POWERED BY YOLE DÉVELOPPEMENT

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# POWERDev'

*Connecting the Power Electronic Supply*


INDUSTRY REVIEW

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EDITORIAL

# IGBT power stacks market: first status

Cost reduction, fast development, easy-to-handle product and high reliability: IGBT power stacks seem to efficiently address plenty of requirements. But are they already a real trend? And who benefits, apart from its customers?

First things first: what are power stacks? The definition may vary from player to player, but the most agreed-upon illustration is an assembly of IGBT modules with passive components (busbars, capacitors, resistors), cooling systems and drivers designed to attain optimum efficiency.

This strategy offers many advantages. Not only can designers strive for optimized assembly in order to enhance component reliability and reduce cooling needs, busbar shapes, etc., but customers can benefit from customizable proposals derived from a robust basis that require less development and design time – theoretically equating to reduced maintenance costs in the end. What's more, stack level innovations can even provide new solutions, such as the "plug and play" approach.

**...The IGBT power stacks market is young and promising - but which way is it growing?...**

Yole Développement sees two main orientations so far:

- Low-power applications (below 500kW) in which customers are looking for power stack standardization. It will take time for the different suppliers to find a common path, since the focus is currently on innovation.
- High-power applications (above 500kW), in which customers want customization and optimization. Work is ongoing in every aspect of this field, not just in the stack itself. Each component is being investigated for better efficiency and lifetime - especially capacitors, which are considered to be the next bottleneck; and IGBT drivers, which open many perspectives, because improved control over how and when IBGTs switch can drastically reduce losses.

Who will make the most of this situation? Will it be IGBT module makers, since they represent the most expensive part of the full stack? Some important players would back this claim. What about passive manufacturers eager to diversify their offer? Chinese players are showing some action here. Or perhaps it will be a consortium of component specialists promoting their expertise? Agile Switch and its partners are convinced it will go this way.

Sit back and enjoy. The fight has just begun, and the coming months will not lack for excitement...

Jérôme Azémar
Technology & Market Analyst, Power Electronics
Yole Développement

SEMICON® Europa 2013

EVENTS

- **ICNS-10 Nitride**
  August 25 to 30, 2013 - Washington, DC, USA
- **Power Fortronic Forum**
  September 19, 2013 - Bologna, Italia
- **ICSCRM**
  September 29 to October 7, 2013 - Miyazaki, Japan
- **SEMICON Europa**
  October 8 to 10, 2013 - Dresden, Germany

COMPANY INSIGHT

# Digital approach benefits stack up for IGBT drivers

The SmartPower Stack Consortium is benefiting from start-up AgileSwitch's fresh view on how IGBT drivers can add value to pre-integrated power electronics.

*Rob Weber, Chief Executive Officer, AgileSwitch*

AgileSwitch is looking to overturn power electronics industry thinking on IGBT stacks. That might seem strange, given that that when the Philadelphia, Pennsylvania company was founded in 2010 its main focus was IGBT drivers.

"We came into this industry because technology was not advancing at the rate that customers required," explained Chief Executive Officer Rob Weber. Together he and Chief Technology Officer Albert Charpentier, who led the development team responsible for the Commodore 64 computer, have decades of experience building technology businesses. And so when AgileSwitch launched its first IGBT drivers in 2011 they were innovative outsiders in the power electronics sector. "We found that most companies follow an analog mindset, while we take more of a digital viewpoint," Weber explained. "We looked at how to make drivers programmable, and use the rich IGBT performance data to improve lifetime and the effectiveness of their use."

