BOURNS®

Where Circuit Protection is Needed in PV Microinverters

WHITE PAPER

Introduction

Solar power is transforming electrical grids by supplementing carbon-emitting fossil fuels with a clean renewable energy source. Solar power harnesses the energy from the sun, which would have been wasted otherwise. To businesses and homeowners, solar power is the simplest change they can make to reduce their carbon footprint while also reducing outside electricity dependence. For these rooftop solar panels, the parameters and conditions under which the panels operate can vary widely. This makes organizing and managing the system a significant challenge.

This is where solar or photovoltaic (PV) inverters are implemented. These esssential components monitor and control the power output of the solar panels while also converting the DC PV output into a usable AC main voltage.

In response to the rapid growth of residential solar panels, the solar industry adapted to the demand and developed microinverters. PV microinverters are constantly exposed to harsh environmental conditions, like lightning and storms, causing overcurrent and overvoltage events. Circuit protection is critical in the reliability and operation of microinverters.

This white paper will cover the layout and required circuit protection in a microinverter system. It also provides Bourns' recommended protection component solutions that are designed to meet various needs throughout the system.

String Inverters vs. Microinverters

PV inverters must address the challenge of connecting multiple solar panels to a home's electricity grid. The two most common connection schemes are string inverters and microinverters, each with their own benefits and drawbacks.

String inverters operate using a centralized inversion system. The DC output from a group or string of solar panels is consolidated into a single DC bus, which is then fed into a multi-kilowatt inverter. This inverter is typically housed in a panel located near the building's main circuit breaker. The string inverter converts the high-voltage DC bus into AC voltage that can be supplied to the building's electrical grid. For a small to medium-sized house, one or two string inverters are usually sufficient.

Microinverters operate similarly to string inverters but in a decentralized panel-based configuration. Each microinverter, typically rated around 500 W, is installed on an individual solar panel. This allows the DC power generated by each panel to be immediately converted to AC at the source.

The AC outputs from all microinverters are then combined and fed into the buildings electrical system. Since each panel requires its own microinverter, a small or medium sized house would typically need a dozen or more microinverters.

The main advantage of microinverters lies in their flexibility and modular design. In a string inverter system, if the central inverter fails, the entire solar panel is taken offline. In contrast, with microinverters, a failure affects only the panel to which it is attached, leaving the rest of the system uncompromised. This enhances system reliability, which is especially crucial since continuous electricity is essential. Another benefit of microinverters is their modular architecture: each solar panel has its own dedicated controller and inverter. This results in a simpler expansion process for solar panel networks, along with greater control and monitoring of individual panel output, a perk exclusive to microinverters, as string inverters only manage groups of solar panels.

String Inverters vs. Microinverters (Continued)

