

6.9 Sample Case 8

Normal mode

C-A, ϕ - ϕ fault on Line 512

Hidden failure: Line 504 PCB scheme low set fault detector picked up

This case illustrates the security of the line. With the low set fault detector of the PCB scheme picked up, the scheme operates as an overcurrent relay. The region of vulnerability is any fault with fault current greater than the high-set fault detector setting. In this example, the PCB scheme operates on fault current in 1½ cycles. Zone 1

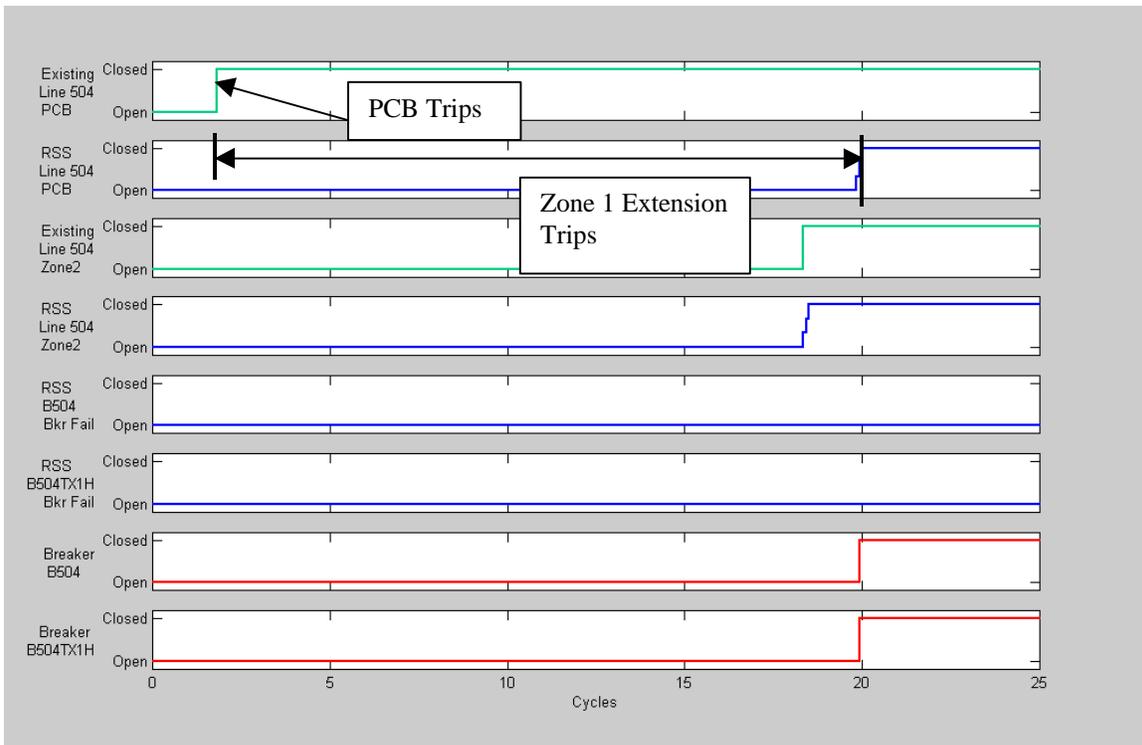


Figure 30: Sample Case 8

Extension supervises the PCB scheme. Since the fault is not a zone 1 fault, but is a zone 2 fault, the method waits until the coordination timer expires before permitting a trip. The protection scheme is still dependable since a trip is eventually allowed.

6.10 Sample Case 9

Normal mode

B ϕ , ϕ -G fault on Line 502

Hidden failure: Line 301 Directional Overcurrent element failed

In this case, the Line 301 Directional Overcurrent directional element fails picked up, turning the relay into a non-directional overcurrent relay. The region of vulnerability depends on fault current. The Line 301 Directional Overcurrent eventually trips on fault current. Voltage and current supervision determines the fault direction, and blocks the