**"Most companies tend to assume that inverters will fail in 7-10 years and will need to be replaced,"** Rob Weber said. **"One of the main reasons is the power stack: capacitor banks wear out or IGBTs fail. We're looking to double the lifetime."**

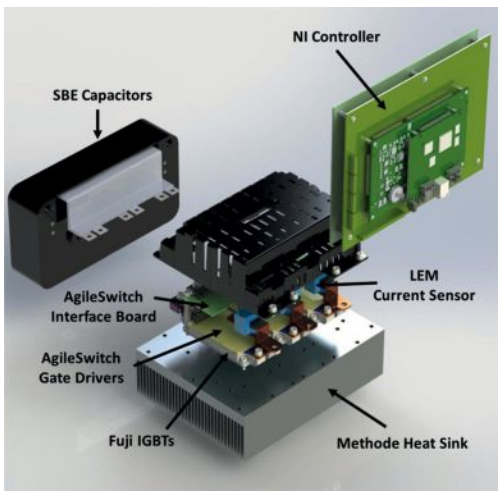
In March 2012, AgileSwitch took a dramatic step, establishing the SmartPower Stack Consortium with four other leading component suppliers. Alongside laminated bus bar and heat sink producer Methode, inverter controller supplier National Instruments, IGBT module vendor Fuji Electric Semiconductors and capacitor manufacturer SBE they now supply IGBT stacks. Their first offering is a 100 kW configuration for use in photovoltaic inverters, using 1200V, 450A IGBTs. Weber underlined the specialist expertise the collaboration can pack into the final design. "Integrating these components into a small footprint, considering all the electrical, thermal and communication requirements takes significant effort," he said. "This consortium has gone through many iterations to get it to where it is today, which would be hard for individual companies to replicate."

That expertise adds to and enhances the benefit that power stacks traditionally bring system makers in cutting the development time needed for their power electronics. "The development cycle time is usually over 12 months," Weber said. "We believe that we can halve that through the library of programs in the controller and our stack design. Our stack is also highly configurable – arguably customisable – to an application, without having to start from scratch. With other suppliers' stacks customers can be forced to compromise in their design if they want a fast process."

Another key difference is that although IGBT module supplier Fuji is a member, the consortium encourages customers to qualify with two suppliers. "IGBT availability is typically feast or famine," Weber said. "There are very few manufacturers and they control the market. Companies would like have a second source IGBT solution, but in reality few do. Some have IGBT preferences. Our approach can help. We decided from the first design meetings to use industry standard packages for the IGBTs. Our stacks are based on Econodual or Econopack packages, because they have multiple vendors. Through software and other configuration, they perform the same way regardless of the IGBT, providing a built-in second source capability. This is the feature that's getting the highest level of interest from customers today."

Given the SmartPower Stack's recent release, sales so far mainly comprise just a few units to these interested customers. "It's still in the test and design-in stage," Weber said. "Dozens of customers are testing and working collaboratively with us to configure the stacks specifically to their application. A lead customer has placed a larger order, and we have just picked up a second order of that size." Nevertheless, the consortium is already planning to expand the power range its stack covers, and also make it compatible with Primepack modules.

The modular design means that customers will also be better placed to upgrade their inverters, or tackle any faults that arise. "Competitive stacks




*IGBT stack, assemble: SmartPower Stacks bring together AgileSwitch drivers with components from many other leading suppliers. (Courtesy of SmartPower Stack Consortium)*

tend to be monolithic, with a single IGBT module and a single gate drive and interface board combination," Weber said. "They have the challenge that if one IGBT fails it means replacing the entire stack. Ours have three Econopacks, three gate drive boards and a fourth interface board. In our case the maintainability is different, and as IGBT technology advances, we can integrate the new modules."

But one of the key SmartPower Stack aims is to reduce those faults, with SBE's film capacitor banks promising dramatic lifetime improvements. "Most companies tend to assume that inverters will fail in 7-10 years and will need to be replaced," Weber said. "One of the main reasons is the power stack: capacitor banks wear out or IGBTs fail. We're looking to double the lifetime."

