



Dr.-Ing. J. Merwerth
BMW Group, München

THE HYBRID-SYNCHRONOUS MACHINE OF THE NEW BMW i3 & i8

CHALLENGES WITH ELECTRIC TRACTION DRIVES FOR VEHICLES
WORKSHOP UNIVERSITY LUND

**BMW
GROUP**




Rolls-Royce
Power Cars Limited

BMW i3. VEHICLE CONCEPT.



Maximum speed v_{\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

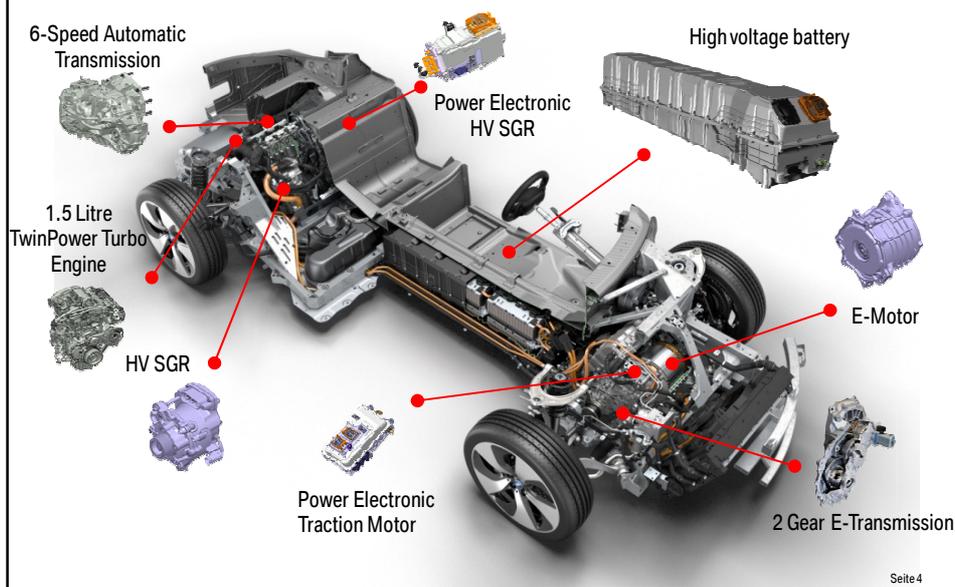
BMW i8. VEHICLE CONCEPT.



Vehicle Type:	Hybrid
Maximum speed v_{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_{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.



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_{max} :	250 Nm
Maximum speed n_{max} :	11.400 1/min
Voltage range:	250 – 400 V
Max. phase current I_{1eff} :	400 A
Number of pole pairs p:	6
Weight:	appr. 65 kg
Cooling:	Liquid

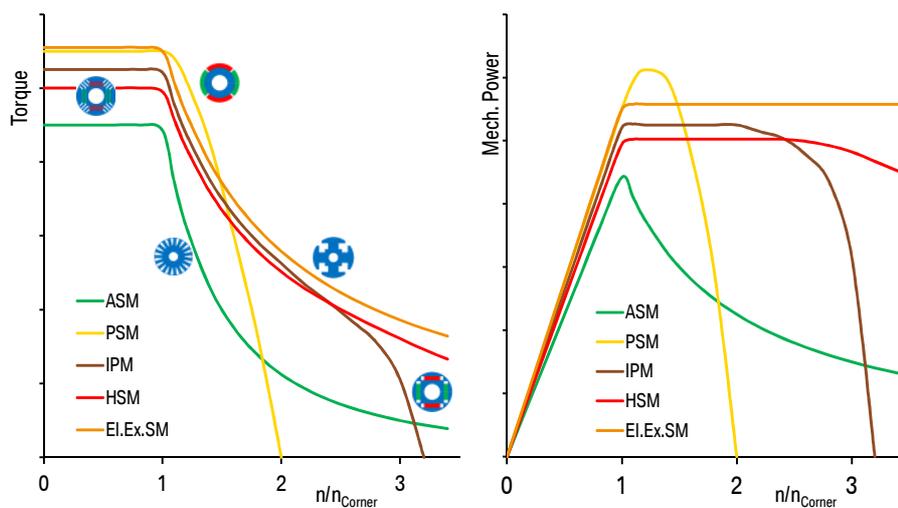
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CHOICE OF THE MACHINE TYPE. CONSIDERED TOPOLOGIES.

