Transformer Protection

Transformer Protection Outline

- Fuses
- Protection Example
- Overcurrent Protection
- Differential Relaying
  - Current Matching
  - Phase Shift Compensation
  - Tap Changing Under Load
  - Magnetizing Inrush
  - Overexcitation
  - Connection Examples
  - Ground Differential
- Sudden-Pressure Relays (63)

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Power Transformer Failure Statistics
1955 - 2002 (3,112 failures)

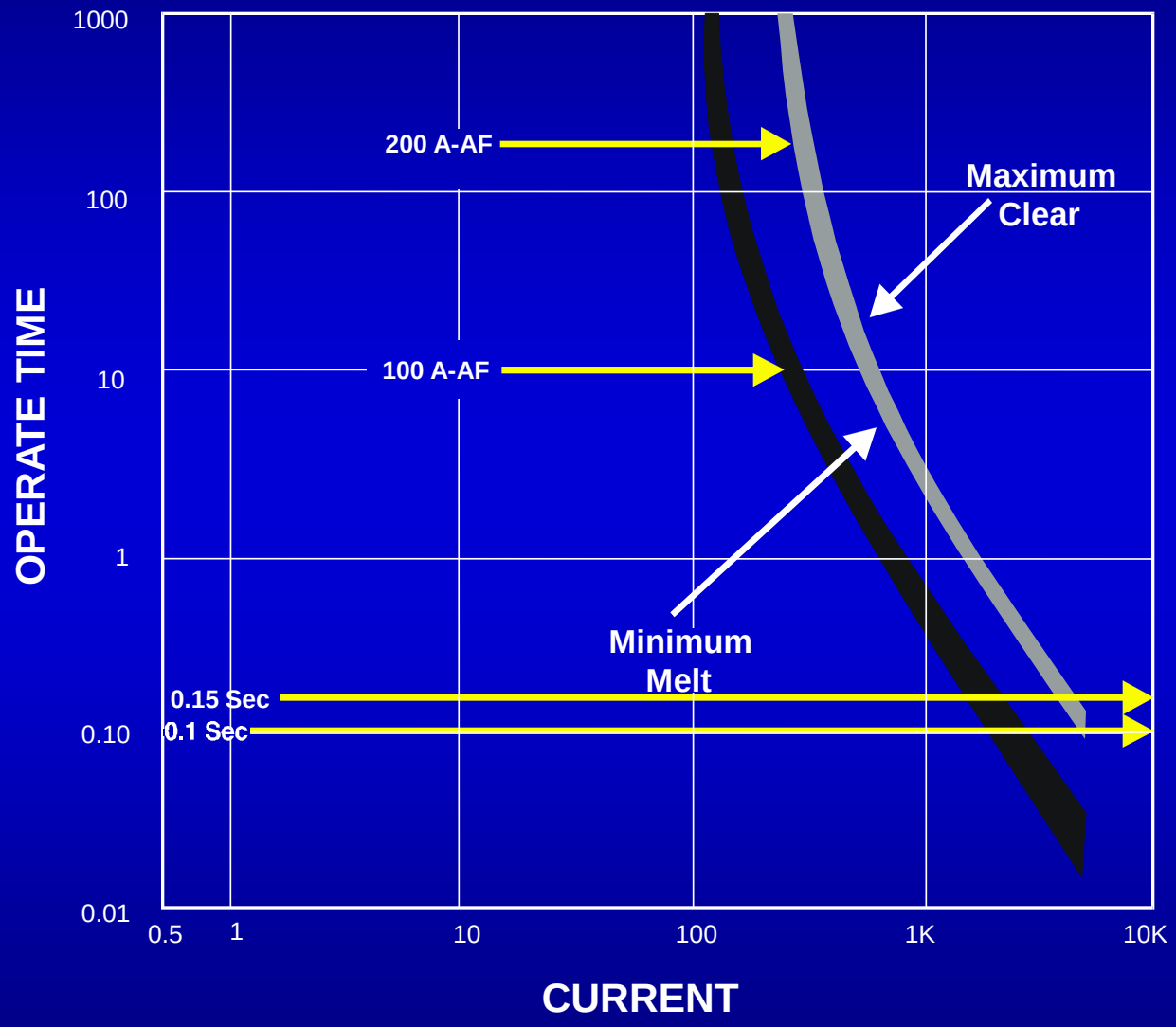
Winding failures	= 31%
Tap changer failures	= 26%
Bushing failures	= 12%
Cooling equipment failures	= 3%
Auxiliary equipment failures	= 3%
Core failures	= 1%
Leads failures	= 1%
Other failures	= 23%

Source: IEEE C37.91-2000

Transformer Fusing

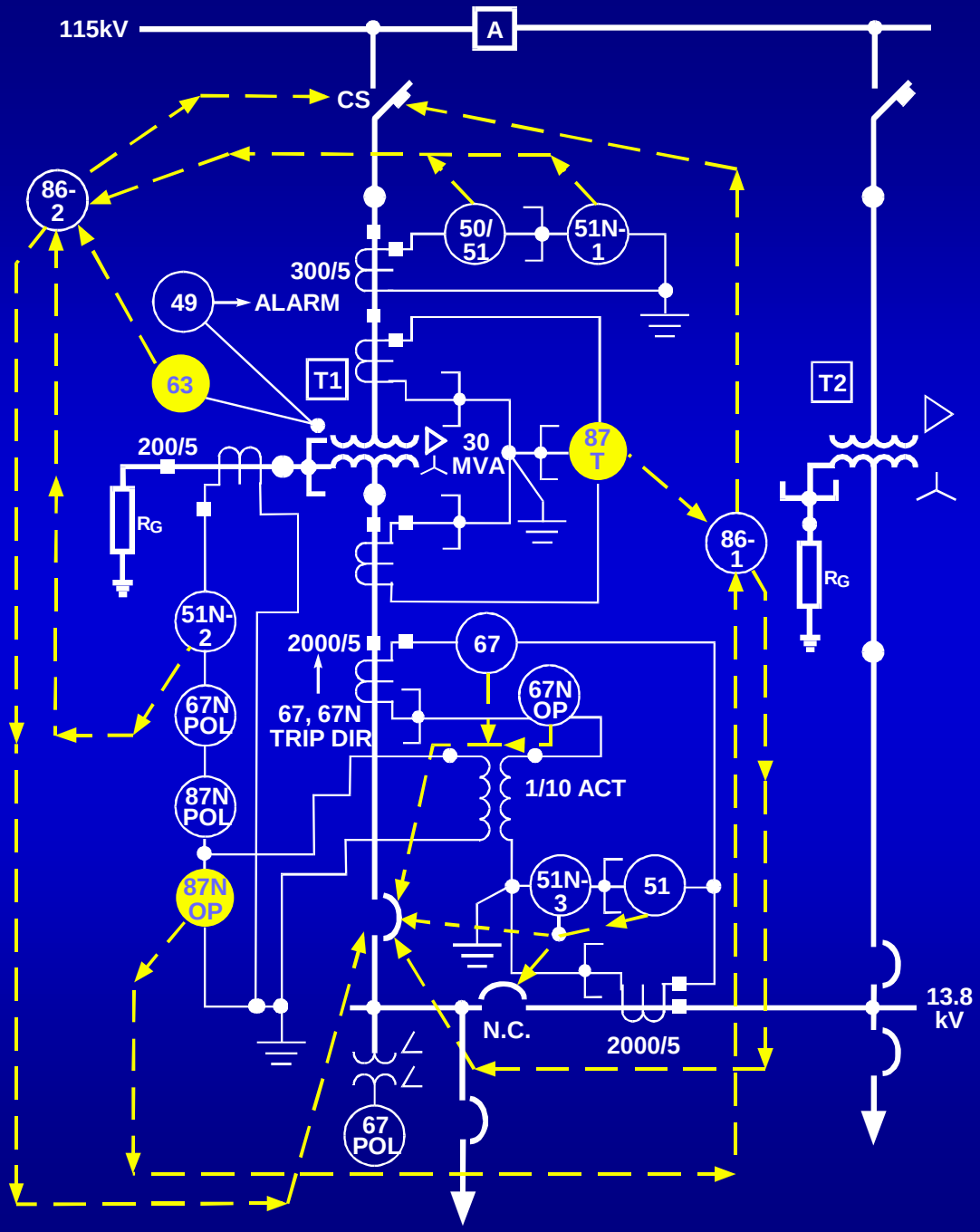
- Normally used at 10MVA and below
- Reference transformer damage curves IEEE C37.91
- Selected to fit below damage curve
- Fuses must be coordinated with relays
- Economical

Fuse Characteristics



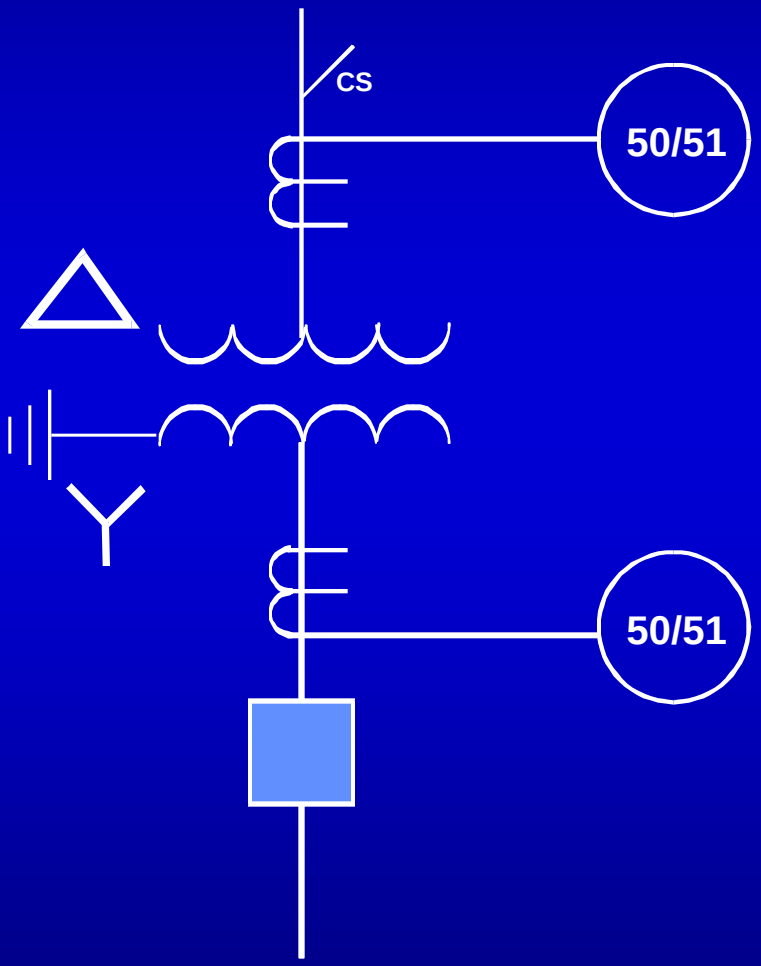
Example: Large Industrial Load

XX Primary Protection



Transformer Overcurrent Protection

High side overcurrent will not see low side ground faults.