AgileSwitch's drivers also include monitoring and analytical capability that helps pre-empt system failure and adjusts overall system performance accordingly. Weber feels this will become the most important capability of all in the future. "It's something that customers indicate that they want, but they don't know how to use it yet," he said. "We want to develop algorithms on what to do about problems, from changing how hard an IGBT's pushed to scheduling maintenance calls."

| | NI embedded customers (2012)[1] | EETimes overall embedded market (2012)[2] | Ratio |
|---|---|---|---|
| Average development team size (HW, SW, Firmware Engineers) | 4.8 | 11.5 | 2.4 |
| Average months to complete project | 6.2 | 12.5 | 2.0 |
| Average person-months to complete project | 30 | 144 | 4.8 (average of 114 person-month savings per design) |
| Average development cost (assuming $100k/person/year with overhead) | $248,000 | $1,198,000 | 4.8 (average $950,000 cost savings per design) |
| Percent of projects completed on or ahead of schedule | 58% of NI customers | 42% of embedded market | 0.7 |
| Percent of projects completed behind schedule/late | 38% of NI customers | 55% of embedded market | 1.4 |

*NOTE1: The overall embedded market study was a global email/web study including over 1,700 responses from embedded engineers from Americas, Europe and Asia*
*NOTE2: The study of NI embedded customers was a global email/web study including over 1,100 responses NI embedded customers from Americas, Europe and Asia*

*Quick developer: The average Non-Recurring Engineering time to complete a typical inverter embedded design is 30 engineer-months for National Instruments LabVIEW/RIO teams when compared to 144 engineer-months for the overall embedded market. That will benefit SmartPower Stack customers. (Courtesy of National Instruments)*

**www.agileswitch.com**

**Rob Weber, Chief Executive Officer, AgileSwitch**
Rob Weber has focused his entire career around starting and building emerging growth technology businesses. Prior to co-founding AgileSwitch serving as President for three companies, and before that served as Marketing Director for Ensoniq Corp, a leading manufacturer of electronic musical instruments and multimedia products, ultimately sold to Creative Technologies. Rob started his career in venture capital with the investment banking firm of Howard, Lawson & Company. He is a co-founder of Robin Hood Ventures and the Mid-Atlantic Angel Group Fund. Rob holds a BS in Economics and Bachelor of Applied Science from the University of Pennsylvania, where he now teaches technology strategy and entrepreneurial management.

ANALYST CORNER

# Power electronic supply chain grabs for IGBT stack chance

Passive component and driver suppliers are trying to edge their way into the fast-growing power stack territory dominated by established module producers, explain Yole Développement's Alexandre Avron and Wenbin Ding.

*Alexandre Avron, Market & Technology Analyst, Power Electronics, Yole Développement*

*Wenbin Ding, Market & Technology Analyst, Power Electronics, Yole Développement*

Passive component suppliers are challenging power electronic module producers' dominance in IGBT power stacks. Gaining a share of this large and expanding sector could provide a significant boost to their fortunes. "The market is growing very fast," Yole Développement power electronics analyst Wenbin Ding commented. "In our opinion, it will reach more than $4 billion in 2016, with a compound annual growth rate of about 51%." And while the incumbent players' position is strong, the invasion looks set to be reinforced by dedicated drivers for IGBT power stacks supplied by specialist manufacturers.