- 
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.
- 
EI.Ex.Sm: Electrically excited synchronous machine.
- 
ASM: Asynchronous machine.

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COMPARISON OF DIFFERENT MACHINE TOPOLOGIES FOR LIMITED STATOR CURRENT.



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COMPARISON OF DIFFERENT MACHINE TOPOLOGIES. CHOICE OF MACHINE TYPE.

	 PSM	 IPM	 HSM	 EI.Ex.SM	 ASM
Constant power over speed range					
Torque per stator current					
Efficiency over complete operating range					
Weight					

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MOTOR OF THE BMW i3. HYBRID SYNCHRONOUS MOTOR.

Two layer magnet arrangement

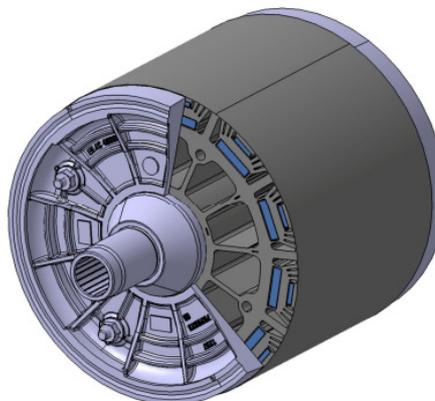
- very sinusoidal induced voltage
- high difference $L_d - L_q$

High Number of pole pairs ($p = 6$)

- to reduce the yoke weight

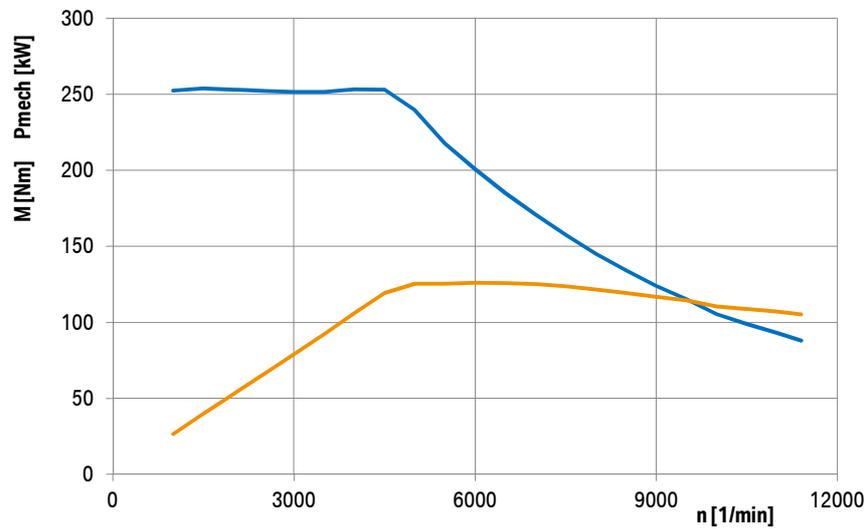
Iron mass reduced to the absolute necessary dimensions

