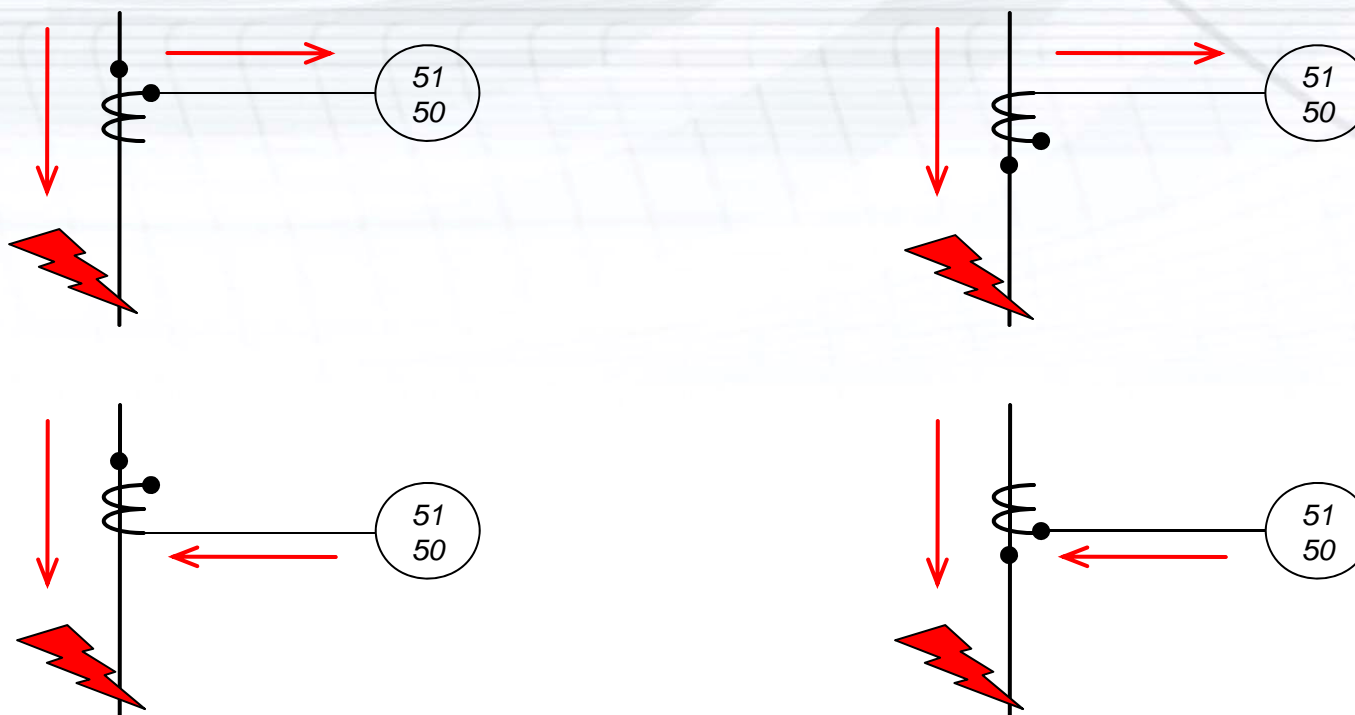


# Overcurrent Protection & Coordination for Industrial Applications

## Annex

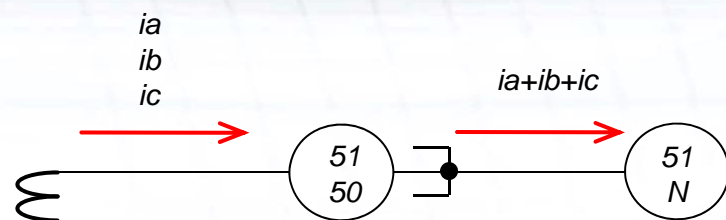
(by Dominik Pieniazek, P.E. – VI Engineering, LLC)

