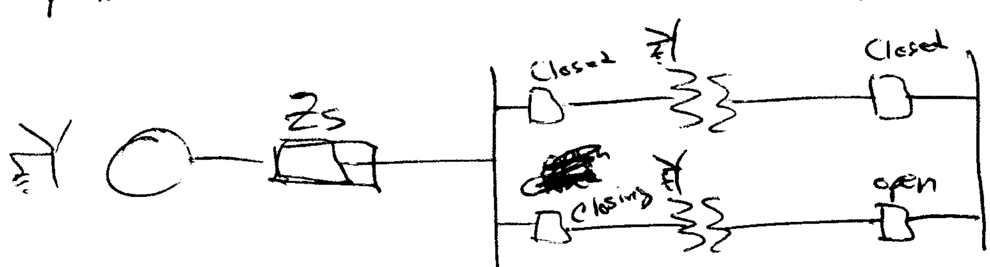
Transformer Protection -

< 10 MVA → use fuses (unless vital)
> 10 MVA → **use diff relays**

Factors to consider:

- Inrush
- Different voltages ~~[illegible]~~ levels
- Phase shifts
- Transformer Taps

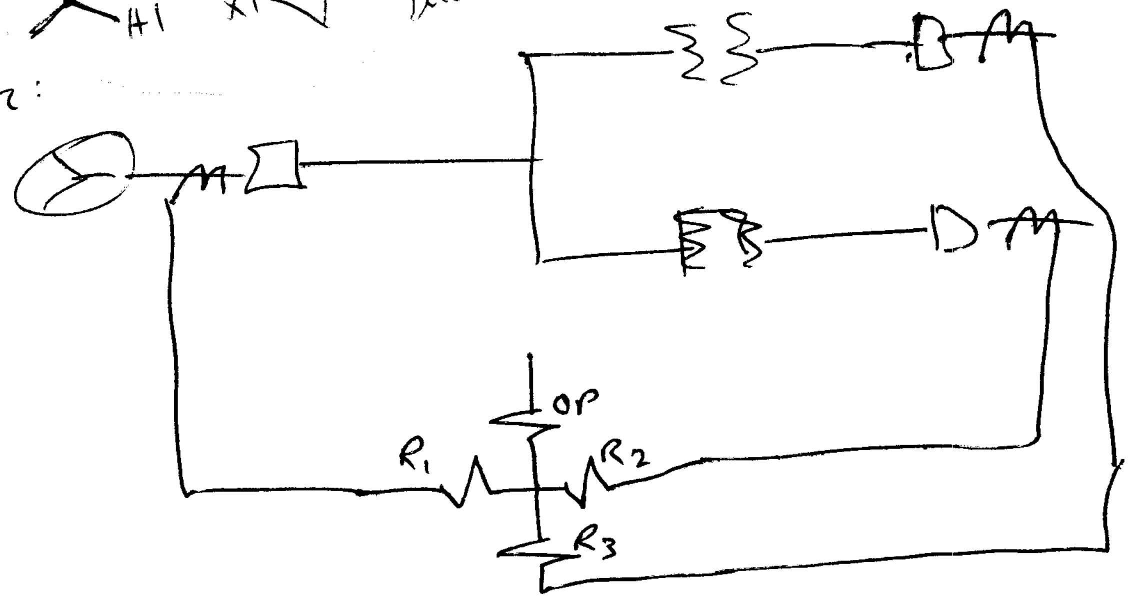
Initial Inrush - Upon Energizing 2nd Harmonics
Recovery Inrush - Voltage pulled down during nearby fault. Inrush up recovery.
Sympathetic Inrush - Paralleled xfmrs.



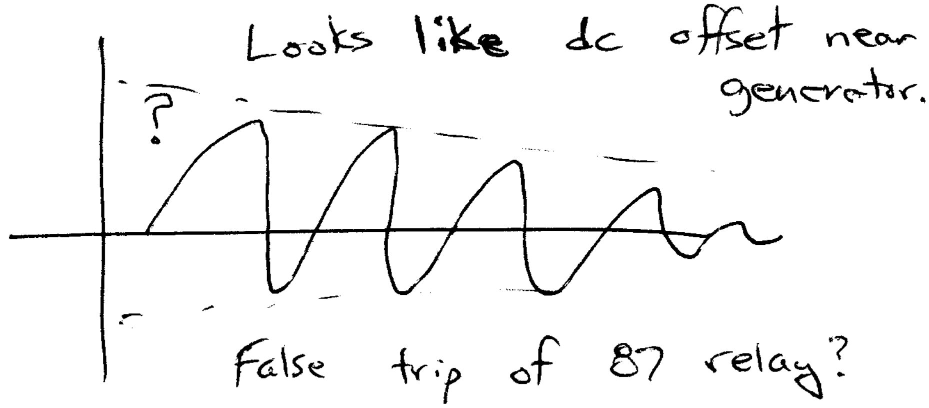
Two effects: closing CB causes inrush current that pulls down bus voltage. Inrush when voltage recovers. At same time, 2nd harmonic of inrush can return thru other xfmr, saturating it.

Harmonic Restraint - Use filter for 2nd harmonic, or detect & block, or time delay.

