

Why use Permanent Magnet Generators in Wind Turbines?

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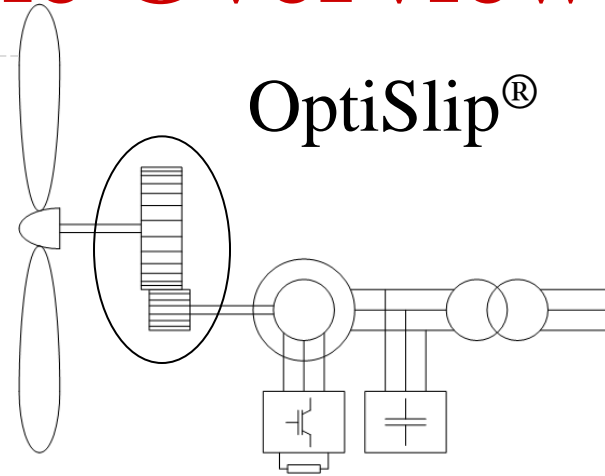
Dansk Selskab
for Vindenergi

Wind Turbine Overview

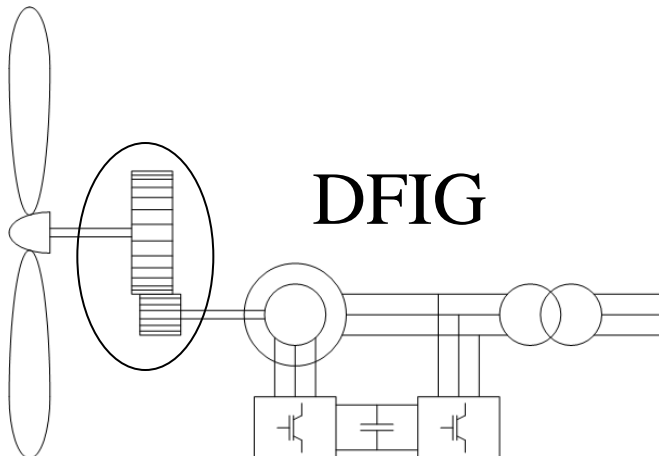
“Danish Concept”



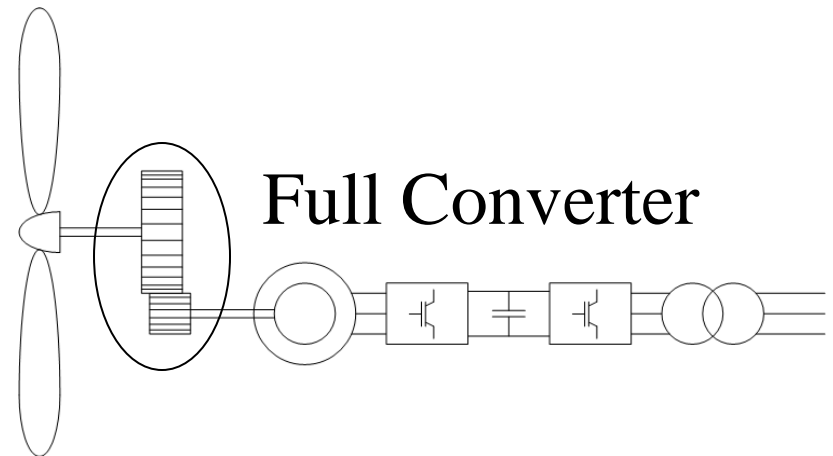
OptiSlip[®]



