

AUXILIARY POWER SOLUTIONS FOR 1500 VDC PHOTOVOLTAIC SYSTEMS



CUI INC[®]

Photovoltaic systems are continually evolving to improve their efficiency and financial viability. One trend is to move to larger strings of cells giving higher dc voltages to be converted to ac voltage for the grid. Cost savings result but auxiliary power supplies for monitoring and control need to accept these higher voltages as inputs.

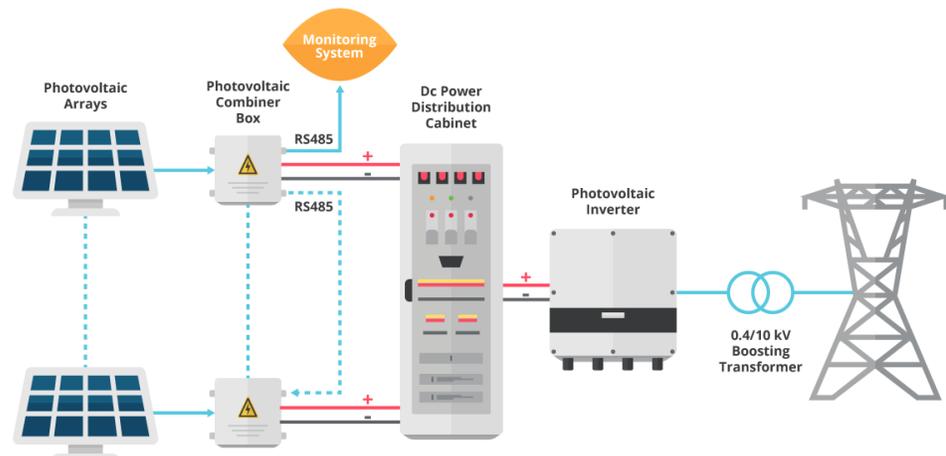
THE SOLAR MARKET

Despite the waxing and waning of government support for photovoltaic (PV) power generation systems, growth is still strong with installed global capacity increasing from 178 GW in 2014 to a projected 540 GW in 2019. Europe leads the way with an expected increase to 158 GW in 2019, but other countries are experiencing much higher growth rates. China, for example, expects a four-fold increase over the same period and the United States a three-fold increase. The solar industry also has a significant economic impact, with around 55 million people directly employed in the sector globally in 2014.

TRANSITION TO 1500 VDC PROVIDES REAL SAVINGS

PV has always fought to justify itself in terms of \$/watt of generated power and is hampered by the initial low efficiency of the panels themselves. Currently, levels of monocrystalline cells at around 25% efficiency would be market-leading and theoretical maximum values are not much higher. Designers therefore continually strive to squeeze the last drop of energy from systems by minimizing losses in connections and the conversion process from panel dc output to ac for the grid. One way to do this is to connect panels in series so that power is processed at high voltages where currents and consequent 'I²R' losses are lower. For example, grid-connected systems typically have blocks of 22 panels with cells connected in strings to give 1000 V producing 5.5 kW per string. 2727 strings might then be combined for a 15 MW installation.

Figure 1:
Typical PV
arrangement



If, however, panel numbers in strings are increased to deliver 1500 V to the combiners, for the same 15 MW of power, current drops to 66.6% of the 1000 V value and resistive cable losses to 44.4% because of the 'I²' in I²R. This gain means higher system efficiency or lower cost of installation with smaller cables and connectors. Because there are fewer strings to achieve 15 MW, there are 31% fewer combiner boxes, for example, 94 compared with 137 assuming each box handles 20 strings. Of course, associated combiner cabling, connector and maintenance costs are lower too. GTM research has analyzed the system cost per watt comparing 1000 V and 1500 V systems in a 10 MW plant showing a potential deployment saving of \$400k, as shown in Figure 2.

Figure 2:
Potential deployment
savings - 10 MW
solar plant

Component	Component Count	Unit Cost	System Cost (per W)
PV Modules	Same	↑ +1~2%	↑ +\$0.02
Cables, Conduits, Trenching	↓ -40~45%	Same	↓ -\$0.03
Combiner Boxes	↓ -33%	↑ +10~20%	↓ -\$0.005
PV Inverters	↓ -40%	↑ +80~100%	↑ +\$0.01
Ac Subsystem	↓ Reduced	↓ -10~15%	↓ -\$0.005
Direct Labor	N/A		↓ -\$0.03

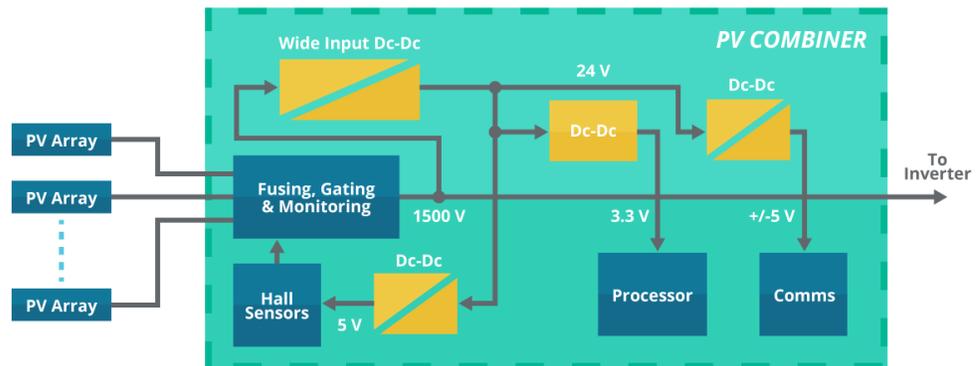
It certainly looks advantageous to move to higher string voltages, but there are some potential downsides; insulation all down the line must be uprated for the higher operating voltage, as do the combiner boxes and grid inverters. This is not necessarily an issue, though, as inverter technology commonly operates at high voltage in other areas such as traction. The latest techniques, which make use of wide bandgap semiconductor devices are still applicable at 1500 V further improving conversion efficiency.

