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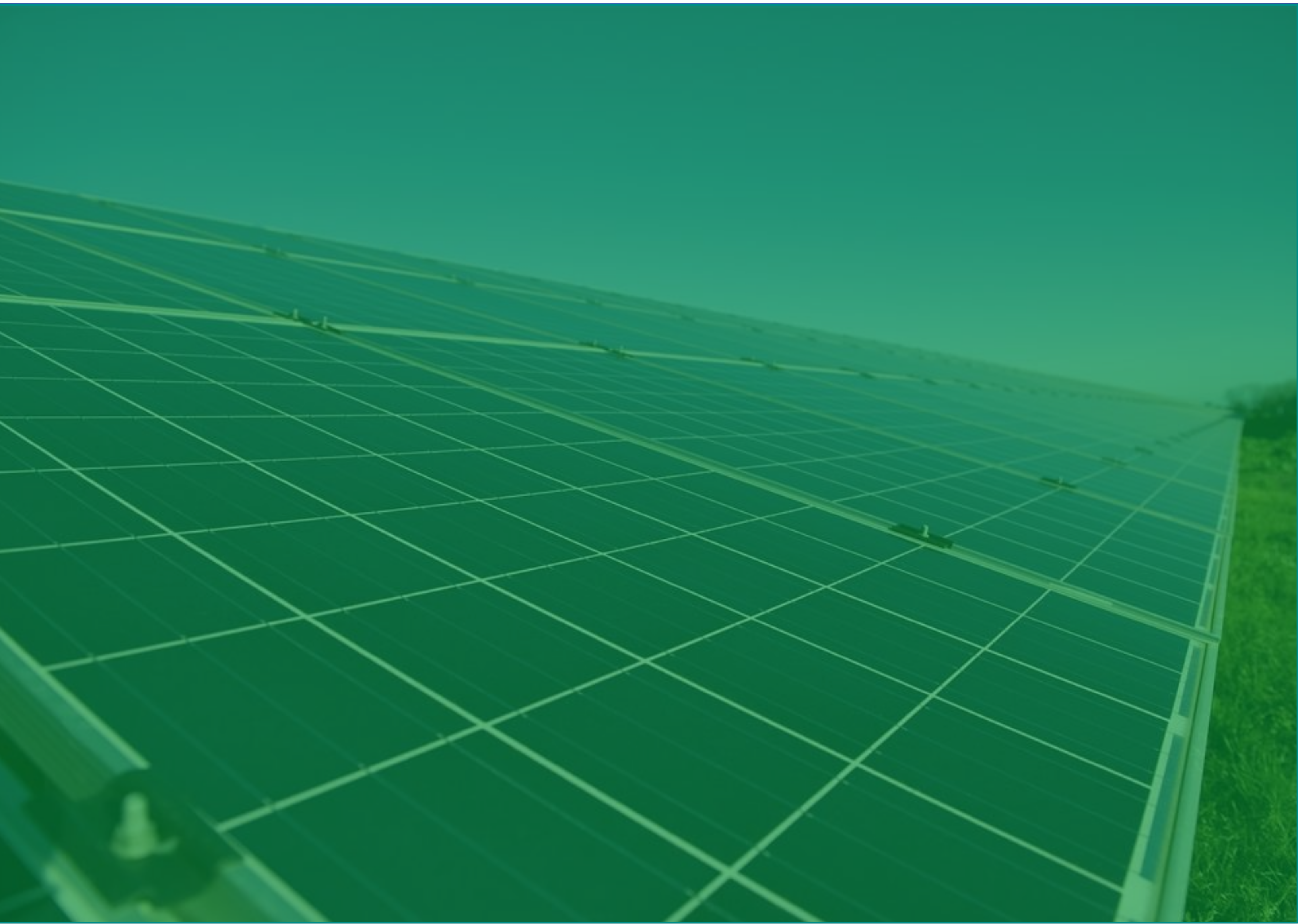
CLEAN ENERGY TECHNOLOGY