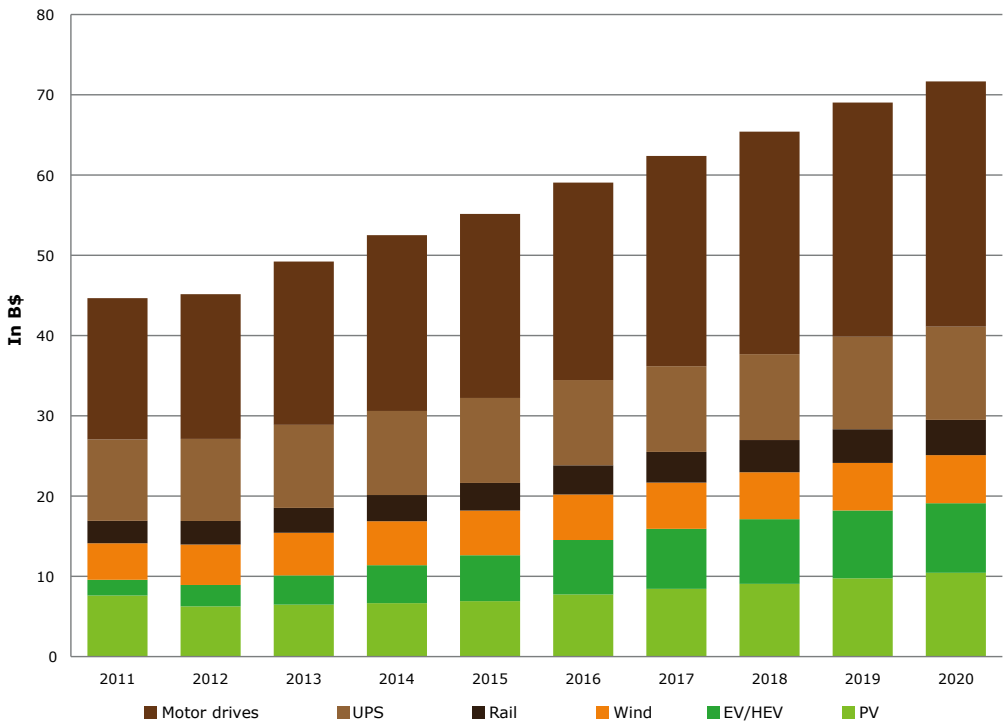
Power stacks typically assemble IGBT modules together with passive components like busbars, capacitors, cooling systems, resistors, and drivers in optimised formats, typically at ratings above 500 kW. "They can make inverter components modular, 'plug and play'," explained Ding's colleague, Alexandre Avron. "For a three-phase inverter, you could have three stacks that each deal with one leg of the inverter. Then, if you've got an issue with one leg, it's easier to replace the stack rather than repair the full cabinet. It's more convenient, beneficial in terms of reliability and maintenance, and also cost effective."

The term 'IGBT power stack' typically refers to readymade solutions supplied to system producers. But increasingly system makers are devising their own modular solutions that package together components in a similar way. One recent example comes from AEG Power Solutions, which is headquartered in Zwanenburg in the Netherlands. In May, it released a 150 kW maximum power PV inverter, built up from 15 kW modules, into the US market. "It's similar to what they have in data centres, where you can plug and unplug modules from racks of servers," Avron said. "AEG has done the same for PV inverters, making them completely modular so it's easy to replace parts, and monitor them as well."

Unlike most of the dominant power stack suppliers, AEG does not produce its own IGBTs. And the fact it's possible to make stacks and stack-like products without that capability opens opportunities for companies throughout the supply chain. "A lot of passive component manufacturers want to get

**Inverters market**

*(Source: Inverter Market Trends for 2013 - 2020 and Major Technology Changes report, February 2013, Yole Développement)*



involved in this business because they are targeting vertical integration," said Ding. "For example, the Chinese company, Eagtop, were originally busbar manufacturers then started to develop capacitors, and now they are doing power stack assembly."

