The Shirpur Education Society's

R. C. Patel College of Engineering and Polytechnic, Shirpur

Department of Electrical Engineering

NOTES

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Course Title: Electrical Vehicle Technology

Subject Teacher :- Ms. H.A.Badgujar

UNIT-02 – (20 MARKS)

ELECTRIC VEHICLE DRIVES

CO Coverage: - Select electrical drives for particular EV application.

Content (Syllabus)

2.1 Classification of electric drives used in EV: DC Motor drives, AC Motor drives.

2.2 Brushed DC Motor, Brushless DC Motor (BLDC), Permanent Magnet Synchronous Motor (PMSM), Induction Motor (IM), Synchronous Reluctance Motor (SynRM), PM Assisted Synchronous Reluctance Motor, Axial Flux Ironless Permanent Magnet Motor: Salient features, characteristics, advantages, limitations, and usage of different motor types in EV models.

2.3 Comparison of EV motors based on power-weight ratio, torque-speed characteristic, cost of controllers required and cost of motors.

2.4 Physical location of motor in EV, Rating of motors, Connections (Mechanical and Electrical), and Selection criteria of various types of EV motors.

2.1 Classification of Electric drives used in EV :-

a) DC motor Drive :-
   i) seperately excited DC motor drive.
   ii) series DC motor Drive.
   iii) Brushless DC motor (BLDC) drive.

b) AC motor Drive :-
   i) Induction motor drive.
   ii) Permanent magnet Synchronous motor (PMSM) drive.
   iii) switchd reluctance motor (SRM) Drive.
   iv) Synchronous reluctance motor (SRM).

2.2. Salient features, characteristics, advantages, limitations, and usage of different motor types in EV models :-

1) Brushed DC motor :- A brushed DC electric motor is an internally commutated electric motor designed to be run from a direct current power source and utilizing an electric brush for contact.

→ These motors have permanent magnets (PM) to make stator.
→ Rotors have brushes to provide supply to stator.
→ The heat is also difficult to remove as it is generated in the center of the rotor.
→ Because of these reasons, brushed DC motors are not used in EV's anymore.

* Features :- Uses mechanical brushes and commutator.

* Characteristics :- Simple construction and speed control via voltage variation.

* Advantages :-
  1) High starting torque.
  2) Simple control
  3) low cost.
  4) More efficiency than I.M.

* Disadvantages :-
  1) High maintenance
  2) Heat generated at brushes.
  3) low efficiency

→ used in early EV's, e-bikes, scooter etc.

2) Brushless DC motor :-

→ A BLDC motor is also commonly known as a brushless DC motor.
→ It is powered by a direct current (DC) voltage supply and does not have brushes or commutator.
→ The difference between brushless DC motors and conventional DC motors is that, in conventional DC motors, brushes are used ~~in~~ to transfer the power to the rotor as they turn in a fixed magnetic field, while brushless DC motors are commutated electronically, thereby eliminating the use of ~~vehicles~~ brushes.

* Features :- Electronic Commutation, No brushes.

* Characteristics :- i) High efficiency.

* Advantages :- 1) Lighter
2) Smaller
3) Better heat dissipation
4) More reliability

* Disadvantages :- High cost because of permanent magnet

* Application :- E-bikes, two wheelers ... etc.

3) Permanent Magnet Synchronous motor :-

→ These machines are one of the most advanced ones, capable of being operated at range of speeds without the need of any gear system.
→ These features make these motors more efficient & compact.
→ This configuration is also very suitable for in wheel application, as it is capable of providing high torque, even at very low speeds.
→ PMSM with an outer rotor are also possible to construct without the need of bearings for the rotor.
→ PMSM is the most used motor in the BEV's available currently at least 26 vehicle models use this motor technology.

* Features :- Uses permanent magnets in rotor.

