

PRIMARY RELAYING SYSTEM FAILURES are associated with long fault durations because backup relaying must be relied upon to clear the fault. A slow trip and the accompanying long-duration voltage dips can be very costly to sensitive customers, such as semiconductor manufacturers, due to product loss. An even worse scenario would be to unnecessarily trip one of these sensitive customers and completely put them in the dark.

The area of the system in which this event occurred is especially important for several of Oncor Electric Delivery's critical customers. The Dallas Switching Station is served by four 138kV lines which are protected by permissive overreaching transfer trip (POTT) schemes using various electromechanical and microprocessor relays. POTT schemes over tone are used to provide high speed tripping and increased security against undesirable trips for external faults.

Relay coordination is challenging because of the number of short lines in the area as well as the number of Y- Δ -Y transformers and their FID ratings. Within just the four lines serving Dallas there are twenty-one Y- Δ -Y distribution transformers which are zero sequence current sources.

FID ratings can cause coordination problems because they are blocked from tripping for faults over 16,000 amperes. Relays on both ends of the line must trip for the 16,000 ampere faults because of the POTT pilot logic used. This requires unusually large distance relay reach settings because fault duties in the corridor range from 30,000 – 60,000 amperes.

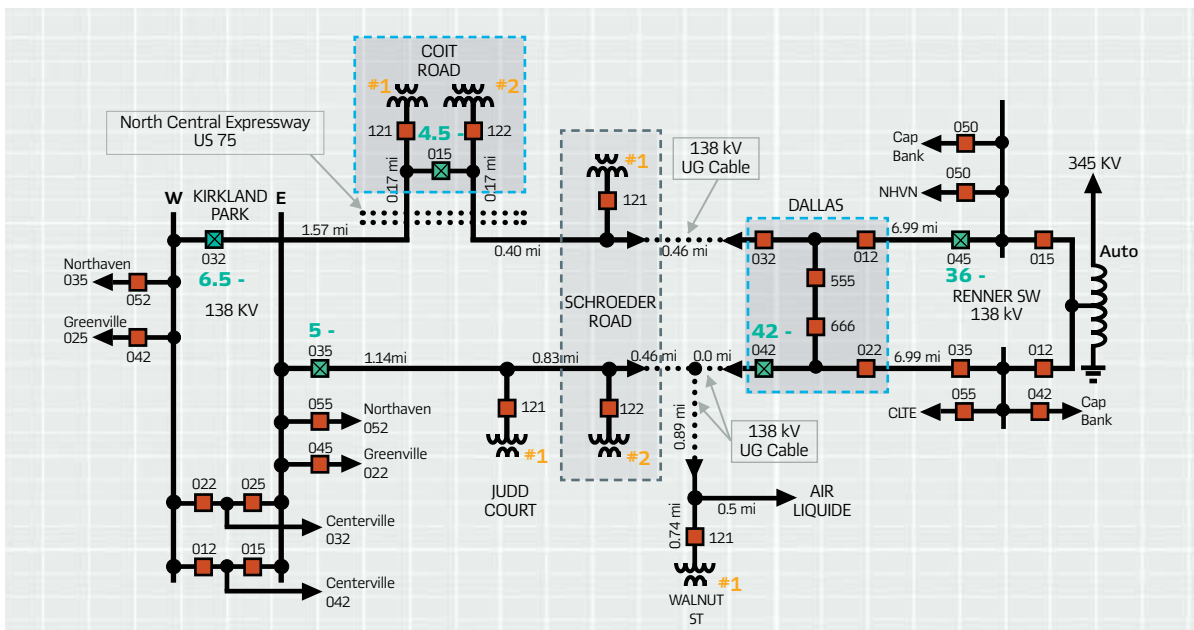
Oncor Electric Delivery maintains an extensive digital fault recorder (DFR) network. Approximately 230 DFRs are scattered around the system and capture more than 15,000 records a year. After the records are collected, they

The cause of the failure to send a trip permissive is improper functional testing during checkout

are automatically converted into a standard report and sorted into low, medium, and high priority groups. The low priority group accounts for 95% of the records and is generally made up of records triggered by remote faults that contain limited useful information. The medium priority group consists of correct fault operations and accounts for about 4% of the records. The high priority group is made up of the remaining 1% of the records that indicate possible slow breakers, slow relays, breaker failures, or carrier problems.

