INNOVATION AND EVOLUTION OF ELECTRIC VEHICLE

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2023 TESLA MODEL S

HISTORY OF THE ELECTRIC CAR [2023 UPDATE]

(Last Update on, 2023)

The history of **electric vehicles** can be divided up into six distinct periods:

- 1830-1880: The early pioneers of electric mobility
- 1880-1914: The transition to motorized transport
- 1914-1970: The rise of the internal combustion engine
- 1970-2003 The return of electric vehicles
- 2003-2020: The electric revolution
- 2021-Present day: The tipping point and beyoung beyond.

- The world's first electric vehicles (EVs) predate gasoline-powered cars, with experimental prototypes emerging in Hungary, the Netherlands, and the UK around the 1830s. The first practical EV is often considered to be American inventor William Morrison's vehicle from around 1890.
- Modern EVs emerged in the late 20th century in response to the 1973 Oil Crisis and growing climate concerns. Starting with the Toyota Prius in 1997, the 2000s marked the re-emergence and development of hybrid vehicles, building to the launch of the first mass-market EV in 2010 with the Nissan Leaf.

First Electric Vehicle 1830-1880

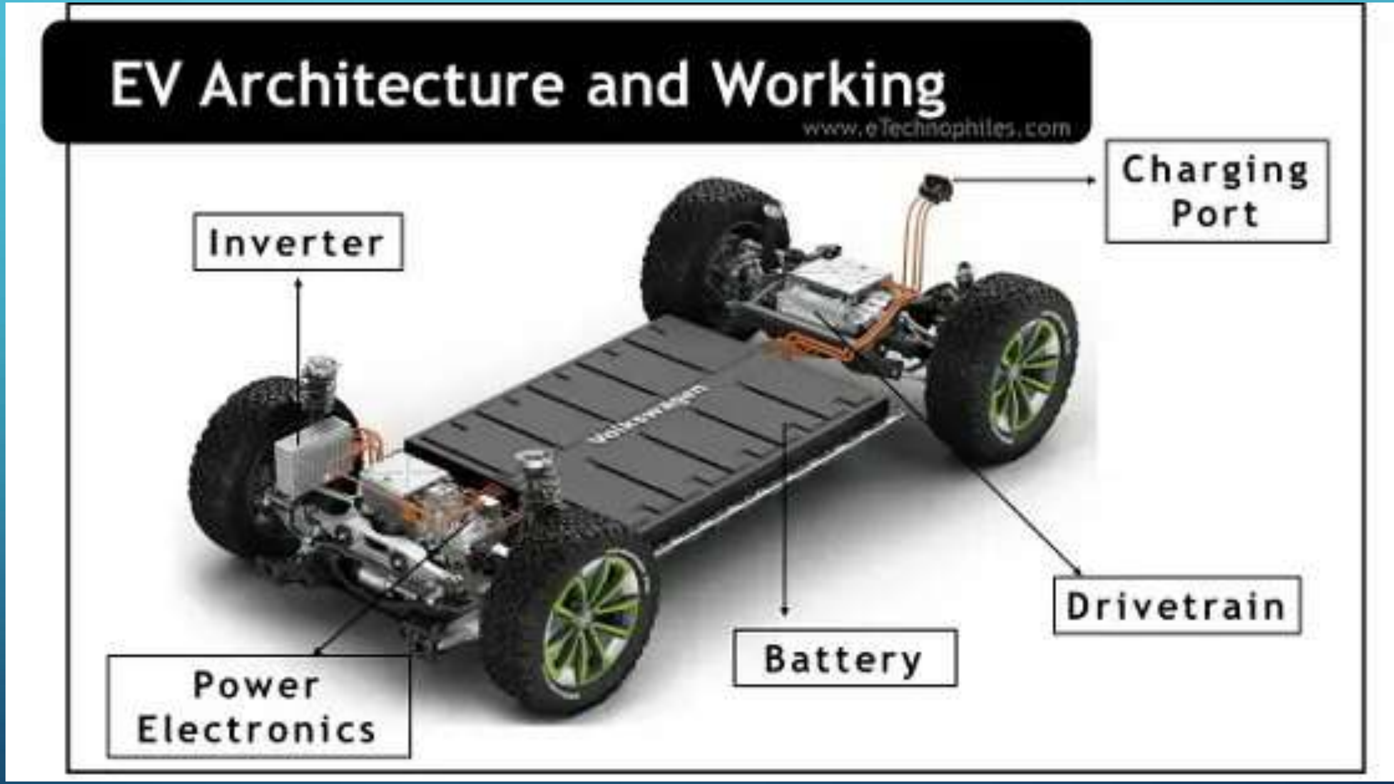
NISAN LEAF 2010 MODEL

- The rise of the internal combustion engine (1914-1970)
- The return of electric vehicles (1970-2003)
- Going electric Vehicles (2003-2023)

2023 NISSAN LEAF

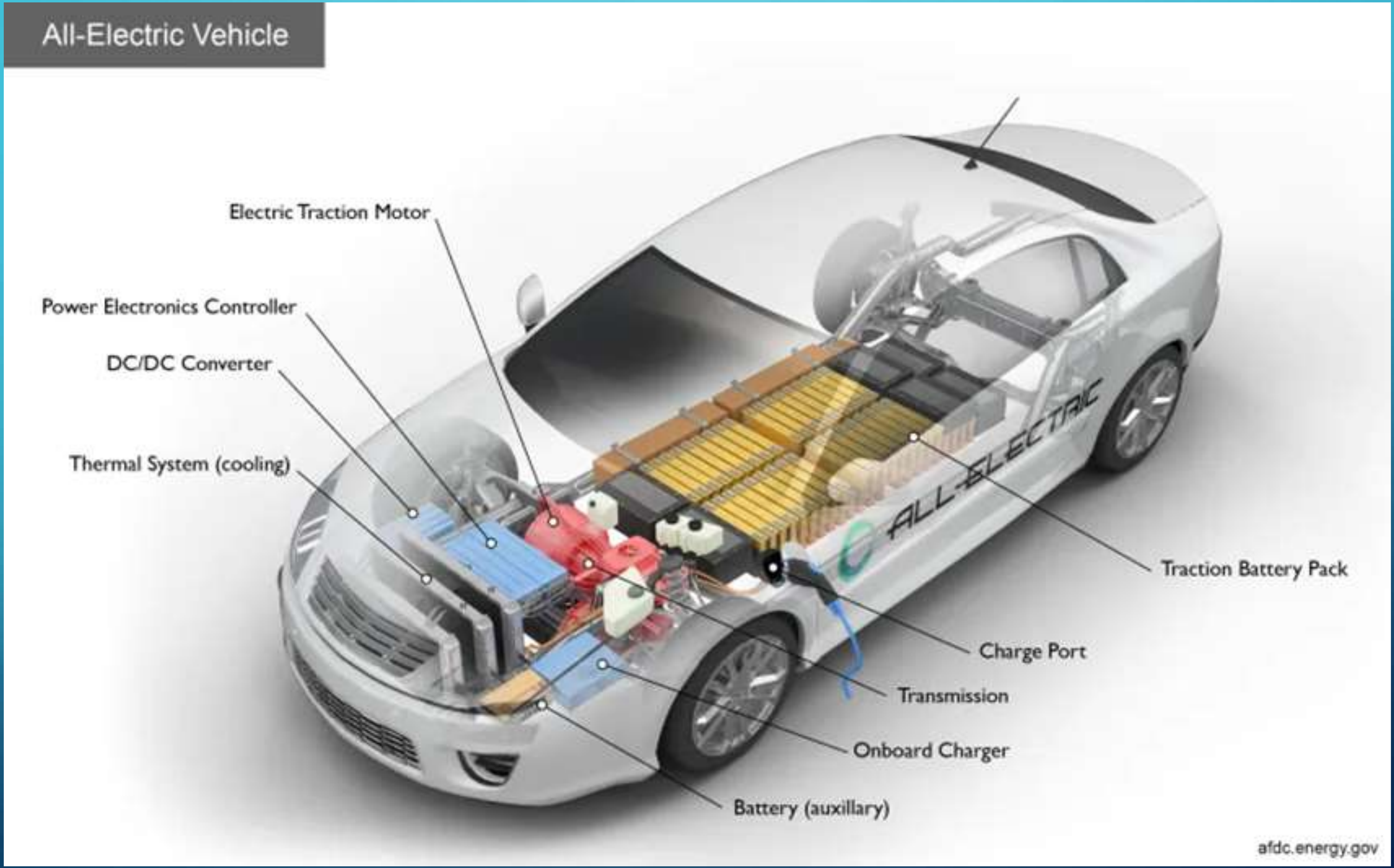
BE YOUNG THE 2023 AND FUTURE EV'S

BASIC OF ELECTRIC VEHICLE



The main components of electric vehicles are:

- Traction battery pack.
- DC-DC Converter.
- Electric motor.
- Power Train/Drive Train.
- Charging and Charge Port.
- Onboard charger.
- Controller.
- Auxiliary batteries.
- Thermal System (Cooling System)


All-Electric Vehicle
Electric Traction Motor
Power Electronics Controller
DC/DC Converter
Thermal System (cooling)
Traction Battery Pack
Charge Port
Transmission
Onboard Charger
Battery (auxillary)
ALL-ELECTRIC
afdc.energy.gov

1. TRACTION BATTERY PACK

NISSAN LEAF BATTERY PACK

GM OBINIC NIMH BATTERY MODULE

TRACTION BATTERIES FOR EV

1. Types of Traction Battery
   - Lead-acid battery
   - Nickel metal hydride battery
   - Zebra battery.
   - Lithium-ion battery

2. COMPOSITION OF TRACTION BATTERY

(A) $PbO2.\ PbO.H2O.H2SO4$.

(B) The positive electrode consists of a **nickel hydroxide/nickel oxyhydroxide ($Ni(OH)_2$/NiOOH) compound, while the negative electrode is metallic cadmium (Cd) and cadmium hydroxide ($Cd(OH)_2$)**. The electrolyte is an aqueous solution of potassium hydroxide (KOH).

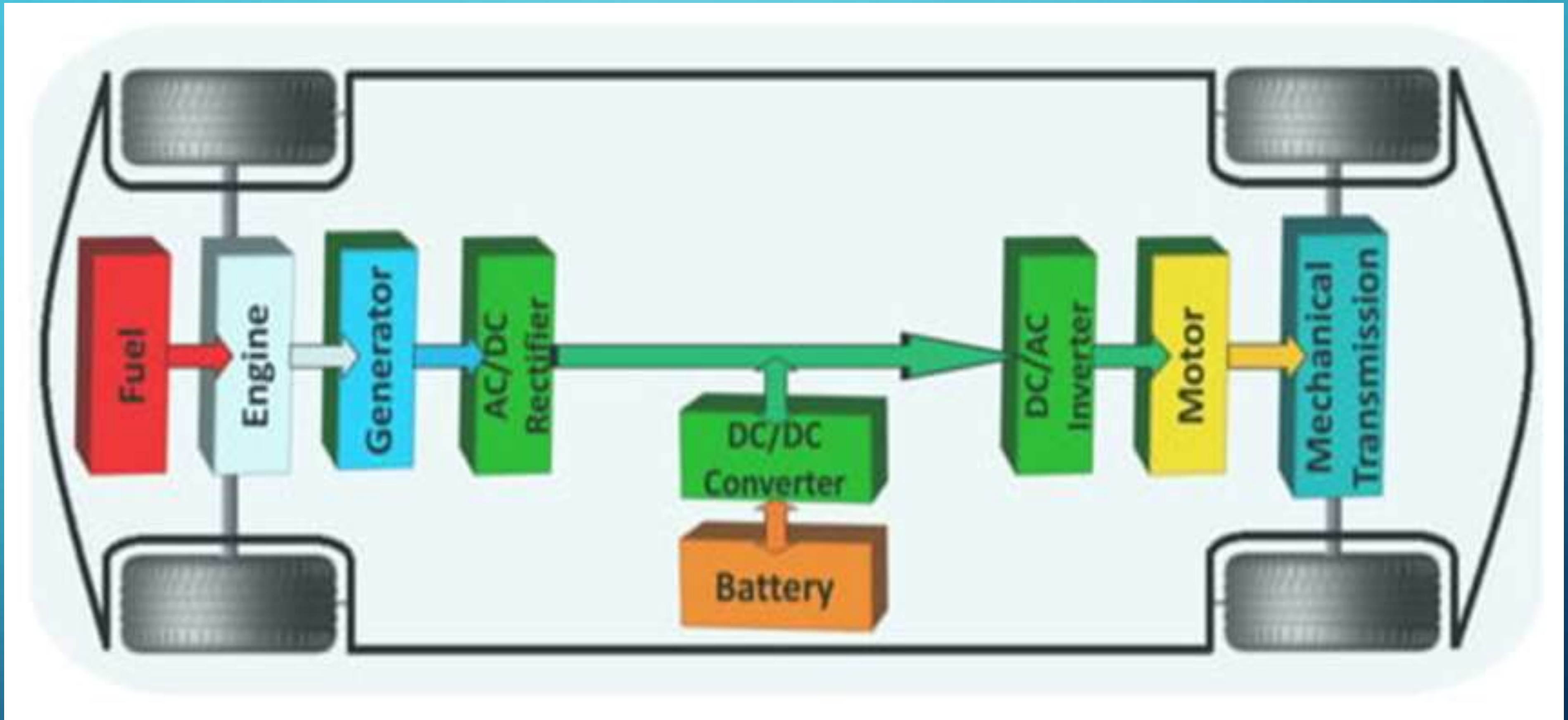
(C) Zebra battery. liquid sodium chloroaluminate (NaAlCl4)

(D) Modern electric vehicles mainly have lithium-ion and lithium polymer batteries due to the relatively higher energy density compared to weight. The major materials required in lithium-ion batteries are the chemical components **lithium, manganese, cobalt, graphite, steel, and nickel**

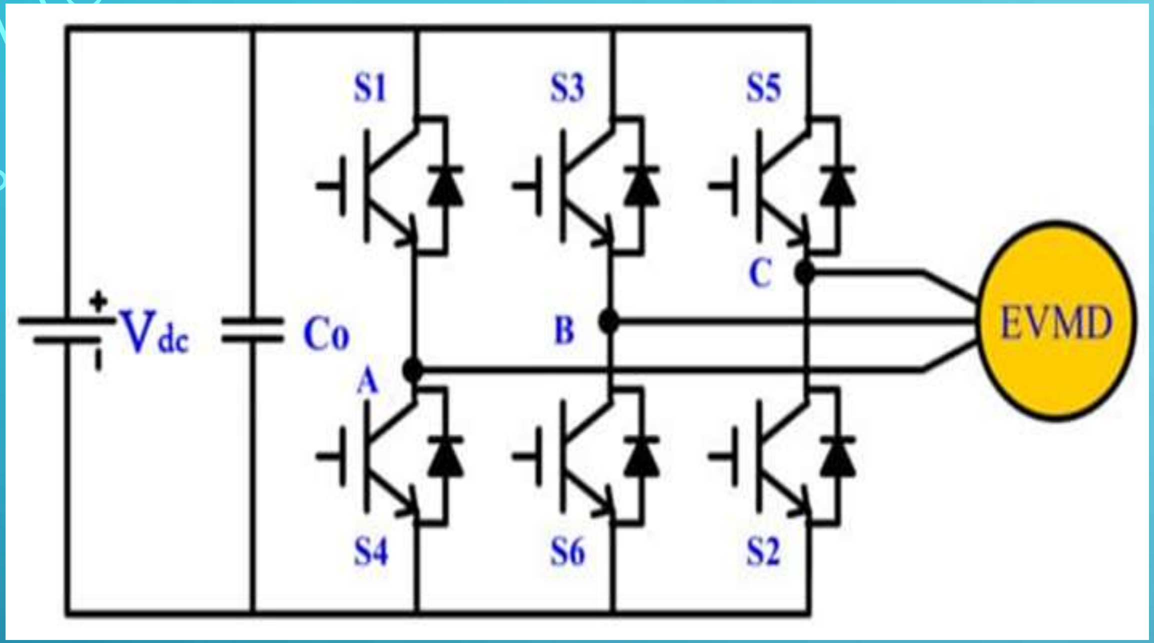
Electric vehicle auxiliary battery

The auxiliary battery is not used by the traction motor but is charged by the traction battery. It is used to support all electrical systems except air conditioning and heating.

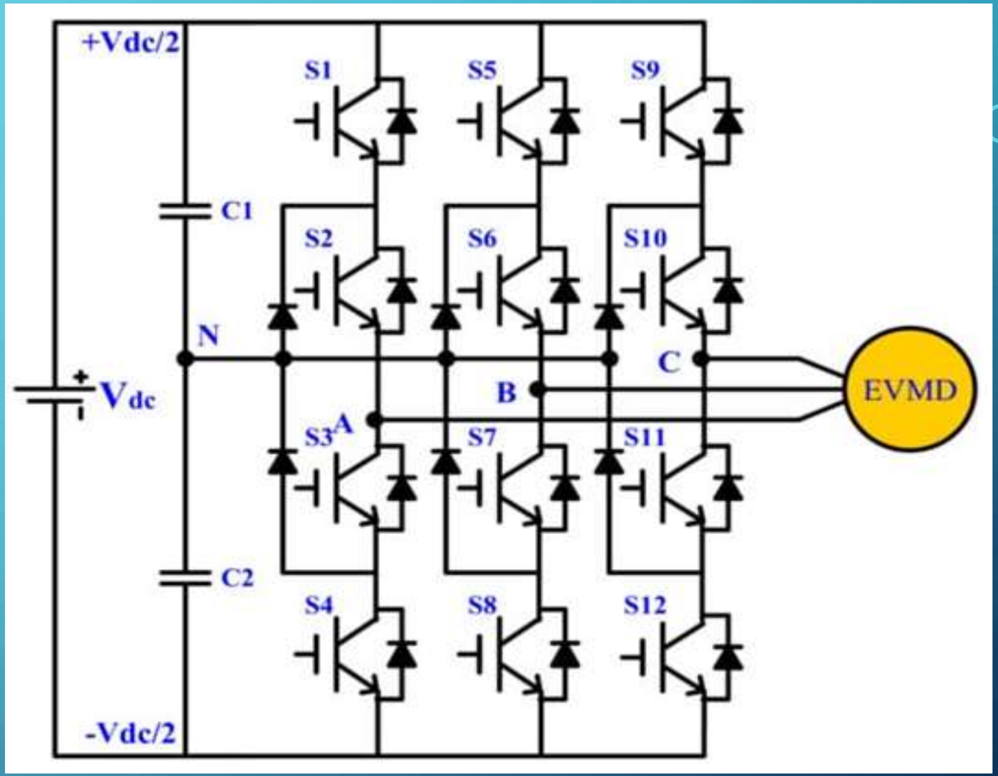
2(A)DC TO AC CONVERTER (INVERTER)



Various types of power electronics converters used in a typical series hybrid vehicle design system

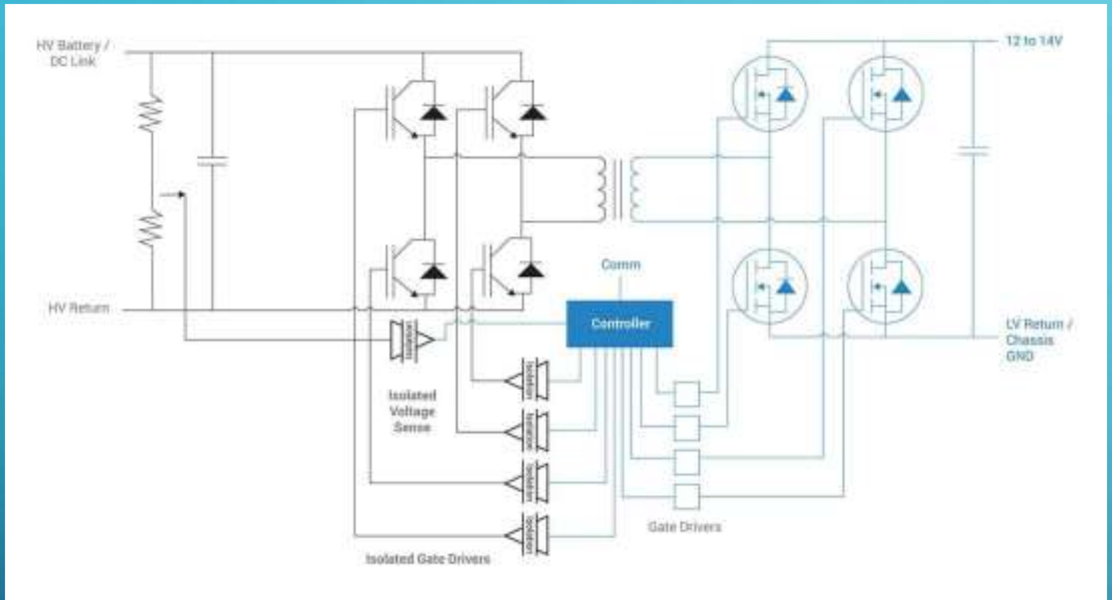


Three Phase Two Level Inverter (TLI) Topology for EV Motor Drive USED SI IGBT(For 400V)

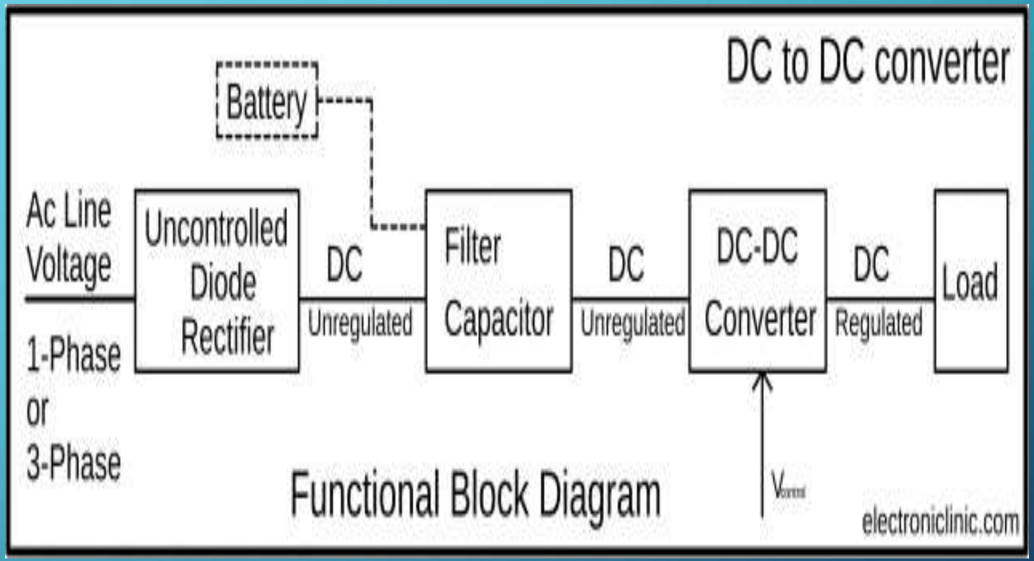


Three Phase three Level – topology Natural Point Clamp, Multi-Level Inverter(NPC-MLI) for EV Motor(800V)

