EE 5200 - Lecture 33 **Friday Nov 15, 2019**

Topics for Today:

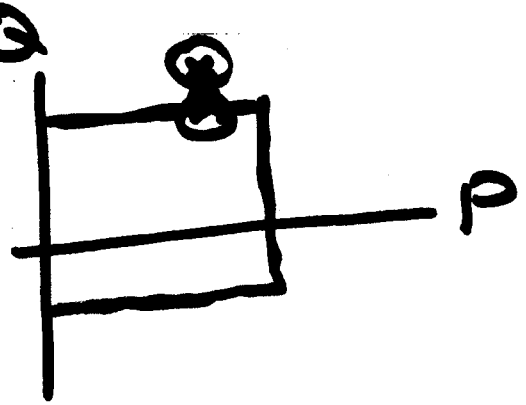
- Announcements
  - Detailed Term Project outline (in format of report Table of Contents) + complete list of references. Take a look at feedback, update, project mgmnt.
  - ASPEN software - remote.mtu.edu server via remote desktop. Take the tutorial as posted on class web page.
  - Office: EERC 614.
  - Recommended problems & all solutions: Ch.9, 13 solns now posted.

- Chapter 9 - Load Flow wrapup
  - Corrective Actions for low or high bus voltage
  - Line Loading concerns
  - Contingencies
  - System Security - Operation, Protection, Cyber-security

Next: Chapter 13 - Power system operation, AGC, economic dispatch
  - Paralleling of Generators, droop characteristics
  - Optimization methods - LaGrange multipliers

Load Flow

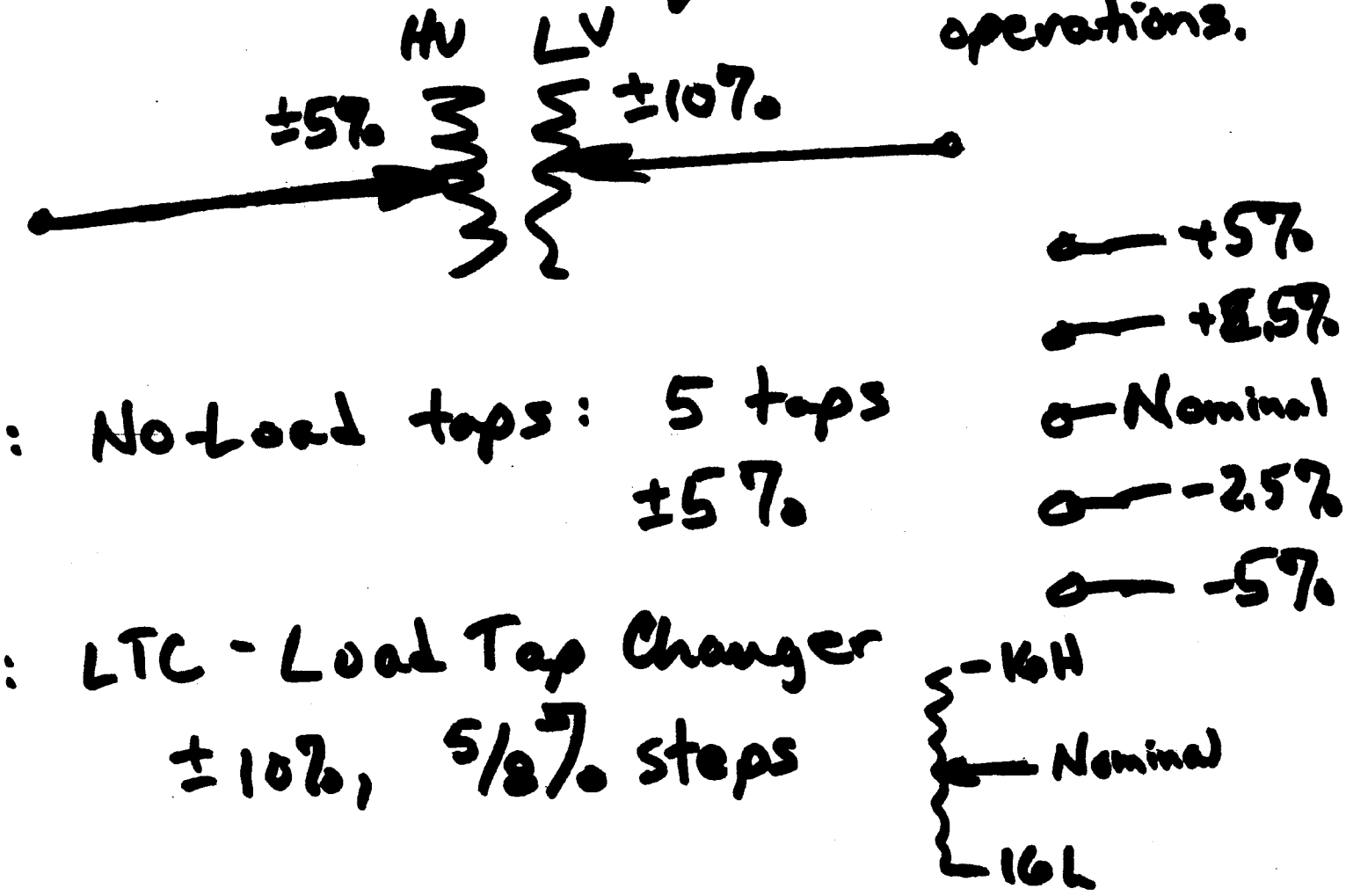
- How set up, i.e. parameter input. ✓
- What to do w/ output? Typical Probs:
  - Bus voltage too high/low
  - T-line loading exceeded.
  - Transformers overloaded.
    - LOL concerns
    - Age concerns
  - Q limits of Gens exceeded.



