Power modules for fast switching motor drive applications

Andreas Johannsen, Product Marketing Manager - Vincotech GmbH

Most of the current high power semiconductors are optimized for switching frequencies between 4 and 8 kHz. Today, however, more and more applications require frequencies of 10 kHz and higher. New power modules can now fill that gap.

According to current surveys, about 40% of the power consumption of motor driven systems in the European Union comes from fans and pumps. Most of these systems are outdated and not electronically controlled. A state-of-the-art system with a high frequency inverter can be up to 30% more efficient. While most of these systems are running day and night, the energy and cost saving potential is enormous. In times of increasing energy costs and the growing importance of environmentally conscious behaviour, energy efficiency is becoming increasingly important.

Reasons for higher switching frequencies

Fans and pumps are often seen in heating, ventilation, air conditioning and refrigeration applications, which are usually, installed in audible noise sensitive environments. Electromechanical effects from switching high power can cause audible noise. For that reason, a common feature in all these application areas is a switching frequency of >16 kHz, above the audible range.

Further application areas include motor drives with highly accurate torque control, e.g. when used for surface processing, or drives for ultra high dynamic operations. Other reasons for higher switching frequencies are the possibility to use smaller passive components, such as capacitors and coils. This leads to smaller packaging sizes and lower system costs.

Power Semiconductors for higher switching frequencies

For a powerful, reliable and cost effective motor drive, the right choice of power semiconductors is very important. Most of the current high power motor inverters use IGBTs (Insulated Gate Bipolar Transistor) for the power switching.

IGBTs currently available in the market are optimized for different application areas. In most cases the optimization is a trade-off between static and dynamic losses, two very important parameters of an IGBT. The static losses are the losses while the

IGBT is switched on, given by the Collector-Emitter-Voltage V_{CEsat}. The dynamic losses are the losses during the switch-on and switch-off of the IGBT. A special disadvantage of the IGBT is their current tail during switch-off. The reason for this is that during turn-off, the electron flow can be stopped rather abruptly by reducing the gate-emitter voltage below the threshold voltage. However, holes are left in the drift region, and there is no way to remove them except via a voltage gradient and recombination. The IGBT exhibits a tail current during turn-off until all the holes are swept out or recombined. A short current tail is therefore a very important feature of an IGBT with low dynamic losses.

Compared with 600V, there are only a few 1200V-rated IGBTs available for higher power applications, running with switching frequencies of more than 10 kHz. The most common components are built in Trench Field Stop technology and are optimized for switching frequencies below 8 kHz. The reason is that the main application field for IGBTs are industrial drives. And most of these applications currently work at switching frequencies between 4 and 8 kHz.

The standard Trench Field Stop IGBTs is optimized for V_{CEsat} and therefore lower switching frequencies and exhibits due to the Trench technology a rather high gate capacity. The gate capacity is up to three times higher compared with devices using planar structures.

Another technology group, optimized for fast switching applications, are the Fast Non Punched (Fast-NPT) Trough IGBTs. They are typically used in applications with switching frequencies from 30 up to a few hundred kHz, e.g. in power supplies or welding equipment. The disadvantages of Fast-NPT are the very high static losses and missing of short circuit capabilities. This makes this technology unusable for motor drive applications.

A real alternative might be the Planar Field Stop technology. It promises low static losses, with much lower gate capacity and faster switching capabilities.

Planar Cell Field Stop – the right choice?

To figure out if the Planar Cell Field Stop technology is the right choice for motor drive applications with higher switching frequencies, the total losses have to be observed. Figure 1 shows the total losses of different chip types in a typical motor drive application. The comparison between two IGBTs with 25 A nominal current (red and blue line) shows, that the losses of the Planar Cell Field Stop technology are also lower for lower switching frequencies. The reason is that the static losses of the two chips are nearly the same, while the dynamic losses are lower for the Planar Cell Field Stop technology (see Figure 2).

But even more interesting is the comparison between devices of the same size. The 35 A Trench Field Stop IGBT (yellow line) and the 25 A Planar Cell Field Stop IGBT (blue line) in Figure 1 have nearly the same chip size. Beginning from switching frequencies of 10 kHz, the total losses of the Planar Cell Field Stop chip are lower than the 35 A Trench Field Stop IGBT and therefore more cost-effective.

At 20 kHz, the power loss is lower by 24%, making an output power of 10 kW possible, which could only be achieved using 50 A to 75 A standard IGBT4 components from Infineon. Because the power losses are much lower, the heat sink can also be sized down. This means the application will not only have much higher energy efficiency, but can also save component costs or provide higher output power at the same size.