2. DC TO DC CONVERTER



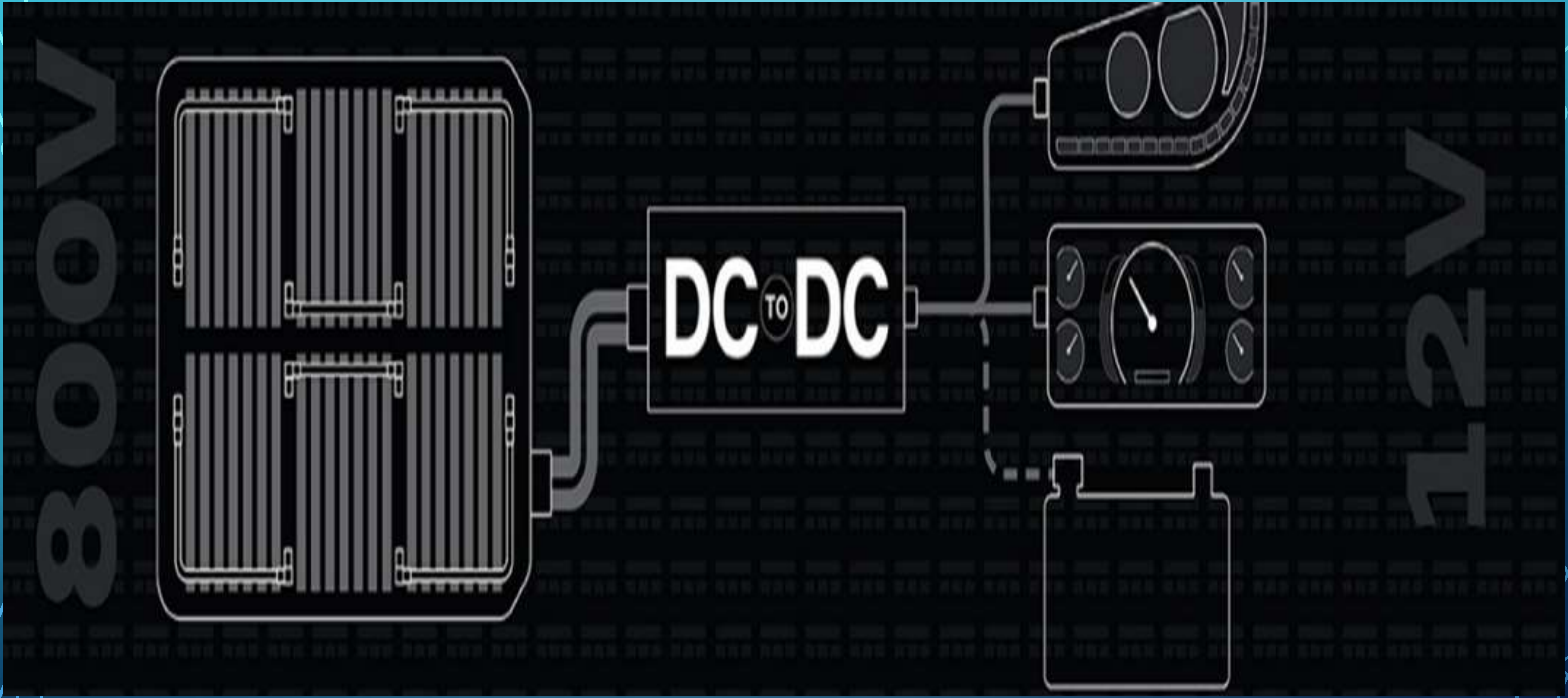
SAMPLE CIRCUIT DIAGRAM OF DC-DC CONVERTER



DC-DC CONVERTER BLOCK DIAGRAM

USING SI IGBT AND SIC MOSFET(SILICON CARBIDE METAL OXIDE FIELD EFFECT TRANSISTOR) SEMI CONDUCTOR,ISOLATED VOLTAGE SENSE

GVD510 Series DC-DC Converter


800V
DC TO DC
12V

3. ELECTRIC MOTOR

These days electric motors can be found in numerous everyday devices. Those that use direct current (DC) motors have quite basic functions. The motor is connected directly to an energy source and its rotation speed depends directly on the intensity of the current. While easy to produce, these electric motors don’t meet the power, reliability or size requirements of an electric vehicle, although you may find them powering the windshield wipers, windows and other smaller mechanisms inside the car.

THE STATOR AND THE ROTOR

If you want to understand how an electric vehicle works, you need to be familiar with the physical elements of its electric motor. And it starts with understanding the principles of its two major parts: the stator and the rotor. The difference between the two is easy to remember: the stator is static, while the rotor rotates. In a motor, the stator uses energy to create a magnetic field that then turns the rotor.

EV ELECTRIC MOTOR

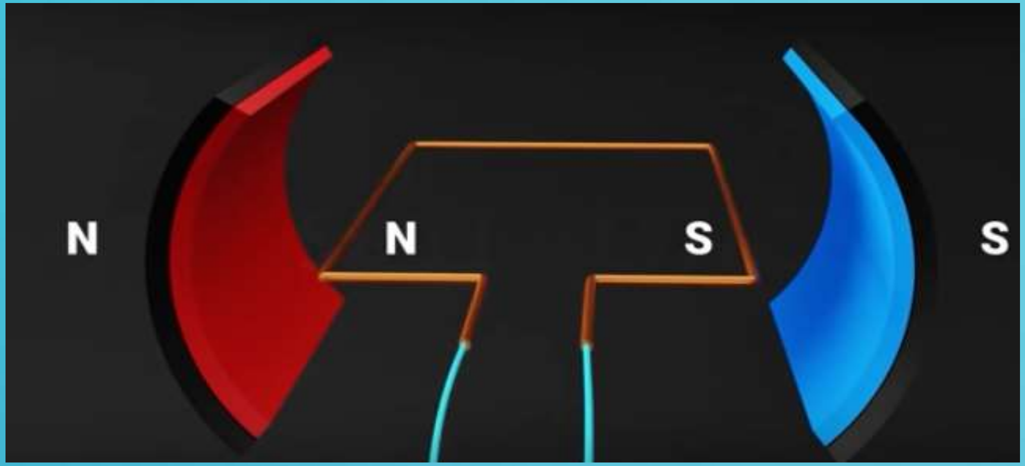
EV motors **turn electricity into motion by creating a rotating magnetic field**. A cylinder called the stator contains tightly-wound copper wires, which the alternating current coming from the inverter runs through. Because the current alternates, the north and south poles of these magnetic fields switch back and forth.

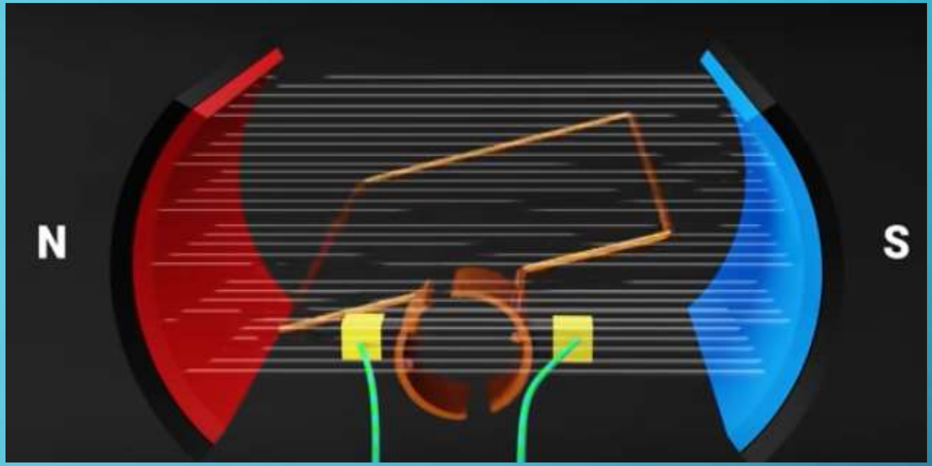
TYPES OF MOTORS(BASE ON USING CURRENT TYPE)

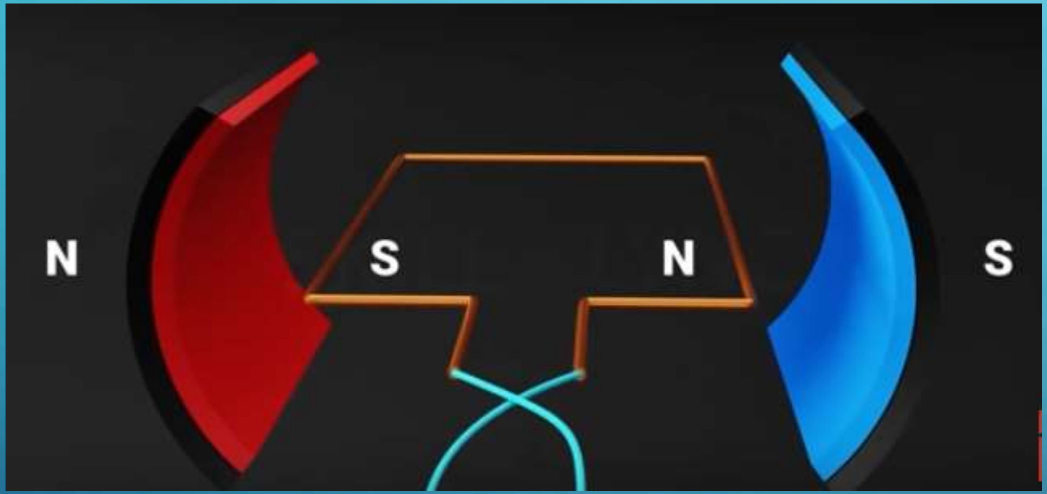
AC motors are the most commonly used in electric cars, as they offer better efficiency and are easier to control. However, DC motors are still used in some electric cars, especially in older models or smaller vehicles.

AM RACING AMR 250-90 SINGLE AC MOTOR - LIQUID COOLED, PERMANENT MAGNET - REMY CARTRIDGE

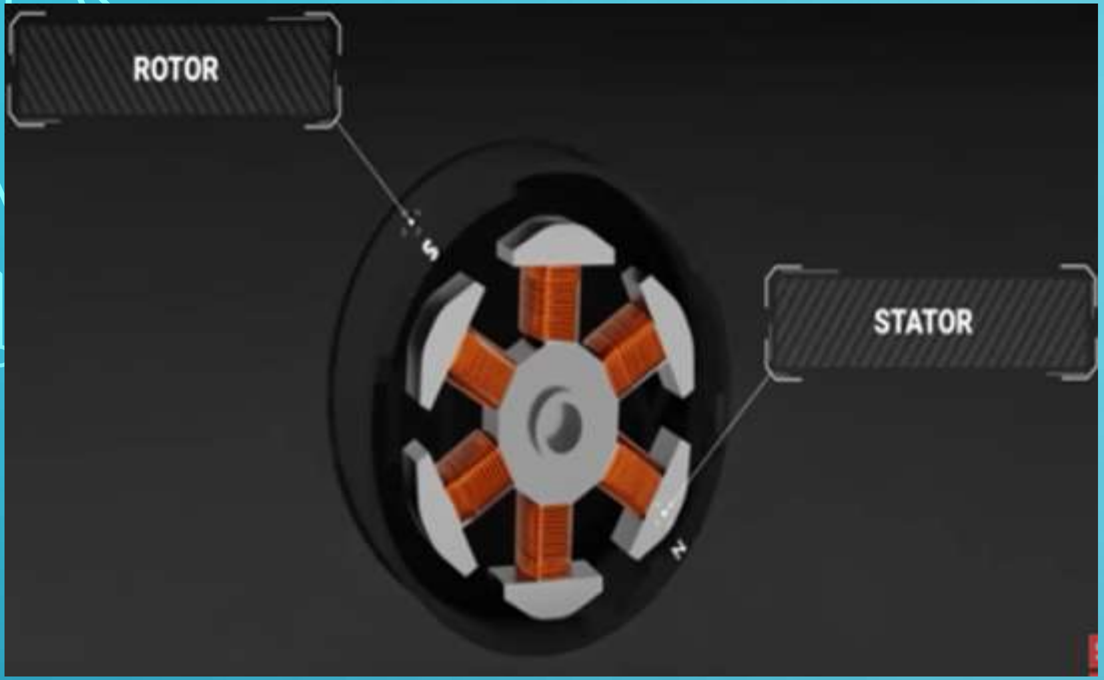
HOW ELECTRIC MOTORS WORK – 3 PHASE AC INDUCTION MOTORS AC MOTOR

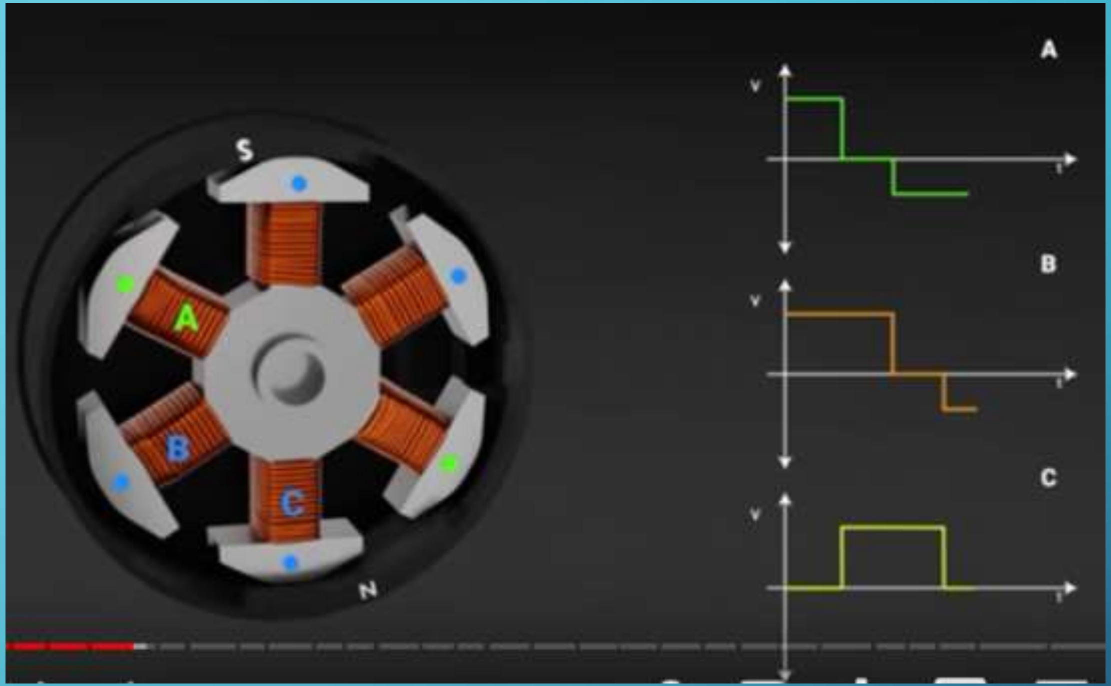






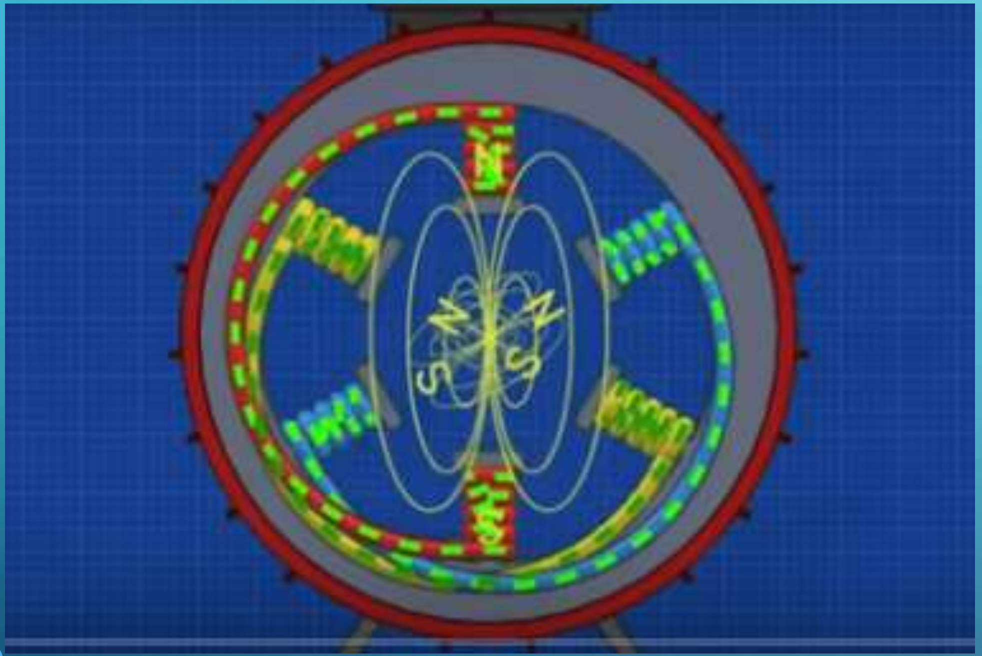
PRINCIPAL OF ELECTRIC MOTOR ROTATING AND BRUSH DC MOTOR

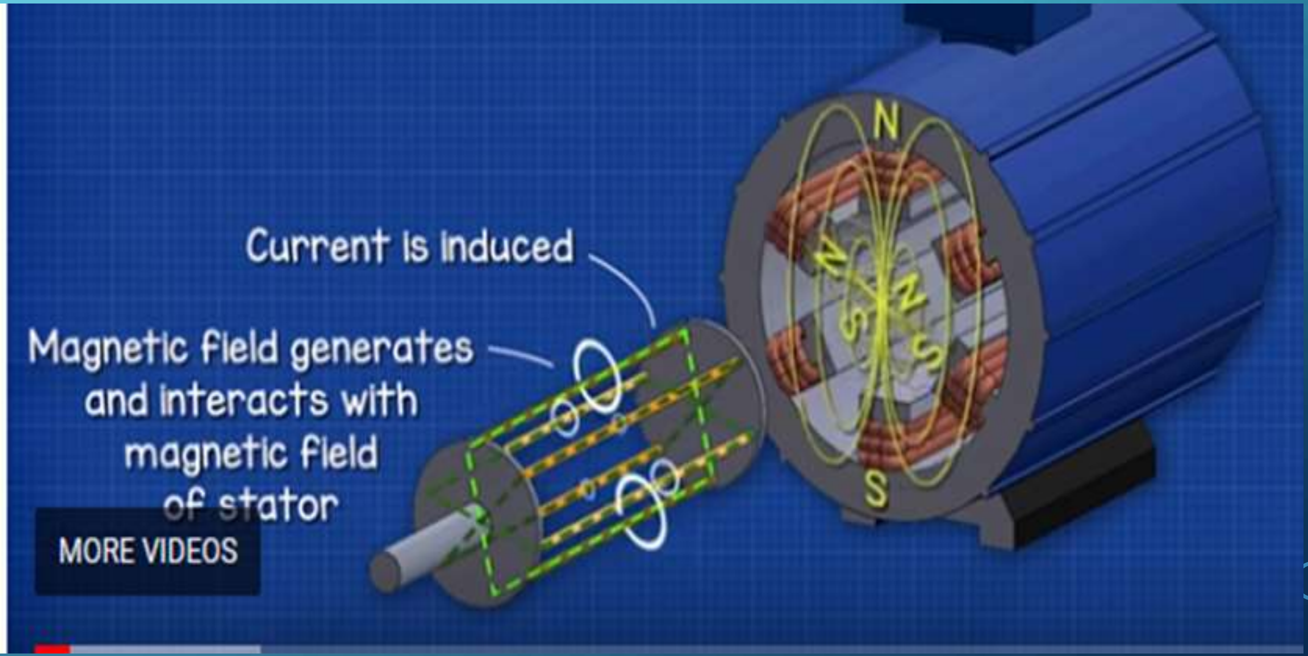




PRINCIPAL OF BLDC MOTOR ROTATING

TYPE OF MOTORS (BASE ON DESIGN)





TYPE OF MOTORS (BASE ON DESIGN)

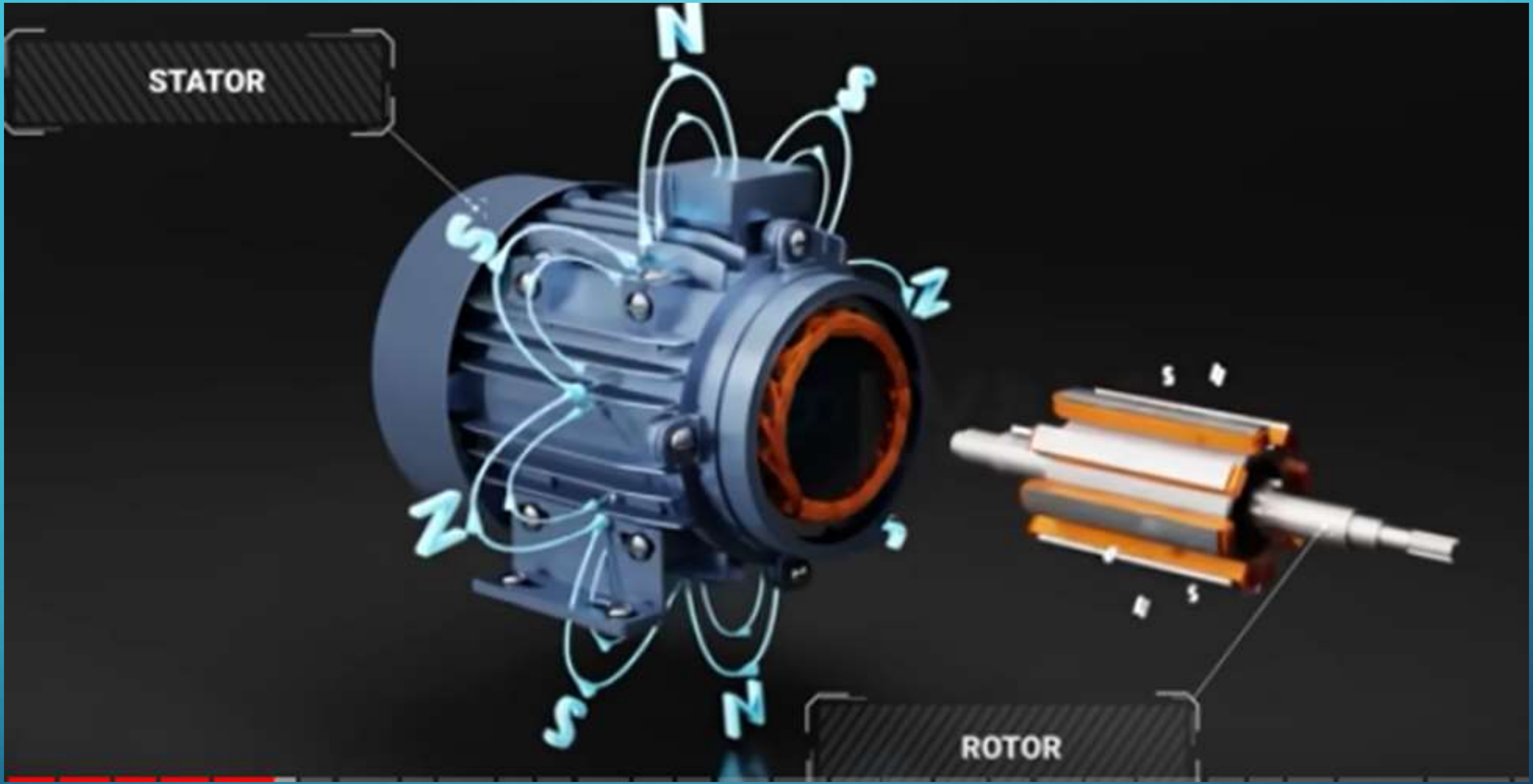
1)BRUSH LESS DC MOTORS (BLDC)

