

Appendix I

Table 23: Hidden Failure Modes of Distance Relay at A

Hidden Failure	Consequence	Region of Vulnerability	Supervision Method
Timer 2 fails closed	CB _A trips for F ₂ without time delay	Zone 2 reach beyond bus B	Step-distance timer
Timer 3 fails closed	CB _A trips for F ₃ without time delay	Zone 3 reach beyond bus B	Step-distance timer

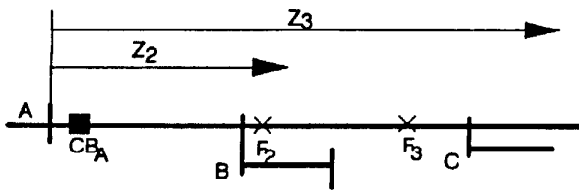


Figure 38: Step-Distance Protection Zone

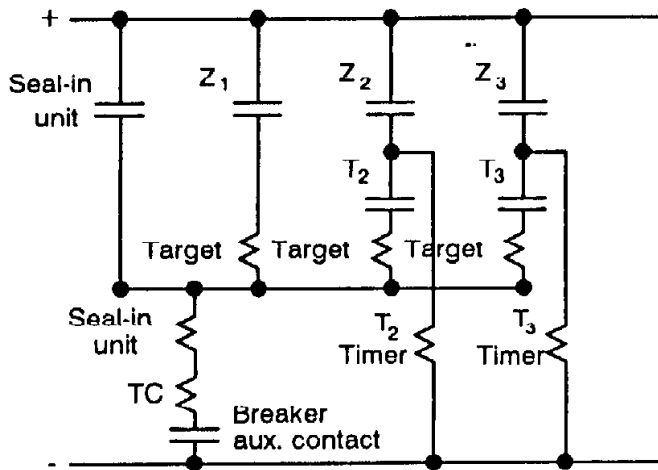


Figure 39: Step-Distance Relay Logic

Table 24: Hidden Failure Modes of Directional Comparison Blocking at A

Hidden Failure	Consequence	Region of Vulnerability	Supervision Method
FD_A can not pick up	CB_B trips for F_A	D_B reach beyond bus A	None
T_A fails to transmit	CB_B trips for F_A	D_B reach beyond bus A	None
R_A can not pick up	CB_A trips for F_B	D_A reach beyond bus B	Extended Zone 1

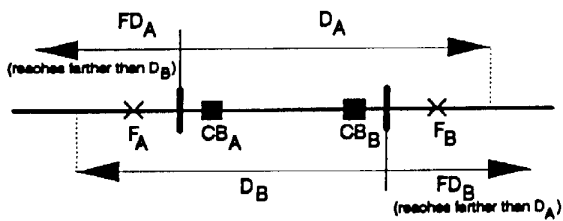


Figure 40: DCB Protection Zone

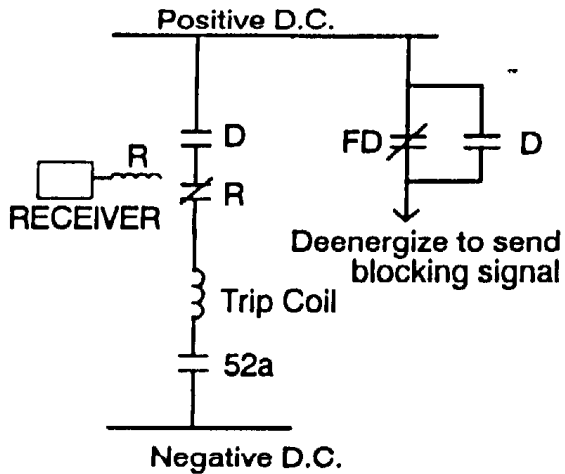


Figure 41: DCB Relay Logic

Table 25: Hidden Failure Modes of Phase Comparison Blocking at A

Hidden Failure	Consequence	Region of Vulnerability	Supervision Method
Loss of signal	Both CBs act as non-directional overcurrent relay	Fault current dependant	Extended Zone 1
FD_{LA} continuously picks up	CB_A acts as an overcurrent relay	Fault current dependant	Extended Zone 1
FD_{LA} can not pick up	CB_B acts as an overcurrent relay	Fault current dependant	None

