Decentralized Motor Drive Applications Raise New Requirements regarding the Drive System

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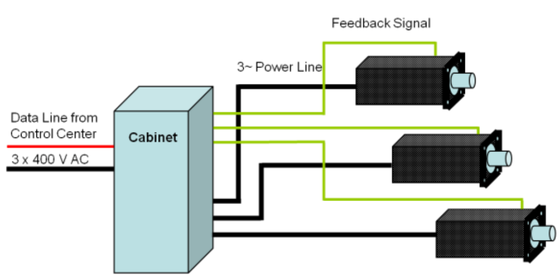
The increasing demand for decentralized motor drives in factory automation makes the new requirements for the implemented inverters in general and for the power section in particular more and more evident. The article will illuminate the reasons for the shift towards decentralized motor drives in factory automation, the special requisitions this implicates for the drive as well as its power section. It shows on a real example how to achieve these additional demands with a highly integrated Power Module from Vincotech.

Decentralized Motor Drives gain Momentum

The complexity of tasks to be handled in factories is increasing from factory generation to generation. Modern factories in the automotive or packaging industry for example are using hundreds of variable speed drives to manage the material flow and the actual production processes like car body assembly, welding and varnishing or bottle cleaning, filling and labeling respectively. In most factories up to now a centralized approach has been implemented, shown in *picture 1*.

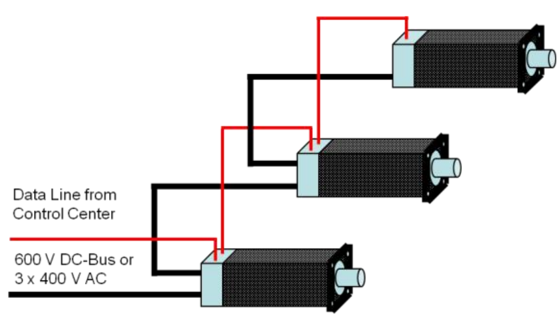


Picture 1: Motor installation with Centralized Inverter

Thereby, all actuators (motors) have been routed with dedicated power and signal cables like a cobweb from a central cabinet containing the frequency inverters. Even though being the right choice in the past, it does not cost effectively accommodate today's increasing amount of installed variable speed drives in newly build factories. In addition, the demand for achieving full control over the complete production process including peripheral tasks at remote places further increases the cost of this cobweb kind of system setup.

The further the drives are away from the cabinet with its centralized inverters the higher the cost for cabling. The more drives are installed in a factory the higher the amount of space occupied by cabinets. Furthermore, the more complicated a cobweb kind of wiring becomes the higher the resulting installation and system costs.

The decentralized motor drive approach is the answer to this changed situation with its new system split and the relocation of the inverter section away from the cabinet into the motor, as shown in *picture 2*.



Picture 2: Decentralized (Cabinetless) System

This new arrangement enables the use of a common power and control cable wiring like the mains grid. This results in dramatic reduction of cables that have to be run. Moreover, a significant simplification in cabling is achieved as only two different wires, one for the power and one for the control circuit, have to be routed. This enables local non-specialized electrician to prepare the installation at reduced cost.

Some of the savings due to the reduced cabling effort will be consumed by the additional requirements the inverter has to fulfill while being relocated from the cabinet into the motor. A study of system cost conducted by the Institute for Machine Tools and Economics at the Technical University of Munich/Germany shows that for machining centers a distributed approach while increasing material cost by 8 %, the assembly cost are cut by 2/3. This results in an over all cost reduction of almost 30 %. The cost saving is even more impressive for transfer lines where traditionally the distances and therefore the cabling efforts are higher. Here the material costs are decreased by about 30 % due to the reduced amount of cables and the elimination of cabinets. In addition, the assembly costs are lowered by 4/5 due to the easier interface which results in total cost reduction of almost 70 %. This explains the triumphal procession of decentralized drives into the factory setups.

Decentralized Drives set New Inverter Requirements

The move of the inverter away from the cabinet into the motor introduces new requisites to the inverter design. One of the most demanding ones is the thermal management. In the cabinet the inverter was installed in a rather friendly environment with no particular demands regarding ingress protection generally classified as IPXX. The motor itself will be installed somewhere in the production line close to the goods to be processed which can be heavy machinery like car bodies or fragile goods like foot. Because of this the motor together with its inverter in case of a decentralized drive system have to be washable with all sorts of detergents and therefore IP65 protected. In an IP65 protected system the dissipated power of all components can only be conducted to the outside world via the surface of the system, mainly the heat sink. Therefore for an inverter used in a decentralized drive it is essential that power dissipation is reduced and all power dissipating components are somehow connected to the heat sink. This is required to keep the over all temperature low and avoid hot spots in the system to ensure overall system reliability.

