# An Introduction to the Solar Inverter Market

**By**

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**This is a short article is to introduce you to the solar inverter marketplace and discusses a neat solution which makes micro-inverters a much more attractive proposition**

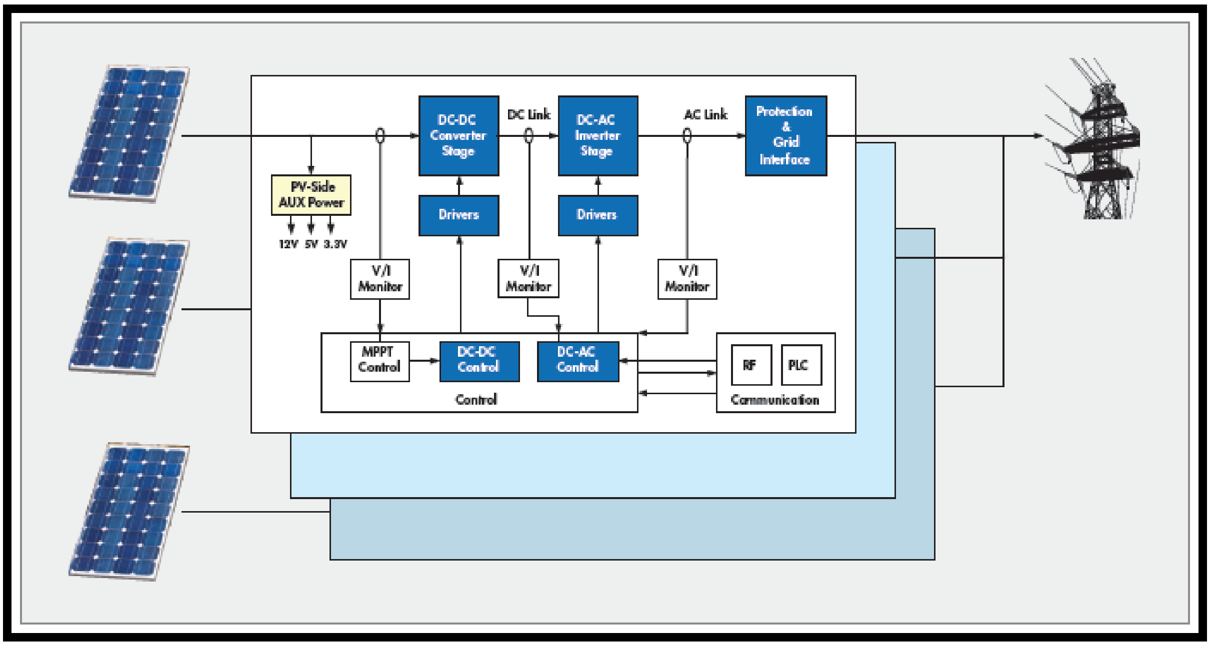
## Introduction

A **solar inverter**, or **PV inverter**, converts the variable direct current (DC) output of a photovoltaic (PV) solar panel into a utility frequency alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network. Nowadays there are usually some sort of energy monitoring systems in the solar inverter (more on this later).

## What is needed in a Solar Inverter?

Solar inverters turn the DC output of a Solar panel into sine wave AC 230 volts at 50Hz or 100V 60Hz, for use either directly in the home or fed into the mains ( Grid Fed). It is extremely important that the solar inverter is highly efficient so that valuable solar generated electricity is not wasted. The best solar panels are 29% efficient and the best solar inverters are about 98 % efficient solar inverters have special functions adapted for use with photovoltaic arrays, including “Maximum Peak Power Tracking” ( MPPT) and “anti-islanding” protection.

Here is the block diagram of a basic inverter, in his example there is one inverter per solar panel.




There are two basic signal paths: a "power path" where the DC voltage generated by the solar panel is converted to AC power and the "control and communication path". The control function monitors the various voltages and currents in the "power path" and implements control loops to create and optimize the grid compatible AC power output. The communication function implements one or more of the grid-based standards discussed above to implement panel or overall inverter function monitoring.

In this design you need a processor to handle the algorithms for the MPPT, controlling the current out. A/D and D/a converters are needed to monitor the signals in and out of the micro-controller.

