University of Idaho

ECE 529
Utility Applications of Power Electronics

Session 35

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ECE 529: Homework #4

Due Session 40 (April 24)

1. Implement a modified averaged model of a three phase VSC from hws 2 and 3 with an AC source voltage of 2.3 kV (L-L), $R = 0.0096\ \Omega$, $X_s = 0.144$ ohm ($X/R = 15$) and a switching frequency of 3060Hz in a transient simulation program.

   The DC link has two 10,000 μF capacitors connected pole to ground. The output of the converter goes to a 2.3kV:24kV, 5 MVA, Y-Yg step up transformer with $X = 0.08$ pu on the transformer rating base and an X/R ratio of 15 and then connects to a power system with a Thevenin equivalent impedance $Z = (0.05 + j\,0.5)$ pu (on a base of 24 kV and 5 MVA) and an equivalent source voltage of 24 kV.

   The point of interconnect is on the high side of the transformer. Take your voltage and current measurements on the high side of the transformer and scale them to the low voltage side for your control loops.

   Recalute gains for current regulators

   A. Implement a phase locked loop for a point of interconnect at the high voltage side of the transformer and test with ideal voltage sources on the dc link and a couple of P and Q commands ranging between 0 and 5 MVA total to the Thevenin source. The converter can supply up to 5 MVAR, but can only absorb about 1.5 - 2 MVAR depending on your controls.

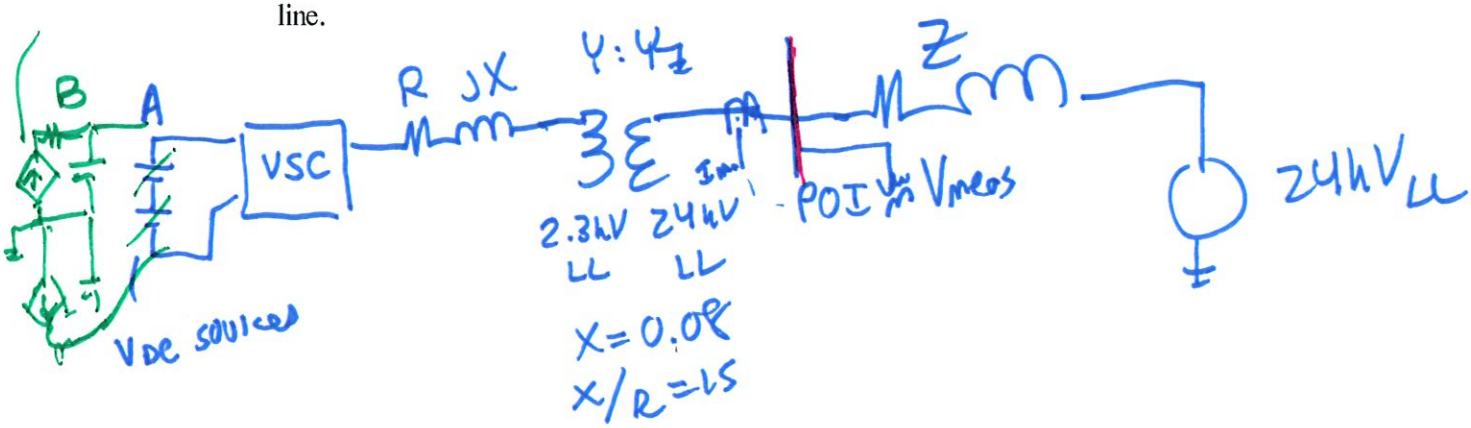
   B. Replace the dc voltage sources with a capacitor banks in parallel with a current source behind a small resistance. Implement a dc bus voltage regulator to determine the direct axis current reference for the controls. Set up the DC current source to be able to ramp from an equivalent of 0 MW to 4 MW in 0.5 seconds while the converter is at unity power factor and the stays at 4 MW for the rest of the simualtion.

   $Q_{ref} = f(P_{ref})$

   C. Repeat part B with a power factor of 0.8 for supplying reactive power and a power factor of 0.966 for absorbing reactve power. Compare the magnitude of the voltage at the point of interconnect the two different power factor cases.

   $I_{dc} = \frac{P_{comm}}{V_{dc}}$

   D. Repeat part B with the quadrature axis current reference determined by a closed loop voltage regulator set to maintain the voltage at the point of interconnect at 24 kV line to line.



