Relay Scheme Design Using Microprocessor Relays

A report to the System Protection Subcommittee of the Power System Relay Committee of the IEEE Power & Energy Society

Prepared by working group C16
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# Members of the working group

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This paper is intended to supplement to the existing 1999 relay trip circuit design paper to address the use of microprocessor relays

- Modern relays are changing the way substations are engineered
- They enable many functions to be carried out through one piece of hardware
- This flexibility and compactness is sometimes the cause of increasing levels of complexity
Typical Trip circuit using Electromechanical relays

G = Green breaker status light
R = Red breaker status light
TC-1 = Breaker trip coil 1
2/Z2 = Zone 2 timer and associated output contact
62X = Auxiliary timer
PR = Protective relay trip contact
SI = Seal-in contact
TSI = Trip seal-in auxiliary relay coil
01/T = Manual control switch trip contact
86/BF = Breaker failure lockout contact
52a = Breaker auxiliary form "a" contact
52b = Breaker auxiliary form "b" contact
BFI = Breaker Failure initiate
79I = Auto reclose initiate
Considerations When Using Microprocessor Relays
Trip circuits

- Typical breaker trip circuit using microprocessor relay

**IN1** = Breaker status input  
**IN2** = Trip circuit monitor input (optional)  
**TC-1** = Breaker trip coil 1  
**TC-2** = Breaker trip coil 2  
**CC** = Breaker close coil  
**OUT1** = Protective relay trip contact  
**OUT2** = Protective relay trip contact (*if second trip coil present)  
**OUT3** = Protective relay close contact (manual or autoreclosing)  
**OUT4** = Protective relay breaker fail initiate contact (*if external BF relay present)  
**OUT5** = Protective relay reclose initiate output (*if external 79 relay present)  
**01/T** = Manual control switch trip contact  
**52a** = Breaker auxiliary form “a” contact  
**86/BF** = Breaker failure lockout contact  
**BFI** = Breaker Failure initiate  
**79 I** = Auto reclose initiate
General Scheme Design
Trip Circuit

- Microprocessor relays can simplify trip circuit design
- Multiple isolated outputs on a single relay can be used to trip multiple breakers
Integration, Separation, and Redundancy

- Combining functions into one relay can reduce size of equipment, reduce wiring, and lower cost.
- However, it can lead to problems such as measurement or programming errors effecting multiple protection functions.
- Thought must be given to creating redundant systems which can function despite total failure of a relay.
  - Ex: Duplicate functions using relay from different manufacturer.
Multiple protection functions, auxiliary timers, etc. included in microprocessor relay logic.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<tr>
<td>52a</td>
<td>Breaker auxiliary form “a” contact</td>
</tr>
<tr>
<td>52b</td>
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</tr>
<tr>
<td>TC-1</td>
<td>Trip Coil 1</td>
</tr>
<tr>
<td>01/T</td>
<td>Breaker control handle Trip</td>
</tr>
<tr>
<td>PR</td>
<td>Protective relay trip contact</td>
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Dual Relay Tripping

Multiple protection functions, auxiliary timers, etc. included in microprocessor relay logic.

52a  Breaker auxiliary form “a” contact
52b  Breaker auxiliary form “b” contact
TC-1  Trip Coil 1
01/T  Breaker control handle Trip
PR  Protective relay trip contact
86/BF  Remote breaker failure trip via lockout relay
Dual Trip Coils with One Relay

52a  Breaker auxiliary form “a” contact
TC-1  Trip Coil 1
TC-2  Trip Coil 2
01/T  Breaker control handle Trip
PR  Protective relay trip contact

Protection logic trips both circuit breaker coils simultaneously.

Microprocessor Relay
PR-1a
PR-1b
Title

1/16/2015

Dual Trip Coils with Two Relays

(+)

01

PR-1

Microprocessor Relay

52a

TC-1

Separate relays trip separate circuit breaker trip coils.

(-)

(+)

PR-2

Microprocessor Relay

52a

TC-2

52a Breaker auxiliary form “a” contact
52b Breaker auxiliary form “b” contact
TC-1 Trip Coil 1
TC-2 Trip Coil 2
01/T Breaker control handle Trip
PR Protective relay trip contact
Dual Trip Coils with Breaker Re-trip

BFR retrips TC-1 on breaker failure initiate.
PR-1b trips TC-2 on backup trip

Legend:
- 52a: Breaker auxiliary form “a” contact
- TC-1: Trip Coil 1
- TC-2: Trip Coil 2
- 01/T: Breaker control handle Trip
- PR: Protective relay trip contact
- PR-1b: Protective relay backup trip contact
- BFR: Breaker failure retrip contact
Dual Trip Coils, Relay Cross-Tripping

Probably most common today
Dual Breaker Scheme

Protection logic trips both circuit breaker coils simultaneously.

