EE 5200 - Lecture 21

Fri Oct 19, 2019

Topics for Today:

- Announcements
  - ATP availabilty is being confirmed. V7.0 is being requested.
  - Term project detailed outline due Mon Oct 23^{rd}, extension given
  - Office: EERC 614.   Phone: 906.487.2857
  - Book exercises from Ch.6,7 solutions posted - required to go thru
  - Upcoming hmwks: Transmission Lines as 2-port networks. Matlab.

Chapter 6 - Shunt Capacitance Transmission Lines

- Using the T-Line models
  - Short Transmission Lines - up to 50 miles (80 km)
  - Voltage Regulation, phasor diagrams
  - Per-phase impedance diagrams (positive seq only)
  - Medium-Length Lines (50 - 150 miles)
  - ABCD parameters for Medium-lines, power flow
  - Long Lines - more than 150 miles (240 km)
  - Derivation of long-line equations, meaning of equations
  - Characteristic Impedance Z_C
  - Propagation Constant $\gamma = \alpha + j\beta$
  - Surge-Impedance Loading (SIL)
  - Wavelength, velocity, Traveling waves, reflections

T-Line Performance

Sagging

S – I^2R heat/temp/losses $\Rightarrow \eta$

M – Voltage Regulation, VR, 0.95 - 1.05 p.u.

L – Stability – EE6210

M/L – Power Flow limits

– ⋮

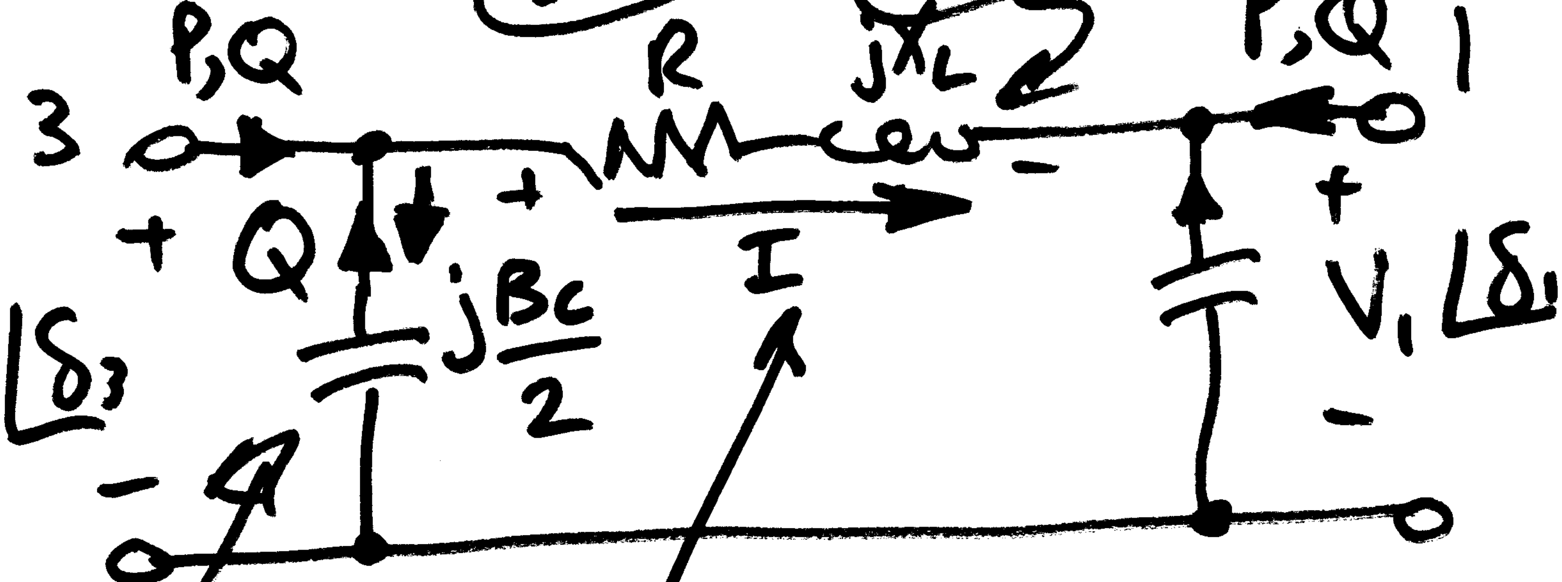
– EE5220 – insulation / over-voltage

Ex:

$1 \to 3$	-174.88	-40.45
$3 \to 1$	$\underbrace{179.54}$	$\underbrace{49.24}$
	$\Delta P = 4.66$	$\Delta Q = 8.79$

