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ECE 525

POWER SYSTEM PROTECTION AND RELAYING

SESSION no. 9

· Circuit that normally lightly load with high fault current levels

→ fault current level for worst case fault (symmetrical current)

↳ ignoring dc offset

Should be 20 x $CT_{secondary}$ rated

⇒ may require higher CTR than load current

C-Class CT's

→ 20 x I_{rated}, standard burden

$\left(1 + \frac{X}{R}\right) I_{pu} Z_{pu} < 20$

Burden

$\frac{Z_B}{V_{rated}/100}$

$\frac{I_p/n}{I_{rated_{sec}}}$

CTR

example: Circuit where $I_{max\,load}$ is 490A

$\Rightarrow$ 500/5 CTR

But fault for 3ϕ is 20kA

$\Rightarrow$ would need CTR of 1000/5

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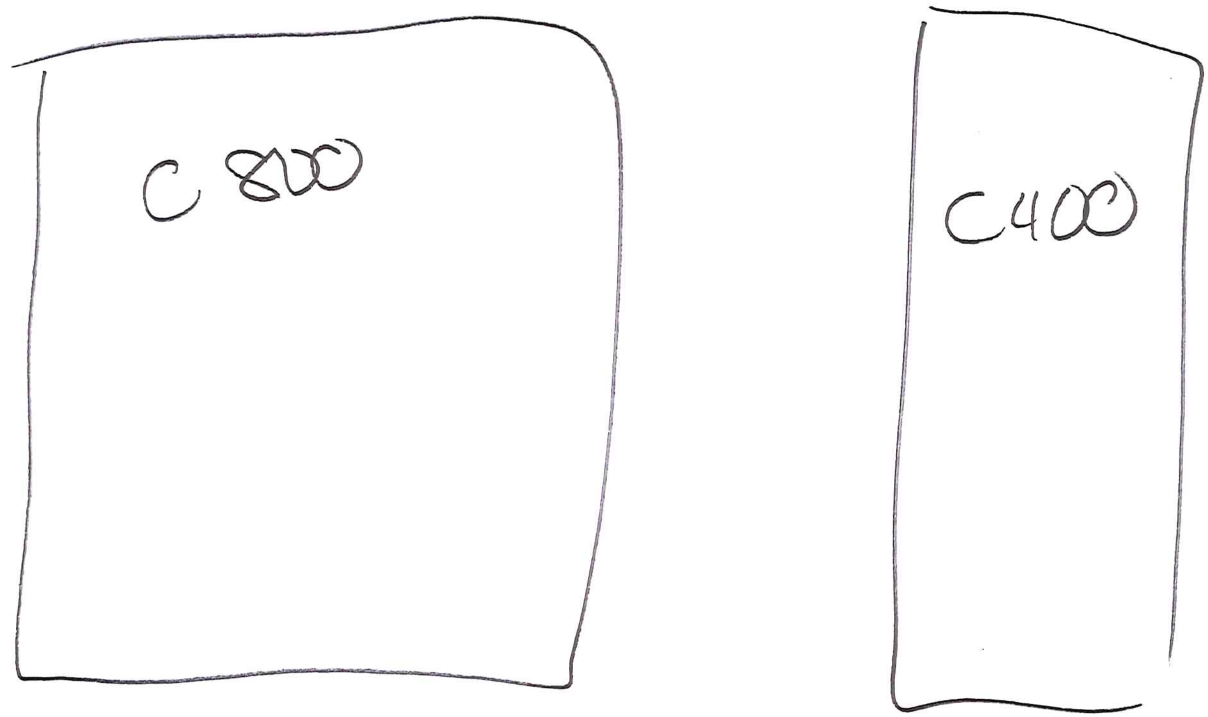

