# The Response of a Transformer Differential Relay to Internal Faults While Influenced by Geomagnetically Induced Currents

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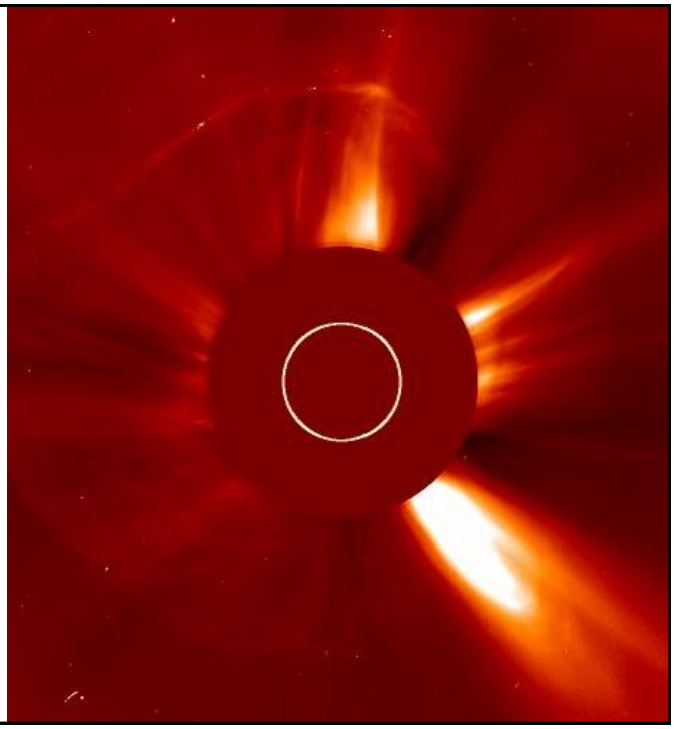
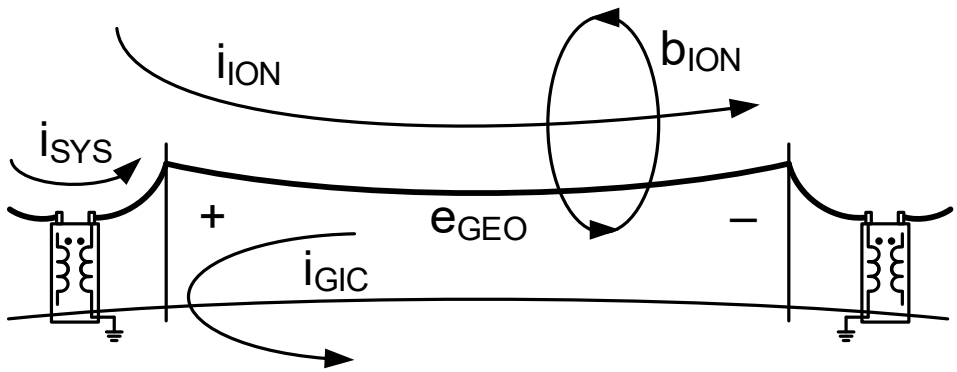
## Overview

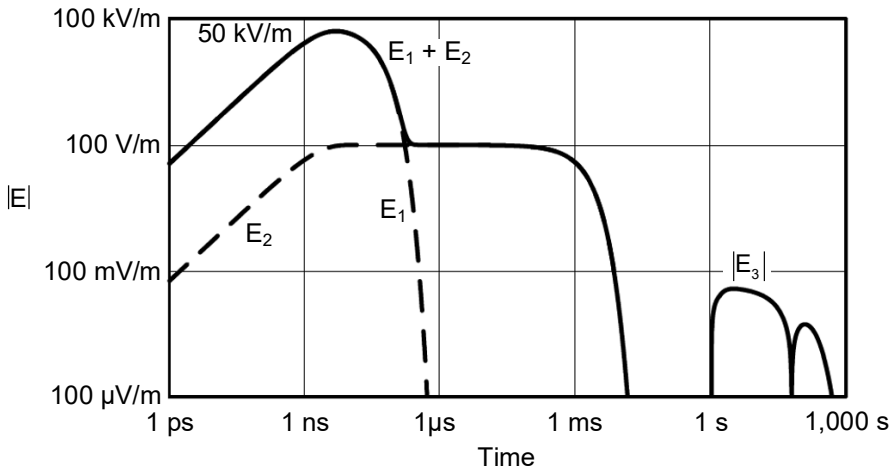
- Background
- Model and simulations
- Protective relay details
- Test results
- Conclusion



