Protection Redundancy

Roy Moxley, Siemens
Unpleasant Facts

- About 1500 False trips in 16 months (NERC)
- 16 Times more False Trips than Failure to Trip
- 41% of False trips are during an external fault
From NERC Report, Jan 2011 – April 2012

One Region

- Unnecessary Trip during fault, 189, 41%
- Unnecessary Trip other than fault, 239, 51%
- Slow trip, 8, 2%
- Failure to Trip, 29, 6%
Why Do We Apply Redundant Protection?

- It Costs More
- Extra Engineering
- Extra Maintenance
- Extra Wiring
Hole Filling
So what Constitutes a Hole?

- Arc Resistance Coverage
- Communication Failure Coverage
- Power Swing Response
- Fuse Failure (loss of potential) Response

It’s only a hole If you hit it.
I've got your back!
Relay Failure Backup
Failure to Trip is Very Very Bad
System Logic Used to be Obvious
Sometimes Differences are Obvious
What Does It Mean to be Different?
Redundancy Effect Easy to Prove With Math

Failure to trip for fault

Main I Operates
Main II Operates

Trip For Non or External Fault Event

Main I Operates
Main II Operates
Multiply And’s

Add Or’s

Failure to tripped for fault

$\left(\%\right)^2$

AND

Main I Operates

Main II Operates

Trip For Non or External Fault Event

$\left(\%\right) \times 2$

OR

Main I Operates

Main II Operates

Main I Operates

Main II Operates
Multiply And’s

Add Or’s for top event

0.0001%
Failure to trip for fault

(%)²

0.2%
Trip For Non or External Fault Event

(%) * 2

AND

Main I Operates
0.1%

Main II Operates
0.1%

OR

Main I Operates
0.1%

Main II Operates
0.1%
Let’s Look At Basic Line Protection

Overreaching Zone
Permissive received

Zone 1

And

Or

Trip
Real Protection is More Complex

Common Dependencies Apply to Both Sides of Equation
Don’t Forget Upstream Functions

Relay Health Monitor
A/D Conversion
Filter: Cosine, Fourier, Half Cycle…
Fault Identification Logic

![Diagram of Fault Identification Logic](image-url)
Modern Relays Contain 1,500,000+ Lines of Code

- Is an error possible?
- Will we find it? When?
- What is the Impact of a code error?
Do “Typo’s” Occur

- 1 Share at 610,000 Yen ≠ 610,000 Shares at 1 Yen
- Cost Company $225,000,000
Who Studies Code Error Rates?

- 0.5% Error Rate in Typing Checked Zip Codes
How Close is “Code” to English?

```java
/**
 * Simple HelloButton() method.
 * @version 1.0
 * @author john doe <doe.j@example.com>
 */

HelloButton()
{
    JButton hello = new JButton( "Hello, wor
    hello.addActionListener( new HelloBtnList

    // use the JFrame type until support for t
    // new component is finished
    JFrame frame = new JFrame( "Hello Button"
    Container pane = frame.getContentPane();
    pane.add( hello );
    frame.pack();
    frame.show(); // display the fra
}
```

- 7.4% Error Rate for Typed Non-Sense Words
What are Other Potential Errors?

- Buffer Overflow -- Has Caused Relay Shutdown
- Communication Conflicts -- Has Caused Comm Lock
- Algorithm Error -- Has Caused Infinite time 50 / 51
Other Common Elements

- Printed Circuit Boards
- Manufacturing Methods and Machines
- Terminal Blocks
- Power Supply
Failure Rates

- 100 Year MTBF and 24 Hr. MTTR = 0.999972 Availability

- 300 Year MTBF and 24 MTTR = 0.9999908 Availability

- 300 Year MTBF and 2 Hr. MTTR = 0.99999923 Availability
Cost of Relays has come down an inflation adjusted 90% since 1980
Two of Three Logic Improves Dependability and Security

Let’s Define (A,C,B):
1% chance of False Trip
95% chance of Correct Trip

\[ A + B = 1\%^2 = 0.01\% \text{ Chance of False Trip} \]
\[ (A+B)\times(A+C)\times(B+C) = 0.03\% \text{ Chance of False Trip} \]

\[ A + B = 95\%^2 = 90.25\% \text{ Chance of Correct Trip} \]
\[ (A+B)\times(A+C)\times(B+C) = 99.9\% \text{ Chance of Correct Trip} \]
Implementing 2 of 3 is Not difficult

Details:
- On Loss of Relay, Revert to 1/2 or 2/2?
- Use Contacts or Logical Derivation?
- Use Same or Different Relays?
Human Error and Training Considerations

- Settings and Calculations
  - Different Schemes
- Operations
  - Maintenance
- Relay Out-of-Service
Questions to Ask

How Many False Trips per Year are Acceptable?

What is the System Cost of a False Trip Coupled with a Correct Trip?
Conclusions

Decide Based on Full Knowledge, Not by Default
Conclusions

• Two Different Hardware ≠ Different Relays

• Duplicate Relays for Maintenance Backup Makes Sense

• If Using Separate Relays for “Hole Filling” Understand the Complete Relay System
“Sometimes the questions are complicated and the answers are simple”

Dr. Suess