DFIG

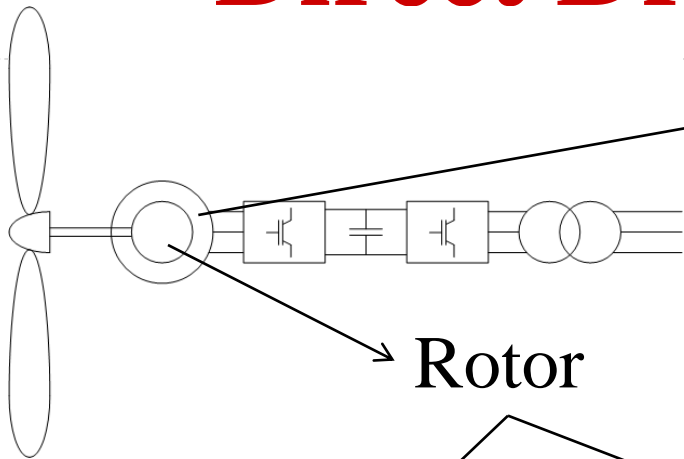


Full Converter



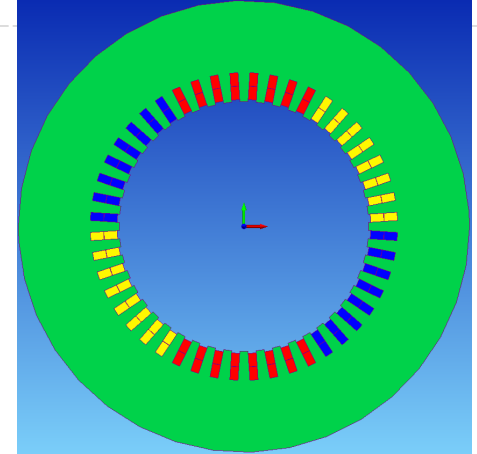
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Direct Drive Topologies



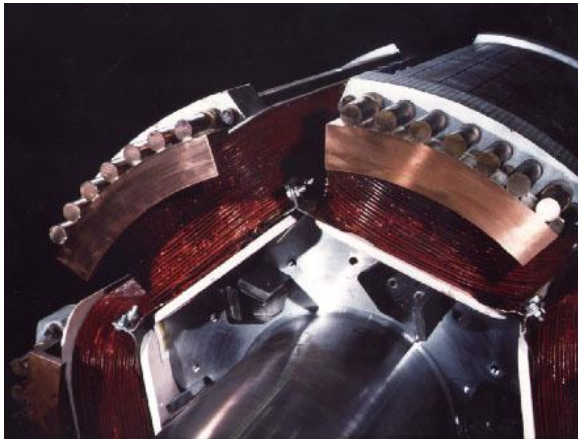
Stator

Almost identical in all of the mentioned machines



Rotor

Wound Field



Source [1]

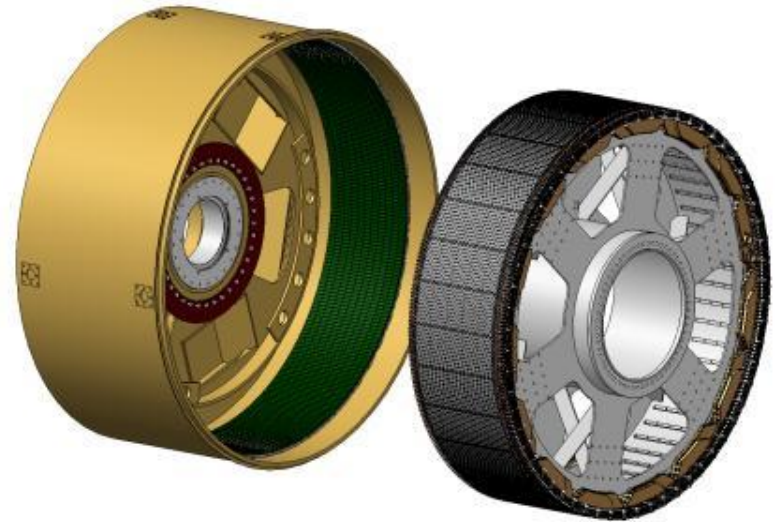
Permanent Magnet



Source [2]

Why use Multi-Pole Generators

- The converter is indifferent
- Power is independent of pole numbers
- Voltage is independent of pole numbers
- Weight (and cost) savings!