2)BRUSH DC MOTOR

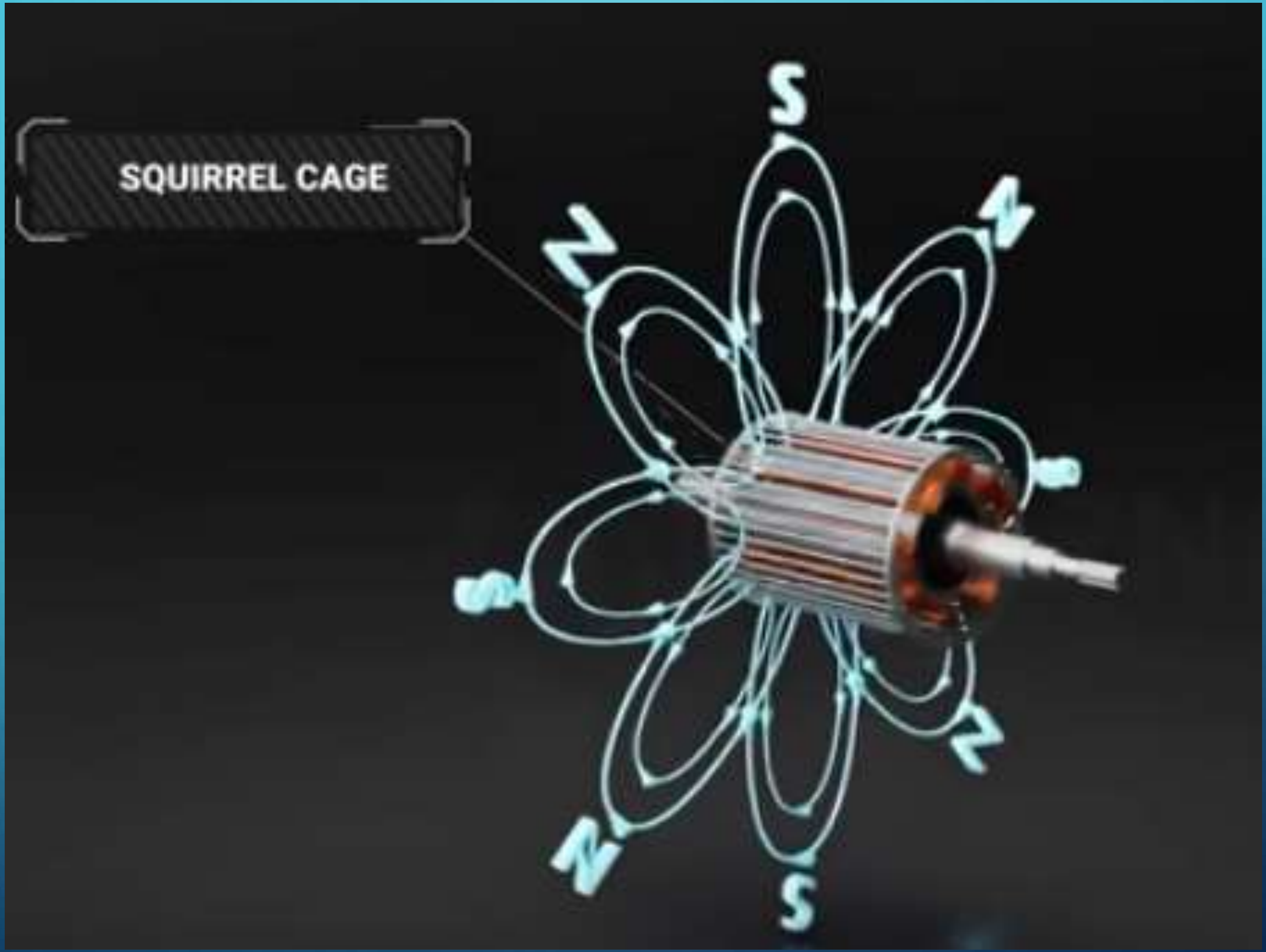
TYPE OF MOTORS (BASE ON DESIGN)

3)PERMANENT MAGNET MOTOR

4)INDUCTION MOTOR



- **AC Permanent Synchronous Motor(Rotate Stator and Rotor)**


SQUIRREL CAGE
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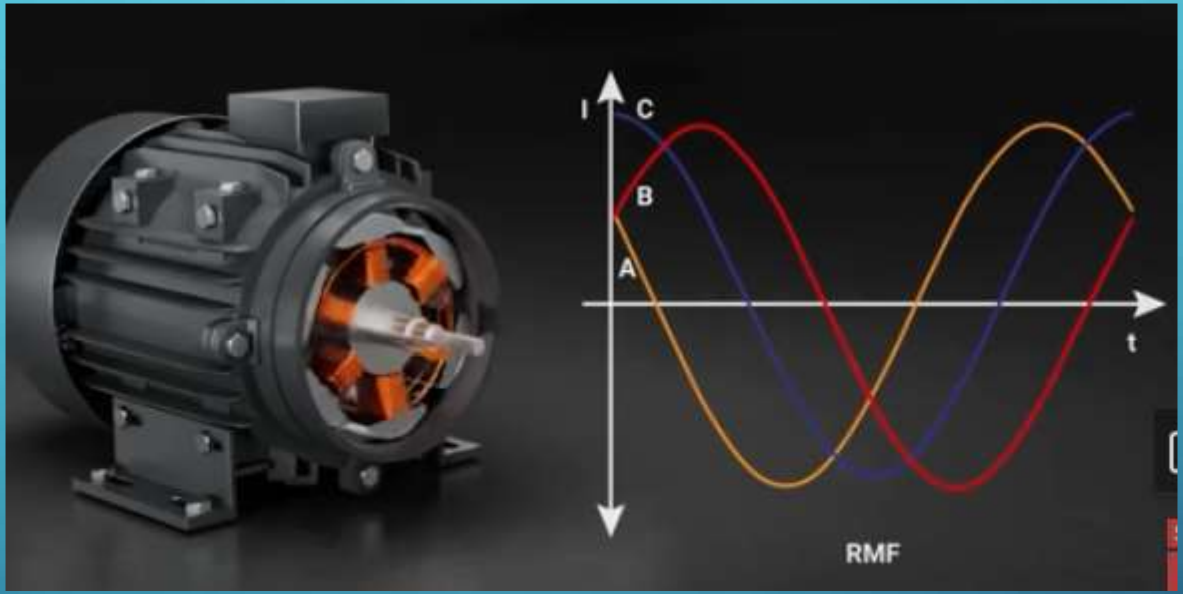
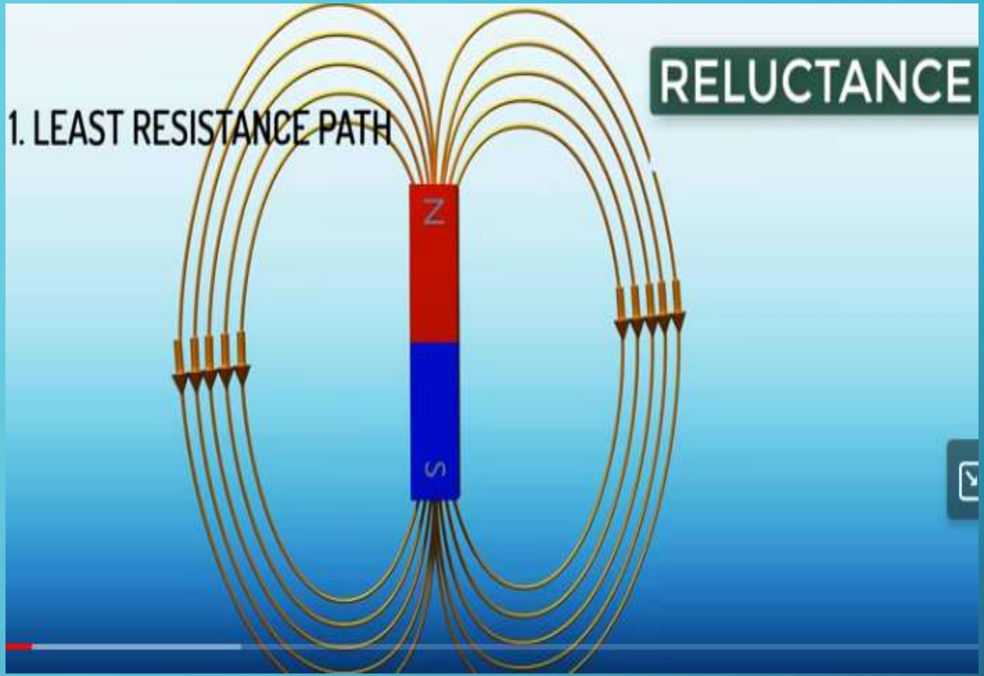
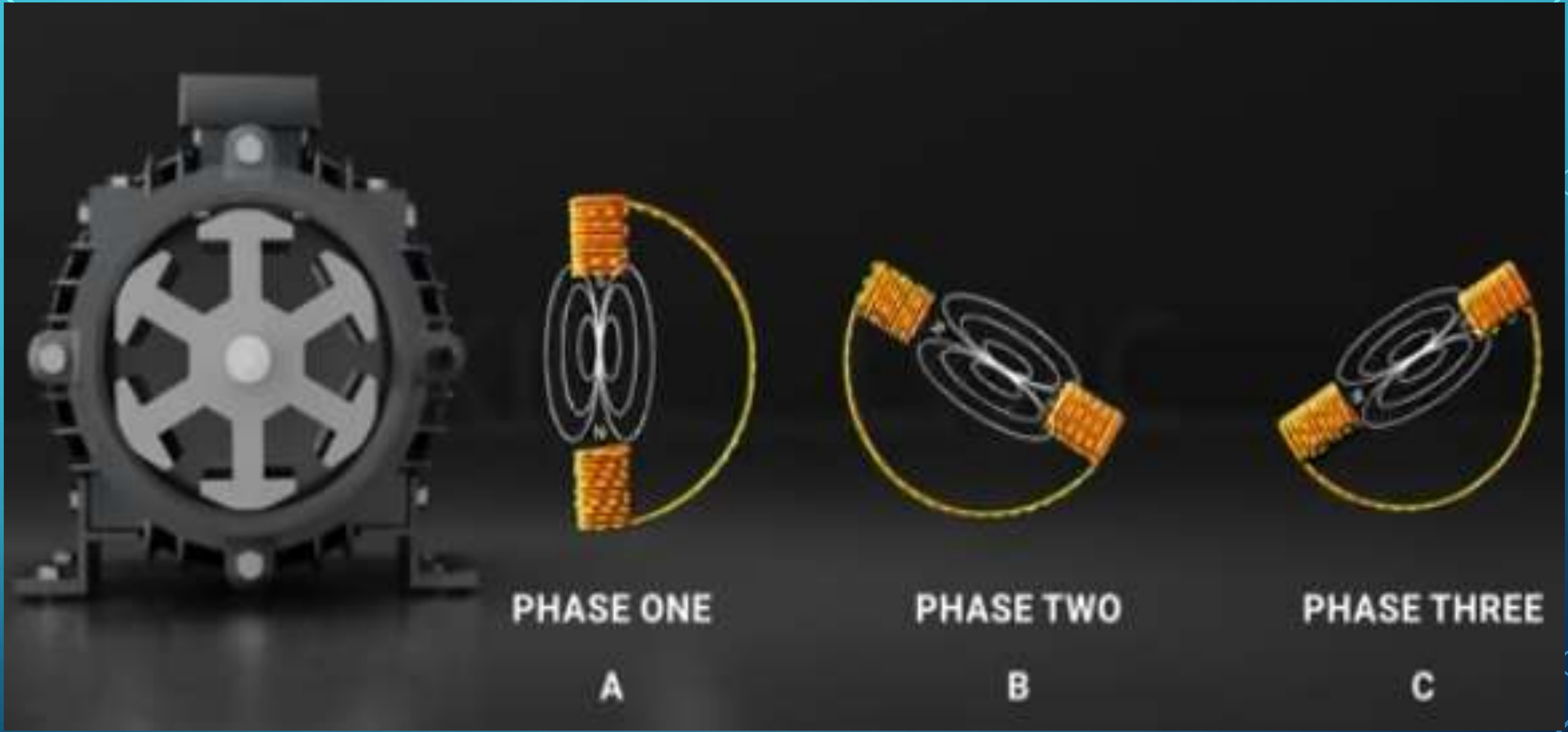


