

# Transformer Differential Protection Setting Calculations

## Objectives

- **Examine CT performance**
- **Calculate winding “tap” values**
- **Determine 87T pickup points**
  - Determine variable percentage slope breakpoints
  - Determine harmonic restraint values
- **Determine 87H pick up**
- **Determine 87GD pick up**

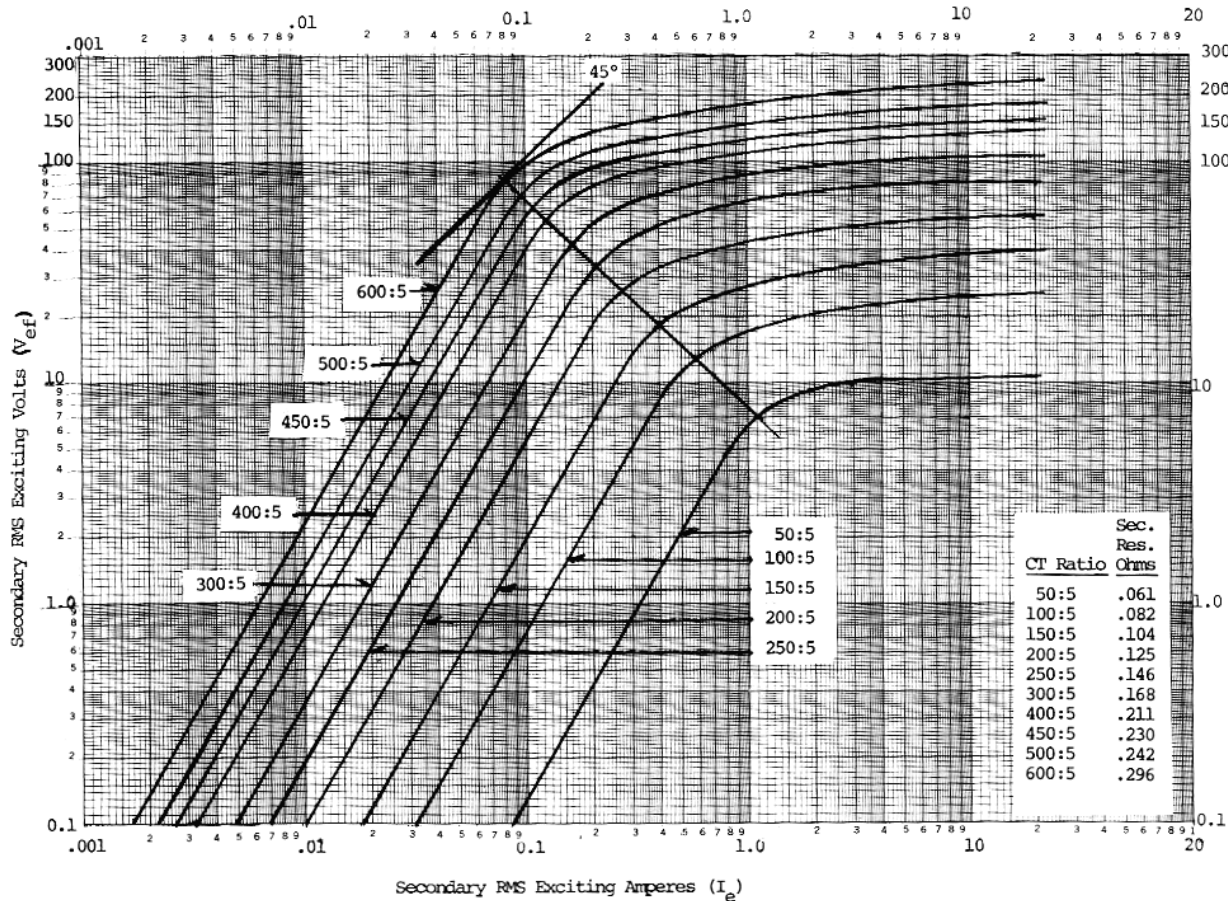
## CT Performance

- **Class “C” CTs have established secondary voltage/burden curves that are used to predict linear performance**
- **Operating a CT at values above the “kneepoint” on the curve invite unfaithful replication of the primary waveform and saturation**
- **Unfaithful replication (including saturation) between measurement CTs in a differential protection causes misoperation**

## Class “C” CTs

- **Class “C” CTs are designed to “faithfully” replicate primary currents to within +/- 10%**
- **Class designations designate maximum secondary CT circuit voltage at standard burden that can be applied to maintain accuracy**
  - $Z_{\text{rated}} = \text{Voltage Class} / 20 * \text{Rated Secondary Current}$
  - $Z_{\text{rated}} = \text{C800} / 20 * 5\text{A} = 8 \Omega, \therefore 800\text{V at } 8\Omega \text{ burden}$
  - $Z_{\text{rated}} = \text{C200} / 20 * 5\text{A} = 2 \Omega, \therefore 200\text{V at } 2\Omega \text{ burden}$

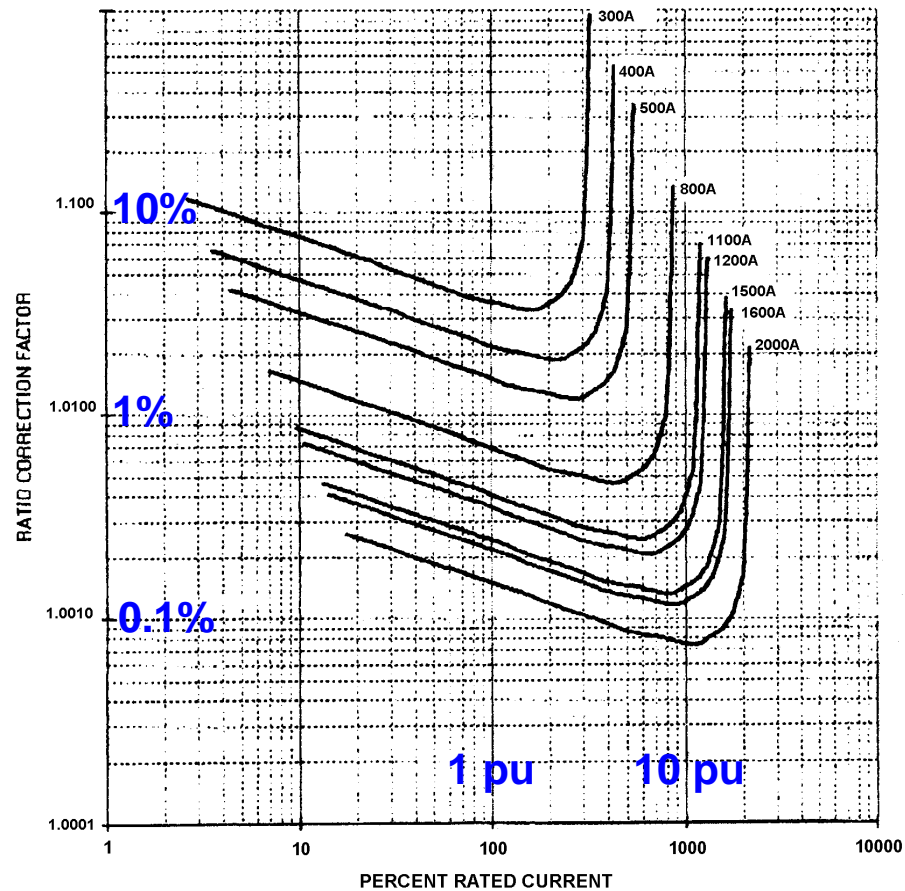
## Class "C" CT Performance Curve



Typical excitation curves for a 600:5 multiratio class C100 current transformer.

