ET3034TUx - 7.5.2 - Batteries 2 - Battery parameters

Welcome back.

In this block, I will introduce you to the basic parameters of the battery.

We will learn about the different battery ratings and parameters.

So let's get started.

I will first start with the voltage and capacity ratings of the battery.

Every battery is rated with a certain voltage and capacity.

The battery rated voltage is the nominal voltage at which the battery is supposed to operate.

The so-called solar batteries or lead-acid grid plate batteries are usually rated at 12 V, 24 V or 48 V.

Of course, the battery system in your PV system can attain any voltage based on the interconnection of several batteries at the system level.

The term capacity in the domain of batteries refers to the amount of charge that the battery can deliver at the rated voltage.

The capacity is directly proportional to the amount of electrode material in the battery.

This explains why a small cell has lesser capacity than a large cell based on the same chemistry, even though the open-circuit voltage across the cell will be the same for both the cells.

Thus, the voltage of the cell is more chemistry based, while the capacity is more based on the quantity of the active materials used.

The unit for measuring the battery capacity is ampere-hour or amp-hour, denoted as Ah.

It's good to recollect from high school physics, that amount of charge is usually measured in Coulombs.

As the electric current is defined as the rate of flow of electric charge, the charge can also be equivalently measured in ampere-hour.

Therefore, we can quantify charge in both Coulombs or amp-hours.

But we will stick to the more convenient unit of amp-hours for measuring the battery capacity.

I'll shortly explain the reason for this.

We must not confuse the battery capacity with the energy capacity.

Energy capacity of the battery or any storage device for that matter is the total amount of energy that the device can store.

This is usually measured in watt-hours.

How do we calculate the energy capacity of the battery, knowing the voltage and the battery capacity?

The energy capacity is nothing but rated battery voltage in volts multiplied by battery capacity in amp-hours, giving the total battery energy capacity in watt-hours.

You must be wondering what is the significance of amp-hours as the unit of battery capacity?

The unit itself gives us some important clues about the battery properties.

If we take a brand new battery with a 10 amp-hour capacity, it can theoretically deliver a 1 A current for 10 hours at room temperature.

Of course, in practice this is seldom the case due to several factors, as we will see later.

We now come to another useful battery specification, called the C-rate.

Let's first understand how the battery charges and discharges.

As discussed in the previous video, the charging and discharging of the battery at the cell level is just the right kind of chemical reaction taking place.

At an electric level, charging and discharging depend on the direction of current into and from the battery respectively.

How does this relate to the battery capacity?

This is where the C-rate comes in.

C-rate is a measure of the rate of discharge of the battery relative to its capacity.

The C-rate 'number' is nothing but the multiple of the current over the discharge current that the battery can sustain over one hour.

For example, a C-rate of 1C for 10 Ah capacity battery would correspond to a discharge current of 10 A over 1 hour.

On the other hand, a C-rate of 2C for the same battery would correspond to a discharge current of 20 A over half an hour.

Similarly, a C-rate of 0.5C implies a discharge current of 5 A over 2 hours.

In general, it can be said that a C-rate of n-C corresponds to the battery getting fully discharged in 1/n of an hour, irrespective of the battery capacity.

In general, a higher or lower C-rate will depend on the charging and discharging current that the battery with a certain capacity experiences.

Like every other component in the PV system, the efficiency of the storage system is also of high importance.

In the last video you saw how we selected battery from a host of other storage choices.

We said that batteries, apart from the ease of implementation, offer some of the highest efficiencies.

Usually, for storage technologies, we talk about round trip efficiencies.

In simple terms: It is the ratio of total storage system input to the total storage system output.

For example if 10 kWh is pumped into the storage system while charging, and you can effectively retrieve only 8 kWh while discharging, then the round trip efficiency of the storage system is 80%.

The round trip efficiency, in case of the batteries, can be broken down and studied further.

The batteries are reported to have two kinds of efficiencies: voltaic efficiency.

It is the ratio of the average discharging voltage to the average charging voltage.