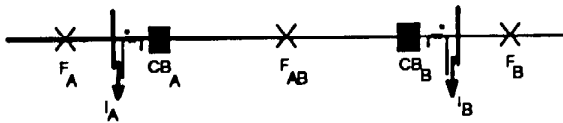


Figure 42: PCB Protection Zone

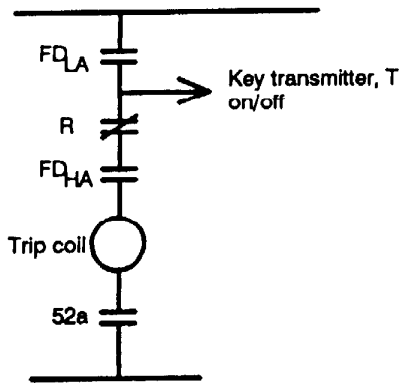


Figure 43: PCB Relay Logic

Table 26: Hidden Failure Modes of Direction Overcurrent at A

Hidden Failure	Consequence	Region of Vulnerability	Supervision Method
Polarizing source or coil shorted	Trips for reverse fault	Fault current dependant	Voltage and current polarization

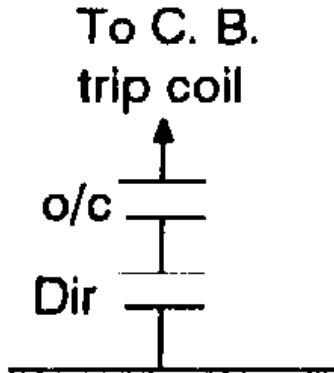


Figure 44: Directional OC Relay Logic

Table 27: Hidden Failure Modes of Transformer Differential at A

Hidden Failure	Consequence	Region of Vulnerability	Supervision Method
Restraint coil shorted	Trips on heavy load current	Load current dependant	Transformer differential

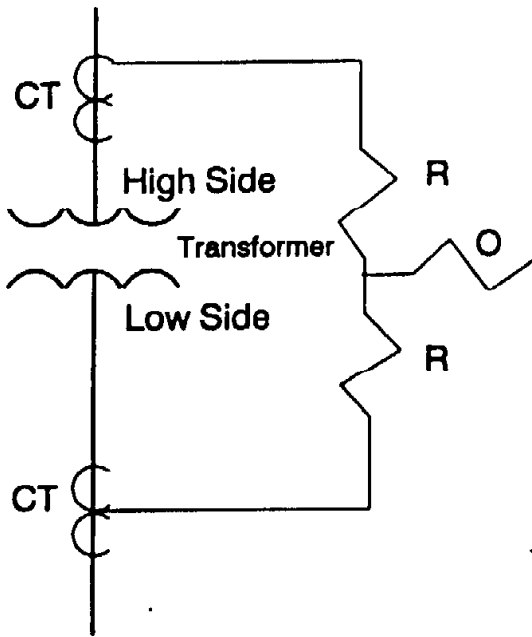


Figure 45: Transformer Differential Relay Protection Zone

Table 28: Hidden Failure Modes of Breaker Failure

Hidden Failure	Consequence	Region of Vulnerability	Supervision Method
Timer fails picked up	Lockout relay trips without time delay	Any relay zone for breaker	Timer

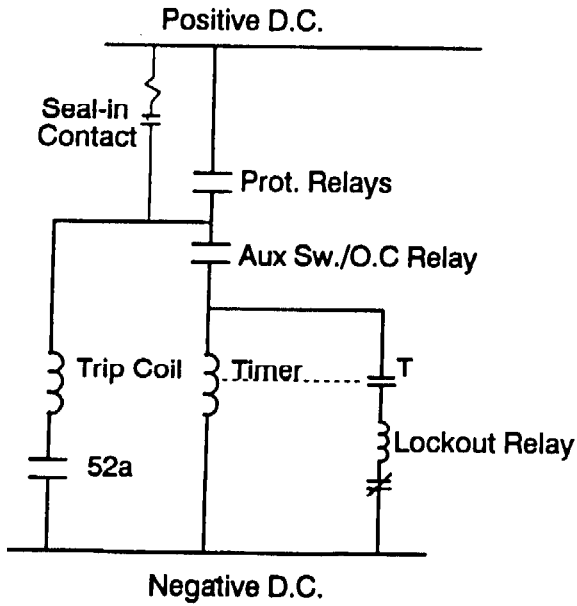


Figure 46: Breaker Failure Relay Logic