ELECTRIC VEHICLE

DIPLOMA WALLAH

UNIT II: ELECTRIC VEHICLE DRIVES

2.1 Classification of Electric Drives Used in EV: DC Motor Drives, AC Motor Drives

Definition 💙

Electric vehicle (EV) drives refer to the electric motor systems that convert electrical energy into mechanical energy to propel the vehicle. EV drives mainly classify into two broad categories: **DC motor drives** and **AC motor drives**. DC motor drives utilize direct current to power motors like brushed and brushless DC motors, offering simple and effective speed control. AC motor drives use alternating current systems, typically employing motors such as induction motors or permanent magnet synchronous motors (PMSM), known for higher efficiency and reliability in modern EVs. The choice between DC and AC drives affects vehicle efficiency, cost, maintenance, and performance.

Explanation (8 key points)

1. EV drives convert electrical energy to mechanical rotation for vehicle motion.
2. DC motor drives run on direct current and include brushed and brushless types.
3. AC motor drives use alternating current with motors like IM and PMSM.
4. DC motors offer simple controller designs with easy speed control.
5. AC motors provide better efficiency at higher speeds and lower maintenance.
6. AC drives are prevalent in modern EVs for their robustness and scalability.
7. DC drives still find niche applications in low-cost or low-speed EVs.
8. The drive type selection depends on vehicle requirements including cost, efficiency, and power.

Real-Life Example

- **DC Motor Drive:** Old Electric Golf Carts and some electric scooters use brushed DC motors.
- **AC Motor Drive:** Tesla Model S uses AC induction motors; Nissan Leaf uses PMSM AC motors.

Working / Operation 💚

1. Power source supplies electricity from battery.
2. Motor controller converts DC battery power to DC or AC power depending on motor type.
3. For DC motors, direct current drives the motor's rotor via brushes or inverter.
4. For AC motors, inverter creates AC waveforms feeding motor coils.
5. Motor produces torque based on electromagnetic principles.
6. Torque drives wheels causing vehicle motion.
7. Controller adjusts current or frequency to control speed and torque.
8. Feedback systems optimize drive efficiency and safety.

Applications 🔴

- Electric scooters and low-speed transport vehicles (DC motor drives).
- Passenger cars and buses utilizing high-efficiency AC drives.
- Hybrid electric vehicles combining both drive types.
- Industrial electric vehicles like forklifts.
- Automated guided vehicles in factories.

Advantages

- DC drives: simple, low initial cost, easy speed control.
- AC drives: higher efficiency, robustness, better high-speed performance.
- Improved vehicle range with efficient drive selection.
- Electric regenerative braking compatible.
- Lower maintenance for AC drives.
- Flexible integration with modern electronics.

Disadvantages

- DC drives: brush wear, higher maintenance.
- AC drives: complex controller and higher cost.
- DC drives less efficient at high speeds.
- AC drives require advanced power electronics.
- Cooling requirements for high-power motors.

- Initial investment for sophisticated AC drive systems.

Flowchart / Working Diagram

text

[Battery] --> [Controller (DC or Inverter AC)] --> [DC or AC Motor] --> [Wheels]

Common Errors or Misconceptions

- All EVs use only AC motors (false; DC used in many low-cost vehicles).
- AC motors are always better regardless of cost and application.

Keywords Box

- DC Motor
- AC Motor
- Motor Controller
- Inverter
- Regenerative Braking

Summary (Hinglish)

Electric Vehicle drives basically do electric se gaadi chalate hain. Do pramukh type hain — DC motor drives jo direct current use karte hain, aur AC motor drives jo alternating current mein chalti hain. DC drives simple aur saste hote hain par zyada maintenance chahiye. AC drives efficient aur zyada power dene wale hote hain, isliye modern EVs mein popular hain. Dono ka apna use aur faayde hain.

2.2 Motor Types in EV: Brushed DC, Brushless DC (BLDC), PMSM, Induction Motor (IM), Synchronous Reluctance Motor (SynRM), PM Assisted SynRM, Axial Flux Ironless PM Motor

Definition 💙

EV motors are critical components converting electrical energy to mechanical torque. Different motor types optimized for EV use include:

- **Brushed DC Motor:** Classic motor with brushes for commutation.
- **Brushless DC Motor (BLDC):** Uses electronic commutation; compact and efficient.
- **Permanent Magnet Synchronous Motor (PMSM):** Uses permanent magnets for high efficiency and performance.
- **Induction Motor (IM):** Robust AC motor without permanent magnets.

