ECE 404-TD / 504-TD

ST: T&D APPLICATIONS OF
VOLTAGE SOURCE CONVERTERS

SESSION no. 34

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ECE 404/504: Homework #5

Due Session 37 (April 17)

1. Implement an averaged model of a three VSC with an AC source voltage of 2.4kV (L-L), R = 0.096 Ω, L = 3,82mH (X/R = 15) and a switching frequency of 3600Hz.
   A. Determine V_{dc} if the maximum amplitude of the modulating function is 0.8 and the maximum reactive power the converter can supply is 4MVAR while transferring 0 MW (both measured at the source side of the R-L). Round up to nearest 10 V.
   C. Generate open loop modulating functions ($m_a(t)$, $m_b(t)$, and $m_c(t)$ such that P=4MW and Q=0. Verify that the converter supplies this using averaged models.
   D. Generate open loop modulating functions such that P=3.71MW and Q=1.5MVAR. Verify that the converter supplies this.
   E. Generate open loop modulating functions such that P=3.71MW and Q=-1.5MVAR. Verify that the converver supplies this.
   F. Generate open loop modulating functions such that P=-3.71MW and Q=-1.5MVAR. Verify that the converver supplies this.
   G. ECE 504 students, implement using a switching model. Compare ac currents to those from the averaged models and the fundamental component of converter terminal voltages to averaged model results.

