PM Assisted Reluctance Motors

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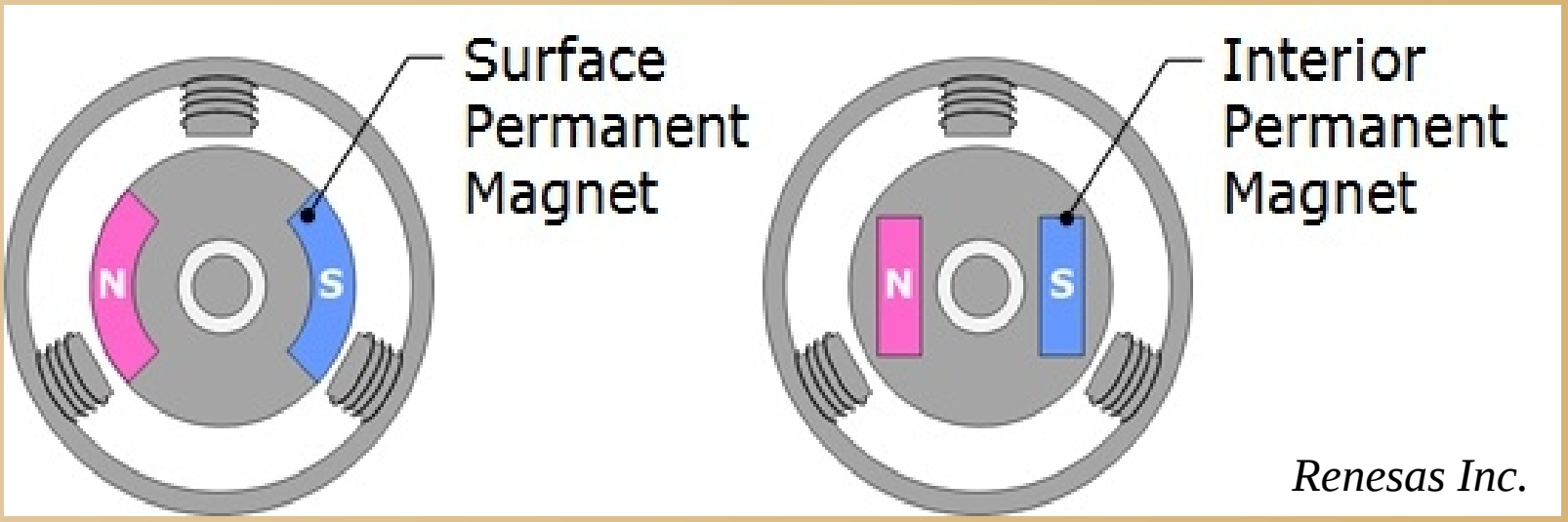
EE564: Design of Electrical Machines

Outline:

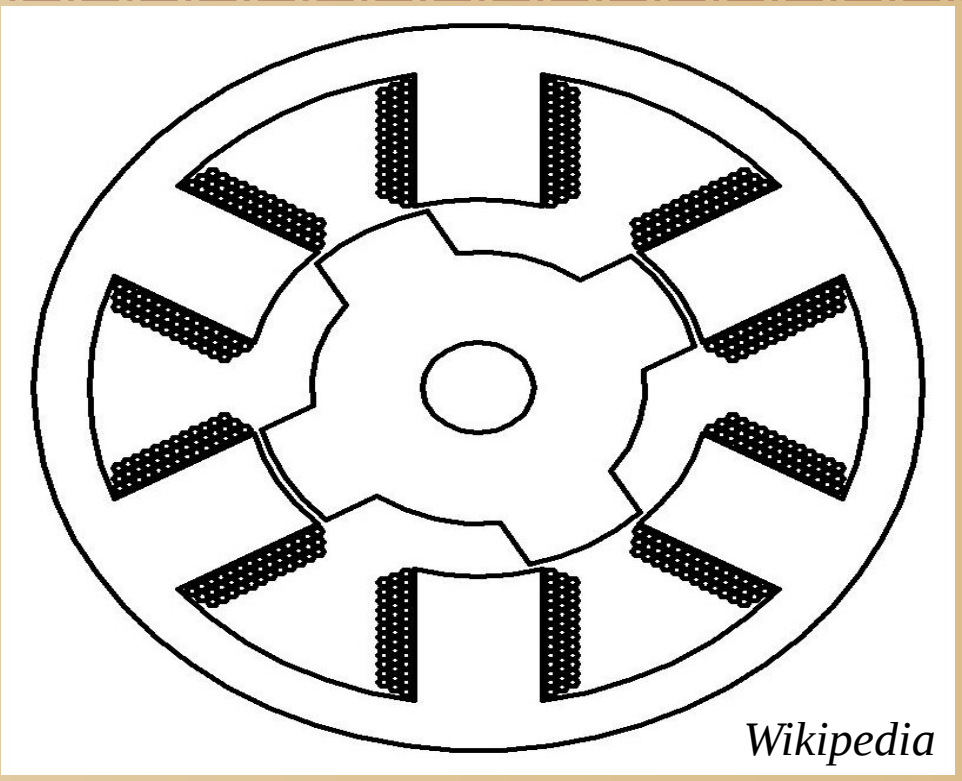
- Working Principle of PM Assisted RM:
  - Permanent Magnet Brushless DC Motor (PMBLDC)
  - Reluctance Motor (RM)
  - PM Assisted Reluctance Motor
- History & Modern Trends
- Advantages & Disadvantages
- Application Areas
- PM Assisted Reluctance Motor Design
- Conclusion
- References