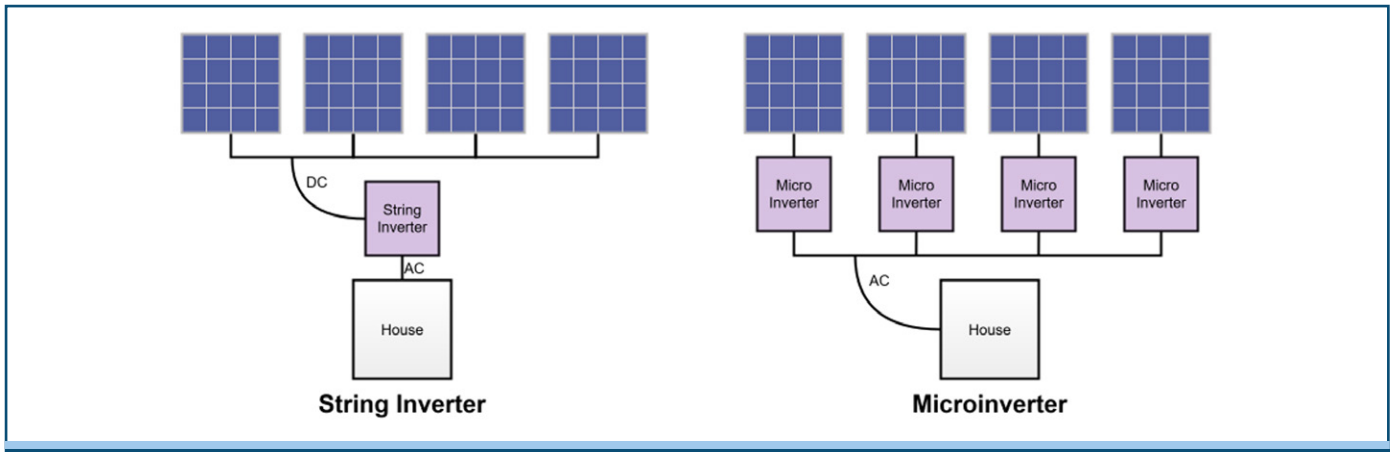

Figure 1. | *Diagram of string and microinverters*

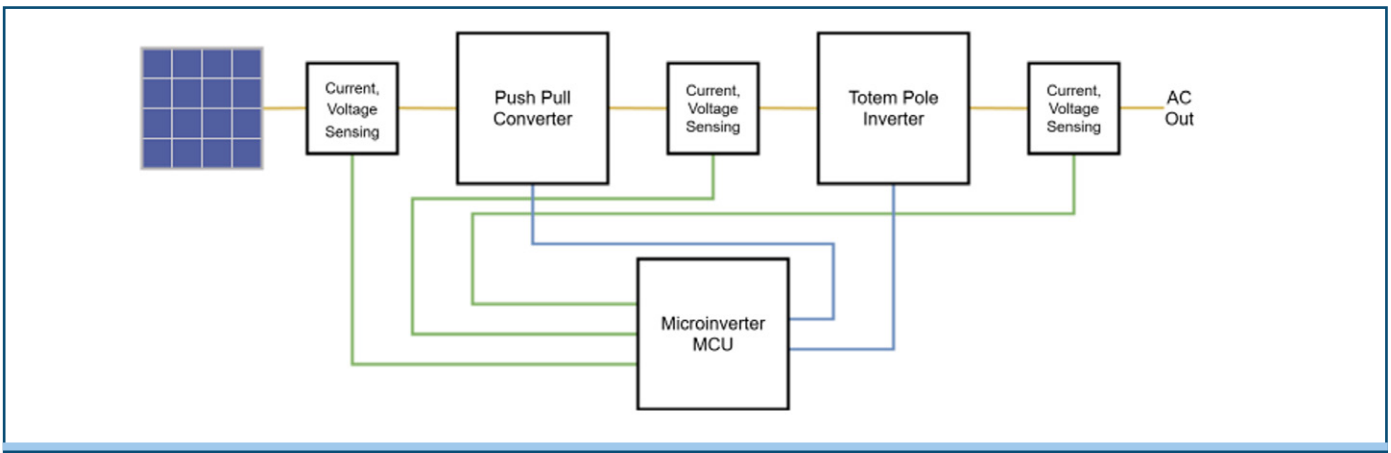

Figure 2. | *Block diagram of parts of a microinverter*

Microinverters

A microinverter consists of four equally critical components: a push pull converter, totem pole inverter, current and voltage sensing circuitry, and a feedback microcontroller.

Push-Pull Converters

The first step in conditioning the PV voltage is to step it up using a DC-DC converter. A boost or a push pull converter are the most common topologies of DC-DC converters. This white paper focuses on the push-pull converter due to its suitability for high power applications. Unlike the boost converter, the push-pull converter utilizes a center- tapped transformer. The transformer provides the primary source of voltage gain in the system, determined by the ratio between the primary and secondary windings. However, since a transformer is a type of inductor, it cannot sustain constant DC current. Under DC conditions, it will become saturated, leading to excessive current flow and potentially shorting the circuit. To avoid a steady state condition, the push-pull converter implements two switching transistors that are on opposite ends of the center tapped transformer. Whenever transistor S1 is switched on, the current flows upward through the top primary winding. This induces a higher voltage that flows downward through the bottom secondary winding, feeding the high voltage DC bus. The second transistor, S2, complements S1 in both timing and direction.