- **Synchronous Reluctance Motor (SynRM):** Uses variable reluctance for torque.
- **PM Assisted SynRM:** Combines PMSM and SynRM benefits.
- **Axial Flux Ironless PM Motor:** Innovative flat design with high power/weight.
  Each type has unique characteristics suited for different EV requirements.

Explanation (8 key points)

1. Brushed DC motors are simple but wear brushes and need maintenance.
2. BLDC motors eliminate brushes offering longer life and better efficiency.
3. PMSM motors have permanent magnets offering high torque and efficiency.
4. Induction motors widely used for robustness and moderate cost.
5. SynRM motors provide efficient torque with no magnets.
6. PM Assisted SynRM combine advantages of PMSM and SynRM.
7. Axial flux motors are compact and have high power density but costly.
8. Motors chosen based on performance, cost, efficiency, and application.

Real-Life Example

- Brushed DC: Early golf carts.
- BLDC: Electric bikes and scooters (e.g., Goenka Electric Motors).
- PMSM: Tesla Model 3, Toyota Prius.
- Induction Motor: Tesla Model S.
- SynRM and PM Assisted models emerging in advanced EVs.
- Axial Flux Motors in luxury EV or in-wheel applications.

Working / Operation 💚

1. Electrical input energizes stator coils.
2. Magnetic fields interact with rotor magnets or windings.
3. Motor produces torque to rotate shaft.
4. Electronic controller manages commutation in BLDC and PMSM.
5. Induction motor rotor induced by stator magnetic field.
6. SynRM rotor aligns with minimum reluctance path.
7. Axial flux motor's disc-shaped magnets produce torque along axis.

8. Feedback keeps speed and torque optimized.

Applications 🔴

- Brushed DC: Low-cost applications.
- BLDC: Scooters, three-wheelers.
- PMSM: Passenger cars, buses.
- Induction Motors: High performance EVs.
- SynRM & PM Assisted: Emerging in efficient mid/high-range EVs.
- Axial Flux: High power density needs, premium EV models.

Advantages

- Brushed DC: Simple control and low cost.
- BLDC: Low maintenance, good efficiency.
- PMSM: High torque, high efficiency.
- Induction: Robust, cost-effective.
- SynRM: No magnets cost, durable.
- Axial Flux: Better power-to-weight.

Disadvantages

- Brushed DC: Brush wear, high maintenance.
- BLDC: Higher cost due to magnets.
- PMSM: Expensive magnets and lower high-speed efficiency.
- Induction: Lower efficiency than PMSM.
- SynRM: Complex control.
- Axial Flux: Manufacturing complexity and cost.

Flowchart / Working Diagram

text

[Power Supply] --> [Controller] --> [Motor (BLDC/PMSM/IM etc.)] --> [Vehicle Wheels]

Common Errors or Misconceptions

- BLDC and PMSM are same (No, PMSM uses sinusoidal back-EMF; BLDC uses trapezoidal).
- Induction motors require permanent magnets (No, use induced current).

Keywords Box

- BLDC
- PMSM
- Induction Motor
- SynRM
- Axial Flux

Summary (Hinglish)

Electric vehicles mein alag alag motor types hote hain jinke advantages aur limitations hote hain. Brushed DC purana aur maintenance wala type hai, jabki BLDC brushless aur efficient hai. PMSM sabse popular high performance EVs mein use hota hai, induction motor bhi robuste aur cost-effective hai. SynRM aur axial flux naye aur high-tech motors hain jo future mein zyada chalenge.

2.3 Comparison of EV Motors

Definition 💙

EV motors differ significantly in power to weight ratio, torque-speed characteristics, and costs of motors and controllers. These comparisons guide manufacturers and engineers to select the optimal motor suited for specific vehicle performance, size, and budget. Power-weight ratio indicates motor performance relative to its mass. Torque-speed curves reveal motor behavior across speed ranges. Controller costs vary with motor complexity and power requirements, impacting overall vehicle cost.