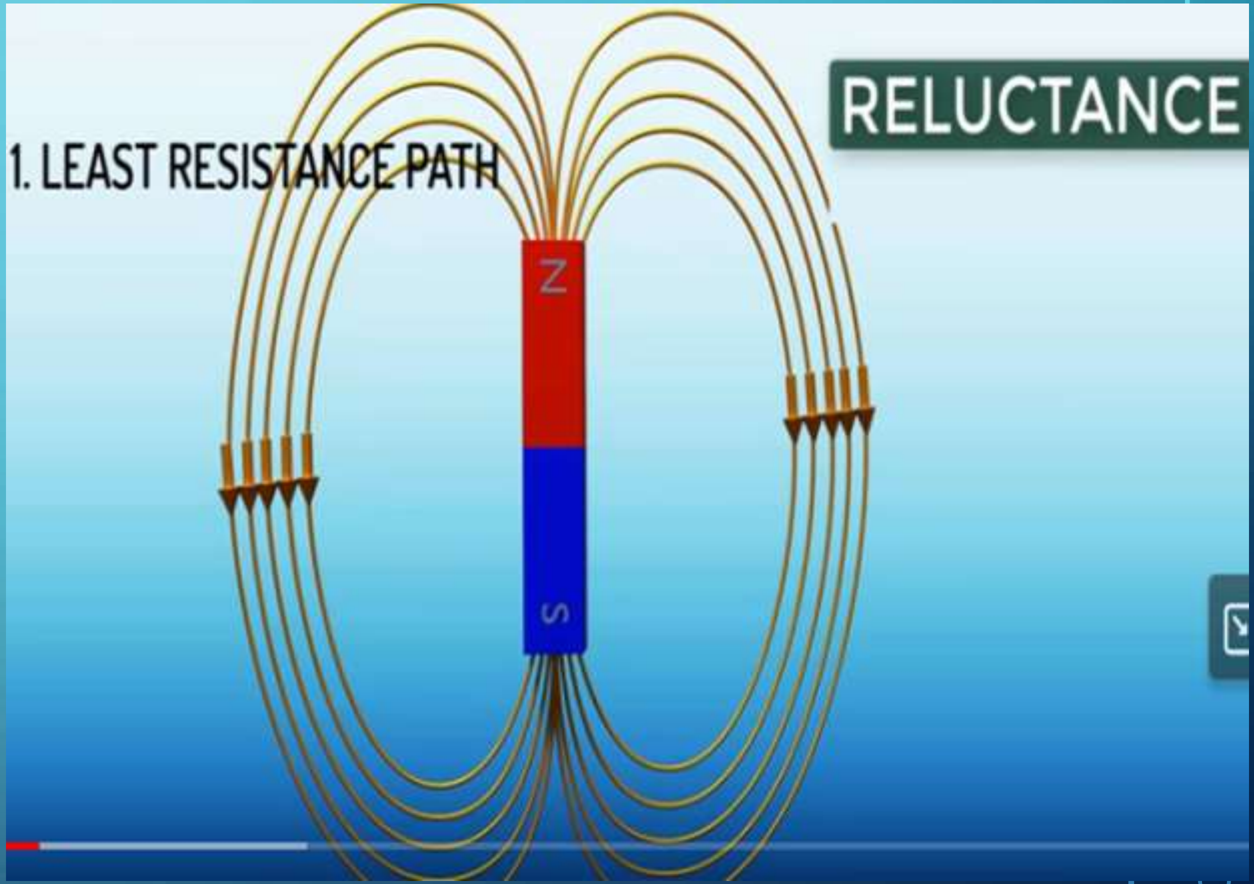
- A Synchronous Motor/ induction Motor

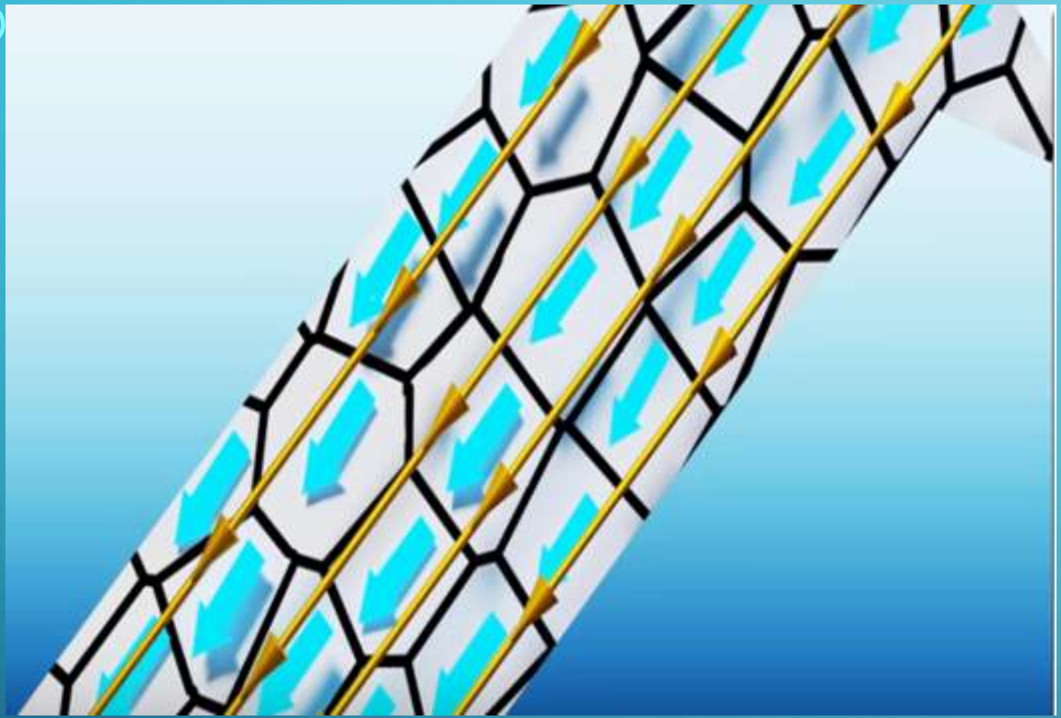


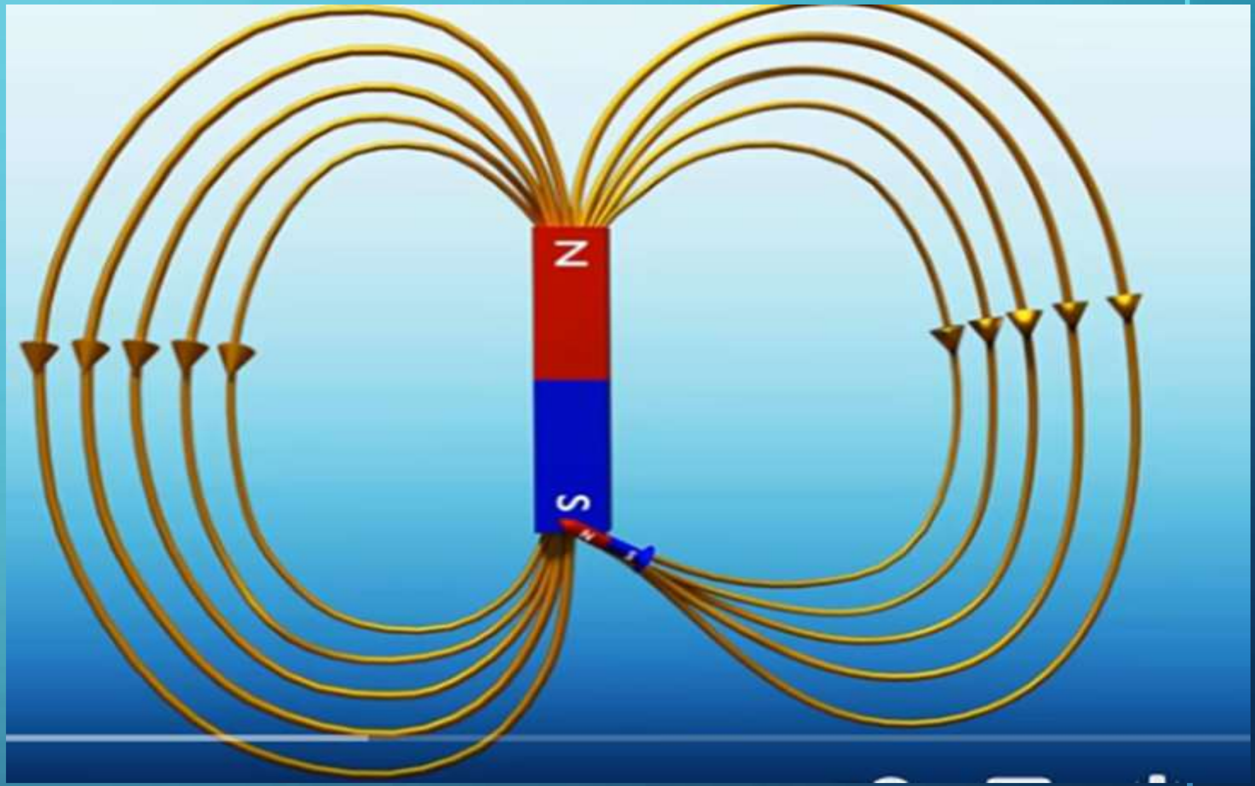
- **Synchronous Reluctance Motor**


PHASE ONE
A
PHASE TWO
B
PHASE THREE
C

Synchronous Reluctance Motor



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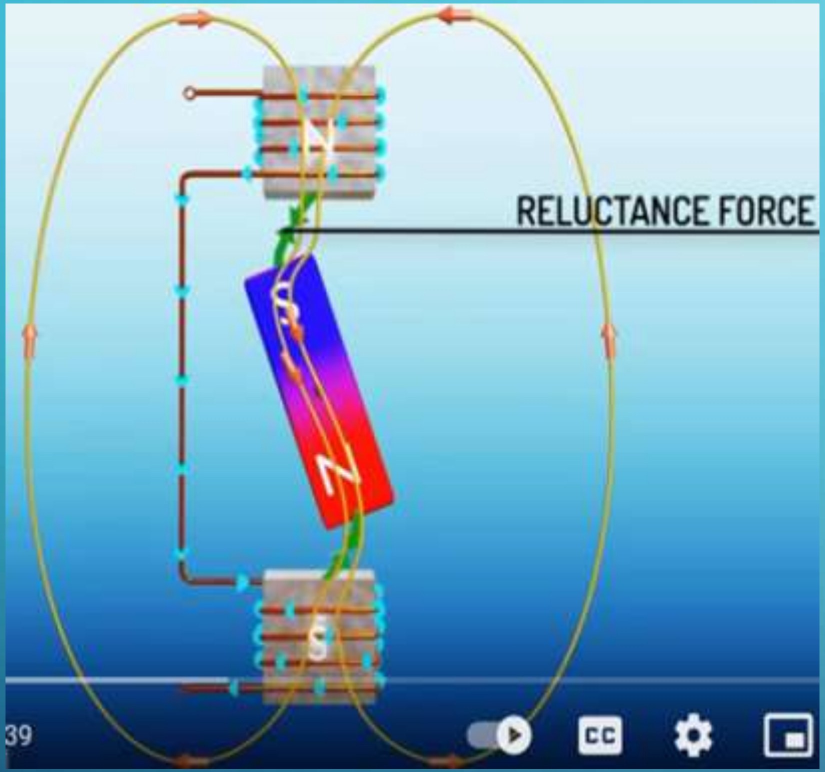
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RELUCTANCE FORCE
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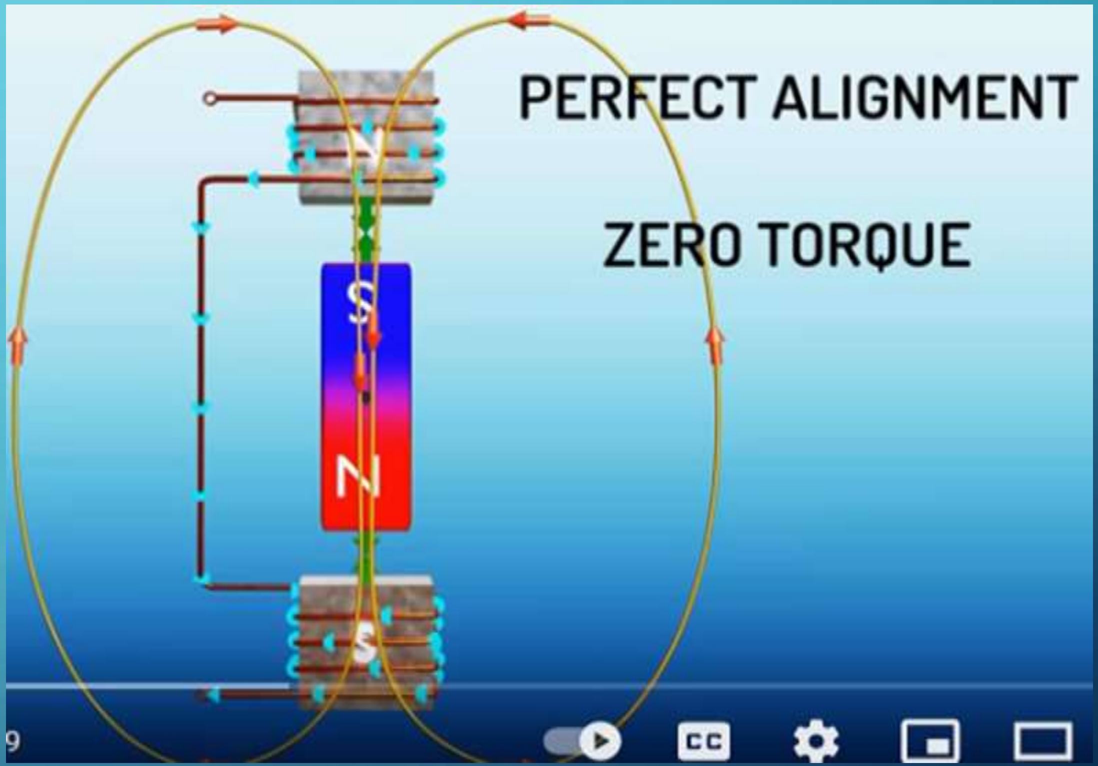
PERFECT ALIGNMENT
ZERO TORQUE
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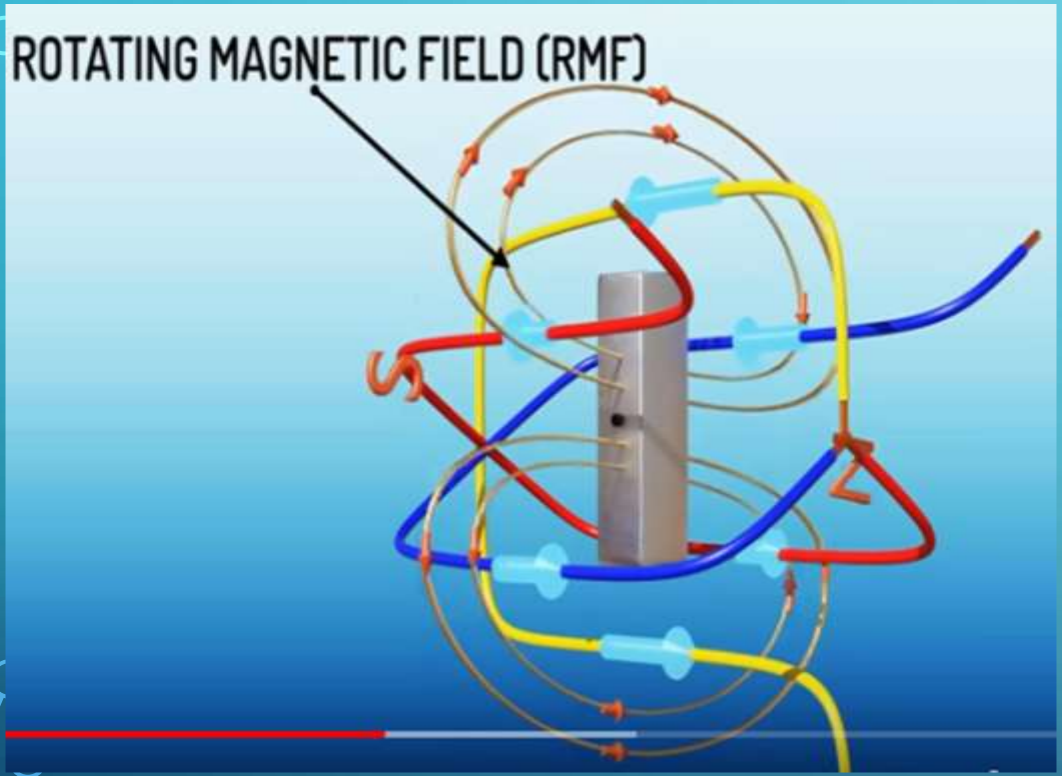
ROTATING MAGNETIC FIELD (RMF)
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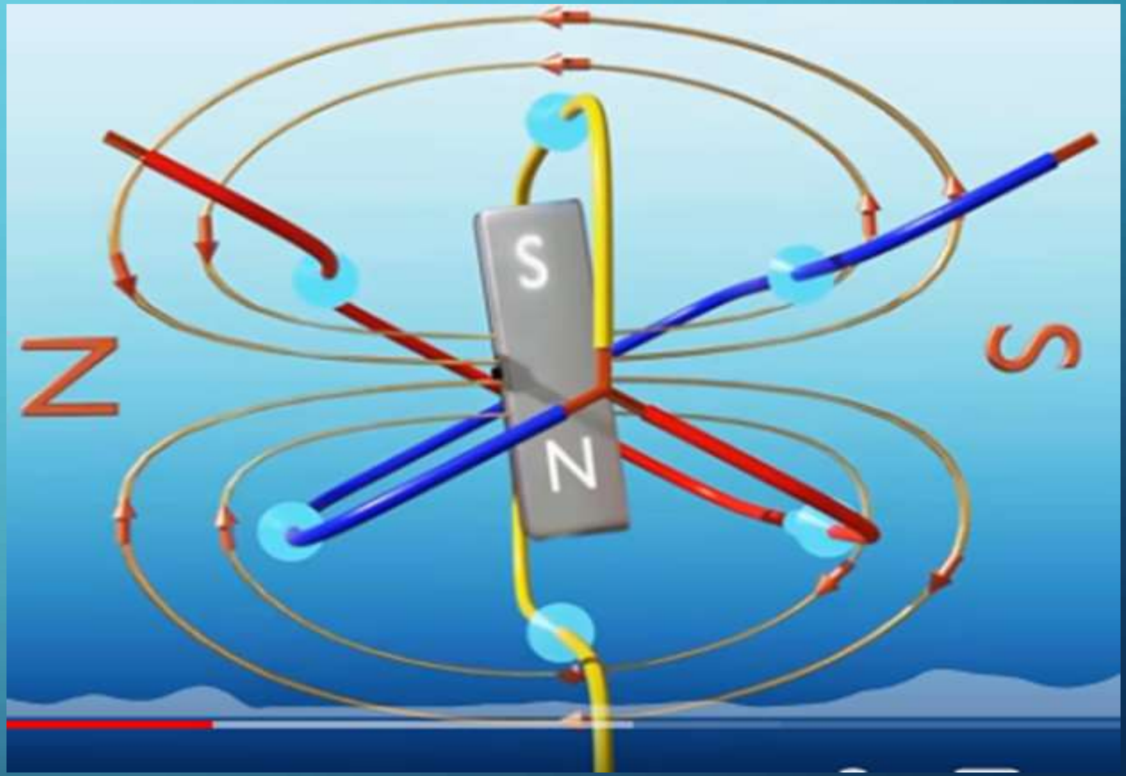
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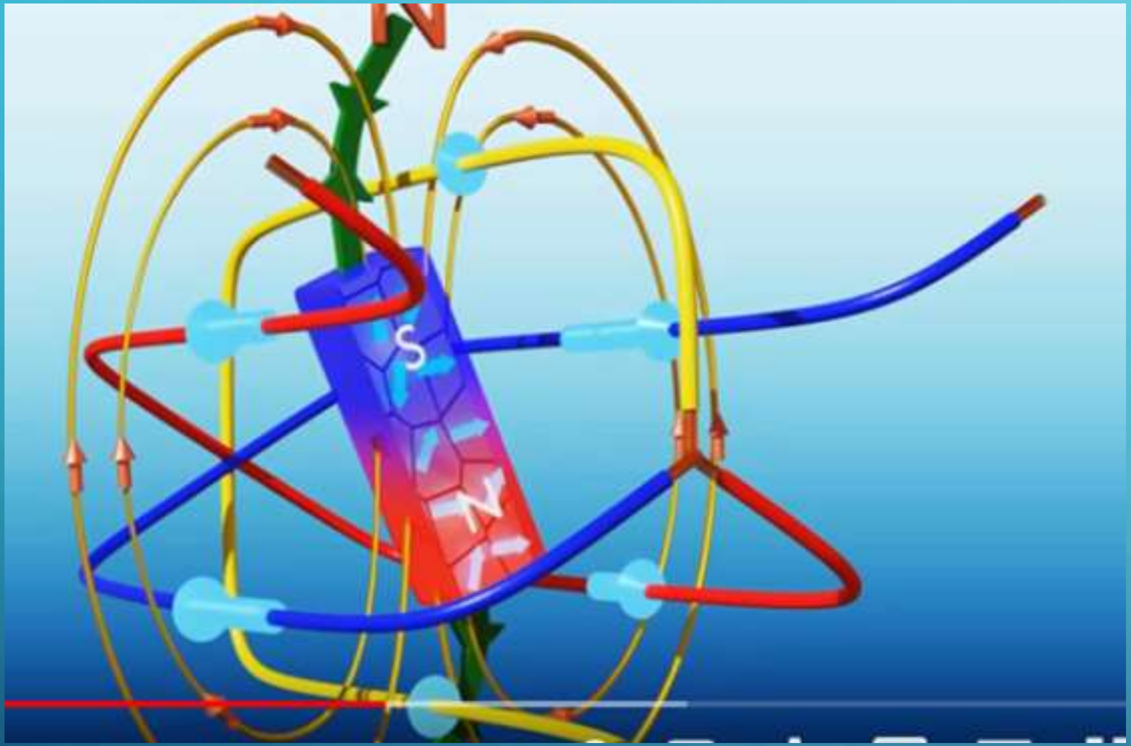
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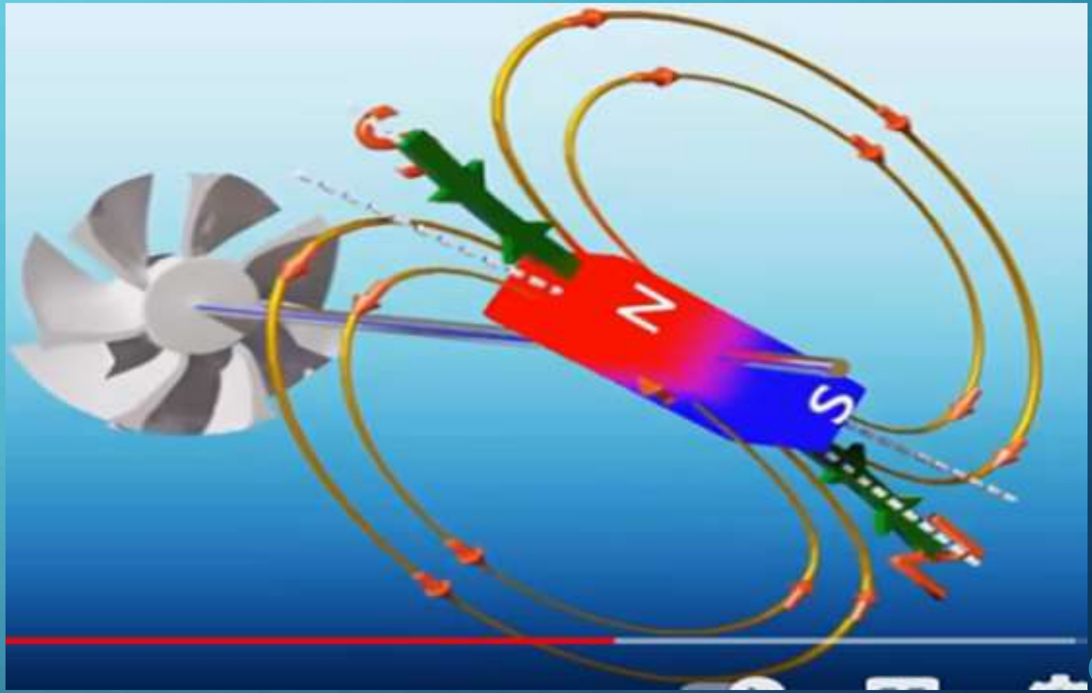
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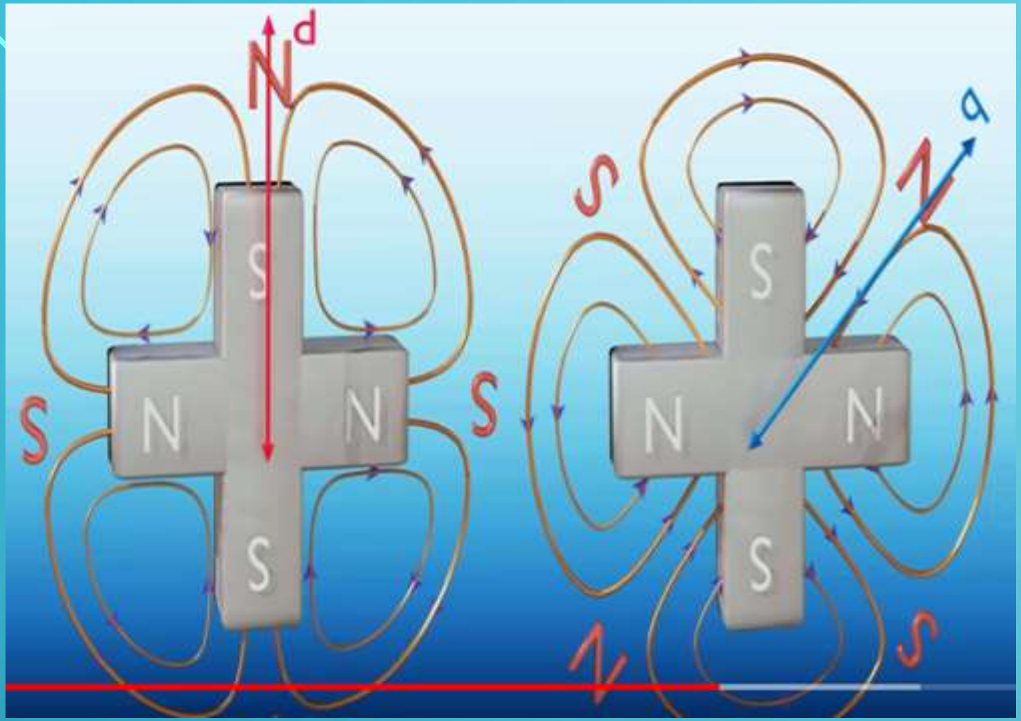
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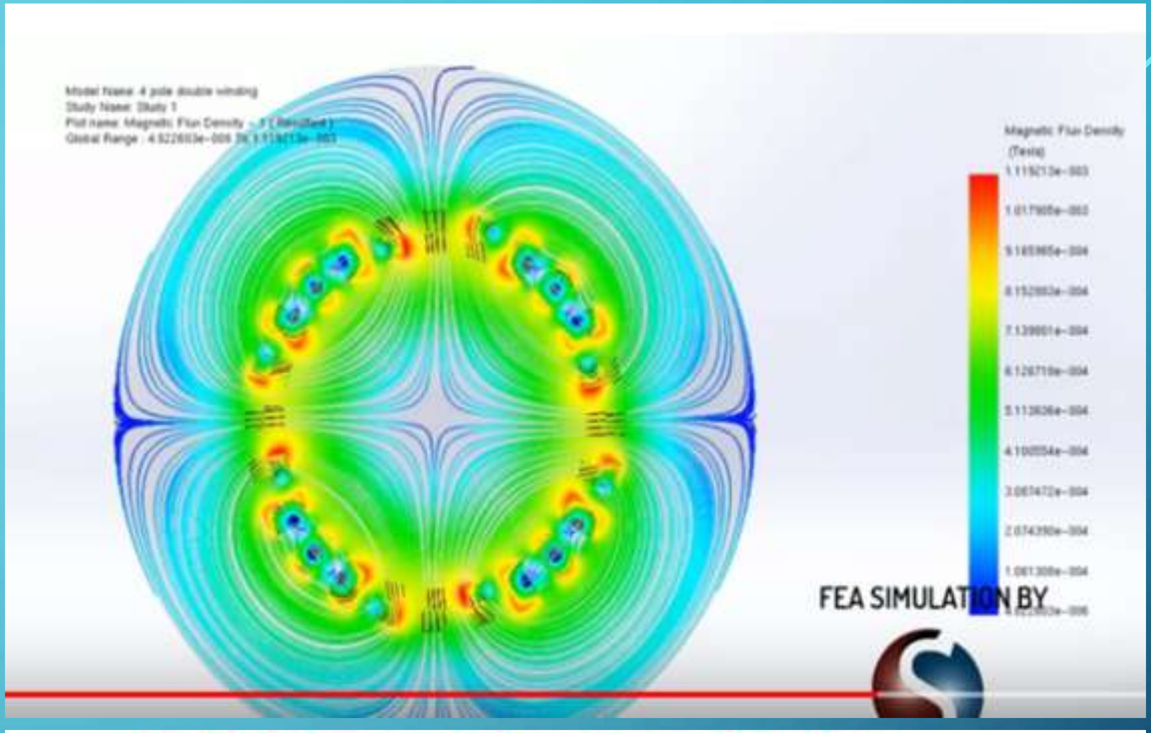
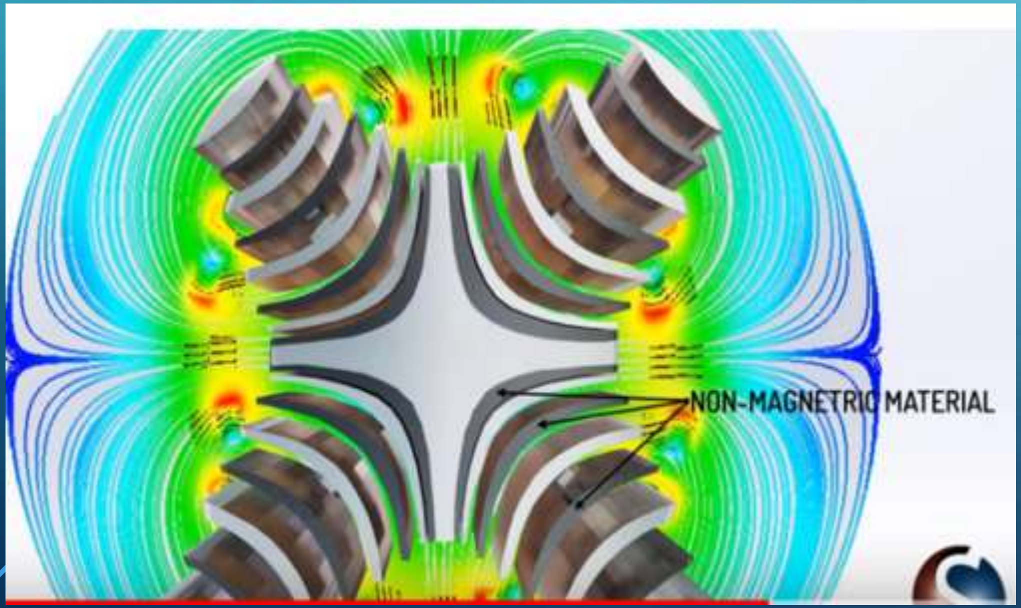
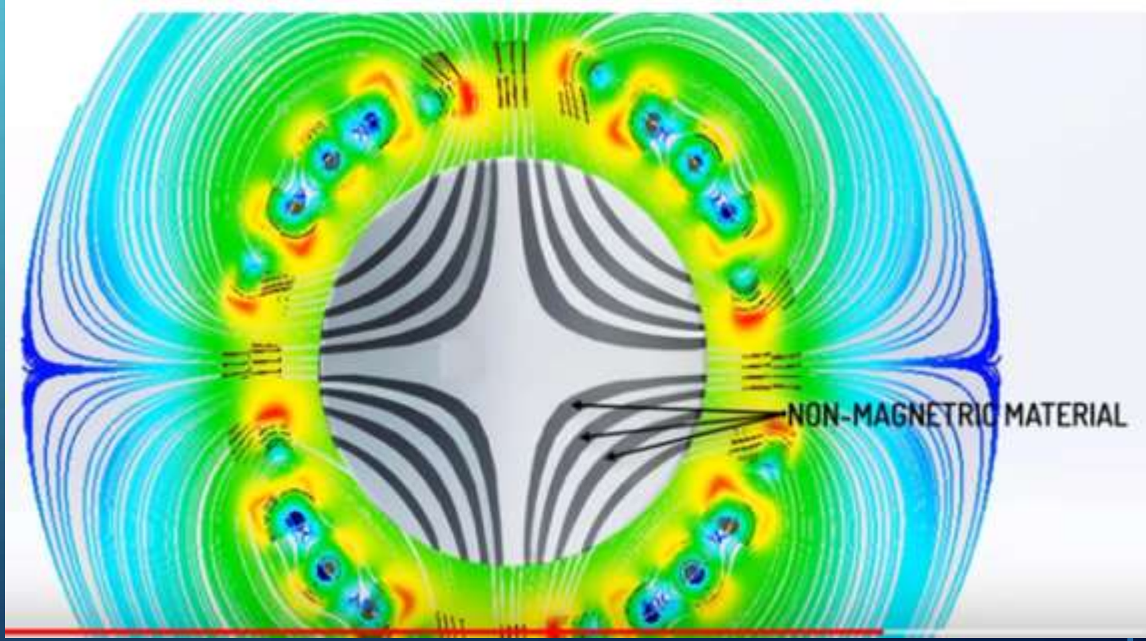
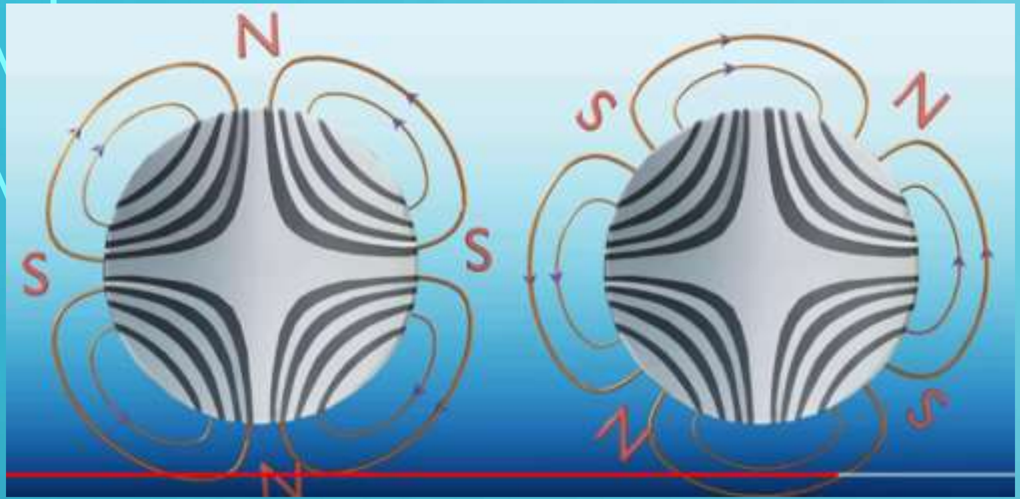

