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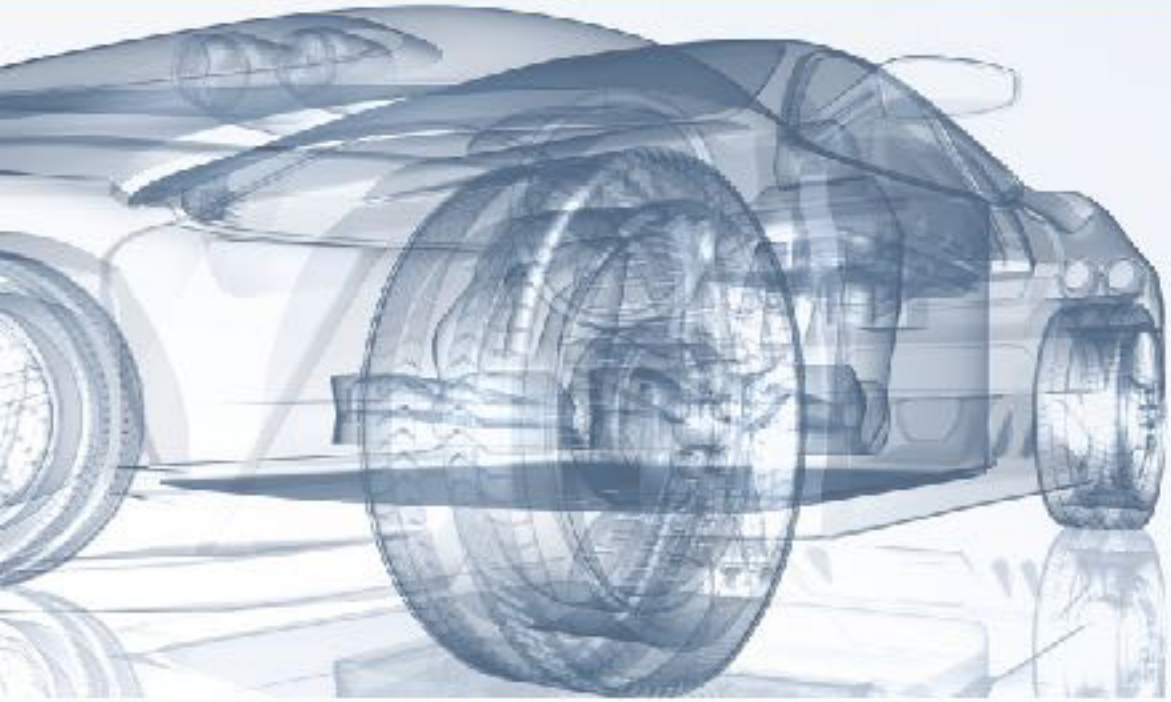

The 30th International
Electric Vehicle
Symposium & Exhibition

October 9–11, 2017

Messe Stuttgart, Germany

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COST OPTIMIZED INTEGRATED ELECTRIC POWERTRAIN CONTAINING THE FIRST SILENT SWITCHED RELUCTANCE MOTOR FOR PASSENGER VEHICLES

Steven Bervoets

Fabien Chauvicourt

Agenda

1. The ARMEVA project
2. Switched Reluctance Motor
3. Multiphysics modelling
4. Integrated Electric Powertrain
5. Testing and Characterization
6. Demonstrator
7. Conclusions

ARMEVA
Advanced Reluctance Motors for Electric Vehicle Applications

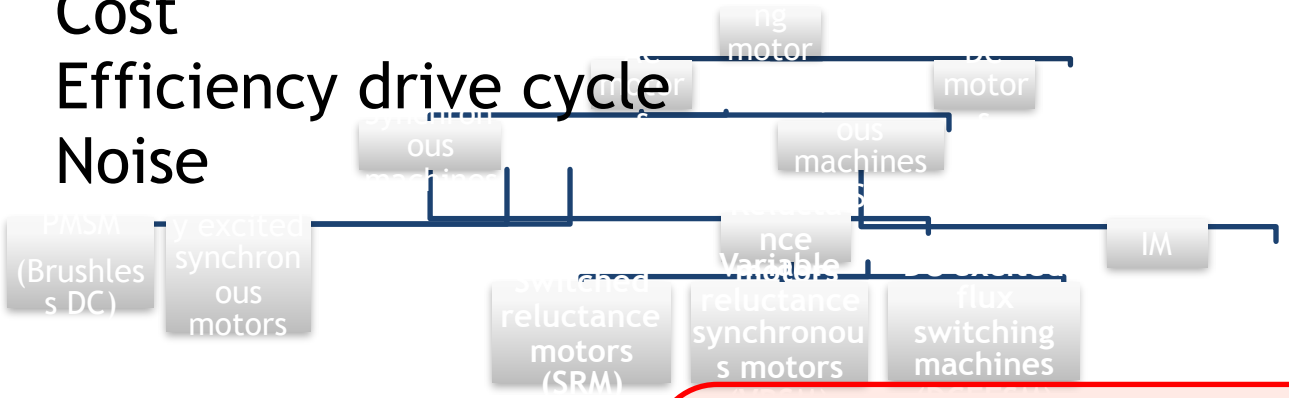
Punch Powertrain	Punch Powertrain N.V.
SIEMENS	Siemens SISW
TU/e	Technische Universiteit Eindhoven
PRODRIVE TECHNOLOGIES	Prodrive B.V.
TeKshift	TeKshift GmbH
UNIVERSITATEA TEHNICĂ	Universitatea Tehnica din Cluj-Napoca
SIEMENS	Siemens SISW

