Evaluation of DC Link Capacitors in Integrated Modular Motor Drives

Abstract

In this research work, a review of integrated modular motor drive (IMMD) technologies is performed. Current research and future prospects are studied. Challenges of the IMMD technologies are discussed. Inverter topologies and gate drive techniques are evaluated in terms of DC link performance. DC Link capacitor types are discussed and critical aspects in selecting the DC links capacitor are listed. Analytical modeling of DC link capacitor parameters is performed and it is verified by simulations conducted using MATLAB/Simulink. Selection of optimum DC Link capacitor is achieved based on the model, capacitor selection algorithm and simulation results.

Keywords

integrated modular motor drive; split winding motor; DC Link capacitor; interleaving; GaN transistor

Introduction

Electric motor drives constitute nearly 45 % of global electricity usage [ref]. Presently, most of the electric energy is generated by means of fossil fuels which means that increase in energy efficiency in motor drive systems will yield not only economical but also environmental benefits.

In conventional motor drive systems, drive units are placed in a cabinet and connected to the motor by means of long cables. Placing the motor and its drive separately increases to the volume and weight of the system decreasing the system power density. In applications such as aerospace or electric traction where motor drives are fundamental elements, power density plays an important role in the design.

In addition, due to the long connection cables, high voltage transients on the motor windings caused by PWM operation occurs on the motor terminals causing leakage currents through stator winding insulation. This effect leads to aging of insulations and shortening of motor lifetime. One measure for this effect is the utilization of filters between motor drive and inverters which is a bulky and costly solution.

In recent years, a new concept called Integrated Modular Motor Drives (IMMDs) has emerged to overcome the aforementioned problems. This concept suggests that, the drive stage of a motor drive system including power stage, control electronics, passive elements and heatsink can be integrated to the motor resulting in a single integrated unit. This integration phenomena brings several advantages.

The power density of the motor drive system is significantly incrased. furthermore, the long cables are eliminated so that the lifetime of the motor is increased and EMI problems are minimized. In addition, this concept aims to modularize the overall system, dividing it into several identical parts. Winding terminals of the motor poles are taken out separately to be driven by its own power electronics. By this way, a motor drive system is composed of a number of identical modules sharing the total power requirement equally. This technique significantly incrases the fault tolerance of the motor and drive as the motor can continue its operation even if a fault occurs on one of the modules. Moreover, the voltage stress on each module and motor winding group is reduced which also enables the utilization of power semiconductor devices with low breakdown voltage ratings. The thermal performance of the drive is also improved as the heat sources in the system are now distributed on a larger surface area, and hot spot temperatures are reduced. In addition, fabrication, installation, maintenance and repairment costs are also drastically reduced thanks to the modular structure.

Alongside of these benefits, integration of the motor and drive brings about several challenges to the designer. First of all, fitting all the drive componenets to such a small footprint requires size optimization and optimum placement of components. Moreover, cooling of motor and drive simultaneously is very difficult. In addition, the electronics is directly subjected to the physical vibration caused by the motor. To reduce the size of passive elements, incrasing the operation frequency by the utilization of new generation wide bandgap power semiconductors is proposed. Because of that, parasitic inductances on both power stage and gate drive circuitry become more significant which requires careful layout design.

All these challenges imply new research opportunities.

Bizim önerdiğimiz yeniliklerden bahsedecek miyiz???

IMMD Technology Review

- Concept of IMMD

Buraya bir-iki görsel gelecek (referans) □□

Yukarıda yazan kısımların bir kısmı buraya alınacak.

- IMMD topologies
- Wide Bandgap Power Semicondcutor Devices
- Modular Motor with Split Winding

In a conventional motor, the stator coils in different poles are usually connected in series forming a single winding for each phase. In a modular motor design, these pole windings can be connected to separate drive inverters. such kind of machines are called split winding machines. This technique can be visualised in Figure.

□ Figür yeniden çizilecek.

DC Link Modeling

As seen in the figure, in a modern power electronics system, passive elements take a significant portion of overall volume and cost (Marz, 2010). □

Therefore, reducing DC link capacitor size is critical in IMMD design.

Decresing the volume of capacitors is not sufficient alone, the height of the capacitors should also be minimized. □

- Analytical Modeling

- Effect of Interleaving

DC Link Capacitor Evaluation

- Types of Capacitors

Capacitor Types

Aluminium electrolytic capacitor

- ++ High capacitance per volume
- ++ Low cost
- ++ Suitable for vibrational environment
- -- Sensitive to temperature change
- -- Low RMS current rating per volume

Polypropylene film capacitor

- ++ High RMS current rating per volume
- ++ Small ESL
- ++ Better temperature stability
- ++ Suitable for vibrational environment
- -- Low capacitance per volume
- -- High cost

Multi-layer ceramic capacitor (MLCC)

- ++ Low cost
- ++ High RMS current rating per volume
- -- Low capacitance per volume
- -- No self-healing capability

- -- Limited power rating (multiple series and parallel capacitors)

- Capacitor Selection Aspects

- Capacitor Selection Algorithm

Results

Conclusions

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