PM motors for railway applications

Åsa Sandberg, Bombardier
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

Compact and compatible → improved overall vehicle optimization

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

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Train competitiveness: performance density

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

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

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<th>Year, tests</th>
<th>Bogie 1</th>
<th>Bogie 2</th>
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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

MITRAC PM motor
Backups
MITRAC Permanent Magnet (PM) motor
Ongoing delivery projects

- **BOMBARDIER OMNÉO**
  Régio2N for SNCF (France)
  - Contract signed February 2010
  - Up to 860 double-decker 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

- Wide range performance
- Low losses
- Mechanically robust rotor
- Electrically robust
- Low voltage/current demand

- Simplified cooling
- High speed
- Converter utilization

- Mechanical compatibility
- Electrical compatibility
- Re-use of motor design

- Compact drive system

- Vehicle optimization

- High reliability
Permanent Magnet Motors - part of \textit{eco}^4

Main challenges:
- Global Warming
- Energy Cost Increase
- Urbanization
- Demographic Change

\textit{eco}^4, a new formula for economic sustainability:
- Energy
- Efficiency
- Ecology
- Economy

The Permanent Magnet Motor drive system is one of the solutions in the \textit{eco}^4 portfolio

\textit{BOMBARDIER} \textit{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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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)