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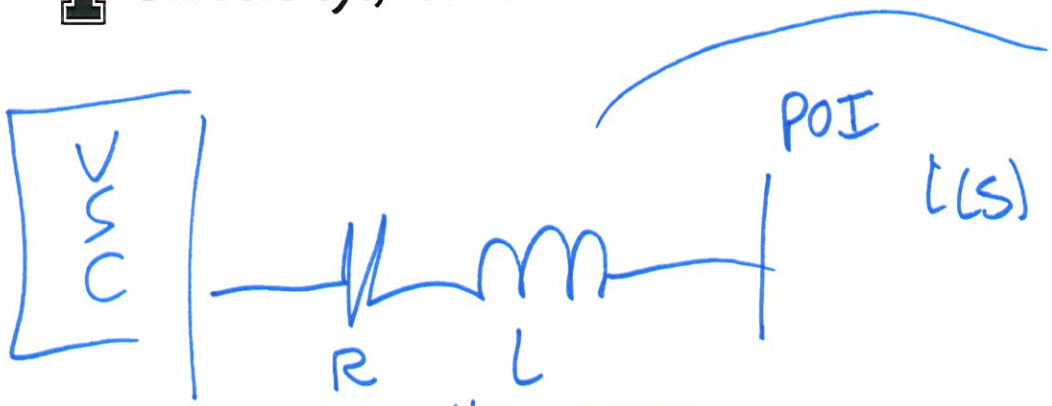
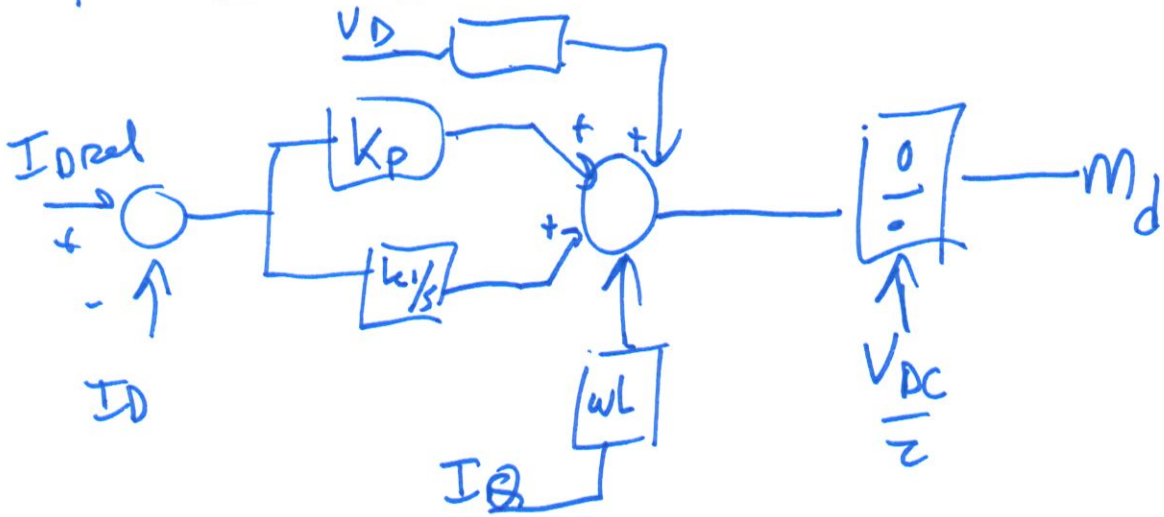
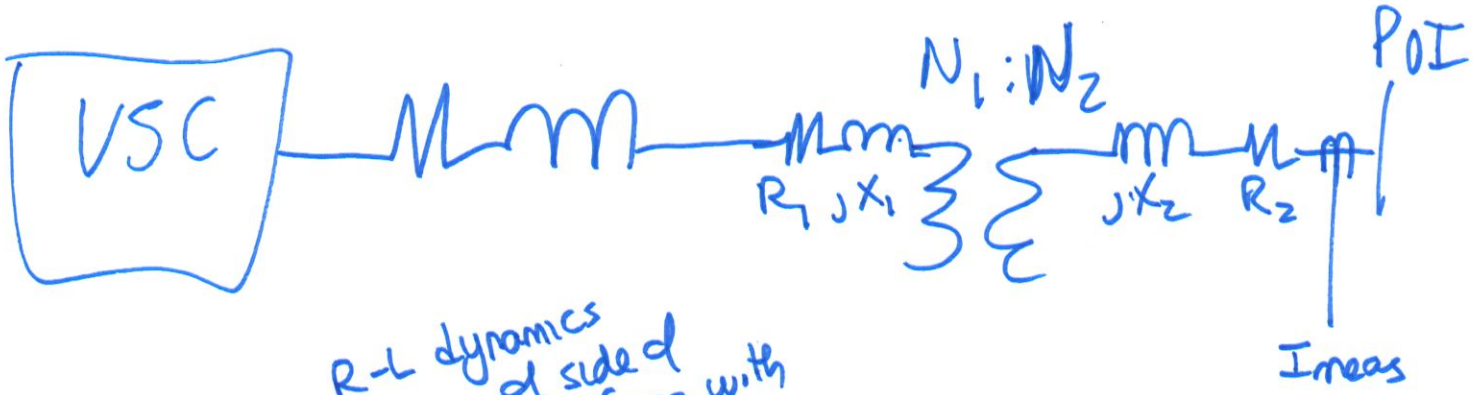