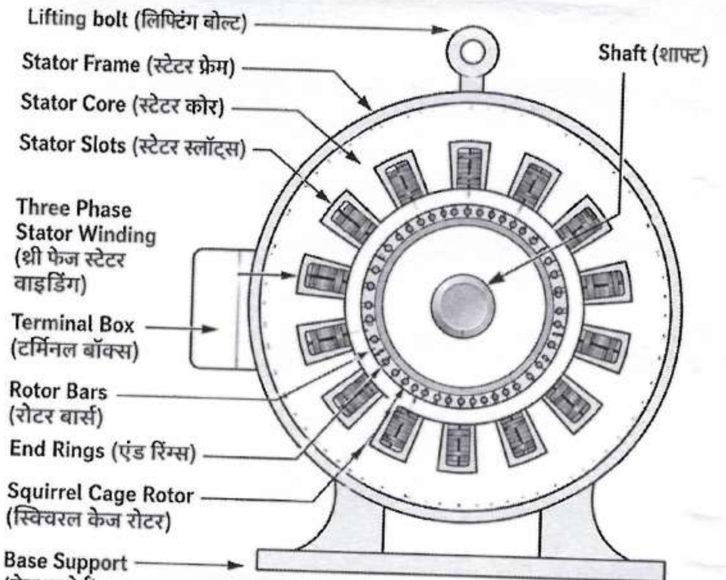
* Characteristics :- 1) Sinusoidal back emf.
2) Precise Control.

* Advantages :- 1) High efficiency
2) High power Density
3) Silent operation.
4) High torque even at low speed.

* Disadvantages :- 1) High cost.
2) Demagnetisation Risk.
3) VFD is required.

* Applications :- 1) EV's, Hybrid electric vehicles etc.
2) Industrial Automation & Robotics.
3) HVAC System - pumps, fans, compressors.
4) Home Appliances - washing machines, Refrigerators.

4) Induction Motor :- (IM) :=> Construction of Induction motor is as shown in fig.



Sectional View (सेक्शनल व्यू)

Fig. 2.4 - Induction Motor.

Following are components of induction motor :-

1) Stator :- The stationary part of the motor that produces a rotating magnetic field using laminated silicon steel & copper windings.

2) Rotor :- It is a rotating part of an induction motor. It consists of a core with embedded conductive bars. Typically made up of

Aluminium or copper. These bars are short circuited at both ends by end rings, forming a squirrel cage motor. The rotor has no direct electrical connections to the power supply.

→ Induction motors are used in early EV's like the GM EV1 as well as current models like the teslas.

→ Flux weakening can extend the speed range over the base speed while keeping the power constant.

→ Field orientation control can achieve a range three to five times the base speed with an IM that is properly designed.

→ Three phase, 4 pole AC motors with copper rotors are seen to be employed in current EV's.

* Features :- No permanent magnets, rotor with induced current.

* Characteristics :- Robust and cost effective.

* Advantages :- 1) Robust
  2) No magnets.
  3) maintenance free.

* Disadvantages :- 1) Lower efficiency
  2) Requires more cooling.

* Used in EV models :- 1) Tesla model S
  2) Mahindra E-20

5) Synchronous Reluctance motor :- (SynRM) :→ A Synchronous reluctance motor is type of AC Synchronous motor that produces torque due to the reluctance principle i.e. the rotor naturally aligns itself along the path of minimum magnetic resistance.

→ From EV's perspective, Syn RM is becoming increasingly attractive because it offers :- 1) High efficiency
  2) Low manufacturing cost.
  3) No dependence on expensive rare-earth magnets.
  4) Simple and rugged rotor construction.

→ The synchronous reluctance motor runs at synchronous speed while combining the advantages of ~~of~~ both pm and induction motors.

→ They are robust and fault tolerant like an IM, efficient and small like a pm motor.

→ The synchronous motor cannot be connected directly to the battery. It always requires inverter.

→ The inverter controls :- voltage, frequency, speed, torque.

→ The problems with synRM can be pointed as the ones associated with controllability, manufacturing and low power factor which abstract it's use in EV's.

→ Improved design techniques, control systems and advanced ~~fa~~ manufacturing can help it make it's way into EV applicat^n^'s.

* Features :- 1) No permanent magnets.
  2) No Rotor Copper loss.

* Characteristics :- 1) simple & cheap.
  2) High speed.
  3) No rare earths.

* Limitations :- 1) low power density.
  2) complex Control.
  3) Poor self starting.
  4) Low torque density.

