PROTECTION SIGNALLING[1]

Directional Comparison Distance Protection Schemes

The importance of transmission system integrity necessitates high-speed fault clearing times and highspeed auto reclosing to avoid system instability and total collapse. A disadvantage of stepped distance protection is that 30–40 percent of the line length is not covered by high-speed instantaneous protection because the Zone 1 distance setting is limited to 80–85 percent of the protected line with the exception of the Z1X scheme and its disadvantages discussed earlier. This is not acceptable for most EHV transmission systems, and a distance unit protection system utilizing a communications channel between distance protection relays at the two line ends is required to speed up the fault detection and clearing time.

One such application where communications schemes are needed is where high-speed auto reclosing is desired at both ends of the transmission line. With time-stepped distance schemes, a fault near one end of the transmission line must be cleared in Zone 2 time from one source. This does not permit highspeed auto reclose. If a communications scheme is employed, the dead period required to be certain both ends have cleared their contributions to the fault is greatly reduced. It is important to remember that the faster faults are cleared from the system, the faster that transmission line can be restored (assuming the fault is transient) and the more likely the entire system is to remain stable.

In networked transmission systems, power system faults on a protected line segment will be seen from both ends of the line. With step-distance protection, line end faults must be cleared from the remote terminal with a coordinating time delay resulting in delayed clearing of the fault from that line terminal. Various communications-aided protection schemes have been developed to provide high speed tripping from both ends of the line.

High-speed clearing of faults along the entire line segment is required for several reasons.

- When a short circuit exists on a power system, the ability to transfer power across the power system is reduced. Reducing the time that the short circuit exists on the power system reduces the likelihood of the power system going unstable.
- High-speed reclosing is another means to improve power system stability. Power transfer capability is reduced when a line is out of service. Automatically restoring the line with minimal delay, allowing only for arc deionizing time, can also reduce the likelihood of the power system going unstable. However, in order to achieve this, both line terminals must clear the fault instantaneously.
- In step-distance applications where a long line is adjacent to a short line, it may not be possible to coordinate the reach of Zone 2 for the long line with the reach of Zone 1 for the short line. Thus, the entire short line may have to be cleared instantaneously for coordination reasons.

High-speed fault clearing offers the following additional advantages:

- Minimizes the duration of the voltage sag caused by the short circuit that affects power quality.
- Reduces through-fault duty on power transformers, insulator damage due to sustained arcing, etc.

[1] Extract from CIGRE Publication
Modern Distance Protection Functions and Applications
Working Group B5.15
October 2008

Generally, a pilot protection scheme requires a communications channel between each end of the line. Information regarding the fault direction at each line end is transmitted to the remote end in order for the pilot protection system to determine whether the fault is internal or external to the protected line section.

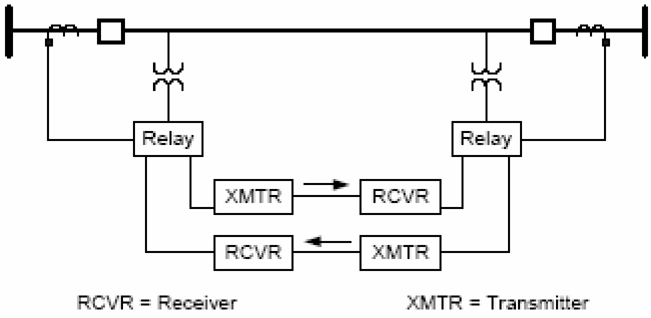

Figure 2.35 Pilot protection scheme

There are many ways to create a communications channel between remote substations.

- Optical fiber communication channels are becoming more available for power system protection applications. A fiber-optic channel can consist of a direct point-to-point fiber connection or a multiplexed fiber link. SONET (Synchronous Optical Network) or SDH (Synchronous Digital Hierarchy) can be part of a wide-area communications network for voice and data traffic. The concern with a nondedicated teleprotection channel is that the channel delays may change as the network reconfigures when a link fails.
- Microwave systems can be either digital or analog. These are often part of a wide-area communications network for voice and data traffic as well. Analog systems generally require audio tone FSK (frequency shift keying) sets to put the teleprotection information into a voice channel. Channel delays for audio tone sets on analog microwave can be 14–20 milliseconds. Digital microwave can provide channel delays in the 3–4 millisecond range.
- Power line carrier (PLC) is used as a reliable point-to-point path for sending teleprotection information from point to point. The equipment to couple the signal to the high voltage power line can be expensive. Also, the teleprotection scheme used must be designed to work if the channel is lost during an internal fault that short circuits the communications channel. PLC channel equipment usually comes in two types, on/off and FSK. The type used is dependent upon the requirements of the teleprotection scheme.
- Private or leased lines are also used for digital and audio tone communications channels.

Pilot protection schemes typically fall into three possible categories.

- Directional comparison schemes use distance or directional relays to determine whether each terminal sees the fault as forward or reverse. By exchanging this information, the fault can be classified as either internal or external to the protected line segment.
- Phase comparison is a form of current only pilot protection. Phase comparison protection systems compare the phase angles of currents entering at one terminal of the line and the currents leaving at the other terminal of the line. If the fault is external, the currents entering and exiting the line should be in phase with each other.
- Current differential schemes send information about the magnitude and angle of the currents entering and exiting the line. This type of pilot protection requires higher bandwidth teleprotection channels, and it is becoming more common with the availability of fiber-optic networks.

