Electric motors for electric vehicles

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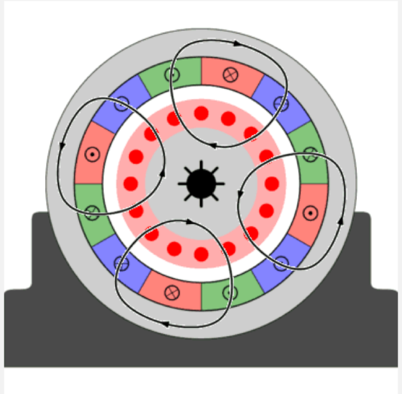
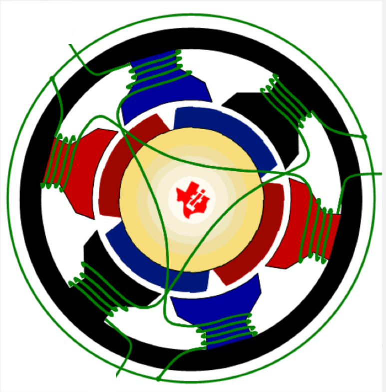
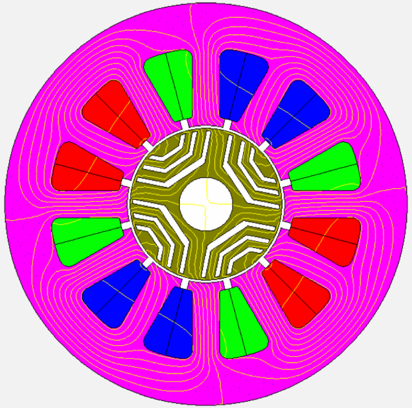


Induction



Permanent Magnet



Synchronous Reluctance

TUDelft

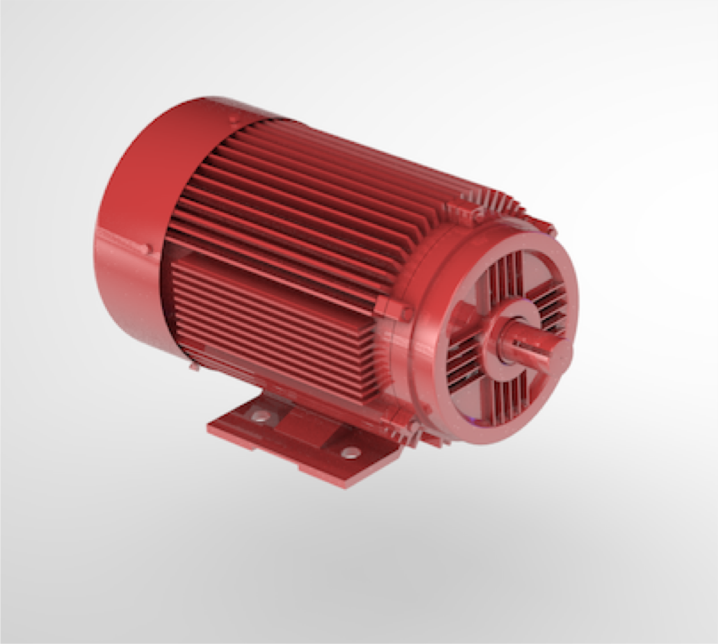
dutch-incert

TU/e Technische Universiteit Eindhoven University of Technology

What is the best motor for your EV project?

Many different angles:

- Electrotechnical
- Mechanical
- Practical
- Economic
- Environmental



Only three types of motors for EVs

L. Kumar and S. Jain, “Electric propulsion system for electric vehicular technology: A review,” *Renew. Sustain. Energy Rev.*, vol. 29, pp. 924–940, Jan. 2014.

