Lesson Learned

Mixing Relay Technologies in Directional Comparison Blocking Schemes

Primary Interest Groups

Transmission Owners (TOs)

Problem Statement

Multiple composite protection system misoperations have occurred on the Bulk Electric System (BES) as a result of mixing protective relay technologies at the remote terminals of directional comparison blocking (DCB) schemes. One of the most challenging mix of technologies is utilizing a relay system based on newer microprocessors (µP) at one terminal and an older electromechanical (EM) relay system at the opposite terminal (examples shown in the figures below). Utilizing different models of µP based relays at each terminal can also be problematic. Often, only one terminal of a DCB system is upgraded to µP based relays due to various reasons, including different ownership of terminals, budget constraints, and emergency replacements. Relay timing and directional coordination is critical in DCB schemes that may be overlooked when relay technology or relay models vary between terminals.

Details

Electromechanical DCB Schemes

DCB schemes that utilize EM relays are high speed protective schemes that use very fast phase and ground fault detectors to transmit or “start” a blocking signal by opening contacts. Opening contacts to start a blocking signal allows quicker operation by minimizing the time required to overcome inertia in EM relays. It is common to have this blocking signal transmission initiated within a quarter cycle of the start of a fault in EM DCB schemes. Also in this scheme, one cycle or more is usually required for EM relays to determine the directionality of a fault and issue a trip to open a local breaker if the fault is internal to the line. This time difference between block and trip provides an inherent margin of error within EM schemes for relays at the remote terminal(s) to receive a blocking signal and prevent tripping for faults beyond the remote terminal. Figure 1 demonstrates this timing difference between block and trip associated with EM DCB schemes. The blocking signal is started and received at both terminals before the directionality of a fault is determined between either internal or external faults. Once directionality is determined and it is found that a fault is internal, the blocking signal is removed and tripping is allowed at the opposite terminal.