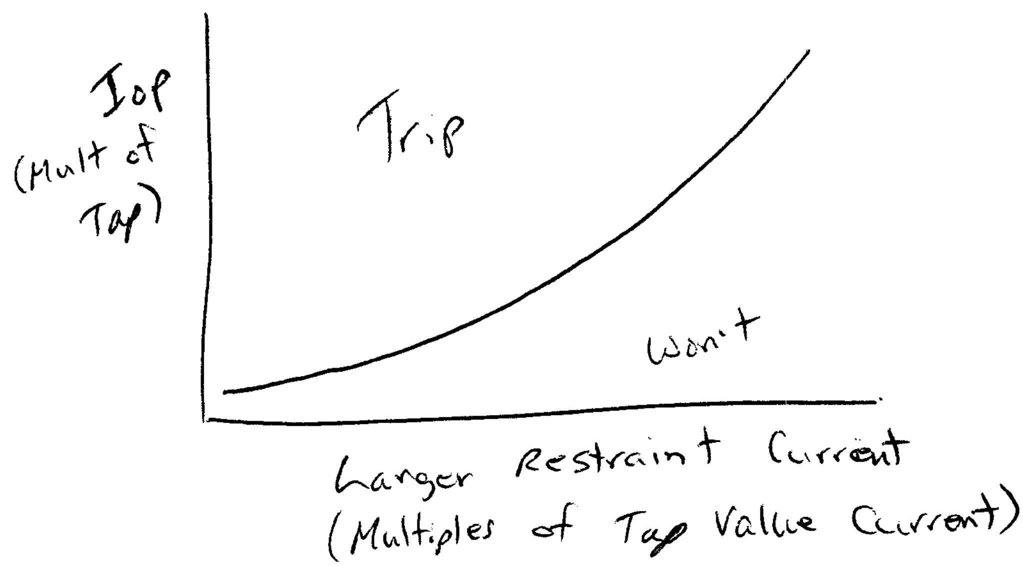
Problem:



Symp Inrush :



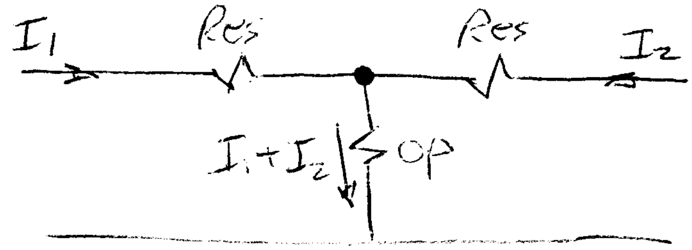
∴ Better to use Sep 87T relay, each XFMR.

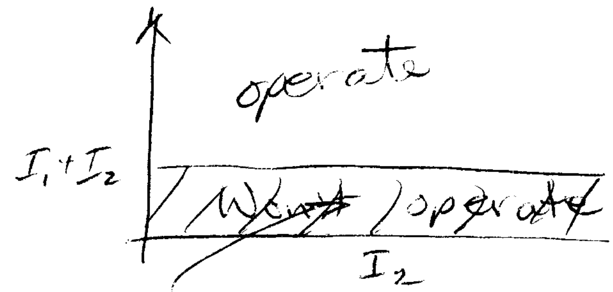


Hu
HU-1
HU-4

Mismatch

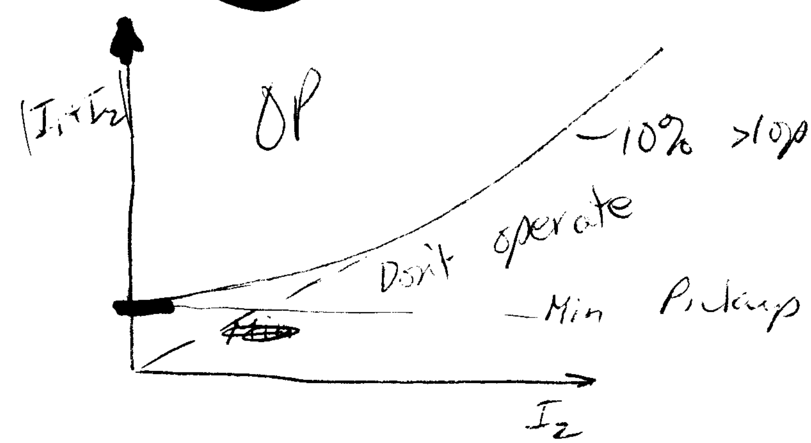
DIFF RELAYS (ANSI 87)





Problems with CT mismatch at high I, so put dead band to be safe

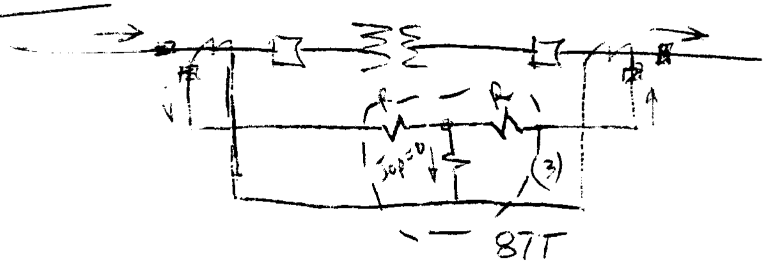
Some (87) relays don't have restraint coils.



$$\left(\frac{I_1+I_2}{I_2}=0.1\right)$$

So it takes a larger differential at larger currents to operate.

ex: XFMR

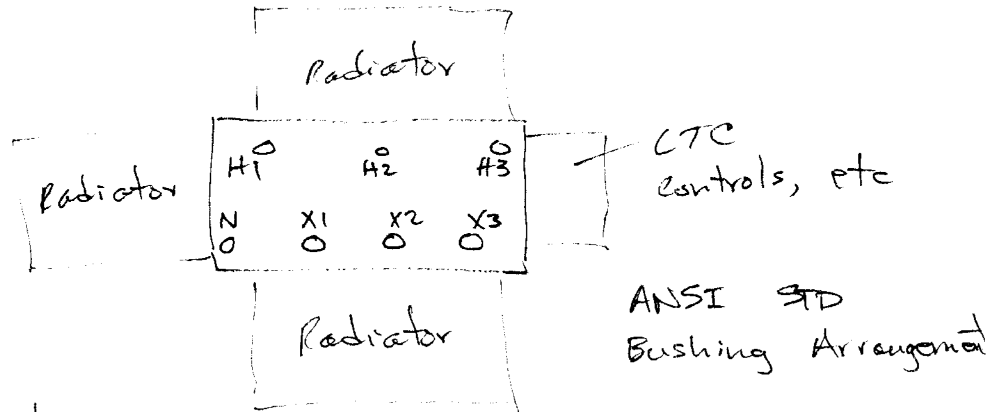


Bruce Mork

Power Transformers:

