ELECTRIC VEHICLES MACHINES AND DRIVES - part 2

University of East Sarajevo
Faculty of Electrical Engineering
Bosnia and Herzegovina

LEARNING OUTCOMES

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

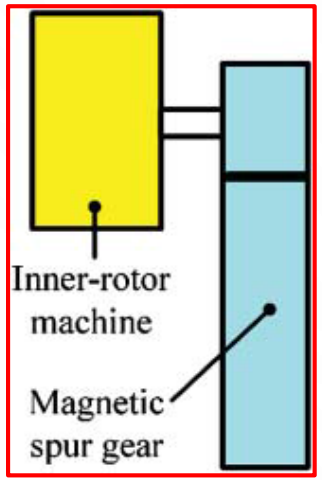
- Demonstrate understanding of the function of basic design parameters and their impact on the electric motors for electric vehicles (EV).
- Demonstrate knowledge of trends in research and development in electric motors for EV / Hybrid electric vehicles (HEV).
- Assimilate research results in the field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

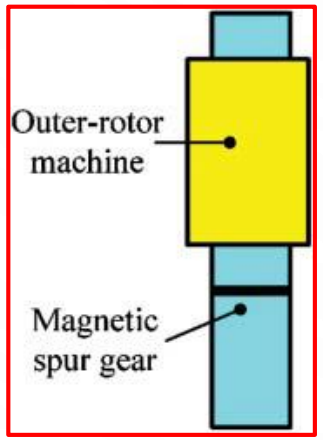
SUBJECT CONTENT

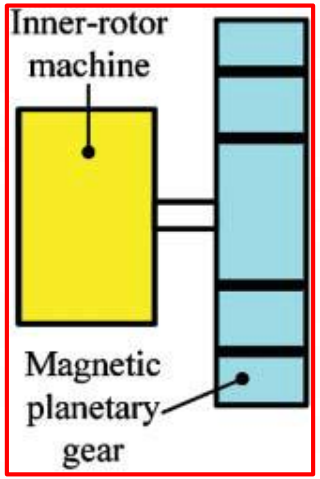
1. Introduction of EV. Classification, challenges, overview of various developed technologies
2. DC motor drives for EVs
3. Induction motor drives for EVs
4. Permanent magnet brushless motor drives for EVs
5. Switched reluctance motor drives for EVs
6. Advanced motor drives for EV
7. Stator-Permanent 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

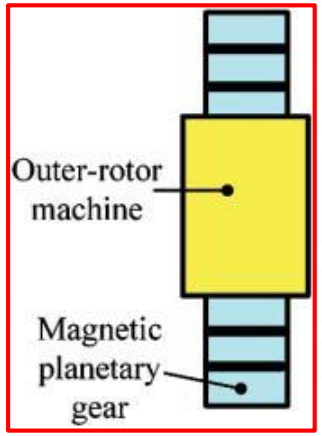
8. MAGNETIC-GEARED (MG) MOTOR DRIVES

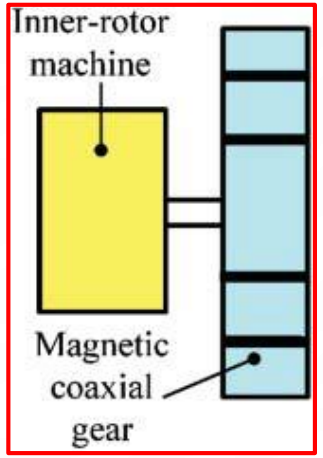
- The MG machine can be classified into the following six types:
  - Inner-rotor machine coupled with magnetic spur gear.
  - Outer-rotor machine coupled with magnetic spur gear.
  - Inner-rotor machine coupled with magnetic planetary gear.
  - Outer-rotor machine coupled with magnetic planetary gear.
  - Inner-rotor machine coupled with magnetic coaxial gear.
  - Outer-rotor machine coupled with magnetic coaxial gear.

