Voltage Transformers

Power System Protection

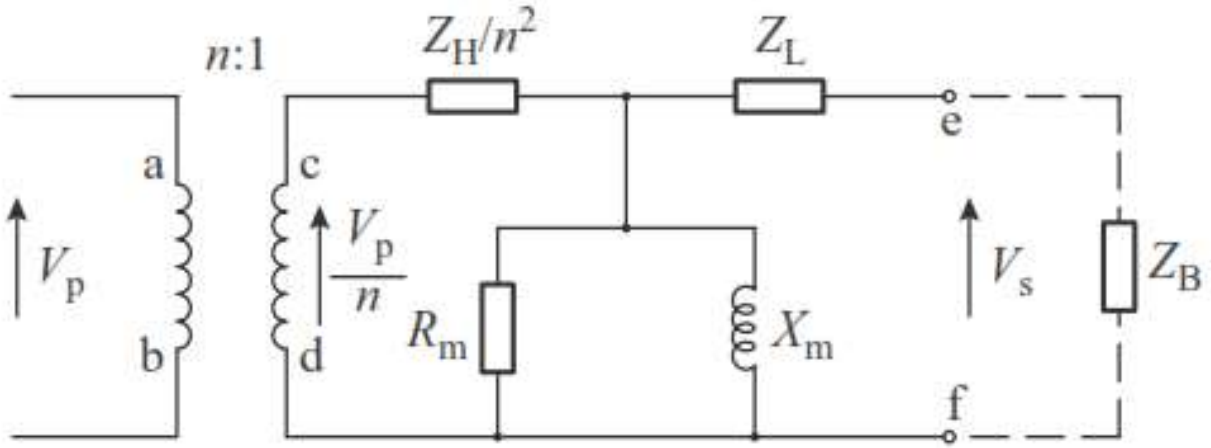
Abdul Basit

Voltage Transformer

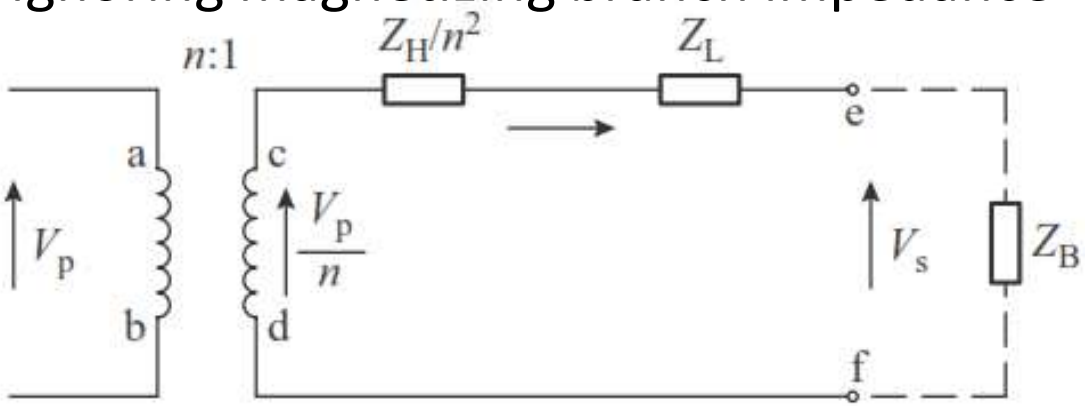
- Requirements:
  - Secondary voltage should be proportional to the primary voltage.
  - Less voltage drop in windings
  - Flux density well below the saturation value
    - Small magnetization current results in constant magnetization
  - Secondary voltage of a VT is usually 110 V with corresponding line-to-neutral values.