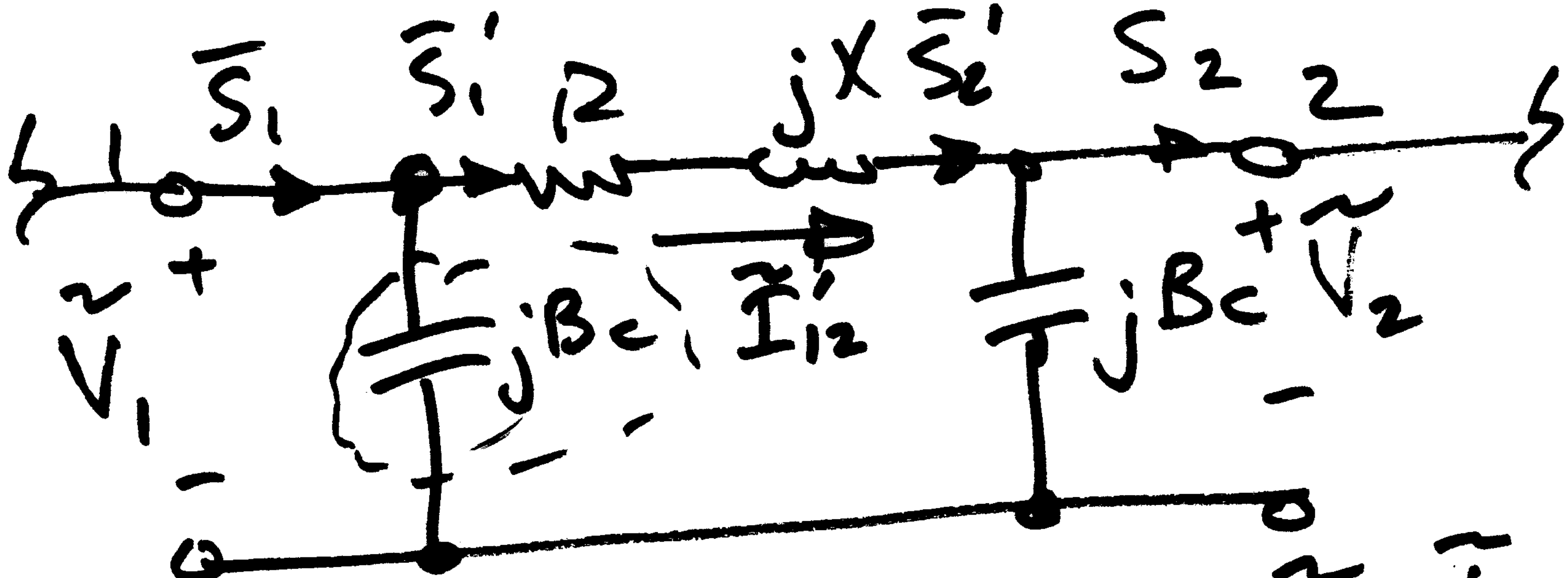
$\bar{S} = \tilde{V}_3 \tilde{I}_3^*$

I^2R $\quad$ I^2X_L



$Q = V_3^2 \frac{B_c}{2}$

$\tilde{I} = \frac{\tilde{V}_3 - \tilde{V}_1}{R + jX_L} = I \angle \theta$



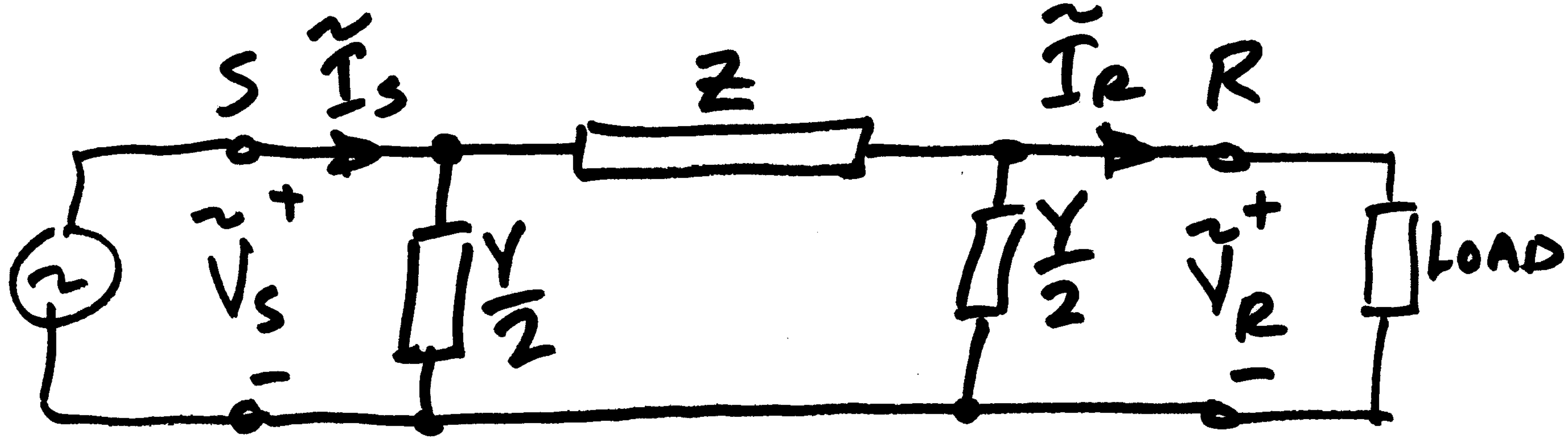
$$\tilde{I}_{12}' = \frac{\tilde{V}_1 - \tilde{V}_2}{R + jX}$$