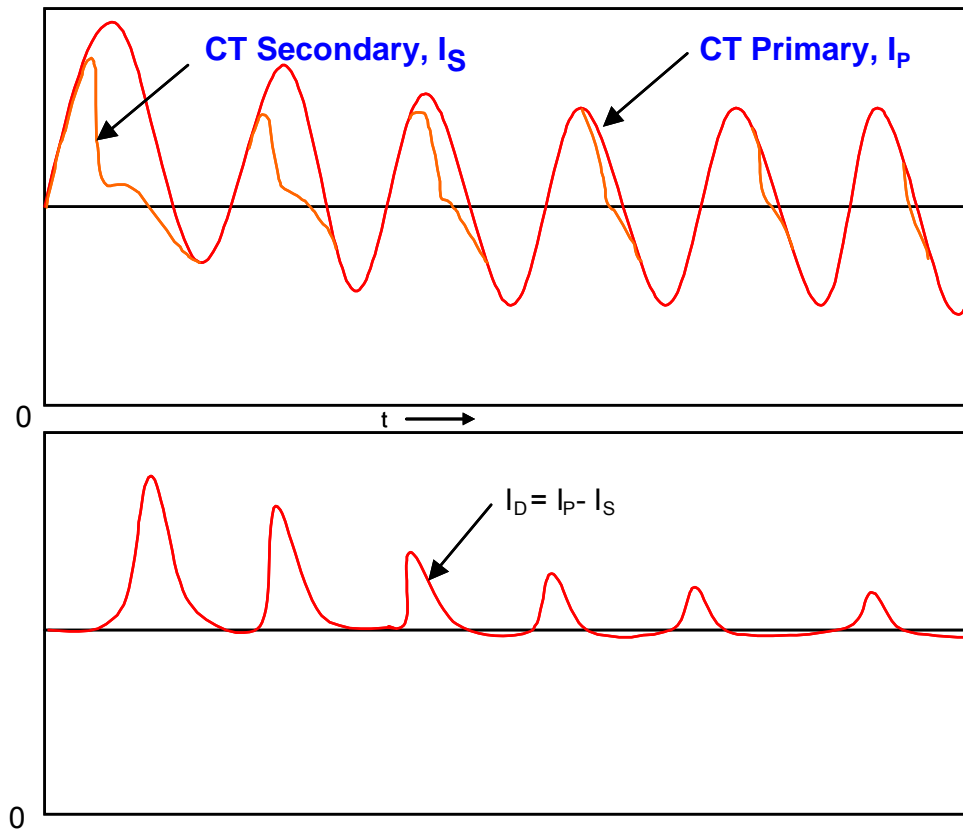
**More than 100V secondary and you're in trouble**

## CT Performance: +/- 10%



Accuracy curve for Class "C" 2000:5 multitap CT

## CT Performance



Comparison of primary to secondary waveforms with saturation

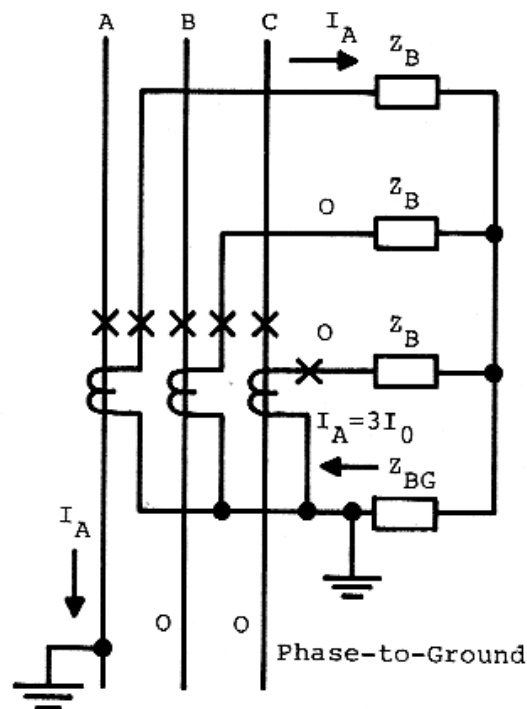
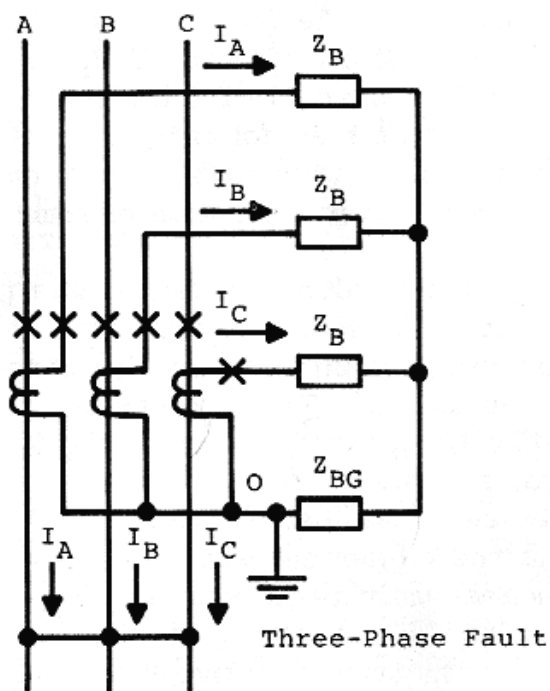
## CT Performance Calculation

### Use with Class “C” CTs

- Determine maximum primary phase and ground fault current
- Calculate secondary current based on CTR and CT connection type (wye or delta)
- Determine secondary CT circuit burden
- Determine maximum secondary voltage produced from burden with secondary fault currents
- Check maximum secondary voltage against CT capability

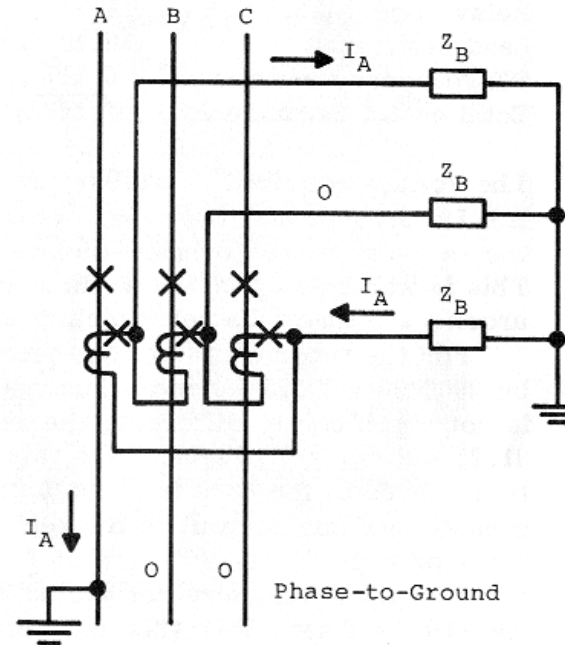
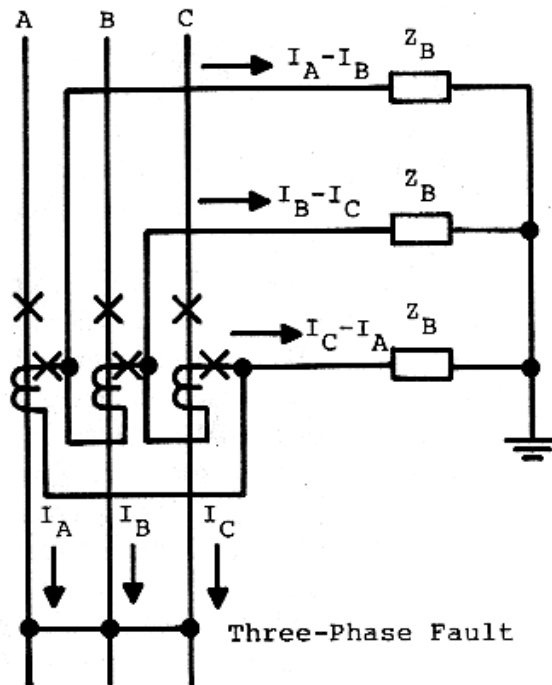


## Fault Types and Currents in Secondary Circuits



For WYE connected CTs, to obtain secondary current,  
use:  $(1X) I_{PRI} / CTR = I_{SEC}$

## Fault Types and Currents in Secondary Circuits



For Delta connected CTs, to obtain secondary current,  
use:  $(1.73) I_{PRI} / CTR = I_{SEC}$