- Breaker auxiliary form “a” contact
- Trip Coil
- Breaker control handle Trip
- Protective relay trip contact
There are a few problems
Circuit Contacts

- One leading cause of failure is burned and failed output contacts due to inductive DC current
- Must ensure circuit contact being used is properly rated for all possible signals
- Often can assess by calculating L/R rating:
  
  \[
  \text{Load Inductance} \div \left( \text{Load Resistance} + \text{Cable Resistance to Load} \right)
  \]

- Relay manufacturers are developing ways to mitigate burnout
• Speed of relay contacts must be considered
• Typical closing time is 3 to 8 milliseconds
• Choosing incorrect contacts can lead to leakage or sneak currents
• Extend Seal-in time and/or add arc suppression
PRO

- Low CT burden
CON

Battery Creep

- Upgrading stations typically leads to increased continuous DC system loads
- Once adequate DC supply systems may need to be revisited
Sneak Currents

- Sneak currents are unintended design flaws that can result in serious consequences.
- With increased complexity, sneak currents are more likely.
- With Microprocessors, the sneak circuits have often moved inside.
- Systematic testing and inspection is most common way to prevent.
- Many sneak conditions are located through trial and error over time in the field.
- Can use spare input contacts on relay to monitor grounding conditions of DC system
It’s Not All Bad
there are a few new perks
Trip Circuit Monitoring

- Typical breaker trip circuit using microprocessor relay

IN1 = Breaker status input
IN2 = Trip circuit monitor input (optional)
TC-1 = Breaker trip coil 1
TC-2 = Breaker trip coil 2
CC = Breaker close coil
OUT1 = Protective relay trip contact
OUT2 = Protective relay trip contact (*if second trip coil present)
OUT3 = Protective relay close contact (manual or autoreclosing)
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Lockout Function

PR-LO is lockout contact contained in relay. Can be bistable relay (ideal), controlled through logic.

- 52a: Breaker auxiliary form “a” contact
- TC: Trip Coil
- CC: Close Coil
- 01/T: Breaker control handle Trip
- PR: Protective relay trip or close contact
- PR-LO: Protective relay lockout contact
Pr-1b closes circuit breaker. Relay logic includes control handle supervision.

- 52a  Breaker auxiliary form "a" contact
- TC   Trip Coil
- CC   Close Coil
- 01/T  Breaker control handle Trip
- 01/C  Breaker control handle Close
- PR   Protective relay trip contact
SCADA Functions
SCADA Control

- An RTU or other gateway is used to issue open/close commands to circuit breakers, motor-operated switches, and other devices remotely.
- Microprocessor relays can act as I/O hardware to implement commands.
SCADA Circuit Breaker Control

- CB control implemented using “select-before-operate” concept
- This is intended to prevent any other device from issuing untimely commands to the breaker with unintended results
SCADA Metering and Monitoring

- Microprocessors can greatly simplify monitoring and metering of stations through digital communication through the gateway
- SCADA data collection can be distributed to the microprocessor relays
- These functions used to require an independent electromechanical unit for each
Maintainability and Testing
Multifunction Relay Testing Considerations

- Testing occurs at many stages: acceptance, commission, and as scheduled.
- Desire method to conduct tests without changing any relay settings since this could introduce unintended errors.
- Some designs may allow for spare contacts which can be used for testing.
- Built-in recording functions can be used to determine if appropriate response to test occurred.
A couple of additional issues
Test Switches

- Approach on test switches can vary widely
- Test switches may become more rare with microprocessor units since removing all the functions of a single relay at once may be unacceptable
- Test switches enable a relay to be isolated for hot change out
Test Switches part 2

- Testing relays has become more complicated since each relay may be programmed completely differently.
- Test switches enable more isolation for testing to prevent inadvertant trips (ie breaker fail outputs).
- Consistent design methods are needed to decrease complexity.
Logic Performance Considerations

- Loss of power or network connection can dramatically effect output from relay logic
- Consideration must be given for the default state given either condition
- Volatile memory will reset whereas non-volatile memory will maintain the previous value
Questions?