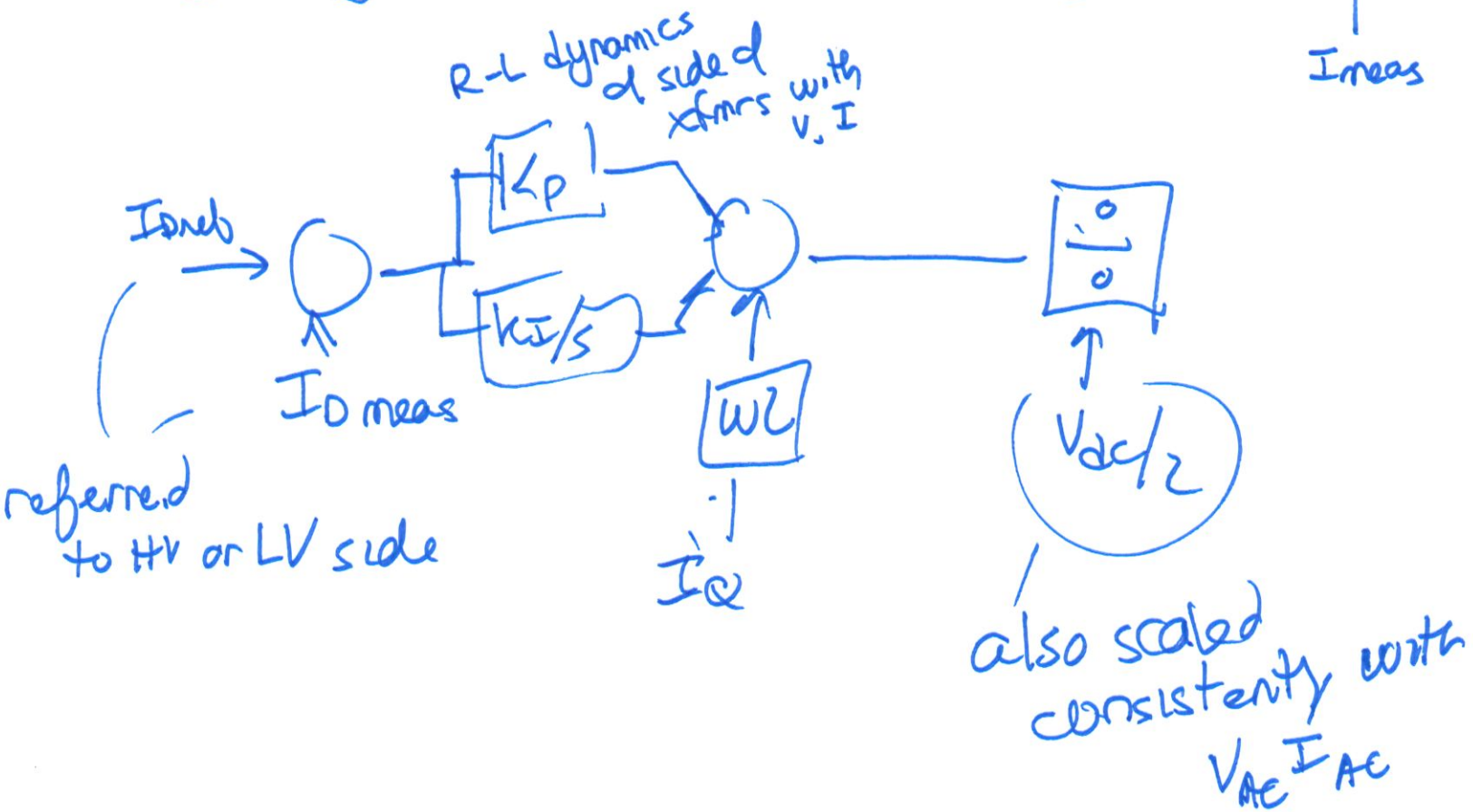
$$i(s) = \frac{V_t - V_s}{R + sL}$$



P.I controller gains: canceling pole associate with R/L time const

→ we want τ_{set} for controller time const.


VSC
$N_1 : N_2$
POI
R_1, jX_1
jX_2
R_2
Imeas


R-L dynamics of side of xfmrs with V, I
I_{Dref}
K_P
K_I/s
I_D meas
ωL
I_Q
$V_{dc}/2$
referred to HV or LV side
also scaled consistently with $V_{AC} I_{AC}$

