ELECTRIC VEHICLES MACHINES AND DRIVES - part 1

University of East Sarajevo
Faculty of Electrical Engineering
Bosnia and Herzegovina

LEARNING OUTCOMES

By mastering this subject, the students will be able to:

- Demonstrate understanding of the function of basic design parameters and their impact on the electric motors for electric vehicles (EV).
- Demonstrate knowledge of trends in research and development in electric motors for EV / Hybrid electric vehicles (HEV).
- Assimilate research results in the field of electrical motors and its application in EV/HEV.

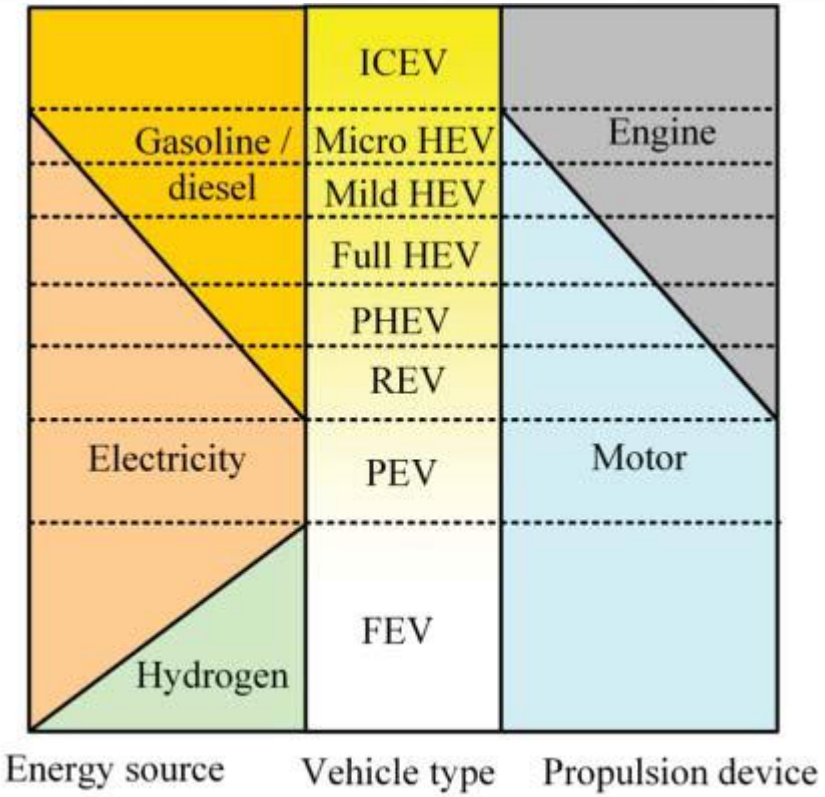
SUBJECT CONTENT

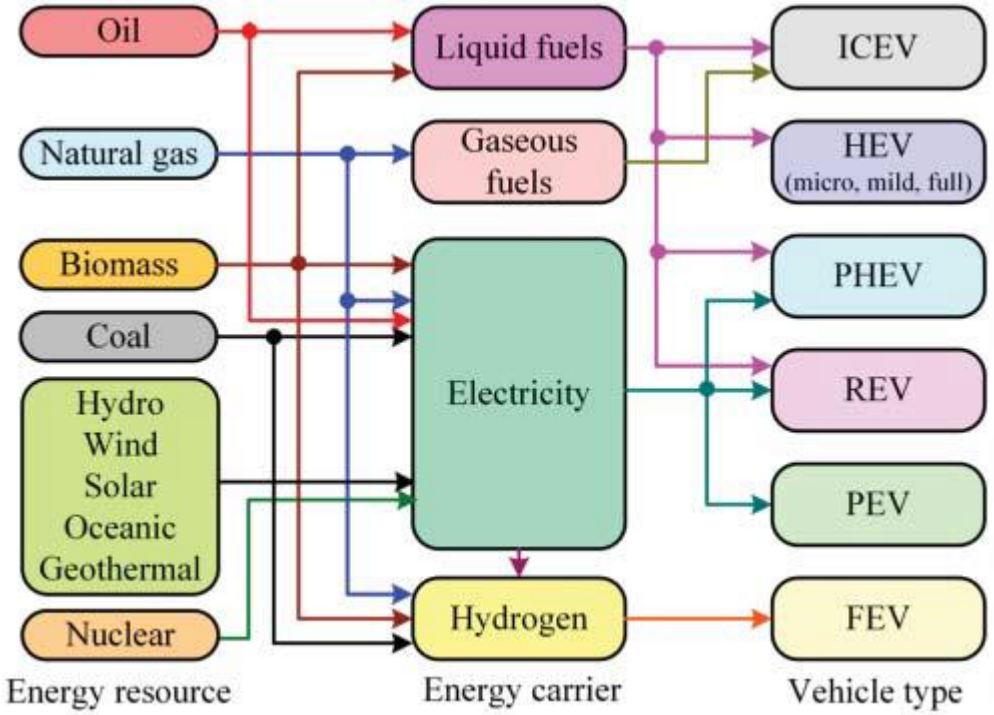
1. Introduction of EV. Classification, challenges, overview of various developed technologies
2. DC motor drives for EVs
3. Induction motor drives for EVs
4. Permanent magnet brushless motor drives for EVs
5. Switched reluctance motor drives for EVs
6. Advanced motor drives for EV
7. Stator-Permanent Magnet Motor Drives
8. Magnetic-Geared Motor Drives
9. Vernier Permanent Magnet Motor Drives
10. Structure of Hybrid EVs
11. Advanced Magnetless Motor Drives
12. Integrated-Starter-Generator Systems
13. Planetary-Geared Electric Variable Transmission Systems
14. Double-Rotor Electric Variable Transmission Systems
15. Magnetic-Geared Electric Variable Transmission Systems

1. INTRODUCTION OF EV. CLASSIFICATION, CHALLENGES, OVERVIEW OF VARIOUS DEVELOPED TECHNOLOGIES

- EVs are classified as the PEV (pure electric vehicle), HEV (hybrid electric vehicle), and FEV (fuel-cell electric vehicle) types based on their energy sources and the propulsion devices.
- In essence, the PEV is purely fed from electricity, while the propulsion is solely driven by the electric motor; the HEV is sourced from both electricity and gasoline/diesel, while the propulsion involves both the electric motor and engine; and the FEV is directly or indirectly sourced from hydrogen, while the propulsion is solely driven by the electric motor.
- In order to distinguish the refueling means, the HEV can be further categorized into the conventional HEV and the gridable HEV. The conventional one is solely refueled with gasoline/diesel in filling stations, whereas the gridable one can be recharged by electricity via charging ports. Based on the coordination between the electric motor and engine, the gridable HEV can be further split into the plug-in hybrid electric vehicle (PHEV) and range-extended electric vehicle (REV).

