Tribhuvan University
Institute of Engineering
Pulchowk Campus
Accredited by University Grants Commission (UGC) Nepal 2020

Unit: II- Power Electronic Converters used in Electric Drives

Class-06:
19th January 2024

Presented by
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Subject Name
EE: Modelling and Control of Electric Drives

Discussed in the Previous Class

In the previous class discussed the following topics:

- Components of Load Torque
- Classifications of Load Torque
- Time and Energy Loss in Transient Operations
- Steady State Stability of an Electric Drive System

Lecture Outcomes

- ❖ Power Electronics Converters ✓
- ❖ Introduction of Electric Vehicles ✓
- ❖ Types of Converters used in Electric Drives ✓
- ❖ Battery Management Systems for Electric Vehicles ✓
- ❖ Lecture remarks: Key points of today’s class

Introduction of Power Electronics Converters

- Power electronics converters play a crucial role in controlling and optimizing the performance of electric drives.

- These converters facilitate the efficient and precise conversion of electrical energy, enabling the speed and torque control of electric motors.

- Types of converters:

1. **AC to DC converters (Rectifiers)**
2. **DC to AC converters (Inverters)**
3. **DC to DC converters (Choppers)**
4. **AC to AC converters (Cyclo-converters)**

IGBT, MOSFET ⇒ controllable

Diode ⇒ uncontrollable

230 to 150 V AC

Applications of Power Electronics Converters in Electric Drives

Variable Frequency Drives (VFDs):

- Power electronics converters, such as inverters, are widely used in Variable Frequency Drives.
- They convert fixed AC voltage and frequency from the power supply to variable voltage and frequency, allowing precise control of motor speed.
- VFDs are extensively used in industrial applications for energy savings and process control.

Applications of Power Electronics Converters in Electric Drives

Electric Vehicle Drives:

- In electric vehicles (EVs) and hybrid electric vehicles (HEVs), power electronics converters are employed to control the energy flow between the battery and the electric motor.

- Converters, including inverters and DC-DC converters, manage power distribution, enable regenerative braking, and control the speed of the electric motor.

Applications of Power Electronics Converters in Electric Drives

Renewable Energy Systems:

- Power electronics converters are essential in renewable energy systems where electric drives are used to harness energy from sources like wind turbines and solar panels.
- Converters interface with these systems, ensuring the efficient transfer of power to the electrical grid or energy storage systems.

Applications of Power Electronics Converters in Electric Drives

Uninterruptible Power Supplies (UPS):

- In UPS systems, power electronics converters provide a seamless transition between the utility power and backup energy sources.
- Converters maintain a stable and reliable power supply during grid disturbances or power outages, ensuring continuous operation of critical equipment.

Applications of Power Electronics Converters in Electric Drives

Industrial Motor Drives:

- Power electronics converters are extensively applied in industrial motor drives for various applications such as pumps, fans, and conveyors.

- These converters enable precise speed and torque control, leading to improved energy efficiency and process control.

Applications of Power Electronics Converters in Electric Drives

Home Appliances and HVAC Systems:

- Electric drives powered by converters are used in home appliances like washing machines, refrigerators, and air conditioners.

- By controlling the speed and operation of the motors in these devices, converters enhance energy efficiency and overall performance.

Applications of Power Electronics Converters in Electric Drives

High-Speed Trains and Locomotives:

- Power electronics converters are crucial in the traction systems of high-speed trains and locomotives.
- They control the speed and torque of electric motors, ensuring efficient and smooth operation while optimizing energy consumption.

Applications of Power Electronics Converters in Electric Drives

Flywheel Energy Storage Systems:

- Power electronics converters are employed in flywheel energy storage systems to manage the charging and discharging of the flywheel.
- Converters play a key role in regulating the flow of energy between the flywheel and the electrical grid.

Applications of Power Electronics Converters in Electric Drives

Aerospace Applications:

- Electric drives in aerospace applications, such as aircraft and satellites, utilize power electronics converters for motor control, contributing to improved efficiency and reliability.

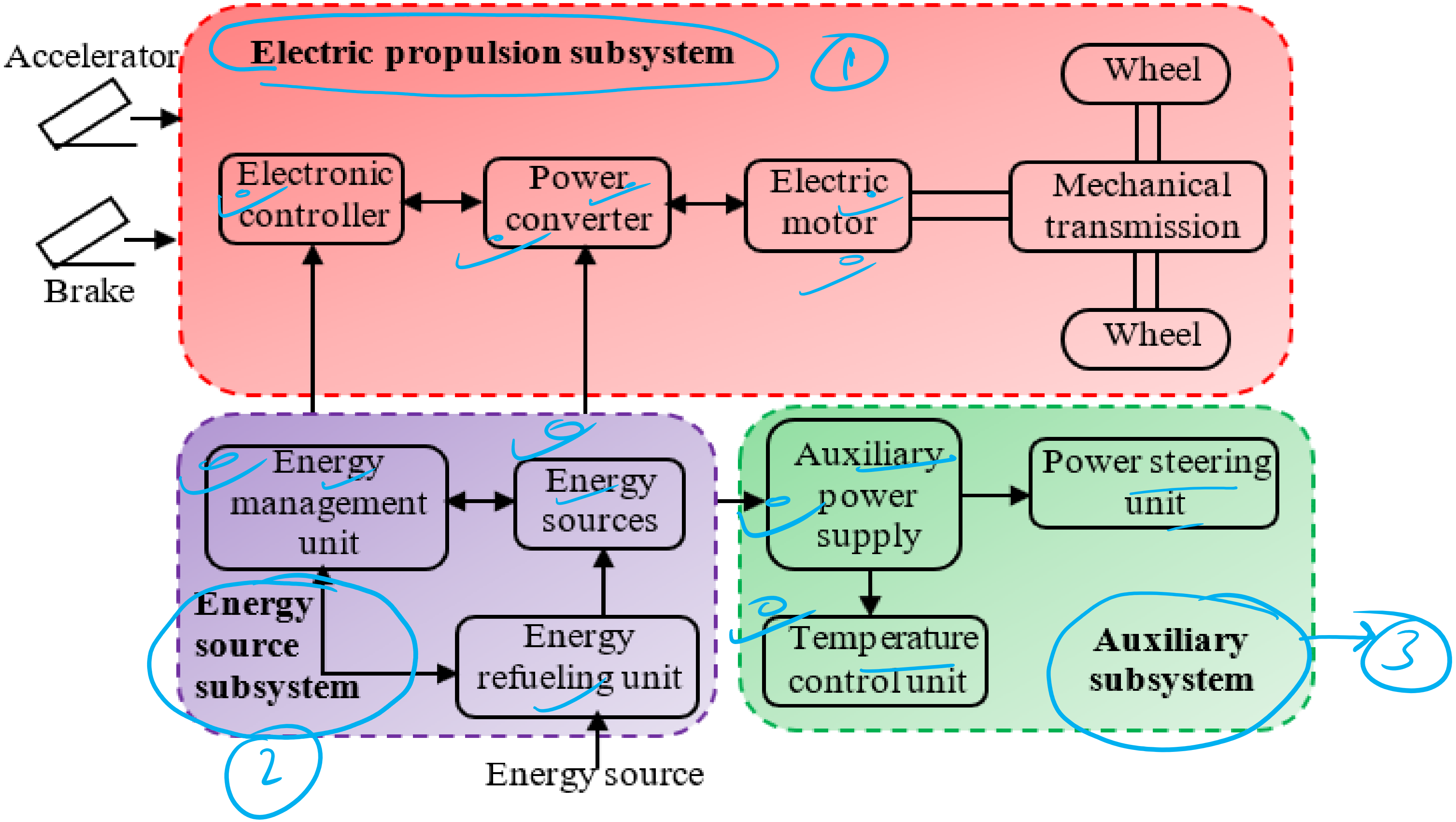
Applications of Power Electronics Converters in Electric Drives

Medical Devices:

- Power electronics converters are used in various medical devices, including pumps, ventilators, and robotic surgical systems.
- They enable precise control of motorized components, enhancing the performance and accuracy of medical equipment.