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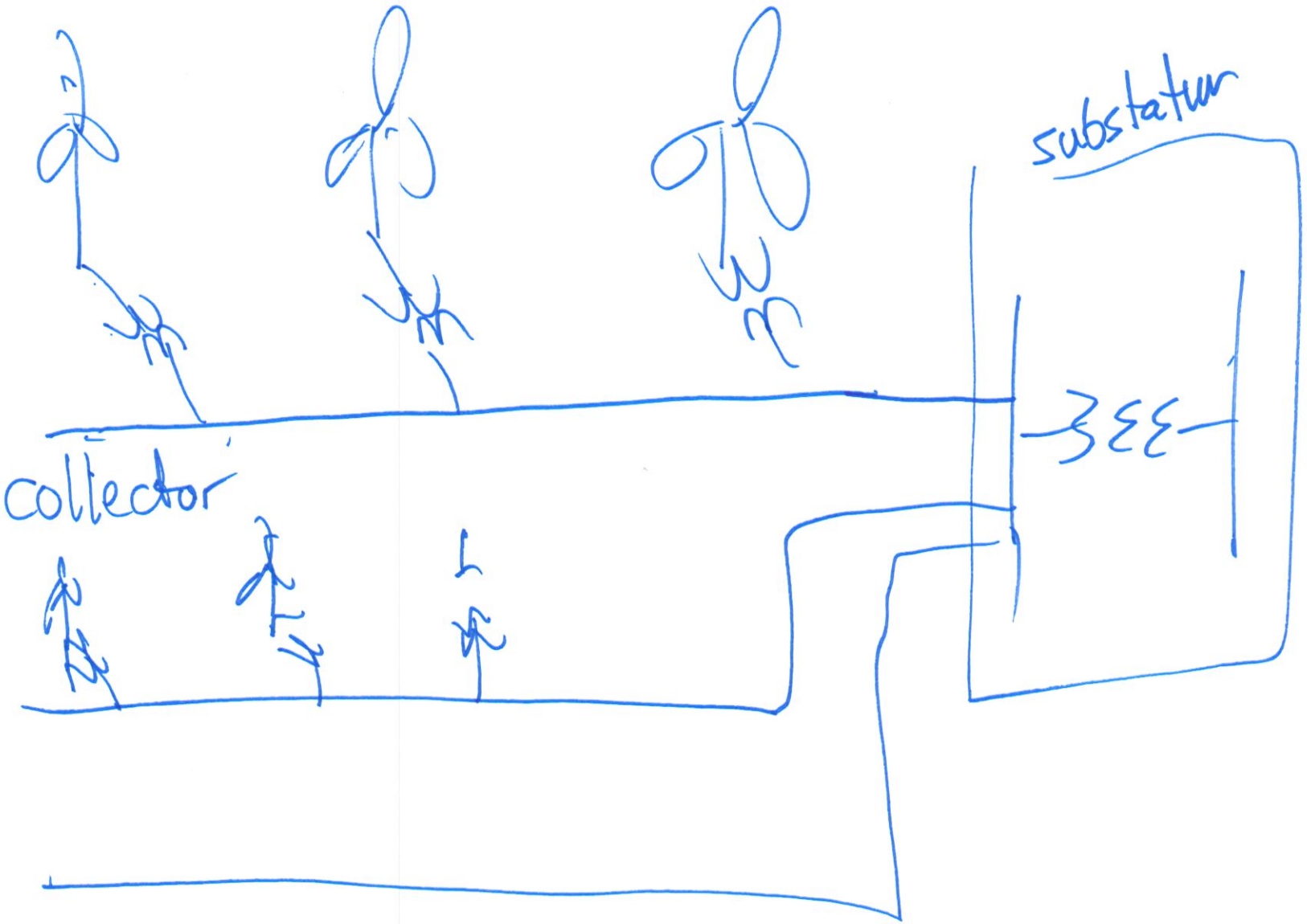