Load flow software:
- Change Bus to PQ bus.

Transformer Taps:

High Maintenance
100,000 - 500,000 operations.

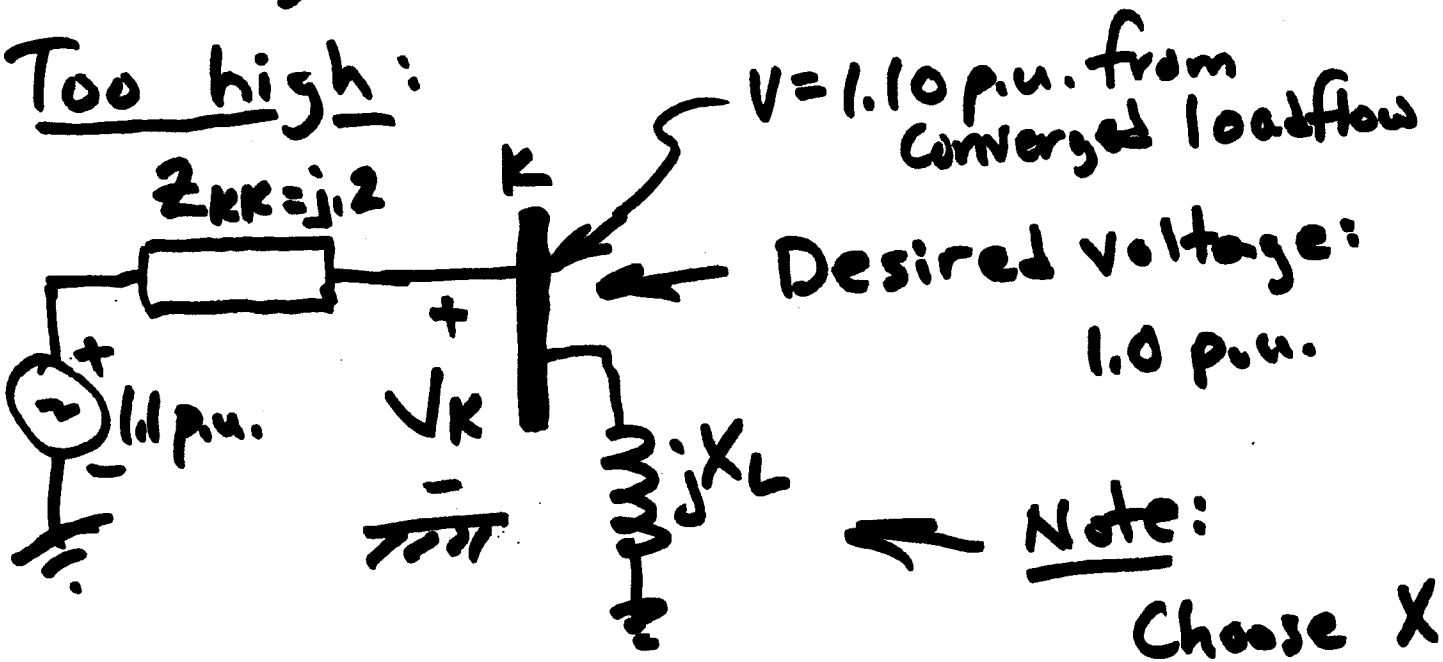


HV: No Load taps: 5 taps
±5%

LV: LTC - Load Tap Changer
±10%, 5/8% steps

Bus voltage high/low.

Too high:



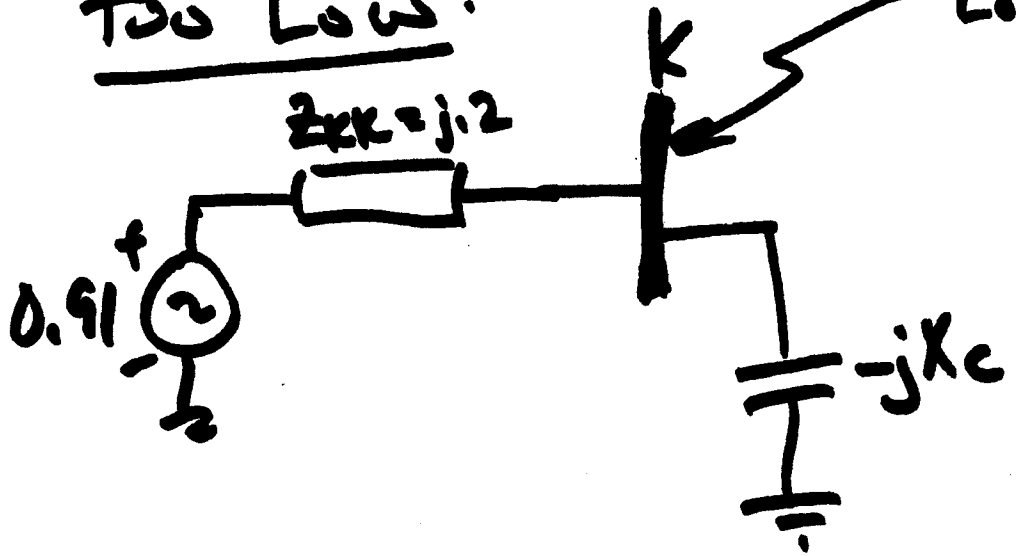
$$V_K = 1.0 = 1.1 \frac{jX_L}{j.2 + jX_L}$$

$$.2 + X_L = 1.1 X_L$$

$$.2 = .1 X_L$$

$$\boxed{X_L = 2 \text{ p.u.}}$$

Too Low:



$$X_c = \frac{1}{\omega C}$$

$$1.0 = 0.91 \frac{-jX_c}{j.2 - jX_c}$$

Solving: $X_c = 2.22$ p.u.

$$Q = \frac{V^2}{X_c} = V^2 B_c \qquad X_c = \frac{1}{\omega C} \qquad B_c = \omega C$$

What if Z_{KK} includes R?

$$1.0 = 0.91 \left| \frac{-jX_c}{(0.05+j.2) - jX_c} \right|$$

← Must take abs. value.

square both sides,

$\Rightarrow$ gives quadratic,

2 solns for X_c.