Explanation (8 key points)

1. Power-weight ratio measures power output per unit motor mass.
2. Higher power-weight ratio is desirable for performance and compactness.
3. Torque-speed characteristic curve shows torque availability over speed range.
4. Some motors provide high starting torque, others better efficiency at cruising.
5. Cost of motors varies with technology, materials (magnets, copper, steel).
6. Controllers for PMSM and BLDC tend to cost more than for brushed DC.
7. Induction motors have moderate cost for motor and controller.
8. Selection balances performance requirements with cost targets.

Real-Life Example

- Tesla Model S motors are known for excellent power-to-weight ratios and torque at high speeds.
- Low-cost electric scooters use brushed DC motors with simple controllers.

Working / Operation 💚

Comparison based on standardized motor ratings and performance tests under similar load conditions.

Applications 🔴

- High performance EVs prioritize power-weight and torque.
- Economy EVs emphasize lower motor/controller cost.
- Commercial EVs may trade some efficiency for durability.
- Motor choice impacts battery size and vehicle weight.

Advantages

- Helps optimize vehicle design.
- Facilitates cost-effective motor selection.
- Improves driving dynamics.
- Reduces vehicle weight.
- Enhances energy efficiency.

Disadvantages

- Overemphasis on power-weight may ignore reliability.
- High-cost motors/controllers may inflate vehicle price.
- Complex trade-offs may confuse manufacturers.
- Performance curves may differ in real world.
- Data availability may be limited.

Common Errors or Misconceptions

- Higher power-weight always means better motor (depends also on durability).

Keywords Box

- Power-to-weight ratio
- Torque-speed curve
- Motor cost

- Controller cost
- Efficiency

Summary (Hinglish)

Motor ka selection power, weight, torque aur cost ke hisaab se hota hai. High performance EVs mein lightweight aur high power motor lagti hai, jabki budget model mein simple aur sasta motor hota hai. Torque aur speed curves ek important factor hain motor selection ke liye.

2.4 Physical Location, Rating, Connections, and Selection Criteria of EV Motors

Definition 💙

The physical location of EV motors varies depending on vehicle design — motors can be mounted on the chassis, at the wheels (in-wheel motors), or integrated with the transmission system. Ratings like voltage, power, torque, and speed define motor capabilities. Mechanical and electrical connections must suit the motor type and vehicle layout. Proper selection criteria consider range, torque requirements, cost, size, efficiency, and durability to match the EV's intended use.

Explanation (8 key points)

1. Motors can be chassis-mounted, in-wheel, or integrated into drivetrain.
2. In-wheel motors reduce transmission losses but add unsprung mass.
3. Motor ratings include voltage, power output (kW), max torque (Nm), and speed (rpm).
4. Electrical connections vary: DC motors require DC supply; AC motors need inverters.
5. Mechanical connections link motor shaft to wheels directly or via gears.
6. Selection depends on vehicle type (car, bike, bus), desired speed, and load.
7. Size and weight constraints influence motor placement.
8. Cooling, maintenance access, and safety considerations impact installation.

Real-Life Example

- Tesla Model S uses dual AC motors integrated into vehicle chassis.
- Electric scooters often have in-wheel BLDC motors.

Working / Operation 💚

Motor placement affects torque delivery efficiency and vehicle dynamics. Ratings ensure motor can meet power and torque demands without overheating.

Applications 🔴

- Personal electric cars, bikes, and commercial electric buses.
- Industrial EVs requiring robust motor mounting.
- EVs using in-wheel motors for independent wheel control.

Advantages

- Proper placement optimizes performance and vehicle handling.
- Accurate rating ensures reliability and battery optimization.
- Correct connections reduce losses and improve control.
- Selection criteria ensure vehicle meets use-case demands.
- Facilitates maintenance and safety.

Disadvantages

- In-wheel motors add unsprung weight affecting ride.
- Large motors need space and cooling.
- Complex connections increase cost and failure points.
- Poor selection leads to inefficient performance.

Flowchart / Working Diagram

text

[Battery] --> [Controller] --> [Motor (placed in chassis/in-wheel)] --> [Wheel]

Common Errors or Misconceptions

- In-wheel motors are always better (unsprung weight affects ride quality).