Higher Voltage Standards Help Reduce LCOE for PV Systems



Introduction

Increasing the voltage standards for PV systems has been a critical driver of reducing the levelized cost of energy (LCOE) for PV systems for customers. As a result, the PV industry has rapidly adopted higher system voltages, from 600 V initially, then to 1000 V, and currently to 1500 V over the past 10 years. This whitepaper outlines the need for higher PV system voltages, the evolving market for PV hardware technology especially solar inverters, the regulatory and technology barriers to achieve higher system voltages, and the financial benefits that can be achieved using higher voltages.

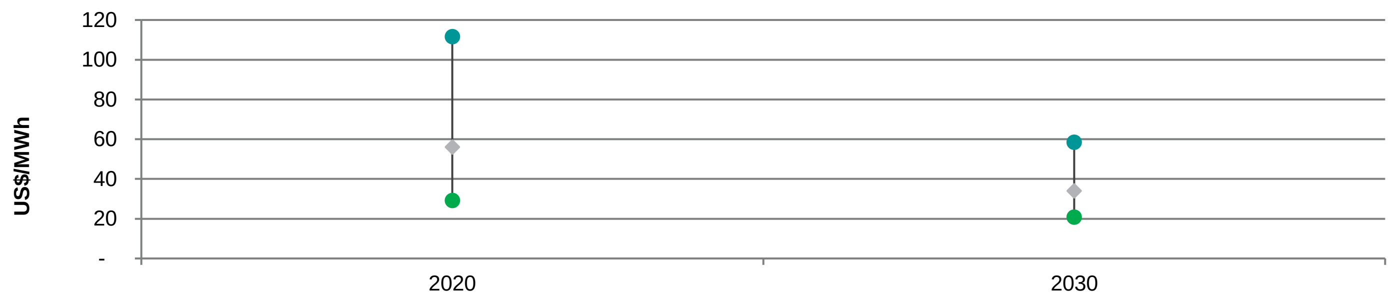
Key takeaways:

- Moving to higher voltage standards have allowed PV system designers to reduce LCOE for customers by simplifying system design and enabling PV technology manufacturers to launch higher density, lower cost PV equipment.
- The market for 1500 V PV inverters has rapidly grown, tripling from 2018 to 2020. IHS Markit forecasts the global market for 1500 V PV inverters to reach 83 GW in 2021 as 1500 V becomes the standard for utility-scale installations globally.
- Key stakeholders across the solar industry are carefully watching for new developments in higher voltage standards. Higher voltages, such as 2000 V or 3000 V may allow for even greater cost savings, however technology companies such as PV inverters and module suppliers must innovate with next-generation technologies.

The benefits of moving to higher voltages

The primary purpose of moving to higher voltages in PV systems is to reduce the LCOE. Higher voltages can help customers realize lower LCOE in several ways, including cost advantages related to system design, lower component prices, higher power density, and reduced operations and maintenance costs. IHS Markit forecasts that the global average LCOE for utility-scale solar PV will fall by 39% from 2020 to 2030. Higher operating voltages will help contribute to this decline in LCOE. In addition, continued cost reductions across the balance of system, from modules, inverters, and other hardware is expected to continue driving down LCOE over the forecast period. Finally, greater efficiency in module and inverter technology will contribute to increased average yields of PV systems, which will further lower LCOE.

Benchmark global LCOE for utility-scale PV solar



Notes: Maximum and minimum values correspond to average LCOE in the highest and lowest cost countries, respectively. The dots in the middle represent the weighted global average.
Source: IHS Markit

Regarding system design, one of the major advantages of increasing the voltage of a PV system is that it allows for longer module strings. PV modules are installed in series known as a string. The number of modules able to be installed in a string is dependent on the voltage of the PV system. For example, using modules rated at 45 Vdc, 22 modules can be installed in a string for a 1000 V rated PV system (22 x 45Dc = 1000 Vdc). Using the same modules but increasing the PV system voltage to 1500 V, 33 modules can be installed in a string. There are several cost savings benefits to using longer strings in a PV system. Longer module strings allow for fewer strings for a given size of PV system. Fewer strings imply less equipment required such as cables, combiner boxes, and PV inverters.