AUXILIARY CIRCUITS NEED ATTENTION TOO

However, there is an area in the system that requires attention; PV combiners and inverters need low voltage isolated power for monitoring and control derived from the 1500 V line and small dc-dc converters that operate at these levels are not common. The lower voltage

end is important too as the supply could dip to 200 V under particular conditions, so the converter needs to provide at least a 7.5:1 input range, again not a common specification. Figure 3 shows a typical solar combiner unit illustrating the power architecture: a 200 – 1500 Vdc input dc-dc converter with a 24 Vdc output feeding additional isolated and non-isolated converters for communications and processor/sensor power. The main high voltage dc-dc converter needs fully reinforced safety isolation and would typically be specified as 4000 Vac-rated.

Figure 3:
Typical solar
combiner box
internal power
architecture



The standard that relates to the safety of PV systems is IEC 62109-1 'Safety of Power Converters for use in Photovoltaic Power Systems'. Part 1 specifies general requirements and part 2 defines specific requirements for inverters. The standard is relevant to systems up to 1500 V and its scope outlines the design and construction methods required to ensure protection against common hazards such as electrical shock, mechanical, temperature, fire, chemical and more. Of particular relevance to dc-dc converters is the reference to IEC 60664 'Insulation Coordination for Equipment within Low-Voltage Systems'. Unlike some older standards, IEC 60664 does include requirements for operating at altitudes above 2000 m and partial discharge testing which is very relevant to 1500 Vdc operating voltages. Partial discharge is the gradual breakdown of microvoids in insulation at high voltage leading to degradation and eventually complete failure. Partial discharge is required to be absent during tests and necessitates particular construction of the isolation barrier in a dc-dc converter. As in all safety standards, insulation requirements depend on the system voltage, installation over-voltage (OV) category and pollution degree (PD) of the environment. For PV systems with a 1500 Vdc bus, OV II is used for the PV panel circuits with minimum impulse withstand of 6000 V. Whereas, OV III is used for the grid-connected inverter stage and requires 8000 V impulse withstand. As the installations are considered industrial grade with some environmental protection, PD 2 is generally applicable, which allows only non-conductive pollution with occasional condensation. Designing to meet standards such as IEC 62109-1 is not trivial, with many more considerations required than mentioned.

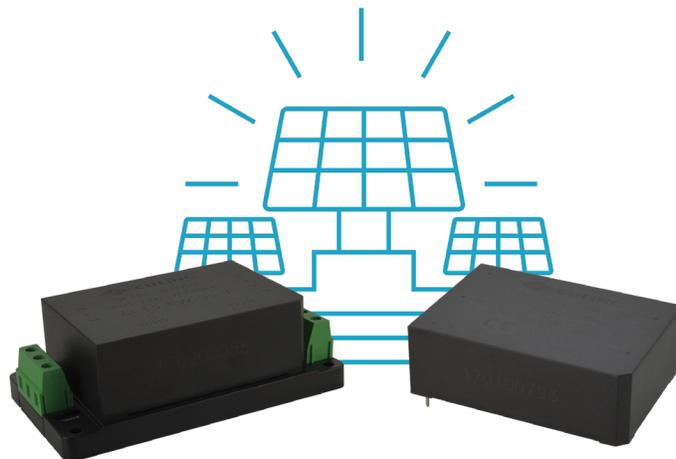
Another standard relevant to the US PV market is UL 1741, which is for the more general application of 'Distributed Energy Resources' but includes requirements for 'converters and controllers'.

Auxiliary dc-dc converters working in this environment must have specific performance. The very wide input range is difficult to achieve with standard flyback or forward converter topologies, especially with the high maximum input voltages. With variation in pulse width to regulate the output, internal peak voltages and currents can be extreme, necessitating a more complex topology that limits peak stress. Protection is key as well; the converters need to operate with frequent 'brown-outs' as the input dips below the minimum under different illumination conditions. The converter must not be damaged by this or other fault conditions that might be seen in a typical remote installation such as overloads, short circuits and over-voltages. Environmental conditions are tough as well; you really want your PV system to be in full sun, so temperatures in control cabinets are likely to be high. With the agency-specified isolation ratings presenting another challenge, dc-dc converter design for PV applications is not a minor task.

OFF-THE-SHELF SOLUTIONS

Fortunately, there are ready-made solutions available on the market to address these design challenges. For example, CUI has recently launched a range of dc-dc converters specifically designed for 1500 Vdc photovoltaic systems. The AE series includes the required 200~1500 V input with variants available at 5, 10, 15 and 40 W ratings. Available outputs are 5, 9, 12, 15 or 24 V, depending on series, and the parts are approved to EN 62109-1, the European version of IEC 62109-1, while some further meet UL 1741. The units also feature 5600 Vdc isolation up to 5000 m altitude and are encapsulated in a choice of board mount, chassis mount or DIN rail formats with an operating temperature up to 70°C with no derating.

*Figure 4:
CUI's AE series of
dc-dc converters
ranging from 5 W
to 40 W*



THE 'FIT-AND-FORGET' ROUTE TO 1500 V PV SYSTEMS

PV systems are all about efficient energy conversion up to the GW level, but require comprehensive control and monitoring to get the best performance. Auxiliary power supplies are not an insignificant part of the system and need special characteristics to withstand the high operating voltages while complying with reliability and safety standards. CUI now offers this as a 'fit-and-forget' package for PV system designers and integrators.



View CUI's ultra-wide input voltage dc-dc converters

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