2 System Configuration After Fault was Cleared

Dallas is being served by a single 138kV line from Renner CB 035



Faults with known locations are used to verify the system model.

DFRs are powerful tools to use when analyzing system operations, but they are only as good as the information being fed to them. Sometimes they contain very valuable “hidden” information that can easily be missed at first glance. The rest of this article describes the process through which Oncor Electric Delivery went to get to the bottom of a relaying system failure, and find the true root cause.

EVENT

On May 5, 2006 at 2:55:34AM an apparent lightning strike occurred on a double circuit 138kV transmission line approximately one mile north of Kirkland Park Switching Station causing simultaneous A-phase to ground faults on the Kirkland Park – Coit Road and Kirkland Park – Dallas circuits. The line at this point has a concrete/steel pole construction with a single static wire on top and one vertical circuit on each side. The top conductor on each circuit is A-phase.

From fault inception, Coit Road CB 015 tripped in 4.5 cycles followed by Kirkland Park CB 035 at 5 cycles followed by Kirkland Park CB 032 at 6.5 cycles. At this point the Kirkland Park – Coit Road line is open and the Kirkland Park end of the Kirkland Park – Dallas line is open. The fault is no longer a simultaneous fault, but is a single-line-to-ground fault being fed radially by Dallas CB 042 (Figure 1).

In this configuration, Renner CB 045 tripped at 36 cycles (Zone 2/Time flags) and Dallas CB 042 tripped to clear the fault at 42 cycles

(ground time-overcurrent flags). At this point, Dallas was being served by a single 138kV line from Renner CB 035 (Figure 2). This configuration continued for 4 seconds until Renner CB045 reclosed.

Two separate misoperations can be observed from the sequence of events:

- Dallas CB 042 did not trip on pilot, causing the fault to last 42 cycles

- Renner CB 045 overtripped for the fault

The analysis of the first misoperation is included in this article, while the analysis of both is available in the online version.

MODELING

It is very important to have an accurate system model to use when making relay settings and performing fault locations. Faults with known locations are used to verify the system model.

Usually, the system model matches the DFR values within 5-10%. In some cases the model deviates more than usual due to zero sequence mutual coupling, large numbers of Y-Δ-Y transformers, system changes, and modeling errors. Large differences between the model and DFR data are investigated to help improve the model by revealing modeling inaccuracies and changes in system topology. These differences can also be an indicator of mismatches between the DFR configuration and actual connected CT ratios.

The fault location for the 5-5-06 event was estimated to be one mile north of Kirkland Park Switching Station. Lightning detection software verified that there was lightning at that time and location. Physical evidence of the fault location was not found even after flying the line and performing inspections from the ground. Kirkland Park, Dallas and Renner are equipped with DFRs which successfully recorded the fault. Table 1 shows the modeled vs. observed residual fault currents and the percent differenc-

es at two points during the fault. The first point is fifteen cycles into the fault as shown in Figure 1, the second point is forty cycles into the fault when the fault is being served radially from Renner CB 035. This analysis used corrected data for Renner CB 035 and CB 045 as described in the online version.

The low percent differences, especially for Renner CB 045 and Dallas CB 042, verify that the system model is accurate and can be used to analyze the relay operations with confidence.

RELAY SYSTEM FAILURE #1

All lines directly connected to Dallas use a POTT scheme to provide high speed tripping with increased security. POTT schemes require that a permissive signal be received before Zone 2 and directional ground relays are allowed to trip without a time delay.

