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 Settings and Timing
- Impacts from Changing Technology
- Testing and Maintenance of BF Schemes

Primary Reference:
What is a Breaker Failure?
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
Protection System Failures and Breaker Failures

BF Protection versus BF Relaying

BF Relay Schemes and Logic

Special BF Situations

BF Settings and Timing

Impacts from Changing Technology

Testing and Maintenance of BF Schemes
Breaker Failure Protection by Coordination
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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

Diagram showing a power grid with marked nodes and loads.
IEEE Example – Proper Clearing
IEEE Example
IEEE Example – Breaker Failure
IEEE Example – Breaker Failure

A

Load

1

2

B

5

Load

4

6

C

Load

7

Load

8

Load

C

A
IEEE Example – Remote Backup
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
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]
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Breaker Failure Relaying

- trip all breakers on bus
- trip all adjacent breakers
- DTT/RC to remote breakers
- trip all breakers on bus
- DTT/RC to remote breakers
Breaker Failure Relaying
BREAKER FAILURE RELAYING
Example Logic: BE1-50BF

This is consistent with actual operation of switches.
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
Breaker Failure Logic – Basic

Four Parts to a Breaker Failure Scheme:

- Fault Detector (50BF) or other Failure Detectors
- Initiator Circuit (BFI)
- Logic and Timers (62)
- Output Circuit (BFT)
50BF Torque Control: BFI is timed; current is checked once
Prevents chattering or restart of the timer due to 50BF

- 50BF can be Fault Detector, Load Current Detector, or Low Current Detector
Retrip is common for dual trip coil breakers

Timer 62-1 set differently depending on the scheme strategy
  - Example: retrip with alarm

Timer 62-2 always greater than 62-1
  - Example: 3 cycle breaker, 62-1 retrip and alarm at 5 cycles, 62-2 BFT at 10 cycles
Breaker Failure Logic – BFI Control Timer

- Prevents misoperations due to an erroneous BFI when used with fault detector 50BF
- Can alarm on CTRL time out
- CTRL always greater than 62-2
BFI Seal-In may be necessary when the BFI signal is momentary

- Can only be used when there is a BFI Control Timer (CTRL)
- May conflict with retrip strategy
Breaker Failure Logic – Minimal Current Scheme

“a-finger breaker fail”
- Examples: Transformer Sudden Pressure Trip; Generator Inadvertent Energization

Relay Techs Beware! These schemes commonly make relay techs famous!
Breaker Failure Logic – 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.
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.
But 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.
Special Schemes

Voltage differential
Frame leakage detection
Breaker differential
IPO breakers
Redundant breakers
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Breaker Failure Relay Settings

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

Normal Operation (above the axis)

Breaker Failure Operation (below the axis)
Calculating Breaker Failure Timers

Normal Operation (above the axis)

Breaker Failure Operation (below the axis)
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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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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 (fault detector)
- 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.**
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Testing and Maintenance of BF Protection

Challenges with BF Protection

- Difficult to test intentionally
- Easy to test unintentionally
Testing and Maintenance of BF Protection

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 CTs/PTs
- Maintenance program for the Battery and DC system
- Maintenance of the BF Protection System must include:
  - Rolling lockout relays and tripping breakers
  - Best practice: simultaneous functional test (clear the bus)
  - Typical practice: send in the new guy to check the BF relay, and you’ll probably get a complete functional test!
Thank You

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