* Advantages :- 1) High efficiency
  2) low manufacturing Cost.
  3) Light weight rotor.
  4) low maintenance.
  5) Reliable operation.

* Applications :- 1) Passenger Electric Cars.
  2) Electric buses.
  3) Commercial EV's
  4) Hybrid Electric Vehicles.
  5) Electric Buses.

6) PM Assisted Synchronous Reluctance motor :-

→ PM Assisted Synchronous Reluctance motor is an advanced synchronous motor that combines the operating principles of a Synchronous Reluctance motor & PMSM motor.

→ Greater power factor can be achieved from syn PM's by integrating some PMs in the rotors.

→ Creating a PM Assisted Synchronous reluctance motor.

→ PM's added in the right amount to the core of the rotor increase the efficiency with negligible back emf & little change to the stator.

→ This concept is free from the problems associated with demagnetisation resulting from the problems associated with demagnetisation resulting from overloading and high temperature observed in IPM's.

→ With a proper efficiency optimization techniques, this motor can have the performance similar to IPM motor.

* Features :- 1) operates at synchronous speed.
  2) compact and lightweight design.

* Characteristics :- 1) High efficiency
  2) Higher torque density than SynRM.
  3) Excellent thermal performance.
  4) Low maintenance.

* Advantages :- 1) High efficiency than SynRM.
  2) Improved Power factor.
  3) Excellent dynamic response.
  4) High Reliability & Long service life.
  5) Suitable for both city & highway driving in EV's.

* Limitations :- 1) More expensive than SynRM due to permanent magnets.

* Applications :- 1) In electric passenger Cars.
  2) Hybrid Electric vehicles.
  3) Electric buses.
  4) High efficiency electric Drives.

7) Axial Flux Ironless Permanent Magnet Motors :-

→ This motor is a high performance PMSM in which the magnetic flux flows parallel to the motor shaft instead of radially, as in conventional motors.

→ This motor is most advanced one to be used in EV's.

→ It has an outer rotor with no slots, use of iron is avoided here as well.

→ The stator core is absent too, reducing the weight of machine.

→ The stator is coreless and when supplied with 3φ AC current from the inverter, the stator generates a rotating magnetic field.

→ The rotor magnets interact with the stators rotating magnetic field to produce torque.

→ In Conventional motor magnetic flux travels radially (from center → outward). But in axial flux motor magnetic flux travels parallel to the shaft (axially).

→ The slotless design also improves the efficiency by minimizing copper loss as there is space available.

* Features :-
1) Compact design.
2) Coreless Stator.
3) High torque density
4) very high efficiency.
5) Low weight.

* Characteristics :-
1) Very high torque - to - weight ratio.
2) smooth operation due to the absence of cogging torque.
3) Excellent regenerative performance.
4) Compact size for given output.

* Advantages :-
1) High efficiency.
2) Compact design.
3) Better Cooling.
4) Low noise & vibrations.
5) Rapid acceleration and deacceleration.

* Applications :- 1) High performance electric cars.
2) Electric sport cars.
3) Racing EV's.
4) High Performance hybrid vehicles.

2.3 - Comparison of EV motors based on power-weight ratio, torque-speed characteristics, cost of controller required and cost of motors.

Motor Type	Power Density	Torque-Speed (Range & Smoothness)	Controller Cost	Motor Cost
PMSM	Excellent	Excellent	High	High
Induction Motor	Good	Good	Moderate	Low
SynRM	High	Good (Wide Range, potential ripple)	High	Low
PMaSynRM	Excellent	Very Good (Wide Range, smooth)	High	Moderate
Axial Flux Ironless PM	Exceptional	Exceptional (Smooth, direct drive)	Very High	Very High

2.4.1 Physical location of motor in EV :->

EV motors can be installed at different physical locations based on vehicle design and applications :-

1) Central Drive :- The motor is mounted centrally, usually between the axles, similar to the position of an internal combustion engine. It drives the front, rear, or all four wheels through a conventional differential & half-shafts, often using a single-speed reduction gearbox.

-> Examples - 1) Tesla Model 3
2) kia EV6
3) Volkswagen ID.4

-> Advantages :- 1) Excellent weight distribution.

2) Improve ride quality & vehicle handling.

