Test the Right Stuff: Using Data to Improve Relay Availability, Reduce Failures, and Optimize Test Intervals

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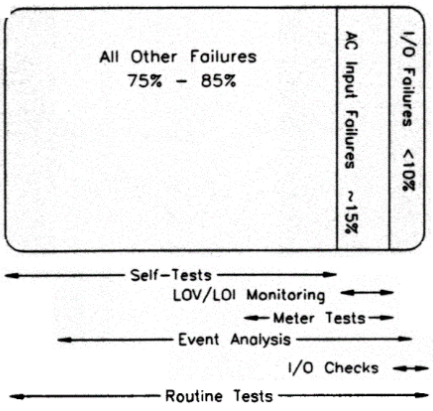
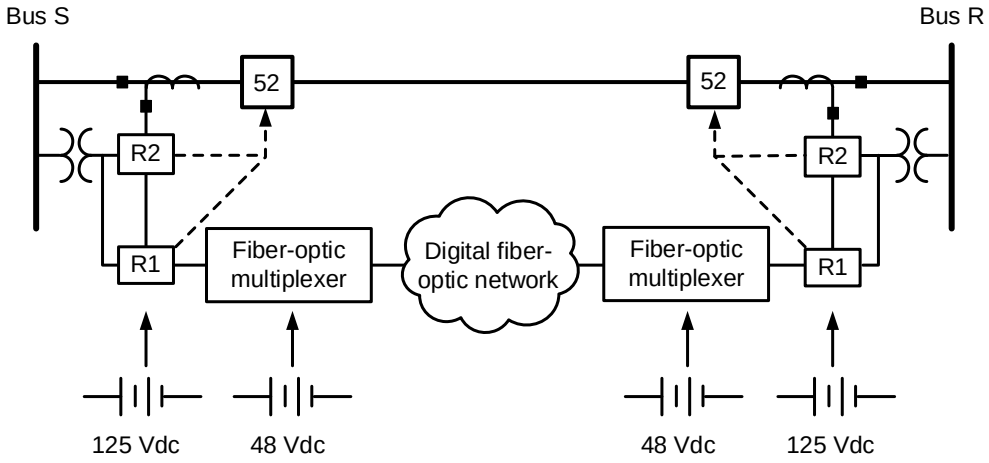
1990s technical paper promotes system approach

"Assessing the Effectiveness of Self-Tests and Other Monitoring Means in Protective Relays"

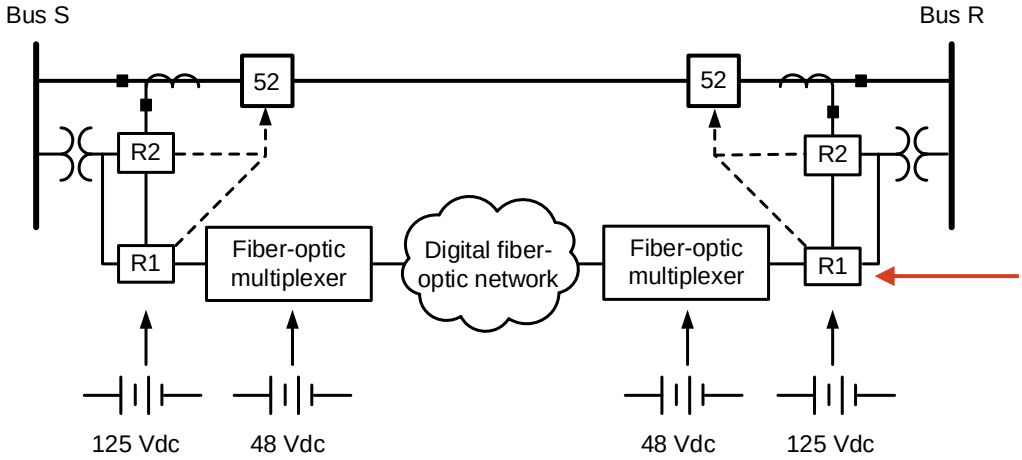
—J. Kumm, E. O. Schweitzer, III, and D. Hou