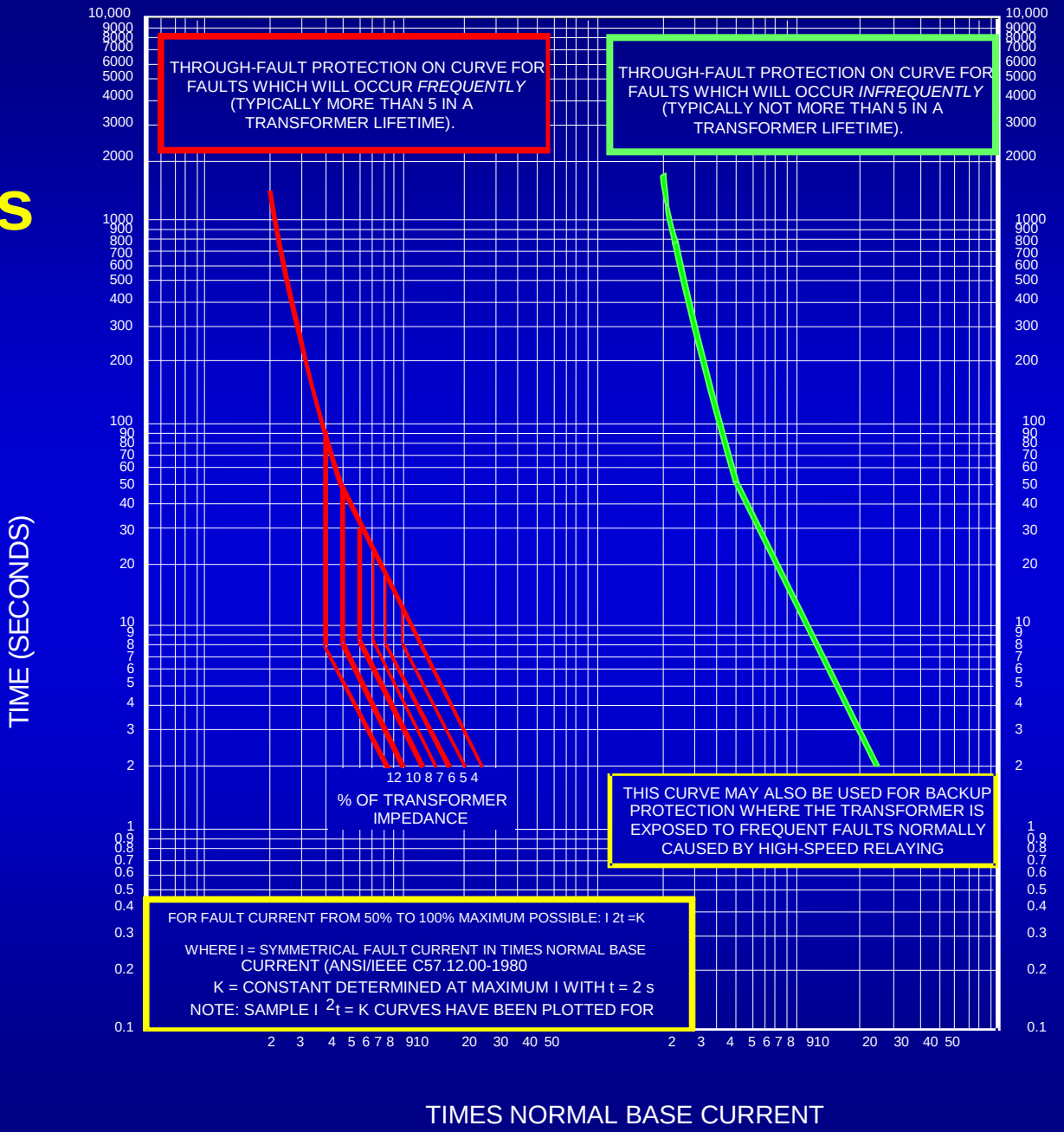
High Side Overcurrent

- Coordinate with upstream devices
- Backup transformer differential / sudden pressure
- Thermal overload
- Set above Inrush, 2-8 X Load

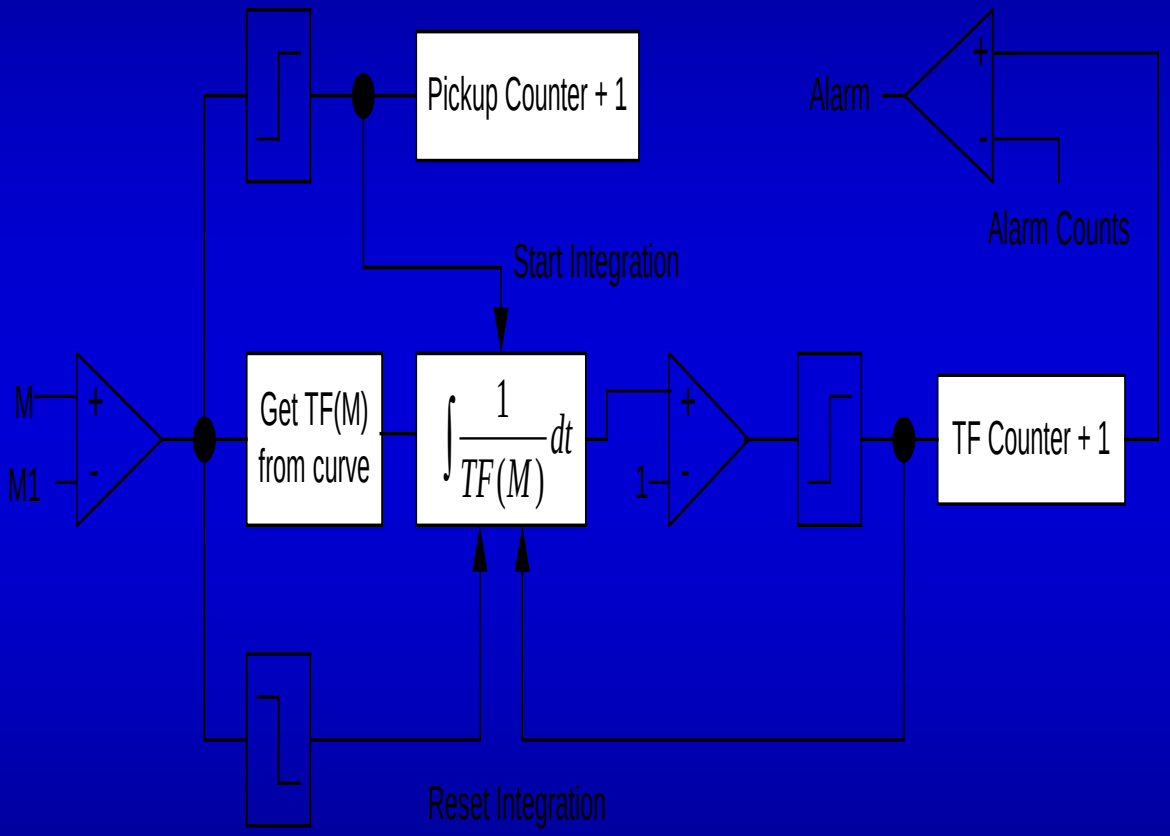
Low Side Overcurrent

- Coordinate with downstream devices (radial)
- Bus backup scheme
- Thermal overload

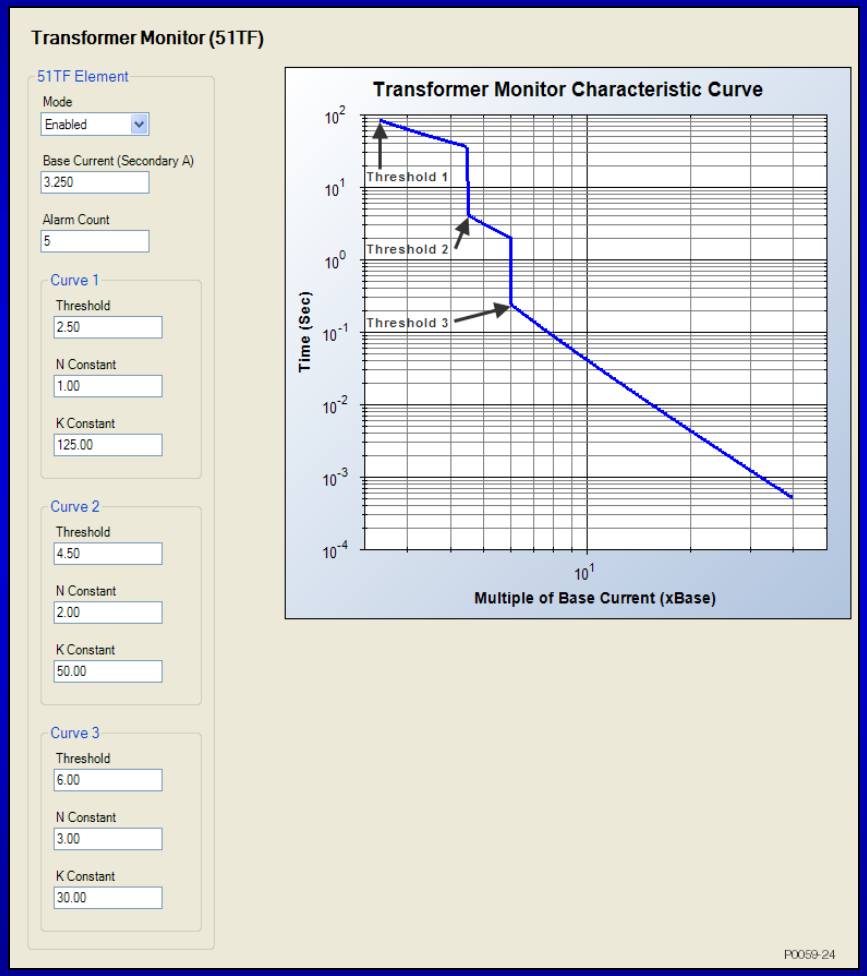
“Frequent” and “Infrequent” Operating Limits



Transformer Monitor (51TF)



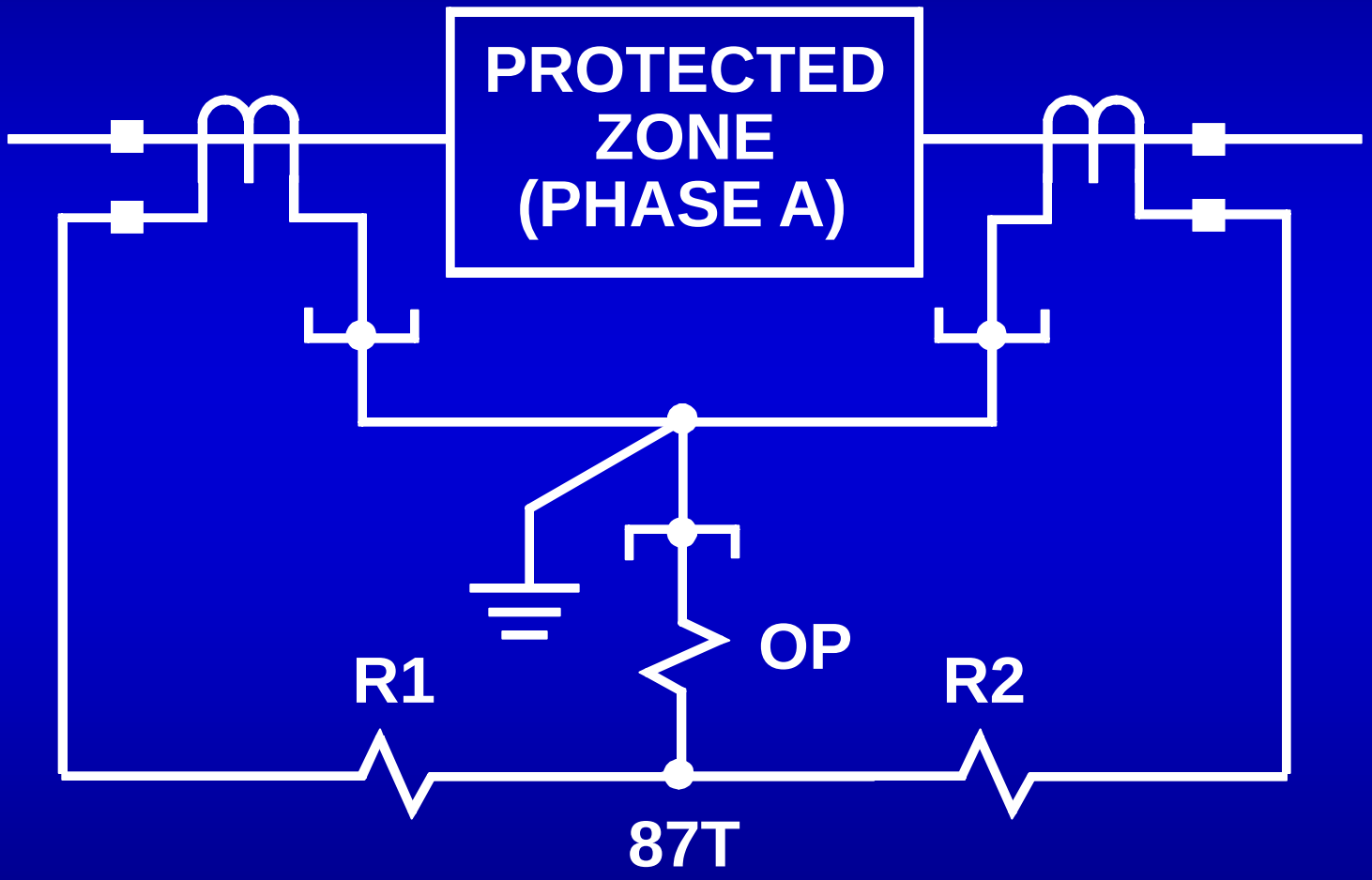
Transformer Monitor (51TF)