Permanent Magnet Brushless DC:



- PM-BLDC: an AC Motor Type
- Can be (theoretically) derived from both Brushed DC and Synchronous AC machines.
- Driven by power electronics: Square-Wave or Sinusoidal PWM

Reluctance Motors:

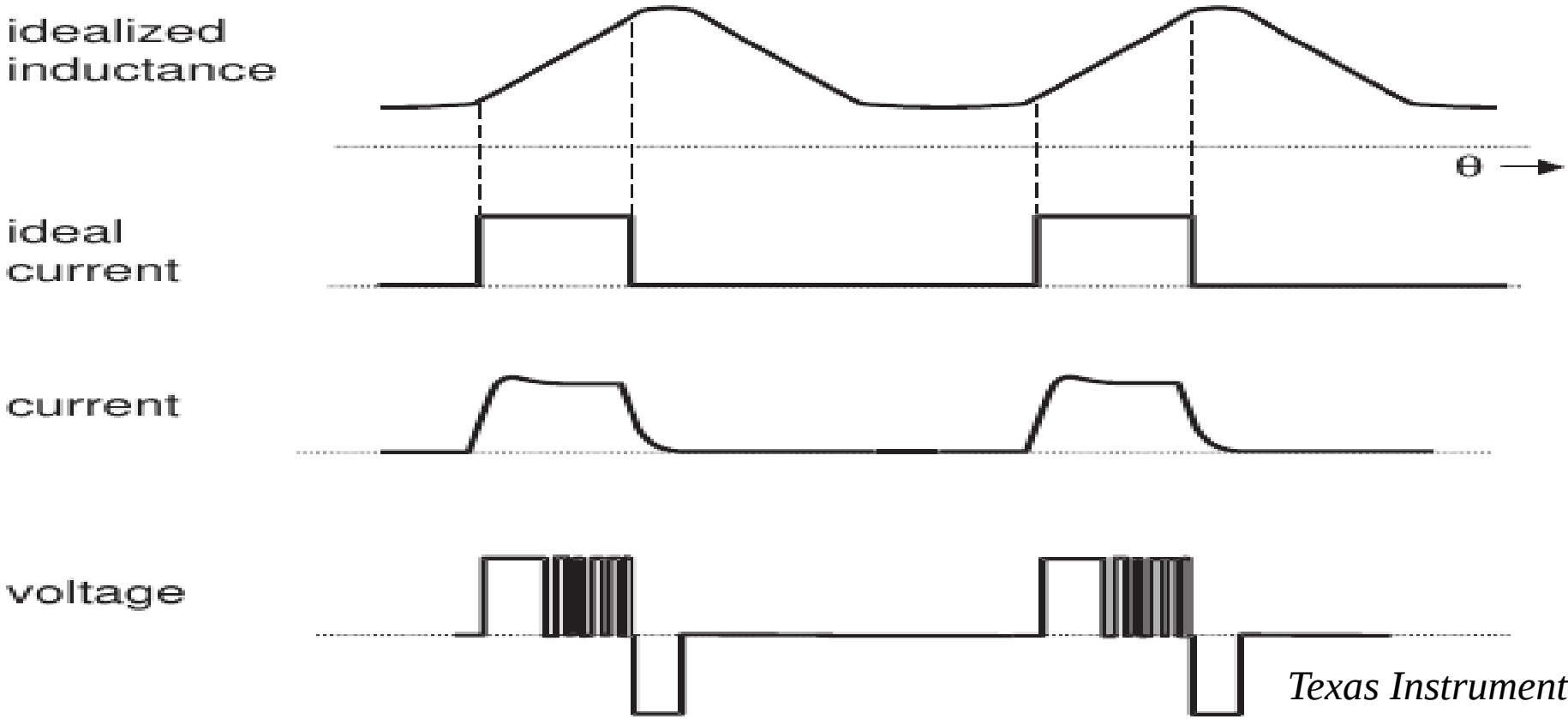


Wikipedia

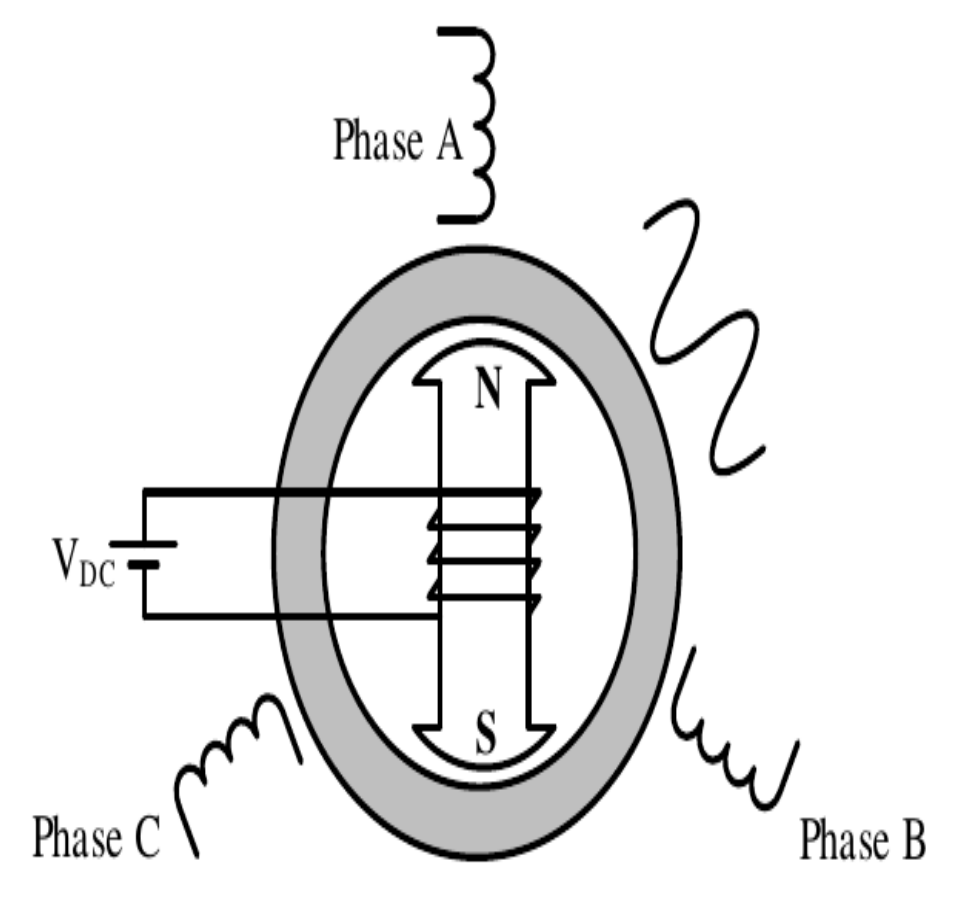
- Operation principle: Change of reluctance due to saliency.
- Solid rotor without coils or PMs.
- Concentrated windings on stator.
- Driven by power electronics.