FEA SIMULATION BY


NON-MAGNETIC MATERIAL


NON-MAGNETIC MATERIAL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A GOOD DESIGN
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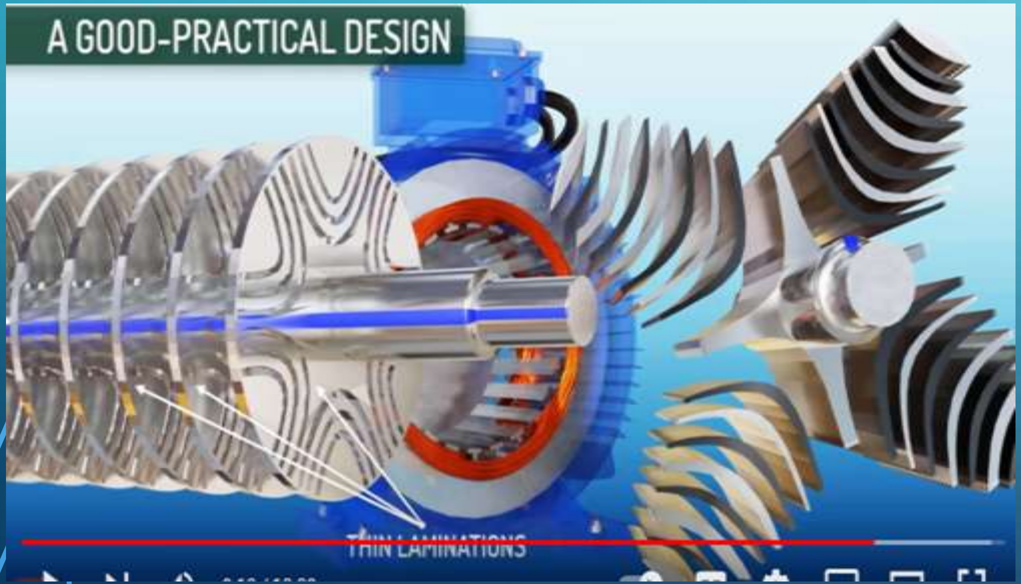
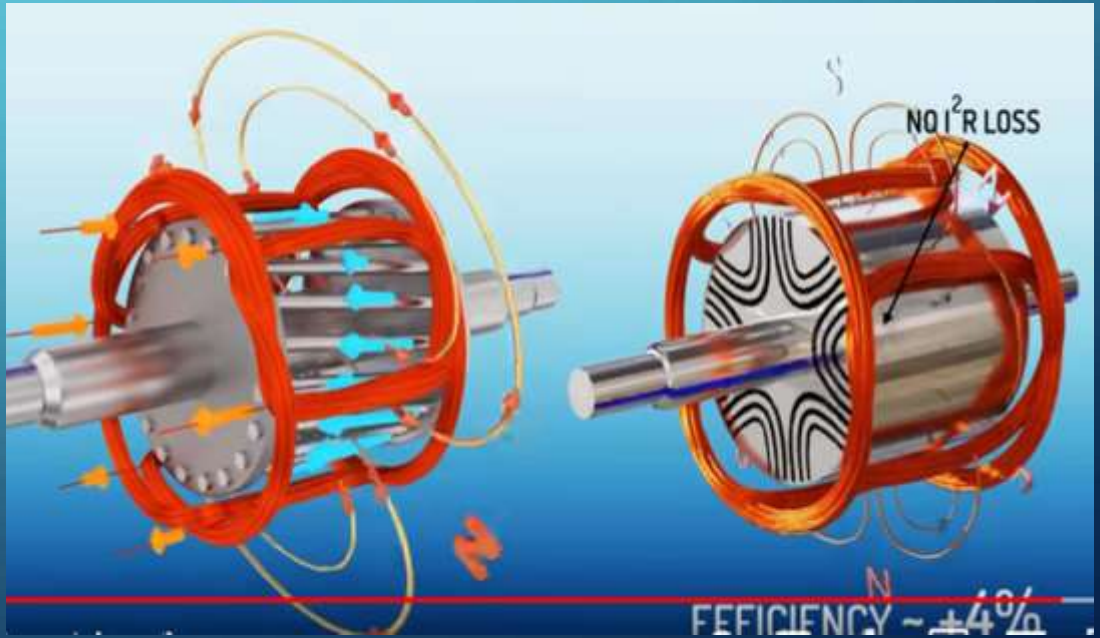
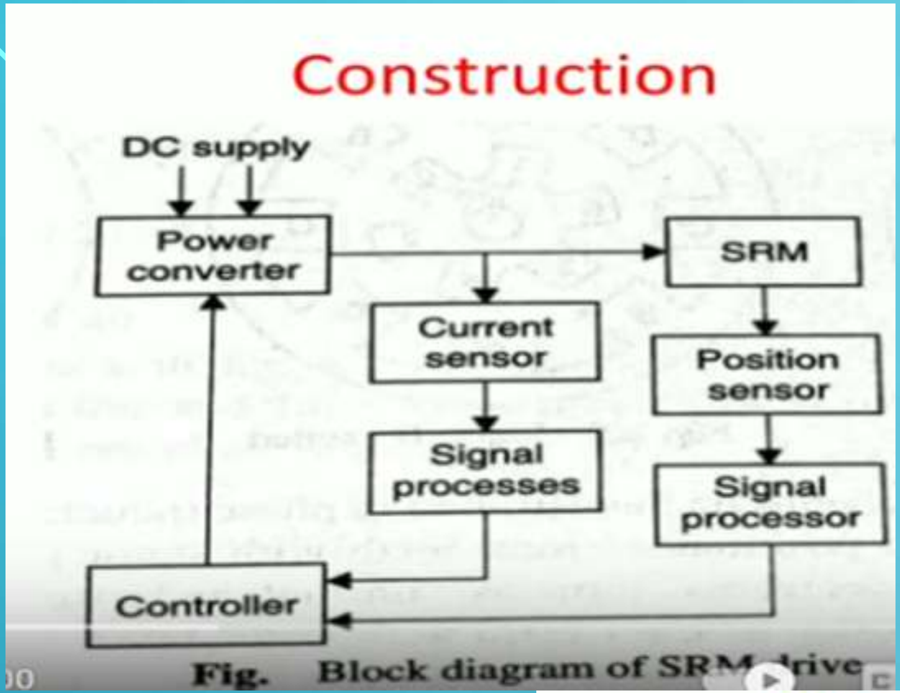
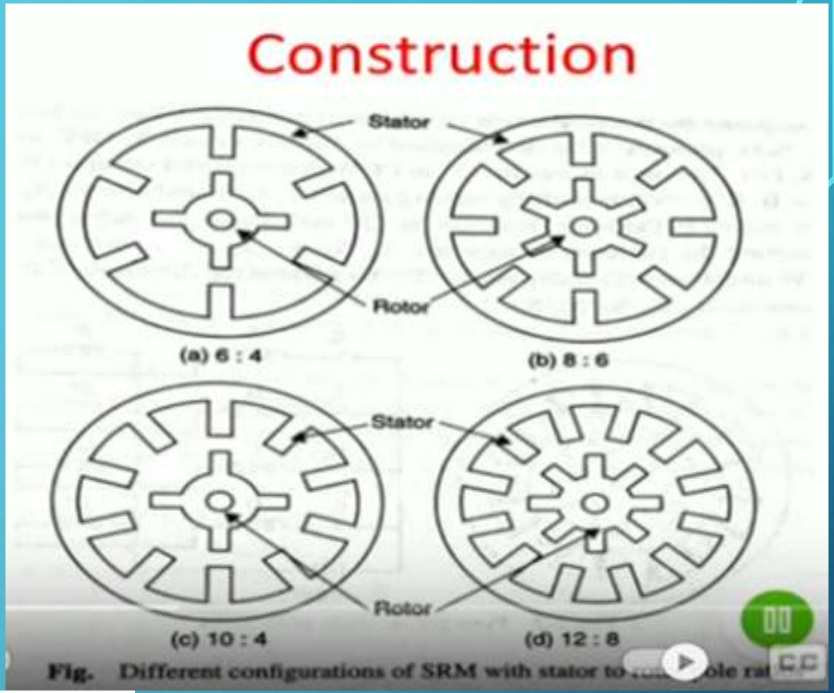
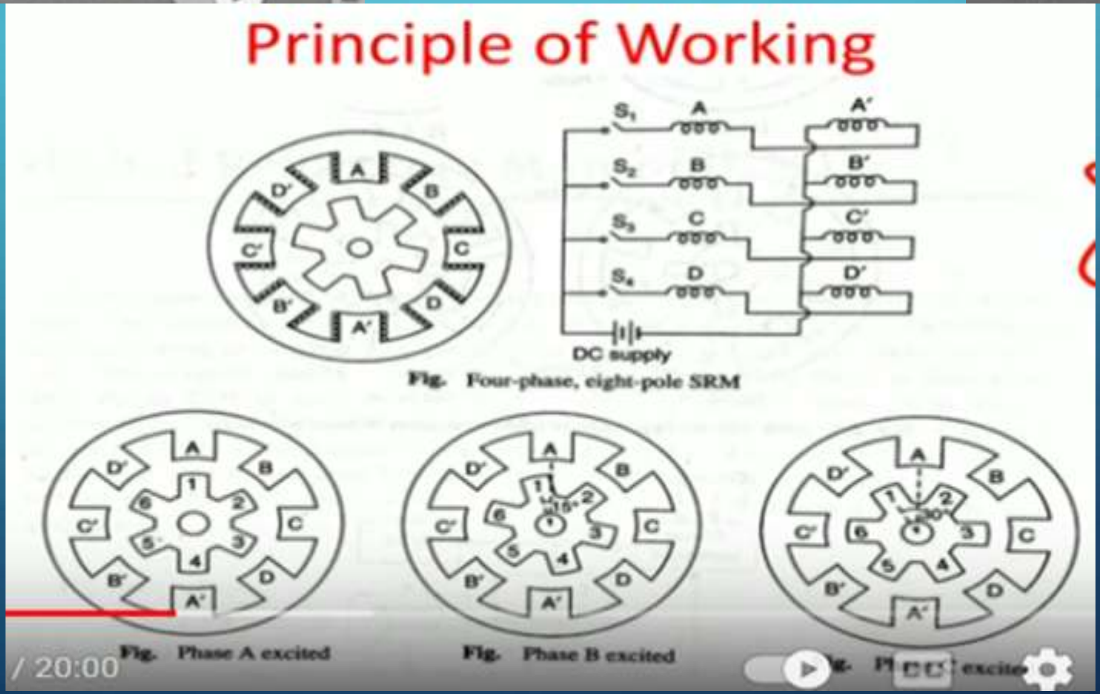

A GOOD-PRACTICAL DESIGN
THIN LAMINATIONS

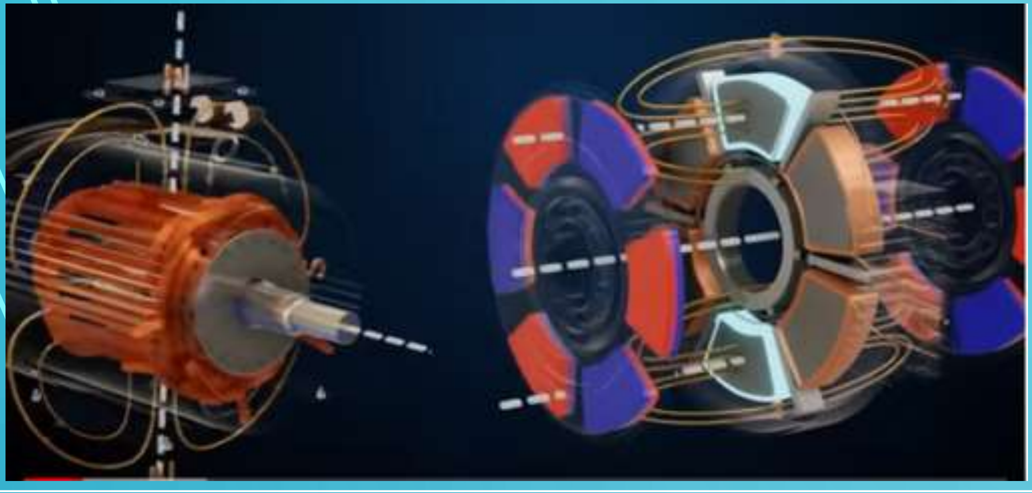

NO I^2R LOSS
N

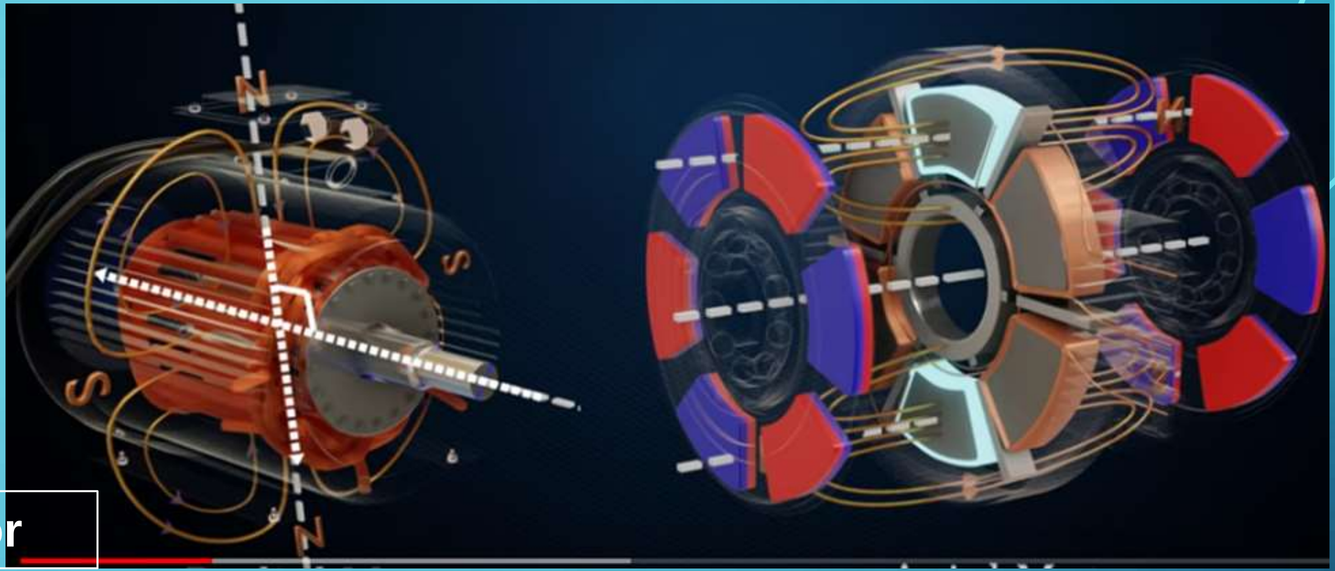

Construction
DC supply
Power converter
SRM
Current sensor
Position sensor
Signal processes
Signal processor
Controller
Fig. Block diagram of SRM drive

SRM Motor

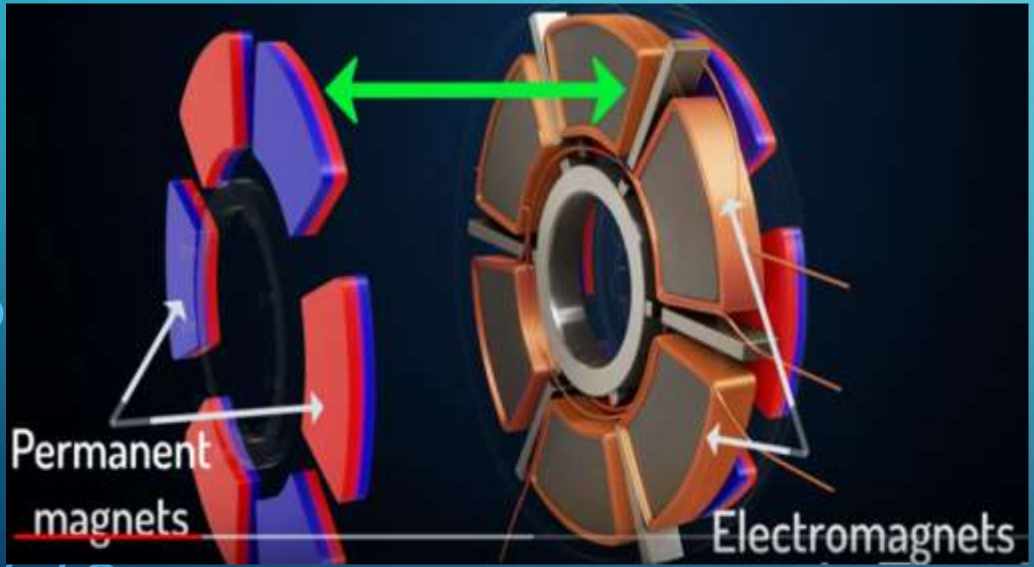

Construction
Stator
Rotor
(a) 6 : 4
(b) 8 : 6
Stator
Rotor
(c) 10 : 4
(d) 12 : 8
Fig. Different configurations of SRM with stator to

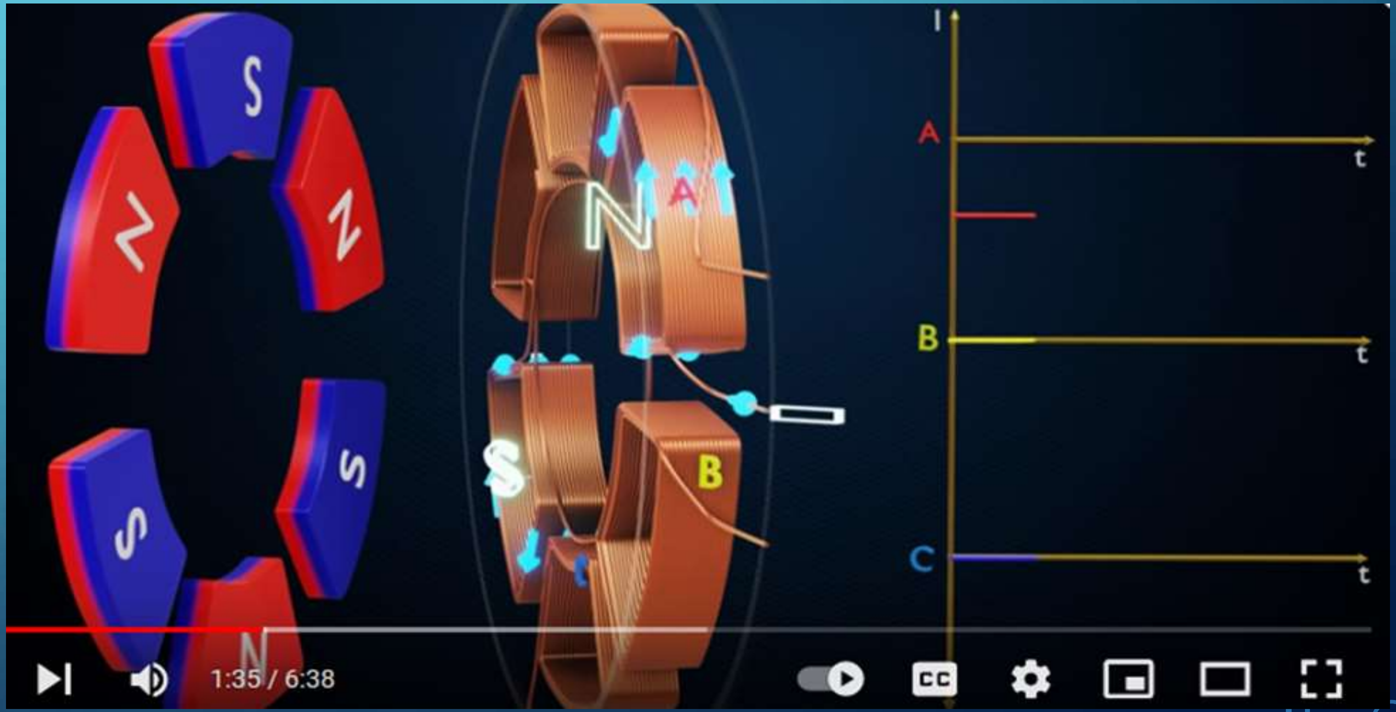

Principle of Working
A
B
C
D
A'
B'
C'
D'
S1
S2
S3
S4
DC supply
Fig. Four-phase, eight-pole SRM
Fig. Phase A excited
Fig. Phase B excited
20:00