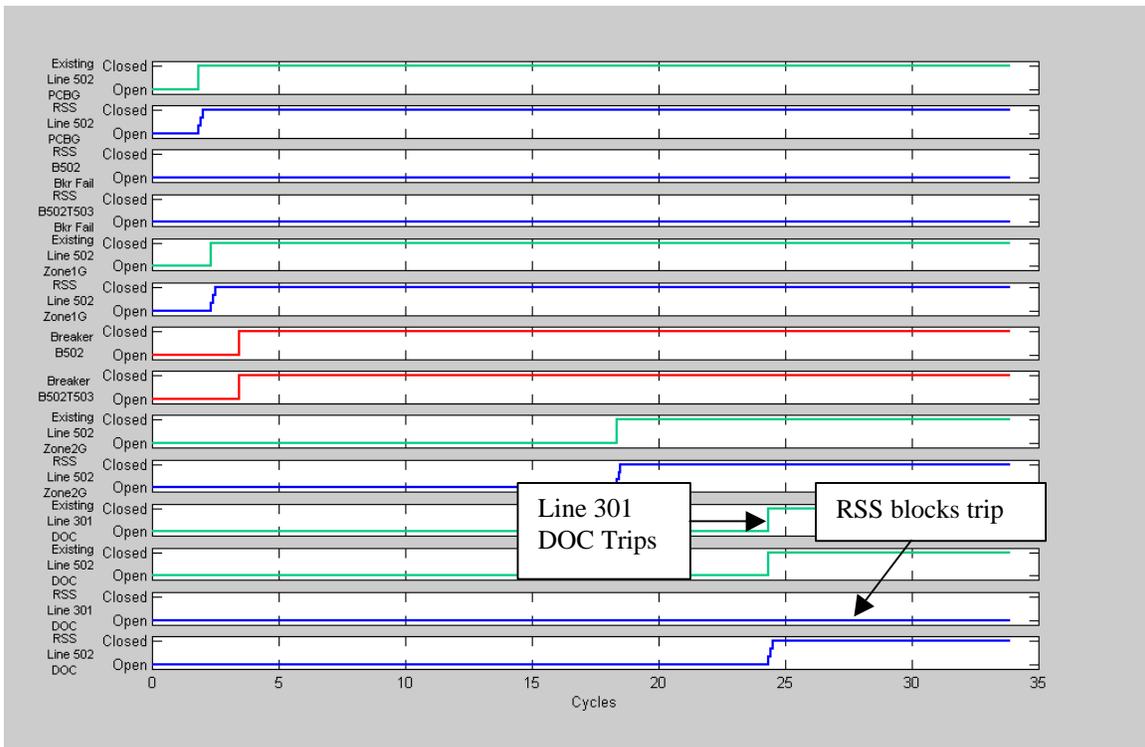


Figure 31: Sample Case 9

trip of the relay. Therefore, line security is increased. In reality, Line 502 relays clear the fault before the overcurrent relay operates.

6.11 Sample Case 10

Normal mode

B-C, ϕ - ϕ internal fault, Transformer #1

No hidden failure

This is an internal ϕ - ϕ transformer fault. The harmonic restraint percentage differential method supervises the existing transformer differential relay. The existing relay recognizes a fault in approximately 1 cycle, and the RSS permits a trip $\frac{1}{4}$ cycle

