

## Electrical and EMC Insulation Materials and Heat Dissipation Materials for Solar Inverters



PV inverters are the most complex part of a PV system and the most likely to fail from internal (spikes, heat, shorts) and external (temperature and humidity extremes) factors.

The photovoltaic (PV) cells in solar electric panels convert the sun's rays into direct current (DC) which goes through a solar inverter where it is changed into alternating current before it can be fed into the utility grid. A good inverter needs to deliver clean energy efficiently without overheating and shutting down.

For inverter manufacturers, efficiency and reliability are key factors. According to a 2008 Sandia National Laboratories report, 59% of all unexpected maintenance costs were due to PV inverter failures. Increasing reliability, especially with the renewed emphasis in the solar industry on warranties, may be pushing ahead of efficiency as the top PV inverter concern.

### Key Inverter Functions

The key functions for any grid-tied inverter are:

- Inversion;
- Maximum power point tracking;
- Grid disconnection;
- Integration and packaging.

In an inverter, dc power from the PV array is inverted to ac power using solid state switches, MOSFETs or IGBTs, that flip the dc power back-and-forth, turning it into ac power.

Maximum power point tracking allows the inverter to remain where the PV array will yield the maximum power. This could vary by up to 25% depending on cell temperature and sunlight intensity. PV output current can vary from zero to full array output. Inverters need to work with arrays at their lowest voltages, under load on the hottest days, and highest voltages, unloaded on the coldest days.

Inverters are required to disconnect from the grid if the ac line voltage goes above or below pre-set limits described in UL 1741 and IEEE 1547, and shut down if it does not detect the presence of the utility grid. These disconnections eliminate the chance that a PV system will send voltage or current into a disconnected utility wire or switch and endanger utility personnel.

The final inverter package can include: ac disconnect, dc disconnect, EMI/RFI filtering, transformer, cooling system, GFID circuit, LED indicators or display, communication connections, and packaging that can withstand environmental extremes.

### **PV Inverter Efficiency**

Inverter manufacturers are continuing to push efficiencies from their current 95% levels to maximum efficiencies near 99%. While gains are nearing maximum potential, increasing efficiency can translate into smaller, cheaper, and longer-lasting devices. Manufacturers and researchers are investigating low-loss inductive components for improved energy efficiencies. Innovative semiconductor devices based on silicon carbide (SiC) and gallium nitride on silicon (GaN-on-Si) are also being developed.

### **PV Inverter Reliability**

Solar power plants are becoming more of an integral part of the power base for utilities. Pressure is being put on power plant owners/managers to increase and maintain PV system reliability. PV inverters are the most complex components in the system and the most likely to fail. Internal (spikes and energy cycling) and external (temperature extremes and humidity) factors take a large potential toll on inverters.

Inverter manufacturers are always looking at new and improved designs to make inverters smaller, lighter, and more efficient. They investigate ways to reduce component count, employ hardened components that can withstand environmental extremes, and generally improve inverter reliability.

Grid-friendly inverters will also use bi-directional communications features for performance modeling and other features that make inverters “smarter”.



Identifying and using the right materials and adhesives for electrical insulation, thermal management, and EMI/EMC shielding impacts inverter efficiency and reliability.

These intelligent inverters will enhance grid stability and help utilities to integrate higher levels of PV power.

### **The Right Materials to Improve Efficiency and Reliability**

There are three key areas where identifying and using the right materials and adhesives can impact inverter efficiency, operation, and reliability:

- Electrical insulation
- Thermal management
- EMI/EMC shielding

As components become more durable, complex, and compact, choosing the appropriate electrical insulation materials in the right thickness and shape gains importance. Electrical insulation materials could include electrical grade papers, films, coated cloths, laminates and tapes for:

- Core insulation
- Barrier insulation
- Layer insulation
- Lead pads
- Magnet wire insulation
- Phase separators

As inverter manufacturers pack more electronic functionality into smaller packages, thermal management assumes a higher priority. To keep inverter temperatures within safe operating limits as more components are packed into less space, inverter manufacturers are including more heat dissipation materials that include:

- Phase change materials
- Insulating greases and pads
- Gap fillers

Engineered thermal transfer materials can offer high thermal conductivity and low thermal impedance superior to traditional thermal grease. In addition, solid thermal transfer materials allow for new designs and die-cut shapes with better gap filling. Coupled with traditional heat sinks, these new materials help to keep PV inverters cool despite internal and external heat.