Figures 3 and 4 show the DFR traces for Kirkland Park CB 035 and Dallas CB 042.

Dallas CB 042 did not receive a trip permissive signal from Kirkland Park CB 035 and, thus, did not issue a high speed pilot trip. After 42 cycles, Dallas CB 042 eventually tripped on ground time-overcurrent to clear the fault. Figure 3 clearly shows that the DFR for Kirkland Park CB 035 observed a trip permissive signal being sent to Dallas CB 042. The question is why did Dallas CB 042 not receive the permissive signal.

It was found that Kirkland Park CB 035 failed to send a trip permissive to Dallas CB 042 because of a diode across the operate coil of a high speed auxiliary tripping relay

Why did Dallas
CB 042
not receive
the permissive
signal?

that is used to key the transmitter. The diode caused the relay coil to be shorted out and never pickup even though voltage was applied. The nameplate Style # and Internal Schematic # attached to the high speed auxiliary tripping relay did not call for a diode. Relays with a diode are a completely different Style # and Internal Schematic #, so it is still unknown as to how the relay was mislabeled or if it was modified in the field. The correct relay schematic is shown in Figure 5.

Polarity of the coil does not matter for this style of relay. Figure 6 shows the incorrect relay schematic that corresponds to what was actually installed at Kirkland Park CB 035. It is crucial to have the correct polarity for this style of high speed auxiliary tripping relay. Figure 8 shows the diode across the relay coil found at Kirkland Park CB 035.

The relay (85/XX) was wired according to the print (shown in Figure 7), which calls for terminal 9 to be positive and terminal 10 to be negative. This caused the coil of the relay to be shorted out by the parallel diode. If the coil polarity had been reversed as it is required for that style of relay, then the POTT scheme would have operated correctly.

This relay was installed when the Kirkland Park – Dallas line was converted from DCB to POTT in 2000. It is now obvious that a full functional test was not performed when the POTT scheme was put in service. The functional test would have included keying the local transmitter via the local relays and verifying that the remote end received a permissive signal. If a proper functional test had been performed when the relay was installed, then the diode would have been discovered.

The root cause of the failure to send a trip permissive is improper functional testing during checkout.

Contributing Factors

Three factors were identified that perpetuated the problem and kept it from being caught sooner:

- Testing procedure – A full functional checkout of the scheme was not performed. This is the root cause of the failure.

- Relay did not match nameplate – It is reasonable to expect a relay to be wired correctly, have the correct components, and match the attached nameplate.

- DFR records - Kirkland Park CB 035 DFR records show that a



permissive signal was being transmitted to Dallas CB 042. This is because the DFR key permissive digital input was monitoring the DC voltage going to the high speed auxiliary tripping relay coil, not the actual key permissive contacts. The DFR sensed the voltage at the relay coil and indicated that a permissive signal was being sent even though the relay coil was shorted.

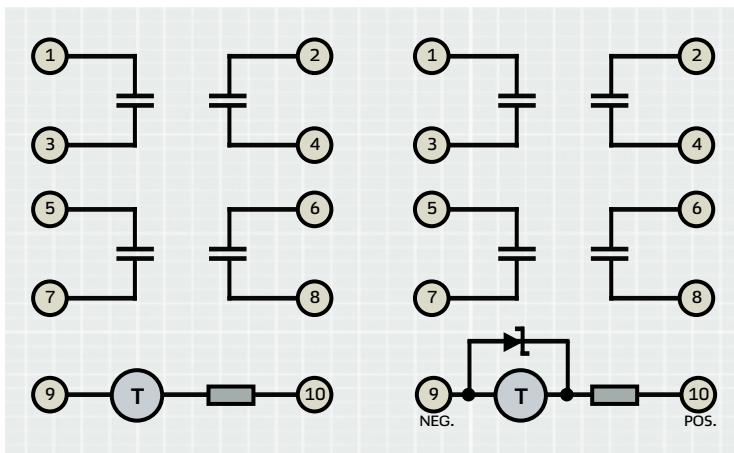
This contributed to the belief that the POTT scheme was working correctly.