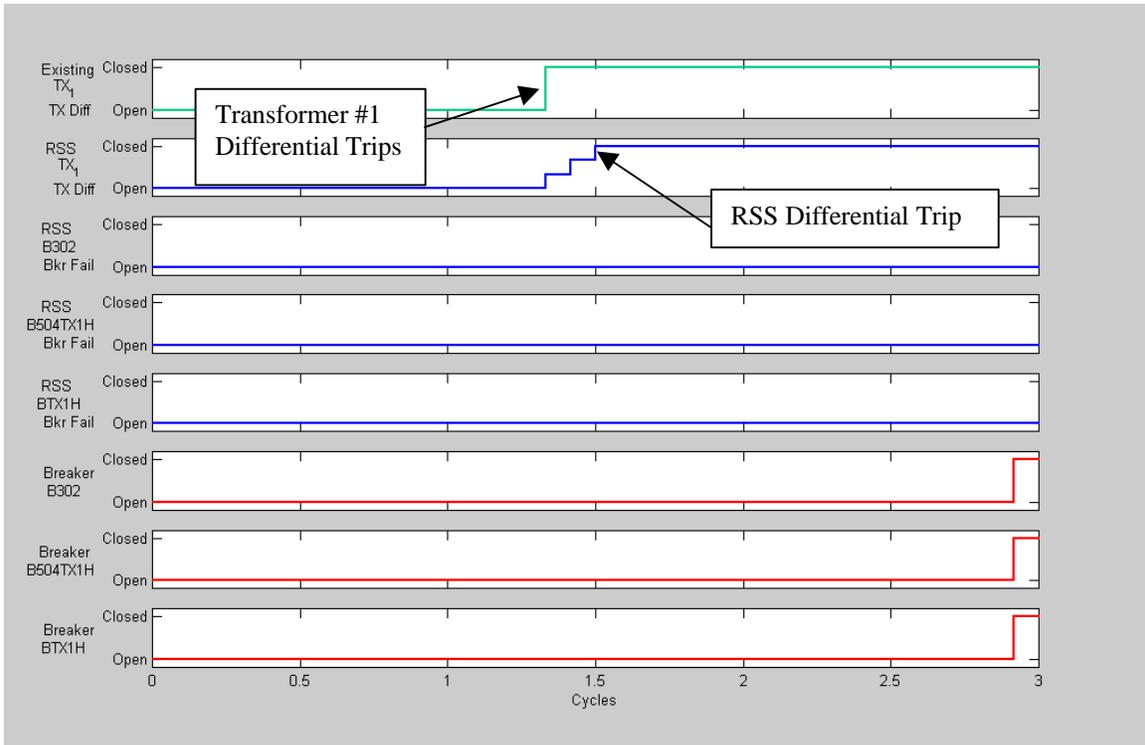


Figure 32: Sample Case 10

later. Protection system security and dependability is maintained.

6.12 Sample Case 11

Normal mode

Transformer #1 Energization

Hidden failure: Transformer #1 restraint coil shorted

This case illustrates the harmonic restraint of the differential supervision method. With a restraint coil shorted, the existing transformer differential relay trips during energization of the transformer. Inrush currents are high in 2nd harmonics. The Diff

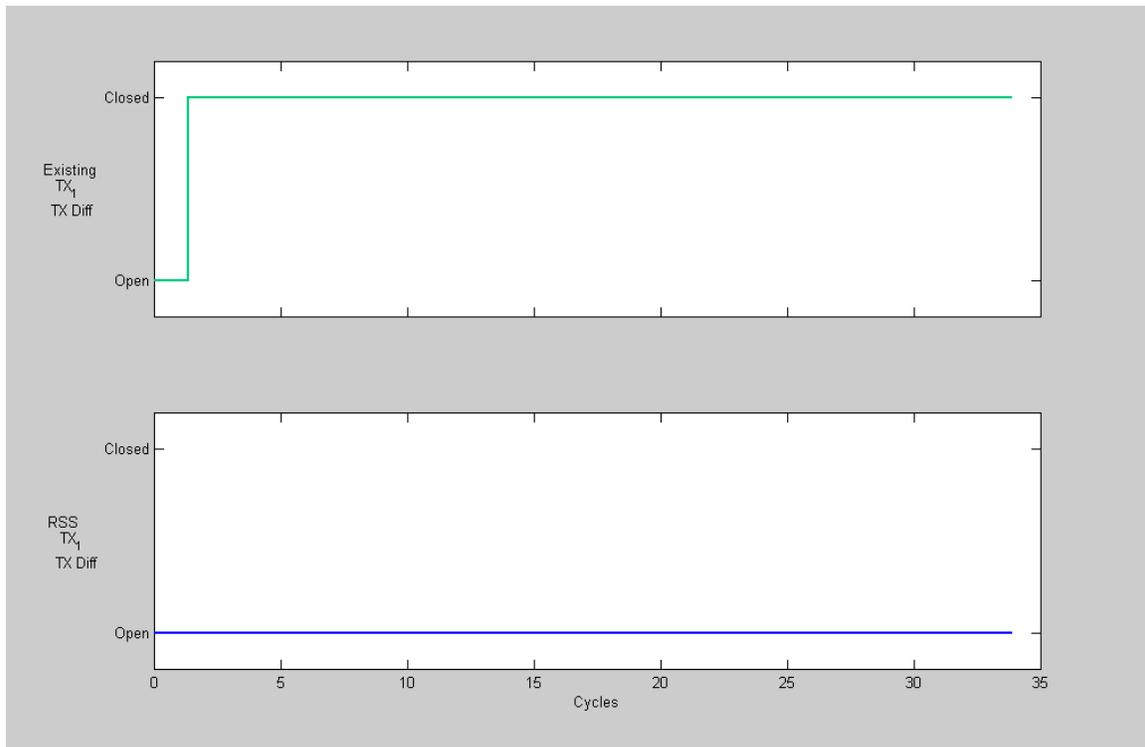


Figure 33: Sample Case 11

method restrains trip for high levels of 2nd harmonics. This results in improved security of the protection system.