Source [3]

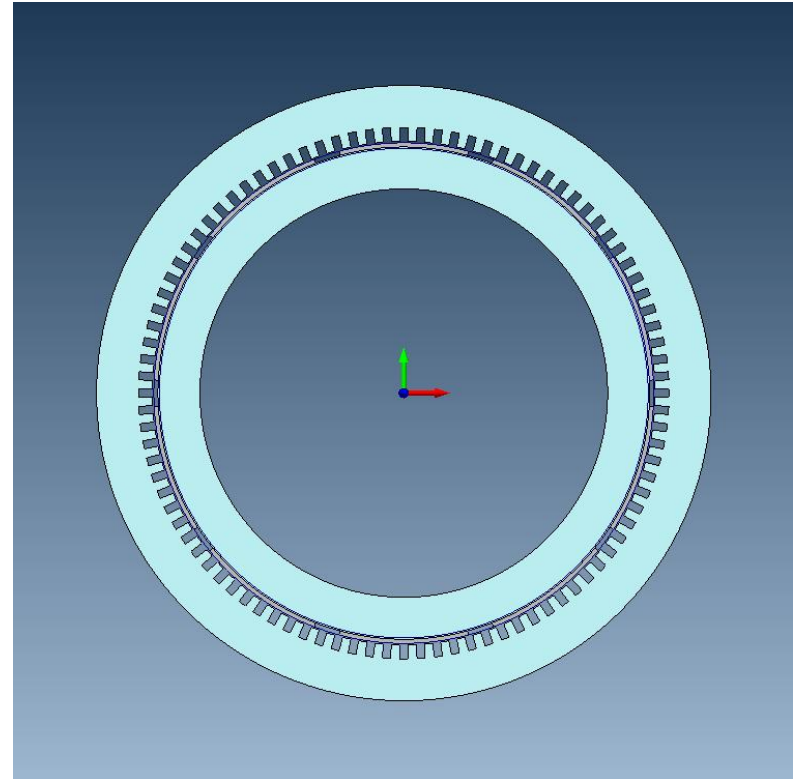
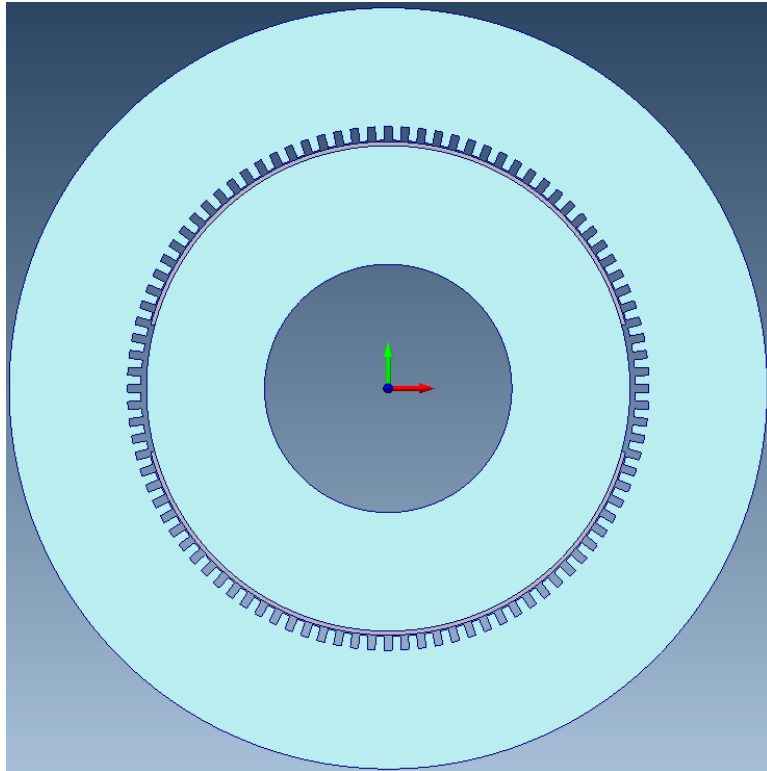