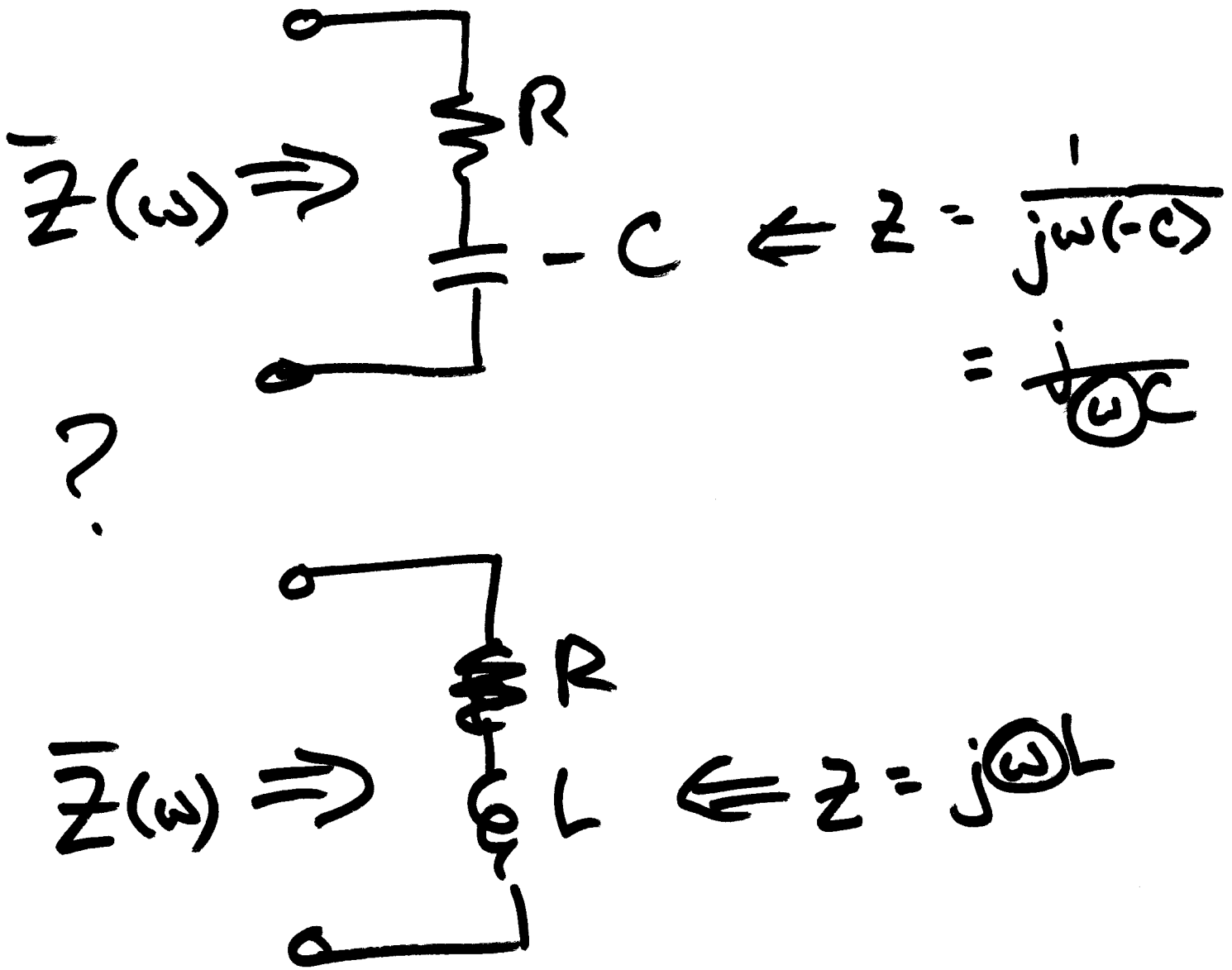
$X_c = \frac{1}{\omega C}$

Which X_c is "correct" to spec.

Case 1: X_{c_1} is pos, X_{c_2} is neg. (React.)

Case 2: X_{c_1} is pos, X_{c_2} is pos.

$X_{c_1} > X_{c_2}$.



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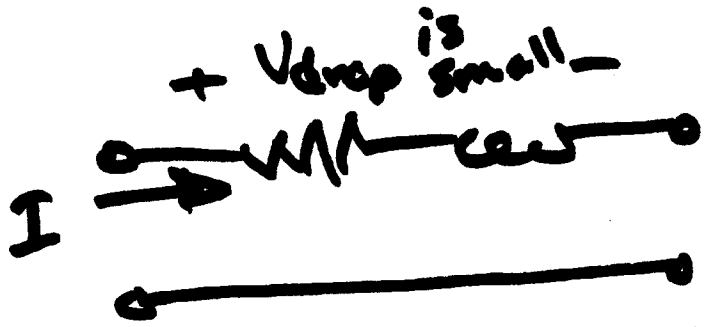
-Freq Scan