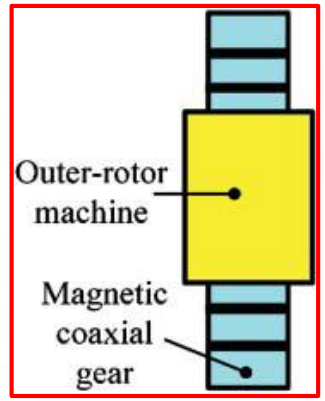






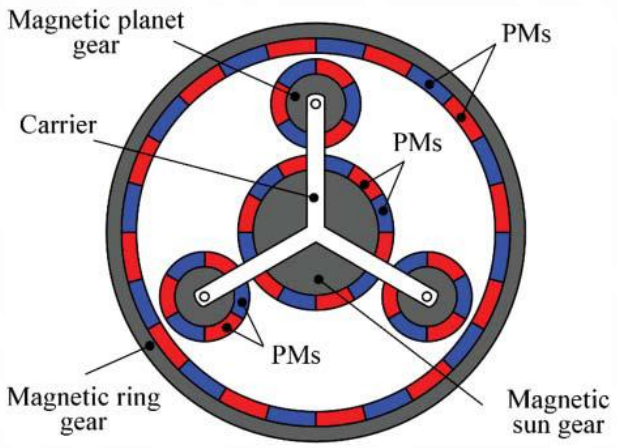


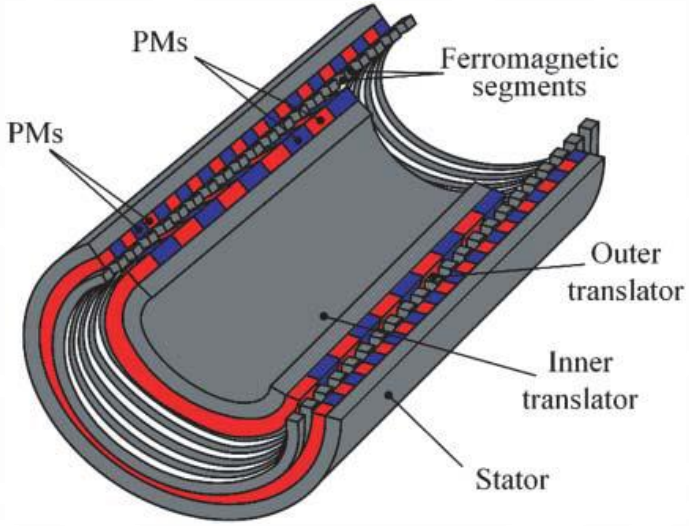


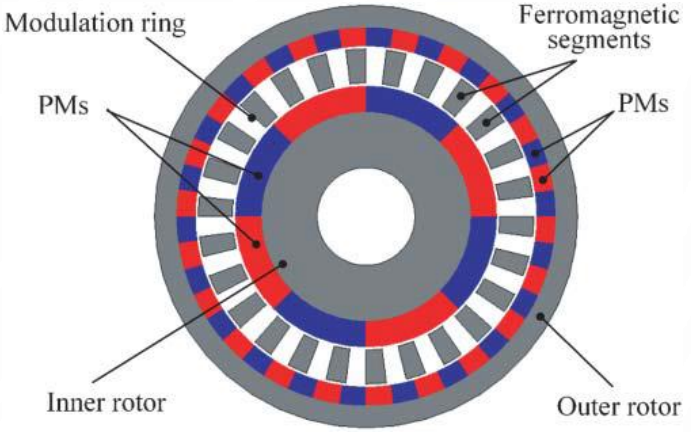


8. MAGNETIC-GEARED (MG) MOTOR DRIVES

- Magnetic planet gear, linear gear, and coaxial gear

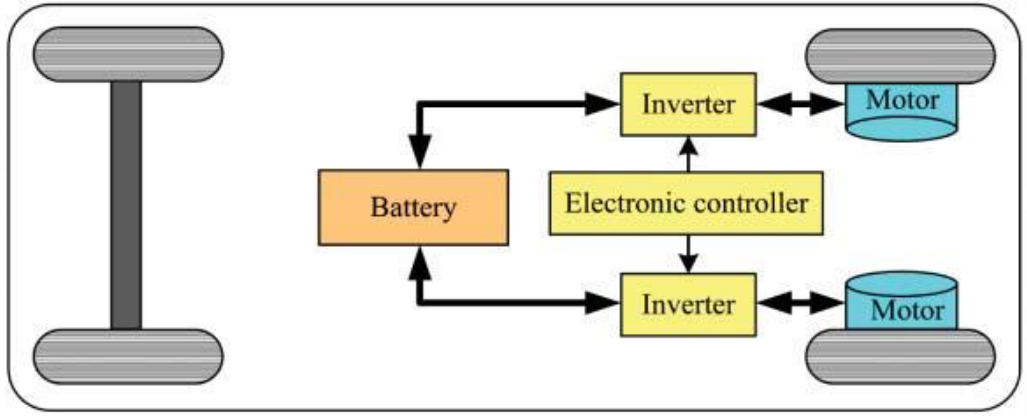


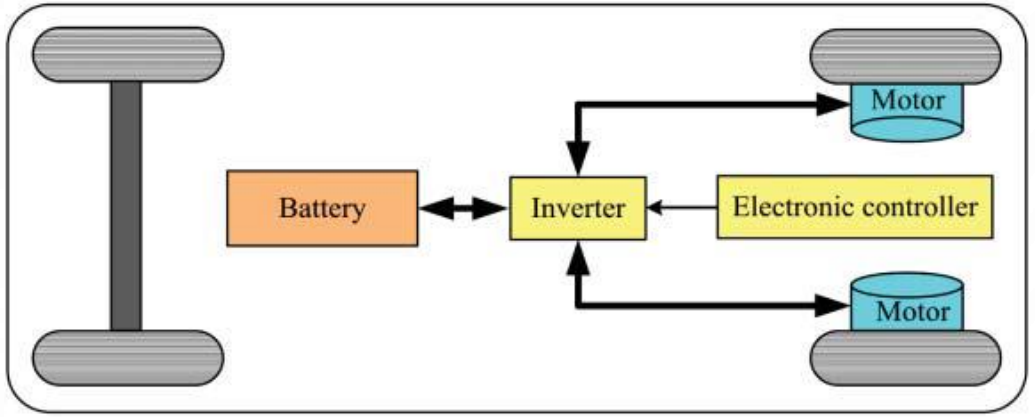




9. VERNIER PERMANENT MAGNET (VPM) MOTOR DRIVES

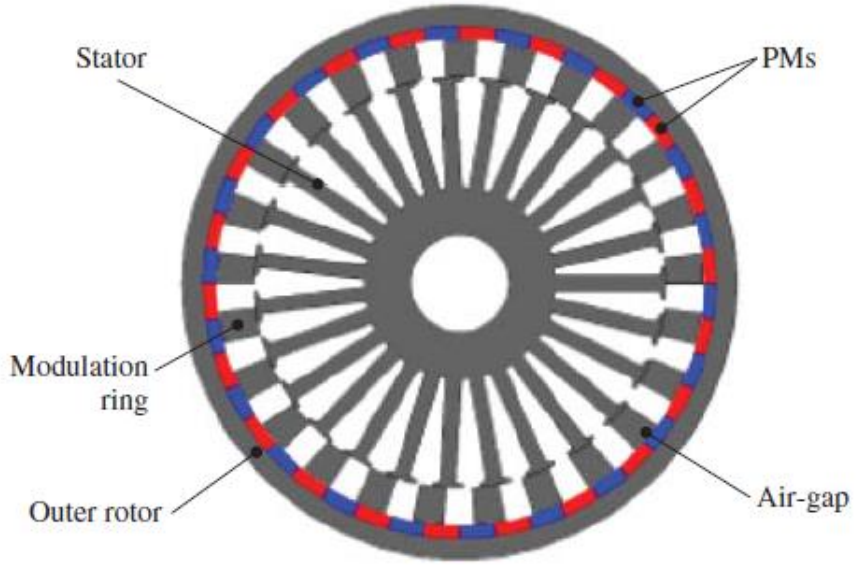
- The VPM machine is a kind of synchronous machine so that the configuration of the VPM motor drive is like that of the PM brushless motor drive, which consists of an electric motor, an electronic controller, a power inverter, and an optional transmission gear. Because of the inherent low-speed high-torque operation of the VPM machine, the VPM motor drive is preferred to serve as a direct drive for in-wheel propulsion, thus eliminating the use of transmission gear.