Introduction of Electric Vehicles

Components of Electric Vehicles



Source: C. C. Chan, "The State of the Art of Electric and Hybrid Vehicles." Proc. IEEE 2002, 90, 247–275, 2002

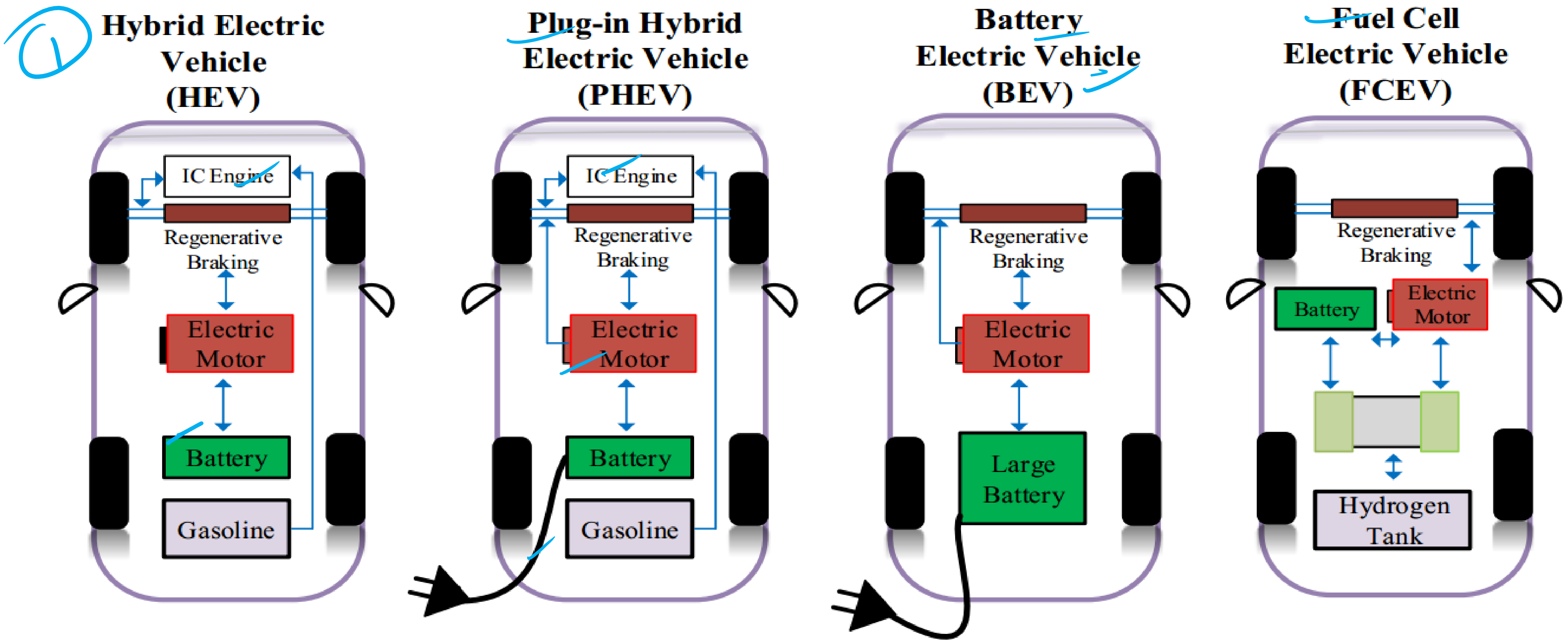
Introduction of Electric Vehicles

Table I. Comparison of EV motors

EV motors	Key challenges	Control techniques	Design topology
BLDC	High-cost magnet, torque ripples, reliability issues, (EMI, acoustic noise, fault tolerant), Less efficiency.	FOC, DTC, MPC, intelligent controller, and sensorless controller.	Opening stator slot wedges, Changing magnet pole arc width position, interior rotor (surface mounted, buried, inserted in-wheel motor.
PMSM	High-cost magnet (Neodymium, samarium), demagnetization, torque ripple, fault tolerant.	Low-cost ferrite material, FOC, DTC-SVM, MPC-PTC, SMC, intelligent controller, and sensor less controller.	PMAsynRM, PM Axial flux motor, PM spoke type motor.
IM	Material loss (Al, Cu), high core loss, low efficiency.	High conductivity material, material cost trade off, sensorless control, FOC, DTC and MPC-PTC.	Increased axial length, modelling skewed rotor.
SRM	Less torque density, high acoustic noise and vibration, high torque ripple.	TSF, DTC, DITC, MPC, FOC, MPC, SMC, and intelligent controller.	Increasing stator and rotor poles, axial flux SRM, optimize stator/rotor pole arc and length.

