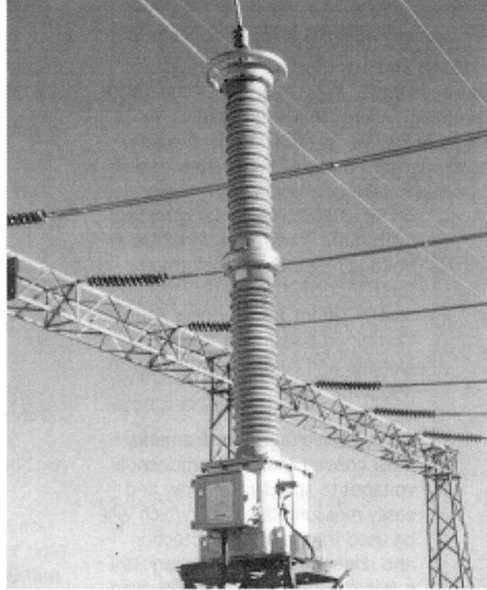
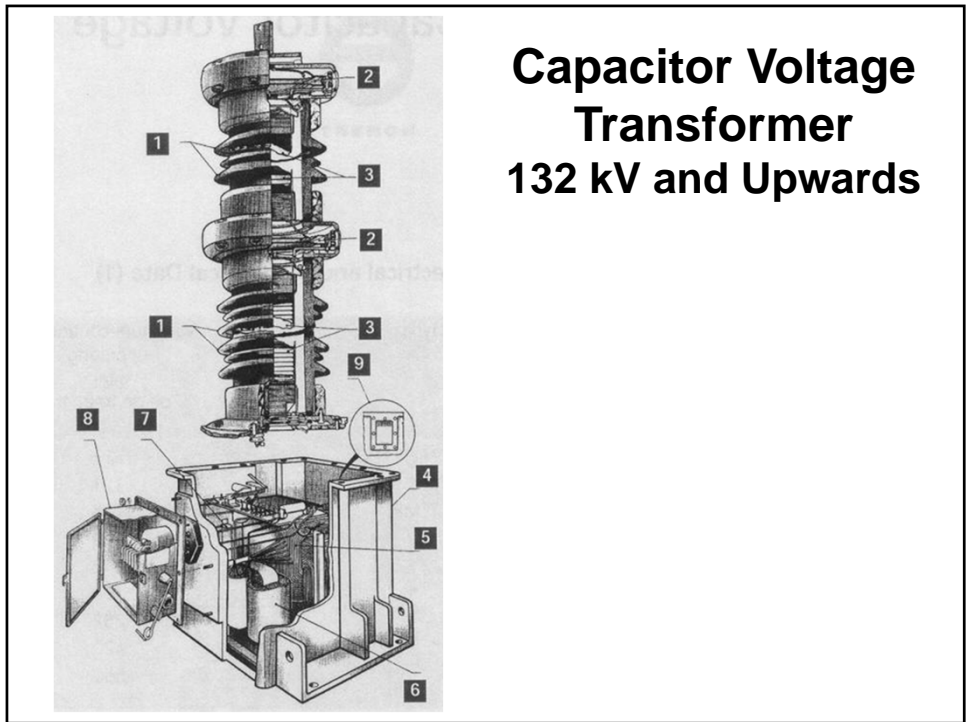
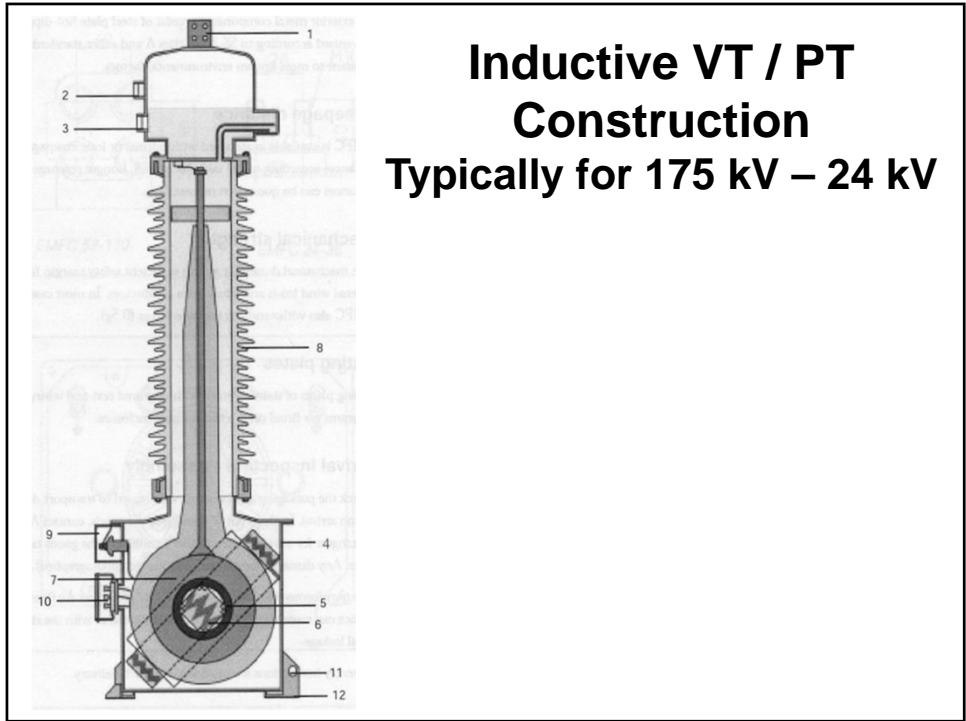