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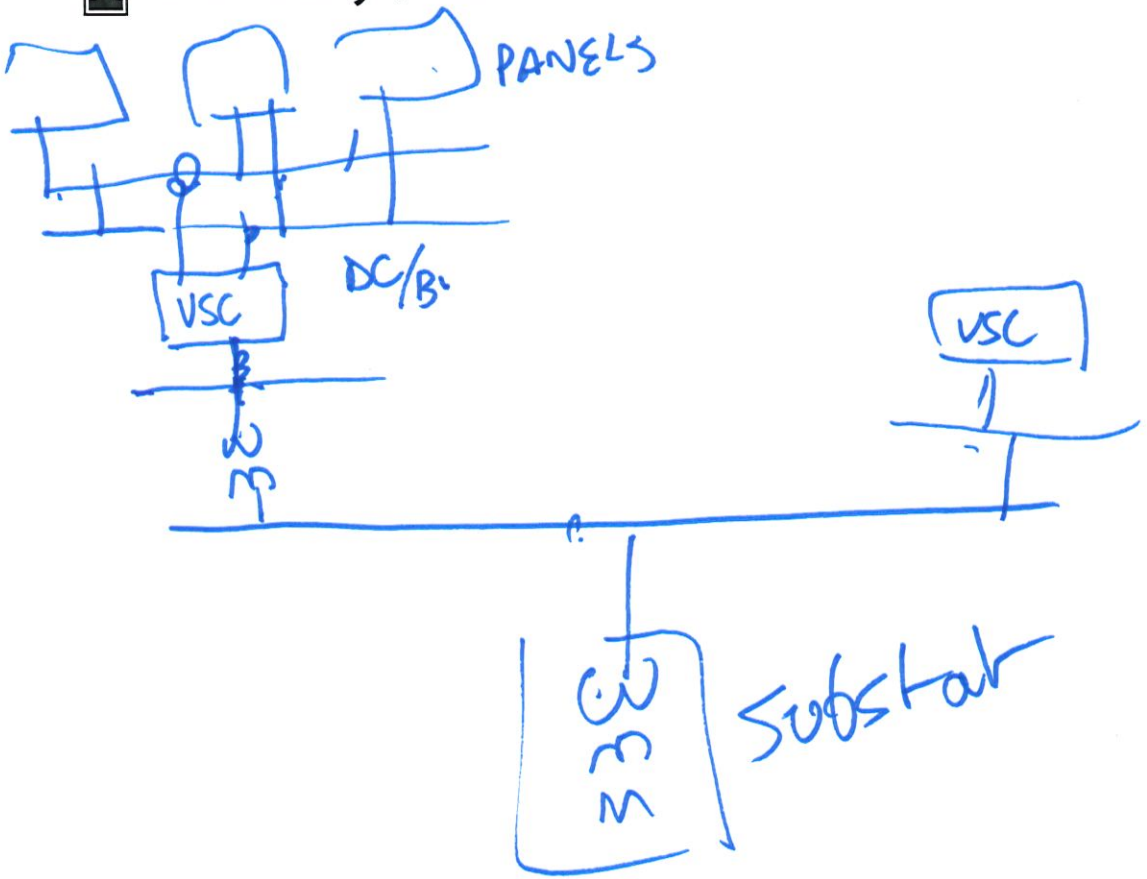

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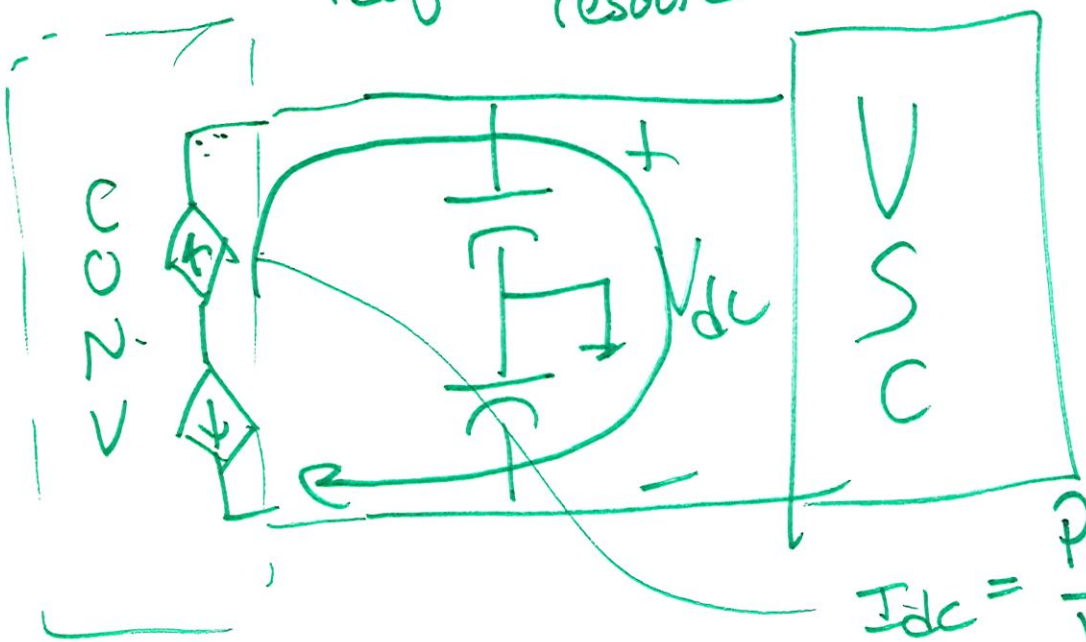
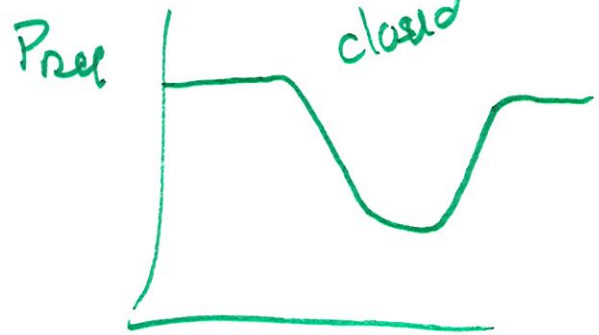
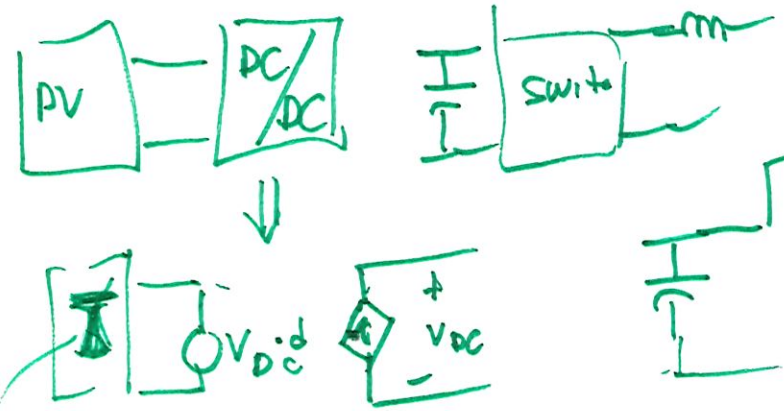
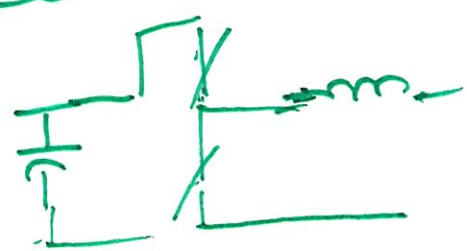
P_{ref} → solar or wind resource