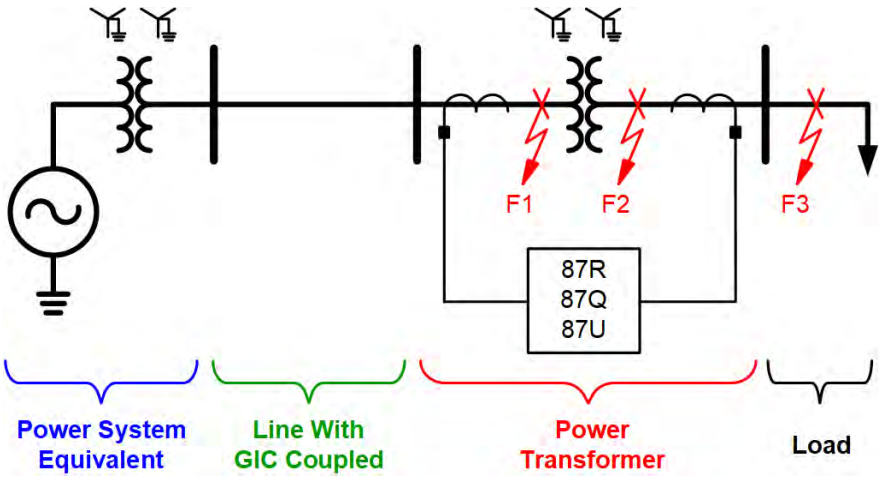
## GIC mechanism




## HEMP causes similar currents to GIC

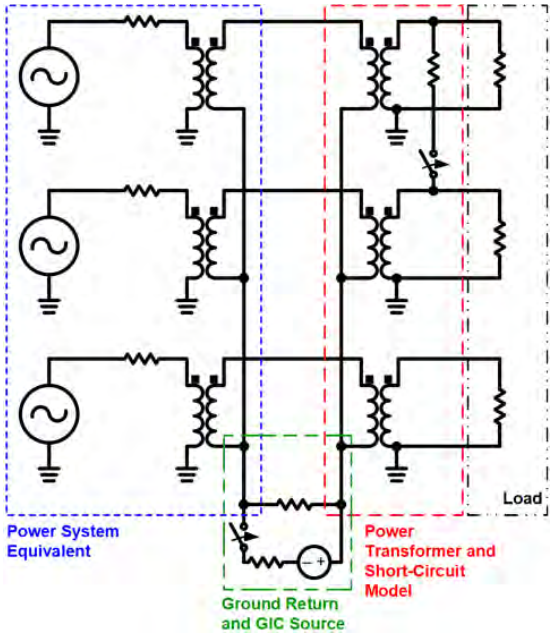


## Simulation scenarios



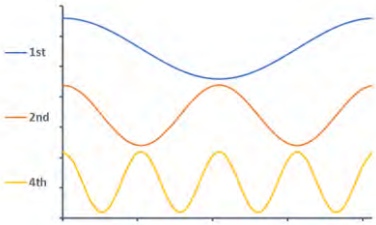

## Model details

Baylor lab transformer test bench

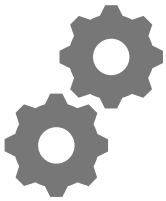


## Protective relay details

Two microprocessor-based transformer differential relays that had different manufacture dates

