Design of an Integrated Modular Motor Drive System

In conventional motor drive systems, drive units and motors are designed as two different modules which brings increased volume and weight to the system. This causes limitations in applications such as electric traction and aerospace where power density is critical. The Integrated Modular Motor Drive (IMMD) concept proposes that the motor drive unit can be integrated directly to the motor back-end such that, power density of the overall system can be enhanced significantly. Modularization of the system suggests that the whole system can be divided into several parts, which increases the fault tolerance, i.e., the system can continue to operate with reduced power rating in case of failures. Apart from these advantages, integration of the motor and the drive brings some challenges. All the drive components including power semiconductor devices, passive elements, control electronics and heat sink should fit into a much smaller volume. Moreover, the power electronics and control electronics are directly subjected to vibration. These challenges can be addressed by the utilization of wide band-gap (WBG) power semiconductor devices such as SiC or GaN. DC link capacitor banks usually constitute the largest volume of motor drive systems; therefore, selection of optimum DC link capacitor is also critical in IMMD design. Analytical modeling of the DC link has been achieved considering DC link ripple voltage, DC link RMS ripple current and temperature rise, for optimum capacitor selection. Commercially available off-the-shelf DC link capacitors are considered and an algorithm has been developed for the selection of optimum DC link capacitor bank. An IMMD prototype design is performed with a 7 kW permanent magnet synchronous motor having fractional slot concentrated windings. The stator is divided into four identical parts each having three-phases. A dedicated motor drive and control PCB is developed for each module. The modules are connected with two-series/two-parallel structure on the DC link such that, 650V 30A rated GaN transistors can be used. Performance index of the designed system are evaluated such as efficiency, power density, and fault tolerance.