1. INTRODUCTION OF EV. CLASSIFICATION, CHALLENGES, OVERVIEW OF VARIOUS DEVELOPED TECHNOLOGIES



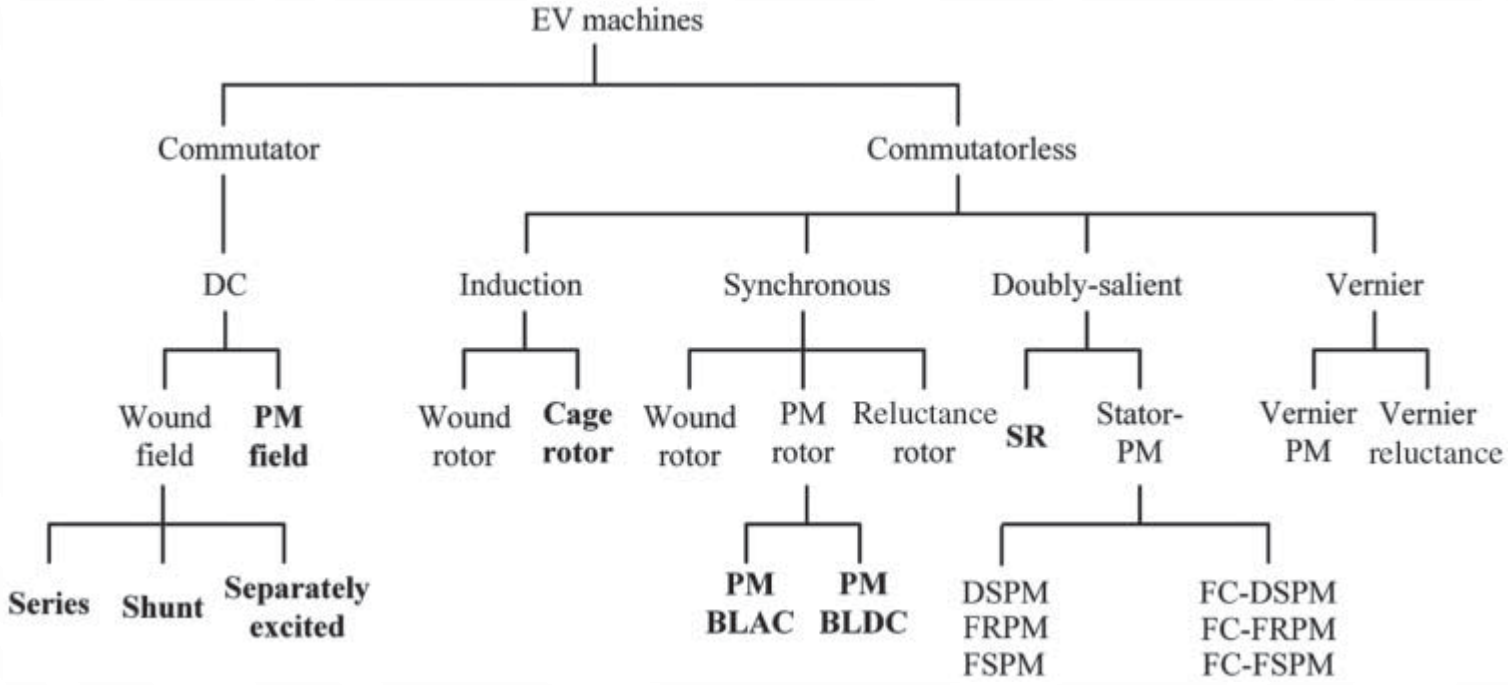


1. INTRODUCTION OF EV. CLASSIFICATION, CHALLENGES, OVERVIEW OF VARIOUS DEVELOPED TECHNOLOGIES

- As an overview of key technologies for various types of EVs, the motor drive technology is most actively developed in recent years where there are many innovations and advancements in the design, analysis, and control of motor drives.
- Motor drives are the core technology for EVs that convert the on-board electrical energy to the desired mechanical motion. The main requirements of electric machines for EVs are:
    - High torque density and high power density
    - Wide speed range, covering low-speed creeping and high-speed cruising
    - High efficiency over wide torque and speed ranges
    - Wide constant-power operating capability
    - High torque capability for electric launch and hill climbing
    - High intermittent overload capability for overtaking
    - High reliability and robustness for vehicular environment
    - Low acoustic noise
    - Reasonable cost

1. INTRODUCTION OF EV. CLASSIFICATION, CHALLENGES, OVERVIEW OF VARIOUS DEVELOPED TECHNOLOGIES

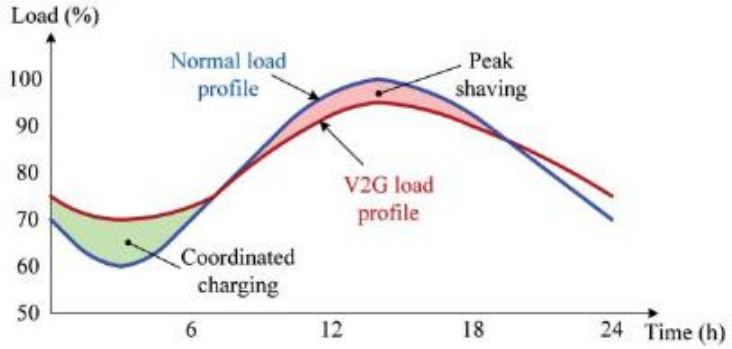
Classification of EV machines

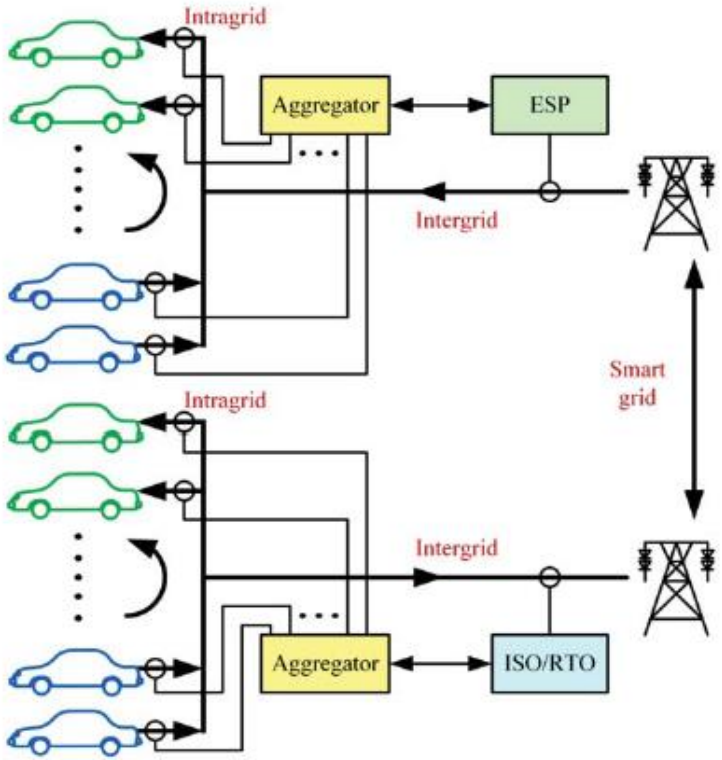


1. INTRODUCTION OF EV. CLASSIFICATION, CHALLENGES, OVERVIEW OF VARIOUS DEVELOPED TECHNOLOGIES

Major batteries developed for EVs

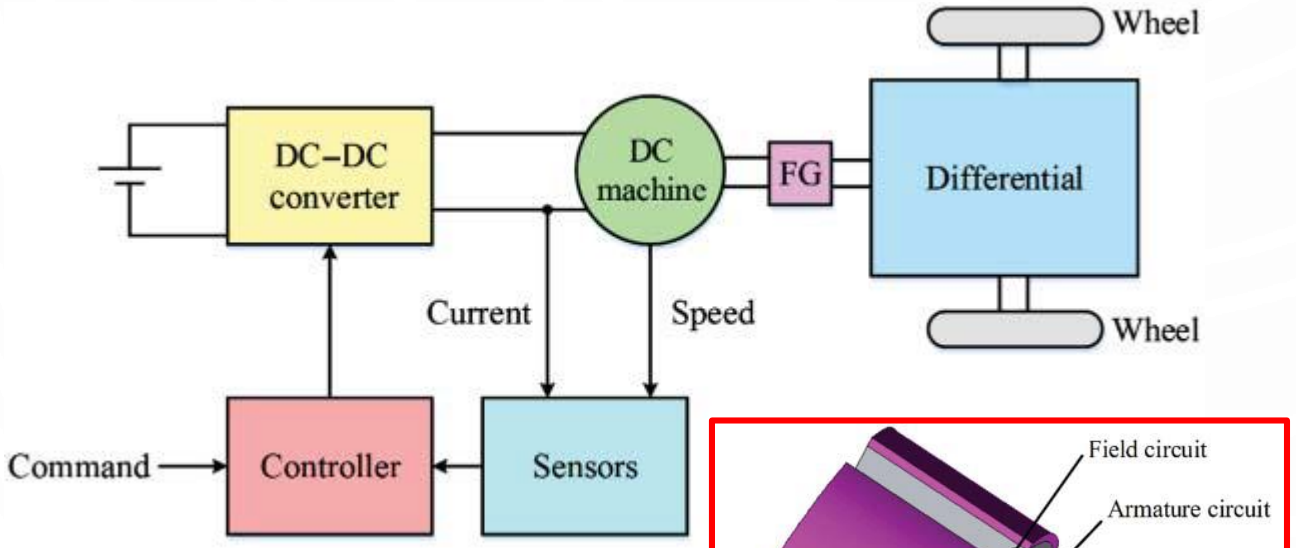
	Specific energy (Wh/kg)	Specific power (W/kg)	Cycle life (cycles)	Cost (USD/kWh)
VRLA	30–45	200–300	400–600	150
Ni-Cd	40–60	150–350	600–1200	300
Ni-MH	60–120	150–400	600–1200	200–350
Zn/air	230	105	NA	90–120
Na/S	100	200	800	250–450
Li-ion	90–160	250–450	1200–2000	600–1000

