Driving 3-Phase Induction Motors

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Although an increasing interest and use of Permanent Magnet Synchronous Motors (PMSM) can be observed during the last decade, the standard 3-phase Induction Motor (IM) is still the most widely used electrical motor. The simplest way to start an IM is to connect the motor directly to the 3-phase main supply. Star-Delta Start and Soft-Starter were introduced in the past to overcome the extremely high starting current of a Direct-on-Line Start. All mentioned methods have in common that the frequency of the drive is fixed. Frequency converters allow adjusting the speed and current. For this purpose different control strategies adequate for the desired dynamic responds have to be considered. The simplicity of scalar control (V/f control) ensures ruggedness but on the other hand it satisfies only moderate dynamic requirements. Higher dynamic response can be achieved by vector control (Field Oriented Control). To enable these drives, semiconductor suppliers have traditionally relied on discrete IGBT solutions. Intelligent Power Modules are now replacing these discrete solutions. These new solutions enable designers to develop cost-effective solutions.

INDUCTION MOTORS AS COMMODITY

IMs are the world's most common electrical motor in the power range from 100W to several 100kW. They are characterized by a rugged and a simple construction, a long lifetime, relatively low cost and fair-to-high efficiency. General purpose IMs are constitute a majority of the market whose main characteristics are standardized and can be grouped in different efficiency classes. The standardization of mounting arrangement, mechanical size, cooling and protection against contact and penetration of solid objects and protection against water allows motors to be easily exchanged around the world by motors made by different manufacturers meeting same requirements.

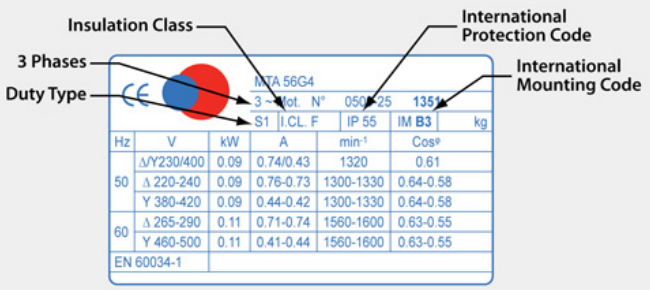

Figure 1. Rating Plate of Induction Motor

Figure 1 shows a typical rating plate of an IM. This foot-mounted 3-phase IM can be mounted either on floor, wall or ceiling (IM B3), is design for uninterrupted operation at constant load (S1), is protected against dust and water jets (IP 55) and is dimensioned for a maximum temperature rise of 75K (I.CL. F). Beside the operation of an IM fed with a frequency converter, the IM has captured the market of servo applications where such servo drives are an alternative solution if highest dynamic performance is not mandatory. Servo motors based on IM offer a very high dynamic response. Its compact design and low inertia results in an excellent density of performance. For

this purpose a servo converter is mandatory.

IM FED WITH FREQUENCY CONVERTER

The use of frequency converters enables the tailoring of voltages and currents needed by the AC motor. In prior times, the limitation was the use of Direct-on-Line Start, Star-Delta Start, Soft-Starter and similar techniques that were repealed by adaption of frequency converters whose basic design is pictured in Figure 2. The main core consists of 6 IGBTs/diodes and gate drivers building a 3-phase Voltage Source Inverter (VSI). Intelligent Power Modules (IPM) becomes more and more an alternative solution. A typical so-called smart power module (SPM®) is shown in the Figure and is designed up to an output power of 7kW. Now a fully four quadrant operation of the drive is possible. Control signals in a correct order allow adjusting the current and the speed of motor. The direction of rotating as well the direction of energy transport is selectable provided that the energy of DC bulk capacitance in Figure 2 can be dissipated by a brake chopper.