Keywords Box

- Motor location
- Motor rating
- Mechanical connection
- Electrical connection
- Selection criteria

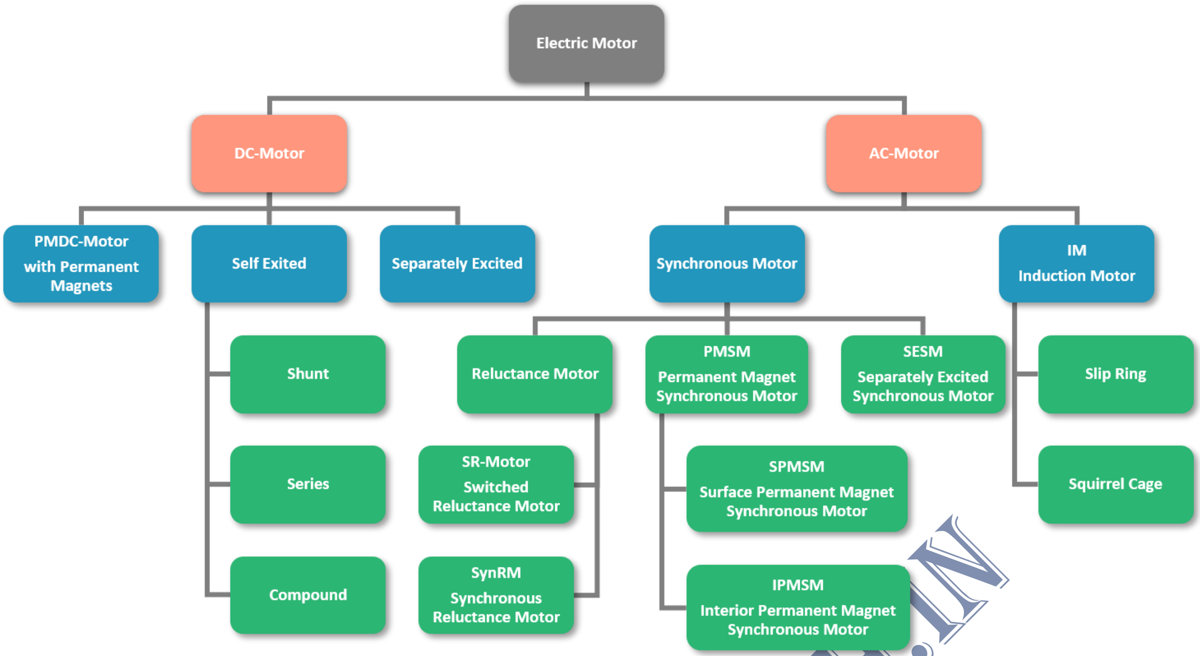
Summary (Hinglish)

EV motor ki jagah alag alag ho sakti hai—chassis mein ya wheel ke andar. Motor ki rating power aur torque batati hai. Connection aur placement sahi hona chahiye jisse gaadi smooth chale. Selection mein motor ki efficiency, weight, aur cost dhyan mein rakhte hain.

Mini Review Questions

1. Name the main types of electric drives used in EVs.
2. What are the advantages of PMSM motors compared to Induction motors?
3. How does motor placement affect EV performance?

1. https://ijret.org/volumes/2017v06/i09/IJRET20170609004.pdf
2. https://bilitielectric.com/blog/types-of-motors-in-electric-vehicles/
3. https://www.fukuta-motor.com.tw/en/news_i/K06/N2024060700001
4. https://ennovi.com/types-of-electric-motors-for-evs/
5. https://ijsra.net/sites/default/files/IJSRA-2023-1074.pdf
6. https://circuitdigest.com/article/different-types-of-motors-used-in-electric-vehicles-ev
7. https://www.youtube.com/watch?v=Bu3p2uf74r8
8. https://rgnpublications.com/ICACTCE2021/manuscripts/080-189.pdf
9. https://journal.esrgroups.org/jes/article/download/4522/3325/8206
10. https://e-amrit.niti.gov.in/types-of-electric-vehicles



