Performance Evaluation of an Enhanced Bus Differential Protection Relay

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Presentation Outline

- Introduction to differential protection
- Protection concepts
- Simulations
- Test Results
- Conclusions
Introduction

- Dual slope characteristics of conventional relays
  
  \[ I_0 = I_1 + I_2 + I_3 + I_4 + I_5 + I_6 \]
  for all a, b, c phases
  
  \[ I_r = \frac{(|I_1| + |I_2| + |I_3| + |I_4| + |I_5| + |I_6|)}{2} \]
  for all a, b, c phases

- Dual slope provides some security against CT errors.
  - normal load conditions
  - external fault conditions

- Not adequate for all practical scenarios.
  - CT saturations during close-in external faults
  - subsidence currents present after clearing external faults
Methods for internal/external fault identification

- **Method A**: Phase angle comparison method
  - compares phase angles of currents

- **Method B**: Rate of change of differential method
  - compares rates of change of operating and restraint currents
Phase Angle Comparison Method

- Compares phase angles of currents

This function may block the operation during high impedance internal faults if there is only one active source.
Rate of Change of Differential Method

- Compares rates of change of operating and restraint currents

\[
\frac{dI_0}{dt} > \frac{dI_r}{dt} > 0 \quad \text{Internal fault}
\]

\[
\text{other cases} \quad \text{External fault}
\]
Filtering

Before

After
Overall Differential Protection Scheme

- Basic logic

- Algorithm for detection of CT saturations
Support for Multiple Feeders

- Support up to 24 feeders: 6 feeders per IED
- IEC 61850 9-2: 8 s/cycle
Support for Multiple Feeders with Two IEDs
Test Setup

- Equipment setup for closed loop testing
Test Network

- 230 kV test network

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Diagram showing a 230 kV test network with protected bus, 600 MVA transformers, and two T-lines: one 200 km and one 100 km.
CT Saturation During External Faults

- External fault
  - Phase B-G

- Dual slope characteristics
CT Saturation During External Faults cont.

- Variations of phase currents
CT Saturation During External Faults cont.

- Variations of operating and restraint currents
High Impedance Fault

- Internal Fault
  - Phase A-G with 200 ohms fault resistance
High Impedance Fault cont.

- Variations of phase currents

![Graph showing variations of phase currents](image)
High Impedance Fault cont.

- Variations of operating and restraint currents
Speed of Operation with Sample Exchange
Summary

- Performance of a bus differential protection scheme was investigated using a transmission network simulated in RTDS.

- Different types of faults were simulated with different practical scenarios.
  - fast CT saturation
  - slow CT saturation
  - high fault impedances,
  - dc offset, etc..

- The results showed the capability of the proposed algorithm in detecting faults accurately.
Thank you!