ECE 404-TD / 504-TD

ST: T&D APPLICATIONS OF VOLTAGE SOURCE CONVERTERS

SESSION no. 21

ECE 404 / 504 T&D Applications of Voltage Sourced Converters — Due: Monday 4 March

Homework #4

Multilevel Converters

1. For a four-level NPC converter, find all the available switching states. Let the total dc link voltage be 8.0kV.

   a. List the switching states in a table showing the voltage across each switch and the components of a space vector representation thereof. You may work in a per unit system of your choice if you prefer.
   b. Create a plot similar to what was presented in class. Plot all the vectors. Label each vector in the first hextant; that's plenty. You can check your plot using Prof. Corzine's reference.

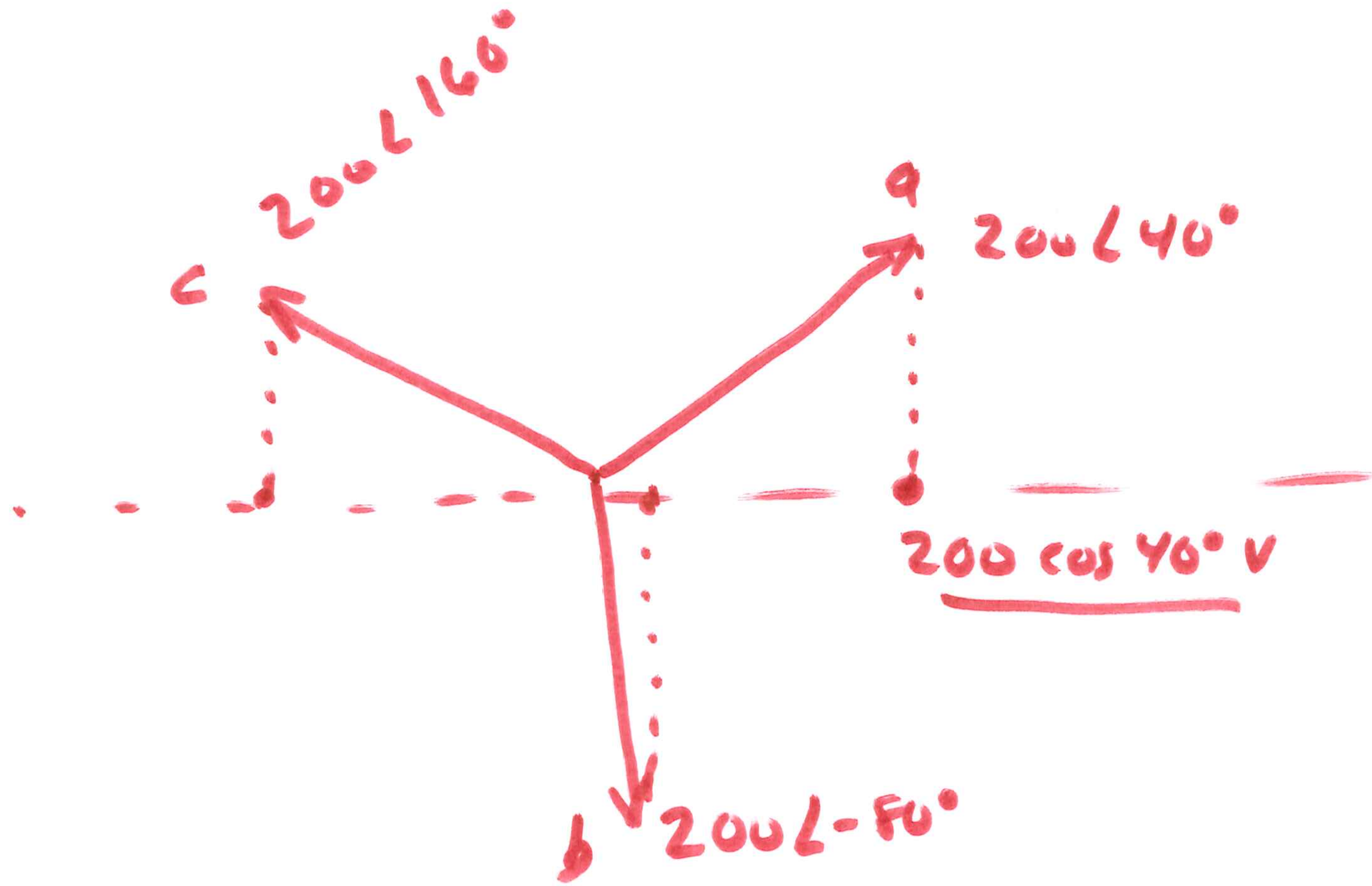
2. Find and plot one cycle of the dc current that accompanies a <u>three-level</u> space vector PWM that yields a vector of ~~0.60~~ 0.50 $V_{dc} \angle 40°$ Volts. The load current is 200 Amps with a power factor of 1.00. A number for V_{dc} is not necessary, but if you want one, make one up and declare it.