6.13 Sample Case 12

Normal mode

A-B, ϕ - ϕ fault on Line 502

Breaker B502T503 failed

This is a normal breaker failure case. Line 502 relays operate for a ϕ - ϕ fault. B502 and B502T503 should operate to clear the fault, but B502T503 fails. Breaker failure is supervised by a timer in the RSS. The RSS permits the breaker failure scheme to operate when this timer expires, and if the breaker is still closed. In this instance, the

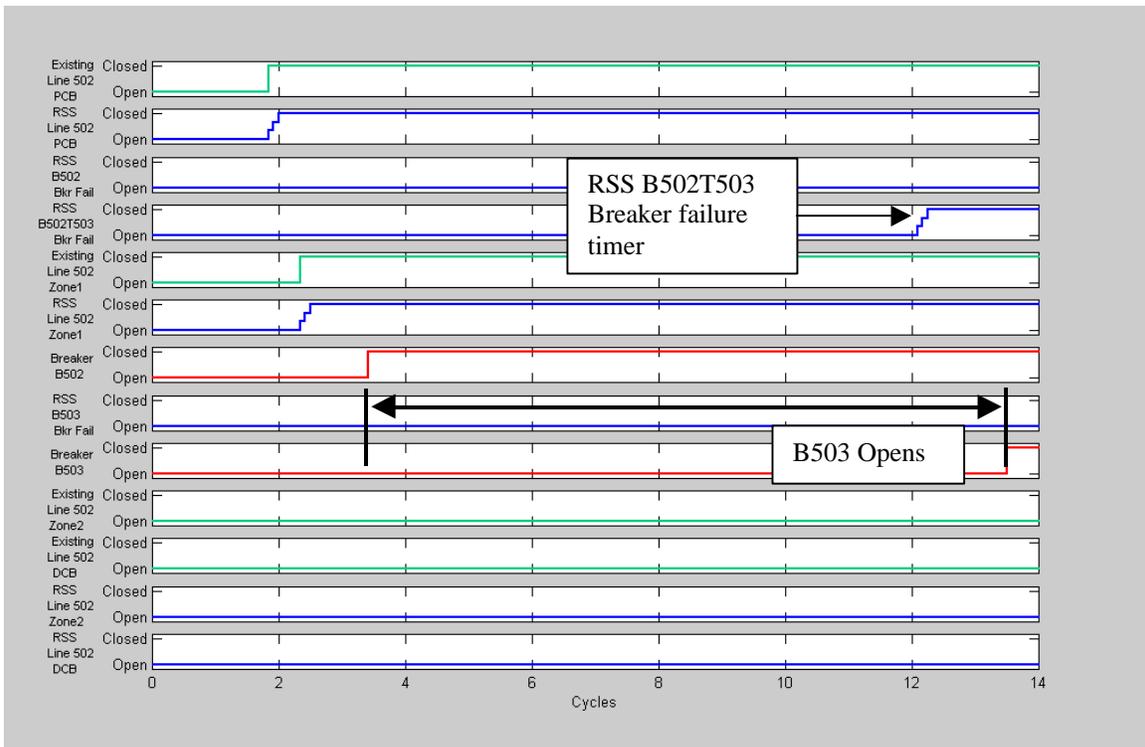


Figure 34: Sample Case 12

breaker failure scheme opens B503. Therefore, the RSS maintains dependability.

6.14 Sample Case 13

Normal Mode

A-B, ϕ - ϕ fault on Line 502

Hidden failure: B502T503 breaker failure timer fails picked up

In this case, the B502T503 breaker failure timer fails picked up, causing an immediate operation of the breaker failure scheme on a line trip, even though B502T503 opens successfully. The RSS supervises breaker failure through a timer. The timer

