Module Level Power Electronics

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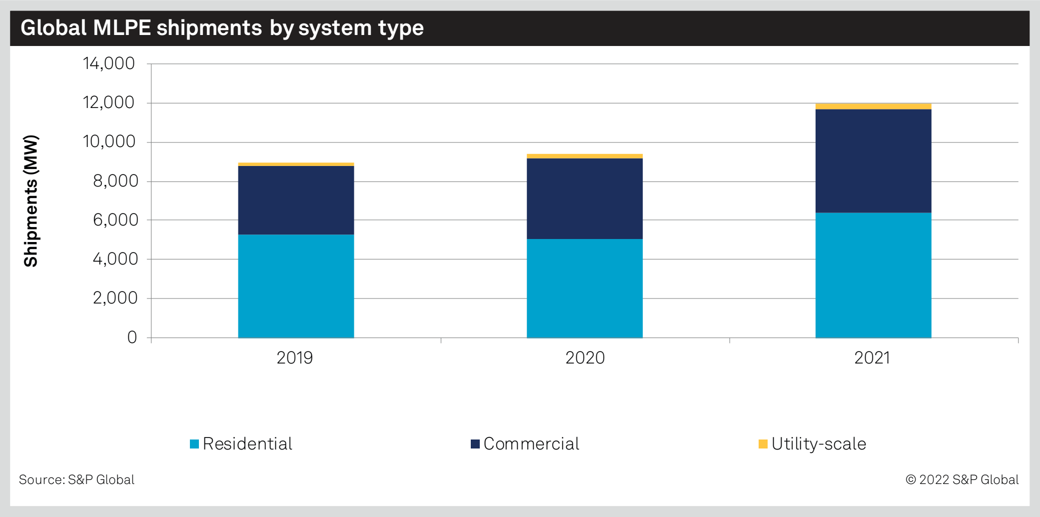
Module level power electronics to be increasingly used in distributed generation solar

Module level power electronics (MLPE) such as solar power optimisers and microinverters are increasingly being used in distributed generation (DG) solar globally. While MLPE technology has been commercially available for over 15 years, it is increasingly being considered in residential and commercial and industrial (C&I) applications due to heightened awareness of improved safety features and improved energy production. The latest generation of MLPE technology is incorporating advanced technology such as artificial intelligence (AI) and software to simplify and accelerate installation.

Key takeaways

- Usage of MLPE technology is increasingly driven by added benefits such as improved safety capabilities, enhanced energy yield and improved fault detection.
- The MLPE market has grown rapidly globally, increasing 33% from 2019 to 2021. S&P Global Commodity Insights estimates that MLPE was accounted for over one third of residential solar installations in 2021.
- A large opportunity exists for greater MLPE adoption as demand from the distributed generation installations is expected to comprise 43% of global PV installations between 2022 and 2025.
- Digitalization which includes the increased use of AI, software and satellites will help increase the efficiency of installation, operation, and maintenance (O&M) of MLPE technology globally.



The benefits of MLPE in DG solar

One of the major benefits of MLPE is the ability to provide module-level rapid shutdown, which eliminates safety concerns of high direct current (DC) voltages. In solar systems, PV modules are installed in series known as a string, where the DC voltages can range from 600V to 1000V in most rooftop applications. When problems such as electric arcs and hot spots occur due to component defects or faulty installation, fires can occur rendering the high DC voltages life-threatening to firefighters. Under such circumstances, rapid shutdown at module-level is essential, as it can reduce the DC voltages to safe levels in a short period of time. An increasing number of countries such as the United States, Philippines, and Thailand have mandated rapid shutdown as an electrical safety requirement for rooftop PV systems. Other markets, such as China (mainland), are currently discussing proposals to make rapid shutdown a safety requirement for rooftop systems. The United States was the first to implement this requirement and other countries have used it as a benchmark. In the United States, the National Electrical Code (NEC 2017), written by the National Fire Protection Association, mandates module-level rapid shutdown to lower the voltage in the DC system conductors to 30 volts or less within 30 seconds of initiation. Currently, MLPE technology is one of the most commonly used ways to fulfil rapid shutdown requirements in specific markets by installers and this capability continues to be a key driver of the growth of MLPE.