Both transistors working together has the effect that the output voltage is facing the one direction and the voltage magnitude is greater. The addition of inductors and capacitors results in a more stable output.The push pull converter features many extra benefits outside of purely DC to DC conversion. The transformer provides galvanic isolation for the system, which is critical as a microinverter directly interacts with high power and the electrical grid. Although often overlooked, diodes play a crucial role in protecting the downstream sub-circuits from unintentional negative voltages. Microcontrollers also offer adaptability and adjustability, which is possible by switching transistors. An important quality of diodes and transistors are their performance and effectiveness in fast switching applications. Bourns SiC diodes and Bourns IGBTs transistors are semiconductor devices that are proficient in a variety of applications, especially in power switching applications.

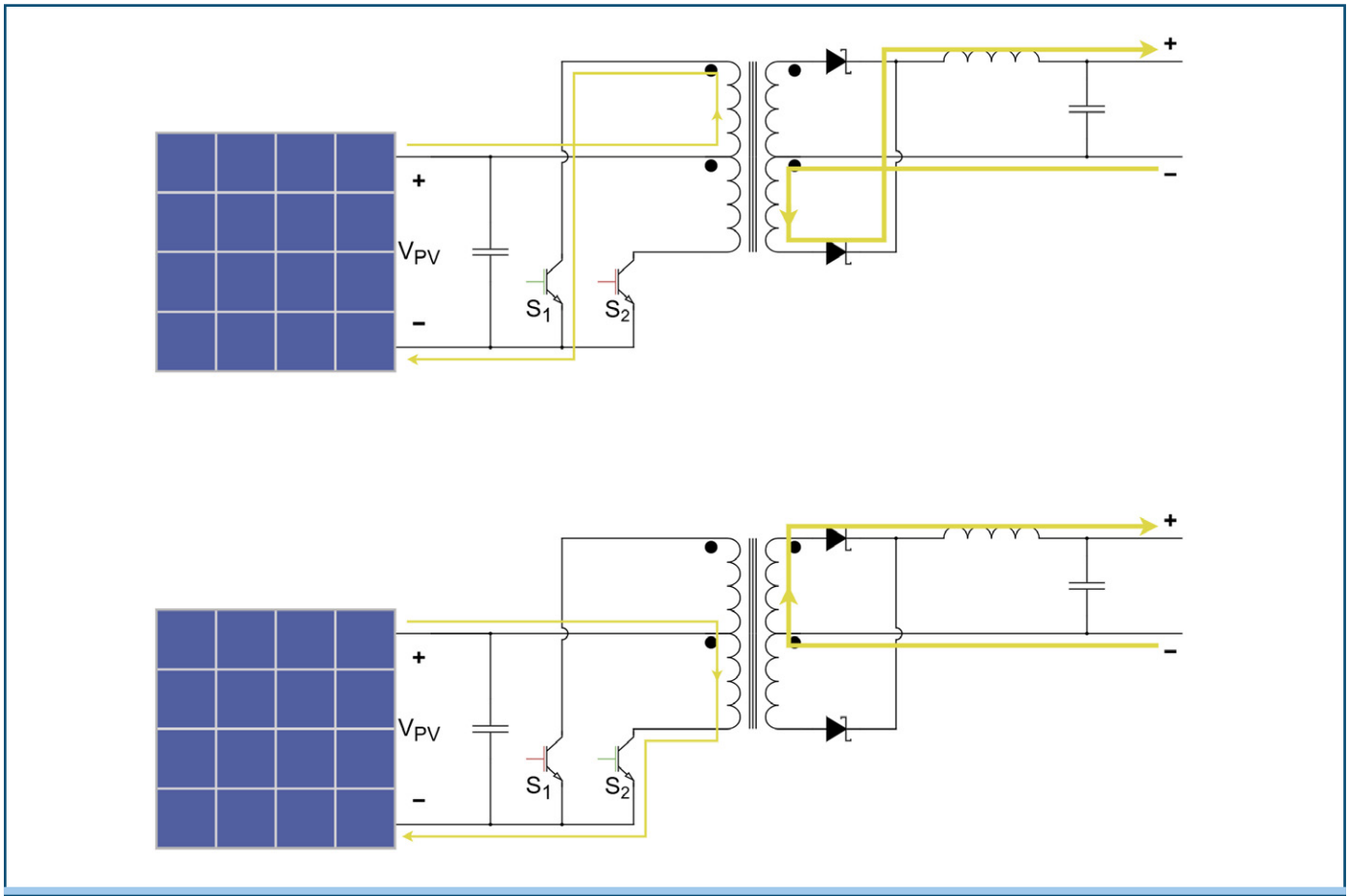

Figure 3. | *Push Pull converter, with current flow in both half cycles*

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Totem-Pole Inverters

The next stage of the microinverter involves converting DC voltage into a 60Hz AC signal while minimizing any side effects or distortion. The totem pole inverter achieves both of those goals by utilizing two pairs of switching transistors. One pair is set to a low frequency, 50 or 60 Hz, and the other is set to a high frequency, 100 kHz. In both pairs, the top and bottom transistors perform in a complementary way, allowing the AC output to be positive or a negative voltage.