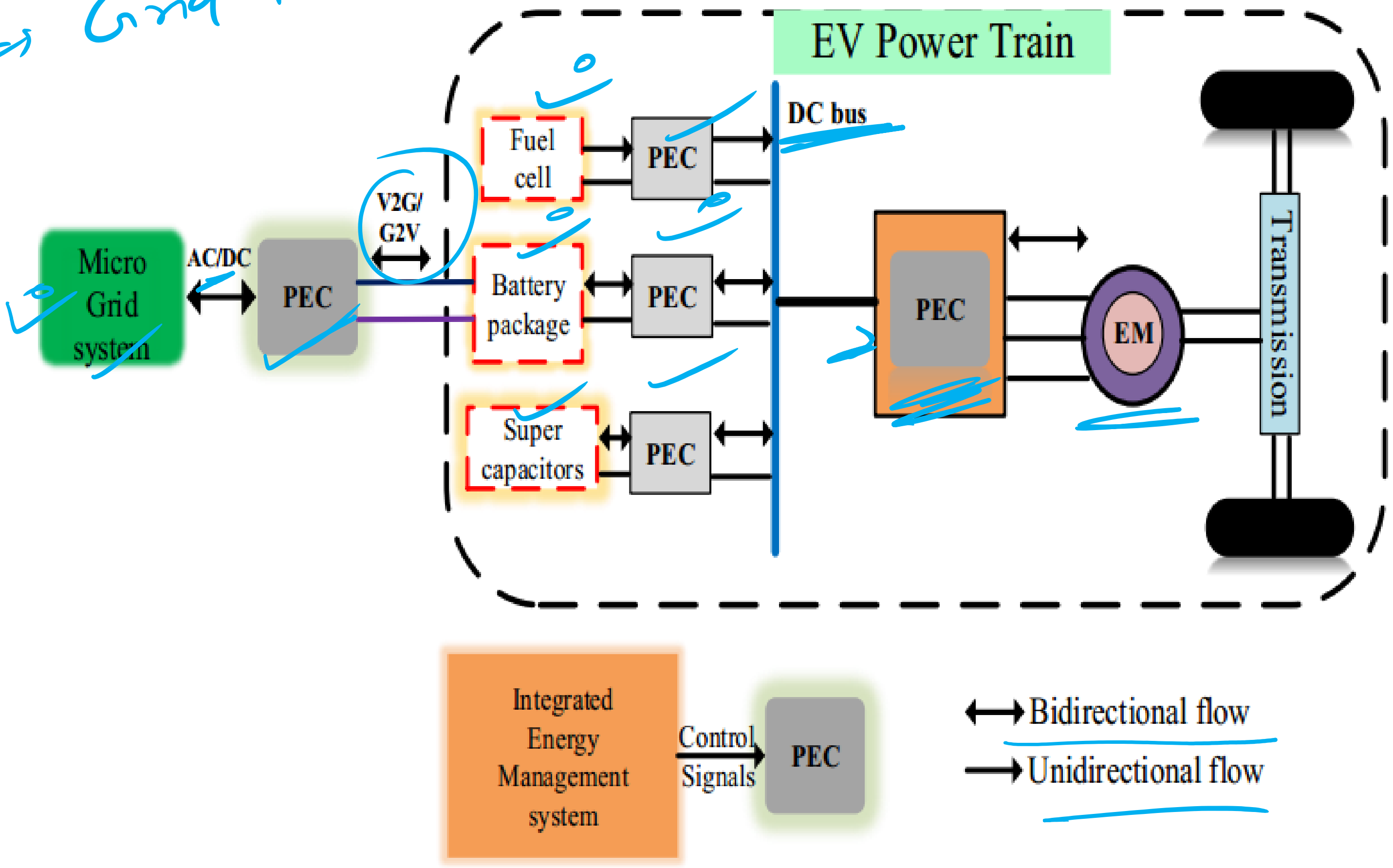
Types of Electric Vehicles

Green Hydrogen



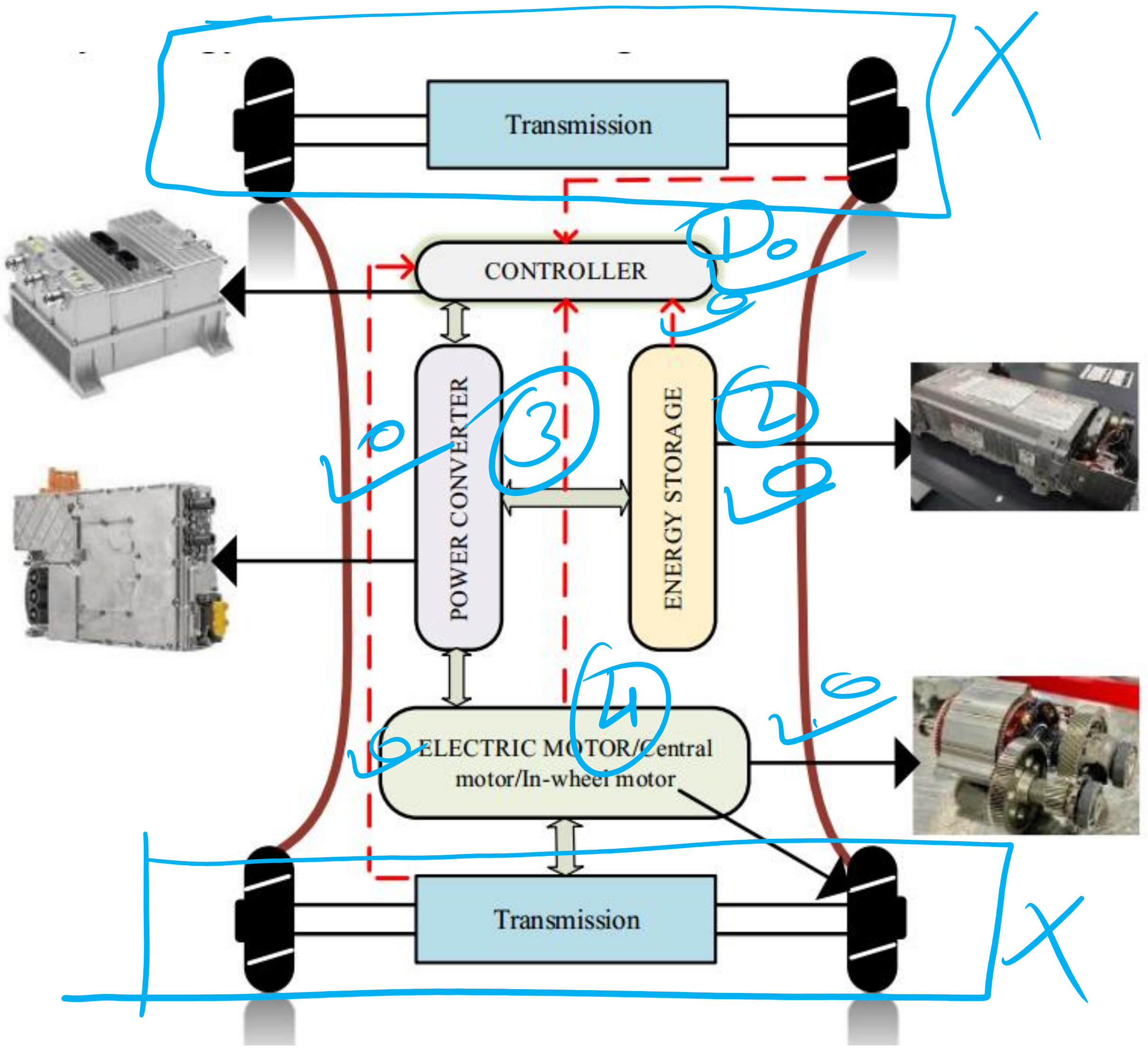
New Electrical Energy Storage Sources for Electric Vehicles

V2G ⇒ vehicle to Grid
G2V ⇒ Grid to vehicle

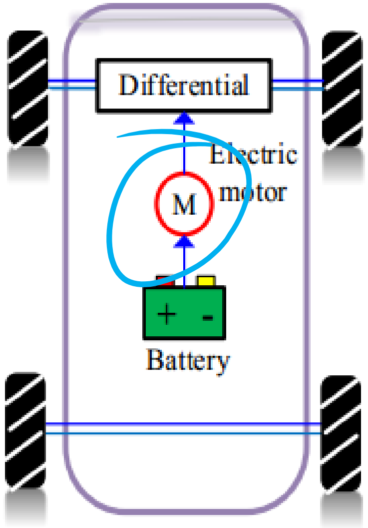
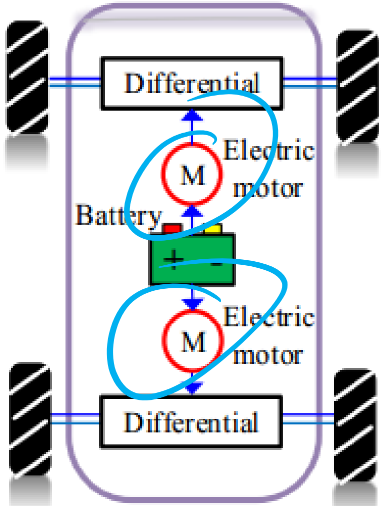
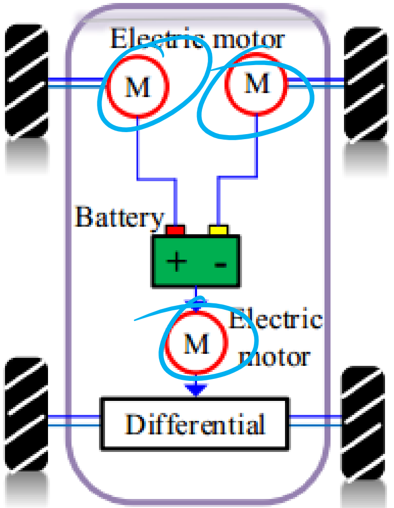
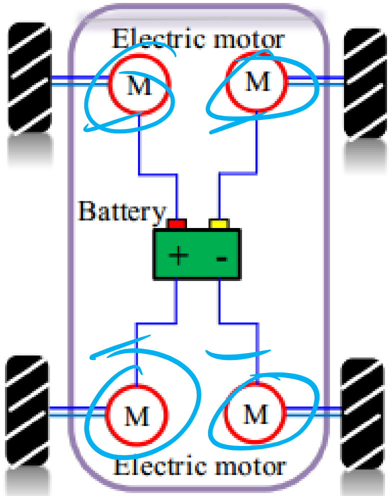


