The *flow*7PACK Power Module –A Flexible, Cost-effective Solution for Industrial Drives

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1 Abstract

Power electronics designers are constantly seeking innovative, flexible solutions to satisfy the industry's tough demands for EMC, small footprints and low system costs. The *flow*7PACK line is a remarkably flexible and convenient option for applications in which EMC presents a major challenge. This paper looks at a typical industrial application, variable frequency drives, to illustrate how the *flow*7PACK module can serve to meet those requirements.

2 Mitigating harmonics with a DC link reactor

Variable frequency drives have featured prominently in industrial applications for years because they provide precise process control. Most variable frequency drives work with a bridge rectifier to convert incoming AC voltage from the grid into DC voltage as shown in figure 1. The drive's inverter then converts the DC voltage into controlled AC voltage and control frequencies that start and stop the motor, determine its direction of rotation, and regulate its speed and torque. When the motor decelerates, it feeds energy back to the intermediate circuit. In this case a braking chopper limits DC bus voltage by feeding the braking energy to a resistor where it is converted to heat. All these drive functions can be incorporated in a single power module called a PIM (Power Integrated Module).

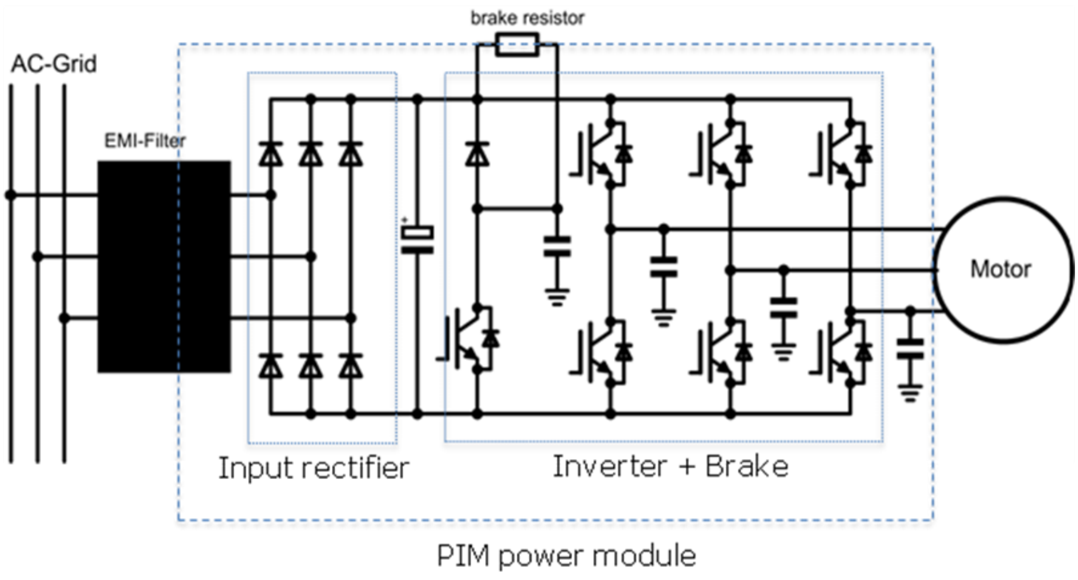

Figure 1: An AC line reactor inserted in front the PIM power module's rectifier

The downside of variable frequency drives is that electronic engineers have to cope with EMI (electromagnetic interference) issues. Given the nature of the AC-to-DC rectifiers used for this purpose, all drives generate harmonics within the system. The consequences can be dire if these harmonics are not mitigated. The electrical system may be overloaded, power demand and outages may increase, systems can fail, and equipment may expire prematurely. There are many ways to mitigate harmonics, and they vary depending on the nature of the load and the connected equipment's power demands. An EMI filter, also known as a choke or line reactor, is one of the most common solutions. Reactors to reduce harmonics can be added to a variable frequency drive in one of two places.

AC line reactors are inserted in the drive's input, in series with the incoming line. They help mitigate harmonics, and because they reside between the line and drive, they are able to buffer surges and other transients. An AC line reactor's great drawback is the intervening voltage drop. It can cause under-voltage trips in systems where the input voltage is not as stable as it should be. On top of that, this voltage drop can lower DC bus voltage and adversely affect the drive's output. Finally, AC reactors are usually larger than DC chokes and more expensive. One way of redressing this drawback is to use DC link chokes as shown in figure 2. DC link chokes are connected between diodes and the DC bus and can be slightly less or slightly more effective at removing harmonics than AC line reactors, depending on the order of harmonic. DC link chokes are generally smaller than AC chokes and they add the impedance needed to reduce harmonics without having the voltage drop. Although the DC choke does not add any extra buffering for voltage surges seen by the rectifier, it does protect against current surges.