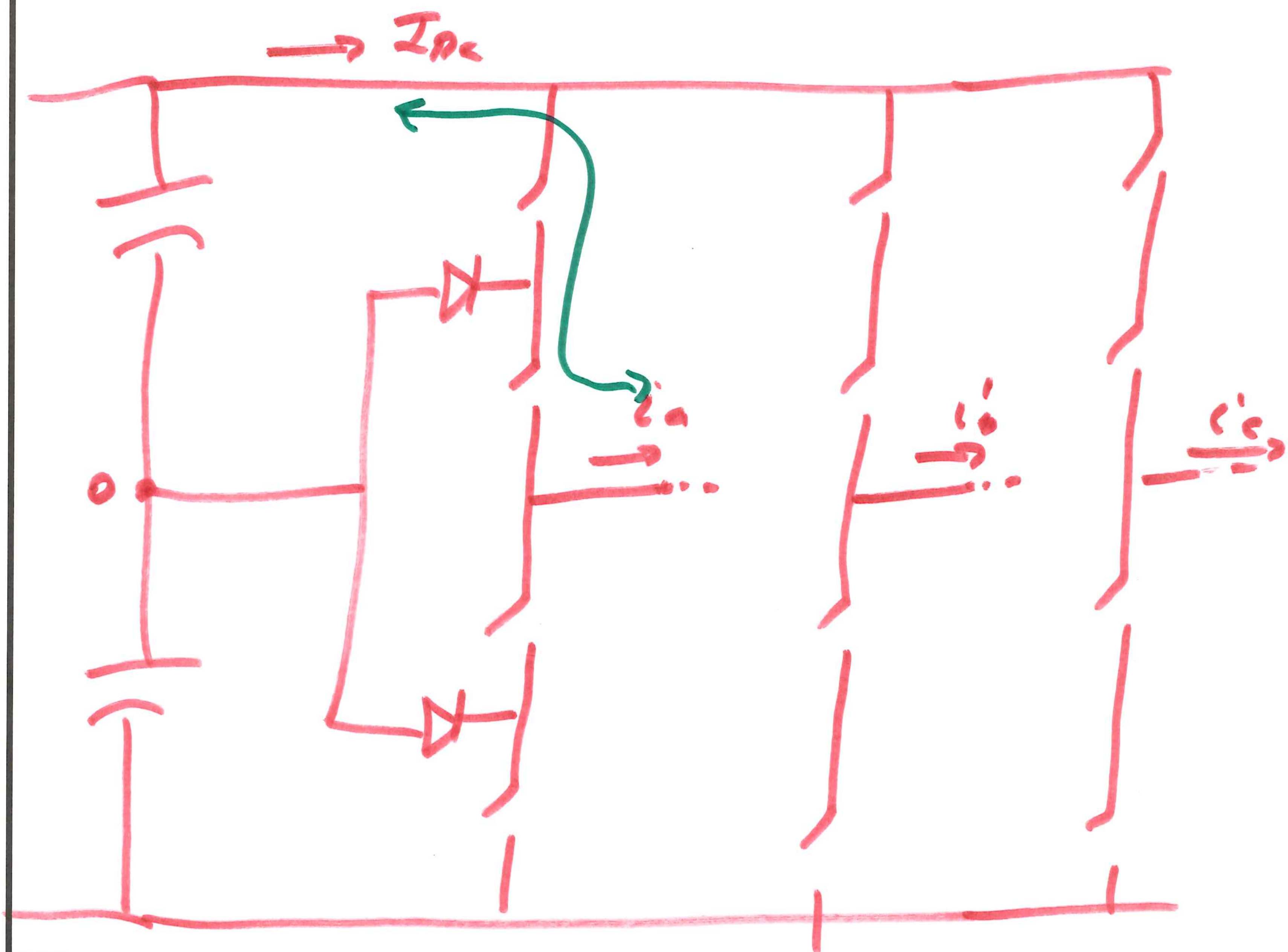
3. For a four-level NPC, apply sine-triangle modulation at a 5kHz:50Hz frequency ratio between triangle and sine wave frequencies. Set the sine wave's amplitude at ¾ of the sum of the applied triangle wave. Let the dc link voltage be 8kV.

