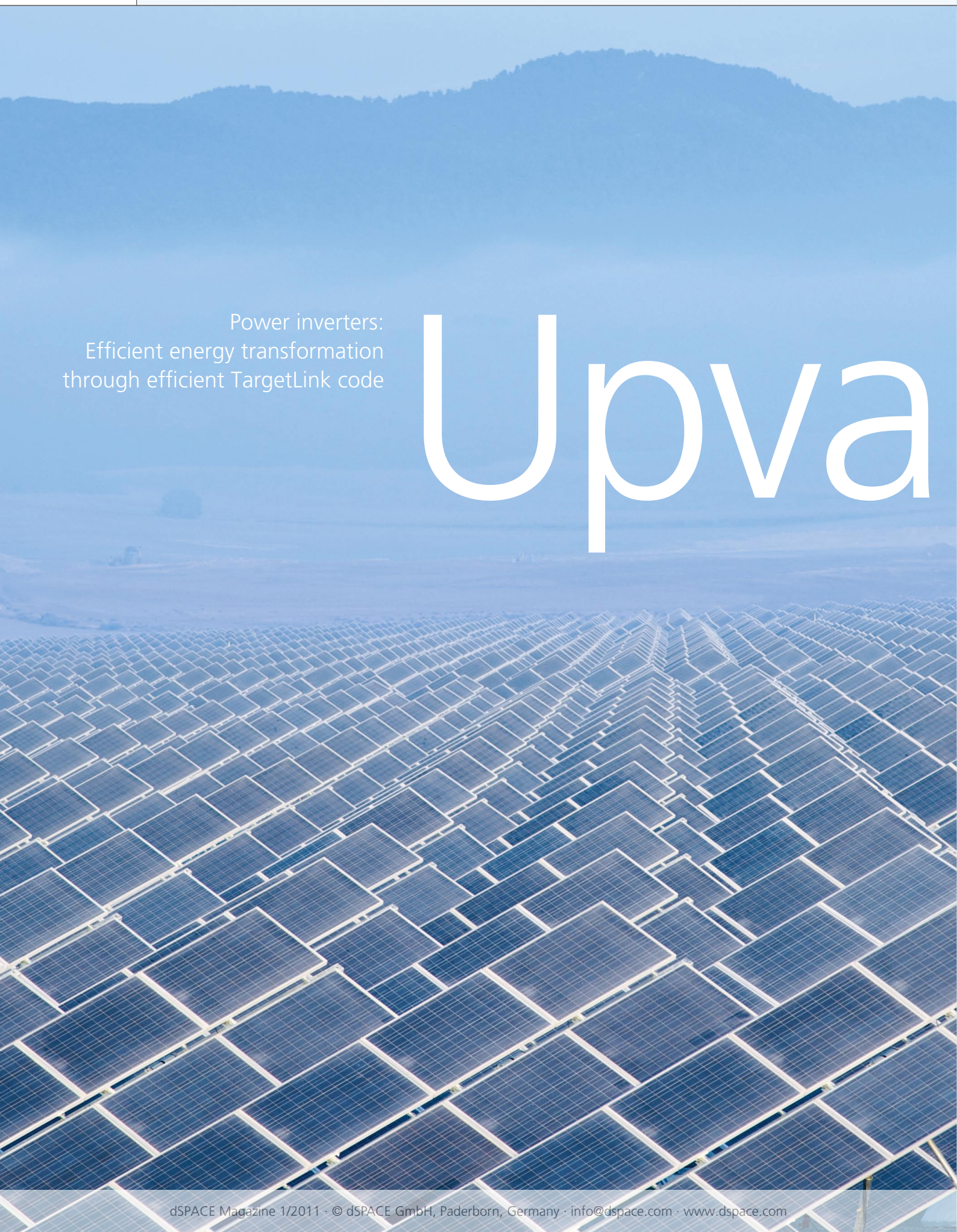
Power inverters:
Efficient energy transformation
through efficient TargetLink code

Upva



lue Energy

Every day, the amount of energy delivered by the sun is 15,000 times the current energy consumption worldwide. To exploit this natural energy source, solar energy has to be transformed into electrical energy. That's where Santerno's inverters are making a big impact.

Solar fields are made more efficient by intelligent controllers.