Voltage Transformers

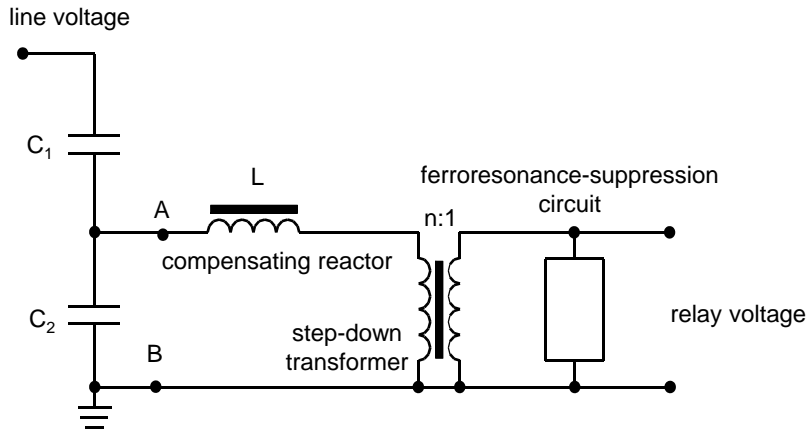


Overview

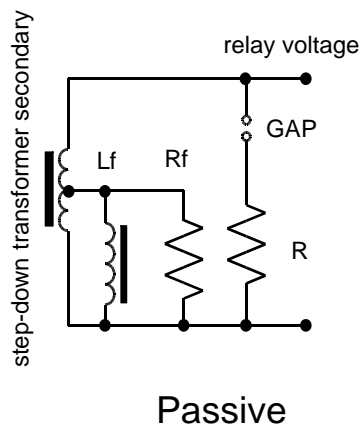
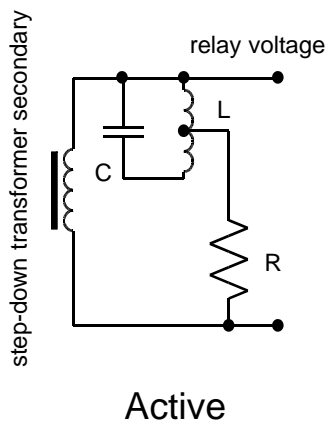
- VT and CVT construction
- VT and CVT equivalent circuit
- What is CVT transient?
- Why do CVT transients cause distance relay overreach?
- What determines CVT transient?
- What are some solutions?



