Using Spartan Technology to Support Development of Green Energy

The Xilinx Spartan-3A FPGA augments control algorithm implementation for a multiterminal DRI power inverter.

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Product development for industrial applications involves extensive research and preparation in an environment of rolling deadlines and ever-evolving product specifications. While time-to-market for this sector may not be as short as it is for consumer electronics, products must ship quickly and with as many essential functions, features and potential hooks for the next generation as possible. Companies vie to be industry leaders in their respective competitive arenas—especially in new markets such as green power, which in their infancy and without defined leaders require pioneers to design, develop and deliver new products. Success depends not only on an inspired, dedicated team of engineers, advanced computing technology and new materials, but also on angel investors or government agencies to provide grants for promising approaches to improved energy generation, distribution, monitoring, metering and consumption.

In the fall of 2011, engineers from Princeton Power Systems (PPS), a New Jersey-based manufacturer of advanced power-conversion products and alternative-energy systems, demonstrated their latest green power product. This demand response inverter (DRI) was the result of a three-year collaboration between PPS, the United States Department of Energy and Sandia National Laboratories' Solar Energy Grid Integration Systems (SEGIS).

The resulting multiterminal DRI (Figure 1) is uniquely flexible to be more reliable, more efficient and more cost-effective than currently available inverters. Equipped with multiple AC and DC terminals, the DRI can route power to the grid, a microgrid, DC energy storage or dynamic loads. Programmable power curves and charge profiles enhance control for generators, loads and batteries, ensuring greater efficiency. And the use of advanced high-capacity long-lifespan switches maximizes reliability.

Princeton Power Systems showcased features of the DRI that improve electrical-grid interconnectivity and efficiency, enhance the performance of renewable energy systems and allow for better integration of electric vehicles and distributed power generation. The DRI was part of the company's "An Island in the Sun" microgrid demonstration (Figure 2), which detailed key advancements in clean technology and manufacturing, including a 200-kilowatt solar array and lithium-ion battery system.

A microgrid can operate independently of a major utility grid to supply reliable, low-carbon-emission energy. PPS' DRI is compatible with AC generators such as diesel or gas, and with photovoltaic (PV) or wind inputs. A small community using a DRI is less dependent on the grid and can reduce its carbon footprint and utility costs. The DRI can also provide grid services, PV with storage and charging for electric vehicles.

XILINX SPARTAN TECHNOLOGY

To meet the demands of industrial product design, companies like Princeton Power Systems leverage flexible development vehicles such as Xilinx's Targeted Design Platforms (TDPs), with their rich ecosystem of design services support. In this case, however, the engineering team faced an initial challenge of determining how to expand the inputs and outputs of the DRI system's digital signal processor, and how to implement control and communication interfaces that functioned in parallel. PDS Consulting

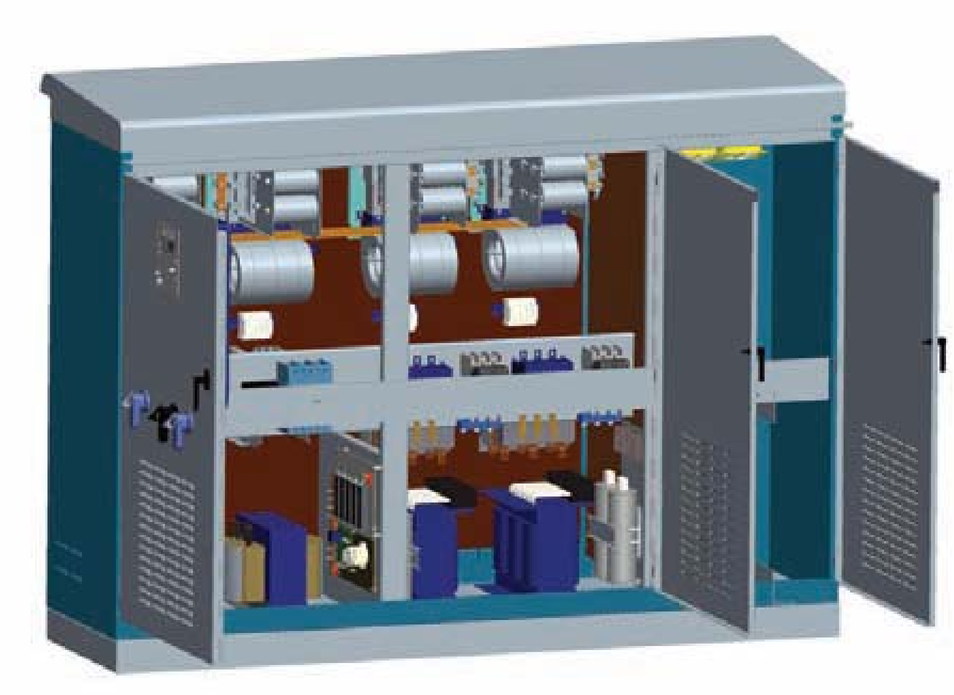

Figure 1 – The flexibility in Princeton Power Systems' demand response inverter comes from FPGAs.