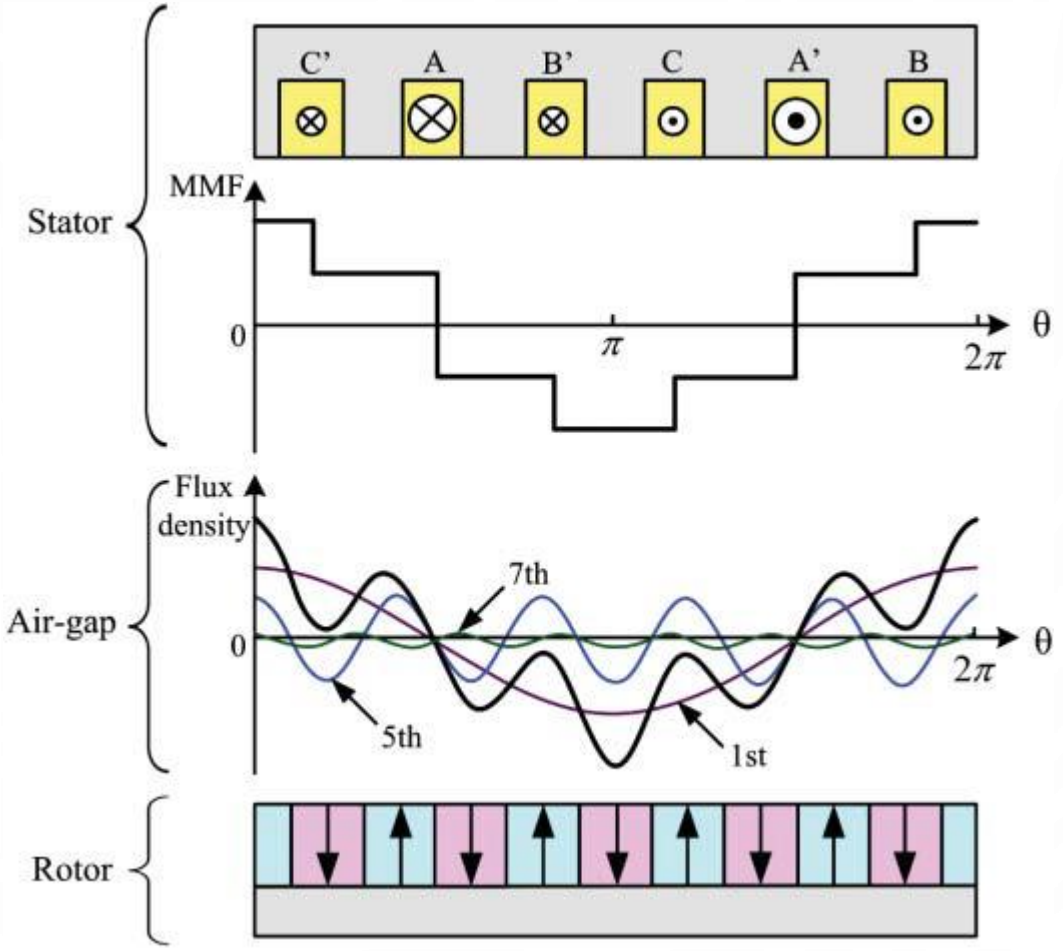




9. VERNIER PERMANENT MAGNET (VPM) MOTOR DRIVES

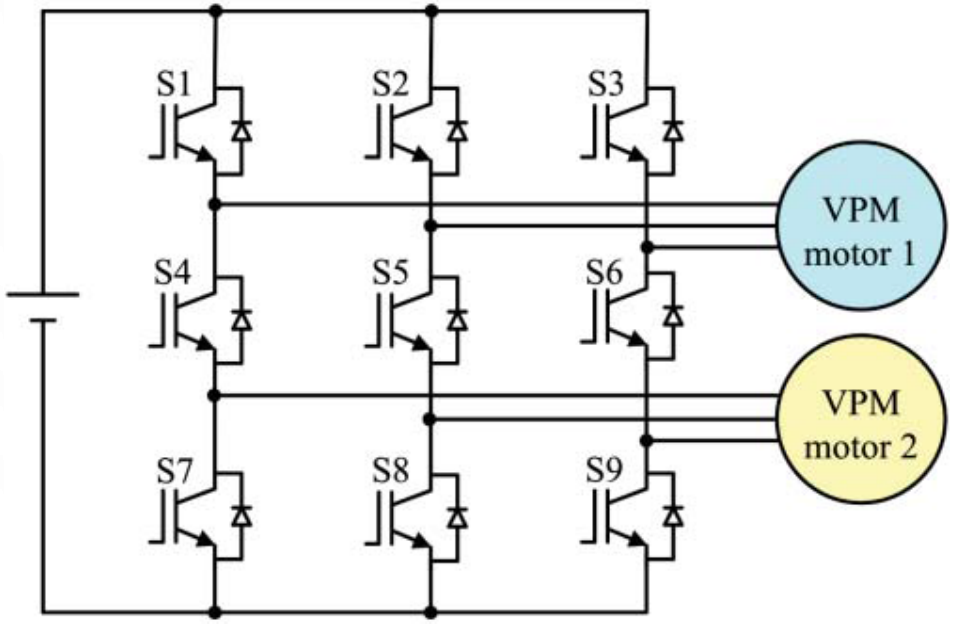
- Principle of operation of VPM machines

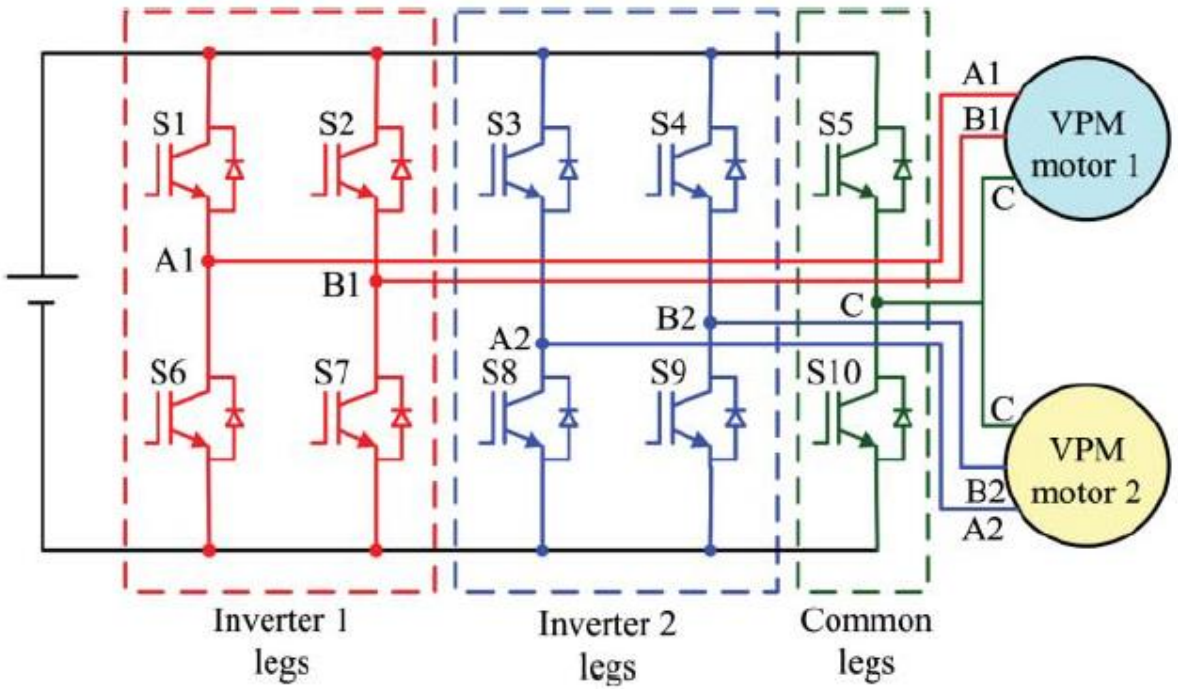




9. VERNIER PERMANENT MAGNET (VPM) MOTOR DRIVES

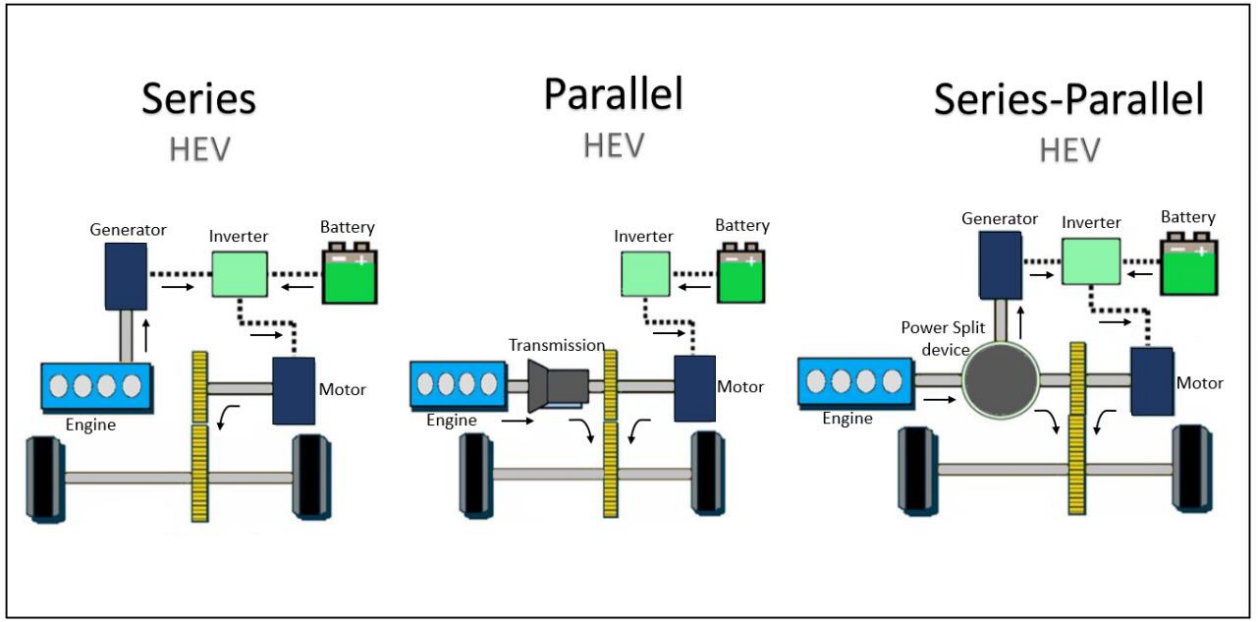
- Nine-switch inverter for dual VPM machines vs. Five-leg inverter for dual VPM machines





