

# User's Perspective - Protection with Harmonic Restraint Settings

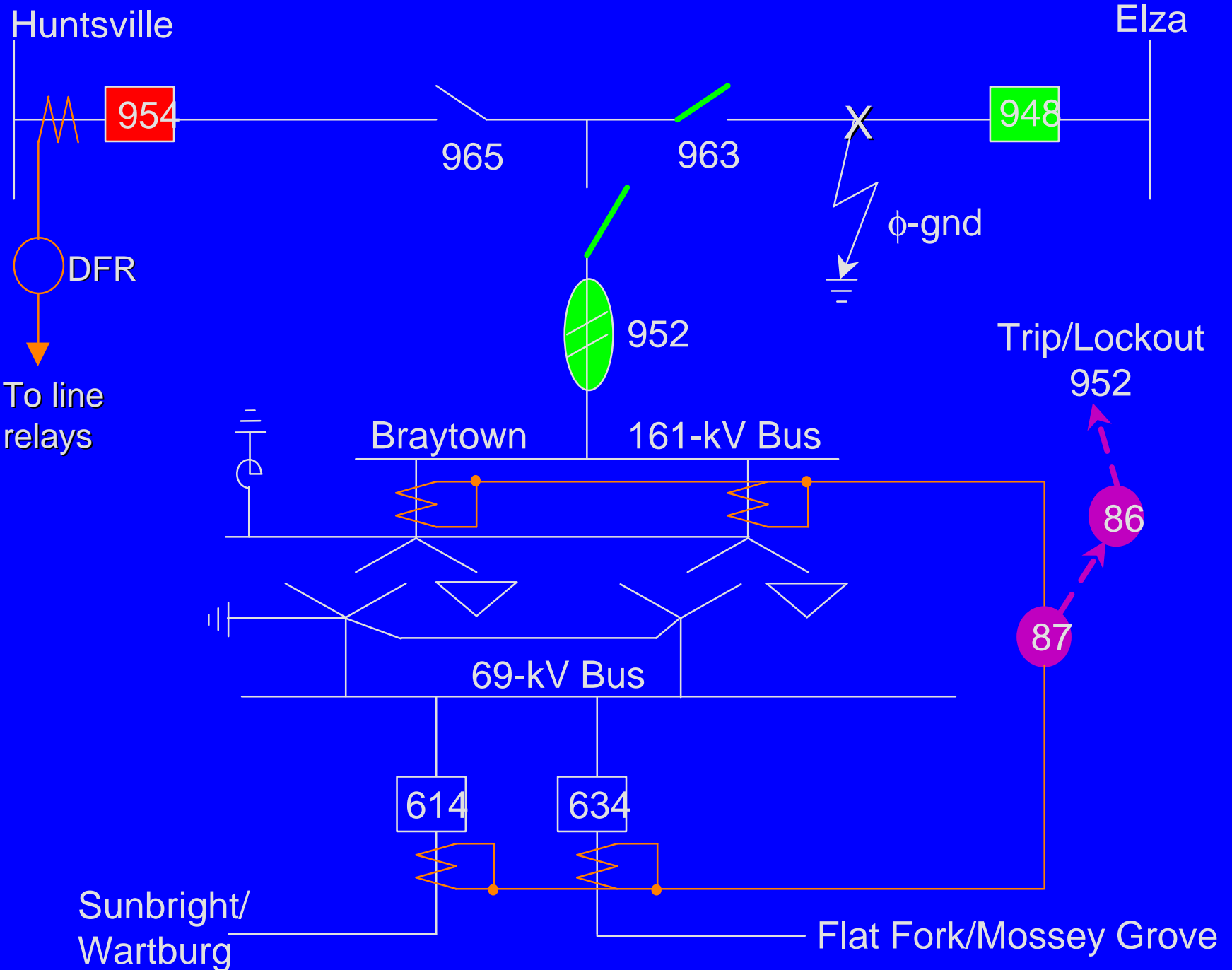
Gary L. Kobet, P.E.