Type of EV	Components	Emissions	Battery capacity	Examples
Battery electric vehicle (BEV)	Electric motor and rechargeable battery pack	Zero	30–200 kWh	MG ZS, TATA Nexon, Tigor, Mahindra E20 Plus, Hyundai Kona, Mahindra Verito
Fuel cell electric vehicle (FCEV)	Electric motor, fuel-cell stack, hydrogen storage tank, battery with converter	Zero	-	Toyota Mirai, Hyundai Tucson FCEV, Honda Clarity Fuel Cell, Hyundai Nexo
Mild hybrid electric vehicle (MHEV)	Internal combustion engine, electric motor, battery pack	More than PHEV	1–2 kWh	Maruti Suzuki Ertiga, XL6, Ciaz, S-Cross, Brezza, Mercedes Benz C – Class, Jaguar F-PACE
Full hybrid electric vehicle (FHEV)	Internal combustion engine, electric motor, battery pack	More than PHEV	8 kWh	Maruti Grand Vitara, Honda City (Hybrid), Civic (Hybrid), Toyota Hyryder, Camry, Lexus Hybrid Range
Plug-in hybrid electric vehicle (PHEV)	Internal combustion engine, electric motor, rechargeable battery pack	Less than MHEV, FHEV	15 kWh	Porsche Cayenne S E-Hybrid, BMW 330e, Mercedes C350e, S550e, GLE550e, BMW i8, X5 xdrive40e, Hyundai Sonata, Volvo XC90 T8

2021 MAKE & MODEL	TYPE OF VEHICLE	EQUIVALENT MILES PER GALLON
Ford F150	Gasoline Pickup Truck	20 MPG
Jeep Wrangler 4xe	Plug-in Hybrid SUV	29 MPGe
Subaru Crosstrek AWD PHEV	Plug-In Hybrid SUV	48 MPGe
Toyota Prius	Gasoline Hybrid Hatchback	52 MPG
Toyota Prius Prime	Plug-in Hybrid Hatchback	82 MPGe
Nissan Leaf (62 kWh)	All-Electric Hatchback	125 MPGe
Hyundai Kona Electric	All-Electric Crossover SUV	138 MPGe
Tesla Model 3 Long Range AWD	All-Electric Sedan	155 MPGe