The slow pair of transistors imitates the AC grid waveform allowing for cross compatibility. While on the other hand the fast pair of transistors is more concerned with improving energy efficiency. This is done by improving the power factor of the system. In total, the totem pole inverter converts the PV DC voltage into usable electricity for a building or appliance and the primary device used are high performance transistors. A popular choice of high-speed transistor is Bourns IGBT.

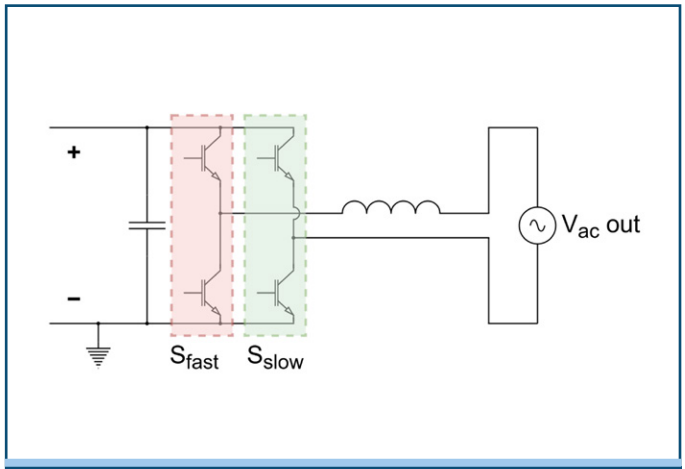

Figure 4. | *Totem-pole inverter, slow and fast pair of IGBTs*

Current and Voltage Sensing

Both the push-pull converter and the totem-pole inverter are dynamic systems, where minor and automatic adjustments are constantly being made. To facilitate these dynamic operations, the microinverter needs to know the current and voltage before and after every stage. This then requires the sensing capabilities implemented to be precise, accurate, fast, and reliable.

For current sensing and voltage sensing, Bourns recommends shunt resistors and voltage dividers. A resistor shunt is used to measure current through a wire with a voltmeter. Current is then found by measuring the voltage difference across the known resistance value and applying Ohm's Law (V = IR). Using a shunt resistor is of great importance as the solution employed needs to be capable of withstanding high-voltages, two-digit currents, featuring low tolerance and low resistance in a durable construction design. Bourns high power shunts are specially made for current sensing applications with their bare metal design.

Voltage dividers are critical layouts for measuring the voltage of a wire. They work by implementing a pair of series resistors that are connected to the power bus. The voltage between the resistors is the ratio of the resistance values ($V_{out} = V_{in} \frac{R_2}{R_1+R_2}$).