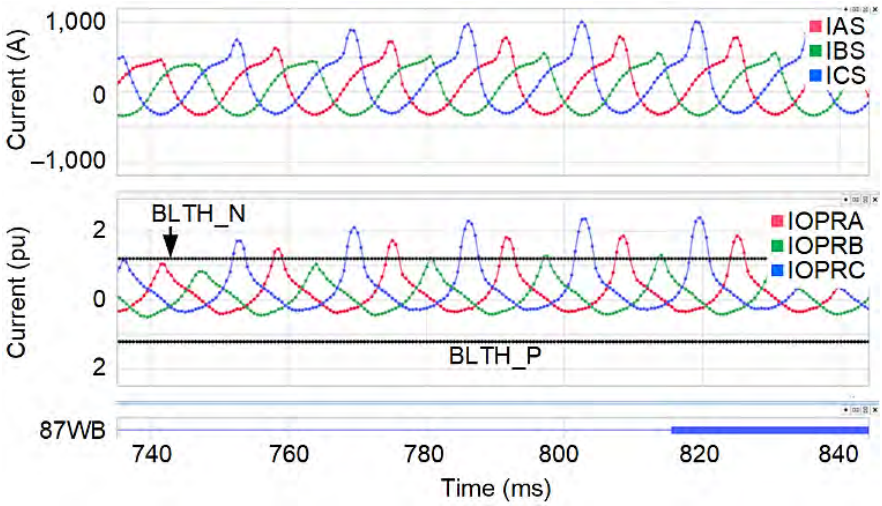



Relay 1 used harmonic blocking and harmonic restraint for inrush restraint

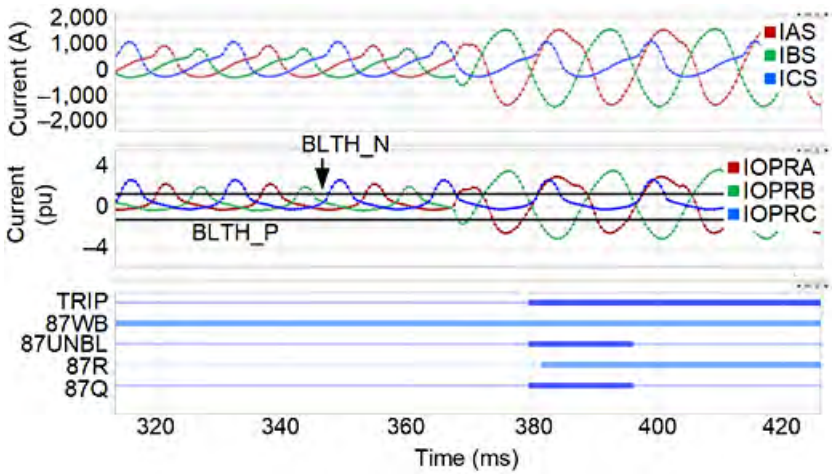


Relay 2 had same capabilities as Relay 1 but with enhanced inrush restraint features

## Waveshape blocking during GIC saturation



## Waveshape blocking during GIC saturation and internal fault



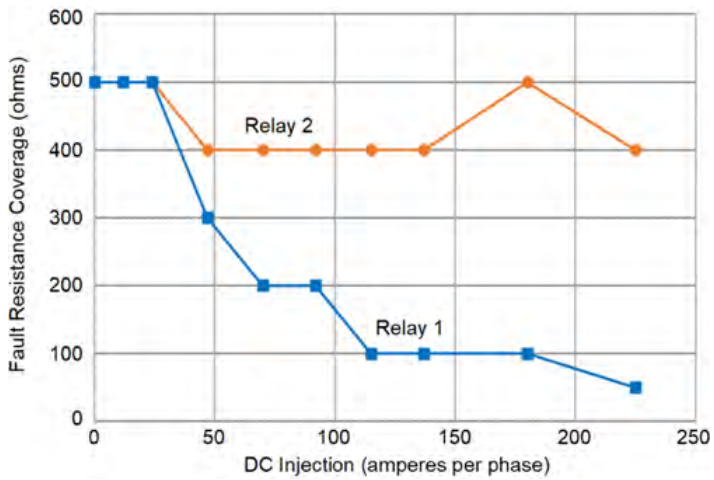

## Differential settings

| Setting | Value |
|---|---|
| 87U pickup | 8 per unit |
| 87R pickup | 0.5 per unit |
| 87R primary slope | 20% |
| 87R high-security slope | 37.5% |
| Second-harmonic blocking pickup | 15% |
| Fourth-harmonic blocking pickup | 15% |