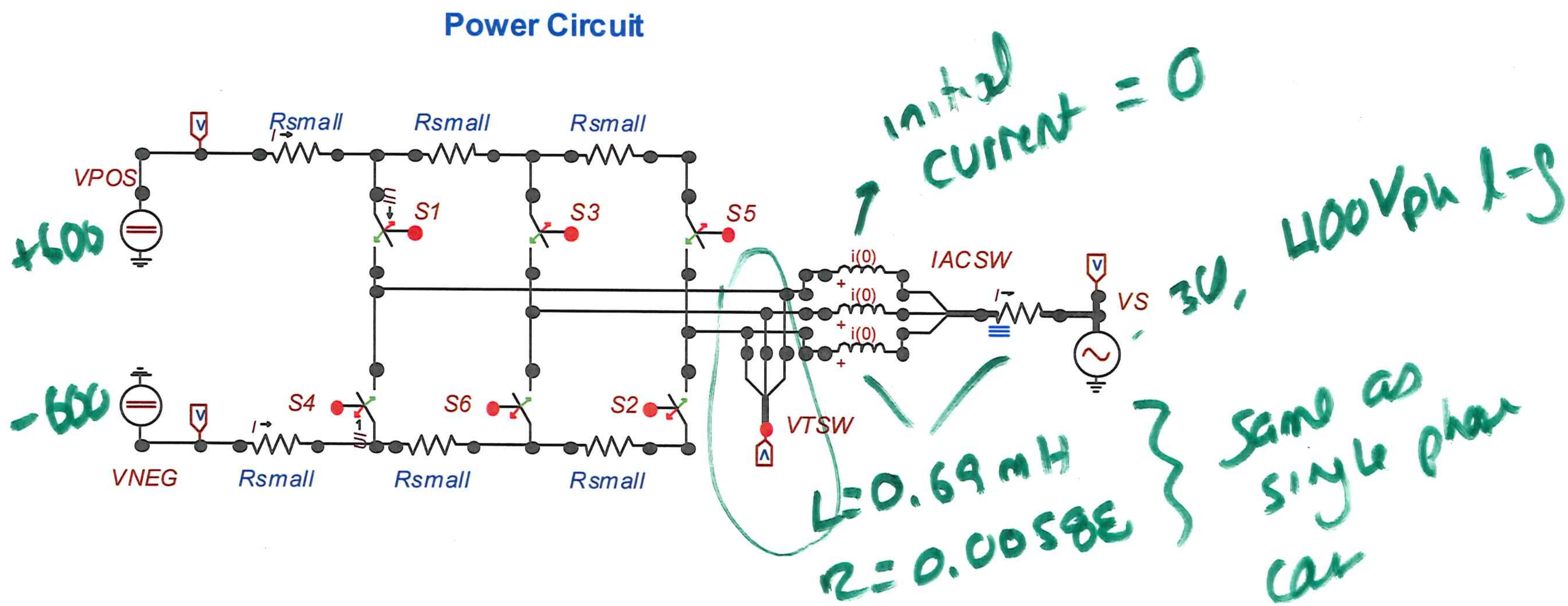
|m| δ_m

2. Now the VSC from problem 1 has a closed loop control scheme implemented in the synchronously rotating d-q reference frame. Assume that the source voltage is constant.
   A. Determine the i_{dref} and i_{qref} such that P=4MW and Q=0.
   B. Determine the i_{dref} and i_{qref} such that P=3.71MW and Q=1.5MVAR.
   C. Determine the i_{dref} and i_{qref} such that P=3.71MW and Q=-1.5MVAR
   D. Determine the i_{dref} and i_{qref} such that P=3.71MW and Q=-1.5MVAR
   E. ECE 504 students implement cases A-D using closed loop control in your EMT program using averaged models.

