ET3034TUx - 7.4 - Inverters in PV systems

Welcome back.

Now we come to an important power electronic device that makes the modern PV system widely usable.

I am talking about the solar inverter.

To know what an inverter is, we must first understand its need in the PV system.

All the discussions we have had so far on the PV electrical output in terms of current, voltage and power have all been DC in nature.

What do I mean by DC?

DC, or direct current is the unidirectional flow of electric charge.

DC is produced by power sources like batteries, solar cells, dynamo's, etc.

The term DC is broad enough to be used for any electric signal that is unidirectional.

Thus, it is common to talk of quantities like DC voltage, power and current.

The symbol for DC power is this.

AC, or alternating current on the other hand, is the flow of electric charge such that it constantly reverses direction.

The usual form of an AC power is a sine wave.

The symbol for AC signal is this.

As a thought, DC signals can be looked upon as a signal with zero frequency.

So why do we need AC power?

After a brief 'war of the currents' in the 19th century, AC power was chosen as the standard for central power generation, transmission and distribution.

Till this day, almost all national electric grids are based on AC.

Almost all households have what are known as the "AC mains sockets".

Consequently, most household electric appliances expect to be fed AC power, even though sometimes the internal circuitry of the appliances might use DC.

Nevertheless, the fact remains the solar power produced needs to be converted to an AC form, so that the solar power is more usable in the electricity framework we have today.

How do we make this conversion from DC solar power to the easily usable AC power?

We need a device which can simply convert a DC electric signal to an AC one.

The device which can make this possible is an inverter.

Given the time constraints, we will not go into the internal circuitry of the inverter.

But we will talk about the features of the solar inverter and its application in the modern PV system.

Now inverters could be classified based on their size, mode of operation, or implementation topology.

Here I will talk about the classification based on the mode of operation; under this the inverters can be classified into 3 broad categories: stand-alone inverters, grid-connected inverters and bimodal inverters.

Here, a typical off-grid or stand-alone PV system is shown.

Consequently, the inverter is a stand-alone inverter.

In this case, the PV system is stand-alone, the load can only depend on the PV system for power.

So the inverter that supplies AC power to the load has to appear as a voltage source with a stable voltage and frequency, supplying power at 230 V_AC or 110 V_AC or as is the voltage standard at the location.

Here, a typical grid-connected PV system is shown.

Consequently, the inverter is a grid-connected or grid-tied inverter.

In this case, the PV system is grid-connected; the load can depend on the PV system as well as the grid for power.

There is an exchange of power between the grid, the inverter and the load.

The inverter latches onto the grid frequency and voltage.

The inverter's main task is to only pump power into the grid.

So the inverter that supplies AC power to the grid as a current source, while the role of the constant voltage source in the system is fulfilled by the grid.

Here we see a hybrid system.

These configurations are much rarer.

The PV system is capable of functioning either as a stand-alone system with battery storage or as a grid-connected mode.

The inverter plays a crucial role, as it has the necessary hardware implementation to work in either mode, based on the operating conditions.

In the stand-alone mode, the grid is disconnected, and the system might cater to some special backup loads with the inverter behaving as an AC voltage source.

In the grid-connected mode, the inverter behaves as an AC current source.

These bimodal inverters are usually more expensive, and are used less often.

Now we already know the basic application of an inverter in the PV system: power conversion from DC to AC.

Can the inverter perform any additional function?

The answer is yes, and thanks to the advancements in power electronics, it is common to have inverters that implement an MPPT mechanism before inverting the voltage, thus ensuring that the PV modules or arrays are operating at their MPP.

Apart from the modes of operation, inverters are also classified on the basis of the implementation topology.

There can be 4 different categories under this classification.

Central inverters, which are usually around several kW to 100 MW range.

Module inverters or micro inverters, typically rated around 50 to 500 W.

String inverters, typically rated around 500 W to a few kW.

A string is nothing but a number of PV modules connected in series.