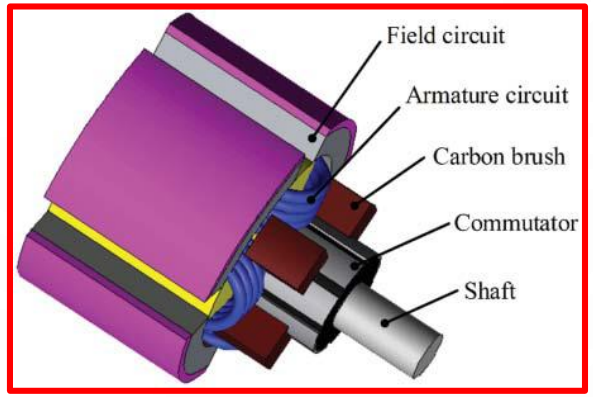


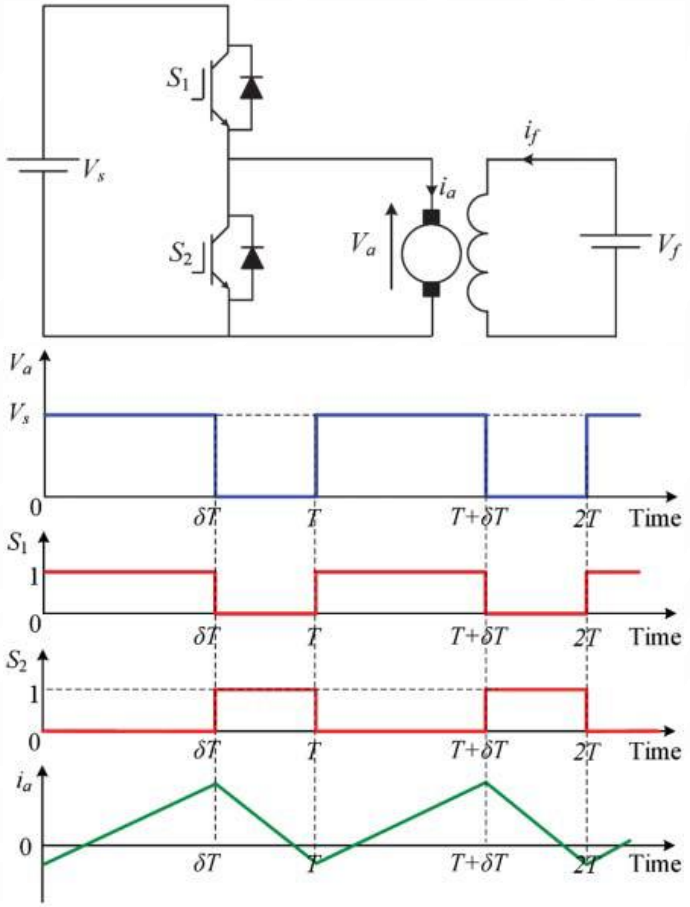


2. DC MOTOR DRIVES FOR EVS

- Basic configuration of DC motor drives







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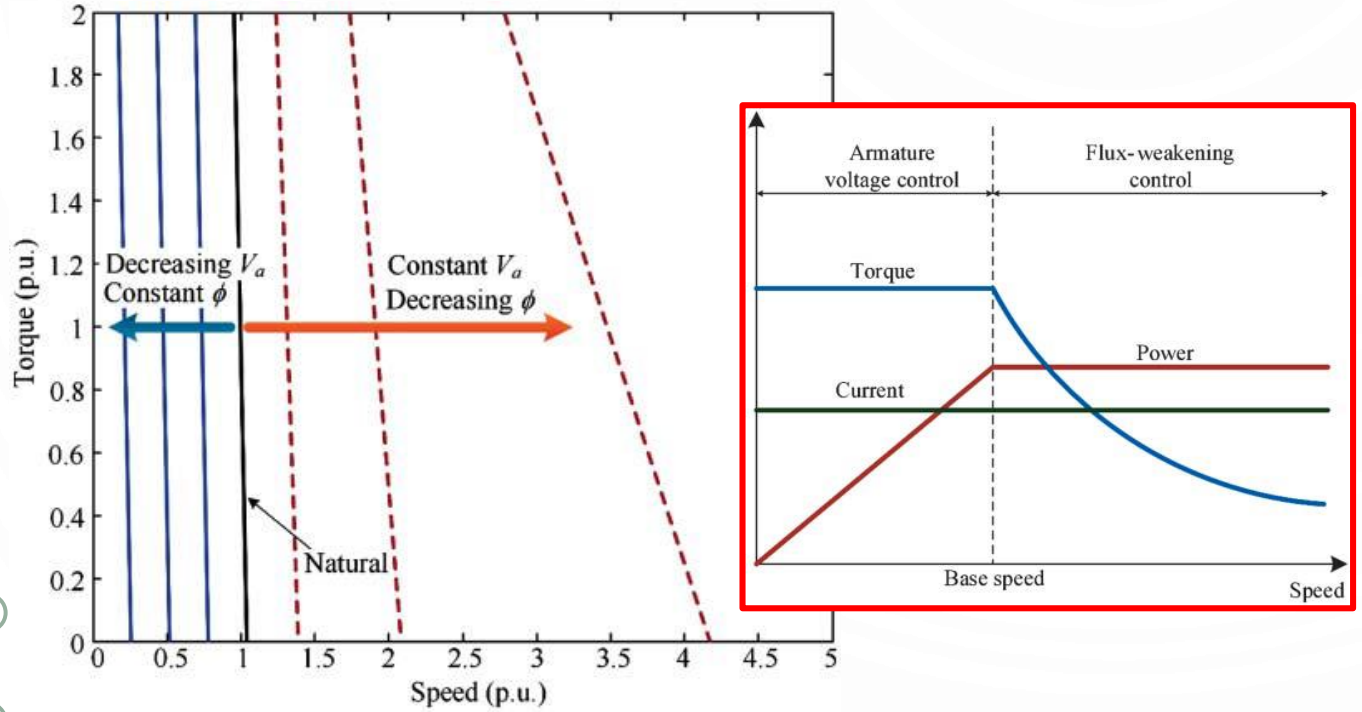
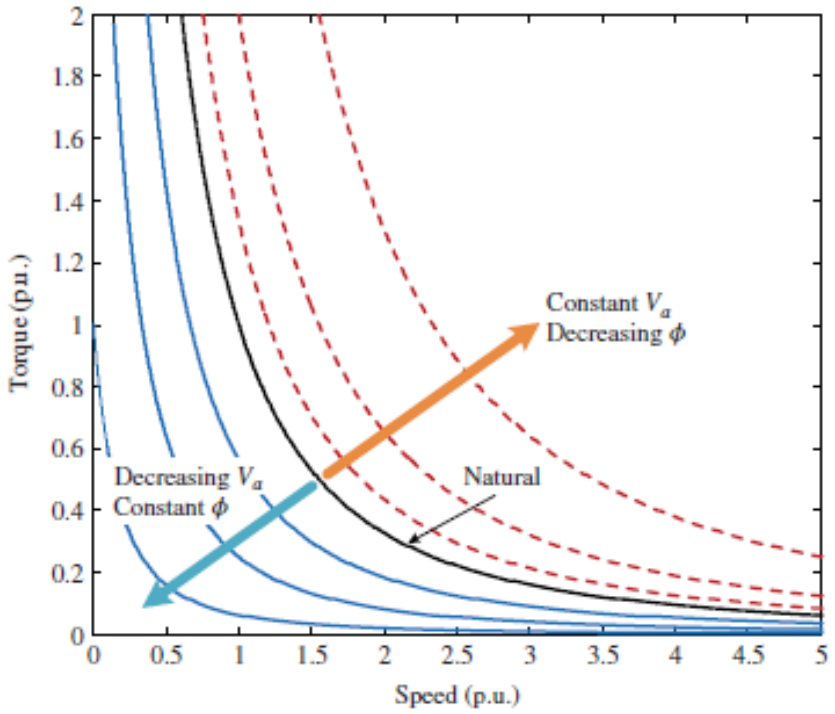