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PM Direct Drive Generator

2 Poles

10 Poles



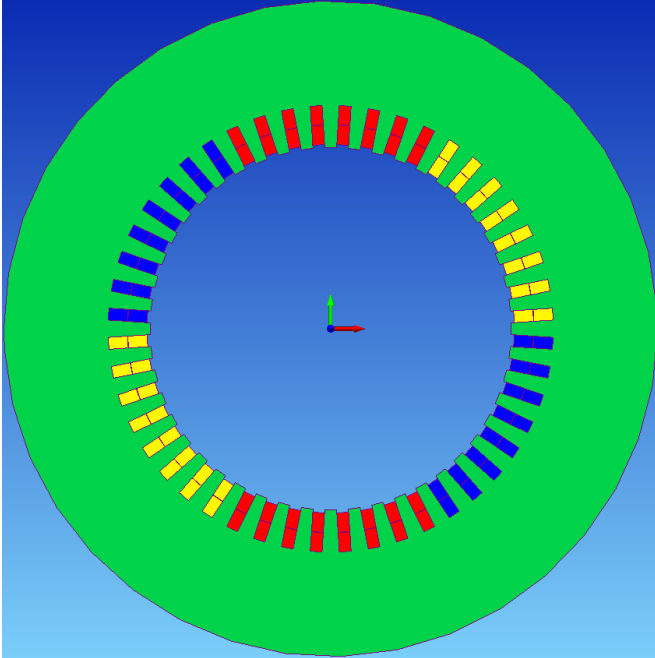
The mass of the nacelle can be significantly reduced



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End Windings

2 Pole



Multi-Pole



Source [4]

Copper can be saved

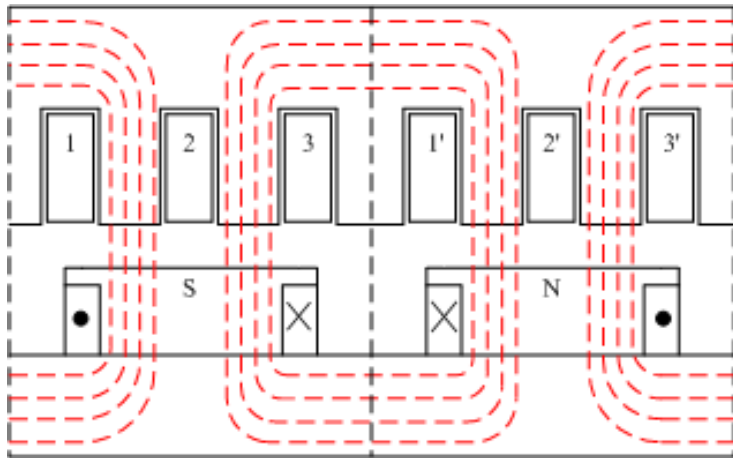


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WF vs. PM

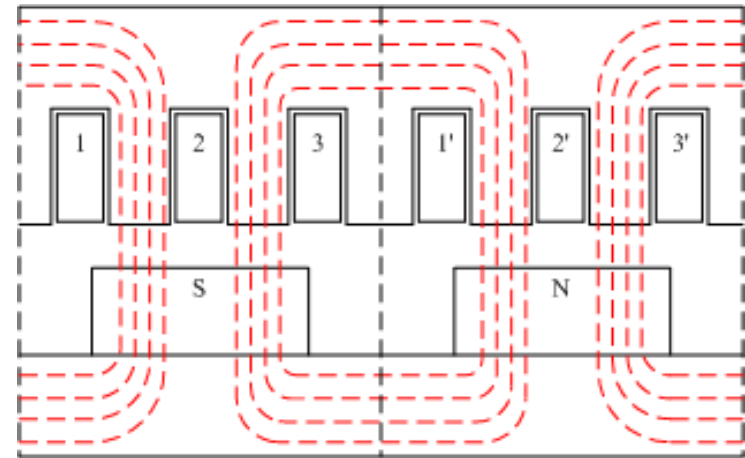
Wound Field



- Excitation losses
- Variable excitation
- More complex rotor

$$mmf \propto \text{total current}$$

Permanent Magnet



- No excitation losses
- Constant excitation
- Simple rotor – reliability?