   a. Plot the triangle waves superimposed on a three phase sine wave.
   b. Show one (sine) cycle of the resulting pulse width modulation.
   c. Show a harmonic spectrum that reveals at least the first half dozen nonzero voltage harmonics.

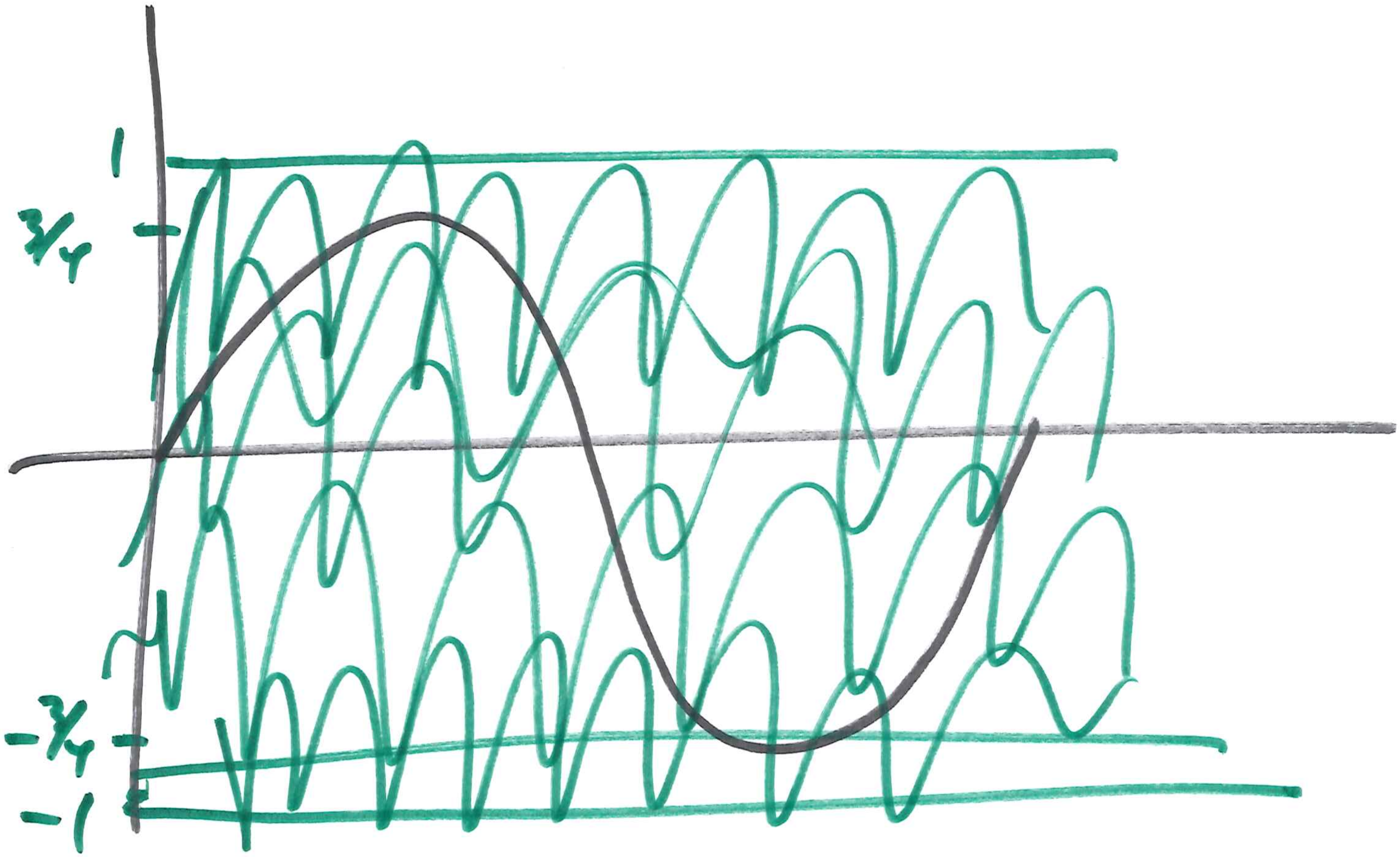
4. For a Multimodal Multilevel Converter (MMC) with four-modules in each leg and balanced capacitor voltages of 2kV for each switch and diode,

