THE HYBRID-SYNCHRONOUS MACHINE OF
THE NEW BMW i3 & i8
CHALLENGES WITH ELECTRIC TRACTION DRIVES FOR VEHICLES
WORKSHOP UNIVERSITY LUND

BMW GROUP

BMW i3.
VEHICLE CONCEPT.

Maximum speed $v_{\text{max}}$: 150 km/h
Acceleration 0-100 km/h: 7.2 s
Range
  - KV01 cycle: 190 km
  - FTP72 cycle: 225 km (140 mls)
Vehicle weight $m_{Fzg}$: 1195 kg
Battery energy content: 22 kWh
Peak power (ECE R85): 125 kW
30 min power (ECE R85): 75 kW
**BMW i8. VEHICLE CONCEPT.**

- **Vehicle Type:** Hybrid
- **Maximum speed** $v_{\text{max}}$: 250 km/h
- **Acceleration 0-100 km/h:** 4.4 s
- **Fuel Consumption:** 2.5 l/100km
- **Electric Range:** 35 km
- **Vehicle weight** $m_{\text{Fzg}}$: 1490 kg
- **Power (el + ICE):** 96 kW + 170kW
- **Torque (el + ICE):** 250 Nm + 320Nm

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**THE POWERTRAIN OF THE BMW i8. POWERTRAIN SYSTEM OVERVIEW.**

- 6-Speed Automatic Transmission
- High voltage battery
- 1.5 Litre TwinPower Turbo Engine
- Power Electronic HV SGR
- E-Motor
- 2 Gear E-Transmission
- Power Electronic Traction Motor
- HV SGR
BMW i3 AND i8.
GENERAL POWERTRAIN DEMANDS.

- **High efficiency**
  Increase range and reduce battery costs
- **Low weight**
  Due to the Light weight concept i3 & i8
- **Direct connected power electronic**
  Avoiding EMC problems and plugs
- **Lowest possible AC current**
  Reducing connections and inverter costs
- **Single speed gearbox (i3)**
  Reducing system complexity and weight
- **Wide range of constant power**
  Necessary due to single speed gearbox

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BMW i3.
DRIVE UNIT - TECHNICAL DATA.

- **Machine type:** PM-Motor (HSM)
- **Maximum torque** $M_{\text{max}}$: 250 Nm
- **Maximum speed** $n_{\text{max}}$: 11,400 1/min
- **Voltage range:** 250 – 400 V
- **Max. phase current** $I_{\text{eff}}$: 400 A
- **Number of pole pairs** $p$: 6
- **Weight:** appr. 65 kg
- **Cooling:** Liquid

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CHOICE OF THE MACHINE TYPE.
CONSIDERED TOPOLOGIES.

- **PSM:** Permanent magnet motor with surface mounted magnets.
- **IPM:** Motor with buried magnets. Different geometries possible.
- **HSM:** “Hybrid synchronous motor”. Special geometry of an IPM. Designed for high reluctance torque.
- **El.Ex.Sm:** Electrically excited synchronous machine.
- **ASM:** Asynchronous machine.

**COMPORATION OF DIFFERENT MACHINE TOPOLOGIES FOR LIMITATED STATOR CURRENT.**
**COMPARATION OF DIFFERENT MACHINE TOPOLOGIES. CHOICE OF MACHINE TYPE.**

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<th>PSM</th>
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**MOTOR OF THE BMW i3. HYBRID SYNCHRONOUS MOTOR.**

Two layer magnet arrangement
- very sinusoidal induced voltage
- high difference \( L_d - L_q \)
High Number of pole pairs \((p = 6)\)
- to reduce the yoke weight
Iron mass reduced to the absolute necessary dimensions
- special attention to the mechanical strength

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MOTOR PERFORMANCE.
MEASURED MAXIMUM TORQUE CURVE.

M [Nm] | Pmech [kW]
-------|----------
0      | 0
250    | 250
50     | 50
150    | 150
200    | 200
250    | 250
300    | 300

n [1/min] 0 3000 6000 9000 12000

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MOTOR PERFORMANCE.
MEASURED EFFICIENCY OF THE MOTOR.

FTP72 Cycle
Full- and partial Load
Highway

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MOTOR PERFORMANCE. MEASURED EFFICIENCY.

- During a normal drive cycle the most energy conversion will take part at low torque.
- In this operating area, the iron losses are dominant and have to be minimized.

- Machine topology (HSM)
- Thin iron sheets in the stator
- Special rotor geometry (additional slits)

MECHANICAL DESIGN AND LIGHT WEIGHT CONCEPT. COMPLETE MOTOR.
MECHANICAL DESIGN.
LIGHT WEIGHT CONCEPT.

-- High number of pole pairs (6) to reduce the mass of the stator and rotor yoke.

-- Rotor iron reduced to the absolute necessary dimensions regarding:
   -- Flux conduction
   -- Mechanical strength

CONCLUSIONES.

-- The hybrid synchronous motor is the most suitable drive regarding the powertrain demands of the i3 & i8.

-- The use of the reluctance torque provides a high available power in the upper speed range.

-- Furthermore the efficiency is very high in a wide operating area.

-- First electric Motor completely designed and produced by the BMW Group.
THANK YOU FOR YOUR ATTENTION.