Advanced Electric Machines – University R&D Role

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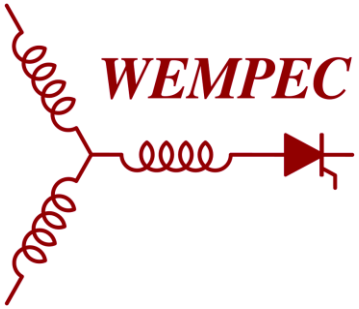
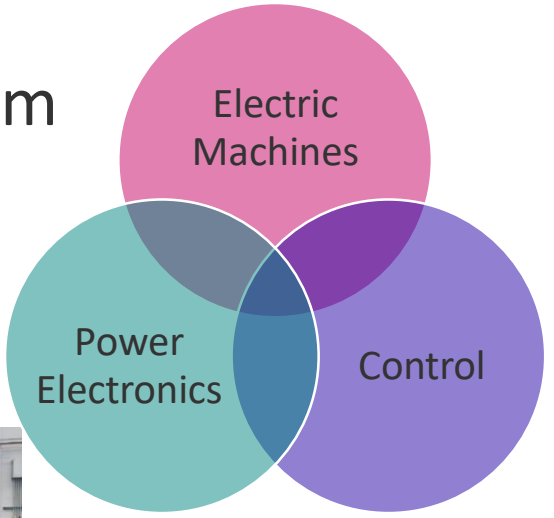
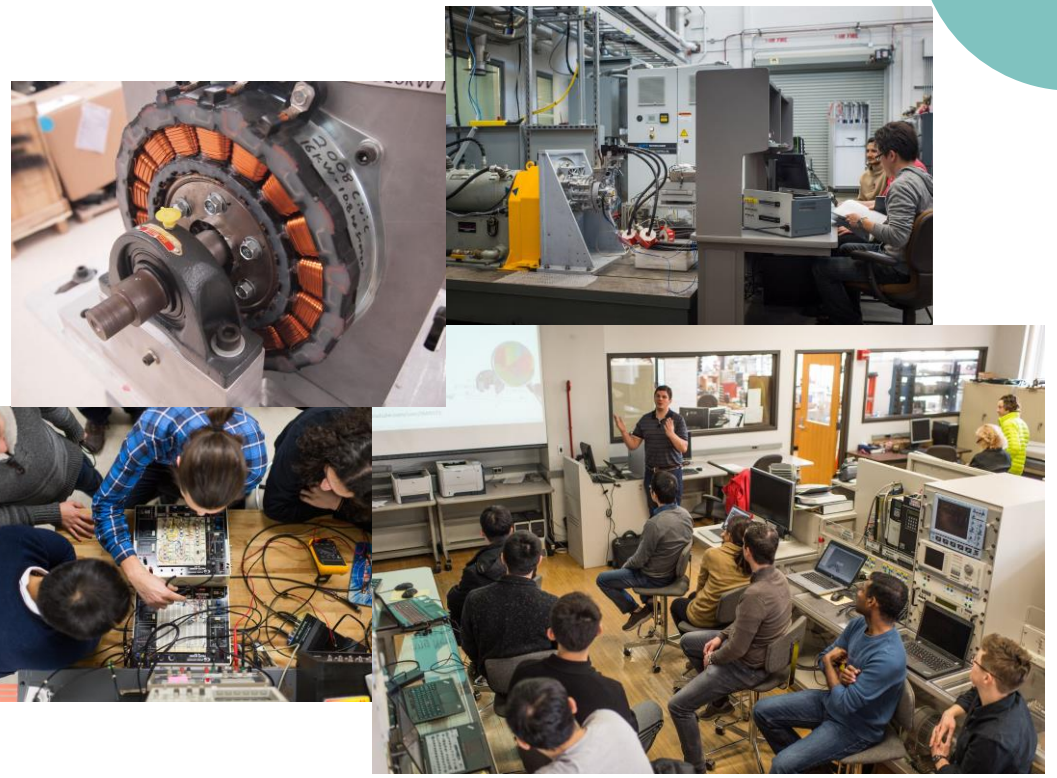