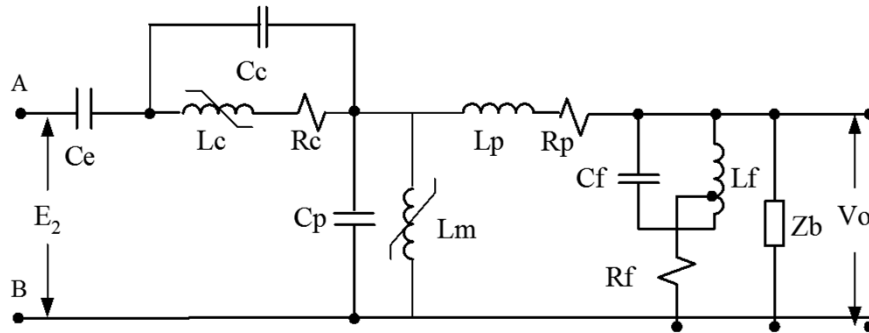
CVT Structure



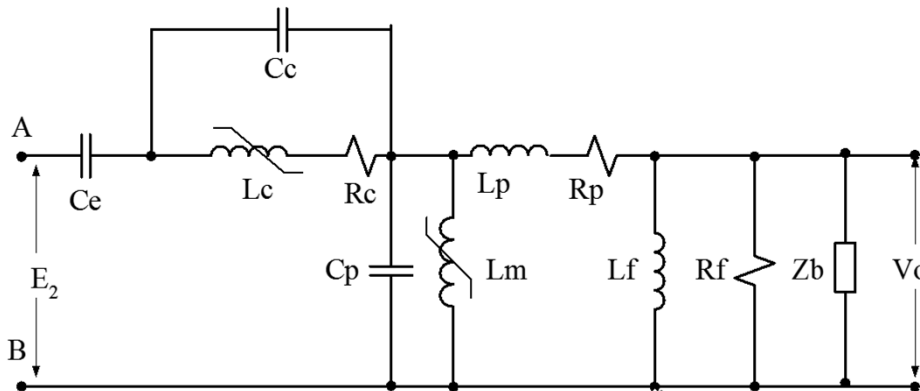
Ferroresonance-Suppression Circuits



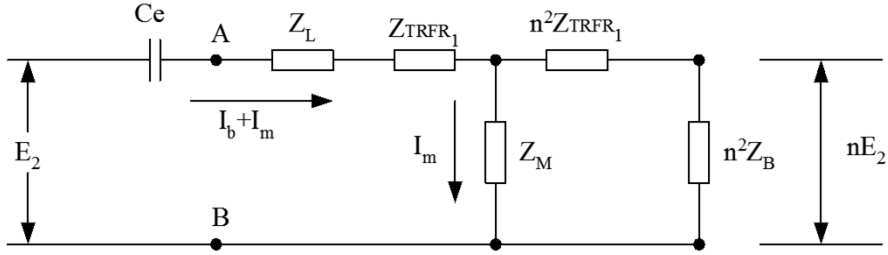
CVT Model With Active Ferro-Suppression Circuit Used for Transient Studies



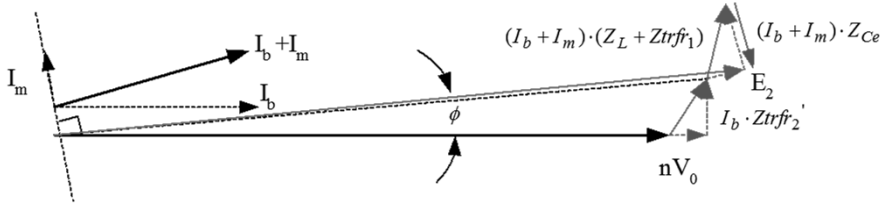
CVT Model With Passive Ferro-Suppression Circuit Used for Transient Analysis



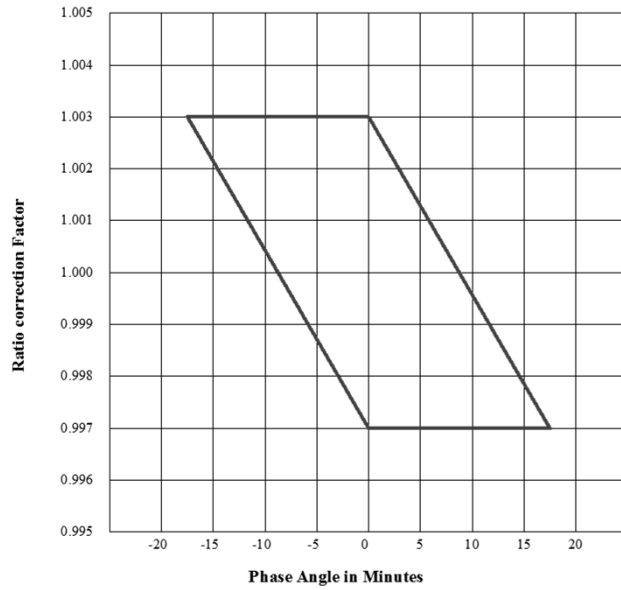
CVT Model for Analysis



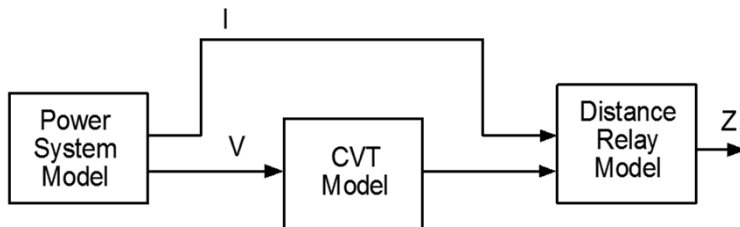
Phasor Diagram for CVT At Unity Power Factor



