Design of an Integrated Modular Motor Drive System

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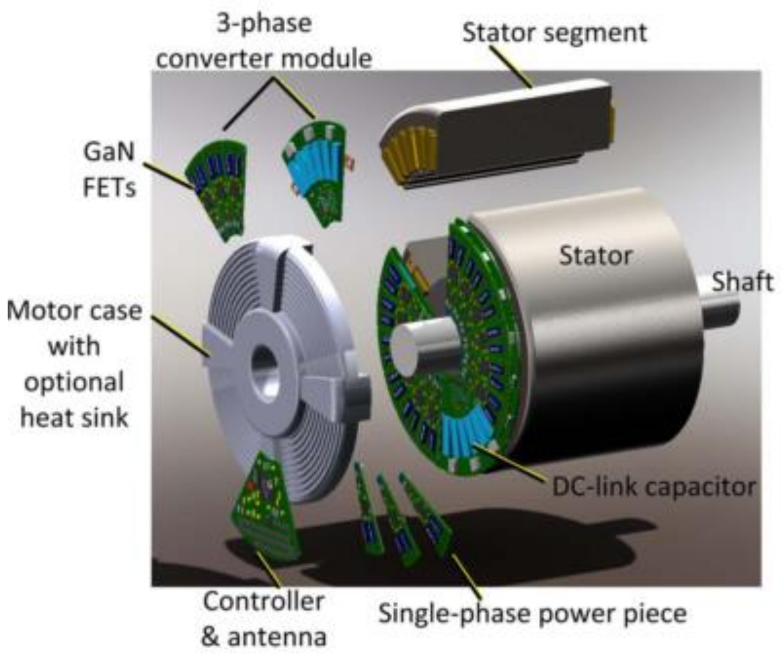
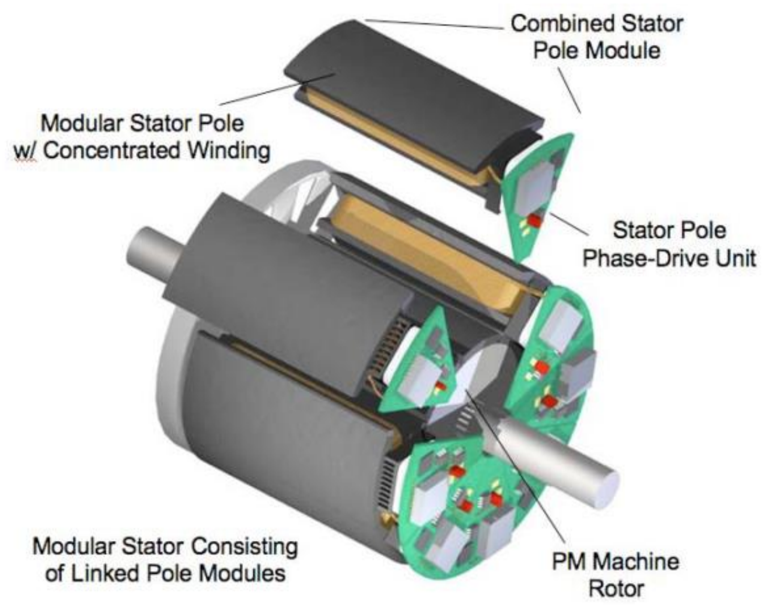
Introduction

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 [1].





Motivation

Integration

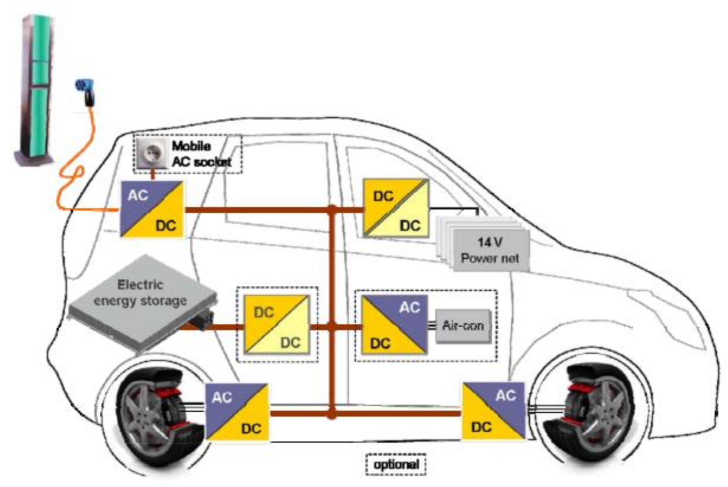
- ✓ **Power density** of the overall system is enhanced significantly [2].
- ✓ **Voltage overshoots** due to cabling effect is eliminated.