Equivalent circuit

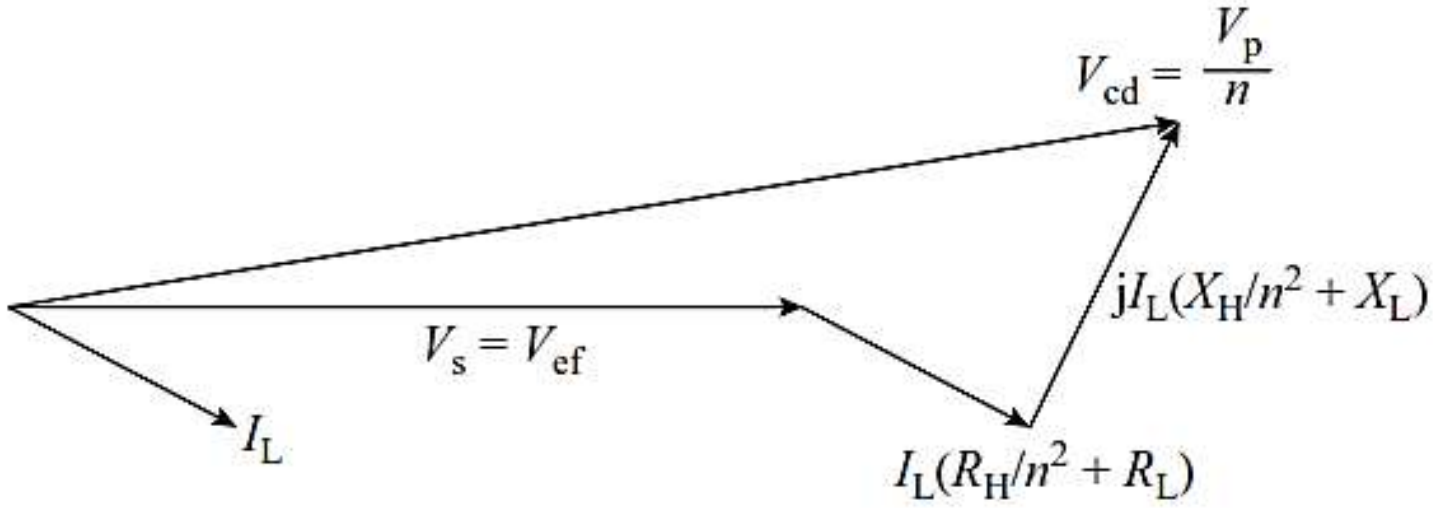
- VTs can be considered as small power transformers



Ignoring magnetizing branch impedance



Vector Diagram



- Secondary voltage V_S lags the voltage V_p/n and is smaller in magnitude.
- Nominal maximum errors are relatively small.
- VTs have an excellent transient behavior and accurately reproduce abrupt changes in the primary voltage

