# Development of an Integrated Modular Motor Drive (IMMD) System


**Mesut Uğur**
ugurm@metu.edu.tr

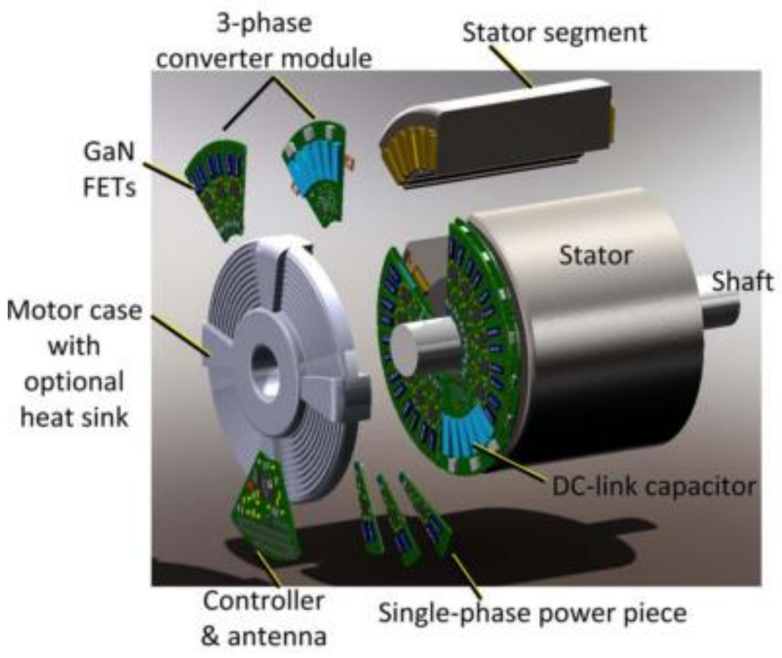
**Ozan Keysan**
keysan@metu.edu.tr

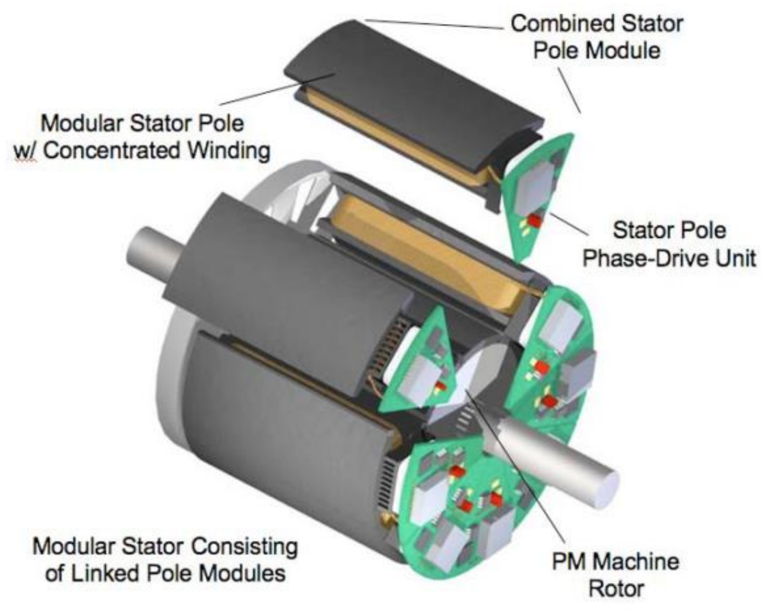
*Department of Electrical and Electronics Engineering*
*Middle East Technical University*