## Current Transformer Basics

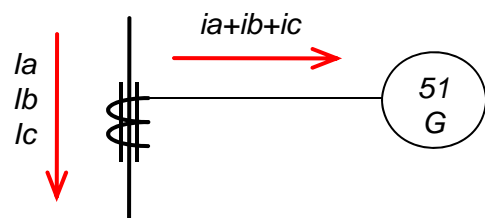


***Don't let polarity marks fool you!***

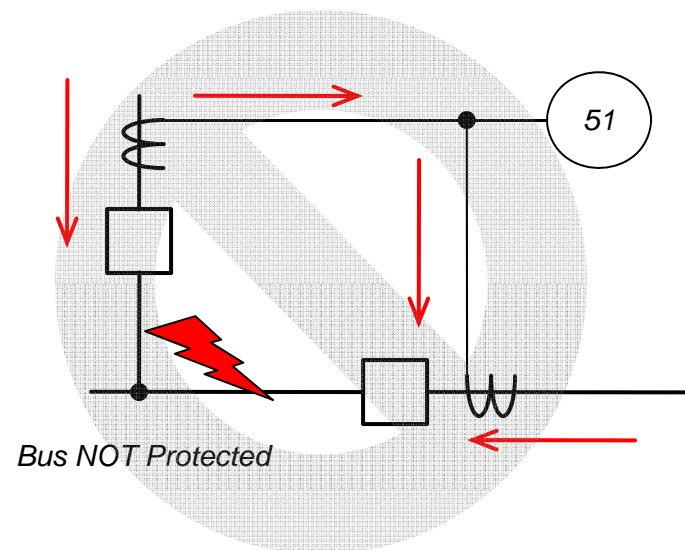
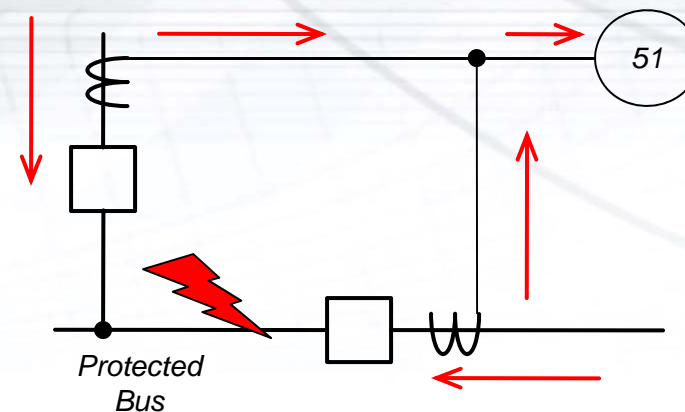
# Current Transformer Basics



*Residual CT connection*



*Zero sequence CT*



# Current Transformer Basics

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## ***Understand How CTs work!***

***IEEE Guide for the Application of Current  
Transformers Used for Protective  
Relaying Purposes - IEEE Std C37.110***

## Basic Guides for Protective Relay Settings

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### *Suggested “Rules of Thumb” for MV Equipment*

- *Transformers*
- *Bus*
- *Feeders*
- *Motors*
- *Capacitors*

## Basic Guides for Protective Relay Settings

### ***Suggested “Rules of Thumb” for MV Equipment***

- *The intent of this section is to provide a range of “typical” settings. It is the engineer’s responsibility to verify the application on an individual basis.*
- *This section does NOT apply to equipment 600 V and below.*
- *Care must be taken when coordinating a microprocessor TOC element with an electromechanical relay downstream. The electromechanical relay may respond to a fundamental phasor magnitude, true RMS, or rectified magnitude .*

## Rules of Thumb...(above 600 V)

### Power Transformers

Phase Relays  
(delta – wye)