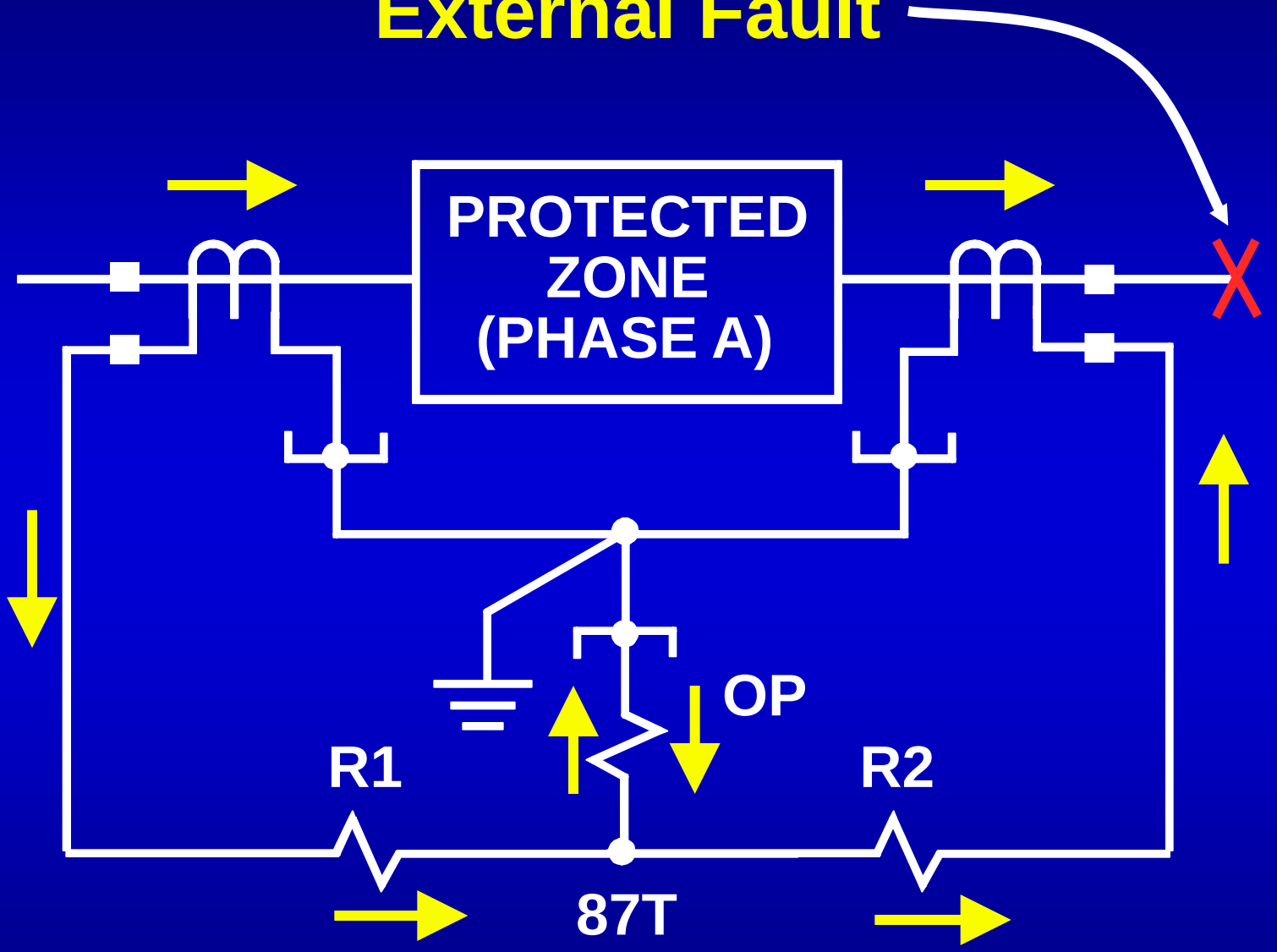
Transformer Differential Relays

- Faster
- More sensitive
- Eliminates single phasing problem
- More selective

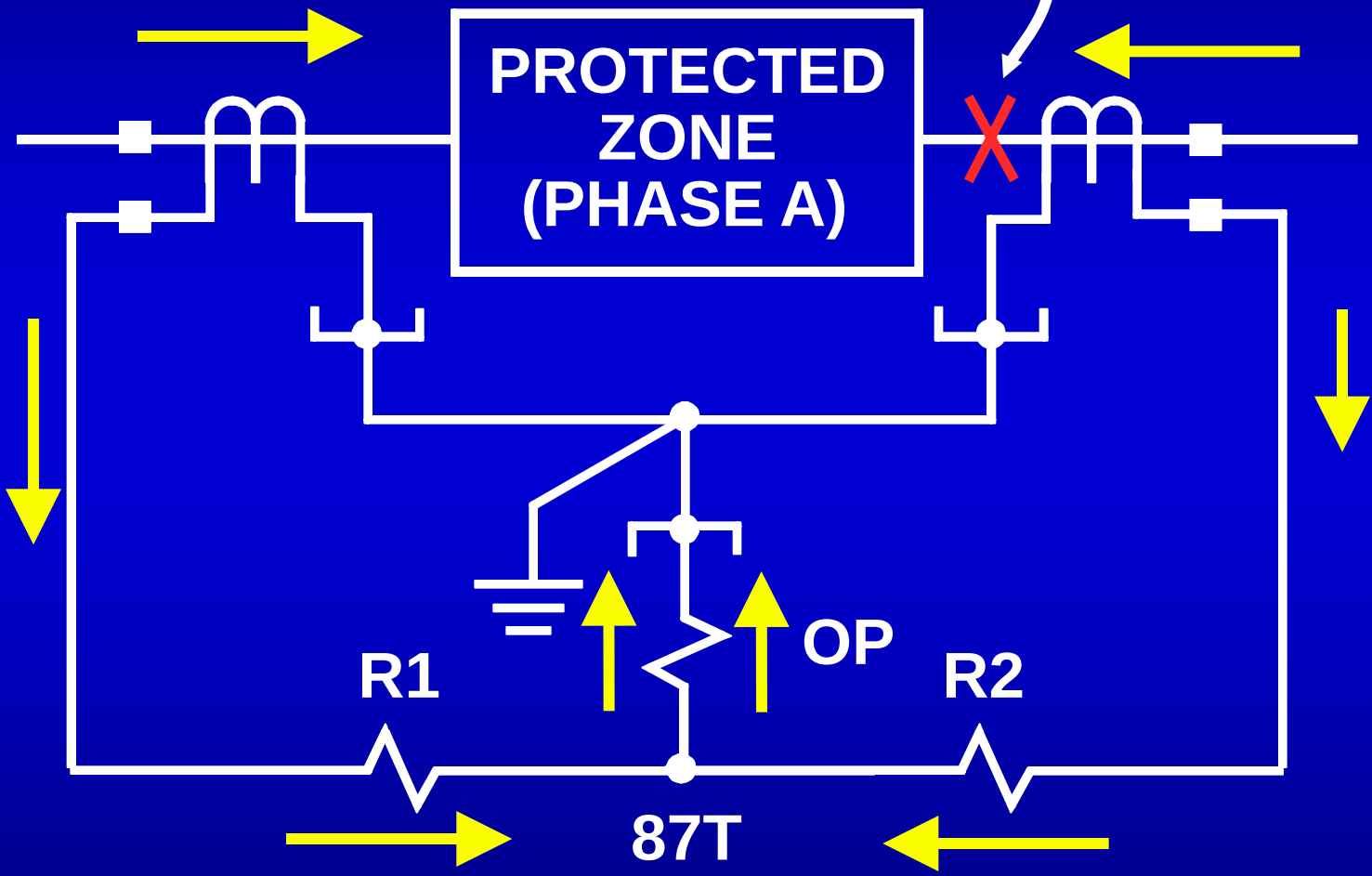
Percentage Differential



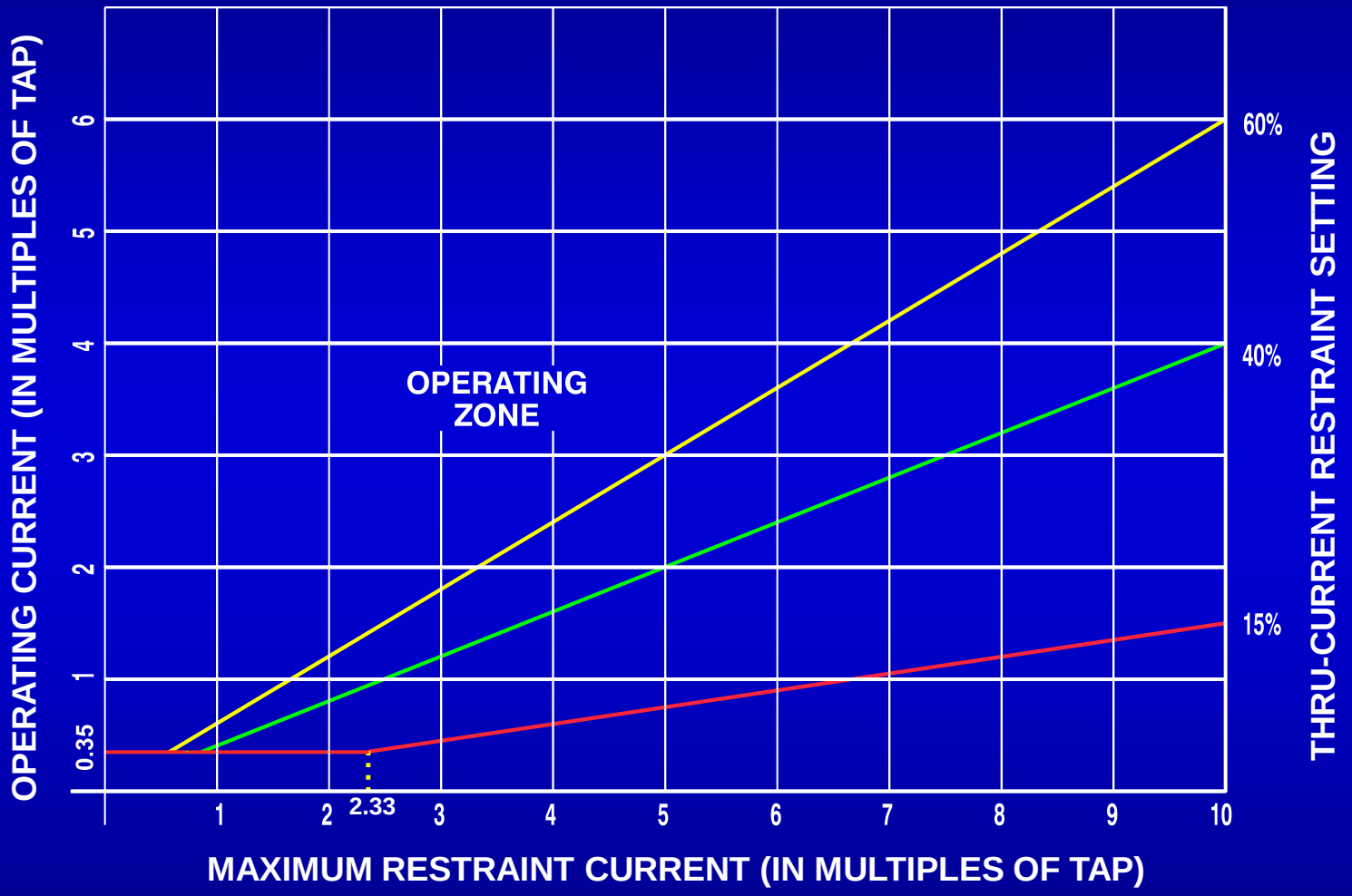
External Fault



Internal Fault



Percentage Differential Characteristic



Transformer Differential Limitations

- Unequal secondary currents, because of the different turns ratios of the power transformer windings and the CTs
- Phase shift of wye-delta banks
- Tap changing under load
- Magnetizing inrush

