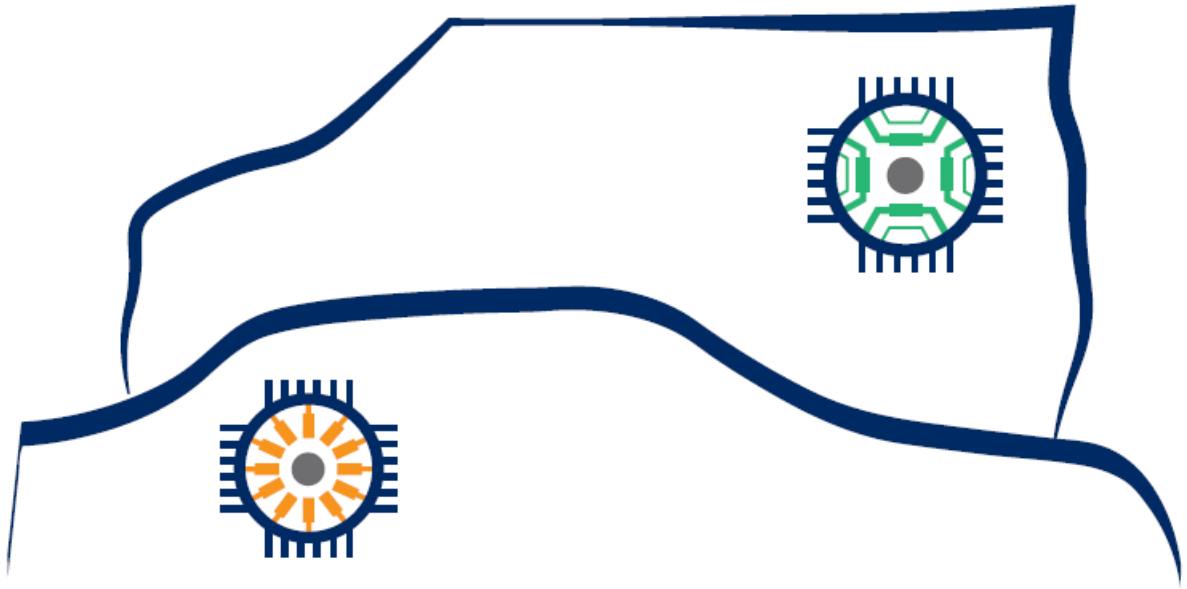


ReFreeDrive

High-speed 200 kW Ferrite-assisted SynRel motor for electrical vehicles

André Nasr - IFPEN

ReFreeDrive

Outline

- Introduction
- Design of a 200 kW PM SynRel Motor using ferrite magnets
  - Requirements
  - Stator and rotor design
  - Electromagnetic performances
- Design of a 75 kW motor – use of scalability
- Conclusion