Protection operates as a system impacted by all subsystems



Protective relays are interconnected with all other subsystems



Protective relays are the "brains" of the protection system

2022 – evaluation of root cause failure data

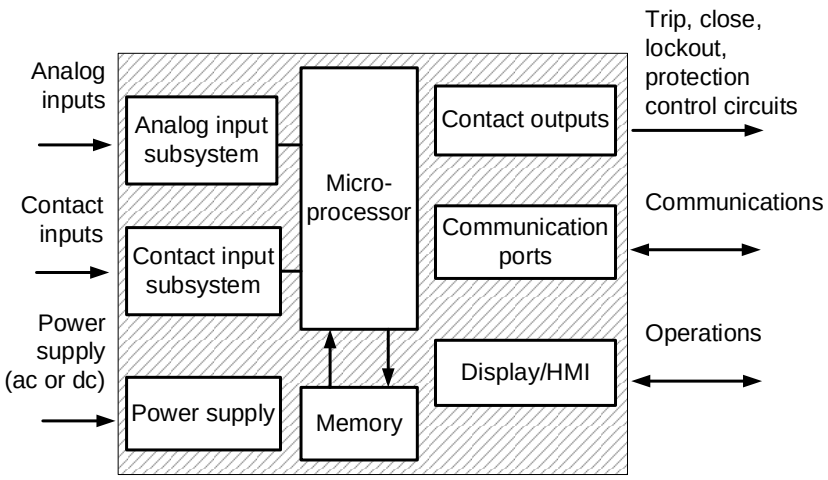
- Based on 3,300 relays returned
- Performed for different product models and vintages
- What changed?
  - Communications now used for protection
  - More use of displays and HMIs
- Assumes successful acceptance and commissioning testing

Distribution of failures not detected by self-test diagnostics

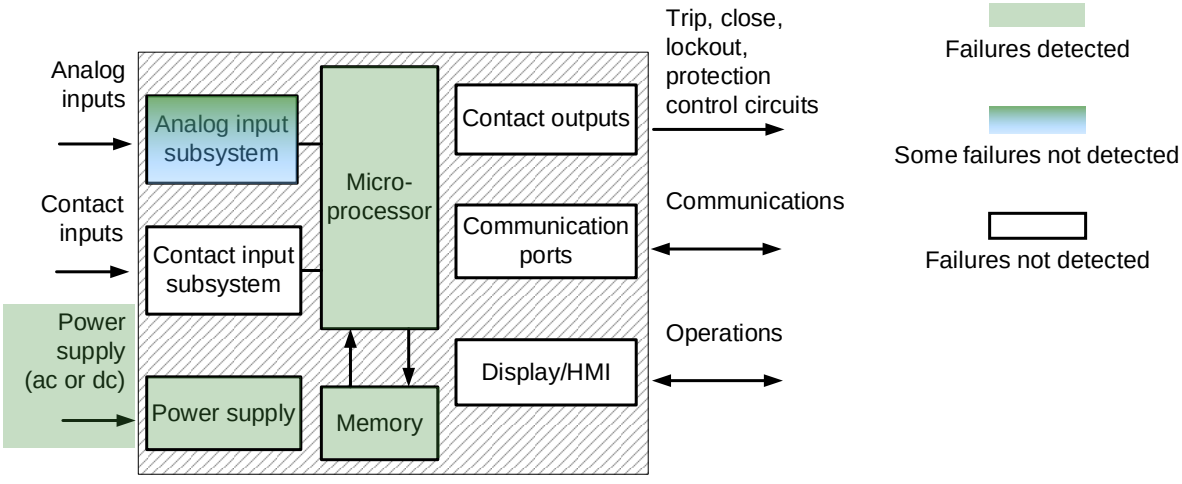
Self-test diagnostics detect 75.1% of relay failures

Failure category	Percentage not detected by self-test diagnostics (%)
HMI	8.9
I/O	5.9
Analog inputs	4.6
Communications	4.1
Other	1.4