$$Q = V_1^2 B_c$$

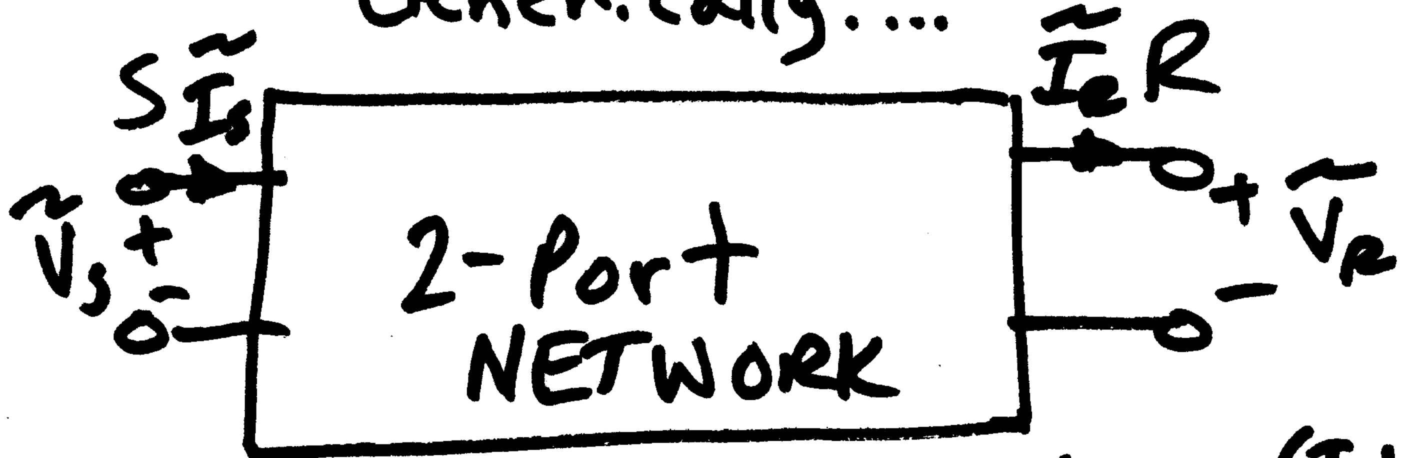
$$\bar{S}_1' = \bar{S}_1 + V_1^2 B_c$$

$$\bar{S}_2' = \bar{S}_1' - P_R - Q_x$$

$$= \bar{S}_1' - \left(\tilde{I}_{12}'\right)^2 (R) - \left(I_{12}'\right)^2 X$$



Generically....



- ABCD Parameters (T-Lines)
- H parameters (electronics)
- Many others.

$$\begin{bmatrix} \tilde{V}_S \\ \tilde{I}_S \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} \tilde{V}_R \\ \tilde{I}_R \end{bmatrix}$$

$A = \left.\dfrac{\tilde{V}_S}{\tilde{V}_R}\right|_{I_R=0}$ (O.C. Receiving end) (No-Load)

$B = \left.\dfrac{\tilde{V}_S}{\tilde{I}_R}\right|_{V_R=0}$ (S.C. " ")

$C = \left.\dfrac{\tilde{I}_S}{\tilde{V}_R}\right|_{I_R=0}$ (O.C. " ")

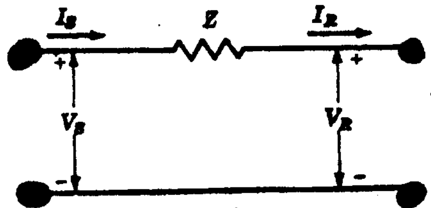
$D = \left.\dfrac{\tilde{I}_S}{I_R}\right|_{V_R=0}$ (S.C. " ")

