



1 PV power plant.

2 Transformerless "Flying-Cap" PV inverter with grounded DC pole and HERIC® topology.

STRING INVERTERS AND POWER ELECTRONICS FOR GRID-CONNECTED BATTERIES

String inverters still have the highest share of annual sales among PV inverters. Their rated power ranges from a few hundred watts up to several kilowatts for multi-string types.

Because of the steadily rising share of PV in the global energy mix, grid codes are becoming more demanding. Also, due to the increasing interest in direct consumption of solar power, string inverters must be able to manage new energy flows and control storage systems. Increasing competition means they must become more efficient, more compact and better engineered to have longer service lives.

The business area Energy Efficient Power Electronics at Fraunhofer ISE has unique knowledge in this field. We are specialized in customized power electronics developments for grid-feeding and energy

storage systems using lead-acid, lithium and redox-flow batteries, fuel cells, and electrolyzers.

Lab Equipment

- 15 kWp roof-mounted PV generator
- 30 kW three-phase grid simulator
- 128 kW DC source / PV simulator
- 128 kW bidirectional DC source cell / battery simulator
- battery and super-cap banks
- high-precision power analyzers
- 110 kW roof-mounted dump load
- EMC test equipment
- burst and surge generators
- high-resolution thermography equipment
- development environments for μC , DSP and FPGA
- numerous simulation software

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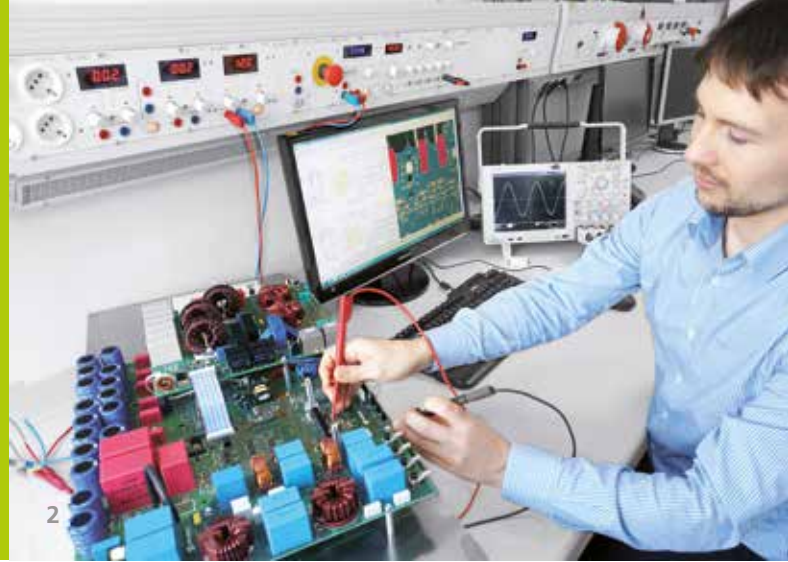
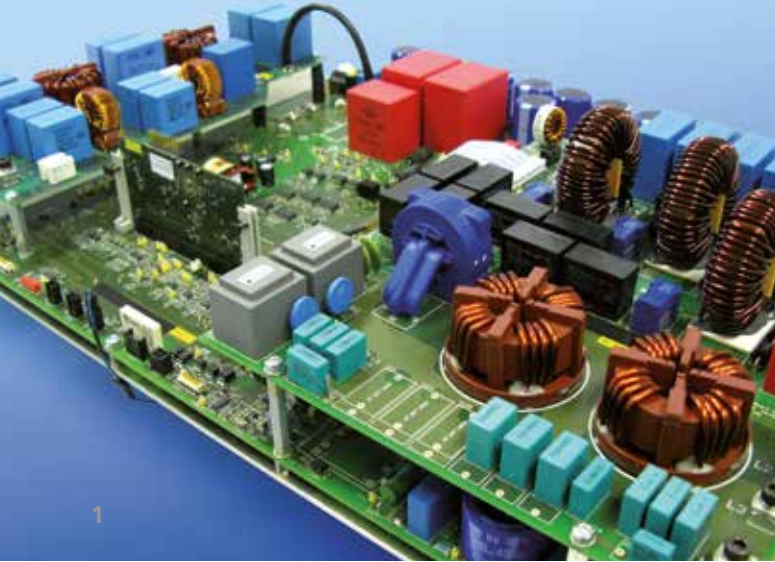
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Customized Circuit Design

For any new circuit design, customer-oriented discussions are mandatory. In-house standards are analyzed in detail and ambitious project milestones defined. Innovative ideas are discussed to create a successful product. Along with our client or partner, our experienced engineers find the optimum circuit and controllers to fulfill all technical requirements and specifications.

Power Electronics Development

Once the main circuit design is defined, hardware experts work out the technical details of the active stage, design passive components, develop a cooling system and elaborate all other electronic sub-assemblies and wiring needed for the final device. We use calculation, simulation and device-oriented design programs – such as Mathcad®, PLECS®, Flotherm® and Altium Designer – to develop high-quality designs.

Advanced Control Design

Our qualified software engineers develop professional approaches for analog and digital controls of advanced power electronics circuits. One focus lies on current and voltage controllers with the best properties for grid integration. Simulation models based on MATLAB® / Simulink® allow controllers to be tested in order to verify that they fulfill the required specifications. Customized control boards with the latest processors, extended peripheral units and particular timing concepts can be developed on demand.

Close-to-Production Prototypes

Because the quality of a design is not fully demonstrated until it works properly in practice, our qualified technicians frequently set up small series of prototypes. The development of electrical schematics and the design of complex multi-layer Printed Circuit Boards (PCB) are two of our activities. We design close-to-production prototypes to reduce the remaining development steps before our clients start serial production.

Multi-Level and Multi-Stage Circuits

Since higher conversion efficiencies and more compact devices are in great demand, taking the best from multi-level topologies is necessary. Some of these topologies – such as the “Flying-Cap”, the “Fixed Potential” and the well-known HERIC® topology – were invented and developed at Fraunhofer ISE. This high level of knowledge allows our engineers to design advanced circuits with newest semiconductors, stepping away from standard solutions. Also, when interconnecting different power conversion stages, advanced control strategies must act in concert to avoid undesirable over-sizing of hardware components.

Grid-Connected Battery Systems

More and more battery-based storage systems are coming onto the market due to the growing interest for direct consumption of solar power. These storage systems can be implemented by using a great variety of approaches.

The following are examples of important decisions:

- AC or DC coupling
- high- or low-voltage battery
- galvanic isolation or transformerless
- battery control on stack or cell level

Our experience in this area and customer-oriented discussions allows us to develop well-suited products to meet all application requests.

Consulting and Design Optimization

Besides new developments, we also provide knowledge and perform practical analysis to improve existing designs. Our main consulting activities concern MPPT algorithms, digital controllers, efficiency measurement and improvement, thermal concepts and power electronics designs.

1 *3-phase and 3-level multi-string PV inverter with dual-booster.*

2 *Measurement and optimization of an in-house 3-phase inverter.*