## 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

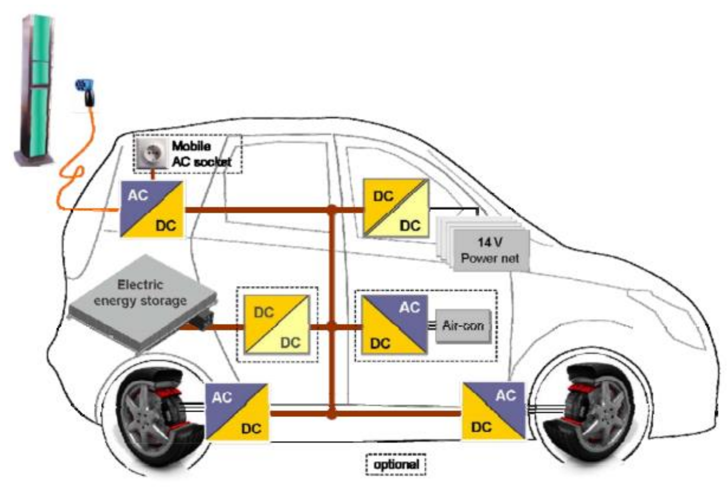
- ✓ **Power density** of the overall system is enhanced significantly [2].
- ✓ **Voltage overshoots** due to cabling effect is eliminated.