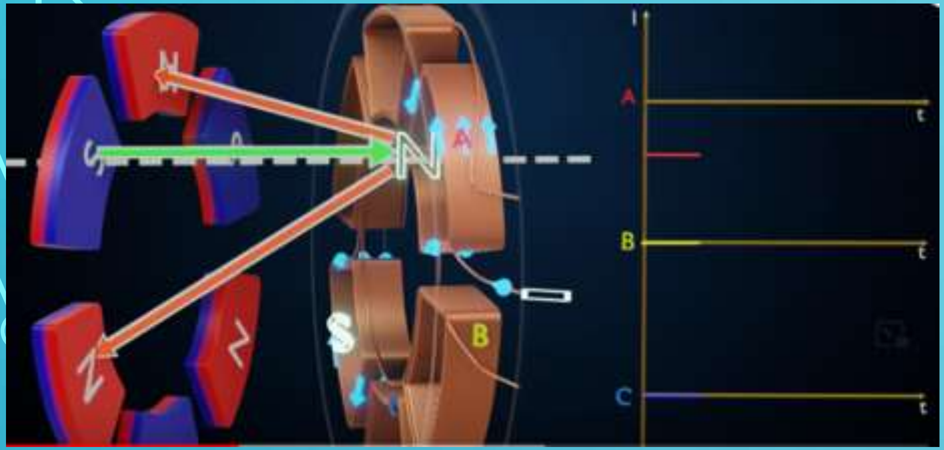




Left(Radial Flow Motor), Right(Axial Flow Motor



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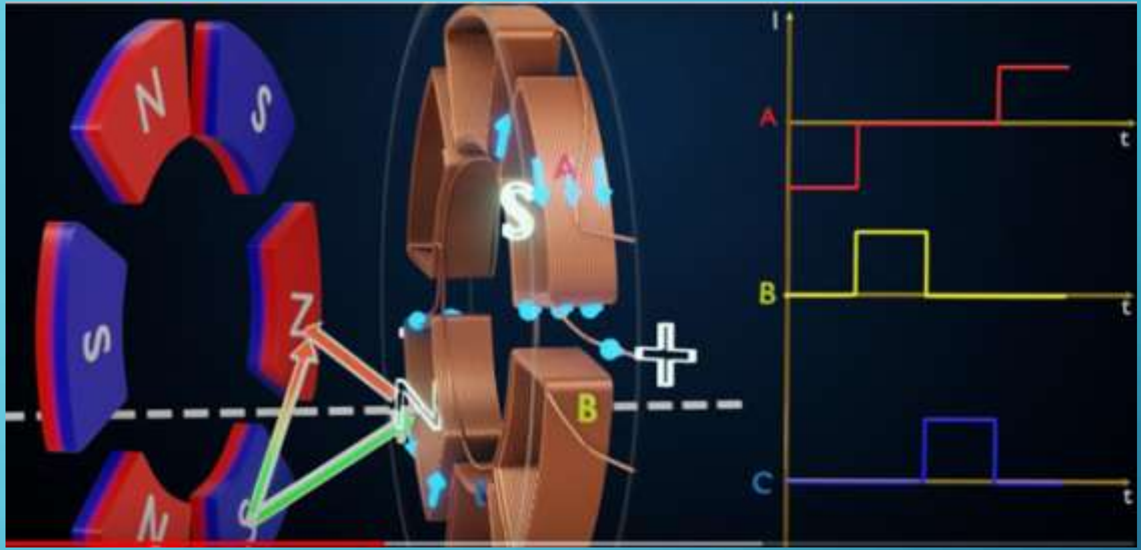
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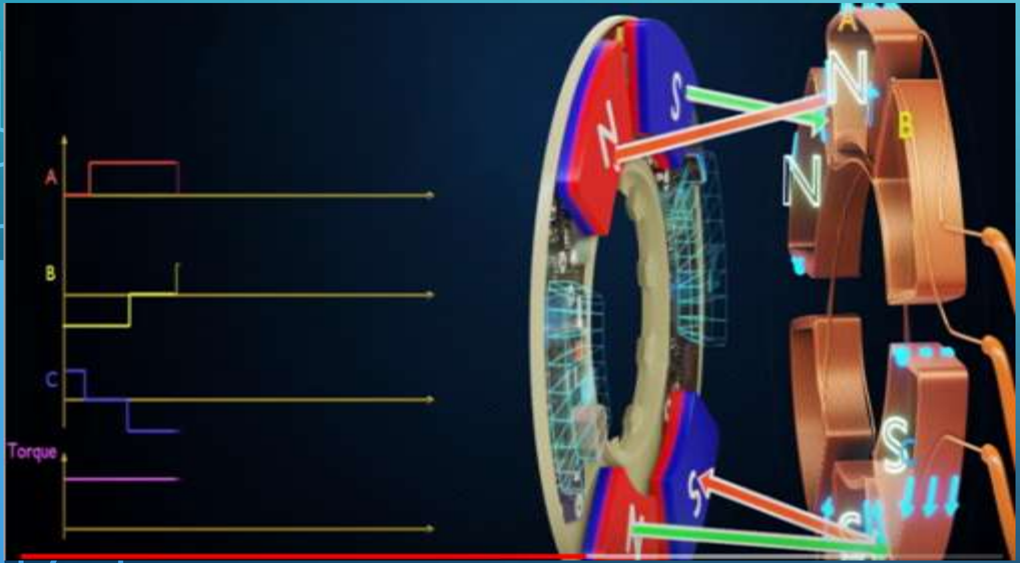
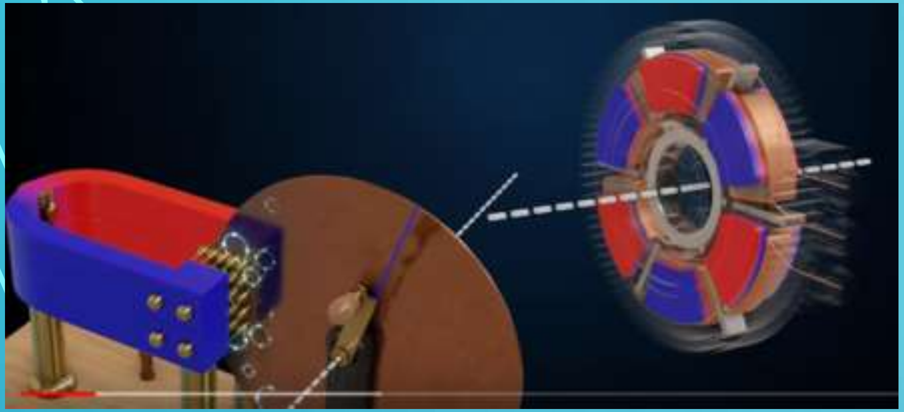
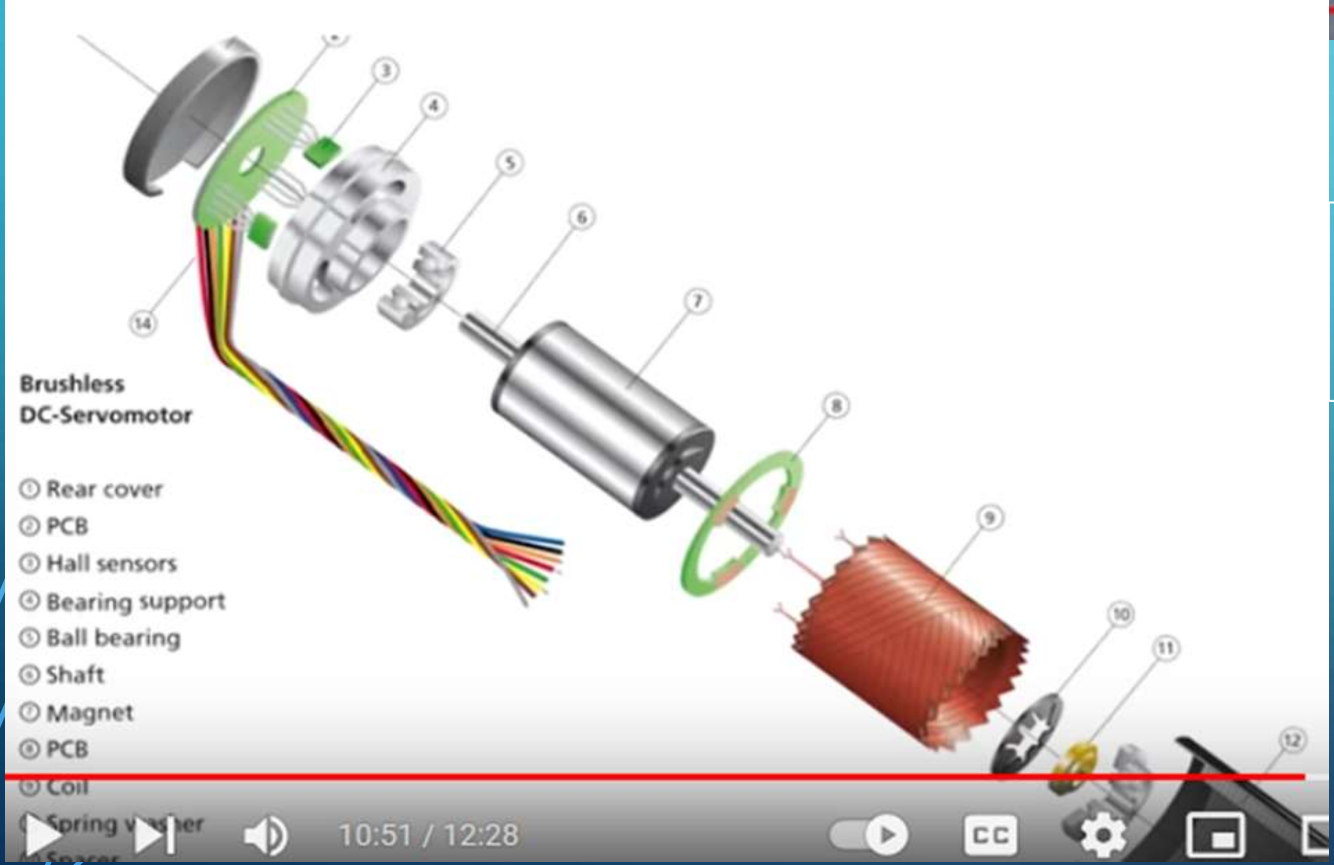

A
B
C
Torque
N
S

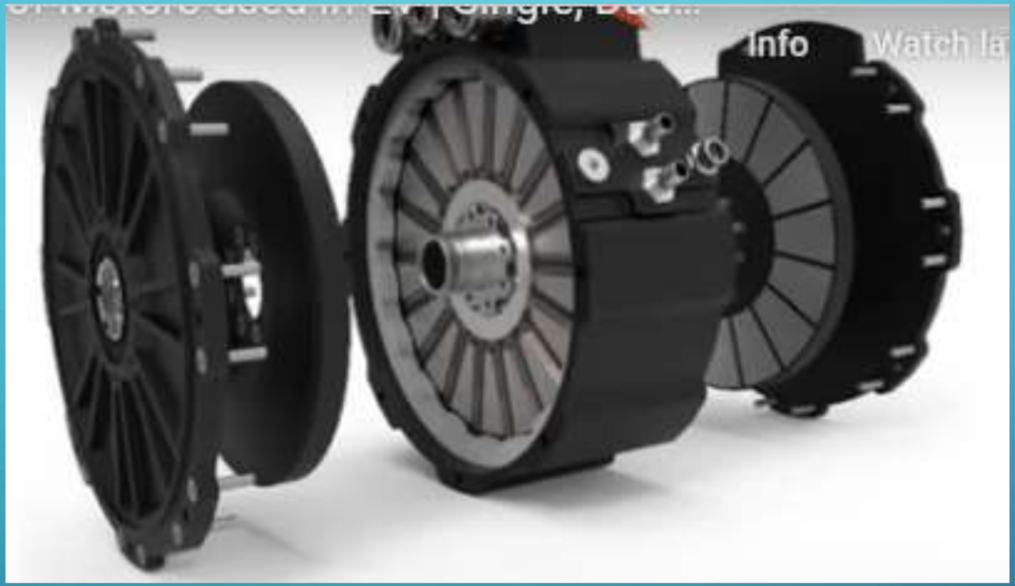

TORUS-STYLE
DOUBLE STATOR
3:16 / 12:29





2020 Mercedes Benz used Axial Flux Motor

TYPE OF MOTORS (BASE ON DESIGN)



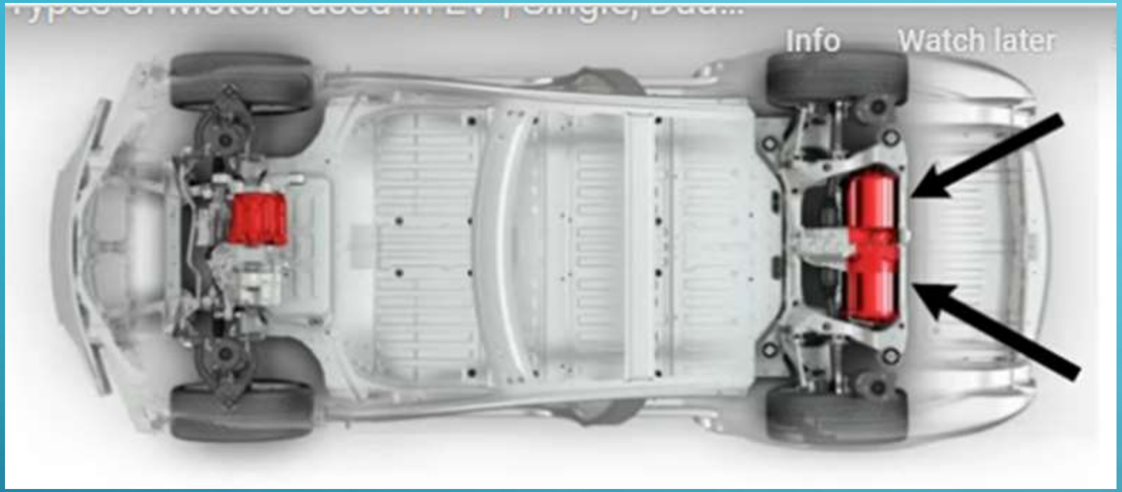
7)AXIAL FLUX IRONLESS PERMANENT MAGNET MOTOR

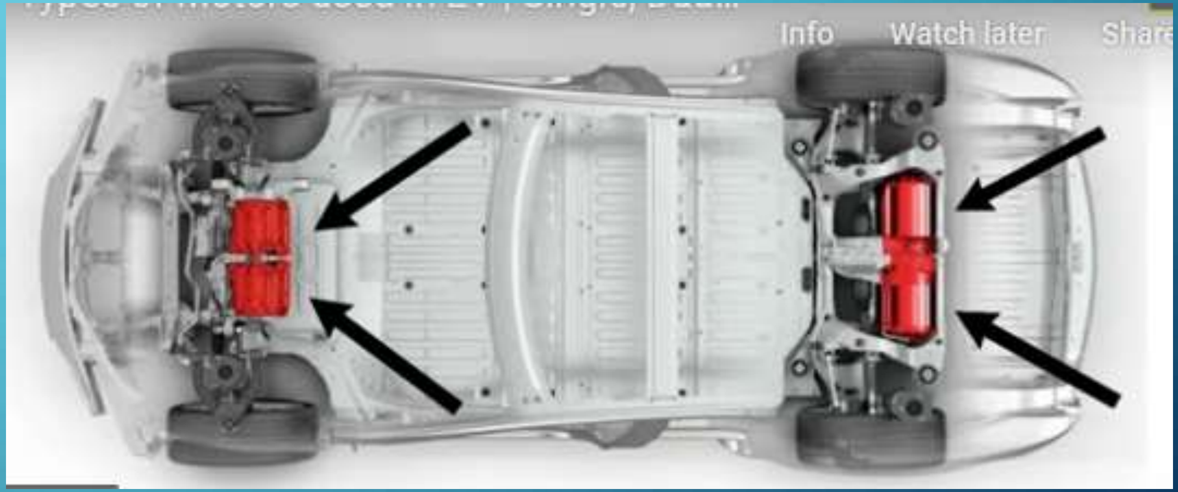
TYPE OF EV (BASED ON USING QUANTITY OF MOTOR)

SINGLE MOTOR EV

DUAL MOTOR EV

TYPE OF EV (BASED ON USING QUANTITY OF MOTOR)





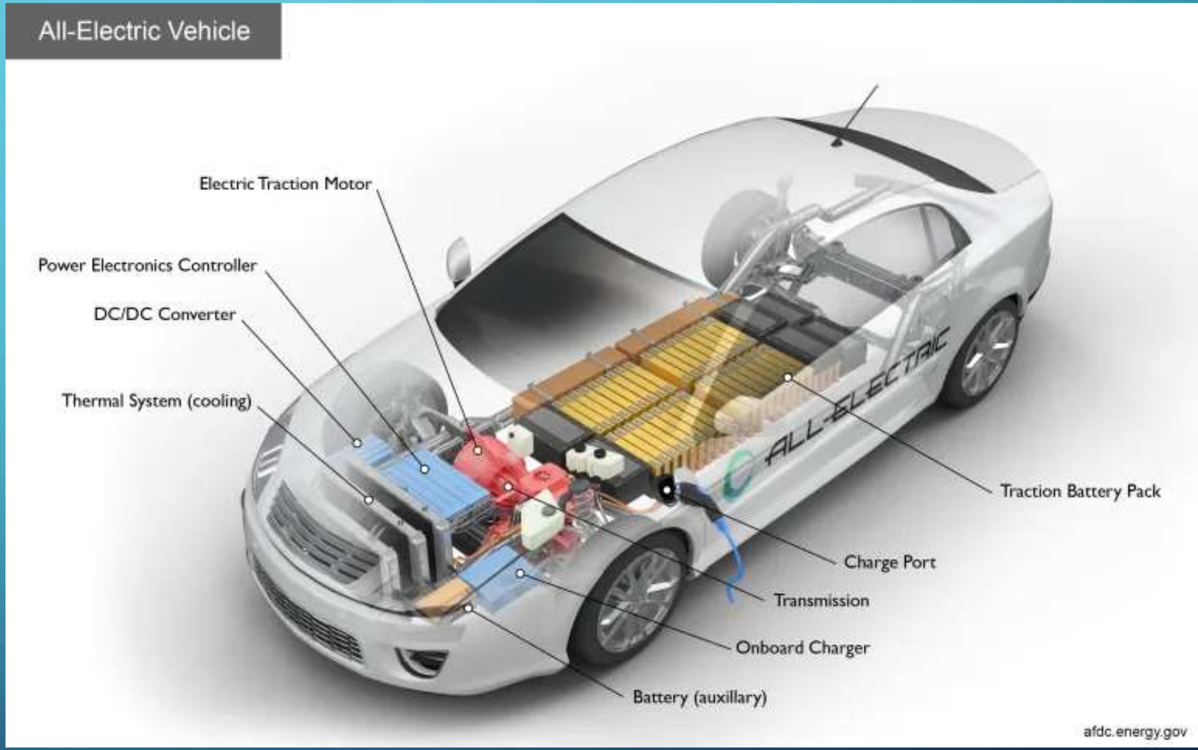
THREE MOTOR EV

FOUR MOTOR EV

4. POWER TRAIN

Electric Power Train

A typical EV powertrain consists of a battery pack, inverters for power transfer and electric motor(s) through a final reduction drive. For hybrid vehicles and plug-in hybrid vehicles, there are additional components in the powertrain, like an Internal Combustion Engine(ICE), dedicated transmission and exhaust system.



- Battery pack. A battery pack consists of cells connected in groups of series and parallel configurations. The battery voltage and current limits are set by the number of series and parallel connections to control the power output.
- Traction inverters. Traction inverters primarily convert the DC from the battery pack to AC output for running the electric motor. Another significant feature is electric braking, which improves the life of mechanical braking systems by reducing unnecessary wear and tear.
- Electric motor and reduction drive. The electric motor produces the mechanical energy for propulsion based on the dynamics of the electric power received from the transmission. The final reduction drive transforms the input from the motor to a high-torque output to the wheels to accelerate the vehicle. To optimize battery usage and improve mileage, EVs are designed to set the final drive ratio per vehicle specification and driving conditions. It is the ratio of the motor’s input speed to the wheel’s output speed. A higher final drive ratio leads to higher torque or better acceleration, whereas a lower torque ratio allows maximum vehicle speeds.
- On-board charger (OBC). The OBC controls the AC received through the charging port and converts it to DC for battery storage.

Multiple software runs with the specific EV powertrain components for data exchange and processing. Such firmware is called the electronic control unit (ECU). A primary example of this is the powertrain ECU, which controls the DC/AC converter to modulate the amount and frequency of the voltage supplied to the motor based on the car driver's inputs from acceleration and braking.

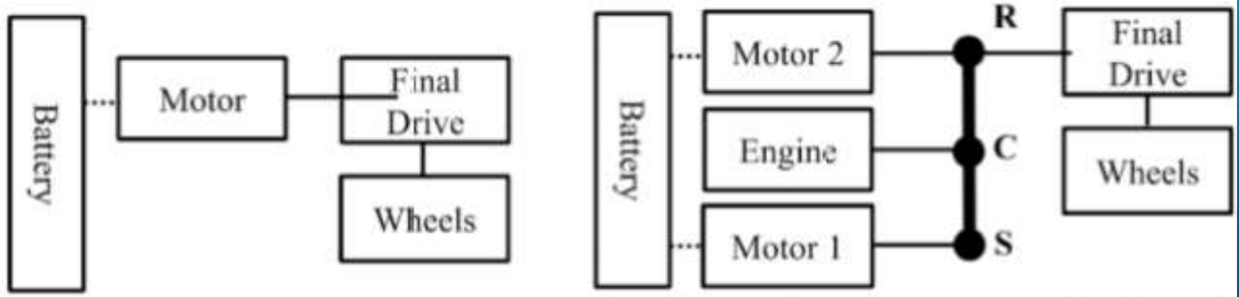
Some other essential ECUs in an EV powertrain system are a battery management system (BMS) to monitor the health of the battery pack; a DC/DC converter to convert the voltage from the battery pack to auxiliary car components like wipers, lights and power windows as per their voltage requirement; a thermal management system to control the firmware necessary to maintain optimal temperature for the powertrain system; and a body control module to control auxiliary components like power windows and mirrors.

For EVs, each component can be classified into one of three powertrain categories:

- Power generation system: battery pack, OBC
- Power distribution (transmission) system: DC/AC converter (traction inverter), DC/DC converter, BMS
- Mechanical components: Electric motors, final reduction drive, components for electronic accessories like power windows and mirrors

EV POWERTRAIN DESIGN

The efficiency, mileage and overall performance of an EV can be optimized at the components, architecture and control levels.



(a) Nissan Leaf (b) Toyota hybrid system (for Prius)

NISSAN LEAF 2023 MODEL

TOYOTA PRIUS 2023 MODEL

Powertrain examples (Source: Kang et al., “Public investment and electric vehicle design: A model-based market analysis framework with application to a USA-China comparison study,” Design Science, January 2016)

For example, the battery, motor(s) and engine are sized at the component level to meet target driving requirements, like short-range city drive or long-range highway drive. Also, the EV powertrain architecture can significantly improve the performance of the vehicles by integrating and switching between multiple driving modes based on the conditions. A driving mode is a configuration of components specific to a particular use case, such as vehicle acceleration (high torque) or cruising (high speeds). ECUs augment the existing hardware architecture to convert throttle from the driver to instructions for the battery and motor(s) to meet performance requirements such as 0- to 60-mph acceleration at near-optimal energy consumption. The optimal control policies are determined using algorithms like dynamic programming, Pontryagin’s minimum principle or the equivalent consumption minimization strategy.

Power electronics’ role

The main objective in designing an EV powertrain is efficiency, as higher efficiency leads to better thermal management and range. Lower efficiency results in higher power loss, causing extra heating, for which the size of the EV must be increased for heat dissipation. Another critical parameter for optimizing EV powertrains is power density (the power delivered per vehicle unit volume).

To achieve those two objectives, apart from the powertrain design, semiconductor-based power electronics switches play a crucial role in improving efficiency and power density. The exponential demand for EVs is prompting extensive research in power electronics switches like silicon (Si)-based IGBTs and MOSFETs to improve switching characteristics for better efficiency.

Additionally, there has been an increasing interest in using silicon carbide (SiC) MOSFETs based on their potential to improve efficiency and reduce the size of the power converter:

- SiC MOSFETs, as wide-bandgap devices, provide many merits that are favorable to the EV industry. SiC MOSFETs have lower switching and conduction losses than Si IGBTs or MOSFETs, which are essential to increase the mileage of EVs.
- SiC-based switching devices have a higher junction temperature of 175°C, compared with 150°C for Si-based devices, which makes it possible to design an integrated powertrain with a reduced cooling requirement.
- In addition, the high switching frequency of SiC-based devices minimizes the size of passive components like the DC-link capacitor, boost inductor and EMI filter. These features of SiC-based semiconductor devices enable the reduction of the overall size of the powertrain, which indirectly achieves a much higher power density for an EV.

Apart from better efficiency, semiconductor manufacturers are upgrading silicon packaging technologies to address various automotive applications like thermal management and improving the semiconductor packages for challenging power densities.

Irrespective of semiconductor materials like Si or SiC, the IGBT- and MOSFET-based solutions are evolving for high thermal management to reduce the EV size and cost by reducing the need for expensive cooling systems. Compact dual-side–cooling 750-V IGBT modules with chip-level temperature and current-sensor ECUs have started coming up for 400-V traction inverter applications. Also, MOSFET packages with innovative surface-mount packaging and top-side cooling provide compact traction inverter packaging, reducing the vehicle's size.

