EE 5200 - Lecture 19 Tuesday Oct 31, 2000

Topics for Today:

- Questions from last lectures?
- Questions/Comments on Assignment #8 ?
- Topics for Today:
  - Intro to Power System Operation
  - Frequency Control, droop characteristic
  - Intro to $[Z_{BUS}]$ and short-circuit studies
- Assn #9
  - Run Aspen tutorial (manuals in lab)
  - Perform small system study
  - Work in pairs
  - Write short but complete report

- Term Proj

will be investigated. Focus will be placed on interactions between torque angle δ, internal voltage E_f, bus voltage V_T, real and reactive power, and PF. Just as at a power plant, the only two parameters you will be able to directly control are the excitation (magnitude of E_f) and the governor (steam flow to the turbine ==> mechanical power input).

From: Gross, 2nd Ed.

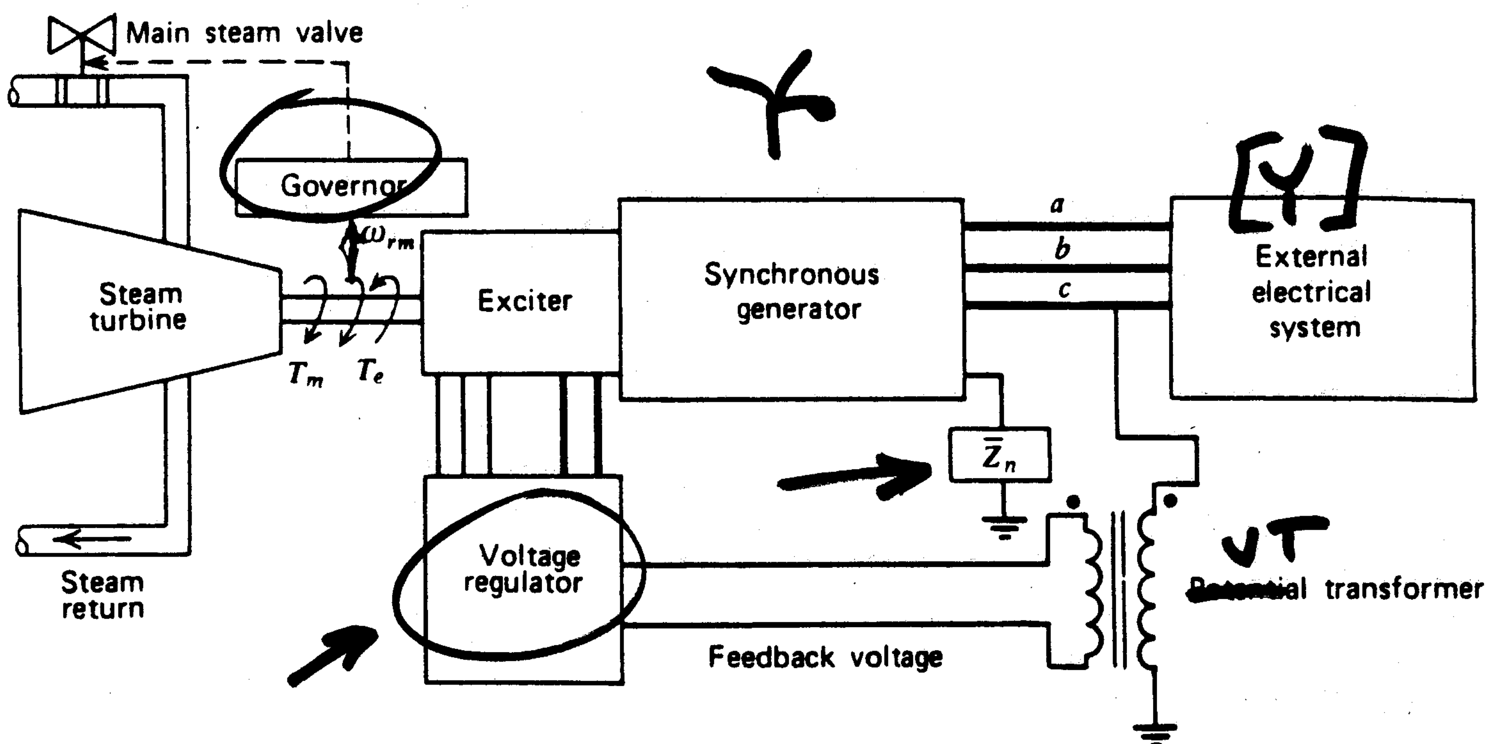


Figure 6.10. Turbine–generator–exciter system.

