Distribution Protection – Optimizing the Fast Bus Trip Scheme

Introduction

The fast bus trip (FBT) scheme provides bus protection for radial systems. This protection has a short time delay on pickup in the order of three cycles and does not require extra CTs needed for a differential scheme. FBT also reduces the number of relays required, wiring and testing. Take the extra steps to make this protection scheme both reliable and secure.

Fast Bus Trip Scheme

Figure 1 is a one-line diagram for a distribution bus with one main (source) and two feeders. Each breaker has a non-directional definite time overcurrent relay (i.e., 50M, 50F2 and 50F3). These are the relays used for the traditional scheme. The feeder relays (50F1 and 50F2) send a blocking signal to the bus relay (50M) when they detect a feeder fault to prevent it from tripping.

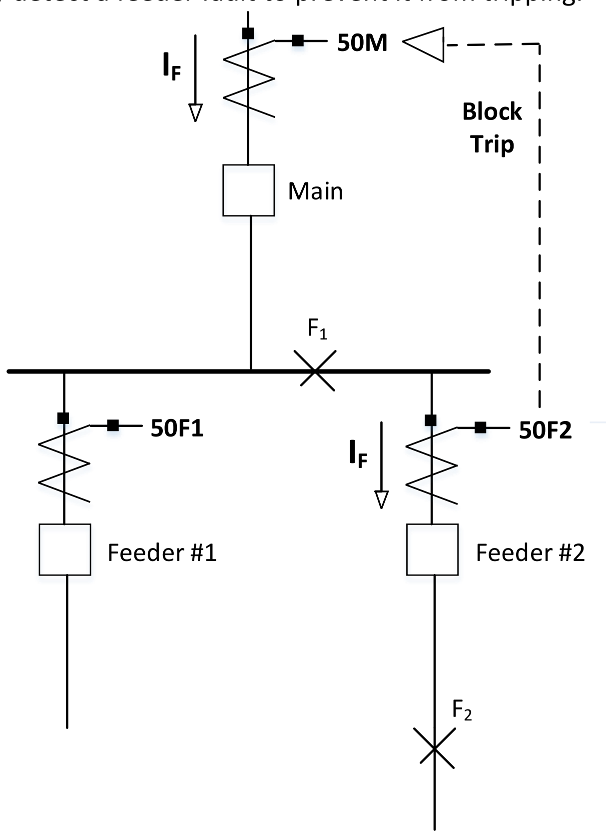

FIGURE 1 – Radial Distribution System with Two Feeders

Figure 2 illustrates the traditional logic used for this protection scheme.

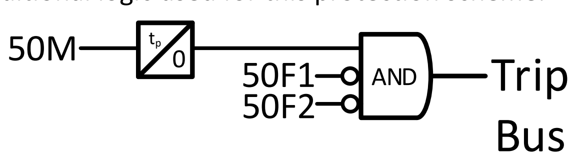

FIGURE 2 – Traditional FBT Logic Diagram

If a fault is located at F_1 (bus) there is no blocking signal from either feeder relay and the bus relay 50M trips after a short time delay (t_p) typically set at 3 cycles. If a fault is on a feeder such as F_2 then the feeder relay blocks the bus relay and prevents tripping the bus. Typically an output contact from each

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feeder relay is wired to an input of the bus relay in order to transmit the blocking signal during feeder faults. Use phase overcurrent elements for this scheme and set the pickup for the overcurrent elements to operate for faults close in to the bus.

Directional Overcurrent Blocking

Figure 3 illustrates a ground fault on the bus (for example a bushing flashes over) and there is a transformer connected to feeder 2 that has a winding connected grounded wye facing the distribution system. Ground fault current (I_G) comes up the neutral of the wye connected winding from ground flowing through the feeder back into the bus fault and as a result 50F2 *incorrectly* blocks fast bus tripping.