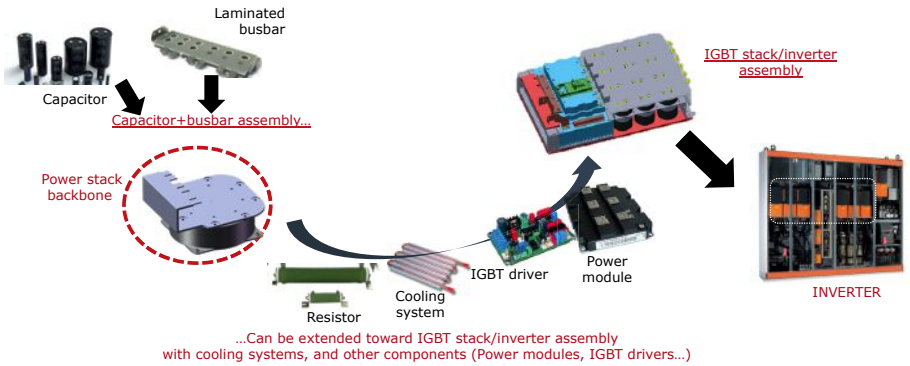
These companies feel that they can exploit their particular expertise to enhance performance. "Having know-how for several components allows them to adjust the solution, giving better performance for the whole power stack," Ding said. "We're seeing companies that were targeting higher levels of integration make their move," Avron added. "There will be competition, and so each company has to find how they're going to add value. The idea is not only to provide the components but also to create more margin in doing design or customization for their customers."

## Difficult territory

Another example is materials expert Mersen, based in Paris, France, which manufactures cooling systems for power modules. In 2012, it acquired Rochester, New York's Eldre, which produces laminated busbars that are also used in modules. Now it has brought the knowledge of those areas together to help customise integrated products in ways that overlap with IGBT stack offerings. "It has a team of power electronics specialists able to combine components from different business units of the company, which is new," Avron said. "If you have only one company or team designing the capacitors, busbar and cooling at the same time, they know what the possibilities are and can provide designs to better fit customer needs."

**Powerstacks: a trend toward more integration**

*(Source: Inverter Market Trends for 2013 - 2020 and Major Technology Changes report, February 2013, Yole Développement)*




*Up the chain: component producers are trying to use their expertise with their products to make more integrated products, potentially increase their addressible markets. (Courtesy of Yole Développement)*

Goldwind are doing power stack assembly for their high power wind turbines, and CSR, the train manufacturer is looking at complete vertical integration." Goldwind has gained the ability to produce power stacks in-house thanks to a licensing deal with Neubiberg, Germany's Infineon signed in 2010.

But companies offering new solutions into IGBT stack markets face some considerable obstacles. "There may be resistance to the new solutions, as we're talking about high power applications, where companies are more conservative," Avron said. "Rail traction particularly likes to stick with solutions if they still work. Also, the stack approach can make it more difficult to have a second source ready in case of supply issues. They are potentially giving the whole design to one company, and for real custom-made designs they will have only one supplier for all the components."

**"There may be resistance to the new solutions, as we're talking about high power applications, where companies are more conservative,"** Alexandre Avron said.

Meanwhile, power electronic system users are keen to get the cost effectiveness and improved reliability modular IGBT stacks can provide. That makes it beneficial for system makers like AEG Power Solutions to provide these capabilities, and inevitably they also develop their own stacks and stack-like solutions. "That's been the general trend among Asian players, who are planning vertical integration," Ding said. "It is a very hot topic in China. System players like

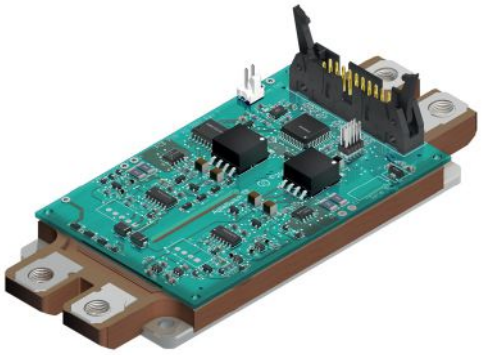
Newcomers with power stack offerings are also unlikely to flourish if they threaten the business of IGBT module makers like Infineon, Nuremberg, Germany's Semikron, or Nordborg, Denmark's Danfoss. "The most important component in a power stack is the IGBT module," Ding underlined. "The market is still led by IGBT module makers like Semikron, Infineon and Danfoss because it's a huge part of the power stack cost." Perhaps for this reason Barre, Vermont, capacitor manufacturer SBE is ascending the value chain by developing fully integrated IGBT modules with Danfoss, rather than making its own modular stacks.