Another major advantage of using MLPE is to reduce energy losses and maximize the energy yield of a solar system. A string inverter performs maximum power point tracking (MPPT) at an array level and optimizes energy output when all modules in the array are identical, operating under the same temperature and irradiance, and with no shading. However, more complicated solar systems, particularly rooftop systems for residential or commercial use, require more precise MPPT, as modules installed for such systems operate under different conditions, including different temperatures, irradiances, and shading. In this case, the energy output of a string inverter will be constrained by the module of the lowest output. In contrast, MLPE has the advantage of MPPT at a module level, where the current and voltage combination of each module can be adjusted individually, thereby, minimizing energy losses. This feature also allows for more flexibility on the number and type of modules to be installed. Therefore, MLPE can optimise the energy yield of the whole system and generate higher revenues.

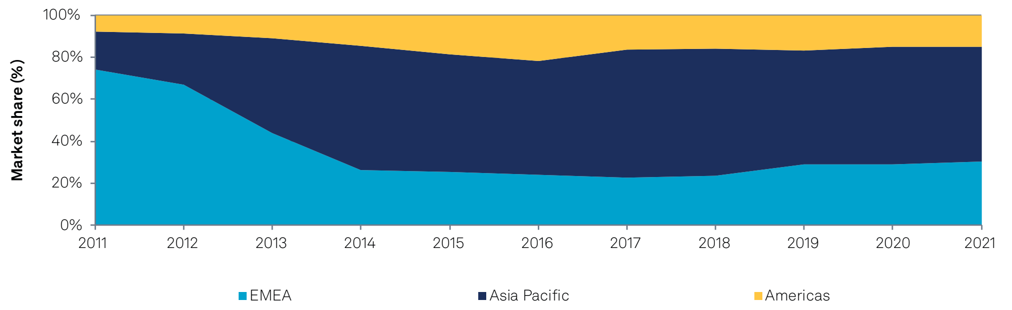
MLPE can also provide more granularity in terms of monitoring performance and diagnosis of faults at a module level. In contrast, string-level monitoring may sometimes fail to detect faults in a single module when irregularities are hidden within the string. As a result, MLPE can lead to lower O&M costs and shorter downtime, as less time is needed to locate and correct faults.

Strong growth of DG solar to help drive demand for MLPE

Demand from the distributed generation (DG) solar segment has been steadily growing and is expected to comprise 46% of global PV installations between 2022–2026. Key drivers for the uptake in demand are accommodative government policies in major markets such as in China (mainland), net-metering policies which enable home and business owners to become prosumers, and consumer desire for independence from the grid (self-consumption) amid rising electricity prices and unstable electricity supply. DG solar has also become significantly cost competitive with retail electricity tariffs in many markets. In addition, increasing innovation around the financing of residential and commercial and industrial (C&I) projects has rapidly improved the affordability, which is important given that solutions using MLPE typically have a higher upfront cost.

Ten years ago, rooftop installations were largely concentrated in Europe, however as other markets have developed, a more diverse picture has emerged. China (mainland) has since bolstered rooftop PV installations which has contributed to Asia Pacific surpassing EMEA as the main market for rooftop PV. China (mainland) is expected to comprise 32% of global rooftop installations in 2022, while EMEA is expected to represent 27%, driven by Germany, Netherlands, and Poland. The Americas region is set to comprise 16% in 2022, supported by the United States and Brazil.