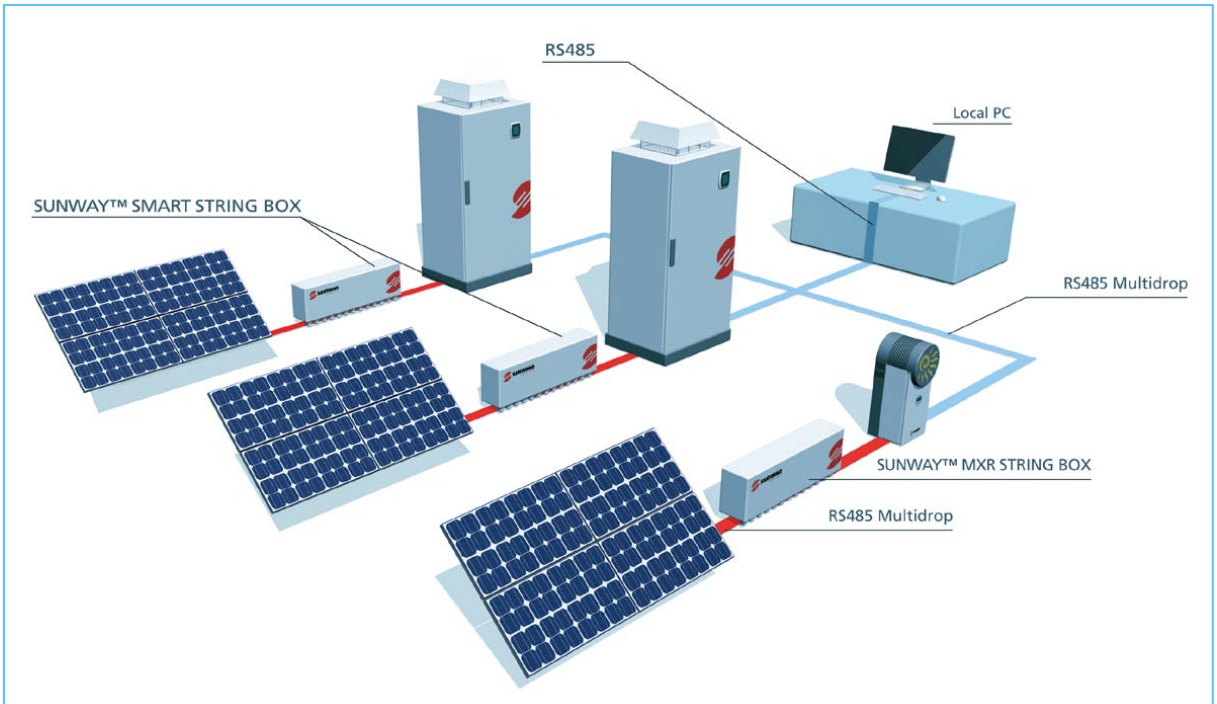
Inverters and Their Application Fields

Controlling industrial devices, solar fields, wind turbines and hybrid drives means controlling electric drives and handling high voltages and currents. A key part of the job is to convert direct current (DC) to alternating current (AC); this is done by a device called an inverter. A modern inverter can be described as a controller plus power stage electronics. For the application fields where Santerno's products are used (see below), controllers have to be able to handle various hard real-time requirements and complex tasks depending on the application.

- *Solar Fields*

  A photovoltaic (PV) field has to be controlled in terms of its optimal working point and efficient energy conversion. This is done by maximum power point tracking algorithms (MPPT) that find the best working point on the PV field, which varies throughout the day and in different weather conditions. The inverter DC link voltage has to be regulated to achieve efficient energy conversion, and the electrical current fed into the grid has to be regulated too. To meet certification standards, which also vary from country to country, several diagnostic and safety control functions have to be modeled to ensure a sufficient level of efficiency, total harmonic distortion (THD) and safety.

Setup of a solar field with inverters and control station.



"When we use TargetLink, our power inverter mass production starts on time and meets our high quality standards."

Fabio Gianstefani, Santerno

- *Wind Turbines*
  Harnessing wind energy involves controlling the wind mill for optimal orientation, speed and safety conditions. The principles of DC link regulation and grid-injected current regulation are generally the same as for the solar applications.

- *Industrial Automation*
  The enormous dynamics, high precision and accurate synchronization of modern drives and motion controls all need to be controlled. A typical example is a three-phase AC motor control by field-oriented control algorithms (FOC), vector torque control algorithms (VTC), and voltage on frequency (V/f) algorithms.