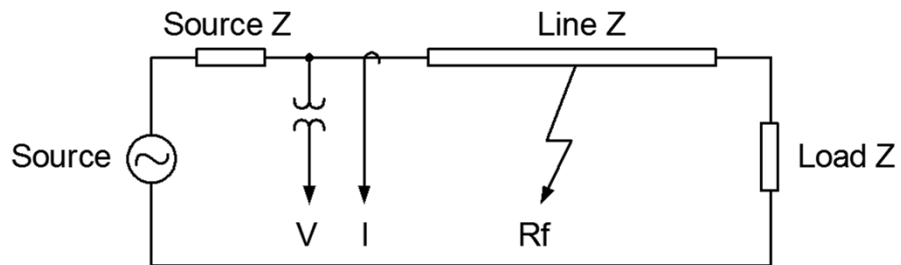
Farben Diagrams



CVT and Distance Element Evaluation System



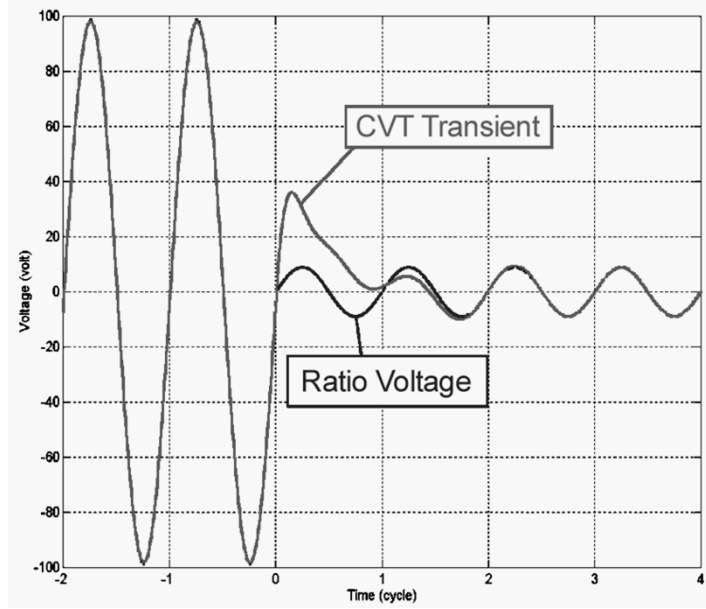
Power System Model



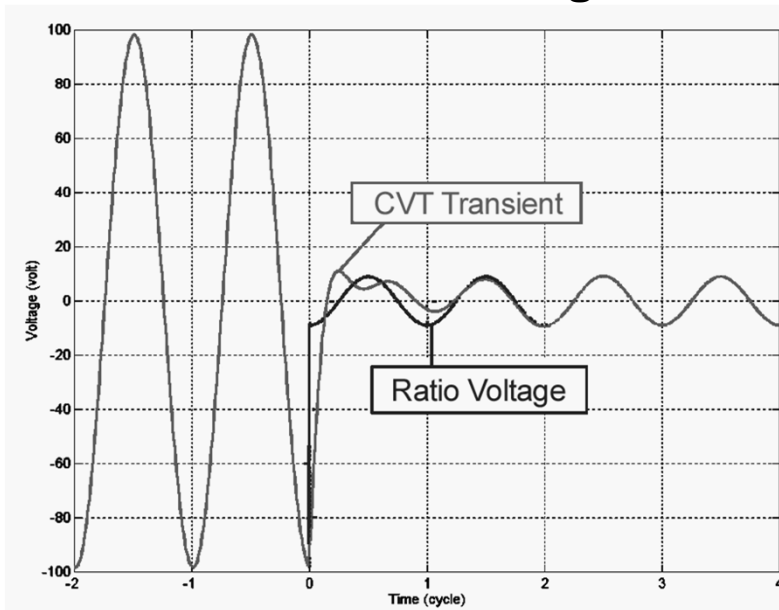
Microprocessor Relay Model



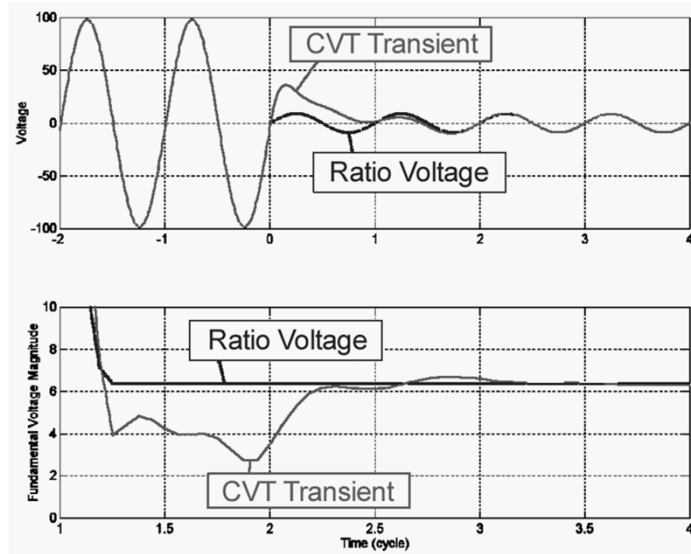