#### **Primary – Phase Settings**

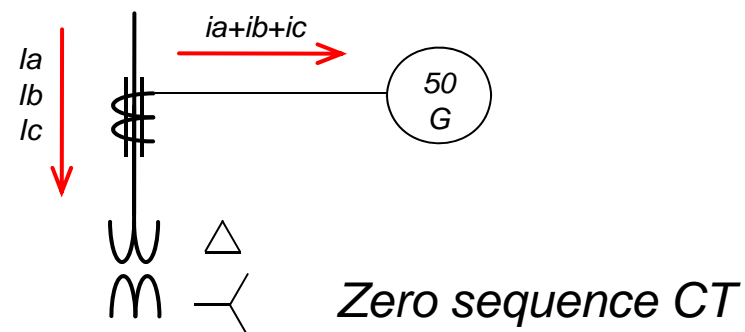
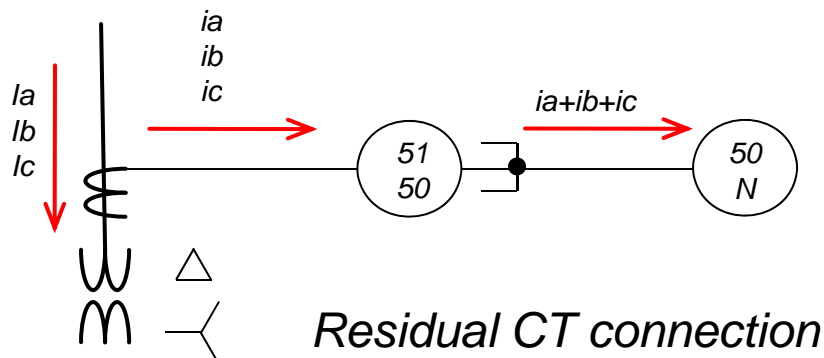
- CT Ratio: 200% FLA
- Set pickup to comply with NEC 450-3, but as a rule of thumb setting should be less than 300% of transformer self cooled rating or 150% of transformer maximum rating.
- Try to set the time dial such that pickup time for maximum through fault is in the neighborhood of 1.0 seconds or less. If higher, ensure that ANSI damage points are not exceeded.
- Set instantaneous at between 160% and 200% of maximum through fault (assume infinite bus). Ensure that available system short circuit allows this.
- Time Dial set at 1.0 to 1.5 seconds at maximum fault. Do not exceed 2.0 seconds which is the mechanical damage point.

## Rules of Thumb...(above 600 V)

### Power Transformers Primary Ground Relay Settings

#### Primary – Ground Settings

- Set 50G if primary winding is delta connected.
- Provide time delay (approx 20 msec) when setting digital relays with zero sequence CTs. No time delay when using electro-mechanical relays with zero sequence CTs.
- CT considerations:
  - Residually connected neutral. CT mismatch and residual magnetization will not allow the most sensitive setting. Recommend to delay above inrush.
  - Zero sequence CT. Care must be taken to ensure that cables are properly placed and cable shields are properly terminated.





## Rules of Thumb...( above 600 V)

### Power Transformers Primary Fuse Phase Protection

***Primary Fuse Rating of power transformer:***

*135% FLA < Fuse < 250% FLA. Try to stay in the range of 150%.*

*Primary fuse rating of power transformer should be approximately 200% FLA if transformer has a secondary main.*

*Generally use E-rated fuses. Note that TOC characteristics of fuses are not all the same.*

## Rules of Thumb...( above 600 V)

### Power Transformers Secondary Resistance Grounded

#### **Secondary Low-Resistance Grounded**

- *Set pickup for 20% to 50% of maximum ground fault. Note that ground resistors typically have a continuous rating of 25-50% of nominal. This value can be specified when purchasing the equipment.*

**Example:** 2000 A main breaker (2000:5 CTs), it may make sense to specify an 400 A ground resistor with a continuous rating of 50% (200 A) such that a 2000:5 residually connected CT input can be used with a minimum pickup ( $0.1 \times CT = 0.5 \text{ A secondary, } 200 \text{ A primary}$ ).

- *Set the time dial such that at the time to trip is 2.0 seconds at maximum ground fault*
- *Protect resistor using  $I^2t$  curve. Typical resistor is rated for 10 seconds at nominal current (to be specified at time of order).*