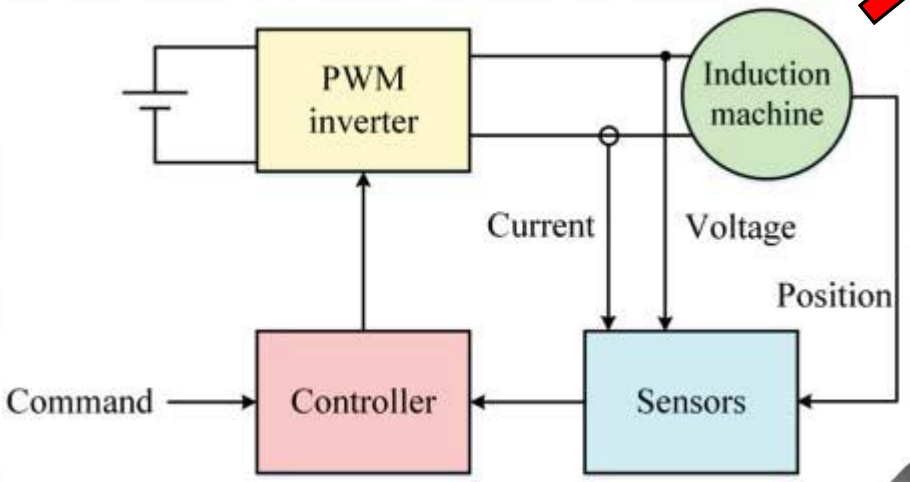
Characteristics of separately excited DC motor control

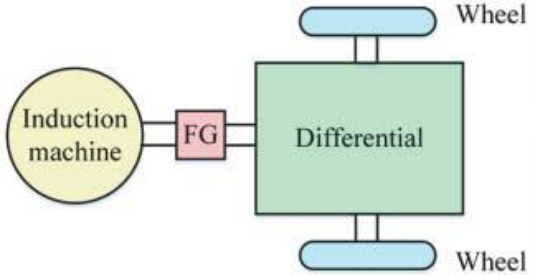


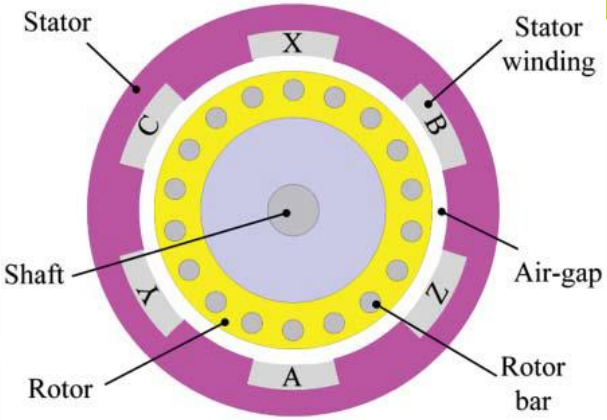
Characteristics of series DC motor control

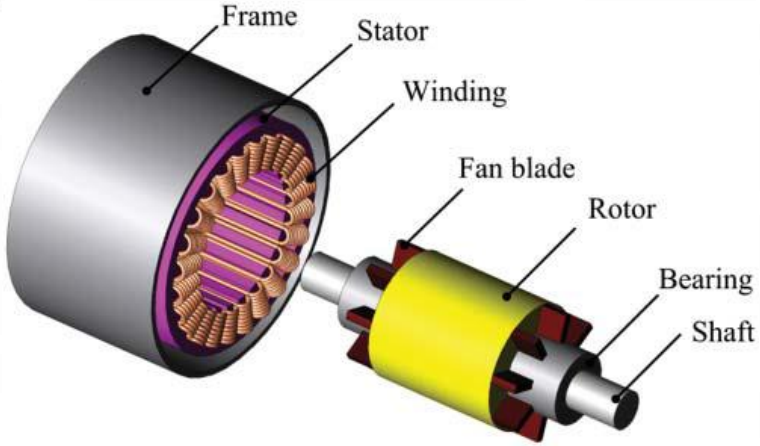
3. INDUCTION MOTOR DRIVES FOR EVS

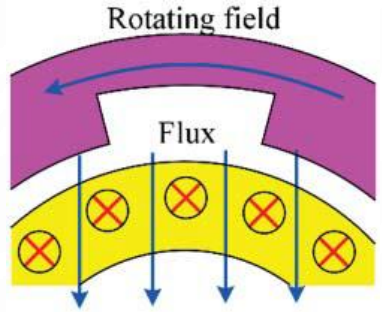
- Basic configuration of induction motor drive

