29th Annual
HANDS-ON
RELAY SCHOOL
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BREAKER FAILURE PROTECTION

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OUTLINE

- Protection System Failures and Breaker Failures
- BF Protection versus BF Relaying
- BF Relay Schemes and Logic
- Special BF Situations
- BF Setting Calculation Exercise
- Impacts from Changing Technology
- Testing and Maintenance of BF Schemes

Primary Reference:
C37.119 -2005 IEEE Guide for Breaker Failure Protection of Power Circuit Breakers

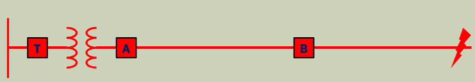
PROTECTION FAILURE

Protection System Failures
- Relay failure
- Settings failure
- Control system failure
- CT/PT failure
- Battery system failure
- Catastrophic control house failure (fire)

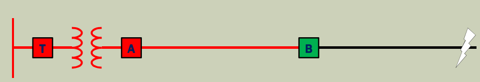
Breaker Failures
- Fails to trip
- Trips too slow
- Fails to interrupt fault current
- Fails to interrupt load current
- Flashover when open
- Fails to close
- Auxiliary contact problems
- Catastrophic failure

Breaker Failure *Protection*
versus
Breaker Failure *Relaying*

BREAKER FAILURE PROTECTION BY COORDINATION



BREAKER FAILURE PROTECTION BY COORDINATION



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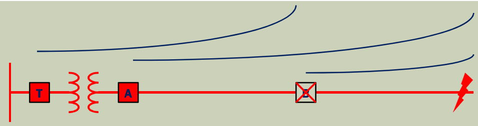

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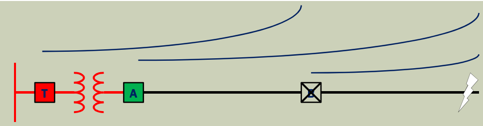
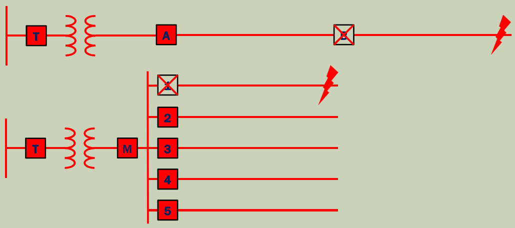


Advantages:
- Simple – No extra equipment
- Simple – No risk of misoperation
- Ultimate protection. Covers ALL failures, not just Breaker Failure (failure of breaker, relay, settings, controls and wiring, battery, etc.)

Disadvantages:
- Slow
- May not be possible for the backup relaying at [A] to see all faults

Conclusions:
- *Common practice for Distribution, but typically not sufficient for Transmission.*
- *There is "Breaker Fail Protection" even though there is not "Breaker Fail Relaying".*
- *Breaker failure protection is built-in to good protection practices.*

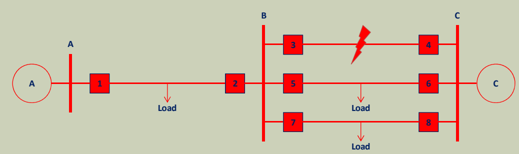
BREAKER FAILURE PROTECTION BY COORDINATION



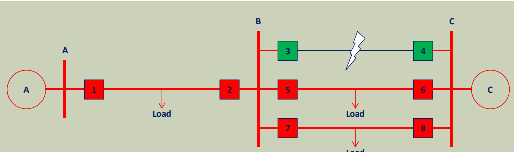
[A] can *probably* back up [B] and see a minimum fault all the way at the end of the line.
[M] *may not* be able to fully back up the feeder breakers for an end of line fault.

Example: Assume 200A load per feeder section, and 800A minimum fault current at the end of line.
[A] has 400A max load and needs to pickup on an 800A fault.
[M] has 1000A max load, so it cannot be set to pickup on an 800A fault.