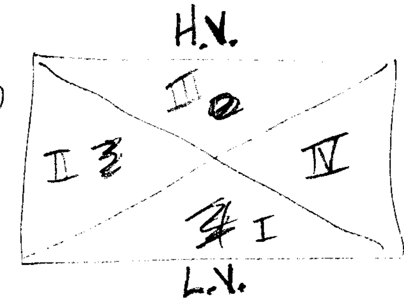
Physical Construction:

Two-Winding:



XFMR'S described by quadrant:

Ansi C57.12.10 1977



Windings - immersed in oil for cooling and insulation

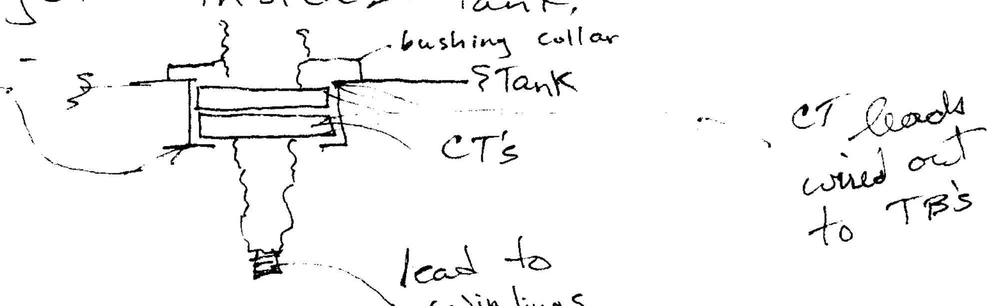
Bushings - Oil-filled ~ 69 KV and above
- "Dry" below ~ 69-KV

Tank - usually sealed from atmosphere

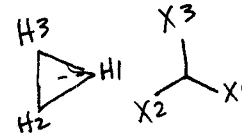
dry **Nitrogen "blanket"** - keep positive pressure inside tank to keep moisture out 2-5 psig

Winding Insulation - paper (oil-impregnated)
This paper will soak up water like a wick if moisture does get inside tank.

Bushing Wells -



ANSI C57.12



Power Transformers -

Ratings: Typical to See: 18/24/30 MVA 55C
20.25/27/33.75 MVA 65C

OA - self - cooled
FA - fan - cooled through radiators, oil moves by convection (heat)
FOA - oil is pumped (circulated) through radiators and air is blown through radiators
FOW - oil pumped through heat exchanger - water cooled.

OA/FA/FA
OA/FA/FOA
OA/~~FA~~/FOW

p. 105 (W) T&D, 1964

EX:

OA/FA/FA		1 - self-cooled
	75°C,	2 - stage one fans
	85°C,	3 - stage 1 + stage 2 fans
OA/FA/FOA		1 - self-cooled
	75°C	2 - stage one cooling - fans
	85°C	3 - stage two cooling - fans + pumps
		4 - alarm

Temp ratings:	Windings	Top Oil Temp
Max Ambient	40°C	40°C
Rated Temp Rise	65°C	65°C
Winding Hot spot allowance	15°C	
Actual Max Temp:	120°C	105°C

Hot spot Winding Temp

75 -	#1
85 -	#2
110 -	Alarm
120 -	trip

Cummulative T - Temp damage above 120°C

5.1 Cooling classes of transformers

"New Designations"

Transformers shall be identified according to the cooling method employed. For liquid-immersed transformers, this identification is expressed by a four-letter code as described below. These designations are consistent with IEC 60076-2: 1993.

First letter: Internal cooling medium in contact with the windings:

O	mineral oil or synthetic insulating liquid with fire point[7] $\leq$ 300 °C
K	insulating liquid with fire point > 300 °C
L	insulating liquid with no measurable fire point

Second letter: Circulation mechanism for internal cooling medium:

N	*natural* convection flow through cooling equipment and in windings
F	*forced* circulation through cooling equipment (i.e., coolant pumps), natural convection flow in windings (also called nondirected flow)
D	forced circulation through cooling equipment, *directed* from the cooling equipment into at least the main windings

Third letter: External cooling medium:

A	air
W	water

Fourth letter: Circulation mechanism for external cooling medium:

N	natural convection
F	forced circulation [fans (air cooling), pumps (water cooling)]

NOTES:

1—In a transformer with forced, nondirected cooling, (second code letter F), the rates of coolant flow through all the windings vary with the loading, and are not directly controlled by the pumps. The pumped oil flows freely inside the tank and is not forced to flow through the windings.

2—In a transformer designated as having forced directed coolant circulation (second code letter D), the rate of coolant flow through the main windings is determined by the pumps and not by the loading. A minor fraction of the coolant flow through the cooling equipment may be directed outside the main windings to provide cooling for core and other parts. Regulating windings and/or other windings having relatively low power may also have nondirected coolant circulation.

A transformer may be specified with more than one power rating (also referred to as cooling stages). The transformer nameplate shall list the rated power and cooling class designation for each rating. The ratings shall be listed in order of increasing power. The cooling class designations are normally listed in order with a diagonal slash separating each one.

Examples:

ONAN/ONAF. The transformer has a set of fans which may be put in service as desired at high loading. The coolant circulation is by natural convection only.

ONAN/OFAF. The coolant circulation is by natural convection only at base loading. However, the transformer has cooling equipment with pumps and fans to increase the power-carrying capacity at high loading.

Examples of the cooling class designations used in IEEE Std C57.12.00-1993 and in previous revisions, and the corresponding new designations, are provided in Table 2.

[7]Fire point—The lowest temperature at which a specimen will sustain burning for 5 s. (ASTM D92-1998, "Cleveland Open Cup" test method.)