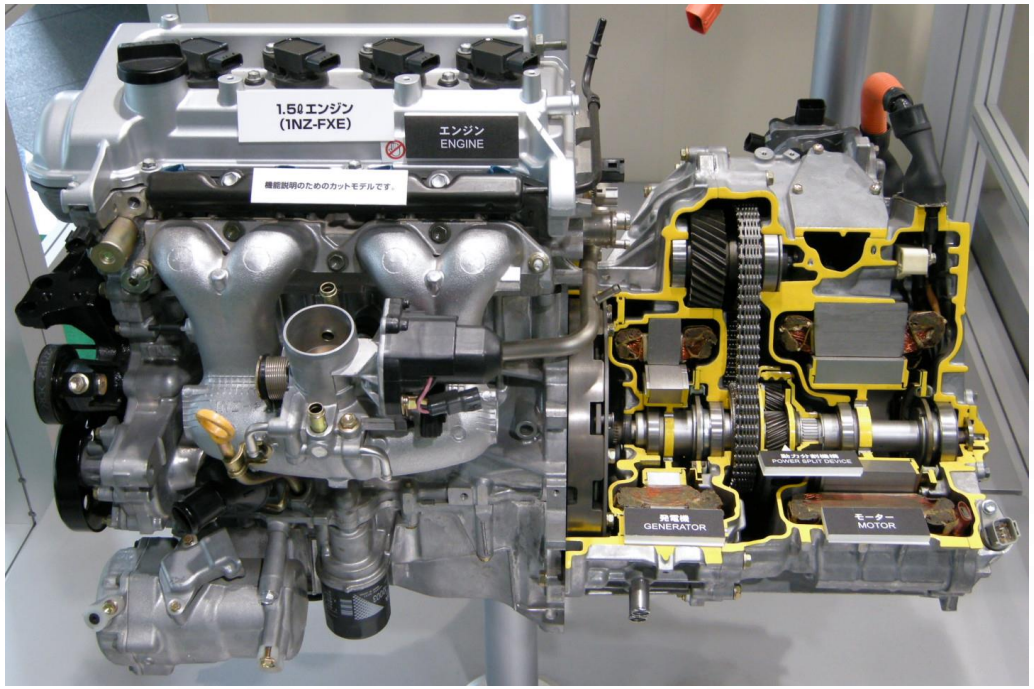
10. STRUCTURE OF HYBRID EVS

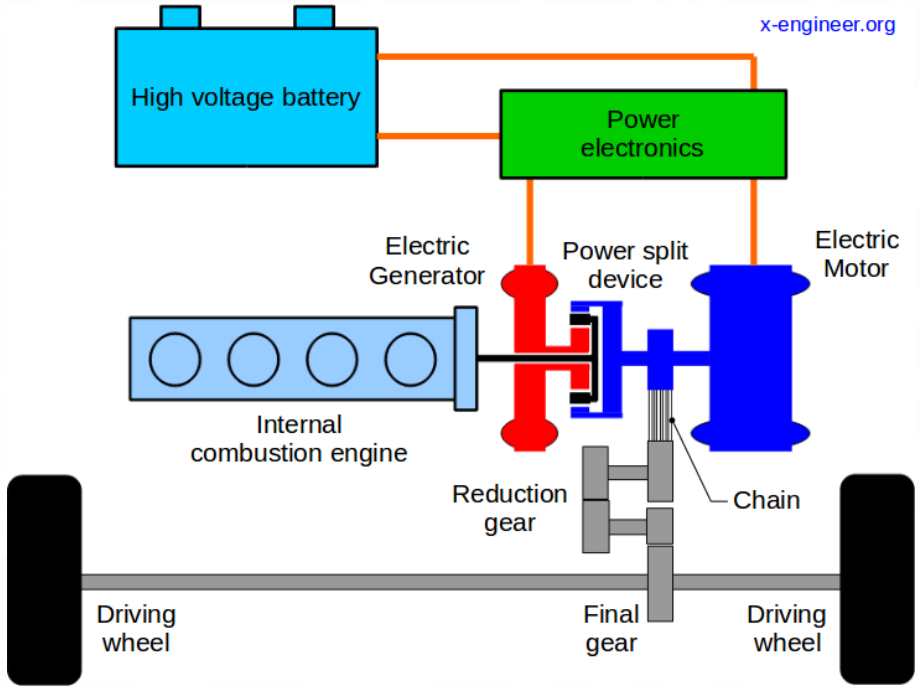
- A hybrid electric vehicle (HEV) combines an internal combustion engine with one or more electric motors and a battery pack, operating through a power control unit and a specialized transmission.
- The electric motor handles low-speed driving and assists the engine during acceleration to improve fuel economy and reduce emissions, while the engine powers the vehicle at higher speeds.
- Energy is stored in the battery, which is recharged through regenerative braking (capturing energy during deceleration) and the internal combustion engine.



10. STRUCTURE OF HYBRID EVS

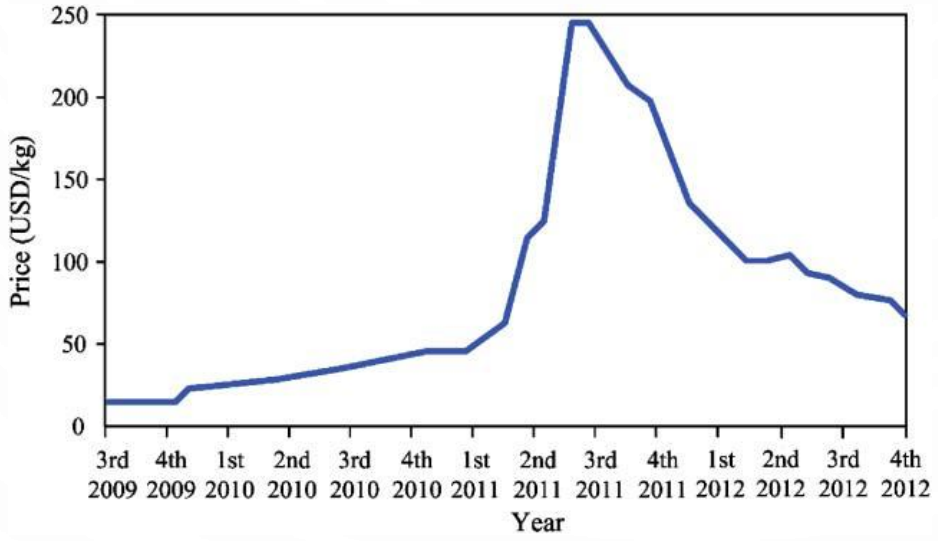
- Example!

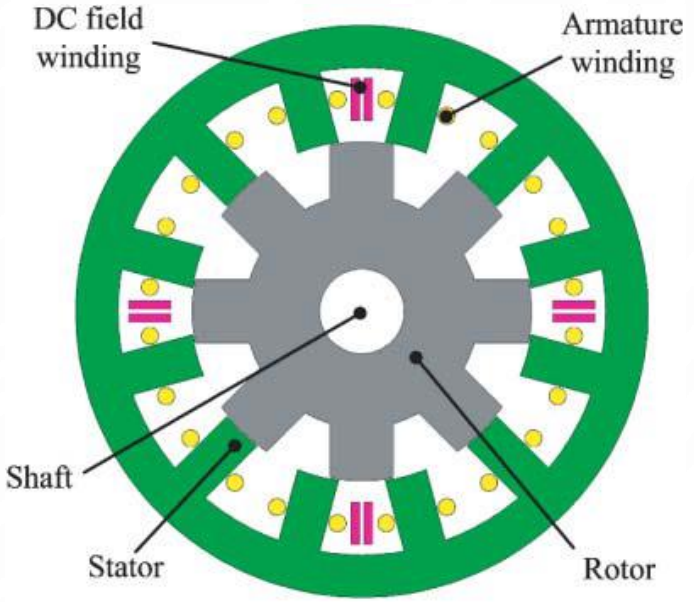




11. ADVANCED MAGNETLESS MOTOR DRIVES

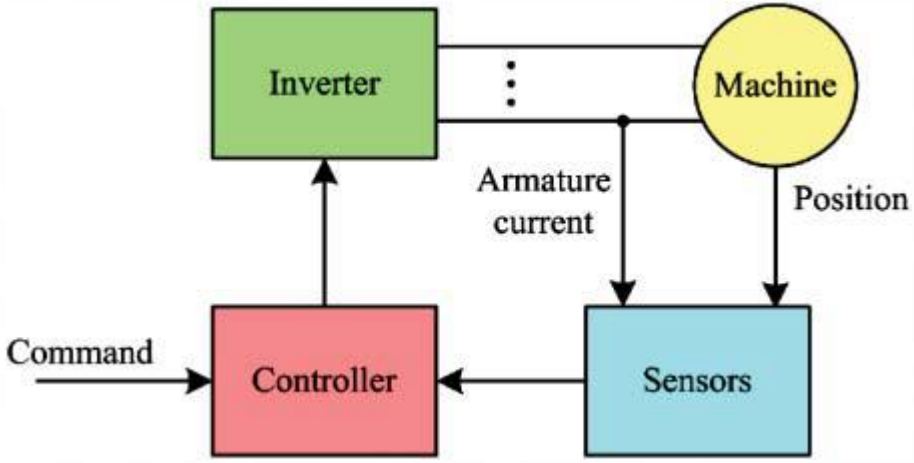
- With ever-increasing popularity of PM machines for EVs, the demand of neodymium-iron-boron (Nd-Fe-B) PM material is drastically soaring. The price of the raw material neodymium is the determining factor in pricing the Nd-Fe-B PM.
- Focusing on those advanced magnetless machines that are viable for EV propulsion, five major types are identified:
  - SynR machine
  - DSDC machine
  - FSDC machine
  - VR machine
  - DFVR machine