CVT Transient at Voltage Zero



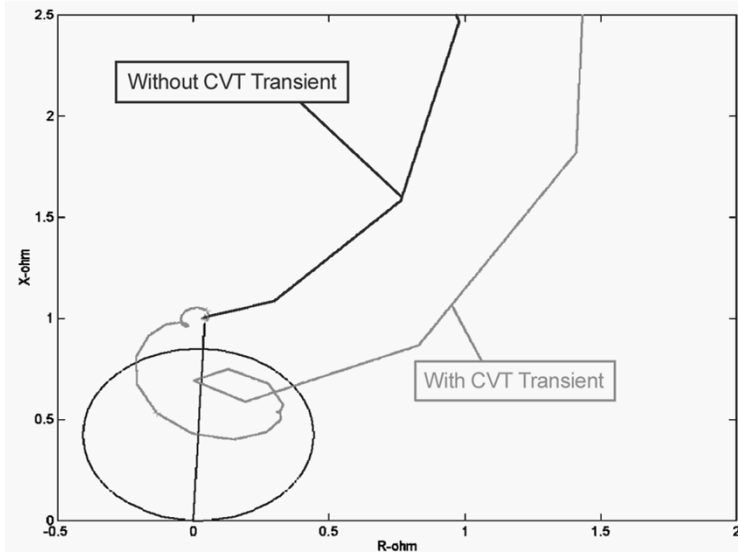
CVT Transient at Voltage Peak



CVT Transient Reduces Fundamental Voltage Component



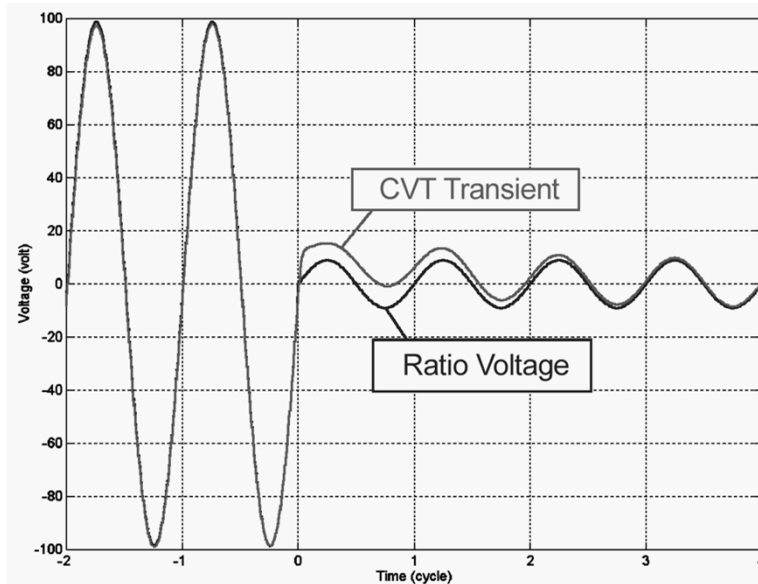
Reduced Fundamental Voltage Decreases Fault Impedance Calculation