Figure 2 – Princeton Power's flexible, multiterminal DRI is here configured for an electrical microgrid.

offers design services in programmable digital systems for a variety of markets including aerospace and defense, broadcast, industrial, scientific and medical. The firm supported work on the project as a member of Xilinx's Alliance Program.

The PDS Consulting team provided on-site, hands-on system debug and PCB bring-up, as well as off-site RTL and IP design services. We also advised Princeton Power Systems developers on how to implement the system control interface for their green power control algorithm. In the end, engineers chose a Xilinx® Spartan® XC3SD3400A FPGA married to a DSP as a prime system control component (Figure 3).

The Spartan-3A FPGA, with its extensive SelectIO™ capabilities, offered flexibility in implementation, particularly for trigger signals and ADC input channels. Xilinx's Spartan-3A family is a superior alternative to mask-programmed ASICs because these FPGAs permit design upgrades in the field and avoid the high initial cost, lengthy development cycles and inherent inflexibility of conventional ASICs. The integrated technology afforded by the Spartan-3A made the implementation of Princeton Power Systems' patented control algorithm for green power conversion a possibility.

It took more than 300 I/Os to implement the DRI system interface, which enabled access to 8 Mbytes of flash, a 256-Mbit SDRAM and USB/RS-232 at >900 kbits/second. In addition, the team also utilized the generous amount of fast, distributed 32-bit dual-port RAM inherent to the Spartan architecture. The configurable logic block (CLB) lookup tables used as dual-port RAMs enabled the efficient local storage of new energy waveform samples that the ADCs supplied, while the DSP read the previous samples and a PicoBlaze™ embedded processor analyzed new values from the second port concurrently.

THE BENEFITS OF XILINX FPGAS

Princeton Power Systems' algorithms required extensive calculations that can only be accomplished by floating-point DSPs, which traditionally do not have the same features as FPGAs. Some of the features of Xilinx FPGAs that particularly suited the PPS project included multivoltage, multistandard SelectIO I/O pins; configurable logic blocks; block RAM; and memory interfaces that can implement a large number of programmable trigger signals. These signals generate and execute pulse trains that trigger power electronic switches like IGBTs and control a large number of fast ADC channels to read important system measurements on every pulse or custom high-speed serial interfaces.

FPGAs not only allowed Princeton Power Systems to design and implement custom peripherals that matched its specific requirements, but also provided additional computational resources for the processing of input values, which otherwise would have to be done by the DSP. The Spartan-3 FPGA-based design completes several processes: It accomplishes system error checking using the values read from ADCs connected to the DSP. It implements timer-driven activities like reading ADCs precisely when necessary. And it does an averaging of ADC values.

Without the FPGA, some of these functional requirements would have been impossible to implement. Other functionalities would have required more components on the DRI's control board or a significantly more complex software architecture. The PPS team knew it was crucial to avoid the latter, since the control board acts as the heart of the DRI system.

"While an increasing number of DSPs now offer peripherals that were previously absent, the importance of having an FPGA still remains," said Frank Hoffmann, the R&D manager at Princeton Power Systems. "With each new generation, the amount of computational resources inside the FPGA increases—for example, from a Spartan-3 to a Spartan-6—and it has now become possible to outsource more computational work to the FPGA. And this could mean running our complex control algorithms faster and therefore improving the quality of a generated output like the one in the DRI."

THE BOTTOM LINE

While the technical benefits of using an FPGA are clear (quick prototyping, flexible architecture, advanced support tools like Xilinx's ChipScope™ Integrated Logic Analyzer for quick in-system debug), the decision has also affected Princeton Power Systems' bottom line.

"Using an FPGA has made development much faster, reducing R&D expenses and time-to-market for new and innovative alternative-energy systems," said executive vice president Darren Hammell. "The programming environment was easy to use and enabled us to rapidly develop and test our innovative software. This enabled us to complete the prototype for the demonstration much quicker than otherwise would have been possible." The product is now shipping, and PPS has added two new customers: BMW and SuperPlug have included a DRI in new power system designs.

