ECE 523
Symmetrical Components

Session 30

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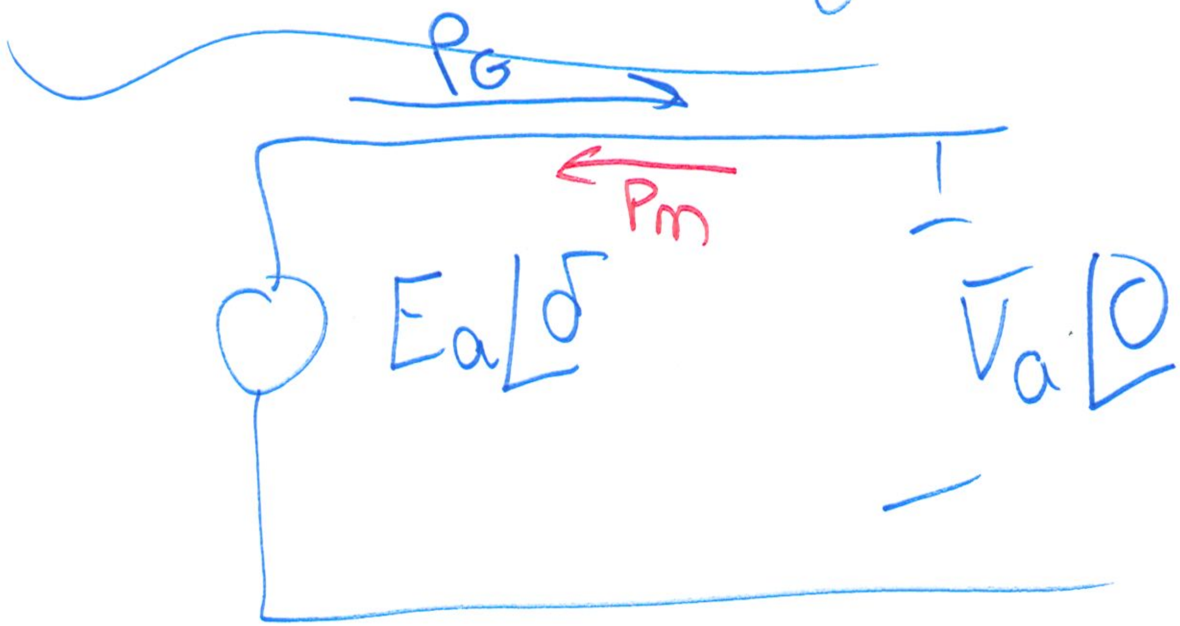
Synch Machine

Pos Sequence fault response

~~X~~ is time varying



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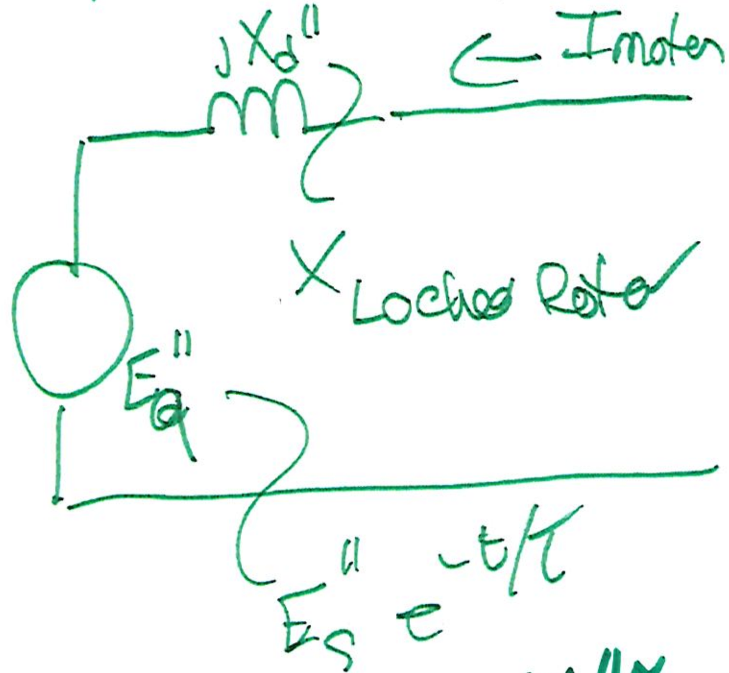
Induction Machines

