EE 5200 - Lecture 28 **Monday Nov 4, 2019**

Topics for Today:

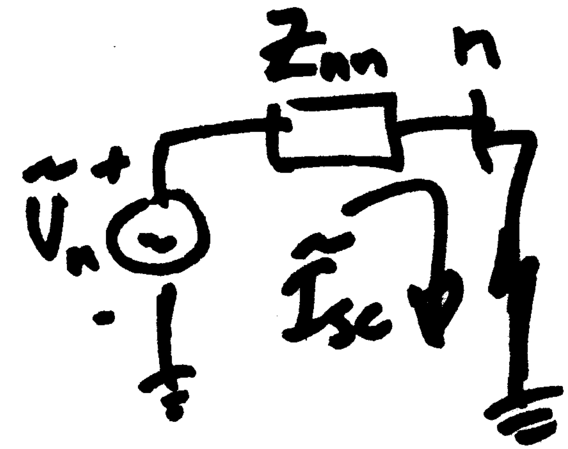
- Announcements
  - Nov 8th - Detailed Term Project outline (suggest 3-levels) in format of report Table of Contents + complete list of references.
  - Software: ATP/ATPDraw is supposed to be fixed by IT by now, checking...
  - ASPEN OneLiner - runs off of MTU server via internet: remote.mtu.edu
  - Office: EERC 614
  - Recommended problems & all solutions: Ch.7, 8 solns now posted.

- Chapter 7,10 - Network Equations, Basic Fault applications
  - Fault current - dc offset. Section 10.1
  - Importance of X/R ratio
  - Circuit breaker ratings
  - Three-Phase fault calcs using [Zbus]. Section 10.3
  - Fault current contributions using [Zbus]. Eqn. (10.21)
  - Admittance approach using [Ybus]

$$[Y]^{-1} = [Z] \quad \left([Y_{Bus}]^{-1} = [Z_{Bus}] \right)$$

Look at $[Z]$ in regards to S.C. calcs.

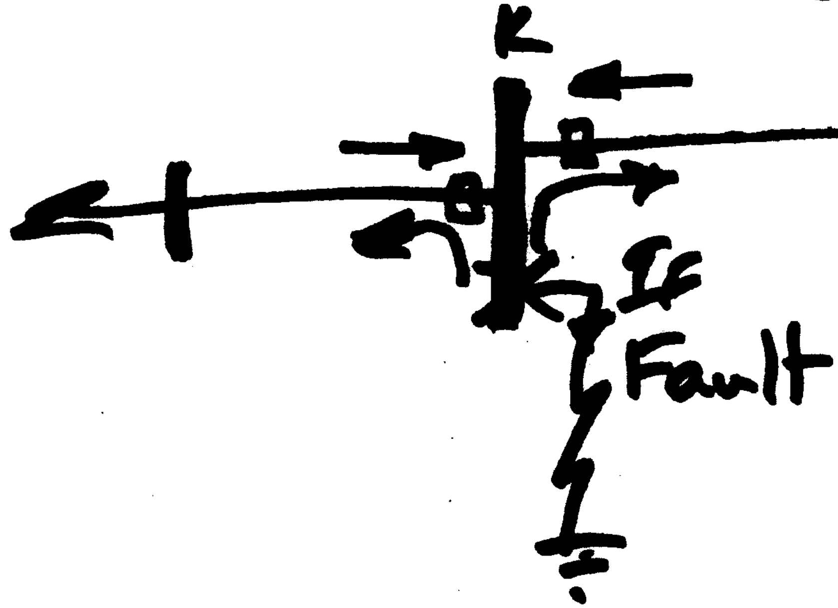
$$\begin{bmatrix} Z_{11} & Z_{12} & Z_{1n} & \cdots & Z_{1N} \\ \vdots & \ddots & & & \vdots \\ Z_{n1} & & Z_{nn} & & Z_{nN} \\ \vdots & & & \ddots & \\ Z_{N1} & \cdots & Z_{Nn} & & Z_{NN} \end{bmatrix}$$

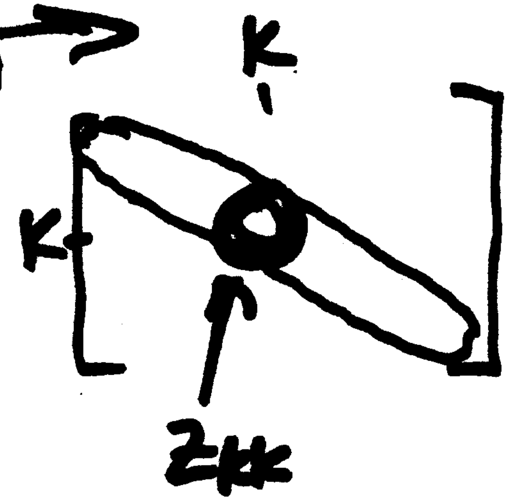


If $[Z]$ is symmetric about the main diagonal (bilateral) then use either row or col.