Higher voltages allow for reduced costs for certain components, especially PV cabling. Higher voltages equate to lower current for the same level of power. Therefore, lower gauge cables are required, leading to savings on materials costs for copper. Higher voltages also enable the design of higher-powered PV inverters. Although some components such as insulated gate bipolar transistor (IGBTs), diodes, and fuses necessary for higher voltages may come at a higher cost, a higher voltage PV system and higher power density can offer lower overall costs on a dollar-per-watt basis. Additionally, the cost of specialized components is expected to decrease over time as economies of scale are realized, further reducing the cost of the PV inverter per watt.

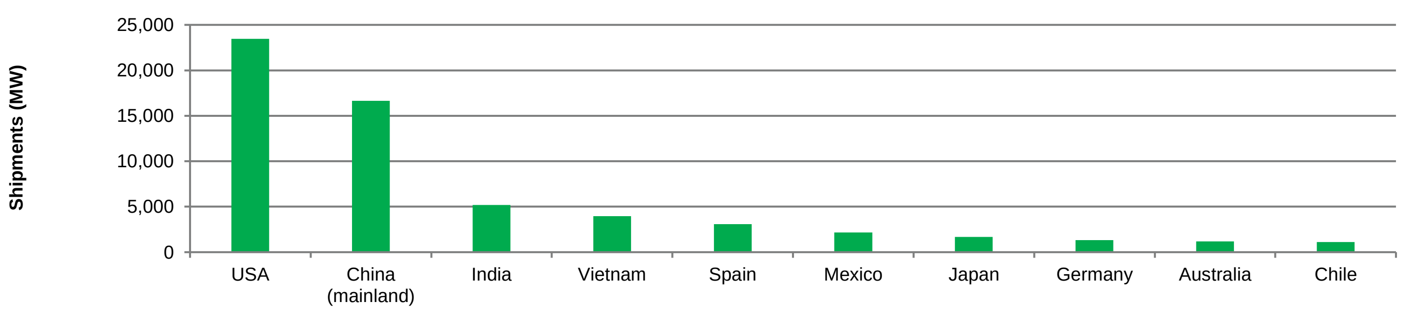
Finally, simplified system designs due to longer, fewer strings lead to shorter installation times and lower labor costs. Ongoing operations and maintenance costs can also be reduced due to fewer critical components such as PV inverters requiring maintenance. Development and construction costs are also lowered due to simplified PV system designs enabled by using higher voltages.

1500 V PV inverter market to reach 83 GW in 2021

Leading solar developers and EPCs globally have embraced 1500 V technology over the last few years to drive down the LCOE of ground-mount solar projects. PV inverter suppliers have leveraged the benefits of this technology to introduce larger inverter power ratings. For example, three-phase central inverters are now typically available from 3 MW and three-phase string inverters are approaching or exceeding 200 kW. While central inverter suppliers have been offering 1500 V rated inverters for some time, three-phase string inverter suppliers have been rapidly increasing shipments of 1500 V rated inverters as they are increasingly used in utility-scale projects.

The global market for 1500 V PV inverters is estimated to have tripled from 2018 to 2020. The top 10 markets for 1500 V PV inverters are expected to have accounted for 60 GW in 2020. China, the United States, and India are currently the largest markets for 1500 V PV inverters.