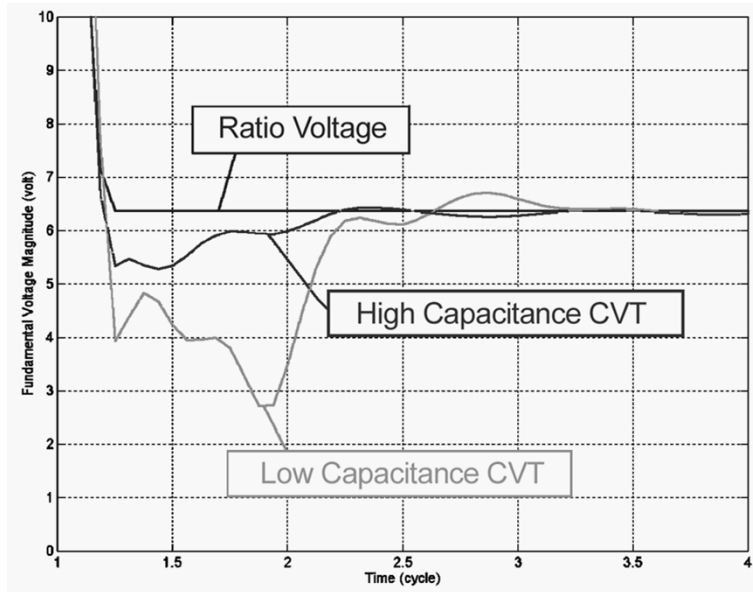
CVT Components Affect CVT Transient

- 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

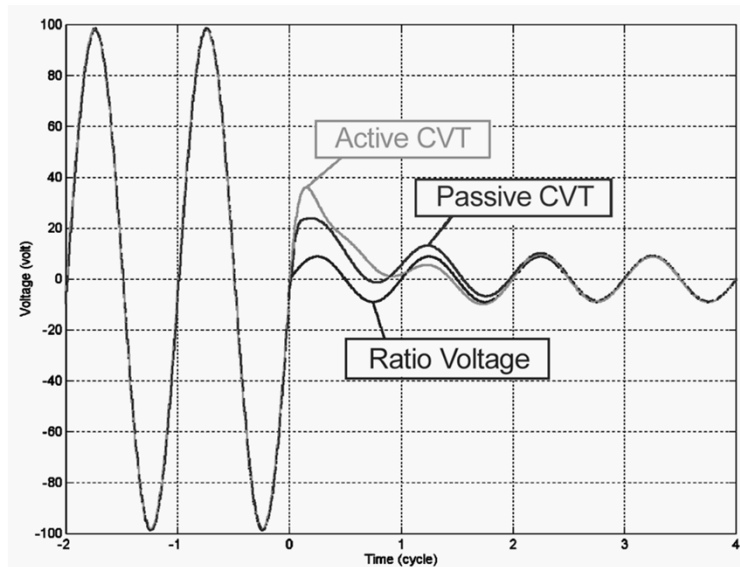
High-C CVT Causes Less Transient



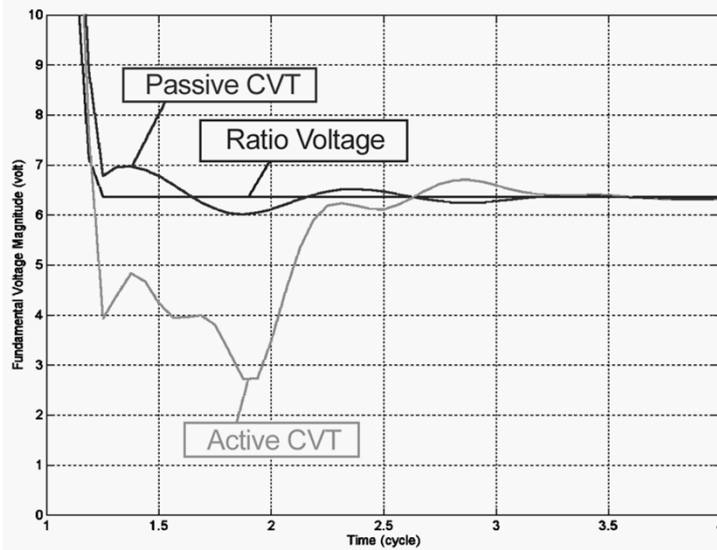
High- and Low-C CVT Comparison



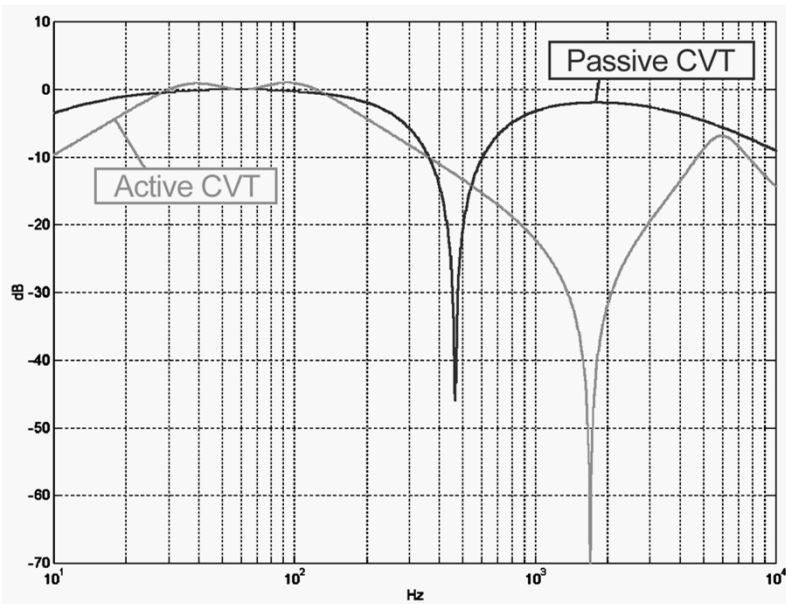
Active Suppression Circuit Aggravates CVT Transient



Active Suppression Circuit Aggravates CVT Transient



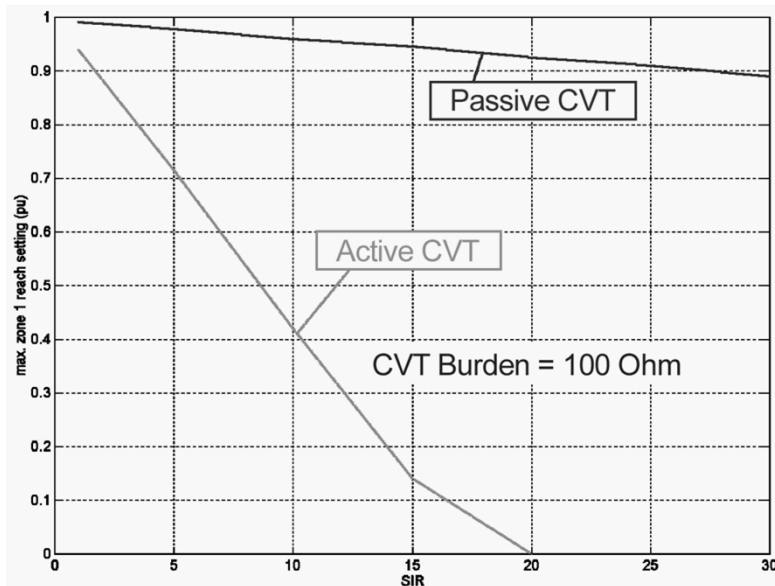
Frequency Response of CVT



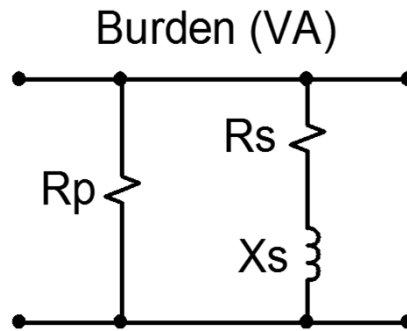
System Conditions Affect CVT Transient

- Point of wave, where the fault occurs
- System Impedance Ratio (SIR)
- CVT burden