In fields like green power technology, engineers face new challenges, including determining how to optimize algorithm implementation while retaining necessary functionality. With the right tools, technology and team, enhancements in this field lie just within reach.

For more information on Princeton Power's multiterminal DRI, please visit *http://www.princetonpower.com/prod_demand.shtml.*

You can reach PDS Consulting at *sales@pds-consulting.com.*

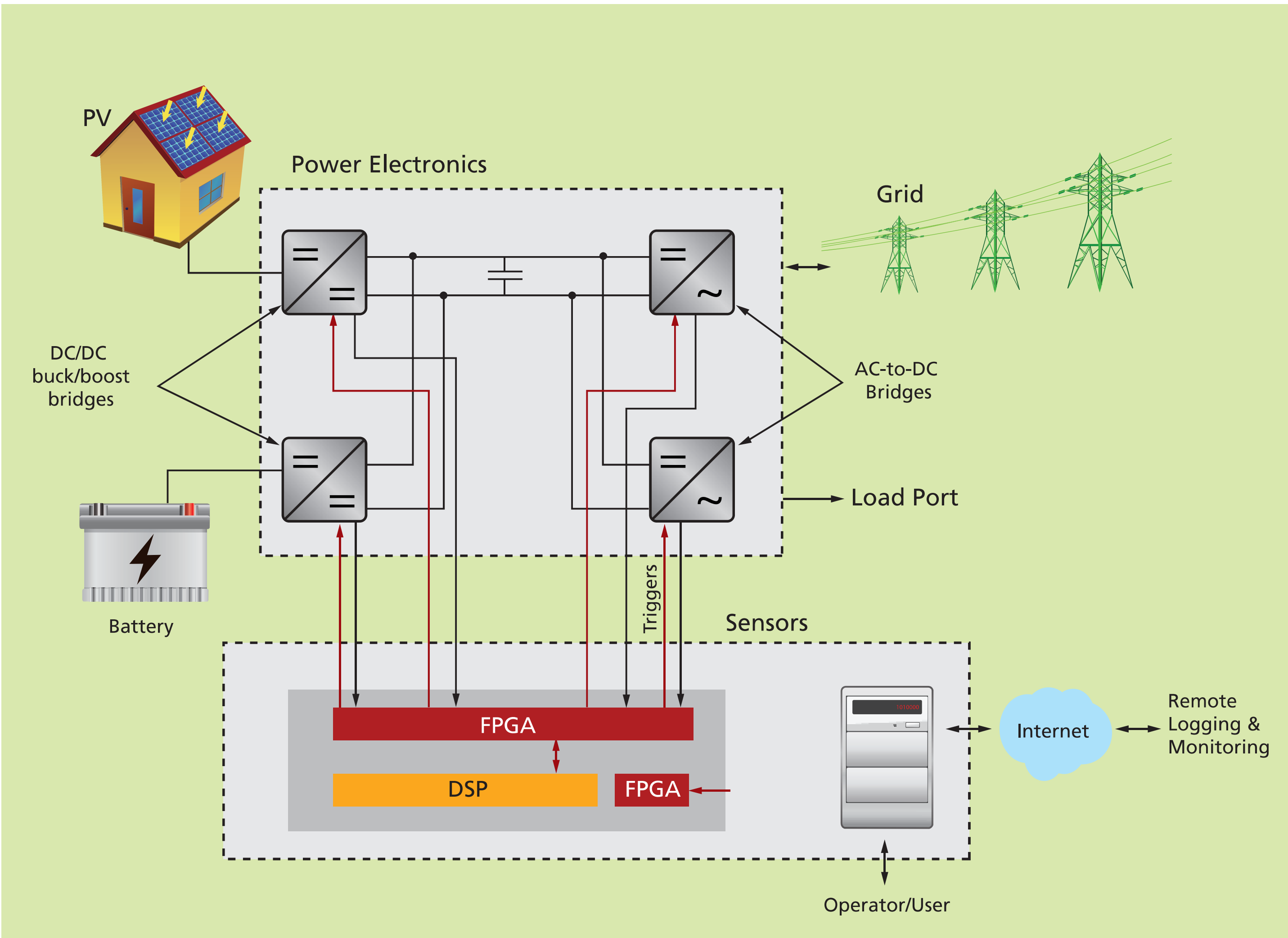

Figure 3 – Engineers chose a Spartan-3A FPGA, with its extensive SelectIO capabilities, as the main system peripheral.