In this section, the focus is on directional comparison pilot schemes based on distance relay elements.

Directional comparison pilot protection schemes are designed around sending one bit of data across the teleprotection channel at a very high speed. In some schemes, this one bit tells the other end that it has permission to trip (permissive). In other schemes, the bit represents a signal to tell the other end not to trip (block). There are many variations, but the following are the most prevalent:

- Permissive overreaching transfer trip (POTT)
- Permissive underreaching transfer trip (PUTT)
- Direct underreaching transfer trip (DUTT)
- Directional comparison blocking (DCB)
- Directional comparison unblocking (DCUB)

Permissive Overreaching Transfer Trip

At a minimum, a POTT scheme requires a forward-overreaching element at each end of the line. This is typically provided by a Zone 2 element set to reach around 120–150 percent of the line length. If each relay sees the fault in the forward direction, then the fault can be determined to be internal to the protected line.

In Figure 2.36, Relay 3 will key permission if it sees the fault in a forward direction. Then Relay 4 will be allowed to trip if it sees the fault in a forward direction AND it receives permission from Relay 3. A reverse element is required for reasons that will be described shortly. This is typically provided by a Zone 3 element set in the reverse direction. It is important that the reverse Zone 3 element be set to reach such that it always picks up for faults that can be seen by the remote Zone 2 overreaching element. It is important to note that in all of these schemes, an underreaching Zone 1 element is typically used that will trip for non-end-zone faults independent of the pilot protection scheme.

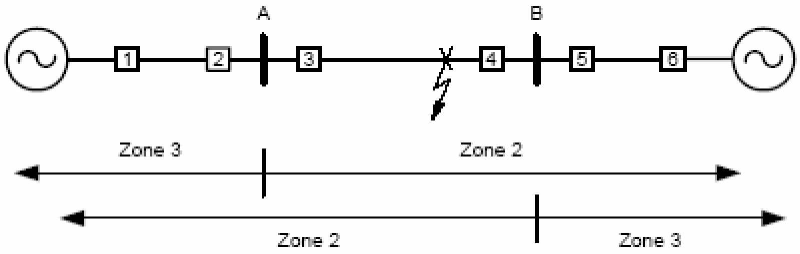

Figure 2.36 Distance zones and their direction as applied in a POTT scheme

The basic logic for a POTT scheme is shown in Figure 2.37. A trip requires Zone 2 overreaching elements to be picked up AND permission received (RCVR) from the remote end. The pickup of Zone 2 overreaching elements keys transmission of a permissive trip signal (Key XMTR) to the remote end.

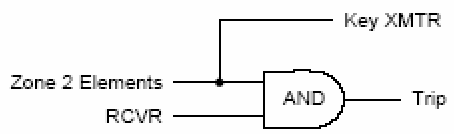

Figure 2.37 Basic POTT logic

There are a number of system conditions and line circuit breaker states during faults that require additional logic to that shown in Figure 2.37 in order for the POTT scheme to work properly. Current reversals during fault clearing in parallel transmission lines can cause the healthy line to trip incorrectly. Below, we outline some of those conditions:

- When the remote terminal is open, the relay at that terminal will not see the fault; therefore, it is unable to send trip permission to the remote end.
- If one terminal is a much weaker source of fault current than the other or its normal source is out of service, it may not produce sufficient current during a fault to allow pickup of the

distance elements. In this case, the weak terminal will not send permission to allow tripping at the strong terminal.

- If the channel fails completely, permission to trip cannot be transmitted. To overcome this, the Zone 2 overreaching element typically starts a Zone 2 timer to allow backup tripping after a coordinating time interval to provide backup step-distance mode of operation in case of channel failure.

Current Reversals

In double-circuit line applications, faults near one end of the line may result in a sequential trip operation. This sequential trip happens when the instantaneous relay elements trip the breaker nearest to the fault location (this trip is independent from the communications tripping scheme). The breaker farthest from the fault must wait for a permissive signal. The major problem with this sequential fault current clearance is that it creates a current reversal in the healthy parallel line. If the protection for the healthy line is not equipped to address this reversal, one terminal of the healthy (nonfaulted) line may trip incorrectly.

Figure 2.38 shows the status at the inception of the fault. Relaying at Breaker 3 detects the fault as being within Zones 1 and 2. The instantaneous Zone 1 element issues a trip signal to the breaker independent of the communications-assisted tripping scheme. It is the Zone 2 elements at Breaker 3 that issue a permissive signal to the protection at Breaker 4. The protection at Breaker 4 detects the fault within Zone 2 but must wait for the permissive signal from Breaker 3 before issuing a permissive trip output. In the event that the permissive trip signal never arrives and the fault persists, Breaker 4 is tripped by Zone 2 time-delayed protection.

The Zone 2 element at Breaker 2 also picks up at fault inception and issues a permissive signal to the protection scheme at Breaker 1. At this time, the Zone 3 elements at Breaker 1 also pick up and identify the fault as being reverse (or out of section) to its location.