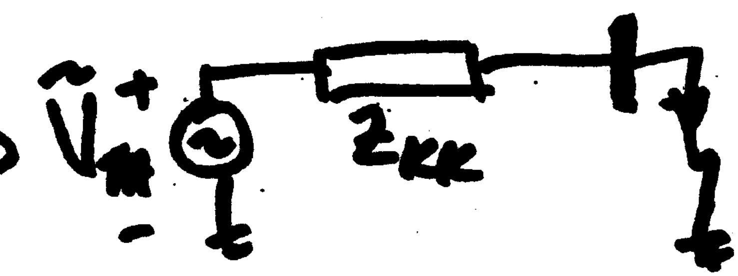
Begin with practical use of [Z]

Thevenin Impedance: Main diagonal element of [Zbus]



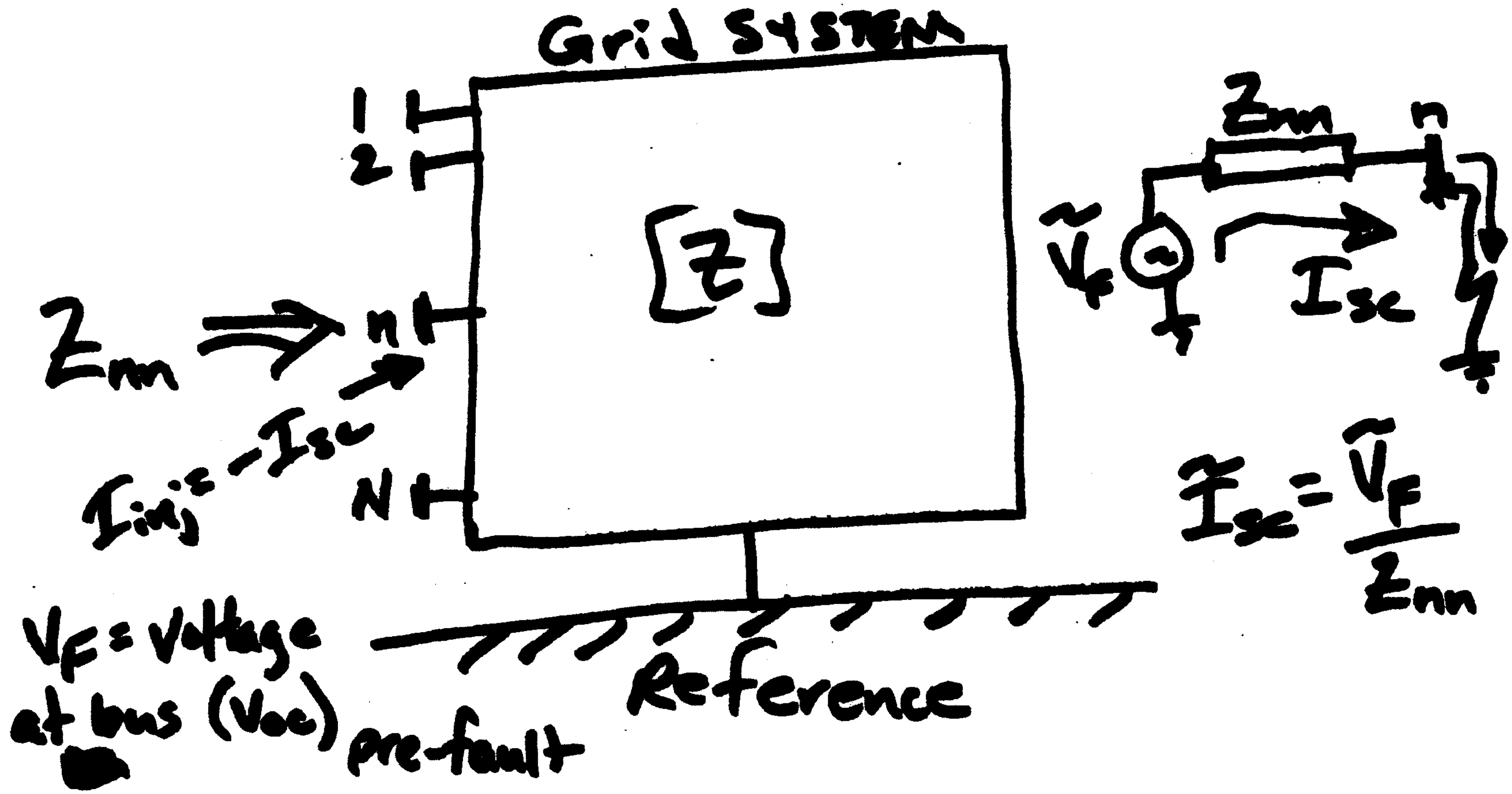


Useful to know Z_{TH} at bus



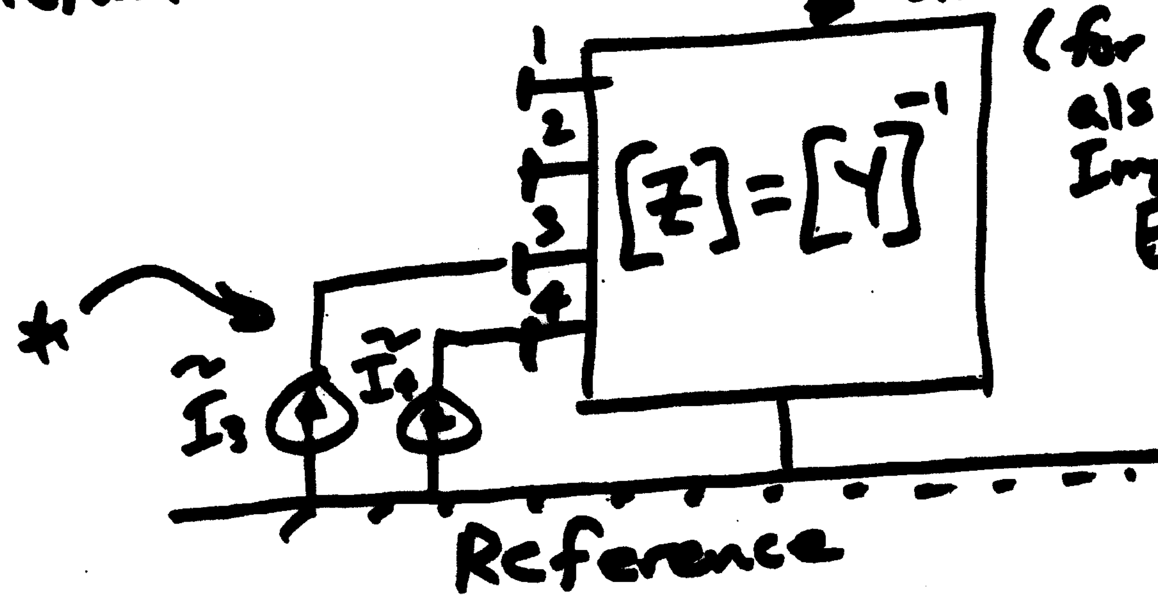
$$\tilde{I}_F = \frac{\tilde{V}_{TH}}{Z_{KK}}$$

* $Z_{nn} = Z_{TH}$ at bus n.
* Off-diagonal Z's represent the mutual impedences between bus n & all other buses.



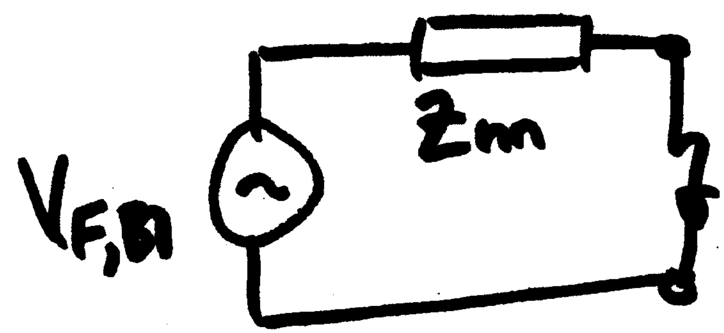
$$\tilde{I}_{sc} = \frac{\tilde{V}_F}{Z_{nn}}$$

"Prefault" situation



Ex: Fig 7.5

IF there is a fault at bus n in system,



$$\tilde{I}_F = \frac{\tilde{V}_F}{Z_{nn}}$$

Often assume that $V_F = 1.05\angle 0^\circ$ p.u.

$$(n)\begin{bmatrix} \cdots & Z_{1n} & \cdots \\ & Z_{2n} & \\ & \vdots & \\ & Z_{nn} & \\ & \vdots & \\ & Z_{nN} & \end{bmatrix} \begin{bmatrix} 0 \\ \vdots \\ 0 \\ I_n \\ 0 \\ \vdots \\ 0 \end{bmatrix} = \begin{bmatrix} I_n Z_{1n} \\ I_n Z_{2n} \\ \vdots \\ I_n Z_{nn} \\ \vdots \\ I_n Z_{nN} \end{bmatrix}$$

