ESCI-61 Final Project Guidelines

IMPORTANT: there is no exact list of steps that one must follow to design a PV system. The steps described below are the most common ones used to design a grid tied PV system with no backup. Many of the steps to design and size a PV system can be done in a slightly different order; the following is just an example. Some of the steps must be repeated multiple times before you find the optimal answer.

In the following, we are assuming the following:

- You want to design and size a grid tied PV system (as opposed to standalone or bimodal PV systems), so there are no batteries
- You want to use flat plate collectors (as opposed to concentrating collectors)
- You will install the modules at fixed tilt (as opposed to 1- or 2-Axis tracking system).
- You want to optimize the average annual energy, as recommended by California Solar Initiative rebate program

Step 1: Energy Audit

Look at your electricity bills of at least the last 12 months, 24 months is better; and determine the average number of KWh of electricity that you use per year; this is usually available online from the utility website.

Try to identify where and how electricity is being used; from the electricity bills, you can see if there are abnormal usages.

The audit should identify which appliances consume more electricity than others, which appliances are old enough to be replaced in the near future. If some appliances are consuming too much electricity, do not wait until they break to replace them. For example, don't wait for light bulbs to break before you replace them with CFLs. From the energy audit you can also determine what you can do to reduce your electricity bill.

After factoring all the above from the energy audit, you can determine if your electricity usage is going to decrease or increase in the near future. Experience tells that some people could cut in half their electricity usage after upgrading their appliances, light bulbs, …, etc. This is very common.

Try to get an idea how much of your electricity do you want to generate from a PV system. You can first assume that you want to generate 100% of your electricity and restart the process if you realize later on that the PV system is too big to fit on your roof or too expensive to fit tin your budget.

At the end of this step, you know the average number of KWh per day, per month and per year that your PV systems must generate.

Step 2: Site Survey

Determine the location of the PV array, measure roof space, determine orientation, roof slope. Use shading measurement tools, like PathFinder or SunEye, to determine the exact shading of your location. The survey also determines roof conditions: if your roof is very old, you might need to consult with a roofing expert to see if it would support the PV modules. You will also determine if you need a special mounting system, if flat on the roof does not give your PV system a good orientation and tilt angle.

At the end of this step, you have an idea if your site is good or not for a PV system. You might realize that orientation is too far away from due South, or that your roof is too shaded, or that you do not have enough roof space, or that your roof space is composed of multiple small areas and therefore is more adequate for multiple-inverter or micro-inverter options, …, etc.

In the following, we assume that site survey conclusions are in favor of a single-array, or at most two-array PV system. If you think two arrays are more convenient for your site, you need to decide if you want a single inverter that supports two Maximum Power Point Tracking (MPPT) feature, or if you prefer a design with two inverters.

Step 3: Size You PV System

Use an online tool like PVWatts (www.pvwatt.com) to determine the size of your PV System. Version 1 should be sufficient at this step, but you can fine tune your design by using Version 2, which allows you to select your exact location. You might need multiple iterations to determine the size of your system because, counter-intuitively, PVWatts starts with the DC Rating of the system and not AC Rating, so you need to determine the DC size of the PV system that generates the annual energy you need, taking into account tilt, azimuth and all other de-rating factors. Notice that some de-rating factors depend on which inverter and which modules you use, because inverters' efficiencies and modules' power tolerances vary per vendor.

At the end of this step, you know the DC Rating of your PV system; this is the DC power (W_{DC}) of the PV system under Standard Test Conditions (STC).

Step 4: Shop for Modules and Inverter

Now that you know the DC Rating of your system, you can start shopping. This is an iterative process because you may choose a module type that will not fit nicely with the inverter when you start sizing. For the inverter, start trying with the one which size is immediately above your DC rating. For the modules, there are multiple options based on your preference for efficiency, cost, color, manufacturer, brand, …, etc.

The important thing to do is that every time you select a PV module or an iverter, you need to check if they are in the CEC certified equipment list, other wise, you will not qualify for the CSI rebate; these information are found at the following website www.gosolarcalifornia.ca.gov/equipment.

Make sure you don't choose a 3-phase inverter that's more destined for commercial and industrial use. It is recommended to short list multiple inverters and multiple modules because your first choice might not be the right one.

You may need multiple iterations of Step 4, Step 5 and Step 6 until you find the right combination of modules and inverter.

Step 5: String Sizing

You can either do this work manually or use an online tool; most inverters' vendors have a web sizing tool on their website. Before using their tool, determine weather condition of your location; you can get these info for example from www.weather.com. Weather conditions are important because record low temperature will determine the highest Voc of the array, and therefore the maximum number of modules per string not to exceed the inverter's max input voltage; average high temperature will determine the lowest Voc and therefore the minimum number of modules per string so that the inverter can still perform Maximum Power Point Tracking.

Use NEC book 2008 to determine temperature correction factors for your location.

These sizing tools may suggest array sizes that do not match exactly your needs so you may need to run multiple iterations by using a different inverter or different modules until you hit your optimal size. If there's no web sizing tool, you'll need to do all this work manually, by taking into account vendors' specs. The main important parameters to take into account for manual sizing are the highest Voc of the array including temperature correction, the inverter's maximum input current and maximum input voltage, the inverter's MPPT voltage range

Also, don't forget to take into account the roof area needed for your PV system: you may need to use more efficient modules to reduce roof space.

At the end of this step, you know exactly what inverter, what modules and how many you're using, and how you array is designed (number of strings x number of modules per string)

Step 6: Finances

You can now use the CSI calculator to finalize your design and calculate your rebate (www.csi-epbb.com); don't forget about PBI option, it may be more interesting on the long term; you can also estimate the Federal Investment Tax Credit and the overall net cost of your system.

You may want to use online tools for financial analysis like https://tools.cleanpowerfinance.com/ or http://www.ongrid.net. Websites like www.findsolar.com have simple calculators that can give you a very rough approximation of the net cost of your system.

Step 7: Decision

This is where you need to answer questions like:

- Is this PV system OK for you?
- Is it a good investment for you?
- Can you afford it?
- Do you want to reduce the size and restart the process from Step 4
- Are you going to install it yourself or look for an installer? If you're going to do it yourself, you need to shop for the other system components, aka BOS (mounting system, wires, disconnects, …, etc.)

Good luck and enjoy the "free" electricity from your PV system!