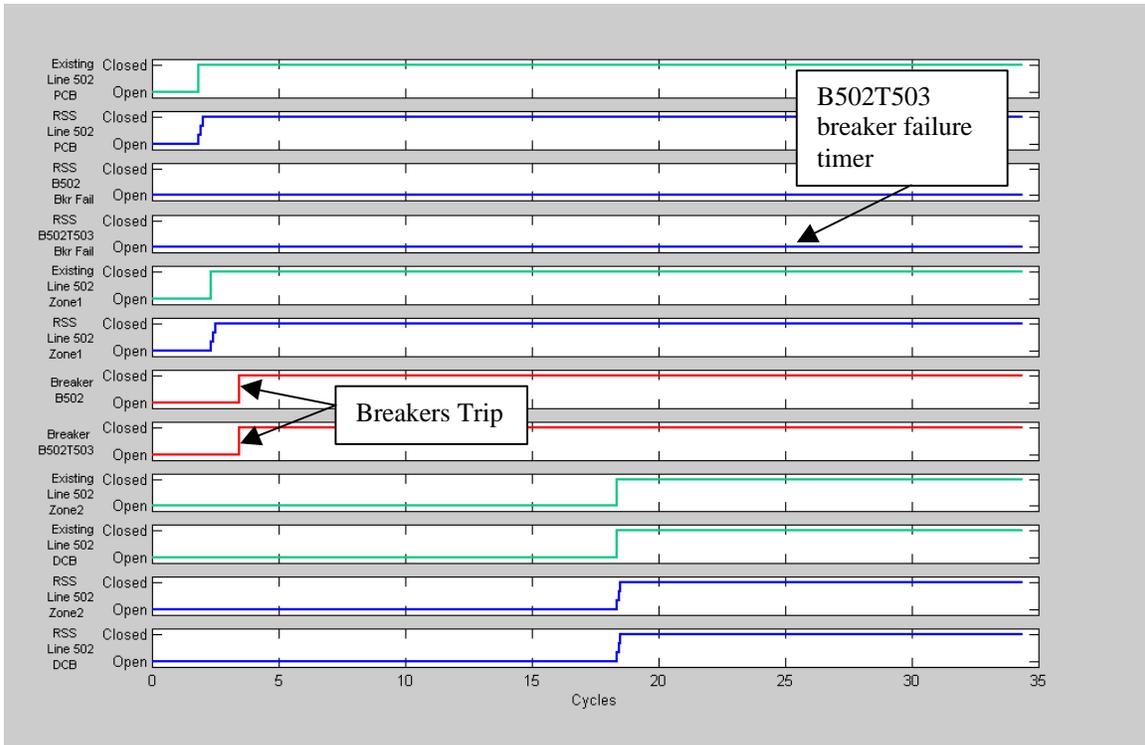


Figure 35: Sample Case 13

permits the breaker failure scheme to operate when the timer expires, and if the breaker is closed. B502T503 is open in this case, so the RSS blocks the B502T503 breaker failure scheme from tripping anymore breakers. This increases protection system security.

6.15 Sample Case 14

Out-of-Service mode

A-B, $\phi-\phi$ fault on Line 501

No hidden failure

This case illustrates the Out-of-Service mode of the RSS. The Line 501 PCB scheme trips for the $\phi-\phi$ fault on the line, and the associated breakers operate $\frac{1}{2}$ cycle later, with no involvement from the RSS. All output contacts controlled by the RSS are