### 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

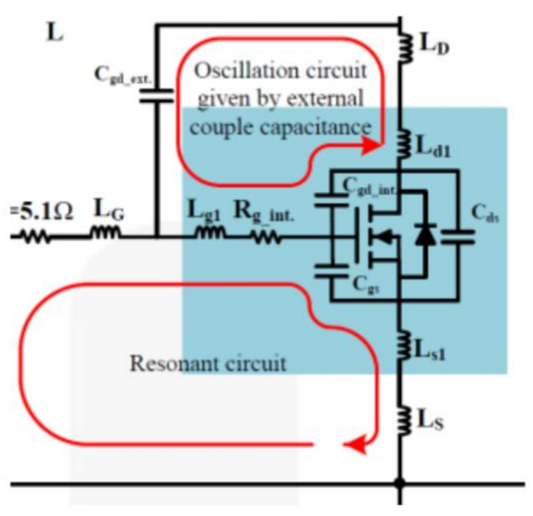


## Challenges

- ❖ 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

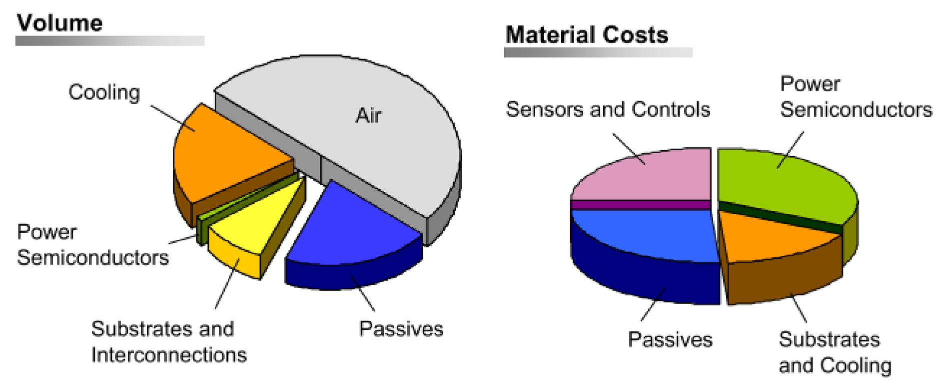



**Additional challenges**
Parasitic components become significant
Careful layout design is required

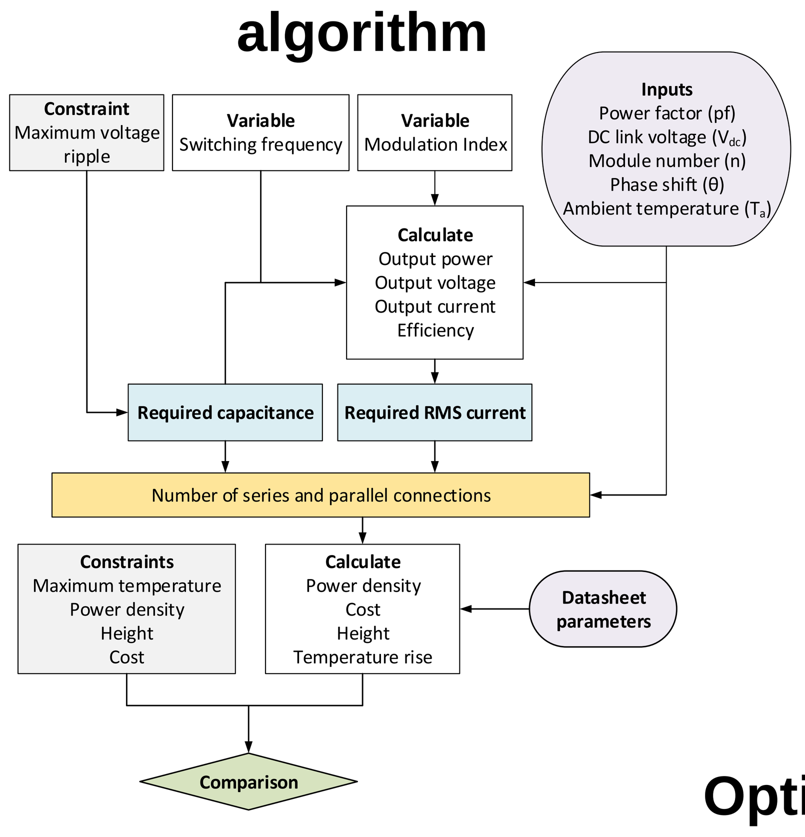
## DC link capacitor optimization

DC link capacitors constitute:

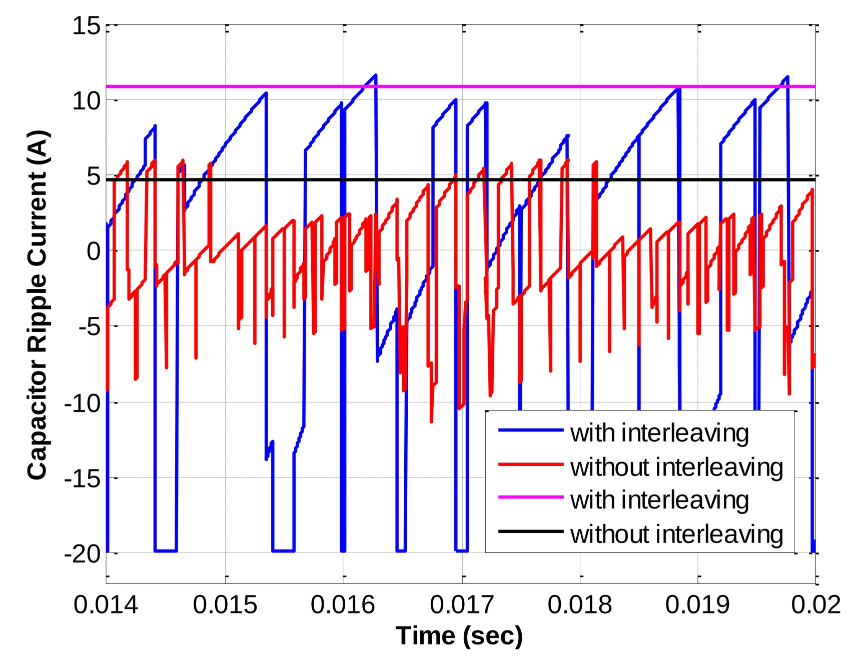
- 20% of **cost** and **weight,**
- 30% of **volume** [1].




