Residential Solar: Part 1 of 4 Editorial Series sponsored by Infineon; Harnessing the sun with residential solar solutions

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Infineon's role in enabling the growth of residential solar PV generators

The global capacity to generate renewable power is growing rapidly — faster than any period in the recent past. In 2023, about 510 GW[1]of renewable power supply was added globally, with solar photovoltaic (PV) generation accounting for 75 percent of the addition. The next five years will see the fastest growth yet, driven by various reasons, such as:

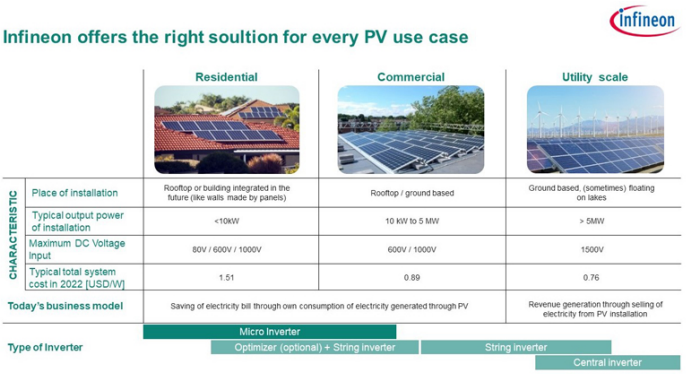

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Figure 1: Types of solar PV installations

- The global warming limit of 1.5°C set in 2015 at COP28 has already been breached, and its effects are now clearly visible.
- Governments around the world are adopting policies and introducing regulatory reforms to achieve the COP28 target of tripling global renewable capacity by 2030 [1].

Residential solar: A key player

Residential solar contributes significantly to this growth, with 365 GW of new rooftop solar installations in 2023 [2], equivalent to 111 million solar-powered homes. This growth is forecasted to skyrocket until 2030 at a CAGR of 20.9 percent [2]. Residential solar offers a sustainable and cost-effective way for homeowners to generate their own electricity, reduce reliance on fossil fuels, and lower their energy bills.

Residential solar adoption is naturally high in countries with abundant sunlight, such as India, Australia, and Brazil. India, in particular, with 300 days of clear sunlight, is seeing massive growth in its solar capabilities. In 2023, India surpassed Japan to become the third-largestsolar energy producer [3]. This growth will continue thanks to Indian government's numerous schemes and incentives to integrate renewable energy, such as the performance linked initiative (PLI) scheme [4] (2022) for manufacturers of high-efficiency solar PV panels.

Interestingly, adoption is also increasing in countries like Germany, Netherlands, and Sweden [7] despite the absence of consistent sunlight, again driven by government incentives, falling prices of solar panels, and heightened environmental awareness.

Clearly, for consumers, manufacturers, or solution providers, residential solar is an essential focus in the coming years. This article – the first part of a four-part series – delves into the critical components of residential solar, things to watch out for as a designer or consumer, and Infineon's role in enabling residential solar

solutions.

What is residential solar?

Unlike front-of-the-meter systems, which involve large-scale energy generation, transmission, and distribution infrastructure, solar PV solutions are an example of behind-the-meter systems — localized energy generation and storage systems that help consumers generate their own energy, store it for later use, and even feed it back to the grid. Based on the power output, solar PV installations can be classified into:

- **Residential:** Designed for residential use, with power output up to 20 kW.
- **Commercial:** Designed for small business and organization requirements, with power output reaching up to 5 MW.
- **Utility:** Large-scale installations for industrial requirements, reaching up to 10 MW.

This article primarily focuses on residential solar installations.

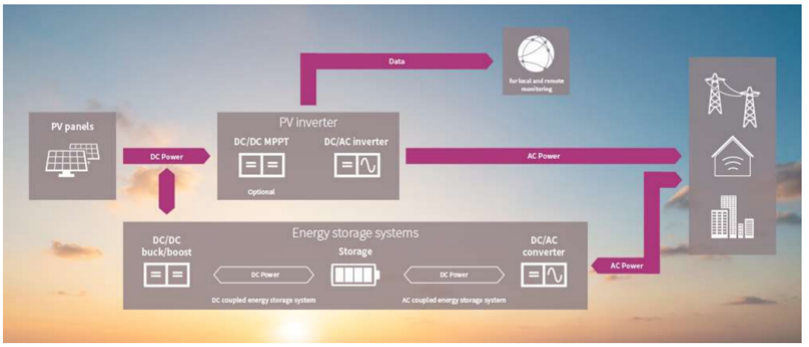

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Figure 2: Structure of solar PV system

The main building blocks of a solar PV system are:

- **Solar/PV panels:** When exposed to sunlight, PV cells produce direct current, that is subsequently stored in batteries or transferred to the grid for immediate consumption.
- **Energy storage systems (ESS):** Store excess energy to use later.
- **Inverters:** DC-to-AC converters used in different parts of a PV system for converting the captured sunlight into energy suitable for home appliances or feeding into the grid. Inverters are also used for energy conversion in ESS, stabilize fluctuating energy, or communicate with monitoring devices.