PART I

Set up a spreadsheet program to solve for the values needed to draw the voltage phasor diagrams and the phasor currents for both cases below. Neglect the armature resistance and give I_A a reference direction **out** of the machine terminals.

a) Round rotor machine: given the synchronous reactance X_S, the magnitude of E_f in per unit, the mechanical input power in per unit, and the per unit bus voltage (assume an angle of 0°)

3

Figures from Glover & Sarma, 2nd Ed.

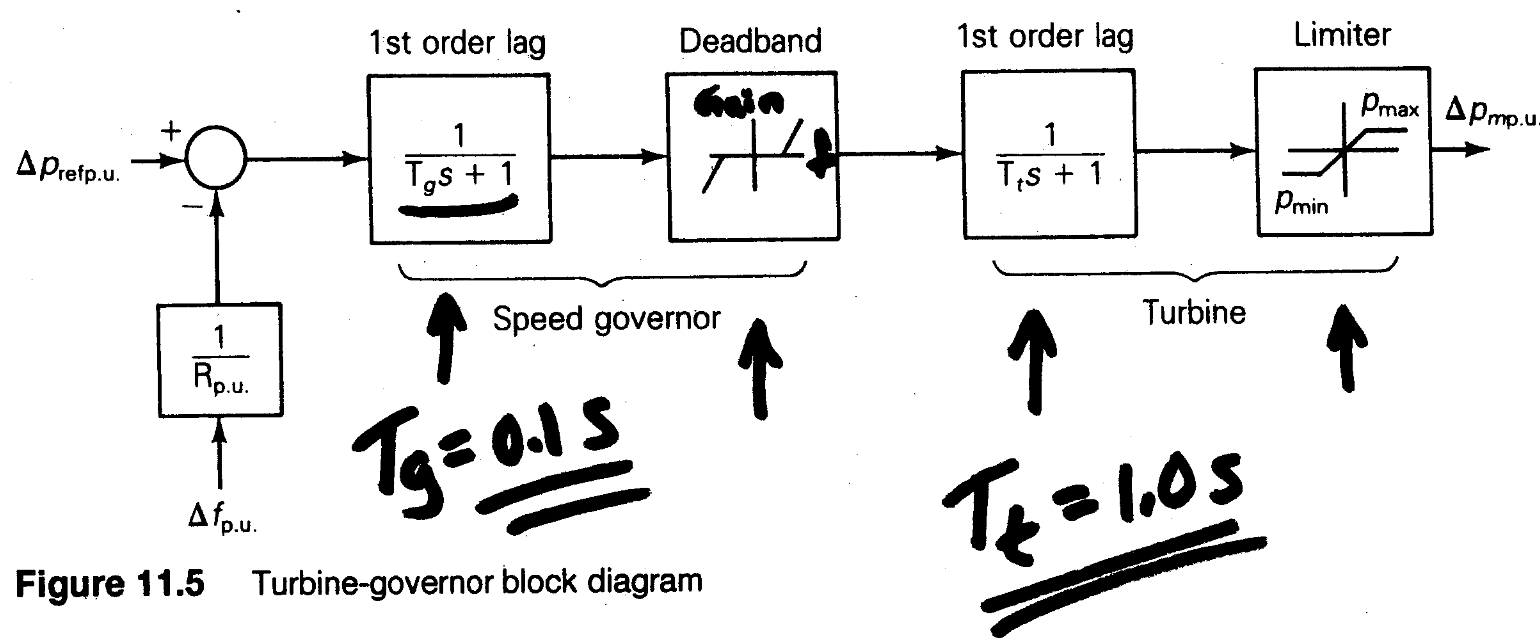


Figure 11.5 Turbine-governor block diagram

accounts for the fact that turbines have minimum and maximum outputs. The $1/(Ts + 1)$ blocks account for time delays, where s is the Laplace operator and T is a time constant. Typical values are $T_g = 0.10$ and $T_t = 1.0$ seconds. Block diagrams for steam turbine-governors with reheat and hydro turbine-governors are also available [3].