With the advent of " Smart Home " technologies many inverter companies offer the ability for the user to be able to monitor the power on some sort of In Home display and this can be a computer, Android or IOS tablet.

Some level of control of the inverter is needed too. One basic and obvious example is to be able to shut down the solar panels and the inverters in the case of an emergency. A "fireman's" switch.

There are many communications technologies available. The choice is wired or wireless technologies.

- Wireless such as ZigBee, to ZWave , Bluetooth and Bluetooth Smart, Wi-Fi
- Wired technologies, such as Ethernet, RS-485, power-line communications

Solar panels are usually on the roof of a residential property and the inverters need to be hidden away somewhere out of sight.  This is usually in the attic of the property.  This means that the wireless signal has to get from the attic to the ground floor and give good solid coverage so that the user on his pc in any part of the house can conveniently view the data on his tablet or PC. Wireless coverage can be patchy and unreliable in bigger houses. This results in unpredictable and unreliable communications. In the case of needing to shut down power in an emergency this is not acceptable.

Wired solutions are much more predictable but there is the cost of running cabling down through possibly several floors of the house and the possibility of ruining the house decoration in the process.

Power-line communications provides the benefit of a wired solution but using the existing cables so the costs to install are lower. It is also the most secure!

## Maximum Peak Power Tracking (MPPT)

This is a technique that the inverter uses to get the maximum possible power from the solar panel array. Solar cells have a complex relationship between solar irradiation, temperature and total resistance that produces a non-linear output efficiency which can be analysed based on the I-V curve. It is the purpose of the MPPT system to sample the output of the cells and apply the proper resistance (load) to obtain maximum power. MPPT in its simplest form is making the resistance value of the inverter appear to be the same resistance value of the solar panel. That is the point when the maximum energy transfer is made. The solar panel resistance varies according to the amount of sunlight hitting the panel so this process of MPPT is dynamic and is constantly adjusting the effective load resistance of the inverter.  This is one area where the solar inverter companies differentiate themselves through their in-house developed MPPT algorithms. It is an area that impacts the overall efficiency of the panel/ inverter combination

## Anti –Islanding

**Islanding** refers to the condition in which the solar array continues to power a location even though electrical grid power from the electric utility is no longer present. Islanding can be dangerous to utility workers, who may not realize that a circuit is still powered, and it may prevent automatic re-connection of devices. For that reason, solar panel homes must detect islanding and immediately stop producing power; this is referred to as **anti-islanding**.

The common example of islanding is a grid supply line that has solar panels attached to it. In the case of a blackout, the solar panels will continue to deliver power as long as there is sufficient energy to power the home.   In this case, the supply line becomes an "island" with power surrounded by a "sea" of unpowered lines. For this reason, solar inverters that are designed to supply power to the grid are generally required to have some sort of automatic anti-islanding circuitry in them.

In **intentional islanding**, the generator disconnects from the grid, and forces the distributed generator to power the local circuit. This is often used as a power backup system for buildings that normally sell their excess power to the grid.

There are about 15 different ways to implement anti-islanding.

**Different Types of Architectures of using inverters with Solar panels**

- **One Main Inverter**

  The traditional home installation had all the solar panels connected in series and they were connected to one main inverter. A solar panel typically outputs around 30 volts.

  The limitation of this architecture is that the system fails if any one panel fails. If one panel is shaded then the total power generated is limited by this panel. It like water running through a hose and you squeeze just one point in the hose and this limits the water flow through the whole hose. The MPPT has to be an average of all the panels so this in itself is inefficient and results in power loss from the solar panels. If the inverter fails, the whole system fails. This is the lowest cost at about €0.10 per peak watt.  As the inverter is critical to the whole system, users end up paying for a service contract

  If we want to add panels in the future we either have to buy a bigger capacity inverter up front now, or spend more money on a new inverter when we add the new panels.

  There is usually some simple form of monitoring offered using for example Wi-Fi. However the inverter is usually mounted in the roof space and the signal is at best poor with only some parts of the house receiving the signal. The alternative was to install Ethernet cables in the home and this ruins the home decoration and adds to the installation cost.