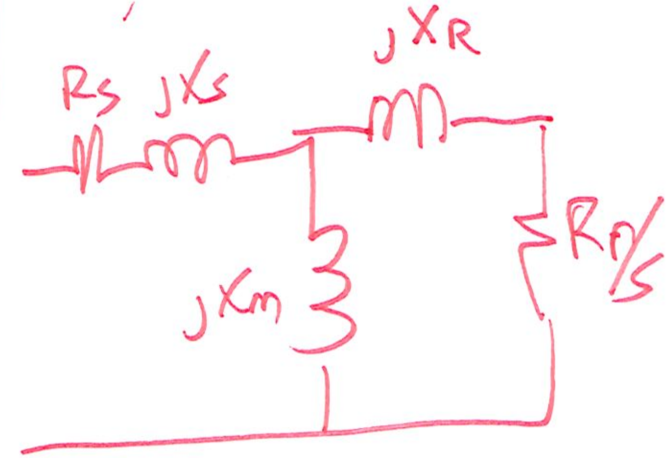
fault studies

positive seq



$X_d''\approx X_s + X_R$

Steinmetz model



- motor operation
  slip is positive
- generator
  slip negative

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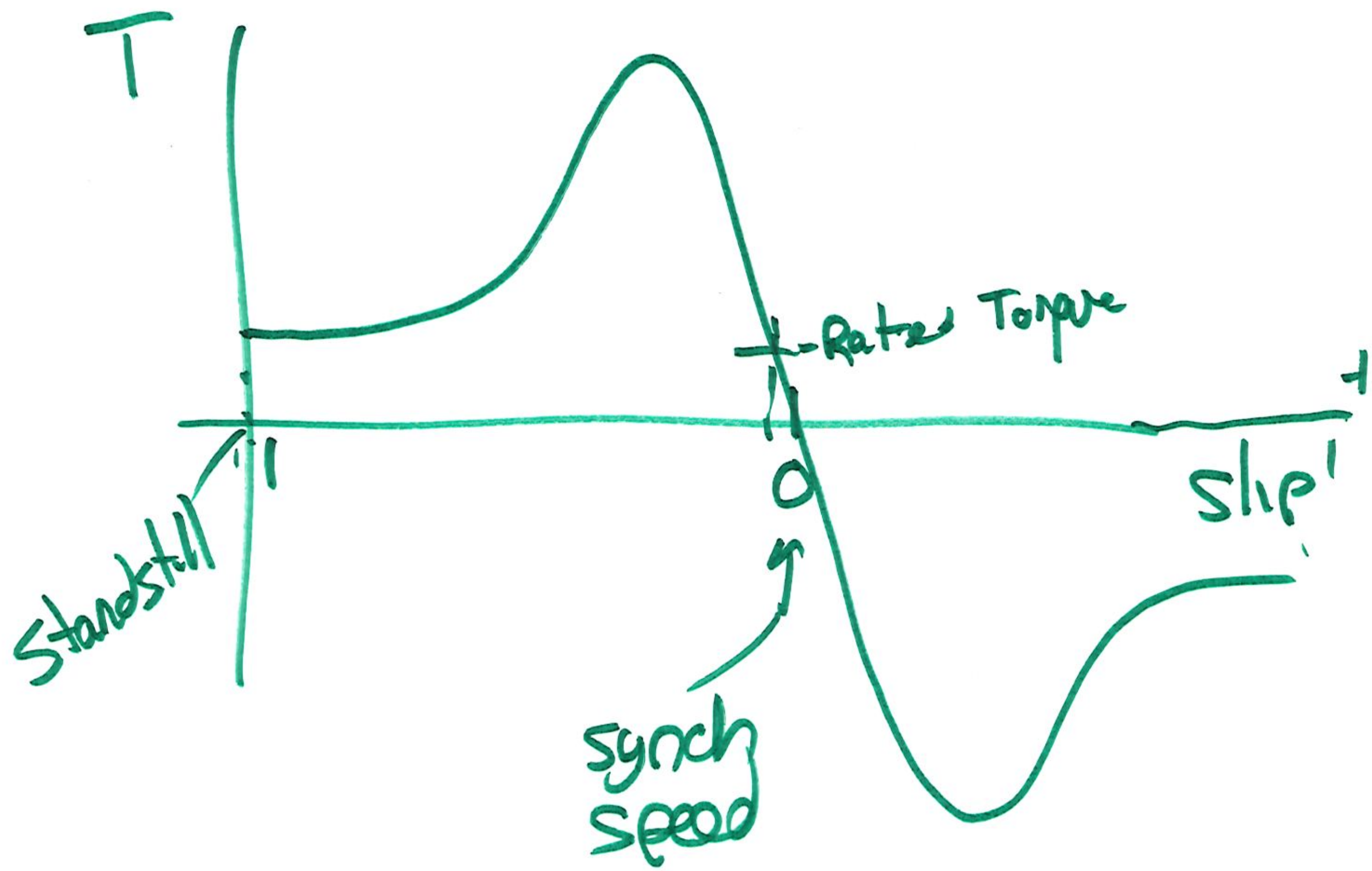
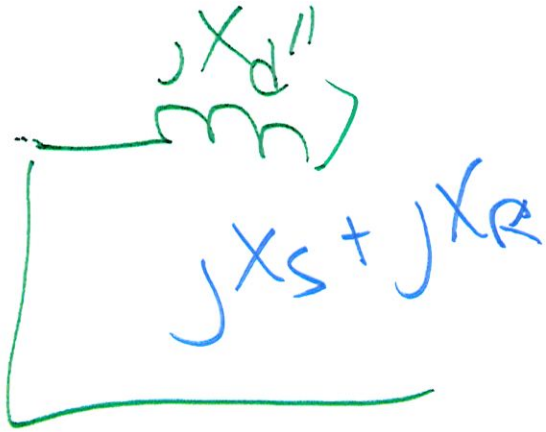
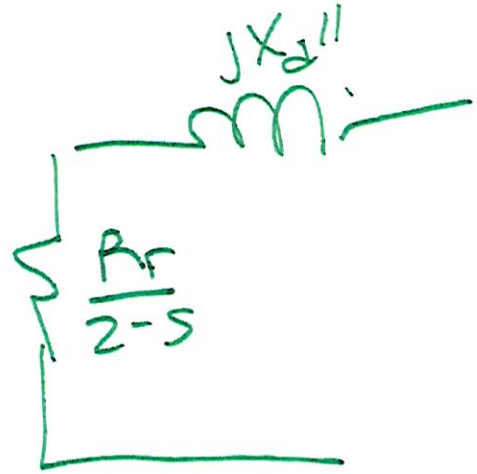