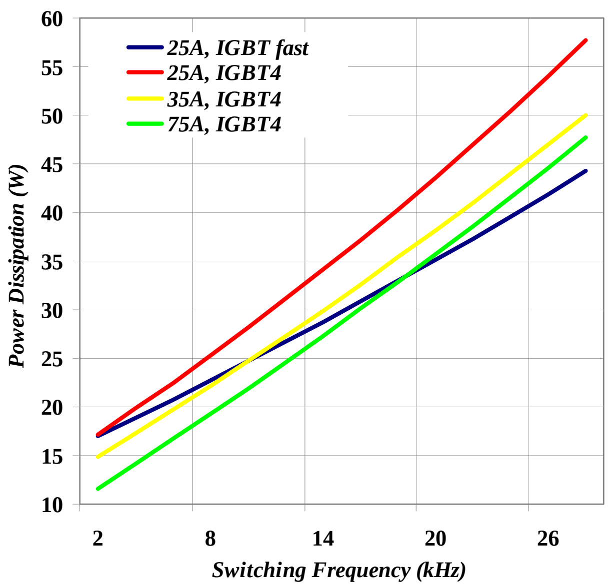

Figure 1: Total power dissipation of different IGBT as a function of switching frequency (10kW DC link power, 50Hz output motor frequency)

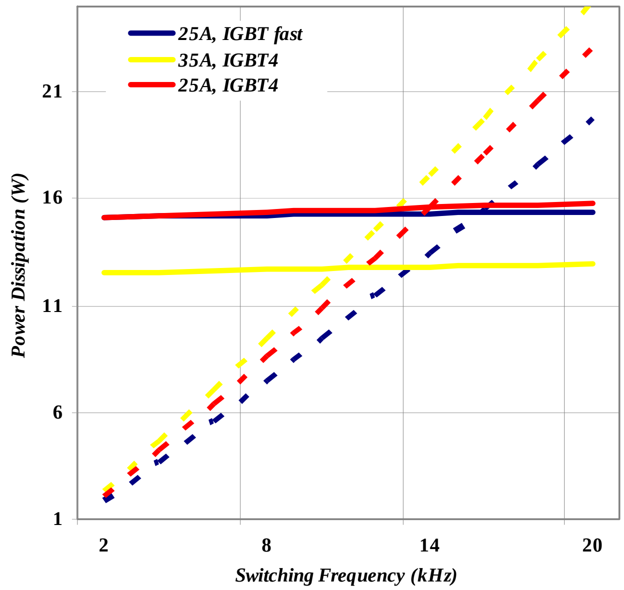

Figure 2: Static (solid) and dynamic (dotted) losses as a function of switching frequency (10kW DC link power, 50Hz output motor frequency)

Disadvantages of Planar Cell Field Stop

One might ask “Nothing is for free. What are the disadvantages of Planar Cell Field Stop technology?”

The Planar Cell Field Stop IGBT is more sensitive to parasitic inductance that can cause problems in the switch-off behaviour. This can be solved with a conclusive, low inductive module design. Furthermore, an additional emitter contact directly wire-bonded onto the chip is required. This measure protects the gate-emitter-voltage from any parasitic inductance.

Another disadvantage is the bigger chip size, compared to Trench Field Stop IGBTs with the same nominal current. But the comparison for different switching frequencies shows that for higher frequencies the dynamic losses become increasingly important. At switching frequencies higher than 10 kHz the Planar Cell technology can compete or even outperform chips at the same size and much higher current rating.

Available module solutions

Vincotech offers several module solutions optimized for fast switching applications. All these modules supporting the above mentioned design requirements, like low inductive design and emitter sensing down to chip level. As part of the *flow*PIM 1 family, the V23990-P589-A31-PM integrates all the power semiconductors needed for motor drive applications (rectifier, inverter and optional brake). The module has a voltage rating of 1200 V and a nominal current of 25 A.

For higher power requirements, a half-bridge module with 1200 V and 100 A is also available. The name of this module is V23990-P569-F31-PM and it is part of the *fast*PHASE 0 family.

To make full use of the advantages of the Planar Cell Field Stop IGBTs, the modules feature also special fast free-wheeling diodes. More information about the P589-A31 can be found at www.vincotech.com.

Conclusion

The Trench Field Stop IGBT is designed for motor drive applications with a typical switching frequency of up to 4 kHz. At higher frequencies, the Planar Cell Field Stop components are the optimal choice. This technology seems to be the favourite for nearly all 1200V motor drive applications using switching frequencies above 8 kHz.