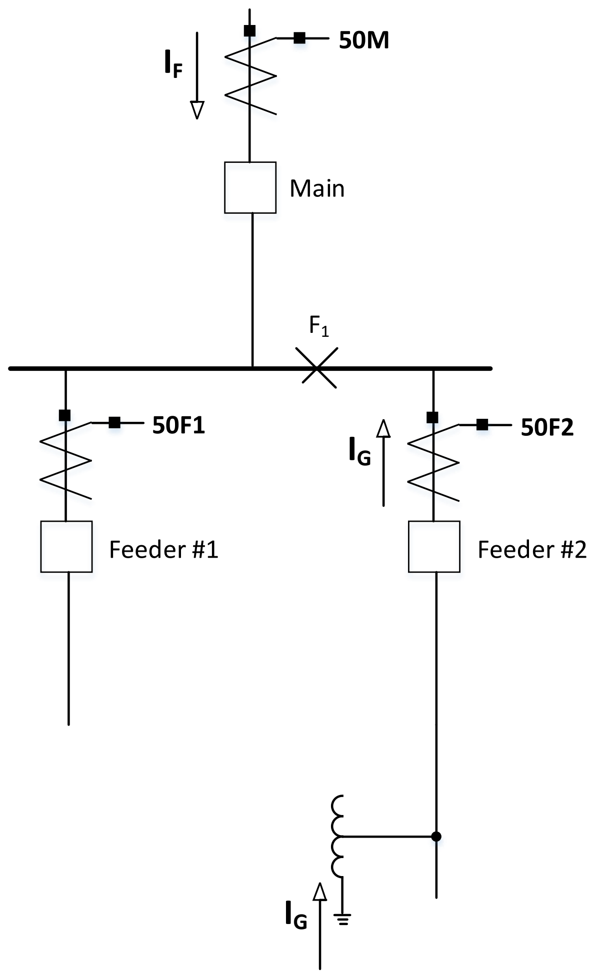

FIGURE 3 – Ground Fault on Bus with Ground Source on Feeder

The solution is to use forward looking directional overcurrent elements (67F1 and 67F2) to block the bus relay. Using directional overcurrent to block properly discriminates between bus and feeder faults, which in turn prevents delayed tripping for cases such as shown above in Figure 3.

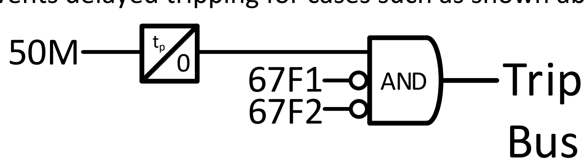

FIGURE 4 – FBT Logic Diagram with Directional Blocking

Time Delay on Dropout

Figure 5 illustrates a three-phase overhead feeder. A fault occurs which is first A-Phase-to-ground. The fault then evolves into A-Phase-to-B-Phase-to-ground and finally into a three-phase fault. This could be due to a broken tree limb as it falls across each phase. Therefore, the fault type is initially single phase-to-ground, then phase-to-phase-to-ground and finally three-phase. Positive-sequence current, negative-sequence current and zero-sequence current are present during the initial fault (A-G) and subsequent fault (A-B-G) but there is only positive-sequence current during the final fault (A-B-C-G).

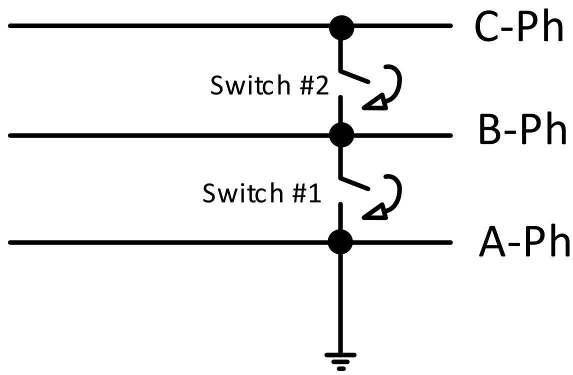

FIGURE 5 – Evolving Fault on Overhead Distribution Feeder

It is a common design for numerical feeder relays to use steering logic that determines which polarizing quantity to use for the ground overcurrent directional elements based upon prevailing fault conditions. For example, a popular choice is to first use negative-sequence voltage polarization followed by zero-sequence voltage-polarization if there is little or no negative-sequence voltage present at the relay voltage terminals; both of these directional elements dropout when the fault evolves into all three phases since there is no longer any unbalance. Therefore, there is no blocking signal for at least one relay processing interval (for example a quarter of a cycle) until the steering logic switches over to positive-sequence voltage polarization. An unwanted bus trip can occur as a result when the blocking signal momentarily drops out.

The solution is to use time delay on dropout for blocking overcurrent elements as illustrated below in Figure 6 so the blocking signal will ride through the final stage of evolving faults.

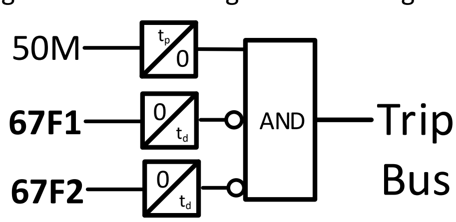

FIGURE 6 – FBT Logic Diagram with Time Delay on Dropout for Directional Blocking

Coordinating Overcurrent Pickup Settings

Figure 7 below illustrates an inter-circuit fault between two distribution feeders. This could be due to a tree branch falling across two feeders running along the same set of overhead poles.