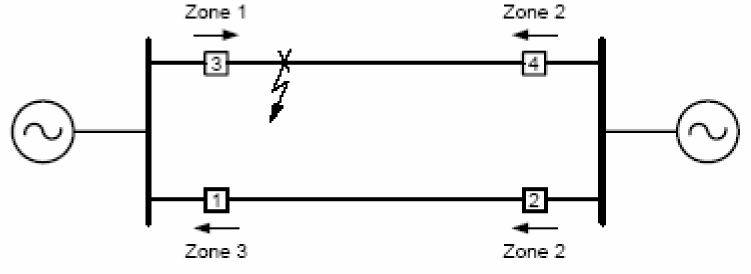

Figure 2.38 Faulted system with all breakers closed

After Breaker 3 opens, the fault currents redistribute. When this redistribution occurs, the Zone 2 element at Breaker 2 and the Zone 3 element at Breaker 1 begin to reset. If the Zone 2 element at Breaker 1 picks up before the received permissive signal resets, Breaker 1 trips as a result of this current reversal. This scenario can easily occur when ground directional overcurrent relay elements are used in a POTT scheme, because they can often see an end-zone fault on an adjacent line. It is less of a factor when ground distance relays are used.

Another factor that contributes to this is the fact that the closing torque of an electromechanical element would be much higher than the opening spring's torque, resulting in a large disparity in pickup versus dropout times. This disparity is also true with numerical relays but to a much lesser degree.

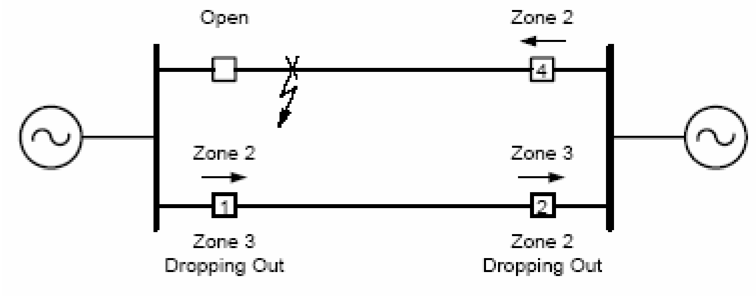

Figure 2.39 Faulted system with Breaker 3 open

Typical current-reversal logic is shown in Figure 2.40. Gate AND 2 represents simple POTT logic. Gate AND 1 is the added logic to prevent tripping on current reversals. The logic of gate AND 1 blocks local tripping and permissive trip keying if the local breaker is closed and the fault is detected by Zone 3 in the reverse direction. The Zone 3 reverse block dropout delay (T1 timer) holds this block for a period of time T1 upon dropout of the Zone 3 reverse element. Factors that influence the T1 timer setting are the remote terminal Zone 2 reset and the channel reset time. To be conservative, some margin should be added to the sum of these times. A safe margin (and known quantity) is the maximum expected operating time of the breaker on the parallel faulted line.

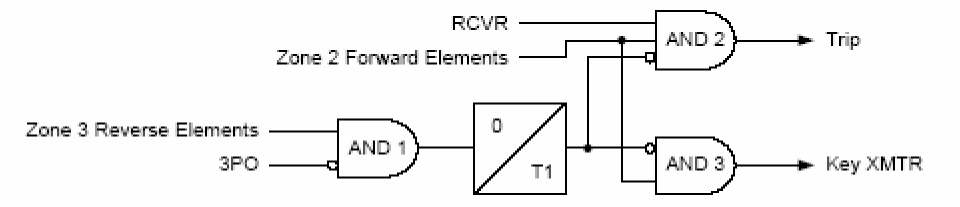

Figure 2.40 Current-reversal logic

POTT schemes require permission from both terminals to achieve accelerated trip times for internal faults along the entire line. When one line terminal is open, as shown in Figure 2.41, the protective relay elements at the open line terminal are unable to detect an internal fault and cannot transmit trip permission to the remote terminal. This is a deficiency of the POTT scheme and usually requires that end-of-line faults be cleared by Zone 2 time-delayed elements, unless additional logic is provided.

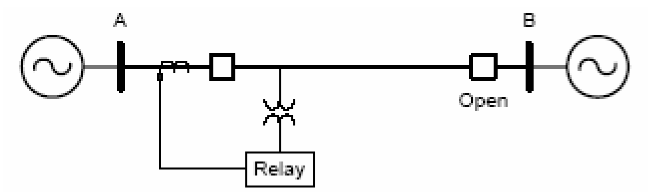

Figure 2.41 Line with remote terminal breaker open

The simplest means of dealing with this is to use a 52b contact of the open breaker to key a constant permissive signal. However, this solution is undesirable for two reasons:

- It results in constant keying of the permissive signal from both terminals after they open to clear an internal fault.
- If the communications equipment requires guard-before-trip for a specified amount of time before accepting the permissive trip signal and if the communications signal fades for whatever reason, the communications-assisted tripping is defeated.

Echo logic is added to the POTT scheme to overcome the deficiency. The echo logic causes the relay at the open breaker terminal to echo back the permissive signal it received from the remote terminal that detected a line fault. Typically, the following conditions must be met before a received permissive signal from the remote terminal is repeated or echoed to the initiating terminal:

- Zone 3 reverse elements did not detect a reverse fault.
- Zone 2 element did not detect a forward fault.

- The permissive trip (PT) input is asserted for a settable length of time.