- Two main categories:
  - Switched Reluctance
  - Synchronous Reluctance

SW Reluctance Motors:

Switched Reluctance Motor Driving Technique



Synch. Reluctance Motors:



Salient Pole Synchronous AC Machine

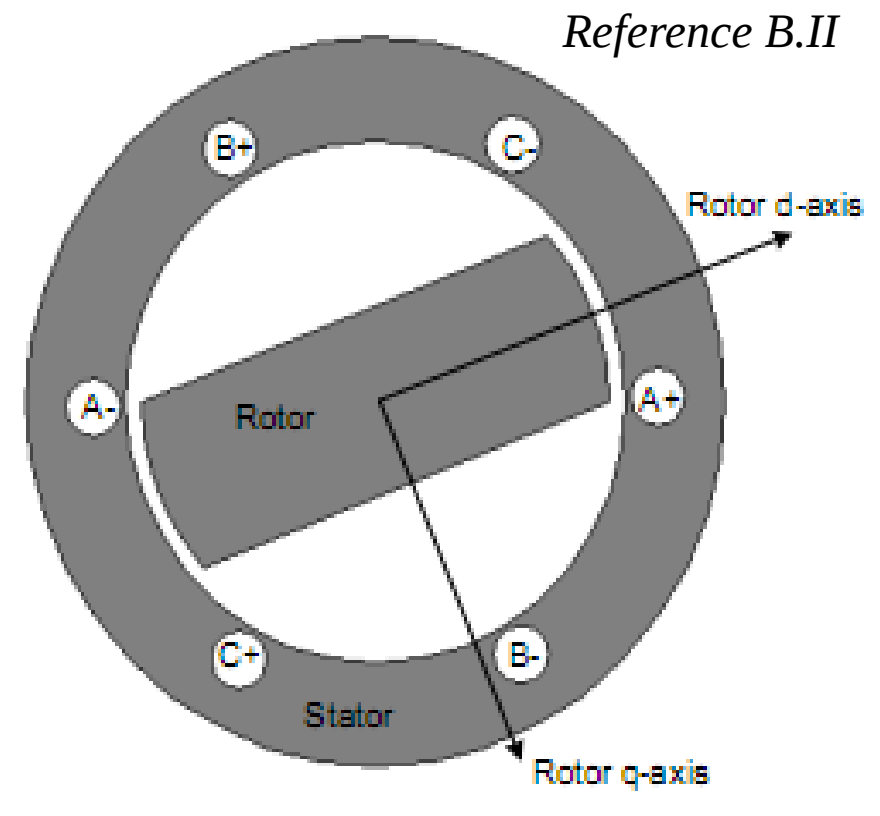
- Synch. machine operation: Flux interaction & Reluctance power.
- Reluctance power: 10-15% of overall power.
- Consider a SM with its field not being excited.
- Stator: Usual 3-phase AC windings. Rotor: Solid, salient, without coils or PMs.

