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Lab 7: Rectifiers & Freewheeling Diodes

Pre Lab

Single-phase rectifiers (AC/DC converters):

PM generator wind turbines work by rectifying the output of the generator, then inverting it back at 60 Hz. Today we'll just look at the rectification part, which is the simpler of the two. Enjoy.

1. Draw the schematic for a full-bridge passive peak rectifier.

2. Draw the input and output waveforms for a full-bridge rectifier as well as for a full-bridge peak rectifier if the input is a pure 60 Hz, $120V_{rms}$ sine wave.

3. Write down the equation for the ripple voltage in terms of input voltage in a **full-bridge** peak rectifier with a resistive load. No need to derive it, just look it up if you can. What big assumption does this equation make?

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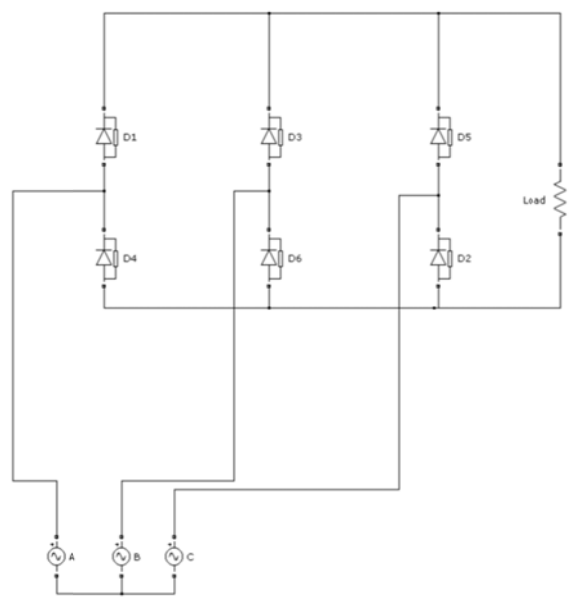
3-phase rectifiers

Following is the schematic for a 3-phase full wave rectifier (disregard the little rectangles next to the diodes):



Circuit 1 3-phase bridge rectifier

For a 3-phase rectifier, the pair of diodes connected between the highest-**magnitude** line-to-line voltage at any given instant conduct. For example, when $|V_{ca}| > |V_{ab}| > |V_{bc}|$ and V_{ca} is positive, D5 & D4 conduct. When $|V_{ca}| > |V_{ab}| > |V_{bc}|$, and V_{ca} is negative, D1 & D2 conduct. Here's one way to think about its operation: the top row of diodes corresponds to "high" line-to-neutral voltages and the bottom row corresponds to "low" line-to-neutral voltages. When $V_{ca} > V_{ab} > V_{bc}$, we know that the outside "columns" of diodes are the possibilities, since they are the ones connected to V_a and V_c. Then, in order for V_{ca} to be positive, V_{cn} must be higher than V_{an}, so the "high" diode connected to phase C (D5) and the "low" diode connected to phase A (D4) will conduct.

1. Which diodes will conduct if $|V_{bc}| > |V_{ab}| > |V_{ca}|$ and V_{bc} is negative?

2. On the bottom axis provided, plot the output voltage as a function of time. Label which diodes conduct for each time interval.

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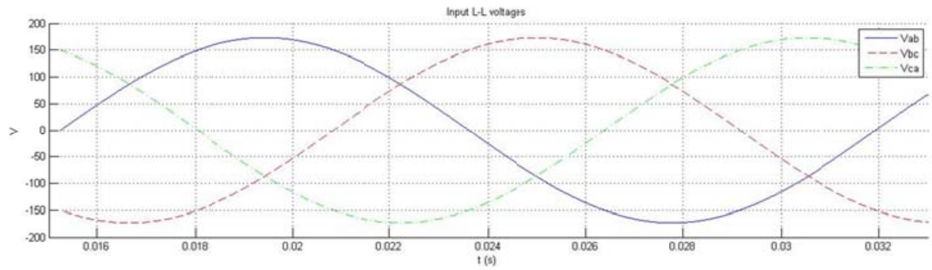

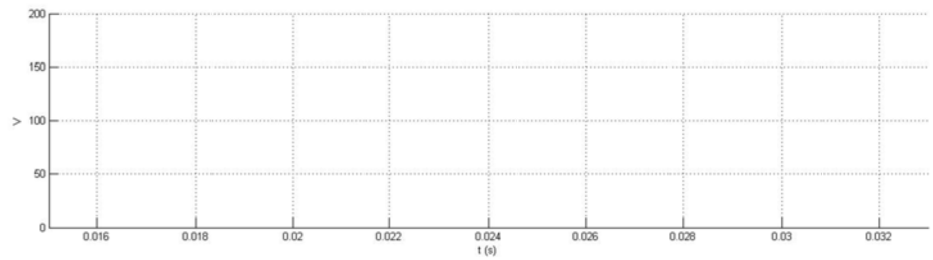

Freewheeling Diodes

1. Briefly explain what freewheeling diodes are and why they're important. Don't just copy what's on Wikipedia either; your lab instructor already knows that Wikipedia says. A picture can be helpful here but is not enough by itself.