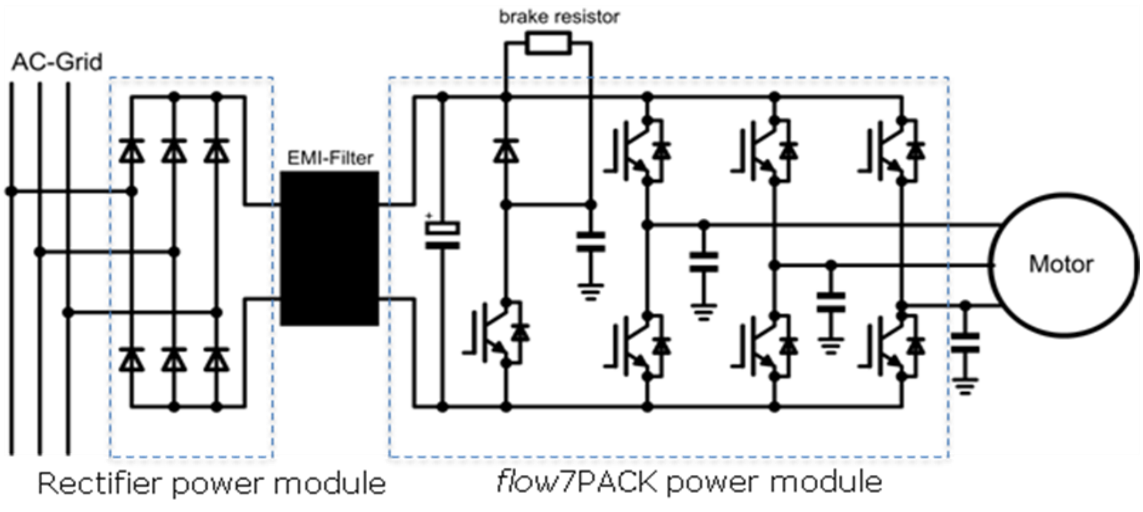

Figure 2: A DC link reactor inserted between the rectifier and flow7PACK power module

The AC line reactor and DC link reactor each have their benefits and drawbacks. Engineers have to weigh these pros and cons and choose the best alternative for the given application. Both solutions help make drives more reliable and comply with EMC standards. An AC line reactor affords rectifier diodes some protection from transient spikes in voltage caused by lightning surges or power factor capacitor switching, whereas a DC line reactor does not. On the other hand, a DC line reactor does not cause the voltage to the input rectifier diodes to drop, but an AC line reactor does. All told, the DC link reactor's greatest advantage is monetary. It comes at just half or as little as a third of the price of an AC line reactor with the same impedance for harmonic mitigation. The *flow*7PACK power module was developed to support this option. Engineers can use DC link reactors and take advantage of a cost effective solution while meeting demanding EMC standards when the input and output are split. This physical separation automatically decouples the heat sink that sits between the input and output, provided the distance between the rectifier power module and flow7PACK power module is within a reasonable range as illustrated in figure 3 below.

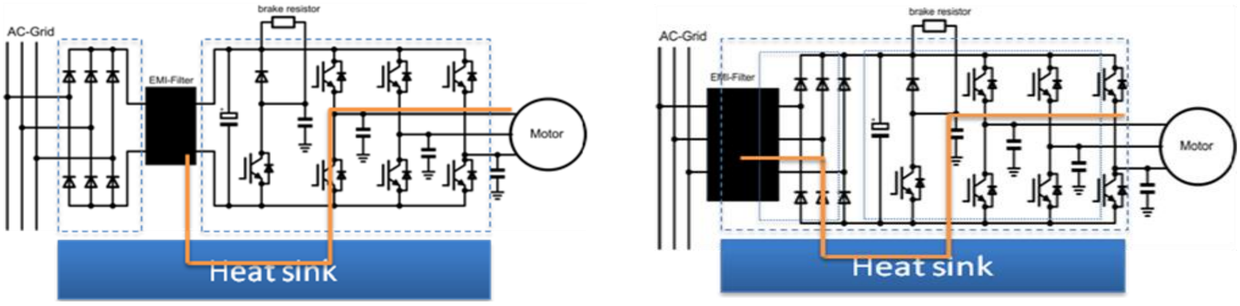

Figure 3: AC motor interference is decoupled between the inverter and rectifier in the left layout with the flow7PACK module; the standard PIM solution is on the right.