V2G
Regenerative Braking
⇓
storage energy
⇓
Grid feeding

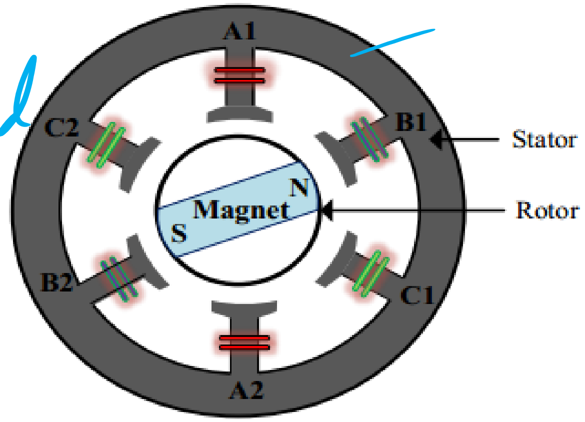
Background of Electric Powertrain



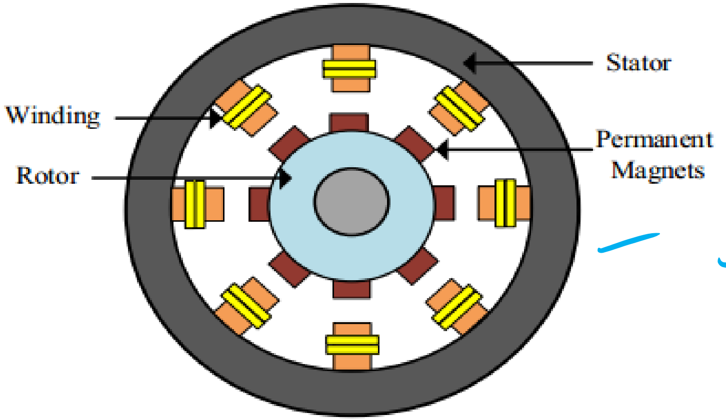
Types of Motor Configuration in EVs

Centralized single motor driven powertrain	Distributed multi motor driven powertrain		
Single motor	**Dual motors**	**Triple motors**	**Four motors**
			
• Compact unit, High efficiency. • Fewer components needed, cheaper to build. • Tesla polestar 2, electric range 425km, top speed 160kmph.	• More HP, high acceleration, efficiency and speed. • The additional degree of the freedom in vehicle for enhancing traction and stability control. • The increased ability of the overall traction system. • Tesla model 3, electric range 575km, 260kmph.	• More HP, high acceleration, efficiency and speed. • Torque coupled and controlled in moving drive efficiently. • All wheel drive handling stability group. • Audi-etron-S, Tesla model S, and Tesla model X.	• More HP, high acceleration, efficiency and speed. • All wheel drive handling stability group. • Four small motors in wheel called in-wheel or hub motor. • Positive and negative torque individually controlled in each motor.
• Not efficient than other motors. • Not suitable for high power.	• More expensive. • Lack of standard transmission. • Control more complex.	• More expensive. • Lack of standard transmission. • Control more complex.	• Torque vectoring control in each In-wheel motor are more complex.