PM Assisted Reluctance Motors:

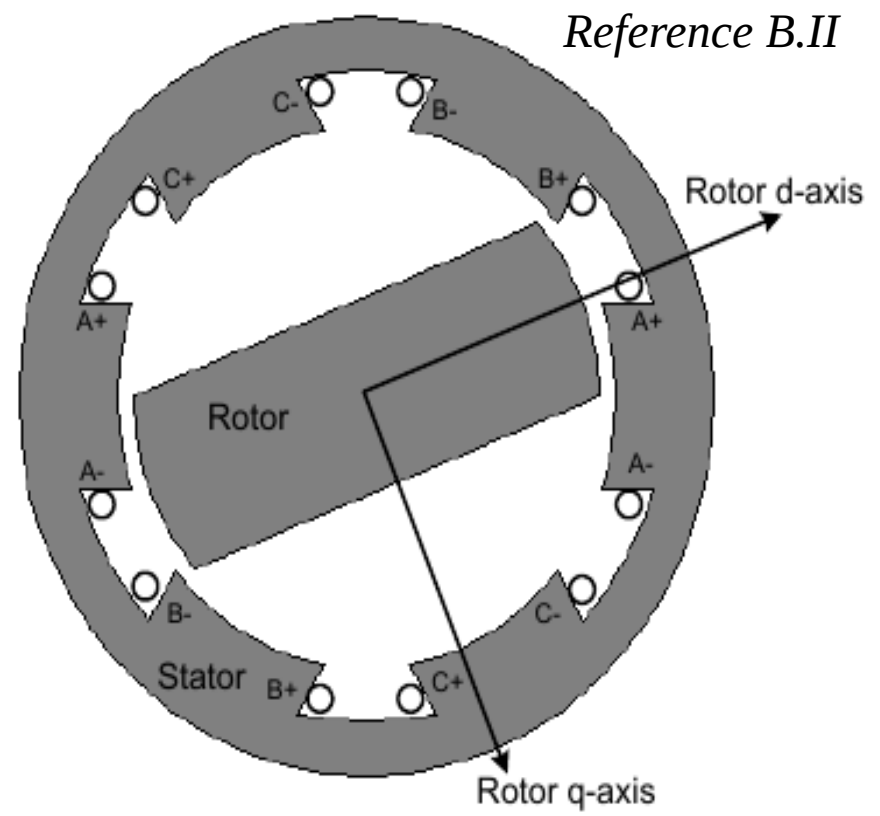
- Utilization of PM in Synchronous Reluctance Motors.
- Terminology: IPM, PMaRM, PMSRM, HSRM
- Aim is to combine reluctance power and PM effect.
- A hybrid solution which tries to obtain the benefits of the two motor families.

PMaRM Rotor:

Three phase, two pole reluctance motor



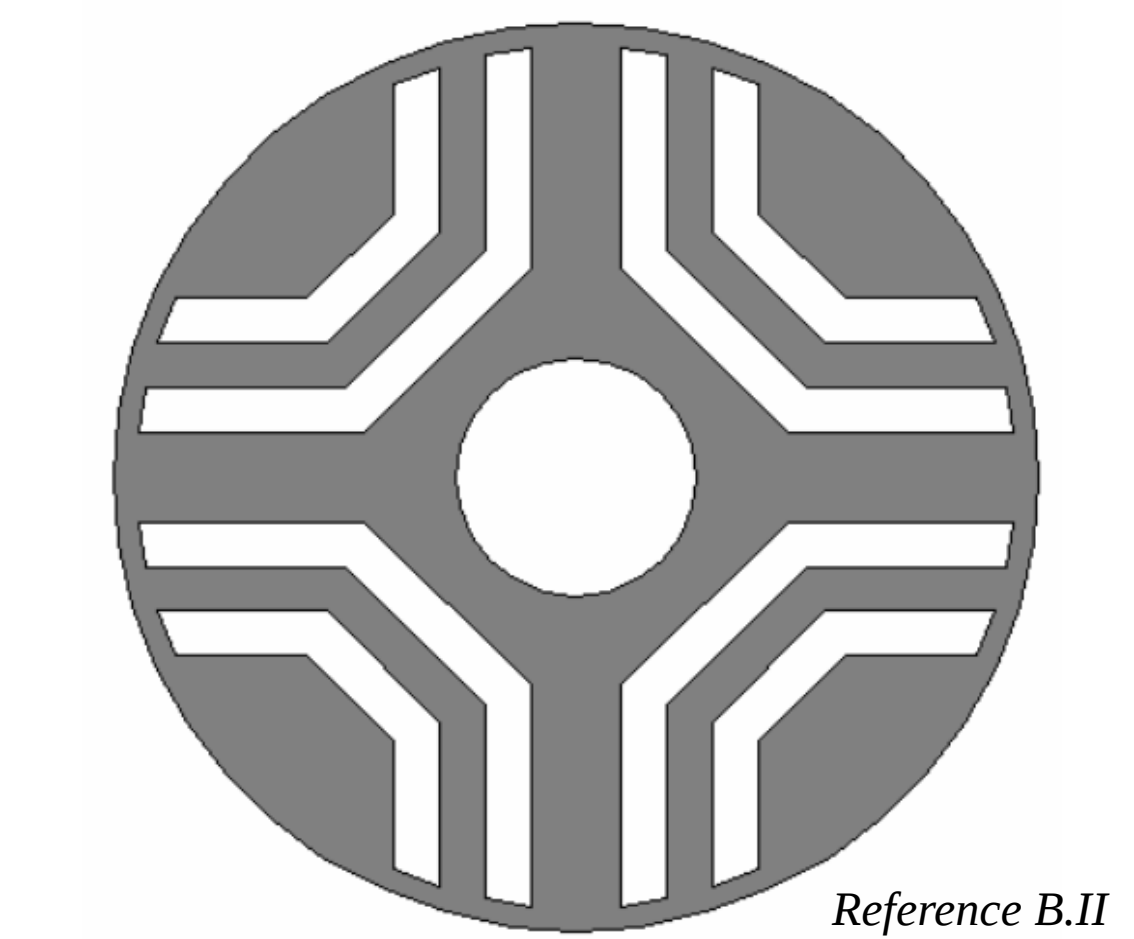
a) Single Saliency



b) Double Saliency

PMaRM Rotor:

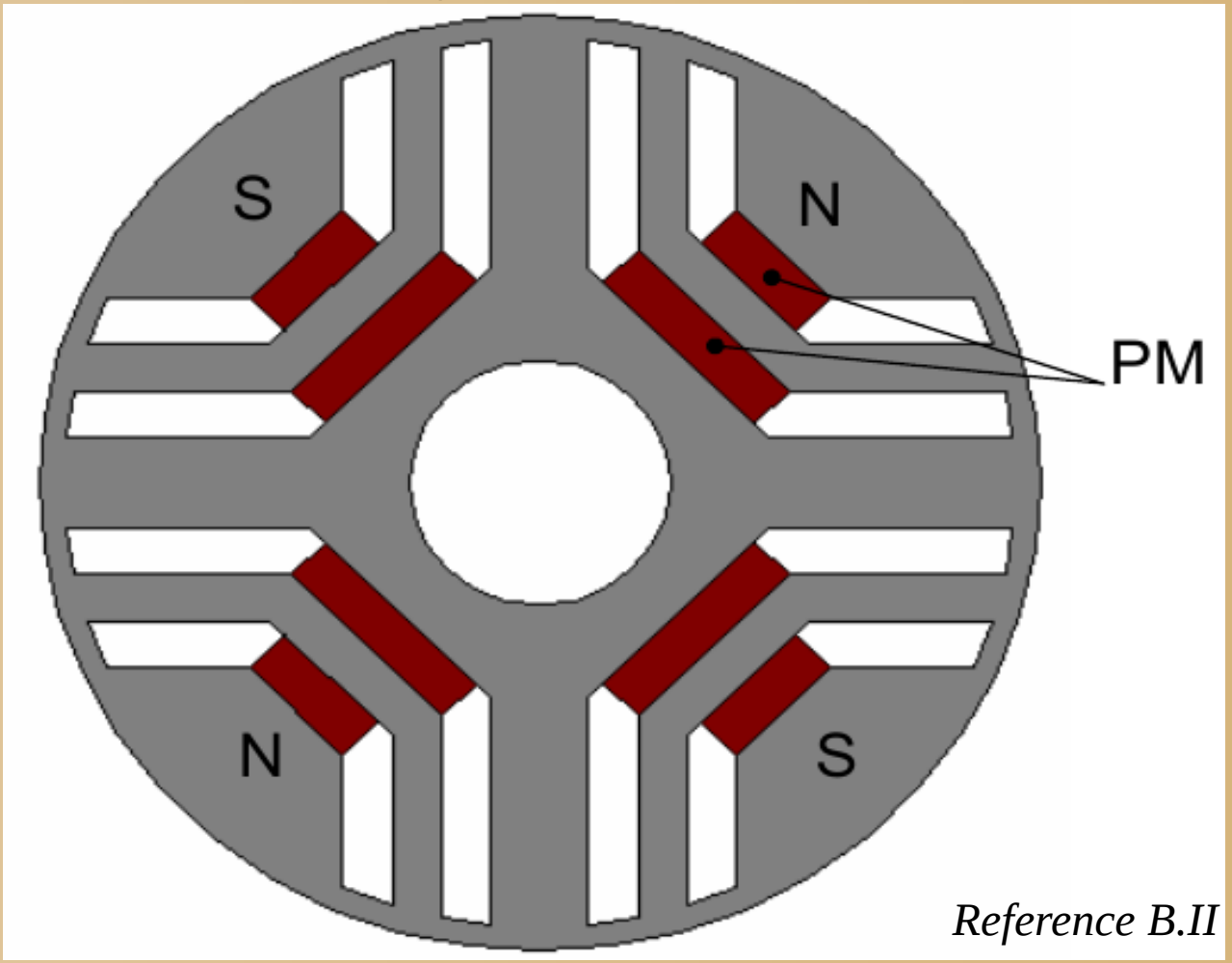
Four pole, transversely laminated rotor design:



Reference B.II

PMaRM Rotor:

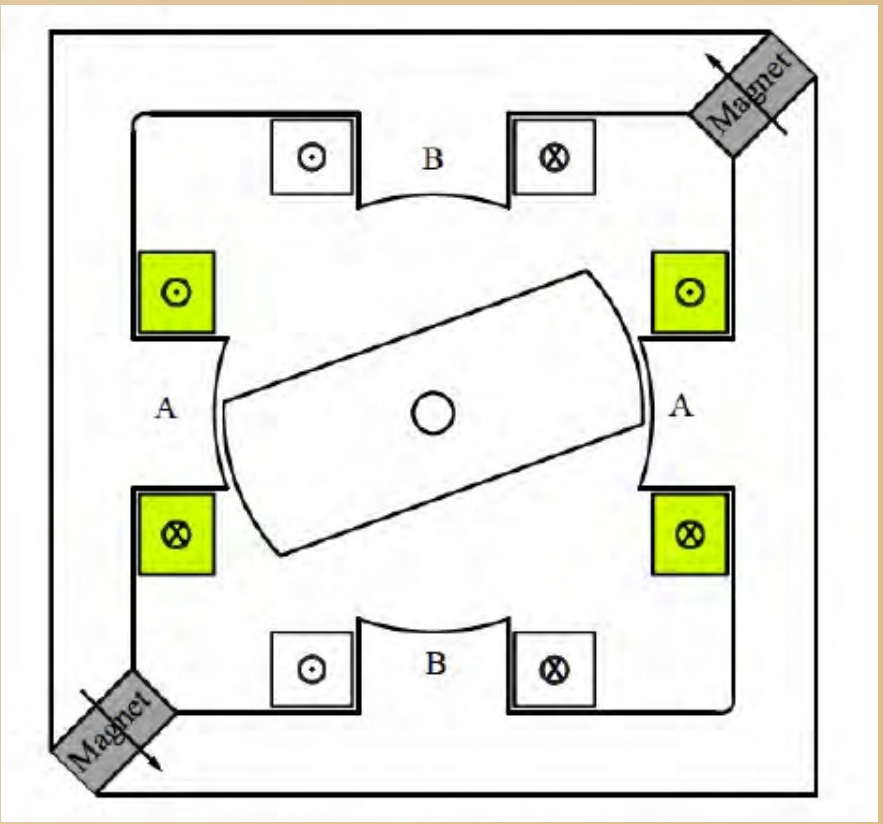
Four pole, transversely laminated, PM assisted rotor design:



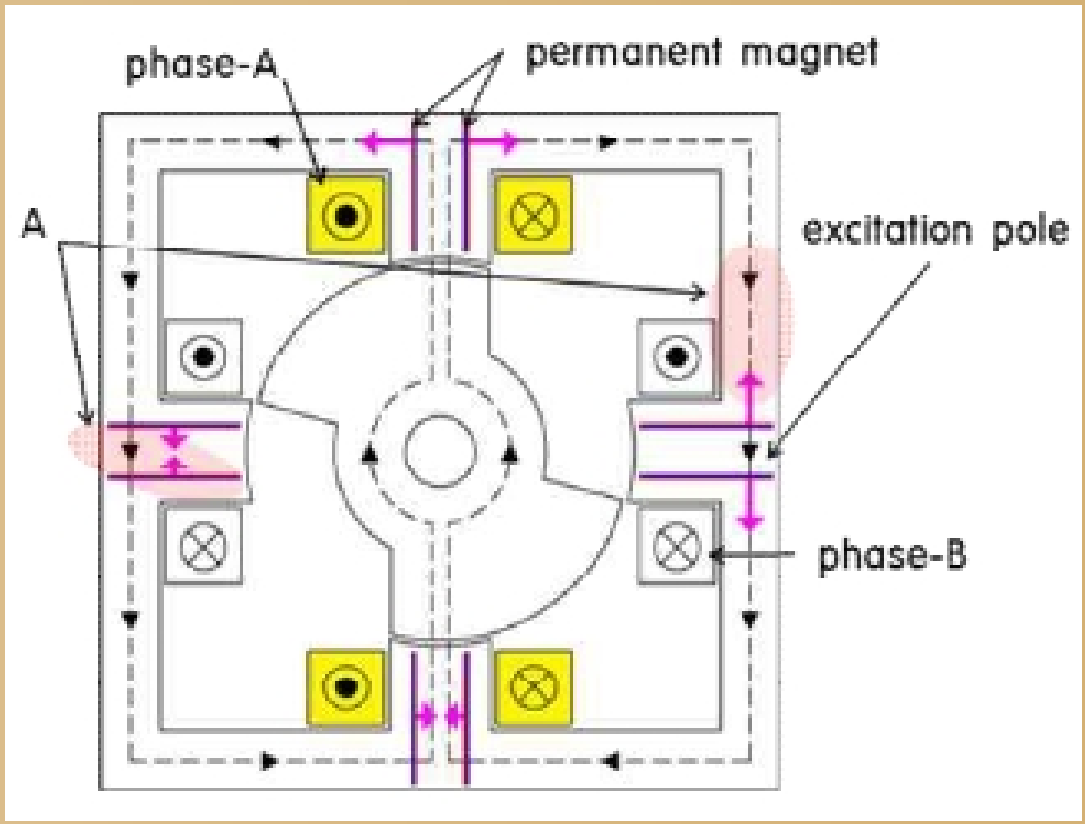
Reference B.II

Other PMaRM Designs:

Designs with PMs in the back iron:



Flux switching motor: Lipo et al.