Negative sequence

approx.



more accurate
- calculate prefault slip



Prefault current

$P_{out} \rightarrow$ shaft power

HP

$\eta = 95\%$

rated pf 0.85 lagging

rated speed or rated slip

$P = T \cdot \omega$

$P_{out\,HP} \rightarrow \omega$

$1\,HP \cong 746\,W$

$\approx 1\,kVA$

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$$\bar{S}_{rated} = \frac{P_{OUT}(W)}{pf \cdot \eta} \angle \cos^{-1}(pf)$$

$$\bar{S}_{pu} = \bar{V}_{pu} \cdot \bar{I}_{pu}^{*}$$ on system base

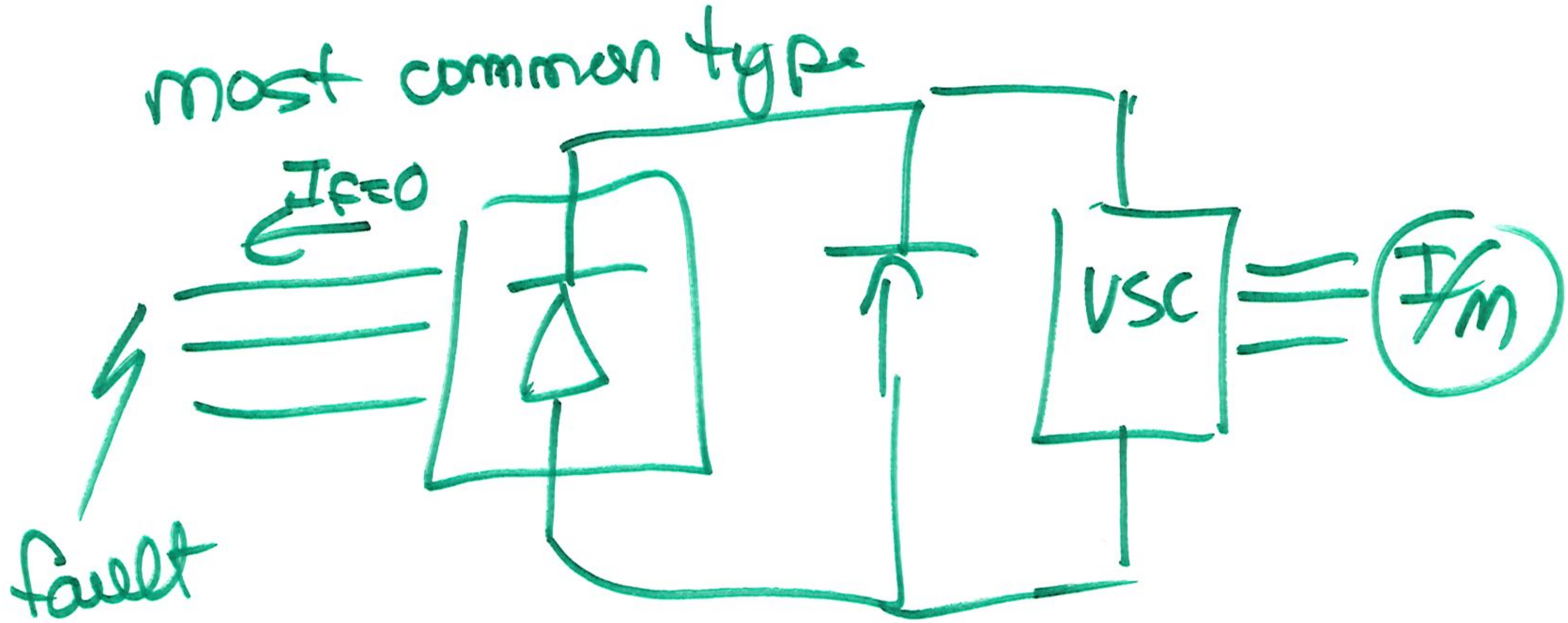
→ can find current

— convert to system base for fault analysis

$\approx E'' e^{-t/\tau}$

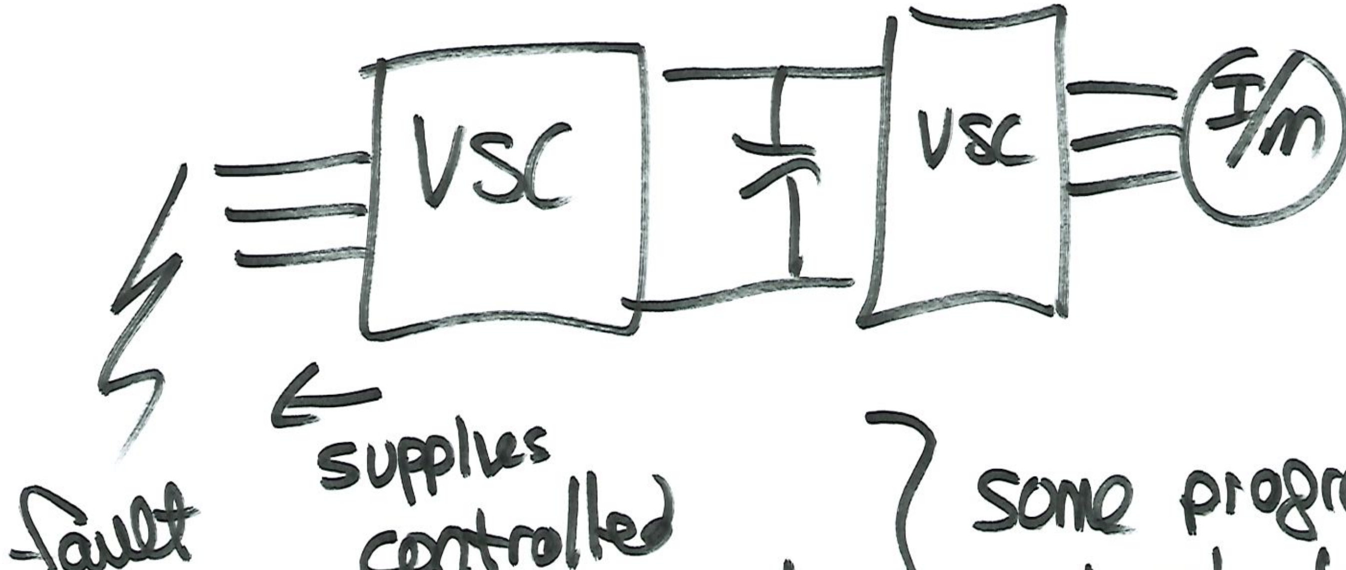
Adjustable speed motor drives

most common type



Regenerative Motor drives

- newer types



supplies controlled fault current ←

} some programmed to only draw current

some can supply limited current

- limited to ≈ |I_{rated}|

- Inverted Based Grid Following Generation & Storage
  - Type 3 & Type 4 wind turbine
  - Photovoltaic Inverters
  - Battery, ultracapacitor, flywheel ...
    - ↳ controlled as grid forming converter (increasing trend)

→ All controlled to track grid frequency/angle with fast time constant
  - ↳ good for getting maximum power from resource

Grid following