WEMPEC

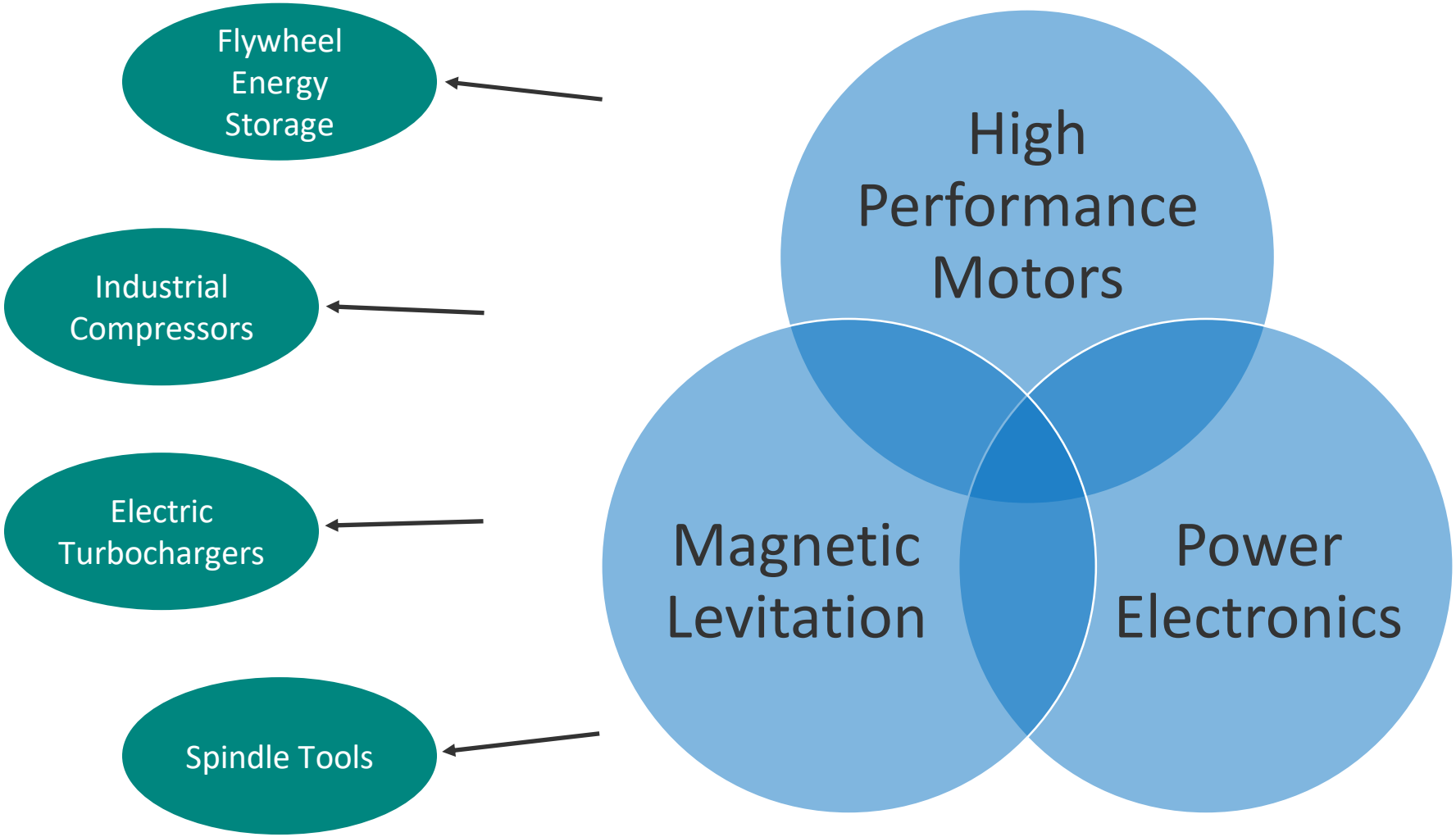
Wisconsin **E**lectric **M**achines and **P**ower **E**lectronics **C**onsortium