   a. Determine the voltage stair step waveform with the ~~same switching losses as the NPC converter of problem 3.~~ 2kV / switch. Use a fundamental output frequency of 50 Hertz.
   b. Identify the fundamental and lowest nonzero harmonic output line-to-neutral voltage, magnitude and frequency. Assume the inductors have no voltage drop.
   c. For a machine load that is modeled as a 50 Hz voltage source of the same amplitude as the fundamental component of the terminal voltage, but lagging three degrees, behind a reactance of 0.35 Ohms at 50 Hz, find the fundamental current and the lowest nonzero current harmonic, magnitude and frequency.


200∠160°
c
a
200∠40°
200 cos 40° V
b
200∠-80°



I_DC
0
i_a
i_b
i_c


1
3/4
-3/4
-1

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$$\frac{V}{freq} = FLUX$$

SATURATION!

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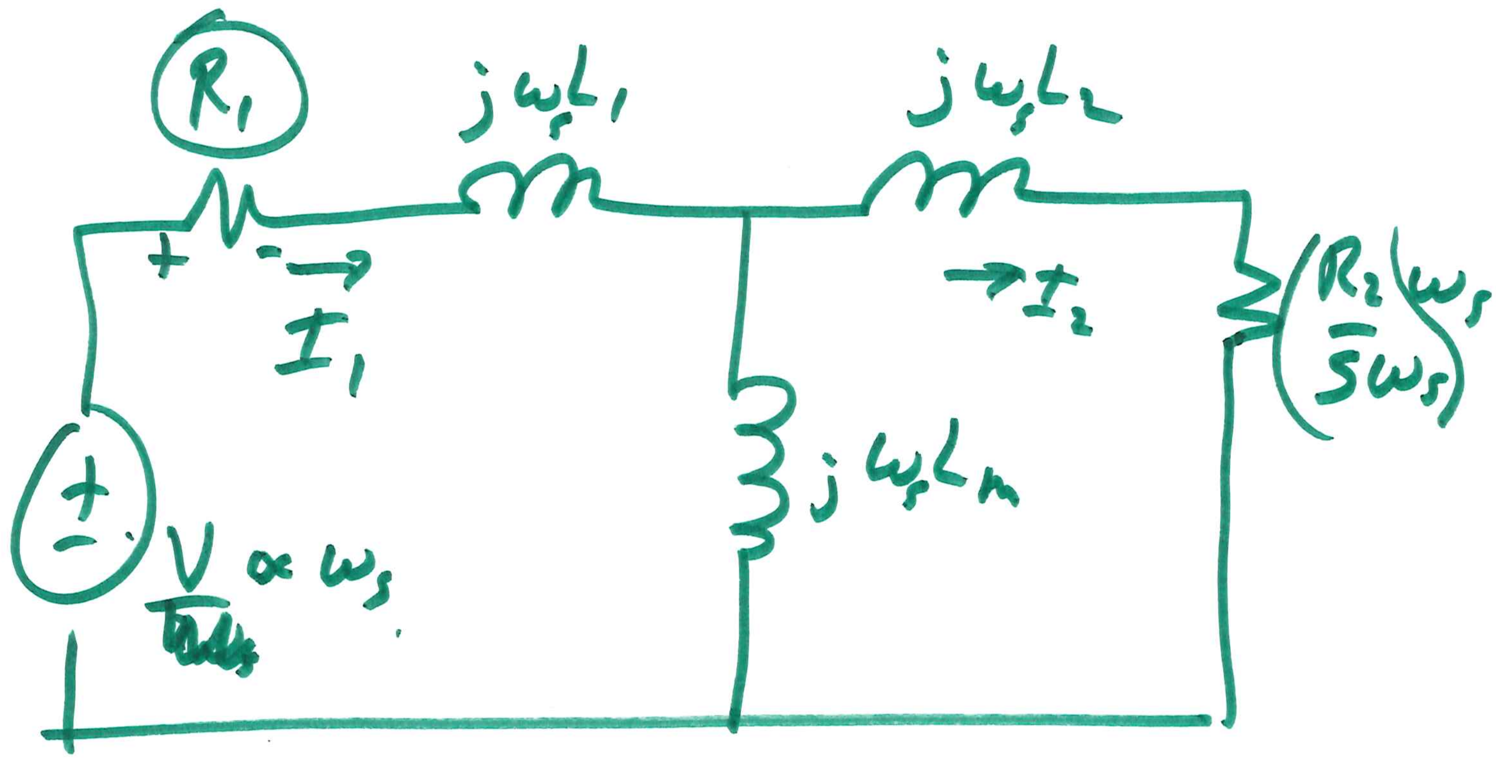