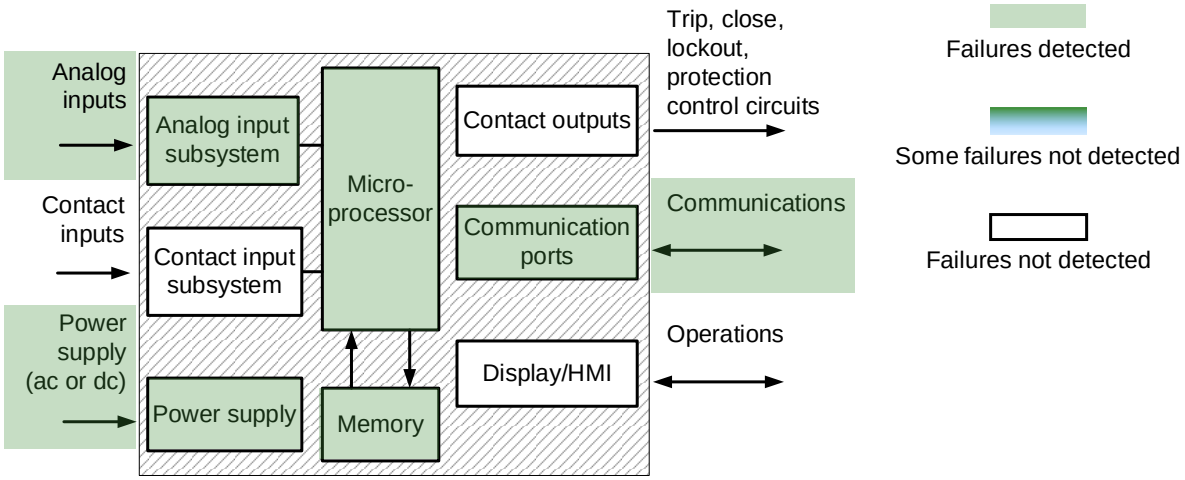
Digital relay block diagram



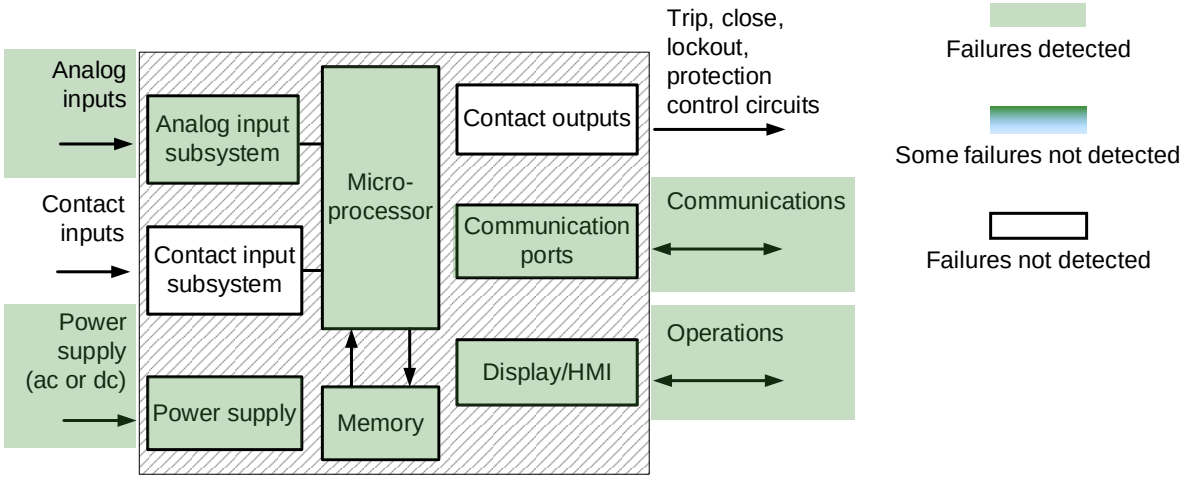
Relay self-test coverage



Relay self-test plus communications and analog monitoring



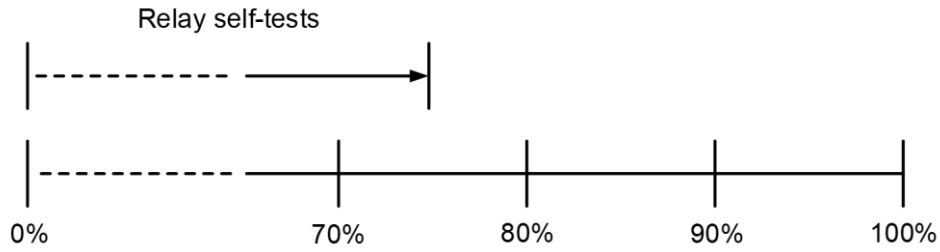
Adding inspection detects HMI and physical failures



Defining four levels of maintenance testing

- Relay self-tests
- Monitoring analog and communications
- Visual and physical inspection
- Maintenance testing, including periodic I/O checks

