PM motors for railway applications

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Bombardier* MITRAC* Permanent Magnet(PM) motor

Technology realizing the ambitions of Gröna Tåget

Compact and compatible → improved overall vehicle optimization

Improved energy efficiency
- Directly by high motor efficiency
- Indirectly by high performance density

”A train that

- significantly boosts the competitiveness of rail,
- is fit for the rigorous Nordic conditions,
- with improved environmental performance,
- and an interior design to win the battle for future passengers”

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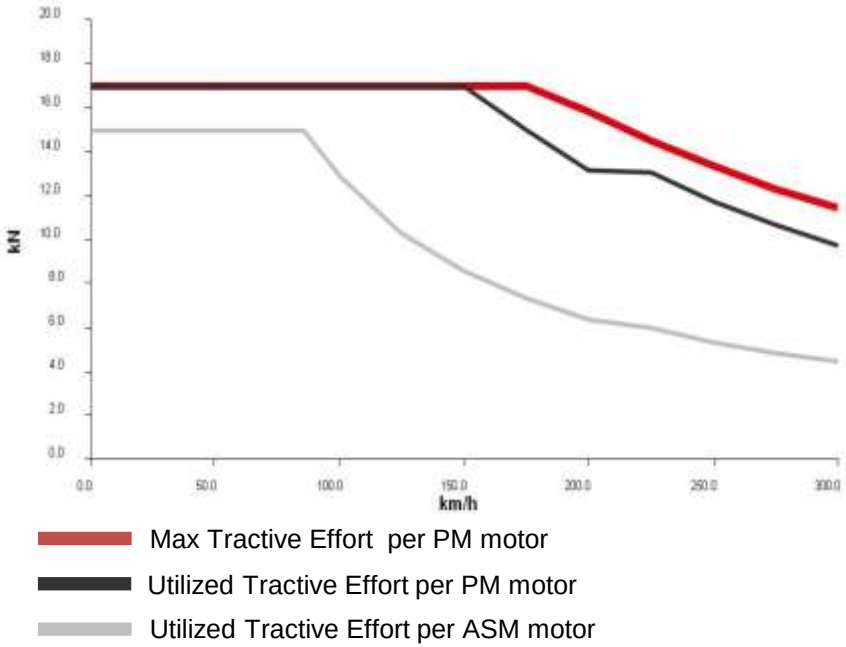
Train competitiveness: performance density

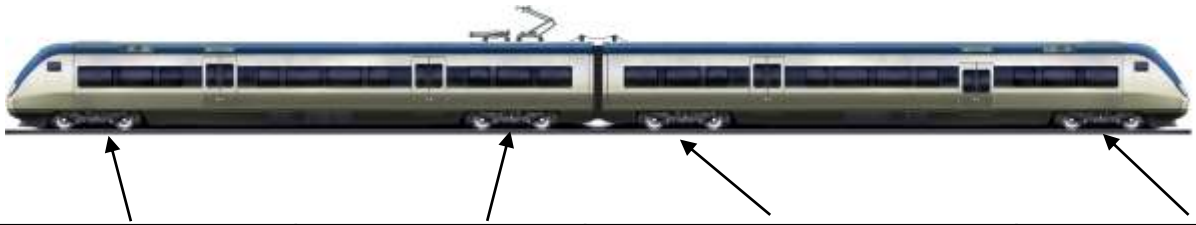
- PM motor
  - General: low rotor losses
    - Number of poles → active volume → max torque
    - Cooling
      - Thermal performance
      - Cooling channel, external fan
  - At high speed
    - IPM = buried magnets → reluctance torque contribution
- Propulsion system
  - IPM → can be optimized for high converter utilization

Performance at speed record 2008



Train competitiveness: high speed tests

Two *MITRAC* PM motors replaced four induction motors at the Nordic speed record 303 km/h 14th September 2008

