to Substation A 138 kV line opening was a misoperation due to a failure to block a permissive trip echo at the Substation A end relay. The two contributing factors were:
   a. Similar blocking elements were not enabled on relays at both ends of the transmission line. The misapplication of pilot logic had existed since the system was originally installed in 2003. The last protection coordination study was performed in 2003 due to Generator installation at an industrial facility and addition of Substation E substation. The last relay maintenance and calibration was performed in April 2003.
   b. The CT ratio in the Substation A relay did not match the wired CT ratio.

All other breakers involved operated as per design during this event. No personnel injuries or other equipment damage were identified.

IV. Response Analysis

Transmission Entity A has taken the following actions to correct the identified problems:

1. A retrofit panel replacement project is in effect to replace the existing protection relays at Substation B and Substation A. This will include a dual primary system.
2. Breaker timing tests were performed on breakers at Substation A and at Substation B. No issues with slow tripping were found.
3. The Weak Infeed Logic setting has been disabled from the relaying at Substation A (138 kV line from Substation A to Substation E). This setting is not necessary for this line.
4. Transmission Entity A has identified 10 substations for silicone coating to reduce buildup of contaminates on insulators. Application of the coating is complete.
5. The Transmission Entity A Operations & Maintenance Manual provides for a thorough inspection of each porcelain insulator's condition in the substation on a quarterly basis. The intensity of the contamination conditions in the area are unprecedented and due, in large measure, to the historic drought. Transmission Entity A had not previously implemented a proactive cleaning program of transmission line or substation insulators. Instead, cleaning has been one of the routine remediation responses applied based on the results of the periodic facility inspections. Transmission Entity A has instituted a proactive program in response to the conditions experienced this year. The program will now be incorporated into Transmission Entity A's O&M Manual as a standard program.

The Program now provides: Rainfall will be monitored in areas of high contamination (facilities near refineries and coastal regions). If there is no significant rainfall in a one month period, Ultra Violet (Corona) inspection will be performed in the early morning hours. The results of the inspection will determine the priority of washing and/or coating of insulators. If no level (or inconclusive, low levels) of corona are found, the station will be re-inspected every two weeks until a period of normal rainfall returns. For stations with higher levels of corona, washing will be scheduled based on severity of corona. The EPRI guide number 1018376 (Field Guide: Daytime Discharge Inspection of Transmission and Distribution Overhead Lines and Substations) will be used for determining severity.

Inspection of insulators will include visual inspection of any silicone or semi-conductive coating of insulators. If any coating degradation on porcelain insulators is discovered, the insulator shall be cleaned and recoated, or replaced with another contamination resistant insulator.

6. Since mid-April Transmission Entity A has been power washing insulators and applying a silicone coating to deter flashovers in the substations and on transmission lines in the industrial area. This effort will continue until all substations and transmission lines in the industrial area have been cleaned. Transmission Entity A personnel are using a UV camera to inspect the transmission lines and prioritize the lines for scheduling to be washed. After the washing has been completed, the substations and transmission lines will be periodically inspected with the UV camera to monitor insulator contamination and schedule additional cleaning as necessary.
7. Due to the unprecedented drought conditions experienced in the area this year, Transmission Entity A has supplemented its standard inspections in the industrial area with UV and Infra-Red (IR) camera surveys. Those camera surveys are conducted at least weekly, with priority facilities being inspected more frequently.
8. The relay elements that caused the misoperations have been removed or corrected. In addition directional instantaneous overcurrent elements are being disabled in the industrial system. They will be replaced with ground impedance (mho) elements. The ground mho elements respond better to changes in the transmission network.
9. Transmission Entity A has obtained the services of an independent engineering firm to review the protective relay scheme and settings for all transmission lines in the area. The 138kV loop in the industrial area will be re-coordinated to eliminate the blocking scheme on the time overcurrent elements.