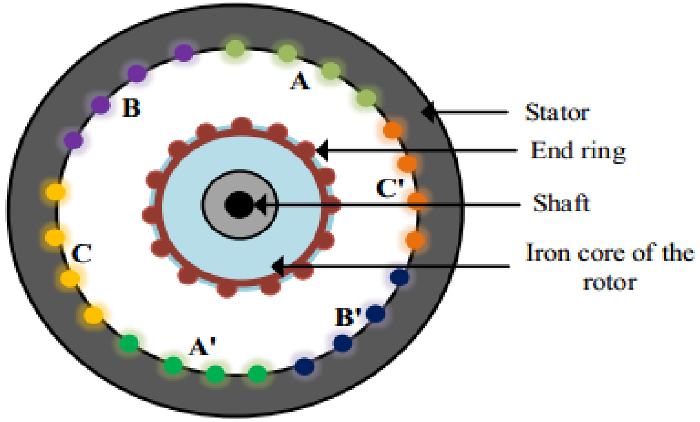
Types of Electric Motors in EVs



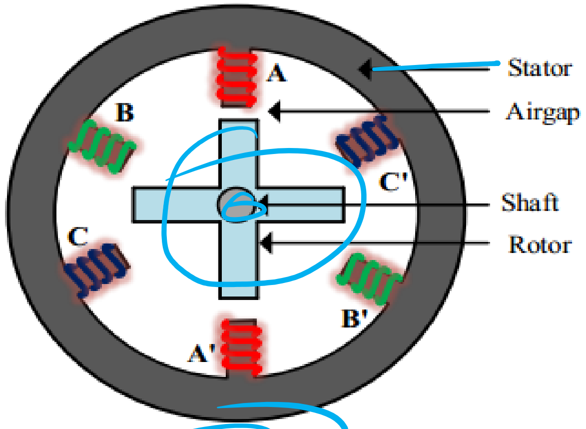
BLDC



PMSM

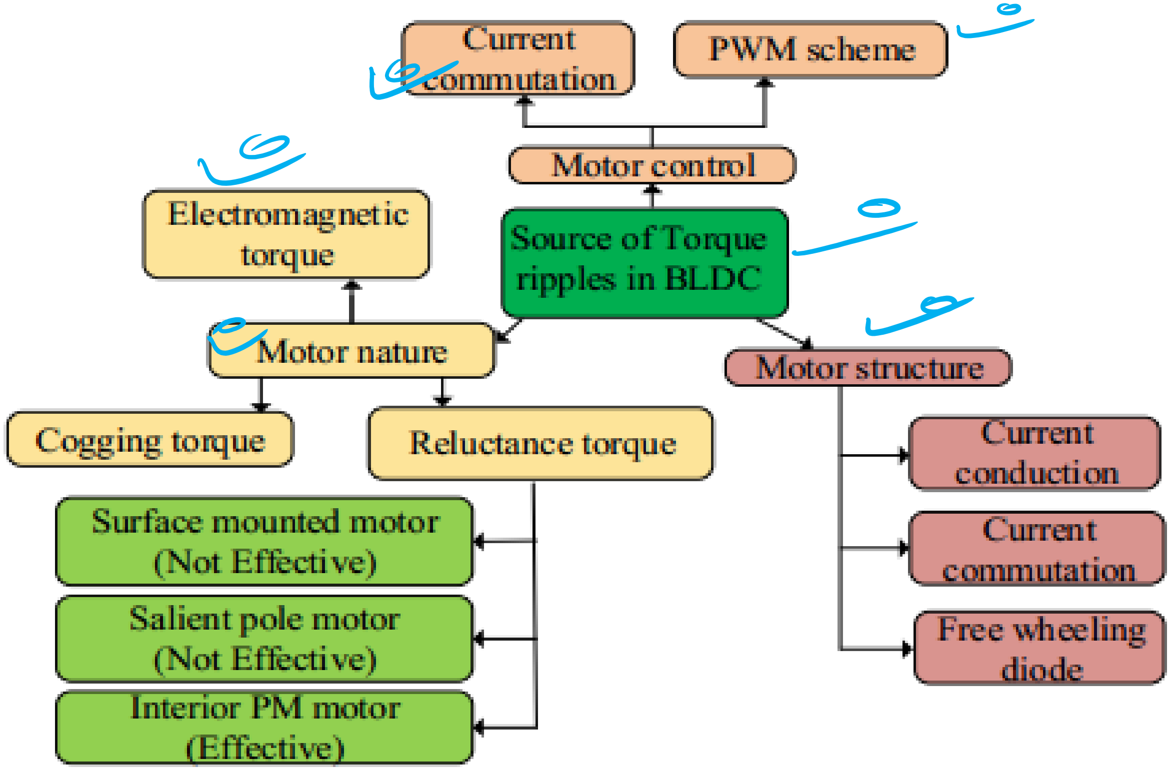


IM



SRM

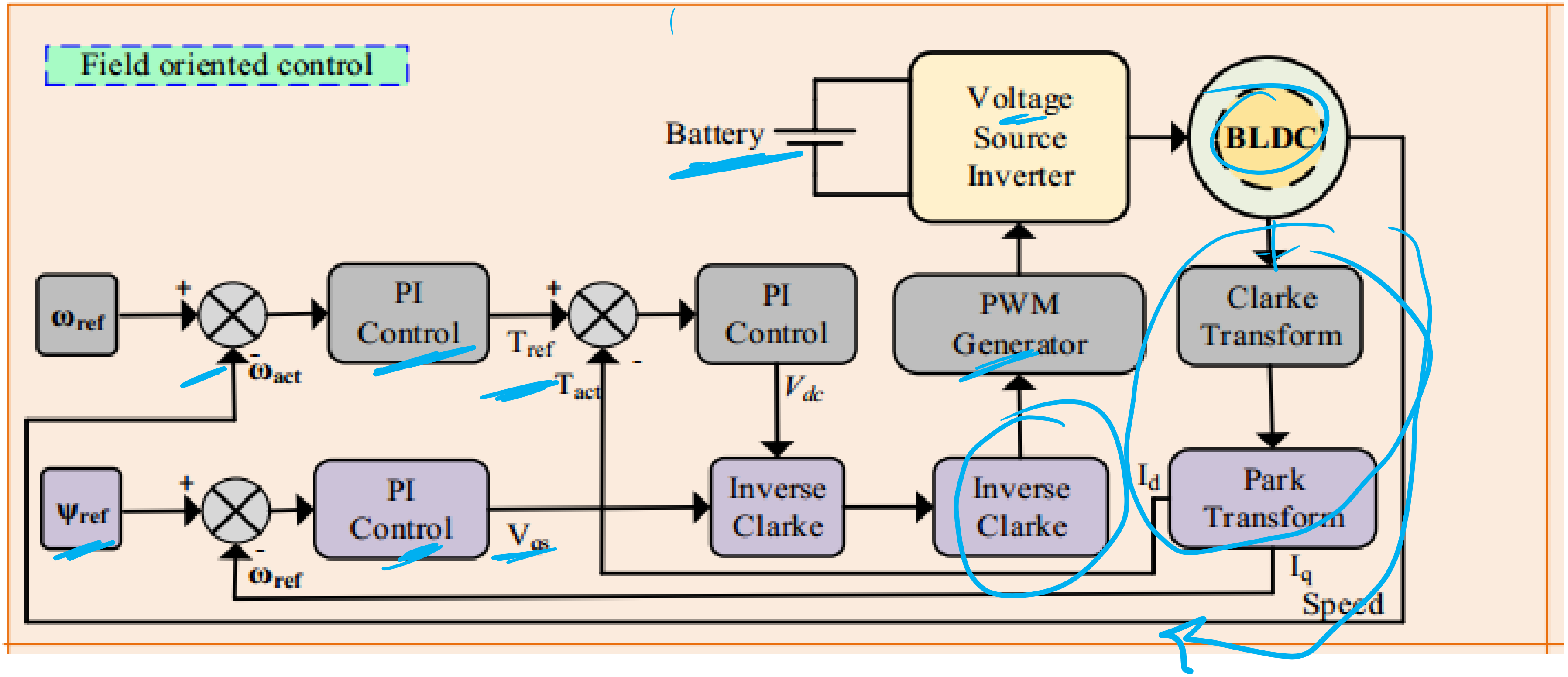
Source of Torque Ripples in BLDC Motor



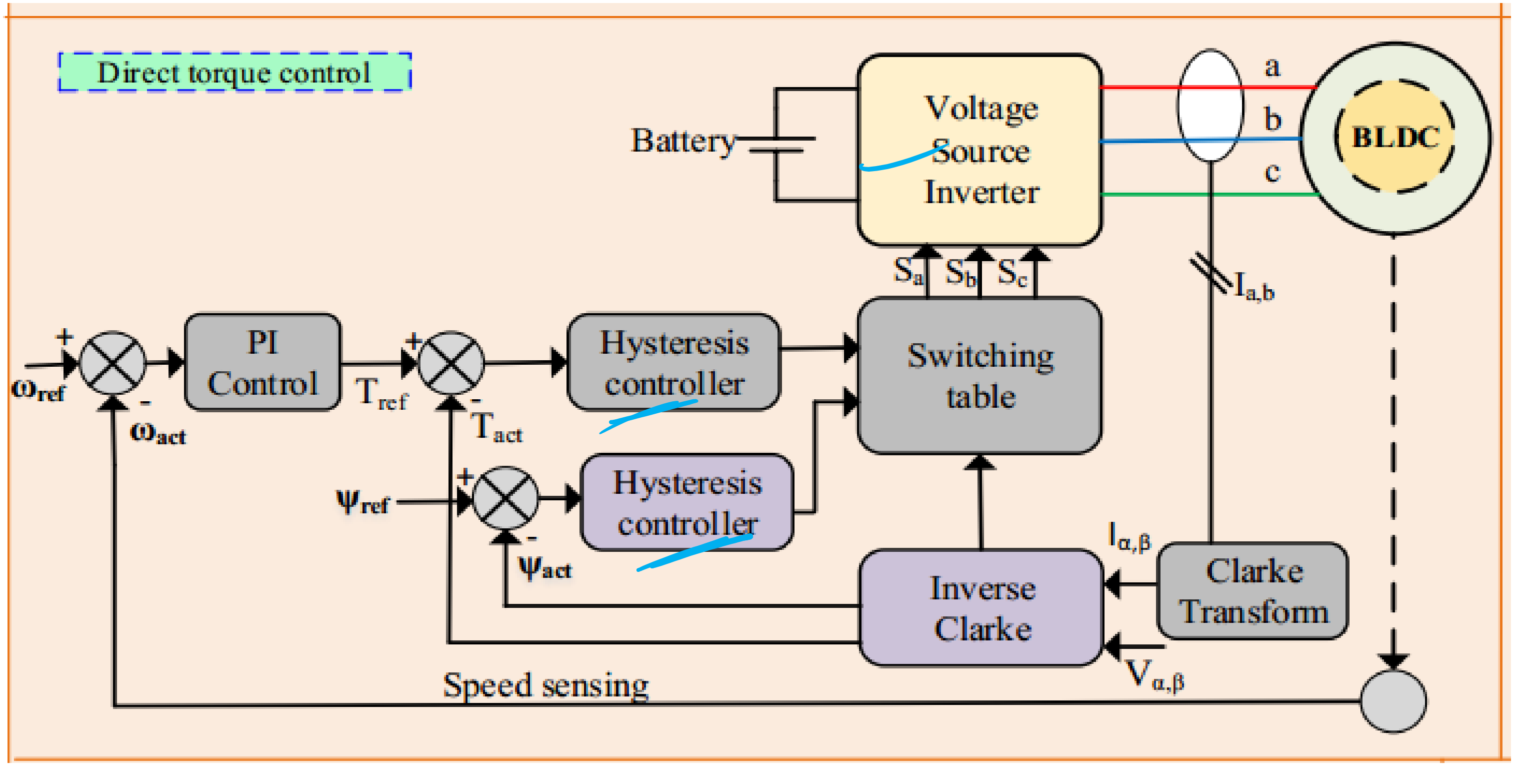
Control Techniques to Mitigate Torque Ripples of BLDC Motor