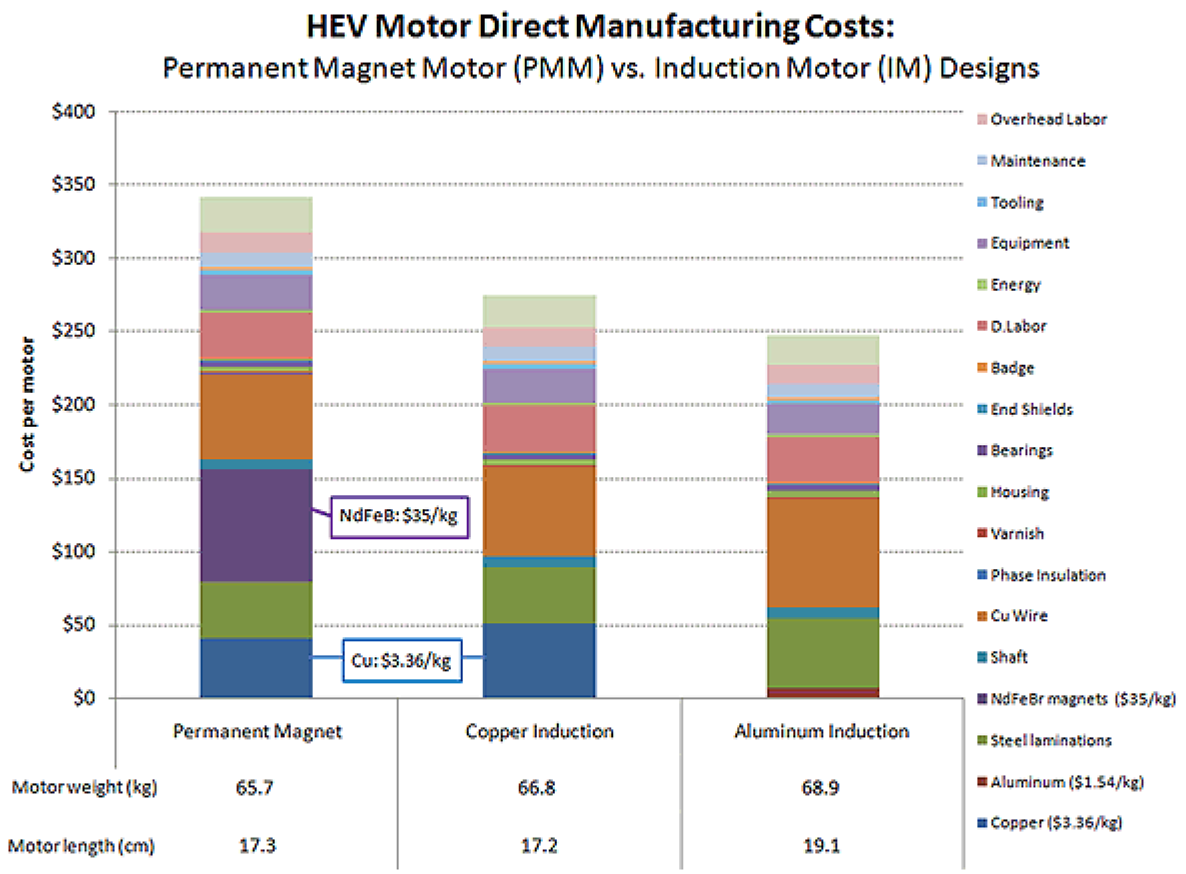
MOTORS				
	DC	AC	BRUSHLESS	UNIVERSAL
VOLTAGE	DC 12V 24V 90V 115V FWR 130V 180V	AC 115V 1 ph 230V 1 ph 230V 3 ph 50 and 60 Hz	AC/DC with control 24V 165/115V	AC/DC 12-240V
SPEED	350 - 6,000 rpm	1,200 - 3,400 rpm	2,300 - 3,800 rpm	8,000 - 20,000+ rpm
POWER	0.01 - 0.52 hp	0.01 - 1.11 hp	0.08 - 0.43 hp	up to 2.5 hp
TORQUE	0.6 - 13.5 in-lb	0.07 - 23.1 in-lb	1.6 - 10.8 in-lb	varies
EFFICIENCY	60-70%	40-80%	65-80%	55-70%
LOW NOISE	●●●●○	●●●●○	●●●●●	●○○○○
LOW MAINTENANCE	●●●○○	●●●●●	●●●●●	●●○○○
LIFE	●●●○○	●●●●●	●●●●●	●●○○○
SPEED REGULATION	●●●○○	●●●●○	●●●●●	●○○○○