Table 2—Cooling class designation

Present designations	Previous designations
ONAN	OA
ONAF	FA
ONAN/ONAF/ONAF	OA/FA/FA
ONAN/ONAF/OFAF	OA/FA/FOA
ONAN/ODAF	OA/FOA[a]
ONAN/ODAF/ODAF	OA/FOA[a]/FOA[a]
OFAF	FOA
OFWF	FOW
ODAF	FOA[a]
ODWF	FOW[a]

[a]Indicates directed oil flow per Table 9, NOTE 2 of IEEE Std C57.12.00-1993.

5.2 Frequency

Unless otherwise specified, transformers shall be designed for operation at a frequency of 60 Hz.

5.3 Phases

5.3.1 General

Transformers described in this standard are either single-phase or three-phase. Standard ratings are included in the product standards for particular types of transformers. When specified, other phase arrangements may be provided.

5.3.2 Scott-connected or T-connected transformers

5.3.2.1 Phase transformation

These may be provided to accomplish three-phase to two-phase transformation, or vice versa; or to accomplish three-phase to three-phase transformation. Several arrangements commonly utilized to accomplish such transformations are described here.

5.3.2.2 Dissimilar single-phase transformers

Two single-phase transformers are assembled in an enclosure, and permanently interconnected, with the following characteristics:

a) Performance characteristics shall be based on bank operation of three-phase to two-phase transformation or vice versa.
b) The single-phase transformers may not be identical or interchangeable.

Other Alarms -

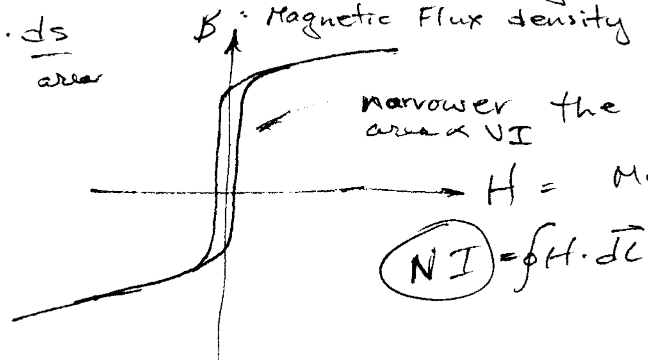
Sudden Pressure (fault) - Trip
low Oil Level - alarm
low - low Oil level - trip
loss of pos. N_2 pressure - Alarm
LTC Min, Max Pos
N_2 bottle low - alarm
Pressure Relief Valve operated - Alarm
Loss of power to cooling, controls

<u>Core construction</u>:
- amorphous
- not-oriented grain ($P_e \propto \tau^2$)
- laminated steel - limit eddy losses

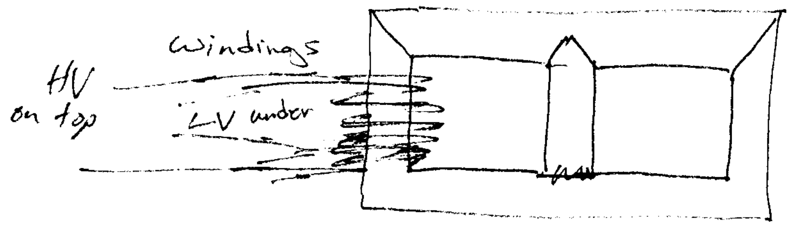
Special low hysteresis loss

$\phi = \iint_{area} B \cdot \underline{ds}$

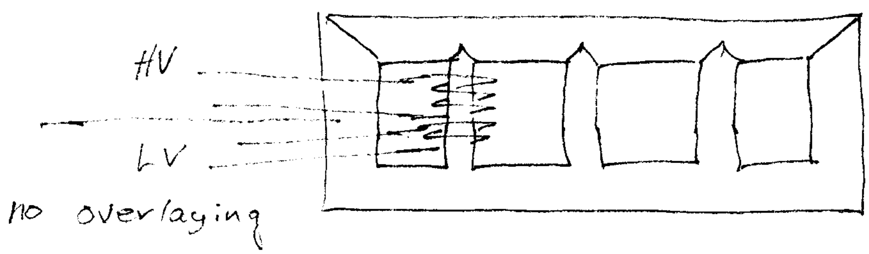
where $MMF = \phi R_{reluctance}$



$NI = \oint H \cdot \vec{dl}$



core form - cheaper (more common)



shell form - behaves more like a bank of single phase XFMRS

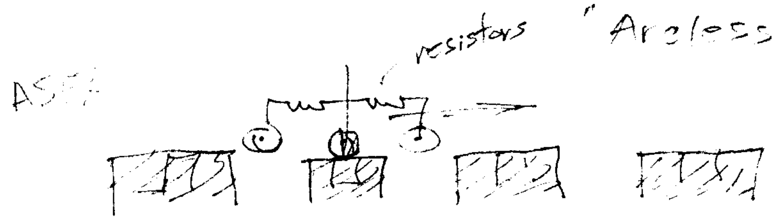
Load Tap Changer: changes XFMR turns ratio under load - on secondary side (±10%, 33 taps) 5/8% ea

Bridging Reactor - Causes arcing
- Keep LTC in seperate compartment to keep contamination out of main tank

talk about buck/boost

"Arcless" LTC:

500,000 operations



No Load Taps - on primary side: ±5% - 5 taps, 2½% each

Shipping XFMR From factory:

1 - No oil - cuts down weight
2 - Radiators Removed } Blanking Plates
Bushings Removed
Surge Arrestors Removed
3 - Sealed, under pressure N_2 -
4 - Impact Recorder - Train (X-y impact - seismic (zones))

Ex: 18/24/30 MVA - 105,000# smallest piece

Delivery - by train
1 - Check impact recorder
2 - Megger core to ground (1000V ac) 1-5 MΩ then connect core ground.
3 - Move to site without dropping.
4 - "Set-up" or assemble all components
Radiators, Bushings, S.A., etc.
5 - TTR - Transformer turns ratio
test - on all phases, all taps
6 - Megger the windings - > 2500 V megger
to check winding insulation to gnd
7 - CT ratio, polarity check - Multiratio CT's
8 - Megger CT's - 1000V
9 - Oil comes in truck
10 - ASTM D1816 test for moisture > 20 KV
11 - Pull vaccuum on tank .01 - .1 atm
Hold vacuum 1 hr for every hour
tank was open -
Vaccuum boils away moisture in tank