And finally, multi-string inverters, typically rated around 1 kW to 10 kW range.

Let's start with the central inverter.

This is the most traditional inverter topology in use.

As seen in the figure this is a simple implementation with one central inverter catering to all the PV modules in a PV system.

While this inverter topology increases the ease of system design and implementation, it suffers from several drawbacks.

In large systems, large amounts of DC power will be transferred over long cables to reach the central inverter.

This increases DC wiring costs, and also decreases safety, as DC fault currents are difficult to interrupt.

An MPPT implementation inside the central inverter will only cater to the entire system as a whole.

If the various modules, strings are mismatched, let's say due to partial shading, the overall system output is drastically reduced.

Also, the system is usually designed for a fixed power.

There is little scope for extendibility of the system if more strings and modules need to be added.

Next, let's look at the micro inverters or module level inverters.

As the name suggests, each module has a dedicated inverter with an MPP tracker.

Therefore the topology is more resilient to partial shading effects as compared to the central inverter topology.

Clearly, the micro inverters provide the highest system flexibility, since extending the size of a system under this topology is far simpler.

Furthermore, the DC wiring costs are greatly reduced.

However, the investment and maintenance costs tend to increase, especially if the cost per Wp are compared.

Then we have the string inverter concept, which seeks to strike a balance between the module level inverter and the central inverter topologies.

The string inverter topology is more resilient to mismatch than the central inverter, because each string is independently operated at its MPP, thus guaranteeing a higher energy yield.

String inverters are smaller than central inverters.

However, the implementation is more complex than the module inverter.

Also, the partial shading will have a greater influence over the string inverter topology than over the micro inverter topology.

Finally, the multi-string inverters.

This concept seeks to combine the higher energy yield of a string inverter with the lower costs of the central inverter.

Each of the strings is pre-power-processed using low power DC-DC converters.

Each string has its own MPP tracker implemented alongside the DC-DC converter.

All the converters are connected via a DC bus to the inverter, and ultimately to the grid.

Within a certain power range, only a new string with a dedicated DC-DC converter has to be included to expand the system size.

We now have an overview about the solar inverters and their topologies.

Of course, the choice of your topology for implementation would depend entirely on the system needs, size, and your system's budget.

But in general, while choosing an inverter for your PV system, what are the requirements from a good solar inverter?

There are several characteristics expected from a good solar inverter.

As every power processing step expends power itself, the solar inverters are expected to be as efficient as possible.

This is because we wish to deliver maximum PV generated power to the load or the grid.

Typical efficiencies are in the range of more than 95% at rated conditions.

Depending on the topology, it is expected that the inverters have in-built MPP trackers.

Grid-tied inverters are expected to have active islanding detection capability.

Islanding refers to the situation in which the inverters in a grid-tied setup continue to power the system even though the power from the grid operator has been restricted.

Due to safety issues, islanding needs to be prevented.

Therefore, inverters are expected to detect and respond by immediately stopping from introducing power into the grid.

This is also referred to as anti-islanding.

Since in a lot of situations, the solar inverters are exposed to ambient conditions, these must comply with the temperature and humidity conditions of the location.

Since grid-tied inverters pump power into the grid, they are expected to maintain very high quality, so as to not corrupt the power flow in the grid.

Thus inverters are expected to have very low harmonic content on the line currents.

It is a work in progress to increase the lifespan of the inverter, the crucial power electronic device in the modern PV system.

A good inverter will probably reach, under favorable conditions, around 10-12 years of lifetime.

This is the bottleneck in the modern PV system's lifetime, especially considering the fact that PV modules can last over 25 years.

We have discussed in this block the need for a solar inverter and also the different types and topologies of inverter implementation.

However, there is one more crucial aspect that I have not talked about so far.

That is the inverter sizing.

This would largely depend on the system and the load requirements, and the size of the rest of the system.

I will discuss the inverter sizing when we know more about the different types of PV systems next week.

So, see you in the next block!