The first requirement assures that the fault is not behind the relay location before transmitting permission to the remote terminal (assuming the Zone 2 elements at the remote breaker detected a fault and sent a permissive signal). The second requirement prevents the relay from issuing a permissive signal to the remote terminal for communications channel noise. It also allows time for the reverse looking elements to operate. The echo time-delay pickup (T3) timer setting determines the permissive trip signal qualifying time. A typical setting is two cycles.

Once the echoed permissive signal is issued to the remote terminal, its duration must be limited to prevent a scenario where both terminals maintain the permissive signal channel in a continuous “trip keyed” or constantly “on” state. The echo duration (T4) timer limits the echoed permissive trip signal to a settable duration. T4 is typically set greater than the communications channel operation time plus the remote breaker tripping time. It is desirable to maintain the echoed permissive trip signal to the remote breaker until the fault is cleared. Assuming a three-cycle breaker and half-cycle channel operation time, a typical T4 setting would be three and one-half cycles.

The echo logic in Figure 2.42 shows that echo keying will occur if no Zone 3 reverse elements are picked up and a permissive trip signal has been received for a T3 time delay. Logic is also included to block the echo transmit function for a period of time via the echo block dropout delay (T2) timer after a forward fault is detected.

The T2 would typically be set greater than the sum of the following delays:

- Remote Zone 2 pickup equal to one cycle
- Remote breaker trip time equal to three cycles
- Channel reset time equal to one cycle

A typical setting is ten cycles.

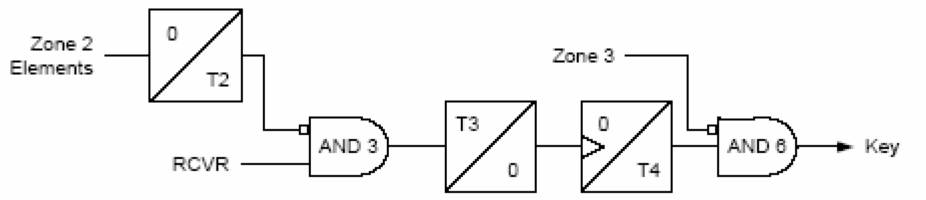

Figure 2.42 Echo logic

In some system configurations, with all sources in, the weak source terminal may not contribute enough fault current to operate its protective relay elements for a fault near the strong terminal. After the strong terminal line breaker opens, the fault current from the weak source terminal may increase sufficiently to permit sequential tripping of the weak source terminal line breaker. If the fault current does not increase sufficiently to operate the protective elements at the weak source terminal, it is still desirable to trip the weak source breaker. This prevents the low-level currents from maintaining the fault arc and allows successful auto reclosure from the strong terminal. When the fault location is near the weak source terminal, the Zone 1 elements of the strong terminal do not pick up, and the fault is not cleared rapidly. This is because the weak terminal protective elements do not operate.

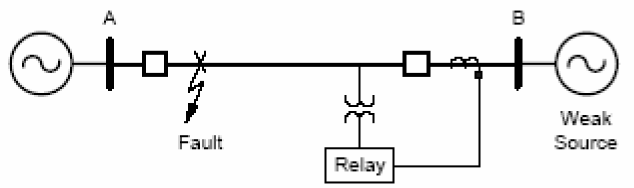

Figure 2.43 Weak-infeed terminal

Even though the weak-infeed terminal contributes low levels of fault current during a fault, the phase voltages are depressed. We can take advantage of the low voltages at the weak source to enable weakinfeed logic tripping. Weak-infeed logic permits rapid tripping of both line terminals for internal faults near the weak terminal. The strong terminal is allowed to trip via the echoed back permissive signal from the weak source terminal. In addition, the weak-infeed logic generates a trip signal at the weak source terminal if all of the following are true:

- A permissive trip (PT) signal is received for T3 time.
- A phase undervoltage or residual overvoltage element is picked up.
- No reverse looking elements are picked up.
- All breaker poles are closed.

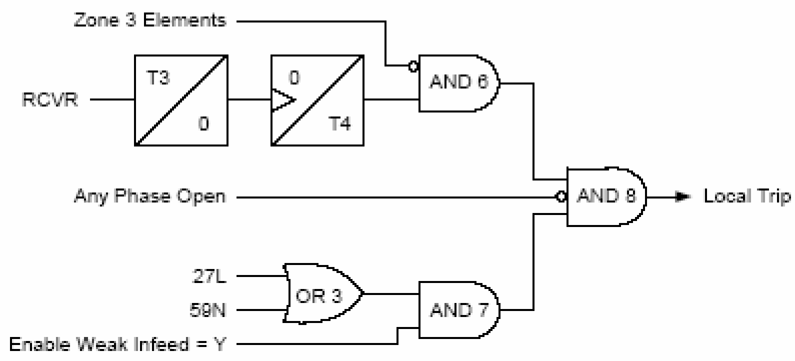

Figure 2.44 Weak-infeed logic

The top half of the logic diagram is from the “breaker open” echo keying logic. If we have a permissive signal to echo transmit AND the breaker is closed AND low voltage is detected at the weak source terminal, the relay will trip the local breaker (echo conversion to trip).