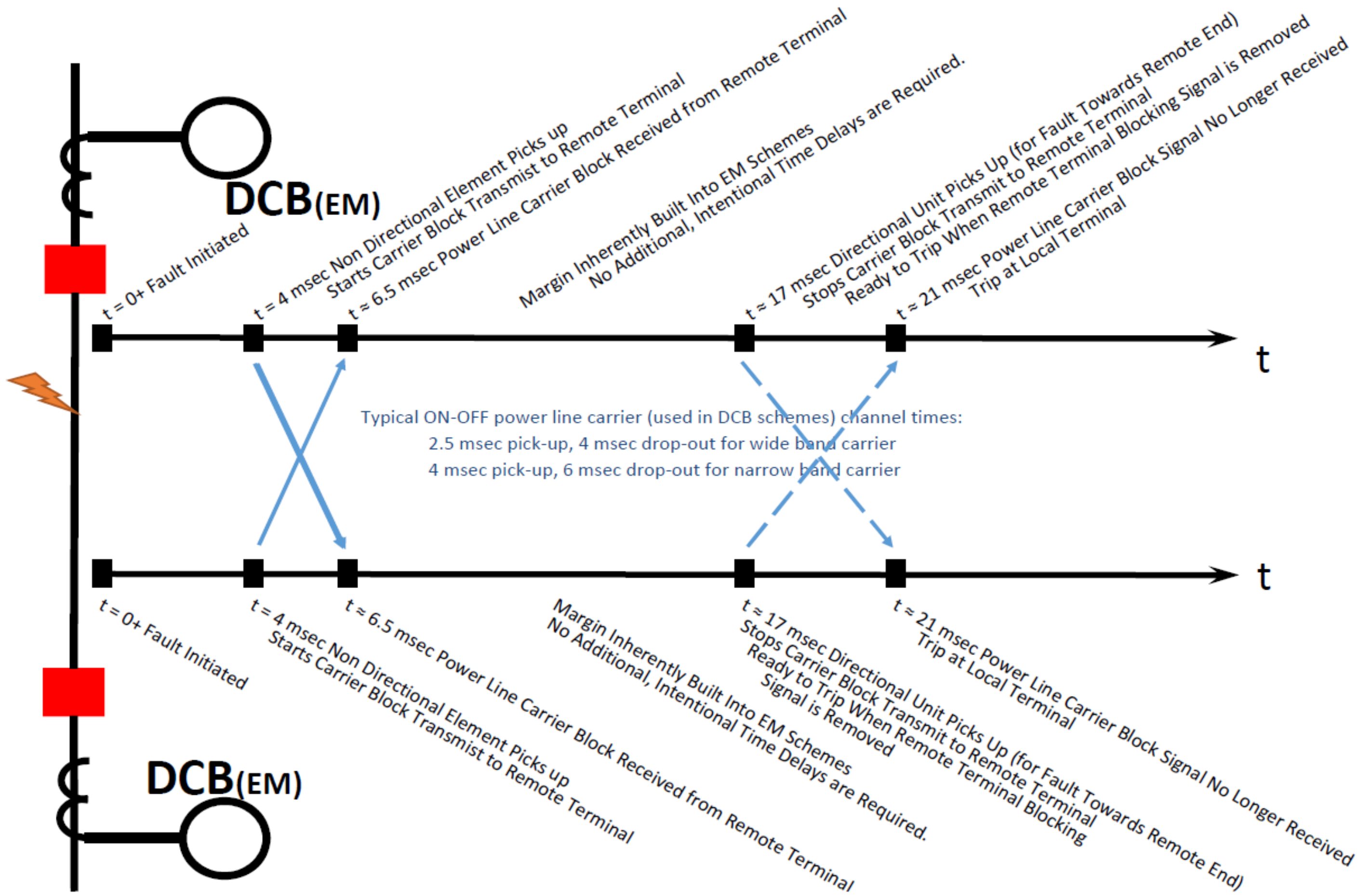

Figure 1: Approximate Timing Associated with a typical EM DCB schemes

Microprocessor DCB Schemes

Microprocessor DCB schemes work under the same protocols and similar protection elements as an EM scheme. However, due to the need for internal filters in the relay, most (not all) µP relays require one cycle of information to determine that an electrical fault has actually occurred versus the quarter cycle for EM schemes. Thus, µP relays cannot start sending a blocking signal until this determination is made. A time delay between detection of the fault and relay decision to trip is also required to allow for the transmission and receipt of the blocking signal from the remote terminal(s). In addition to this time delay and for the security of the scheme, it is prudent to include an additional margin of time. Figure 2 demonstrates a timing scenario associated with some µP DCB schemes for external faults. No blocking signal should be transmitted for internal faults, and tripping of local breakers should occur after the relay senses the internal fault and the allotted time margin to receive the blocking signal has expired.