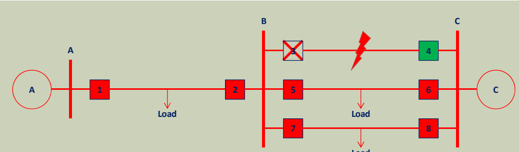
IEEE EXAMPLE



IEEE EXAMPLE PROPER CLEARING



IEEE EXAMPLE BREAKER FAILURE



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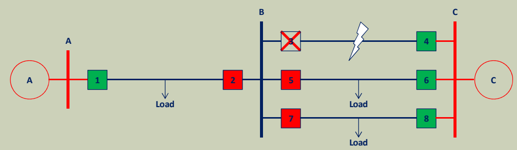
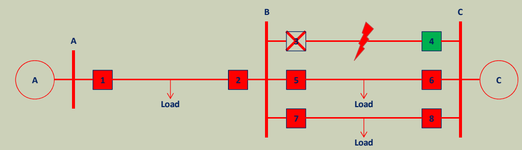
IEEE EXAMPLE
REMOTE BACKUP



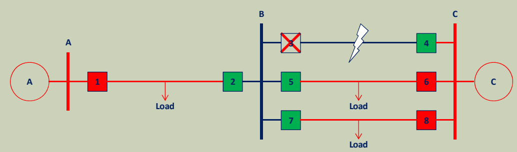
Advantages:
- Completely independent of Substation B.

Disadvantages:
- Slow – system instability
- Slow – voltage dips
- Wide area outage
- May not be possible for the backup relay to see all faults

IEEE EXAMPLE
BREAKER FAILURE RELAYING



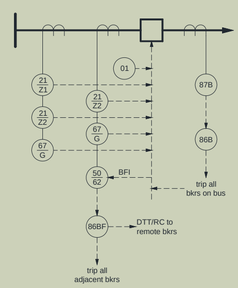
IEEE EXAMPLE
BREAKER FAILURE RELAYING



BFR on breaker [3] detects breaker failure condition
- BFR trips a Lockout relay
- Lockout relay (86) trips breakers [2], [5], and [7]
- Lockout relay blocks close of [2], [5], and [7]

What else?
- Transfer Trip to breaker [4]
- Cancel reclose of [4]

BREAKER FAILURE RELAYING



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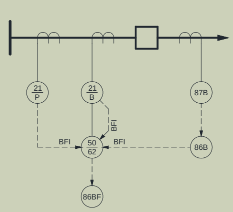
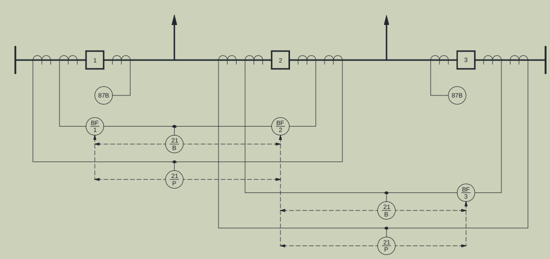


BREAKER FAILURE RELAYING



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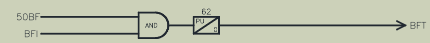
BREAKER FAILURE LOGIC

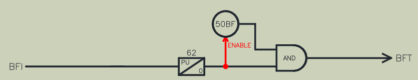
1. Basic Breaker Failure Scheme
2. 50BF Torque Control
3. Breaker Re-Trip Logic
4. BFI Control Timer
5. BFI Seal-In
6. Minimal Current Scheme
7. Timer Bypass Scheme
8. Dual Timer Scheme
9. Special Schemes

BASIC BREAKER FAILURE SCHEME

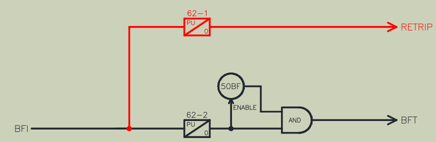


- Four Parts to a Breaker Failure Scheme:
  - Fault Detector (50) or other Failure Detectors
  - Initiator Circuit (BFI)
  - Logic and Timers (62)
  - Output Circuit (BFT)