This weak-infeed trip logic is typically enabled only when necessary. A typical phase undervoltage setting is 70–80 percent of the lowest expected system operating voltage. The residual overvoltage setting should be set to approximately twice the expected standing 3V0 voltage. With the 59N element set at twice the nominal standing 3V0 voltage, the element measures only fault-induced zero-sequence voltage.

Permissive Underreaching Transfer Trip

PUTT uses the same basic logic as POTT but can be even more secure. Underreaching elements are used to key permissive trip to the remote terminal. The remote terminal is allowed to trip if it sees the fault as forward with its overreaching element and the remote end sees it with its underreaching element. Because the permissive keying elements can only see faults within the protected line, there is no danger of misoperation on current-reversal situations. Because the tripping elements are not set with as great a reach, the PUTT is slightly slower and provides less fault resistance coverage. This scheme should not be used in applications where weak-infeed conditions exist in one of the line terminals.

Direct Underreaching Transfer Trip

DUTT schemes work on the principle that any time an underreaching phase or ground element picks up, a trip signal is issued to the remote end of the transmission line. DUTT schemes require a very secure communications channel because the received trip signal at the remote end is not supervised by a protective element.

Direct transfer trip (DTT) schemes are similar to DUTT schemes with the difference being that the trip signal is issued to the remote end any time the local breaker is called on to trip, except when operating personnel trip the breaker manually.

Directional Comparison Blocking

In a DCB scheme, each line terminal has reverse elements (Zone 3) and forward-overreaching elements (Zone 2). Zone 1 underreaching elements are applied for independent, high-speed clearing of non-end-zone faults from each terminal.

In a DCB scheme, the relay transmits a blocking signal to the remote end if it detects the fault in the reverse direction, indicating that the fault is outside of the protected zone. The DCB logic will issue a local trip signal if the fault is in the forward direction and does not receive a blocking signal from the remote end.

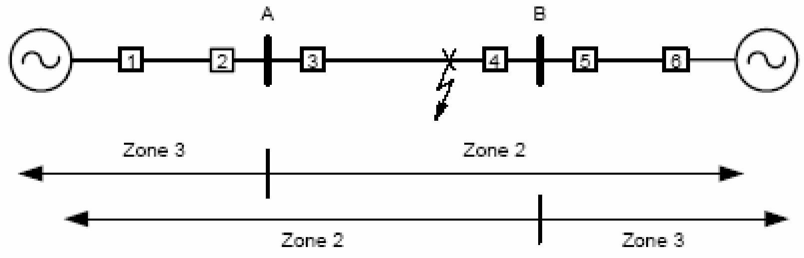

Figure 2.45 Typical zones in a DCB scheme

Figure 2.46 shows the fundamental logic involved in a DCB scheme. Pilot tripping occurs for an internal fault if the local Zone 2 forward-overreaching element operates and no blocking signal has been received from the remote line end within a settable time. This time delay, the channel coordination time delay, is required to allow time for the blocking signal to be received from the remote terminal before the tripping element at the local terminal generates a trip signal. If the blocking signal does not get through or is late, a DCB scheme may overtrip. The DCB scheme uses a PLC channel because the only time that it is necessary to transmit a blocking signal is when the fault is not on the protected line.

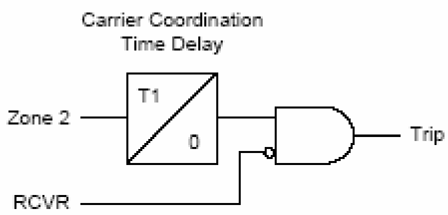

Figure 2.46 Basic DCB logic

There are a number of complications that need to be addressed with DCB schemes. Emphasis is placed on time coordination issues and ways to improve the likelihood of a secure operation of a DCB scheme. Current reversals also have to be addressed.

Loss of channel in DCB schemes can cause a line trip for an external fault, because no blocking signal can be received from the remote terminal. This is complicated by the fact that an on/off carrier set is typically used for the highest possible channel speed. An on/off carrier set is off in the normal state, and it is turned on to block the remote end from tripping. For this reason, it is usually desirable to use an automatic carrier check-back system with on/off carrier sets. An automatic carrier check-back system can be programmed to operate several times a day to check the condition of the channel. There is usually a master check-back unit that keys the local transmitter with a series of carrier pulses. The slave check-back units monitor their local receiver and recognize this code as a check-back transmission instead of a fault transmission. Then they respond by keying their local transmitter with an answer code. If the master receives the slave code on its local receiver, it knows that the channel is healthy. If it does not, it will typically generate an alarm to indicate that the channel has failed. If an internal fault occurs during a check-back transmission, the relay will assert its “carrier stop” output. The carrier sets have “carrier stop” over “carrier start” priority that will turn off the transmitter if the fault is internal.

The channel delay coordination timer blocks the local trip signal, so it is desirable to make this delay as short as possible while maintaining security. The local Zone 2 elements are delayed to coordinate with the blocking signal. This channel coordination time delay is improved by the fact that, for an external fault, the local reverse Zone 3 element will be closer to the fault, and the fault will be at a lower percentage of the element reach than the remote forward-reaching Zone 2 element. Thus, the Zone 3 element that is keying the blocking signal will naturally operate faster than the remote Zone 2 tripping element. This allows the coordination delay to be set close to the channel time with the difference in element operate time making up the security margin.