- **String Inverters**

So instead of having all our solar panels connected to one inverters, we connect several of the panels in series (this is a “string”) and connect them to one inverter. For example we may have three rows of 8 panels on a roof. We connect 8 panels in series and then to one inverter. We therefore have 3 string inverters in this installation.

So now we can do MPPT for the three groups of 8 panels. However, all the panels in one string all need to be facing the same way. However if a tall building or tree shades one panel at some point in the day we lose the maximum power in that string.

If we want to add panels later then we need to add in typically another group of 8 and add another inverter

If the string inverter fails we lose a third of our power generation .If one panel fails in the string we lose one third of our power.

A string inverter system costs €0.15 per peak watt generated.

- **Micro-Inverters**
  A Micro-inverter is used for each individual solar panel and are usually mounted on the back of the photo voltaic panel to make a “mains” panel. This reduces installation cost
  The advantages of the micro-inverter is that each panel has its own MPPT and this maximises the power extracted from each panel. Also if one is in the shade then the others are not affected so again maximum power is extracted. If a solar panel/ micro inverter set fails, then in my early example of 24 panels you only loose one twenty fourth of the power. The micro-inverter set up is the most reliable and has the highest overall efficiency of the three architectures.

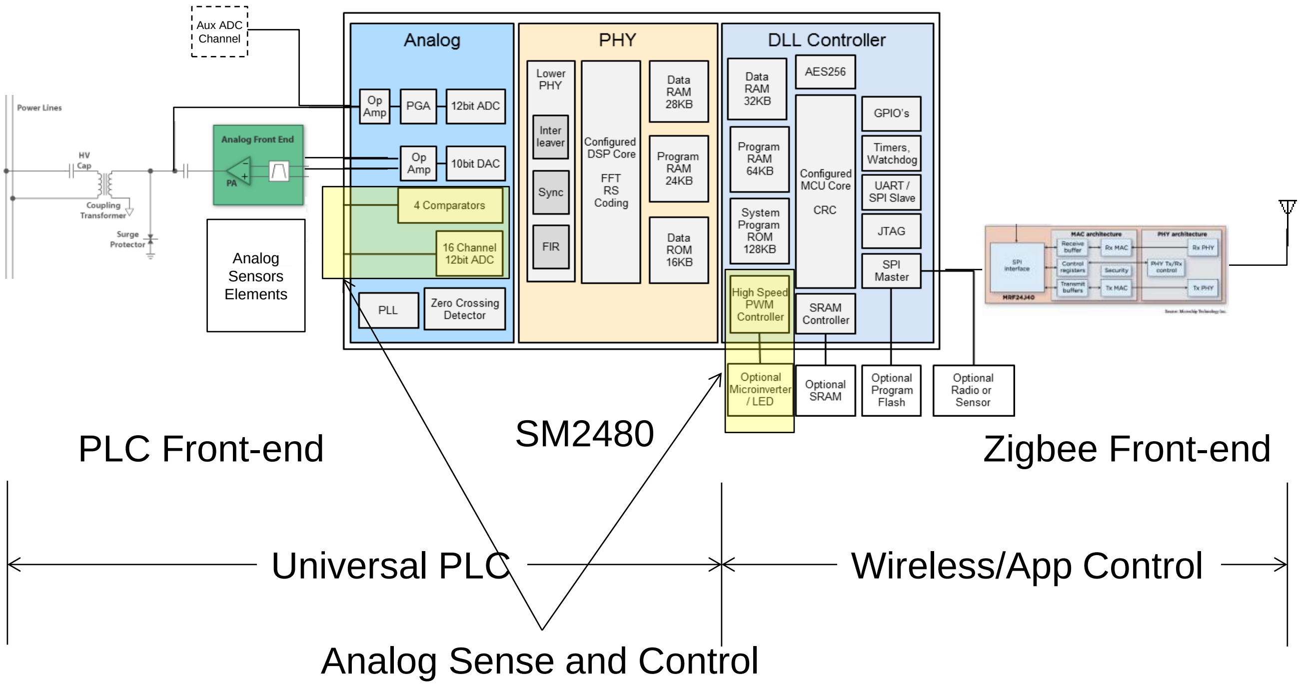
  Initially, the cost of using micro inverters was much more expensive at €0.40 per peak watt. However this cost is rapidly dropping. The advantages of using micro-inverters has driven the market to reduce the costs which are now down to €0.25 per watt.