SECTION 11.3

LOAD-FREQUENCY CONTROL

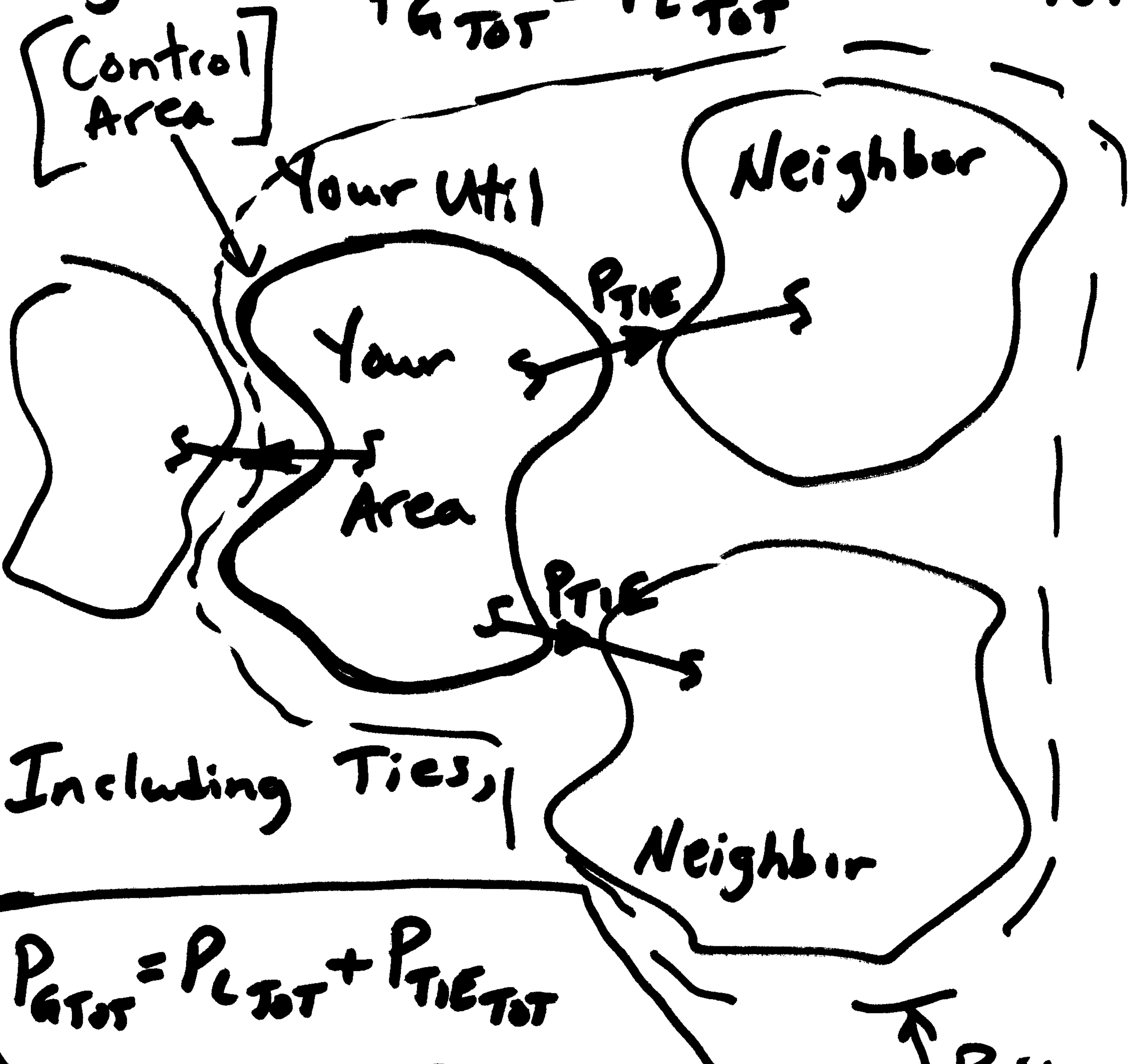
As shown in Section 11.2, turbine-governor control eliminates rotor acceler-

System Operation -

Automatic Generator Control (AGC)

