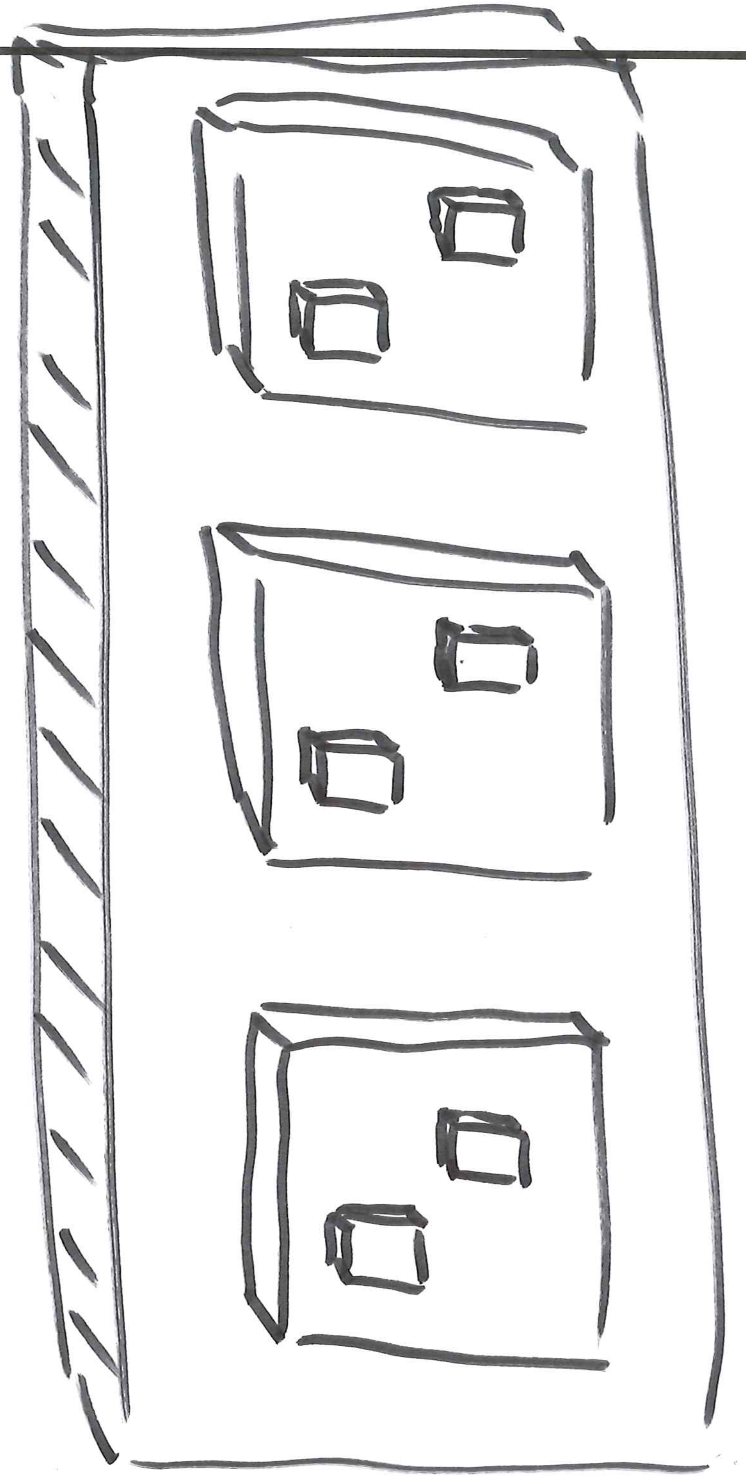
ECE 404-TD / 504-TD

ST: T&D APPLICATIONS OF VOLTAGE SOURCE CONVERTERS

SESSION no. 22



ECE 404 / 504
Transmission and Distribution Protection of Voltage Sourced Converters
Examination #1

INSTRUCTIONS:

A. This is a "take-home" exam. As such, this exam is an open-book, open-notes, open computer, and open-neighbor examination. You may use any appropriate resource.

B. You may make a hardcopy of this exam if you wish, but you need not to submit a hardcopy of the exam problem statements. A copy of your solutions to each of the four problem sets is sufficient.

C. If you write computer code or script language and wish to receive partial credit in the event of a programming error, please include your code or script.