Share of global rooftop installations, by region



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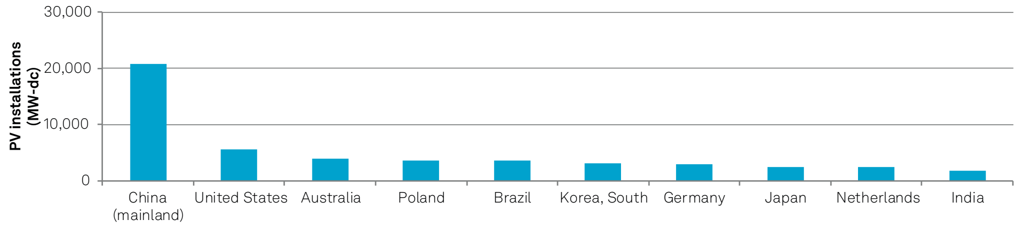
The United States has remained the largest market for MLPE representing around 44% of global shipments in 2021. The National Electric Code (NEC) has been a key driver of growth for MLPE here given the mandatory module-level rooftop rapid shutdown requirements. Currently, 40 states have adopted the NEC code for all rooftop solar installations. There are three iterations of the code, with NEC 2020 code being the most recent. As of June 2021, eleven states had enacted the NEC 2020 code, with a further eleven having begun updating their current version to the NEC 2020 code. The Philippines joined the United States in instituting mandatory requirements for rapid shutdown devices in domestic rooftop installations which are largely based on the 2017 NEC standards. The Philippine Electrical Code of 2017 (PEC 2017) requires a Rapid Shutdown Switch (RSS) in Article 6.90.2.6 for rooftop PV installations. Other markets considering introducing similar rapid shutdown requirements include Thailand and China (mainland).

In recent years, the United States' dominance in the MLPE market has been challenged by certain markets in Europe such as Netherlands and Germany, in South America such as Brazil and in Asia such as Australia. This uptake, however, has not been driven by mandatory fire-safety regulations, but rather by the steady growth of rooftop PV installations. While consumers are not obliged to adopt these technologies, they have been persuaded by other benefits such as optimized yield, enhanced monitoring capabilities, and in certain cases, easier installation. Other driving factors have included the rise in popularity of the 'smart home' concept where multiple appliances communicate with each other, and the homeowner can control their energy production and consumption seamlessly.

Top 10 markets for distributed generation in 2021



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Future growth opportunities for MLPE in DG solar

MLPE suppliers continue to innovate and release new products that help ease installation and O&M. For example, power optimizer suppliers have partnered with module suppliers to offer a product called a 'Smart Module'. These are solar modules which have the power optimizer embedded directly into the module and sold (and installed) as a single product. The benefit of this product is that it reduces the time and cost of installation on-site because all power optimizer installations take place at the factory. It also reduces the risk of incorrect installations as the power optimizer is perfectly integrated into the module. Recent trends have included an expansion in the rated input DC power offered by power optimizers to match the higher power modules being offered in the market.

Initially, the value-add of installing MLPE was mainly realised on asymmetric rooftops and where there was shading. Hence, most installations of these technologies occurred in the residential segment. However, in recent years, growth opportunities have opened in the commercial and industrial rooftop segment with demand within this system type gaining ground over the residential segment. Fire safety concerns, module-level monitoring abilities, self-consumption optimization, installation flexibility, and net-metering applications have driven the uptake of these solutions in the commercial and industrial segment. Also, new MLPE products have been released that can work with different numbers of modules such as single, dual, or quad configurations.

Mandatory fire safety requirements have helped drive adoption of MLPE in key markets such as the United States. However, in many other regions globally, there is a lack of such mandatory requirements. Despite this, business owners are installing MLPE devices to safeguard their assets for future safety requirements and to address personal safety concerns. The safety features of MLPE devices allow them to control the output voltage in the event of a fire; during a malfunction of the system; or during system maintenance. These devices are also able to withstand high temperatures and harsh environmental conditions making them ideal for optimal PV system operation in areas of high solar radiance.

In addition, increased energy yield has driven uptake of MLPE technology as more commercial and industrial installations are incorporating battery energy storage systems and considering increasing levels of self-consumption. In doing so, the solar energy industry has evolved to offering cloud-based monitoring platforms, and inverters which are compatible with batteries and can interact with electric vehicle (EV) chargers and smart meters. Collectively, these components comprise the Smart Home and Smart Building solution, where owners can optimize their electricity costs; monitor and predict their production and consumption; and improve their PV-system functionality by optimizing the energy yield per module and by monitoring the granular output data of the entire system. Overall, this caters to the market's growing desire for a system which can be operated and monitored through a single platform, and which is able to easily identify and isolate faults within the system. Leading inverter and MLPE suppliers have begun offering this solution either independently, or through partnerships with module, battery and EV charger suppliers.