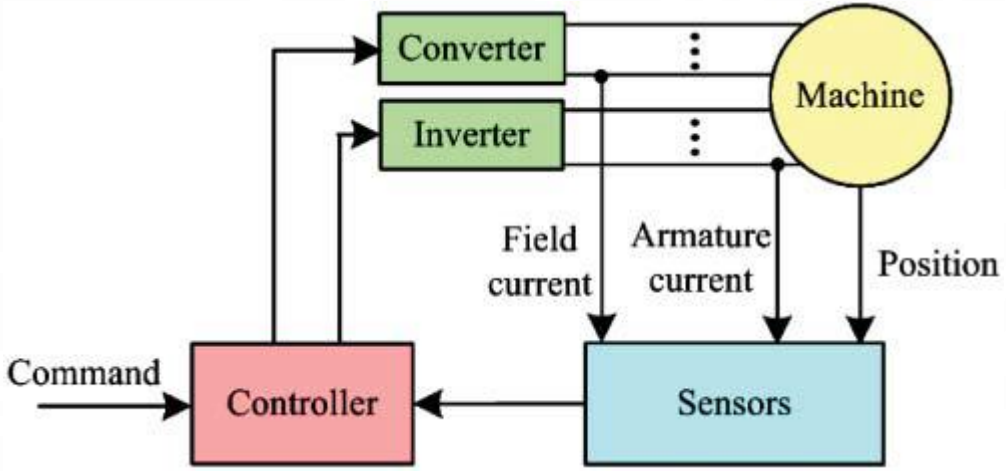




11. ADVANCED MAGNETLESS MOTOR DRIVES

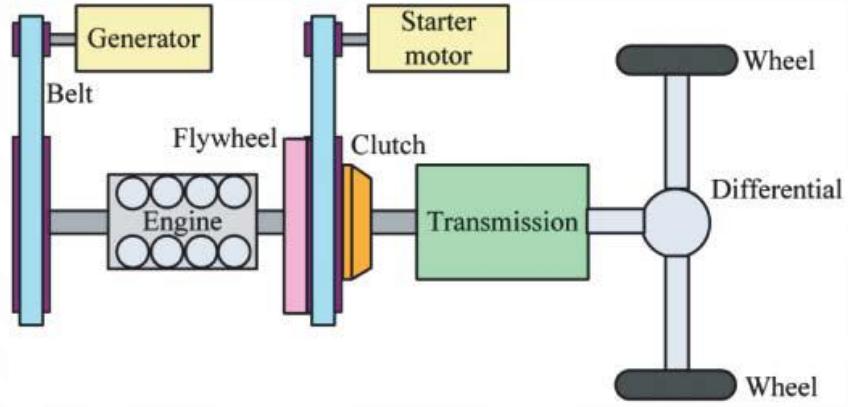
- Configuration of single-fed and doubly-fed advanced magnetless motor drive

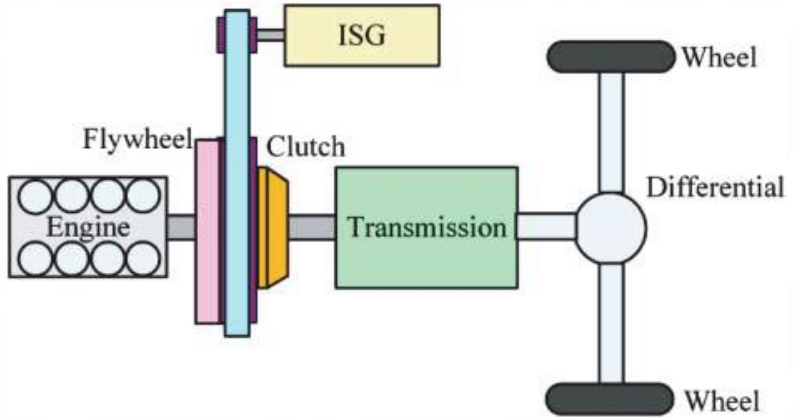


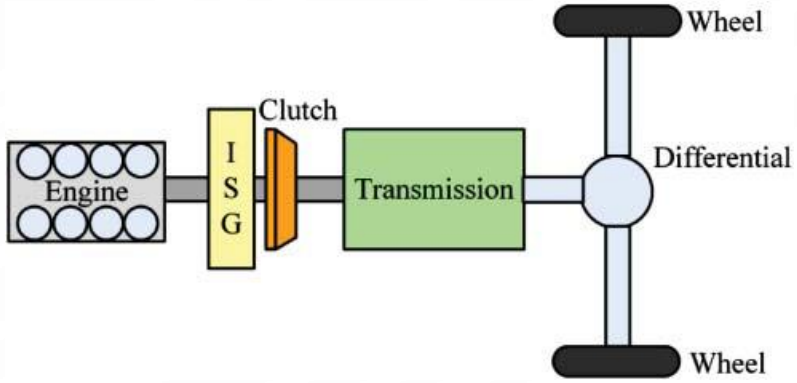


12. INTEGRATED-STARTER-GENERATOR SYSTEMS

- The integrated-starter-generator (ISG) is an important device for hybrid electric vehicles (HEVs), which replaces the conventional starter motor and the generator (also called alternator or dynamo). Its other common name is the integrated-starter-alternator (ISA). Apart from cranking the engine and generating electricity to charge the battery, the ISG provides three unique functions for micro and mild HEVs: idle stop-start, regenerative braking, and power assistance.

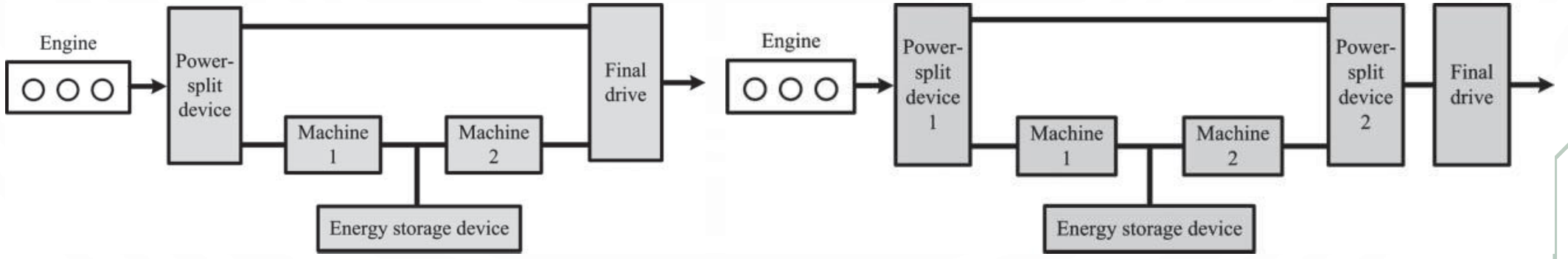






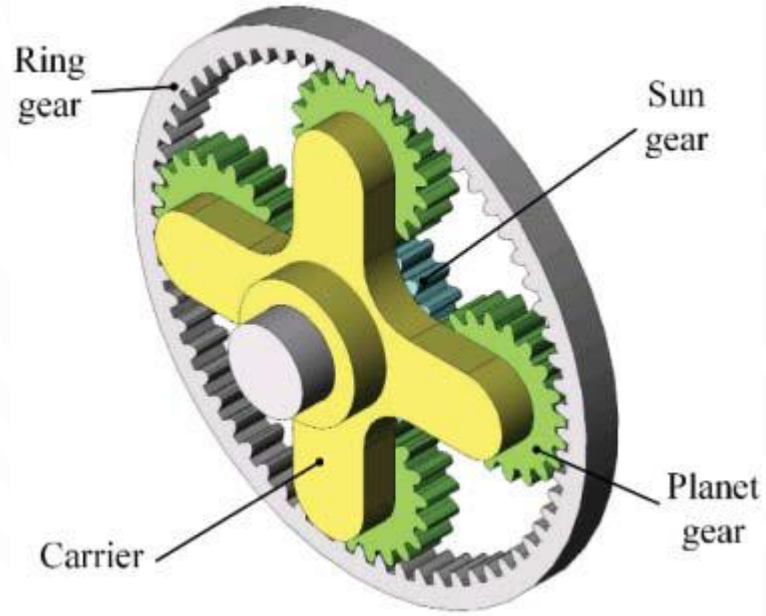
13. PLANETARY-GEARED ELECTRIC VARIABLE TRANSMISSION SYSTEMS

- While the micro and mild hybrids take the advantages of using the integrated-starter-generator to offer some hybrid features, the full hybrid can provide all hybrid features and thereby achieve the highest fuel economy. The key technology of the full hybrid is the electric variable transmission (EVT) system, also called the electronic-continuously variable transmission system. Since the introduction of the first EVT system in 1997, there have been many derivatives developed by different automakers. Essentially, most of them are based on the use of planetary gearing to perform power-split, hence achieving EVT.
- Input-split PG EVT system configuration and Compound-split PG EVT system configuration are shown at figures.