- special attention to the mechanical strength



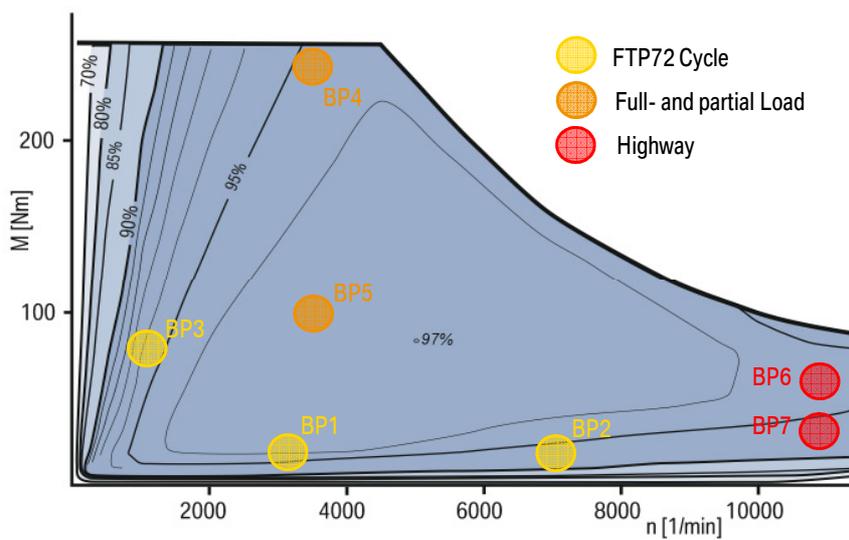
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MOTOR PERFORMANCE. MEASURED MAXIMUM TORQUE CURVE.



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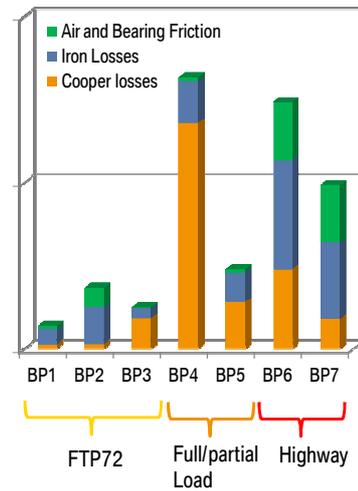
MOTOR PERFORMANCE. MEASURED EFFICIENCY OF THE MOTOR.



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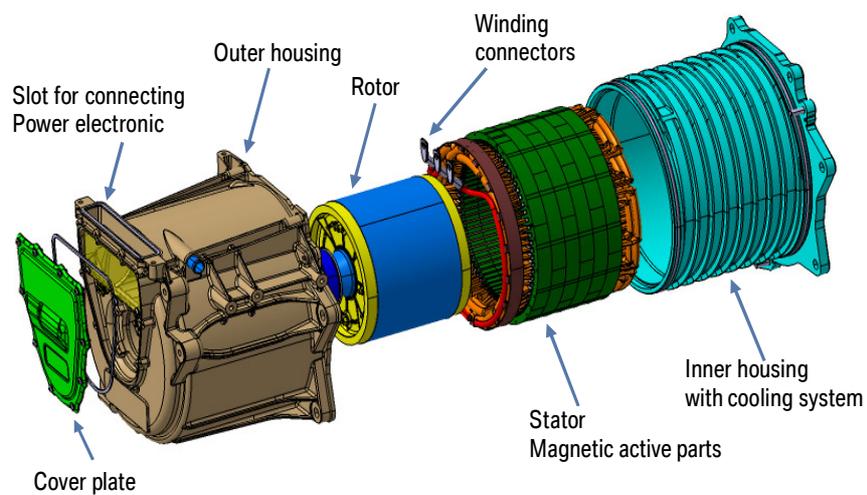
MOTOR PERFORMANCE. MEASURED EFFICIENCY.

- 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)



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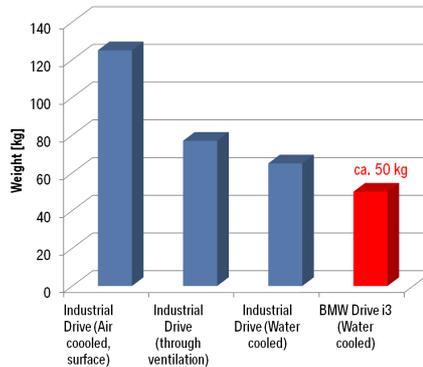
MECHANICAL DESIGN AND LIGHT WEIGHT CONCEPT. COMPLETE MOTOR.



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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



(Comparison based on the same S1 Torque)

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CONCLUSIONS.

- 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.



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THANK YOU FOR YOUR ATTENTION.



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