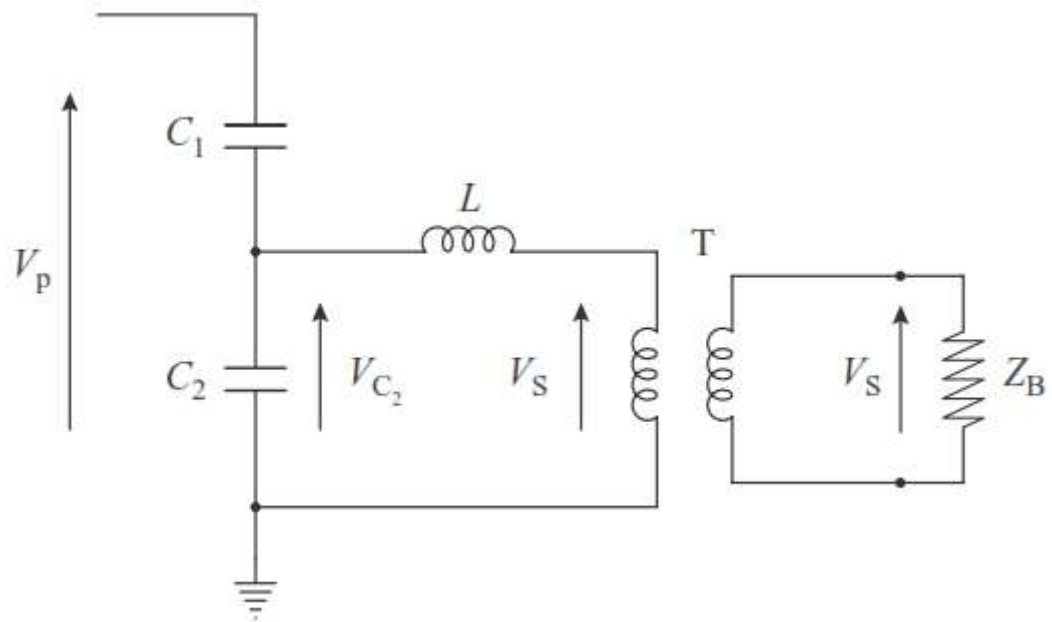
VT accuracy

- Errors should be contained within narrow limits over a wide range of possible voltages under fault conditions.
  - between 5% and 173% of the nominal primary voltage
- Errors in a VT are due to differences in magnitude and phase between primary and secondary voltage
  - Under open-circuit conditions the circulation of the magnetization current through the primary winding produces drop in secondary voltage
  - Heavy load current resulting in voltage drop

Capacitor voltage transformers

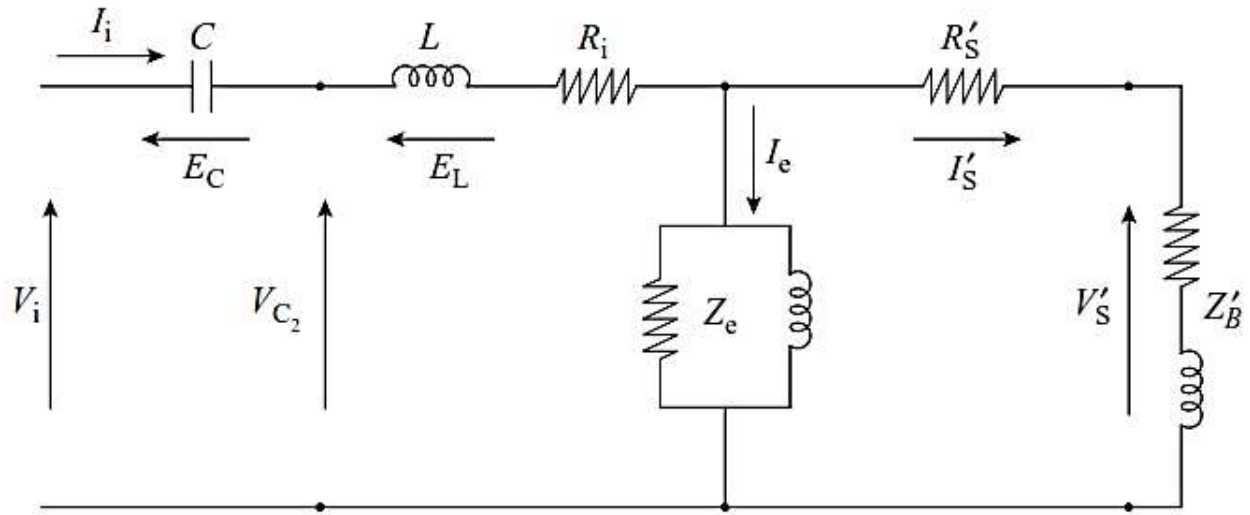
- Size and cost of VT is proportional to its nominal voltage
- To cut down the VT size and cost, a capacitance potential divider is used.
  - Reduced voltage is fed to primary of the transformer reduces the size of VT through coupling capacitor voltage transformers (CCVT)
- Capacitance divider affects the voltage received by the relay.
  - Voltage drop compensated by connecting reactance in series at the point of connection
  - Tuning inductor‘s value is so chosen that it compensates for the ‘net C' at power frequency