TABLE A.6
***ABCD* constants for various networks**

Eqn. 6.8, 6.9

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} \tilde{V}_R \\ \tilde{I}_R \end{bmatrix} = \begin{bmatrix} \tilde{V}_S \\ \tilde{I}_S \end{bmatrix}$$

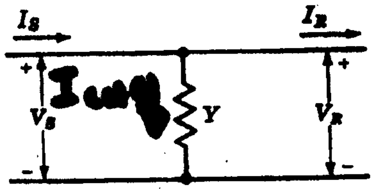
S



R

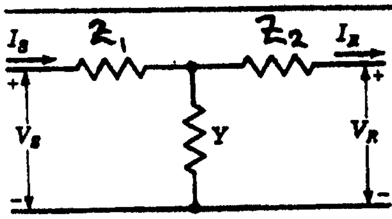
Series impedance

$A = 1$
$B = Z$
$C = 0$
$D = 1$



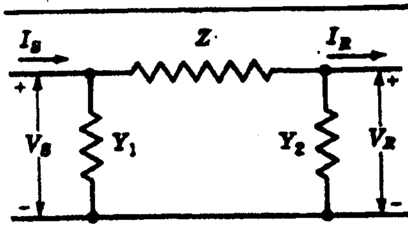
Shunt admittance

$A = 1$
$B = 0$
$C = Y$
$D = 1$



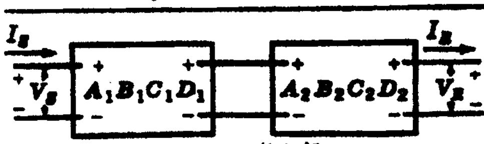
Unsymmetrical T

$A = 1 + YZ_1$
$B = Z_1 + Z_2 + YZ_1Z_2$
$C = Y$
$D = 1 + YZ_2$



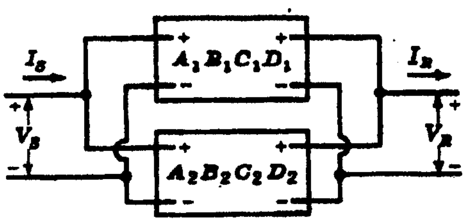
Unsymmetrical π

$A = 1 + Y_2Z$
$B = Z$
$C = Y_1 + Y_2 + ZY_1Y_2$
$D = 1 + Y_1Z$



Networks in cascade

$A = A_1A_2 + B_1C_2$
$B = A_1B_2 + B_1D_2$
$C = A_2C_1 + C_2D_1$
$D = B_2C_1 + D_1D_2$

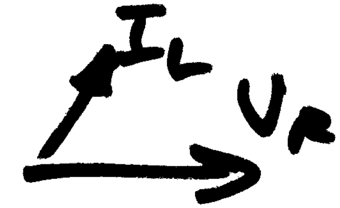


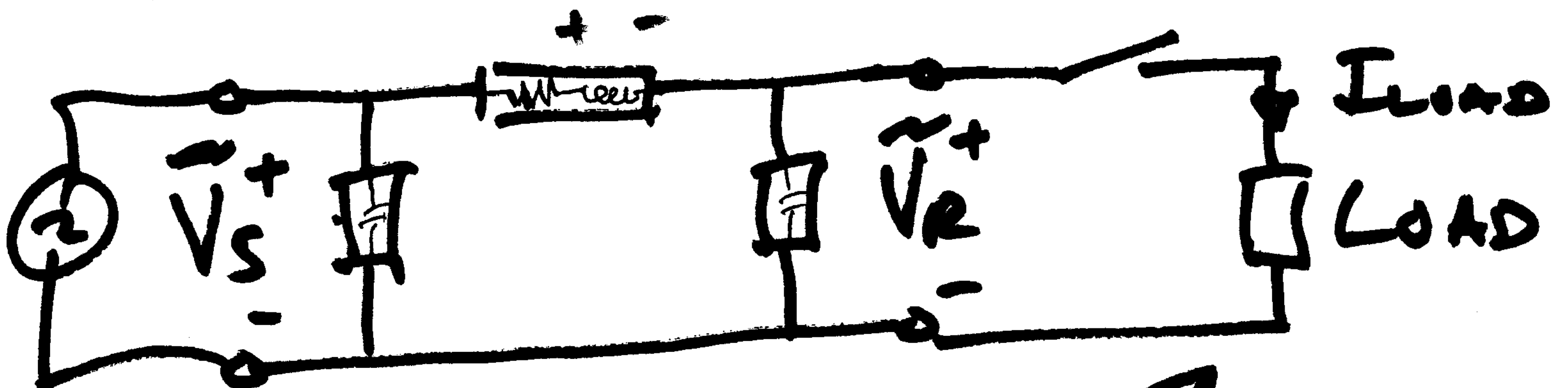
Networks in parallel

$A = (A_1B_2 + A_2B_1)/(B_1 + B_2)$
$B = B_1B_2/(B_1 + B_2)$
$C = C_1 + C_2 + (A_1 - A_2)(D_2 - D_1)/(B_1 + B_2)$
$D = (B_2D_1 + B_1D_2)/(B_1 + B_2)$