Goal:

To develop a new generation of rare-earth free electric motors based on magnetic reluctance.

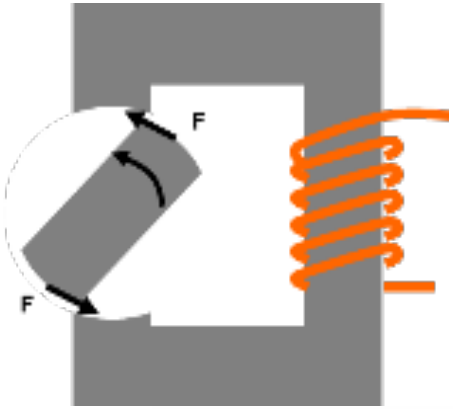
ARMEVA research scope

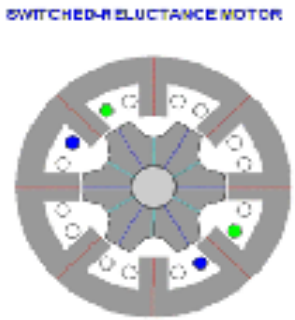
- Cost
- Efficiency drive cycle
- Noise



Switched Reluctance Motor

Basic Principle: Magnetic Reluctance





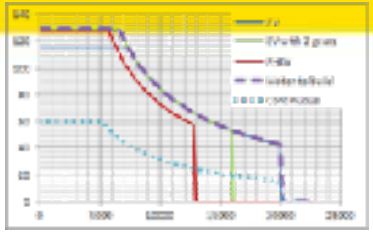
Advantages

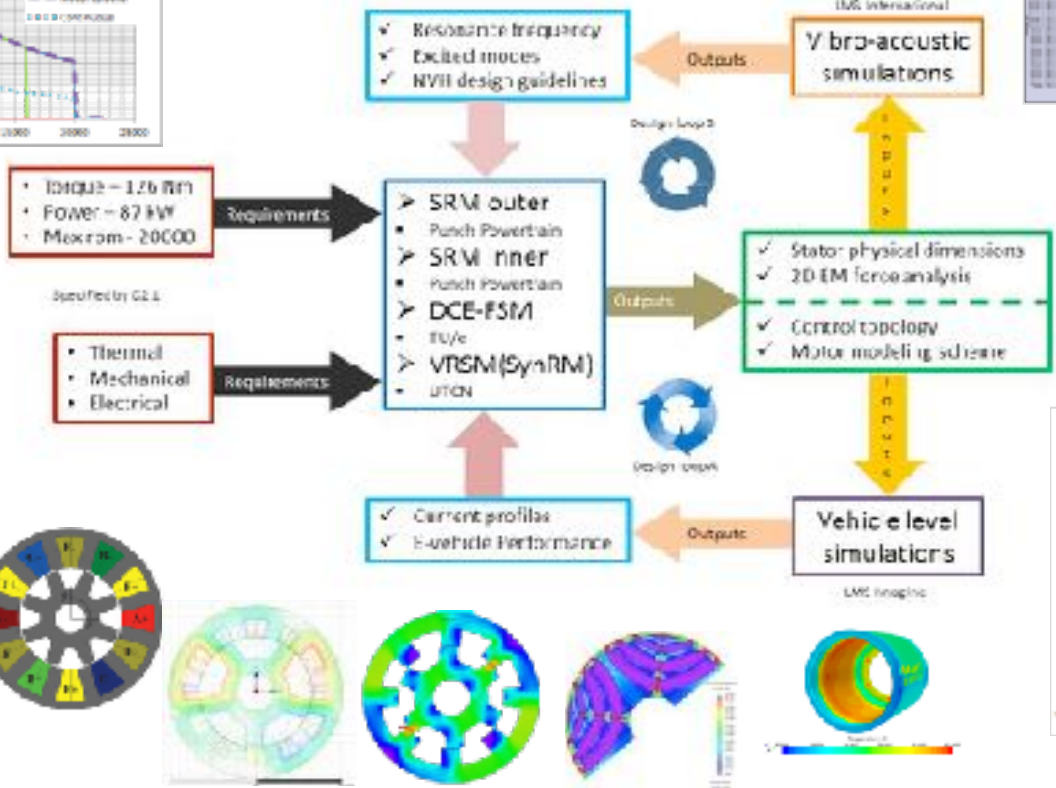
- Simple, robust construction
- No permanent magnets
- High efficiency
- High speed capability
- Low cost
- Safe Operation