Method	Adapted techniques	Advantages	Disadvantages
Modified PWM control	• PWM chopping method. • Low-cost digital control technique.	• Higher output torque lower ripples. • Minimum cost. • Motor control hardware is complex.	• Eliminating only torque ripple caused by stator magnetic field.
DC bus voltage control	• Cascade buck converter	• Reduce torque ripples. • Harmonics using analytical computation.	• Eliminate only the commutation torque ripple.
Current control-based technique	• Repetitive current control. • Predict current commutation. • Eliminate negative DC.	• Low-cost drive strategy. • Smooth commutation.	• Commutation torque ripples. • Minimized torque ripple during low speed.
Phase conduction method	• Current overlapping method.	• Miniature motors used sensor less control for BLDC motors.	• Reducing the torque ripple components.
Model predictive control	• Estimation function using virtual vector delay time MPC-FCS.	• Good dynamic performance and robustness	• Number of subsystem parts increases.
Direct torque control	• Torque estimation with control torque by a hysteresis controller. • Active-null vector modulation strategy.	• Structure very simple. • No coordinate transformations. • No PWM generation.	• Reduce low-frequency torque ripples.
FOC control	• Flux and current in the steady-state.	• An efficient control flux and torque.	• SVPWM complex to reduce the torque ripple.
Model Adaptive control	• Fuzzy-logic controller for speed control. • Reduction of torque ripples.	• The gain of the filter is adapted to reduce torque ripple.	• High sampling rate. • Maximum precision requires high computing power. • Increasing the cost of digital controllers.
Soft computing technique	• Neuro-fuzzy observer. • Artificial neural network (ANN)	• Minimize the torque ripples using soft computing techniques.	• Complex computational algorithm. • Real-time difficult.