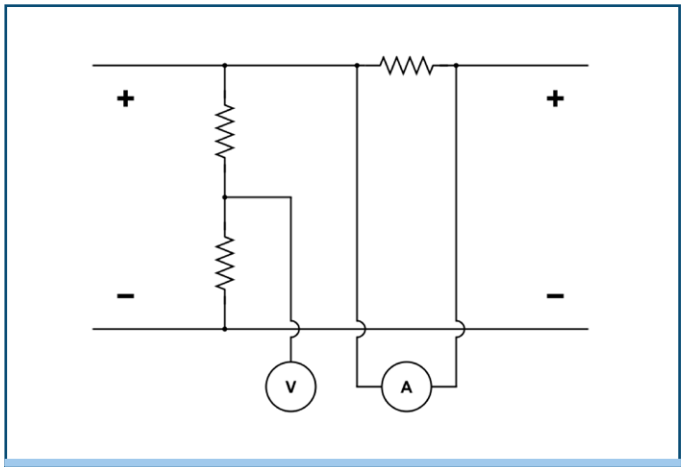

Figure 5. | *Voltage divider and shunt resistor for measuring voltage and current*

The reason designers prefer using a voltage divider to measure voltage compared to directly measuring the power bus is because the current passing through the voltmeter would be near zero, and the voltage would be a known fraction of the original voltage. This ensures that the voltage sensor is more durable and reliable with little to no impact on performance. Precision and accuracy is critical in sensing applications, and Bourns resistors are manufactrued with low tolerances and reliability.

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Circuit Protection

Microinverters face electrical threats often including overvoltage and overcurrent events from a multitude of sources. The outside environment, internal load changes, and the connected electrical grid are all potential threats. It is important to have multiple layers of circuit protection in place for solar panel microinverters. Bourns recommends implementing overvoltage and overcurrent devices for both the power bus and data lines. For the power bus of the microinverter, Bourns offers various high-power rated devices, such as Metal Oxide Varistors (MOVs) or its IsoMOV™ hybrid protectors for overvoltage protection and fuses for overcurrent protection.

- The MOV works as a clamping device, absorbing high voltages.
- Bourns® IsoMOV® hybrid protection devices, combine MOV and GDT technology in a single space-saving package. Together, they operate similarly to an MOV but leverage the low capacitance levels of the GDT, resulting in a higher performance and more reliable solution.
- Fuses are considered the most reliable solution for redundant protection as they safeguard the circuit if every other device has failed.

Data lines, such as those controlling the switching of the push-pull converter and totem-pole converter, operate under microsecond time frames where even minor variations can render the microinverter inoperable. To protect these sensitive data lines, Bourns recommends integrating Transient Voltage Suppressor (TVS) diode arrays with TBU® High-Speed Protectors (HSPs) for a reliable solution. These components feature low capacitance to handle very high-speed applications.

Bourns Component Benefits

Bourns components play a pivotal role in enhancing the performance, safety, and reliability of microinverter systems. From push-pull isolation transformers and robust IGBT transistors to precision current sensing shunts and resistors, Bourns offers advanced component solutions tailored for high-power, high-frequency applications. Bourns components are designed to meet the rigorous demands of solar energy systems, delivering fast switching capabilities and accurate sensing. Adding these components to a microinverter system are essential for optimizing energy conversion and ensuring long-term reliability. Additionally, Bourns' circuit protection solutions safeguard both power and data lines from transient threats, ensuring uninterrupted operation in diverse environmental conditions.

Conclusion

As the demand for residential solar energy continues to rise, microinverters have emerged as a critical innovation for maximizing efficiency, flexibility, and dependability in solar panel systems. Their modular design, enhanced monitoring capabilities, and fault-tolerant architecture make them an ideal solution for modern energy needs. Bourns engineers understand microinverter requirements, and are available to help guide designers in selecting the right push-pull isolation transformers, SiC diodes, IGBT transistors, precision shunt resistors, and robust circuit protection devices for these important systems. Designed to meet the demanding requirements of solar energy applications, Bourns' components provide the features that help ensure efficient energy conversion, accurate sensing, and protection against electrical transients. By leveraging Bourns' innovative technologies, microinverter systems can achieve superior operational stability and longevity, making them a dependable choice for modern residential solar installations.