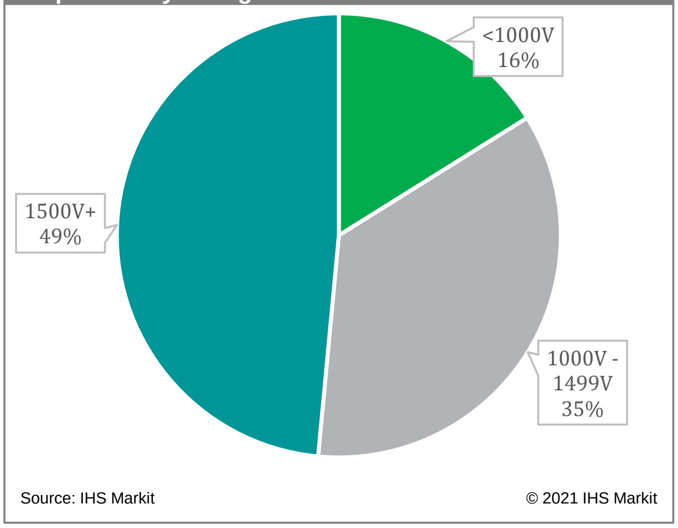
Top-10 markets for 1500 V PV inverters in 2020



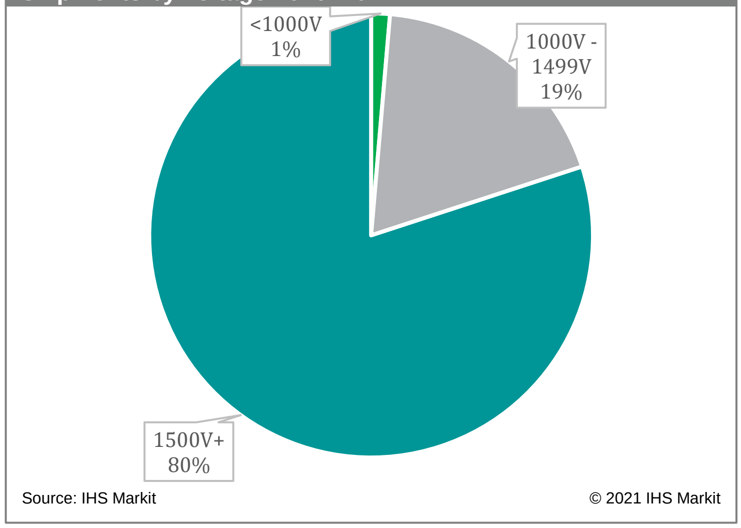
Source: IHS Markit

IHS Markit forecasts the global market for 1500 V PV inverters to exceed 83 GW in 2021 as suppliers release next generation products. In addition, 1500 V is expected to account for a higher share of global shipments of both three-phase string and three-phase central PV inverters throughout the forecast period with just under half of global three-phase low power (≤500 KW) PV inverter shipments expected to be rate at 1500 V or higher and 75% of three-phase higher power (>501 kW) PV inverter shipments expected to be rated to 1500 V or higher.

Global three-phase low power (≤500 kW) PV inverter shipments by voltage 2020–2024



Global three-phase high power (>500 kW) PV inverter shipments by voltage 2020–2024



The entire PV industry will need to work together to increase voltage standards

As customers continue to push for greater cost savings and lower LCOE, several key stakeholders across the entire PV industry will be responsible for coordinating efforts to raise voltage standards for PV systems. It is likely that a higher voltage standard above 1500 V will be established for the same reasons that 1500 V became a standard in recent years.

For example, national and local regulators as well as electrical grid operators are often responsible for setting and enforcing electrical standards for the safe and stable operation of PV systems. Conflicting codes between neighboring countries can impede the adoption of specific technologies, including voltages above 1500 V for PV systems. Local grid codes may even specifically set an upper limit for PV system voltages, as is the case in Europe with the International Electrotechnical Commission (IEC) upper limit for low voltage systems being 1500 V. Regulators and electrical grid operators may be slow to update grid codes as they await for proven, viable technologies such as PV inverters, modules and other electrical balance of system components to be widely available. As a result of changing regulatory and safety standards, PV hardware suppliers are faced with the challenge of testing and certifying their products to ensure they comply with local and regional requirements.