### DC link capacitor selection algorithm



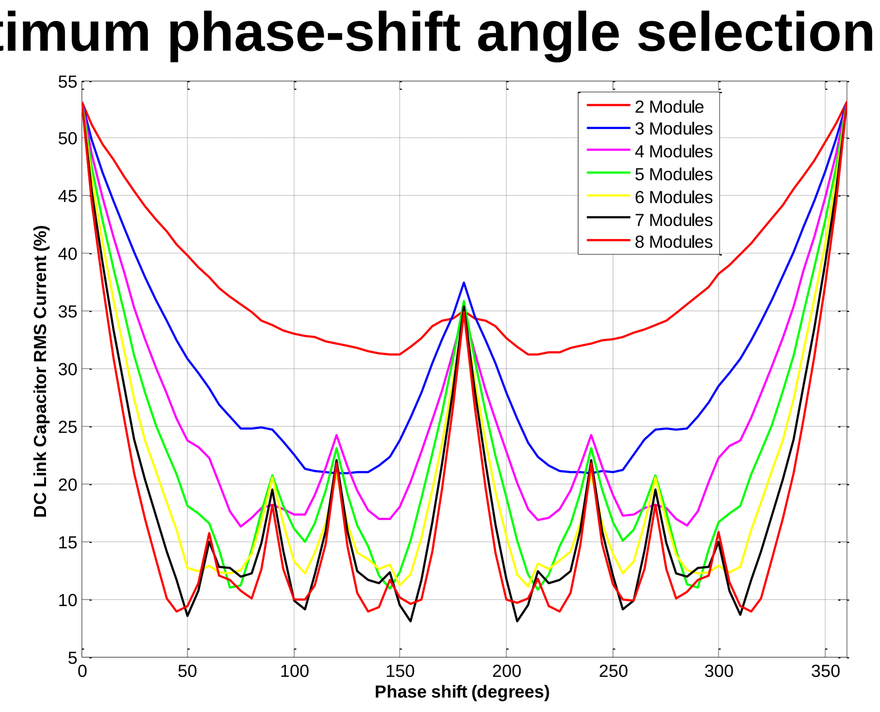

### Effect of interleaving




### 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

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

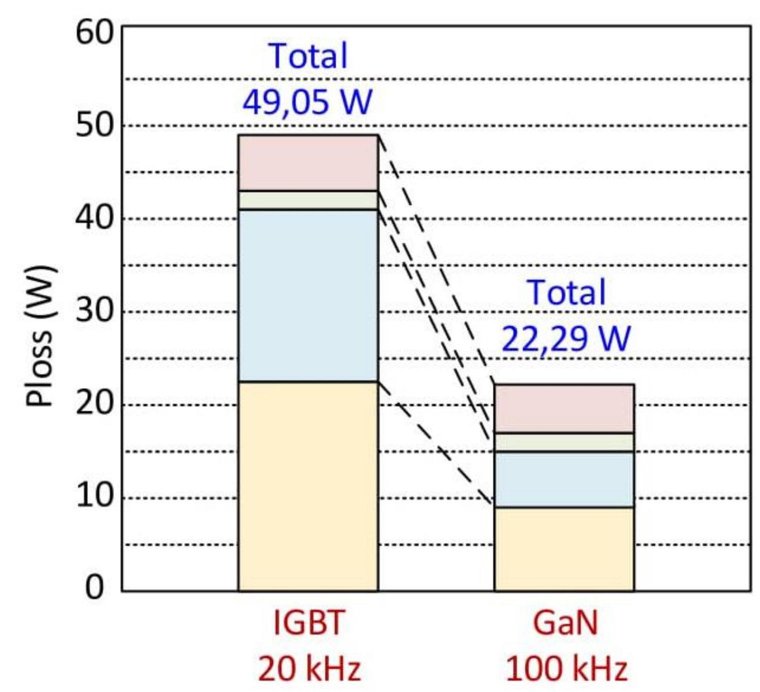
### Specifications

- Four three-phase modules
- 7kW total output power
- 24 slot double layer stator
- 20 pole rotor
- 600V – 20A GaN FETs
- Four 20uF, 450V capacitors

### Results

- ❑ Drive efficiency**: 99%**
- ❑ Power density**: 40 W/cm³**
- ❑ What else ???

### Loss Characterization




## Conclusions & Planned Work

A laboratory prototype is being developed