D. The four problem groups are as follows:

1. (25 points) Power poles

    a. (7 points) In this class, we derived the steady state voltage gain (Vo/Vd) for an ideal buck converter as being equal to the duty cycle. Now under similar steady state conditions, derive the voltage gain for an ideal boost converter. The Mohan textbook has an explanation of the boost converter's operation in section 3.6, as well as the correct voltage gain expression. Therefore, your explanation must contain a good description of each step that you follow. Begin by describing the problem and finish by obtaining the correct result with a good explanation.

    b. (12 points) The buck converter having a switching power pole, as described in Figure 1.24 of the Mohan textbook, has an input voltage of 48 Volts dc and a duty cycle of 0.35. Its inductance is 6.2 μH and its capacitance is large enough to ensure negligible voltage ripple on the 5.1-Ohm load resistance. If the diode has a forward voltage drop of 0.7 Volts and the transistor has an on-resistance of 0.075 Ohms, determine the output voltage and the conduction losses.

    c. (6 points) What advantages can we gain by using a Schottky diode instead of an ordinary fast diode in a buck converter?

2. (25 points) Heat sinking and switching losses

    a. (10 points) In many heat sinking designs, multiple devices are placed into a single package or on a large heat sink. Such is the case shown below. The package contains a transistor and a diode. Three identical packages fit onto the same heat sink. Each transistor dissipates 14.0 Watts and each diode dissipates 8.8 Watts. Thermal resistances are given below:

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	Transistor	Diode
Junction to Case	Rjc=0.55°C/W	Rjc=0.42°C/W
Case to Package	Rcp=0.75°C/W	Rcp=0.58°C/W
Package to Heat Sink	Rps=0.40°C/W	Rps=0.37°C/W

Allow all semiconductor junctions to go no higher in temperature than 150°C for a 25°C ambient. Design the heat sink to ambient thermal resistance.

b. (7 points) The current in a certain switching transistor is 4.0 Amps DC when conducting. Its voltage is 300 Volts when blocking. For its current, the turn-on time (for the current) is 80ns and the turn-off time is 240ns. For its voltage, the turn-on and turn-off times are both 35ns. Determine its switching power losses at a switching frequency of 100kHz.

c. (8 points) Although reverse recovery is a diode behavior, it seems that the power losses that reverse recovery creates in a buck converter appear mostly on the transistor. Using appropriate waveforms, explain how this happens.

3. (25 points) Pulse Width Modulation

   a. (15 points) For a two-level, six-switch Voltage Sourced Converter (VSC), determine and plot the pulse width modulated voltage provided to the load using sine-triangle modulation. Show appropriate diagrams and calculations to prove that your output is indeed as requested: The dc link voltage is 600V. The switching frequency is 5kHz. The output ac voltage amplitude is 240V AC. The fundamental frequency of the load is 50Hz.
   rms

   b. (10 points) Why do we use pulse width modulation? What advantages does it give us?

4. (25 points) Multilevel Converter

   a. (15 points) At a given point in time, a certain three-level NPC converter has a dc link voltage of 2.5kV, split equally at 1250V across each of its dc link capacitors. Using the neutral point between the capacitors as a zero voltage reference point, we find that in the load at the same point in time, phase a has 1250V, phase b has zero Volts, and phase c has -1250V. The current is split so that phase a has 591A, phase b has -205A, and phase c has -386A. The rectifier provides 400A DC. Each capacitor is a bank totalling 40,000µF. Find the dc link capacitor voltages after 1 ms of this condition.

   b. (10 points) Why is the switching frequency of a large multilevel converter, NPC or MMC, rated at many kilovolts AC output, generally maintained somewhat lower than the switching frequency of a two-level variable speed drive rated at a somewhat lower voltage, perhaps just a few hundred volts AC output?

$$\omega_s = \omega_m + \omega_{sl}$$

$$\underset{elec}{\boxed{\omega_s}} = \omega_{\substack{mech \\ \cancel{rotor}}} + \underset{elec}{\boxed{\omega_{slip}}}$$

ECE 404 / 504

T & D Applications of Voltage Sourced Converters

Lesson 22

Exam 1 due date:

Friday (Lesson 24)

EO: Monday 11 March

ECE 527

Machines that have two set of terminals:

Field: DC

Armature: AC 3 phase

Synchronous machine

Two magnetic fields which lock into each other to provide torque.

From the rotor perspective:

Two magnets, stationary, that are separated by a torque angle.

Is it possible to do this stationary for real?

DC machine

Brushless dc machine? A synchronous machine switched. Inside out of a common dc machine.

Can we have a machine with three phase windings on both stator and rotor? And run it as an induction machine? Or perhaps an asynchronous machine?

The poles…must be in phase.

Different frequencies…variable speed asynchronous motor…or generator. Doubly fed induction motor. The difference between the two frequencies is the rotation speed.

We get generation for a wide range of rotor frequency (and speed), both above and below synchronous frequency.