Voltage Regulation

$V_{drop} = \tilde{I} jX_L$





$\tilde{I}_R = 0$

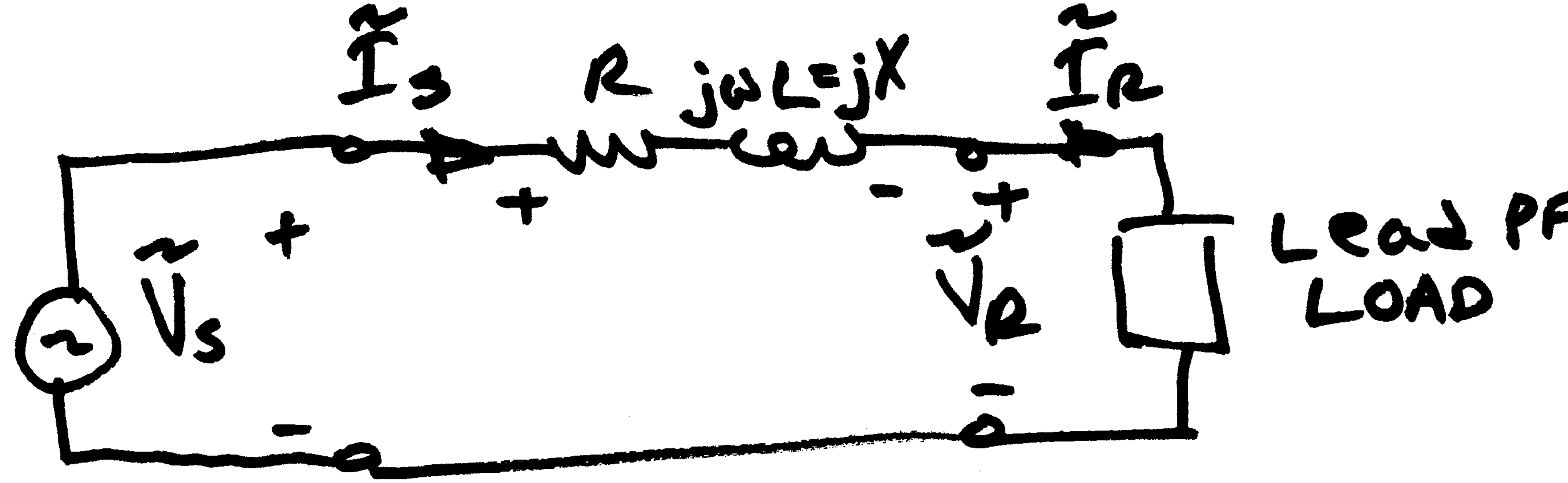
$$VR = \frac{V_{NL} - V_{FL}}{V_{FL}}$$

Load Voltages!

