Electric Vehicles

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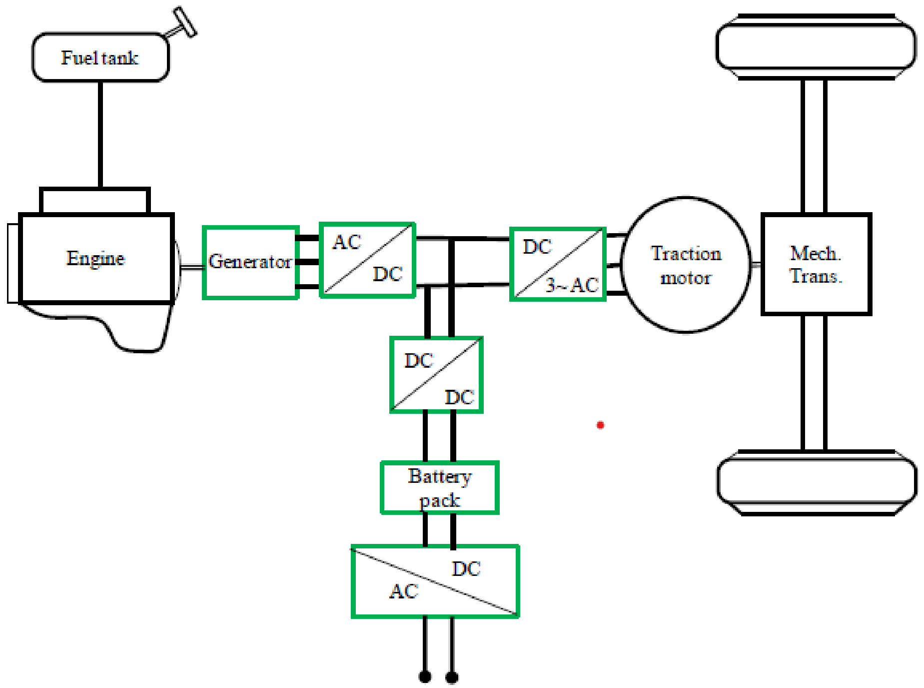
AC motors –Induction motor

- This AC Induction motor – or Induction motor for short – needs no permanent magnets.
- Instead, the magnetic field is produced by a current that flows through the windings in the housing or stator. The magnetic field from the stator will induce a voltage and current in the windings of the rotor.
- That is the reason why it is called the induction motor. This, in turn, leads to the rotor producing its own magnetic field. And this magnetic field will make the rotor turn so as to align itself with the magnetic field from the stator.

- The stator is supplied alternating current which means the magnetic field in the stator is also alternating. If you do this cleverly enough you can create a so-called rotating magnetic field or RMF.
- And the rotor will follow this rotating magnetic field in the stator, without the need for a commutator with brushes.
- Since the rotor follows the rotating magnetic field only after it has created an induced electric field itself, it is always lagging behind a bit.
- The amount that the rotor lags behind is called “slip”. This slip causes the rotor to always be out of sync with the rotating magnetic field a bit. That’s why an induction motor is called an asynchronous motor.


Fuel tank
Engine
Generator
AC
DC
DC
3~AC
Traction
motor
Mech.
Trans.
DC
DC
Battery
pack
DC
AC

- it is possible to vary the frequency of the alternating current using a variable frequency drive or VFD. Using the VFD you can vary how fast the magnetic field turns by varying your alternating current or AC frequency.
- Other names for VFD are Variable Speed Drive, Adjustable Frequency Drive, AC drive converter.
- In 2017 over 90% of industrial motors were still induction motors. It was also used in the first range of cars from the Tesla motor company.

The induction motor has many advantages:

- it is so very simple to construct.
- It also has the lower price because it has no permanent magnet, no brushes, no position sensor, no starting mechanism since it is self-starting.
- Speed control is easy. You simply control the frequency of the alternating current with a variable frequency drive.