## Burden Calculation

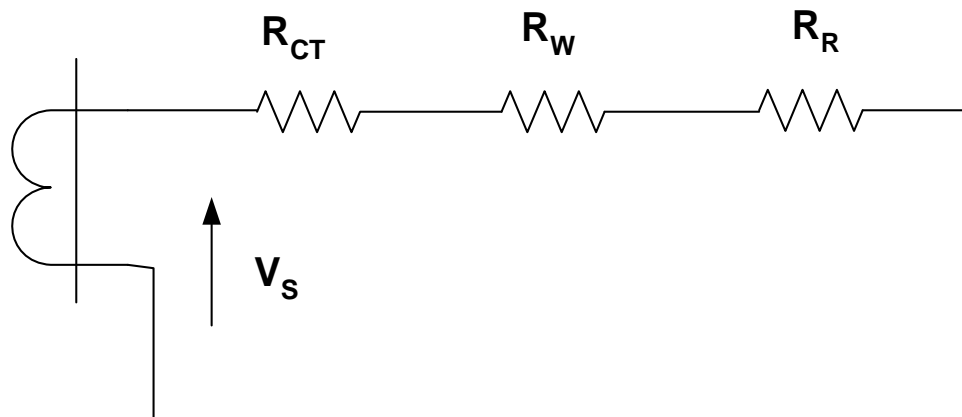
- **Determine all device burdens in secondary circuit**
  - Relays, meters, instrumentation
- **Determine lead burden**
  - Use wire tables (AWG @ ohms/ft)
- **Determine CT impedance**
- **Use CT data sheet (typ. 0.4 ohm or less)**

## Equivalent circuit of the CT Secondary wiring

Where  $R_{CT}$  is CT burden (internal)  
 $R_W$  total resistance of the ct secondary wiring.  
 $R_R$  is relay burden

$$V_S = I (R_{CT} + R_W + R_R)$$

Where  $I$  is the fault current and  $V_S$  is the ct secondary voltage. In order to make sure that the ct is in the linear range (to avoid ac saturation of the ct's),  $V_S$  should be less than the knee-point voltage of the ct excitation characteristics. (See IEEE Guide for the Application of Current Transformers Used for Protective Relaying Purposes C37.110-1996).



Equivalent circuit of the CT secondary wiring

## Burden Calculation

### Example

- **Relay = 0.5VA @ 5 A**  
 $R_R = VA/A^2$  ,  $R_R = 0.5/25 = 0.02 \Omega$
- $R_W = 2 \Omega$  (round trip)
- $R_{CT} = 0.20 \Omega$
- **Total = 2.22  $\Omega$**

## Secondary CT Circuit Voltage

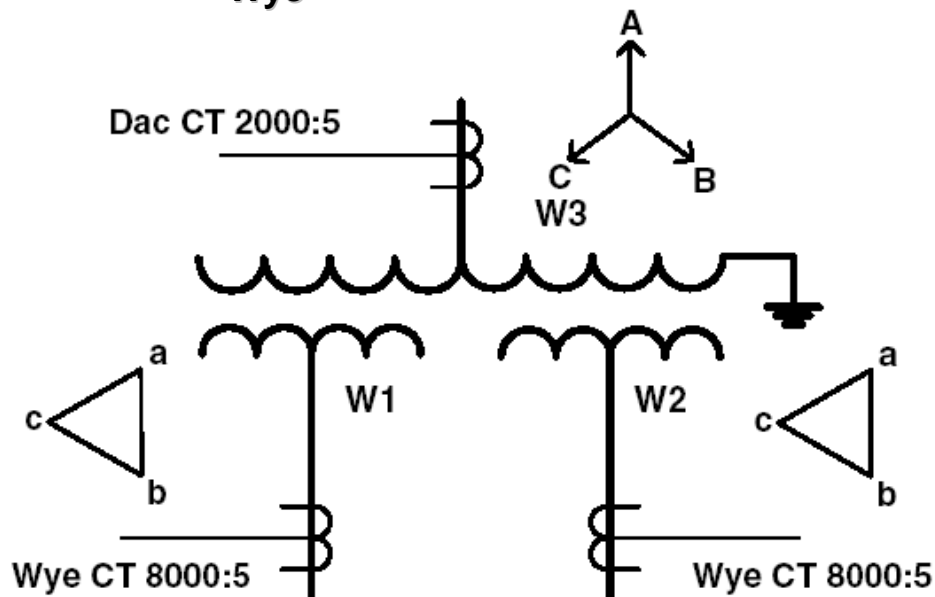
- Assume maximum secondary current of 90A and wye CTs
- $V_S = I (R_{CT} + R_W + R_R) * (F_{\Delta-Y})$ 
  - $(F_{\Delta-Y})$  = delta or wye CT factor
  - Use 1 for wye; use 1.73 for delta
- $V_S = 90 \times 2.22 * (1) = 199.8 \text{ V}$
- $V_S * 2 = 199.8 * 2 = 399.6 \text{ V}$ 
  - The 2X factor accounts for full DC offset
- Use at least a C400

## Power-Current Conversion

- **Used to determine current at rated transformer capacity**
  - Normally pick highest rating of multiple MVA rated transformers
- **Allows “nominalization” of the transformer windings**
- **Used to obtain “tap” that is digitally set**
- $I_{\text{tap}} = VA / [\sqrt{3} * V_{LL}] * CTR$
- **This accommodates:**
  - Transformer winding ratios
  - CT ratios

## Calculating “Tap”

**Transformer Rating**  
**392.8 MVA / 196.4 MVA / 196.4 MVA**  
**161 kV / 17.1 kV / 17.1 kV**  
 Wye



**Use highest rating as basis for tap calculations**



## Calculating “Tap”

$$87 \text{ CT Tap}_{w_1} = \frac{392.8 \text{ MVA} \times 10^3}{\sqrt{3} \times 17.1 \text{ kV} \times 1600} = 8.29$$

$$87 \text{ CT Tap}_{w_2} = \frac{392.8 \text{ MVA} \times 10^3}{\sqrt{3} \times 17.1 \text{ kV} \times 1600} = 8.29$$

$$87 \text{ CT Tap}_{w_3} = \frac{392.8 \text{ MVA} \times 10^3}{\sqrt{3} \times 161 \text{ kV} \times 400} = 3.52$$

- This nominalizes the current flow with respect to transformation ratios and CT ratios
- Rated power passing through any winding would yield these currents to the protection system