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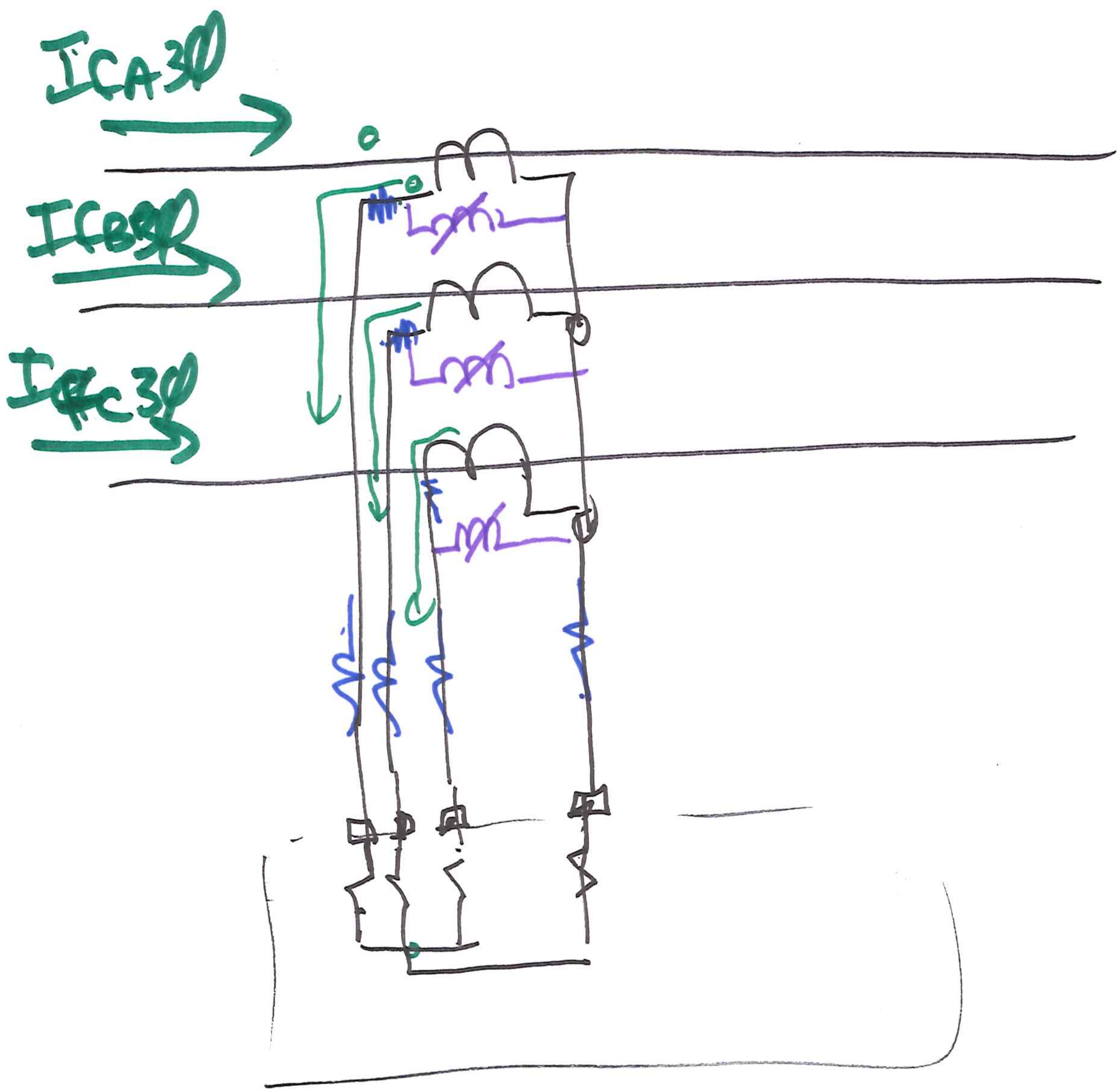
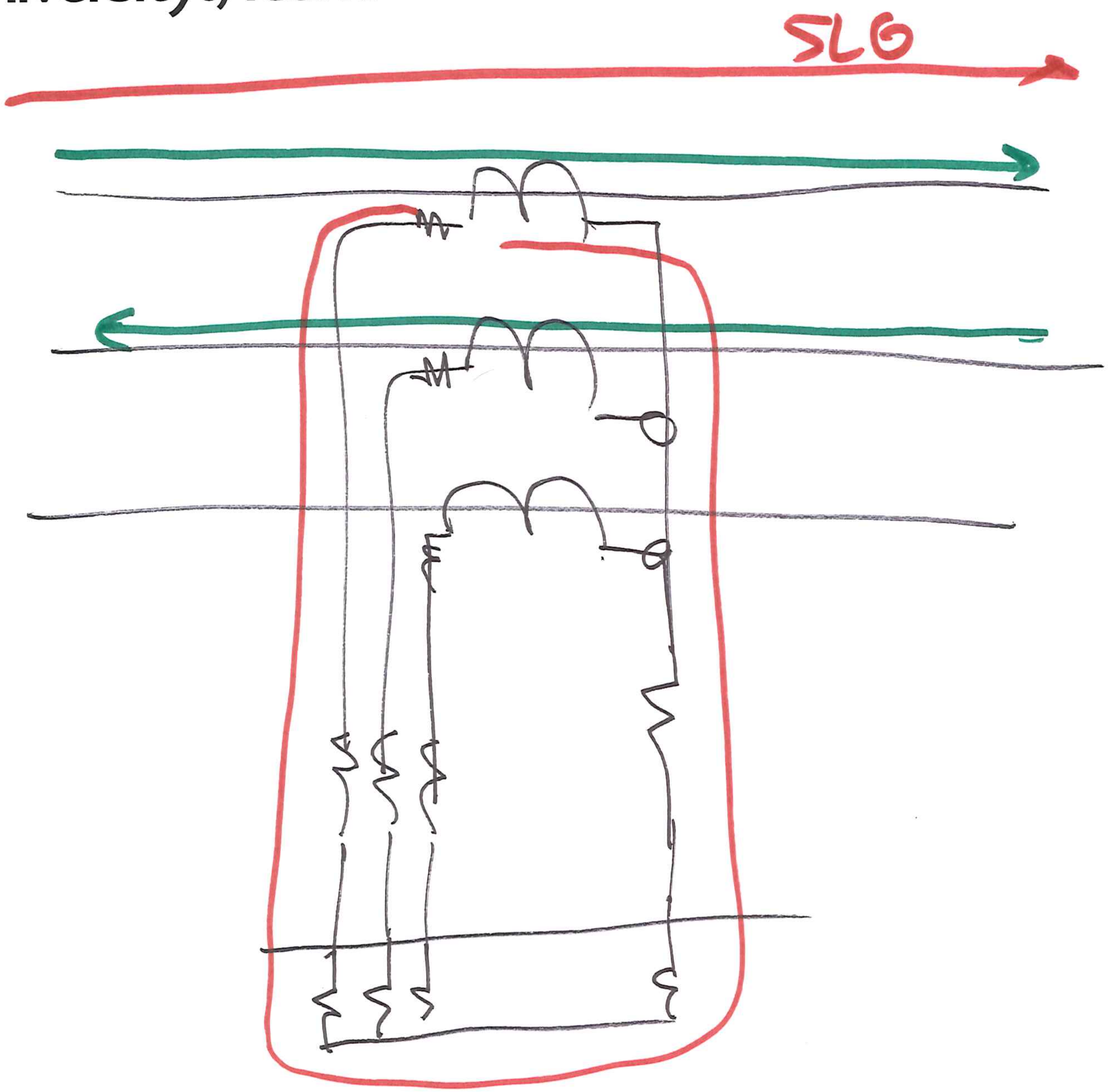



SLG

LS 7h4

ECE 525: Homework #2

Due Session 11 (September 25)

250kA

1. Recommend an appropriate CTR ratio for CT's connected at the terminals of a synchronous generator rated as follows: $P_{rated} = 500$ MW, $pf_{rated} = 0.8$, $V_{ratedLL} = 22$ kV, X/R = 40. The maximum available fault current is for a three phase fault, with a current level of 500 kA. Assume 5A secondary currents, and steps in primary side CT current ratings of 500 A for the range in question (so for example, ratios go up as 3000/5, 3500/5, on up).

2. You need to determine the C-class rating for 2000/5 CTs applied on a transmission system. The X/R ratio for the fault impedance for the worst case fault seen by the CTs is 8. The CTs have a winding resistance of 0.0030 ohms/turn, relay is connected to the CT by 2500 feet of number 10 AWG, and the relay burden is 50mΩ. The magnitude of the impedance of the lead wire can be calculated using the formula below. A typical angle of the impedance of the lead wire is about 12-15 degrees (so highly resistive). For this problem you just need to use the magnitude.

   - Recall that for 3 phase faults, you only need one length of lead wire, but for SLG and LL faults you need to include two lengths in lead resistance calculations

$$R_{AWG\_wire} = e^{0.232 \cdot Gauge - 2.32} \quad \text{in ohm/1000ft}$$

(a) Determine the C-class to never saturate if the decaying DC offset is neglected and the maximum fault current is 21000A (assume the worst case fault is SLG). Verify with the Mathcad CT model from class.

(b) Determine the C-class to never saturate with the decaying DC offset included and the maximum fault current is 21000A (assume you can go up to very high knee voltages). Again, verify with the Mathcad CT model from class.

(c) You are limited to using a C800 CT. Determine how long it will take the CT to saturate under the conditions of part (b). Again, verify with the Mathcad CT model.

(d) Repeat parts (a)-(c) for a 3 phase fault of 27000 A with the same burden and X/R ratio.

3. Repeat problem **2.** except with an X/R ratio of 35, and a fault current of 12000 A for a SLG fault and a 3 phase fault of 15000 A.

Continued on page 2

4. Suppose the CT with the characteristic described below is carrying 1128 A primary and is using a 1200/5 secondary tap and a resistive burden of 4 ohms. Neglecting the core loss resistance of the CT, (1) calculate the approximate initial voltage that would result across the CT secondaries if the CT secondary is accidentally opened (2) calculate the approximate final voltage it would reach if the insulation survives the initial overvoltage. Explain where the current is flowing.