For established module makers to maintain the same level of dominance over the IGBT stack market, they must deal with changes happening on more than just one front. That's because there is also an influx of new companies producing IGBT module drivers, namely Philadelphia, Pennsylvania's AgileSwitch, Amantys in Cambridge, UK, and Pürgen, Germany's InPower.

"The driver comes between the power module and the software control systems – the brain of an inverter – deciding when and how to switch the IGBT," Avron said. "It directs current from a module's capacitors to load and open or close the IGBT gate to make it switch efficiently. These start-ups are bringing innovation into the driver area, helping improve performance and bringing new possibilities in how power modules and power stacks work together."

## Rapid switch

All the start-ups exploit different approaches to IGBT switching, Avron added. "They can be applied through software or hardware," he said. "They can help make two IGBT power modules switch at the same time, which is difficult, or help the IGBT switch more efficiently by reducing the switching losses. They can help switch different types of power modules in the same stack or system, which give more flexibility when choosing power modules for an IGBT stack. That opens possibilities for inverter design and supplier choice. You have less constraints on making it work well, and can use lower quality IGBTs to get the same result."



*Driving ahead: As well as its drivers for EconoDual IGBT modules, shown here, AgileSwitch suppliers drivers as part of the SmartPower Stack Consortium. (Courtesy of AgileSwitch)*

With driver innovation most applicable to medium and high power applications, the new companies must also face this sector's inertia. "A very big part of the market is closed," Avron said. "Many inverter makers want to do their own IGBT drivers. They have their own techniques, for example French traction manufacturers Alstom do their own IGBT drivers because there are specific operations in starting a train. So these new companies have to be innovative to compete and get market share in IGBT drivers."

**"Power module producers are the decision makers, the heart of the business, but these new innovations and companies are bringing some fresh air,"** explains Alexandre Avron.

And AgileSwitch's strategy to overcome this problem is a familiar one – to begin offering power stacks. In this case it's as part of the SmartPower Stack Consortium, which includes Tokyo, Japan's Fuji Electric as the main IGBT module supplier. And although IGBT stacks are today used at very high powers, the SmartPower Stack Consortium's is rated at 100 kW. "AEG Power Solutions is also proposing modular systems down to 15 kW," Avron said. "The market is growing at these power levels, with renewable energies now part of the equation, which wasn't the case five years ago. It's a bigger market with new needs, which is why we're seeing more power stacks."

IGBT suppliers could benefit from the added performance these innovations promise, reducing any advantages of upcoming wide bandgap SiC and GaN rivals. However they may ultimately help devices made using these materials, Avron noted. "These improvements make IGBTs moving targets for SiC and GaN," he said. "IGBTs are mature, with few device innovations left to make. They already have outstanding performance, so now manufacturers are improving what surrounds the IGBTs. That's helping improve inverters' overall operation which we think will give IGBTs a longer life cycle. But improving what surrounds the IGBT will also benefit SiC and GaN in the end. We really believe that power stack improvements for IGBTs will also transfer to SiC devices, when they are ready, though it will require some adaptation and variation. Keep in mind that they are still for high power and SiC hasn't yet reached this range."

Regardless of who benefits most, Avron stressed that these events represent some of the fastest changes in the power electronics industry in recent years. "Power module producers are the decision makers, the heart of the business, but these new innovations and companies are bringing some fresh air," he said. "These events are not really changing the market now, but are big signs of evolution. I don't think that we have seen so many new companies proposing IGBT solutions in such a short time in the past."


*In the closet: In design and in approach, AEG Power Systems' new modular PV inverters take inspiration from data centre servers. (Courtesy of AEG Power Systems)*

**www.yole.fr**

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