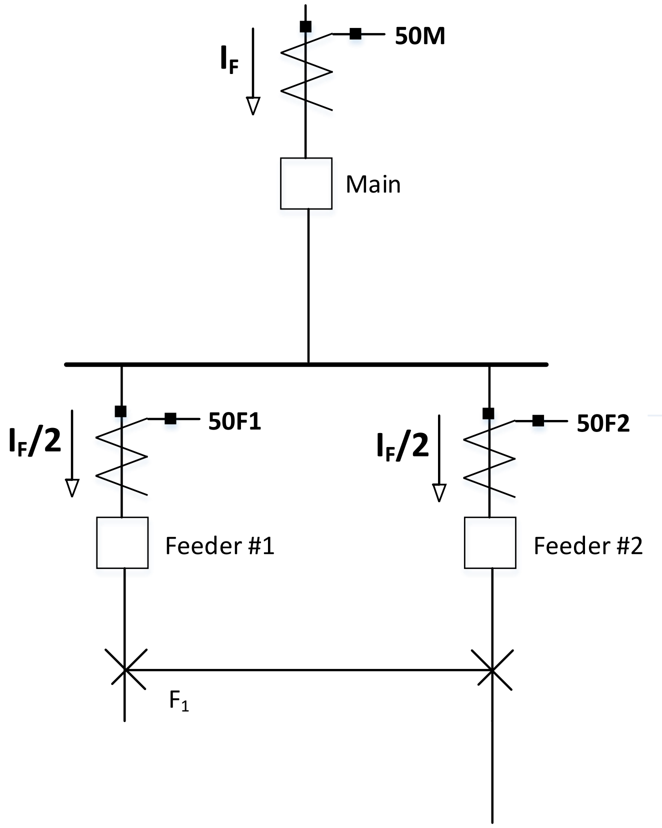

FIGURE 7 – Inter-Circuit Fault Involving Two Overhead Distribution Feeders

The bus relay 50M sees the total fault current I_F while each feeder relay (50F1 and 50F2) only see half that magnitude. Therefore, if these relays' overcurrent elements are set with the same pickup setting then the feeder relays will not detect the inter-circuit fault and an unwanted bus trip occurs. Use the following criteria when setting the pickup:

50F#P < 50MP/2

Where:

50F#P = Feeder Relay Overcurrent Pickup Setting
50MP = Bus Relay Overcurrent Pickup Settings

Partial Differential Bus Scheme

Figure 8 below illustrates a distribution bus with three feeders. There is one main source and a tie breaker in case the main breaker is open. 51B1 is an overcurrent relay that detects bus faults and also provides backup for the feeder relays. Use partial differential bus protection for buses that have more than one source. 51B1 only sees internal faults with respect to Bus 1 when the tie breaker is closed. 51B1 can act as 50M for the fast bus trip scheme and time overcurrent elements must coordinate with the feeder relays 51F1, 51F2 and 51F3.

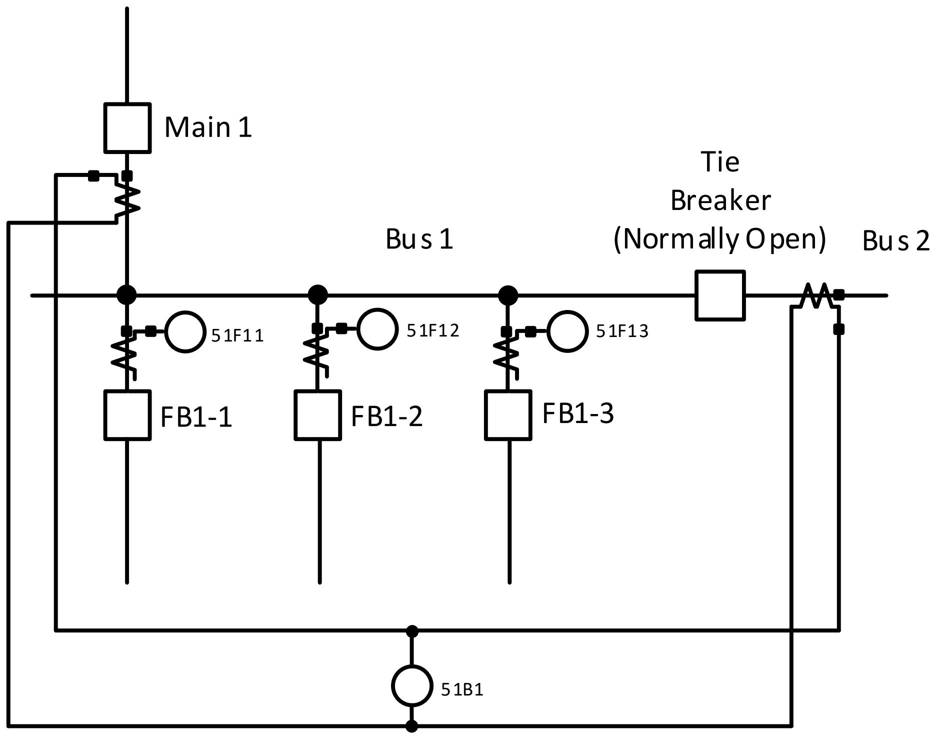

Figure 8 – Partial Bus Differential Protection Scheme

Partial differential bus protection can also be applied for buses where the tie breaker is normally closed and the sources are paralleled. 50M from the fast bus trip scheme only see bus faults on Bus 1 due to the CT connections shown in Figure 8.

Conclusion

Fast bus trip protection is simple to implement and provides economical bus protection for radial distribution systems. Traditional scheme logic is reliable but not secure due to the simplicity. The following steps make fast bus trip more secure as well:

- Use forward looking directional overcurrent elements to block so that the fast bus trip occurs during back feed on any feeders
- Time delay on dropout for the blocking elements prevents unwanted bus trips if the signal momentarily drops out during an external fault
- Set the overcurrent pickup for the blocking elements more than twice as sensitive as the bus tripping element
- Partial differential protection can provide an additional level of protection for buses with more than one source (that is not radial)