Induction	**Permanent Magnet**	**Synchronous Reluctance**
Ford ECOstar (1992)	Nissan Al tra (1997)	Holden Ecommodore (2007)
Ford Ranger EV (1999)	Toyota Prius (2004)	Renault Fluence ZOE (2011)
GM EVI (1999)	Mitsubishi Miev (2009)	
Tesla Roadster (2008)	Nissan Leaf (2010)	
Ford Think City (2008)	Tata Indica Vista EV (2011)	
Fiat Panda (2009)	Fiat Peogeot ION (2011)	
Chevrolet Silverado (2010)	Chevrolet Volt (2011)	
Ford Focus Electric (2011)	Hyundai Blueon (2012)	
REVA NXR (2011)	Honda Fit EV (2012)	
Tesla Model S (2012)	Honda Civic (2013)	
Honda Fit EV (2012)	Volkswagen eGolf (2015)	
Toyota Reva 4 (2012)	Chevrolet Bolt (2017)	
Mahindra Reva e20 (2012)	Tesla Model 3 (2017)	

Brushed DC motor

- The classic electric motor
- Movement is sustained by switching polarity using commutator connected by brushes
- Brushes can cause sparks and malfunctions and need regular replacements
- No longer used in EVs

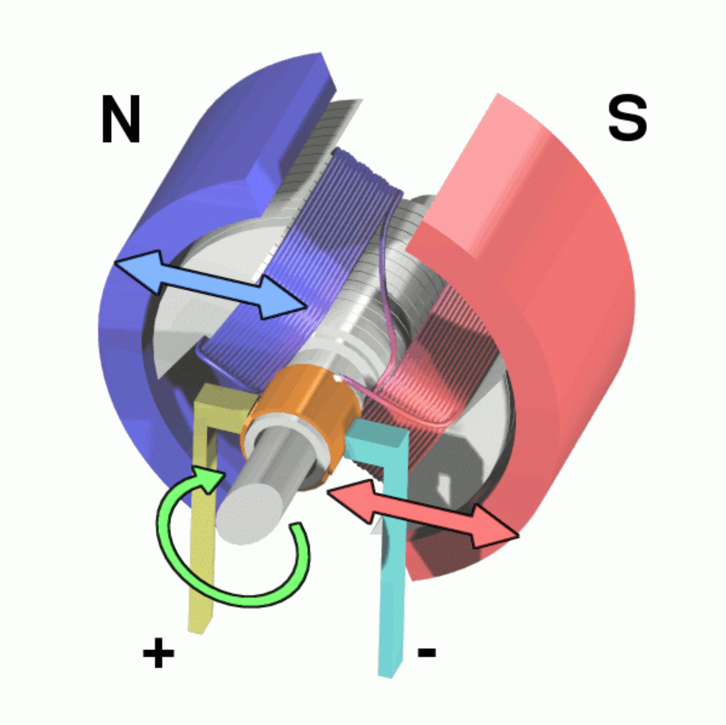


Image source: Electric motor – Abnormaal, Wikipedia

Induction Motor
How it works

- Magnetic field in the stator from electrified windings
- Through induction the rotor is magnetized and aligns to stator
- By alternating current the stator can produced rotating magnetic field (RMF) that is followed by rotor
- Rotor is always lagging behind a bit: this “slip” means it’s an asynchronous motor

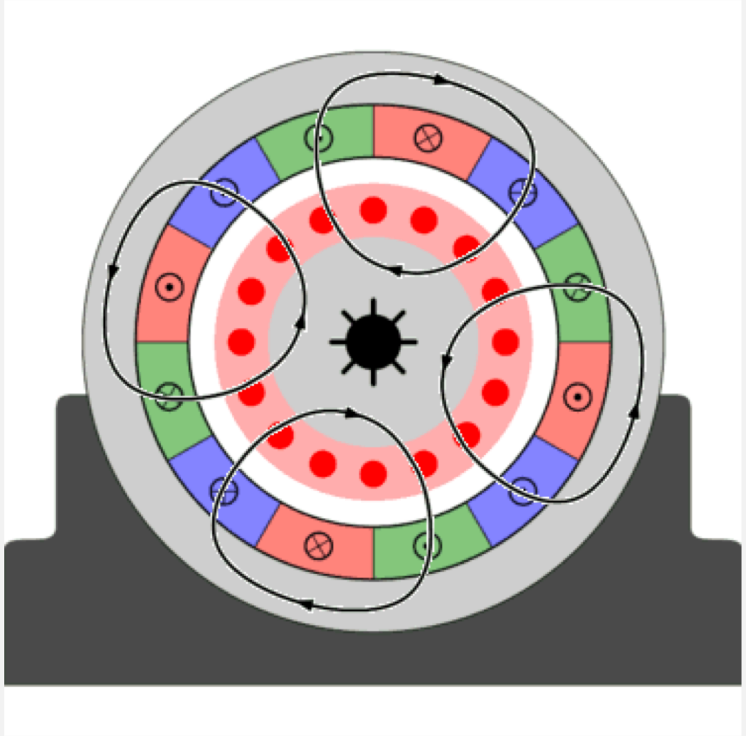


Image source: Asynchron motor animation – Burnsburnsburns, Wikipedia

Induction motor Applications

- Used in 90% of industrial motors
- Variable frequency drive (VFC) makes speed control easy
- Used in the Tesla Roadster and Model S and X (but not in the Model 3)