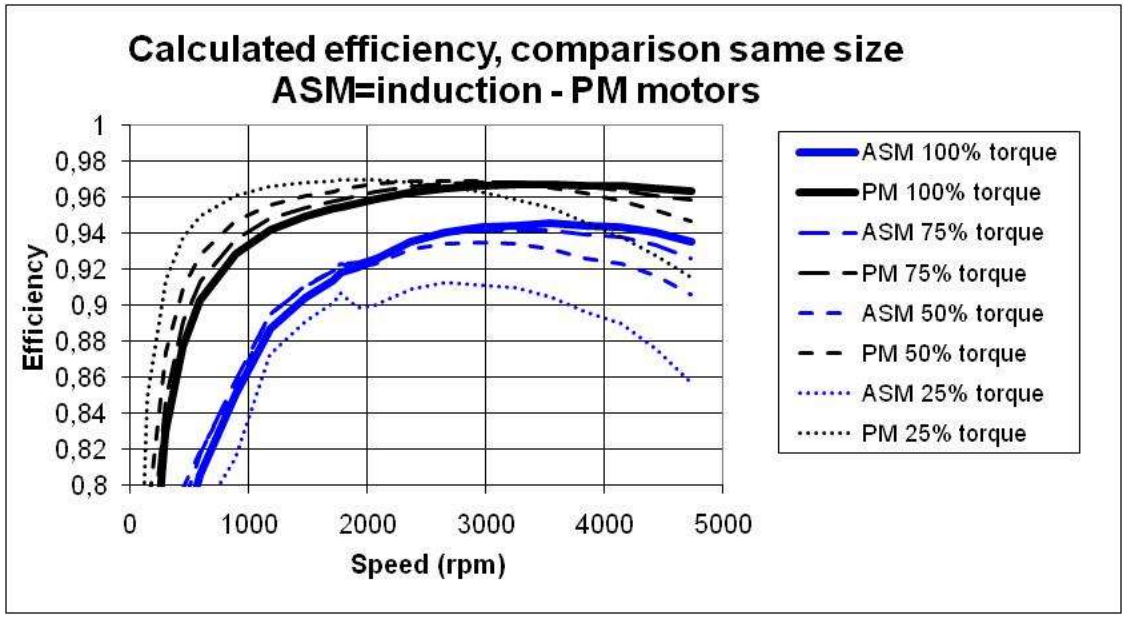


Year, tests	Bogie 1	Bogie 2	Bogie 3	Bogie 4
2008-2011	Induction motors	Induction motors	PM motors	Non-driven
2006-2007	Induction motors	Induction motors	Induction motors	Induction motors

Gröna Tåget PM motor: Self ventilated, efficiency 97%
Compared to Regina conventional motor:

- Same weight, appr same outer dimensions, mechanically interchangeable
- Max tractive effort from one PM-motor 2.6 times higher than ASM at 300 kph

Environmental performance: motor efficiency



- High efficiency, especially in vehicle operation
  - Maintained at low torque
  - Maintained in a large speed range
- High torque at high speed → increased possibility for regeneration of braking energy

Fit for the rigorous Nordic conditions

- Robust motor
  - PM technology introduced with a focus on robustness
  - Second generation of proven three phase motor design
- Electrically and mechanically compatible with proven systems
- Gröna Tåget offered unique testing opportunities
  - > 505 000 kms including challenging winter conditions

The Gröna Tåget research programme: a valuable opportunity

- Cooperation
  - KTH Electrical Energy Conversion, Juliette Soulard
  - Cross discipline contacts
- Testing opportunities
- Adding to our knowledge, indicating large future opportunities