Exploiting SiC MOSFET to power EV's innovation

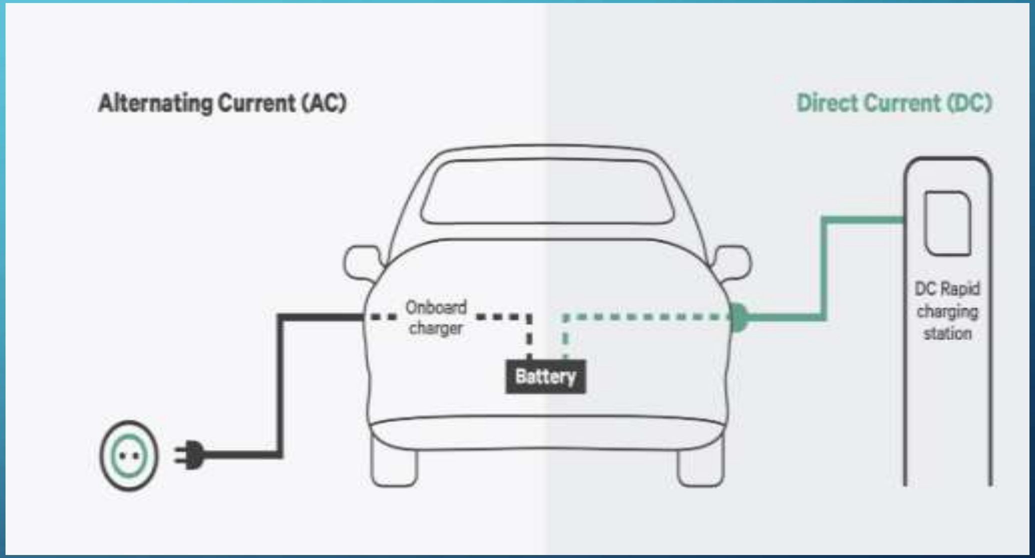
- ***Higher power densities***
- Designers are working hard to reduce the size of high-power electronic subsystems, such as traction inverters and onboard chargers (OBCs) as both a cost-saving measure and to maximize the vehicle's usable space. When applied to bridge inverters, using smaller, cooler-running drive modules allows designers to place them closer to their point of load (PoL), often co-located with the motor/transaxle assembly *(Fig. Below)*.

Compact, Cool-Running SiC MOSFETs enable the design of save -spacing traction inverters that occupied little or no area, and can even be co-located with EV's drive train.

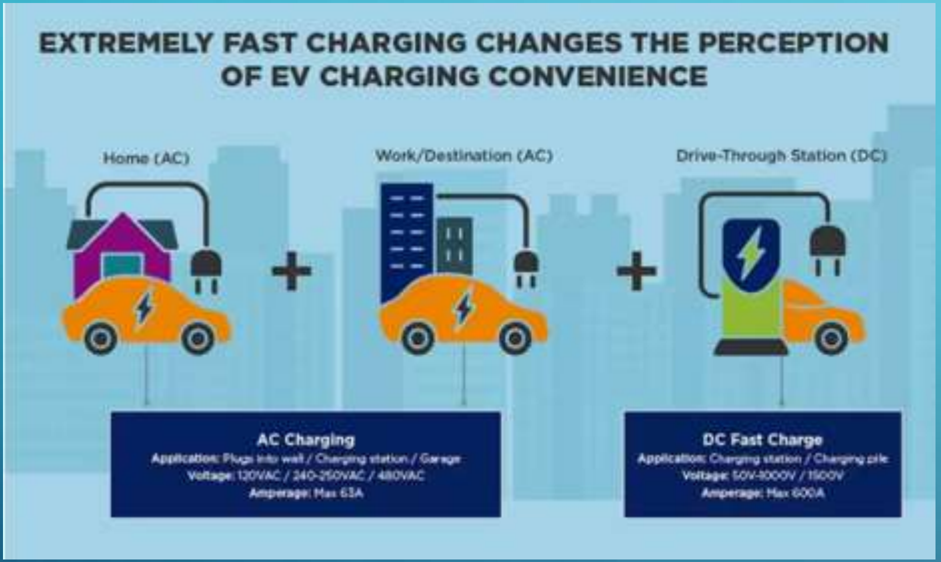
5. CHARGING OF ELECTRIC VEHICLES

AC CHARGING

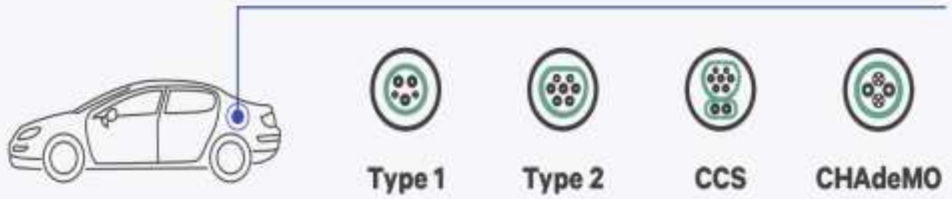
DC CHARGING



FAST CHARGING VIEW



DIFFERENT TYPES OF CHARGING PORT



There are Two Type of AC Charging Ports

Type 1 is a single-phase plug and is standard for EVs from America and Asia. It allows you to charge your car at a speed of up to 7.4 kW, depending on the charging power of your car and grid capability.

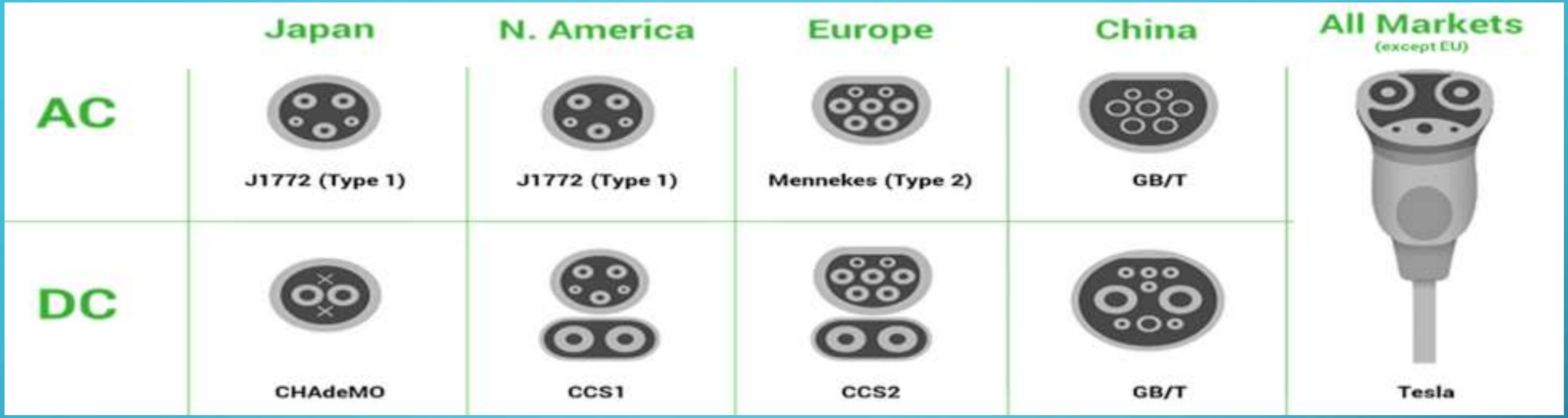
Type 2 plugs are triple-phase plugs because they have three additional wires to let current run through. So naturally, they can charge your car faster. At home, the highest charging power rate is 22 kW, while public charging stations can have a charging power up to 43 kW, again depending on the charging power of your car and grid capability.

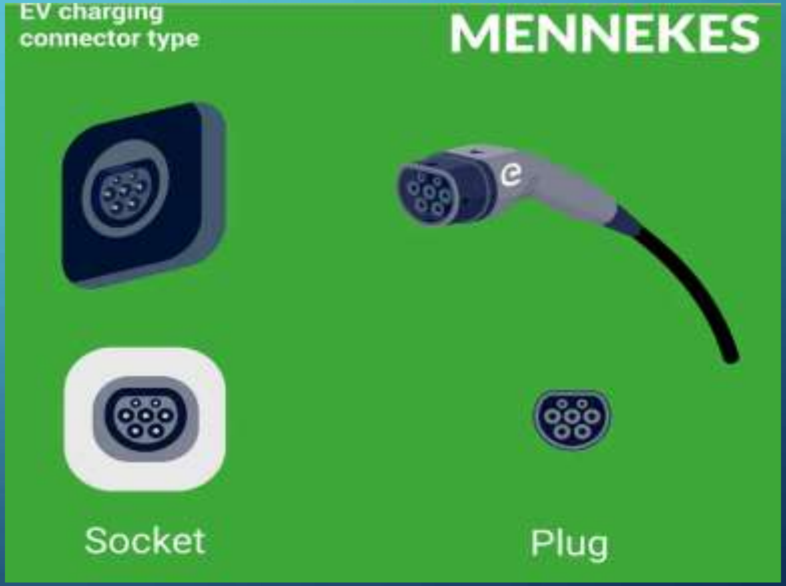
Two types of plugs exist for DC charging:

- CHAdeMO: This quick charging system was developed in Japan, and allows for very high charging capacities as well as bidirectional charging. Currently, Asian car manufacturers are leading the way in offering electric cars that are compatible with a CHAdeMO plug. It allows charging up to 100 kW.
- CCS: The CCS plug is an enhanced version of the type 2 plug, with two additional power contacts for the purposes of quick charging. It supports AC and DC charging. It allows charging at a speed of up to 350 kW.

SUMMERY

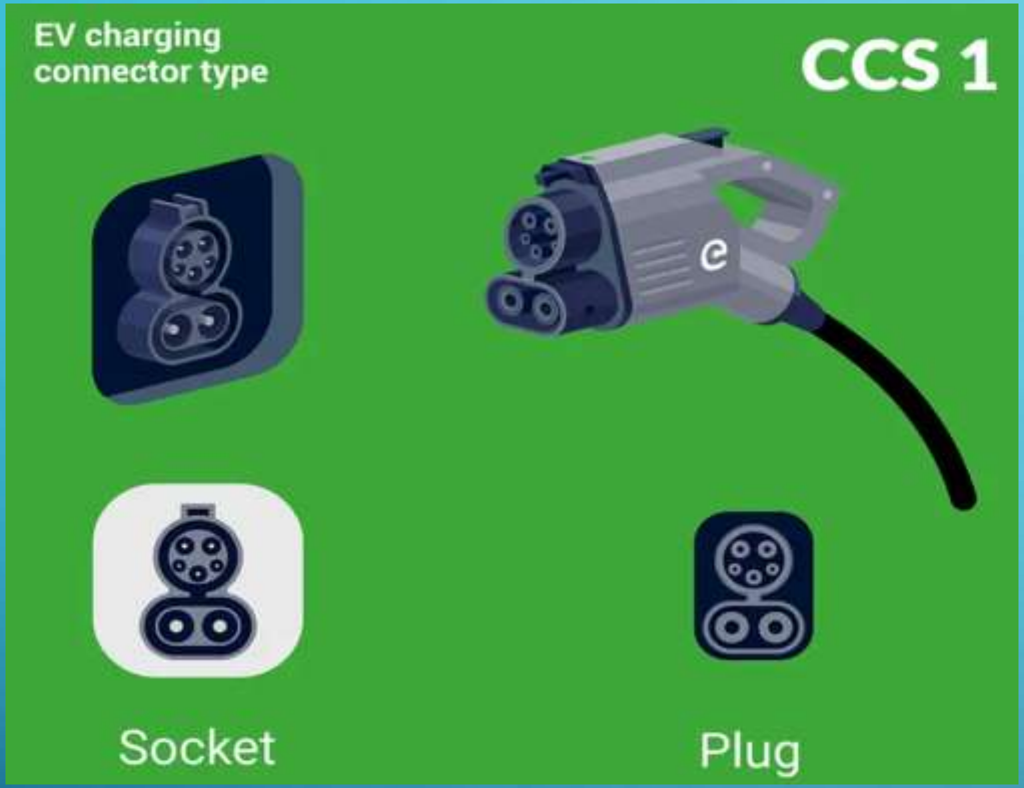
- Four types of plug exist, two for AC (type 1 and 2) and two for DC (CHAdeMo and CCS).
- **Type 1** is common for American vehicles, it’s a single-phase plug and can charge at a speed of up to 7.4 kW.
- **Type 2** is standard for European and Asian vehicles from 2018 onwards, it’s a triple-phase plug and can charge at a level of up to 43 kW.
- **CCS (Combine Charging System)** is a version of type 2 with two additional power contacts. It allows very fast charging.
- **CHAdeMO** can be found in Asian cars and allows for high charging capacities as well as bidirectional charging.
- CHAdeMO’ is a play on the phrase ‘CHArge de MOve’, which means ‘charge for moving’. It’s a pun on the Japanese phrase ‘O cha demo ikaga desuka’, which translates to ‘let’s have a cup of tea while charging’.

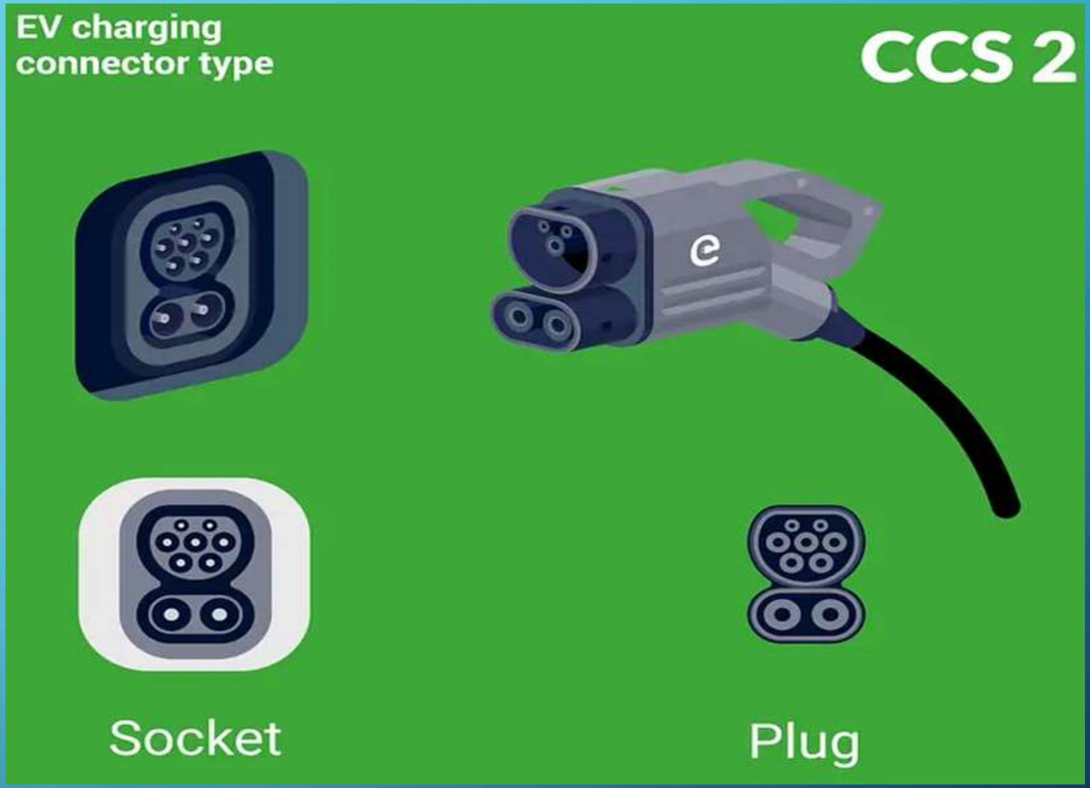




LARGE SIZE VIEW FOR TYPE 1 AC

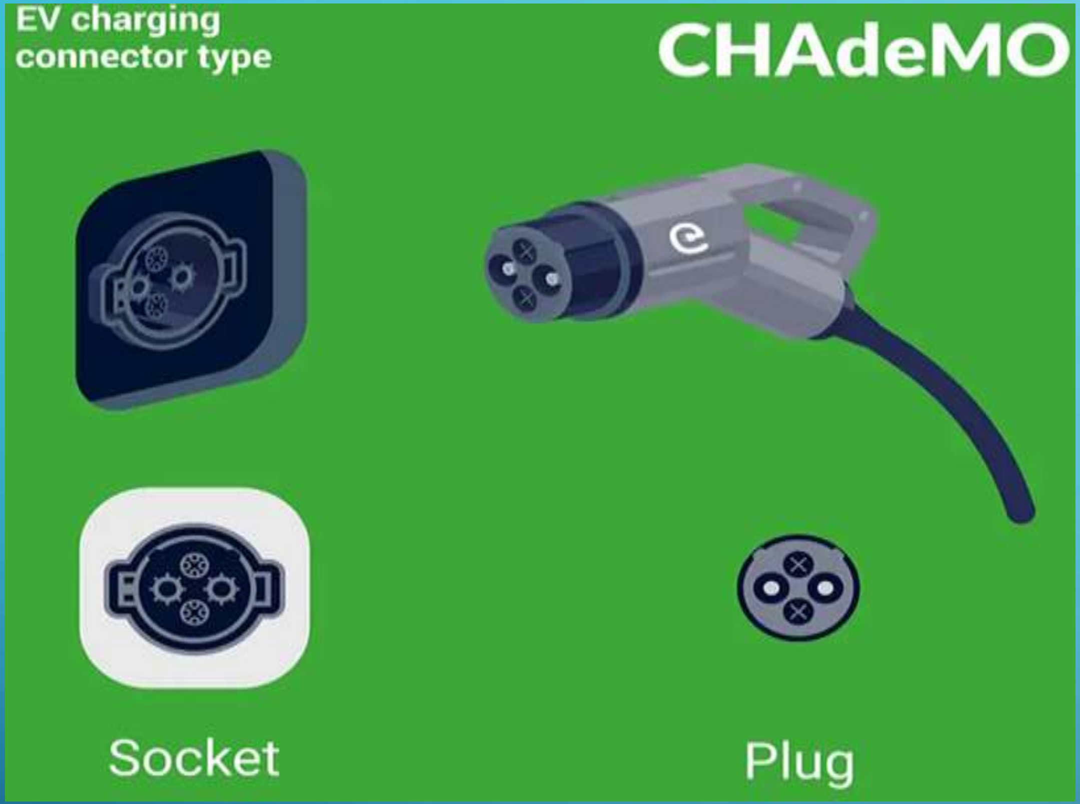
LARGE SIZE VIEW FOR TYPE 2 AC

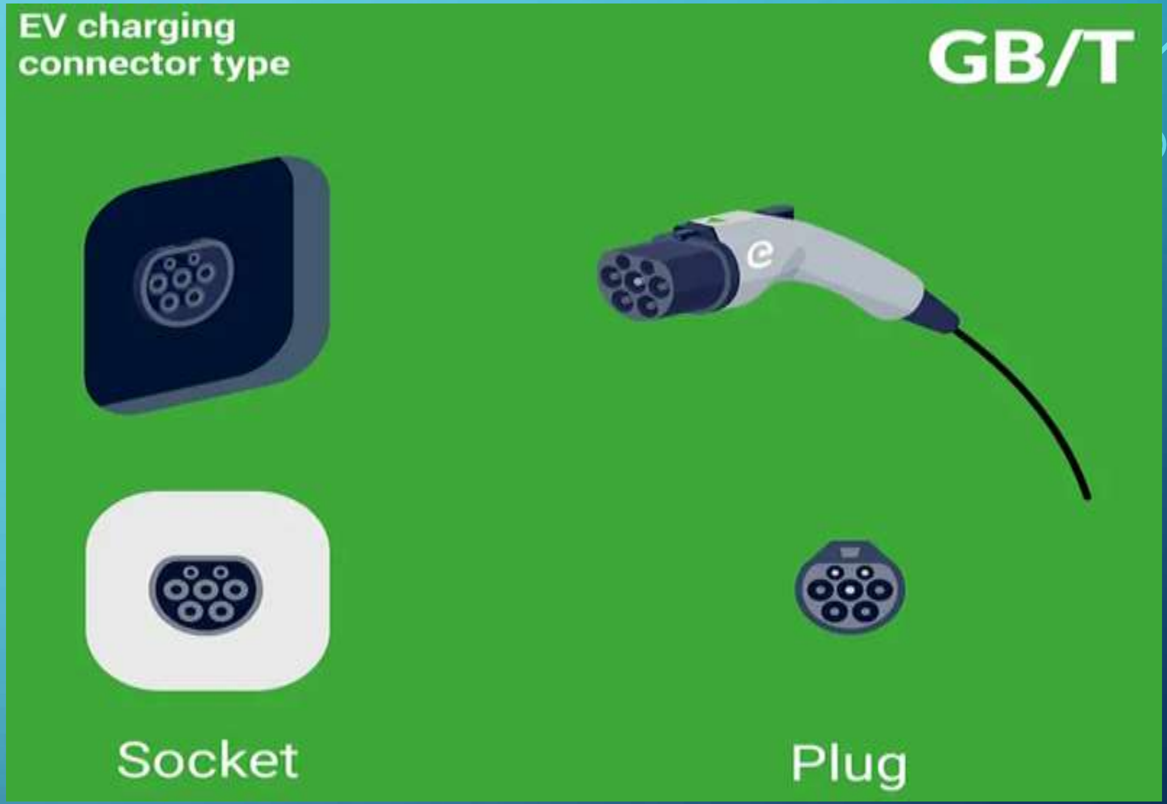




LARGE VIEW OF TYPE CCS TYPE 1 DC

LARGE VIEW OF TYPE CCS TYPE 2 DC

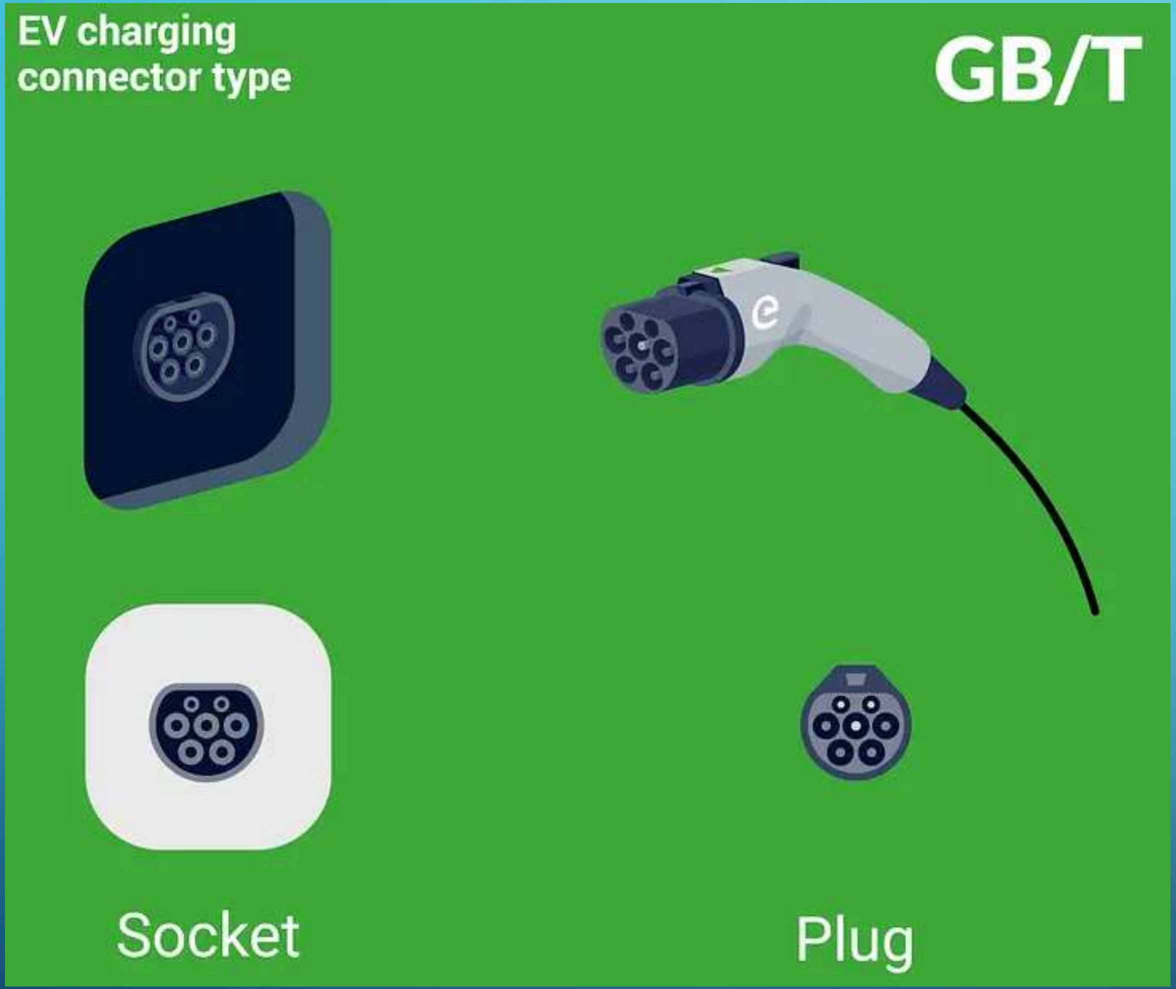


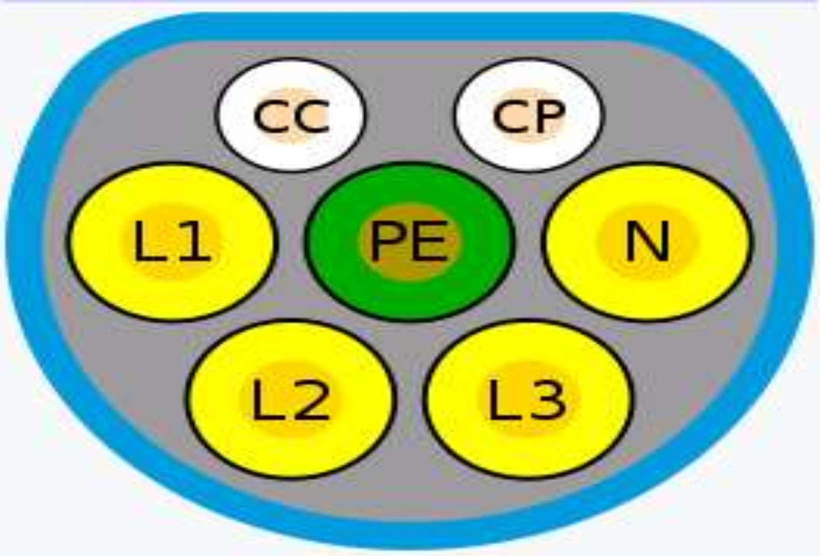


LARGE VIEW OF TYPE CHA DE MO,DC

LARGE VIEW OF TYPE GB/T, AC

GB/T OR GBT IS AN ABBREVIATION FOR **GUOBIAO TUIJIAN** IN CHINESE, WHICH TRANSLATES TO "NATIONAL STANDARD RECOMMENDED.