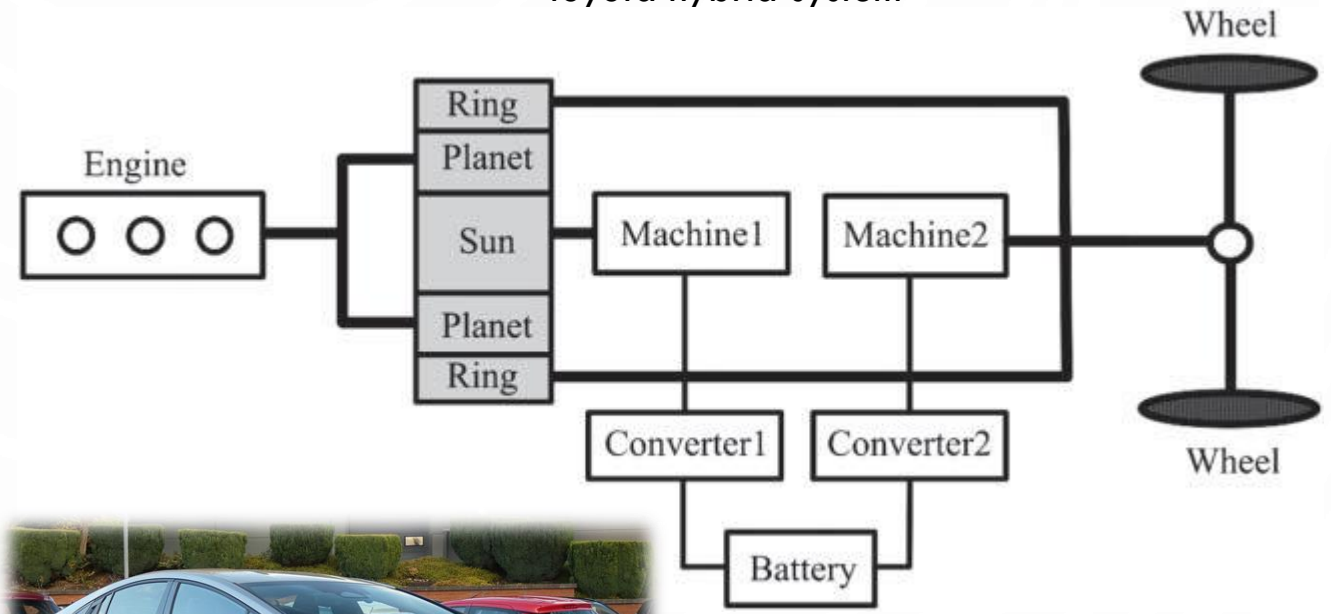


13. PLANETARY-GEARED ELECTRIC VARIABLE TRANSMISSION SYSTEMS

- Planetary gear structure

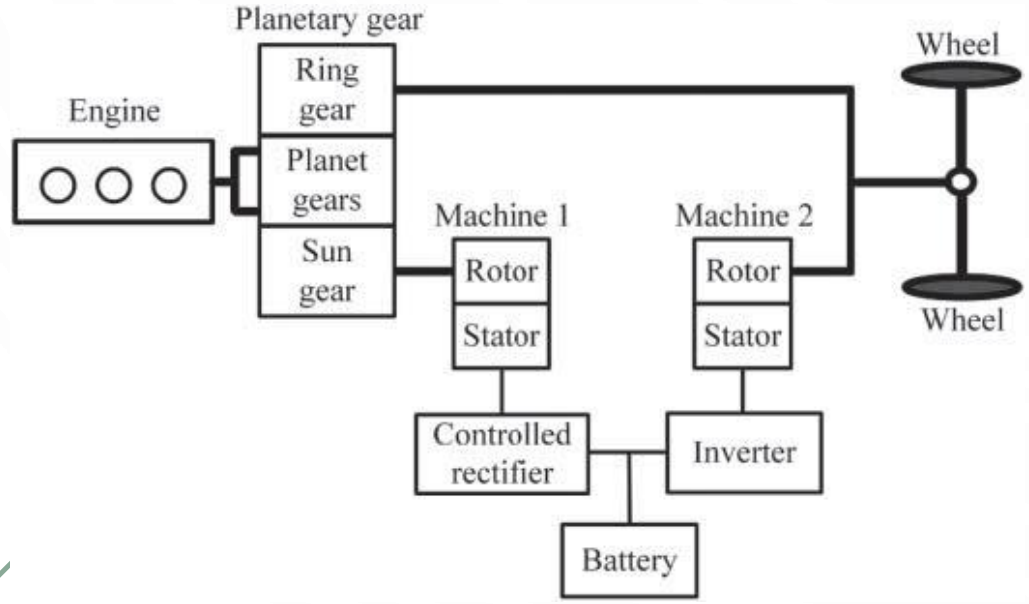


Toyota hybrid system

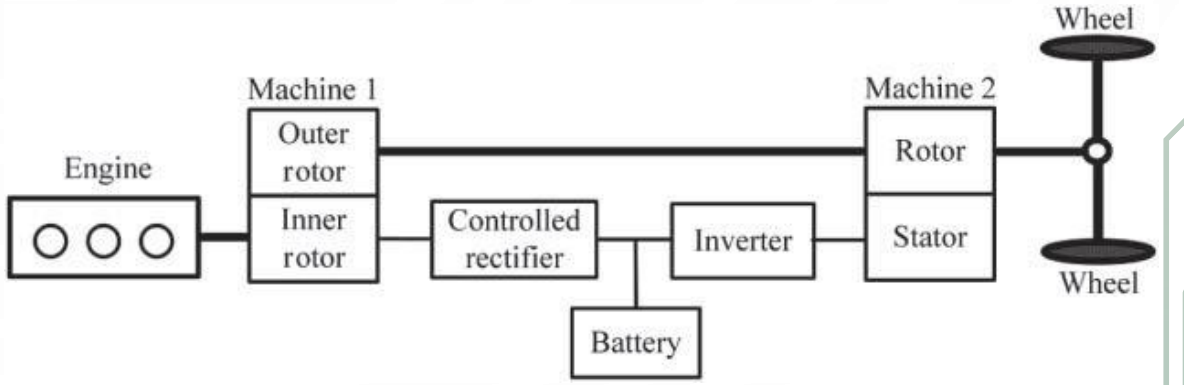


14. DOUBLE-ROTOR ELECTRIC VARIABLE TRANSMISSION SYSTEMS

- As the electric variable transmission (EVT) system is the core technology for full hybrids, it is undergoing continual development. The existing EVT systems are all based on the use of planetary gearing, which inherently suffers from transmission loss, gear noise, and need for regular lubrication. In order to overcome these drawbacks, a new class of EVT systems has been developed. The key is to employ a double-rotor (DR) machine to perform the desired power-split.

