JULY / AUGUST
2009

Photovoltaics World

THE MAGAZINE FOR SOLAR POWER
By Renewable Energy World Network

Can CPV be Cost-competitive? p. 12

PennWell

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Transformerless inverters maximize power, reduce system complexity

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Next-generation transformerless technology offers integrators, independent power producers (IPPs), and utilities maximum power delivery as well as reduced system complexity for the two most common types of commercial PV installations—direct inverter connections to a local grid, and utility-scale installations generating power for transmission.

Employing this new technology, direct inversion (i.e., with no transformer) onto a three-phase grid to 480VAC for North America is achieved using arrays constructed with bipolar +600 and -600VDC panel strings. Not only does this configuration offer a more efficient method of generating power, it eliminates inverter-centric transformers, associated balance-of-system (BoS) costs, as well as unnecessary wiring losses associated with monopolar configurations.

Integrators, independent power producers, and utilities can unlock new capability by combining multiple transformerless inverters directly to the grid or to medium voltage

This same technology offers integrators, IPPs, and utilities the additional benefits for large commercial or utility-scale installations. For example, a conventional 1–2MW commercial installation with tie points at the low-voltage side of the facility transformer requires two to eight inverters, each paired with a single or custom isolating transformer—whether the transformer is integrated with the inverter or not. Only a truly transformerless design allows direct facility connection without any additional transformer equipment, customization, or BoS costs. For utility-scale installations with tie points to medium-voltage transformers in the 5–12.7kV range, multiple transformerless inverters can be combined with just one, standard, medium-voltage transformer. That transformer in turn can be installed anywhere in the system—near to the inverters or close to the power lines—while complying with all NEC regulations.

This article describes a game-changing transformerless inverter architecture currently in use in commercial and utility-scale PV installations in North America. It examines how integrators and IPPs can unlock new capability by combining multiple inverters directly to the grid or with just one medium-voltage transformer. Finally, it details

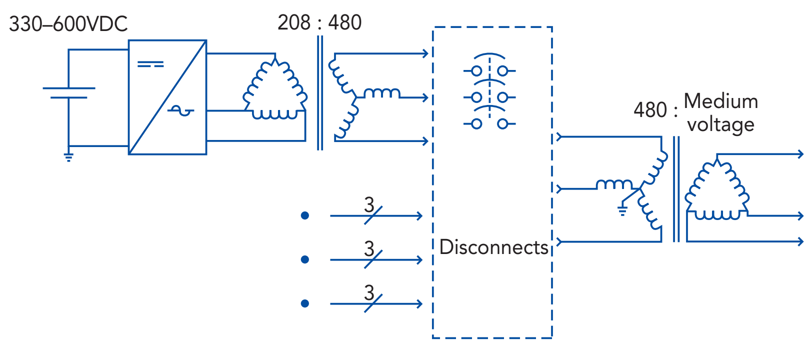

Figure 1. For commercial installations, the traditional transformer-centric unipolar system connection.

the advantages achieved in maximum power generation and reduced system complexity.

Transformerless inverter technology

Although the price of solar PV power is becoming more and more competitive, it is vitally important for the industry to continue to find ways to enhance performance, improve efficiency, and drive down costs. Evaluating the quality and performance of large capital equipment is one way to continue to make gains, and just as significant as PV modules and arrays is the performance and efficiency of inverters. In commercial PV system designs, integrators, IPPs, and utilities are beginning to choose state-of-the-art transformerless inverter technology over conventional inverter equipment to maximize power delivery and reduce system complexity. A closer look at how transformerless inverter technology is helping to change the competitive landscape—with impacts on system designs, efficiency, and BoS costs—is warranted.

A solar PV system with transformerless inverter technology generates power without any transformers between the PV modules and the 60Hz, 480V/277Y load—typically HVAC equipment, commercial fluorescent lighting, or other 480V loads. Despite some manufacturers' claims of transformerless technology, their inverters actually require an isolation transformer between the inverter and the load. Truly transformerless inverters convert and transfer power directly from the inverter to the attached load. This is made possible by using a bipolar ±600 VDC array configuration that ties to a three-phase distribution system at the facility entrance. The benefits for integrators and IPPs are improved system performance and reduced BoS costs: higher efficiency, reduced size and amount of equipment and conductor, and reduced material and labor costs.