Finally, new materials are also providing better EMI/RFI/EMC shielding for inverters. Today, assuring EMC compliance is difficult. As solar inverters reach high efficiencies, high voltage and fast-rising voltage spikes have unintended EMI side effects. Common EMI/RFI materials include:

- Foil tapes: relatively easy to fabricate, tapes with aluminum- and copper-foil backings eliminate the need for costly metal plating of enclosures to provide shielding properties;
- Metal-filled elastomers: suitable for shielding applications that require gap-filling and cushioning;
- Wire mesh: used for EMI gaskets, mesh materials handle heat better than foils but are also heavier and take up more space.

### **The Role of the Converter**

The right converted materials can play a key role in the manufacture of inverters. What is a “converted” material? Simply, a raw material that has been converted into finished parts for an end product.

Fabrico, a converter with experience in solar technology, offers a comprehensive selection of flexible materials provided by leading suppliers. At the outset of a project, Fabrico’s engineering teams help OEMs select materials that are best suited for electrical insulation, thermal management, and EMC shielding applications.

To get an idea of the potential value of this input, consider a situation where an OEM specifies a copper EMC material as a shielding strategy. Copper provides excellent shielding properties but is also relatively expensive. In such a case, Fabrico might determine that aluminum foil tape, which is much less costly than copper alternatives, will work as well.



A fully equipped test lab ensures that materials and adhesives meet specifications before they reach the factory floor.

In other cases, Fabrico’s engineering team might recommend concurrent testing of more and less robust shielding options. With a fully equipped test laboratory, Fabrico ensures that customer materials meet designed-in specifications before they move to the factory floor, often eliminating the need to test materials at the customer’s facility. Testing capabilities include:

- Accurate and precise part dimension measurement and verification;
- Adhesive/release liner testing to determine converting properties and high speed application characteristics;
- Material strength measured to ensure that material meets application requirements;
- Static shear testing to measure the cohesive strength of the adhesive to withstand a fixed load over time;
- Material weight measurement to determine adhesive coating weight;
- Microscopic imaging to determine differences between adhesive and material over time;
- Dielectric testing to determine material’s electrical insulation properties;
- Resistance and voltage testing to provide a complete profile of the electrical properties of an adhesive.



Fabrico provides precision die-cutting and slitting capabilities to exceedingly tight tolerances.

All test and measurement equipment is calibrated annually per ISO 17025 standards. Tests are performed to ASTM (American Society for Testing and Materials) International standards. ASTM International standards are tools for customer satisfaction for a wide range of markets including materials and adhesives testing. Typical ASTM tests performed in Fabrico's laboratory include:

- Adhesion Test Methods – 90 degree and 180 degree
  - ASTM D 3330
  - ASTM D 6265
  - PSTC tests
- Tensile Test ASTM D 828;
- Dielectric Tests ASTM D 149 and 150;
- Coat Weight Tests ASTM F2217;
- Resistance, capacitance, and voltage measurements.

Testing gives customers the option of going with a less robust (and less expensive) option if tests show that it meets the requirements of the application.

At the request of a customer, Fabrico can arrange with the material supplier to provide EMI/RFI testing services. Sometimes, such testing might show that the customer's original design provides inadequate shielding. When this happens, Fabrico's engineers might assist by recommending a foil tape to enhance the shielding.

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### About Fabrico

Fabrico's materials converting capabilities include: custom design solutions for applications that require slitting, laminating, and die-cutting. Laser die-cutting, kiss-cut, and water jet die-cutting are available depending on the application and materials being used.

With more than 30 years of materials experience, Fabrico engineers also understand the impact of a material selection on the overall manufacturing process, and design material systems that optimize production efficiency and improve overall cost-effectiveness.

### Material Partners

Fabrico has strategic relationships with world-class materials and adhesives suppliers, such as 3M, Loctite, Adhesives Research, DuPont and others, to assist its customers in selecting the best material for the intended use and to expedite materials sourcing. Whether adhesive films or liquid, all critical material properties are considered in any Fabrico project, including chemical, thermal, and moisture resistance.



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