Capacitor voltage transformers



Capacitor voltage transformers

V_i is equal to the nominal primary voltage, *C is the numerically equivalent* impedance equal to ($C_1 + C_2$), *L is the resonance inductance*, *Ri* represents the resistance of the primary winding of transformer *T plus the losses in C and L, and Ze is the magnetization impedance of transformer*



Resistance of the secondary circuit and the load impedance are represented by R_S` and $Z_B$`, respectively, whereas *Vs`* and *Is` represents the secondary voltage.*

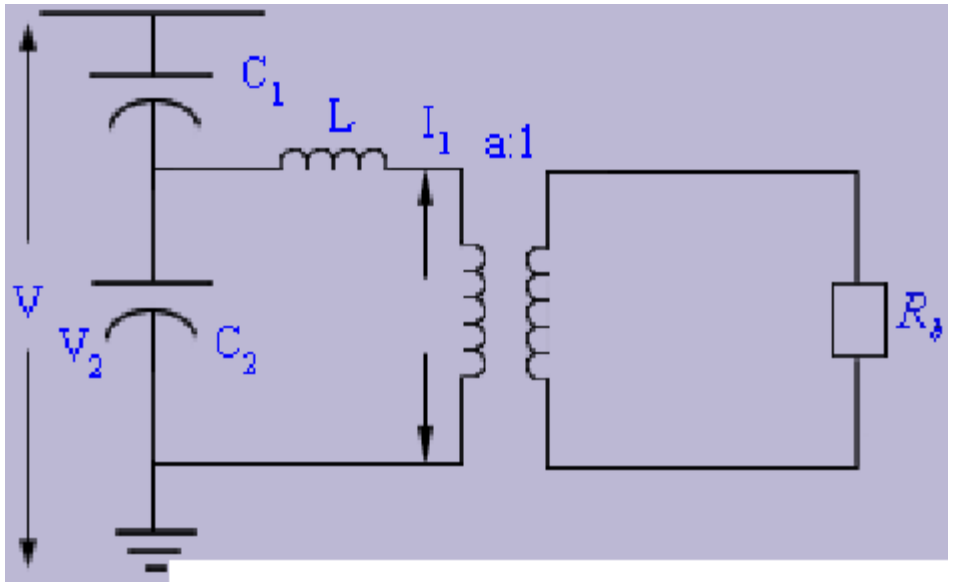
Capacitor Voltage Transformers

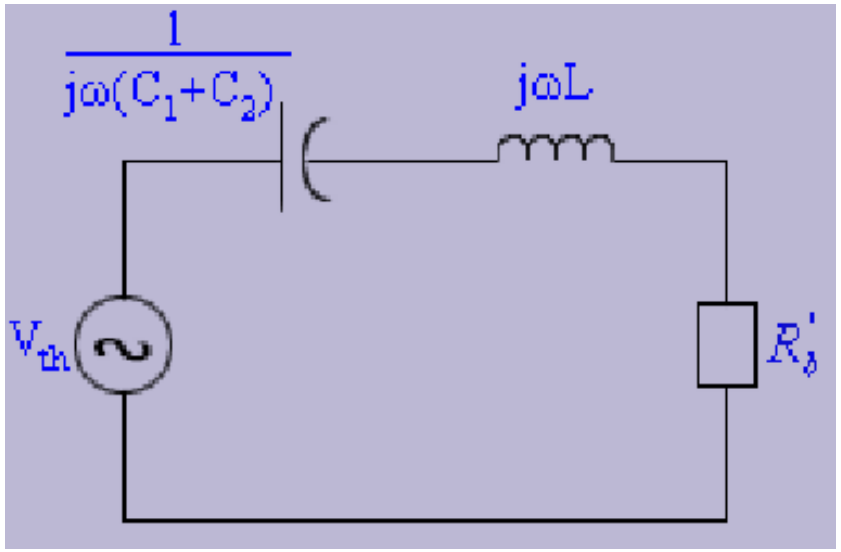
- With exception of C, the circuit is same as the equivalent circuit of a power transformer.
- At system frequency when C and L are resonating and cancelling out each other, under stable system conditions the capacitor VT acts like a conventional transformer.
- Small R and I_e compared with I_s results in small error in the capacitor VT.
- Capacitor VTs have a better transient behavior as the inductive and capacitive reactances in series are large in relation to the load impedance referred to the secondary voltage and thus, when the primary voltage collapses, the secondary voltage is maintained for some milliseconds because of the combination of the series and parallel resonant circuits represented by *L, C and the transformer.*