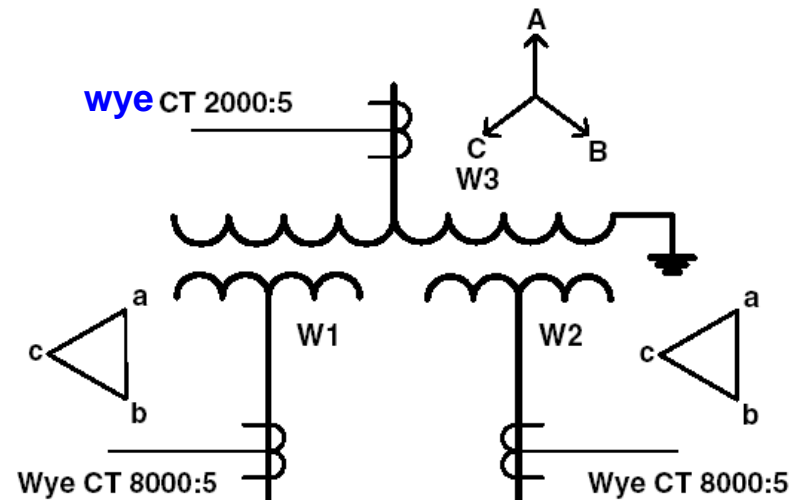
## Phase Shift Compensation

- From 3-Line Diagram, determine transformer and CT winding arrangements

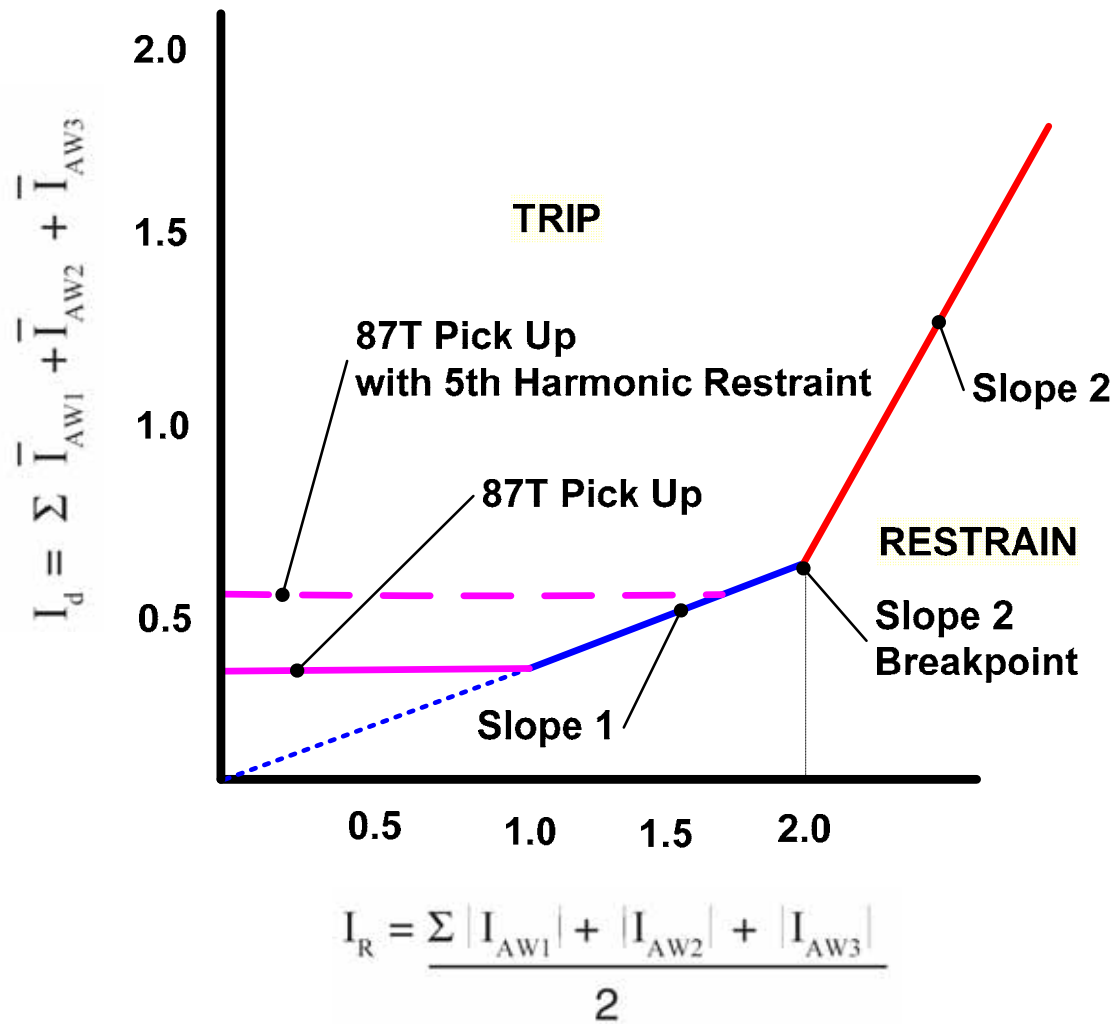
- Example**

- $W1 = DAC$ , wye CTs
- $W2 = DAC$ , wye CTs
- $W3 = Wye$ , wye CTs

Transformer Rating  
 392.8 MVA / 196.4 MVA / 196.4 MVA  
 161 kV / 17.1 kV / 17.1 kV



## Trip Characteristic – 87T



## Trip Characteristic – 87T

- **87T Pickup**
  - Set above the magnetizing current and other CT inaccuracies
  - 0.2 to 0.4 p.u. (typical setting)
- **Slope 1**
  - Set to accommodate +/- 10% CT inaccuracies
  - LTC adds another +/- 10%
  - Used for currents < 2X nominal
  - Typically set for 25% to 30% (can be set lower for non LTC transformers)
- **Slope 2 “breakpoint”**
  - Typically set at 2X rated current
  - This setting assumes that any current over 2X rated is a fault condition and is used to desensitize the element against unfaithful replication of currents due to CT saturation

## Trip Characteristic – 87T

- **Slope 2**
  - Typically set at 50% to 70%
  - Prevents relay misoperation for through faults with CT saturation.
  
- **Inrush Restraint (2<sup>nd</sup> and 4<sup>th</sup> harmonic)**
  - Typically set from 10-20%
  - Employ cross phase averaging (harmonic sharing) blocking for security – especially for modern transformers where the harmonic content is low
  
- **Overexcitation Restraint (5<sup>th</sup> harmonic)**
  - Typically set at 30%
  - Raise 87T pickup to 0.60 pu during overexcitation
  - No cross phase averaging is needed, as the magnetizing currents during overexcitation condition are symmetrical

## Trip Characteristic – 87H

- **87H Pickup**

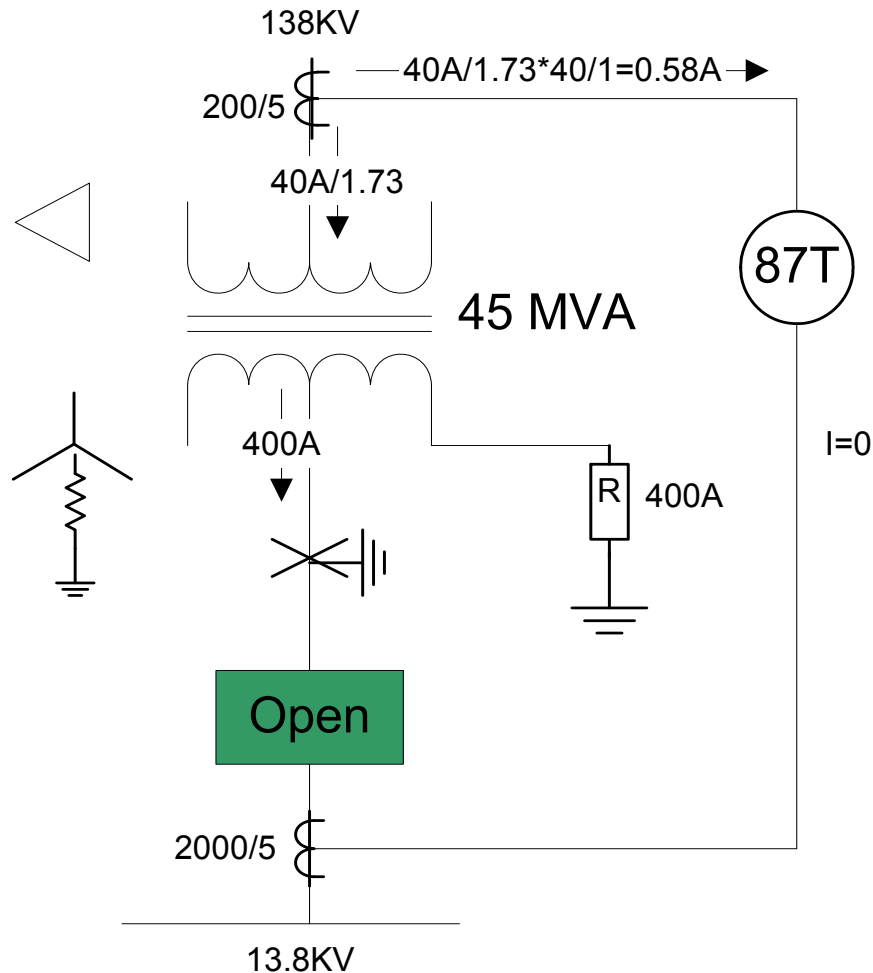
- Typically set at 8 to 12 pu rated current
- This value should be set to above the maximum possible inrush current.
- Relay oscillograph analysis software can be used determine the inrush current level and fine tune the setting.
- Also, need to know if the high set element uses fundamental component of current (typically the case) or total RMS current and set the pickup appropriately.

