

## Application Guidelines for Microprocessor-Based High Impedance Bus Differential Relays

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### Abstract

High impedance bus differential relays have been applied successfully for decades. These relays are preferred for many reasons, including their speed, security, easy settings and wiring, and the high number of breakers that can be included in the zone of protection. However, there are challenging application considerations. The operation of a high impedance relay, and the performance of CTs connected to it, during faults is largely misunderstood. The relationship between the CT knee-point voltage and the relay voltage setting remains mysterious to many.

This paper provides a review of the high impedance differential principle. The performance of CTs used in high impedance applications is detailed. The CT and relay current waveforms experienced during faults as captured during high current lab testing are shared. The digital filtering and resulting signals used by the relay are explained. Dependability for internal faults, sensitivity for low-magnitude faults, and security for external faults is investigated.

Throughout the paper, practical application guidelines will be provided for these common and challenging applications.

### Discussion Points

- We explain CT performance as it relates to high impedance circuits.
- We share the methodology and results of high-current and low-current testing performed in the Spring of 2008.
- We explain these unusual and interesting raw and digitally-filtered waveforms.
- We investigate and propose practical guidelines to the following challenging questions -
  - a. Can we apply different CTRs (for example 1200:5 paralleled with 2000:5 MRCT)?
  - b. Does the CT connection we use limit load flow (due to thermal SF rating of CTs)?
  - c. Can we apply different C-rating CTs (C200 paralleled with C400)?
  - d. Can we apply the same C-rating CTs if their knee-point voltages are different?
  - e. What is the relationship of CT knee-point voltage to relay voltage setting?
  - f. What is the minimum CT C-rating we should use?
  - g. What special challenges do switchgear applications present?
  - h. Is there a practical limit to the number of breakers that can be paralleled?
  - i. What is the sensitivity limit of a high-impedance relay (related to impedance-grounded systems)?
  - j. What is best practice with regard to CTs, wiring, and settings?