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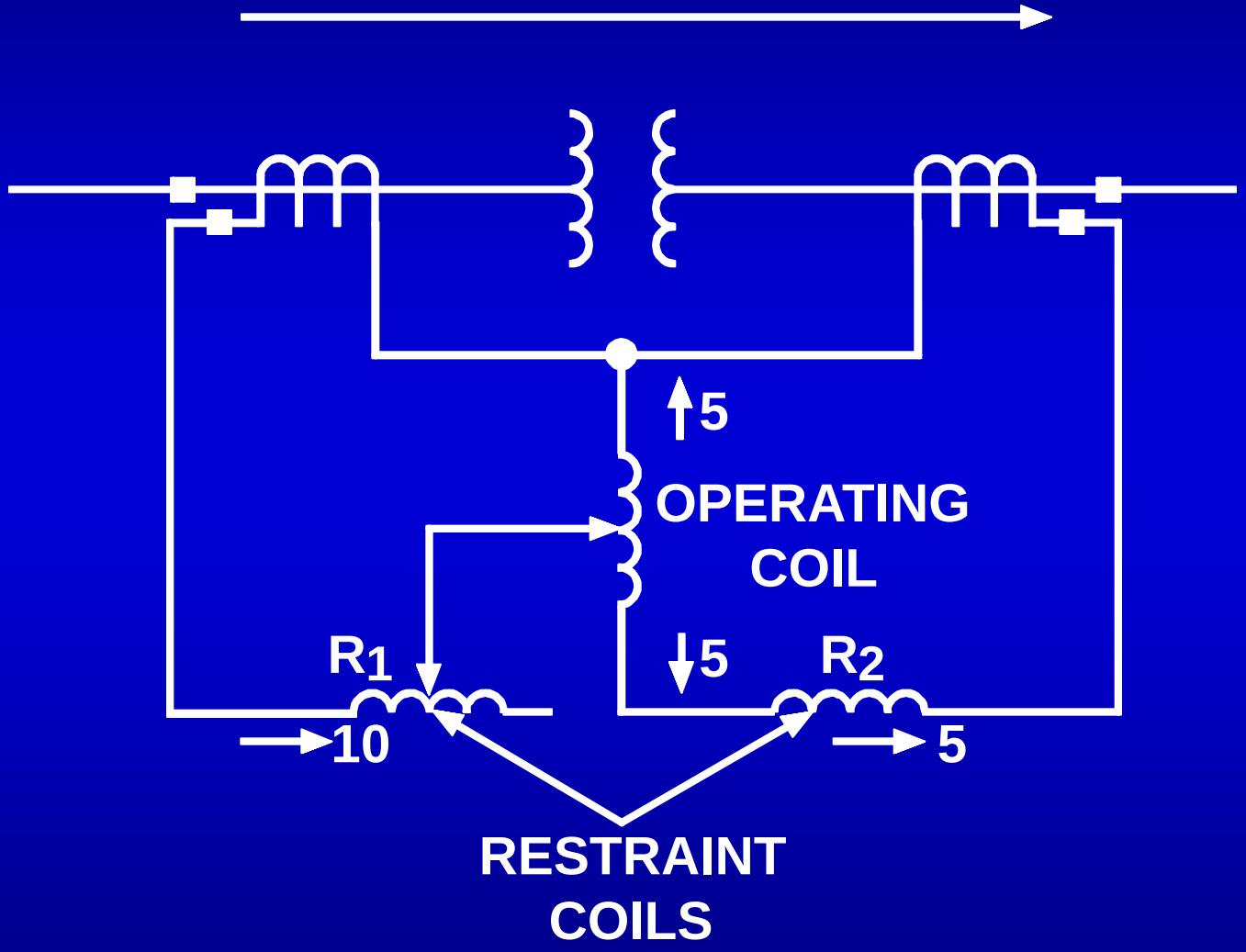
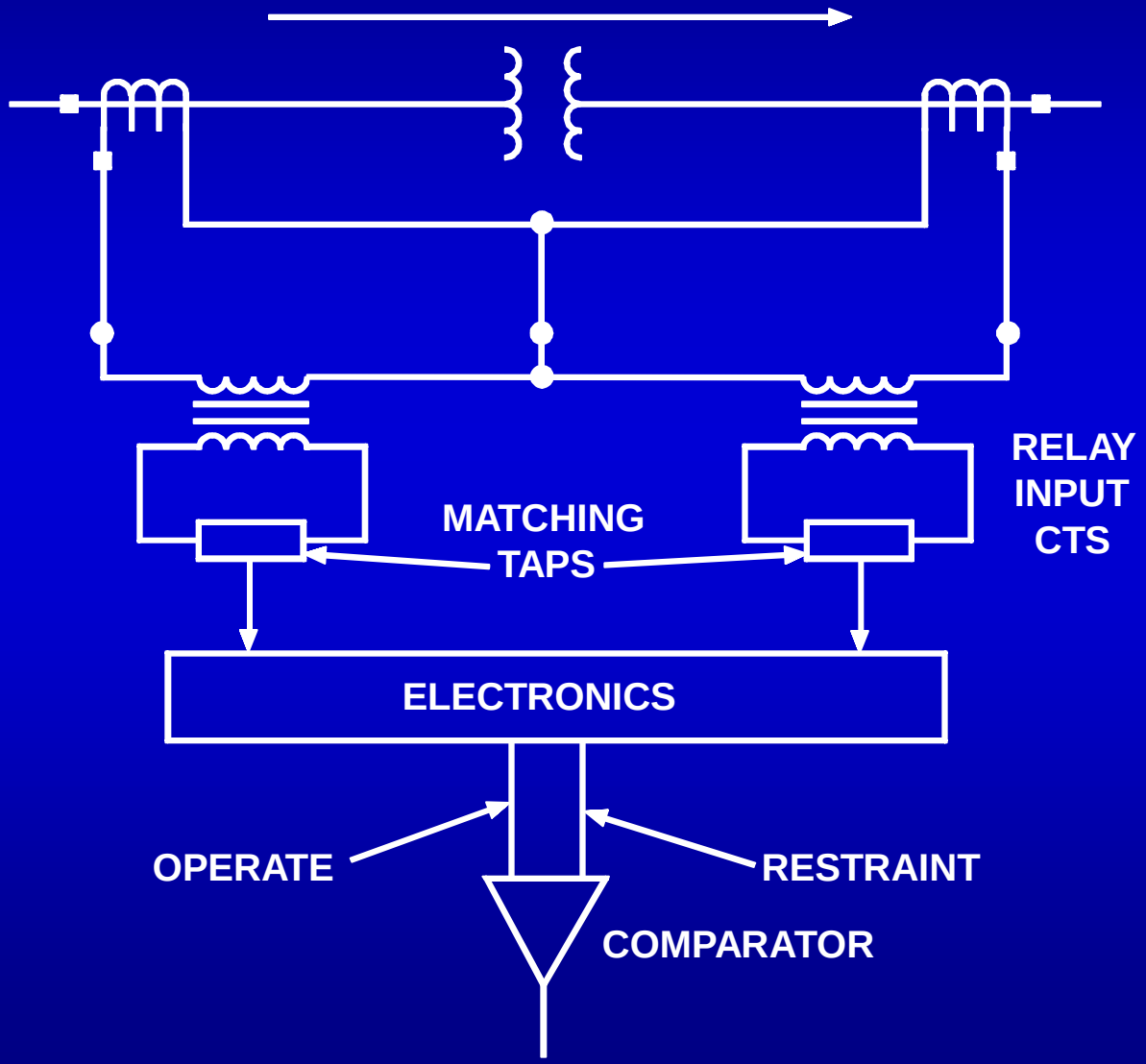
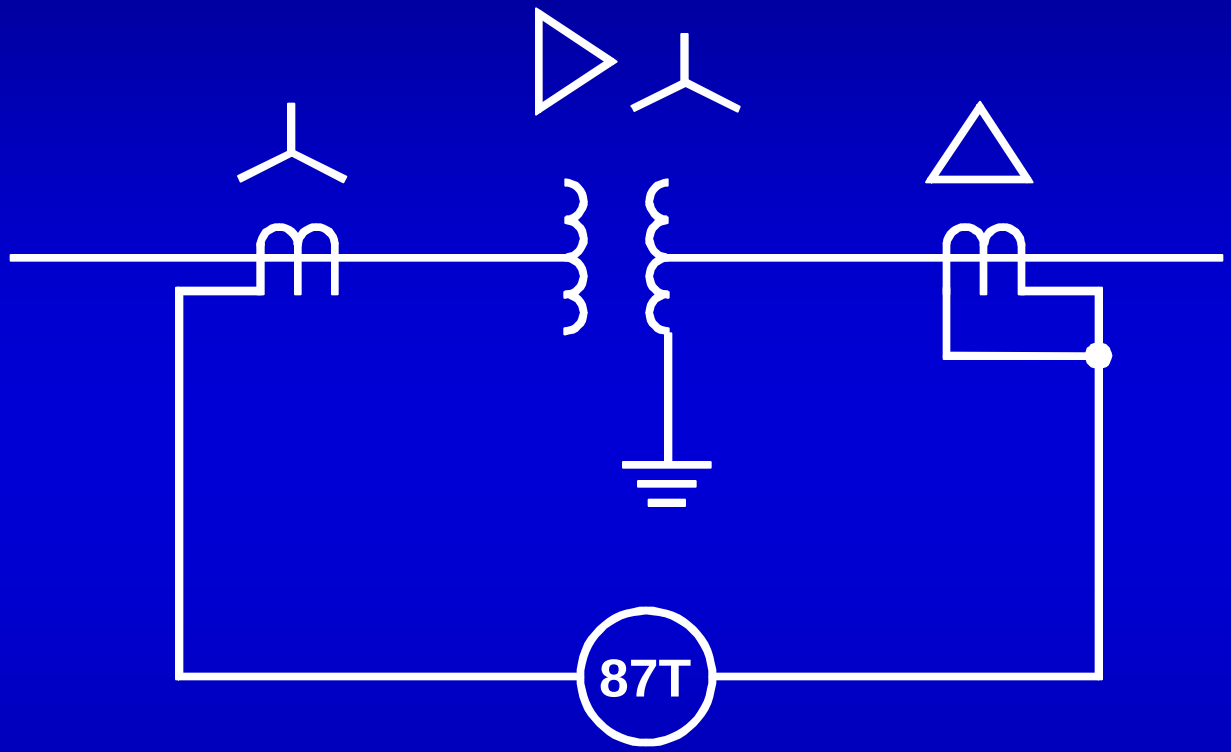
Current Matching