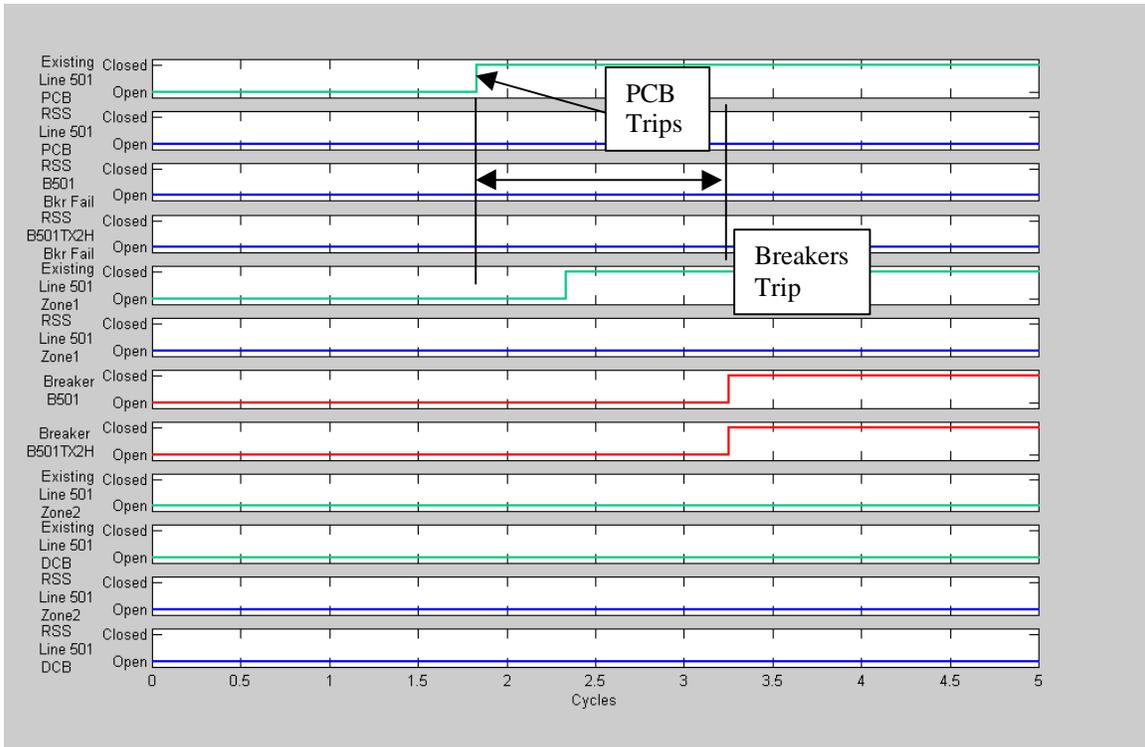


Figure 36: Sample Case 14

set closed for this mode.

6.16 Sample Case 15

Out-of-Service mode

A-B, ϕ - ϕ fault on Line 507

Hidden failure: Line 501 Zone 3 Timer fails picked up

This case shows the Out-of-Service mode associated with a hidden failure. The region of vulnerability for the zone 3 timer failure is the zone 3 reach beyond the remote bus. The ϕ - ϕ fault is in this region. The zone 3 relay operates in approximately 2 cycles after the fault. Since the RSS is Out-of-Service, and has set all output contacts closed, the breakers trip 1½ cycle after the zone 3 incorrectly operates.

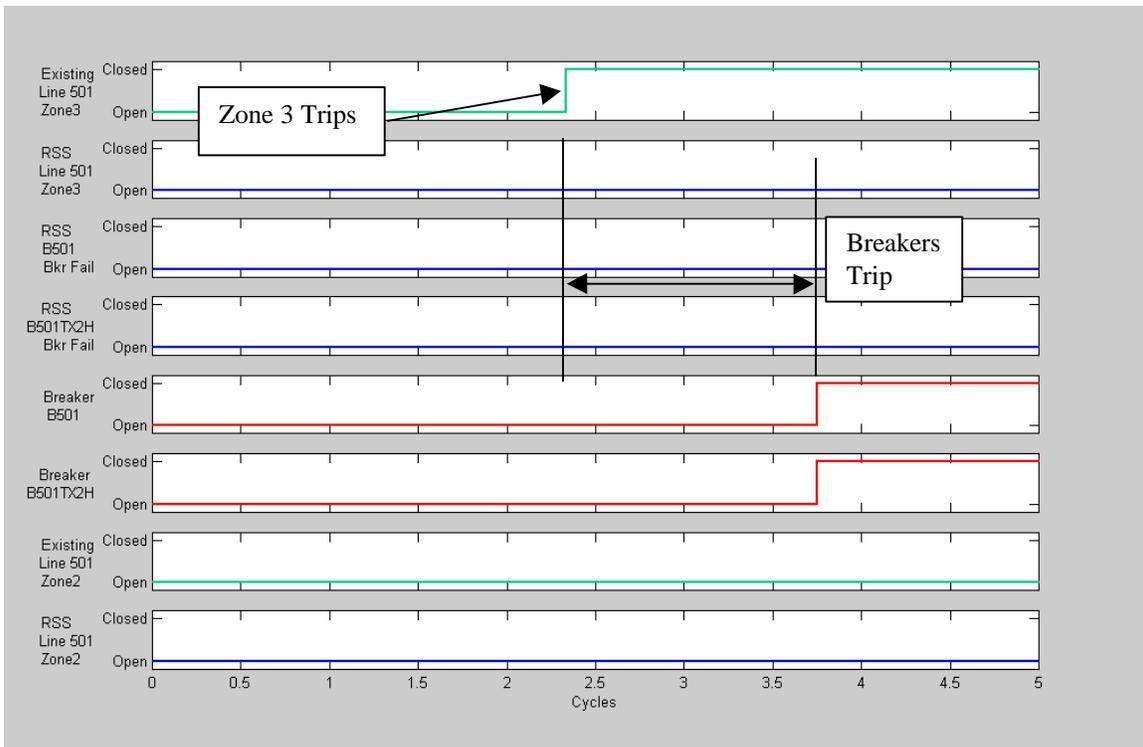


Figure 37: Sample Case 15

the breakers trip 1½ cycle after the zone 3 incorrectly operates.