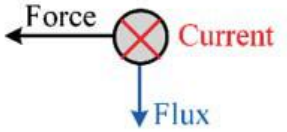






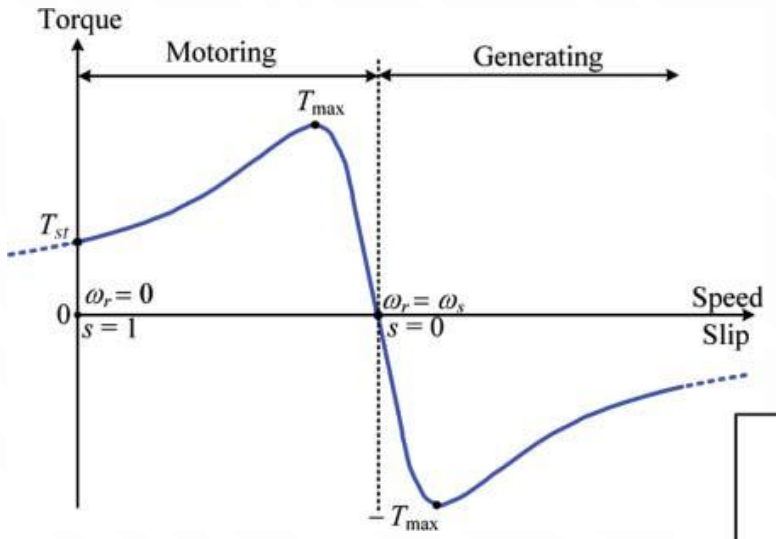


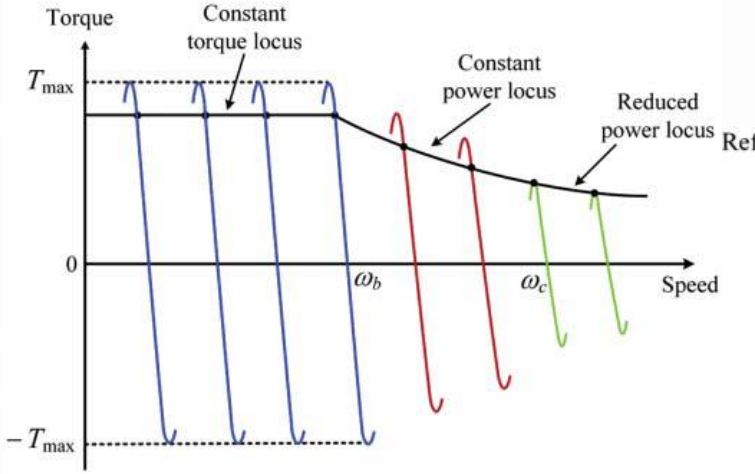


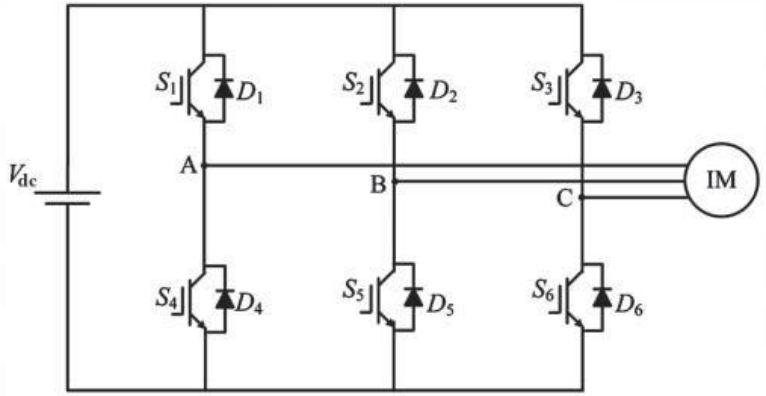


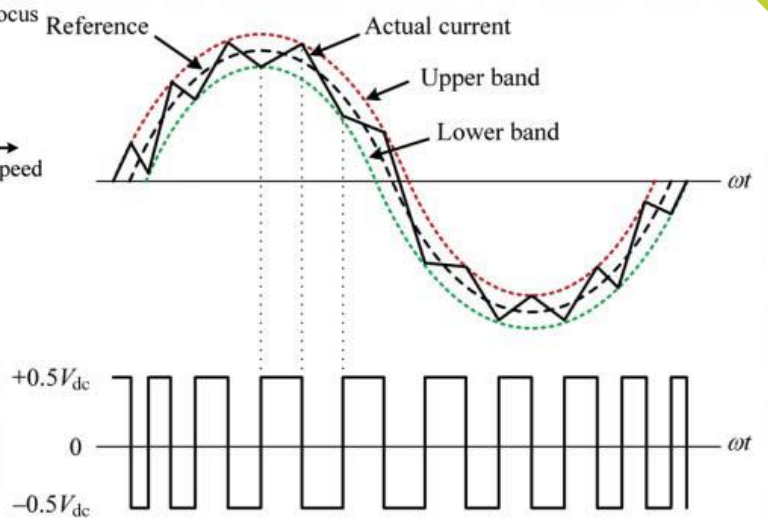
3. INDUCTION MOTOR DRIVES FOR EVS

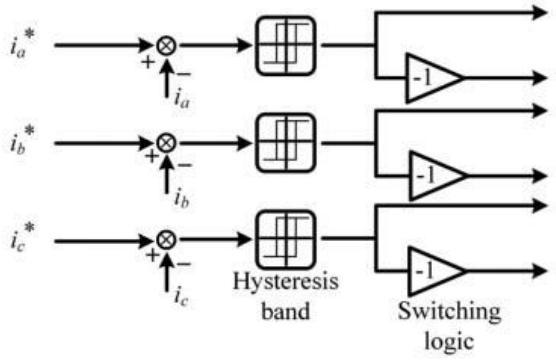
- Torque-speed characteristic of induction machine