Most Loads are Lagging PF $\Rightarrow V_{NL} > V_{FL}$

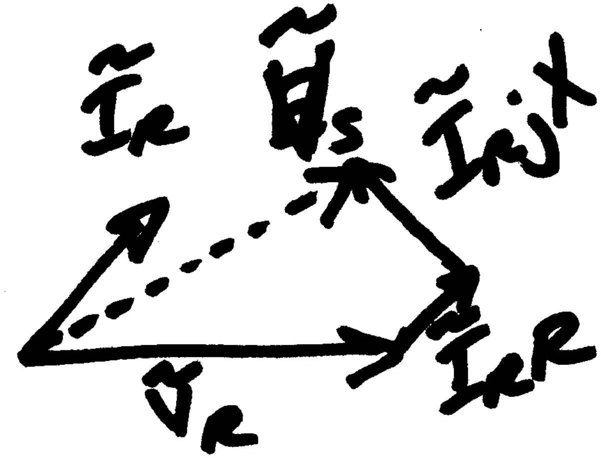
$VR > 0.$

If Load is Leading PF $\Rightarrow V_{NL} < V_{FL} \Rightarrow VR < 0.$

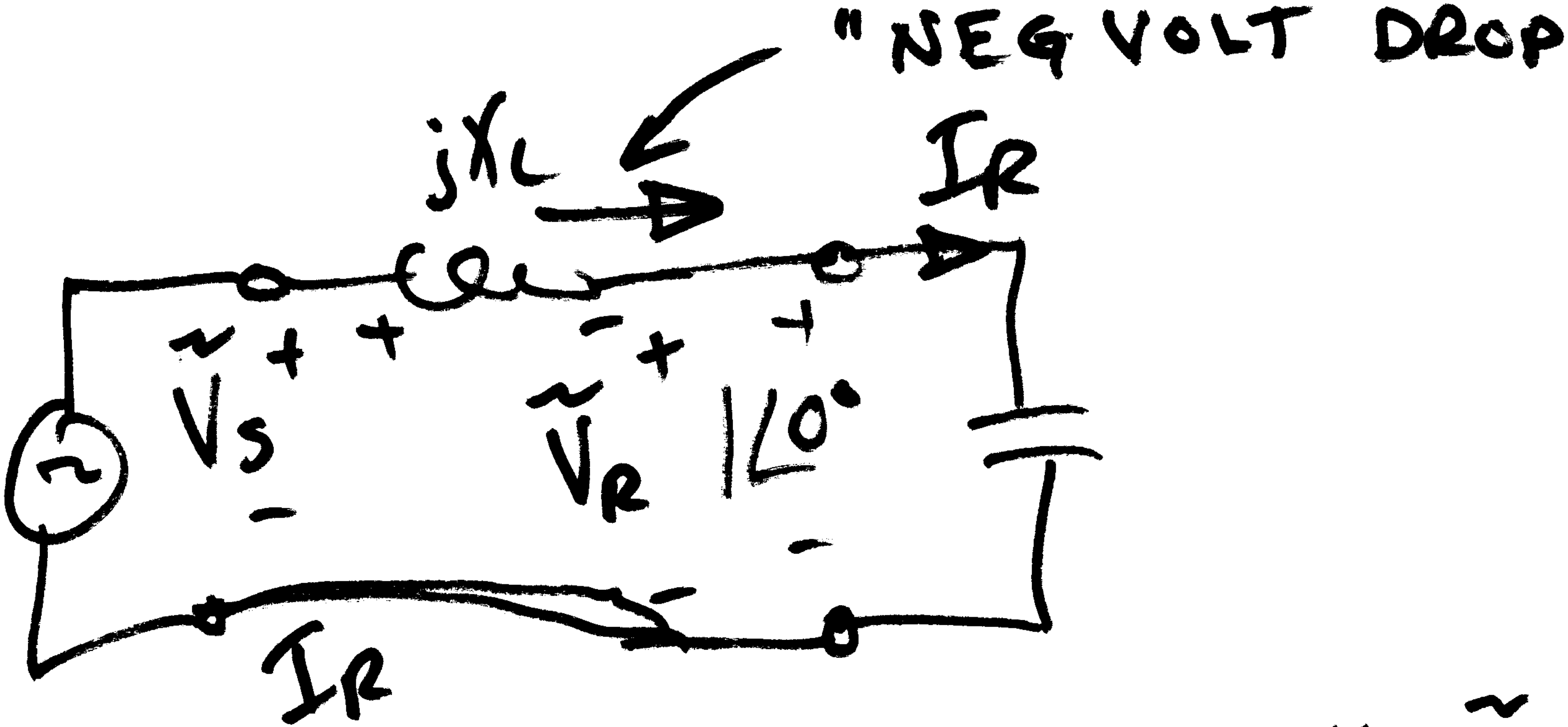


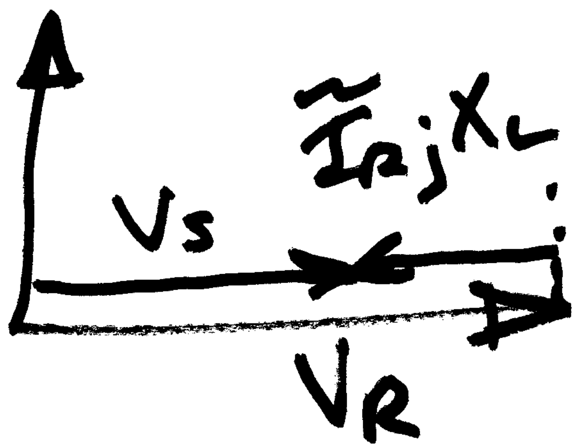
$$\tilde{V}_S = \tilde{I}_R(R + jX) + \tilde{V}_R = \underline{\underline{V_{NL}}}$$

