ET3034TUx - 8.1 - Standalone PV systems

Welcome back to the last week of this course.

In week 7 you saw the various PV system components and their characteristics.

Now, we will see how these components come together and make up a PV system.

In doing so, we will not only look at the characteristics of these PV systems, but also look at some of their basic design rules.

We will first start with the stand-alone PV system.

It is also called the off-grid PV system, simply because it functions independent of the electric grid.

As discussed before, the stand-alone PV system has these important PV system components.

The PV array is an interconnection of modules that supplies the required photogenerated power to the system.

The power rating of the array is determined based on the load requirements.

The battery bank is the lifeline of the stand-alone PV system, as it greatly increases the usability of the PV system.

Without the battery, the system would be unable to meet the load demands outside the available daylight.

As discussed last week, the charge controller is singlehandedly responsible for ensuring the smooth functioning of the battery.

Given the complexity of the functioning of a battery, the use of a good charge controller can increase the lifetime of the battery manifold.

This is more than welcome, as the battery is often the biggest bottleneck in a stand-alone PV system's lifetime.

The stand-alone inverter has to be responsible for efficient power conversion from DC to AC power over a wide range of the loads.

The better the inverter, the higher the efficiency over a variety of loads.

Together, the charge controller, battery, inverter, distribution panels and the wiring make up the balance of system.

In general, everything in the PV system minus the PV array constitutes the balance of system, or BOS.

The system could be connected to both DC and AC loads.

Of course, the DC loads would be powered by the DC power before the inversion stage.

Now let us look at the features of such a PV system.

If such a system is used to feed loads that are powered on at different parts of the day, how will the system cope with such a power demand?

What happens when the PV array is producing more power than the load demand?

Let us understand this using a simple animation.

On a normal day with the sun out, the PV modules on top of this rooftop are busy converting the incoming irradiance into photogenerated power.

The battery is constantly being charged or discharged through the charge controller, depending on the difference between PV supply and load demand.

The off-grid or stand-alone inverter is continuously converting the DC power to AC and supplying this AC power to the loads.

The system is designed and sized such that during the day with the sun shining, the system generates enough power to at least meet the load demand for the rest of the day.

Therefore, the PV system acts such that the battery is net charged over the day.

After daylight, the rest of the power demand is fulfilled by the battery.

Now you might be thinking what happens if it's not a sunny day, or even worse, there is a string of dark days, like in many parts of the world.

In such a case, if you have to meet the load demand, then there is no option but to oversize the battery so that the expected days of autonomy can be dealt with.

Now, let's go on to the more interesting aspect of designing an off-grid system for a house in a remote location.

We shall look at the designing and sizing of a PV system, based on the load demands and the available components.

Let's go to this example.

I will introduce you to a simple flowchart that helps to design an off-grid PV system.

We will walk through all the stages of this flowchart while considering an example.

Let us first define the load demand that has to be powered with an off-grid PV system.

The total days of autonomy required should also be specified.

Consider a house that is to be powered independent of the electric grid by means of a stand-alone PV system.

Let's assume that 3 simple kinds of loads are required to be powered: light, TV and desktop computer.

The lights are supposed to be DC powered, while the TV and the desktop computer are AC powered.

The required quantities of each kind of load, along with their duration of usage are also mentioned.

The total power and energy requirements have been tabulated here as well.

Both the DC loads and the AC loads require a total energy of 300 Wh each per day.

It is required that the system enjoys a total autonomy of 2 days, that is, a fully charged battery should be able to feed the load when there are 2 days without solar power.

Now we must account for the various losses in the system.

In doing so, we want to estimate the minimum power that the PV array is expected to deliver.

Here we have the various efficiencies of the system components mentioned.

The inverter is supposed to have an efficiency of 90%, while the combined efficiency of the charge controller, battery and cables is 85%.

First we have the DC and AC load energy required.

Now, we must transpose these energy needs to the input of the inverter.

The DC load energy remains unchanged, while the AC load energy is changed into the equivalent DC load energy based on the inverter efficiency as shown.

Now these equivalent load energies should be transposed again, to the output of the PV array.

This is so that we can get the actual amount of PV energy expected by the system per day.

Again, we arrive at this total energy need by using the combined efficiency of charge controller, battery and the cables as shown.

This is calculated to be 745 Wh.

