University of Washington
Department of Electrical Engineering
EE 351: Energy Systems

Lab 2: Power Electronics and Photovoltaic

IMPORTANT: Do not look directly at the bright spotlight (Sunglasses are recommended)
Do not stand between the spotlight and the solar panel
Do not touch the spotlight frame, it is usually very hot.
Do not touch the stand of the spotlight, it can tip over.

Introduction

For this lab we will use two very bright halogen spotlights to simulate solar rays and generate electricity from photovoltaic panels. The light intensity of the spotlights is controlled by using ac/ac converter consisting of two SCRs in the back-to-back configuration in Figure 1. We will explore the relationship between SCR firing angle and light intensity as well as the relationship between light intensity and power output of the photovoltaic panels.

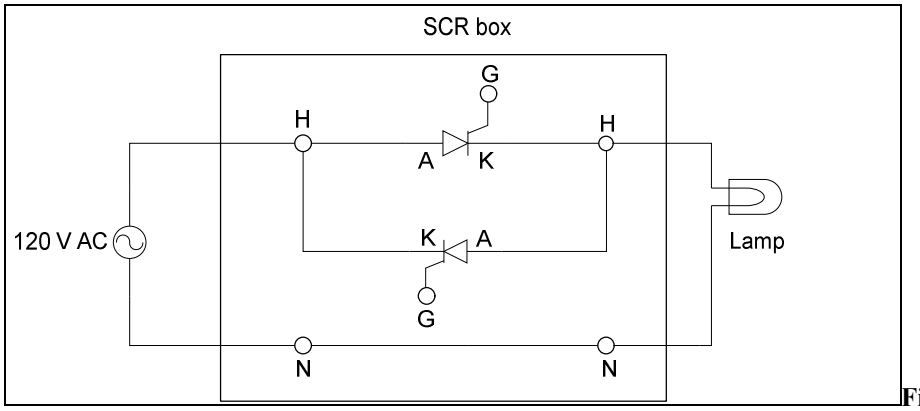

Figure 1: AC/AC back-to-back SCR dimmer circuit used to control lamp.

Safety Notes

1. The halogen light bulbs are very bright at maximum intensity. Do not look at them directly or they could cause eye damage. Use the baffles to shield your eyes at all time.
2. The spotlight lamps can be very hot. Do not touch any of the metal parts of the lamp assembly.
3. Do not stand between the spotlight and the solar panel
4. Do not touch the spotlight stand, it can tip over.

5. Again, we will be working with high voltages and currents. Do not turn on the power to your circuit until the TA has checked your circuit and told you to proceed.
6. Do not use ground leads on the oscilloscope probes. Doing so could short 120 V to ground through a very small wire causing damage to the wires and equipment and possible fire.
7. Follow start-up and shut-down procedure carefully to prevent electric shock or fire hazard.

Part A: AC/AC Converter as Light Dimmer

In this experiment, you will be using a single phase, full wave SCR circuit as a light dimmer. The circuit uses two SCRs (Silicon-Controlled Rectifiers, SCRs) in the back-to-back configuration as shown in Figure 1. To trigger the SCRs, use the triggering box provided in the lab. The terminals of this box are shown in Figure 2. The input to the box is a reference signal, and the outputs are triggering pulses at adjustable angles.

