Development of an Integrated Modular Motor Drive (IMMD) System

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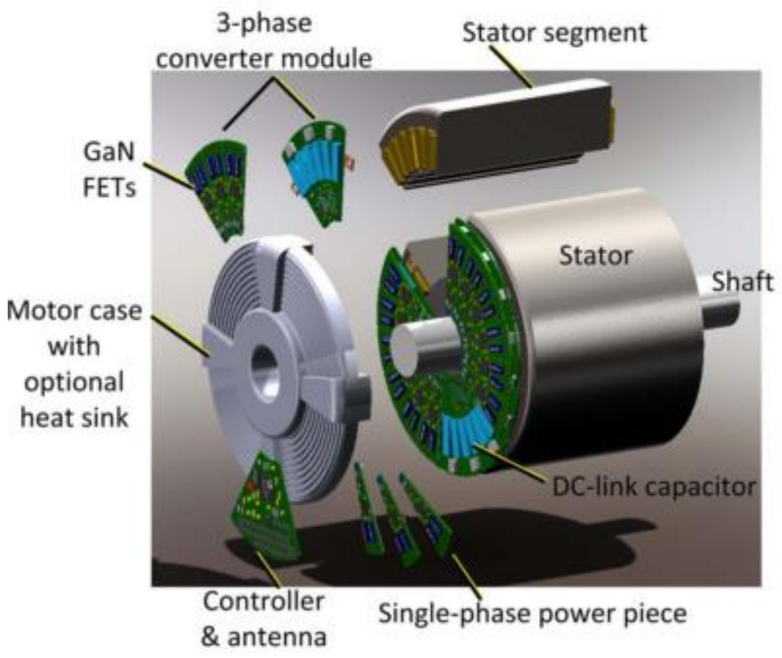
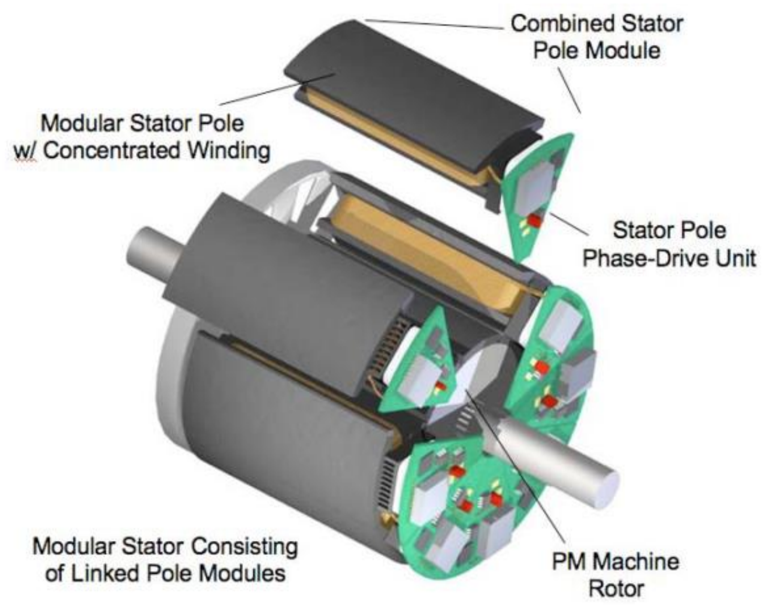
Introduction

In **conventional motor drive** systems, drive units are placed in a separate cabinet, and they are connected to the motor via long cables. This brings increased volume and weight as well as increased voltage overshoot and electromagnetic interference (EMI) problems.

In **integrated modular motor drives (IMMD),** the motor drive is integrated directly to the motor back-end and the system is modularized by dividing into several parts.





Motivation

Integration

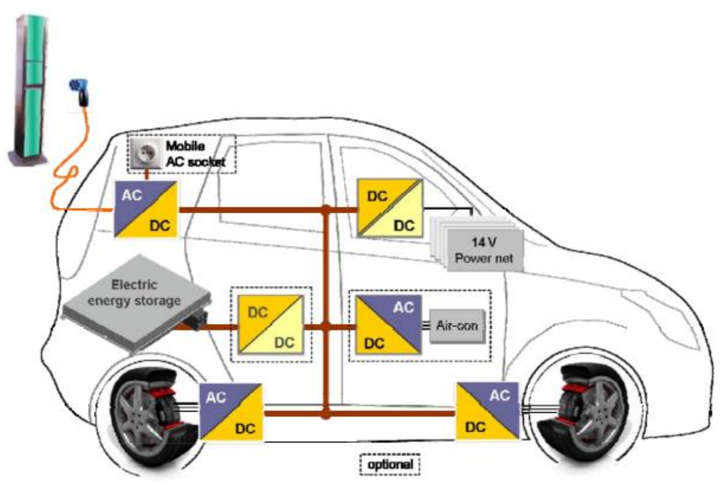
- ✓ **Power density** of the overall system is enhanced significantly.
- ✓ **Voltage overshoots** due to cabling effect is eliminated.