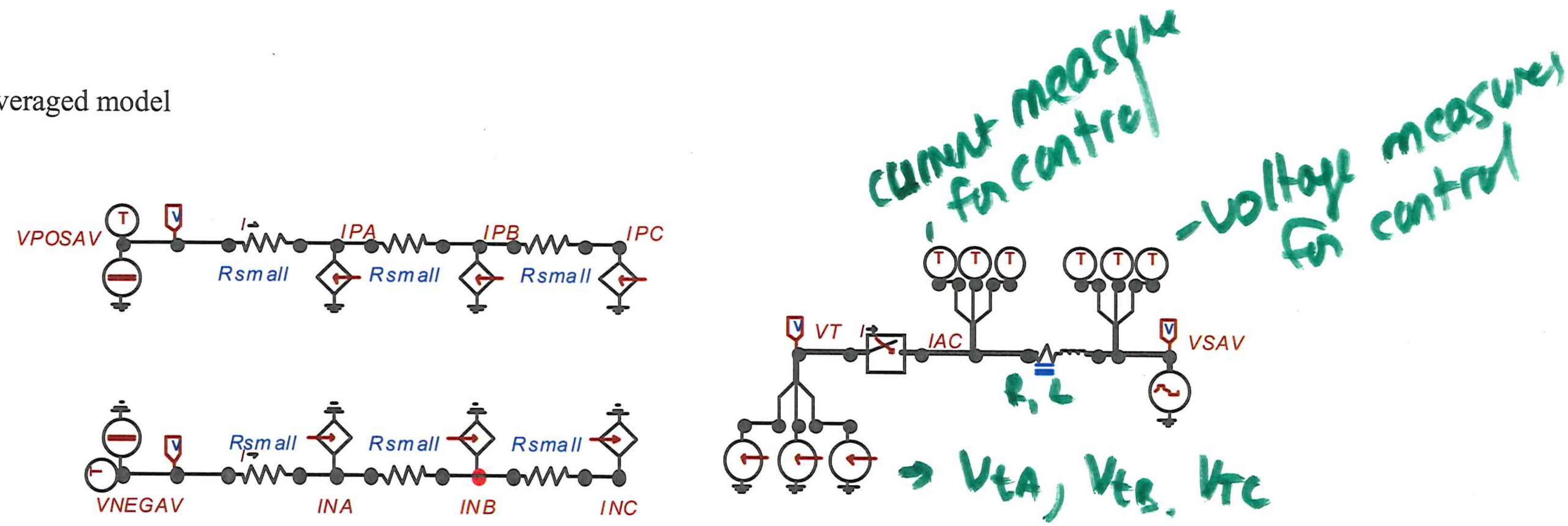
Assume PLL → $V_{sq} = 0$

Three Phase Phase VSC Averaged Model

- Switching model



- Averaged model