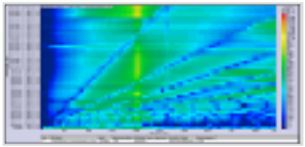
Challenges:

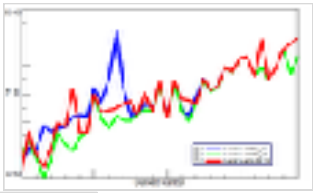
- Torque Ripple
- Controls
- Electronics
- Acoustics

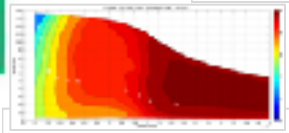
Multi-Disciplinary design approach

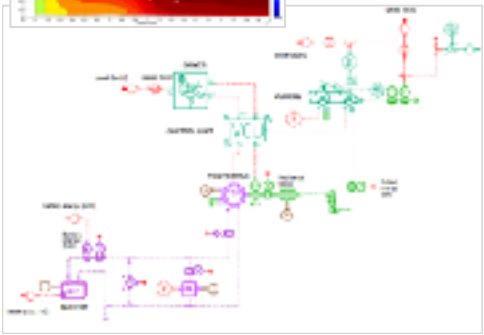








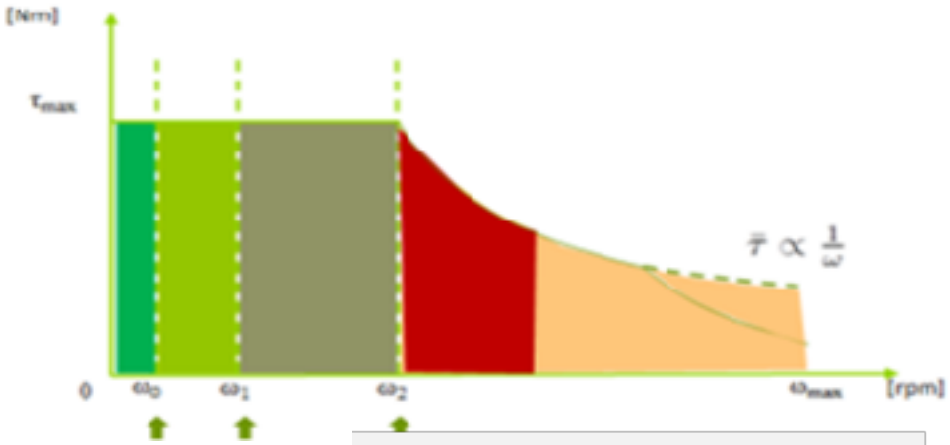


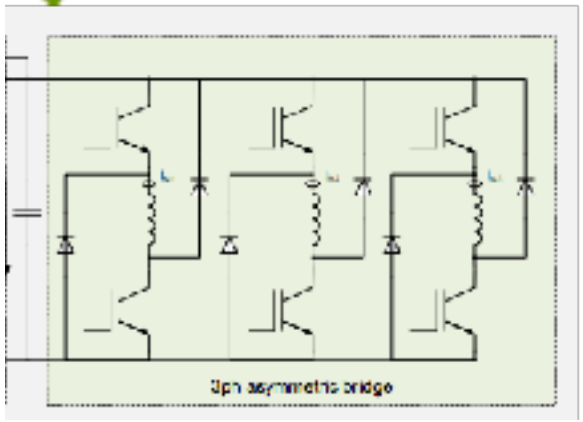


Inverter design incl controls

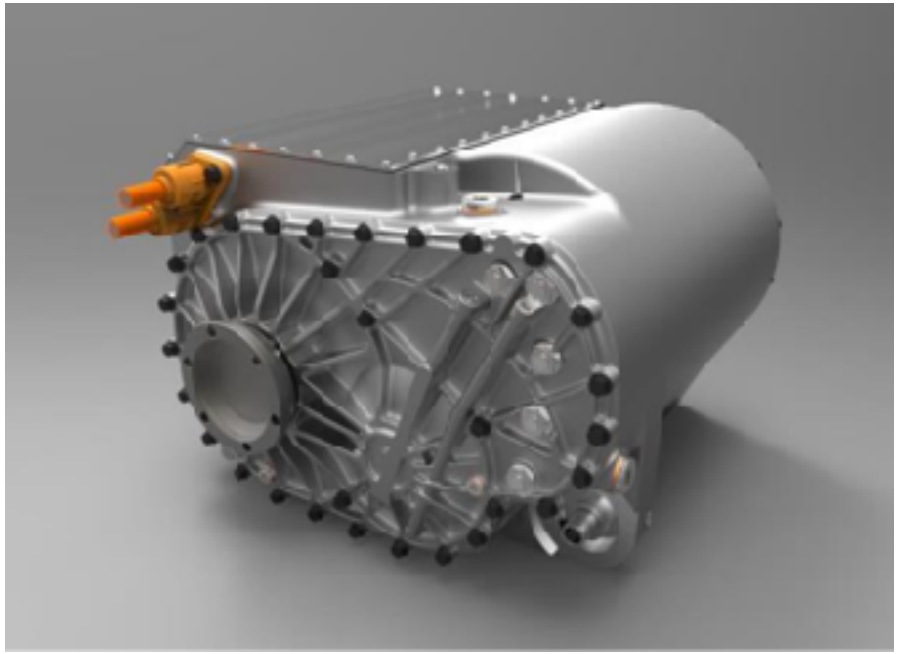
- Asymmetric half bridge
- State of the art control strategies: PWM-DITC, DATC, CCM, PASTA, ATC, TSF,
- Zynq SoC device: FPGA+processor
- VHDL made from Model Based Design

- Validation on HIL before HW was ready