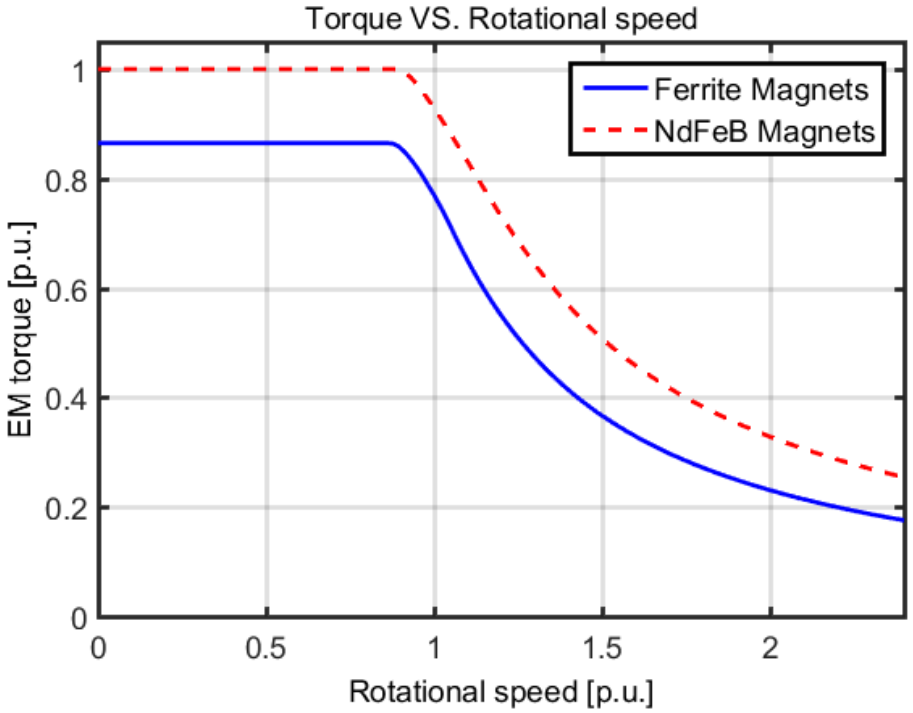
Introduction

Comparison between NdFeB and Ferrite magnets

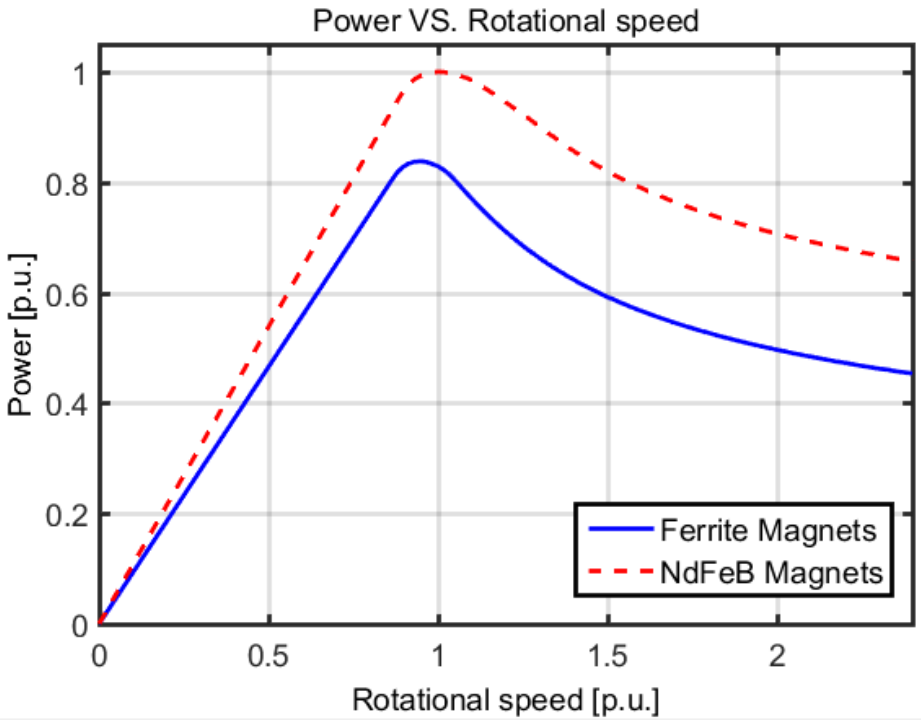
NdFeB	Ferrite
Most powerful magnets • Br ~1.2 T • Hcj ~ 2000 kA/m	Low magnetic properties • Br ~ 0.4 T • Hcj ~ 450 kA/m
Surface protection required	No coating needed
High cost (volatile costs and market uncertainty)	Inexpensive (~10 times less)
No particular problems with manufacturing small magnets	High machining costs when making small magnets

Introduction

Comparison between NdFeB and Ferrite magnets



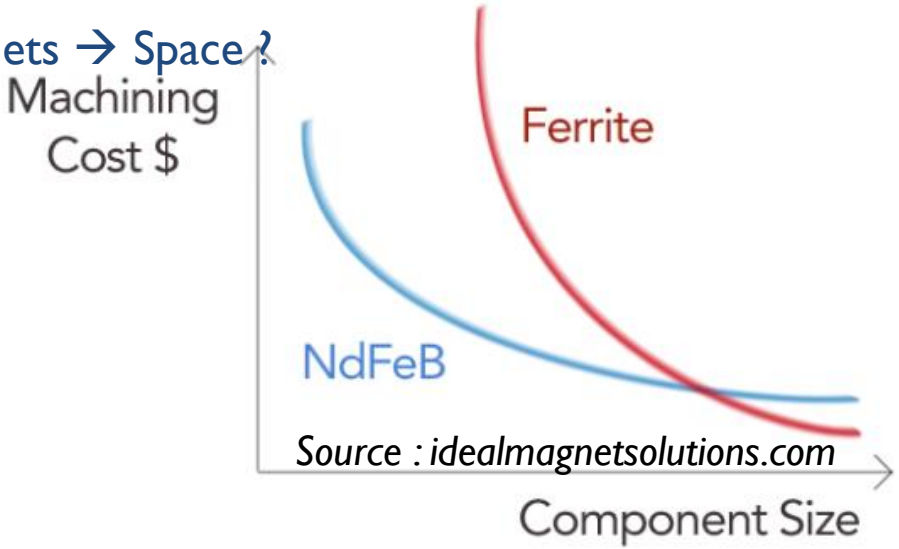
- - 13 % for maximum torque
- - 16 % for peak power
- - 31 % of torque at maximum speed