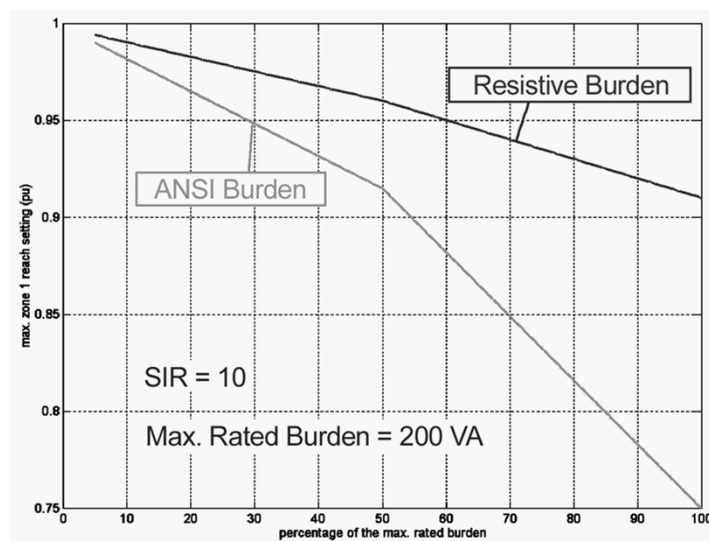
CVT Transient Related to System SIR



ANSI Burden for CVT Transient Testing



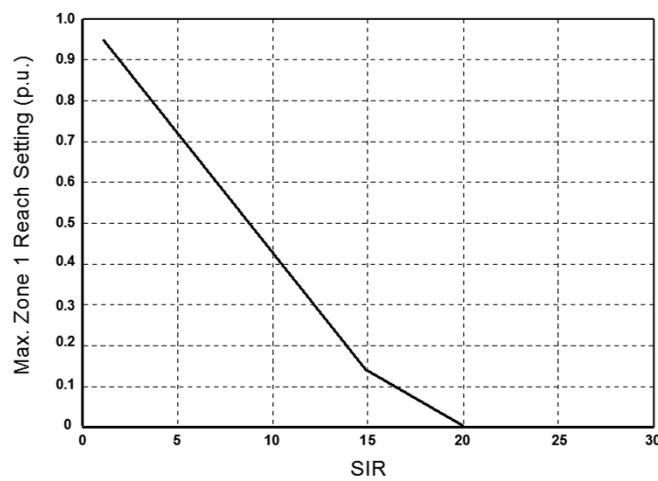
Inductive Loading Increases Distance Overreach



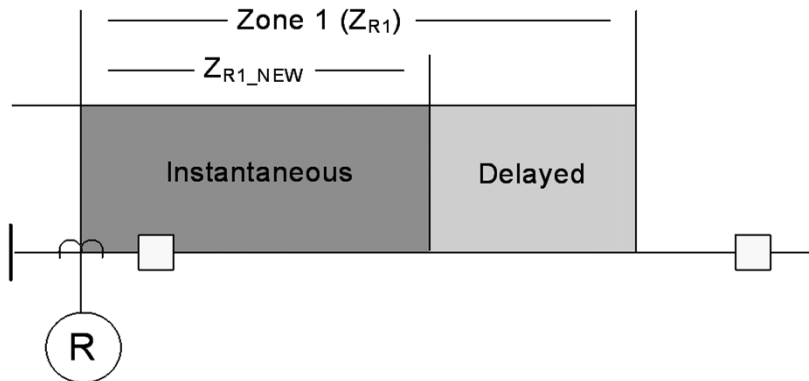
Solutions to Distance Overreach

- Reducing Zone 1 reach
- Introducing time delay

CVT Transient-Induced Distance Element Overreach Depends on SIR



Secure Zone 1



Conclusion

- Faults at voltage zero generate worst CVT transient
- Passive ferro-suppression circuit produces much less CVT transient
- Low SIR application does not cause overreach concern