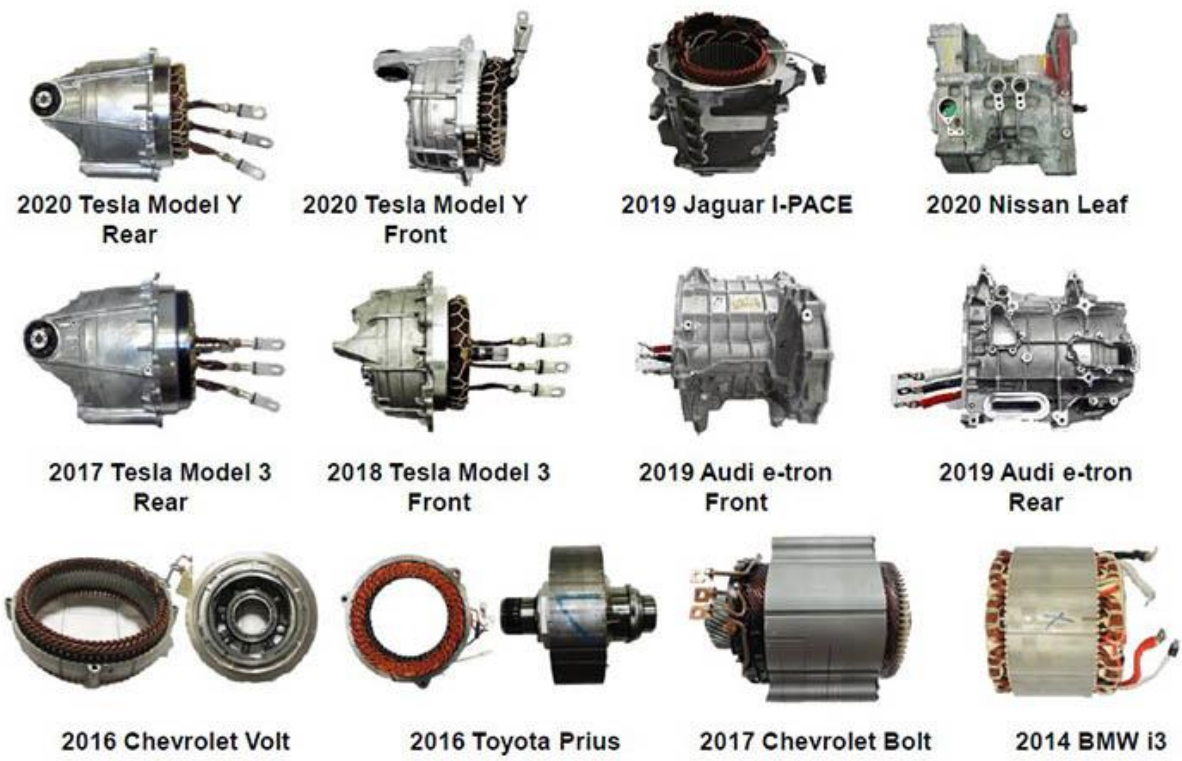
GEAR MOTORS				
	PARALLEL SHAFT	PLANETARY	RIGHT ANGLE	RIGHT ANGLE PLANETARY
GEARS	spur and helical	spur and helical	worm	spur and bevel
MAX INPUT SPEED	4000 rpm	4000 rpm	2800 rpm	3500 rpm
MAX OUTPUT TORQUE	322 in-lb	1062 in-lb	708 in-lb	885 in-lb
MAX EFFICIENCY	90%	95%	80%	90%
BACK DRIVABILITY	yes	yes	yes (below 30:1 ratio)	yes
GEAR RATIOS	5:1 - 320:1	5:1 - 1000:1	5:1 - 100:1	5:1 - 1000:1

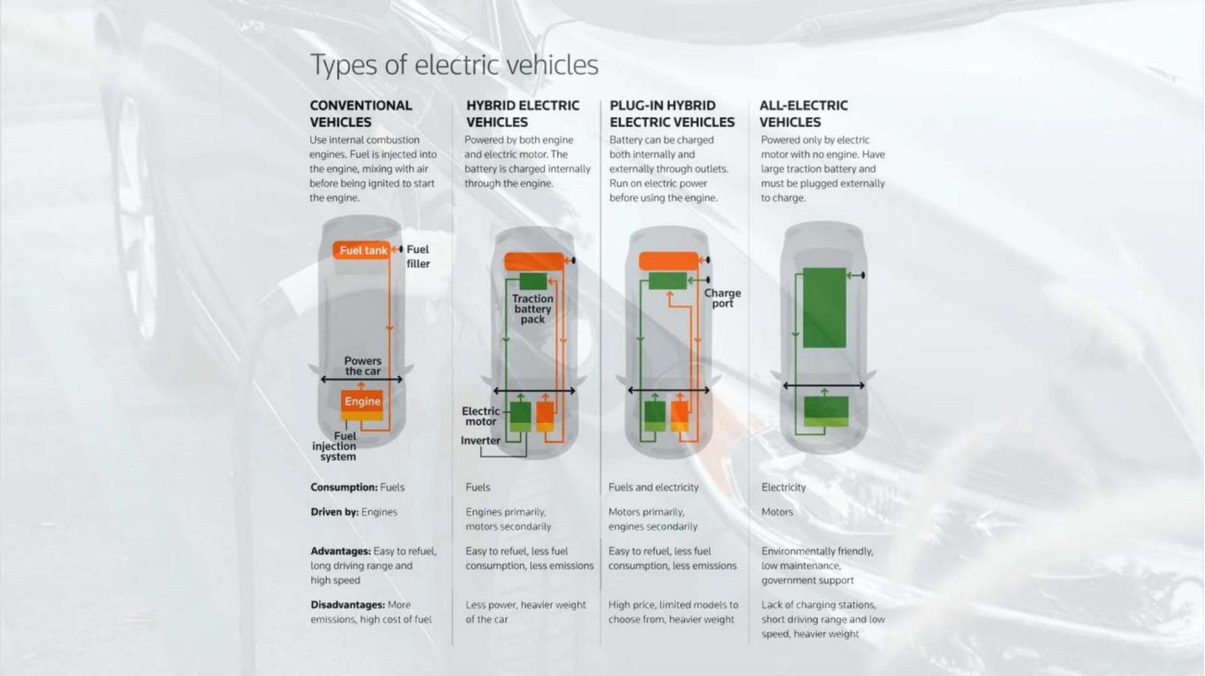
*Numbers based on optimal gear life at continuous duty