Tennessee Valley Authority

IEEE Transformers Committee

Inrush Current Seminar

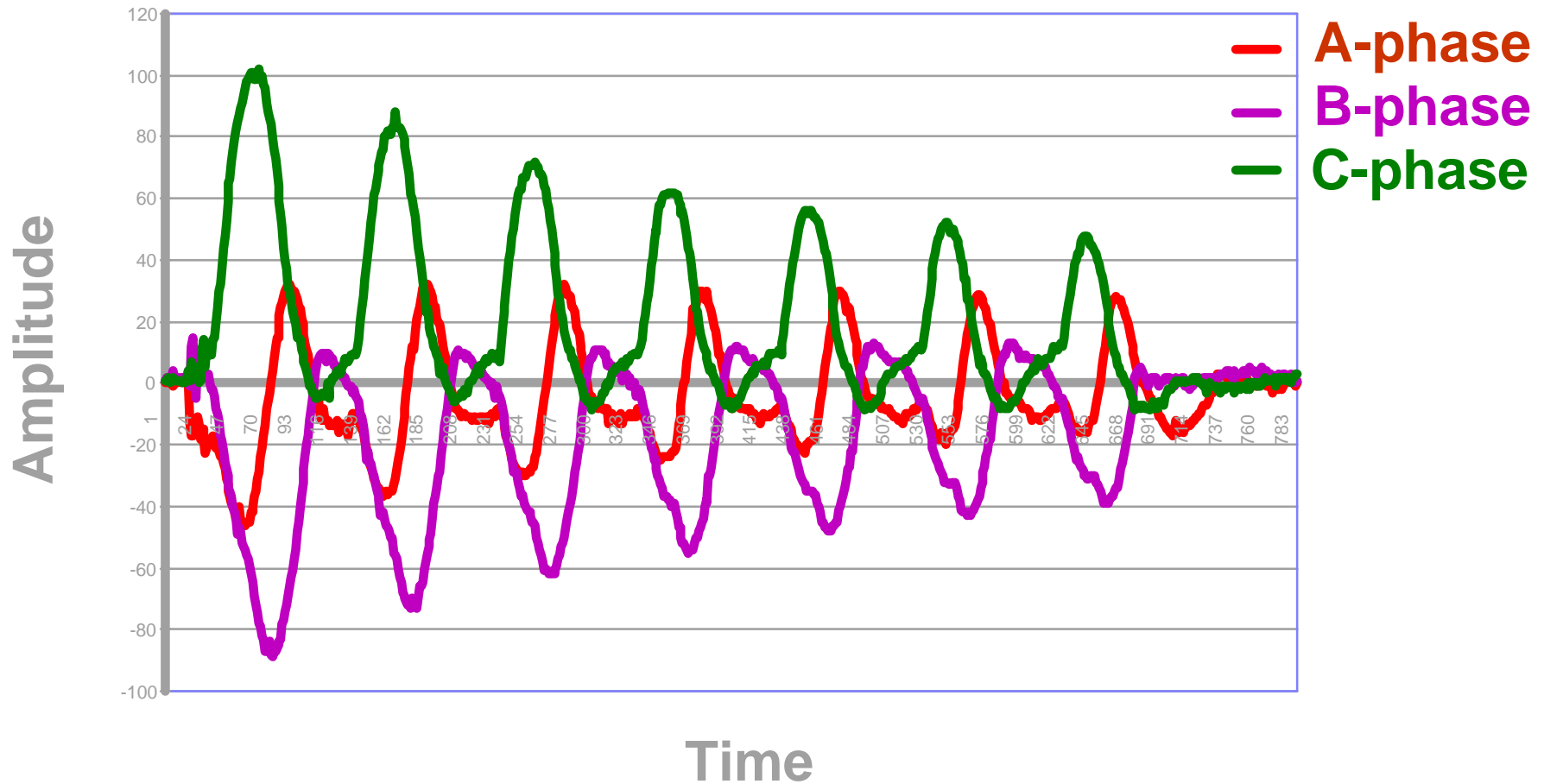
October 15, 2001



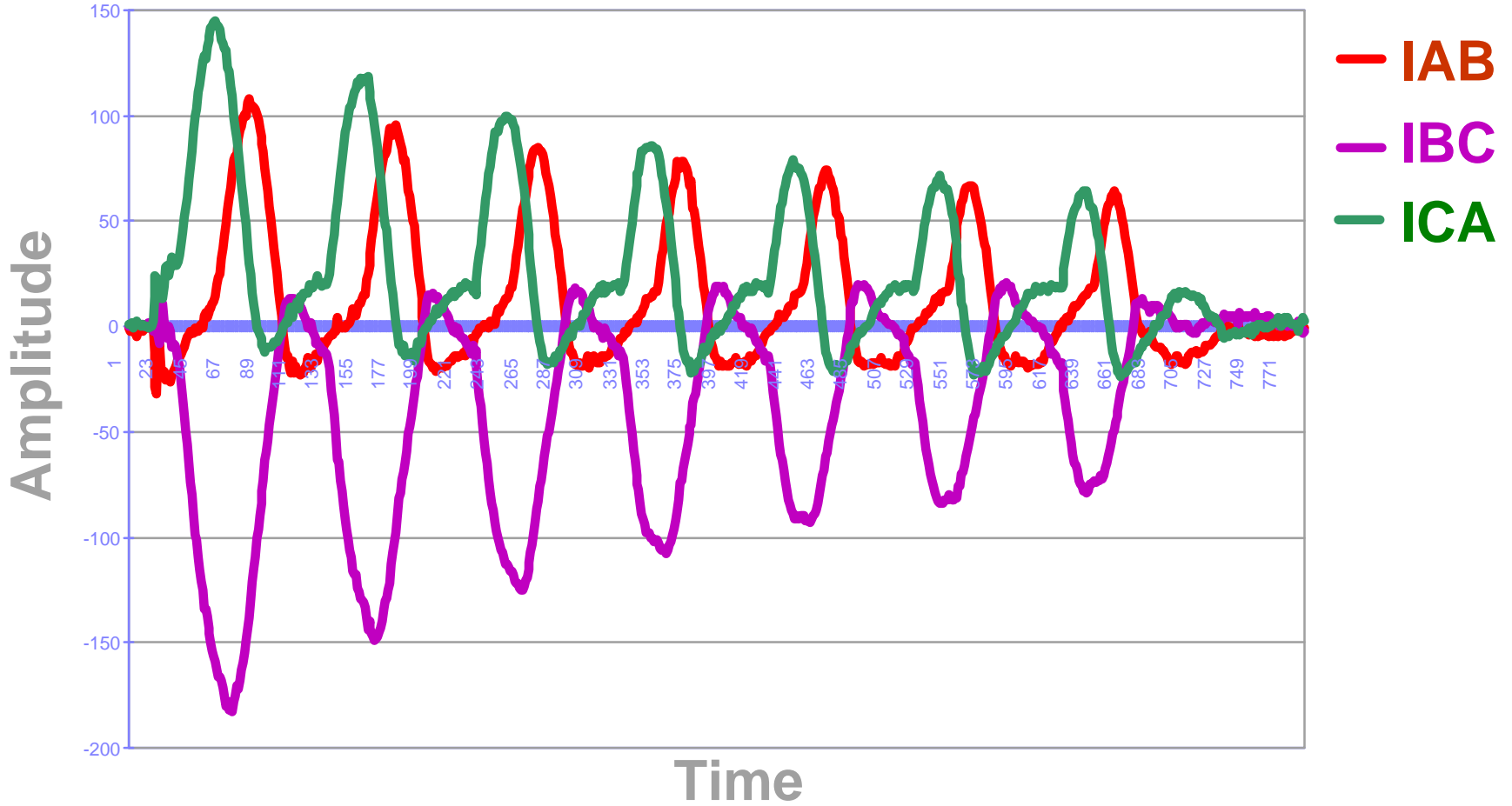
# Analysis

- Differential relays had harmonic restraint - fixed threshold 20% THD
- Suspected misoperation on inrush
- Raised tap settings to decrease sensitivity
- Remote DFR at Huntsville provided currents to verify cause of trip