Example 1

Design a CCVT for a 132kV transmission line using the following data. Resistive Burden (3φ) = 150VA, frequency deviation to be subjected to, phase angle error β = 40 minutes. Consider four choices of V_2 as 33 kV, 11 kV, 6.6 kV and 3.3 kV. Transmission line voltage V = 132 kV. The standardized VT secondary voltage is 110 volts (L - L).

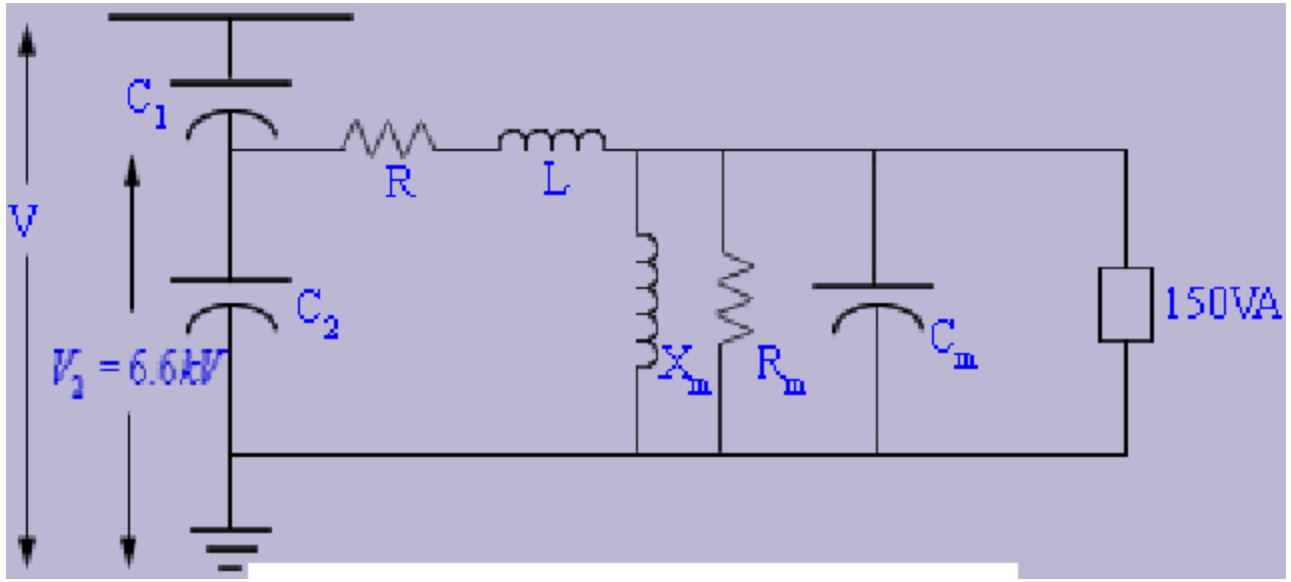
Example 1





Example 2

The equivalent circuit of a CCVT is shown in figure. The values of C1 and C2 are 0.0018 µF and 0.0186 µF respectively. Tuning inductor has an inductance of 497H and resistance of 4620 Ω. X_m of the VT referred to 6.6 kV side is 1MΩ , core loss = 20 watts per phase, VA burden = 150VA per phase. Value of Cm for compensating the current drawn by Xm is equal to 3.183 nF.



Example 2

a) Verify the appropriateness of choice of L and Cm.
b) Find out the nominal value of V/V2
c) If the frequency drops from 50Hz to 47Hz, what would be the values of ratio error and phase angle error?