One of the newer growth opportunities for MLPE technologies includes the ability to offer either grid services and/or virtual power plant (VPP) capabilities. A VPP is a network of decentralised power generating units such as residential homes with solar and energy storage that are managed via aggregation software and can replicate the functions of a traditional power plant. Multiple MLPE suppliers have been participating in VPP trials in markets such as the United States and Australia in recent years. Typical grid services relate to enhancing power quality such as providing voltage support or helping to inject power during periods of high electricity demand. The rise in these grid resources is creating another requirement for MLPE technology because a VPP needs every asset in the network to be efficiently monitored, coordinated, and controlled by the central control system.

Digitalisation to expand market opportunity for MLPE

Increasing levels of digitalization are set to create new and larger market opportunities for MLPE technology in distributed generation markets globally. Digitalisation can help simplify the installation and improve O&M efficiency of solar PV systems, with application in arc fault detection, physical layout mapping and MLPE system design.

Arc fault detection

One common cause of fires in solar systems are electric arc faults. As solar installations in residential and commercial and industrial (C&I) systems continue to grow globally, so too does the potential risk of fires. Therefore, adequate detection and prevention of electrical arc has become more critical. The integration of artificial intelligence (AI) into Arc Fault Circuit Interrupters (AFCIs) which detect and interrupt electric arc faults, enhances the safety of solar PV systems. Based on a deep learning approach, an AI algorithm is trained and self-upgraded by simultaneously calculating and iterating data from PV system to find electrical arc signals. In addition, AI-driven AFCI is able to distinguish between true and false arc signals, which help to avoid false alarms. While AFCI operates at string level, with the installation of MLPE, operators are able to easily pinpoint the location of arc faults to an individual module, which saves time and labour from examining an entire string of modules. With the development of MLPE, it is likely that the module-level arc detection function is added to MLPE so that operators can more precisely track electrical arc between modules.

PV system physical layout mapping

The use of AI also helps with mapping physical layout of PV systems, which is critical for systems using power optimizers. This feature allows users such as installers to quickly locate faulty or disconnected optimizers. Traditionally, to generate a physical layout of a PV system requires users to manually match power optimizers with modules based on the serial number of each power optimizer, which is time consuming especially for large commercial projects with many power optimizers being installed.
On the contrary, with an image recognition feature driven by AI, users simply need to attach the QR code of each optimizer to a physical layout template based on the actual position where the optimizer is installed, take a photo of the template, and upload it to a layout generation app. AI is able to automatically convert the QR code template into a layout map. This feature enhances user experience by saving time of recording the layout of power optimisers physically in system and improves the accuracy so that in the event of a problem, the mis-performing module or power optimiser can be located rapidly in the overall PV system.

Satellite based MLPE design

Satellite based MLPE design is another example of how digitalisation is being increasingly applied to solar systems. Installers, particularly those from markets that are not familiar with MLPE, may face difficulty designing systems using MLPE. In this case, satellite based MLPE system design collects environment data and guides them with system design and installation. This technology improves the ease of installation and saves time for installers, thereby increasing installers' willingness to install MLPE and improving the penetration of MLPE in emerging markets.

Multiple factors to drive strong growth of the global MLPE market

The rapidly increasing growth of roof-top solar installations has triggered growing awareness of system safety enhancement, energy output optimization, and O&M efficiency improvement. MLPE is expected to benefit significantly from the sustained growth of the global DG market due to its ability to provide rapid shutdown and monitoring at module level. In addition, leading MLPE suppliers continue to release new advanced products not only for application in solar PV area, but also for integration in adjacent areas such as energy storage, EV charging, and smart home and smart building solutions.

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