3 *flow*7PACK line

The previous section described an application where new *flow*7PACK modules can serve as a more flexible and cost-effective alternative to fully assembled PIM modules. *flow*7PACK power modules are equipped with more components than PIM power modules such as those of the *flow*PIM line. Specifically, they feature a three-phase inverter bridge and a braking chopper as shown in figure 4. The latter serves to limit DC bus voltage in cases where braking energy flows back to the circuit as described above. The inverter stage was designed with an open emitter structure in the low-side switches, so three external shunt resistors may be connected to provide a simple, cost-effective means of sensing current. While *flow*7PACK modules come in *flow* 0 and *flow* 1 housings without a base plate to serve a wide range of applications, the modules designed for higher power ratings come in *flow* 2 housings with a base plate and the latest chip technologies. With all these features shoehorned into a compact low-inductance design, these power modules are able to deliver superior power output performance. They can achieve up to 60 kW output power and 97.5% efficiency in a typical variable frequency drive application with a DC link voltage of 600 V (Tj 150°C, cosphi 0.8) and a switching frequency of 8 kHz. See table 1 and figures 5 and 6 for more on this. The maximum achievable efficiency is more than 98.2% for all three packages.

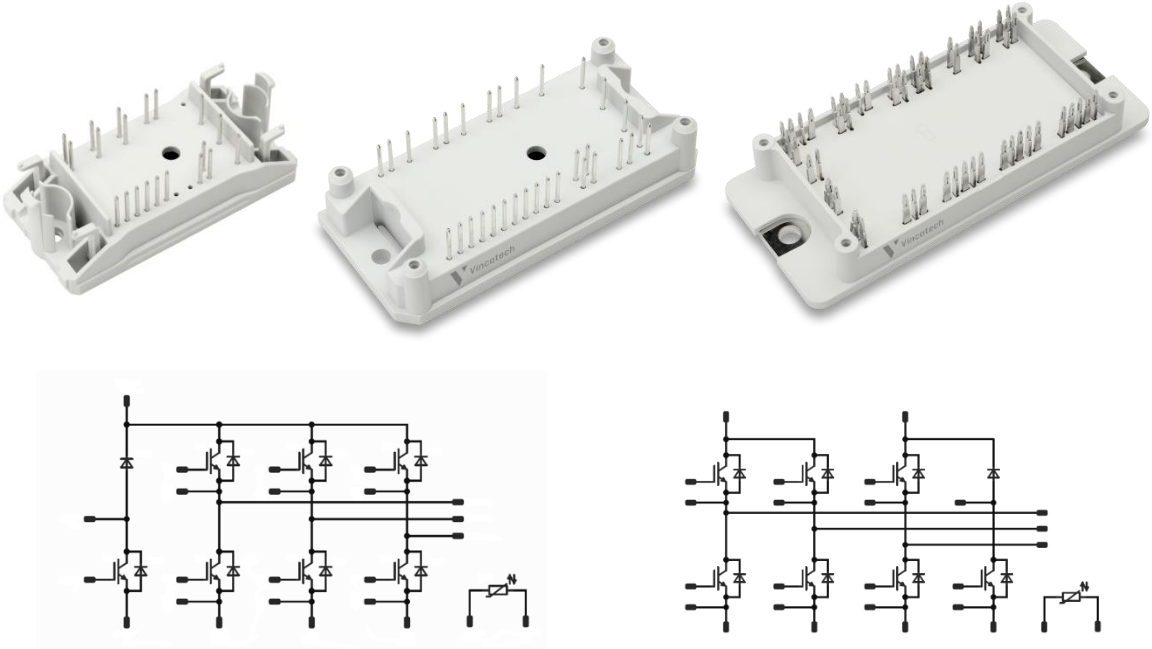

Figure 4: The flow7PACK in 0 & 1 size housings at the left and center with the schematic below; the flow7PACK in the 2 size housing with a base plate on the right and the schematic below

