Lesson Learned

Distributed Energy Resource Performance Characteristics during a Disturbance

Primary Interest Groups
Generator Owners (GOs)
Generator Operators (GOPs)
Transmission Owners (TOs)
Transmission Operators (TOPs)

Problem Statement
A three-phase-to-ground fault resulted in two 500 kV circuits being removed from service. This led to a net loss of approximately 1,300 MW of voltage-sensitive loads as well as at least 300 MW of supply from distributed energy resources (DER) also occurred.

Details
During the restoration of a circuit terminal to service from a planned outage at a 500 kV transformer station, the line was inadvertently energized while still grounded. This resulted in a permanent three-phase-to-ground fault (see **Figure 1**).

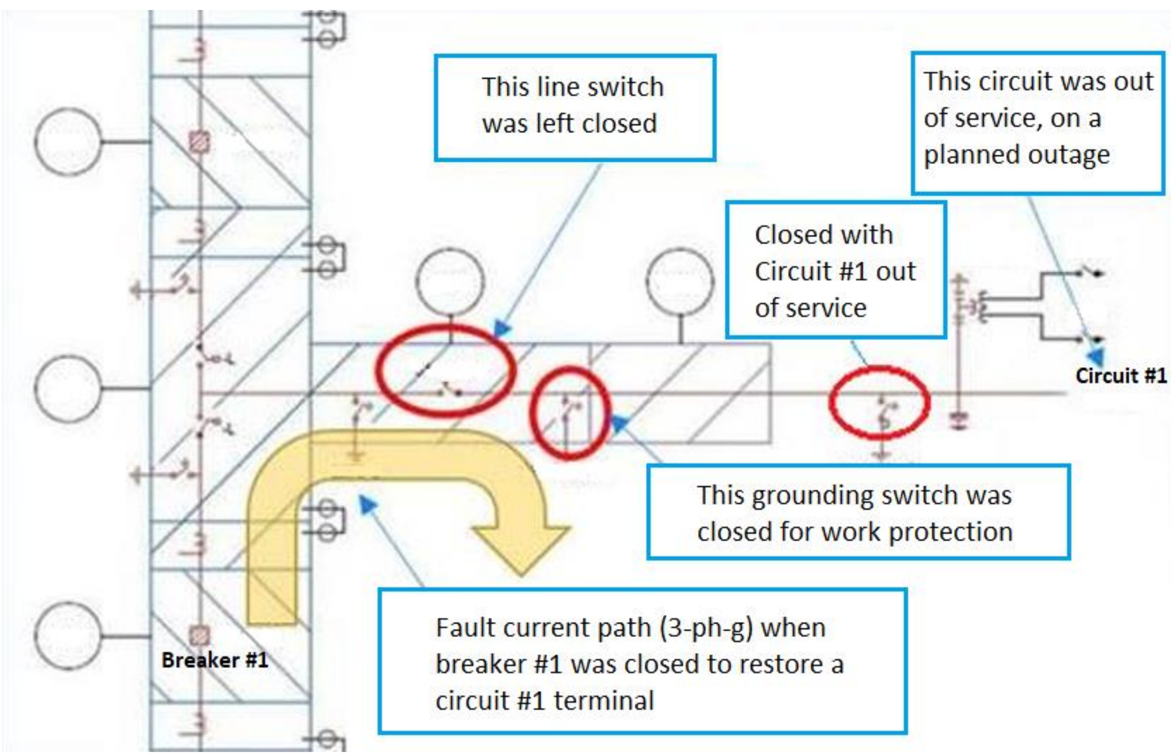

Figure 1: Diagram of switches involved in setting up the fault

In addition to the initial circuit, two 500 kV circuits were tripped unexpectedly by Zone 1 protection at a nearby transformer station. The TO identified the cause as a SEL-321 relay incorrectly assessing an out-of-zone fault as within its Zone 1 coverage. Proper relay functioning was impacted by a combination of an older capacitor voltage transformer and a high source impedance ratio measurement.

The TO normally manages this issue by introducing a 25 millisecond (ms) delay to the relay's measuring process. However, this delay had not been added to the relays on these additional circuits prior to this event occurring.

The event resulted in 300 MW of generation being briefly lost.[1] System frequency oscillated sharply before settling at approximately 60 Hz. The maximum peak and lowest trough during the oscillation was 62.15 Hz and 56.78 Hz measured at a station near the fault.

At the time of the occurrence, the weather conditions were mild, demand was low, and DERs were only delivering at 30% of capacity when the fault occurred, limiting the impact of this event.

The DERs known to have tripped were able to reconnect within 10 minutes, while load that was lost during the event took approximately 90 minutes to reconnect.

Adverse Consequences Observed:

- There was a net loss of approximately 1,300 MW of voltage-sensitive loads and at least 300 MW of supply from DERs.
- Power system stabilizers at all units of a nuclear generating facility tripped during the fault but returned to service after approximately 160 seconds. The Power system stabilizer failures were thought to be as a result of the torsional frequency component in the speed signal being outside of defined ranges of +3 revolutions per minute. Their failure caused the switch of the main automatic voltage regulator (AVR) to the standby AVR.
- The AVRs at a nearby generating facility switched from auto to manual modes of operation during the event. The GOP determined the switchover was due to a potential transformer fuse failure alarm.

Corrective Actions

- The TO initiated a protection settings review with the aim of developing corrective actions for pertinent circuits. This review was based on the findings from the relay manufacturer and their own special studies group.
- The TO implemented a 25 ms delay to Zone 1 circuit protection to allow capacitor voltage transformer transients to stabilize when a Zone 1 distance element is picked up and a high source impedance ratio is detected.

[1] Generally, older DERS without smart inverters would not be able to ride-through the event while newer DERs with smart inverters that are set correctly could provide ride-through capability. See reports referenced by footnotes in the Lessons Learned section.

- The TOP performed system studies to validate and revise system limits as a result of the new relay behavior uncovered during this event and to incorporate new delays in Zone 1 fault clearing as applicable.
- The TOP initiated work with stakeholders to identify required interim and enduring changes to improve the performance of protections and AVRs.

The TOP also performed the following:

- Updated performance requirements to ensure that future DERs are better able to remain connected during system events and support voltage
- Started the stakeholder process to modify equipment requirements to install more Phasor measurement unit (PMU) devices to have better visibility of the system performance (Furthermore, the system operator implemented a technical working group with TOs to set the prioritization criteria for installing PMUs.)

Lesson Learned

- Switching procedures, particularly at high-risk facilities, should be designed to mitigate the risk of human error.
- DERS without smart inverters generally do not have adequate ride-through capability and can exacerbate the impact of a power system event by tripping off due to a voltage or frequency transient. Performance requirements for DERs need to be such that they are better able to cope with and endure disturbances on the electricity grid[2] ,[3] ,[4]
- There is a need to understand how distribution system connected generation and loads will behave and how they can accurately be modeled under expected system contingencies. Entities should know the behavioral characteristics of DER inverters on their system (both new and old) as well as their number, capabilities, and locations and then report that information to their Balancing Authorities and Reliability Coordinators so their models can be accurate.

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)

[2] See the 2016 Bluecut fire event "1,200 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report" and IEEE standard 1547
[3] See NERC "Inverter-Based Resource Performance Guideline"
[4] See the "Odessa Disturbance Report"

Lesson Learned #:	20220401
Date Published:	4/13/2022
Category:	Bulk Power System Operations, Transmission Facilities, Generation Facilities