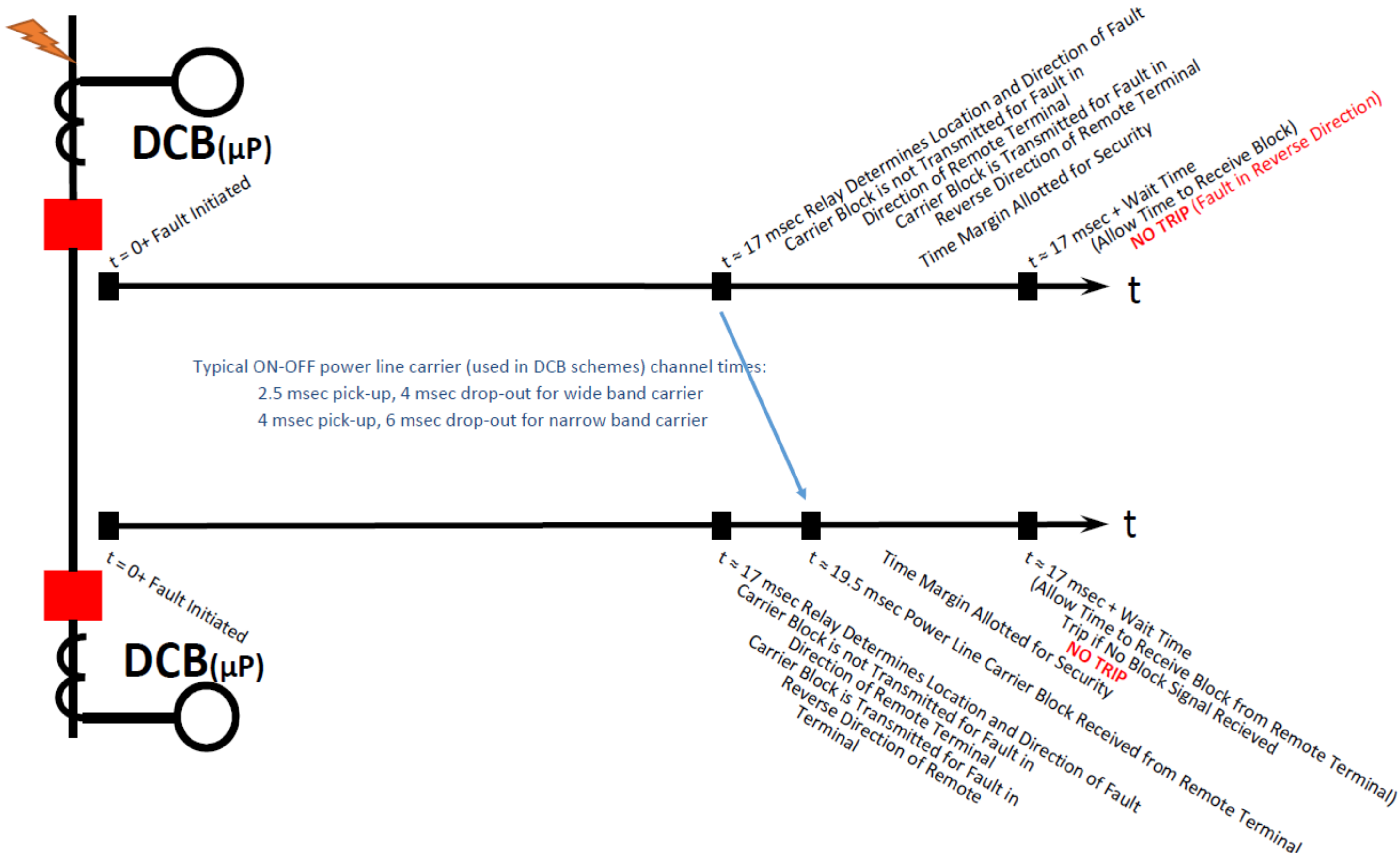

Figure 2: Approximate Timing Associated with typical µP DCB Schemes

Mixing Technologies

Mixing these technologies between EM and µP relay models can introduce timing problems. The EM relay can send a blocking signal fast enough for the remote µP terminal to detect and block tripping for external faults. However, the µP relay at the remote terminal may not send a blocking signal until <u>after</u> the EM terminal relay(s) has made a decision to trip, thus causing the EM end to incorrectly trip. **Figure 3** demonstrates likely timing problems associated with mixing these technologies.