Introduction

Comparison between NdFeB and Ferrite magnets

- In terms of magnetic performances, NdFeB motors are always superior to ferrite motors. How to reduce the gap ?
- The motor size is an important factor in reducing the gap
  - High machining costs if very small magnets (no more price advantage) → Use standard ferrite magnets dimensions to reduce the machining costs
  - 3 times less Br → More ferrite magnets → Space ?



Source : idealmagnetsolutions.com

Introduction

Comparison between NdFeB and Ferrite magnets

- In terms of magnetic performances, NdFeB motors are always superior to ferrite motors. How to reduce the gap ?
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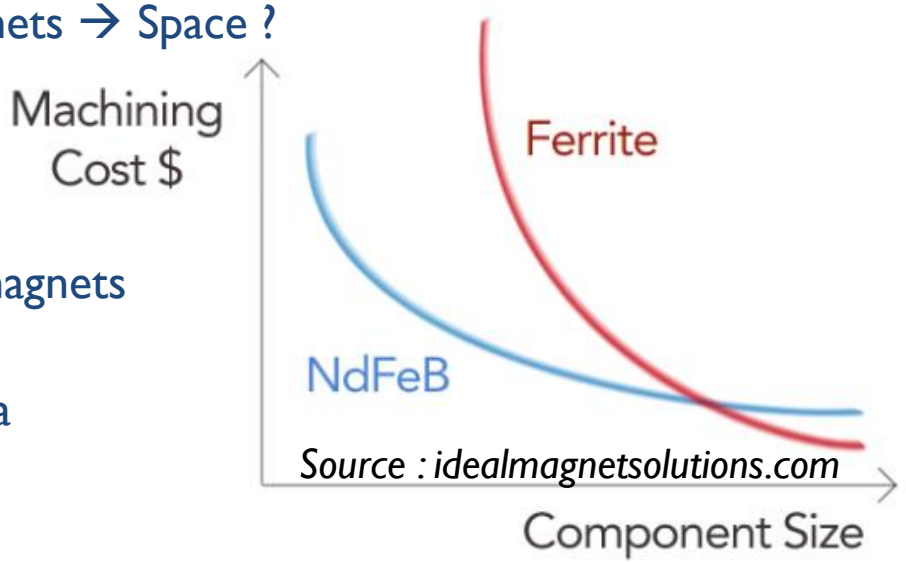
  - 3 times less Br → More ferrite magnets → Space ?
- The motor technology
  - In PM assisted SynRel motors, only 40 % of the torque is generated from magnets (60 % is reluctance torque).
  - Surface-mounted PM motors is not a good technology for ferrite magnets.



Source : idealmagnetsolutions.com

Design of a 200 kW PM SynRel Motor using ferrites

Requirements

Parameter	Unit	75 kW	200 kW
Specific Power	kW/kg	> 2.52	> 4.3
Specific Torque	Nm/kg	> 8.2	> 8.2
Active parts weight	kg	< 30	< 47
Maximum speed	rpm	15000 - 18000	
Peak efficiency	%	> 96%	