Controller Software Structure for the Inverters

The software for the "inverter system" can be functionally divided into an application layer and the platform software, which consists of a hardware abstraction layer (HAL), drivers, and services. Since services such as communication, diagnostics and calibration management and the hard real-time constraints are more or less identical in all the products, the platform software is the same for all controllers. Each controller only needs to be configured individually regarding real-time configurations, HAL mappings and service configurations to take specifics of the individual product into account. The cross-platform characteristic ensures better modularity and a shorter time to market for newer products. The application layer controls a physical plant such as a PV plant, a wind turbine, or a vehicle system and is developed individually for each product. The application layer can be further divided into subsystems such as the inverter layer and the application control layer, and is developed with dSPACE TargetLink®.

Controller Software Development Process

The application layer is suited for model-based development.
The tool chain at Santerno is based on MATLAB®/Simulink®/Stateflow® for model-based design and TargetLink for design, automatic production code generation and module testing. This tool chain is used in two different ways:

- Refinements of existing controllers are often developed with TargetLink, which is used to generate code for the additional functionality that is afterwards integrated with the controller's legacy code. These implementations are in floating-point arithmetic.
- New controller developments are carried out exclusively using the model-based approach with automatic production code generation. This means that the complete application layer is generated automatically with TargetLink. The size of the control software is typically about 15,000-20,000 lines of code. The most recent projects are developed in fixed-point arithmetic.

Challenges for Controller Development

On the whole, there were two major challenges that had to be mastered for controller development. The first was optimization: because the controller software runs on a task synchronized with the bridge PWM carrier, for example 11 kHz, its periodicity is lower than 100 microseconds. These imposed execution time requirements could be handled due to TargetLink's code efficiency in combination with using

In Brief

The exploitation of natural energy sources requires efficient electrical devices. Part of the job is using inverters to convert direct current (DC) to alternating current (AC). Santerno's inverters are equipped with controllers that ensure the greatest possible efficiency. Santerno has set up a development process that uses model-based design and automatic code generation for all controllers in the solar and wind energy application fields as well as in industrial automation. The experience from many production projects is that the benefits of using the dSPACE TargetLink code generator helped the company to meet its high time-to-market and quality objectives. The development department therefore aims to extend this approach to all new product developments.

The SUNWAY™ TG 600V and the SUNWAY M are examples of the inverter product line-up, equipped with control software generated by TargetLink.

modeling guidelines to optimize the CPU usage that runs at 72 Mhz. The second challenge was the scaling technique: because the production code has to control different power electronic sizes, where the maximum currents and voltages may vary a lot, a worst-case scaling approach was not affordable, so all the electrical current and voltage magnitudes had to be normalized to the range of [-1…1] by means of division by the sensor/actuator maximum.

Experience Gained

Model-based design and automatic production code generation have proven to be a reliable and convincing method for developing control software. In particular, the testing, traceability and documentation in TargetLink's development approach have turned out to be indispensable benefits for an efficient development process as they are decisive for high productivity and good quality:

- *Quick Back-to-Back Testing*
  Executing the automatically generated code on the host PC in a software-in-the-loop test allows fewer and faster iterations and ensures high quality code once it is integrated on the real target for the first time. Software-in-the-loop simulations also help greatly in properly scaling floating-point models for fixed-point implementations. The goal in the future will be to further increase the test coverage before the real integration of the product.

- *Proper Traceability*
  Teamwork in development benefits from easy-to-understand models, which are basically a part of the specification, and good code readability, which is important during code reviews. The complete traceability between the model and the C code turned out to be especially useful for improving code maintenance.

- *Automatic Documentation*
  Another time saver is the automatically generated documentation in HTML or PDF formats. The model serves as an executable specification and the automatically generated

The solar field at Fuente Alamo, Spain, delivers up to 26 MW energy using inverters from Santerno.

documentation of model and code can be extracted and integrated in specification and design documents as part of the documentation process.

Conclusions and Outlook

Many production projects have already been successfully completed at Santerno. During all of them, the time-to-market, performance and high quality objectives of the company were met. The goal of the development department is therefore to extend the model-based approach to all new product developments. In brief, the goal is to have more and more software automatically generated and meeting the stringent efficiency and quality requirements for Santerno's products. Improving the development process based on the selected tools is one of the constant challenges. One of the reasons to choose TargetLink is that certification of the code for solar inverters (both the platform and the application layer) is likely to be needed in some countries in the future, for example according to the ANSI/UL1998 standard in the USA. Using a model-based approach with TargetLink will help meet those requirements. ■

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