Image source: Liquid cooling pumps, hydro station L'ange Gardien – Ceedub13, Wikipedia

Induction Motor

Advantages

- Simple and rugged
- No brushes
- No permanent magnet
- No position sensor
- No starting mechanism
- Easy speed control

Disadvantages

- Induced currents in rotor cause losses and heat
- Not the lightest and most compact motor

Permanent Magnet Motor
How it works

- Rotor is magnetized using permanent magnets
- Follows RMF without induced currents (heat, losses)
- Synchronous
- Often with the rotor outside: out-runner.
- Also available with rotor inside: in-runner or interior PM motor

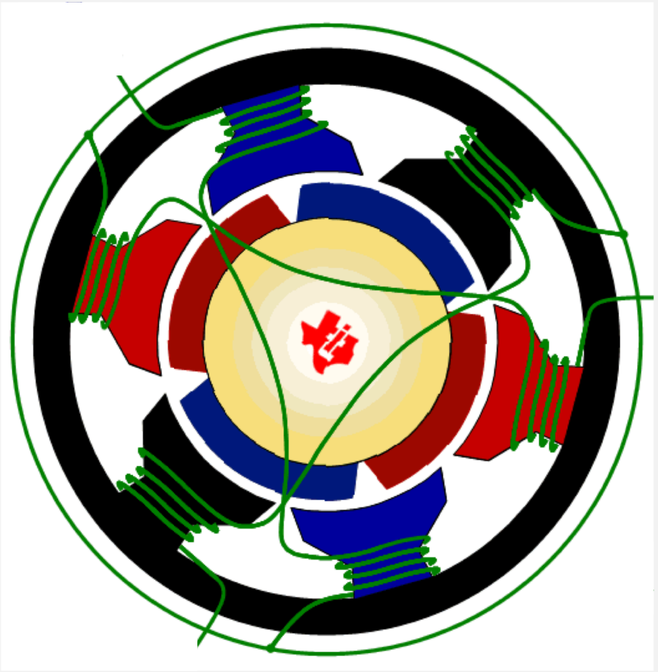


Image source: InstaSPIN™-BLDC Motor Control Solution - Courtesy of Texas Instruments

Permanent Magnet Motor Applications

- Increasingly used in all kinds of high-performance applications
- Seems to replace the induction motor in electric vehicles

Image source: Tesla Model 3 – Leo Nguyen, Wikipedia

Permanent Magnet Motor

Advantages

- Light and small
- Silent
- Efficient
  (especially at lower speeds)

Disadvantages

Needs:

- Permanent magnets (cost + environment + can demagnetise)
- Position sensor
- Starter mechanism
- Electronic controller

Synchronous Reluctance Motor
How it works

- Similar to permanent magnet motor but with steel rotor
- Steel rotor design aligns itself to the flux lines of the magnetic field