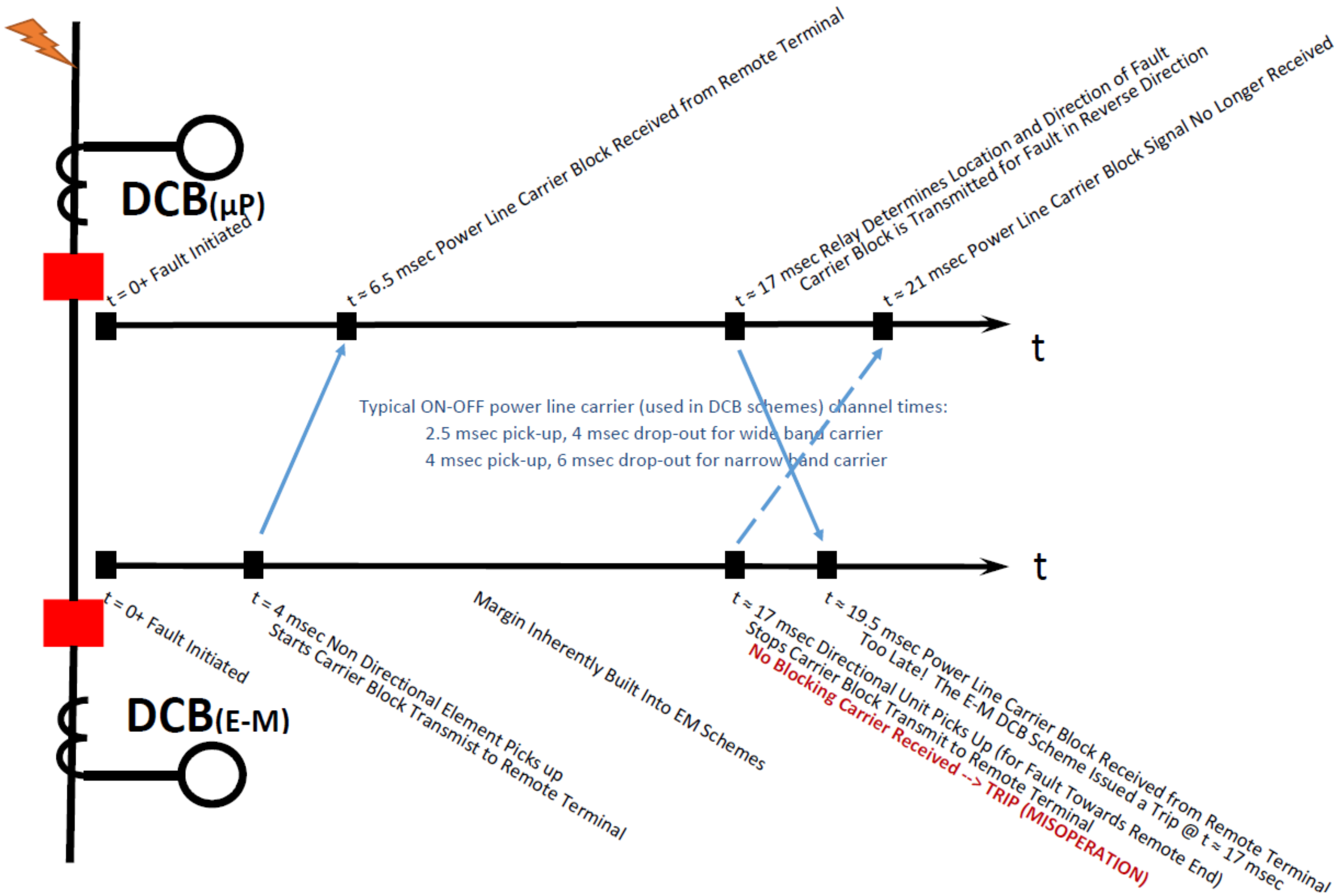

Figure 3: Timing Demonstrated with Mixing EM and µP Technologies

Timing Issues with Mixing EM and µP Technologies
Timing differences are seen when differing technologies are used at opposing terminals. In general, Electro-mechanical relays are seen as slower to operate than solid-state or microprocessor-based relays. However, Electro-mechanical relays are usually quicker than most microprocessor based relays regarding sending a blocking signal.

In April 2013, the Protection System Misoperation Task Force (PSMTF) issued the *Misoperations Report*[1]. It has information relevant to this Lessons Learned:

On page 34 –
"…As a practice, the timing issues should be studied and the appropriate delays applied to the faster terminal to allow for coordination. Timers available in both microprocessor-based relays and newer carrier equipment can be used to eliminate most misoperations due to carrier signal dropout during faults. Use of a carrier hole override timer on digital systems may be used, in part, to replace the override inherent in the magnetic circuits of electro-mechanical systems. While carrier hole timers can provide added security to DCB schemes, they may also mask carrier system setting or component deficiencies. Similar to carrier coordination timers, care should be applied to avoid unwanted interactions with other DCB logic. Intermittent carrier signals are often an indication that maintenance is required. The recording and logic capability of these newer devices can be used to detect carrier holes and alert maintenance personnel to the need for maintenance. Regular maintenance of coupling equipment, wave traps, and spark gaps can improve communication performance."

On Page 35 -
"Proper Application of Relay Elements
Applications requiring coordination of functionally different relay elements should be avoided. This type of coordination is virtually always problematic, and is the cause of numerous misoperations reported in the study period. Some examples to avoid include:

- coordination of distance elements and overcurrent elements
- coordination of distance or directional overcurrent elements that use different directional polarization methods
- distance and directional overcurrent elements at opposite line terminals that use different directional polarization methods, particularly in the same pilot scheme
- overcurrent elements that use different measurement methods, such as phase vs. residual ground vs. negative-sequence current measurement

If mixed measurement or polarization methods cannot be avoided, then there must be a clear understanding of how these elements respond to different fault types under normal and abnormal source conditions to ensure their proper application and coordination."

[1] https://www.nerc.com/comm/PC/Protection%20System%20Misoperations%20Task%20Force%20PSMTF%202/PSMTF_Report.pdf

Corrective Actions

The best and preferred method to mitigate the problems discussed is to assure all terminals of a single composite protection scheme utilize the same manufacturer, make, and model of protection equipment to implement a DCB scheme. When utilizing the same equipment at all terminals of a DCB scheme is not possible, the following corrective actions have been used to mitigate timing issues associated with mixing technologies or µP relay models in DCB schemes:

- Add an additional time delay(s) where required to prevent tripping by allowing the block signal(s) to be received from the remote system(s) or introduce an additional time delay where the remote system(s) may be slower to transmit the blocking signal.
- Start the µP blocking signal transmission quickly at the earliest signs of a fault on the system then remove the blocking signal after relays have determined directionality and security timing margins have expired. Some µP relays do provide a high speed, nondirectional, current-only fault detector that can be used to start blocking signal communications. The blocking signal can then be removed if required after correct directionality of the fault is determined.
- Disable the DCB tripping at the faster terminal until the relay system can be replaced with a like-kind relay system (ensure blocking remains enabled). This option may be dependent on system studies to determine if a high speed tripping scheme is required at the affected terminal.

Lesson Learned

It is imperative that sufficient time be provided to first receive a blocking signal from the remote terminal in any DCB schemes prior to permitting a trip. The timing of the protection elements at each terminal of a DCB scheme must be understood so as to provide appropriate time margins in the receipt of a blocking signal from the remote terminal.

The following actions could be applied to prevent problems associated with mixing technologies in DCB schemes:

- Establish a design philosophy that does not mix relay technology (incl. different manufacturers and models) in directional comparison blocking (DCB) schemes.
- Work with neighboring entities to eliminate mixing relay technology at the ties/seams.
- If unable to avoid mixing relay technologies in DCB schemes, consider corrective actions listed above.

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