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

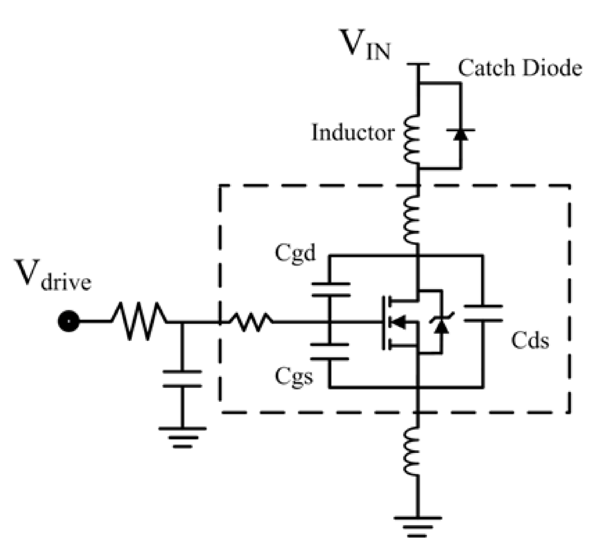
- ❖ Fitting into a small volume requires size reduction and optimum placement of components.
- ❖ Cooling of both units should be achieved simultaneously.
- ❖ Power and control electronics components are subjected to high temperature and vibration [3].

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 due to GaN

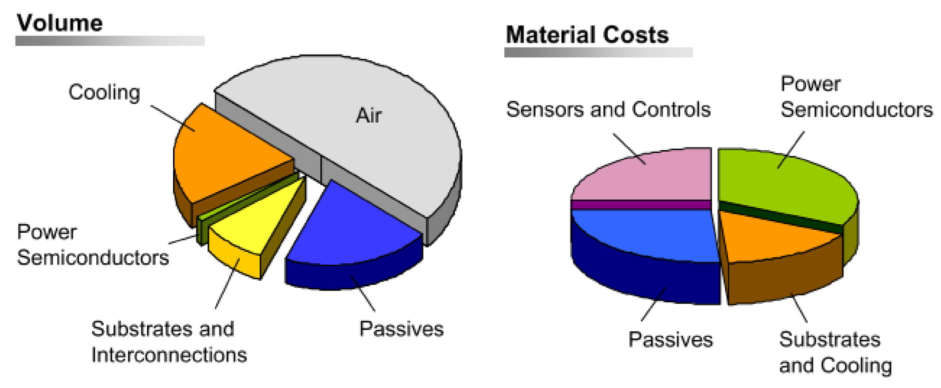
- Parasitic components become significant
- Careful layout design is required