$I_n Z_{nn} = V_F$

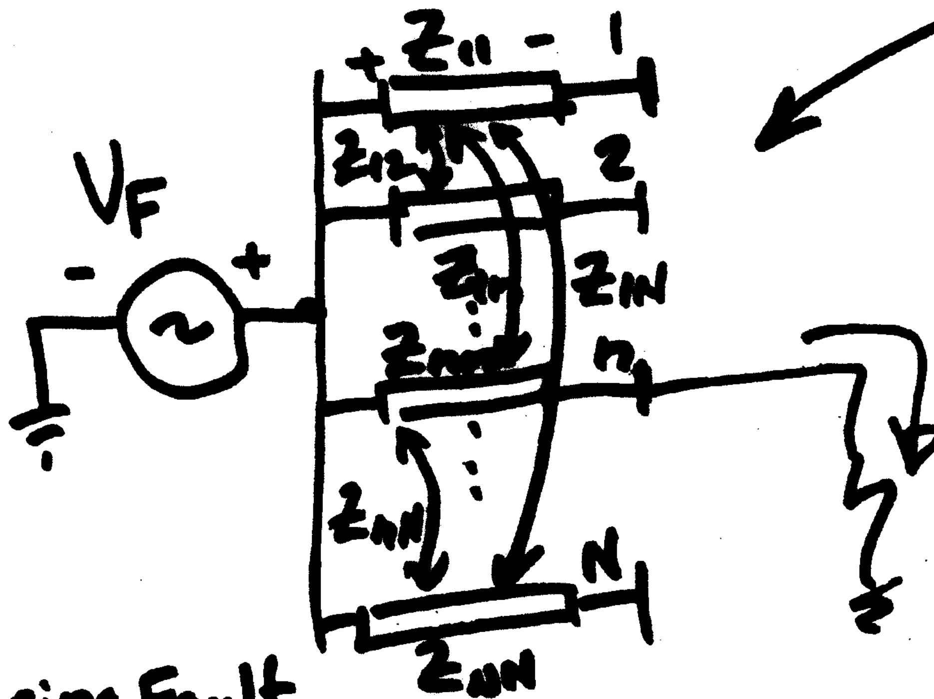
V drops due to $-I_F$

$I_n = -I_F$, injected into bus n

$$V_1 = V_F - I_F \underline{\underline{Z_{1n}}}$$

What happens at other buses during the fault? All bus voltages will dip. How much?

"RAKE EQUIV"



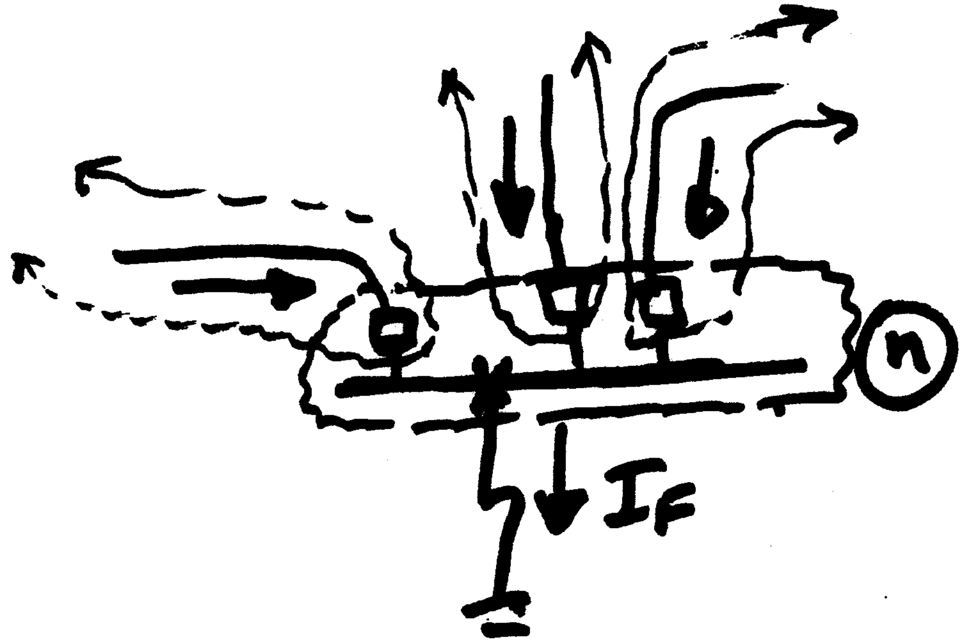
$$\tilde{I}_F = \frac{\tilde{V}_F}{Z_{nn}}$$

During Fault

$$\underline{E}_1 = V_F - \underline{\tilde{I}_F}\,\underline{Z}_{1n}$$

$$= V_F - \frac{V_F}{Z_{nn}} Z_{1n} = V_F - \frac{Z_{1n}}{Z_{nn}} V_F = \tilde{V}_F\left(1 - \frac{Z_{1N}}{Z_{NN}}\right)$$

Fault Contributions (i.e. current)