- But there are some disadvantages: the induced currents in the coil cause efficiency losses.
- The induced losses also mean induced heat in the rotor and thus the need for cooling the rotor.
- It is also not the lightest nor most compact electric motor.

Permanent Magnet Synchronous Motor

- Recent advances in material science have made it possible to produce very powerful permanent magnets using neodymium.
- If we construct a rotor with permanent magnets we no longer need to induce a magnetic field in the rotor. This avoids losses and heat development in the rotor. Because of all this, permanent magnet motors are currently the smallest and lightest electric motors you can buy.
- Because the rotor is already magnetized it is always in sync with the rotating magnetic field. That is why permanent magnet motors are also classified as synchronous motors.

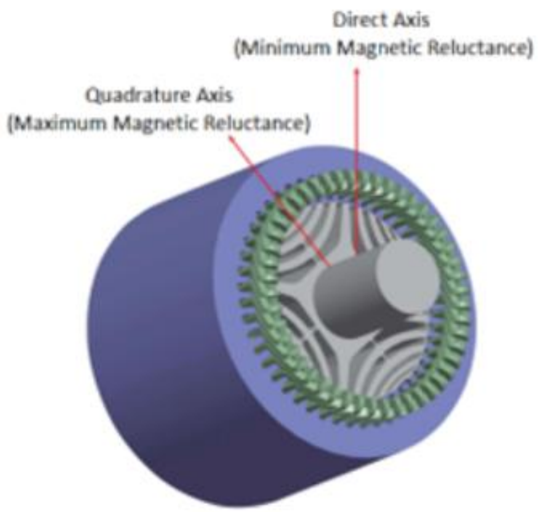
- Often the rotor with the permanent magnets on it runs at the outside. This is called an out-runner. An out-runner can deliver higher torque at lower speeds.
- Sometimes the rotor and the permanent magnets run at the inside and this is called an in-runner. An in-runner can quickly spin up to high speeds. So when high speed is not a problem, an in-runner can provide the same power in a smaller, lighter and cheaper package.

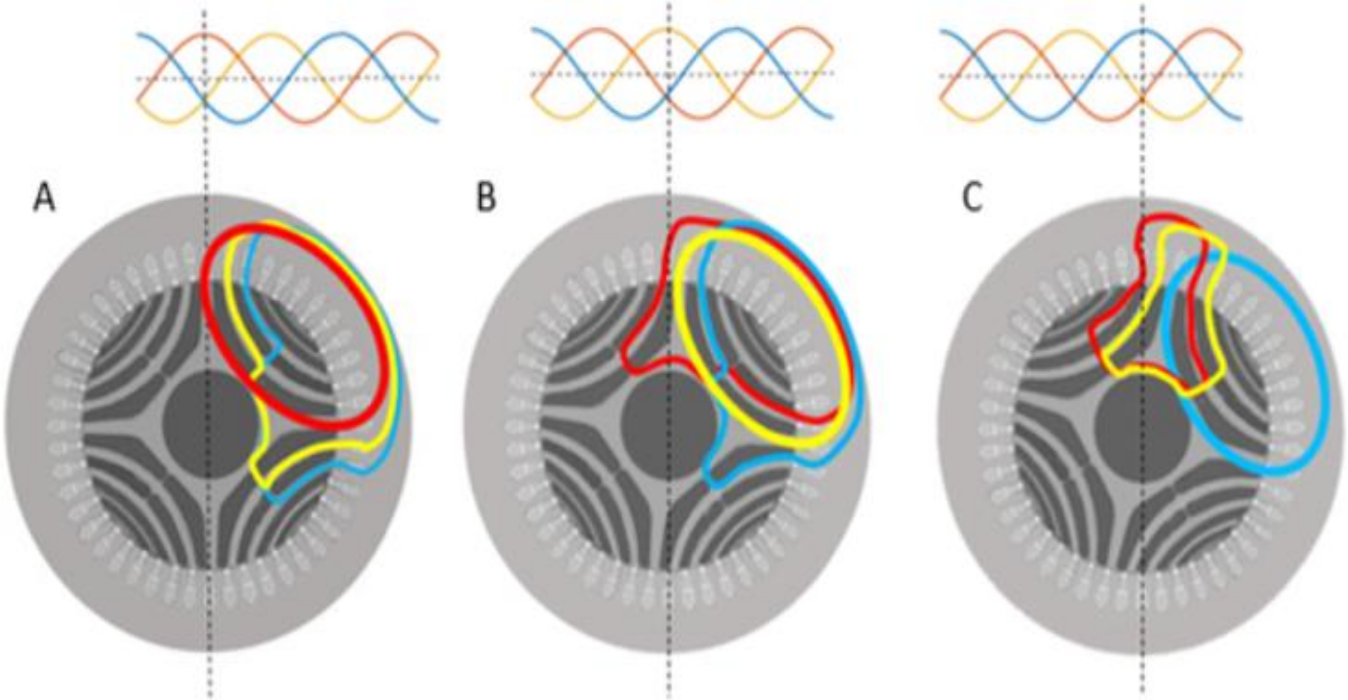
- The permanent magnet motor is increasingly used in all kinds of high-performance applications
- Electric vehicles are no exception. More and more electric vehicle manufacturers are replacing induction motor with permanent magnet motors. A good example is Tesla. its new models use the permanent magnet motor.