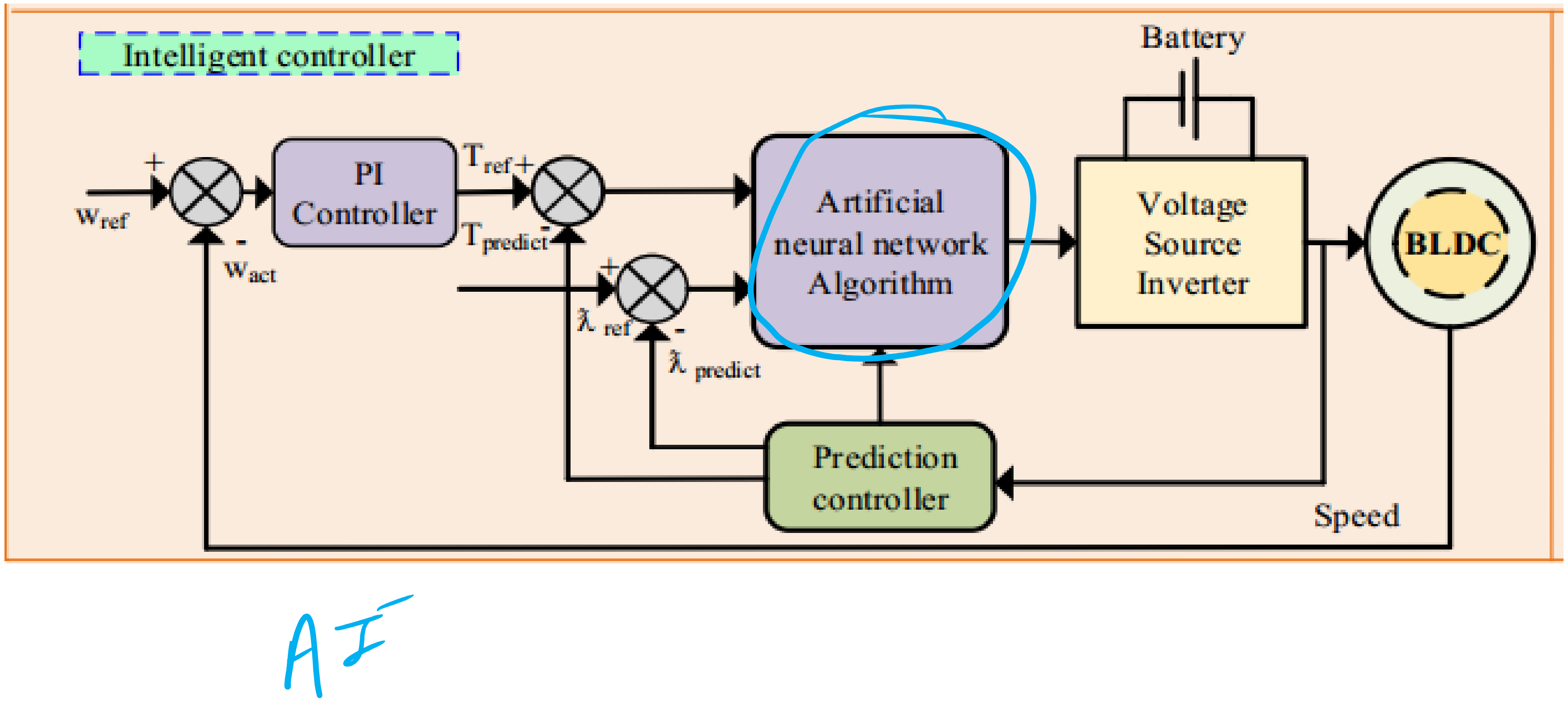
FOC Technique to Control of BLDC Motor



DTC Technique to Control of BLDC Motor



Intelligent Controller Technique to Control of BLDC Motor



Research Domain in EVs

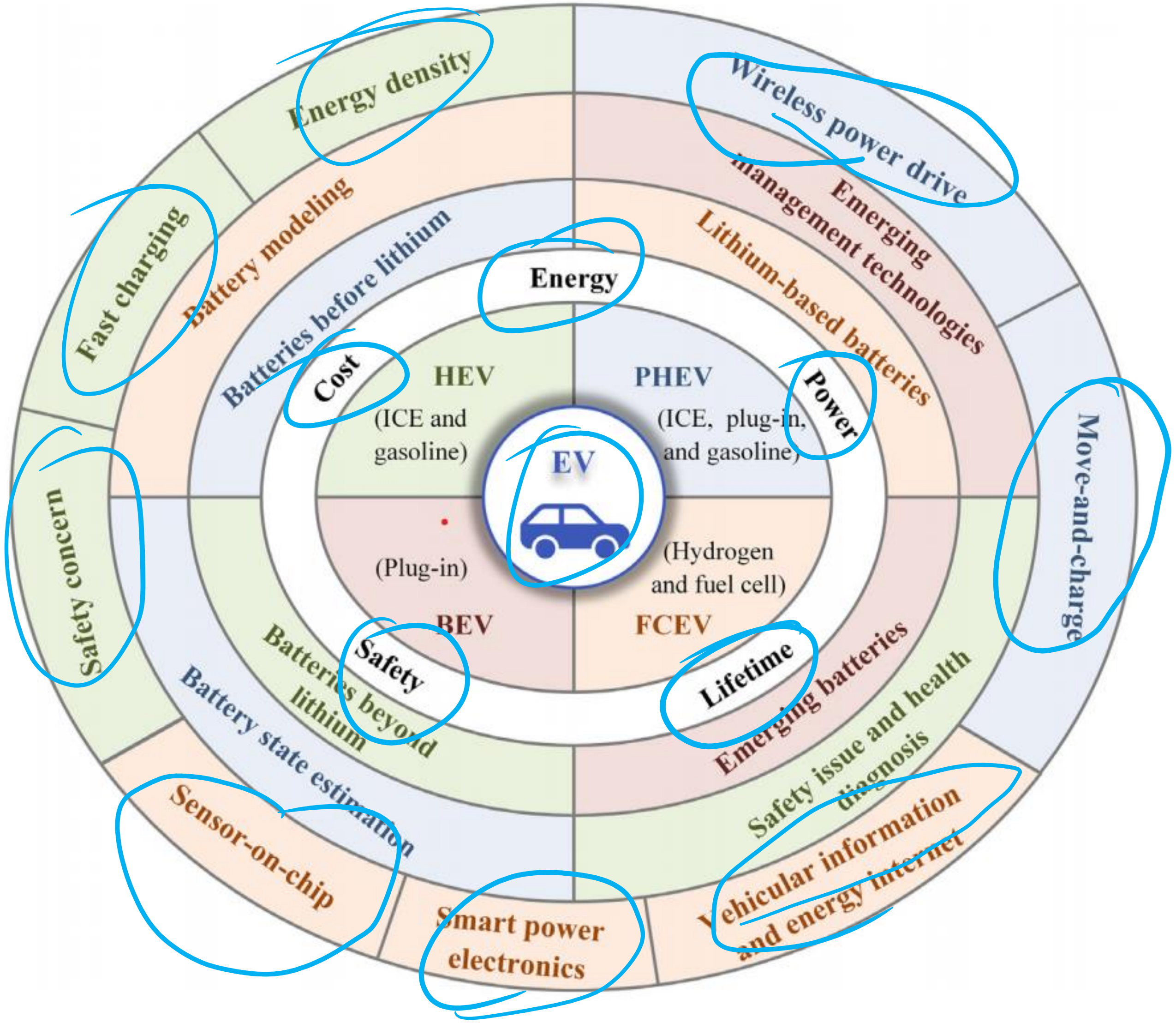


Fig. 1. Research domain in EVs.

BMS
Battery management systems

Source: W. Liu, T. Placke, and K.T. Chau, "Overview of Batteries and Battery Management for Electric Vehicles," in *Science Direct*, *Energy Report*, vol. 8, pp. 4058-4084, 2022.

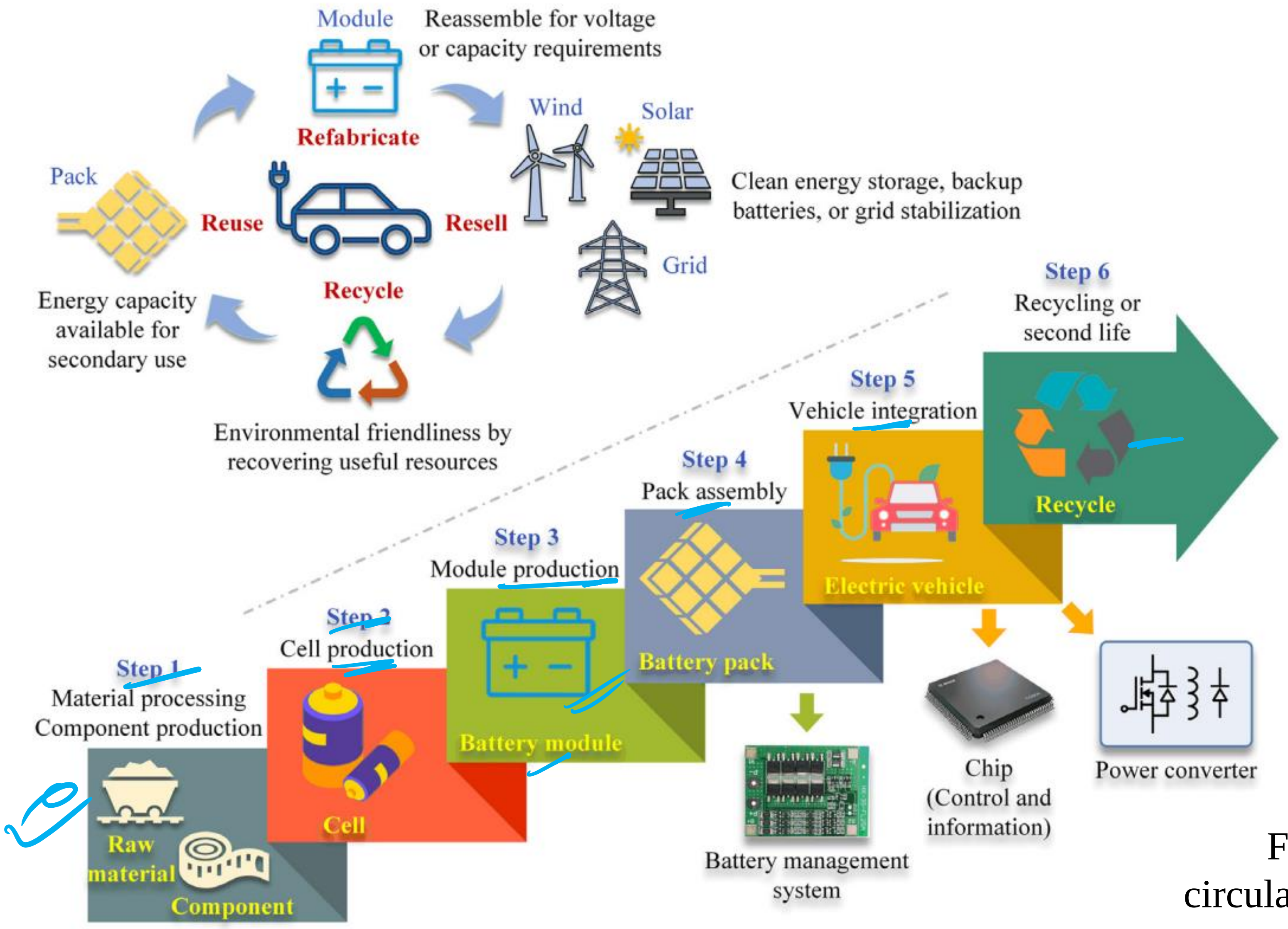


Fig. 2. Industrial value chain and circulation of rechargeable battery for EVs.

Source: W. Liu, T. Placke, and K.T. Chau, "Overview of Batteries and Battery Management for Electric Vehicles," in *Science Direct*, *Energy Report*, vol. 8, pp. 4058-4084, 2022.