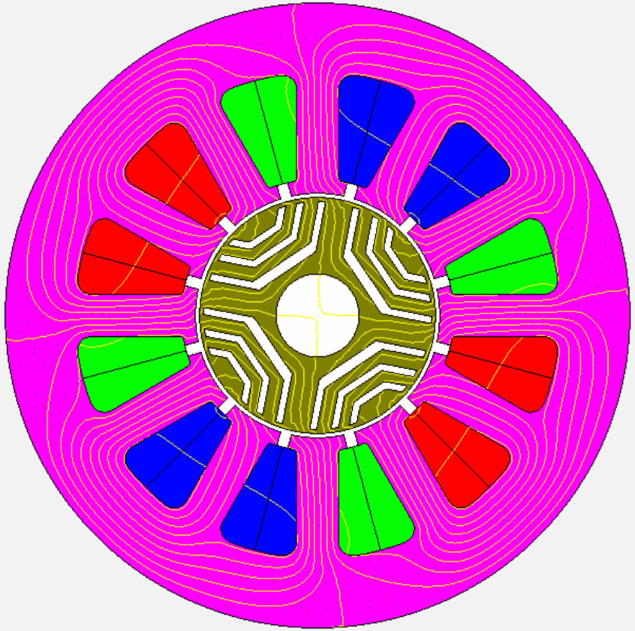


Image source: Synchronous Reluctance Motor – Technelec, technelec.co.uk

Synchronous Reluctance Motor

Advantages

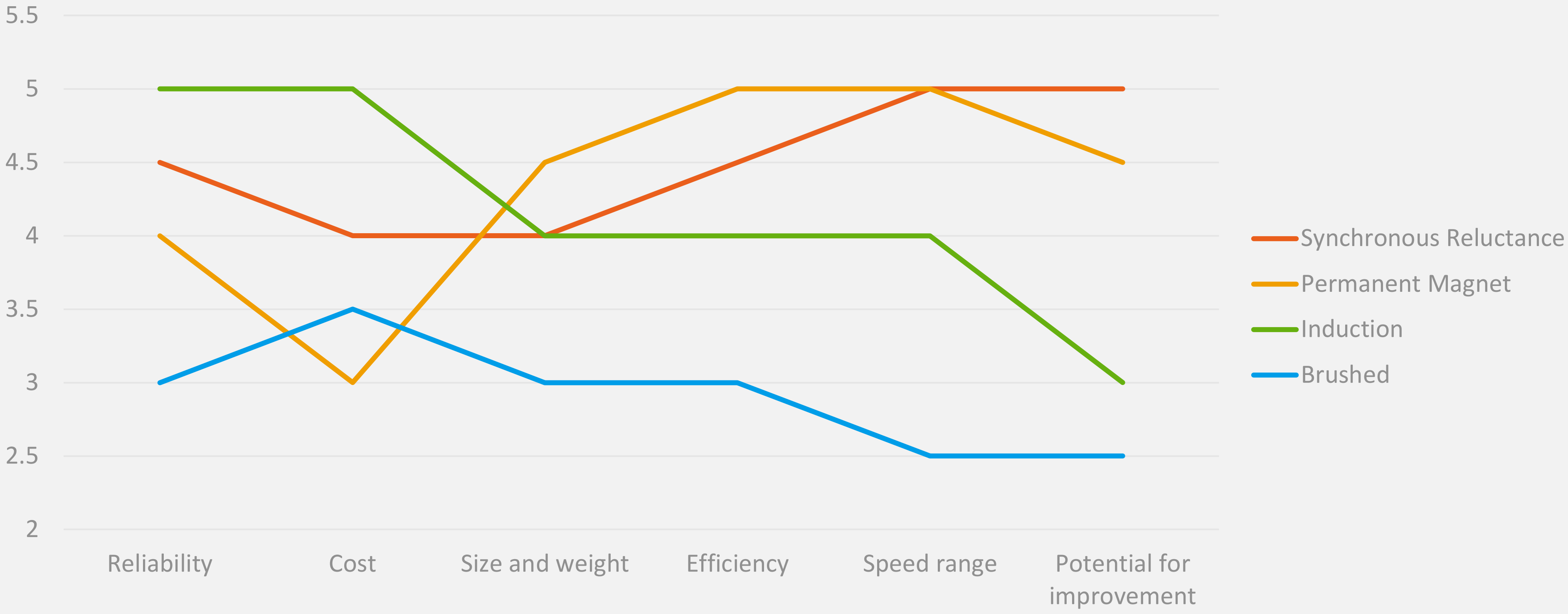
- Torque comparable to permanent magnet motor
- Efficient at higher speeds
- Cheap and clean to produce (no permanent magnets)

Disadvantages

- Lower efficiencies at lower speeds
- Higher inherent noise and torque ripple (but increasingly dampened by advanced controllers)

Final Motor Comparison

L. Kumar and S. Jain, “Electric propulsion system for electric vehicular technology: A review,” Renew. Sustain. Energy Rev., vol. 29, pp. 924–940, Jan. 2014.



Thank you for your attention