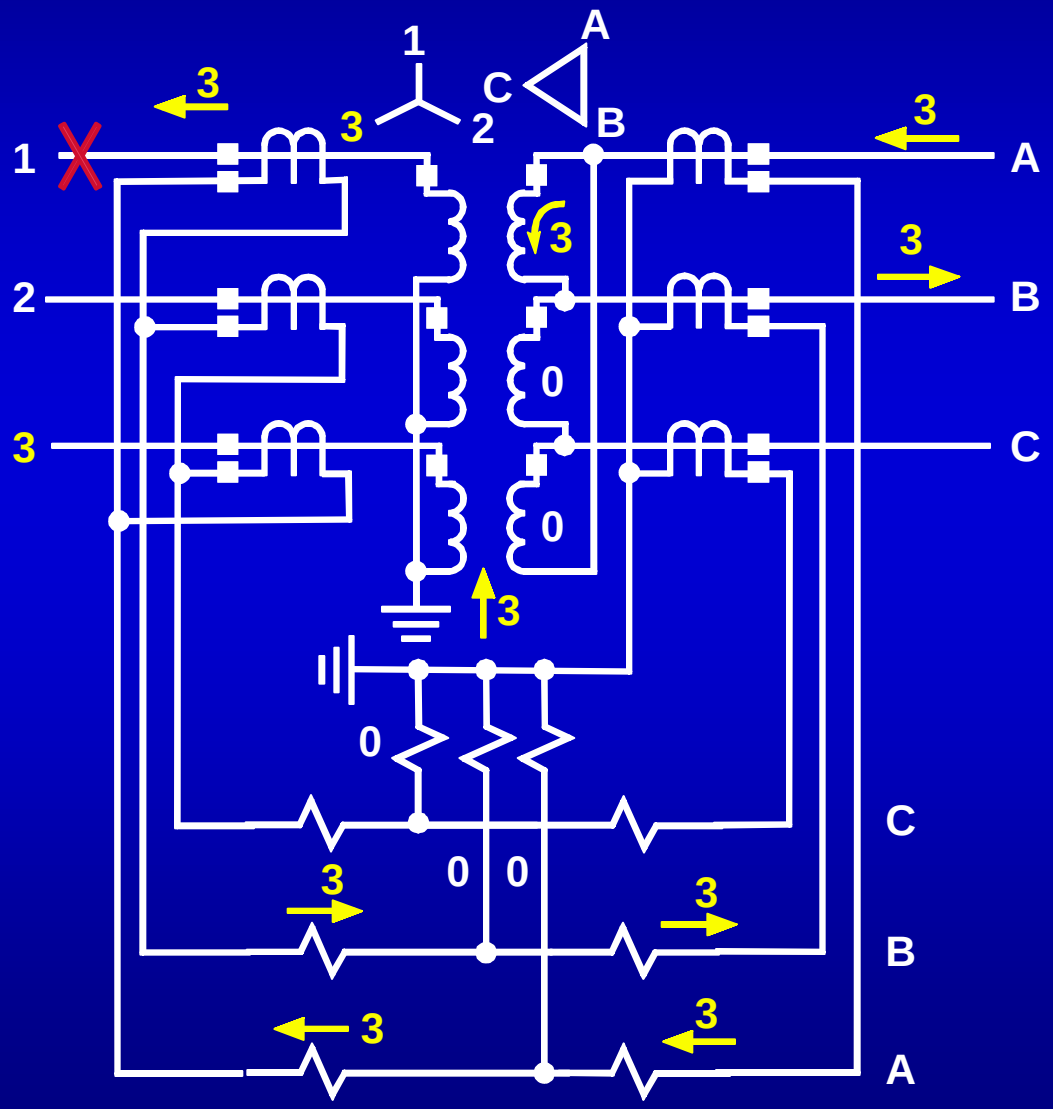
Current Matching



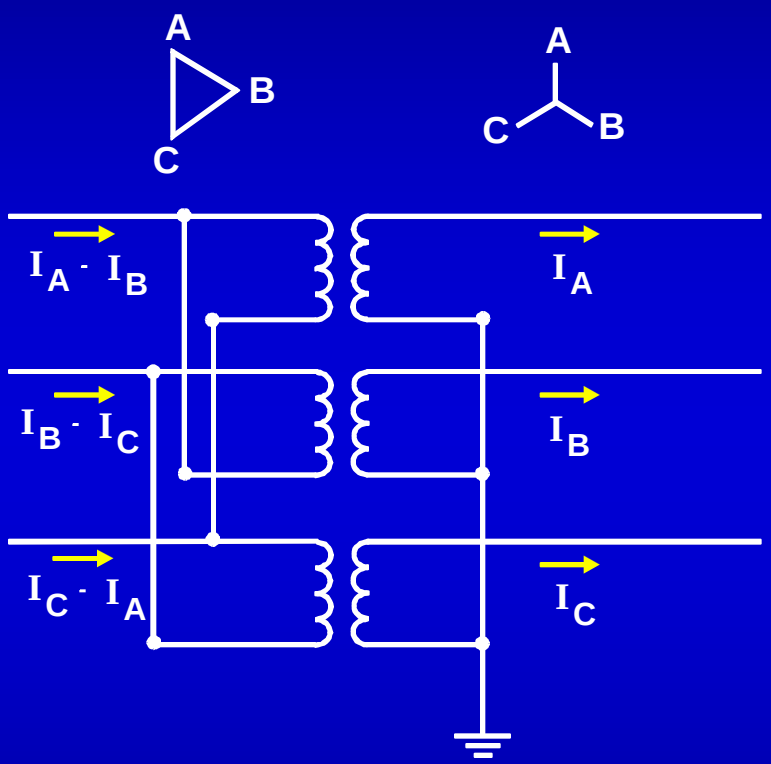
Phase Shift Compensation

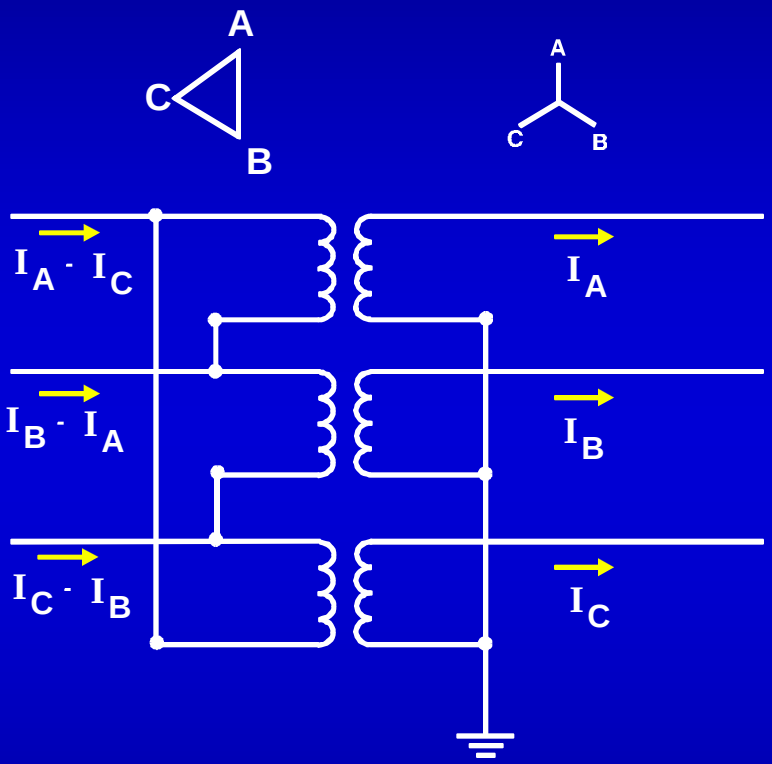


Phase Shift Compensation / Zero Sequence Trap



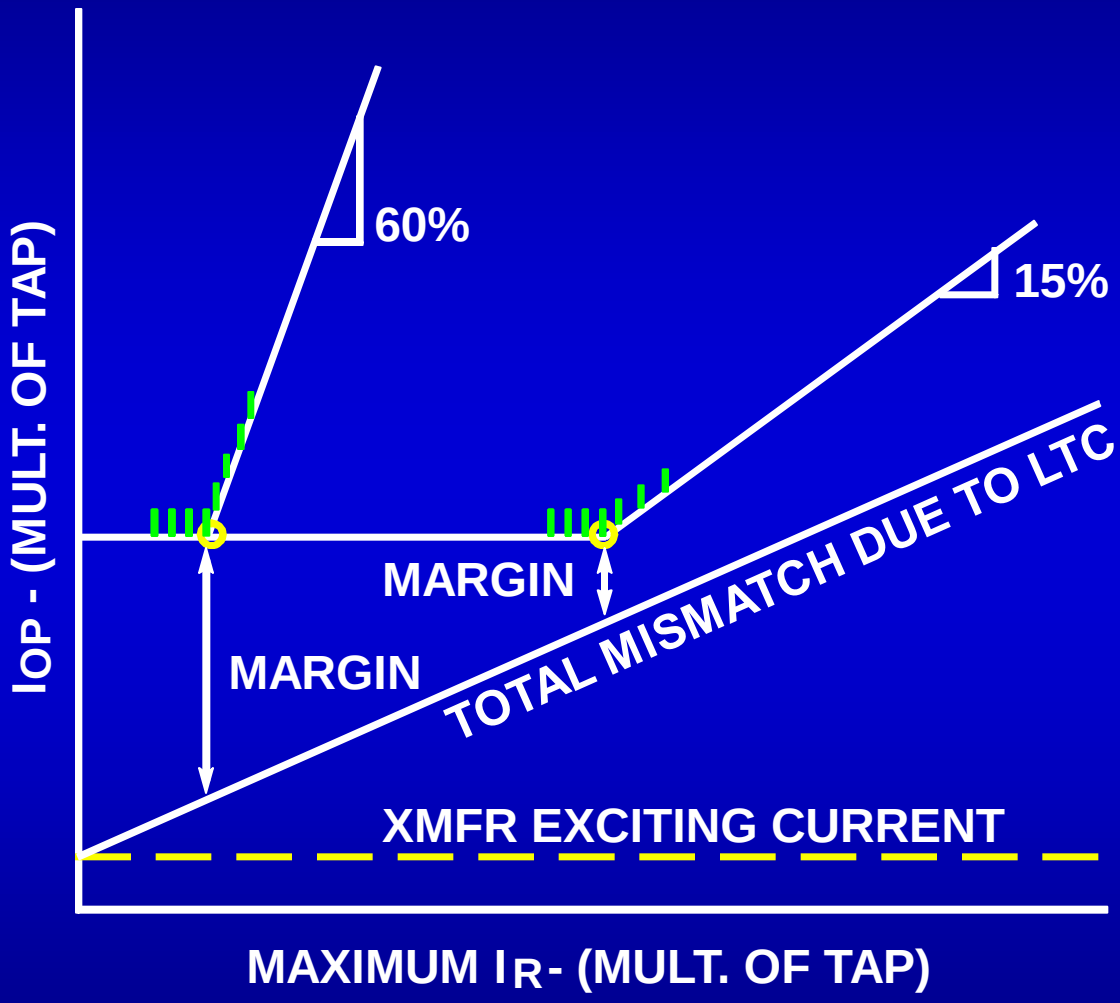
Two Kinds of Delta Connections



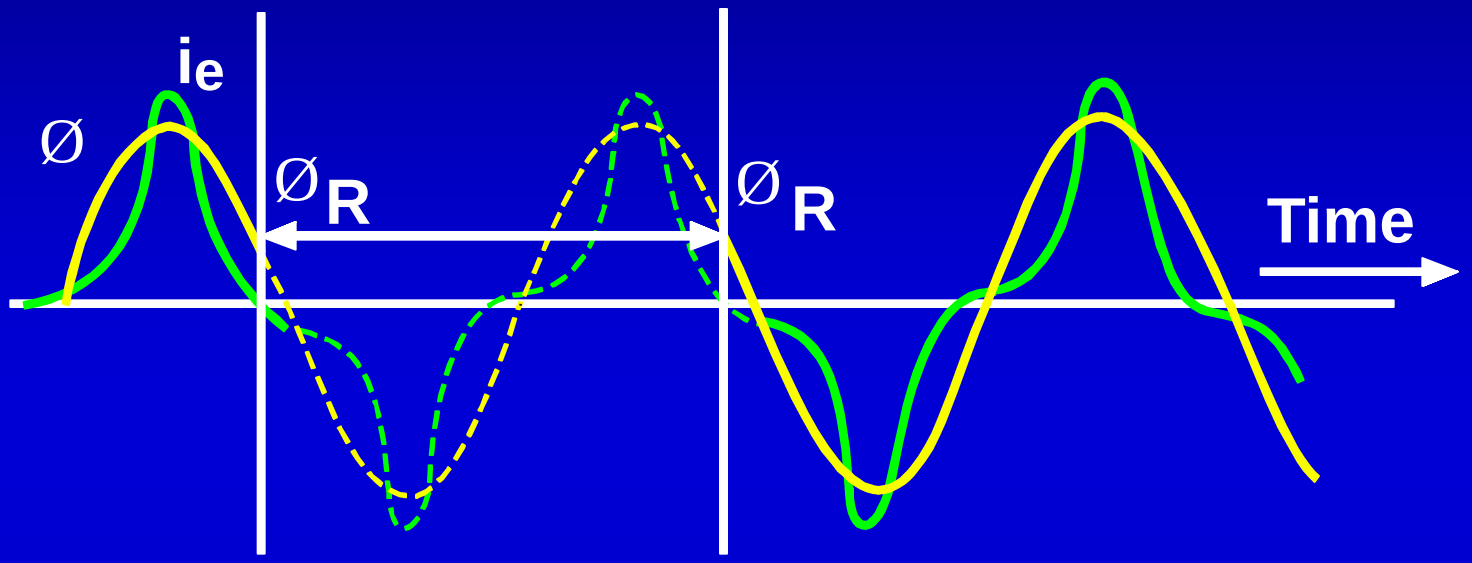


Percentage Differential Characteristic

Tap Changing Under Load



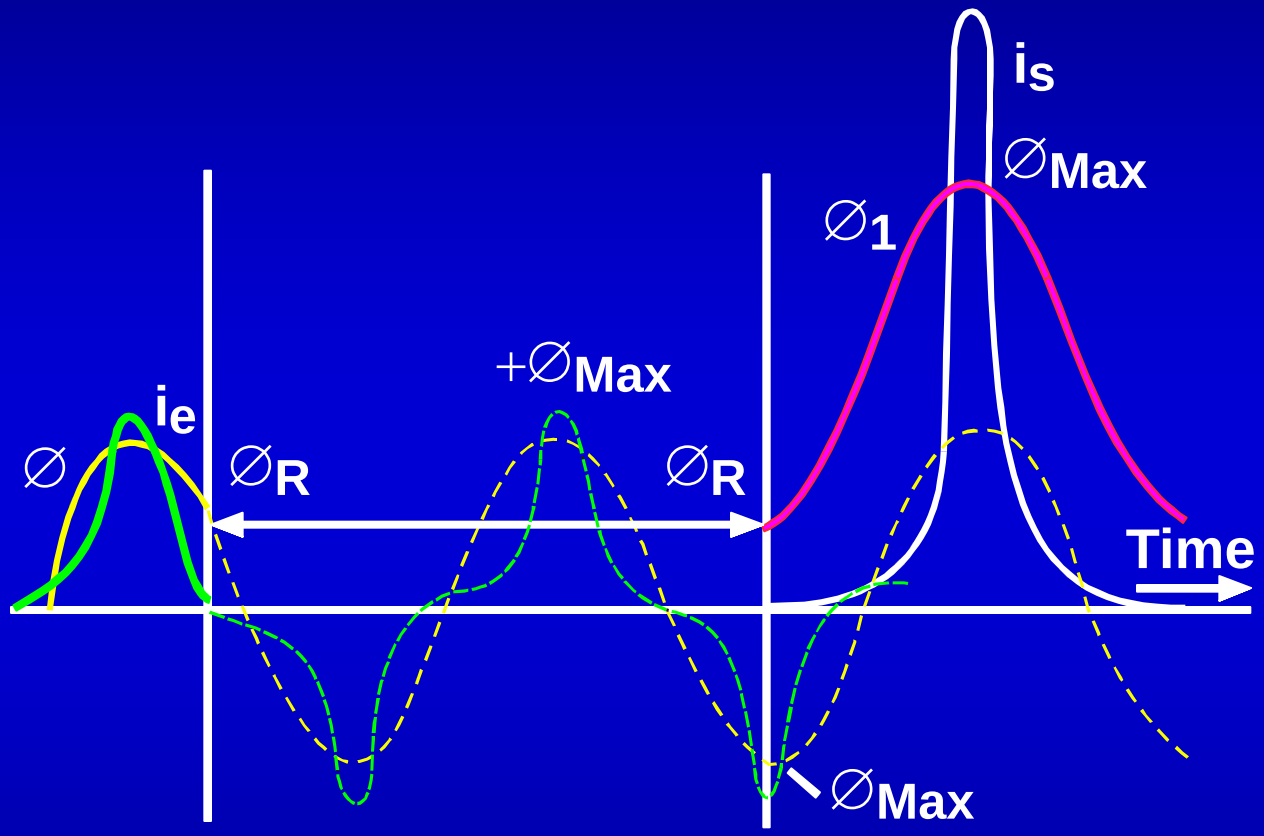
Magnetizing Inrush



Transformer Deenergized at This Point

Transformer Reenergized at This Point

Magnetizing Inrush



Transformer Deenergized at This Point