## Trip Characteristic – 87GD

### ■ 87GD Pickup

- Element normally uses directional comparison between phase residual current ( $3I_0$ ) and measured ground current ( $I_G$ ). The element becomes non-directional when the  $3I_0$  current is small (example  $< 140$  ma).
- Pickup of 0.2 to 0.5 A (5A rated CTs) can be applied when using same ratio CTs on both phase and ground circuits.
- When CT correction factor higher than 1.0 is applied, the pickup needs to be increased to account for noise amplification due to high CT ratio correction.
- Use 6 cycle time delay to provide security against misoperations during external phase-to-phase to ground faults with CT saturation. The time delay must not be set below 2 cycles.

# Improved Ground Fault Sensitivity



## Typical Pickup of 87T:

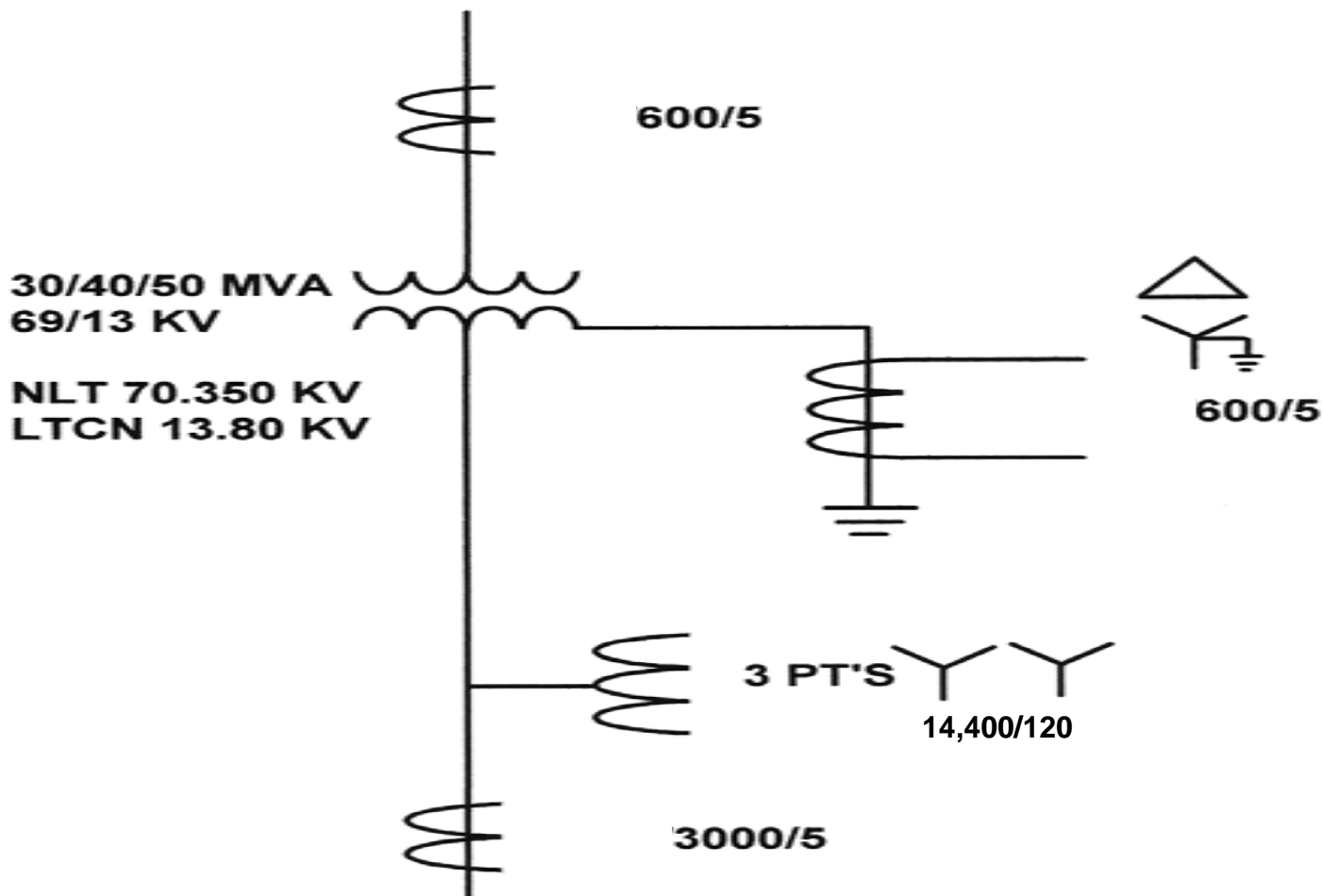
- 0.3 pu pickup
- Relay Tap set at Trans. Rating (45MVA)
  - $I_{FL138KV} = 4.71 \text{ A}$
  - $PU = 4.71\text{A} \times 0.3 = 1.41\text{A}$

- **WITHOUT GROUND DIFF. (87GD) THERE IS NO HIGHSPEED PROTECTION FOR SEC. GND FAULTS**



# **DIGITAL TRANSFORMER DIFFERENTIAL RELAY SETTING EXAMPLE**

# Sample Calculation - 87T

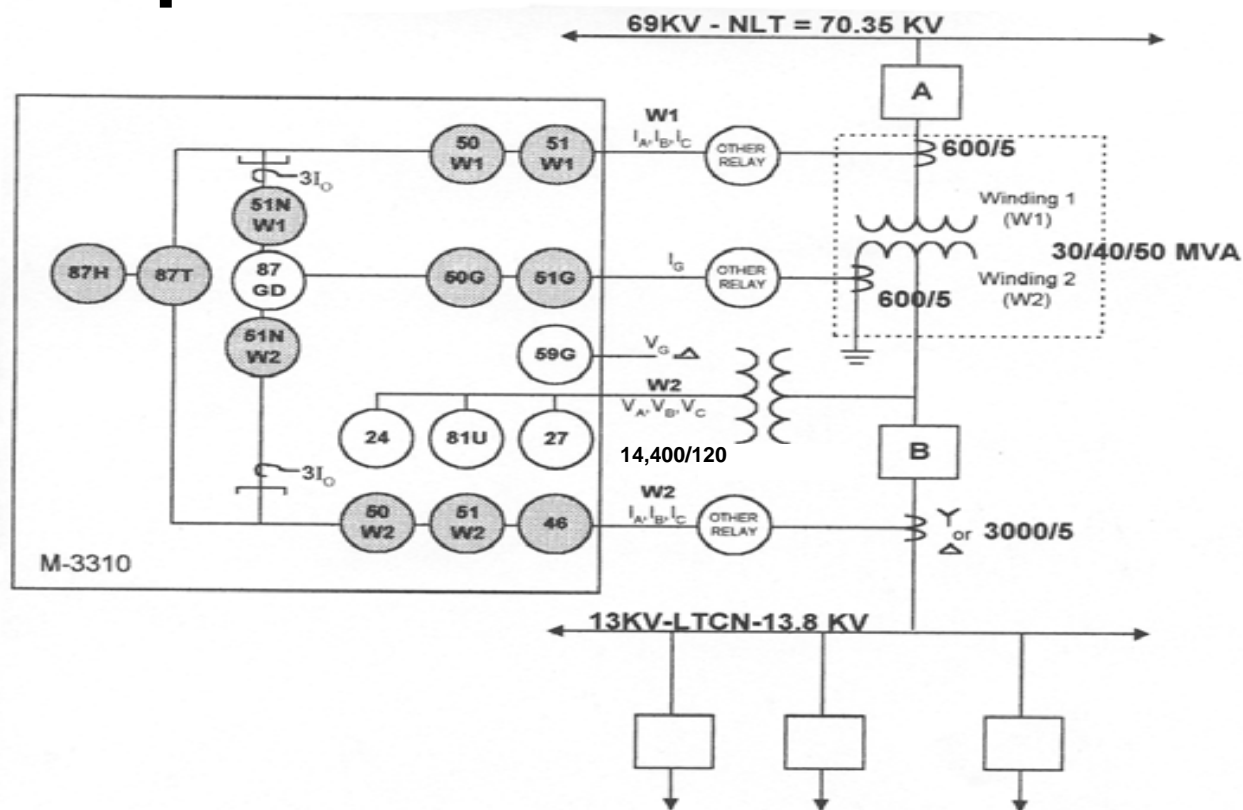


# 87T Sample Calculation

## *Calculating Differential Set Points and System Setup*

- Transformer Size – MVA Rating
- Voltage Taps – No Load
- Transformer Connection
- Current Transformer Ratios
- Current Transformer Connection
- Voltage Transformer Ratios
- Voltage Transformer Connections
  - L-G or L-L
- LTC Tap Information