How does a solar PV system work?

Solar/PV panels generate DC electricity when they are exposed to sunlight. Inverters take this raw DC electricity and convert it into AC electricity that home appliances can use. Residential PVs typically use microinverters or string inverters. Microinverters are placed directly on each solar panel, letting them convert the DC at the source. String converters, connected to multiple solar panels wired together in a series, convert the DC from multiple solar panels at a central location.

Used along with string inverters, power optimizers[5] can greatly improve the efficiency of a PV system. These DC-DC converters employ the maximum power point tracking (MPPT) algorithm to extract the maximum available power from the PV panels under any environmental conditions by stabilizing the variable DC voltage.

Rather than feeding back the excess panel-generated energy into the grid, the ESS stores this DC output from the panels. In addition to the battery itself, an ESS includes the power conversion system (PCS) and the battery management system (BMS).

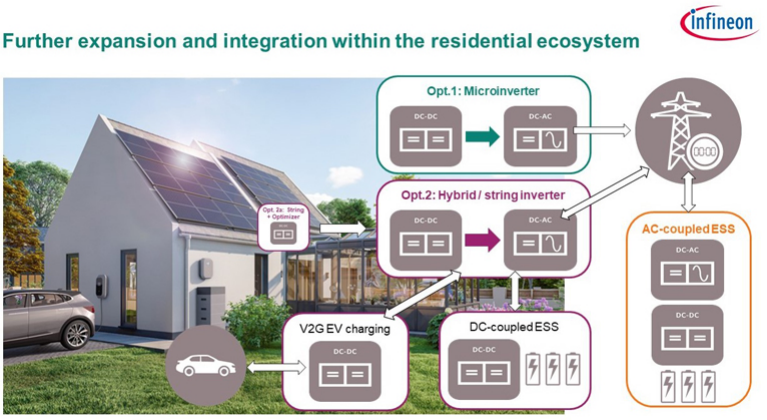

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Figure 3: Types of ESS in residential solar PV installations

ESS systems generally used with PV installations are categorized into AC-coupled and DC-coupled systems. A DC-coupled system (or hybrid inverter system), typically used in residential solar installations, includes PV panels, an MPPT DC-DC stage, a bidirectional connection, and a single inverter stage for both the battery and PV panel. This system eliminates one power conversion stage, improving efficiency and reducing costs. The specific topology of the system varies depending on whether it is a single- or three-phase system and the battery voltage.

The microcontroller (MCU), the brain of the ESS, manages the control algorithms for power conversion, ensuring the efficient operation of the MPPT DC-DC converters, inverters, and more. Other vital components include the auxiliary power supply, digital isolators, and voltage and current sensors.

The BMS constantly monitors the state of the ESS battery cells and adjusts the charging rate to ensure they remain healthy.

Infineon's value-add in the entire chain

Infineon is committed to supporting the global transition to renewable energy by providing a comprehensive range of components and solutions for all aspects of a solar PV solution – from power generation and conversion to energy storage and management.

Since no single solution can meet every design requirement, Infineon offers numerous products to design a highly efficient solar PV solution. Since low losses and reliability are essential to inverter designs, Infineon's CoolMOS™ superjunction (SJ) MOSFETs with high ruggedness and fast body diode are a good fit. They also offer the optimal cost-performance ratio with a low gate charge and $R_{DS(ON)}$.