Lab Exercises

Rectification for PM Generators

As mentioned in the pre lab, rectification is the first step towards making a PM wind turbine generator grid-connectable. Let's pretend, like we did last week, that the synchronous machines in the lab are the permanent magnet variety.

1. Design and implement a single-phase full-wave rectifier (not a peak rectifier) for one phase of a synchronous machine. With full excitation, make the generator produce 140 $V_{LL,rms}$ with no load attached. Don't use any of the bridge rectifiers that are already assembled. Once the generator

is producing the correct voltage, attach a 200 Ω resistor as a load. Include a screenshot of the input and output voltage waveforms.

2. How much ripple is present in the output voltage?

3. What's the average (DC) output voltage?

4. Design and implement a 3-phase rectifier for the same synchronous machine setup and load. Don't use three single-phase rectifiers. Include a screenshot of the output voltage waveform and one input L-L voltage.

5. How much ripple is present in the output voltage?

6. What's the average (DC) output voltage?

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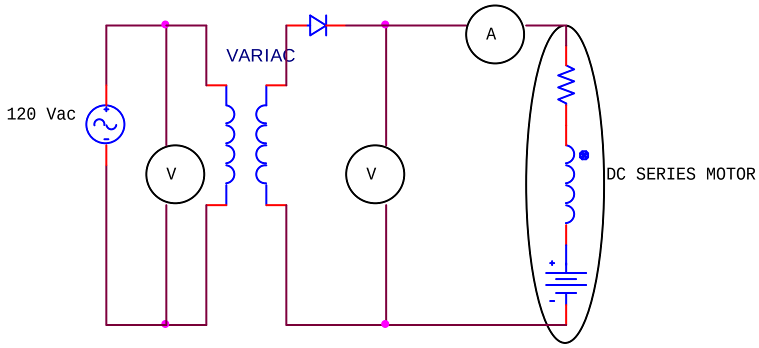
7. If you were designing a wind turbine generator whose output was to be rectified and then inverted, would you choose a single-phase or a 3-phase generator and why?

8. Comment on the shape of the input voltage waveform.

Freewheeling Diodes

1. Set up a series DC motor and a 3-phase induction machine on a mounting plate. Couple them together with a timing belt. Don't connect the induction machine to power; it's just there to act as a light load.
2. Connect the following circuit: Use a variac as the transformer and the DAC for the meters.



3. Set up the LVDAC-EMS scope to monitor both voltages and the current simultaneously.
4. Starting with the variac at 0, turn it on and turn it up until the AC voltage is 115 V_{rms}. Don't leave it running for very long. Note: don't trust either the marking on the variac dial or the meter on the variac. Use the scope or a meter to read the voltage.
5. Is the DC machine spinning?

6. Include a screenshot from the scope with all of your measured quantities displayed simultaneously. Discuss what you see.

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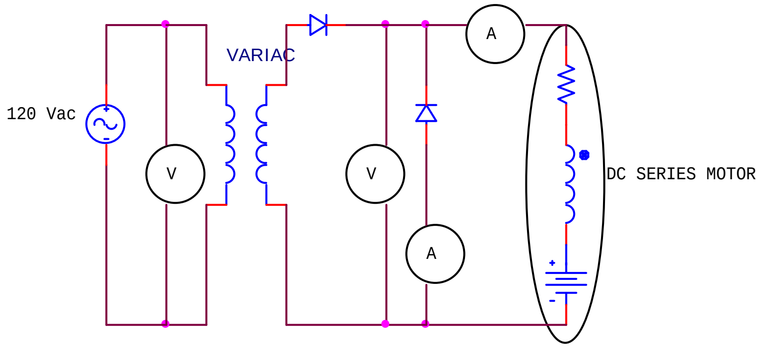
7. Now connect this circuit, which includes a freewheeling diode:



8. Repeat steps 5-7

Real-World Problem:

The Air Breeze wind turbine that's coupled to the LabVolt motor is designed to charge batteries. It's internal battery charge controller works by comparing the voltage of the battery bank with the turbine's output voltage. If it doesn't see at least 21 V across the batteries, the turbine thinks it's open-circuited and it won't produce any power. Air Breeze turbines are small and light, and can work at low wind speeds, and our department has one on the roof of Rathbone. Since batteries take maintenance, we didn't really want them on our roof.

The obvious solution is something like you did in the previous lab when you found the power curve of the Air Breeze. The problem with that is there's not a nice DC power supply on the roof. However, there is 120Vac on the roof.

1. Starting with 120Vac from the grid, design and implement a solution that "fools" the Air Breeze into thinking it's connected to batteries.

   DO NOT CONNECT THE TURBINE DIRECTLY TO THE GRID; IT MAKES DC POWER! Don't try to make the turbine output more than 30 V_{dc}, and don't spin it faster than 650 rpm. For our purposes, assume the output of the Air Breeze looks like a 945 uF capacitor. Be sure your solution includes somewhere for the power generated by the Air Breeze to dissipate. Demonstrate your working solution on the Air Breeze to your lab instructor. Note that the Air Breeze is designed to rotate clockwise as you look at the front of it.