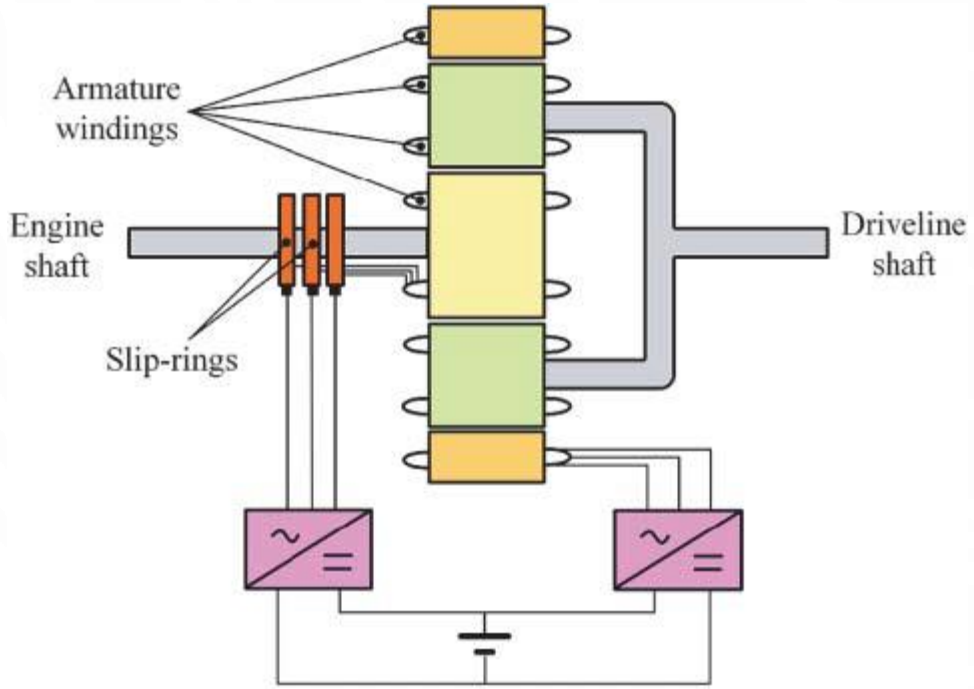


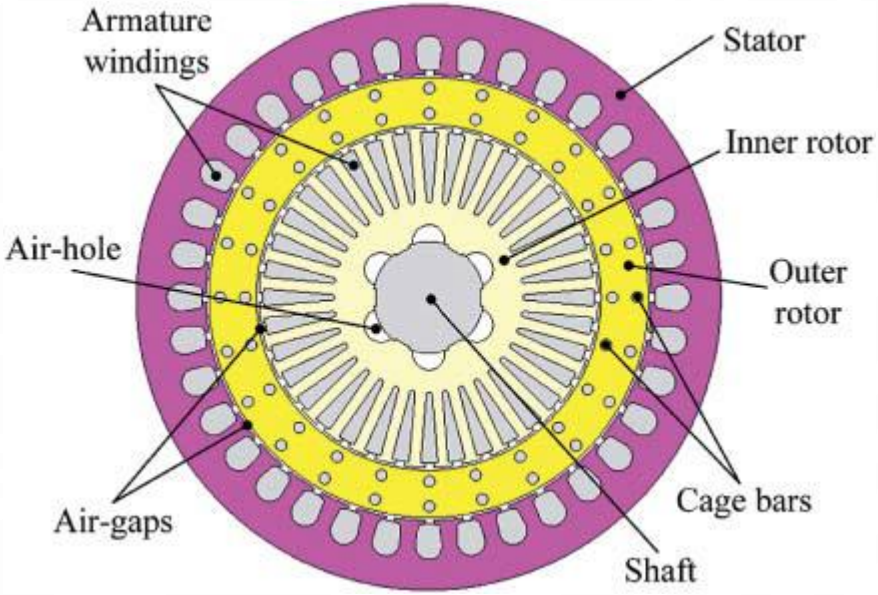
PG EVT vs. DR EVT system configuration



14. DOUBLE-ROTOR ELECTRIC VARIABLE TRANSMISSION SYSTEMS

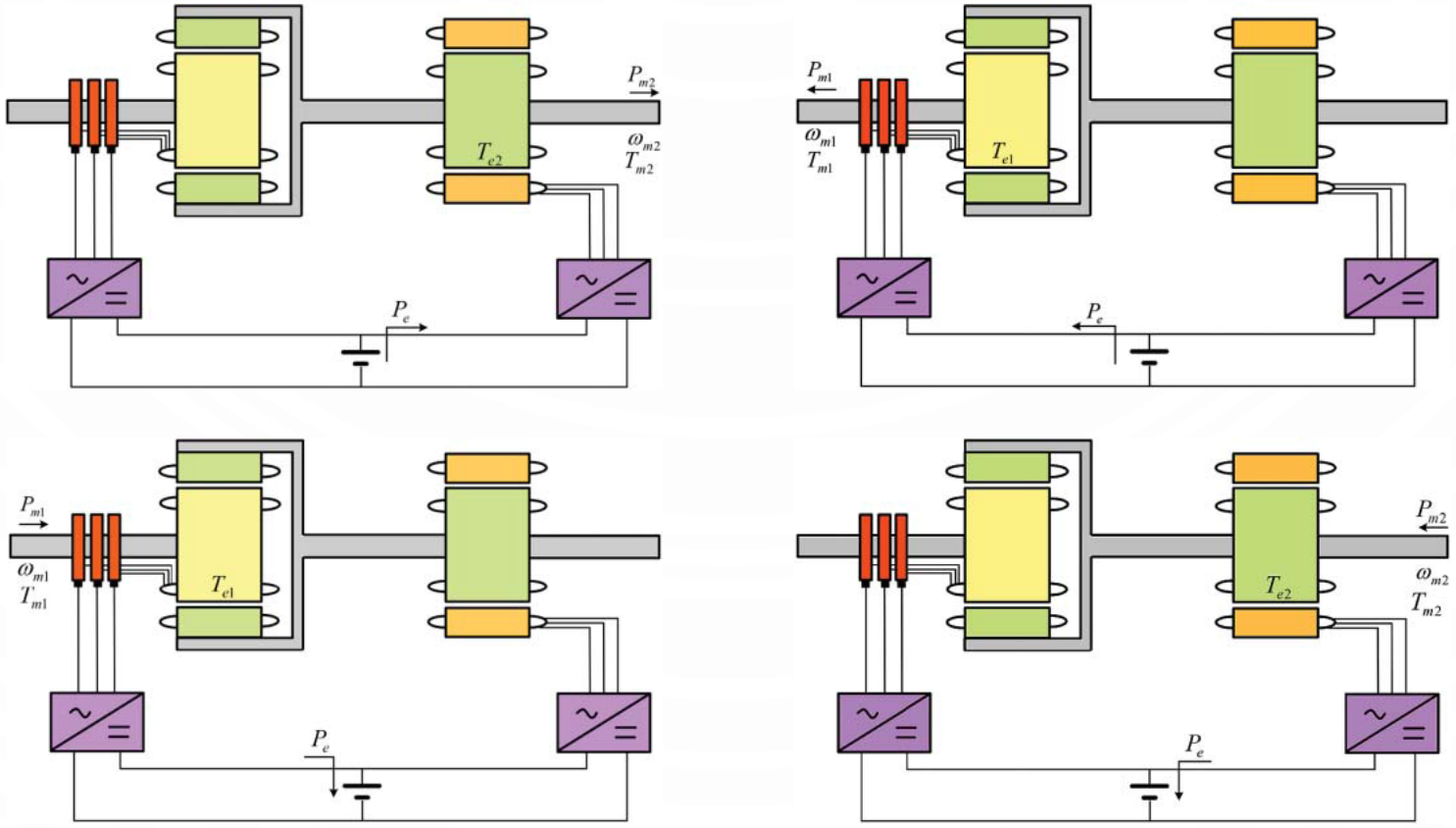
- Induction DR EVT system





14. DOUBLE-ROTOR ELECTRIC VARIABLE TRANSMISSION SYSTEMS

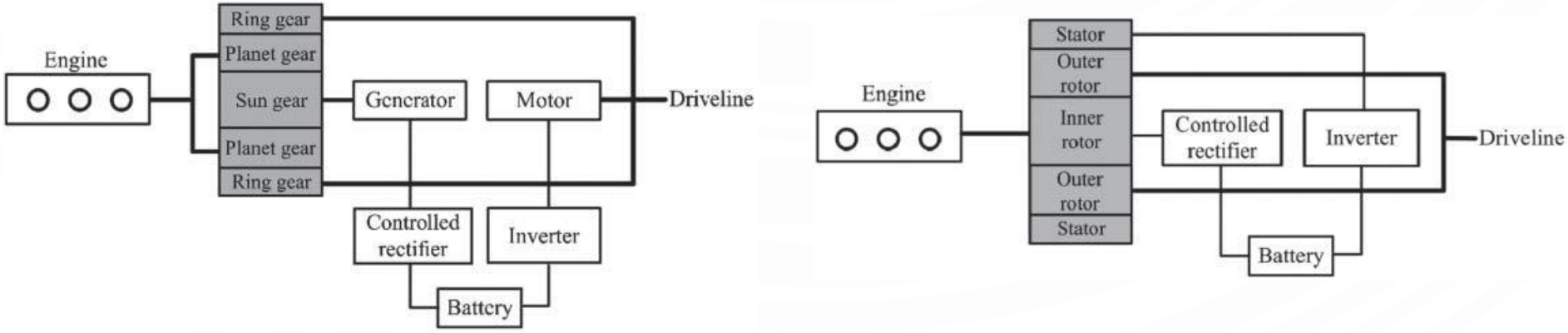
- Power flow during electric launch, cranking, battery charging, and regenerative braking