The availability of compatible hardware is another major challenge. Technology hardware suppliers such as PV inverter, module and other balance of systems must design and manufacture hardware which can operate at higher voltages and which comply with local and national grid codes. However, just as during the transition from 1000 V to 1500 V, suppliers across the balance of systems are playing a careful wait-and-see approach so as not to invest to heavily in new, more expensive component technology before there is ample demand in the market. One of the most important considerations is the higher cost of next generation components such as higher voltage switches, transistors, and silicon carbide-based components which can allow hardware such as PV inverters to operate at voltages above 1500 V. Although some PV inverter suppliers have begun exploring the use of these components in their products, the majority of the PV inverter market has not begun to transition using these advanced components capable of handling higher voltages. This is because other components such as PV modules are not yet designed to operate at higher voltages, which may become a bottle neck for the entire PV industry moving towards higher voltage standards.

For example, module suppliers are currently focused on higher powered modules exceeding 500 W and have not yet released modules that are rated at higher voltages. Stepping up module voltages comes with technical challenges, including the risk of potential induced degradation (PID) which can damage and reduce the output of modules over time. The risk of PID increases with higher voltages. Therefore, module suppliers must experiment with different designs, including frameless modules and new module cell technologies.

In addition, developers and EPCs will need to develop in-house expertise to successfully design and construct higher voltage PV systems. Developers and EPCs must account for the various trade-offs and changes in system design related to higher voltages to be able to realize the full value of moving to higher voltages such as 2000 V or 3000 V. For example, although higher voltages allow for longer strings and simpler design, there may be higher costs for some components which must be rated to perform at higher voltages. Developers and EPCs must conduct lengthy testing and proof of concepts of higher voltage PV systems to convince investors of their commercial viability and prove that they can design systems which achieve a lower LCOE.

Similarly, operations and maintenance (O&M) providers will need to develop and upgrade their qualifications to safely manage PV systems operating at higher voltages. Higher operating voltages in PV systems comes with the risk of greater safety hazards, which O&M providers must consider by properly training and certifying their personnel. Additional certifications are necessary in most markets to be able to safely manage medium voltage PV systems.

Innovative new technologies are required as PV systems move to higher voltages

The central challenge with moving to higher voltage standards for PV systems is the balance between innovating new hardware technologies that are rated to operate at higher voltage levels, with the development of regulations and standards which allow for higher voltages. Developments across the entire PV industry are required for higher PV voltage standards, such as 2000 V or 3000 V to emerge. Technology companies have begun to release innovative new solutions to help accelerate the adoption of higher voltage standards.

For example, suppliers in the commercial rooftop segment have begun trialling higher voltages to help customers reduce LCOE. Traditionally, 1500 V inverters have been the domain of ground-mount installations. Recently, this technology has been trialled in large commercial and industrial (C&I) rooftop applications. 1500 V commercial rooftop systems have been shown to save on costs related to the need for less cabling and other balance of systems when compared with the current standard, 1000 V. The trend towards 1500 V PV systems in commercial systems is still in its early days but there have been some installations in markets such as China, Norway and Saudi Arabia. However, IHS Markit expects the trend to grow as installers and customers realize the cost benefits and as local grid codes begin accommodating higher voltage standards in commercial PV systems.

Another key area of growth is in DC to DC optimizers, or power optimizers, which can increase the performance of a PV system by regulating the output of each string, module, or even module cell in the module array. Power optimizers have also been used to help bridge module arrays with higher voltage PV inverters. For example, an aging 1000 V PV system can be retrofitted with string optimizers, which can boost the output voltage from the module array to 1500 V to feed into a modern 1500 V PV inverter. As voltage standards continue to evolve, the use of technologies such as power optimizers, which can help be the bridge between older 1000 V PV systems and PV inverters which can operate at potentially much higher voltages such as 2000 V or 3000 V, will increase.

For more information ihsmarkit.com/energy

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