- fault response?
  (disturbance response)
  - track change in angle with time constant of a few ms.

→ fast current control
  → limit max SS to 1.1 → 1.4 pu
  → many calculate $|I_{ref}| = P/|V|$ or $Q/|V|$ ← current reference limit
  → about 1 → 2 cycles to settle to steady state

fault current angle?

- unlike S/M
- angle depends on controls
- Initially prefault p.f.
  - If unity pf prefault, will be unity pf in steady-state faulted case

→ For low voltage ride through requirement

→ may provide Q to improve performance

→ I leads V

Zero sequence

open in converter

→ transformer dominates

Δ Y⏚ – individual inverter

on Y Δ Y⏚ } grid interconnecti
or Y⏚ Δ Y⏚ } collector station

Negative sequence

- → older converters
  - → Either regulated phase current → don't control I_2 but stays essentially 0
  - → intentionally regulate $I_2 = 0$
- → New cases – especially at transmission level.

  IEEE 2800, or Grid Codes (Europe especially) require supply $|I_2|$ as percentage of $|I_1|$ and angle relative to V_2

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Summary: Grid following

pos sequence → current source with regulated magnitude & angle

Negative sequence
→ either ① $\bar{I}_c = 0$ (open)
② current source with regulated $|I_2|$ & angle