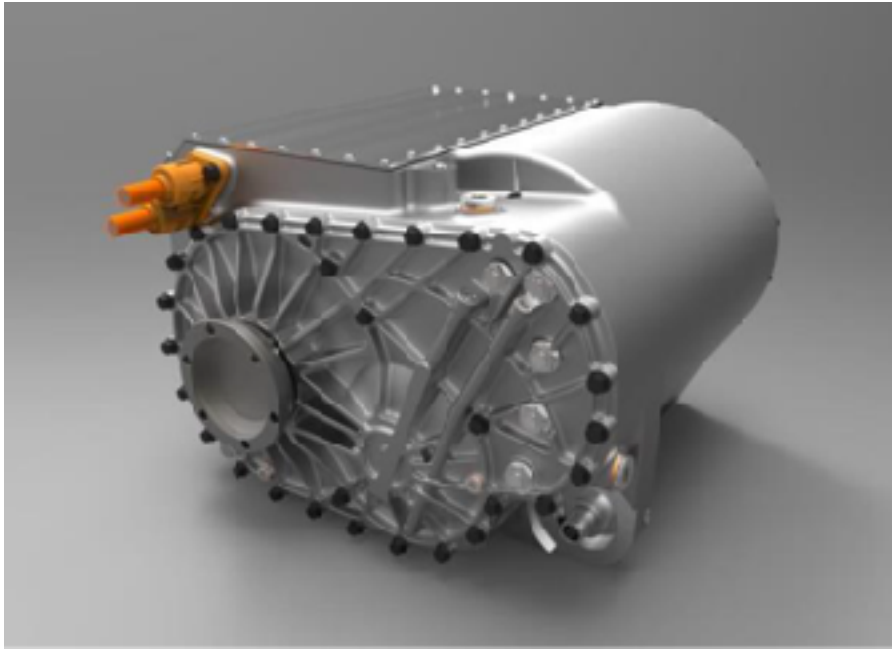


- 427 x 409 x 304 mm
- Optimized cooling, high flow @ low back pressure
- Reduced interfacing:
  - HV from battery
  - CAN-bus & 12V
  - Coolant in and out
  - Powertrain suspension
  - Driveshafts



Integrated Electric Powertrain: Spec Sheet

Motor Technology:	Switched Reluctance
Max. Motor Speed:	20.000 rpm
Max. Motor Stall Torque:	180 Nm
Motor Peak Torque:	180 Nm
Motor Continuous Torque:	90 Nm
Max. Wheel Torque:	2723 Nm
Motor Peak Power:	> 120 kW
Motor Continuous Power:	> 65 kW
Peak Efficiency (Motor + Inverter):	> 92 %
Single Speed Ratio:	15,13
Nominal Input Voltage:	355 V
Max. Input Voltage:	420 V
Min. Input Voltage:	200 V