ORIGIN := 1

CT Data: C600 class, 1200/5

Full ratio: $N_{full} := \frac{1200}{5}$ $\quad N_{full} = 240$

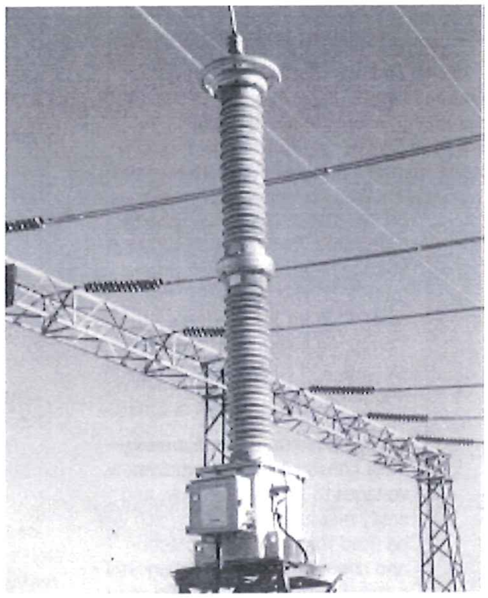
CT Excitation Curve

$$excitation := \begin{pmatrix} .001 & 0.09 \\ .04 & 90 \\ .1 & 428 \\ .12 & 520 \\ .14 & 600 \\ .2 & 700 \\ .3 & 780 \\ .4 & 800 \\ 40 & 927 \end{pmatrix}$$

TAPS

$$t := \begin{pmatrix} 240 \\ 200 \\ 180 \\ 160 \\ 120 \\ 100 \\ 80 \\ 60 \\ 40 \\ 20 \end{pmatrix}$$

Voltage Transformers



Overview

- VT and CVT construction
- VT and CVT equivalent circuit
- What is CVT transient?
- Why do CVT transients cause distance relay overreach?
- What determines CVT transient?
- What are some solutions?

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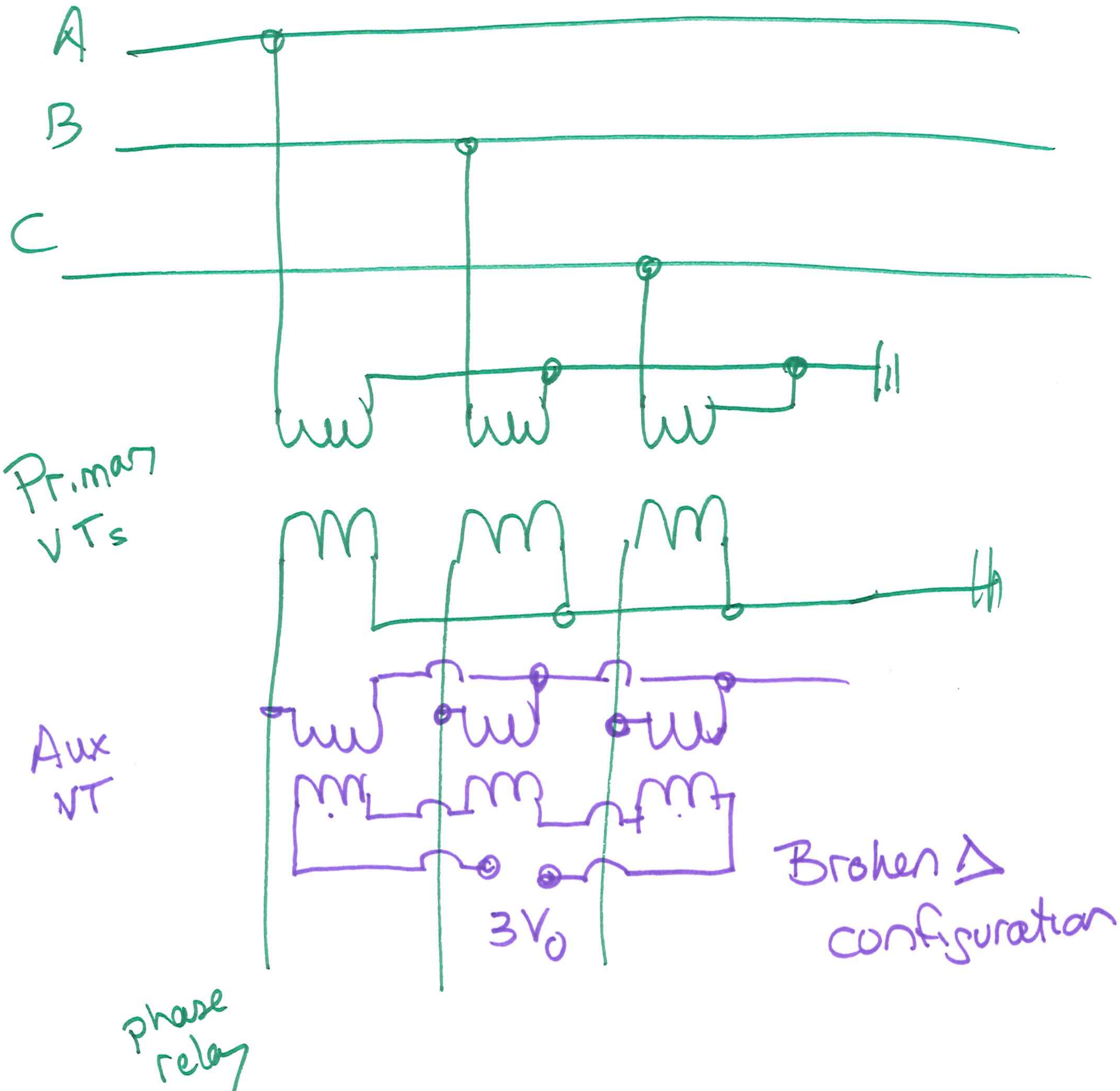
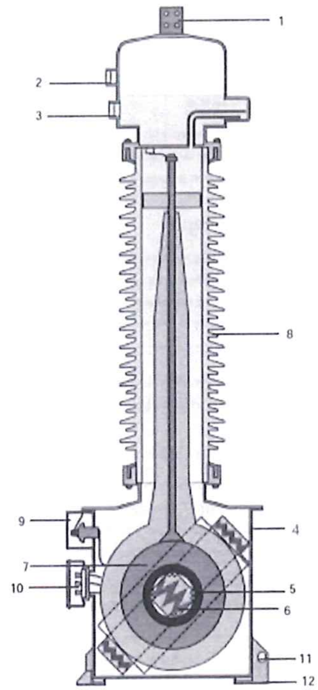