For equilibrium (const speed/freq) system

$$P_{G_{TOT}} = P_{L_{TOT}} + P_{LOSS_{TOT}}$$



Including Ties,

$$\boxed{P_{G_{TOT}} = P_{L_{TOT}} + P_{TIE_{TOT}} + P_{LOSS_{TOT}}}$$

4a

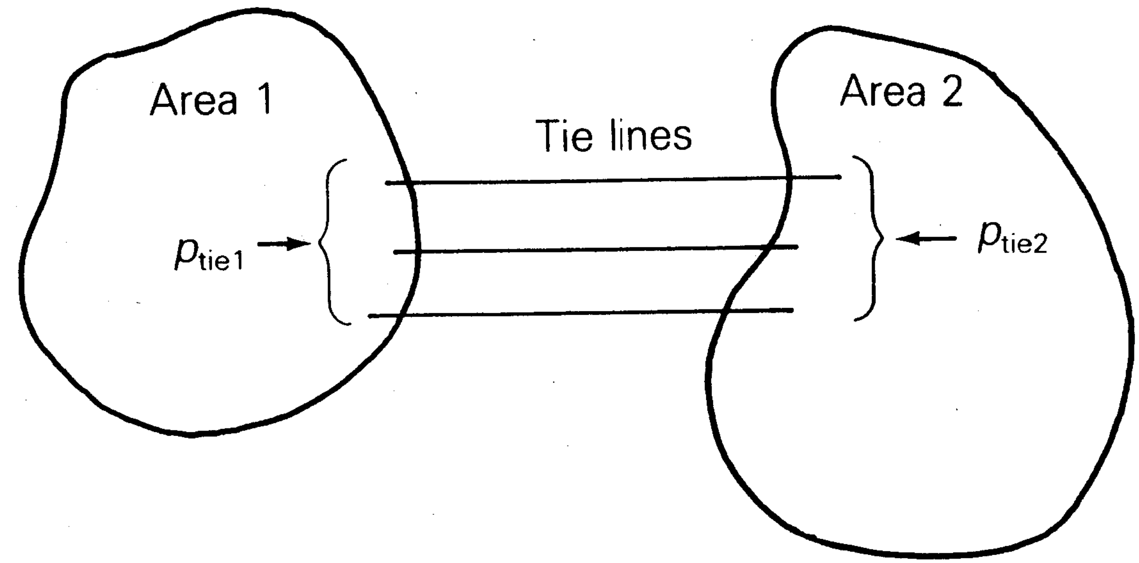


Figure 11.6

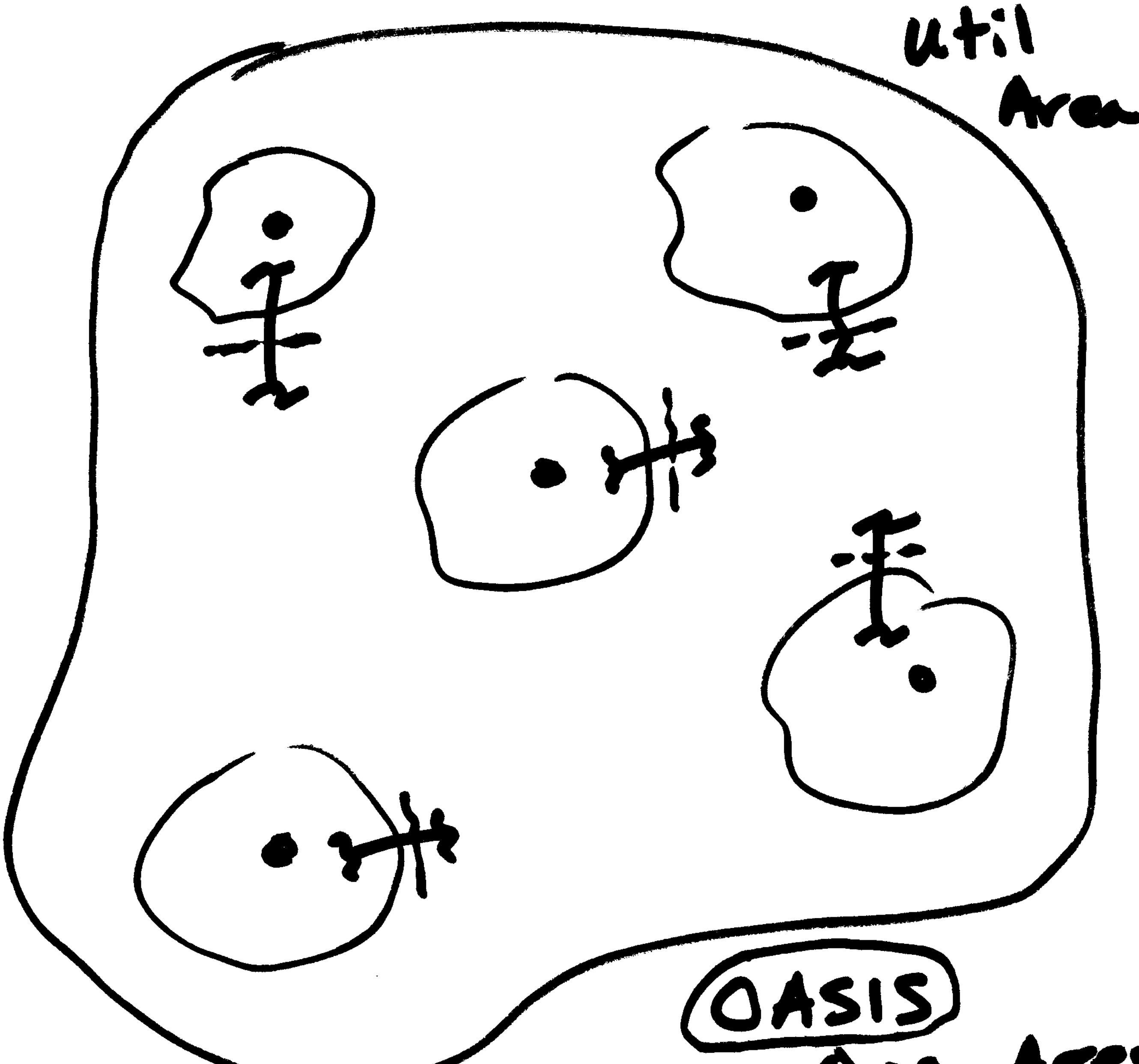
Example 11.3

Solution **a.** Since the two areas are interconnected, the steady-st
is the same for both areas. Adding (11.2.4) for each

$$(\Delta p_{m1} + \Delta p_{m2}) = (\Delta p_{\mathrm{ref}\,1} + \Delta p_{\mathrm{ref}\,2}) - (\beta_1 + \beta_2)$$

Neglecting losses and the dependence of load on
state increase in total mechanical power of both
increase, 100 MW. Also, without LFC, $\Delta p_{\mathrm{ref}\,1}$ and
The above equation then becomes

<u>Power Pools</u> - Group of Utils that operate under Collective control. Municipals seem most common