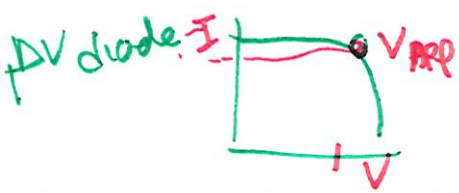


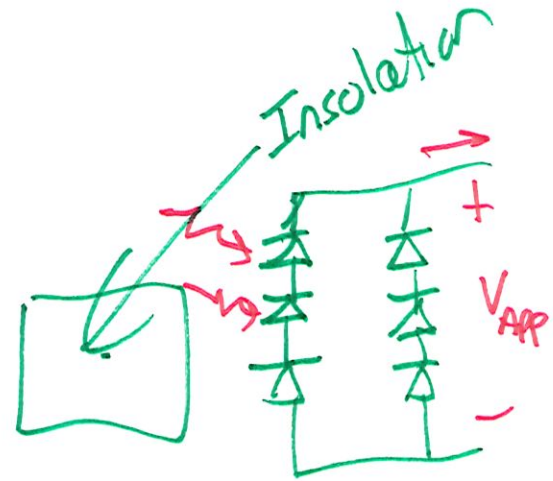


$$I_{dc} = \frac{P_{ref}}{V_{dc_{meas}}}$$









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What is Needed in Transformer Models?

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- Amount of detail depends on frequency of desired response
- Power flow stability often just model leakage, perhaps winding resistance
  - » Tap changing
  - » Perhaps wye-delta phase shift

What is Needed in Transformer Models?

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- Fault studies require more information
  - » Connection info
    - – wye
    - – delta
    - – zig-zag
    - – autotransformer
    - – etc.
  - » Grounding
  - » Possible impact of tertiary

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Low Frequency Transients

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- Similar modeling info to fault programs
  - » Connection information more important
- Magnetizing branch
  - » Saturation
- Core loss term
- Not using per unit
  - » Need to include turns ratio
  - » Divide leakage L, winding R between windings

Single Phase Equivalent Circuit

low freq

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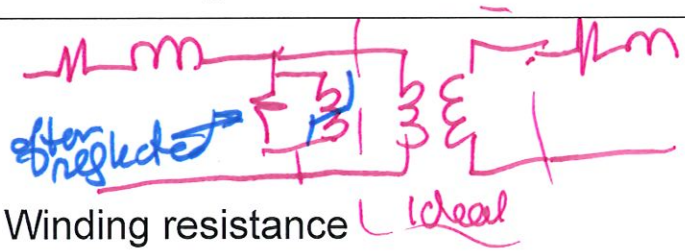
Lecture 37



- Winding resistance
- Leakage inductance
- Core loss--total losses
- Non-linear inductor model for magnetizing branch

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ATP Options

- Ideal transformer component
- Saturable transformer component
- BCTran -- preprocessor that converts description of transformer to coupled RL
- Can also create manually using coupled RL branches

Ideal transformer component

- Combines ideal transformer with ideal source
  - » Simply enter transformation ratio
  - » Can be used to implement floating source too
  - » Uses frequency from basic ATPDraw settings
    - – Need to make sure this matches system frequency
    - – Setting "Branch = 0" forces ATP to use this frequency
    - – "Branch = 1" can avoid this (Vm=1E-20)