# 87T Sample Calculation



## Data Required

MVA - 30/40/50

Voltage Taps - No load

Transformer Connections - US Standard Delta AB

CT W-1 600/5 = 120/1

CT W-2 3000/5 = 600/1

VT Ratio

VT Connection

LTC Tap Range

50 MVA

70.350/13.8 KV

Y-Δ CT's

Y-Y CT's

66.7/1

Y-Y

+/-10%

# 87T Sample Calculation

SETUP SYSTEM [S] [W] [R] [B] [C] [D]

Nominal Frequency: 60 Hz C.T. Secondary Rating: 5 A

Nominal Voltage: 120 60 V 140 V

Winding Selection  
 Three Windings  Two Windings Disable Winding:  W1  W2  W3

Transformer/CT Connection:  Standard  Custom

Transformer Connection (W1)	Transformer Connection (W2)	Transformer Connection (W3)
Dab	Y	Y
C.T. Connection (W1)	C.T. Connection (W2)	C.T. Connection (W3)
Y	Y	Y

Zero Sequence Filter Enable:  W1  W2  W3

Input Active State:

6	5	4	3	2	1
<input type="radio"/> Open	<input type="radio"/> Open	<input type="radio"/> Open	<input type="radio"/> Open	<input type="radio"/> Open	<input type="radio"/> Open
<input checked="" type="radio"/> Close	<input checked="" type="radio"/> Close	<input checked="" type="radio"/> Close	<input checked="" type="radio"/> Close	<input checked="" type="radio"/> Close	<input checked="" type="radio"/> Close

V.T. Configuration:  VA  VB  VC  VAB  VBC  VCA  VG

Phase Rotation:  ABC  ACB

V.T. x Phase Ratio:	120.0	: 1	1.0	6550.0
C.T. W1 Phase Ratio:	120	: 1	1	65500
C.T. W2 Phase Ratio:	600	: 1	1	65500
C.T. W3 Phase Ratio:	1	: 1	1	65500
C.T. W2 Ground Ratio:	120	: 1	1	65500
C.T. W3 Ground Ratio:	1	: 1	1	65500

Relay Seal-in Time

OUT 1:	30	8160 cycles
2:	30	
3:	30	
4:	30	
5:	30	
6:	30	
7:	30	
8:	30	2 cycles

Save Cancel

COMMUNICATES PHASING TO RELAY

COMMUNICATES METERING DATA TO RELAY

# 87T Sample Calculation W-2 Delta CT'S

SETUP SYSTEM [S] [W] [R] [B] [C] [D]

Nominal Frequency: 60 Hz C.T. Secondary Rating: 5 A

Nominal Voltage: 120 60 V 140 V

Winding Selection  
 Three Windings  Two Windings Disable Winding:  W1  W2  W3

Transformer/CT Connection:  Standard  Custom

Transformer Connection (W1)	Transformer Connection (W2)	Transformer Connection (W3)
Dab	Y	Y
C.T. Connection (W1)	C.T. Connection (W2)	C.T. Connection (W3)
Y	Dab	Y

Zero Sequence Filter Enable:  W1  W2  W3

Input Active State:

6	5	4	3	2	1
<input type="radio"/> Open	<input type="radio"/> Open	<input type="radio"/> Open	<input type="radio"/> Open	<input type="radio"/> Open	<input type="radio"/> Open
<input checked="" type="radio"/> Close	<input checked="" type="radio"/> Close	<input checked="" type="radio"/> Close	<input checked="" type="radio"/> Close	<input checked="" type="radio"/> Close	<input checked="" type="radio"/> Close

V.T. Configuration:  VA  VB  VC  VAB  VBC  VCA  VG

Phase Rotation:  ABC  ACB

V.T. x Phase Ratio:	120.0	: 1	1.0	6550.0
C.T. W1 Phase Ratio:	120	: 1	1	65500
C.T. W2 Phase Ratio:	600	: 1	1	65500
C.T. W3 Phase Ratio:	1	: 1	1	65500
C.T. W2 Ground Ratio:	120	: 1	1	65500
C.T. W3 Ground Ratio:	1	: 1	1	65500

Relay Seal-in Time

OUT 1:	30	8160 cycles
2:	30	
3:	30	
4:	30	
5:	30	
6:	30	
7:	30	
8:	30	2 cycles

Save Cancel

COMMUNICATES PHASING TO RELAY

COMMUNICATES METERING DATA TO RELAY

# 87T Sample Calculation

## Step 1 -Check CT and Relay Input Ratings

Sample Transformer Ratings:

$$OA/FA/FA = 30/40/50 \text{ MVA}$$

Short Time Rating of this transformer is

$$1.35 \times 50 \text{ MVA} = 67.5 \text{ MVA}$$

Relay current input is rated at 2X Nominal Rating

i.e. 5A relay = 10 AMPS continuous

$$I_{67.5 \text{ MVA W-2 PRI}} = 67.500 \text{ KVA} / 13.8 \text{ KV} \times \sqrt{3} = 2827 \text{ A}$$

$$I_{67.5 \text{ MVA W-2 SEC}} = 2827 / 600 / 1 = 4.71 \text{ A}$$

For  $\Delta$  CTs relay gets

$$4.71 \times \sqrt{3} = 8.15 \text{ A} < 10 \text{ A Sec. Winding (W2) OK}$$

$$I_{67.5 \text{ MVA W-1 PRI}} = 67.500 \text{ KVA} / 70.35 \text{ KV} \times \sqrt{3} = 554.6 \text{ A}$$

$$I_{67.5 \text{ MVA W-1 SEC}} = 554.6 / 120 / 1 = 4.62 \text{ A} < 10 \text{ A Pri. Winding (W1) OK}$$

# 87T Sample Calculation

Step 2: Select W1 & W2 Tap Settings Balance at OA Rating

$$\boxed{87T \text{ W1 CT Tap}} = \frac{MVA \times 10^3}{\sqrt{3} V_{W1L-L} \cdot CTR1} = \frac{30000}{\sqrt{3} \cdot 70.35 \cdot 120/1} = \boxed{2.05 \text{ A}}$$

- W2

$$\boxed{87T \text{ W2 CT Tap} =}$$

cal A – ΔCTs

$$\begin{aligned} 87T W2 CT Tap = & \frac{MVA \times 10^3}{\sqrt{3} \cdot V_{W2} \cdot CTR2} \cdot \sqrt{3} = \\ & \frac{30000}{\sqrt{3} \cdot 13.8KV \cdot 600/1} = \end{aligned}$$

Handled By Relay

$$\boxed{2.09 \text{ A}}$$

cal B – YCTs

$$\begin{aligned} 87T W2 CT Tap = & \frac{MVA \times 10^3}{\sqrt{3} \cdot V_{W2} \cdot CTR2} = \\ & \frac{30000}{\sqrt{3} \cdot 13.8KV \cdot 600/1} = \end{aligned}$$

$$\boxed{2.09 \text{ A}}$$

or



# 87T Sample Calculation

Step 2: Select W1 & W2 Tap Settings Balance at OA Rating

TAP VALUES

(87) - PHASE DIFFERENTIAL CURRENT

Pickup:  5.0 p.u.   20.0 p.u. 87H

Delay:  1 Cycle   8160 Cycles

OUTPUT @ Blocking Input

8  7  6  5  4  3  2  1  6  5  4  3  2  1

Pickup:  0.10 p.u.   1.00 p.u. 87T

Percent Slope #1:  5%   100%

Percent Slope #2:  5%   200%

Slope Break Point:  1.0 p.u.   4.0 p.u.

Even Harmonics Restraint:  Disable  Enable  Enable w/cross average  
 (2nd, 4th)  5%   50%

5th Harmonic Restraint:  Disable  Enable  Enable w/cross average  
  5%   50%

Pickup at 5th H.R.:  0.10 p.u.   2.00 p.u.