Modularization

- ✓ **Fault tolerance** is increased
- ✓ **Voltage stress** on modules is reduced
- ✓ **Heat dissipation** is distributed to a wider area

Applications

Electric traction: electric vehicles, trains
Aerospace: aircrafts, space crafts

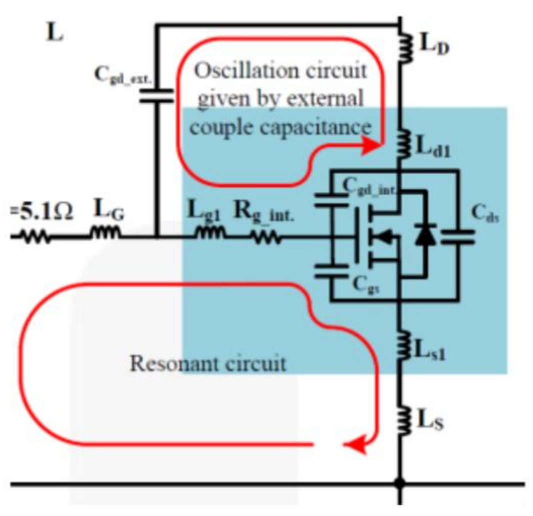


Challenges

- ❖ Fitting into a small volume requires size reduction and optimum placement of components.
- ❖ Cooling of both units should be achieved simultaneously.
- ❖ Power and control electronics components are subjected to high temperature and vibration

These challenges can be addressed by using **wide band-gap (WBG)** power semiconductor devices such as **Gallium Nitride (GaN).**

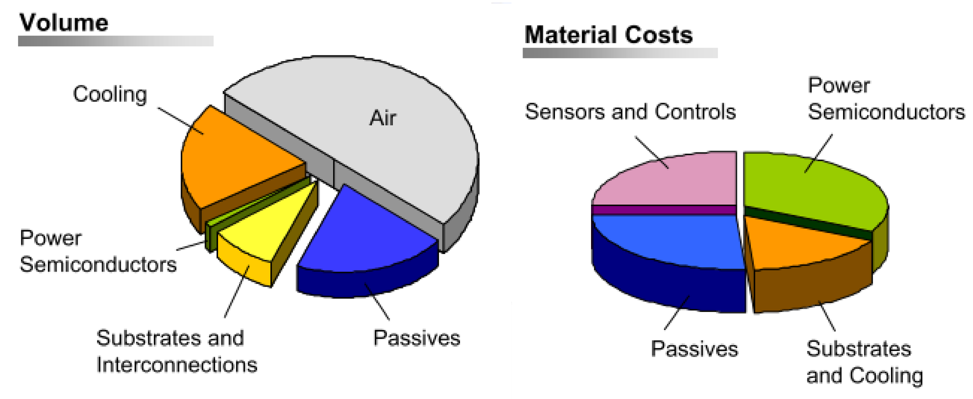
- Low semiconductor loss: **heat sink** size is reduced
- High operation frequency: **passive component** size is reduced



Additional challenges
Parasitic components become significant
Careful layout design is required