BOMBARDIER MITRAC PM motor

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Backups

MITRAC Permanent Magnet (PM) motor

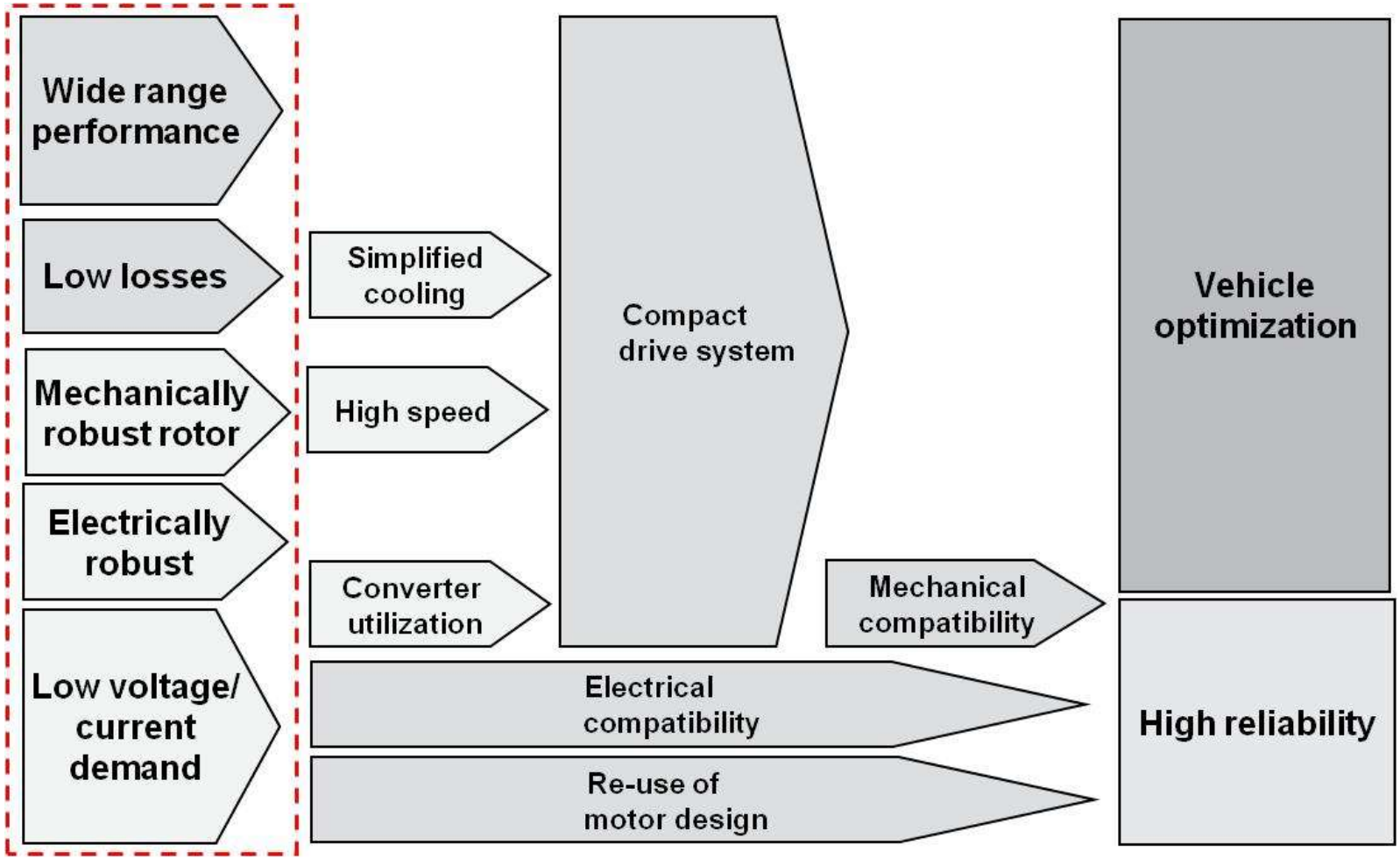
Ongoing delivery projects

- *BOMBARDIER OMNÉO*
  Régio2N for SNCF (France)
  - Contract signed February 2010
  - Up to 860 doubledecker trains
  - Presently 129 trains sold to 6 regions
  - 140 km/h – 200 km/h
  - Self-ventilated air cooled *MITRAC* PM motors

- *BOMBARDIER TWINDEXX*
  Doubledeckers for SBB (Switzerland)
  - Contract signed June 2010
  - 59 trains with option for 112 in addition
  - 160 km/h
  - Water-cooled *MITRAC* PM motors

MITRAC Permanent Magnet motor

Summary main advantages of the MITRAC PM motor concept



Permanent Magnet Motors - part of eco4

Main challenges:

- Global Warming
- Energy Cost Increase
- Urbanization
- Demographic Change

eco4, a new formula for economic sustainability:

- Energy
- Efficiency
- Ecology
- Economy

The Permanent Magnet Motor drive system is one of the solutions in the eco4 portfolio

BOMBARDIER* MITRAC **Permanent Magnet Motor: Second Motor Generation For Selected Applications**

- Improved overall vehicle optimization
- Optimized energy efficiency
- Reduced volume and weight