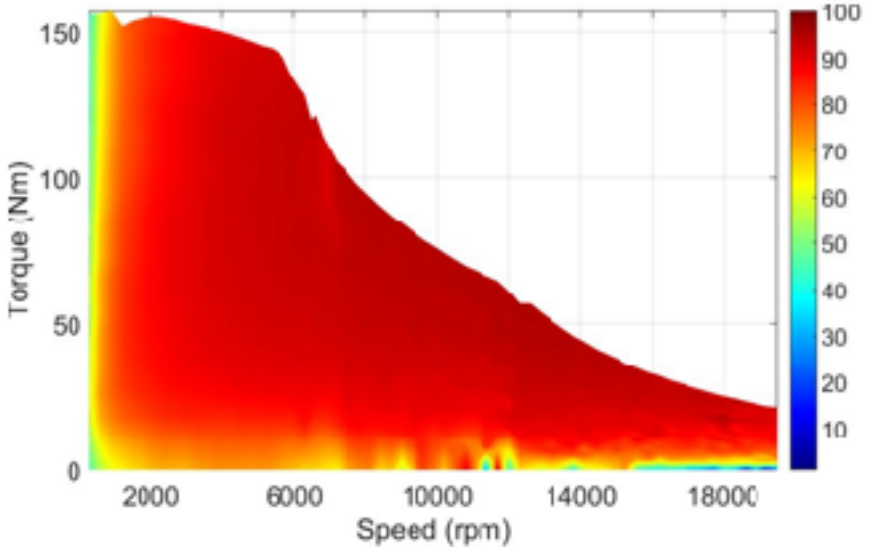
Demonstrator build

The BMW i3 is the demonstrator:

- EV ready
- Replaced standard powertrain by ARMEVA powertrain

- Impressions:
  - Low torque ripple
  - Fast acceleration
  - Very silent

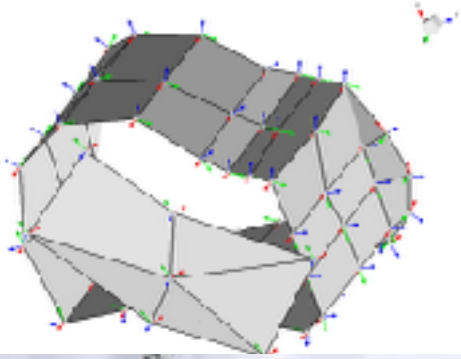
Testing and characterization



NVH performance tests

At a component level – Test bench

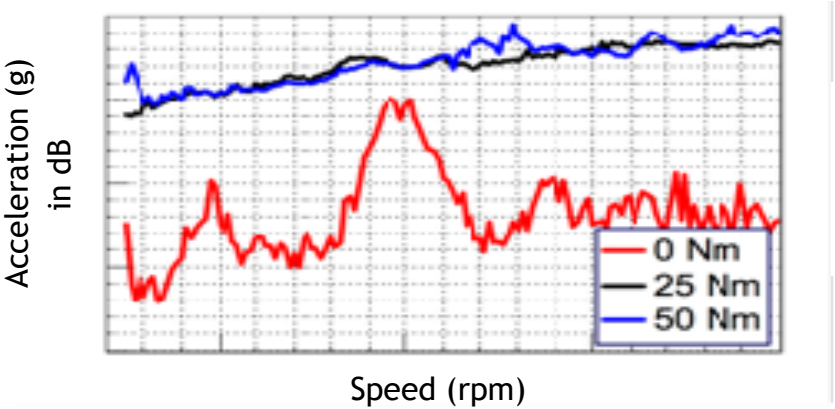
- Run-up vs coast-down operation
- Variable input shaft loads
- Different control strategies: Direct Instantaneous Torque Control (DITC) and Average Torque Control (ATC)

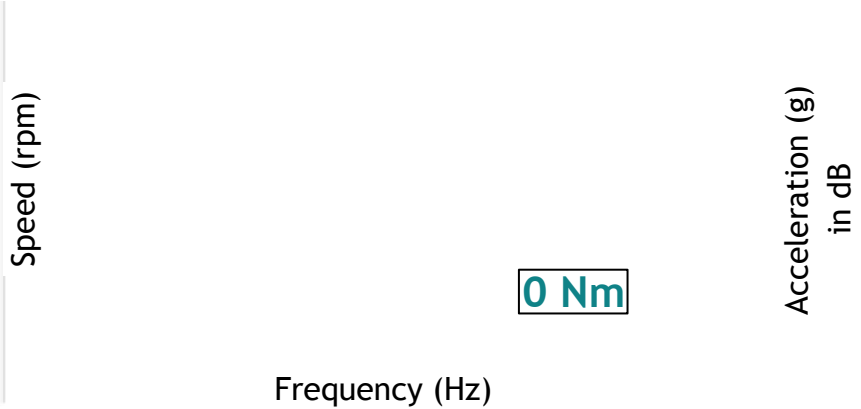


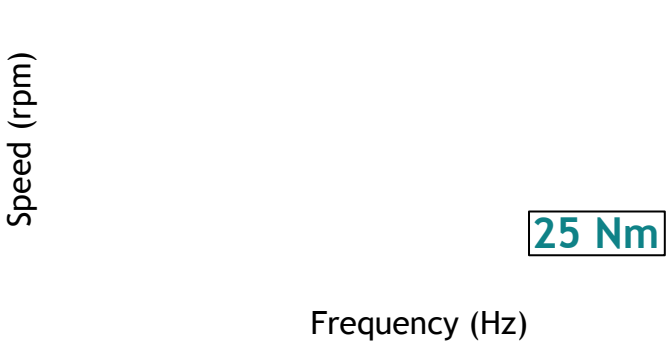
At a system level – Integration to BMW i3