AC CONTROLS										
9 DIGIT NUMBER	AC LINE INPUT			FUSE OR CIRCUIT BREAKER RATING (A)	DRIVE OUTPUT					ENCLOSURES
	VOLTAGE (V) 50/60 HZ	PHASE (Ø)	MAXIMUM CURRENT (A)		VOLTAGE RANGE (V)	PHASE (Ø)	MAX. CONT. LOAD CURRENT (RMS A/Ø)	MAX. POWER		
								HP	KW	
750-10-0000	115	1	9.6	15	0-230	3	2.4	1/2	0.37	CHASSIS
	208/230		6.0	10						
750-10-0001	115	1	14.0	20	0-230	3	4.0	1	0.75	CHASSIS
	208/230		10.0	15						
750-10-0002	115	1	14.4	20	0-208/230	3	3.6	1	0.75	NEMA 4X
	208/230		8.1	15						
750-10-0003	115	1	4.0	5	0-230	3	1.0	1/10	0.07	CHASSIS
	208/230		2.5	5						
750-10-0004	115	1	4.0	5	0-230	3	1.0	1/10	0.07	IP50
	208/230		2.5	5						
750-10-0005	115	1	8.8	15	0-230	3	2.2	1/2	0.37	IP20
	208/230		6.0	10			2.4			

BLDC CONTROLS												
9 DIGIT NUMBER	POWER				SPEED CONTROL				FEATURES			ENCLOSURE TYPE
	VOLTAGE (V)		CURRENT (A)		CLOSED LOOP	SPEED POT.	DC SIGNAL	DIGITAL CONTROL	ACCEL. / DECEL.	BRAKE	INHIBIT	
	AC	DC	CONT.	PEAK								
750-30-0002	–	12-48	7.5	11.3	X	X	0-5V	–	X	X	X	CHASSIS
750-30-0003	–	12-48	7.5	11.3	X	X	0-5V	–	X	X	X	NEMA 4X
750-30-0004	–	12-48	20.0	40.0	X	X	0-6.25V	–	–	–	–	CHASSIS
750-30-0005	–	12-48	20.0	40.0	X	X	0-6.25V	–	–	–	–	NEMA 4X
750-30-0006	–	12-48	8.0	12.0	X	–	–	X	X	X	X	NEMA 4X


HEV Motor Direct Manufacturing Costs:
Permanent Magnet Motor (PMM) vs. Induction Motor (IM) Designs
Cost per motor
$400
$350
$300
$250
$200
$150
$100
$50
$0
NdFeB: $35/kg
Cu: $3.36/kg
Permanent Magnet
Copper Induction
Aluminum Induction
Motor weight (kg) 65.7 66.8 68.9
Motor length (cm) 17.3 17.2 19.1
Overhead Labor
Maintenance
Tooling
Equipment
Energy
D.Labor
Badge
End Shields
Bearings
Housing
Varnish
Phase Insulation
Cu Wire
Shaft
NdFeBr magnets ($35/kg)
Steel laminations
Aluminum ($1.54/kg)
Copper ($3.36/kg)


2020 Tesla Model Y Rear
2020 Tesla Model Y Front
2019 Jaguar I-PACE
2020 Nissan Leaf
2017 Tesla Model 3 Rear
2018 Tesla Model 3 Front
2019 Audi e-tron Front
2019 Audi e-tron Rear
2016 Chevrolet Volt
2016 Toyota Prius
2017 Chevrolet Bolt
2014 BMW i3



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