- Founded in 1981 with 4 corporate sponsors
  - Founders: Prof. Don Novotny and Prof. Tom Lipo
- People
  - 5 Faculty (and growing!)
  - 3 Emeritus Faculty
  - 40 PhD Students$_{\text{(on campus)}}$
  - 13 MS Students$_{\text{(on campus)}}$
  - 97 off campus students
  - 7 Visiting scholars
  - > 510 alumni
- Degrees granted
  - > 425 MS
  - >160 PhD



My Research Interests: design and control of



1kW - 1MW+
100 - 300,000 RPM

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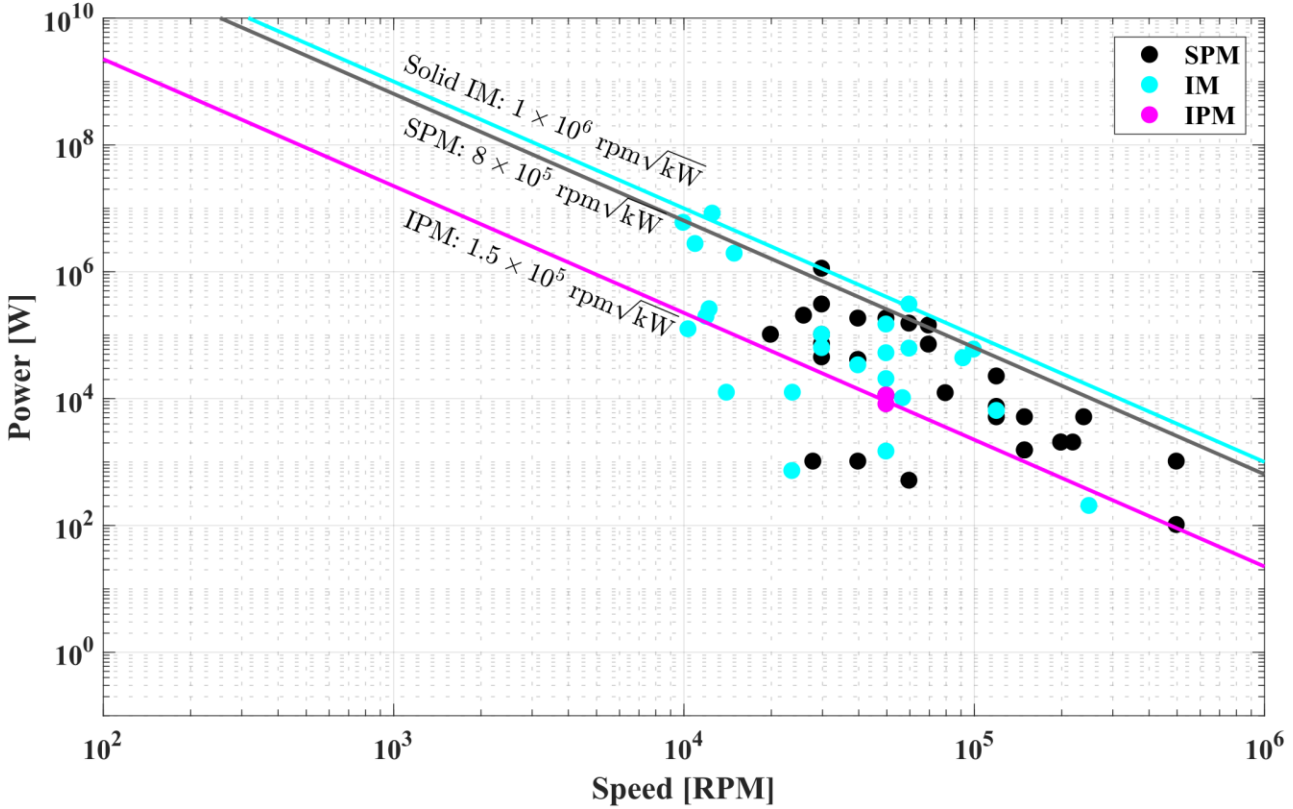
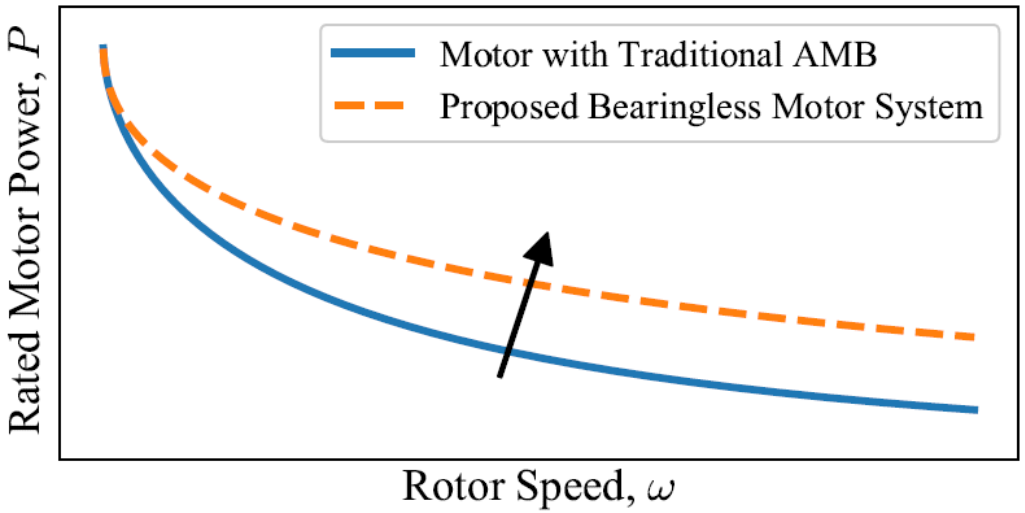
Power-Speed Capability of Electric Machines