15. MAGNETIC-GEARED ELECTRIC VARIABLE TRANSMISSION SYSTEMS

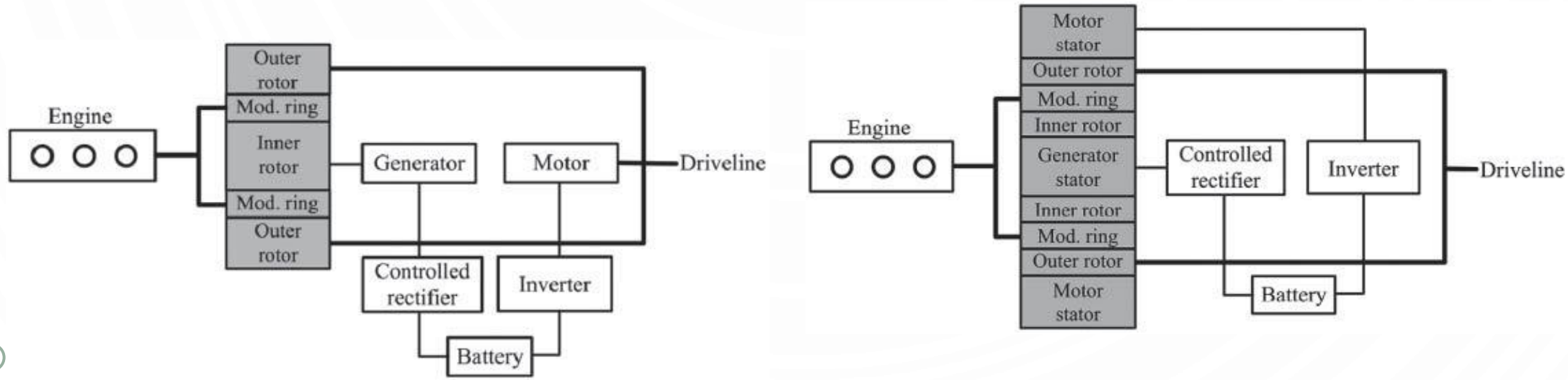
- The key of the electric variable transmission (EVT) systems for hybrid electric vehicles (HEVs) is the power-split device. The planetary gear is the most adopted power-split device. However, it suffers from the problems of transmission loss, gear noise, and need for regular lubrication. The double-rotor (DR) machine is a newly introduced gearless power-split device. However, it requires brushes and slip-rings, which are less reliable and incur need for regular maintenance. To overcome these drawbacks, a new class of magnetic-geared electric variable transmission (MG EVT) systems has been developed based on contactless magnetic gears, which can offer the definite advantage of brushless and pseudo-gearless power-split operation.

Planetary-geared EVT system configuration vs Double-rotor EVT system configuration



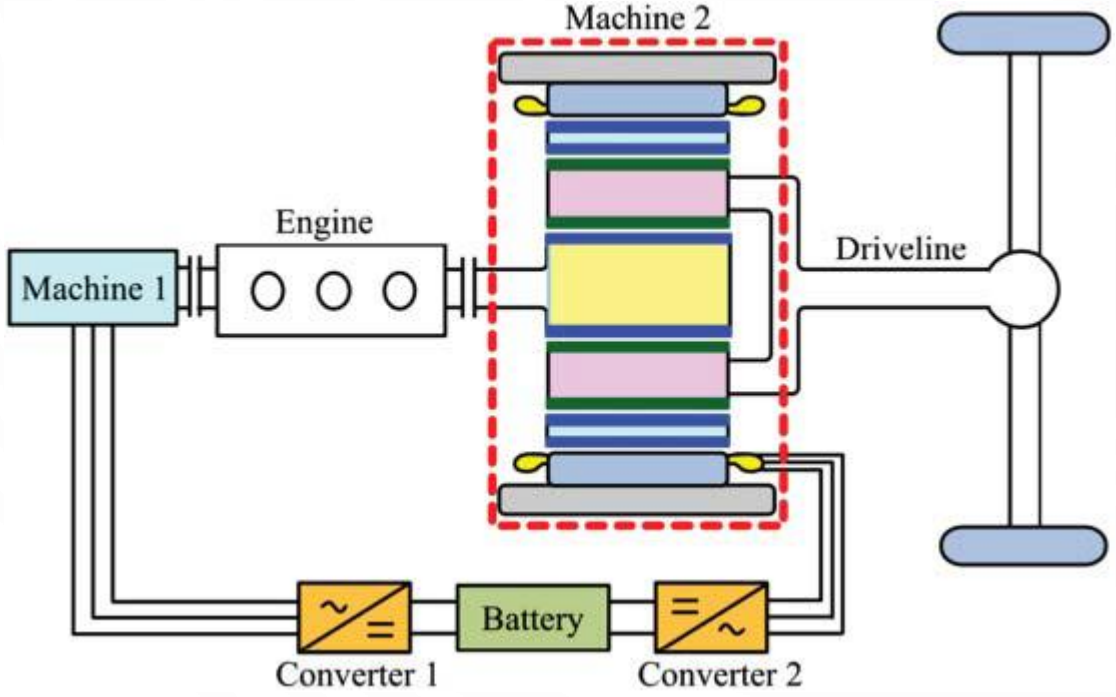
15. MAGNETIC-GEARED ELECTRIC VARIABLE TRANSMISSION SYSTEMS

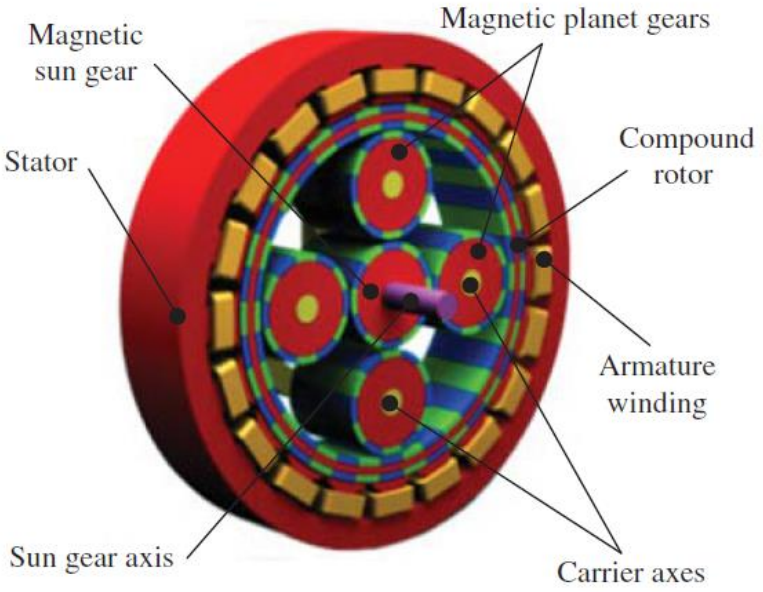
Magnetic-geared EVT system configuration vs. Integrated magnetic-geared EVT system configuration



15. MAGNETIC-GEARED ELECTRIC VARIABLE TRANSMISSION SYSTEMS

- Magnetic planetary-geared EVT system
- Magnetic planetary-geared PM brushless machine





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

University of East Sarajevo
Faculty of Electrical Engineering
Bosnia and Herzegovina