Transformer Reenergized at This Point

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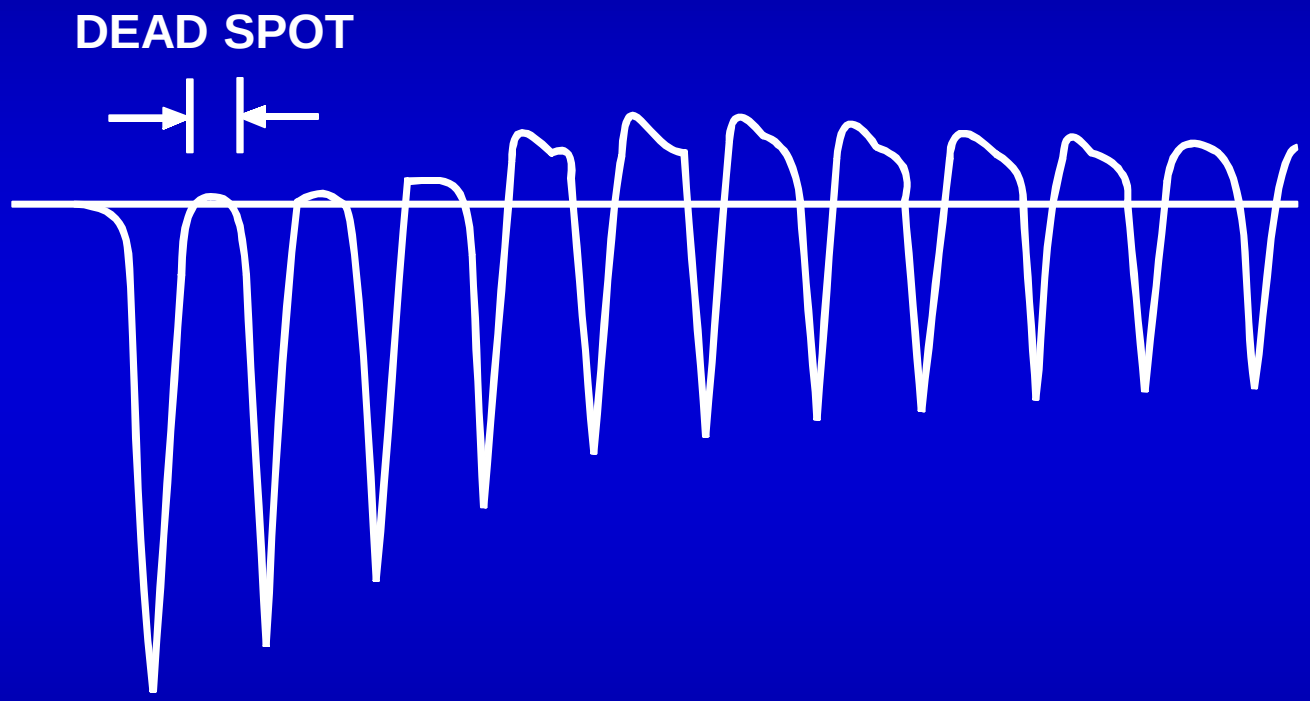
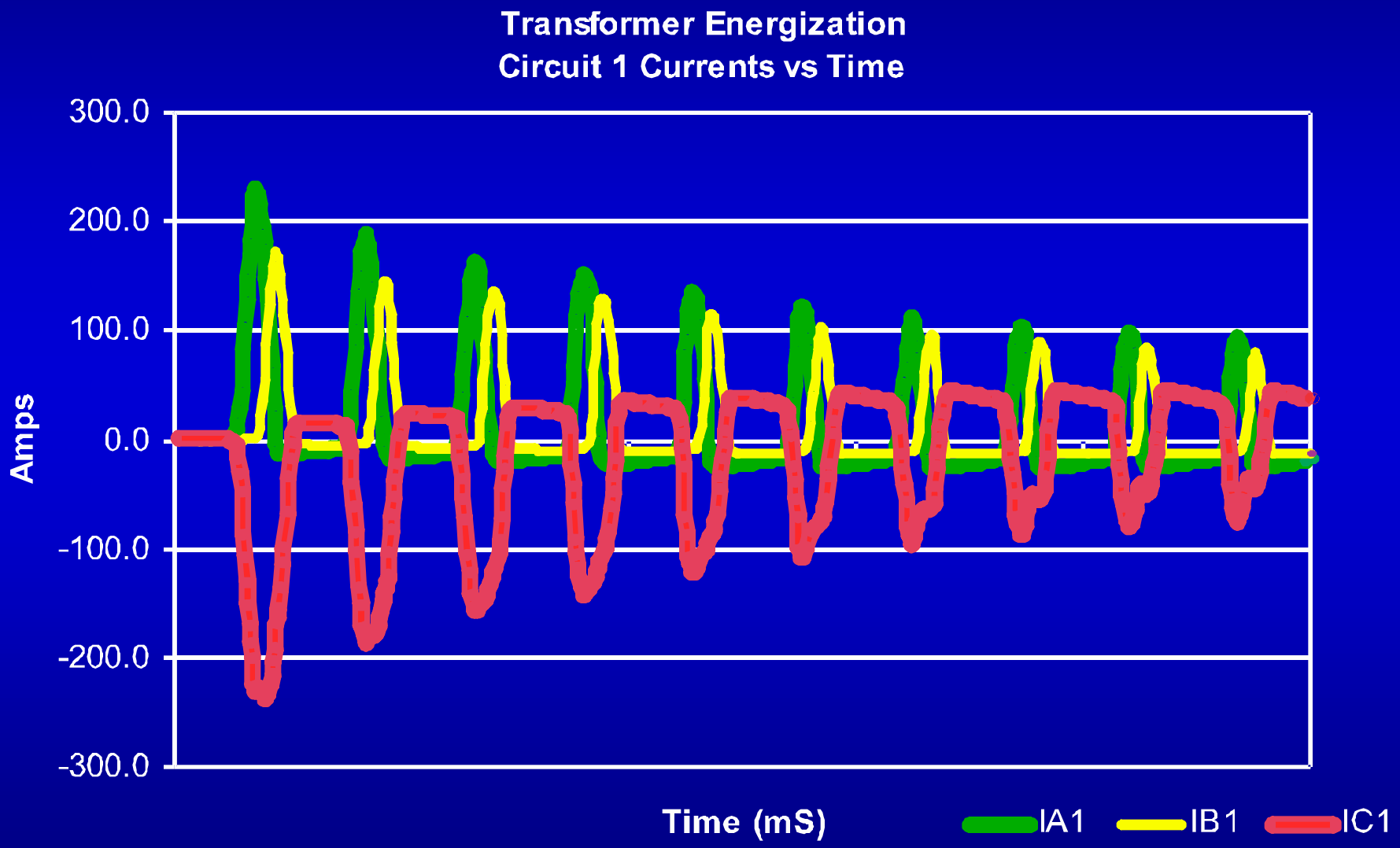
Inrush Waveform



Unbalanced Inrush



Differential Setting Review

- If the transformer connection is a delta-wye the angles of the two currents will not be 180 degrees apart, and must be compensated by 30 degrees
- To compensate with the CT connection, reverse the connection; for delta-wye transformers connect the CT's wye-delta
- Digital relays can be connected wye-wye and set the compensation inside the relay