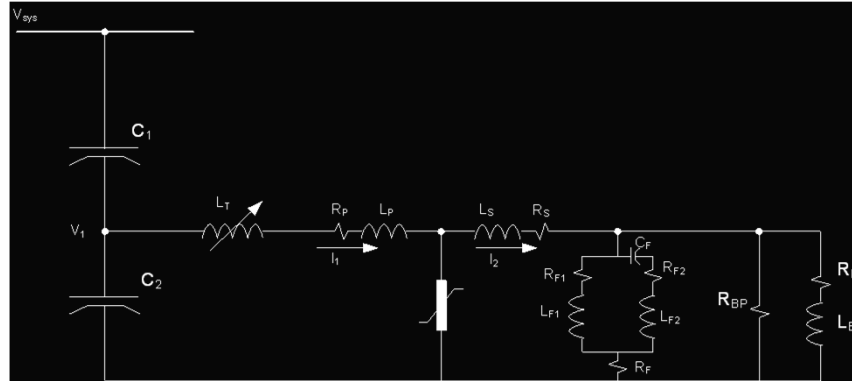
Conclusion

- High-C CVTs reduce distance relay overreach
- Resistive burden causes less CVT transient

Classification of CVTs

- Accuracy class
 - ◆ Protection 3P & 6P (typical)
 - ◆ Metering 0.3 & 0.6
- VA rating
- Voltage factor
 - ◆ $1.2 V_{\text{nom}}$ continuous
 - ◆ 1.5 / 30 sec (effectively earthed)
 - ◆ 1.9 / 8 hrs (unearthed, insulated neutral etc.)

Modeling a CVT in an EMTP like program



Data entry for a CVT model (2)

Name	Description	Value	Unit	Min	Max
Name	CVT Name	CVT3			
F	Base Frequency	60.0	Hz		
C1	Capacitor Divider (Vsys-V1)	1.28962e-2	uF	0.0	
C2	Capacitor Divider (V1-gnd)	2.63974e-1	uF	0.0	
Lt	Tuning Reactor	20.953	H	0.0	
csa	Cross-sectional Area	6.5e-3	m^2	0.0	
PLen	Path Length	0.5	m	0.0	
Rini	Initial Remanence	0.0	p.u.		
PLCrv	Detailed Losses?	No		0	1
ReqP	Assignment of Model to 3PC Card	Manual		0	1
ShrC	-- Manual: Place on 3PC Card	3		1 to 18	1 18
ShrP	-- Manual: Place on 3PC Processor	B		0	2

Buttons: Update, Cancel, Cancel All

Data entry for a CVT model (2)

Diagram showing a circuit with a transformer and a CVT model. The transformer is labeled 'Name = L89b'. The CVT model is labeled 'CVT98' and 'CVT9C'. The software interface shows the following data:

Name	Description	Value	Unit	Min	Max
Rp	Primary Side Resistance	474.0	Ohms	0.0	
Lp	Primary Side Inductance	4.46	H	0.0	
Np	Primary Side Turns	11000	turns	1	
Rs	Secondary Side Resistance	0.18	Ohms	0.0	
Ls	Secondary Side Inductance	0.47e-3	H	0.0	
Ns	Secondary Side Turns	115	turns	1	

Data entry for a CVT model (3)

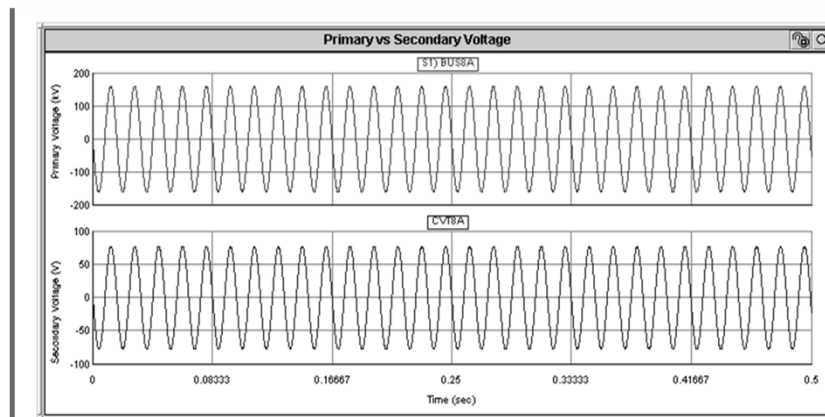
Diagram showing a circuit with a transformer and a CVT model. The transformer is labeled 'Name = L89b'. The CVT model is labeled 'CVT98' and 'CVT9C'. The software interface shows the following data:

Name	Description	Value	Unit	Min	Max
Rb	Burden series resistance	400.9	Ohms	0.0	
Lb	Burden series inductance	1.84	H	0.0	
Rbp	Burden parallel resistance	2298.0	Ohms	0.0	

Data entry for a CVT model (4)

Name	Description	Value	Unit	Min	Max
Rf1		1.06	Ohms	0.0	
Lf1		0.01	H	0.0	
Cf		8.0	uF	0.0	
Rf2		4.24	Ohms	0.0	
Lf2		0.394	H	0.0	
Rf		40.0	Ohms	0.0	

Model Response under Steady State Conditions



Model Response under Transient Conditions