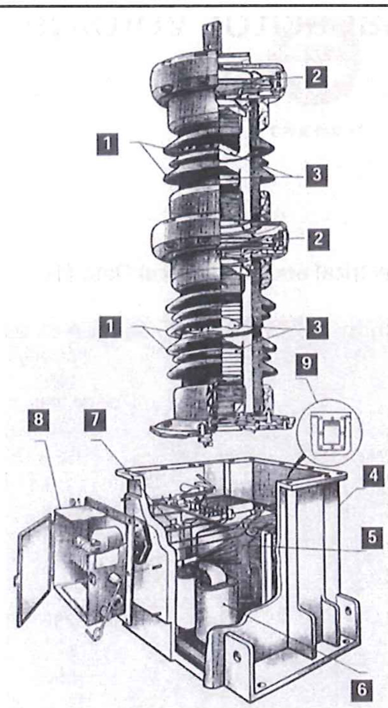


Inductive VT / PT Construction
Typically for 175 kV – 24 kV

⇒ $V_{secondary}$ ≈ 67–70V

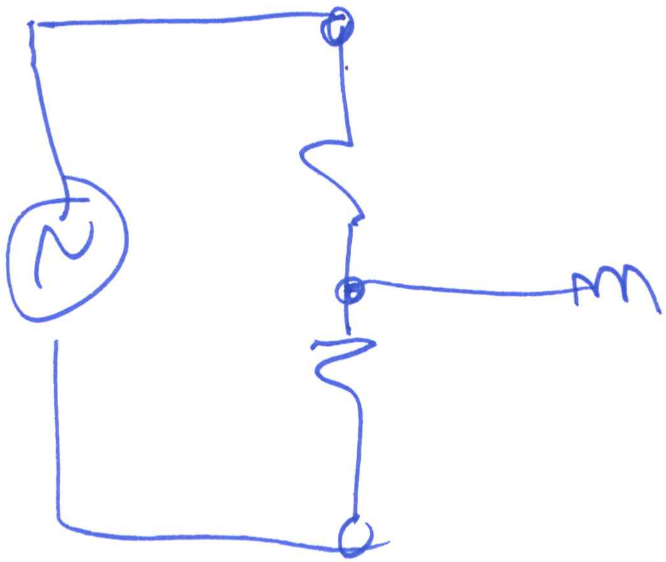
$\left(\frac{115}{\sqrt{3}} - \frac{120}{\sqrt{3}}\right)$

$N_1 : N_2$

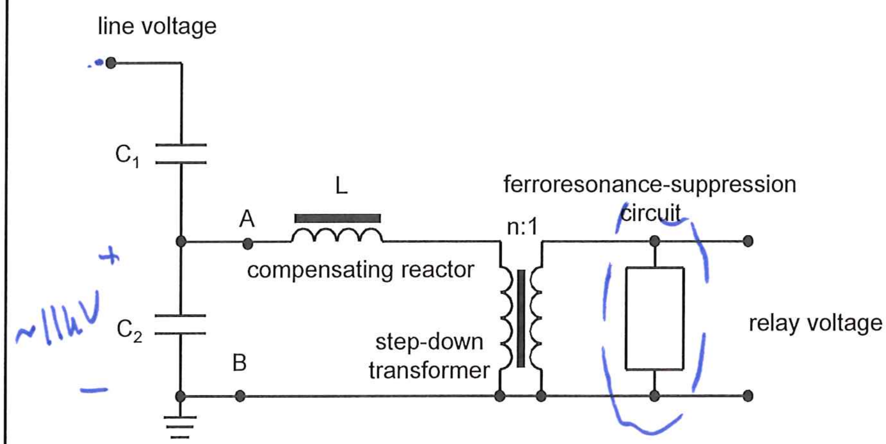


Capacitor Voltage Transformer
132 kV and Upwards

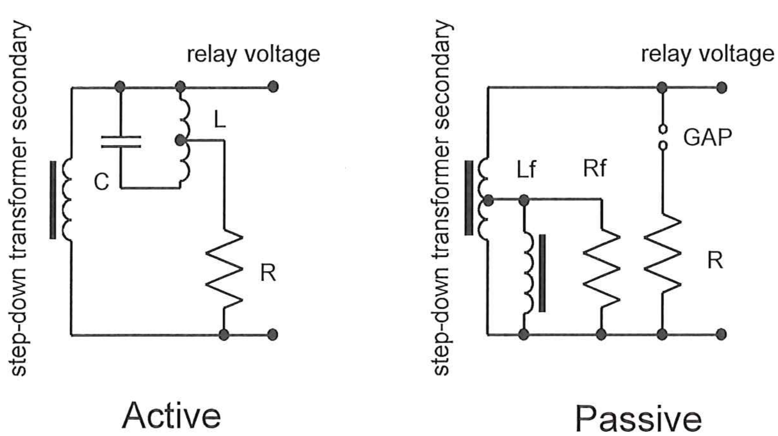
Capacitively coupled voltage transformers (CCVT)