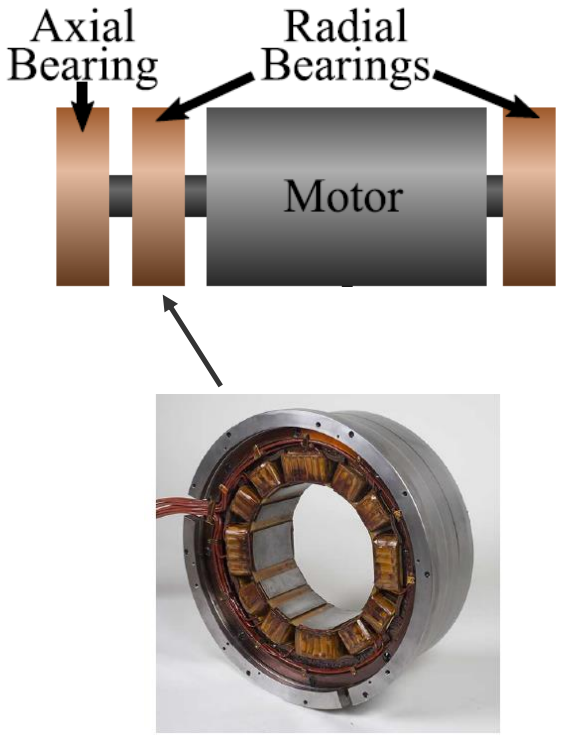


Highest Speed-Power Motors (with bearings)[1]

[1] D. Gerada et al, "High-speed electrical machines: Technologies, trends, and developments," *IEEE Trans on Ind. Elec., 2013*