Differential Setting Review

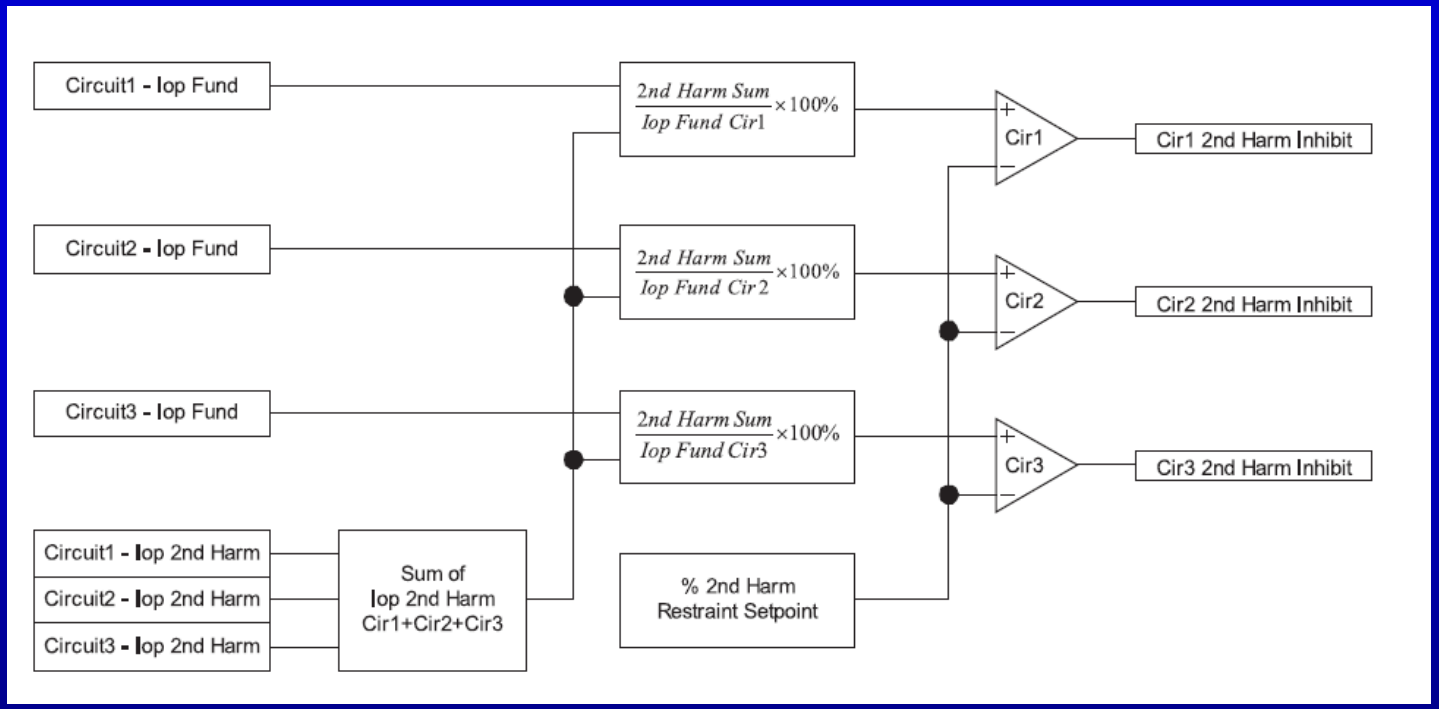
Ratio of taps=Ratio of currents

Differential Setting Review

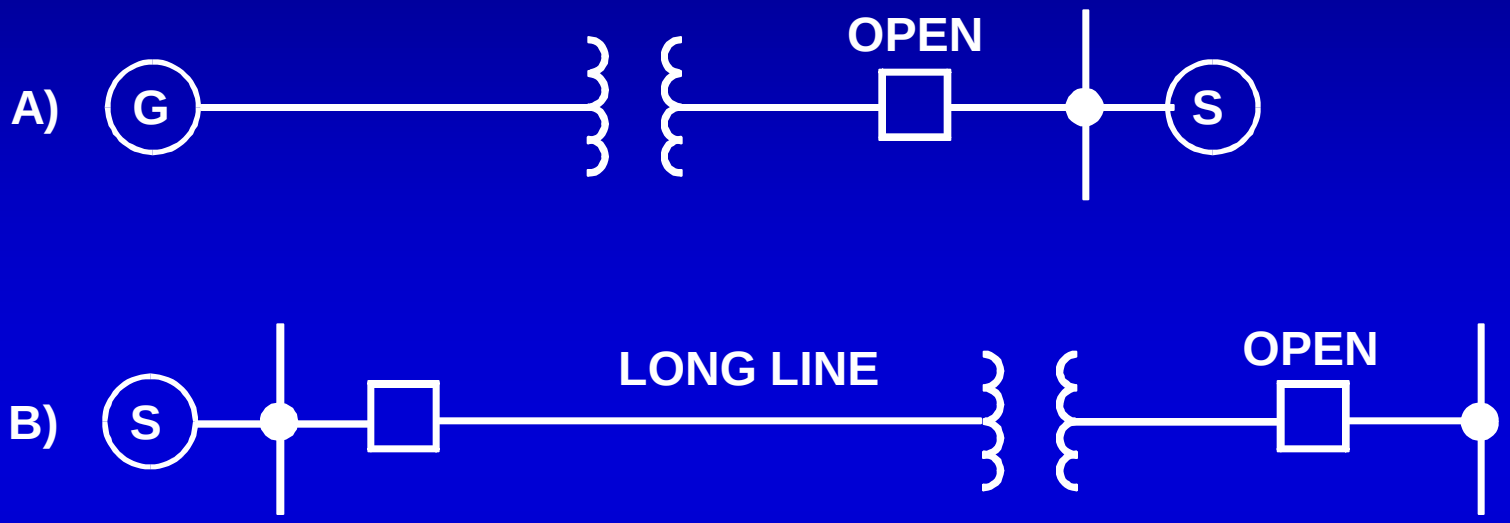
- Set slope low for low mismatch and high quality CTs
- Increase slope setting for tap changer transformers, poor quality CTs or poorly matched CTs
- Use of transient monitor to detect the effect of CT saturation during through-fault => enhance security

Differential Setting Review

- Use of 2nd harmonic sharing for 2nd harmonic inhibit => Superior method to enhance security

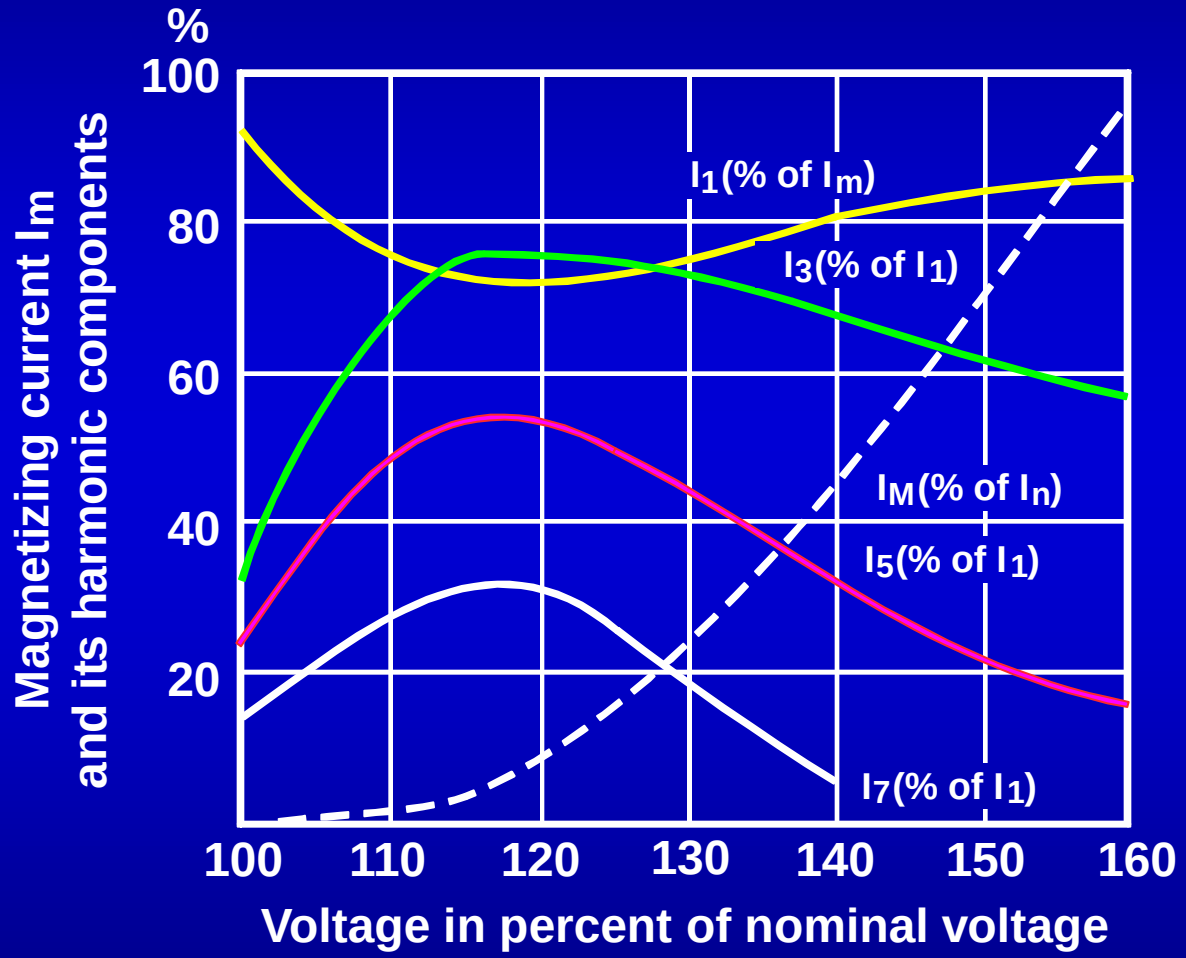


Overexcitation

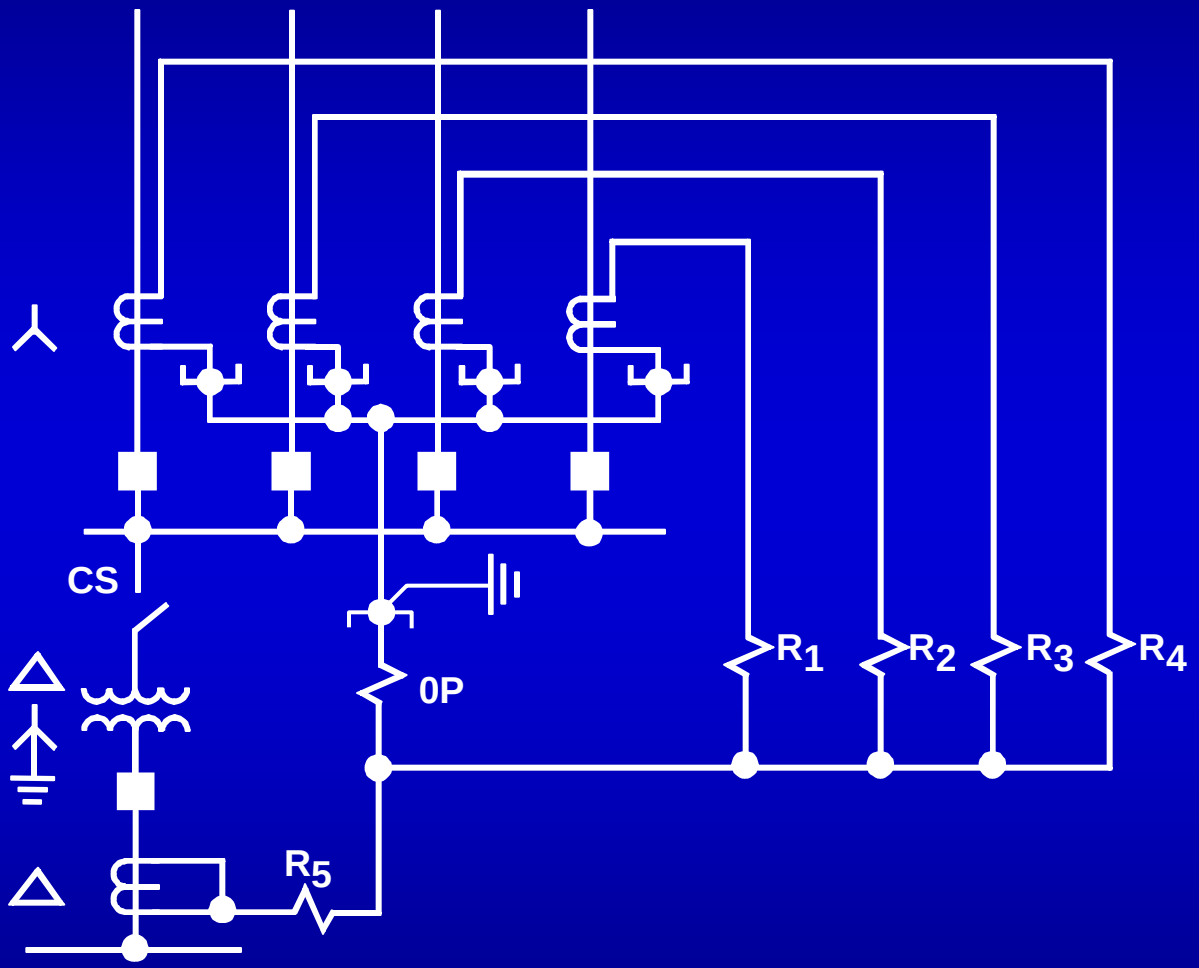


S - POWER SYSTEM

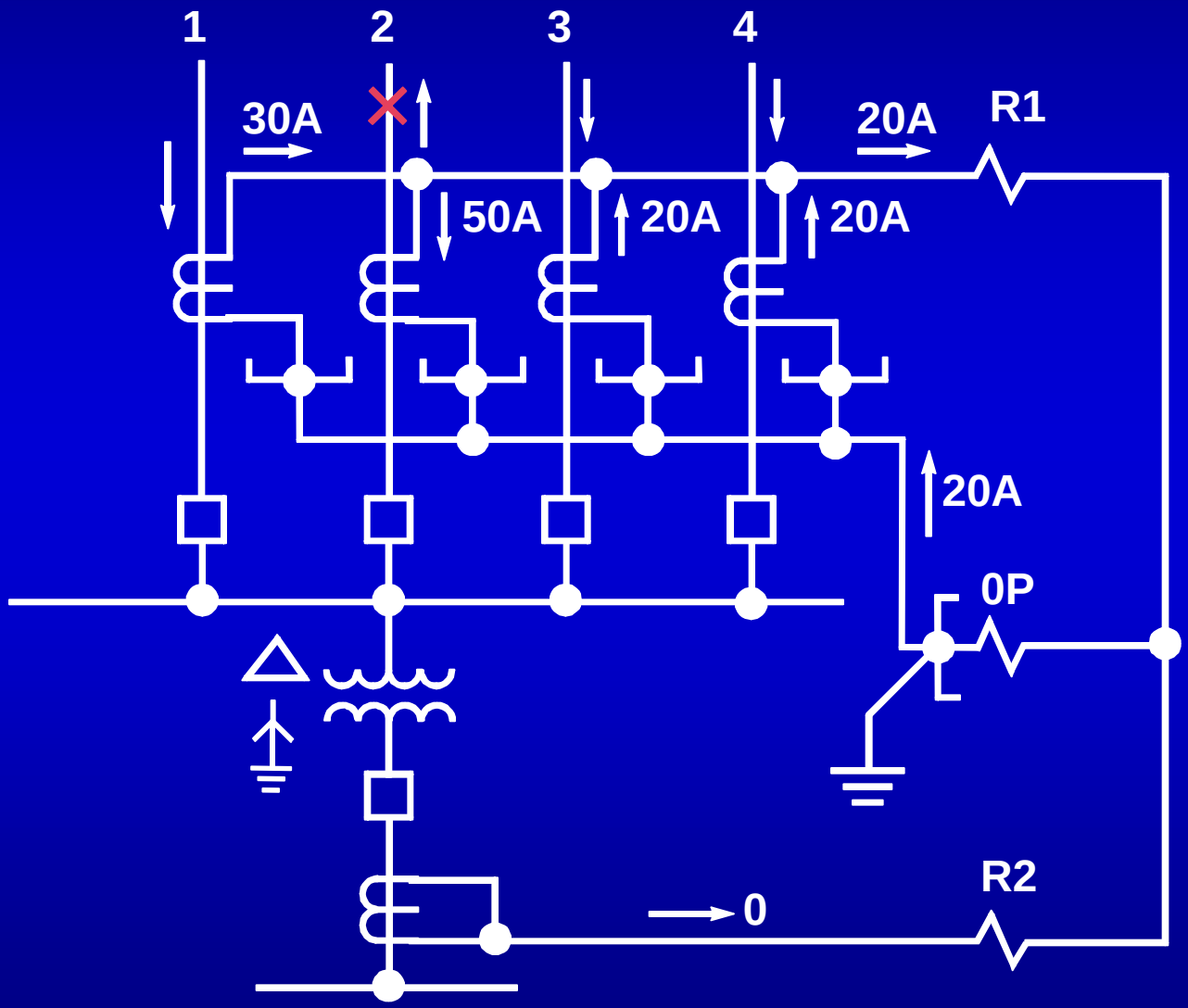
Relay restrains over the voltage range of 104-138% of rated excitation