Assume $\tilde{V}_R = 1\angle 0^\circ$ p.u.
$= \underline{\underline{V_{FL}}}$



VR is neg if $V_S < V_R$.
$(V_{NL} < V_{FL})$

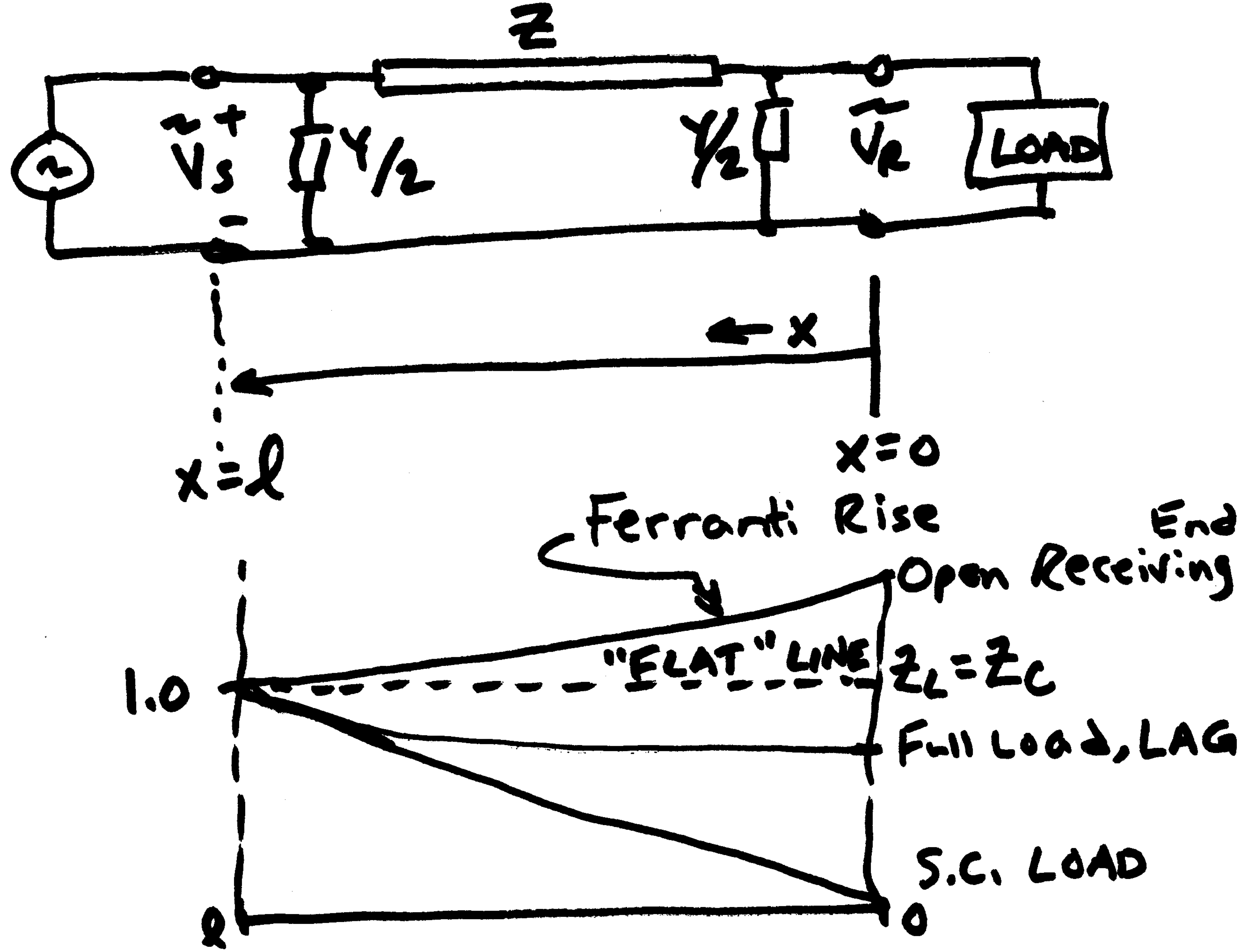




$$\tilde{V}_R = \tilde{V}_S + \underbrace{\tilde{I}_R jX_L}$$

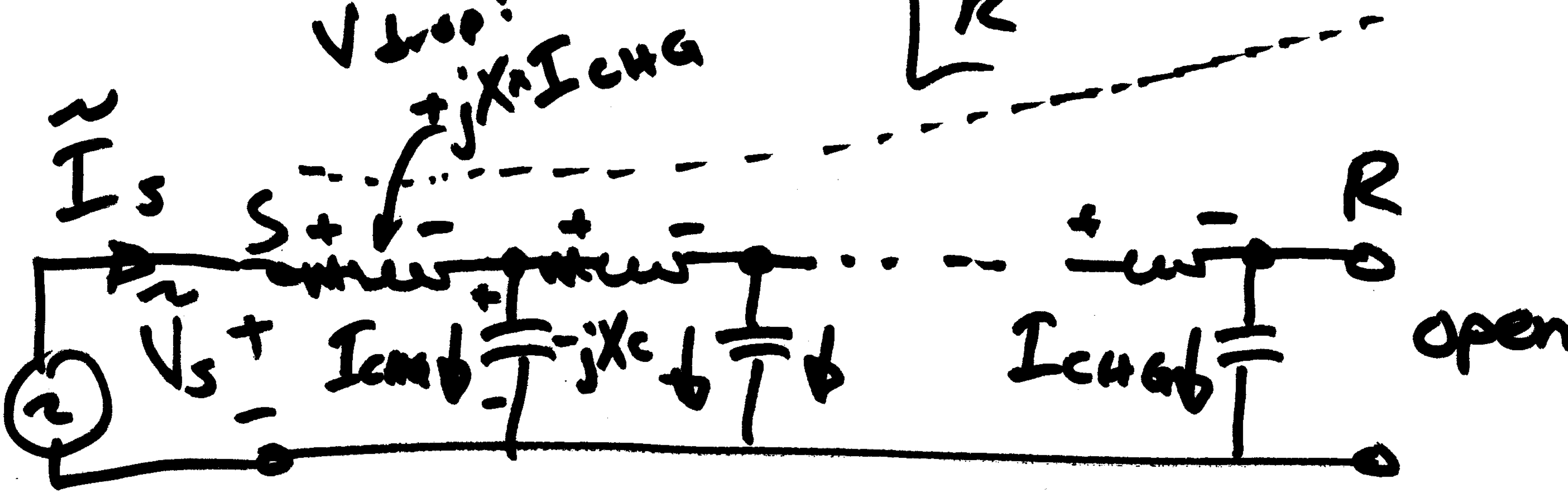