12- Maintain vacuum. Set up filter press to pump oil from tanker, through water filter, into tank. (Ground this pump)

13 - When tank is full, remove vaccuum, put N_2 back on

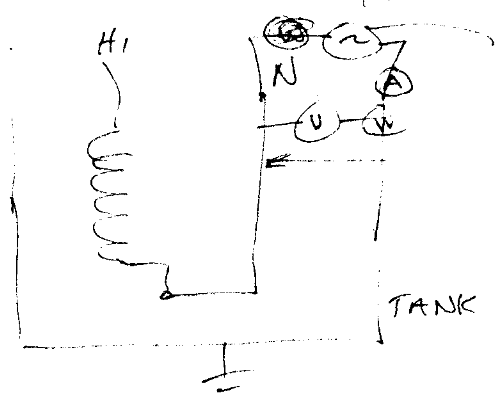
14 - Take 3 samples of oil from tank redo ASTM test >30 KV breakdown.
D1816 - Spherical   ASTM D877 - disk electrodes

15 - "Doble" Tests - Insulation power factor test.

Measures Power Factor of insulation

3 Parts

H1 - GND
X1 - GND
H1-X1



15 KV

PF < .01

.3% Typical

PF increases with moisture or carbon or, other contamination in tank.

Tip-up test --> gradually increase voltage
if PF = K --> moisture
PF increases --> carbon

16 - Hi-Pot Test - 15 KV Winding - 34 KV-AC to ground

(measure leakage current.)

Insulating oil can degrade due to:

1) Age
2) Moisture
3) Carbides from { hot spots ← arcing (mild), corona faults

Gas in oil tests:

Oil decomposes when subjected to heat.

H_2 - Hydrogen
CH_4 - Methane
C_2H_4 - Ethylene
C_2H_2 - Acetylene
C_2H_6 - Ethane
CO - Carbon Monoxide
CO_2 - Carbon Dioxide

Key Gases:

Conductor Overheating	Oil Overheat	Mild Arcing	Arcing
CO / CO_2 (Burnt paper Insulation)	C_2H_4	H_2	C_2H_2

Samples are taken in a "syringe" through a special valve in the tank.

Main Tank / LTC samples taken seperately.

ECP November 1990

Transformer application references

1) "Transformer Gas Analysis Helps Trace Degredation", T.V. Oomen, Electric Light and Power Magazine, Nov. 1979, pp. 26-28.

2) Protective Relaying - Principles & Applications, J Lewis Blackburn, 1987, Marcel Dekker, Chapter 9.

3) "Transformer Connections in Three-Phase Distribution Systems", L.W. Long, IEEE Tutorial Course at Summer Meeting (Portland, OR) July 1976.

4) "Short-Circuit Characteristics of Transformers", W.J. McNutt, IEEE Tutorial Course at Summer Meeting (Portland, OR) July 1976.

5) Electrical Equipment Testing & Maintenance, A.S. Gill, 1982, Reston Publishing.

6) ANSI Standards C57.12 (Power Transformers)

7) ASTM Standards D877, D1816. (Insulating oil)

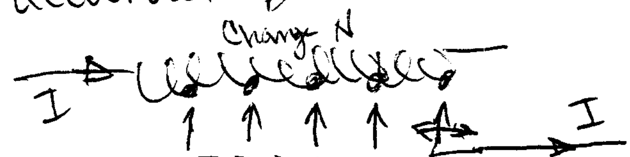
8) ANSI Standard C37.91 (Relaying - Transformers)

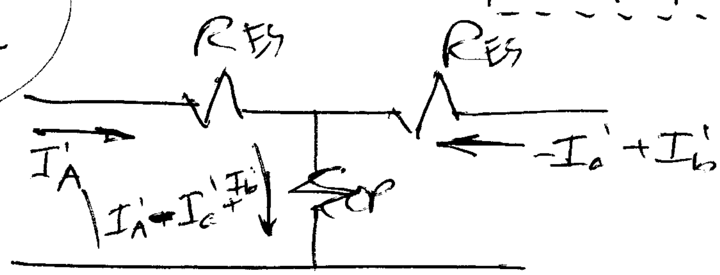
9) ANSI Standard C57.109 (Transformer Thru-Fault)

Note that hookup of Δ CTs on secondary is same as hookup of Δ pri of transformer. (As related to polarity marks)

- Should still double-check connections. (Testing - [illegible] Tests)
- Set CT ratios so $|I_A'| \cong |-I_a' + I_b'|$
- Pick Tap settings to minimize mismatch (in 560) Procedure in relay manual. (Get best match for different CT accuracies)
- Tap settings:

$\phi = \frac{NI}{R}$



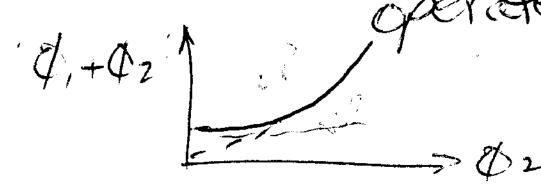


so $|I_{op}| \neq |I_A' - I_a' + I_b'|$ (usually)

But op really depends on difference in flux in magnetic circuit.

So if $\phi_{OP} > \phi_{RES}$, relay operates

Actually Functions: →



- 2nd Harmonic Suppression -
  So Inrush won't cause false trip
  - Small transformers can usually get by without harmonic suppression.
  - Large XFMRS have to have it. (Inrush lasts longer)

Indicating Contactor Switch (ICS)

No setting is required on the ICS unit except the selection of the 0.2 or 2.0 ampere tap setting. This selection is made by connecting the lead located in front of the tap block to the desired setting by means of the connecting screw. When the relay energizes a 125-or 250-volt dc type WL relay switch, or equivalent, use the 0.2-ampere tap; for 48 volt DC applications set relay in 2 tap and use Type WL Relay coil S#304C209G01 or equivalent.