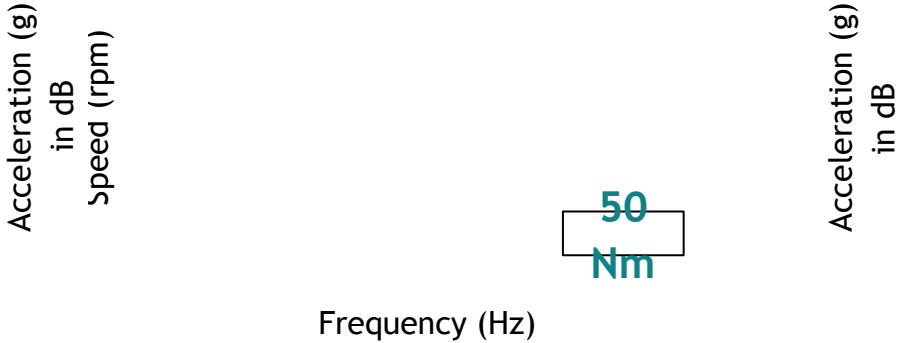
- Chassis dyno measurements
- Real road conditions

Load influence: Acceleration

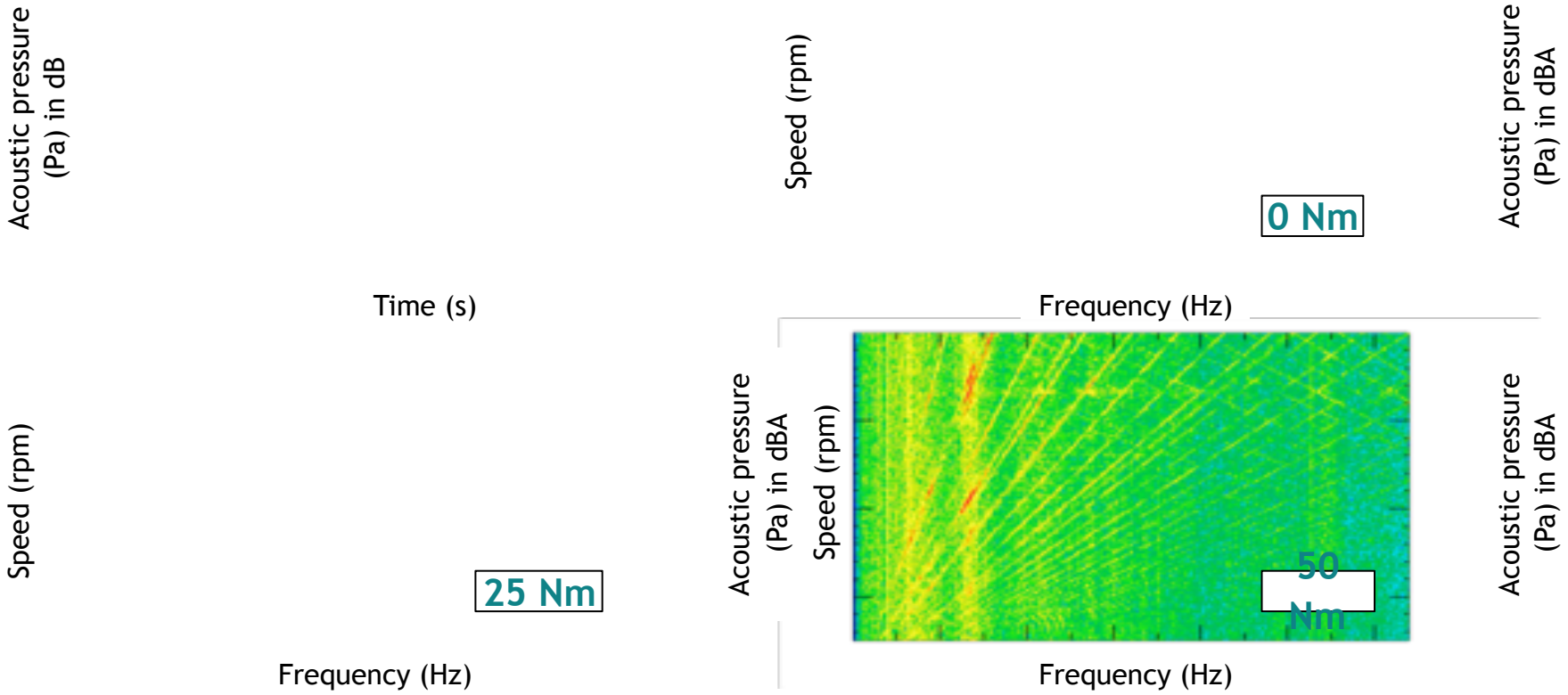




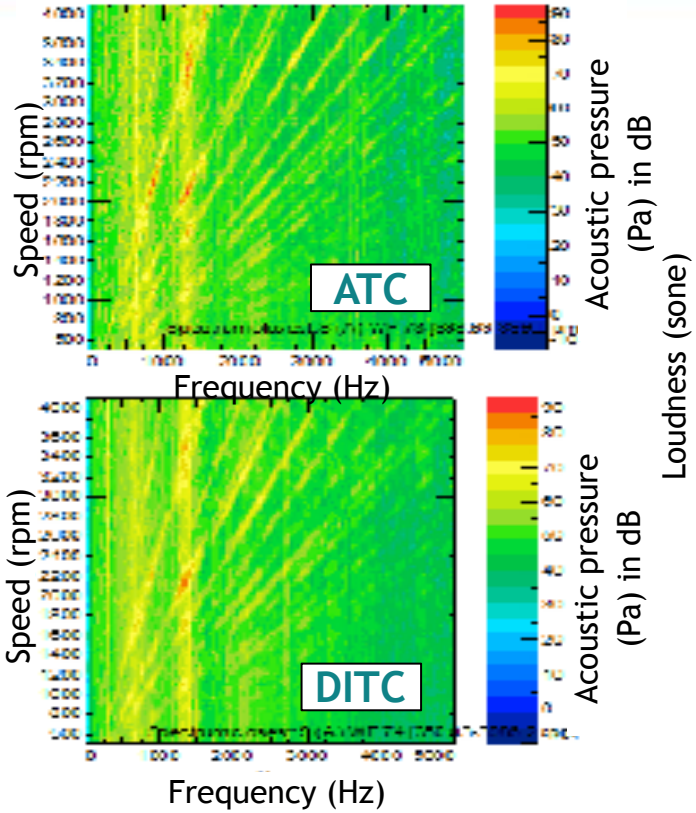


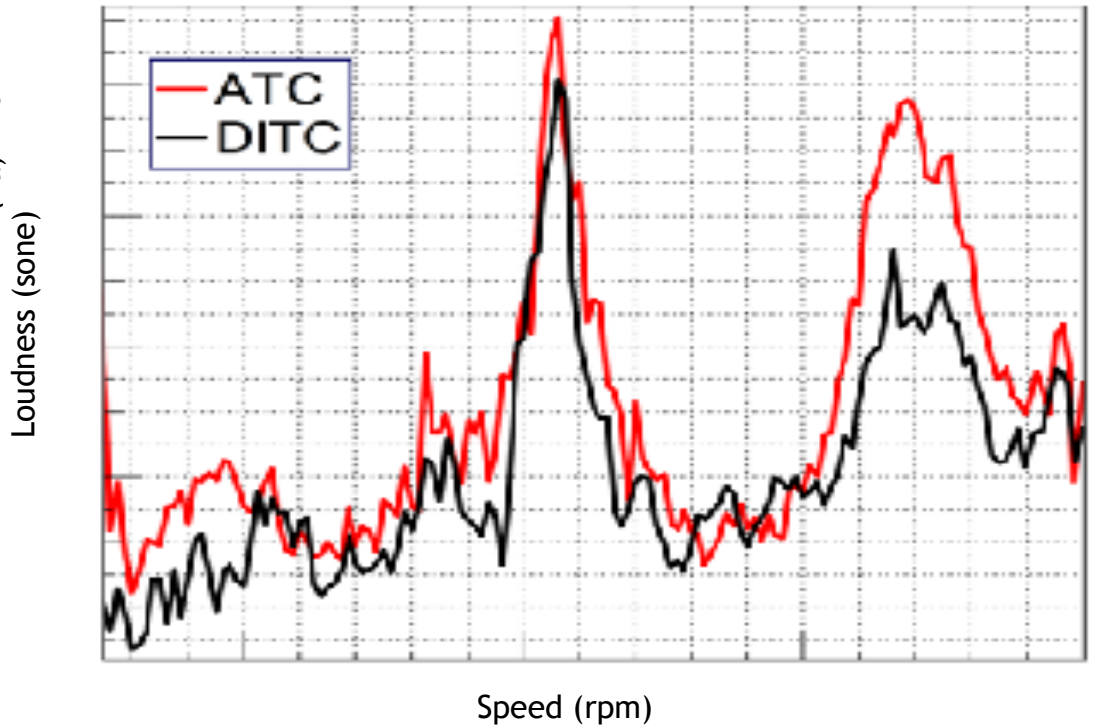