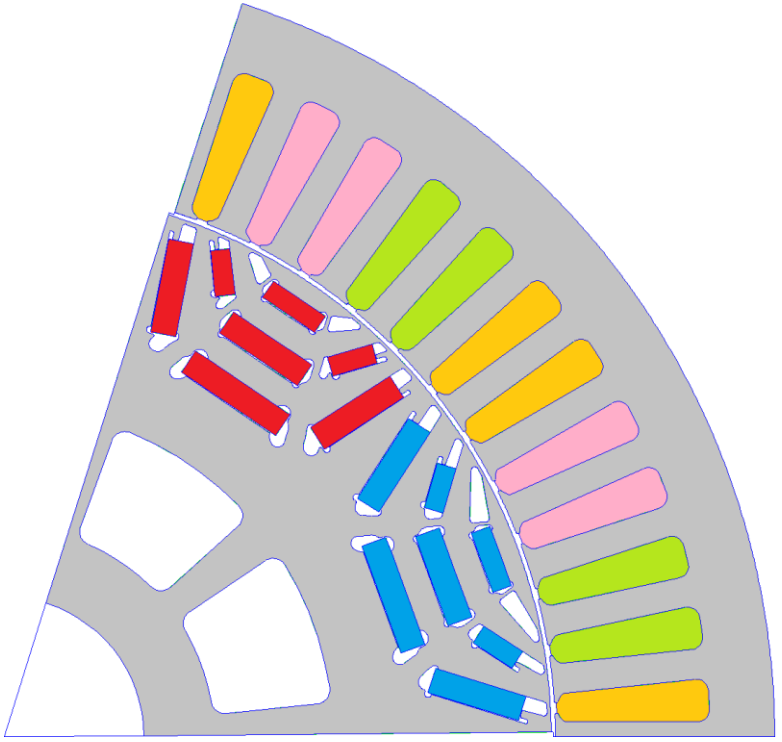
For the 75 kW motor design, scalability has been used (same stator and rotor geometry as the 200 kW motor)

Design of a 200 kW PM SynRel Motor using ferrites

Stator and rotor design

- 5 pole pairs
- SPP = 2
- 7 magnets per pole
- AG = 0.6 mm

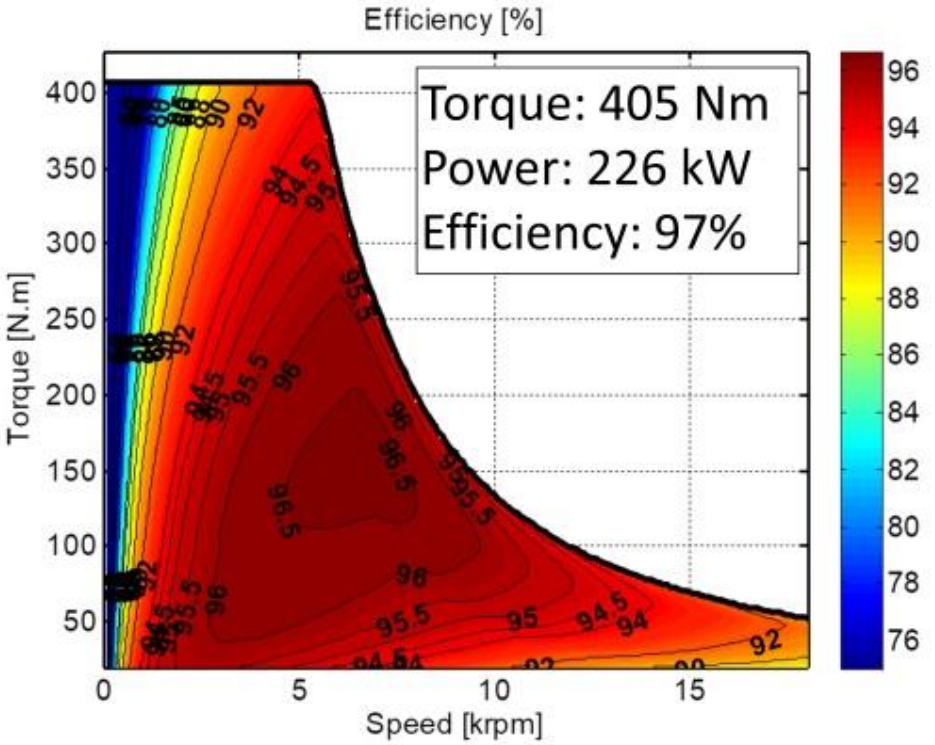
Designation	Material
Lamination	M235-35A
Magnet	Ferrite
Copper wire	G2 H class