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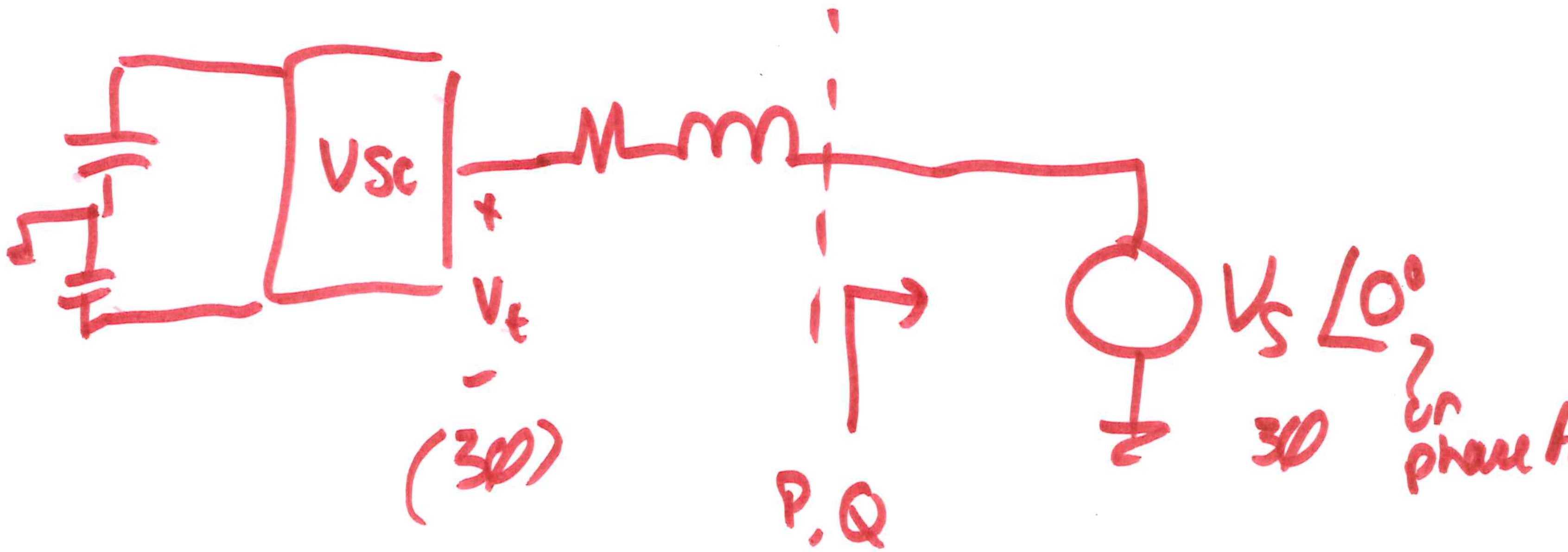
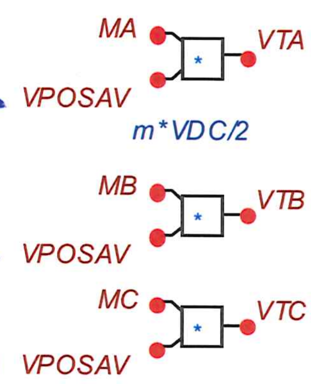
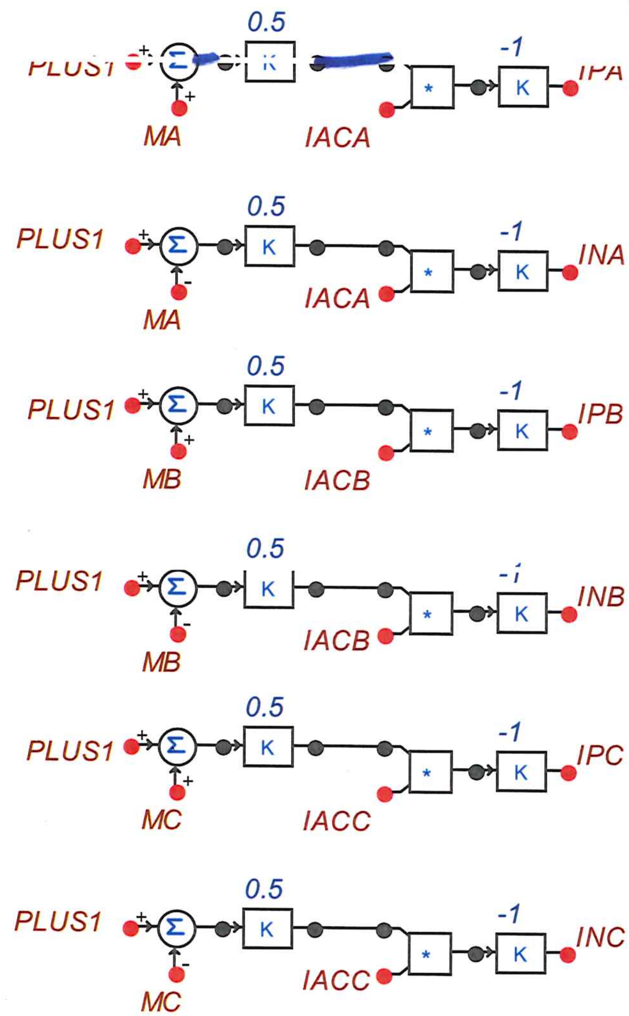