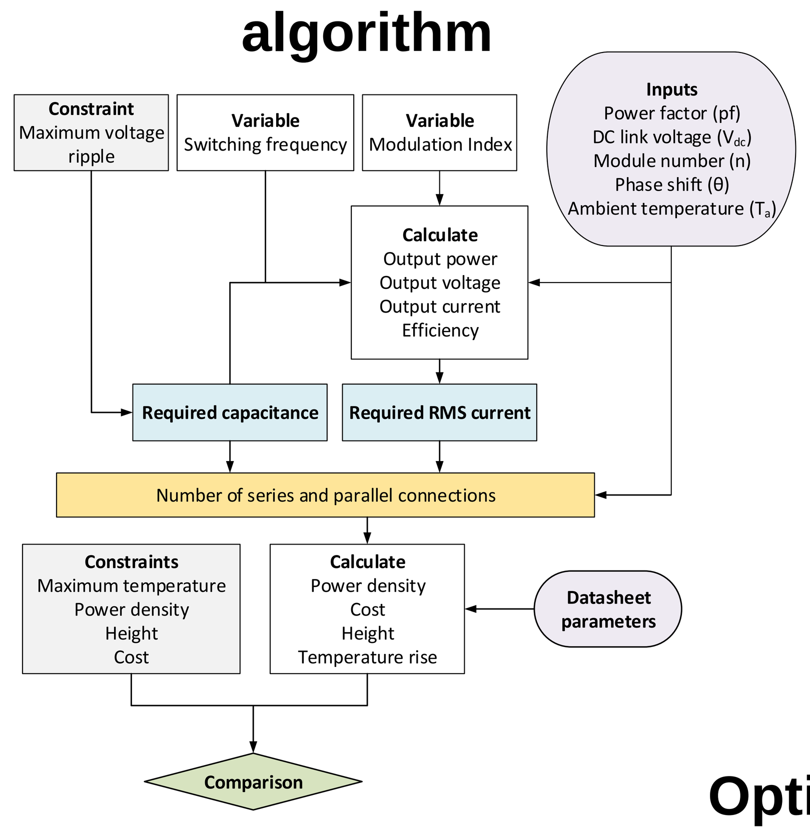
DC link capacitor optimization

DC link capacitors constitute:

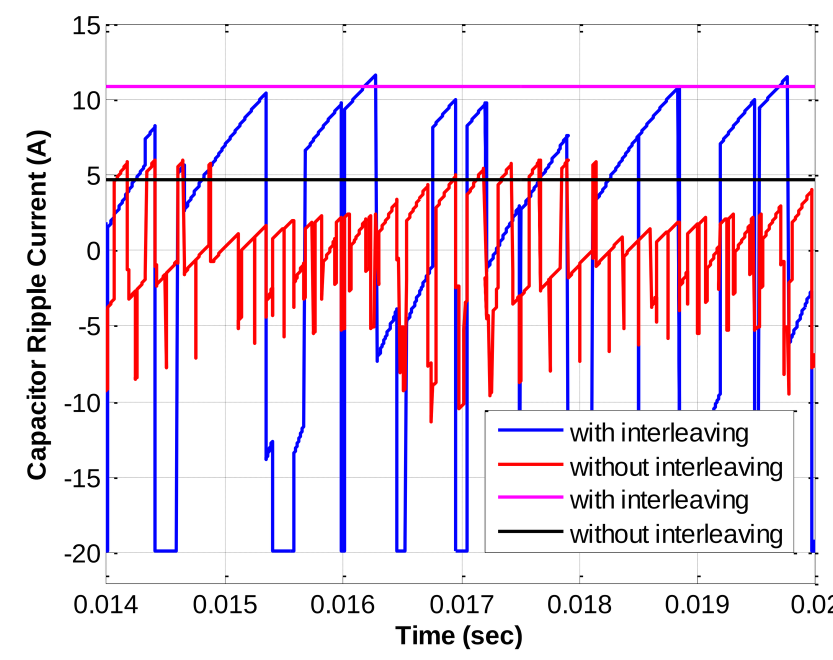
- 20% of **cost** and **weight,**
- 30% of **volume** [1].