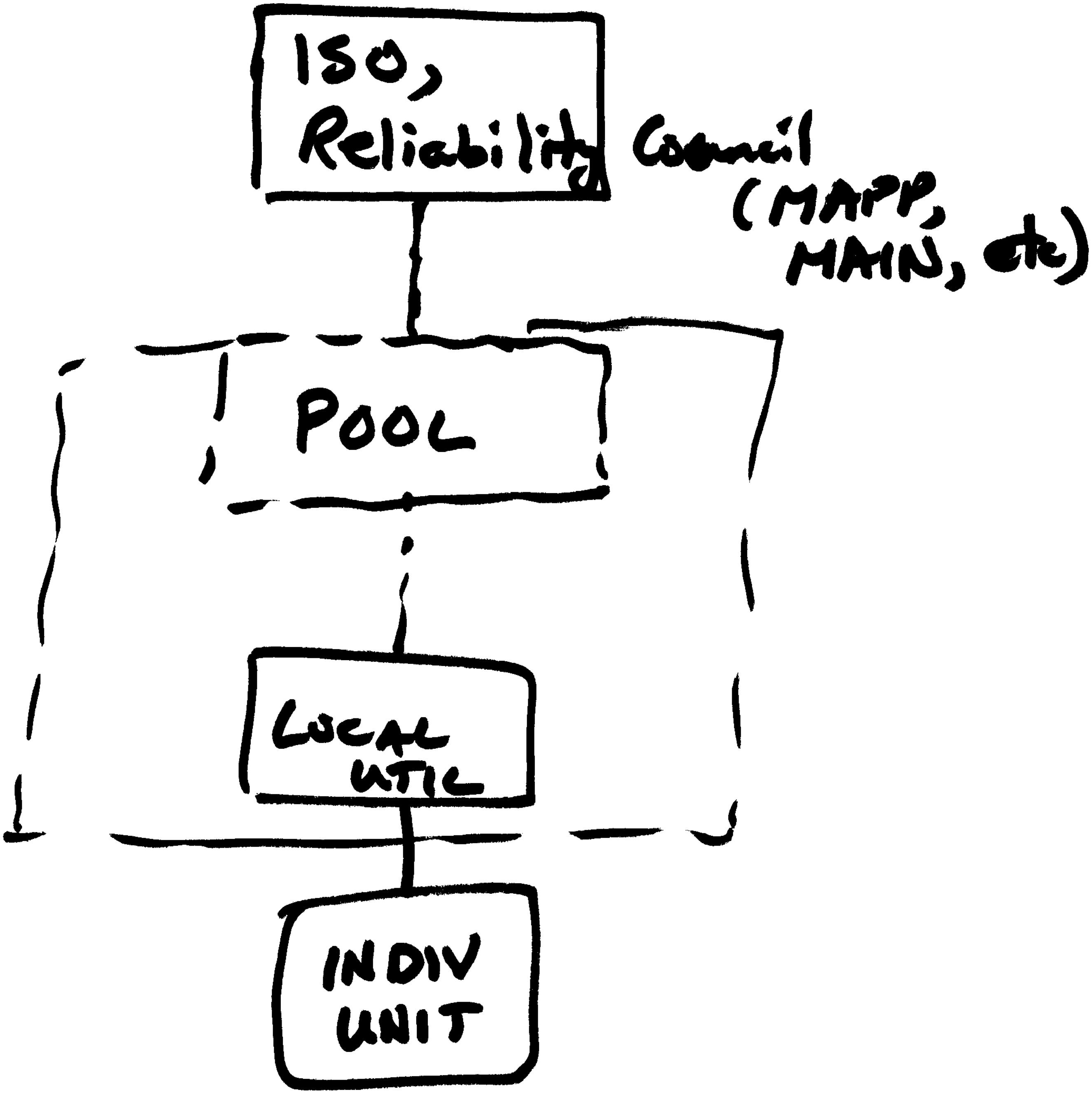


Operation/reliability
NERC
- MAIN - ECAR
- MAPP

OASIS
- Open Access

ISO - Ind. System Operator

ACE, Control Heirarchy



ACE - Area Control Error

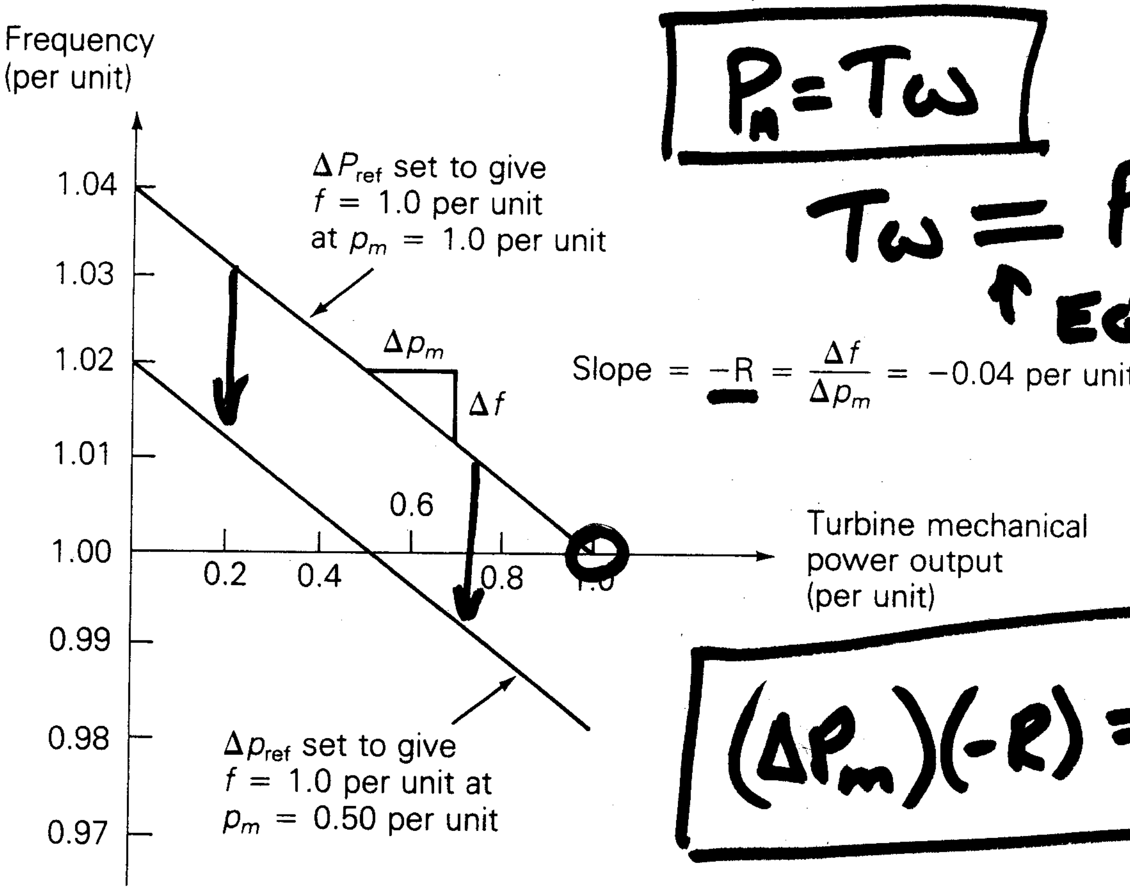
Difference between scheduled and actual tie line flows. ACE is "biased" to include frequency effects... i.e. actual system freq vs. desired freq (or f_{synch}).

Look at indiv. unit.

8

re 11.4

-power
vernor



$\boxed{P_m = T\omega}$

$T\omega = P_E$

↑ EQUILIB

$\boxed{(\Delta P_m)(-R) = \Delta f}$

Δf is in Hz and Δp_m is in MW. When Δf and Δp_m are given in per-unit, however, R is also in per-unit.

11.1 Turbine-governor response to frequency change at a generating unit