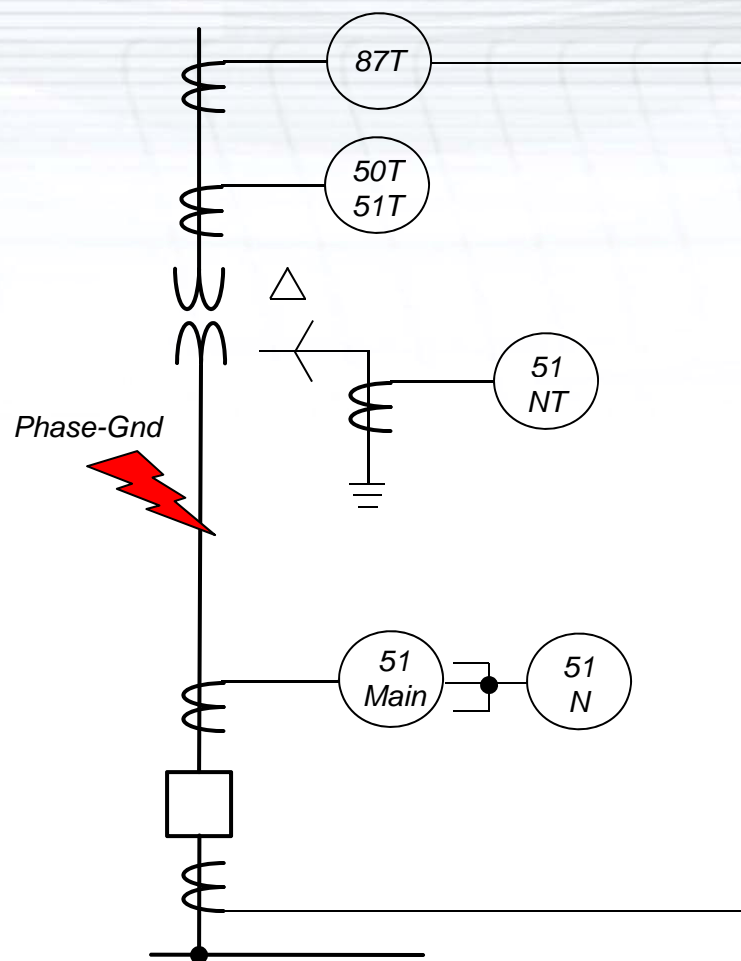
## Rules of Thumb...( above 600 V)

### Power Transformers Secondary Solidly Grounded

#### **Secondary Solidly Grounded** (for balanced three phase industrial loads)

- *If secondary is solidly grounded and neutral relay is available (using CT on X0 bushing), set pickup at approximately 50% of phase element and ensure transformer 2 second damage point is protected. Coordinate TOC with main breaker (or partial differential) ground relay.*
- *Decrease the primary phase element by 58% (to account for transformer damage curve shift). This is the equivalent current seen on the primary (delta) for a secondary ground fault (refer to the Symmetrical Components presentation on Feb 2-3, 2010 by Dr. Kurt Ederhoff).*

## Rules of Thumb...( above 600 V)



### Protection for Transformer

#### Secondary Faults on Solidly Grounded Systems

*It is certainly preferable to rely on the transformer primary phase overcurrent relay for backup of transformer secondary ground faults. However, downstream coordination does not always afford us that luxury (shifting the transformer damage curve and associated transformer primary relay 58%).*

*For solidly grounded transformer secondary installations, an argument can be made that the 87T is the primary protection and 51NT is the backup protection for a transformer secondary ground fault. This will allow you to set the 50T/51T relay without consideration of the 58% shift.*

## Rules of Thumb...( above 600 V)

### Power Transformers

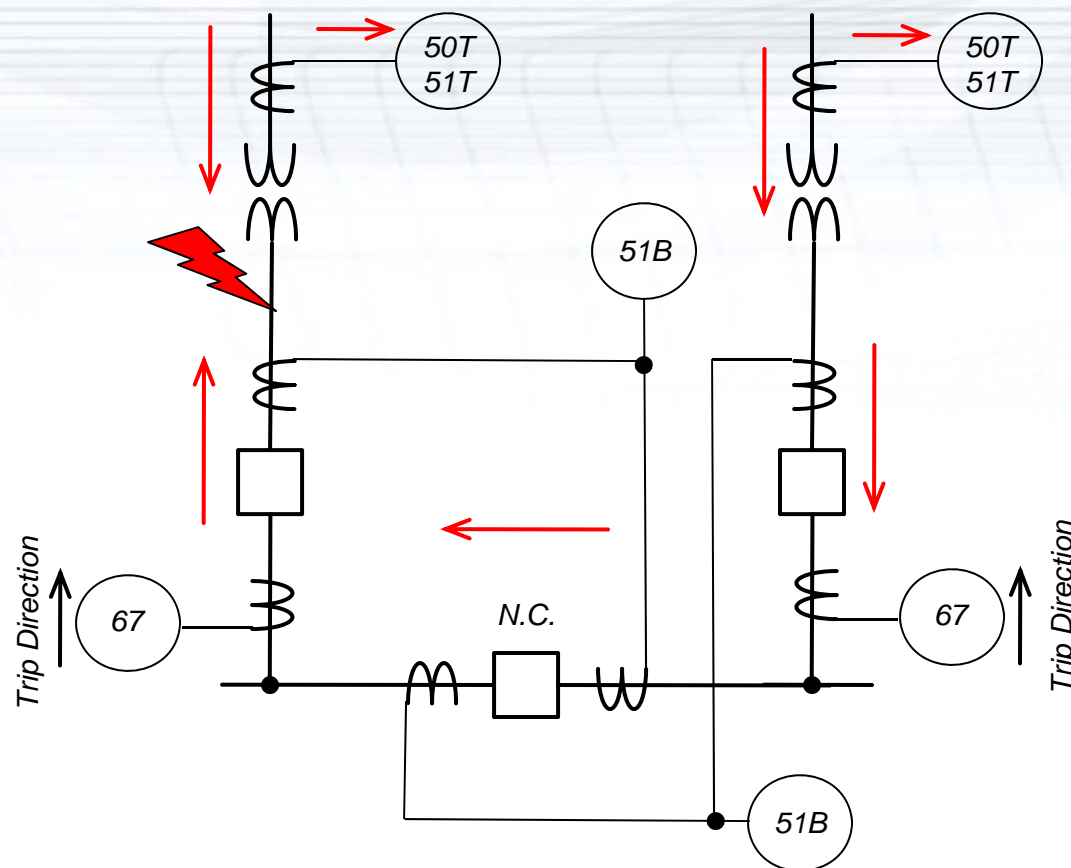
Primary Neutral (wye – delta)