DC link capacitor selection algorithm



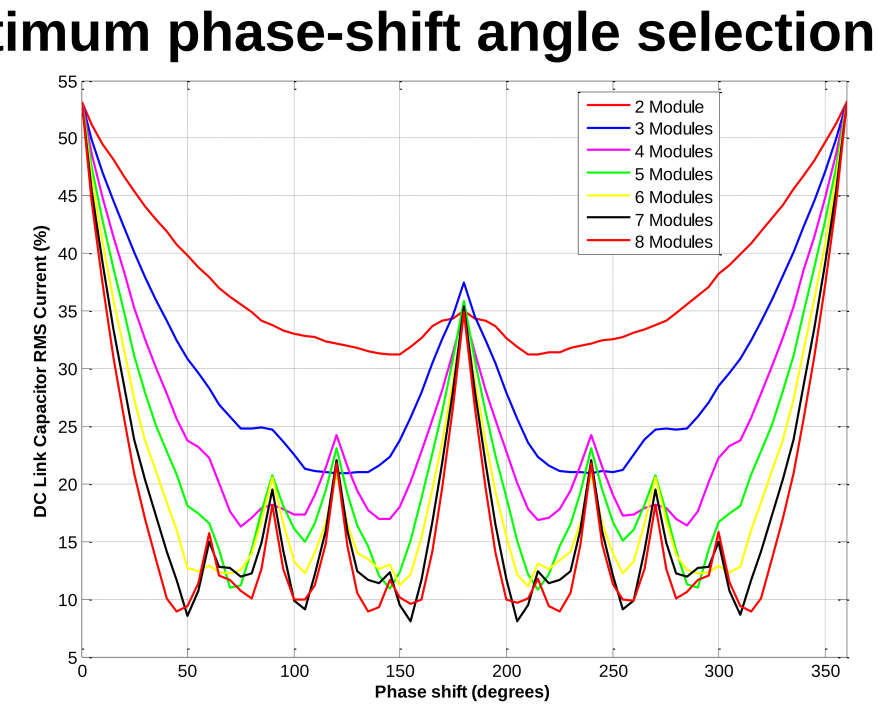
Effect of interleaving



Optimum phase-shift angle selection

A set of **film capacitors** are considered. Optimization is achieved based on:

- Power density
- Cost
- Height
- Temperature rise



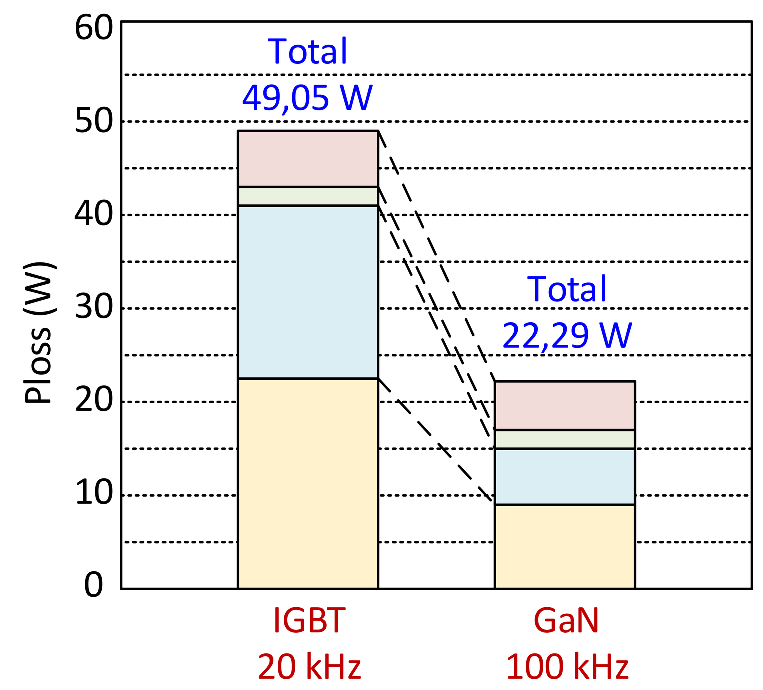
IMMD Design

- ✓ Four three-phase inverter modules (two-series and two-parallel)
- ✓ Power stage with cascode GaN FETs
- ✓ Permanent Magnet Brushless DC (PM-BLDC) motor
- ✓ Fractional Slot Concentrated Winding (FSCW) stator

Specifications

- Four three-phase modules
- 6 kW total output power
- 24 slot double layer stator
- 20 pole PM rotor
- 600V – 20A GaN FETs
- Four 20µF, 450V capacitors

Loss Characterization



Conclusions & Planned Work

An IMMD laboratory prototype is being developed with the given specifications. The aimed performance is:

- ❑ Drive efficiency**: 98.5%**
- ❑ Drive power density**: 15 W/cm^3**
- ❑ Increased **fault tolerance**
- ❑ Motor housing for cooling (**no heatsink**)

References

1. G. Lo Calzo *et al.*, “Integrated motor drives: state of the art and future trends,” *IET Electr. Power Appl.*, vol. 10, no. 8, pp. 757–771, Sep. 2016.
2. J. Wang, Y. Li, and Y. Han, “Integrated Modular Motor Drive Design With GaN Power FETs,” *IEEE Trans. Ind. Appl.*, vol. 51, no. c, pp. 3198–3207, 2015.
3. J. J. Wolmarans, M. B. Gerber, H. Polinder, S. W. H. De Haan, J. A. Ferreira, and D. Clarenbach, “A 50kW integrated fault tolerant permanent magnet machine and motor drive,” *PESC Rec. - IEEE Annu. Power Electron. Spec. Conf.*, pp. 345–351, 2008.