Design of a 200 kW PM SynRel Motor using ferrites

Electromagnetics performances

- DC Voltage = 800 V
- Max current = 416 Arms
- Max torque = 405 N.m > *400 N.m*
- Peak Power = 226 kW (5000 rpm) > *200 kW*
- Max power of 91 kW @ 17500 rpm
- Maximum efficiency = 97 %
- Weight = 46.1 kg (Active Part)
- Peak specific torque = 8.8 N.m/kg
- Peak specific power = 4.9 kW/kg

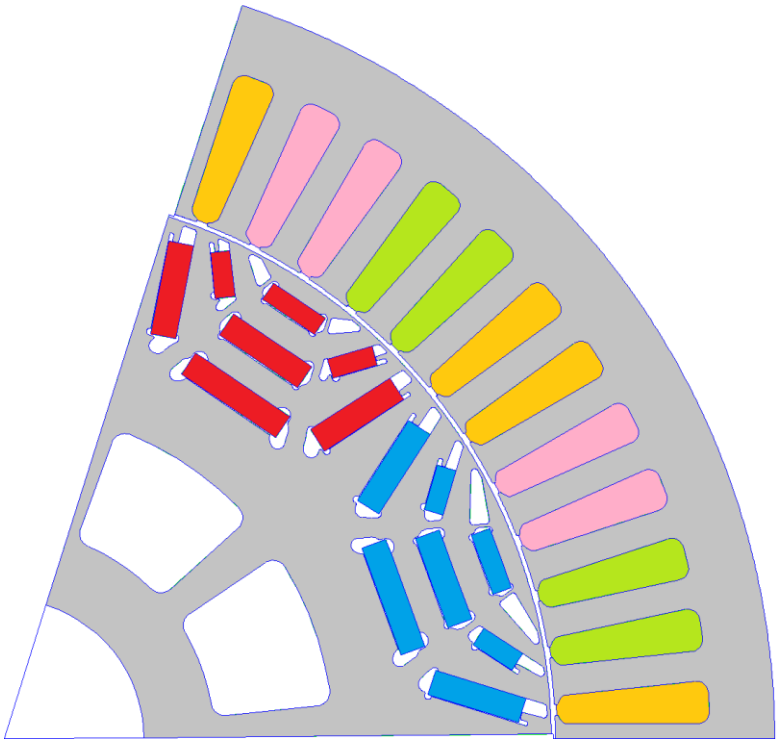


Design of a 75 kW motor – use of scalability

Stator and rotor design

- 800 V → 350 V
- Same housing

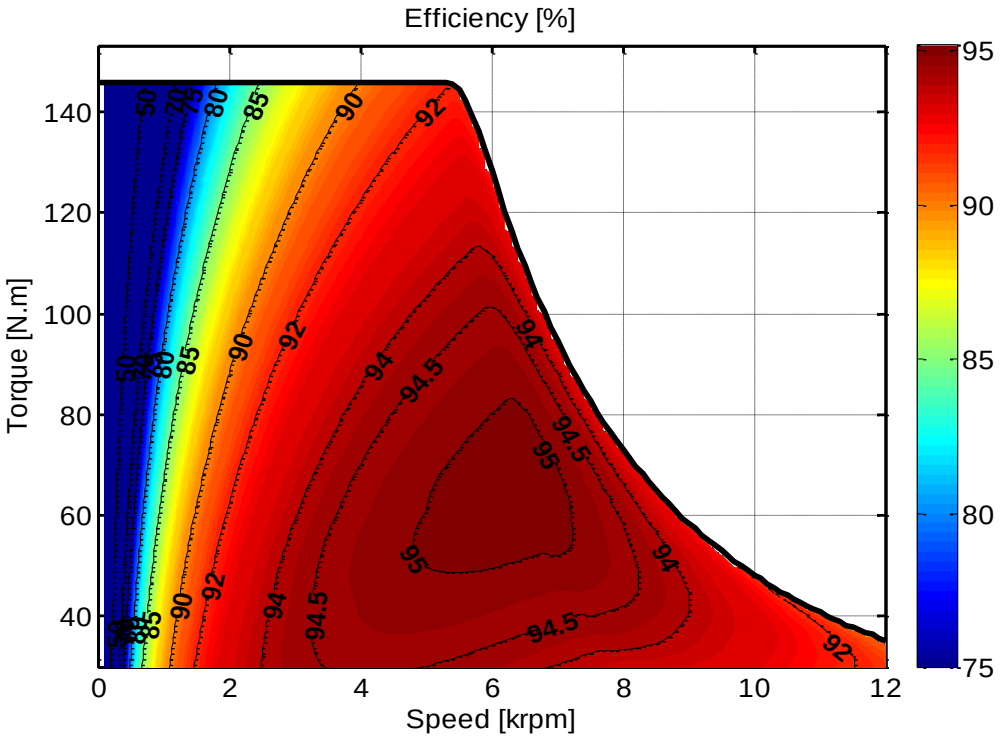
- 200 mm → 75 mm
- 13 turns → 14 turns
- Same rotor and stator geometry
- Same magnets
- Same mechanical parts