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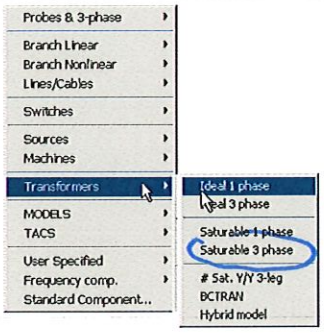
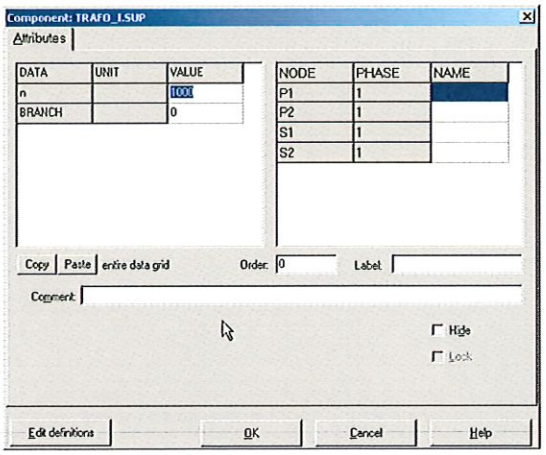
Accessing Transformer Models

- Note that three phase and single phase options



Dialog box



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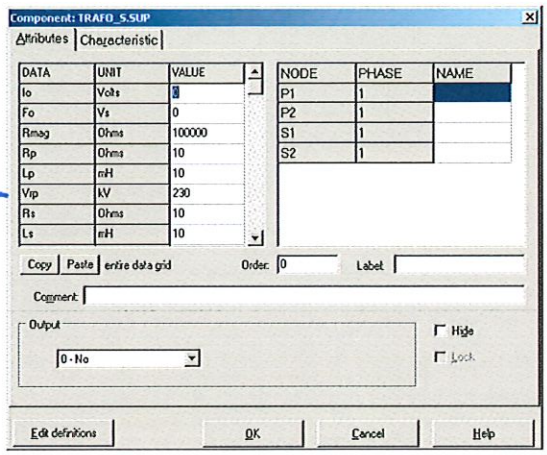
Single Phase Saturable Base Attributes

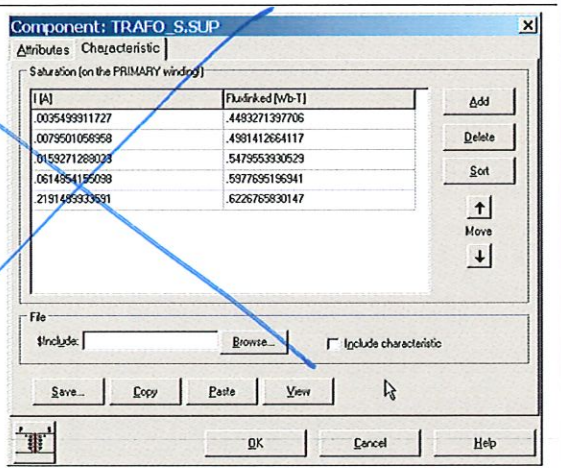


- Io, Fo are steady-state point on saturation characteristic for initial Lm
- RMS = 0 or 1: determines how the saturation characteristic is entered.
- Output is information about mangetization branch

DATA	VALUE
Rmag	100000
Rp	10
Lp	10
Vrp	230
Rs	10
Ls	10
Vrs	24000
RMS	0

Saturation Characteristic

- If RMS = 0, this is current versus flux
- If RMS = 1, this is RMS current versus RMS voltage at frequency of first source in the system
- The 0,0 point is assumed by the program
- Up to 10 points can be entered
  - » Better to limit to 3-5



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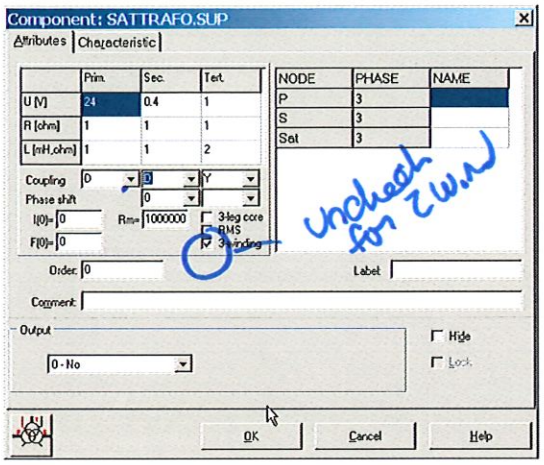
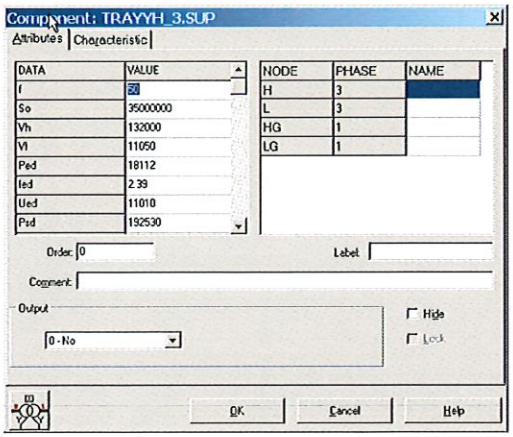
Three Phase Model

- Enter data for each winding
- Select Y, D, or Zig-zag
- Three leg option here, but better to use specific case from pull-down menu.