To illustrate these advantages, let's examine the architecture of the two most common types of commercial installations—direct inverter connections to a local grid and utility-scale installations generating power for transmission.

Commercial installations

A 2MW commercial rooftop system with tie points at the low-voltage side of the facility entrance requires two to eight grid-tie PV inverters. Using conventional inverters, each must be paired with a single or custom isolating transformer—whether the transformer is integrated with the inverter or not. Consequently, power is immediately reduced, since isolating transformers are generally only 98% to 99% efficient and reduce efficiency up to two points.

Bulky and heavy, conventional inverters limit PV system design. A system architecture design employing four, 500kW inverters calls for ground-mounting the inverters simply due to the size and weight of the inverter/ transformer pairs (*Fig. 1*). Even if the isolating transformers can be separated from the inverters, the 208V output voltage and the multiple 208V windings for each inverter limits how far they can be separated due to the high current associated with 208V, 500kW inversion and the costly conductor necessary for the installation.

The question of stability when combining inverters is also of concern. Conventional inverter designs usually use undamped large delta filters that can cause unstable operation when large numbers are placed in parallel or the inverters are placed on long transmission lines. Furthermore, if the inverters are paralleled inside the same box, four smaller 125kW engines drive each 500kW inverter, making the system vulnerable to electrical interference and introducing multiple points of failure to the total PV system.

In contrast, truly transformerless inverters tie directly to a building entrance or even a 480V distribution sub-panel of sufficient size. Without an isolating transformer, an extra 1–2% of efficiency gain from the PV module power goes directly to the load, and at 500kW, that's a minimum of 5kW output for free. Plus, inverting directly into 480V (the North American standard) rather than 208V reduces AC current by more than half, thereby decreasing the cost of the wire on the AC side.

Without a transformer, the inverter is smaller in size and lighter in weight, giving integrators and IPPs much greater freedom in installation and total system design. Whereas it may be cost-prohibitive to install a conventional inverter on the rooftop of a five-story building, simply due to weight restrictions and necessary reinforcements, designers can spec a transformerless inverter on a commercial rooftop (rather than in the basement, for example) where it connects directly to a 480V sub-panel on the 5th floor. Such a design would not only eliminate five stories of expensive DC wiring, it would reduce the length and cost of AC wiring as well.

Finally, multiple inverters can be connected in parallel

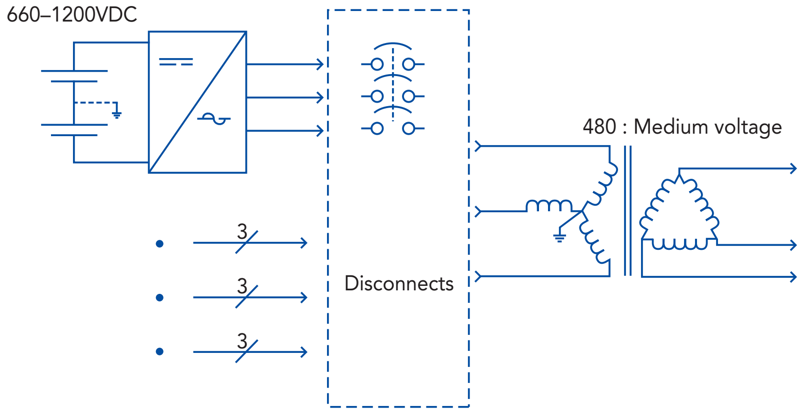

Figure 2. New, transformerless, bi-polar system connection.

In a 2MW block, one to four inverters may be placed on a single pad with a medium-voltage connection to each transformer. Medium-voltage connections are quite expensive and require an increased level of training and certification from the electrician performing the job. Larger equipment pads or utility enclosures are required. If the field has a tracker involved, separate transformers are needed to provide power to the trackers. BoS equipment, material, and installation costs quickly add up.

Conventional inverters also use an active disturbance of the utility line, such as varying VAR generation, in order to detect an islanding situation. This disturbance, when paralleled with many inverters, can produce VAR beat frequencies between all of the inverters that can shut down the field due to false trips. Multiple conventional inverters with their large delta capacitors can also create instabilities and absorb large harmonic currents.