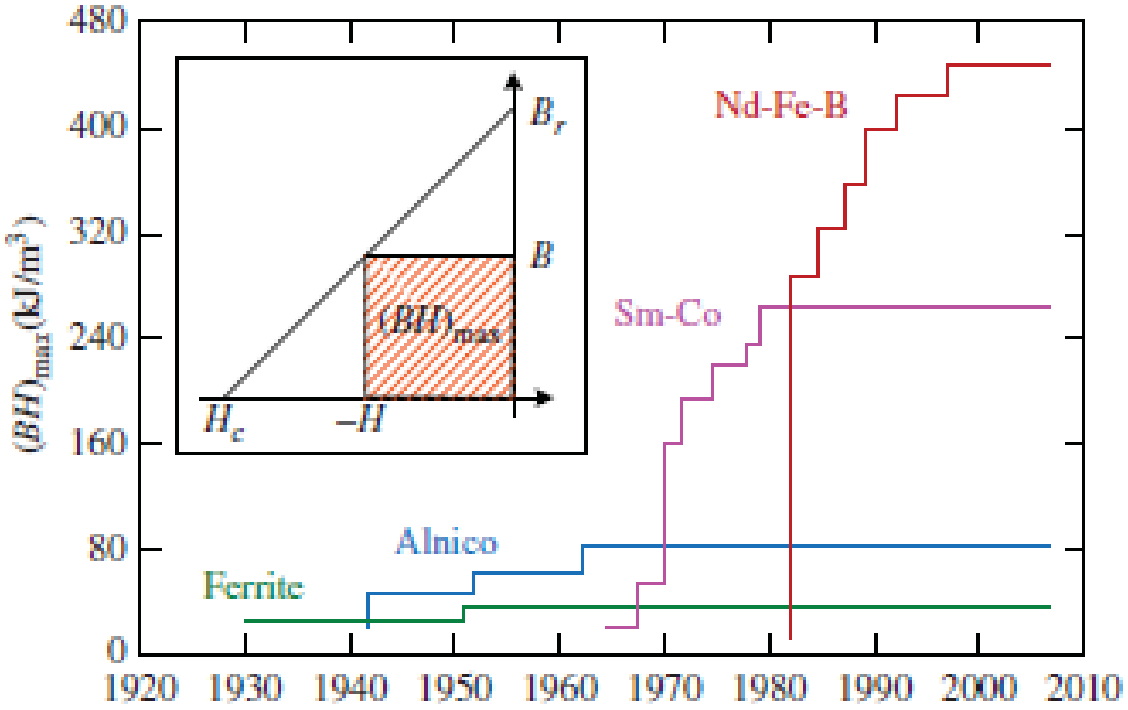


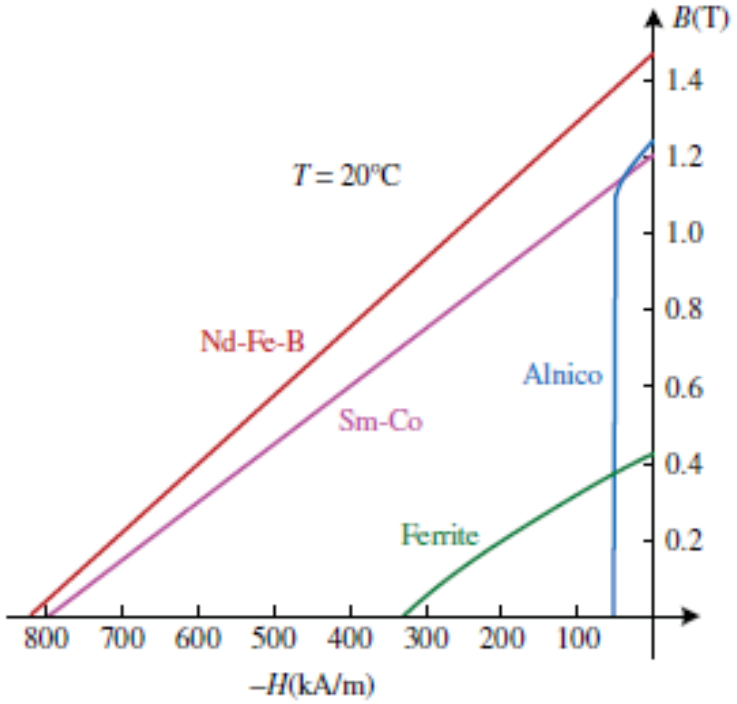




4. PERMANENT MAGNET BRUSHLESS MOTOR DRIVES FOR EVS

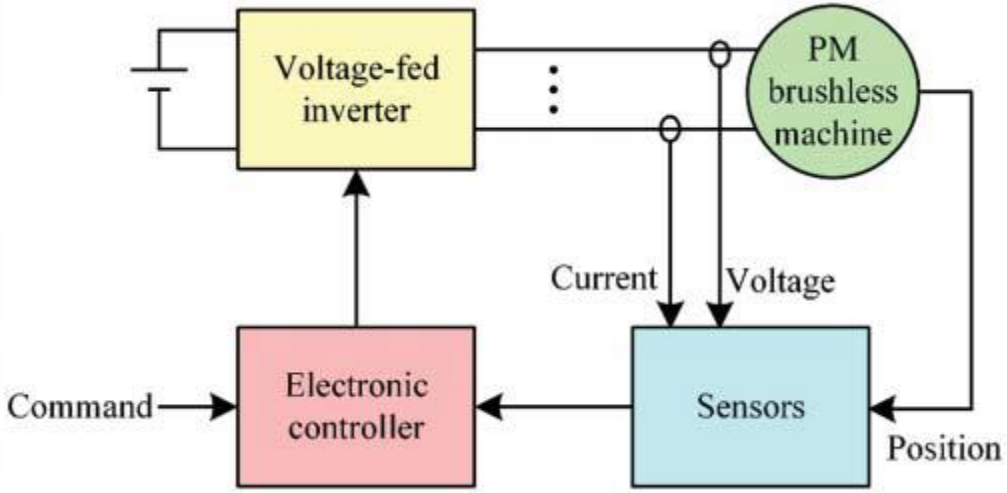
- Development of PM materials and demagnetization curves of PM materials



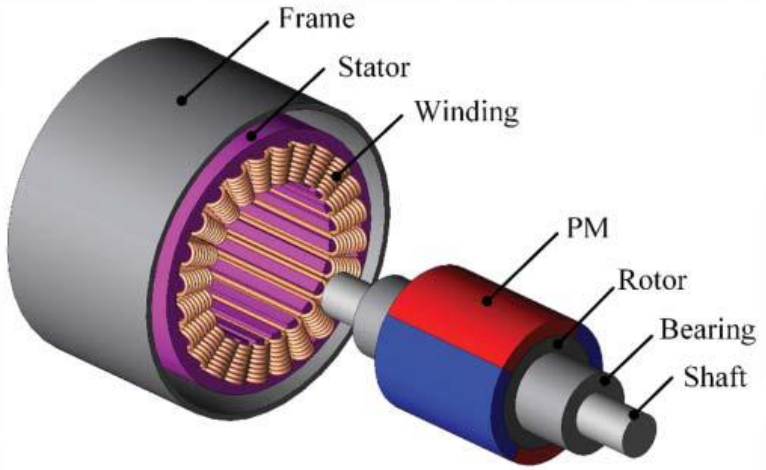


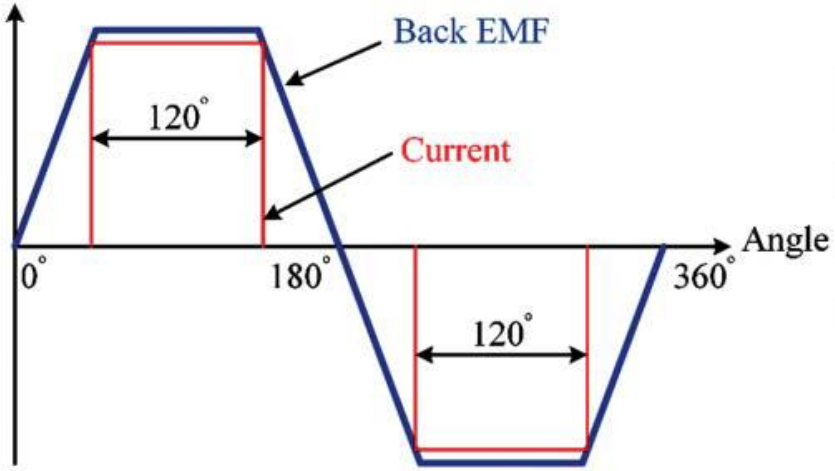
4. PERMANENT MAGNET BRUSHLESS MOTOR DRIVES FOR EVS

- Basic configuration of PM brushless motor drive



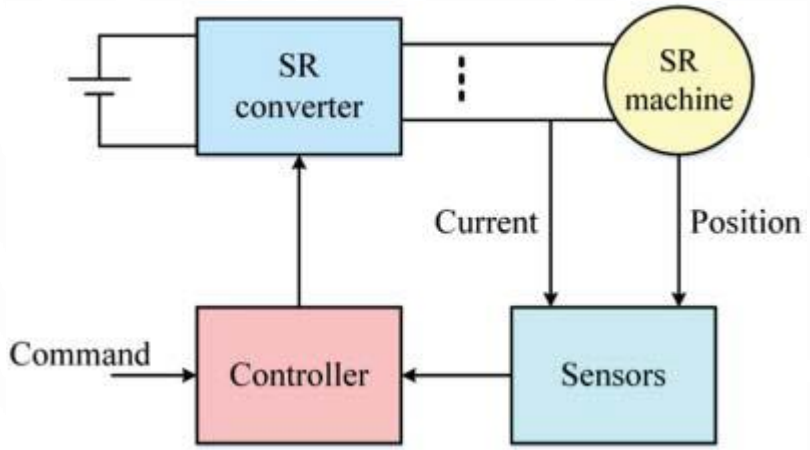
Nissan Leaf

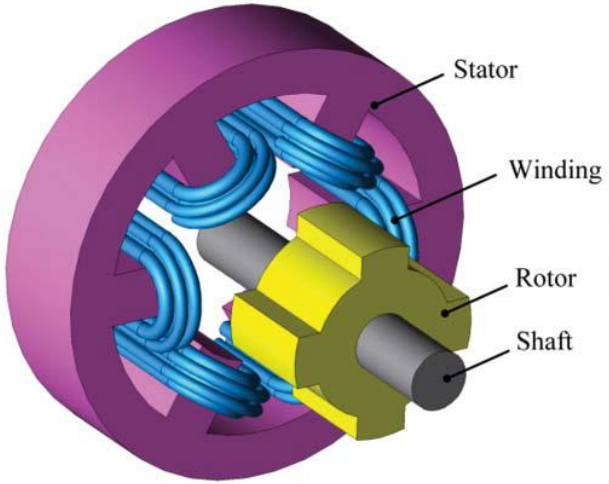


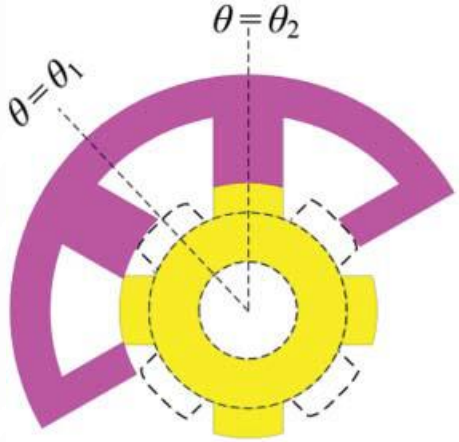


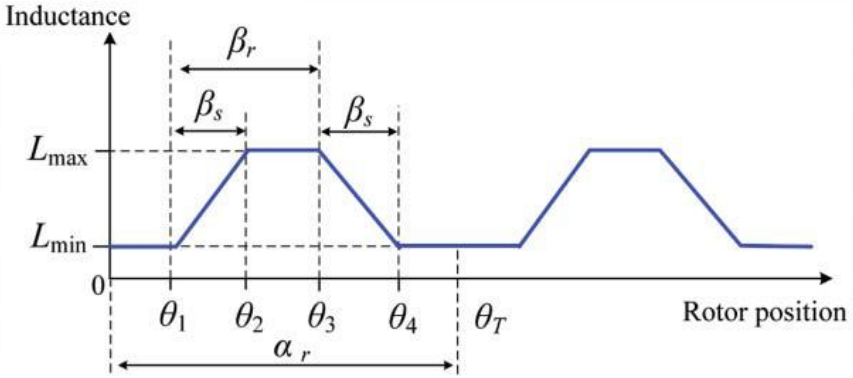
5. SWITCHED RELUCTANCE MOTOR DRIVES FOR EVS