Preventable

Clearly, this misoperation could have been prevented by performing a full functional test of the POTT scheme, but there were also two opportunities to discover the problem by analyzing DFR records. On 10/5/2001 and 5/25/2003 there were phase-ground faults on the Kirkland Park – Dallas line that

5 Correct and 6 Incorrect Schematic

according to style number as-found in the field



Data was available that, if analyzed properly, would have detected the failures and thus avoided the entire situation. The event, relaying failures, contributing factors, and how the situation could have been avoided are discussed.

were both cleared in approximately 5 cycles even though this was after the line was converted to POTT and the “bad” high speed auxiliary tripping relay was installed. These two faults happened to be close enough to the Dallas end of the line for Dallas CB 042 to trip on ground instantaneous instead of requiring a permissive signal. If the DFR records for these faults had been checked closely, then it would have been apparent that Dallas CB 042 never received a permissive signal even though the fault was in the protected line section.

In defense of the engineers checking the DFR records, the fault cleared quickly and, at first glance, the operation may seem correct. It is possible that the Kirkland Park DFR record was checked first, and

since it showed that the POTT scheme operated correctly for the Kirkland Park end, the Dallas CB 042 record was given a cursory glance and assumed to be correct. It is also possible that the engineer assumed the permissive received digital at Dallas CB 042 was not hooked up to the DFR. If this was the case, field personnel should have been notified, and the problem should have been investigated. This misoperation could have been avoided by spending the time necessary to fully understand and investigate DFR records for all faults.

Immediate Fixes

The remedy for this problem was very straightforward – **replace the “bad” high speed auxiliary tripping relay and perform a full functional test.**

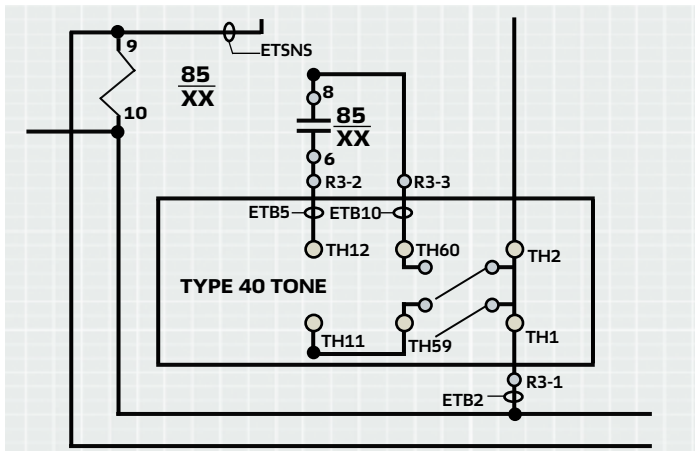
Three factors were identified that perpetuated the problem and kept it from being caught sooner:
 -DFR records,
 -testing procedure,
 -relay did not match name plate.

Table 1 Modeled vs. Recorded Fault Currents

Terminal	15 Cycles into Fault (A)			40 Cycles into Fault (A)		
	Model I _r	DFR I _r	%Diff	Model I _r	DFR I _r	%Diff
Renner CB 035	1471	1587	-7.3%	2014	2400	-16.1%
Renner CB 045	1507	1571	-4.1%	-	-	-
Dallas CB 012	1960	2024	-3.2%	474	564	-16.0%
Dallas CB 022	1939	2070	-6.3%	2378	2840	-16.3%
Dallas CB 032	962	924	4.1%	780	850	-8.2%
Dallas CB 042	10720	10429	2.8%	8393	8127	3.3%

7 Kirkland Park CB035

Keying Circuit



8 Kirkland Park CB035

Relay, close-up of diode across relay coil