Indicating Instantaneous Trip (IIT)

No setting is required on the indicating instantaneous trip unit. This unit is set at the factory to pickup as follows:

HU/HU-1 Relays 10 times tap value current
HU-4 Relay 15 times tap value current

SETTING CALCULATIONS

Select the ratio matching taps. There are no other settings. In order to calculate the required tap settings and check current transformer performance the following information is required.

Required Information

1. Maximum transformer power rating $(KVA)_M$
2. Maximum external fault currents
3. Line-to-Line voltage ratings of power transformer (V_{II}, V_I, V_L)
4. Current transformer ratios, full tap (N_T)
5. Current transformer "C" accuracy class voltage, (or excitation or ratio correction factor curve)
6. One way current transformer lead resistance at 25°C (RL) (when using excitation curve, include ct winding resistance)
7. Current transformer connections (wye or delta)
8. ct secondary winding resistance, R_S.

Definitions of Terms

I_P = Primary current at $(KVA)_M$
I_R = Relay input current at $(KVA)_M$
I_{RH}, I_{RL}, I_{RI} are same as I_R except for high, low and intermediate voltage sides respectively.
I_S = ct secondary current at $(KVA)_M$
T = relay tap setting.
T_H, T_L, T_I = are same as T except for high, low and intermediate voltage windings, respectively.
N = Number of current transformer turns that are in use.
$N_P = N/N_T$ (Proportion of total turns in use)
N_T = Current transformer ratio, full tap
V_{CL} = "C" accuracy class voltage
Z_A = Burden impedance of any devices other than the HU, HU-1, or HU-4 relays, with maximum external fault current flowing.
I_{ext} = max. symmetrical external fault current in secondary RMS amperes.
Z_T = Total secondary burden in ohms (excluding current transformer winding resistance.)

Calculation Procedure

1. *Select current transformer taps,* where multi-ratio types are used. Select a tap to give approximately 5 amperes at maximum load. This will provide good sensitivity and will produce no thermal problem to the ct., the leads or the relay. Better sensitivity can be achieved by selecting a tap to give more than 5 amperes if a careful check is made of the ct, the leads and the relay capability. For determining the required continuous rating of the relay, use the expected two-hour maximum load, since the relay reaches final temperature in this time.

2. *Calculate the relay currents, I_R.* All relay currents for relay tap selection should be based on the same KVA capacity.

3. *Calculate the relay current ratio(s)* using the lowest current as reference.

4. Select the tap ratio as close as possible to relay current ratio from Table 1. Choose the first relay tap ratio using the largest current ratio from step 3. The other tap ratios should be determined using the lower tap from the first tap ratio as reference.

I_R should not exceed relay continuous rating as defined in Energy Requirement Table.

5. *Check IIT operation.* The IIT pickup is ten times the relay tap value for the HU and HU-1, or 15 times tap value for the HU-4. Therefore, the maximum symmetrical error current which is flowing in the differential circuit on external fault current due to dissimilar ct saturation should not exceed 10 or 15 times relay tap.

6. *Determine Mismatch*
For 2 winding banks:

$$\% \text{ mismatch} = 100 \frac{(I_{RL}/I_{RH}) - (T_L/T_H)}{S} \quad (1)$$

where S is the smaller of the two terms, (I_{RL}/I_{RH}) or (T_L/T_H)

For 3 winding banks:

Repeat calculation of equation (1) and apply similar equations to calculate mismatch from the intermediate to high and from the intermediate to low voltage windings.

Where tap changing under load is performed the relays should be set on the basis of the middle or neutral tap position. The total mismatch, including the automatic tap change should not exceed 15% with a 30% sensitivity relay, and 20% with a 35% sensitivity relay. Note from Fig. 11 that an ample safety margin exists at these levels of mismatch.

7. *Check current transformer performance.* Ratio error should not exceed 10% with maximum symmetrical external fault current flowing. An accurate method of determining ratio error is to use ratio-correction-factor curves (RCF). A less accurate, but satisfactory method is to utilize the ANSI relaying accuracy classification. If the "C" accuracy is used, performance will be adequate if:

$[N_p V_{cl} - (I_{ext} - 100) R_S] / I_{ext}$ is greater than Z_T (2)

Note: let $I_{ext} = 100$ where maximum external fault current is less than 100A.

For wye-connected ct:

$$Z_T = \text{lead resistance} + \text{relay burden} + Z_A$$

$$= 1.13\, R_L + \frac{0.15}{T} + Z_A \text{ ohms} \quad (3)$$

(RL multiplier, 1.13, is used to account for temperature rise during faults $\frac{0.15}{T}$ is an approximation. Use 2 way lead resistance for single phase to ground fault.)

For delta-connected ct:

$$Z_T = 3\,(1.13\, R_L + \frac{0.15}{R} + Z_A) \text{ ohms}$$

$$= 3.4\, R_L + \frac{0.45}{T} + 3Z_A \quad (4)$$

*(The factor of 3 accounts for conditions existing during a phase fault.)

8. *Examples*
Refer to pages 19, 20 and 21 and figure 21 for setting examples.