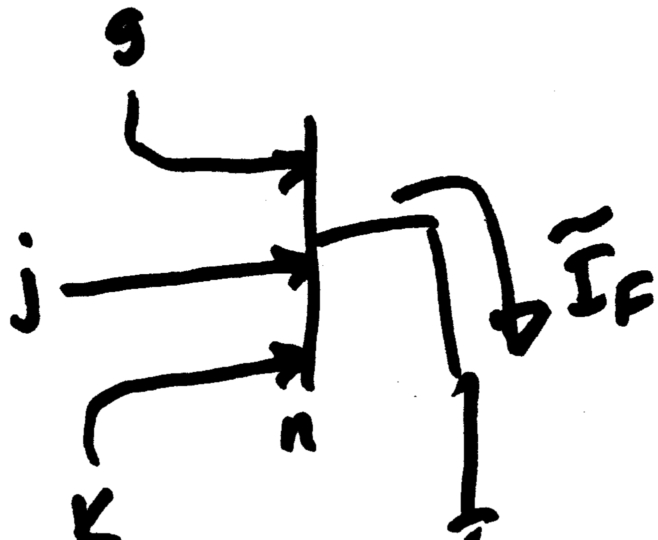


Must Know

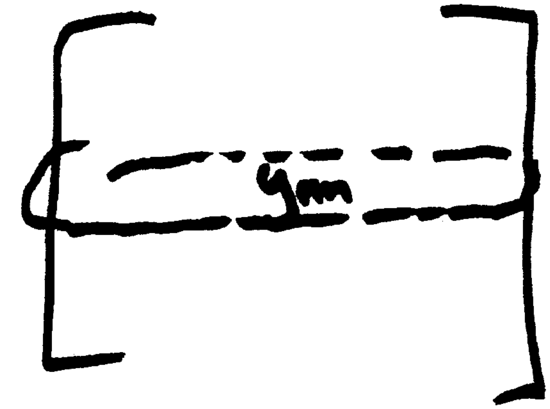
$I_{FAULT\ CONTR}$: Are CBS going to be able to interrupt?

- Relay engineers must know all current flows.

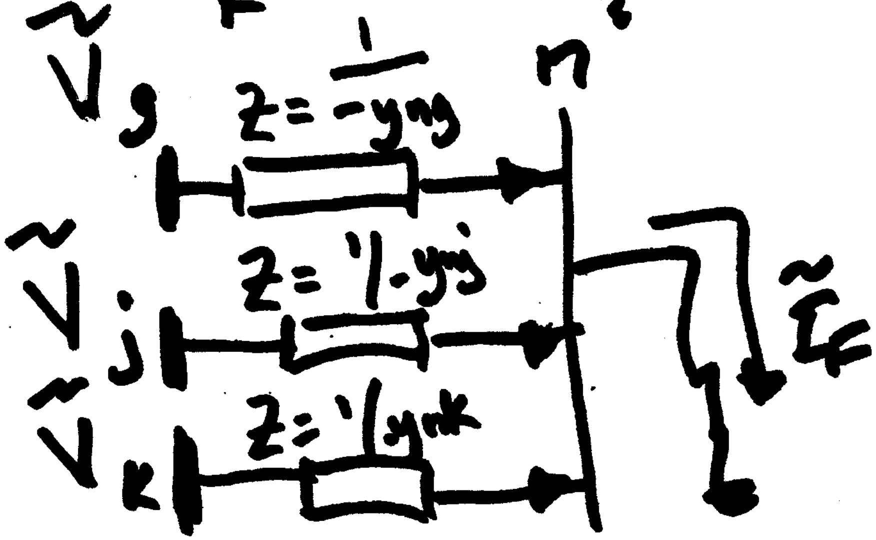
Refering to Y_{BUS}, current contribs are