In addition, the inverter has to be small to admit compact motor designs and high installation density, which enables complex sequences at minimum floor space which also leads to cost savings. Examples can be found in the packaging industry. This compact design makes an optimum thermal management even more important due to the limited surface area of the system. It also requires an intelligent system split to minimize interconnections between the power section, the energy storage, and the control board of the inverter to minimize the total system space.

With the movement of the inverter into the motor also the demand for the mechanical ruggedness of the electronic system has increased. The inverter with its electronics will now see the same mechanical stress as the motor. This can vary from micro vibrations due to the finite stiffness of the motor fitting during acceleration and braking to macro vibrations when the drive is part of the moving system. Examples for this are transportation systems like cranes, elevators or electronic vehicles. Due to resonant effects and amplifications by non-linear structures an acceleration of the motor-inverter system of 5 g (earth gravitation) can result in accelerations of 50 g or higher inside the system. Therefore, special care has to be taken to ensure a particular robust design regarding shock and vibrations.

Moreover, many of the decentralized motors will be used in highly demanding systems with high dynamic output load requirements like servo drives to improve system throughput and overall performance. Thus, high dynamic output load capability together with accurate system parameter sensing should be implemented in the decentralized drive system.

The additional requirements for the inverter of a decentralized drive can be summarized to following points:

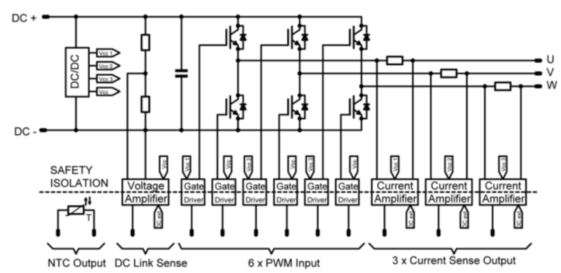
- Improved thermal management to be functional in a fully encapsulated environment (IP65)
- Ultra compact, highly integrated design
- High shock and vibration capability
- High dynamic output load capability

Highly Integrated Intelligent Power Module enables Decentralized Drives

For the former described requirements a new system split for the inverter is reasonable. Because of the encapsulation of the system all major power dissipating components should be mounted onto the heat sink. Due to space constrains the interfacing between the sections should be kept to a minimum. Having this in mind, the optimum system split will result in a power section, a capacitor bank section and a control board. The power section should include the drive circuit, current sense resistors, drive and interface power supply, all with access to the heat sink. The capacitor bank section may include an input rectifier dependent on the system setup (DC or AC bus).

The power section namely a highly integrated intelligent Power Module provides the enabling element for these decentralized drives. *Picture 3* shows the Power Module and *picture 4* the circuit diagram.

Picture 3: P520 (flyerIPM) Power Module



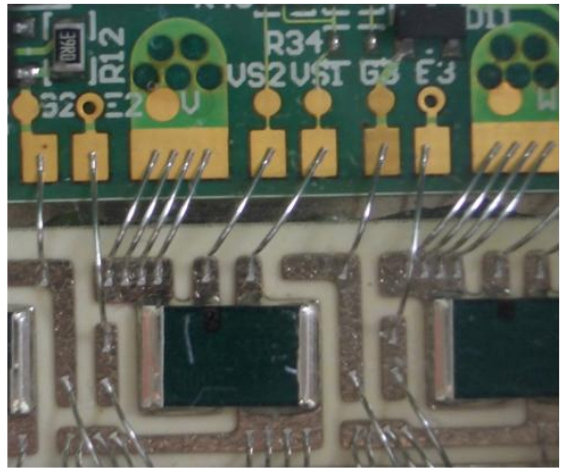
Picture 4: P520 Circuit Diagram

The P520 from Vincotech incorporates a 25 A 1200 V IGBTs sixpack together with freewheeling diodes and 3 current sense resistor placed in the output phases for accurate current sensing on a DCB substrate, similar to a standard Power Module. This Power Module is surrounded by the isolated gate drivers, the circuit for the 3-phase current, the temperature and the DC bus voltage sensing as well as a high voltage DC/DC power supply. This DC/DC converter provides all the required isolated supplies for the gate drivers and the logic interfaces directly from the 600 V bus. The inverter DCB is soldered to the baseplate to ensure optimum heat transfer. All the surrounding components are placed on a FR4 board and glued to the baseplate using thermally conductive glue. This provides a good thermal heat transfer for the surrounding devices as well, enabling the use of optical components such as optocoupler, gate driver and isolation amplifier.