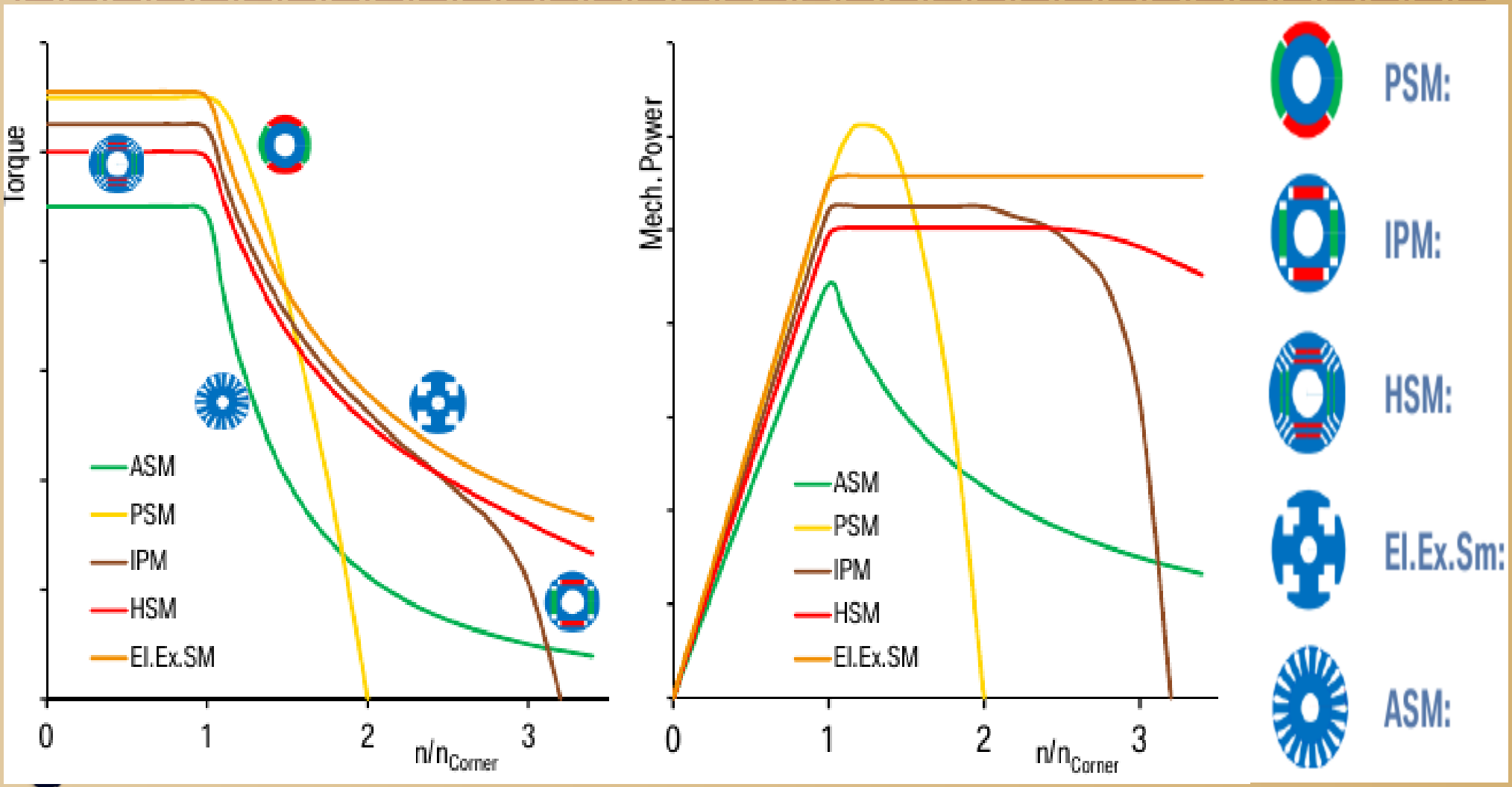


PMaSWR: Lee et al.

History & Modern Trends:

- Early work, studies for proof of concept: Michael Faraday 1821, Joseph Henry 1831.
- First practical SRM: William Taylor 1839
- Resurrected with the emerge of Power Electronics.
- A strong candidate for EV motor.
- Research: motor optimisation, higher performance drives

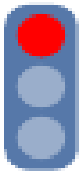
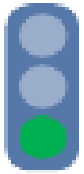
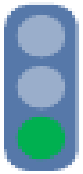
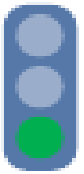
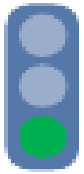
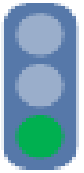
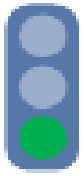
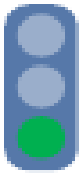
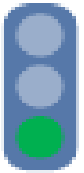
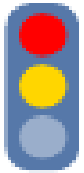
Application Example: EV



BMW

Comparison of Motors for EV

Application Example: EV

	PSM	IPM	HSM	El.Ex.SM	ASM
Constant power over speed range					
Torque per stator current					
Efficiency over complete operating range					
Weight					

Comparison of Motors for EV

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PMaRM Design

Assuming three-phase, distributed AC windings on stator:

- Decide on number of layers
- Decide on PM size and shape
- Decide on size and positions of flux barriers
- Iterative FEM analysis.

Conclusions

- PMaRM: a promising candidate for EVs.
- Hybrid structure: optimization for different goals is possible
- Research for higher performance PMaRM continues.

References:

A)Books:

I. Brushless Permanent Magnet and Reluctance Motor Drives, T. J. E. Miller, 1989.
II. Switched Reluctance Motor Drives, R. Krishnan, 2001.
III. Lessons in Electric Circuits Volume-II AC, T. R. Kuphaldt, 2007

B)Dissertations

I. Permanent Magnet Assisted Synchronous Reluctance Motor Design and Performance Improvement, Ph.D Thesis, P. Niazi, Texas A&M University., 2005.
II. Doubly Salient Permanent Magnet Flux Reversal Free Stator Switched Reluctance Machines, Ph.D Thesis, N. S. Lobo, Virginia Tech., 2011.

C)Other

I. A Status Review of Advances in Hybrid Electric Vehicles, M.A. Rahman, Panel Paper PESGM2606, IEEE PES Annual Meeting , PA, USA, 2014.
II. Switched Reluctance Motor Control, M. T. DiRenzo, Texas Instruments Application Note, 2000.