Magnetically Levitated Motor Systems





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Legacy Bearingless Motors Use Two Windings

- **Reduce torque/power**
  - by 25% – 50%
- **Decrease efficiency**
- **Expensive to manufacture**

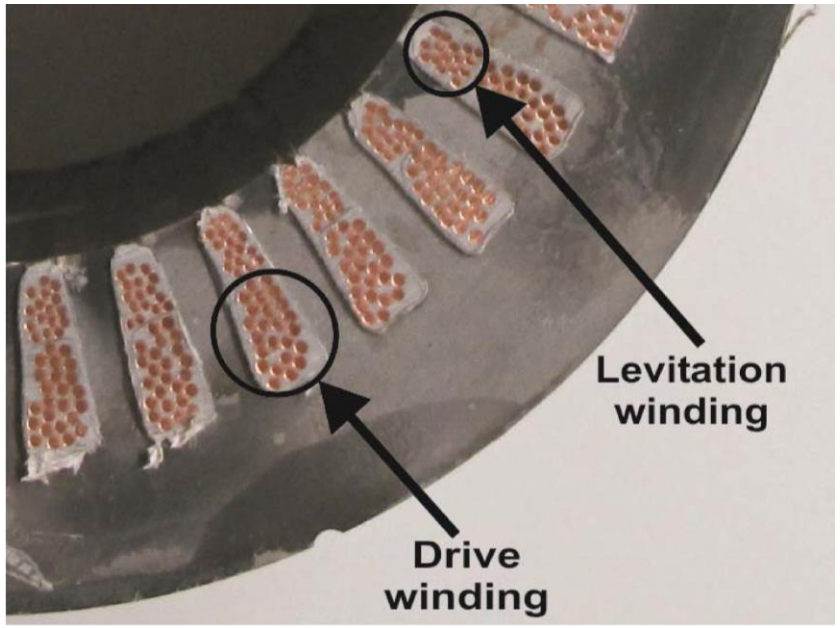
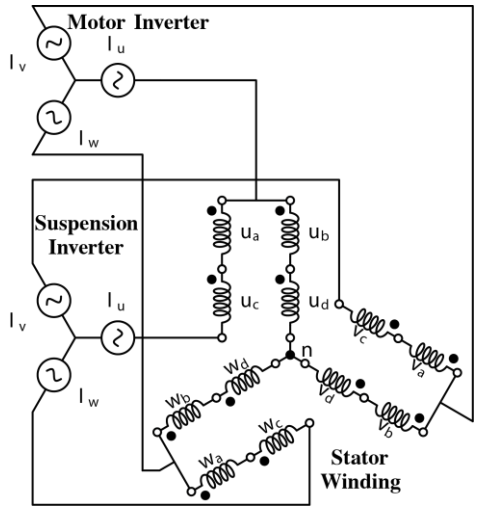


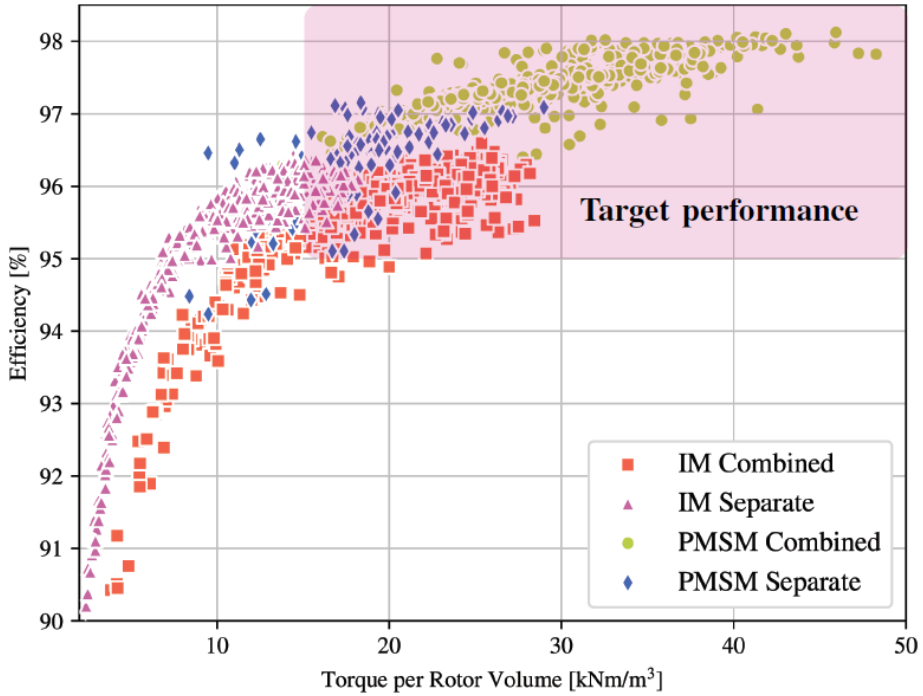
Image from [1]