Load influence: Acoustic pressure

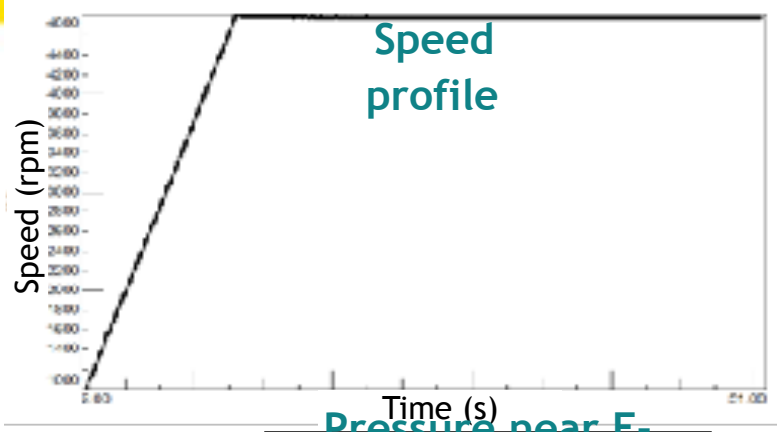


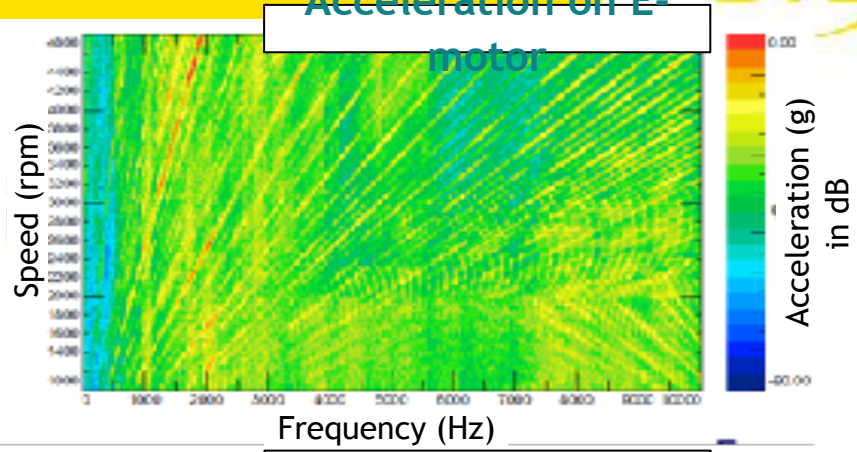
Control strategy NVH comparison

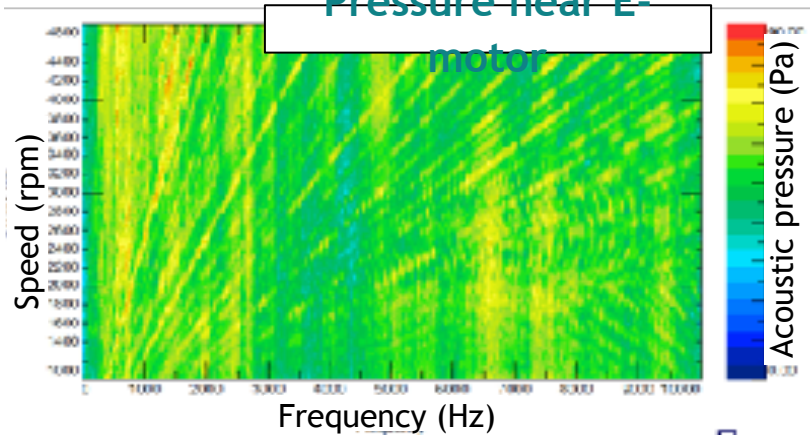


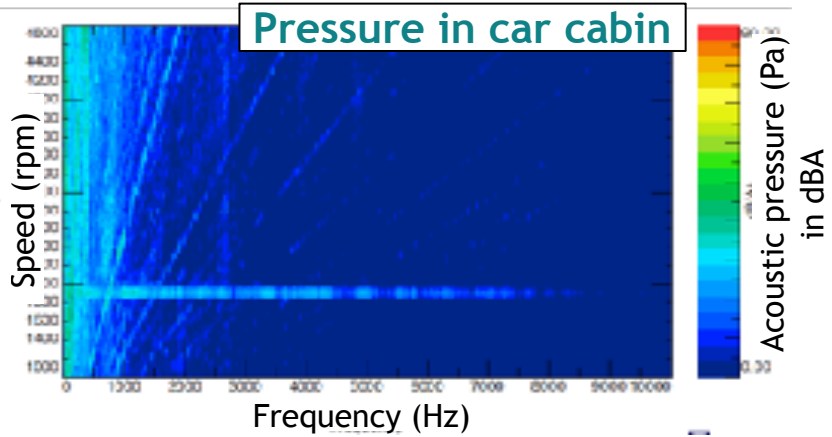


NVH results on Demonstrator vehicle









Conclusion

- Highly integrated Multiphysics design platform is must have for competitive design
- State of technology is ripe for SR motors
- SR motors can be made silent

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