Independent Testing

Inverter-in-the-Loop testing for solar energy plants

To conduct product tests, the makers of photovoltaic systems would rather not have to wait for the sun. For its customer Bosch Power Tec GmbH, ETAS has created a Hardware-in-the-Loop (HiL) testing system that stimulates the solar inverter software without requiring actual voltage or current inputs.

The work performed by photovoltaic systems, also known as PV or solar panel installations, goes beyond the mere production of electrical power. In order to feed their power output into the power grid, the inverters need to convert their direct current (DC) output to single or three-phase alternating current (AC) with a frequency of between 47.5 and 51.5 Hz.

To bring inverters of this kind to market, extensive tests ensuring product safety and addressing software functionality are required. This is where the manufacturers encounter their first problem: To run the required product tests, they have to wait for a sunny day. Also, for cost and safety reasons, they would rather forgo the use of real voltage and current inputs. It was exactly this wish that ETAS has granted Bosch Power Tec GmbH.

More precisely, the project involved function testing of the controller software on both the module and the network or power grid side. While a controller communicates with the power electronics and thus coordinates the conversion of DC to grid-conformant AC, it also requires a second controller to supply a permanent stream of data in order to properly perform the conversion. Both ECUs are permanently connected via a bus system.

In preparation for the tests, Bosch Power Tec has connected the power electronics controller to a simulated periphery. "On both the DC and AC sides," explains Liliane Gasse, Test Manager at Bosch Power Tec GmbH, "the sensors of the HiL system were supplied with actual values from a model that we had developed in-house." Gasse points out "This involved the particular challenge of measuring the pulse-width modulated (PWM) signals for controlling the power electronics at its high frequency."

Their period intervals are typically in the lower two-digit kilohertz range, which is less than 100 µs. Therefore, the remaining intervals have to be used for capturing, calculating, and transferring the data to the ECU in sync with the PWM timing with the controllers synchronized via the data bus. In sync with its timing, the power electronics controller queries data from the second controller, whose function was simulated by the HiL system for the purpose of these tests.

For obvious reasons, the HiL system must ensure that the required data are always available at the right point in time. "Needless to say," explains Henrik Liebau, Senior Manager at ETAS responsible for test system development. "When it comes to these speeds, the function must never be affected by jitter."

In order to run in-the-loop tests of the solar inverters, engineers relied on established ETAS technology from the automotive area. "Our core focus was on the highly dynamic ES5340 Electric Drive Simulation Board," he recalls. The fact is that with its Field Programmable Gate Array (FPGA), this board not only comes with the necessary digital inputs for measuring the PWM signals, but also enables the ETAS team to tailor the measurement and communications technology to the testing requirements.

"In a nutshell," adds Liebau, "the system is configured in the same way as our HiL systems for motor inverters."

The measurement data output by the FPGA board is transferred to the main memory of the Real-Time PC (RTPC), where it is calculated before the second FPGA board transmits the results via the data bus. The connection via PCI express ensures the necessary transfer speed.

The system closes the loop within half a PWM cycle, i.e., within less than a twenty-thousandth of a second. To achieve this speed, the team needed to overcome a few challenges. According to Liebau, help came from the intelligence of the FPGA boards: "We did not need to worry about the evaluation of time stamps nor the timing of the data transfer via the bus." As Liebau sees it, a major contributor to the success of the project was the close and confidential cooperation with Power Tec as a customer who, in addition to allowing access to its simulation models, also granted deep insights into its PV systems.

The HiL system was deployed in 2012 and since then the Bosch colleagues in Böblingen live happily ever after, independent of sun, voltage, and current.