TABLE 1

HU Relay Tap Ratios

	2.9	3.2	3.5	3.8	4.2	4.6	5.0	8.7
2.9	1.000	1.103	1.207	1.310	1.448	1.586	1.724	3.000
3.2		1.000	1.094	1.188	1.313	1.438	1.563	2.719
3.5			1.000	1.086	1.200	1.314	1.429	2.486
3.8				1.000	1.105	1.211	1.316	2.289
4.2					1.000	1.095	1.190	2.071
4.6						1.000	1.087	1.890
5.0							1.000	1.740
8.7								1.000

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from

TWO-WINDING TRANSFORMER CALCULATIONS (See Figure 21)

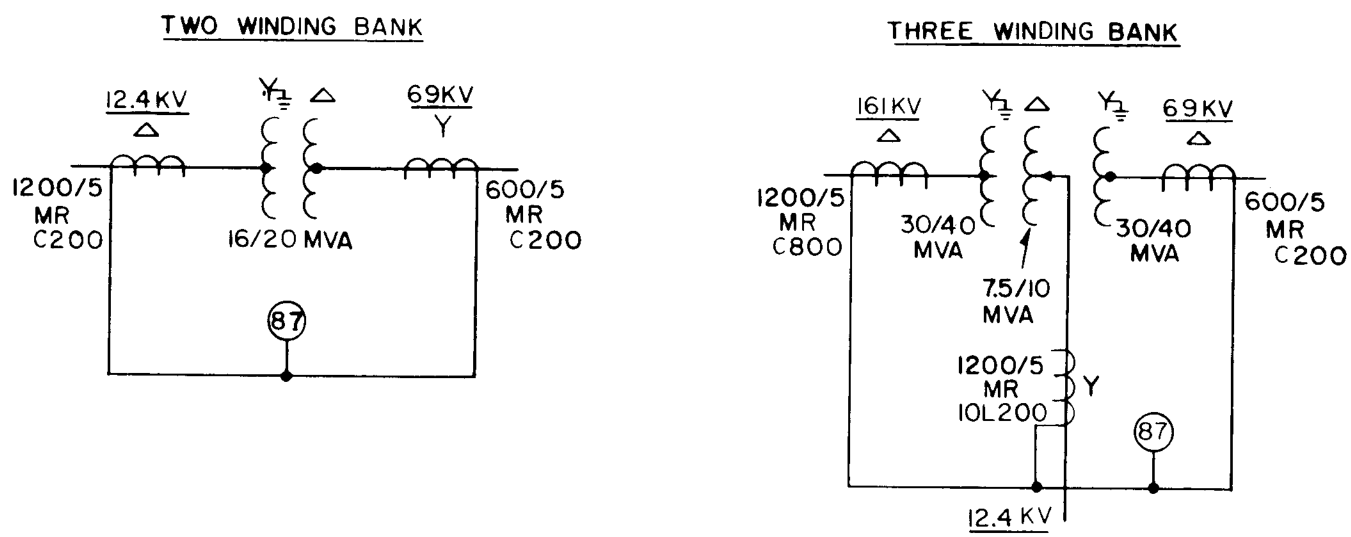
	LOW	HIGH
1. Select ct Ratio		
$I_P = \frac{(KVA)_M}{(KV)\sqrt{3}} =$	$\frac{20,000}{12.4\sqrt{3}} = 930$ Amp.	$\frac{20,000}{69\sqrt{3}} = 167$ Amp
Select Ratio	1000/5 (N = 200)	200/5 (N = 40)
2. Calculate Relay Current:		
$I_S = \frac{I_P}{N} =$	$\frac{930}{200} = 4.65$ Amp.	$\frac{167}{40} = 4.18$ Amp.
$I_R =$	$I_{RL} = 4.65\sqrt{3} = 8.05$ Amp.	$I_{RH} = 4.18$ Amp.
3. Calculate Current Ratio:	$\frac{I_{RL}}{I_{RH}} = \frac{8.05}{4.18} = 1.93$	
4. Select Tap Ratio from Table 1:	$\frac{T_L}{T_H} = \frac{8.7}{4.6} = 1.890$	
$I_R >$ relay continuous rating	No	No
5. Check IIT Operation Max. Symmetrical error current > 10 times relay tap.	No	
6. Determine Mismatch: % Mismatch =		
$100 \frac{(I_{LR}/I_{RH}) - (T_L/T_H)}{T_L/T_H} =$	$100 \frac{(8.05/4.18) - (8.7/4.6)}{8.7/4.6} =$ $100 \frac{1.92 - 1.89}{1.89} = 1.6\%$	
7. Check ct Performance $Z_T =$	$3.4\ R_L + \frac{0.45}{T} =$ $3.4 \times 0.4 + \frac{0.45}{8.7} = 1.36 + 0.05 =$ 1.41 ohms	$1.13\ R_L + \frac{0.15}{T} =$ $1.13 \times 0.4 + \frac{0.15}{4.6} = 0.45 + 0.03 =$ 0.48 ohms
$N_P = \frac{N}{N_T} =$	$\frac{200}{240} = 0.833$	$\frac{40}{120} = 0.333$
$\frac{(N_P\ V_{CL})}{100} =$	$\frac{0.833 \times 200}{100} = 1.67$	$\frac{0.333 \times 200}{100} = 0.67$
$(N_P\ V_{CL}/100) > Z_T$	Yes	Yes
Conclusion:	$T_L = 8.7$	$T_H = 4.6$
	30% sensitivity Relay is adequate	

THREE-WINDING TRANSFORMER CALCULATIONS
(See Figure 21)