A 500-MVA, 60-Hz turbine-generator has a regulation constant R = 0.05 per unit based on its own rating. If the generator frequency increases by 0.01 Hz in steady-state, what is the decrease in turbine mechanical power output? Assume a fixed reference power setting.

lution The per-unit change in frequency is

$$\Delta f_{\text{p.u.}} = \frac{\Delta f}{f_{\text{base}}} = \frac{0.01}{60} = 1.6667 \times 10^{-4} \quad \text{per unit}$$

Then, from (11.2.1), with $\Delta p_{\text{ref}} = 0$,

$R = .05 \text{ p.u} = 5\%$

$\Delta f = +0.01 \text{ HZ}$

$$\Delta f_{pu} = \frac{.01}{60} = 1.667 \times 10^{-4} \text{ p.u.}$$

$$(\Delta P)(-R) = \Delta f$$

$$\Delta P = \Delta f\left(-\frac{1}{R}\right)$$

$$= (1.667 \times 10^{-4})\left(\frac{1}{-.05}\right)$$

$$= -3.33 \times 10^{-3} \text{ p.u.}$$

@ 500 MVA Base,

$$\boxed{\Delta P = -16.7 \text{ MW}}$$

Basics on [Y] & [Z]

<u>Note:</u> $[Y_{BUS}]$ is nodal admit. matrix.