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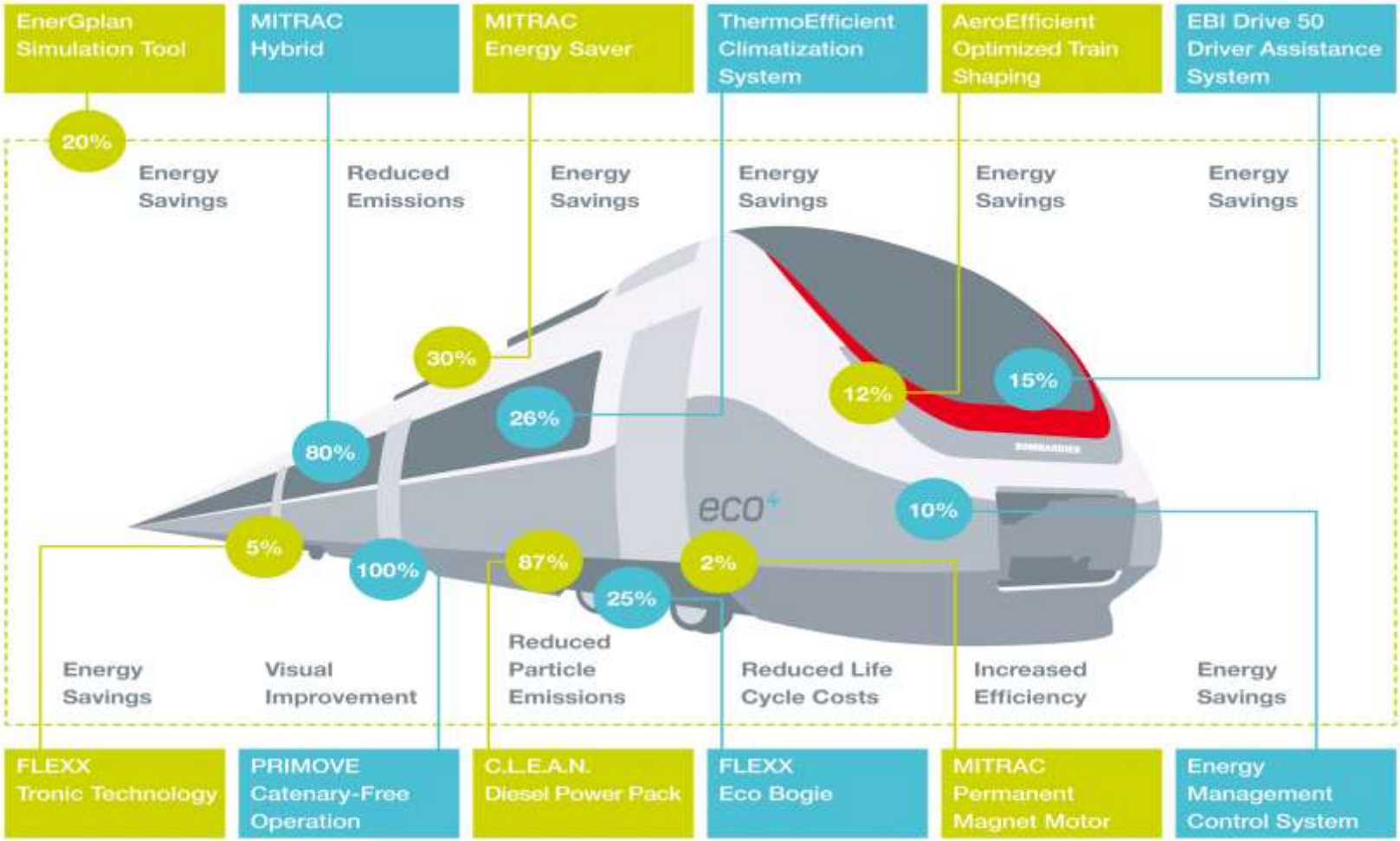
Energy – Efficiency – Ecology - Economy



Modelling and investigation of turn-to-turn winding failure in PM traction motors

Docent Juliette Soulard, KTH

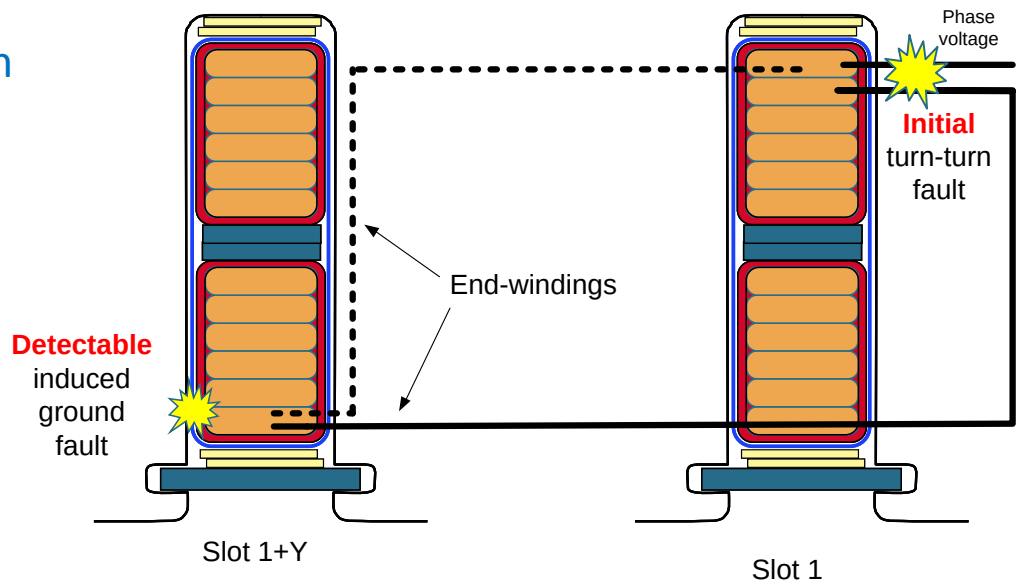
part-time at Bombardier 20% Jan-April 2008 + supervision of

Wallerand Faivre d'Arcier, Laurent Sérillon, Ecole Navale de Brest

final degree project 30 ECTS, Sept-Dec 2007

Johan Smeets, University of Eindhoven

internship 13 ECTS, Sept-Dec 2008



KTH Results:

Original models (FEM + analytical) describing the development of the winding failure from initial local short-circuit to detection of failure by existing protection system in the inverter

2 reports + one conference article (ICEM 2010)