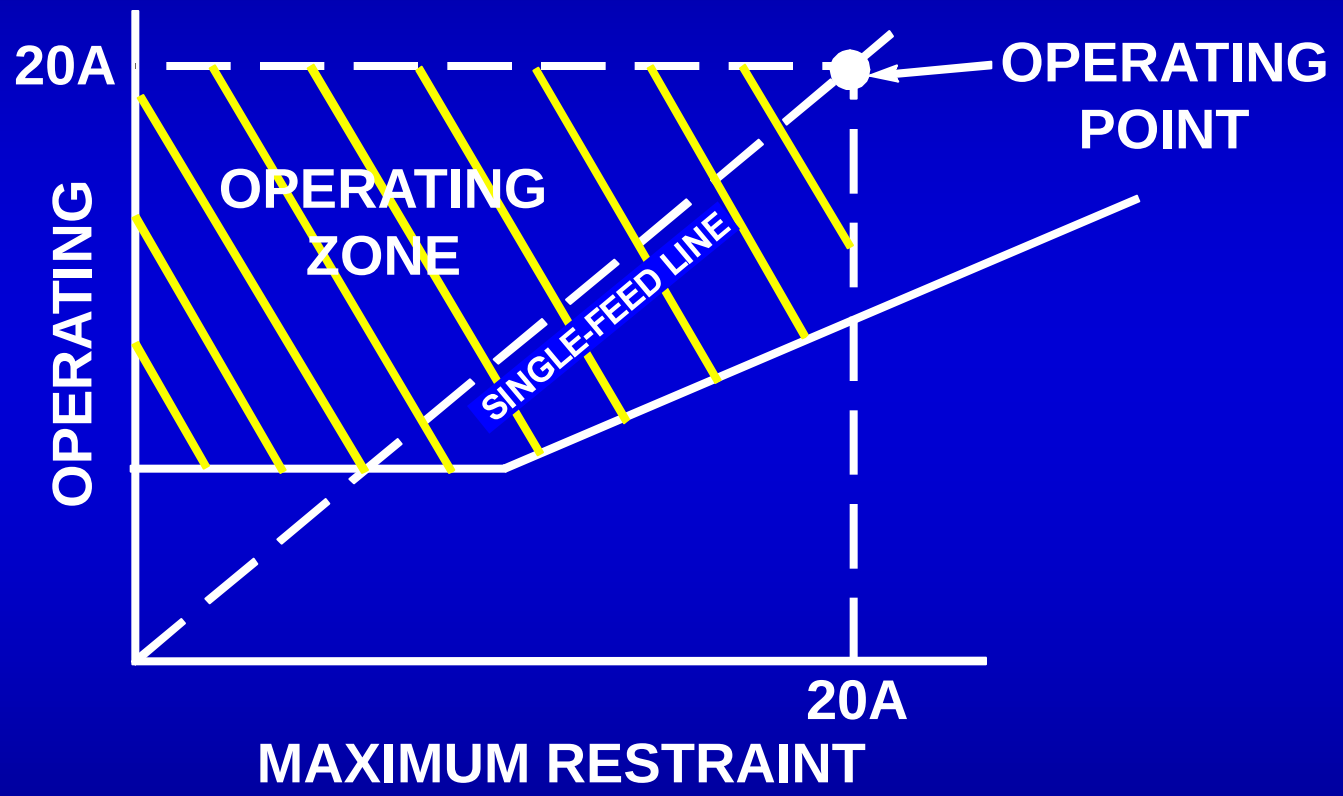
Bus/Transformer Application



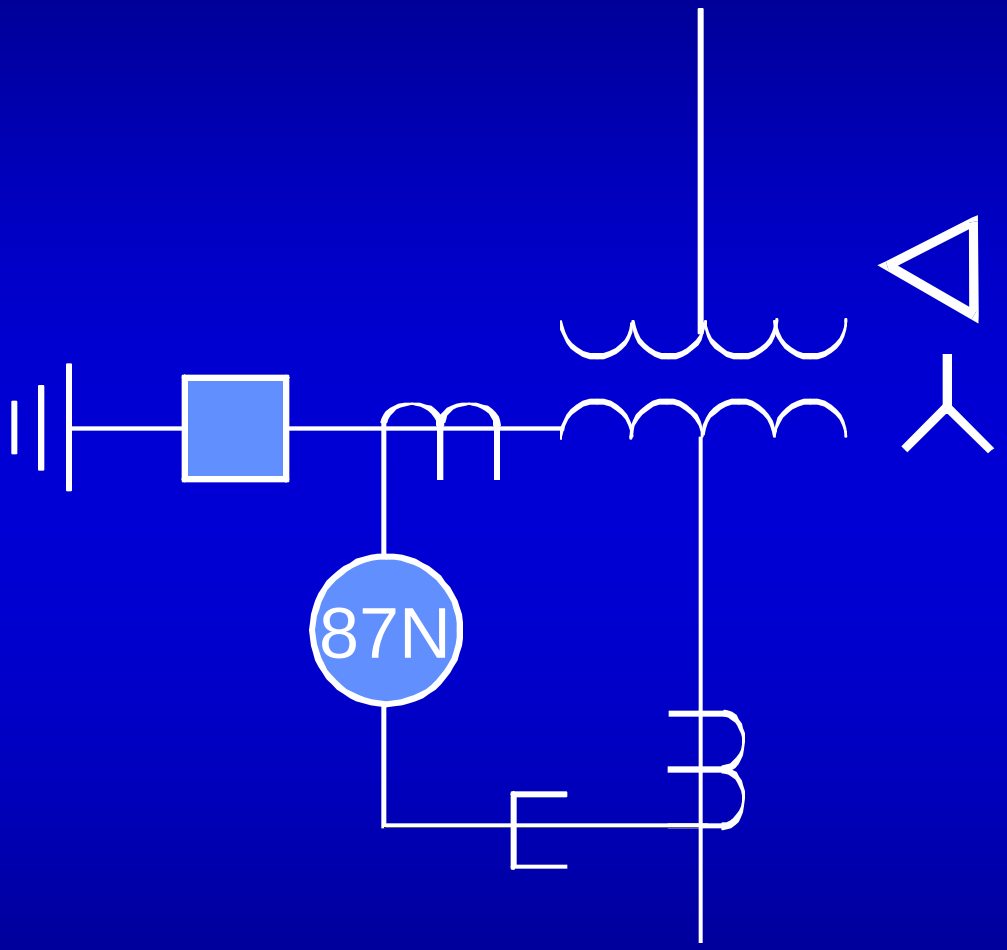
Bus/Transformer Application



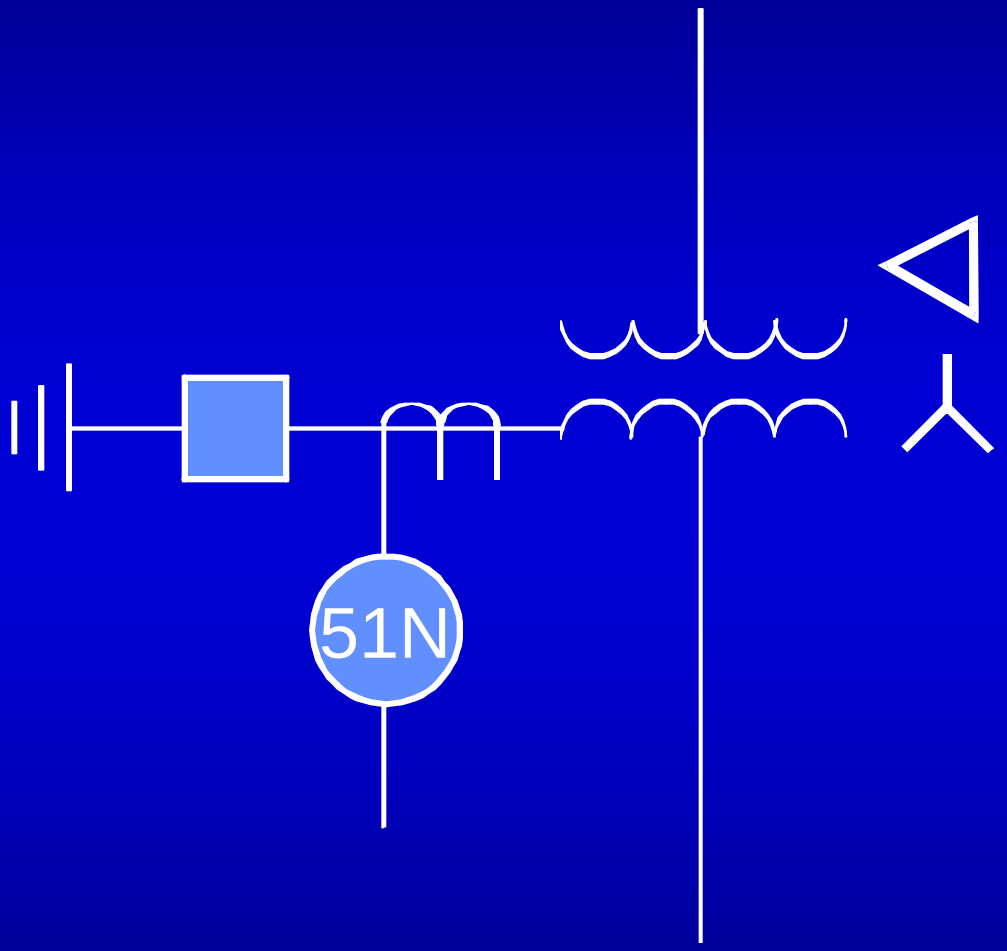
CT Error Produces Incorrect Operation



Ground Differential



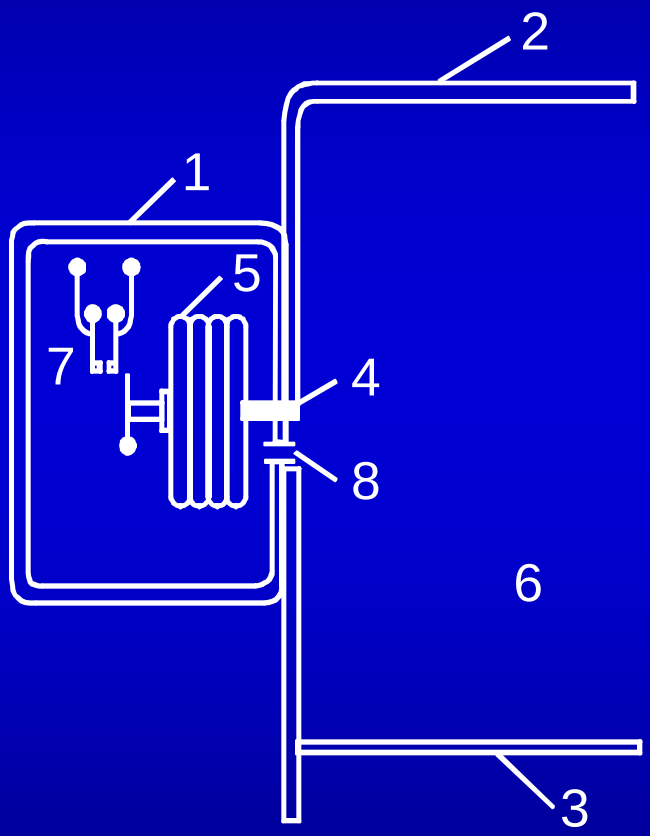
Neutral Overcurrent



Sudden Pressure Protection

- Operates on rate of change in gas or oil pressure
- Detects incipient low magnitude faults
- Protects for faults differential may not see
- Backs up differential for high magnitude internal faults
- Users are split between using sudden pressure for trip or alarm

Sudden Pressure Relay Mounted in Gas Space



1 SUDDEN PRESSURE RELAY

2 TRANSFORMER TANK

3 INSULATING OIL LEVEL

4 MAIN PORT

5 BELLOWS

6 GAS CUSHION

7 SNAP SWITCH

8 EQUALIZER PORT

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Thank You