$$[Y_{BUS}][V_{NODE}] = [I_{INJ}]$$

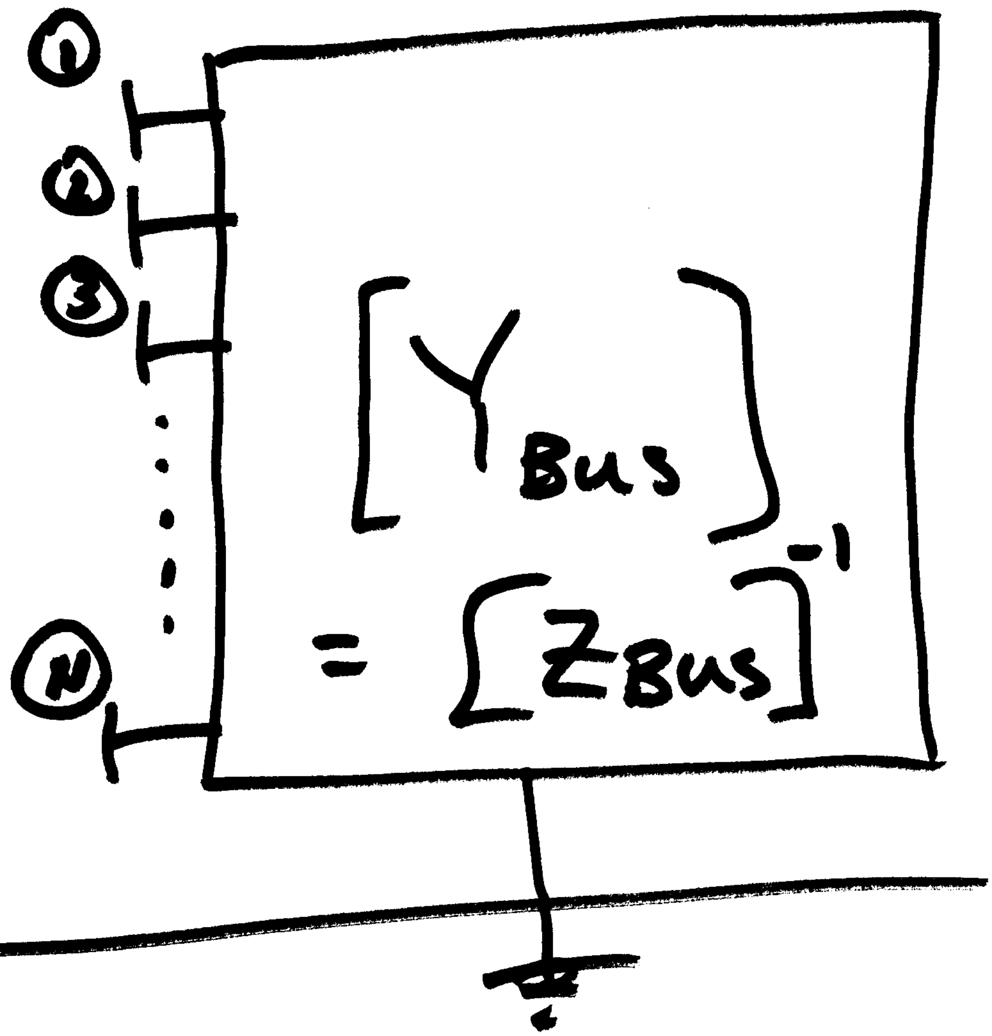
$$[Z_{BUS}] = [Y_{BUS}]^{-1}$$

$$[Z_{BUS}] = \begin{bmatrix} Z_{11} & Z_{12} & \cdots & Z_{1N} \\ \vdots & Z_{22} & & \\ \vdots & & \ddots & \\ Z_{N1} & & & Z_{NN} \end{bmatrix}$$

Z_{KK} = Thev or "Driving Point" Z's

Z_{jK} = Transfer impedances.

Possible to find a given Z_{jk}



$$[Z_{Bus}][I] = [V]$$

$$\begin{bmatrix} & \vdots & & \\ \cdots & Z_{22} & \cdots & \cdots \\ & \vdots & & \\ & \vdots & & \end{bmatrix} \begin{bmatrix} 0 \\ I_2 \\ 0 \\ \vdots \\ 0 \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ \vdots \\ V_n \end{bmatrix} \rightarrow Z_{22} = \frac{V_2}{I_2}$$

If system is in $[Y_{Bus}]$ formation

$$\begin{bmatrix} & & \\ & Y_{Bus} & \\ & & \end{bmatrix} \begin{bmatrix} V_2 \\ \\ \\ \end{bmatrix} = \begin{bmatrix} 0 \\ I_2 \\ 0 \\ \vdots \\ 0 \end{bmatrix} \Rightarrow Z_{22} = \frac{V_2}{I_2}$$