Zero → converter open
→ transformer connection

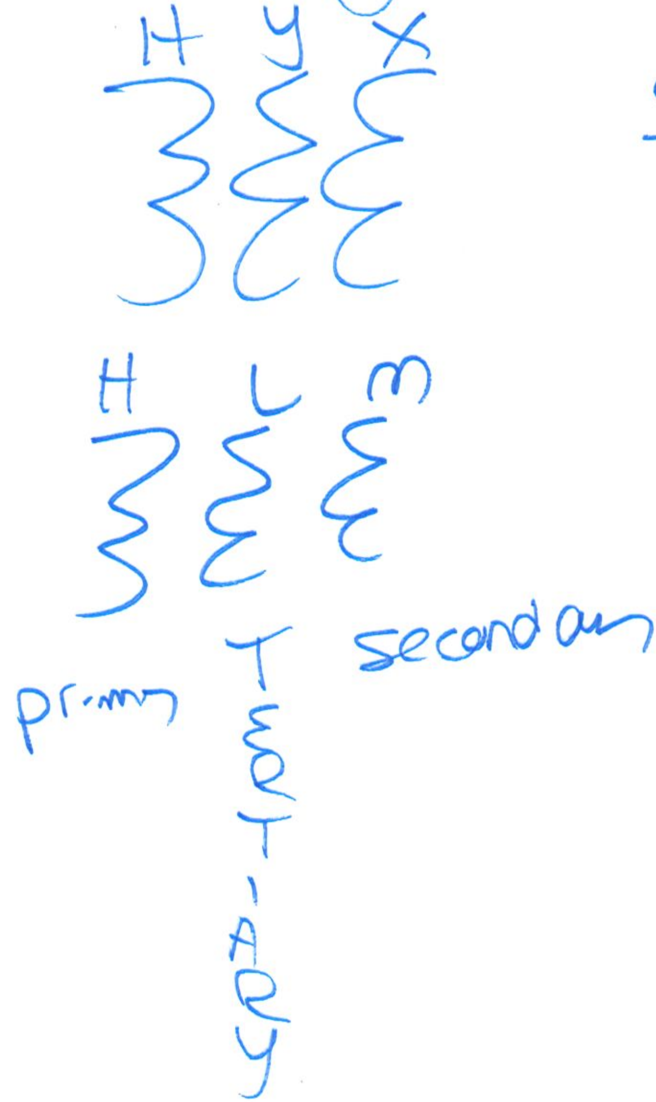
fault analysis

→ need superposition of voltage source driven currents (what we've done all semester) + current sources

→ section 2.6 - simple circuits

section 7.2 → matrix ..

3 winding transformers



short circuit date on xfmr mode

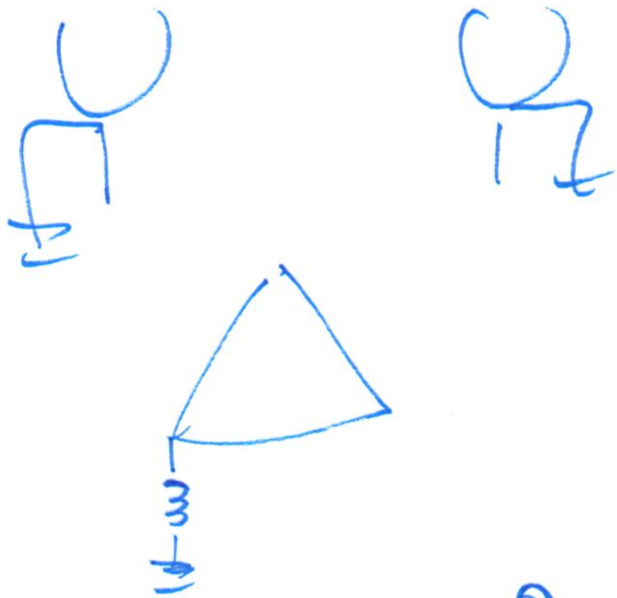
X_{HM} → voltage "applied" at H, M shorted, L open

X_{HL}

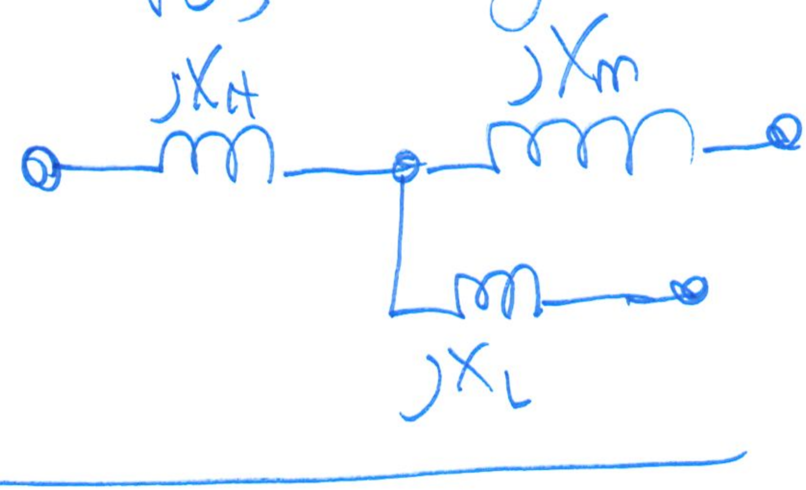
X_{ML}

} per unit

- L winding on MVA base of that winding



Pos & negativ



Zero (depends on connection)