Advanced Battery Management System for EVs

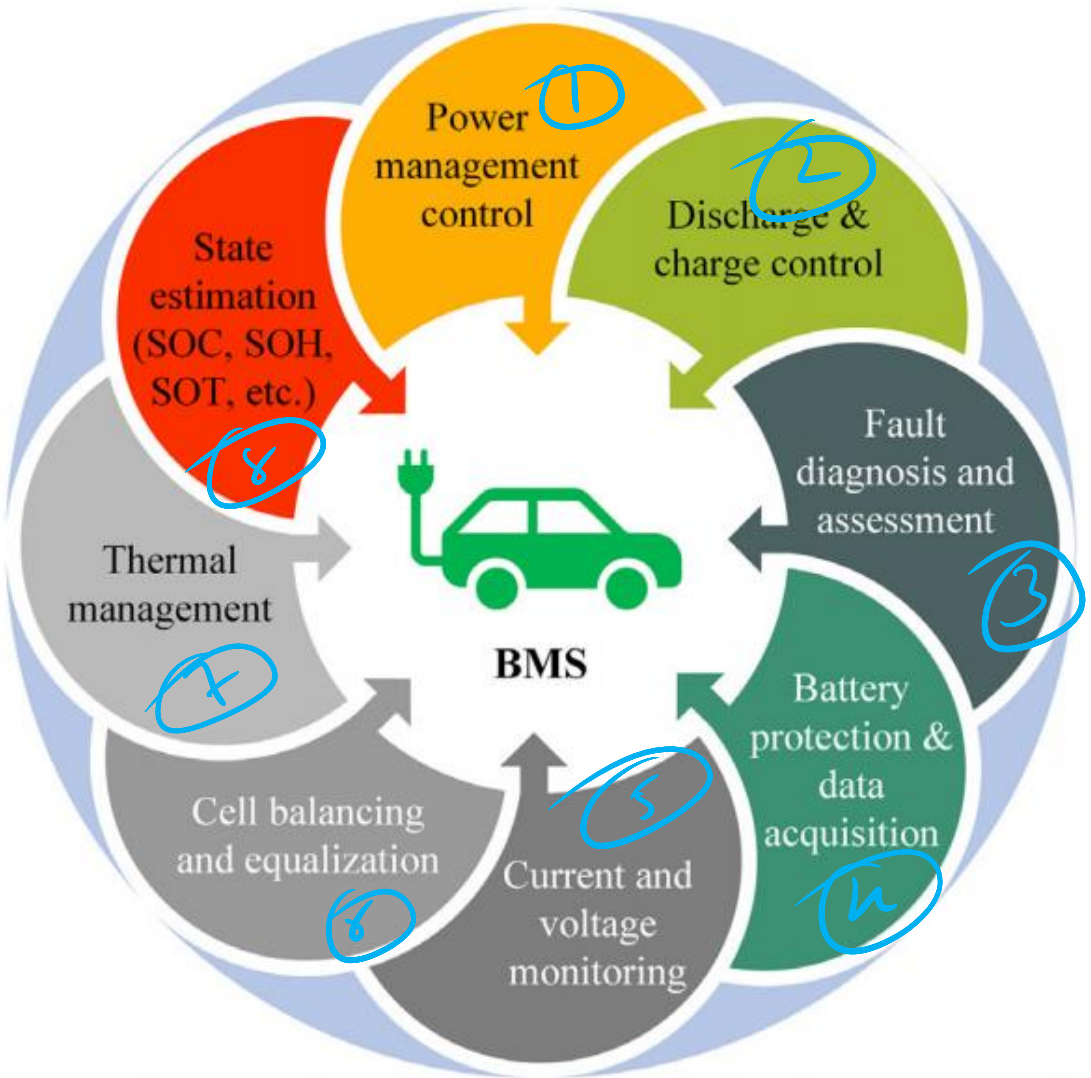


Fig. 2. Advanced Battery Management System for EVs.

Source: W. Liu, T. Placke, and K.T. Chau, “Overview of Batteries and Battery Management for Electric Vehicles,” in *Science Direct, Energy Report*, vol. 8, pp. 4058-4084, 2022.

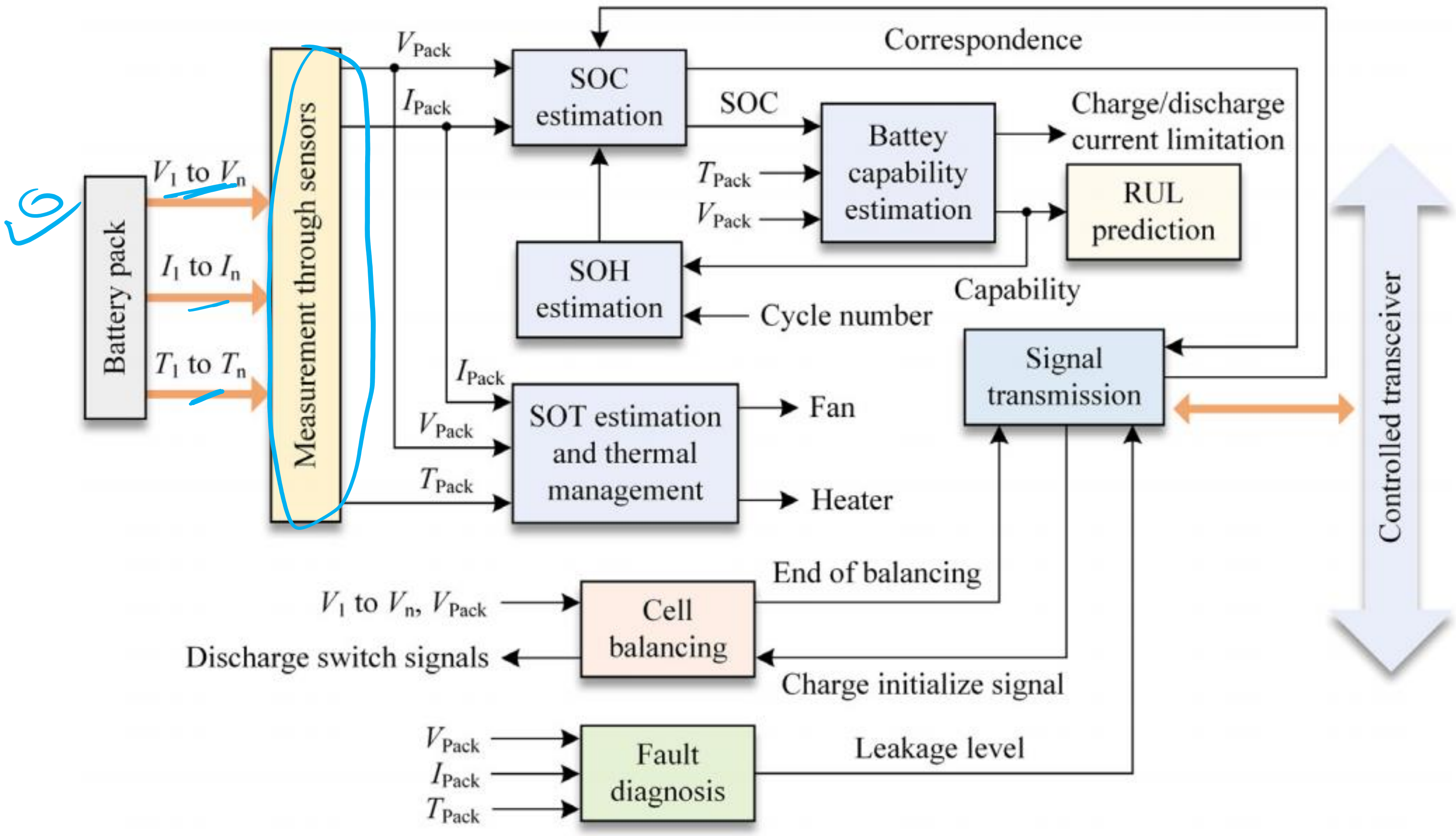


Fig. 2. Functional Block Diagram of Battery Management System for EVs.

Source: W. Liu, T. Placke, and K.T. Chau, "Overview of Batteries and Battery Management for Electric Vehicles," in *Science Direct, Energy Report*, vol. 8, pp. 4058-4084, 2022.

Key Points from Today's Class

- ❖ Power Electronics Converters
- ❖ Introduction of Electric Vehicles
- ❖ Types of Converters used in Electric Drives
- ❖ Battery Management Systems for Electric Vehicles

Key Points from Next Class

In the next class, we will be discussing on the

- Open-loop and closed-loop control techniques for electric drives
- Speed control, torque control, and position control methodologies
- Control of DC drives fed through single-phase and three-phase semi-converter

Thank you so much for your attentions

Q & A