- Voltage command



- Current commands



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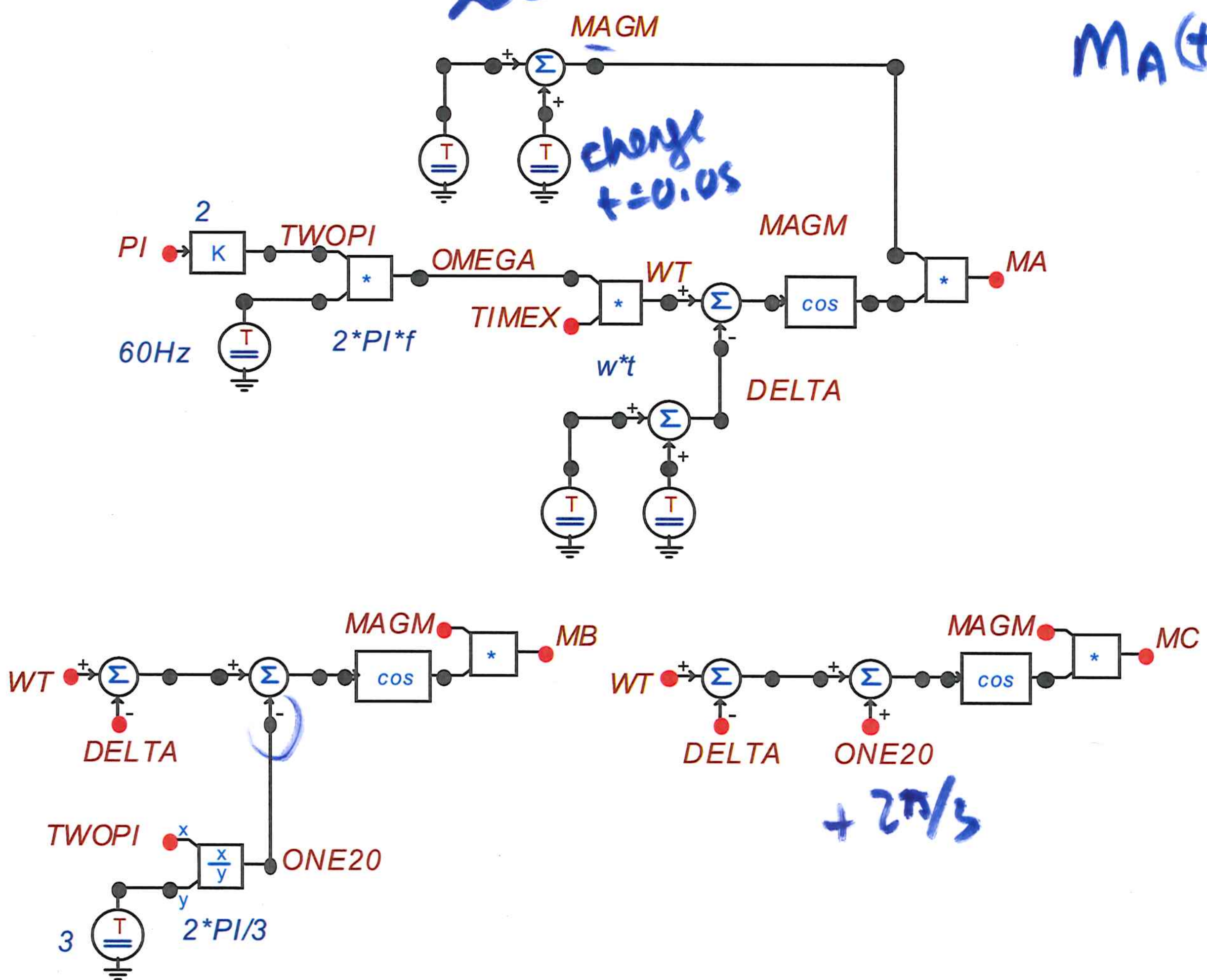
- Generate modulating functions