Line Loading:

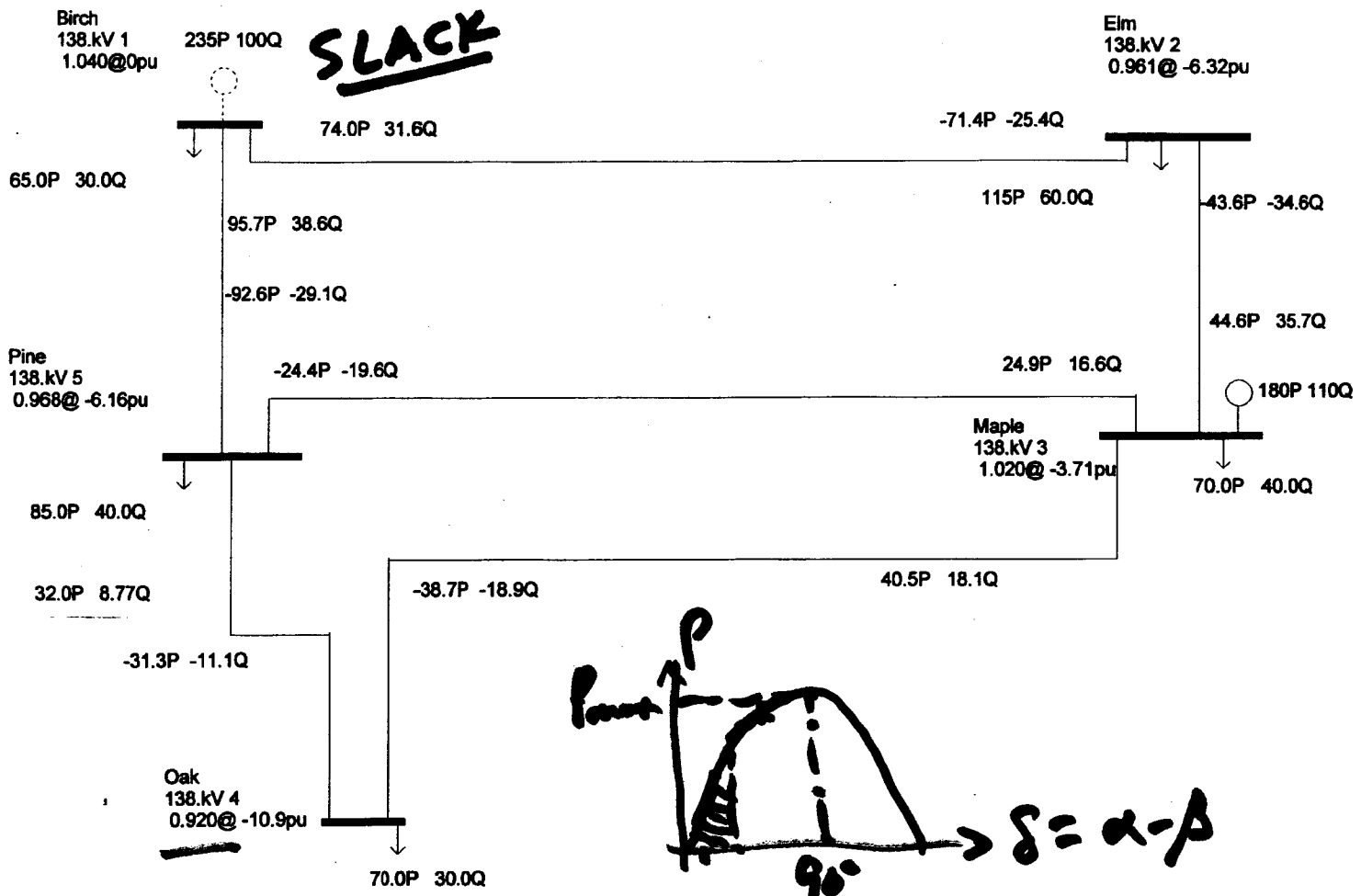


Short Line:

- usually no probs w/ Voltage drop
- Ampacity of line (I^2R heating)
  - $\Rightarrow$ higher R
  - $\Rightarrow$ more sag.
  - NESC.