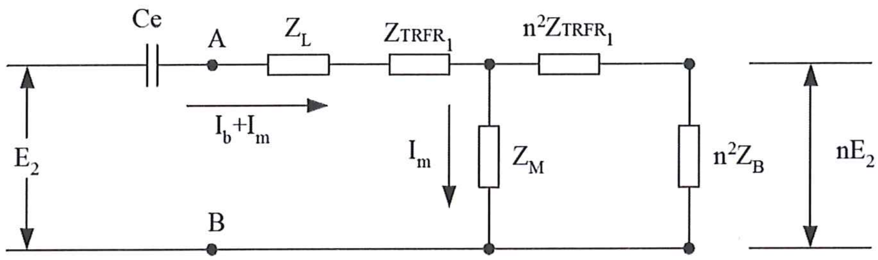
CVT Structure



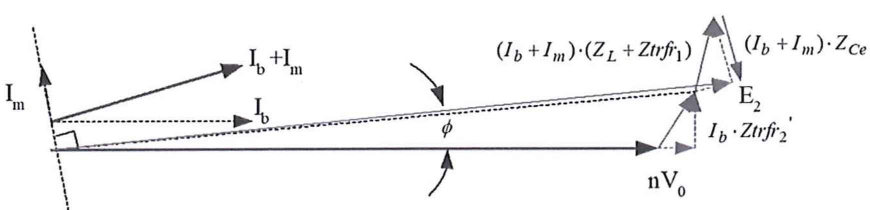
Ferroresonance-Suppression Circuits



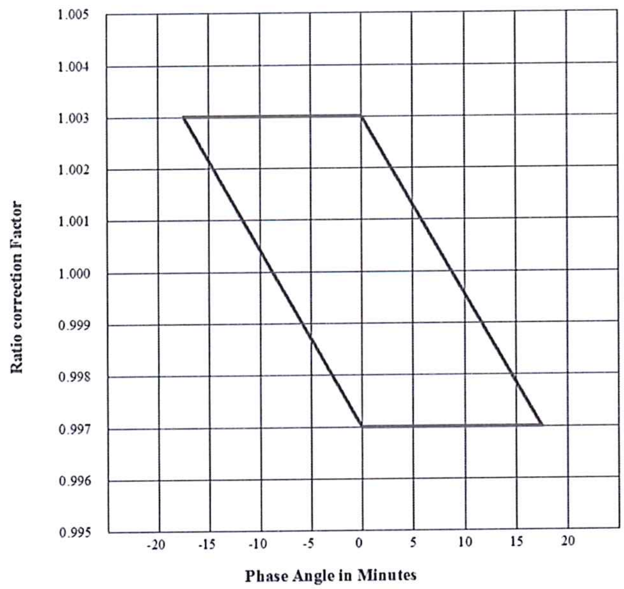
CVT Model for Analysis



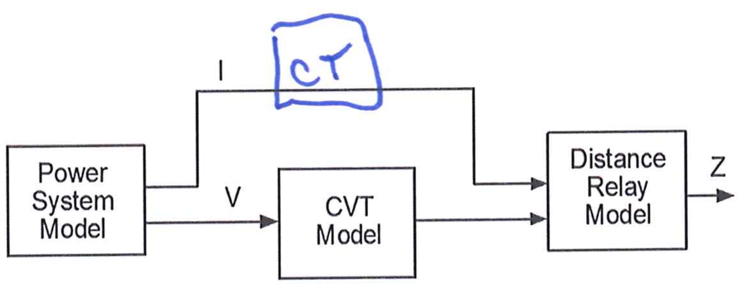
Phasor Diagram for CVT
At Unity Power Factor

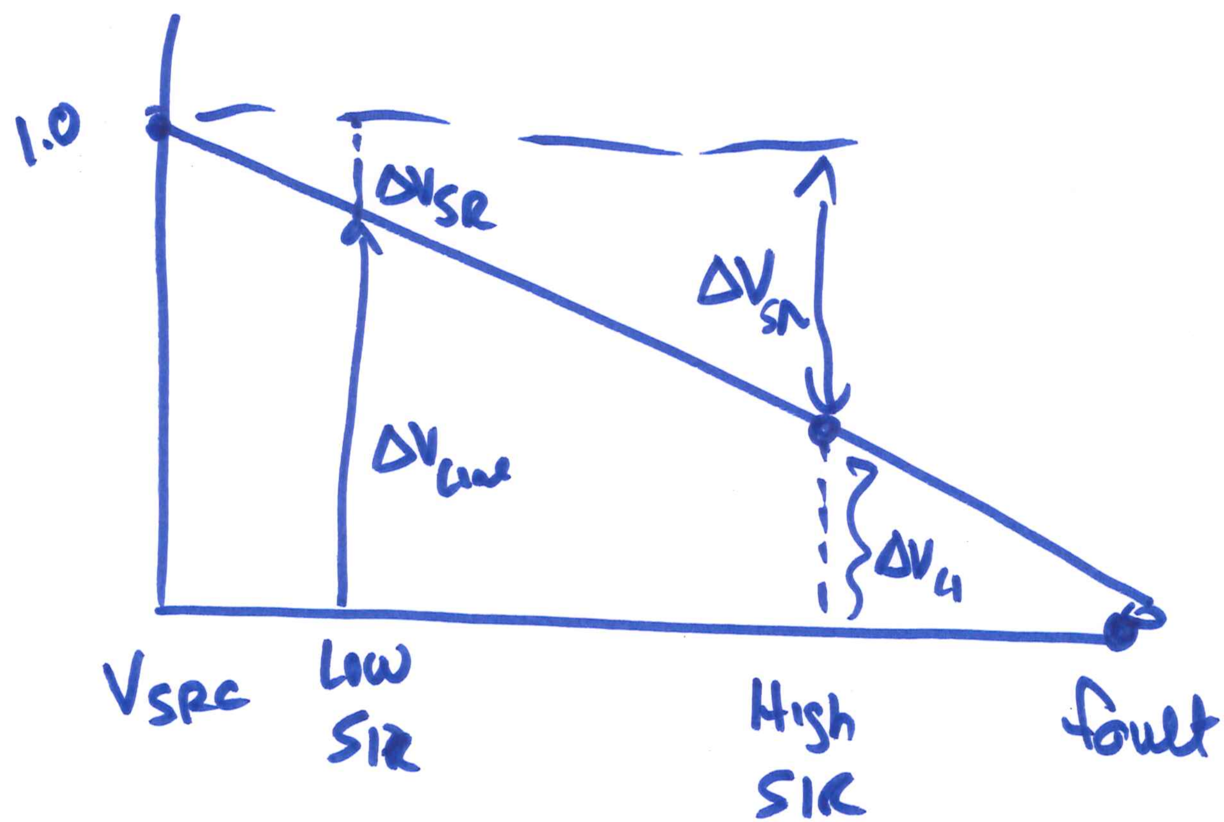


Farben Diagrams



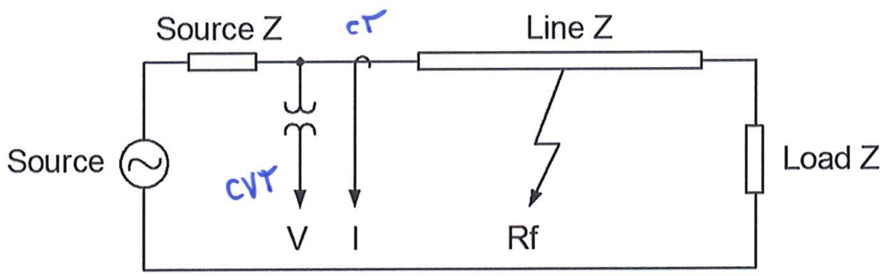
CVT and Distance Element Evaluation System