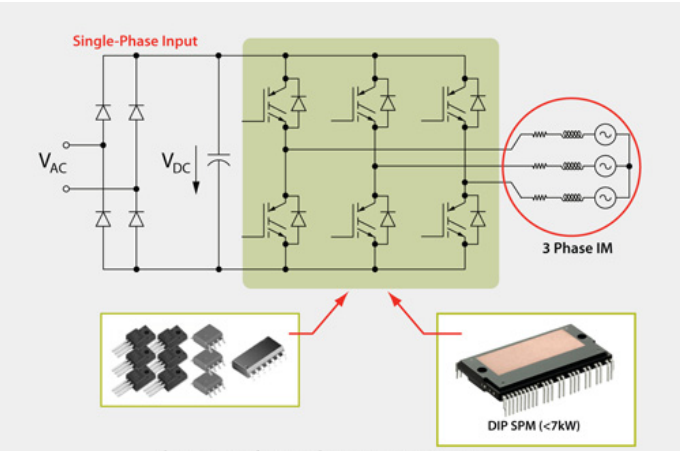

Figure 2. 3-Phase Voltage Source Inverter

Field Oriented Control (FOC) is well popular for 3-phase AC motors to achieve

high dynamic response of the drive, which is also the key technology for servo applications. The approach is to imitate the operation of a DC motor. FOC is based on the decoupling between the current components used for the generation of torque and magnetizing flux of the squirrel cage. The block diagram of FOC including the needed surrounding components is pictures in Figure 3. The three time-variant output current (ia, ib, ic) are transformed into two time-invariant values (Id, Iq) using Clarke and Park. As a result the constant DC values can be easily controlled. The gap between the measured current components and the desired values which depends of course of the needed speed of the IM is the reference values for the PI controller and Inverse Park transformation. The inverse transformation yields in time-variant voltages (Va*, Vb*) which are the input signals for Space Vector Modulation (SVM). Finally the SVM generates the gate signal for the IPM. Sensorless control of AC motors is still an interesting and growing research area. In case of an IM, the sensorless control can be simplified due to the fact that the position of the squirrel cage is not mandatory for the operation of the motor. If a speed control is desired, the rotor position can be directly computed from the so-called back electromagnetic force (BEMF).

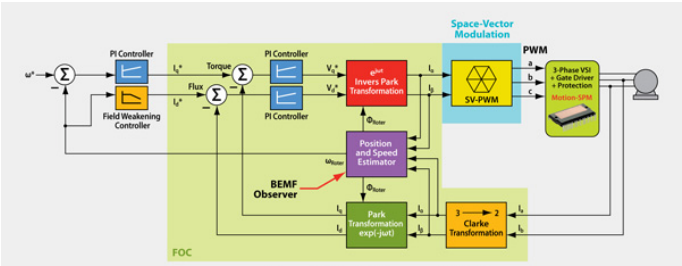

Figure 3. Block Diagram of FOC

BENEFITS OF INTELLIGENT POWER MODULES

IPMs are increasingly used for frequency converters since there are some significant benefits using integrated solutions. Using the example of Motion-SPM® module, which contains a 3-phase VSI including a fine-tuned gate driver and additional protection functions as UVLP, OCP and fault output the benefits become clear. As already shown in the Figure 2 the number of semiconductors is reduced. Hence only one component has to be attached to the heat sink. The precisely matched IGBTs and drivers ensure higher performance. Performance variations are much more controllable compared to a discrete solution. In addition the fully isolated modules reveal increased reliability since the protection functions are close to the power switches and the low thermal resistance of the packages result in lower temperature changes over a load cycle. Using IPM simplified the design-in phase because of an easier and faster design and higher flexibility.

CONCLUSION

The rugged and simple construction of induction motors, whose long lifetime, relatively low cost, high degrees of protection and whose standardization are indicating widespread adoption. The more and more these intelligent power modules are used will ensure that induction motors will keep their position due to higher reliability and performance of the modules compared to discrete solutions. Moreover higher performance of the drive can be archived implementing sensorless Field Oriented Control.

App. Notes:
DIP
SPM:
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MiniDIP
SPM:
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