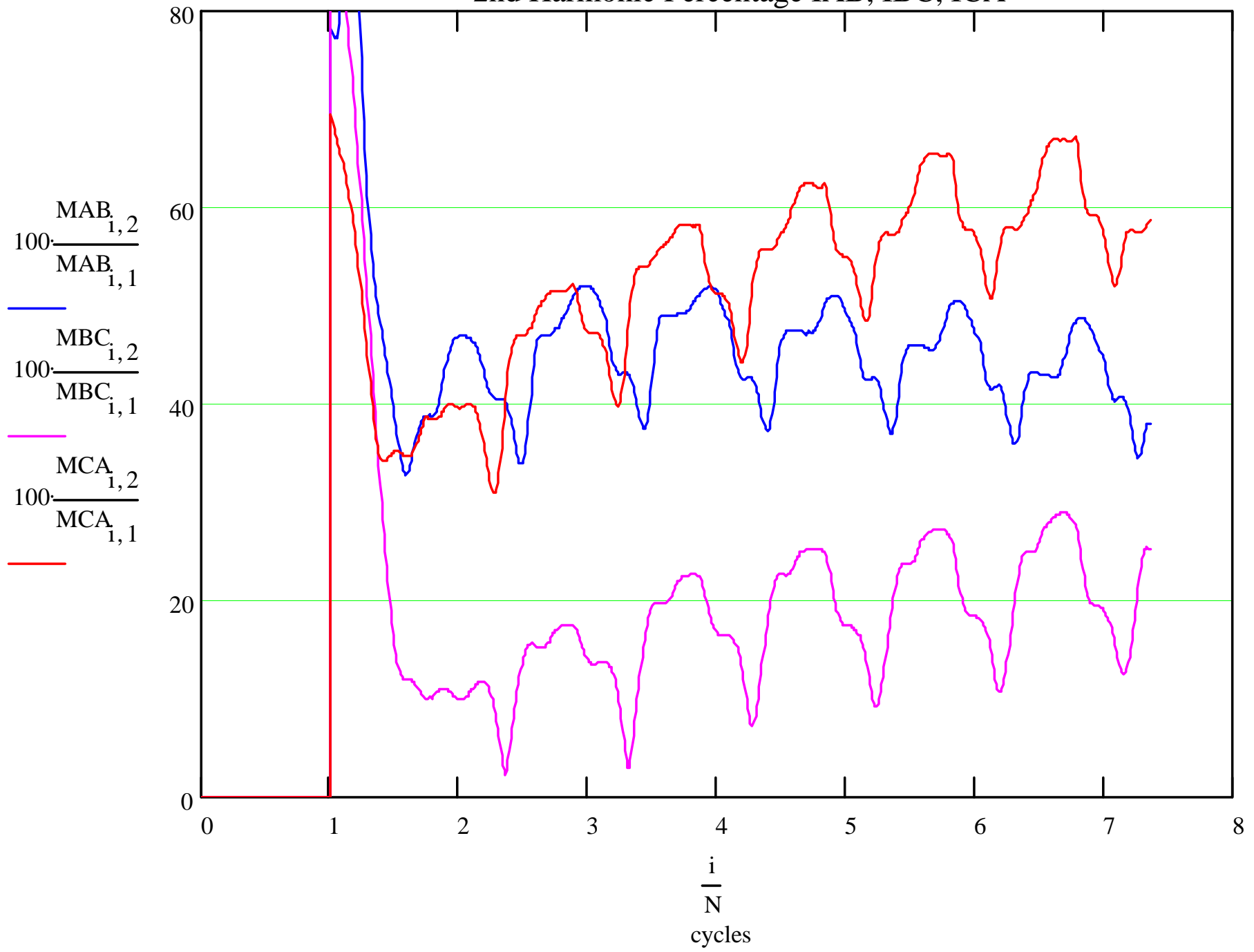
# Braytown Inrush - Phase currents at Huntsville terminal



# Delta currents to Braytown STD relays



2nd Harmonic Percentage IAB, IBC, ICA



## Solutions Considered

- Raising taps
- Lower harmonic restraint setting of existing relay - not easily accomplished
- Replace existing relay with one having variable harmonic restraint - **Our choice** (not implemented as of 10/2001)

This event caused us to work through how our transformer differential relays were restraining on inrush.