Figure 2.47 shows a typical DCB scheme with directional element transmitter start logic. In this case, the block signal is only sent when the relay sees the fault in the reverse direction. Nondirectional carrier start can be used to reduce the channel delay coordination time delay and improve the speed of a DCB scheme. The relay turns on the transmitter as soon as a fault is detected by nondirectional elements to send a block signal as soon as possible. Then, if the slower, forward-overreaching elements pick up, indicating that the fault appears to be in the protected zone, the transmitter stop asserts and turns off the carrier allowing a breaker trip.

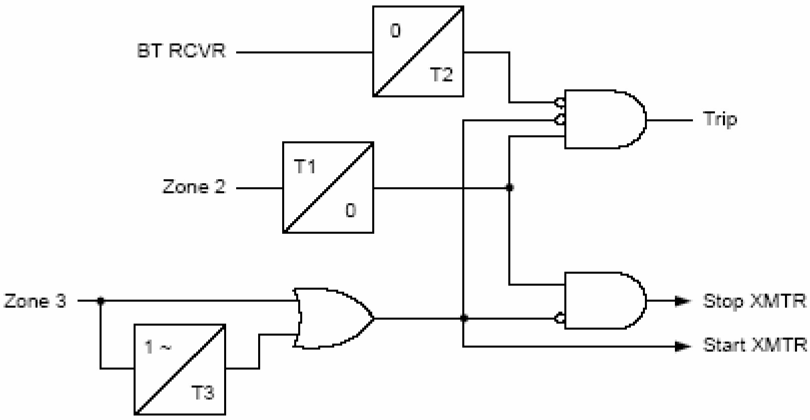

Figure 2.47 Carrier start using directional elements in DCB schemes

Stop preference over start is a feature of on/off teleprotection channel equipment. This feature is required for nondirectional transmitter start because the transmitter is keyed for internal and external faults to reduce the channel coordination delay time. However, for an internal fault, both the transmitter start will be asserted by the nondirectional element and the transmitter stop will be asserted by the forward-overreaching Zone 2 elements. Figure 2.48 shows that numerical and electromechanical nondirectional elements are very close in operating speed. This may not be true for all nondirectional numerical and electromechanical elements.

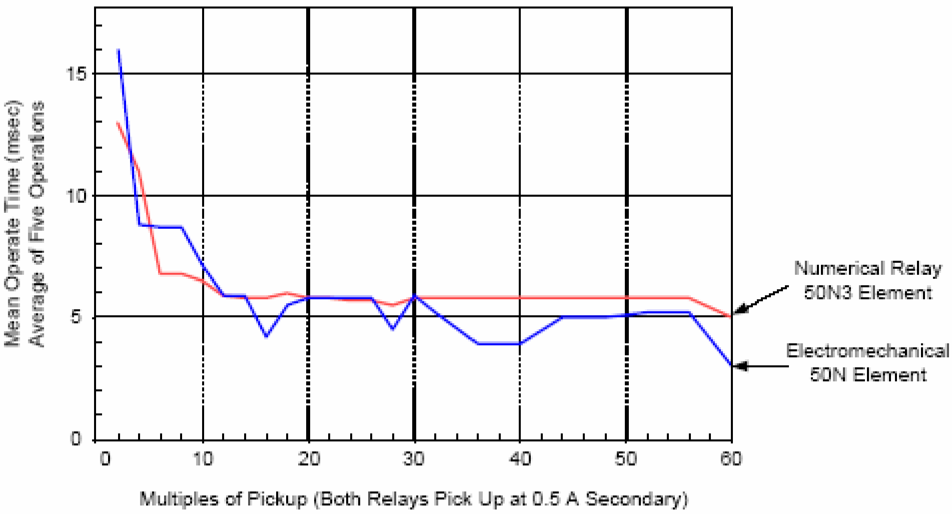

Figure 2.48 Nondirectional overcurrent element (EM vs. µP) speed comparison

Figure 2.49 indicates that a speed improvement can be achieved with nondirectional transmitter start. The nondirectional element is almost a half cycle faster. For an internal fault, approximately a 7–10 millisecond burst of carrier will be present and then it would shut off, allowing the remote end to trip. However, the remote channel delay coordination timer could be set to be 7–10 millisecond less for the same scheme security.

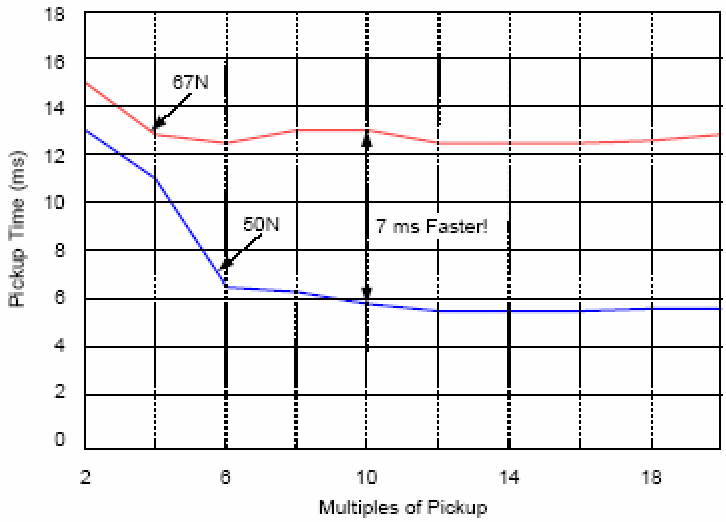

Figure 2.49 Directional and nondirectional overcurrent speed comparison

Figure 2.50 shows typical carrier stop logic that asserts if any of the forward-reaching elements pick up and the reverse elements do not pick up, indicating a possible current-reversal situation.