These problems can be avoided altogether with transformerless inverter technology. Transformerless inverters can be paralleled onto a single winding of a medium-voltage transformer. Only a single, standard, medium-voltage transformer of 1000, 1500, 2000, or 2500 kVAR size is needed per cluster of inverters. This opens up a field of possibilities for site configurations. More freedom is available to place the inverters and transformer because of the lower 480V current compared to the 208V current of conventional inverters.

Approximately half the size of conventional inverters, transformerless inverters convert directly into 480V, reducing the size of real estate required, costs of transporting and lifting equipment—plus incremental equipment pads or utility enclosure construction costs—as well as the size and amount of connecting wiring (*Fig. 2*). Furthermore, a standard 480V panel board connects to the transformerless inverters and may provide power to trackers without using a separate transformer. With fewer transformers, there are fewer reactive elements in the system for the most stable operation. Plus, each inverter is autonomous and individually addressable over Ethernet,

without transformers, and the power can be used directly for stable performance (*Fig. 2*). Transformerless inverter technology uses much larger line reactors and smaller delta filter capacitance. These smaller delta filter capacitors are also damped with a series resistor, increasing the stability of the control system and reducing the interaction between paralleled inverters. A 500kW inverter with a single engine design also reduces parts count, thus increasing the reliability of the entire system.

Utility-scale installations

For utility-scale installations, the same principles apply. However, most utility-scale installations involve large, ground-mounted PV arrays with many inverters that immediately step-up to medium voltages (4160–13.8kV). Again, conventional inverters require a single isolation transformer to be paired with every inverter, forfeiting up to two points of efficiency in unnecessary losses (*Fig. 3*).

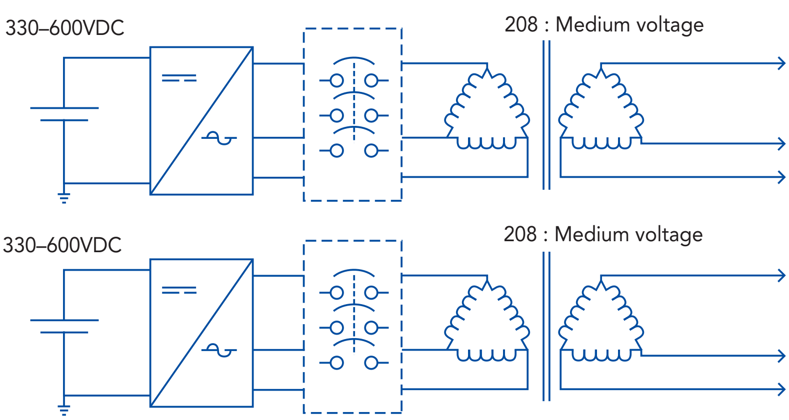

Figure 3. For utility field-connected inverters, the traditional transformer-centric unipolar system connection. Figure 2 shows the new, transformerless, bi-polar system connection.

removing any interference problems.

Add to that an entirely passive anti-islanding technique that does not disturb the utility voltage with VAR variation or place other transients on the line, and you have a recipe for highly efficient, smooth, stable power—all for a nominal installation cost, comparatively.

Transformerless inverters

Integrators, IPPs, and utilities can unlock new capability by combining multiple transformerless inverters directly to the grid or to medium-voltage. The resulting maximum power generation and higher efficiency gains will continue to push solar PV power along the alternative energy continuum to the mainstream. Meanwhile, the broad implications for integrators, IPPs, and utilities in terms of flexibility and reduced costs for new PV system designs—previously unachievable—are profound. Multiple sites currently utilize transformerless inverter technology, and the new configurations are game-changing.

Conclusion

Using transformerless inverter technology, integrators, IPPs, and utilities can maximize power delivery and reduce PV system complexity—whether tied directly to the grid in commercial installations or tied to medium voltage in utility-scale installations. Additionally, transformerless inverter technology enables smaller PV system installation sizes and reduces BoS costs—reversing the trends of late. New trends emphasize the levelized cost of electricity (LCOE), and the next-generation, transformerless inverters discussed here have the ability to lower the LCOE considerably, simply by offering direct inversion. But this is a topic for future consideration.

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