- ACSR
- Composite - 3M.

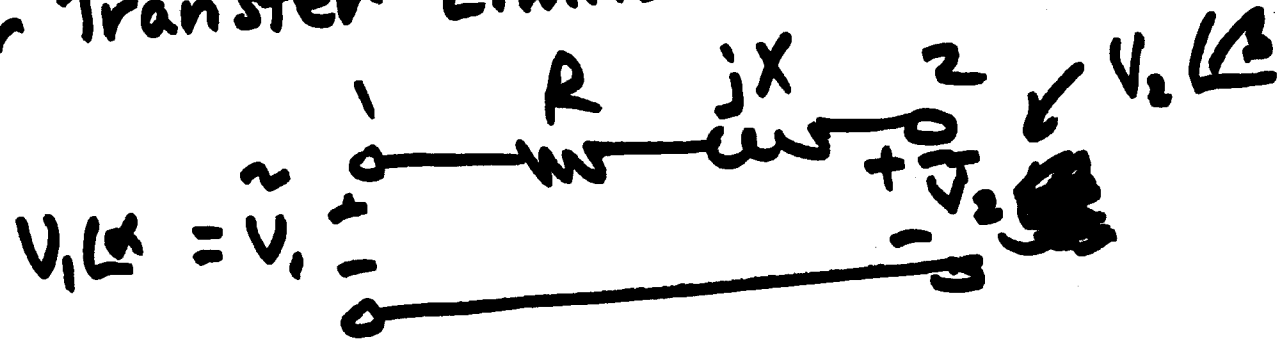
5-Bus System


Birch
138.kV 1
1.040@0pu
235P 100Q
SLACK
74.0P 31.6Q
-71.4P -25.4Q
Elm
138.kV 2
0.961@ -6.32pu
65.0P 30.0Q
115P 60.0Q
43.6P -34.6Q
95.7P 38.6Q
-92.6P -29.1Q
44.6P 35.7Q
Pine
138.kV 5
0.968@ -6.16pu
-24.4P -19.6Q
24.9P 16.6Q
180P 110Q
Maple
138.kV 3
1.020@ -3.71pu
85.0P 40.0Q
70.0P 40.0Q
32.0P 8.77Q
-38.7P -18.9Q
40.5P 18.1Q
-31.3P -11.1Q
Oak
138.kV 4
0.920@ -10.9pu
70.0P 30.0Q
P
Power
90°
δ = α - β
1
2
jX
V1 ∠
V2 ∠β

① – Ampacity

② – Voltage Drop: $\tilde{I}$ ($R+jX$) voltage drop results in low bus voltages.

③ – Power Transfer Limits

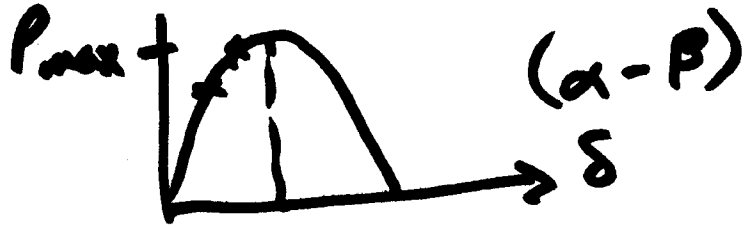


$$P_{1\to 2} = \frac{V_1 V_2}{X} \sin(\text{"}\delta\text{"})$$

$$= \frac{V_1 V_2}{X} \sin(\alpha - \beta)$$

For typical operation,

$\alpha - \beta$ should be limited below $\underline{35\text{-}40^\circ}$.



④ – stability Limits

Contingencies – Major "event" that impacts & System ability to maintain operation within limits.

Planning/design typically for "N-1"

N-1 & implies loss of most critical component.

NERC, regional reliability Councils, also TO's need to be involved.

- Survive N-1, but not N-2.
- System is very vulnerable in N-1 state, must restore system to secure state of operation ASAP.

Security: at least 3 uses/meanings

① - "System Operation" - "secured operation"

② - Cyber-security - keep hackers from getting in, to servers.
- Relays
- Imbedded Processors.

③ - Security: power system protection.