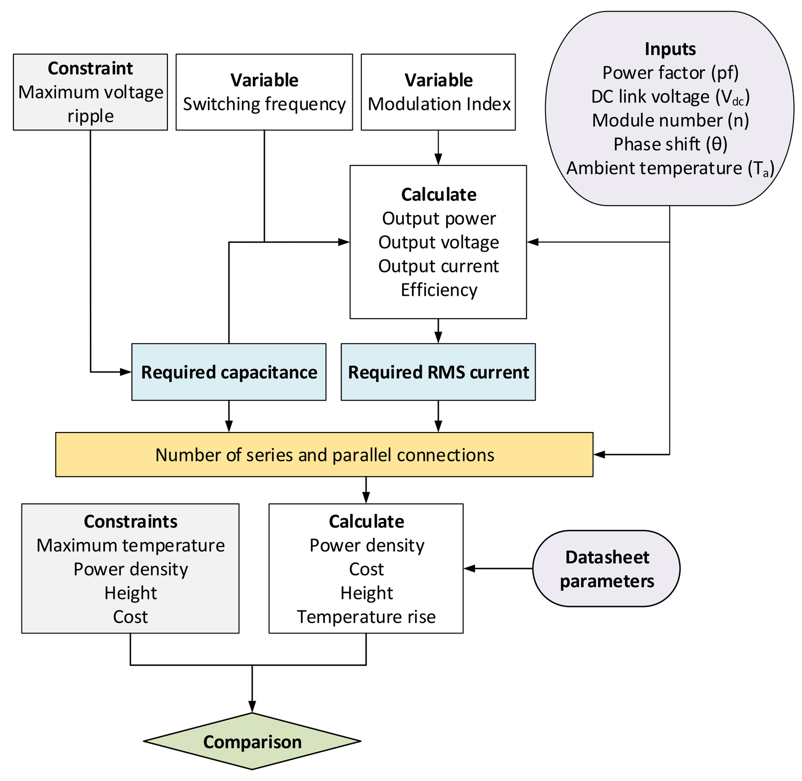
DC link capacitor optimization

DC link capacitors constitute 20% of **cost** and **weight**, and 30% of **volume**

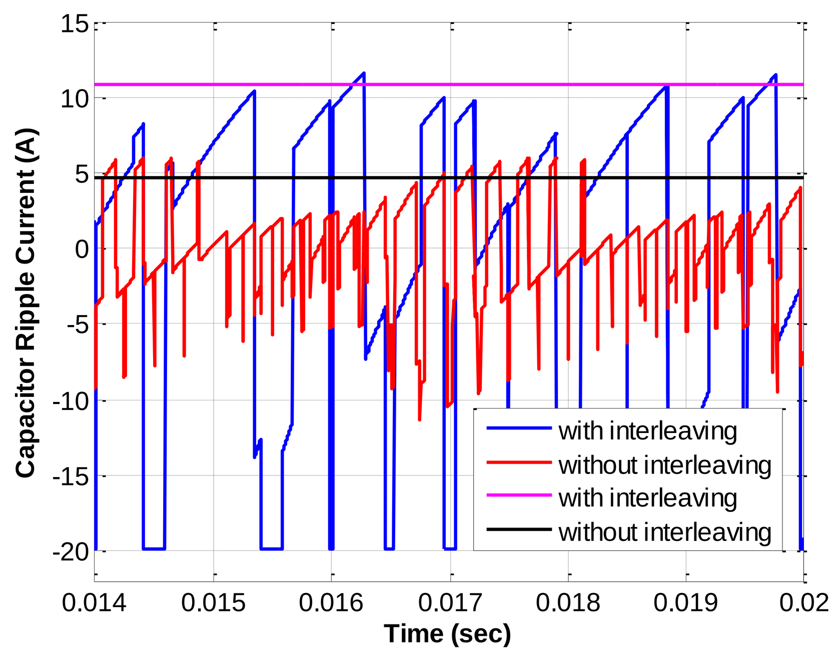


An **analytical model** has been constructed. An **algorithm** has been developed. A set of **film capacitors** are considered. Optimization is achieved based on:

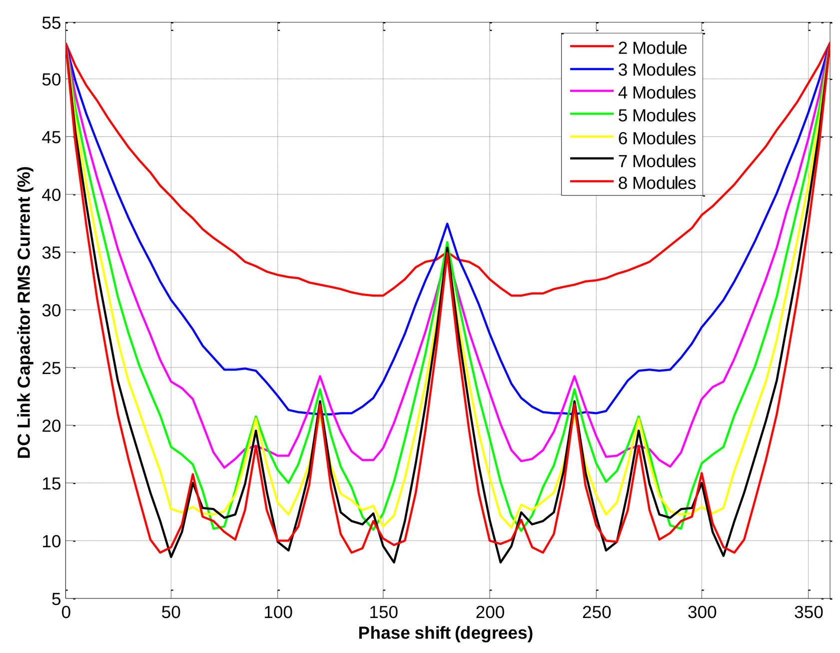
- Power density
- Cost
- Height
- Temperature rise



Effect of interleaving



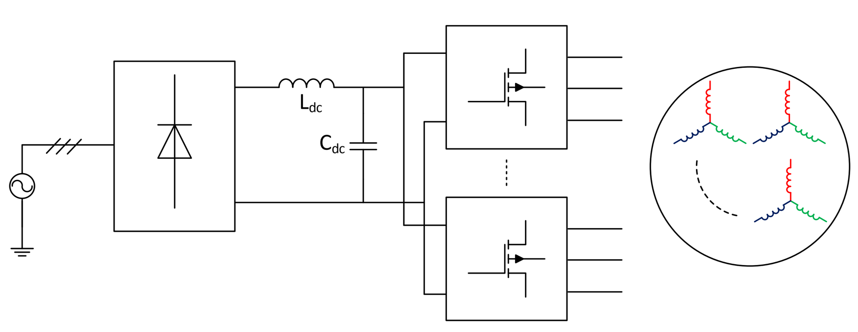
Phase-shift angle



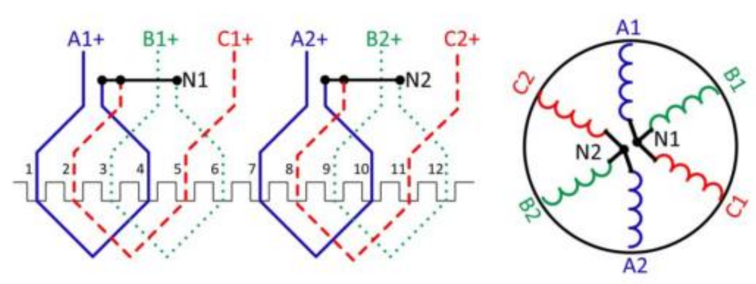
IMMD Design

- ✓ Series and parallel connected three-phase inverter modules
- ✓ Fractional Slot Concentrated Winding (FSCW) stator
- ✓ Permanent Magnet Brushless DC (PM-BLDC) motor

Proposed Topology



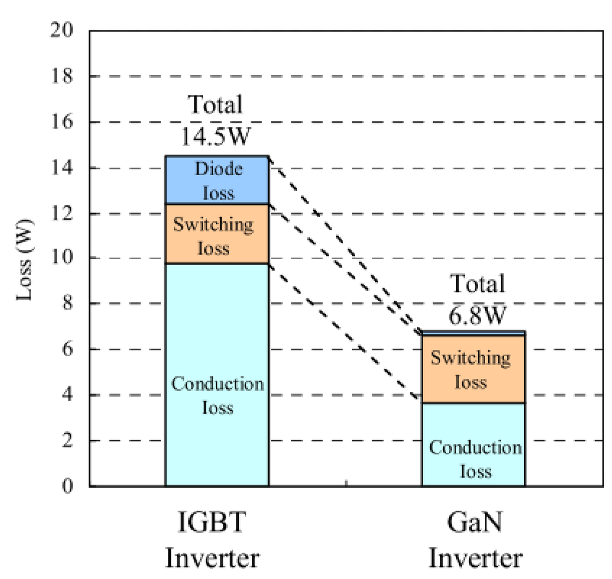
Winding diagram



Specifications

4 three-phase modules
24 slot double layer stator
20 pole rotor
600V – 20A GaN FETs
4 20uF, 450V capacitors, connected in parallel

Loss Characterisation



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