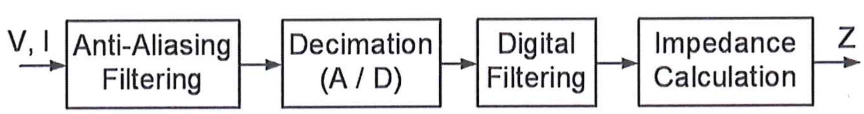

1.0
ΔV_SR
ΔV_SR
ΔV_Line
ΔV_L
V_SRC
Low SIR
High SIR
fault

source impedance ratio (SIR) => Z_{source} / Z_{LINE}

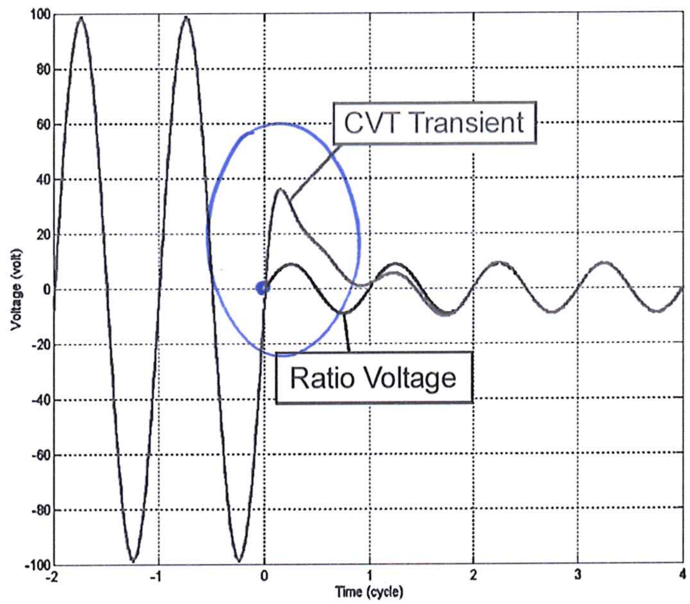
Power System Model



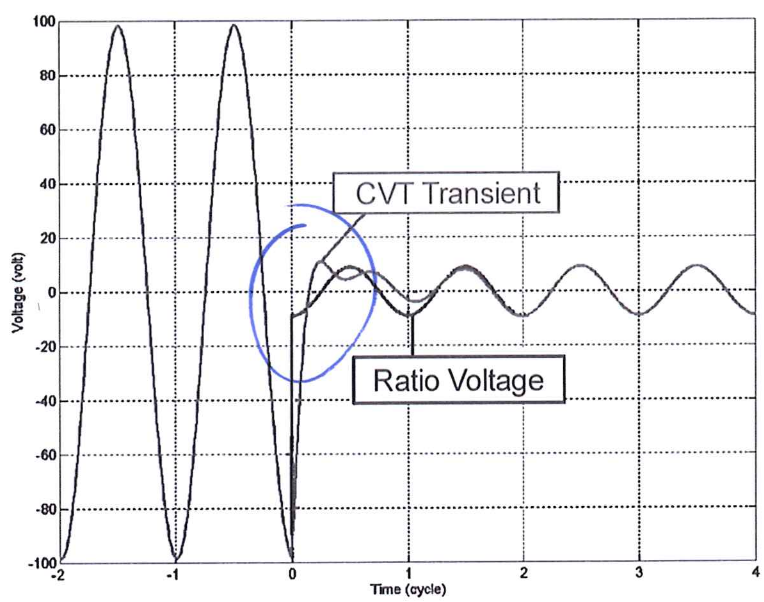
Microprocessor Relay Model

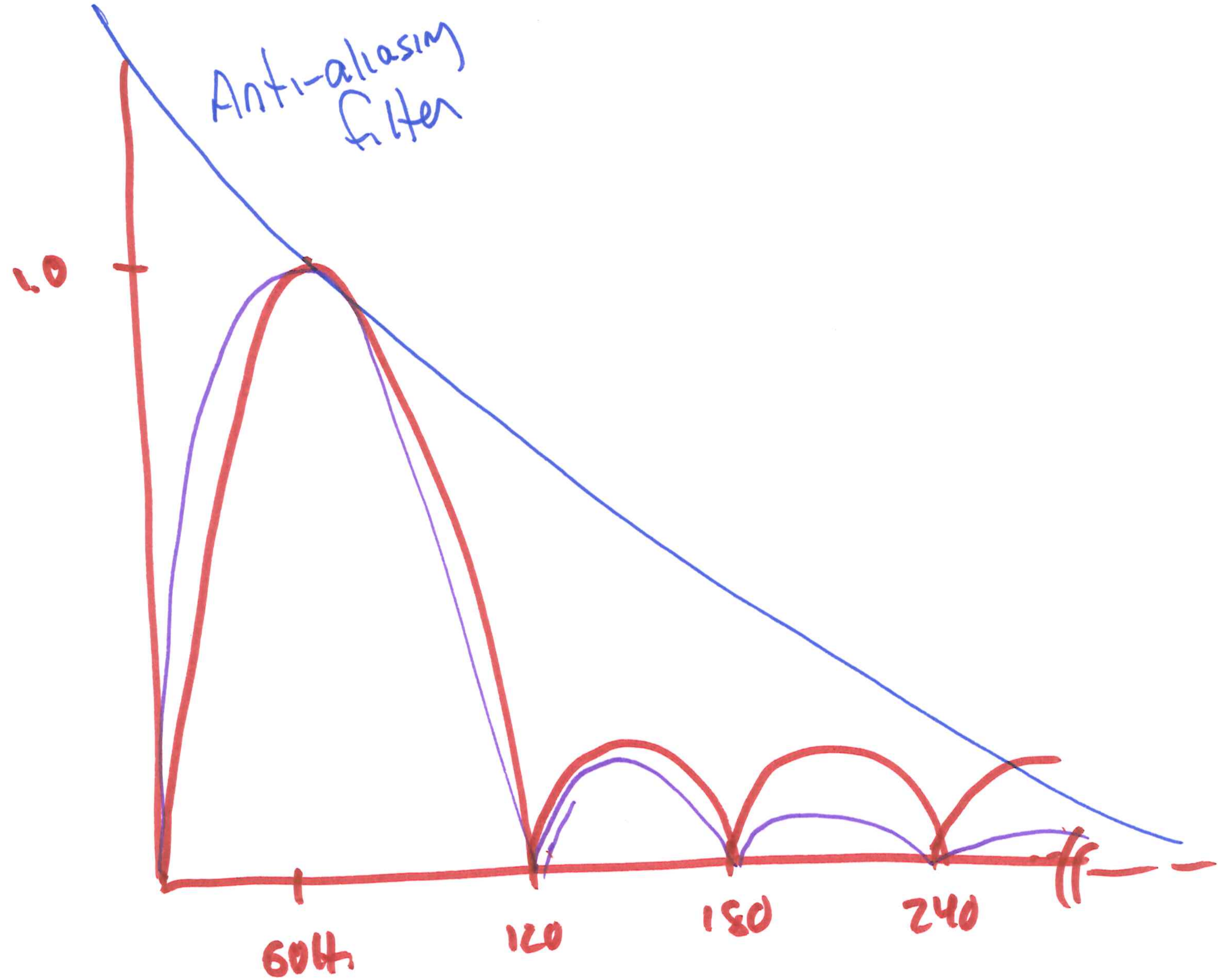


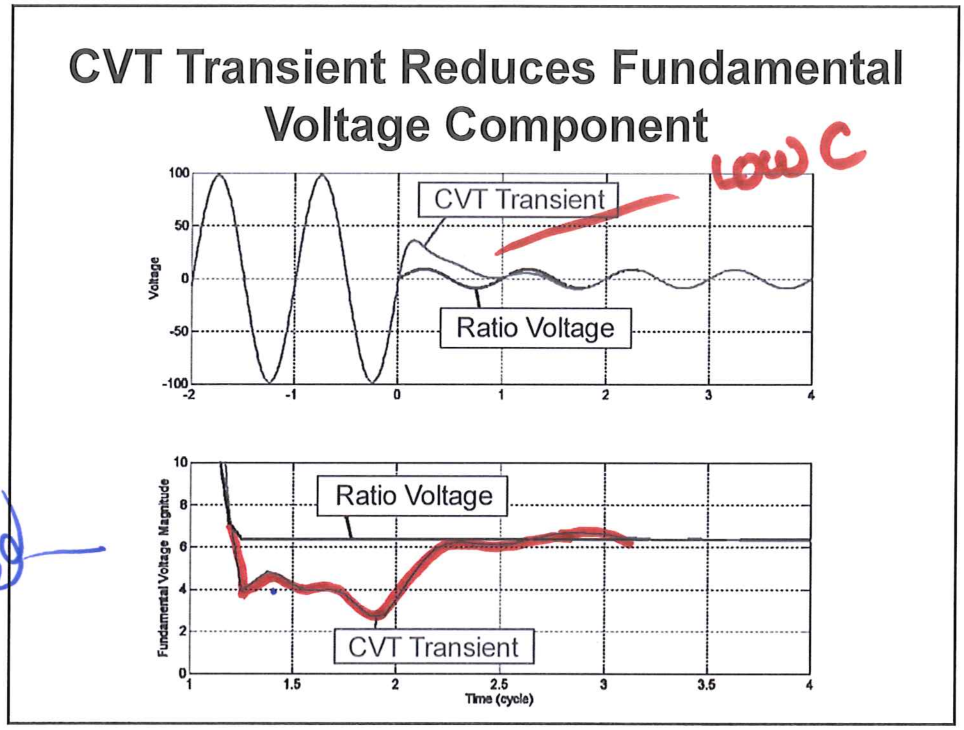
CVT Transient at Voltage Zero

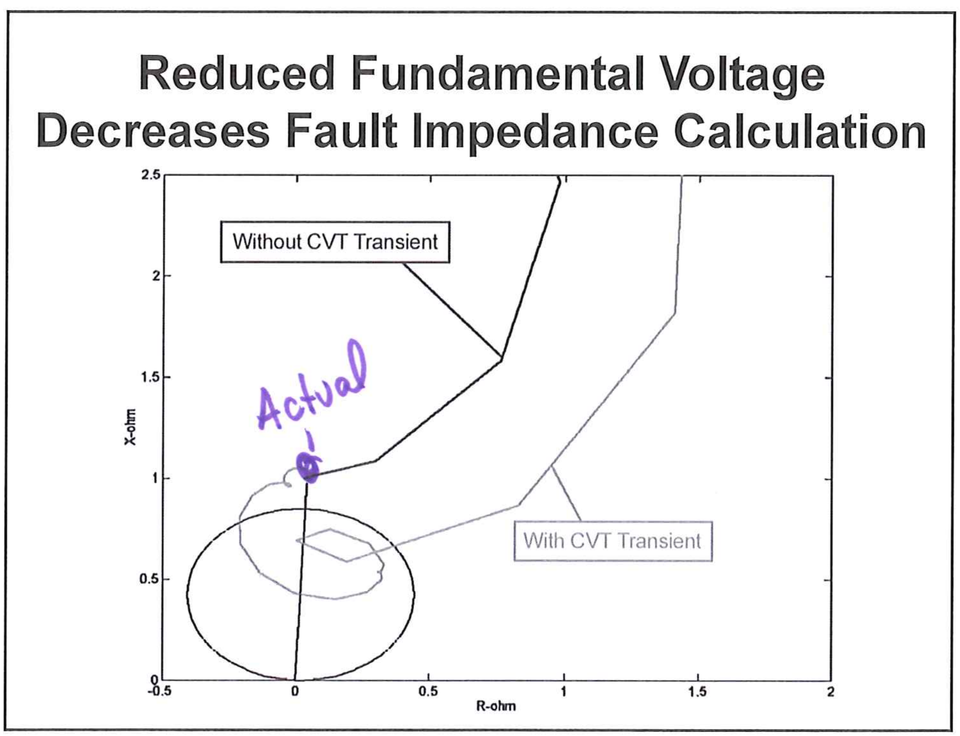


CVT Transient at Voltage Peak