#### ***Primary Side Wye-Grounded Transformer***

*If primary is solidly grounded and neutral relay is available, set pickup at approximately 50% of phase element. This must coordinate with upstream line protection devices (i.e. 21P, 21G, 67, 67G ...). If it's at the utility level, they will review and provide settings.*

*For generator step-up transformers (GSU), the HV 51NT should typically be the last device to trip for upstream ground faults. Ensure that the GSU damage curve and the H0 grounding conductor is protected.*

## Rules of Thumb...( above 600 V)



*Set 67 pickup at 40% of transformer FLA.  
Coordinate with time curve with 50T/51T*

## Directional Overcurrent

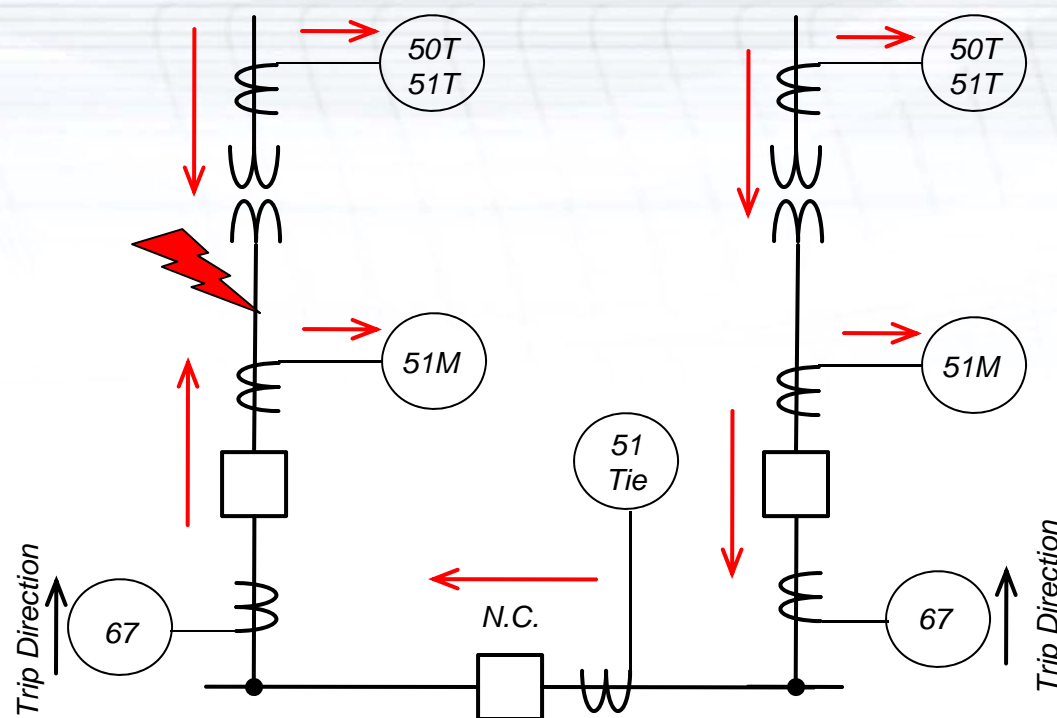
**Consideration for transformer secondary fault**