	Power rating	available peak output power at 80°C heatsink	Efficiency at peak output power	Max. efficiency at output power
flow 7PACK 0	1200 V / 25 A	15 kW	97,5%	98% / 5 kW
flow 7PACK 1	1200 V / 50 A	30 kW	97,5%	98,1% / 10 kW
flow 7PACK 2	1200 V / 100 A	60 kW	97,5%	98,2% / 20 kW

Table 1: A comparison of the three flow housing sizes' available output power and efficiency in a typical variable frequency drive application with 600 V DC link voltage (Tj 150°C, cosphi 0.8) and 8 kHz switching frequency

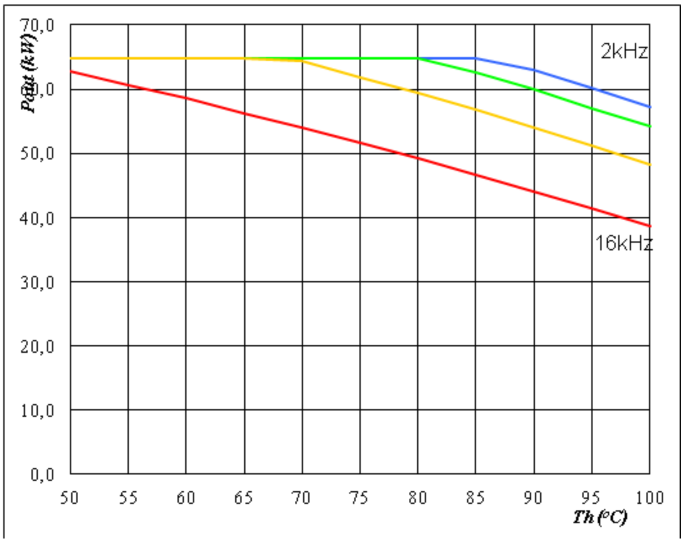

Figure 5: Typical available peak output power as a function of heat sink temperature for flow7PACK (1200 V / 100 A) at Tj 150°C, 600 V DC link, cos φ 0.80, fsw from 2 kHz to 16 kHz in factor 2 steps

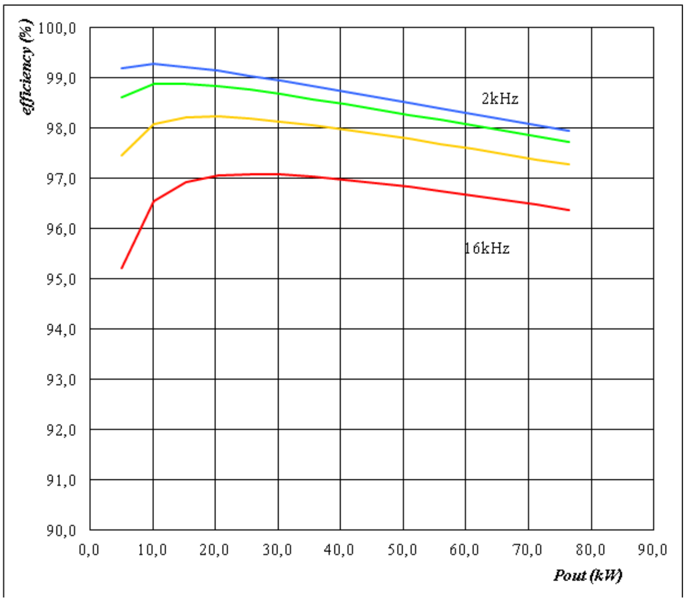

Figure 6: Typical efficiency as a function of output power for flow7PACK (1200 V / 100 A) at Tj 150°C, 600 V DC link, cos φ 0.80, fsw from 2 kHz to 16 kHz in factor 2 steps

*flow*7PACK power modules come with solder pins or Press-fit pins. The latter do not require soldering, which reduces PCB assembly time and effort considerably to speed up production and boost output. The module's creepage and clearance distances meet all the pertinent industrial standards. It imposes no special requirements as to the shape of the heat sink. The thermal interconnection between the module and heat sink is vastly improved by pre-applying phase-change material. The in-house screen-printing process deposits the material uniformly and with great precision to achieve the proper thickness and maximum heat transfer capability.

4 Conclusion

This paper outlines how power electronic designers can use the *flow*7PACK power module in combination with a DC link reactor for harmonic mitigation in a typical variable frequency drive application. It presents a persuasive case that this is indeed a flexible and cost-effective method. This solution based on the *flow*7PACK power module can also be used for other motor drive applications currently undergoing evaluation.