- Develop Simple Models for each Restraint Method

- Gather actual electronically captured transformer inrush currents

- In Matlab<sup>®</sup> and Mathcad<sup>®</sup> evaluate the different restraint methods by using the actual shots

NOTE: This is limited to harmonic restraint methods only (excludes waveform recognition method, power differential method, etc.)

## Simple 2nd Harmonic restraint method

This method compares the 2nd harmonic content of the current waveform to a threshold percentage.

Example: If waveform contains 45A of 2nd harmonic and has 175A of fundamental (60Hz) current then...

$$\%2nd = 45/175 \times 100\% = 25.7\%$$

## Shared 2nd harmonic restraint method

This method is identical to the previous method except the numerator is the sum of all 3 2nd harmonic currents.

Example: If the sum of 2nd harmonic current (magnitudes) from all 3 differential currents is 9A and the fundamental in the phase of interest is 10A then...

$$\% \text{Shared 2nd} = 9\text{A}/10\text{A} \times 100\% = 90\%$$

## Cross Blocking Restraint method

- Not a different “method,” but a choice to block all three elements tripping if any one has detected an inrush.
- Can be implemented with any relay that employs a single-phase inrush detection method.
- Avoids misoperations when one of the differential currents cannot be determined to be inrush.
- Potential problem: The possibility of energizing a faulted transformer.

But the problem remains: On what level of 2nd harmonic should the new relay be set?

## Two Requests of TVA's Transformer Manufacturer/Supplier

As part of our standard power transformer specification, for the condition of inrush with secondary breaker open, calculate and provide:

1. Minimum 2nd harmonic content percentage
2. Peak fundamental current

# Why are we asking?

1. Lower saturation densities in modern power transformers result in lower minimum 2nd harmonic, as low as 7% of fundamental\*.
  - Conventional electromechanical/static relays have fixed 2nd harmonic thresholds - e.g., HU-1 = 15%, STD = 20%
  - Newer microprocessor differential relays have settings available from 5-100%.
2. Peak fundamental current
  - To securely set distance and overcurrent elements looking into transformer banks
  - Presently we guess at 10 times full load self-cooled rating

\*From ABB's Protective Relaying Theory and Applications, page 151, Chapter 10, Section 3.15

# Bottom line

\* Eliminate guesswork \*

\* Maximize relay sensitivity \*

## Example - Widows Creek Intertie Bank

- Bank is made up of 500kV-Y / 165kV-Y / 13.2kV- $\Delta$  single-phase transformers:
  - A, B, spare phases:
    - 240/320/400 MVA OA/FA/FA
    - Minimum 2nd harmonic peak unknown
  - C phase:
    - 269/358/448 MVA OA/FA/FA
    - Minimum 2nd harmonic peak 13.4%
- Bank protected by redundant SEL-387 relays using simple 2nd harmonic restraint
- 2nd harmonic threshold set on 10%, below minimum expected

## Example - Shelby Intertie Bank

- Bank is made up of 500kV-Y / 165kV-Y / 13.2kV- $\Delta$  single-phase transformers:
  - A, B, C, spare phases:
    - 270/360/450 MVA OA/FA/FA
    - Minimum 2nd harmonic peak 7.8%
- Bank protected by redundant SEL-387 relays using simple 2nd harmonic restraint
- 2nd harmonic threshold presently set on 10%
- Plan to reduce setting to 7% or lower (relay minimum setting is 5%)

# Discussion