## Results

### Internal phase-to-ground fault on primary winding

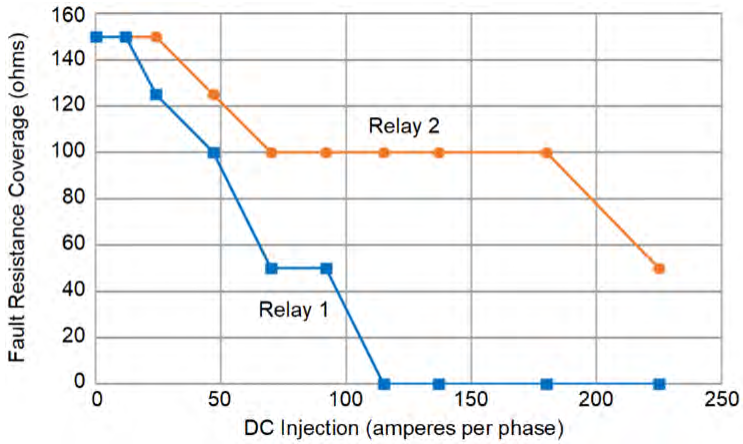
- GIC level varied from 0 to 225 A
- $R_F$ values of 50, 100, 200, 300, 400, and 500 Ω
- Very little impact to sensitivity for test cases for Relay 2




## Results

### Internal phase-to-ground fault on secondary winding

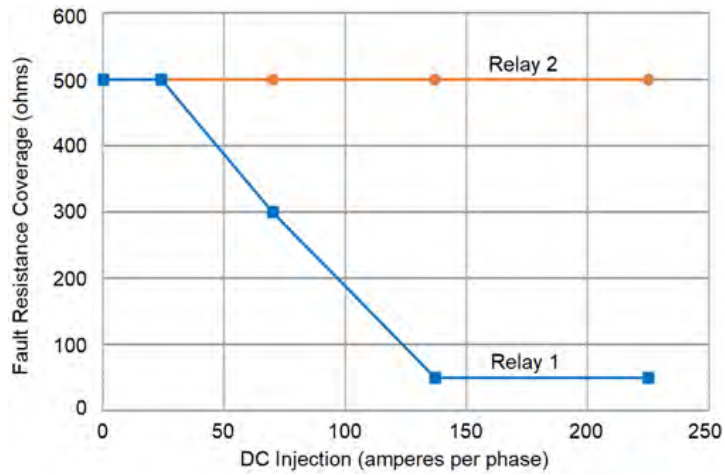
- GIC level varied from 0 to 225 A
- $R_F$ values of 50, 100, 125, and 150 Ω
- Some impact to sensitivity for both relays for higher GIC levels



## Results

### Internal phase-to-phase fault on primary winding

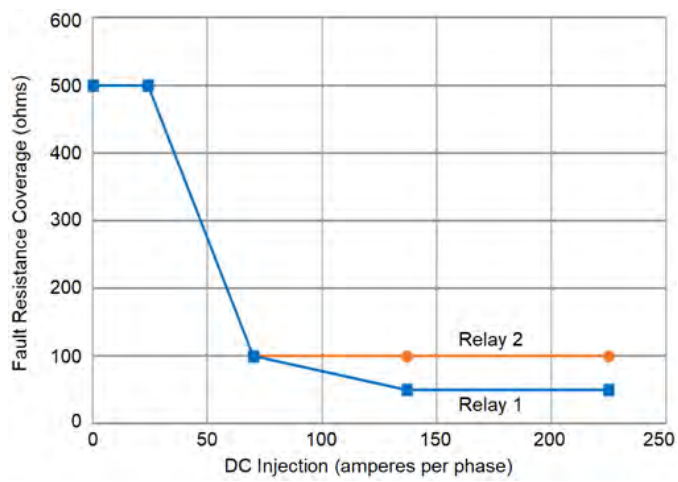
- GIC level varied from 0 to 225 A
- $R_F$ values of 50, 300, 400, and 500 Ω
- No impact to sensitivity for test cases for Relay 2



