Semikron estimates that its components can be found in every second wind turbine worldwide.

Of Mills and Modules

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Power electronics specialist Semikron develops and manufactures key components for inverters. The Nuremberg-based company’s new sinter technology is to help further boost market shares.

Rainer Weiss does not beat about the bush. Taking visitors on a tour of Nuremberg-based Semikron International, the applications engineer’s first stop is a series of power semiconductors. On the example of power modules, Mr. Weiss explains how semiconductors work and the biggest challenge facing electronics in wind power applications. “A 3 MW wind power unit has six of these modules,” he explains. “Each takes up 500 kW of output, with around 20 kW of losses. A heating system in an average family home, in comparison, has an output of 17 kW.” Each chip is 8 x 8 mm in size, and an inverter has 600 chips. “Per chip this might amount to just 35 W in losses,” continues Mr. Weiss. “The problem, however, is removing these losses.” Our development engineers therefore strive to reduce losses to a minimum and transfer the heat to the heat sink as best as possible.

For more than 20 years now, Semikron has been developing and manufacturing power modules for use in inverters, the main requirements being to make modules that are as powerful as possible with a minimum of losses. One of the main reasons for the company’s success is the fact that the silicon chips in the inverters are no longer soldered but cold welded. According to Semikron, its components can be found in 57 GW of installed wind power. This equates to every second wind turbine in operation around the world.

Family company by tradition

In the years 1949/50 Friedrich Fritz Josef Martin established an export trading company under the name of Export Contor. In 1951 he launched the company Omikron, which was later to become Semikron. In this and the following decade, the company began to develop selenium and silicon rectifier technology for the then emerging power electronics market. And so the story began.

Today, the Semikron Group, which is still in the hands of the Martin and Heilbronner families, has 35 affiliated companies. The company has production sites in Brazil, China, Germany, France, India, Italy, Korea, Slovakia, South Africa and the USA. A staff of 3,600 (1,500 of whom are in Nuremberg) work on the development, production and distribution of a wide range of power semiconductor products. The product range includes chips, discrete semiconductors, transistor, diode and thyristor modules, power electronic assemblies and systems. With a market share of 30%, Semikron considers itself a global leader in the area of diode and thyristor semiconductor modules. Here, the company

refers to the study “The global power semiconductor market 2010” conducted by IMS-Research, a market research institute for the electronics industry.

Products for railroad applications

In the early 1990s, wind power plant operators stared to move away from uncontrolled to inverter-controlled plants, recalls Arendt Wintrich. Like Mr. Weiss, Mr. Wintrich is an applications engineer and recently became head of the simulations department at Semikron. “We were fortunate to hit the market with the right product at the right time”. Semikron had long since been producing components for use in high-power areas such as railway applications where sensors and protective devices, as well as current and voltage have to meet comparably high requirements. Likewise in terms of power and environmental impacts such as humidity, moisture and cold, our modules seemed ideally suited to the new application: this was the module development engineers had been looking for,” explains Mr. Wintrich today.

The Semikron power module that went under the name Skiip (Semikron integrated intelligent Power) was further developed for wind power applications. The second generation Skiip 2 started to find its way into the wind power sector. The breakthrough did not come, however, until the development of the 3rd generation in 2003 and 2004. This is when large-scale production began, Mr. Wintrich recalls.

Semikron power modules are used in the inverters in wind turbines, where they are integrated either in the nacelle or the tower base. Semikron also makes Miniskiip modules for the pitch motor in the blades and modules for the primary drive. A Skiip module comprises heat sink, IGBT chips, IGBT driver, sensors and protective functions. The Semikron range also includes complete system solutions. A Skiip stack, which is the same size as a wardrobe, contains the entire power electronics of a system.

“Most customers want our Skiip module,” says Mr. Wintrich. “We are the main supplier of six of the ten biggest manufacturers worldwide,” explains Mr. Wintrich. Semikron supplies either directly to wind power unit operators or to the subcontractors, i.e. to the manufacturers of inverters, for example. And this not only applies to the wind power sector, but to the photovoltaic industry, too. What we don’t want to do is to produce inverters ourselves, explains Rainer Weiss: “We don’t want to be in competition with our customers.”

Solder as a weak point

“When we started making IGBT modules for wind turbines in the early 1990s, we quickly realised that the solder was the crux in component lifetime,” reports Weiss, who prefers to call wind power units simply “mills”. In power modules, the chip lies on a copper substrate. This in turn is connected with a ceramic plate. Beneath the ceramic substrate is the heat sink. The chips are soldered onto the copper substrate in state-of-the-art processes. According to Mr. Weiss, the high temperature differences in the materials are the reason why the solder can be identified as a “knockout” criterion in power modules.