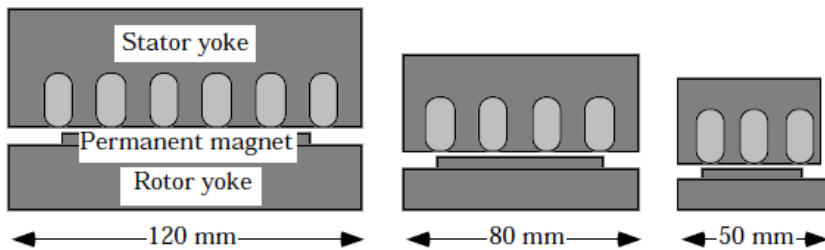
$$mmf \propto \text{magnet depth}$$



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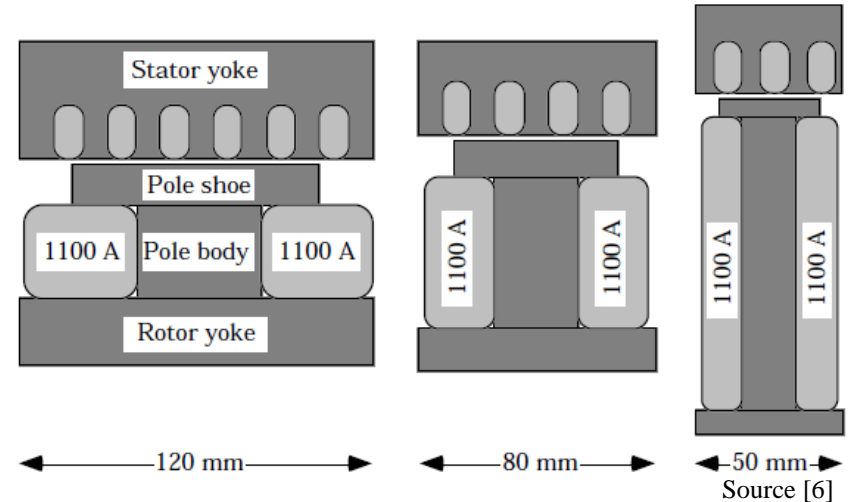
Multi-Pole with PM vs. WF

Permanent Magnet



The magnet mass is almost independent of the number of poles

Wound Field



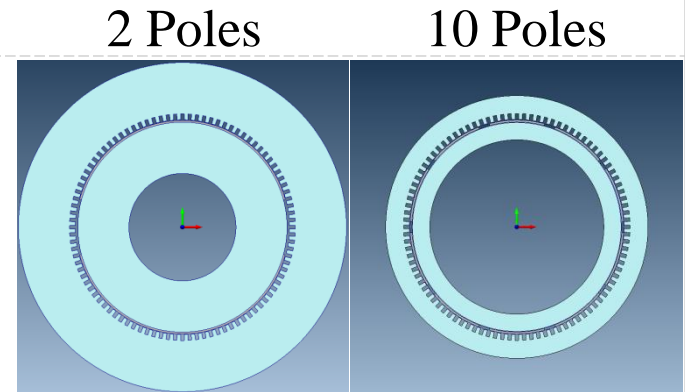
The copper mass is almost proportional to the number of poles



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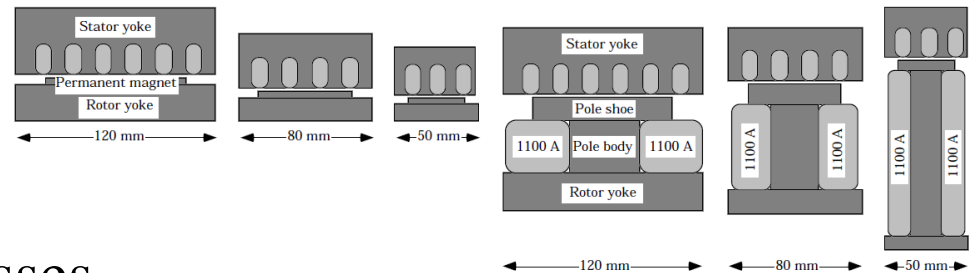
Conclusion on Multi-Pole PM