Anti-aliasing filter
1.0
60Hz
120
180
240


CVT Transient Reduces Fundamental Voltage Component
CVT Transient
Ratio Voltage
Voltage
100
50
0
-50
-100
-2
-1
0
1
2
3
4
Ratio Voltage
CVT Transient
Fundamental Voltage Magnitude
10
8
6
4
2
0
1
1.5
2
2.5
3
3.5
4
Time (cycle)

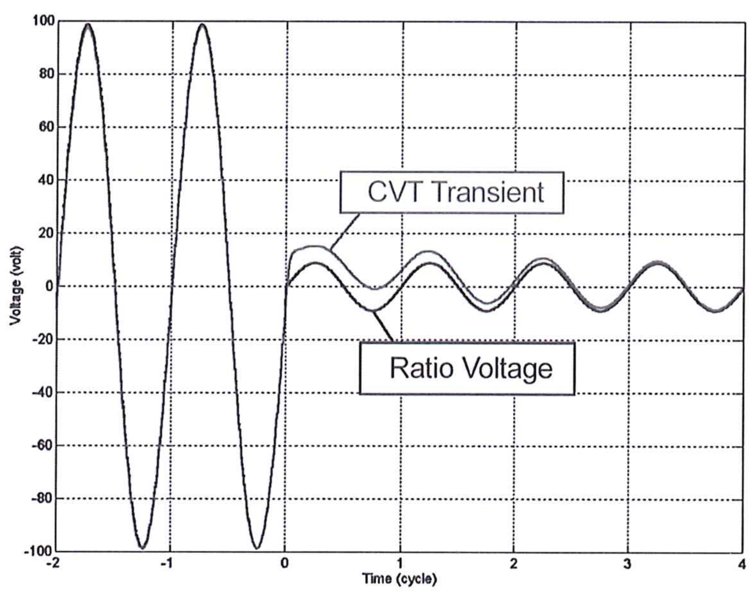

Reduced Fundamental Voltage Decreases Fault Impedance Calculation
Without CVT Transient
With CVT Transient
X-ohm
2.5
2
1.5
1
0.5
0
-0.5
0
0.5
1
1.5
2
R-ohm