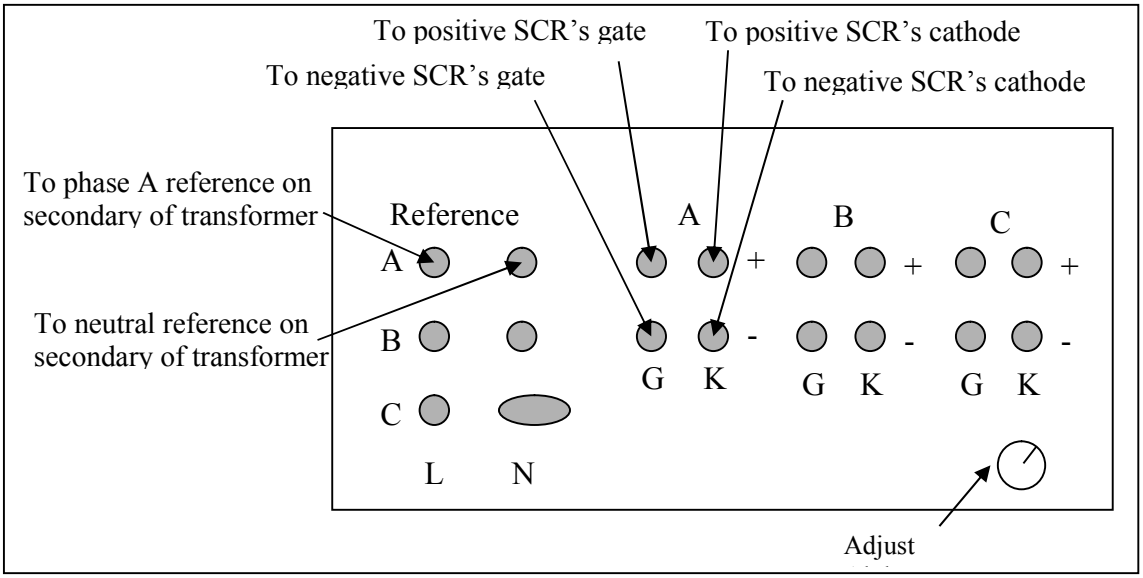

Figure 2: General purpose triggering box

Because the lamps require a large amount of power to generate enough light to illuminate the PV cells you will construct two ac/ac converters; one for each lamp.

Requirements: Observe the voltage and current waveforms across the spotlight. Assume that the light intensity is proportional to the square of the voltage; find the relationship between the light intensity and the triggering angle.

Start-up Procedure

1. Make sure that SCR controller box and SCR box (ac/ac converter) are unplugged.

2. Make sure that the switches of the two flood lights are in the OFF positions.

3. Connect the SCR controller to the SCR box. You will use the same SCR controller box to control both converters.

4. The spotlight lamp uses about 15 amps at full intensity. Keep in mind that the breakers of the outlets in the room trip at 20 A. So you will need to distribute the load accordingly.

5. **You will use an oscilloscope to observe the voltage waveforms but DO NOT USE THE GROUND LEAD ON THE SCOPE PROBE. If the ground lead is connected incorrectly the lead could act as a short to ground, generating much heat, possibly causing a fire in the lab.**

6. **Have your TA check your circuit before proceeding.**

7. Plug in the two SCR boxes to the power outlet in order to power up the lamps.

8. Use the oscilloscopes to save current and voltage waveforms for firing angles from 0º to 180º. (Note that the intensity of the light given off from the lights is proportional to the square of the voltage supplied to the lamp and the intensity of the light incident on the solar panels is proportional to the power output of the solar panels). Compute the RMS voltage for each alpha.

Part B: Solar Panel

Connect the output of the solar panels to the load box as shown in Figure 3. You will use the switches in the load box to add or subtract loads while performing the experiment.

Requirements:

1. Find the relationship between the light intensity and the output power of the PV panel.
2. Find the relationship between the load current of the PV panel and the load voltage
3. Find the relationship between the output load power of the PV panel and the load current.
4. Measure the following:
   - The open circuit voltage
   - The short circuit current
   - The maximum power, and the voltage and current at maximum power
   - The resistance of at least one of the loads (fan, light, or resistor).