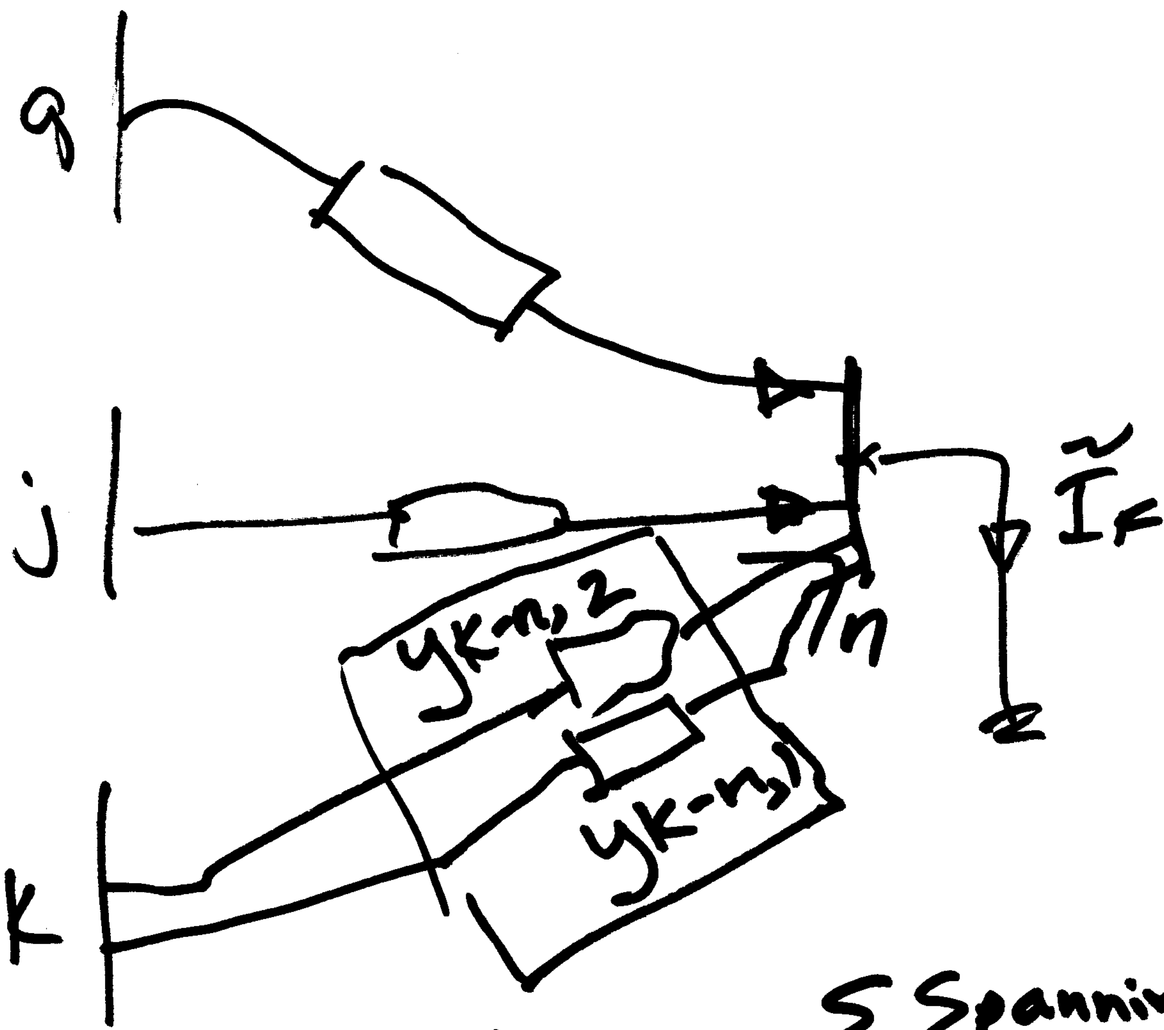
$[Z]^{-1} =$



y_{ng}, y_{nj}, y_{nk} } only other non-zero values in row n.



$\tilde{I}$ From	
g	$I = (V_g - V_n)(-y_{ng})$
j	$I = (V_j - V_n)(-y_{nj})$
K	$I = (V_K - V_n)(-y_{nk})$