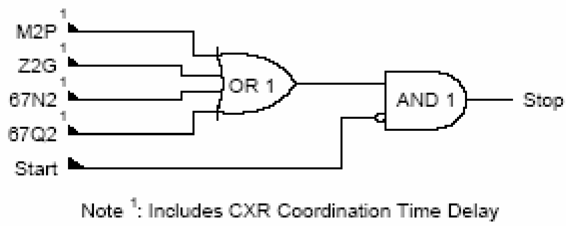

Figure 2.50 Carrier stop logic in DCB schemes

A DCB scheme may lack security during current reversals as well. Figure 2.51 shows the status of the circuit breakers and fault current direction at the inception of the fault.

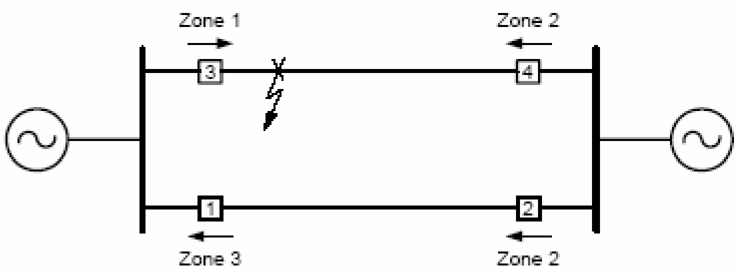

Figure 2.51 In-section line fault with all breakers closed

The distance relay at Breaker 3 detects the fault as being within Zone 1 and issues a trip signal to the breaker independent of the communications-assisted tripping scheme. This trip condition also stops the transmit of a blocking signal. The relay at Breaker 4 detects the fault within Zone 2; however, it has to wait for its channel coordination timer to expire before tripping.

The reverse-reaching Zone 3 element at Breaker 1 is picked up, indicating the fault is initially in the reverse direction. The assertion of the Zone 3 element starts transmission of a blocking signal to block Breaker 2 from operating. At the same time, the Zone 2 element at Breaker 2 is picked up. Because the typical carrier coordination timer setting is less than the breaker operation time, the Zone 2 element will be ready to trip but is being blocked by the signal from Breaker 1. After

Breaker 3 opens, the fault currents redistribute so the forward-overreaching Zone 2 elements at Breaker 2 and the reverse Zone 3 element at Breaker 1 begin to drop out. If the Zone 3 element at Breaker 1 drops out and the channel resets before the Zone 2 element at Breaker 2 drops out, Breaker 2 will perform an unwanted trip.

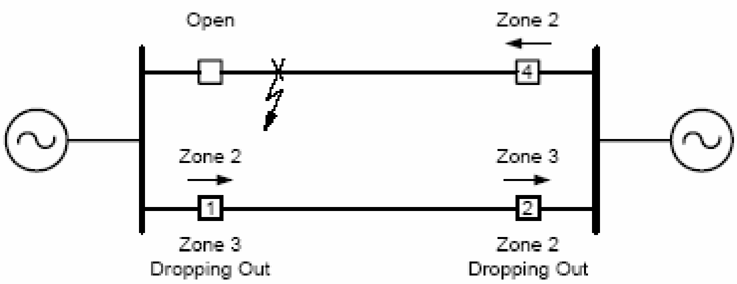

Figure 2.52 Current reversal when Breaker 3 opens

The T3 timer holds the block signal up for a period of time to allow the remote Zone 2 elements to drop out before turning off the blocking signal, as shown in Figure 2.53.

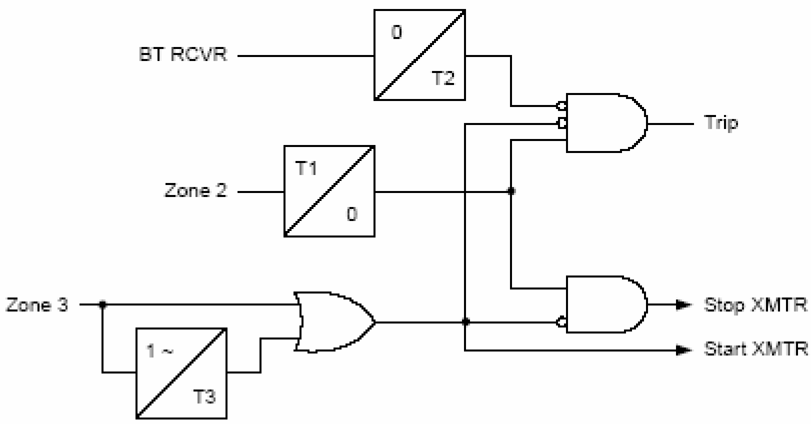

Figure 2.53 Typical current-reversal logic in a DCB scheme

The diagram in Figure 2.54 shows the timing sequence for the scenario just described. For Breaker 2, notice the timing between Zone 2 pickup and receipt of block from Breaker 1. The shaded area represents the carrier coordination timer. Notice that the T3 timer for Breaker 1 starts two cycles after the reverse Zone 3 element picks up, indicating that an out-of-zone fault has been detected. This element then starts timing down upon dropout of the Zone 3 element. Notice also that the block trip (BT) signal at Breaker 2 is maintained until the T3 timer expires at Breaker 1. The result is that there is no race with dropout of Zone 2 elements at Breaker 2.