In the 1990s Semikron developed pressure contact technology that was to combat this weak point. Here, the ceramic substrate (DCB), a ceramic substrate assembled with semiconductor chips, is pressed directly and without the use of solder onto the heat sink, rendering the base plate superfluous and meaning that fewer solder layers were needed in the module. “This reduces the thermo-mechanical stresses in the module,” explains Mr. Weiss.

“We have put 20 years of experience into this new technology, says applications engineer Rainer Weiss.

Two years ago, Semikron launched the fourth generation of Skiip modules. According to Semikron, Skiip 4 boasts 33% more power than its predecessor. A further merit of the 4th generation Skiip modules is the use of a new sintering process developed in-house. In the first Skiip generations, Semikron had eliminated one of two solder layers in the module. In the latest generation, the second solder layer between chip and ceramic substrate was also removed. The IGBT chips, diodes and temperature sensors are now sintered directly onto the ceramic substrate instead.

Arendt Wintrich, Head of simulations department at Semikron: “We were fortunate to hit the market with the right product at the right time”.

In the new sinter process, extreme pressure is applied to “press” the chip onto the copper substrate. “We’re talking tons here,” says Mr. Weiss, describing the pressure applied in this process. As a result, no solder layers are needed and the different coefficients of thermal expansion cause virtually no material fatigue whatsoever. “We have put 20 years of experience into this technology,” says Mr. Weiss, who is convinced that the new sinter process can deliver on its promises. “Others have sneered at us about this, yet now they’re trying to copy us." Mr Weiss and Mr Wintrich both assume that the fourth generation will be used in new systems and installations. Retrofitting existing systems is far too complex, both men agree.

The Skiip 4 module has a unique feature: sinter technology developed in-house which uses extremely high pressure to "press" the chip onto the copper substrate.

**Semikron production at Nuremberg plant:
Manual processes are monitored by computers.**

Worst-case-scenario test

The more electronics a system has, the more susceptible the system is to errors. In order to reduce errors caused by integrated electronics to a minimum, Semikron modules, chips, drivers and systems undergo extensive function and load tests. Semikron staff test the operational function, protective functions and load capability of power modules in six test chambers located at the Nuremberg plant. Since late 2008, Semikron customers have been able to opt for a burn-in test, too.

Here, the modules are subjected to maximum voltage and current ratings: the modules are operated under worst-case-scenario conditions for one hour. The tests are performed at a coolant temperature of up to 80 °C and load cycles at a constant high chip temperature. The junction temperature of the silicon chip is increased to up to 140 °C in order to put the modules under an extremely high load. All modules undergo at least one burn-in cycle. This test – just like the Semikron module – is unique, says Mr. Weiss. What he doesn't disclose so readily, however, is exactly how many modules fail the test: "The failure rate is extremely low." As for the personnel requirements for this test, this is on a par with module assembly.

Every module designated for the wind power sector is a customised, made-to-order product. At the Nuremberg plant, production is semi-automatic, and manual processes such as driver to IGBT module screw connection are checked by computers. "The production numbers are not high enough to warrant fully automatic production lines," comments Mr. Weiss, "but that's something we're working on." Every week more than 1,000 Skiip systems are produced for the wind power market, adds Mr Wintrich. Semikron is profiting from the fact that the wind power market is moving away from double-fed induction motors to full-power converters.

Windfall from wind power

The entry into the wind power sector in the early 90s was a windfall for Semikron. The company's main business field, which makes up 35% of the total turnover, is power electronics for the drives market, closely followed by the wind and solar power sector with a 31% share of turnover. This is broken down into 26% for wind power and 5% for solar power. Next in line are power generation (12%) and electric vehicles (8%). And yet Semikron was not left unscathed by the financial crisis in 2009. "By the end of 2009 things were already starting to look up again," comments International Communications Manager Annette Müller, referring to record turnover figures in August 2010. The turnover figures for the previous year, however, are not specified.

At the moment, production is somewhat limited by supply bottlenecks in IGBT chips and other raw materials. This, however, is not stopping Semikron from investing in new company premises. In December the first sod was cut for the adjacent new logistics building. According to Semikron, this move will mean the company has a gross floor area of 12,300 m² at its disposal.

Mr. Weiss and Mr. Wintrich see the main markets of the future outwith Europe. At present, turnover is split 60%, 30% and 10% to Europe, Asia and North/South America, respectively. "The European market is stagnating. China, on the other hand, is on the way up," says Wintrich. New developments are also in the pipeline: "We're working on the next Skiip generation," reveals Mr Wintrich, head of the simulation department. "The next generation will be even more compact and have even better cooling". Perhaps the sinter technology is not the end of the flagpole after all.

For further information see:
Semikron International GmbH: www.semikron.com