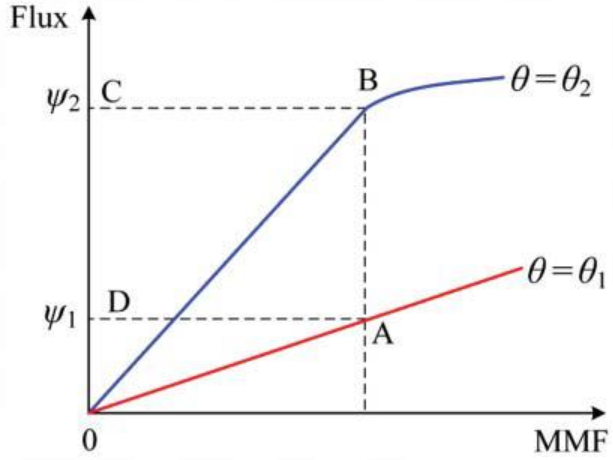
- Basic configuration of SR motor drive





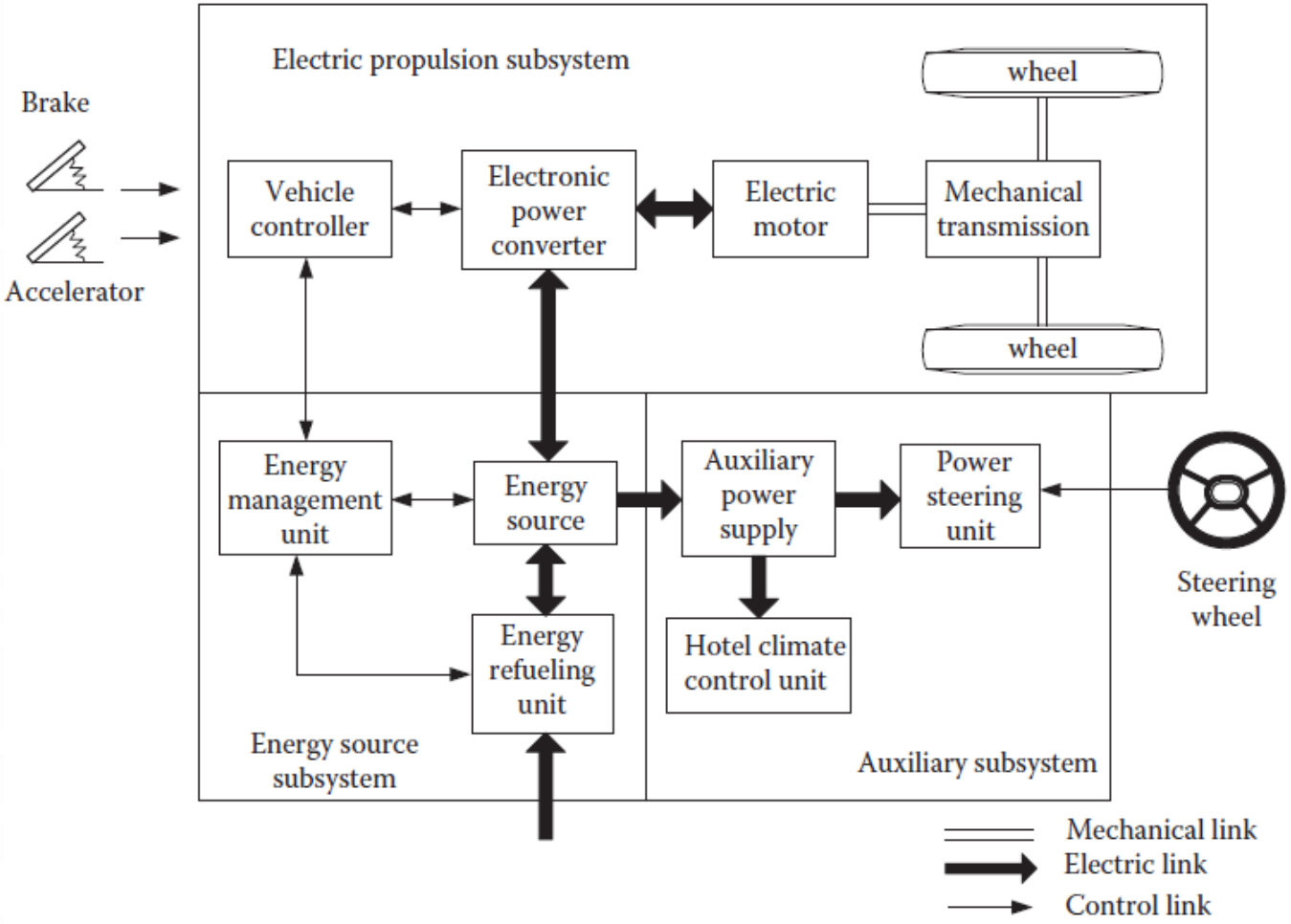






6. ADVANCED MOTOR DRIVES FOR EV

- Advanced reluctance motors, including Switched Reluctance Motors (SRMs) and Synchronous Reluctance Machines (SynRMs), are gaining traction in electric vehicles due to their robustness, cost-effectiveness, and rare-earth-free nature, offering a sustainable alternative to traditional permanent magnet motors. While SRMs present challenges like torque ripple and noise, advanced control strategies and design optimization are improving their viability.