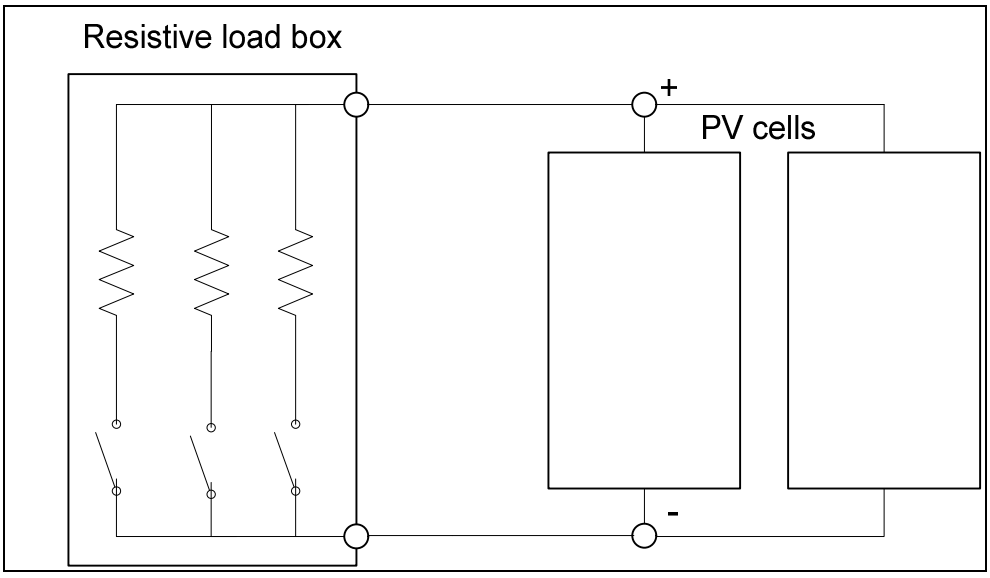

Figure 3: PV circuit to supply resistive loads.

Start-up Procedure

1. Make sure that SCR controller box and SCR box are unplugged.

2. Construct the PV circuit as shown in figure 3. Make sure to measure the appropriate currents and voltages in the circuit needed to achieve the requirements of the experiment. **You will use an oscilloscope to observe the voltage waveforms but DO NOT USE THE GROUND LEAD ON THE SCOPE PROBE. If the ground lead is connected incorrectly the lead could act as a short to ground, dropping a large voltage over a small resistance, generating much heat, possibly causing a fire in the lab.**

3. The spotlight lamp uses about 15 amps at full intensity. Keep in mind that the breakers of the outlets in the room trip at 20 A. So you will need to distribute the load accordingly.

4. **Have your TA check your circuit before proceeding.**

5. Plug in the two SCR boxes to the power outlet in order to power up the lamps.

6. Use the oscilloscopes to save current and voltage waveforms for firing angles from 0º to 180º. (Note that the intensity of the light given off from the lights is proportional to the square of the voltage supplied to the lamp and the intensity of the light incident on the solar panels is proportional to the power output of the solar panels). Use the peak voltage and alpha angle to compute the RMS voltage for each alpha.

7. Using the SCR controller explore the power output of the PV cells using different loading levels and different firing angles.

Shut-down Procedure

1. Turn off bench Main AC Breaker.

2. Unplug **BOTH** SCR boxes from outlets to ensure that no wires are live when you begin disconnecting them.

3. Now that power is turned off to your circuit you may unplug connector wires and place them neatly on the hanger at the end of the bench.

4. Unplug SCR controller box from outlet.

Discussion:

Make a graph of PV cell power output as a function of SCR firing angle as well as a graph of load vs. power for the maximum intensity of light from the lamps.

With maximum intensity of light, at what loading level do you begin to observe voltage sag on the system? What is the reason for the voltage sag as the loading level of the PV cells increases?

What is the maximum power of the solar panel at the maximum light intensity?

How efficient is the system you have constructed at converting electrical power (from the 120V wall outlets) to electrical power (from the PV panels)? Assuming that 5% of the electrical power is converted to "solar power" by the lamps, how efficient is the system you have constructed at converting "solar power" to electrical power?