- The advantages of the permanent magnet motor are that it is the lightest and smallest motor.
- It is also the most silent and efficient motor.
- The biggest disadvantage is that it needs these scarce earth metal magnets and they are expensive.
- They are also a bit more complex to run, requiring a position sensor, starter mechanism and more advanced controller.
- The rotor position is determined using Hall effect sensors then the correct drive frequency and phase is synthesized by the motor controller.

Synchronous reluctance motor

- A recent development is a motor that tries to combine the best of both worlds: the synchronous reluctance motor.
- It has a rotor that contains metal that is formed in such a way that it wants to align itself naturally to the surrounding magnetic field.
- So it does not need to produce its own electric field through induced currents like the induction motor.
- This means fewer losses. And it does not need permanent magnets which makes it much cheaper than a permanent magnet motor.


Direct Axis
(Minimum Magnetic Reluctance)
Quadrature Axis
(Maximum Magnetic Reluctance)


A
B
C

- This bestows the synchronous reluctance motor with some important advantages: it has torque and efficiency (especially at higher speed) that is comparable to permanent magnet motors.
- It does not need permanent magnets which makes it more rugged, cheaper and better for the environment.

- However, it has some disadvantages. Efficiency at a lower speed can be a bit lagging compared to a permanent magnet motor.
- There are higher inherent noise and torque ripple. However, as rotor design improves and especially as advanced motor controllers and algorithms improve the noise and torque ripple might be almost eliminated.
- it could indeed become a motor that combines the best of both worlds.

- **Stator:** The stator has windings that create a rotating magnetic field when a three-phase AC power supply is connected.
- **Rotor:** The rotor is made of a special iron core with flux barriers or saliency, which are designed to create paths of low and high magnetic reluctance.
- **Reluctance Torque:** When the stator's rotating magnetic field is present, the rotor tries to align its low-reluctance path (the iron material) with the field to minimize the overall reluctance. This tendency to align creates torque.

- **Synchronous Speed:** As the stator field rotates, the rotor "pulls in" and locks onto the field, causing it to rotate at the exact same speed (synchronous speed). The rotor constantly follows the path of least reluctance to stay locked.