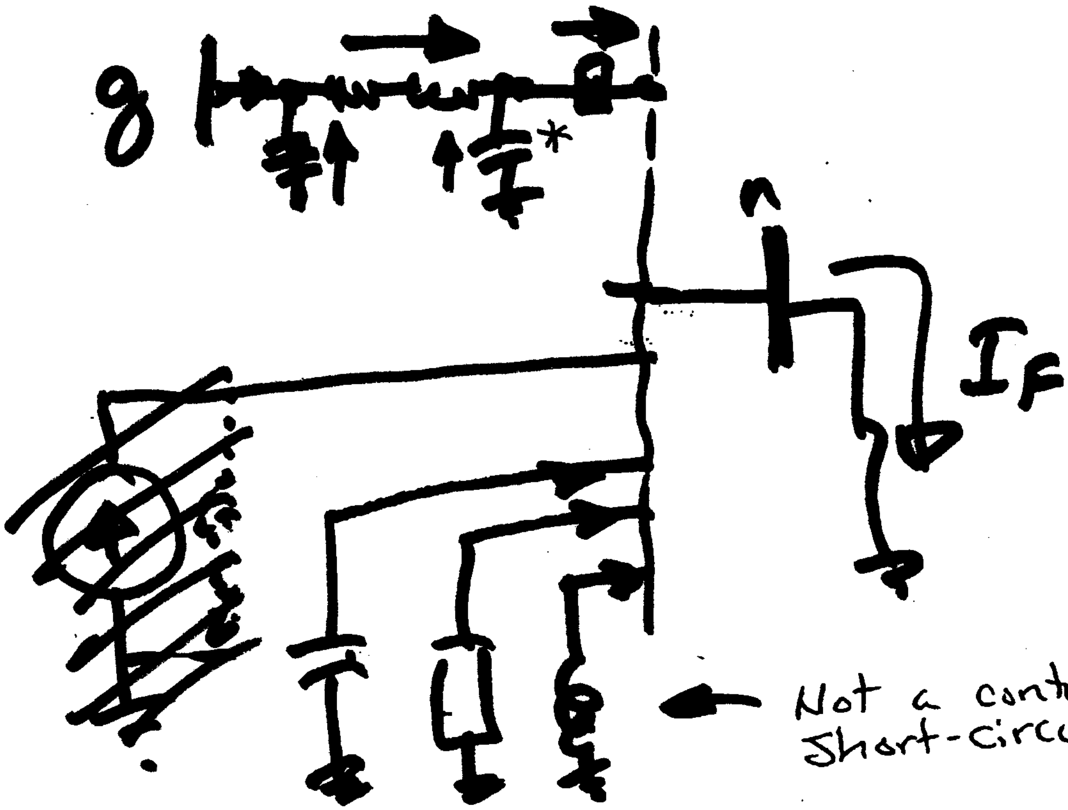
$y_{kn} = -\sum$ Spanning admittances

$$y_{kn} = -y_{k-n,1} - y_{k-n,2}$$

P.6 method ok for Short-Line Connections.

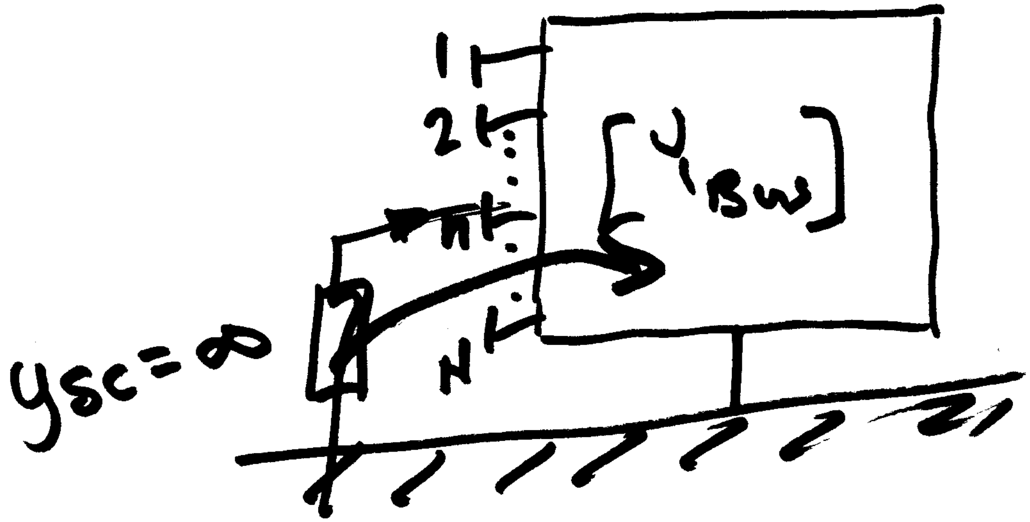
- What about pi-equiv Line *
  - Shunt Load
  - Shunt Cap/React ?

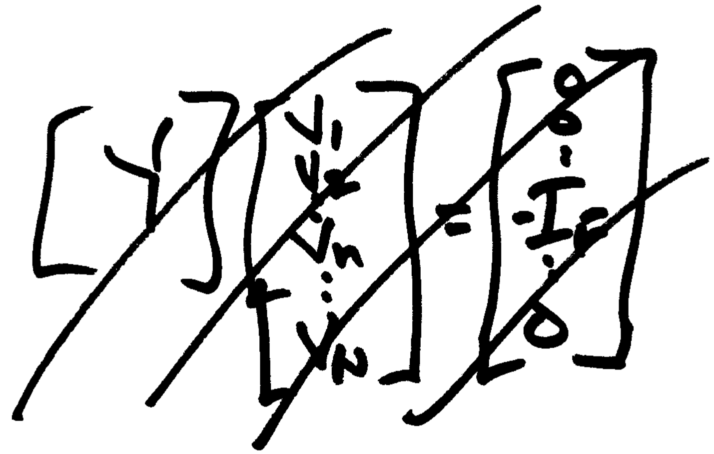
* must include effect of Shunt Cap, unless $V_n = 0$.



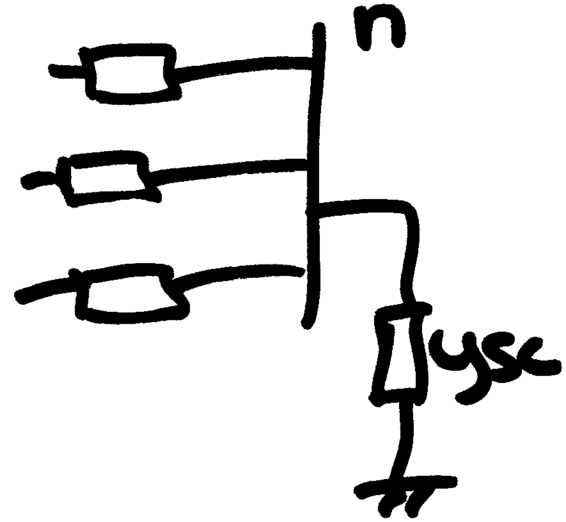
More on this later, and in EE5240.