~ specify magnitude of m

$M_A(t) = MAGM \cdot \cos(\omega t - \delta)$



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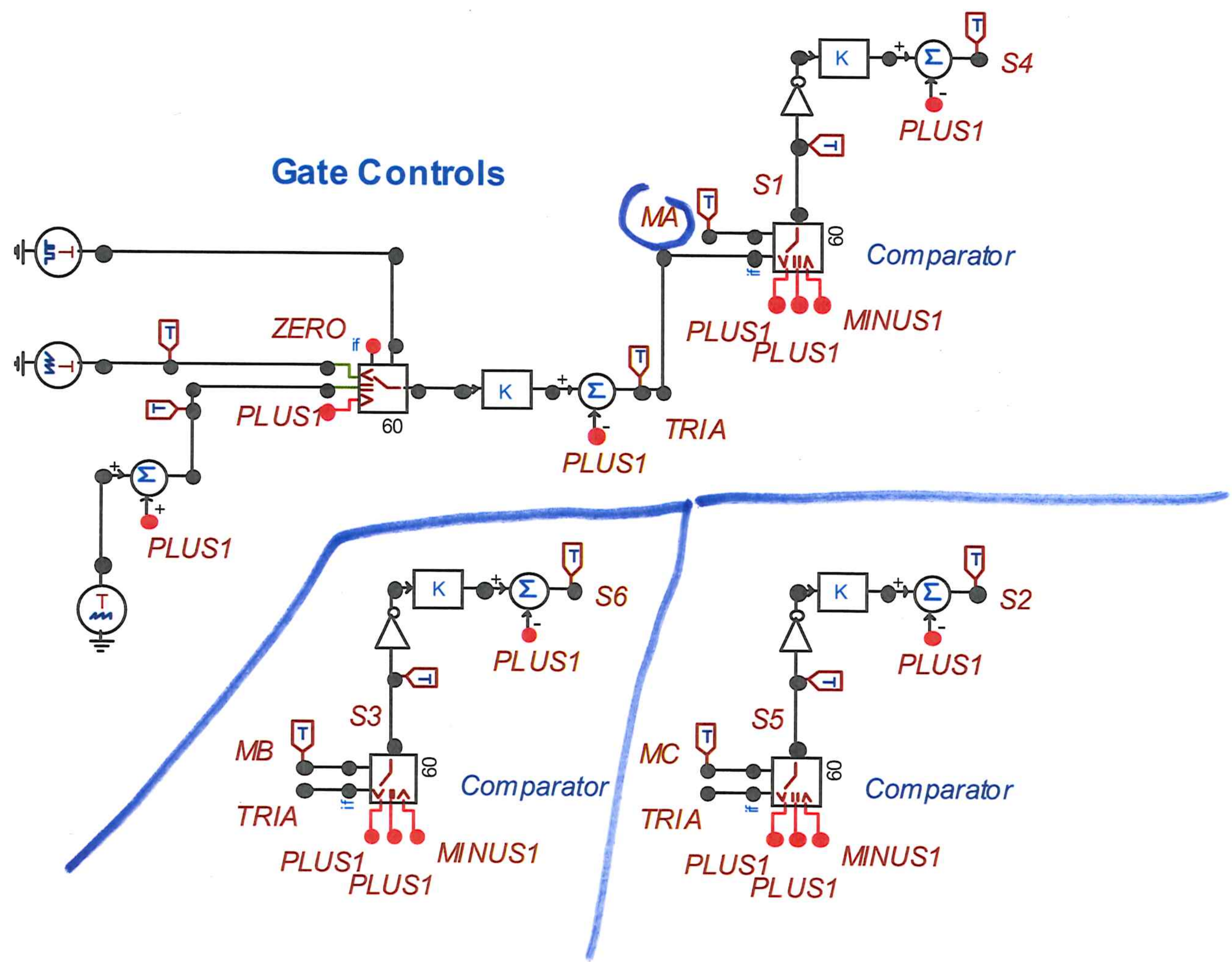
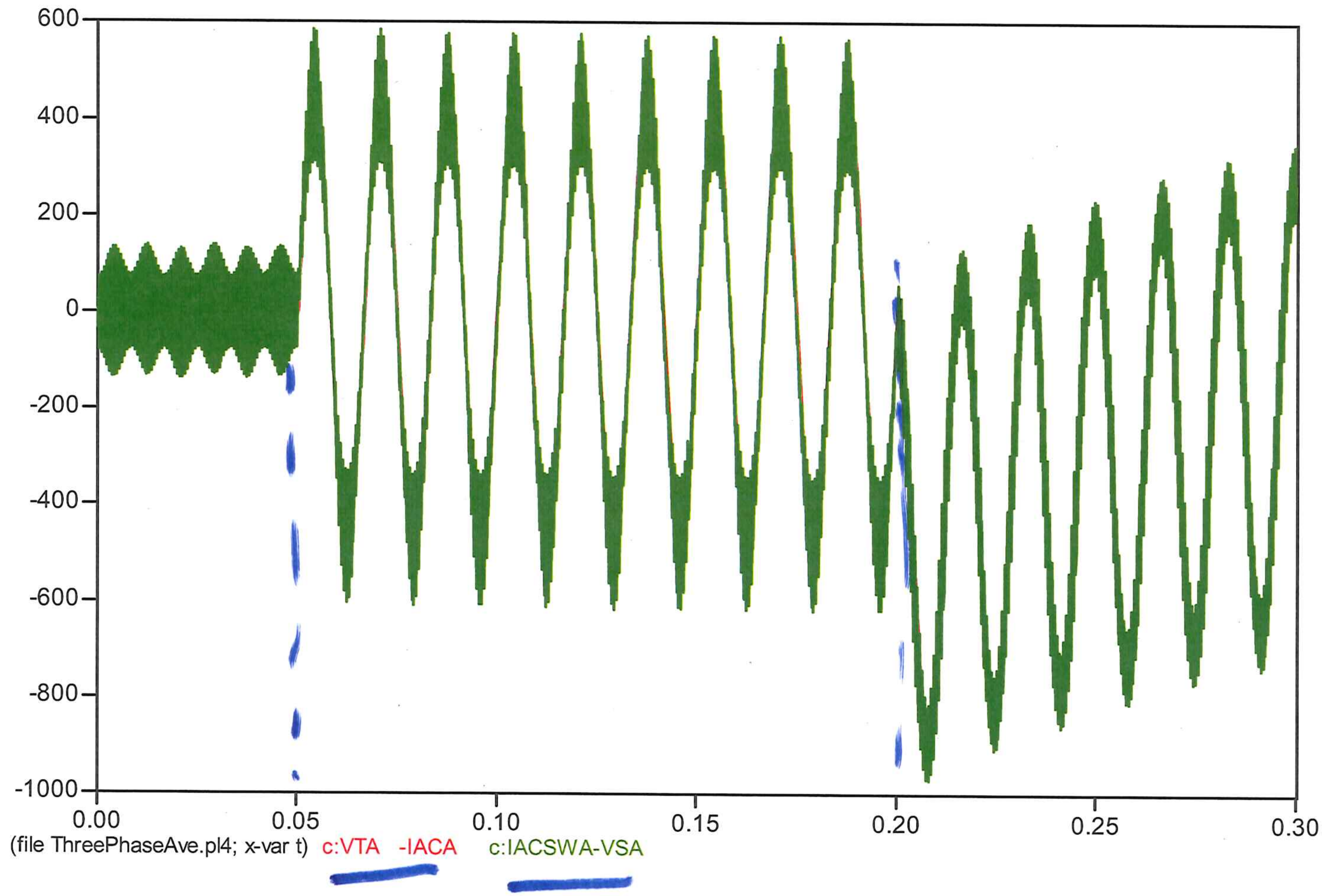
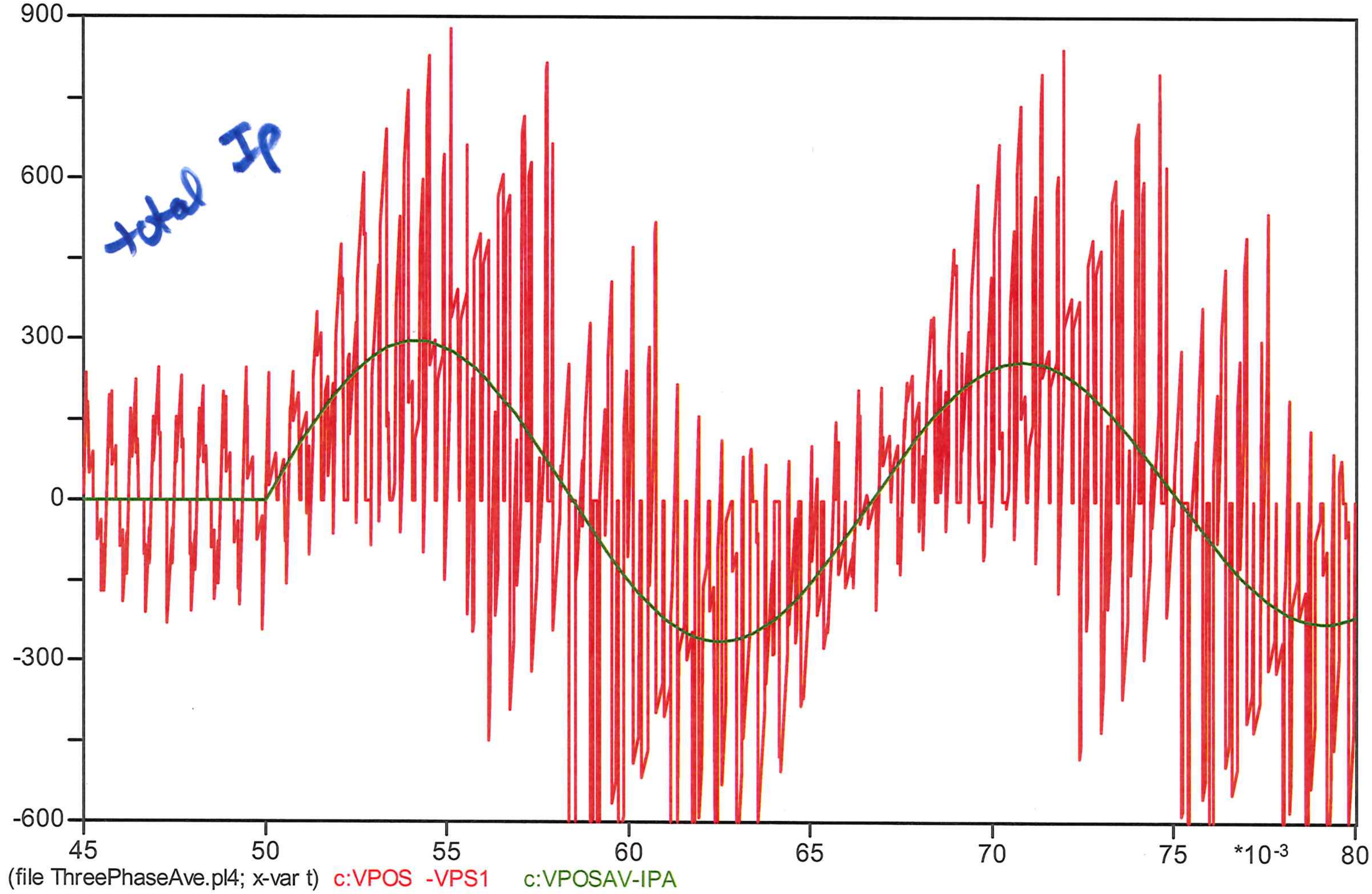
- Firing pulse generation