OUTPUT @ Blocking Input

8  7  6  5  4  3  2  1  6  5  4  3  2  1

W1 C.T. Tap:  2.05   10.00

W2 C.T. Tap:  2.09   10.00

W3 C.T. Tap:  2.00   10.00

@ : WARNING, You have not selected an output!

Save

Cancel

## 87T Sample Calculation

### Step 3: Select minimum pickup of 87T

- Pick up should be set to prevent operation of 87T due to transformer steady-state excitation current.
- Typical Transformer excitation current  $\sim 1\% = .01$  pu
- CT Error  $10\% = .10$  pu
- LTC Error  $10\% = .10$  pu
- Safety Margin Typical  $\underline{5\%} = \underline{.05}$  pu
- Typical setting is 0.26 to 0.35 p.u.

26 % .26 pu

Select p.u. at 0.3

# 87T Sample Calculation

## Step 3: Select minimum pickup of 87T

**MINIMUM PICKUP**

(87) - PHASE DIFFERENTIAL CURRENT

Pickup:  p.u.   20.0 p.u. 87H

Delay:  Cycle   8160 Cycles

OUTPUT  Blocking Input

8  7  6  5  4  3  2  1  6  5  4  3  2  1

Pickup:  p.u.   1.00 p.u. 87T

Percent Slope #1: %   100%

Percent Slope #2: %   200%

Slope Break Point:  p.u.   4.0 p.u.

Even Harmonics Restraint:  Disable  Enable  Enable w/cross average  
%   50%

5th Harmonic Restraint:  Disable  Enable  Enable w/cross average  
%   50%

Pickup at 5th H.R.:  p.u.   2.00 p.u.

OUTPUT  Blocking Input

8  7  6  5  4  3  2  1  6  5  4  3  2  1

W1 C.T. Tap:  1.00   10.00

W2 C.T. Tap:  1.00   10.00

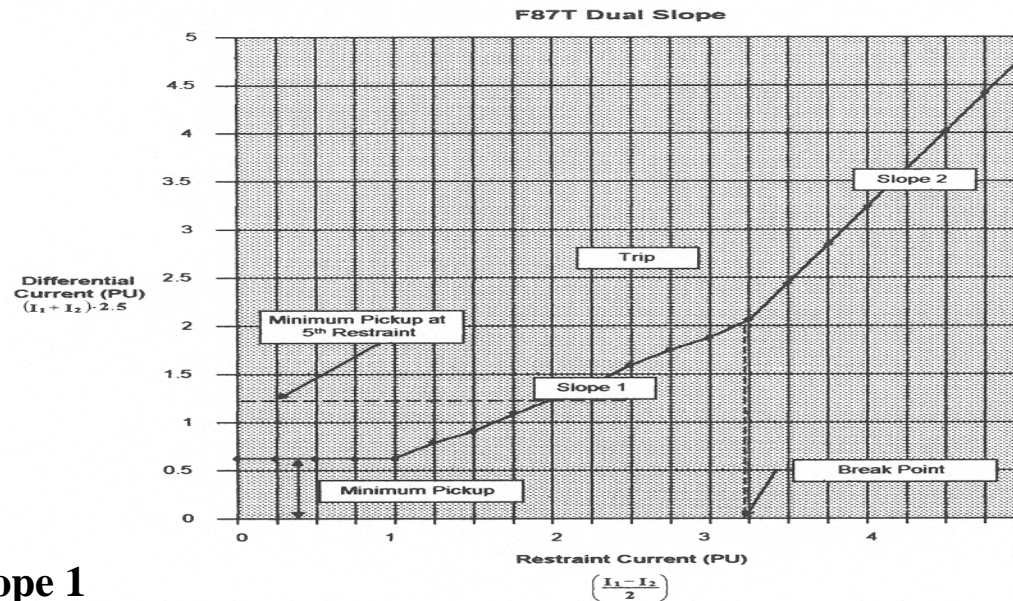
W3 C.T. Tap:  1.00   10.00

@ : WARNING, You have not selected an output!

Save

Cancel

## Step 4: Select Slope # 1 Setting



### Slope 1

The setting of Slope #1 should be set according to various possible errors:

1. Tapchanger operations in the power transformer (worst case  $\pm 10\%$ ) 10%
2. CT mismatch due to ratio errors. Errors can be as high  
as  $\pm 10\%$  10%
3. Transformer excitation current (typical current of 1%) 1%
4. Relay measurement error 5%

**Set Slope # 1 = 30%**

## Step 4: Select Slope # 1 Setting

**SLOPE #1  
SETTING**

(87) - PHASE DIFFERENTIAL CURRENT

Pickup:  p.u.   20.0 p.u.

Delay:  Cycle   8160 Cycles

OUTPUT @ Blocking Input

8  7  6  5  4  3  2  1  6  5  4  3  2  1

---

Pickup:  0.10 p.u.   1.00 p.u.

**Percent Slope #1:**  5%   100%

Percent Slope #2:  5%   200%

Slope Break Point:  1.0 p.u.   4.0 p.u.

Even Harmonics Restraint:  ( 2nd, 4th )  Disable  Enable  Enable w/cross average  
5%   50%

5th Harmonic Restraint:   Disable  Enable  Enable w/cross average  
5%   50%

Pickup at 5th H.R.:  0.10 p.u.   2.00 p.u.

OUTPUT @ Blocking Input

8  7  6  5  4  3  2  1  6  5  4  3  2  1

W1 C.T. Tap:  1.00   10.00

W2 C.T. Tap:  1.00   10.00

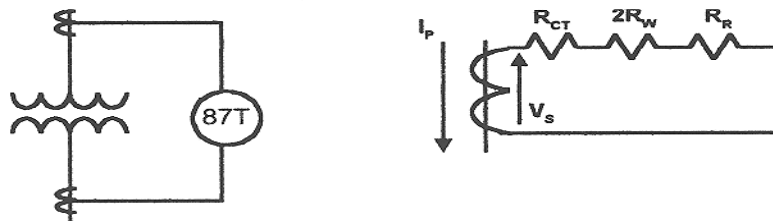
W3 C.T. Tap:  1.00   10.00

@ : WARNING, You have not selected an output!

## Step 5: Select slope #2 Setting

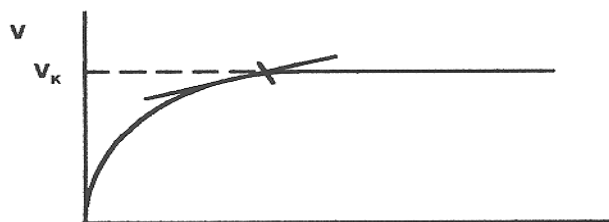
- Provides security for high fault current levels outside the differential zone where CT inputs can saturate.
- Factors effecting CT saturation
  - Residual magnetism in CT core
  - CT characteristic mismatch
  - CT circuit burden

### • CT Burden Check



$$V_S = \frac{I_P}{N} [R_{CT} + 2 R_W + R_R]$$

$$V_S < V_K$$



# 87T Sample Calculation

## Step 5: Select Slope #2 Setting

Typical Slope #2 Settings is Twice  
Slope #2

60%

# 87T Sample Calculation

## Step 5: Select Slope #2 Setting

**SLOPE #2  
SETTING**

(87) - PHASE DIFFERENTIAL CURRENT

Pickup:  p.u.   20.0 p.u.

Delay:  Cycle   8160 Cycles

OUTPUT  Blocking Input

8  7  6  5  4  3  2  1  6  5  4  3  2  1

Pickup:  0.10 p.u.   1.00 p.u.

Percent Slope #1:  5%   100%

**Percent Slope #2:**  5%   200%

Slope Break Point:  p.u.   4.0 p.u.

Even Harmonics Restraint:  Disable  Enable  Enable w/cross average  
( 2nd, 4th )  5%   50%

5th Harmonic Restraint:  Disable  Enable  Enable w/cross average  
 5%   50%

Pickup at 5th H.R.:  p.u.   2.00 p.u.