*For a fault between the transformer and main breaker, the partial differential bus relays will not detect current (other than motor contribution).*

*Both transformer primary overcurrent relays will detect see the same current. A directional overcurrent relay is required to prevent tripping of both transformers via 50T/51T.*



## Rules of Thumb...( above 600 V)



*Set 67 pickup at 40% of transformer FLA.  
Coordinate with time curve with 51Tie*

## Directional Overcurrent

**Consideration for transformer secondary fault**

*For a fault between the transformer and main breaker, the main and tie breaker relays will all see the same current (other than motor contribution).*

*The tie breaker will trip followed by the respective transformer primary overcurrent. A directional overcurrent relay is required to prevent loss of one bus.*

## Rules of Thumb...( above 600 V)

### Bus and Feeders

#### ***Bus Relays (Main Breaker or Partial Differential):***

*Pickup set between 100% and 125% FLA (150% FLA maximum)*

*Set to coordinate with transformer primary protective relaying*

*Do not enable the instantaneous overcurrent element on main breaker relays!*

#### ***Feeder Relays:***

*Set pickup to comply with NEC 240-100 (limited to 600% of rated ampacity of conductor). Actually, pickup permitted by NEC is slightly higher. Keep it down in the neighborhood of 200%. The intent is **NOT** to provide overload protection. The intent is to provide short-circuit protection.*

*Set time dial as required to coordinate with downstream devices while protecting conductor against damage.*

*Enable instantaneous element only if the load has a notable impedance (i.e. transformer, motor, capacitor, etc) or if the load is the end of a radial circuit.*



## Rules of Thumb...( above 600 V)

### Induction Motors

**Pickup** set at 101% - 120% **Nameplate Rating** depending on Service Factor and normal load.

Motor < 1,500 hp

Set at  $1.15 \times FLA$

Motor > 1,500 hp

Set just above  $FLA \times S.F.$

**Instantaneous Trip** set at 200% LRC. A higher pickup may be used depending on system available short circuit, however, do not lower below 160% LRC unless you know that the relay filters/removes the DC component.

Ensure that the instantaneous trip setting will not cause a motor starter to attempt interrupting a fault beyond its rating.

**Ground Overcurrent.** For Zero Sequence CT (BYZ) set ground **Trip** at 10A primary and **Alarm** at 5A primary. Set for instantaneous if using electromechanical and set at 20 msec delay (minimum) if using digital relays.

For solidly grounded systems, ensure that the ground trip setting will not cause a motor starter to attempt interrupting a fault beyond its rating.

**Mechanical Jam** set 150% FLA at 2 sec, unless application does not allow this (i.e. grinder, crusher, etc).

## Rules of Thumb...( above 600 V)

### Capacitors

#### **Capacitor Bank:**

*For individual protection, the **Fuse** protecting the capacitor is chosen such that its continuous current capability is greater than or equal to 135% of rated capacitor current. The feeder cable should be sized as such for continuous operation. This over rating is due to 10% for allowable overvoltage conditions, 15% for capacitor kVAR rating tolerance (this correlates to 15% percent deviation from nominal capacitance) and 10% for overcurrent due to harmonics.*

*For unbalance, set **Alarm** for loss of one capacitor, set **Trip** for overvoltage of 110% rated (nameplate).*

*For feeder protection, set **Pickup** at 135% of FLA, set **Time Dial** at 1.0, set **50P element** above maximum inrush and include a slight time delay to coordinate with individual fuse clear time. Plot TOC to protect the capacitor case rupture curve.*

*Note: Systems with high harmonic content require special attention.*

# Recommended References

# Recommended References

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- *Applied Protective Relaying – Westinghouse*
- *Protective Relaying Theory and Applications – ABB Power T&D Company, Edited by Walter Elmore*
- *Protective Relaying for Power Systems – IEEE Press, Edited by Stanley H. Horowitz*
- *Protective Relaying for Power Systems II – IEEE Press, Edited by Stanley H. Horowitz*
- *Protective Relaying, Principles and Applications – J. Lewis Blackburn*
- *AC Motor Protection – Stanley E. Zocholl*
- *Industrial and Commercial Power System Applications Series – ABB Power T&D Company*
- *Analyzing and Applying Current Transformers - Stanley E. Zocholl*