[1] G. Munteanu, A. Binder, and T. Schneider., “Loss Measurement of a 40 kW High-Speed Bearingless PM Synchronous Motor,” ECCE 2011.

Combined Windings

- Same coils for **force** and **torque**
- Improved performance:
  - $\approx 40\%$ increase in torque density
  - $\approx 1 - 3\%$ increase in efficiency
- "No Voltage Combined Windings"
  - Better performance at extreme speeds



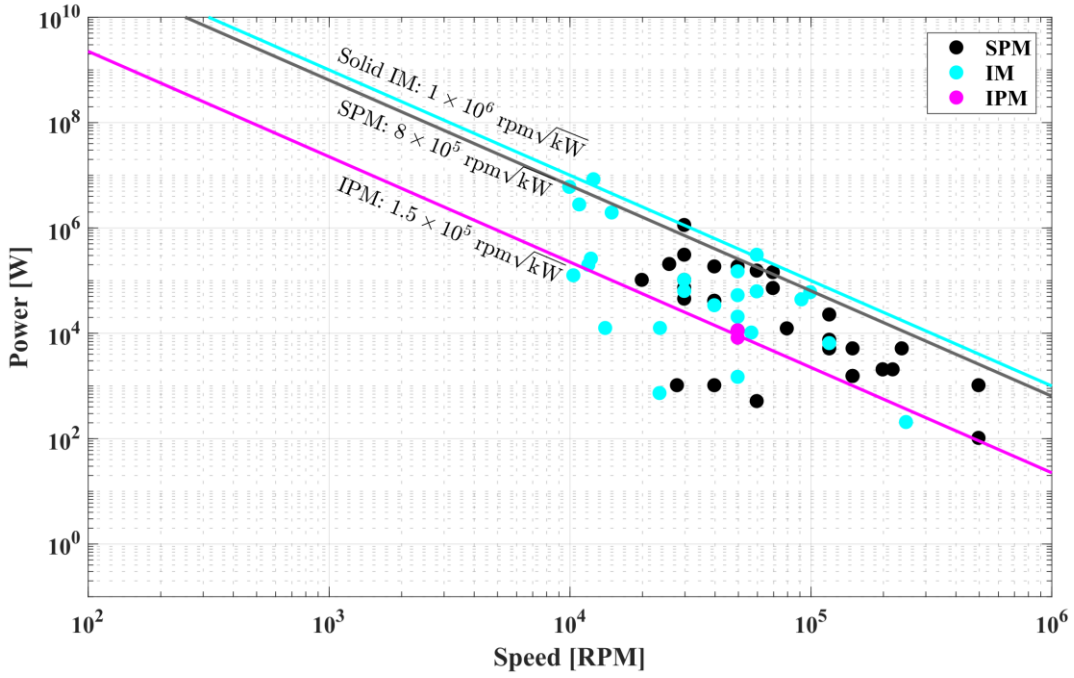


50 kW, 30 kRPM Compressor Optimization