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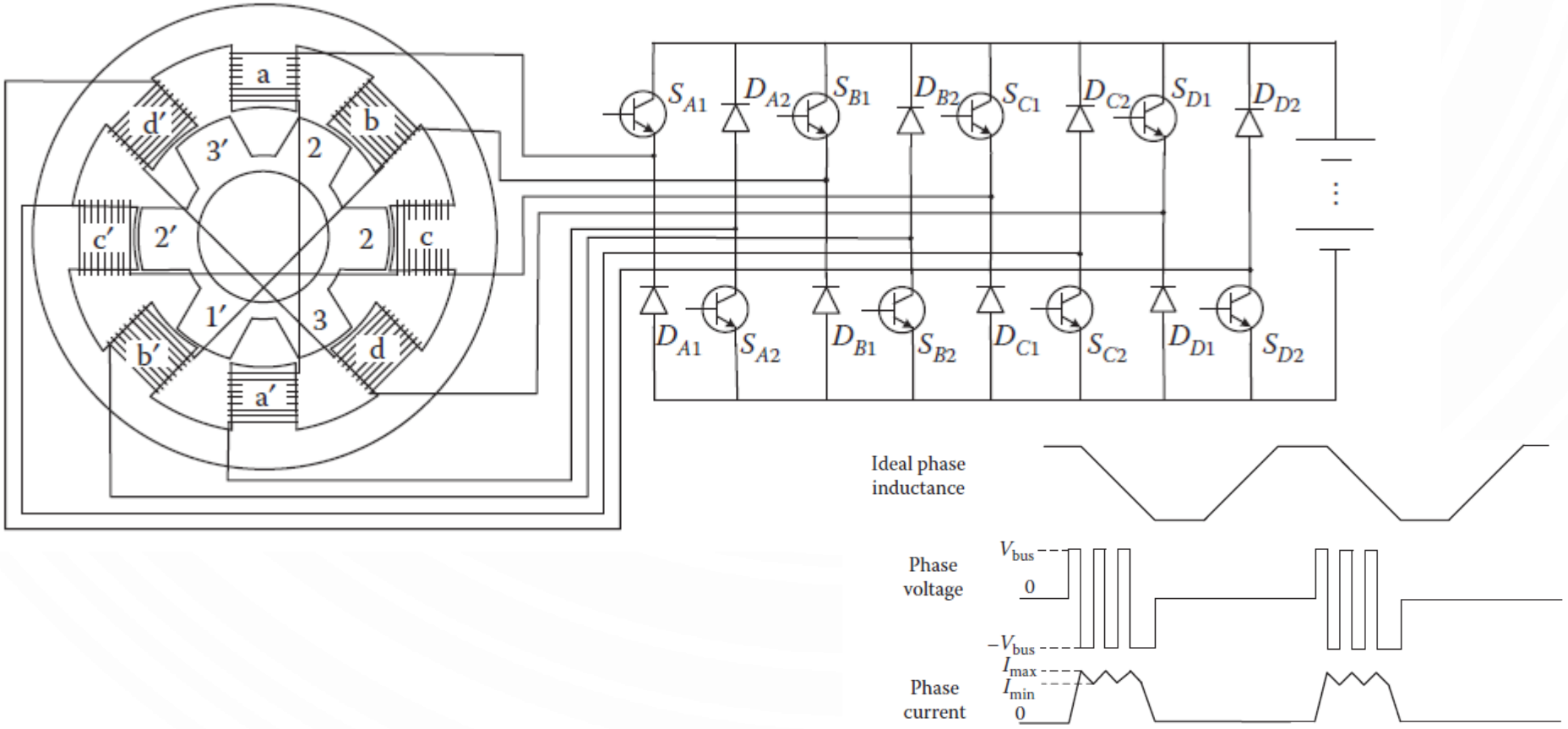
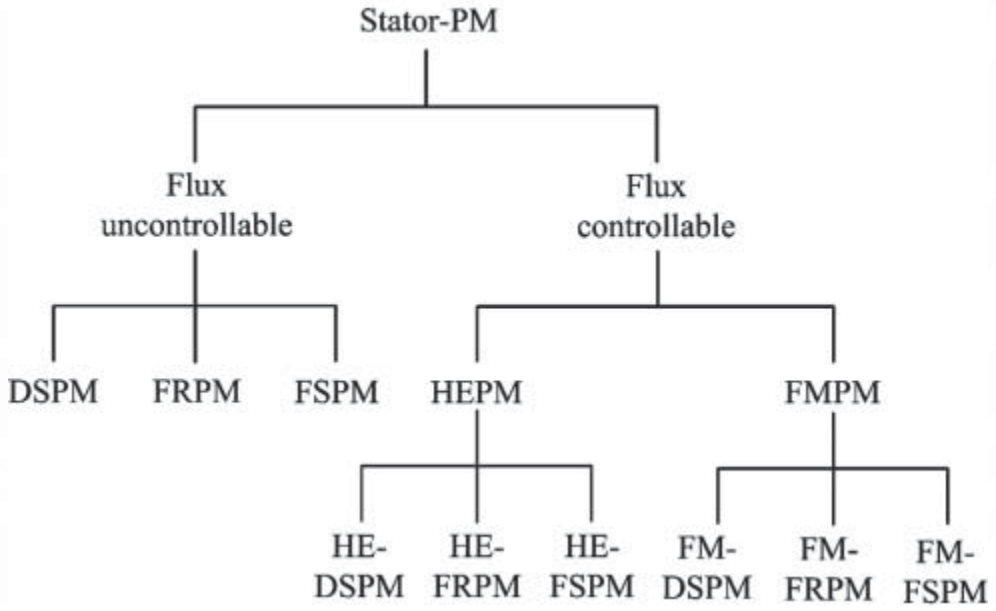


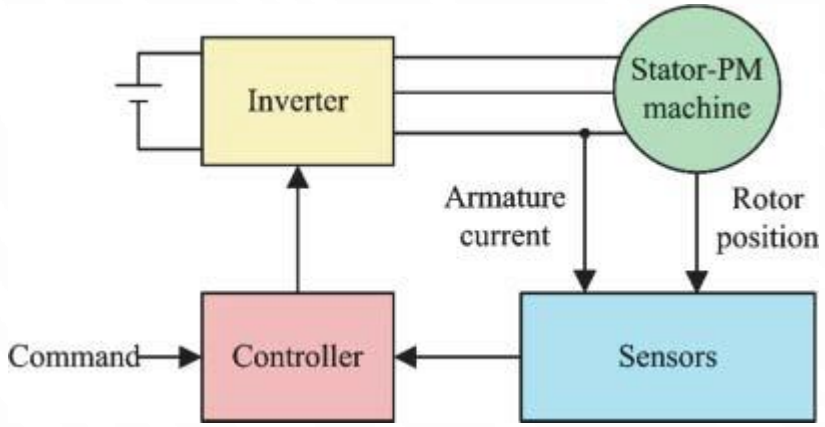
7. STATOR-PERMANENT MAGNET MOTOR DRIVES

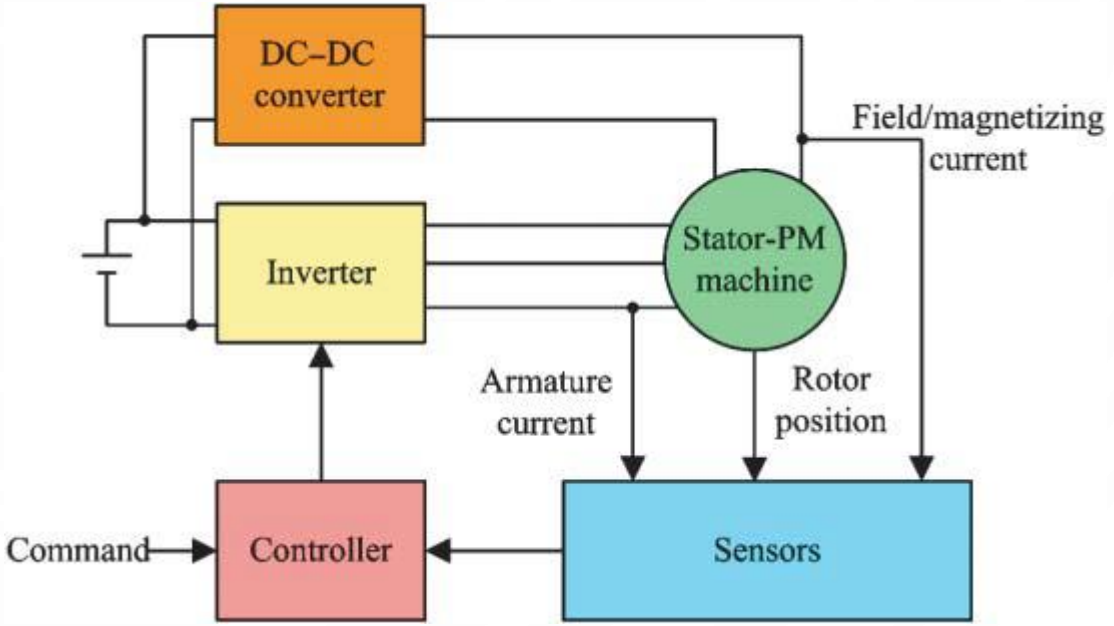
- Differing from traditional permanent magnet (PM) brushless motor drives, stator-PM motor drives takes the definite advantages that all PM materials are in the stator while the rotor is simply iron core with salient poles, leading to offer higher robustness for high-speed operation and better thermal stability for PM materials.
- Stator-PM motor drives:
  - DSPM - doubly-salient permanent magnet
  - FRPM - flux-reversal permanent magnet
  - FSPM - flux-switching permanent magnet
  - HEPM - hybrid-excited permanent magnet
  - FMPM - flux-mnemonic permanent magnet



7. STATOR-PERMANENT MAGNET MOTOR DRIVES

- Configuration of singly-fed and double-fed stator-PM motor drives





Reference: K. T. Chau „Electric Vehicle Machines And Drives. Design, Analysis and Application“

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