This stems from the fact that the charging voltage is always a little above the rated voltage so as to drive the reverse chemical reaction in the battery.

Then we have the coulombic efficiency.

This is defined as the ratio of the total charge out of the battery to the total charge into the battery over a full charge cycle.

Battery efficiency is defined as the product of these two efficiencies.

This overall battery efficiency can be seen as the round trip storage efficiency that is usually considered while comparing different storage devices.

This battery efficiency includes the effects of all the chemical and electrical non-idealities occurring in the battery.

Now let's look at another important battery parameter, the state of charge or the SOC.

This is defined as the percentage of the battery capacity available for discharge.

Thus a 10 Ah rated battery that has been drained by 2 Ah is said to have a SOC of 80%.

Then we also have the depth of discharge or DOD.

Depth of discharge is defined as the percentage of the battery capacity that has been discharged.

Thus, a 10 Ah battery that has been drained by 2 Ah has a depth of discharge of 20%.

Thus the DOD and SOC can be seen as complimentary to each other.

Now we come to a very important parameter: the cycle lifetime of the battery.

Cycle lifetime is defined as the number of charging and discharging cycles after which the battery capacity drops below 80% of the nominal value.

Usually the cycle life is specified as an absolute number.

But it would be a gross generalization to say that the battery lifetime can be stated as a single number, without any other specifications.

Why?

It's because the various battery parameters discussed so far are related not only to each other but are also dependent on temperature.

Let us discuss this interesting interplay of the battery parameters.

Now, the cycle life depends heavily on the depth of discharge until which those charge cycles last.

Also, it depends on temperature.

This can be seen in the graph shown here for a typical maintenance free lead-acid solar battery.

Clearly, the battery lasts longer under colder temperatures of operation.

Furthermore, for a particular temperature, cycle lifetime depends non-linearly on the depth of discharge or DOD.

The smaller the DOD, the higher the cycle life.

However, such a higher cycle life would also mean that those additional cycles you gain can only help you for a smaller depth of discharge.

Thus, it could be said that the battery will last longer if the average DOD could be reduced over its normal operation.

Also, battery overheating should be strictly controlled.

Overheating could occur due to overcharging and subsequent overvoltage of the lead-acid battery.

We will learn more about voltage and charge control of the battery in the next video.

While battery life is increased at lower temperatures, there is one more effect that needs to be considered.

The temperature affects the battery capacity during regular use too.

As seen from the graph, lower the temperature, lower the battery capacity.

Higher the temperature, higher the battery capacity.

This is because, at high temperatures, the chemicals in the battery are more active, and therefore the chemical activity tends to increase the battery capacity.

Conversely, the chemical activity is hampered at lower temperature.

It might seem strange, but it is even possible to reach an above rated capacity of the battery at high temperatures.

However, such high temperatures are severely detrimental to the battery health.

When we say that the battery has a limited cycle life, or that it has permanently "run out of juice", what exactly happens to it?

What is exactly this aging effect on the lead-acid battery?

Let us briefly discuss this.

Sulphation is one of the major causes of aging.

Insufficient recharge after discharges cause sulphate crystals to grow, which cannot be completely transformed back into lead or lead oxide.

Thus the battery slowly loses its active material mass and therefore its discharge capacity.

Corrosion of lead grid at the electrode is another common aging mechanism.

This leads to increased grid resistance due to high positive potentials.

Another cause is the drying out of electrolyte.

Gassing can occur at high charging voltages, resulting in loss of water.

This should be replaced by timely addition of distilled water.

Otherwise it dries out and the battery no longer functions.

Thus the battery also suffers from a limited lifetime.

The battery space is being researched exclusively.

There are already maintenance free lead-acid batteries for solar systems that exhibit very high lifetimes.

Of course, these are also the high-end products and would therefore be more expensive.

Now, we have seen how the battery user has to be very careful in optimally using the battery so as to gain the maximum out of this effective storage system.

But how do we go about controlling the battery parameters?

We will see this in the next block.