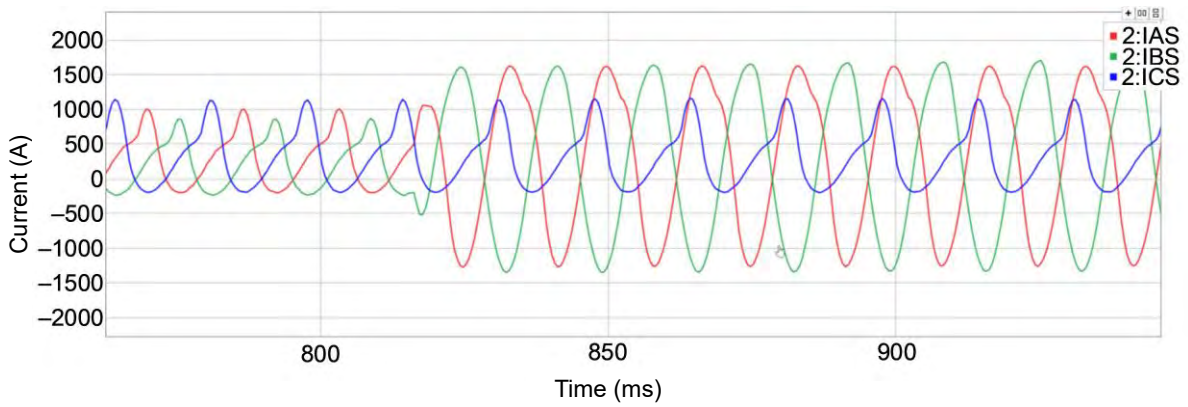

## Results

### Internal phase-to-phase fault on secondary winding

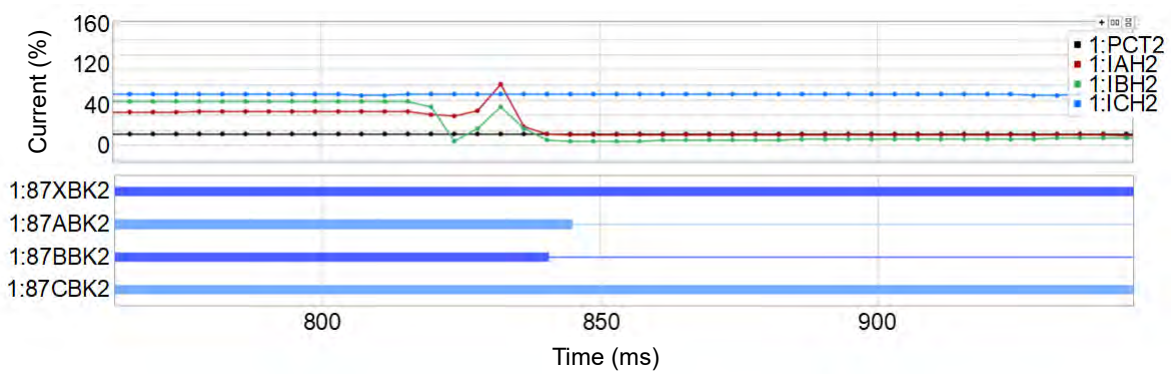
- GIC level varied from 0 to 225 A
- $R_F$ values of 50, 100, 200, and 300 Ω
- Some impact to sensitivity for both relays for higher GIC levels