Additionally a ceramic DC link capacitor of 720 nF is implemented on the P520 FR4 board. This capacitor is placed close to the inverter 6 pack, capable to support the switching current to minimize EMI generation, and to relax the requirement for the external bulk capacitor. With this approach the bulk capacitor can be placed further away form the inverter switches, providing a higher degree of design flexibility.

The system split minimizes the required amount of power interconnections to only five, two for the DC link input and 3 for the motor phases. This, together with the 6 gate drive signals, and the 6 sense signals, results in a minimum amount of interface signals, reducing cost and space for interconnections. All the components on the Power Module are fully enclosed by a high isolation potting material which protects the components and bond wires. Due to this the whole power section can be realized on a footprint of only 99 x 97 mm. Therefore it can be used even for small drives.

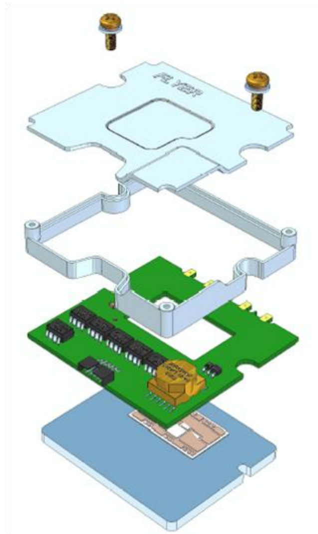
For improved shock and vibration capability only small and light components are used. The DC link capacitor for example is build of six 120 nF 1000 V ceramic capacitors to minimize the weight. The largest component used in the Power Module is the power supply transformer which has been kept to only 15 x 15 mm by using 500 kHz switching frequency. The interconnection between the DCB and the FR4 board is provided by wire bonding, as shown in *picture 5*.



Picture 5: P520 Interconnections

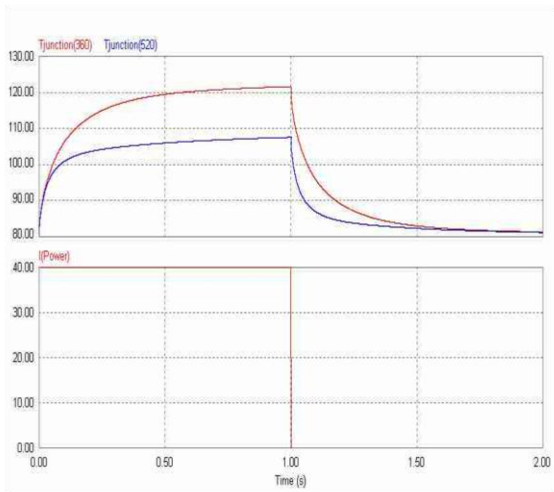
This provides highest reliability at minimum weight ensuring maximum shock and vibration capability. The whole Power Module is able to withstand shock and vibration forces of up to 80 g.

The required dynamic load capability is achieved by the use of a 3 mm thick copper baseplate. In conjunction with a 0.38 mm thin DCB substrate it provides outstanding thermal performance. Compared to a standard Power Module without baseplate the heat rise for a given increase in load is therefore reduced. In the P520 design the baseplate is not only underneath the substrate but also covering the much larger area of the PCB (*picture 6*). This provides additional thermal capacity which further reduces the heat rise for short load cycles; often seen in servo drive applications.



Picture 6: Module Structure

Picture 7 shows the comparison of the P520 and a standard Power Module without baseplate, using the same semiconductors.



Picture 7: Comparsion of P520 (Tj520) with standard power module without baseplate and identical chipset (Tj360)

The measurement is done for a 1 sec. pulse providing 40 W power dissipation. The Power Module without base plate reaches a temperature of 122 °C while the IGBT of the P520 only reaches 108 °C. This reduction in temperature change enhances the lifetime for the P520 according to Coffin-Manson by about five to six times.

Summary

The growing trend of decentralized drives in factory automation demands for a new kind of inverter with widely improved performance. To achieve these requirements a novel Power Module is needed, which incorporates a standard module together with all the drive, sense and interface functions on a very small footprint featuring superior thermal characteristics. The newly introduced P520 from Vincotech is the first representative of this new kind of Power Module available for the open market.

References

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