OUTPUT  Blocking Input

8  7  6  5  4  3  2  1  6  5  4  3  2  1

W1 C.T. Tap:  1.00   10.00

W2 C.T. Tap:  1.00   10.00

W3 C.T. Tap:  1.00   10.00

@ : WARNING, You have not selected an output!



## 87T Sample Calculation

### **Step 6: Select Break Point between Slope 1 and Slope 2**

- Breakpoint is crossover from Slope 1 to Slope 2

**Typical Breakpoint = 2.0**

## Step 6: Select Break Point between Slope 1 and Slope 2

**BREAK POINT  
BETWEEN SLOPES  
1 AND 2**

(87) - PHASE DIFFERENTIAL CURRENT

Pickup:  p.u.  p.u. 87H  
 Delay:  Cycle  Cycles

OUTPUT  8  7  6  5  4  3  2  1  @  
 Blocking Input  6  5  4  3  2  1

Pickup:  0.10 p.u.  p.u. 87T  
 Percent Slope #1:  5%   
 Percent Slope #2:  5%   
 Slope Break Point:  1.0 p.u.  p.u.  
 Even Harmonics Restraint:  Disable  Enable  Enable w/cross average  
 ( 2nd, 4th )  5%   
 5th Harmonic Restraint:  Disable  Enable  Enable w/cross average  
 5%   
 Pickup at 5th H.R.:  p.u.  p.u.

OUTPUT  8  7  6  5  4  3  2  1  @  
 Blocking Input  6  5  4  3  2  1

W1 C.T. Tap:  1.00   
 W2 C.T. Tap:  1.00   
 W3 C.T. Tap:  1.00

@ : WARNING, You have not selected an output!

Save  
Cancel

# 87T Sample Calculation

## Step 7: Select Inrush Harmonic Restraint

- **Relay uses 2<sup>nd</sup> and 4<sup>th</sup> harmonics**
- **Percent harmonics defined as –**
- **Amount of 2<sup>nd</sup> and 4<sup>th</sup> harmonics depend on:**
  - Magnetizing characteristics of transformer core
  - Residual magnetism in core
- **Typical Settings**
  - 15% for most transformers
  - can be 10% or lower on new transformers with low core losses and steep magnetizing curves. Setting below 10% risks blocking for internal faults.

# 87T Sample Calculation

## Step 7: (continued)

### **Cross Phase Averaging (recommended)**

- Inrush harmonic level different in each phase
- Cross phase averaging means each phase restrains on harmonics in other phases. For example:

$$I_{dcPA24} = \sqrt{I_{A_{d24}}^2 + I_{B_{d24}}^2 + I_{C_{d24}}^2}$$

## Step 7: Select Inrush Harmonic Restraint

**INRUSH HARMONIC  
RESTRAINT**

(87) - PHASE DIFFERENTIAL CURRENT

Pickup:  p.u.   20.0 p.u. 87H

Delay:  Cycle   8160 Cycles

OUTPUT @ Blocking Input

8  7  6  5  4  3  2  1  6  5  4  3  2  1

Pickup:  0.10 p.u.   1.00 p.u. 87T

Percent Slope #1:  5%   100%

Percent Slope #2:  5%   200%

Slope Break Point:  1.0 p.u.   4.0 p.u.

Even Harmonics Restraint:  Disable  Enable  Enable w/cross average  
( 2nd, 4th )  5%   50%

5th Harmonic Restraint:  Disable  Enable  Enable w/cross average  
 5%   50%

Pickup at 5th H.R.:  0.10 p.u.   2.00 p.u.

OUTPUT @ Blocking Input

8  7  6  5  4  3  2  1  6  5  4  3  2  1

W1 C.T. Tap:  1.00   10.00

W2 C.T. Tap:  1.00   10.00

W3 C.T. Tap:  1.00   10.00

@ : WARNING, You have not selected an output!

Save

Cancel

# 87T Sample Calculation

## Step 8: Select Overexcitation Harmonic Restraint

- **M-3311 uses 5<sup>th</sup> harmonic.**
- **Overexcitation (V/Hz) produces high amounts of 5<sup>th</sup> harmonic current.**
- **87T in M-3311 shifts minimum pickup to higher value, typically 150 to 200% of normal 87T p.u.**

Typical setting is 200% X 87T pickup, or 0.3 X  
200% = 0.6 p.u.

# 87T Sample Calculation

## Step 8: (continued)

Typical setting is 30%

- Amount of 5<sup>th</sup> harmonic depends on transformer core magnetizing characteristics.
- No cross phase averaging – Overexcitation is symmetrical.

# 87T Sample Calculation

## Step 8: Select Overexcitation Harmonic Restraint

**OVEREXCITATION  
HARMONIC RESTRAINT**

(87) - PHASE DIFFERENTIAL CURRENT

Pickup: 5.0 p.u. 20.0 p.u. 87H  
 Delay: 1 Cycle 8160 Cycles

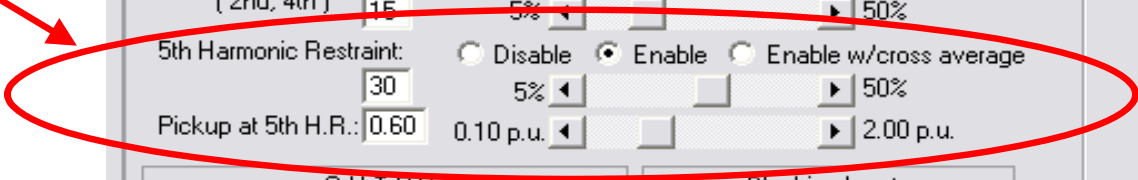
OUTPUT @ Blocking Input  
 8 7 6 5 4 3 2 1  6 5 4 3 2 1

Pickup: 0.30 0.10 p.u. 1.00 p.u. 87T  
 Percent Slope #1: 30 5% 100%  
 Percent Slope #2: 60 5% 200%  
 Slope Break Point: 2.0 1.0 p.u. 4.0 p.u.  
 Even Harmonics Restraint: (2nd, 4th) 15 5% 50%  
 Disable  Enable  Enable w/cross average  
 5th Harmonic Restraint: 30 5% 50%  
 Disable  Enable  Enable w/cross average  
 Pickup at 5th H.R.: 0.60 0.10 p.u. 2.00 p.u.

OUTPUT @ Blocking Input  
 8 7 6 5 4 3 2 1  6 5 4 3 2 1

W1 C.T. Tap: 2.05 1.00 10.00  
 W2 C.T. Tap: 2.09 1.00 10.00  
 W3 C.T. Tap: 2.00 1.00 10.00

@ : WARNING, You have not selected an output!





## **Step 9: Setting 87H Unrestrained High Set Differential**

- 87H function is not blocked by any harmonic restraint
- Pickup must be set above first peak of inrush current
- 87H is used in almost all transformer differentials to overcome restraint of 87T due to CT saturation for high internal transformer faults
- Typical pickup setting is 8 to 12 p.u.

**Set at 10 p.u.**

**Set delay at 1 cycle**

# 87T Sample Calculation

## Step 9: Setting 87H Unrestrained High Set Differential

**UNRESTRAINED  
HIGHSET DIFF.**

(87) - PHASE DIFFERENTIAL CURRENT

Pickup: 10.0 5.0 p.u. 20.0 p.u. 87H

Delay: 1 1 Cycle 8160 Cycles

OUTPUT Blocking Input

8 7 6 5 4 3 2 1 6 5 4 3 2 1

Pickup: 0.30 0.10 p.u. 1.00 p.u. 87T

Percent Slope #1: 30 5% 100%

Percent Slope #2: 60 5% 200%

Slope Break Point: 2.0 1.0 p.u. 4.0 p.u.

Even Harmonics Restraint: ( 2nd, 4th ) 15 5% 50%

5th Harmonic Restraint: 30 5% 50%

Pickup at 5th H.R.: 0.60 0.10 p.u. 2.00 p.u.

OUTPUT Blocking Input

8 7 6 5 4 3 2 1 6 5 4 3 2 1

W1 C.T. Tap: 2.05 1.00 10.00

W2 C.T. Tap: 2.09 1.00 10.00

W3 C.T. Tap: 2.00 1.00 10.00

@ : WARNING, You have not selected an output!