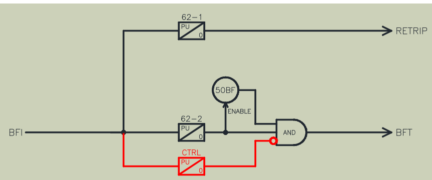
50BF TORQUE CONTROL



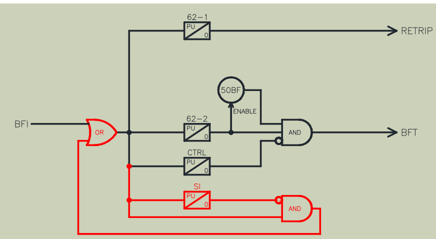
BREAKER RE-TRIP LOGIC



BFI CONTROL TIMER



BFI SEAL-IN



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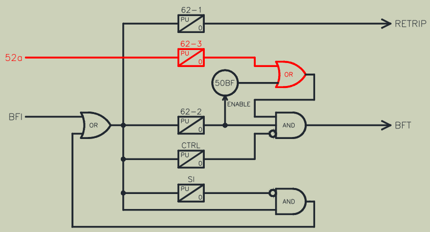
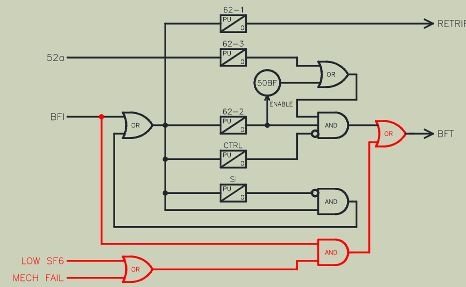
MINIMAL CURRENT SCHEME

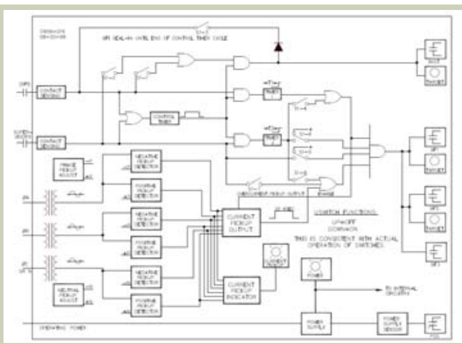


TIMER BYPASS SCHEME



Note: This logic is for illustrative purposes only. Not intended as a complete scheme. The timer bypass scheme should be supervised by a fault detector, which may not be compatible with torque controlled 50BF.

EXAMPLE BE1-50BF LOGIC



DUAL TIMER SCHEMES

- Use fast BF timer for multi-phase faults (L-L, L-L-G, 3P)
- Use slower BF timer for single-phase faults (SLG)

- Multi-phase faults have larger impact on system stability, and may require fast breaker failure times.
- Single-phase faults are more common.

- Dual timer allows fast BFT for the multi-phase fault, but keeps the security of a slower BFT for the most common fault scenario.

SPECIAL SCHEMES

- Voltage differential
- Frame leakage detection
- Breaker differential
- IPO breakers
- Redundant breakers

BF SETTINGS

- Logic
- Fault or Load Current Detector Pickup
- Other Breaker Failure Detectors
- Set Timers

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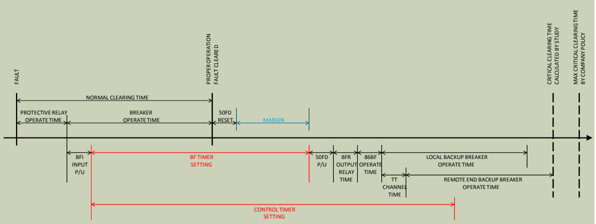
CALCULATING BF SCHEME TIMERS

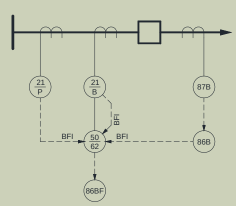


EXERCISE

IMPACT OF CHANGING TECHNOLOGY

- Digital Relay BF Protection: Faster, Better, Cheaper, More
  - Solved transient stability problems previously unsolvable
  - Better protection against wide-area and cascading outages
  - Protect against all breaker failure modes, not just one or two
  - Can be more secure if designed well
- Most utilities moving away from Stand-Alone BF Relays
  - Some utilities (not many) are reversing the trend and going back to stand alone Breaker Failure Relays
    - Reduce ~~misoperations~~ "unscheduled maintenance tests"
    - Use longer maintenance cycles for BF protection systems