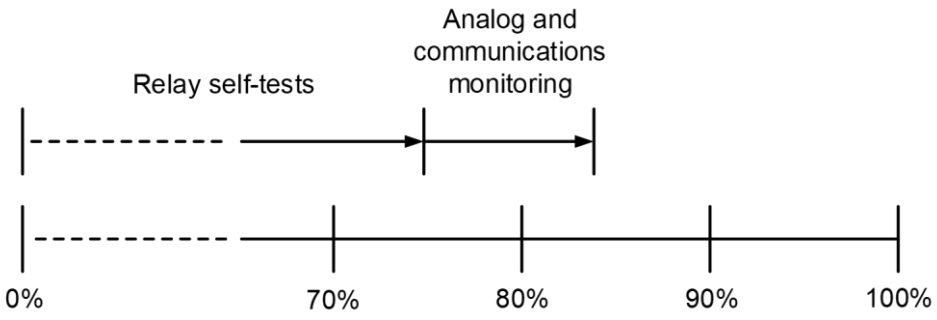
Effective test coverage with relay self-tests



Percentage of test coverage

Based on 2022 data

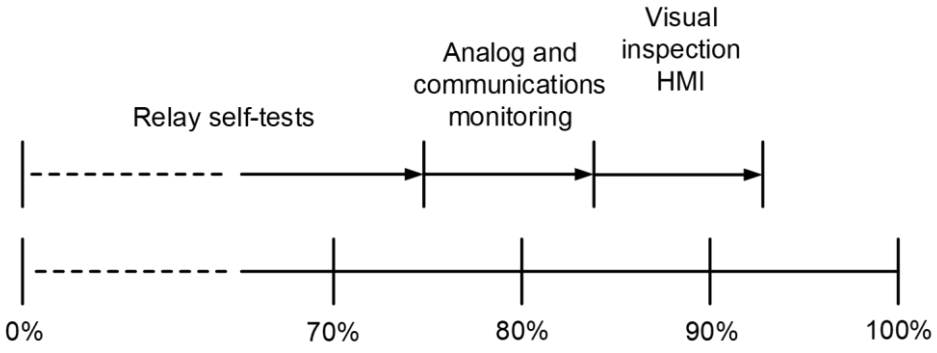
Add failures found by monitoring analogs and communications



Percentage of test coverage

Based on 2022 data

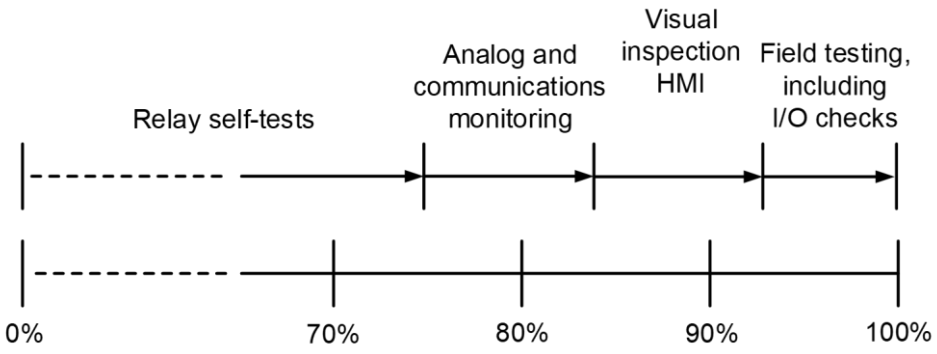
Add failures found by visual and physical inspection