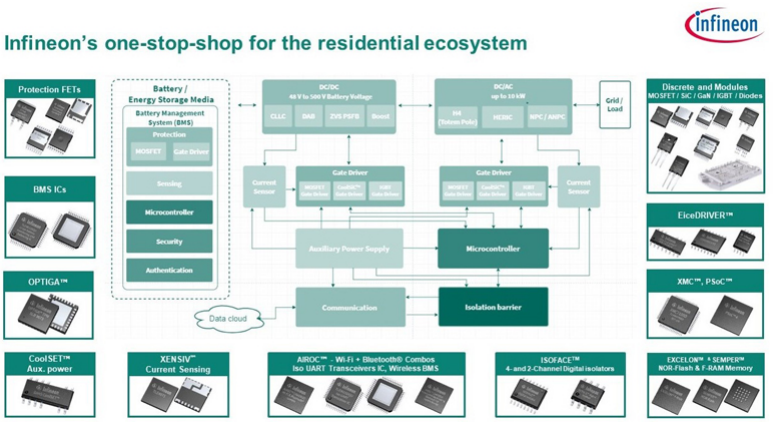

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Figure 4: Residential solar PV solutions with ESS

Also, as solar PV systems need to work in high ambient temperatures, they need to be thermally rugged and efficient. Another consideration is space, especially if you want sleek, wall-mounted devices. Infineon's wide-bandgap (WBG) products like CoolGaN™ and CoolSiC™ offer reliable performance in high voltages and temperatures, and a higher power density. SiC-based CoolSiC MOSFETs, with temperature-independent switching losses and the lowest conduction losses, offer optimal thermal performance resulting in reduced cooling efforts and high ruggedness in harsh environments. For the smallest system designs and reduced system complexity, CoolGaN power transistors — with the lowest switching losses and highest power density — are ideal.

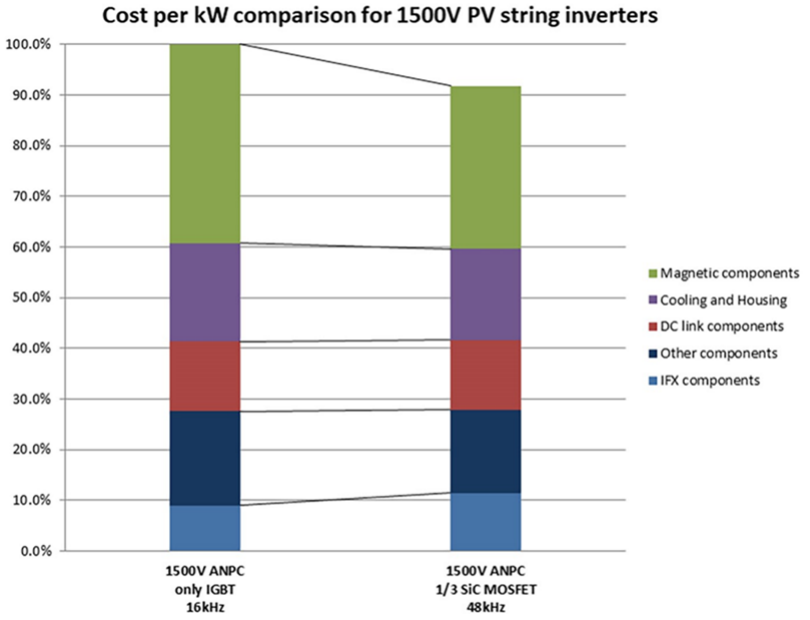

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Figure 5: System cost for string inverters is significantly lower with SiC MOSFETs compared to IGBTs

For microinverter, string inverter, and hybrid inverter designs (ESS installations), leveraging CoolSiC solutions can halve the losses and improve efficiencyby 2 percent [6]. In single-panel and multi-panel power optimizer designs, OptiMOS™ switches with low $R_{DS(ON)}$ and excellent gate charge maximize the energy harvested from each panel. OptiMOS switches are also ideal for efficient microinverter designs on the primary side. For the secondary side, Infineon's cost-effective CoolMOS and fast-switching CoolGaN solutions are ideal. Bidirectional CoolGaN switches can replace two back-to-back Si-based MOSFETs, significantly reducing both system size and cost.

To efficiently operate these switches, Infineon offers EiceDRIVER™ coreless transformer gate drivers. With tight propagation-delay matching, design flexibility, and precise timing control, these drivers can tolerate large voltage swings and reduce power losses. Infineon's XMC™ MCUs, with robust computation and connectivity and advanced peripheral sets, provide precise control over power conversion and reliable operation of the entire system.

For auxiliary power supplies, Infineon CoolSET™ AC-DC integrated power stages with comprehensive protection improve the overall system reliability. Infineon's ISOFACE™digital isolators ensure safe communication between various components.

Conclusion

Residential solar is set to play a critical role in the global transition to renewable energy.

As demand for these systems grows, efficiency will be the key differentiator. Infineon is a key player in the residential solar segment, providing high-performance components and comprehensive support for both designers and consumers. Stay tuned for our next article in the four-part series where we delve deeper into

inverter design and optimization.

Infineon Technologies

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