Three Phase Model- Three Leg Core

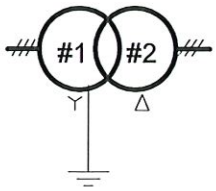
- Option to model homopolar reluctance
  - » Saturable-Three Leg
- Much additional information needed.
- See help menu.



DATA	VALUE
Isd	153.1
Usd	35213
Peh	115325
Ieh	500
Ueh	1183
Psh	8825
Ish	70
RMS	0

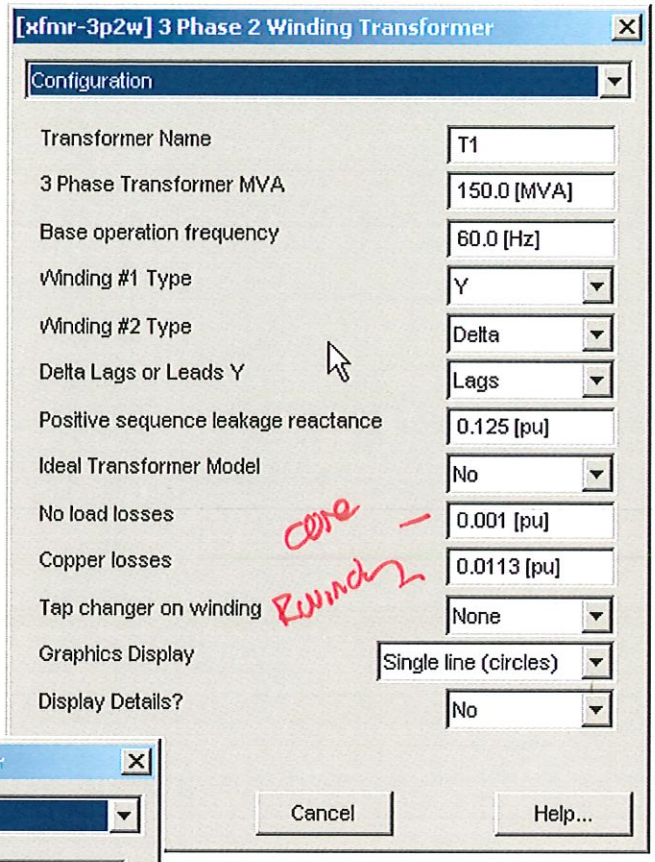
L35 B/B

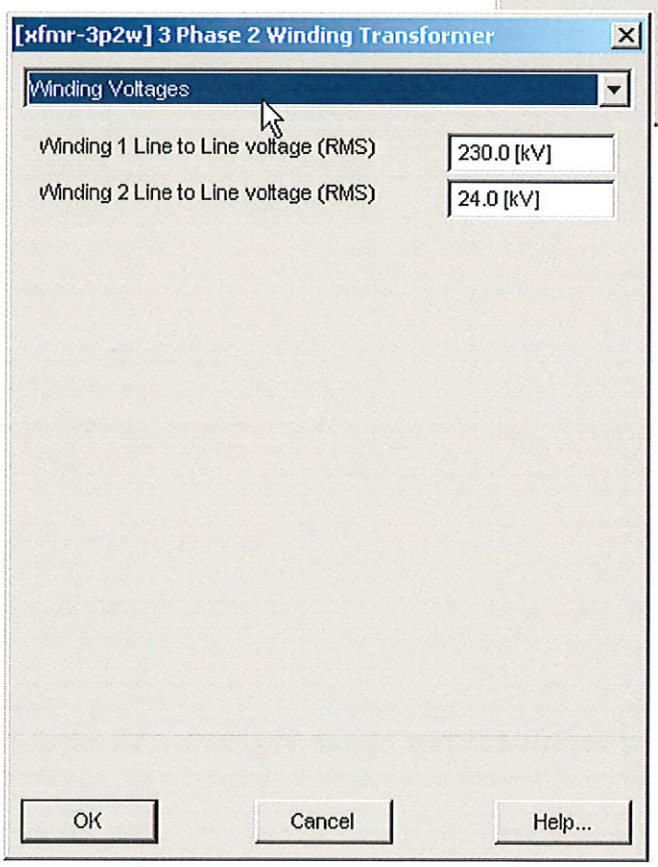
PSCAD Implementation:



Main dialog box

- Note per unit leakage reactance
- No load losses are from open circuit test
- Copper losses are from rated current through the winding resistances as above
- Note that ideal transformer not selected.





- Note that three phase transformer uses RMS L-L voltages for ratio and to convert per unit values to ohms and mH