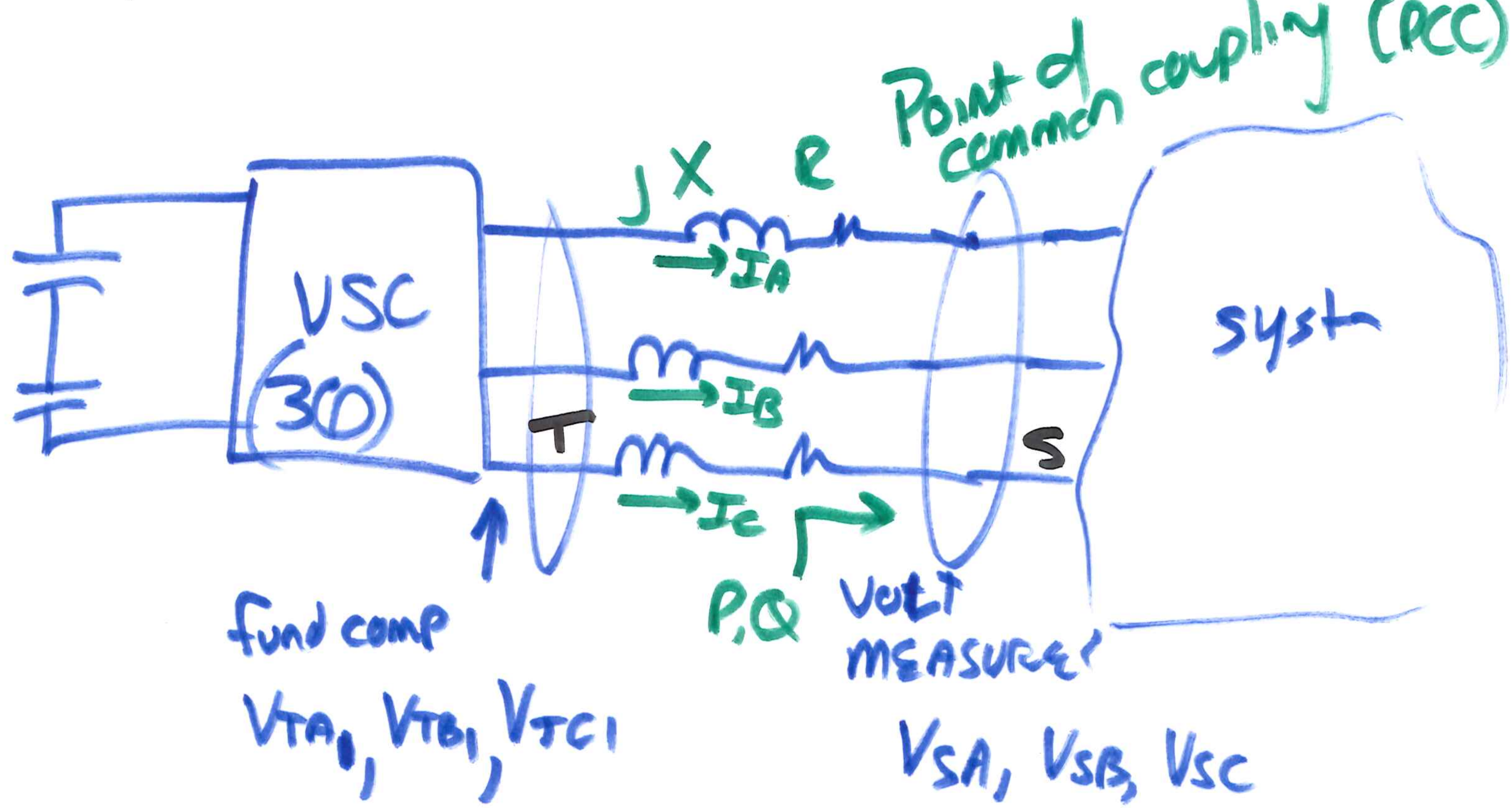


Phase A currents



Positive side DC currents





for now balanced 3Ø

Regulate P, Q at PCC

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If R small compared to X

$X/R > 10$

- $P_{ST} = 3 \cdot \mathrm{Re}(\bar{V}_{S_{ami}} \bar{I}_A)$ ← polarity of I_A coming from T

- $S_{ST} = 3 \bar{V}_{SA} \bar{I}_A^*$

$= 3 \bar{V}_{SA} \left(\frac{V_T - V_{SA}}{R + jX} \right)^*$ ($R \approx 0$)

- $P_{ST} = \frac{3 |V_{SA}| |V_{TA}| \sin(\delta - 0)}{X} = P_{TS}$

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Similarly

$$-Q_{ST} = \frac{-|V_{SA}|^2 + |V_{SA}||V_{TA}|\cos(\delta - 0)}{X}$$

$\neq Q_{TS}$ because of Q "absorbed" in inductor