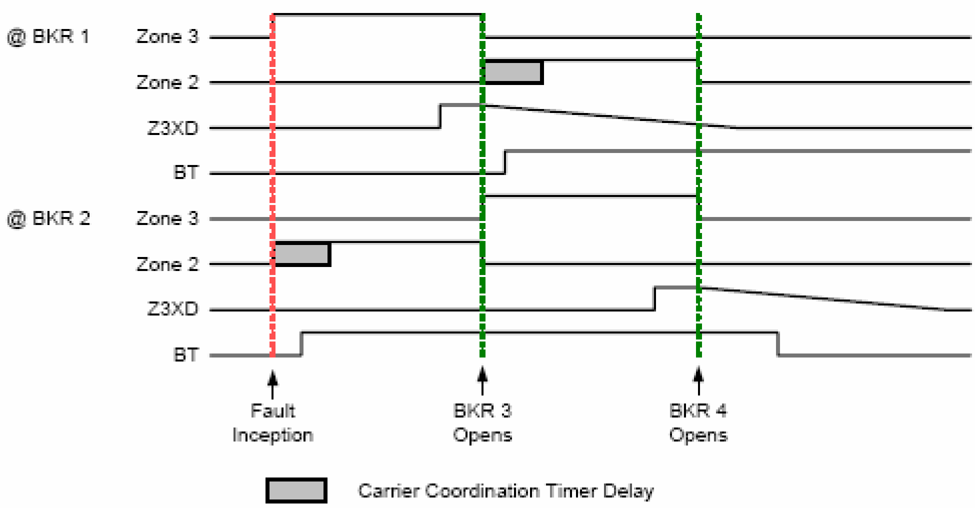

Figure 2.54 Current-reversal timing sequence

Directional Comparison Unblocking Scheme Logic

The basic POTT scheme requires that relays at both ends of the line see the in-section fault and transmit a trip signal to each other by use of a communications channel. Overreaching Zone 2 elements are then allowed to trip with receipt of the permissive signal. Typically, faults within Zone 1 reach are cleared by instantaneous elements without regard for the receipt of the trip signal from the other end. Faults outside Zone 1 but within Zone 2 must receive a permissive signal from the remote relay to trip fast or must wait for the Zone 2 timer to time out.

The communications medium for transmitting the trip signal to the other end may be fiber-optic channels, company owned or leased telephone lines, or PLC. When using PLC in a permissive scheme, getting the trip signal through to the remote end can be difficult. In many instances, the signal is transmitted on the same line that has the fault. This may reduce the signal to the point of not having it received by the remote end. It is these cases where a DCUB scheme can provide the means for fast clearing of the fault.

In a DCUB scheme, FSK carrier equipment is typically used to provide communications between the two ends of the line. This equipment continuously transmits a guard signal on one frequency. When a fault occurs, the protective relay signals the carrier equipment to shift from the guard frequency to the permissive frequency. The receiver at the other end of the line monitors these signals. There is a short transition period in which there is no guard signal and no permissive trip signal received. If the permissive trip signal arrives momentarily, then a normal trip occurs.

Unblocking schemes employ logic whereby if the guard signal is lost and no permissive trip signal is received (because of signal attenuation during a line fault), the requirement for a permissive trip signal is bypassed for 150 milliseconds to allow tripping if a permissive Zone 2 element picks up. After the 150 millisecond time window expires and no trip is issued by the protective relaying, the permissive signal channel is assumed to be faulty and the permissive signal criteria for tripping is not bypassed any longer.

DCUB allows the security of a POTT scheme to be used in situations where the channel is susceptible to failing at the same time as a fault on the power line. It does this by allowing an unsupervised trip for a short time upon failure of the channel. This scheme is appropriate when using PLC, fiber-optic cable in the ground, sometimes wire, or otherwise using a channel strung in the same right-of-way or on the same towers as the protected line. In a DCUB scheme, if the communications equipment at the remote terminal fails at the same time an out-of-section fault occurs that is within the reach of the forwardoverreaching elements at the local end, then an incorrect single-ended trip can occur.

In summary, DCB schemes are not secure and will overtrip if the channel fails or if the channel delay increases. POTT schemes can be less dependable because they will fail to trip for a channel failure. DCUB schemes combine the security of POTT schemes and also allow tripping for a window of time to accommodate channel failure during a fault. FSK channel equipment provides continuous monitoring of the channel by continuously transmitting the guard (block) signal. DCB schemes should not be used with networked communications channels such as SONET where the channel delay can change. A high-speed channel such as a PLC on/off channel is required.

POTT and DCUB schemes will not trip until the permission (unblock) signal arrives, so there are no concerns about channel delay for security. Channel delay does affect ultimate tripping time.