IMPACT OF CHANGING TECHNOLOGY



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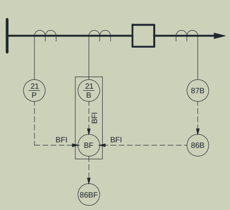
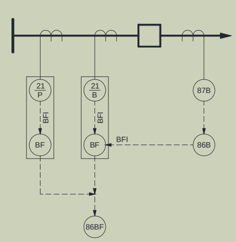
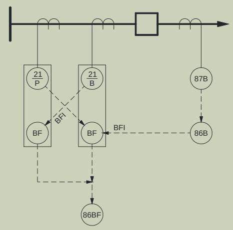


IMPACT OF CHANGING TECHNOLOGY



IMPACT OF CHANGING TECHNOLOGY



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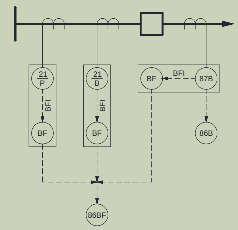

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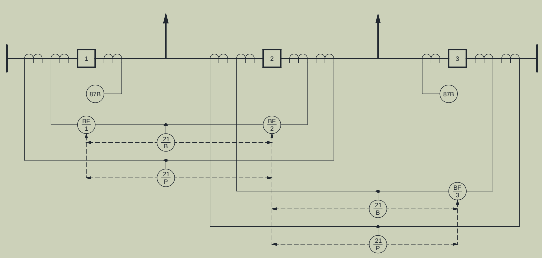

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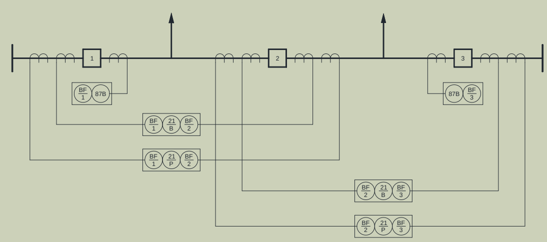

IMPACT OF CHANGING TECHNOLOGY

- Digital Relay Timing and Logic
  - Precise timing eliminates relay misoperations due to calibration drift
  - Precise timing and logic allows reducing "design margins"
- Digital Relay I/O
  - Sensitive BFI inputs (transients, DC grounds)
  - Solid state relay outputs (sneak circuits)
- Digital Relay Protective Elements
  - Used to be limited to a 50FD
  - Now we can use 50L and other sensitive detectors that may pick up a lot
  - *Solution: Consider using other elements to help add Security, not just Sensitivity (negative sequence, voltage elements, synch check and frequency elements, etc.)*

IMPACT OF CHANGING TECHNOLOGY

- Challenges from Complexity
  - Elaborate/exotic BF logic
  - Wide variety of BF schemes, even in the same model of relay at the same utility
  - May have more than one BF scheme in a single relay
  - May have more than one BF scheme for single breaker
  - *Solution: Engineering Standardization*
  - *Solution: Documentation (written setting descriptions, logic diagrams, and test plans)*
- Challenges with Integrated BF
  - May not be able to disable all BFI's
  - May not be able to disable all BFT's
  - Trend is to completely eliminate all hardwired BFT and lockout relays (IEC 61850)
  - *Solution: Design with test switch to relay input that disables the BFI and/or BFT. Especially important for BFTT or 61850.*

TESTING AND MAINTENANCE OF BREAKER FAILURE PROTECTION

Challenges with BF Protection
- Difficult to test intentionally
- Easy to test unintentionally

TESTING AND MAINTENANCE OF BREAKER FAILURE PROTECTION

There is a difference between testing the BF Relay and testing the BF Relaying System

- Many utilities perform maintenance testing of the BF Relay, but are ***not*** testing the entire Breaker Failure Protection System.
- Good maintenance practices (*and NERC compliance requirements*) are to test the Protection System:
  - Maintenance program for the BF Relay
  - Maintenance program for CT's/PT's
  - Maintenance program for the Battery and DC system
  - Maintenance of the BFR Protection System must include:
    - Rolling lockout relays and tripping breakers
    - Best practice: simultaneous functional test (clear the bus)

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