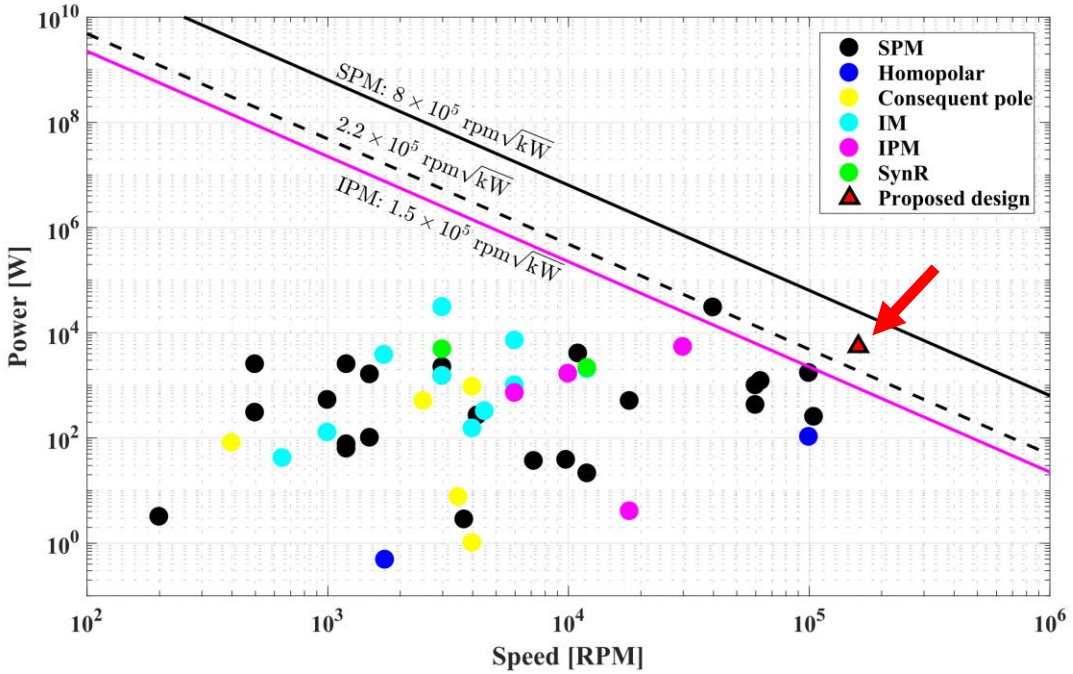
[1] J Chen, J Zhu, E. Severson, "Review of Bearingless Motor Technology for Significant Power Applications," *IEEE Trans on Ind. App., 2020*
[2] E Severson, et al, "Design of dual purpose no voltage combined windings for bearingless motors," *IEEE Trans. on Ind. App.*, 2017.

Enable a Shift in Power-Speed Capability

Highest Speed-Power SPM Motors (with bearings)[1]



Highest Speed-Power Bearingless Motors[2]