Not a contributor to 60-Hz Short-circuit current





$\infty = 10^{15} - 10^{18}$ (max for computer)



$\therefore \quad y_{nn} = y_{nn} + y_{sc}$

$= y_{nn} + 10^{15}$

$\approx \infty$

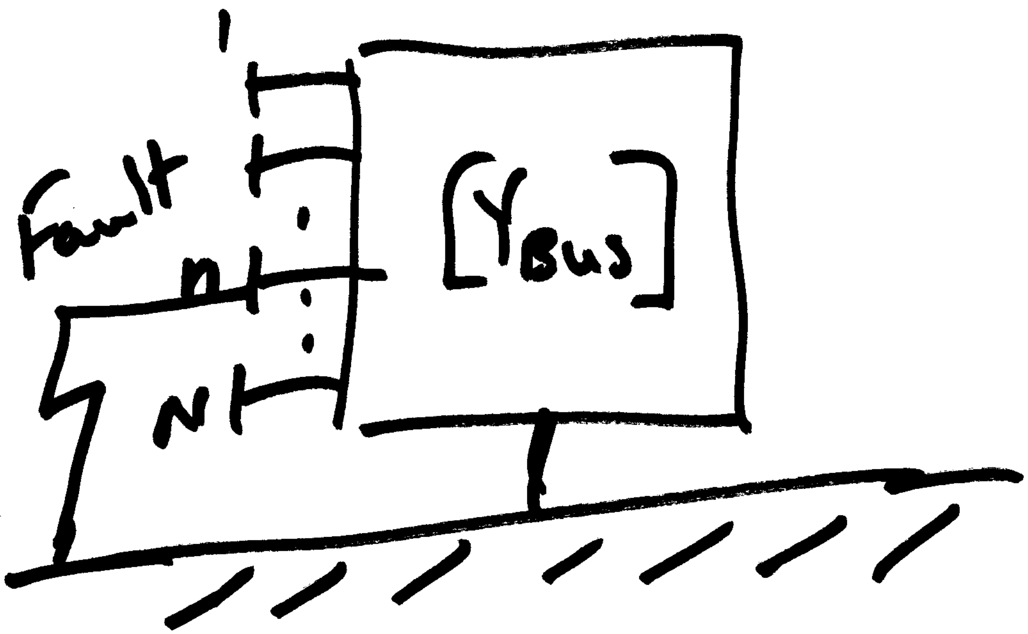
$$\begin{bmatrix} & & \\ & Y & \\ & & \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ \vdots \\ V_n \\ \vdots \\ V_N \end{bmatrix} = \begin{bmatrix} 0 \\ I_2 \\ \vdots \\ I_7 \\ \vdots \\ 0 \\ \vdots \\ I_{23} \\ \vdots \\ 0 \end{bmatrix}$$

$y_{nm} \rightarrow 10^{15}$

↑ unknowns ↑ knowns

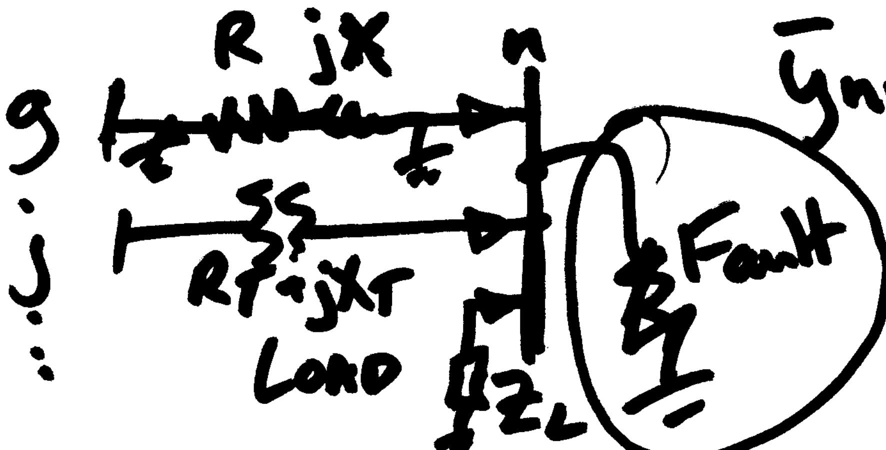
↑ same as $V_F - \Delta V$

Admittance Method to Calculate Isc



$$[Y]\begin{bmatrix} V_1 \\ \vdots \\ V_n \\ \vdots \\ V_N \end{bmatrix} = [I_{inj}]$$

When building [Y Bus]



$$\bar{y}_{nn} = \frac{1}{R+jX} + j^{B_c} + \frac{1}{R_T+jX_T} + \frac{1}{Z_L} + \underbrace{10^{15}}_{Z_F \cong 0} \leftarrow Y_F \cong \infty$$