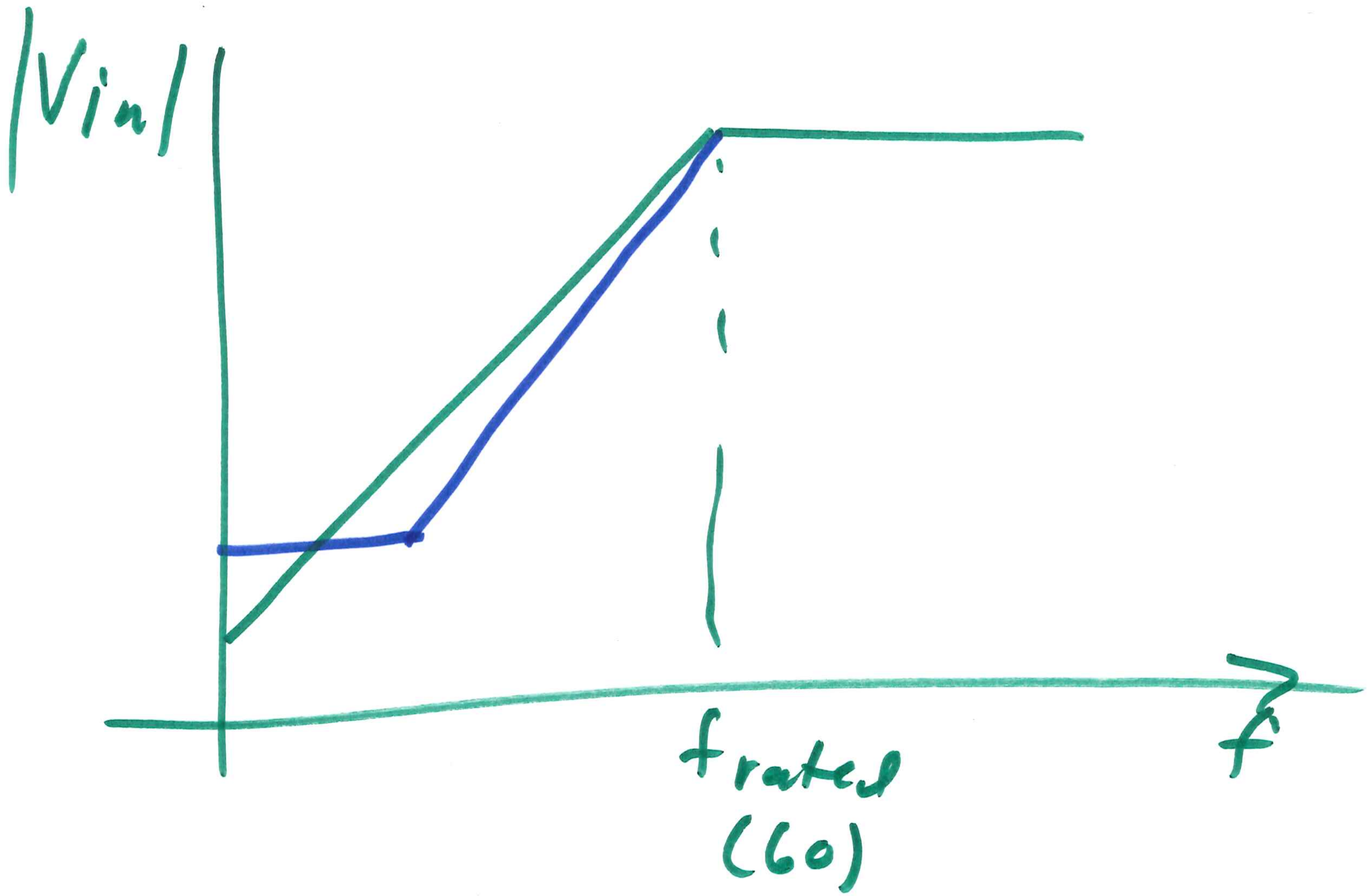
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T & D Applications of Voltage Sourced Converters

Lesson 21

I want to look at the machine and how various influences can affect its behavior. In so doing, I'll find ways to control the machine better.

Wound rotor machine: resistance added to the rotor terminals. The peak torque is unchanged, but the curve gets flattened out.

☺ This allows us to conveniently control the speed.

☺ Immunity to torque pulsations. High slip machines are favored for flywheels.

☹ Less torque at operating point for pump or fan load.

☹ Efficiency degrades quickly. Rotor losses are $|I2|^2 R_2$. The efficiency is NEVER greater than (1-s).

Speed control by varying the frequency

☺ The speed responds nicely to change in synchronous speed (frequency); operation is at the same slip frequency or close to it.

☹ Saturation! It gets worse and worse at lower and lower frequencies. ☹

Voltage control alone…

☹ gives speed control

☹ the loss of torque capability is proportional to voltage squared.

☹ Most machines operate on the edge of saturation.

V/Hz control

☺ I can control the speed nicely… speed follows the synchronous speed (frequency) readily and I can operate at the same slip frequency to get performance.

☹ Conservation of sorrows: Peak torque degrades greatly

at very low speeds. So I add a little "voltage boost" at low speeds.

☺ This affects motor operation. Generator operation is at HIGHER speeds.