Percentage of test coverage

Based on 2022 data

Add field testing, including I/O checks



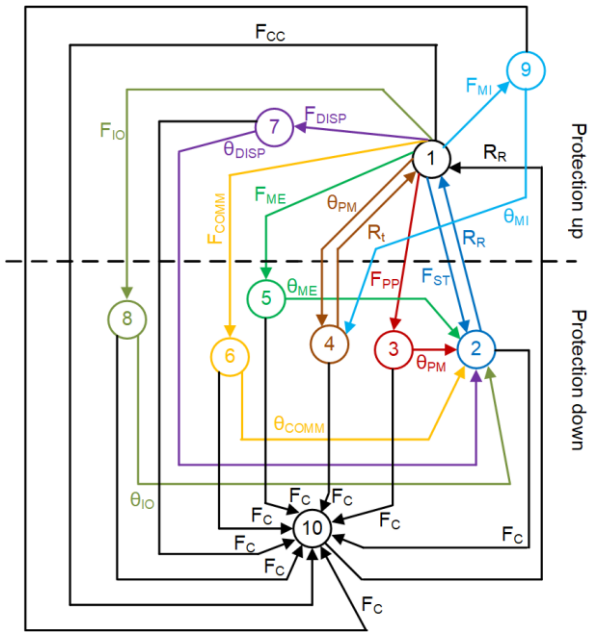
Percentage of test coverage

Based on 2022 data

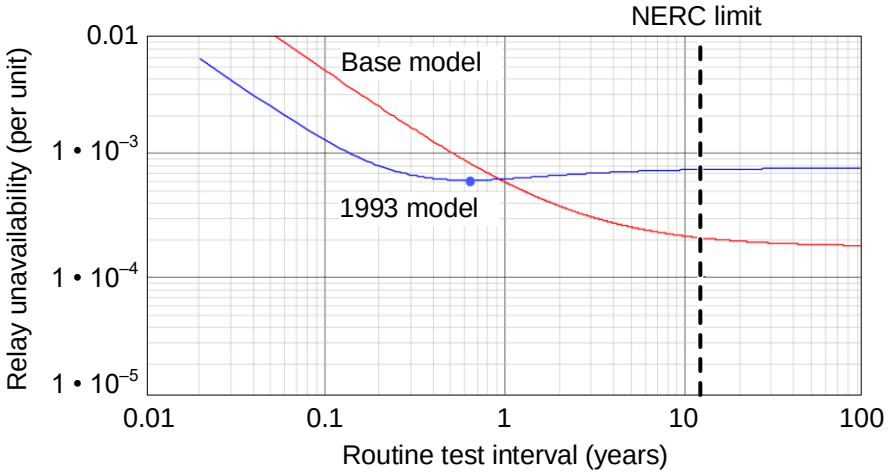
Updated statistical model accounts for 2022 practices

Markov state number	Description
1	Normal operating state
2	Failure detected and waiting for repair
3	Failure occurred and not covered by self-test
4	Device was out of service while being tested
5	Analog/metering failure occurred
6	Communications failure occurred
7	Display failure occurred
8	Input/output failure occurred
9	Firmware update or maintenance identified
10	Fault on power system occurred

