Challenges Facing Protective Relay Engineers in Modern Times

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Awesome South Africa
South Africa: Some Statistics…

- Population: 49 Million
- Area: 1,219,912 km²

In 1996 only 58% of all households had access to electricity
In 2007 this number increased to 80%

- Eskom generates 45% of Africa’s electricity
- Household access to electricity

551 500 km² + 357 022 km² + 243 610 km² = 1 219 912 km²
South African Inventions

Which of the following is NOT an invention from South Africa?

A - Rooibos Tea
B - Dolosse
C - Kreepy Krauly
D - Vuvuzela
Overview

• Testing of electromechanical relays
• Testing of integrated and multifunction relays
• Testing of complex relay algorithms
• Testing of relays in complex network applications
• Testing of IEC61850 IEDs
• Managerial requirements
• Regulatory requirements
• Summary
Numeric IED
Testing Electro-Mechanical Relays

Electro-mechanical relays…
- can be tested with a single phase source
- require huge amount of power
- often are 5A rated
Testing a CDG16 E/F Relay

CDG16 E/F relay:
At 16A (32x pickup)
144Vpk compliance voltage is required
Test Equipment Requirement

Current outputs:

✓ Range: 3x 60A (i.e. > 10x 5A x 1.2)
✓ Compliance voltage: >140Vpk (single phase)

Voltage outputs:

✓ Range: 3x 220V (L-N, for prim. conn. relays)
✓ Load current: 1A (to power the relays)
Integration

Numerical relays…

➢ many protective relays functions are integrated in one relay
➢ incorporates automation functions
➢ incorporates local control
➢ Incorporates measurements functions (for Scada)
Testing Multifunction Relays

OMICRON Control Center - 41M7100R6_19 Sep 11 rev 0_1a: Report View

Test Results for Fault Location L1-E at Reference Side HV

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Operating Characteristic Diagram

Ibias [m] vs Idiff [mA]

For Help, press F1
Numeric IED
Test Equipment Requirement

Testing multi-function relays:
✓ All functions need to be tested in one template

Testing automation and local control functions:
✓ Sufficient binary inputs and outputs

Testing of measurement functions:
✓ Voltage and current outputs need to be at least 0.1% accurate
✓ DC analog inputs to test transducers
Complexity of Relays

Numeric relays...

- have huge amount of settings
- specialized measurement algorithms
- need to be tested with realistic fault simulations
Huge Amount of Settings

Differential Element Configuration and Data

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Realistic Fault Conditions
Separate Arc Resistance Algorithm
Test Equipment Requirement

Testing numeric relays:
- Allow of huge amount of settings according to relay manufacturer setting software
- Import of relay settings from relay database

Testing distance relays:
- Simulate pre-fault $\rightarrow$ faults scenario with transient simulation (DC offset)
- Simulate separate arc resistance algorithm
Transformer Differential Relays

HVCT_{CF} = 1.142

LVCT_{CF} = 0.952
Transformer Differential Relays

Test set with 6*30A

Test set with 3*30A and 3*5A

Test set with 6*15A
Test Equipment Requirement

Testing transformer differential relays:

- Model the complete transformer
- Vector group correction
- CT mismatch correction
- Zero sequence elimination
- Unbalanced faults
- Six independent currents i.t.o. of amplitude and phase angle
- Each current output rated at least 30A
Complex Networks

- High degree of meshed networks
- Short lines
- Low source impedances
GPS Synchronized E2E Tests

- Line differential protection
- GPS synchronized end to end tests
Test Equipment Requirement

Testing of line differential schemes:
✓ GPS synchronized end to end tests
✓ Synchronize to other timing signals (IEEE 1588)
✓ High phase angle stability
✓ High accuracy for low currents
Merging Unit

Test Set

GOOSE

Substation network (LAN)

Scada

Client/Server

Electrical Power System

Sampled Values

IED 1

IED 2

Circuit Breaker
Test Equipment Requirement

Testing IEC61850 substations:

✓ Read IED data models
✓ Read Client / Server communication reports (IEC61850-7-2)
✓ Subscribe / Simulate GOOSE messages (IEC61850-8-1)
✓ Simulate Sampled Values streams (IEC61850-9-2LE)
Managerial Environment

- Loss of expertise / experience
- Automated testing
- Pre-prepared test templates
- Automatic report generation
Automatic Test Templates
Regulatory Environment

- Accurate test records
- Standard test procedures
- Repeatability of tests
- Proof of test having been performed
- Record of test environment
Test equipment for protective relays needs to be able to…

- test electromechanical relays
- test integrated and multi-function relays
- test complex relay algorithms
- test complex network applications
- test IEC61850 IEDs
- support the managerial environment
- adhere to the regulatory environment
Thank You for Your Attention!