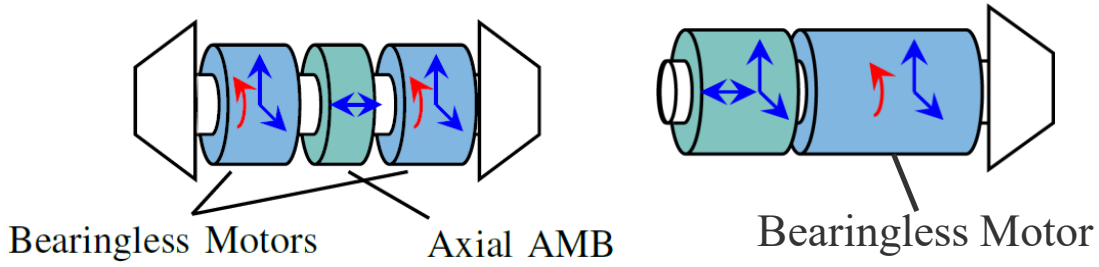


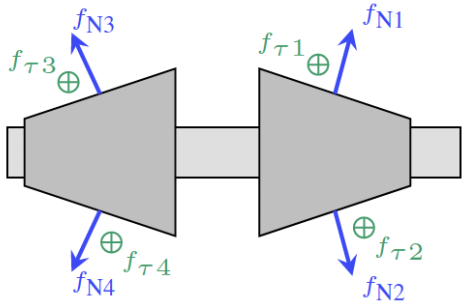
[1] D. Gerada et al, "High-speed electrical machines: Technologies, trends, and developments," *IEEE Trans on Ind. Elec., 2013*

[2] J Chen, J Zhu, E. Severson, "Review of Bearingless Motor Technology for Significant Power Applications," *IEEE Trans on Ind. App., 2020*

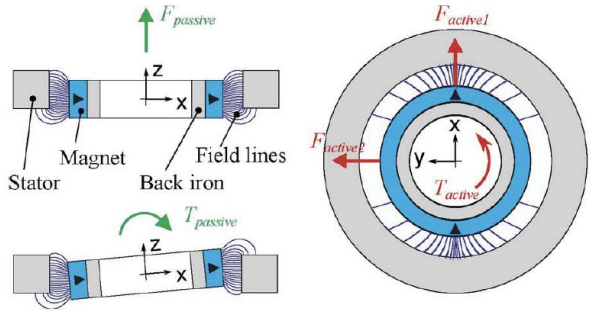
Turbomachinery Bearingless Motor Concepts

1) Complete magnetic levitation



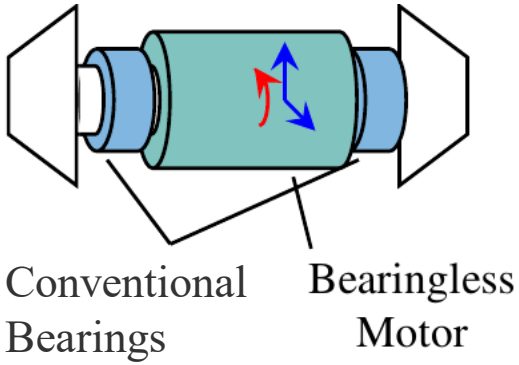


5-DOF Bearingless Motor



2-DOF Bearingless Motor[2]

2) Hybrid: Conventional bearings + bearingless motor



Use bearingless motor to improve rotor dynamics (instead of levitation)

[1] J Chen, J Zhu, E. Severson, "Review of Bearingless Motor Technology for Significant Power Applications," *IEEE Trans on Ind. App., 2020*

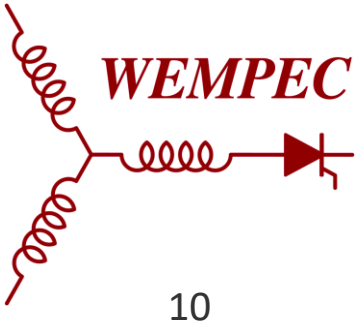
[2] H. Mitterhofer et al, "On the high speed capacity of bearingless drives," *IEEE Trans on Ind. Elec.,* 2014

Role of Universities

- Universities thrive at low TRLs
- Many pathways to funded research:
  - Industrial sponsored research projects
  - Gift funding
  - Industry consortia
  - Collaboration on federal grants and SBIR/STTR
- IP agreements can be difficult, but the trend is toward more flexible terms

University Research Needed:

- **Electric machine design**
  - New topologies and concepts (i.e., magnet-free, hybrid)
  - Design optimization
- **Power electronics**
  - Advanced topologies to reduce cost, increase efficiency
  - Meet unique needs of new electric machinery
- **Control**
  - Self-sensing
  - Precise actuation
  - Rotor dynamics



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Thank you!

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