$$\tilde{V}_S = \tilde{V}_R + \underbrace{\tilde{I}_R jX_L}_{180^\circ}$$

VOLTAGE PROFILE



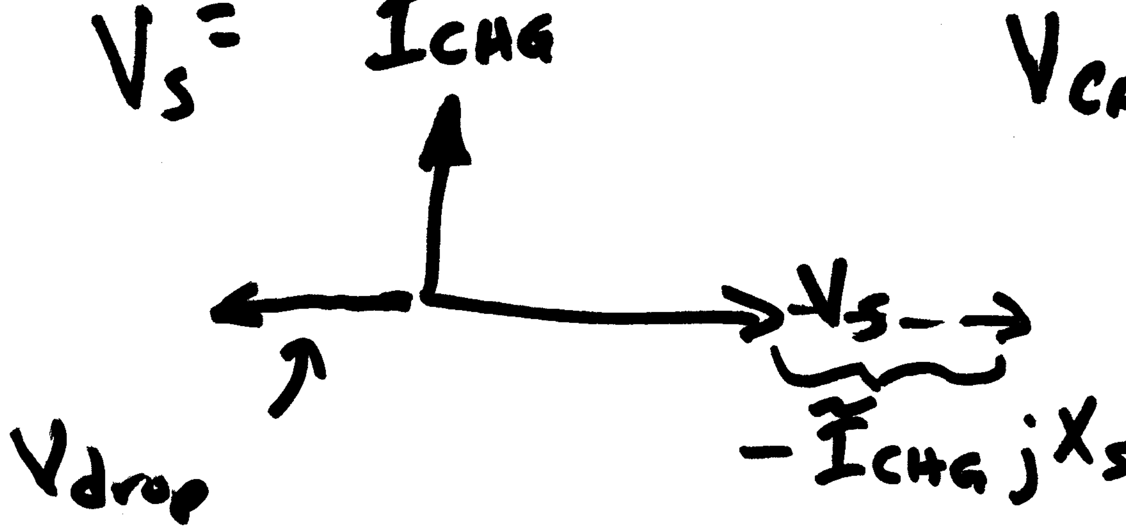
FERRANTI RISE

$\left[\frac{X}{R} \cong 20 \text{ @ } 345\,\text{KV}\right]$



$X_c >> X_L$

$\tilde{V}_s =$



$V_{CAP} = \tilde{V}_s - \tilde{I}_{CHG}\, jX$
$0° - (180°)$

hence the "negative voltage drop"