- Multiple poles allow for significant material savings (Fe and Cu)
 - However the iron losses are increased
 - This is not an issue with slow speed DD



- The use of PM material is independent of the number of poles

- Hence ideal for multi-pole




- PM have no excitation losses
 - Hence better part-load efficiency



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Direct Drive PM Wind Turbines

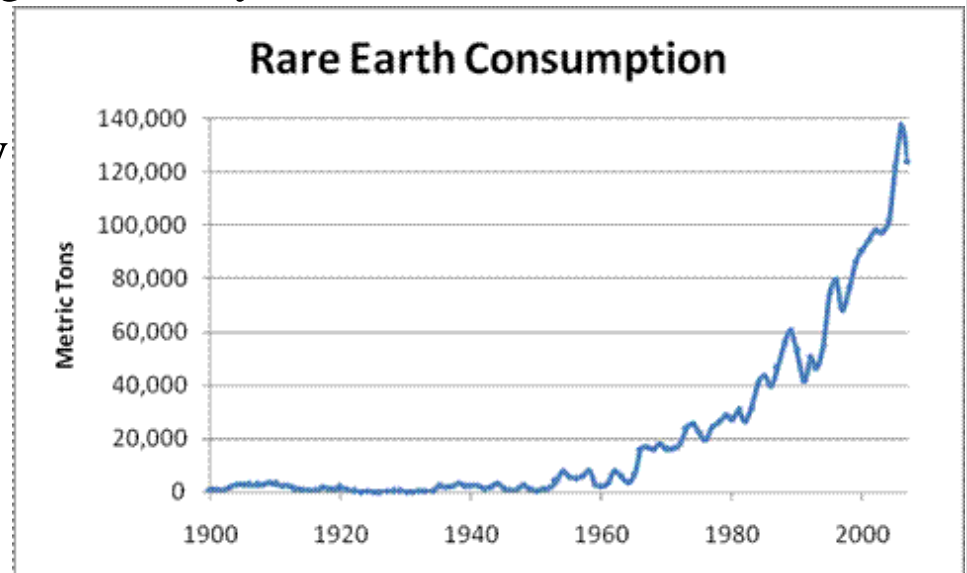
- Depending on the design one can expect around 0.5ton/MW 
- WWEA predicts the globally installed wind power to increase from present 200GW to 1900GW by 2020 [7]
- If 20% of this came from direct drive permanent magnet wind turbines
 - 170kT of NdFeB magnets would be needed in the next 10 years
 - 50-60kT of rare earth materials



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Rare Earth Permanent Magnets

- 50% of worlds reserves of rare earths (RE) are in China
- 95% of RE mining is in China
- Chinese government is clamping down on RE export [8]
 - 40% reduction in RE export over the last 7 years
 - Annual RE export is restricted to 35kT over the next six years
 - Global demand is increasing (200kT by 2014)
- Prices of Nd have risen by 70% this year and 170% since Jan 2009 [9]



Conclusion

- If the gearbox must go, then multi-pole is the favourite
 - Reduced nacelle weight
- At multi-pole, PM generators are the favourite
 - PM mass is independent of the number of poles
 - No excitation losses
 - Very simple rotor
- Their heavy dependence on rare earth materials might be a show stopper



References

- [1] www.tecowestinghouse.com
- [2] www.rcgroups.com
- [3] www.avantis-energy.com
- [4] www.mandc.co.za
- [5] Fitzgerald, A. E., Kingsley, C., Umans, S. D., “Electric Machinery,” 6th edition, McGraw-Hill, 2003.
- [6] Grauers, A., “Design of Direct-driven Permanent-magnet Generators for Wind Turbines”, PhD Thesis at Chalmers University of Technology, 1996.
- [7] www.wwindea.org
- [8] The Independent, 2nd January 2010
- [9] <http://news.alibaba.com/article/detail/china-metal-market/100036625-1-rare-earth--china-market-price.html>



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Thank you!

Questions?



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