Design of a 75 kW motor – use of scalability

Electromagnetics performances

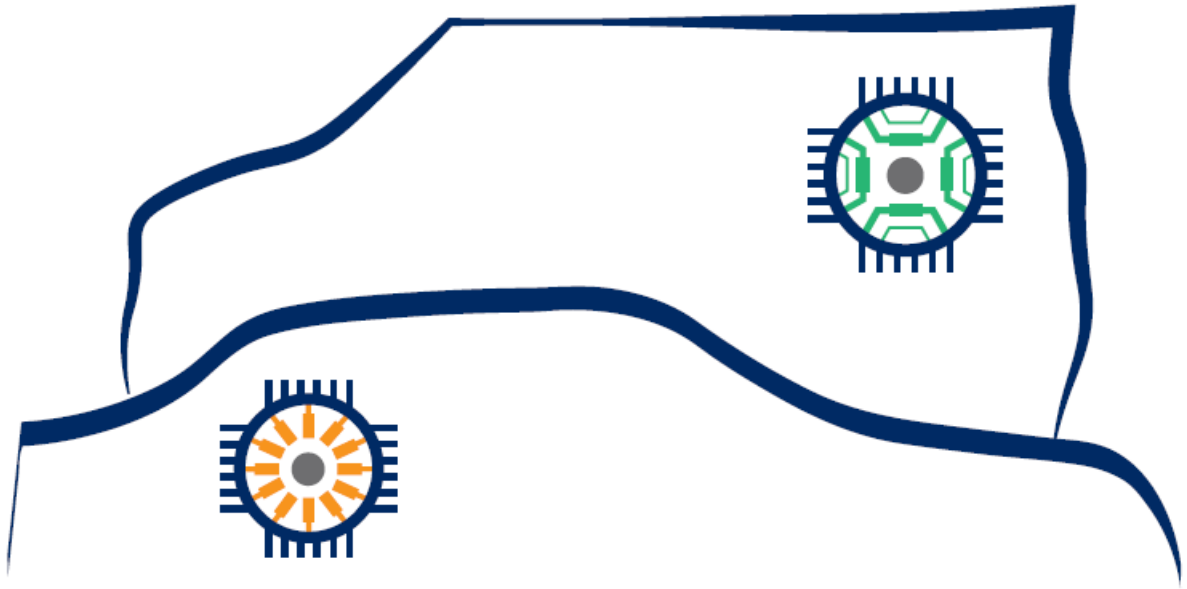
- Max current = 375 Arms
- Max torque = 158 N.m > *140 N.m*
- Peak Power = 92 kW (5300 rpm) > *75 kW*
- Max power of 51 kW @ 12000 rpm
- Maximum efficiency = 95 %
- Weight = 19 kg (Active Part)
- Peak specific torque = 8.3 N.m/kg
- Peak specific power = 4.8 kW/kg



High-speed 200 kW Ferrite-assisted SynRel motor for electrical vehicles

Conclusion

- ✓ Comparison between Neodymium and Ferrite magnets :
  - Motors using Neodymium magnets are always superior to Ferrite motors
  - Design aspects should be taken into consideration to reduce the gap in performance
    - Motor size (rotor diameter)
    - Motor technology
- ✓ A 200 kW SynRel motor design using ferrites magnets has been proposed :
  - The elecromagnetic performances meet the requirements (KPI)
  - Thermal and mechanical analysis has been carried out (not presented)
- ✓ A 75 kW motor design using scalability has been proposed :
  - Same stator and rotor geometry
  - Only modifications are the active length and the number of turns
- ✓ 200 and 75 kW PMa SynRel motors will be prototyped by MAVEL and tested at IFPEN facilities in France



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