Lesson Learned

Consideration of the Effects of Mutual Coupling when Setting Ground Instantaneous Overcurrent Elements

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

Problem Statement
An event occurred that caused the unintended trip of a transmission line connected to a large generation facility. The transmission system and generation response to the loss of this line resulted in an unintended total loss of transmission connection to the generating facility. An investigation revealed that the unintended trip of the transmission line was due to an incorrect setting on a numerical relay directional ground instantaneous overcurrent (IOC) element. This setting caused it to misoperate in response to a fault on a mutually coupled adjacent line. Failure to consider the effects of mutual coupling between adjacent lines led to the improper derivation of the ground IOC element settings, and this resulted in a protection system misoperation.

Details
Mutual coupling exists between two or more transmission lines that are routed in parallel for a substantial distance due to the magnetic fields between the lines. For these configurations, a fault on one line can induce a large zero-sequence current in the unfaulted parallel line and may lead to inappropriate tripping of the unfaulted line. Zero-sequence current is only present during ground faults, so the consideration of mutual coupling effects only applies to the derivation of ground fault protective element settings. For the purpose of this document, a directional ground IOC element is defined as a relay element that trips instantaneously for a quantity of forward zero-sequence current in excess of its set point.

When developing the ground IOC element setting associated with this event, the entity did not consider nor simulate a line-end fault (with end open) on the adjacent line that was mutually coupled to the protected line. The adjacent line ran in the same right of way as the protected line for a significant portion of the protected line’s length. As a result, the associated line relays were placed in service with ground IOC settings that had the potential to misoperate. The setting error remained undetected until the occurrence of the event described above where the relaying operated incorrectly, resulting in an increase in the magnitude and scope of the disturbance.

Corrective Actions
The entity reviewed the composite protection system package on the lines associated with the disturbance, which included both zone 1 directional ground distance elements in addition to ground IOC elements. Since both of these relay elements are set to provide the same unconditional instantaneous

tripping for ground faults that occur on approximately 80 percent of the line nearest the protected terminal, the entity concluded that existing directional ground distance elements would provide adequate zone 1 ground fault coverage by themselves. That being the case as an immediate solution, the entity revised the relay settings on the lines associated with the disturbance to disable the ground IOC elements.

The entity is also conducting a comprehensive review of their transmission system to assess if there are other locations where a line-end fault on a mutually coupled line may not have been considered. The entity is considering changing their protection design philosophy to preclude the use of ground IOC elements if a directional ground distance element is available. For applications where a zone 1 directional ground distance element is not available, the entity has concluded that it is prudent to increase the ground IOC setting design margin applied to the worst-case out-of-zone fault to better account for protection system component tolerances and fault simulation modeling tolerances.

The entity recognizes that while this increased margin provides enhanced security against misoperation, it also reduces the effective fault coverage of the ground IOC element under normal system conditions. The reduction in instantaneous ground fault coverage is an acceptable consequence of mitigating potential ground IOC misoperation because directional ground time overcurrent (TOC) elements are also enabled, providing time-delayed ground fault coverage for the entire line.

Lessons Learned

It is important that the mutual impedances between all line pairs be calculated and included when developing the system model.

The ground IOC element has no time delay and is therefore considered a zone 1 protection element. When this element is used as part of a protection system, it is critical that it be set so that it will not operate for any credible system event beyond the protected line (out of zone), while still providing adequate coverage for ground faults on the protected line. Determining the worst-case out-of-zone fault is typically accomplished through the use of a fault simulation software tool to model the transmission system.

The out-of-zone fault simulations to consider should include:

1. A simulation of a fault on each line connected to each remote terminal that is close to the remote terminal with the remote line end open and closed.
2. Perform the same simulation described in consideration 1 with the contingency of having the largest remaining remote terminal ground source out of service.
3. Simulate a line-end fault (with end open) on all lines that are mutually coupled with the protected line for more than 10 percent of the protected line’s length.
4. Perform the same simulation described in consideration 3 with the contingency of having the largest remaining remote terminal ground source out of service.

It may also be possible to eliminate the use of ground IOC elements if zone 1 ground distance elements can provide adequate ground fault protection and if appropriate consideration is given to providing reliable ground fault protection when a loss of potential condition occurs.

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