	HIGH	INTERMEDIATE	LOW
1. Select ct Ratio: $I_P = \frac{(KVA)_M}{(KV)\sqrt{3}} =$	$\frac{40,000}{161\sqrt{3}} = 143$ Amp.	$\frac{40,000}{69\sqrt{3}} = 334$ Amp	$\frac{10,000}{12.4\sqrt{3}} = 465$ Amp
Select Ratio	400/5 (N = 80)	600/5 (N = 120)	1000/5 (N = 200)
2. Calculate Relay Current: $I_S = \frac{I_P}{N} =$	$\frac{143}{80} = 1.79$ Amp.	$\frac{334}{120} = 2.78$ Amp.	$\frac{465}{200} = 2.33$ Amp.
I_R (At 40 MVA) =	$I_{RH} = 1.79\sqrt{3} = 3.10$ Amp.	$I_{RI} = 2.78\sqrt{3} = 4.82$ Amp.	$I_{RL} = \frac{40}{10} \times 2.33 = 9.32$ Amp.
3. Calculate Current Ratios:		$\frac{I_{RI}}{I_{RH}} = \frac{4.82}{3.10} = 1.55$	$\frac{I_{RL}}{I_{RH}} = \frac{9.32}{3.10} = 3.01$
4. Select Tap Ratio from Table I:		$\frac{T_I}{T_H} = \frac{4.6}{2.9} = 1.586$	$\frac{T_L}{T_H} = \frac{8.7}{2.9} = 3.00$
$I_R >$ relay continuous rating	No	No	No
5. Check IIT operation Max. symmetrical error current > 10 times relay tap.	No	No	No
6. Determine Mismatch: % Mismatch	$100\frac{(I_{RH}/I_{RI}) - (T_H/T_I)}{T_H/T_I} =$	$100\frac{(I_{RI}/I_{RL}) - (T_I/T_L)}{(I_{RI}/I_{LR})} =$	$100\frac{(I_{RL}/I_{RH}) - (T_L/T_H)}{T_L/T_H} =$
	$100\frac{(3.10/4.82) - (2.9/4.6)}{2.9/4.6}$	$100\frac{(4.82/9.32) - (4.6/8.7)}{4.82/9.32} =$	$100\frac{(9.32/3.10) - (8.7/2.9)}{8.7/2.9}$
	$100\frac{0.643 - 0.630}{0.630} =$	$100\frac{0.517 - 0.529}{0.517} =$	$100\frac{3.01 - 3.00}{3.00} =$
	2.1%	-2.3%	0.33%

7. Check ct Performance $Z_T =$	$3.4\ R_L + \frac{0.45}{T} =$	$3.4\ R_L + \frac{0.45}{T} =$	$1.13\ R_L + \frac{0.15}{T} =$
	$3.4 \times 0.5 + \frac{0.45}{2.9} =$	$3.4 \times 0.5 + \frac{0.45}{4.6} =$	$1.13 \times 0.5 + \frac{0.15}{8.7} =$
	1.7 + 0.16 =	1.7 + 0.10 =	0.57 + 0.02 =
	1.86 ohms	1.80 ohms	0.59 ohms
$N_P = \frac{N}{N_T} =$	$\frac{80}{240} = 0.333$	$\frac{120}{120} = 1.0$	$\frac{200}{240} = 0.833$
$\frac{(N_P V_{CL})}{100} =$	$\frac{800 \times 0.333}{100} = 2.67$	$\frac{200 \times 1.0}{100} = 2.0$	$\frac{200 \times 0.833}{100} = 1.67$
$(N_P V_{CL}/100) > Z_T$	Yes	Yes	Yes
Conclusion:	$T_H = 2.9$	$T_I = 4.6$	$T_L = 8.7$

Requires 35% sensitivity Relay since (LTC + M)>15%



Two Winding Bank

LOW	HIGH
$(KVA)_M = 20{,}000$	$(KVA)_M = 20{,}000$
$(KVA)_S = 16{,}000$	$(KVA)_S = 16{,}000$
$V_L = 12{,}400$ VOLTS	$V_H = 69{,}000$
$N_T = 240$ TURNS	$N_T = 120$
$V_{CL} = 200$ VOLTS	$V_{CL} = 200$
$R_L = 0.4$ OHMS	$R_L = 0.4$
DELTA CT	WYE CT
$I_{ext} \leqslant 100A$	

Three Winding Bank

HIGH	INTERMEDIATE	LOW
$(KVA)_M = 40{,}000$	$(KVA)_M = 40{,}000$	$(KVA)_M = 10{,}000$
$(KVA)_S = 30{,}000$	$(KVA)_S = 30{,}000$	$(KVA)_S = 7{,}500$
$V_H = 161{,}000$	$V_I = 69{,}000$	$V_L = 12{,}400$
$N_T = 240$	$N_T = 120$	$N_T = 240$
$V_{CL} = 800$	$V_{CL} = 200$	$V_{CL} = 200$
$R_L = 0.5$	$R_L = 0.5$	$R_L = 0.5$
DELTA CT	DELTA CT	WYE CT
$I_{ext} \leqslant 100A$		

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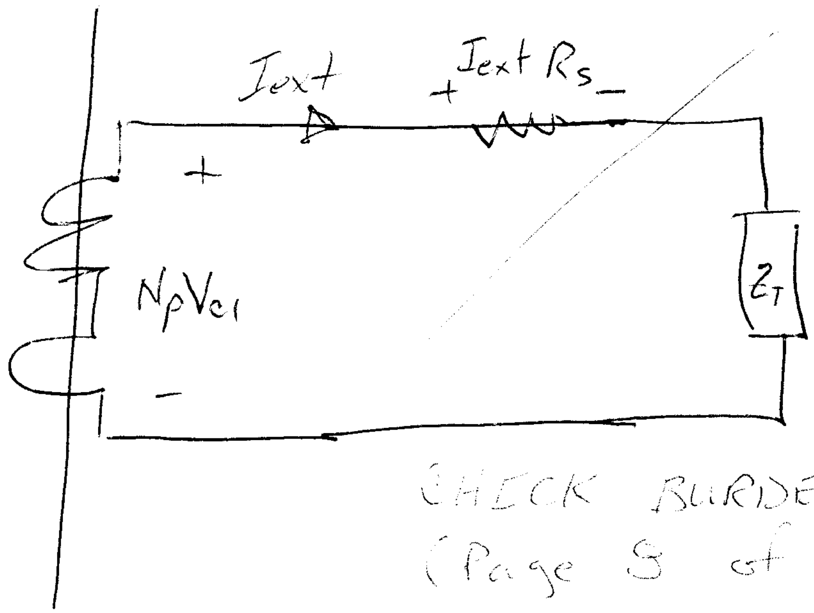
Fig. 21. Example for Setting Calculations.



CHECK BURDEN ON CT!
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Check: $V_{CT\ \text{CAPABLE OF}} - V_{\text{DROP}\ R_W} \overset{?}{>} I_{EXT} Z_B$