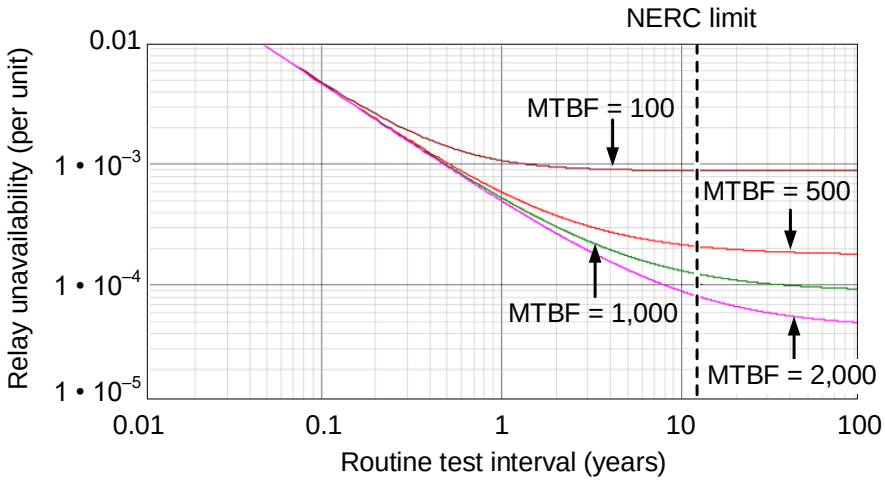
Markov model



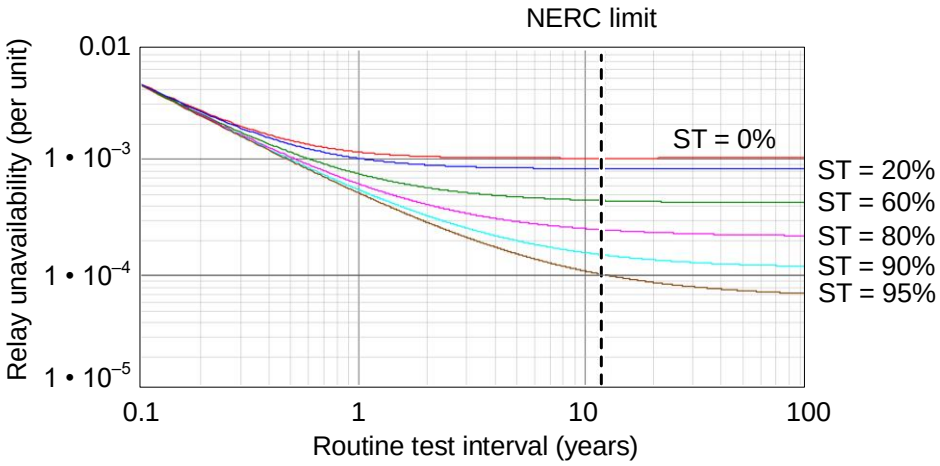
Relay unavailability vs. routine test interval: modern base model vs. 1993 model



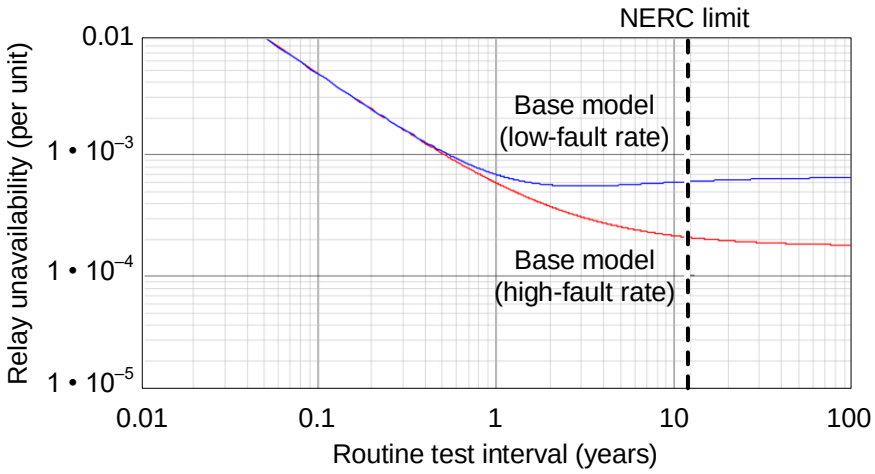
Better MTBF improves unavailability and routine test interval



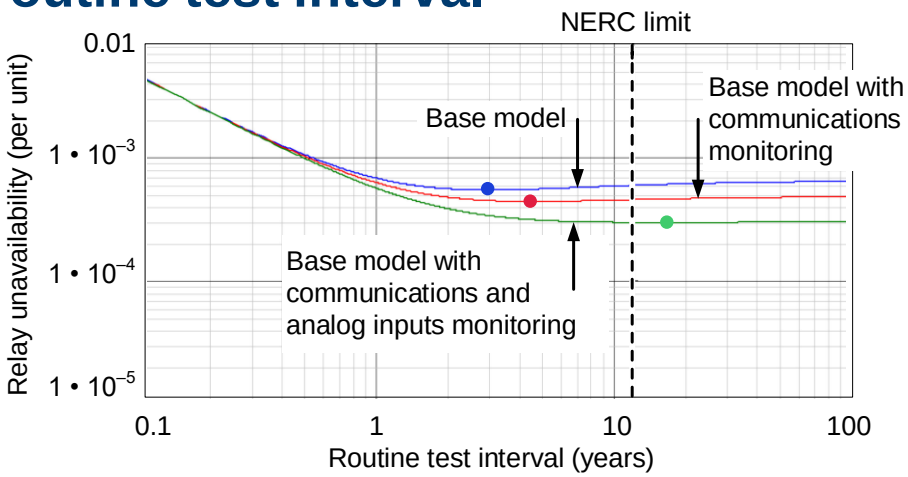
Better self-test effectiveness improves unavailability and routine test interval



Impact of low-fault and high-fault rate



Monitoring communications and analog inputs improves unavailability and routine test interval



Conclusion

- Based on field data, 75.1% of relay failures are detected by self-test diagnostics
- Adding communications and analog inputs monitoring and visual inspections brings test coverage to above 90%
- The NERC-recommended 12-year routine test interval is sufficient but could be extended based on additional levels of testing added
- Testing at least once during the more than 20-year design life of protective relay is sufficient (especially for low-fault rate)

Questions?