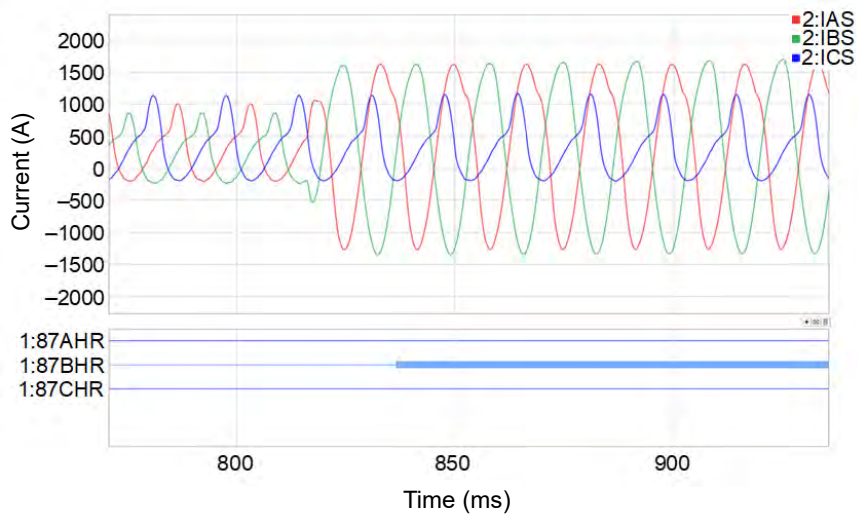
## Example case
Harmonic blocking




## Example case
Harmonic blocking

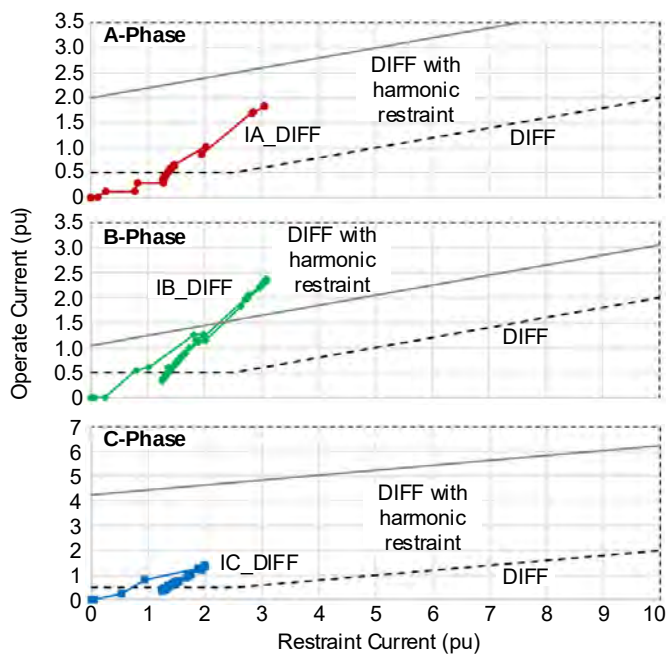


# Example case
## Harmonic restraint



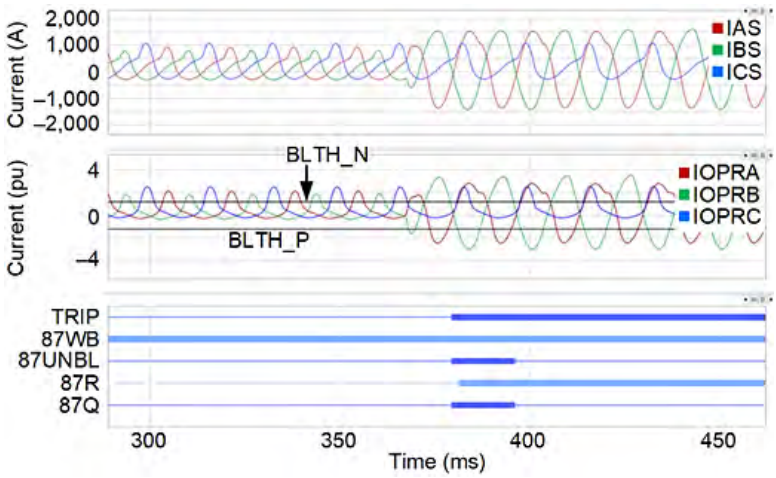

# Example case
## Harmonic restraint

- B-Phase tripped
- Enabling harmonic restraint allowed tripping
- Harmonic restraint did not pick up for all test scenarios



## Example case

Waveshape recognition




## Conclusion

- Additional model refinement needed to generalize model for power transformers
- All methods of inrush restraint remained secure during half-cycle GIC-induced saturation
- Only cross-harmonic blocking led to dependability problems during high levels of GIC

## Conclusion

### Relay 1

- Included harmonic blocking and harmonic restraint
- Lost dependability and sensitivity as level of GIC increased

### Relay 2

- Included traditional methods and enhanced waveshape recognition logic
- No significant change in dependability or sensitivity as level of GIC increased

## Conclusion

- Other protective elements and relays are available that could potentially trip for a fault where traditional schemes fail to operate, such as REF and sudden pressure relays
- Additional testing and simulation are needed to evaluate impact of GIC on other elements such as REF

# Questions?