CVT Components Affect CVT Transient

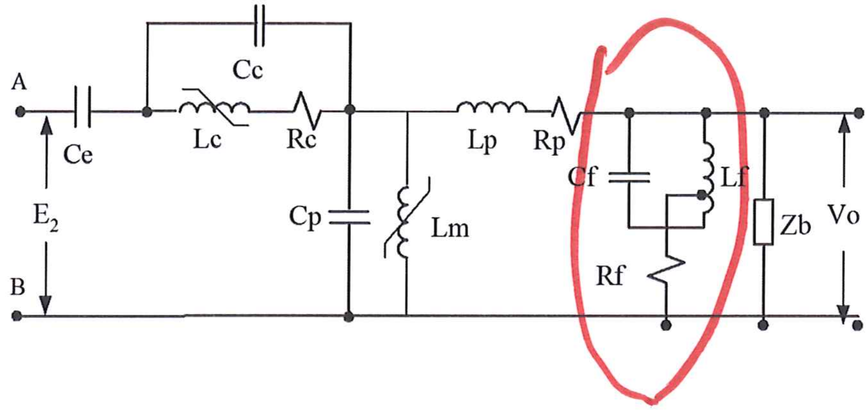
- Coupling capacitors (stack capacitance), magnitude of the tap
- Excitation current of the intermediate transformer
- Turns ratio of the intermediate voltage magnetic transformer
- Ferroresonance-suppression circuits

bigger capacitance

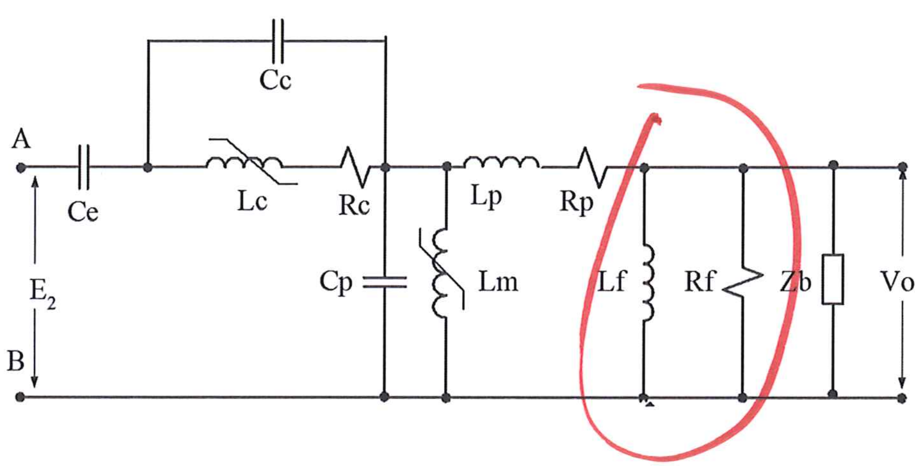
High-C CVT Causes Less Transient



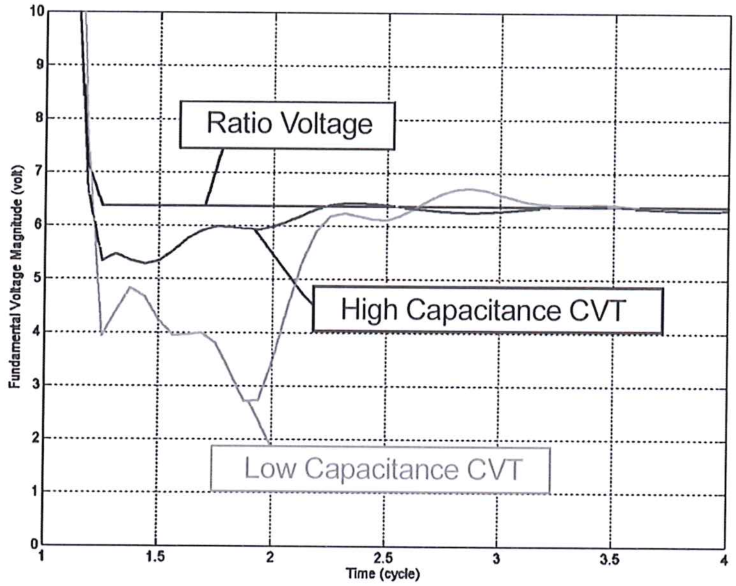
CVT Model With Active Ferro-Suppression Circuit Used for Transient Studies



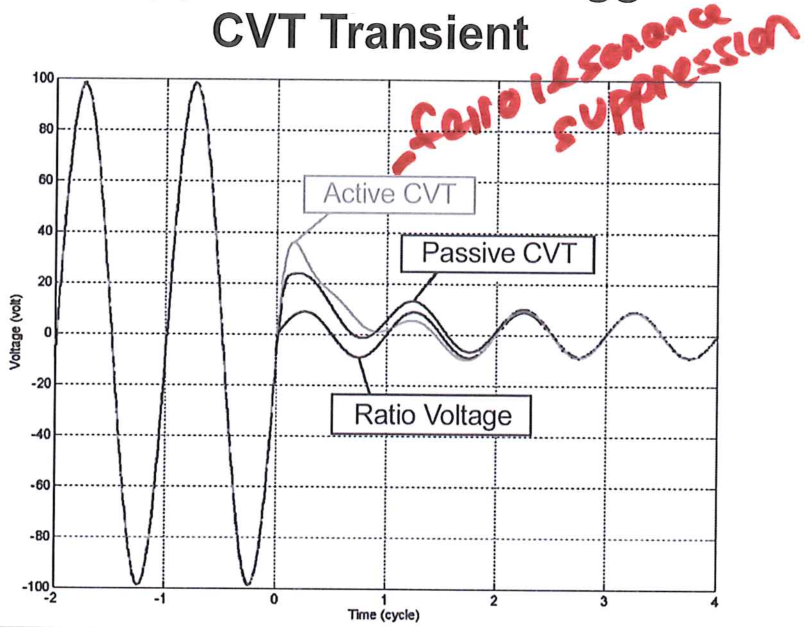
CVT Model With Passive Ferro-Suppression Circuit Used for Transient Analysis



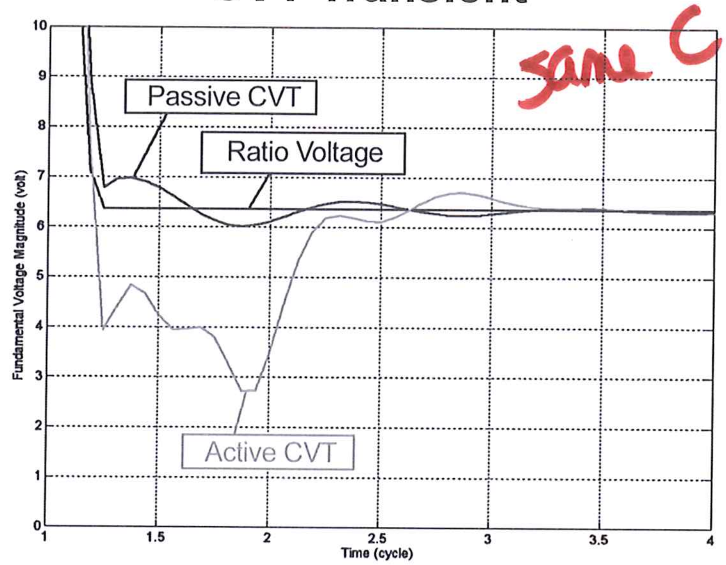
High- and Low-C CVT Comparison



Active Suppression Circuit Aggravates CVT Transient



Active Suppression Circuit Aggravates CVT Transient



Frequency Response of CVT