3) Easier motor cooling.

4) Better protection of the motor from road impacts.

* Disadvantages :- 1) Minor energy losses in the transmission system.

  2) Increases mechanical complexity.

2) In-Wheel Motors :- The motor is integrated directly into the wheels hub, allowing it to drive the wheel without intermediate drivetrain components. Each wheel has it's own dedicated motor.

→ Examples :- 1) Concept Electric Vehicles.
2) Some e-bikes.
3) Low speed electric vehicles.

→ Advantages :- 1) Increases available interior space.
2) provides compact packaging for specific vehicle design.

→ Disadvantages :- 1) Requires complex wiring & cooling arrangement.
2) more damage from road trash.

3) Axle-mounted Motor (Near-Wheel) :- The motor, reduction gear box, and differential are integrated into a compact unit known as an e-Axle or e-drive, which replaces the conventional axle assembly. This unit drives the wheels on a specific axle.

→ Examples :- 1) Hyundai Kona EV
2) BMW I3

→ Advantages :- 1) Highly integrated & compact design.
2) Improved packaging efficiency.
3) Supports all wheel drive configurations.

→ Disadvantages :- 1) More expensive due to high level of integration.
2) Requires efficient thermal management.
(motor, gearbox and power electronics are packaged together)

2.4.2 - Rating of motors

motor rating define the capability & performance chs of the motor :-

1) Power rating :- 30 kw - 300 kw (depends on car segment)
2) Voltage :- 200 V - 650 V (higher voltage = better efficiency)
3) Current :- 100 A - 1000 A
4) Torque :- 100 NM - 600 NM
5) Speed :- upto 16000 rpm.
6) Duty cycle :- Continuous or intermittent (based on use)
7) Efficiency :- 85% to 90%.

2.4.3 connections in EV motors :-

connections in EV motors are :-

1) Mechanical Connections
2) Electrical Connections.

1) Mechanical Connections :-

1) Direct Drive :- motor shaft is directly connected to the driven component. No gearbox is used ~~in~~ between the motor and load.
   - → simple mechanical design with fewer moving parts.
   - → No power losses due to gears or gearbox.

~~2) Single speed~~

2) mounting :- Requires vibration, isolation and alignment.
3) Cooling system integration :- Air or liquid cooling units connected.

2) Electrical Connections :-

1) Power supply :- from battery through inverter / controller.
2) Signal wires :- For feedback (speed, position sensors like encoders, Hall sensors)
3) Grounding & shielding :- To minimize EMI (electromagnetic interference).

key components :-

1) Inverter :- Converts DC to AC for AC motors.
2) motor Controllers :- Regulates speed, torque and direction.
3) Wiring Harness :- Connects battery, controller and motor safety.

2.4.4 :- ~~Sel~~ Selection Criteria of various types of EV motors :-

1) Size and weight :- Heavier vehicle requires higher torque for acceleration and greater power to achieve high speeds. Therefore more powerful motors are needed for larger & heavier electric vehicles.

2) Vehicle configuration :- Such as BEV, series/parallel hybrid determines the motors required power and torque characteristics

3) Driving cycle :- A) Urban driving.
-> Requires high torque at low speed
-> Regenerative capability is highly beneficial for improving energy efficiency.

B) Highway Driving :- 1) Requires efficient operation at high speed.
2) Continuous power capability becomes more important than peak torque.

4) Maximum Speed :- Motor must be capable of achieving the vehicles desired top speed while maintaining stable & efficient operation.

5) efficiency :- A highly efficient motor reduces energy losses, and improves overall vehicle performance.

6) Battery System Compatibility :- motor should be compatible with the battery capacity to achieve the required driving range.

7) Thermal Management :- Electric motors generate heat during continuous operation, high power output and regenerative braking. An effective cooling system cooling system is essential to maintain performance & reliability.

8) Noise & Vibrations :- low noise level and vibration levels improve

passenger comfort and are especially important in urban environment.

9) Overall cost :- A overall system cost is desirable without compromising performance.

10) Environmental factors :- The motor should be protected against water, dust, mud, moisture and other environmental contaminants. proper sealing & protection ensure durability & reliability operation.

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