  Micro -inverter efficiency is very slightly lower but as each panel has its own inverter which is working to ensure each individual panel is transferring the maximum amount of power, it is important to realise that the efficiency of the overall system (panels and inverters) is actually higher than string inverters or having one main inverter. This means more power is available from the same number of panels using micro-inverters and this increase in power is in the range of 5-15%.

**Semitech Semiconductor's Game Changing Solution**

The SM2480 "inverter-on-a-chip " significantly reduces the component count and the cost of a building a micro-inverter. **It can be more than 40% reduction in manufacturing cost.**

So let us look at what is in the SM2480 in the diagram below:

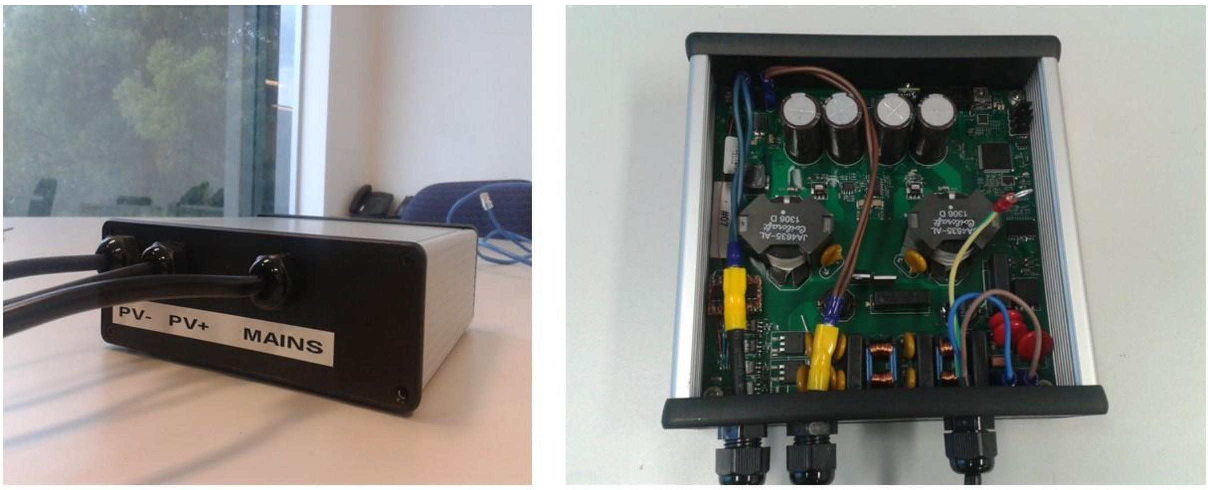



You can see that all the analogue sensing and analogue and digital outputs are built into the SM2480. There are also high accuracy Pulse Width Modulator outputs which is basically the inverter DC /DC and DC/AC inverter stages. The second 32-bit MCU runs all the software in the inverter, which includes the MPPT algorithm etc.

The SM2480 has multi-standard power-line communications inside. In addition through a ZigBee or Wi-Fi module can be connected to the SPI master port. You now have wired and wireless communications for everyone!!

All that is needed externally to the SM2480 are the capacitors, the magnetics, the power transistors, connectors and protection circuits.

Semitech Semiconductor has developed a demonstration micro-inverter and it is fully ready to connect to a solar panel and then to the 230 volt mains. It can supply power into the grid right out of the box. This comes complete with operational software and communications capability. An SM9400 box is used to connect a PC to the power-line communications (using an SM2400) and there is a software package to run on the PC to allow the user to monitor, analyse and control the evaluation micro-inverter. The SM9400 is PC (via USB) to PLC using Semitech Semiconductor's SM2400 multi-standard PLC device.




External and Internal View of the Evaluation Micro-Inverter

Please keep in mind that is an evaluation design. It can be easily made much smaller and you can differentiate your micro-inverter, using your experience in hardware design to optimise, for example, the magnetics for performance and cost. Your expertise in MPPT algorithms can be applied too. Our integration and your expertise will make a market beating profitable product.

**Want to look at this solution?**

Just drop me an email and I will follow up. Detailed information is available under a simple to execute non-disclosure agreement.

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