Motor configuration

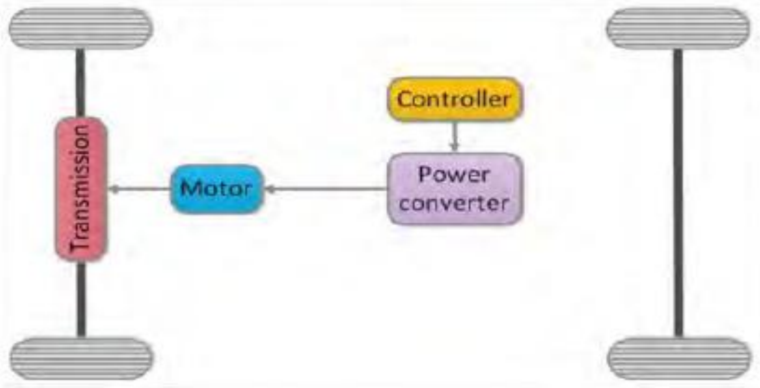


Figure 1.20 Single motor configuration

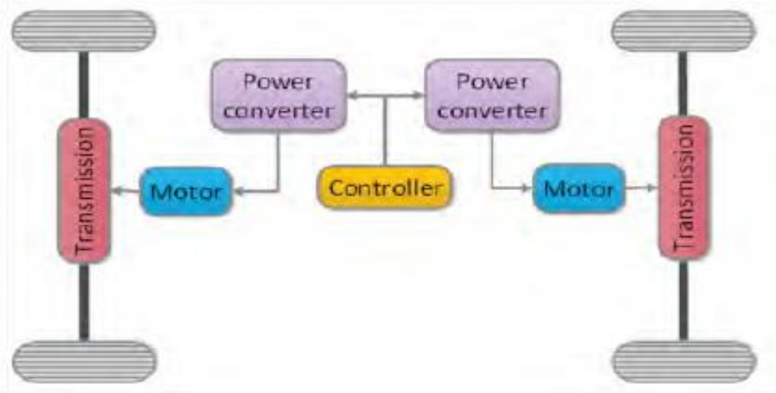


Figure 1.21 Dual motor configuration

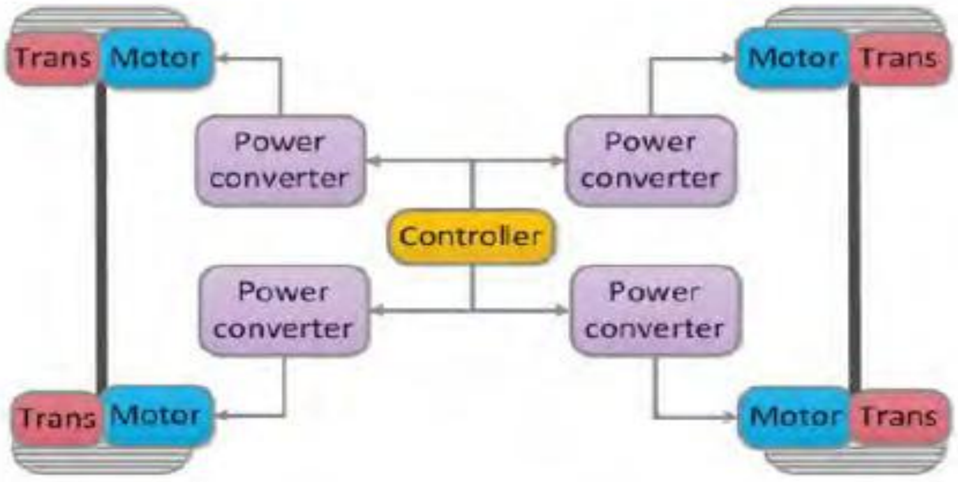


Figure 1.22 In-wheel motor configuration

- Single motor configurations use one motor that drives either the front or rear axles.
- With a dual motor configuration, two motors are used to drive the EV and this can be done in different ways. One possibility is that one motor can power the front axle and the other the rear axle. Second, both the motors can be placed on either the front or rear axle to provide increased torque compared to the single motor configuration. Alternately, the two motors can be used to drive the left and right wheel independently on either the front or rear axle, meaning there is more control over the vehicle when cornering/turning.
- Using a separate motor to drive each of the four wheels independently is another possibility. This can be achieved using an in-wheel where the motor that is placed within the wheel of the car.
- AWD/FWD/2WD