Thus, the PV array on a regular day should be able to supply 745 Wh of photogenerated energy.

The next thing we have to consider is the equivalent sun hours.

This will of course depend on the irradiance that the chosen location enjoys.

In this example, suppose that the place is in a location within India, and that the place enjoys an average of 4.5 equivalent sun hours.

Knowing the load demanded at the PV output, and the equivalent sun hours, we must now estimate the rated PV power required in the PV system.

We have been given a particular type of PV panel that has the electrical parameters as shown.

The panel is rated at 100 Wp.

Assuming that the panel would be operated at its MPP, we can find out the required number of panels as follows.

We can first calculate the amount of minimum PV power required by dividing the total energy demand at the PV output with the equivalent sun hours.

This gives us a power of 165.6 W.

Also, the number of panels could be calculated as shown, which in this case is found to be 2, as the number of panels would always be the upper approximation to a whole number.

Now let us look at the possible PV configurations.

The maximum allowable current and voltage rating can be found by assuming these scenarios.

If the 2 panels are connected in parallel, then a maximum current of 2*Isc is possible, which in this case is 14 A.

On the other hand, if the 2 panels are connected in series, then a maximum voltage of 2*Voc is possible, which will equal 40 V.

Now let's look at the specifications of an available charge controller.

In this case, we need to ensure that the charge controller parameters would conform with the maximum parameters found in the different PV configurations.

The operational voltage is the battery voltage that is supported by the controller.

It is also the voltage at which the DC side of the PV system would operate; in other words, the DC loads would be operated at this voltage.

Thus the nominal operating DC voltage of the system is dictated by the load rating as well as the battery bank.

In this case it is given as 24 V.

This is not to be confused with the maximum voltage, which simply specifies the amount of maximum voltage as provided by the PV output that the charge controller can handle at the input.

We see that the maximum allowable voltage is greater than the series limit of the 2 panels of 40 V, while the maximum current doesn't support the parallel configuration current of 14A.

So we select the series configuration of the panels.

In general, given a choice between series and parallel, series configuration is preferred to keep the current levels down, thereby minimizing the DC cable loss.

Now let's move onto the battery design.

The battery size is greatly affected by the days of autonomous operation expected from the system.

A single battery is given with the specifications as shown.

The depth of discharge or the DOD is the depth until which the battery can be effectively used.

We must now choose how the battery bank must be configured.

That is, how many batteries of the given specification should be there in the battery bank, and how should they be interconnected?

The minimum battery capacity can be derived as follows.

Based on the operational voltage, depth of discharge, and energy demand, the battery capacity can be sized as follows.

Note that the days of autonomy, and the system losses tend to increase the battery bank size.

Also, note that the lower the battery DOD, the higher the battery bank capacity requirement.

On the other hand, the higher the battery DOD, the battery can be discharged more, and therefore, lower the battery bank capacity needed.

So this gives us a minimum battery capacity of 103.5 Ah.

Now this brings us to the number of batteries required.

An operational voltage of 24 V requires 2 batteries of 12 V each in series, whereas a battery capacity of 103.5 Ah requires 5 batteries in parallel.

Therefore, a total of 10 batteries are required to create the battery bank for the PV system.

Lastly, we come to the inverter sizing.

Based on the efficiency of the inverter, the power rating of the inverter needs to be calculated.

An inverter is available with an efficiency of 90%, and operational voltage of 24 V.

What should be the minimum nominal power rating of this inverter?

We know that the power demand of the AC load is 200 W.

Given the rated efficiency of the inverter, we can estimate the minimum nominal power rating as 222.2 W.

Note that the inverter may be less efficient than the rated efficiency, and under such conditions it may be safer to have a margin for the power ratings of the inverter.

So, we have seen a simple method to design a stand-alone PV system based on the load requirements and available system components.

Note, that this is definitely not the most exhaustive way to design the PV system.

This method works better for places with more or less consistent irradiance levels.

For places with severe disparity between the summer and winter irradiances, the number of autonomous days would increase for winter, and the system costs would consequently rise.

Also, the component margins considered for various parameters could differ from place to place based on the system requirements.

Nonetheless, this method is good enough to get a basic estimate of the stand-alone PV system sizing.

You will be able to practice more on this in the exercises of this week.

See you in the next block!