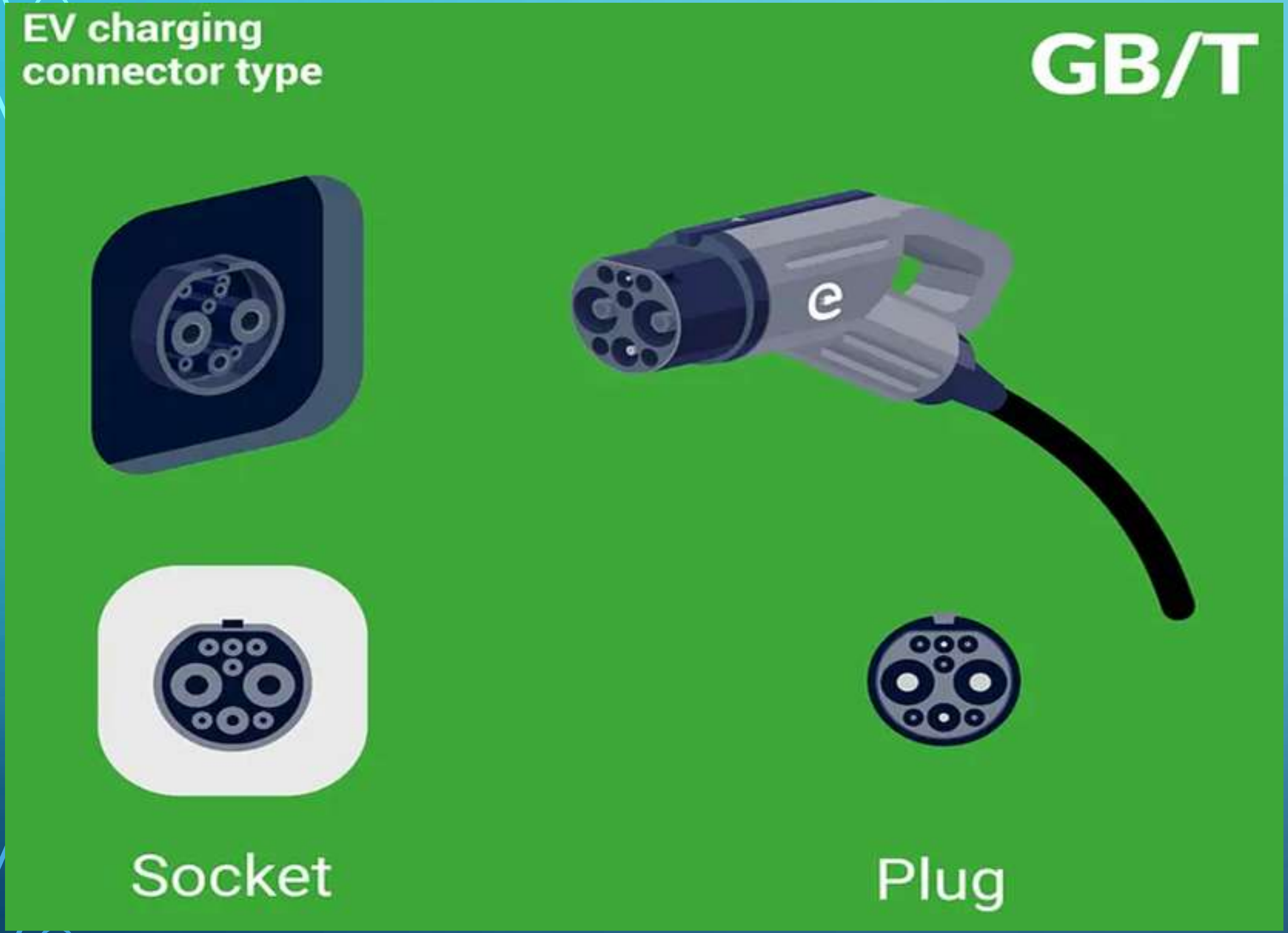


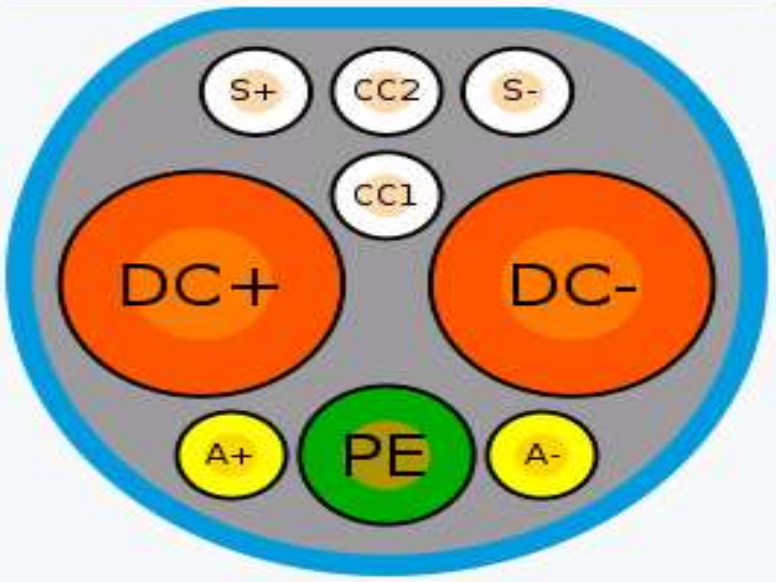


Pinouts for GB/T 20234.2 (male interface)

CC	Charging confirmation	pre-insertion signalling
CP	Control pilot	post-insertion signalling
PE	Protective earth	full-current protective earthing system—6-millimetre (0.24 in) diameter
N	Neutral	single-phase AC
L1	Line 1	single-phase AC
L2	Line 2	back-up contact
L3	Line 3	back-up contact

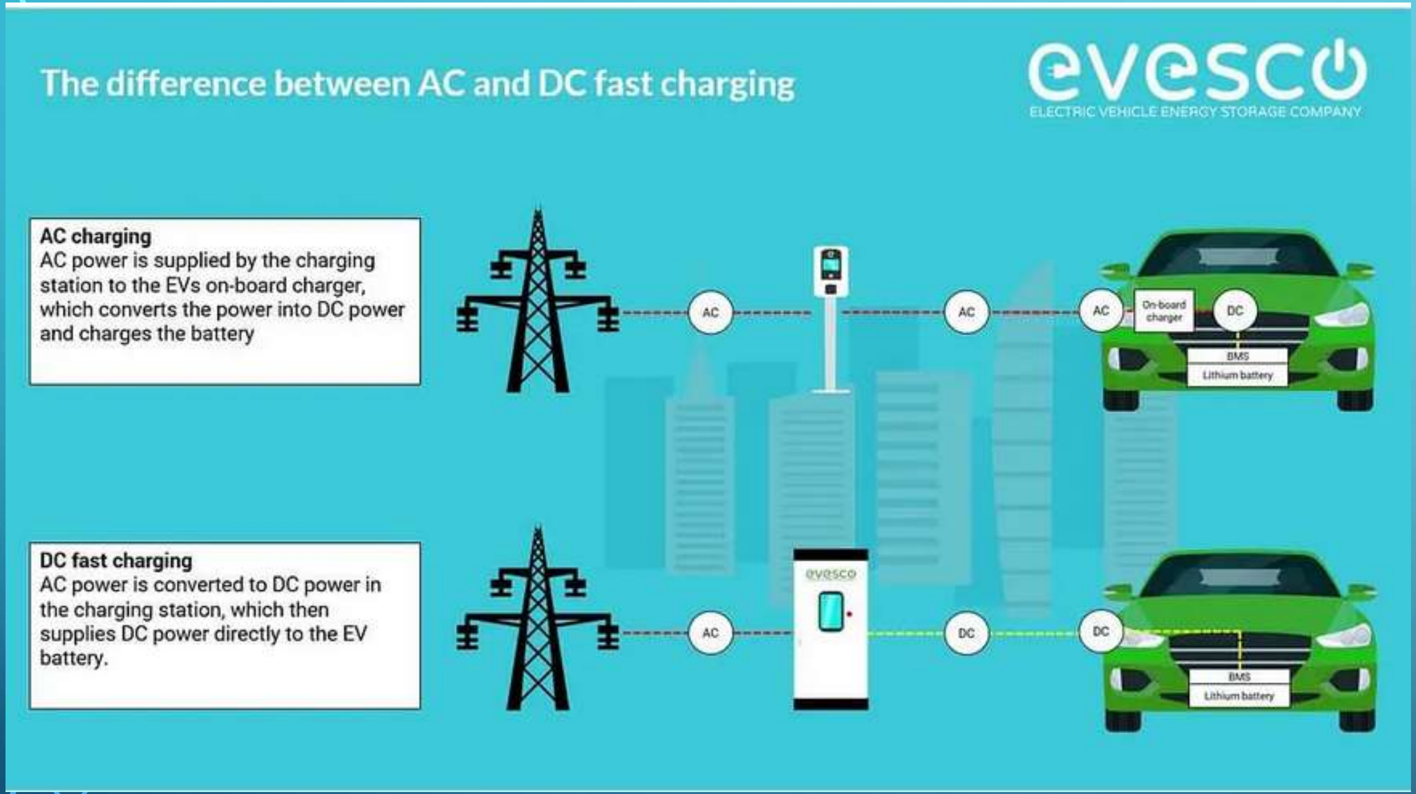
LARGE VIEW OF TYPE GB/T, DC

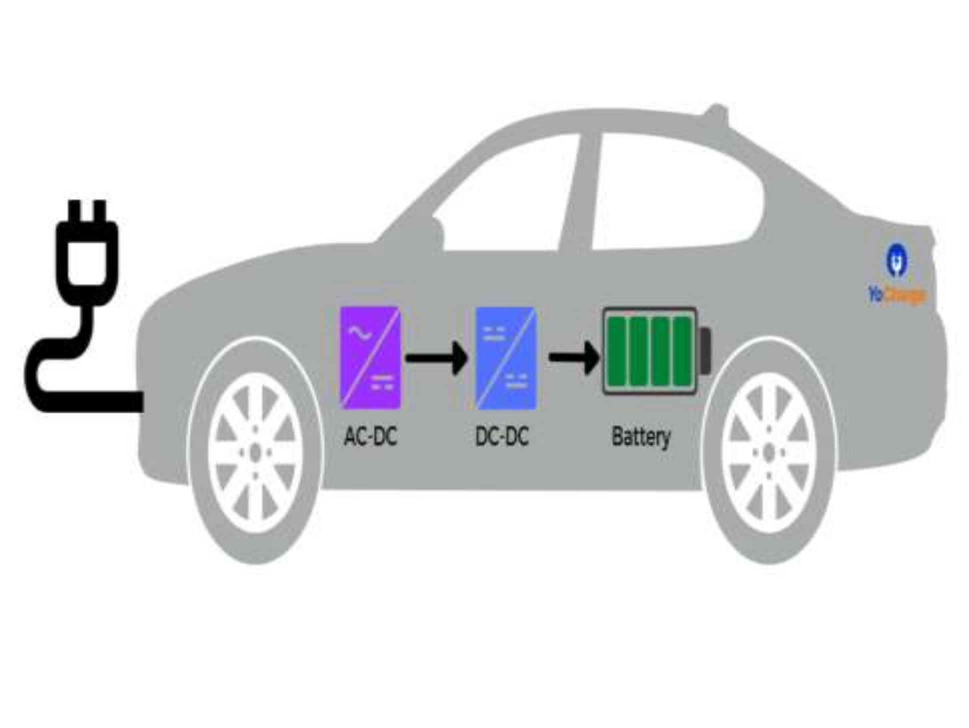




Pinouts for GB/T 20234.3 (male *vehicle connector* interface)

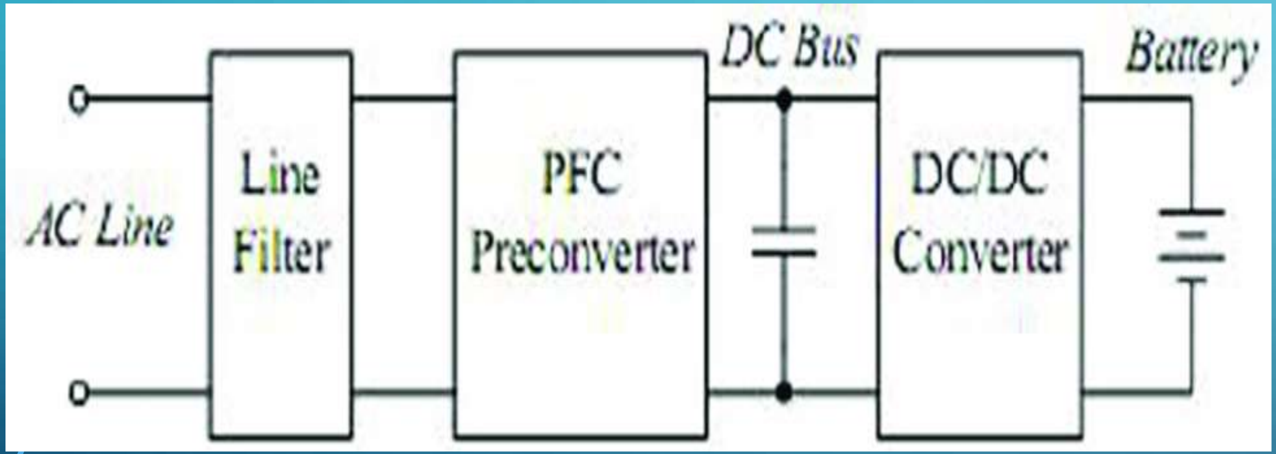
S+ / S-	Charging communication	CAN_H / CAN_L
CC1 / CC2	Charging confirmation	post-insertion signalling
DC+ / DC-	Main DC power	positive / negative
PE	Protective earth	full-current protective earthing system
A+ / A-	Auxiliary DC power	+/-30V, 20A


The difference between AC and DC fast charging
evesco
ELECTRIC VEHICLE ENERGY STORAGE COMPANY
AC charging
AC power is supplied by the charging station to the EVs on-board charger, which converts the power into DC power and charges the battery
AC
AC
AC
On-board charger
DC
BMS
Lithium battery
DC fast charging
AC power is converted to DC power in the charging station, which then supplies DC power directly to the EV battery.
AC
DC
DC
BMS
Lithium battery

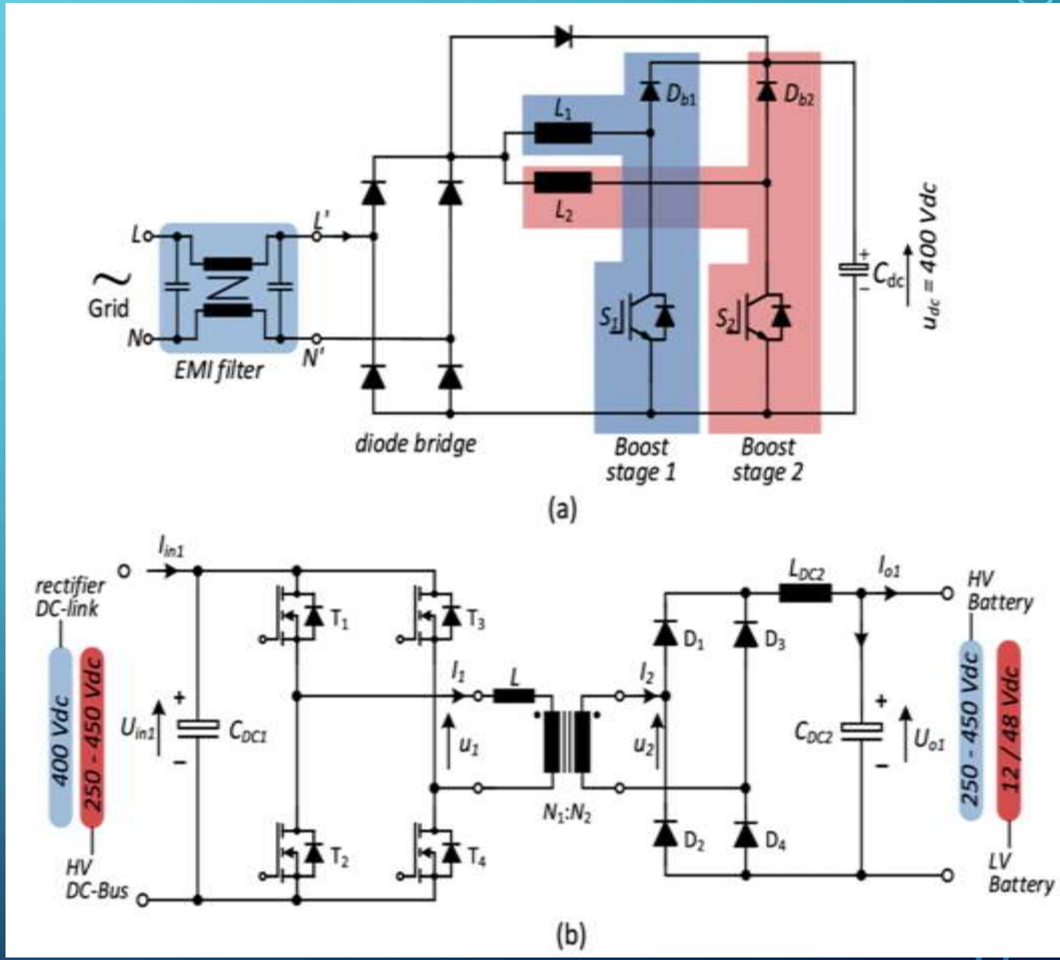

AC-DC
DC-DC
Battery

6. ON BOARD CHARGER(OBC)

BLOCK DIAGRAM OF OBC



PFC = POWER FACTOR CORRECTION



Block diagram of OBC and dc-dc converters. (a) Single-phase ac/dc with interleaved boost PFC topology. (b) Isolated dc-dc converter with unidirectional PSFB configuration.

Phase Shift Full Bridge (PSFB)

As a result, an AC charger is required to transfer power directly from the household grid to the Electric Vehicle (EV). An isolated onboard charger (OBC) using the PFC (Power Factor Correction) boost AC/DC converter and PSFB (Phase Shift Full Bridge) DC/DC converter is present in this work.

EMI (electromagnetic interference) Filter

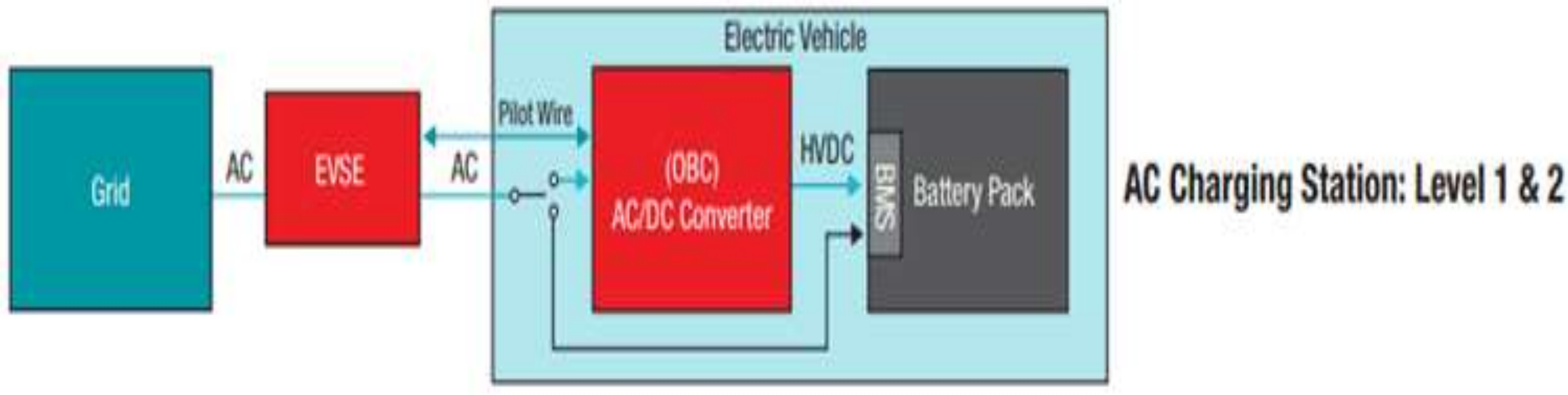
The first stage of the OBC is the EMI filter. During this stage AC power is filtered to remove any unwanted noise from the typical AC sine wave that is expected.

ON BOARD CHARGER WORKING SCHEMATIC DIAGRAM

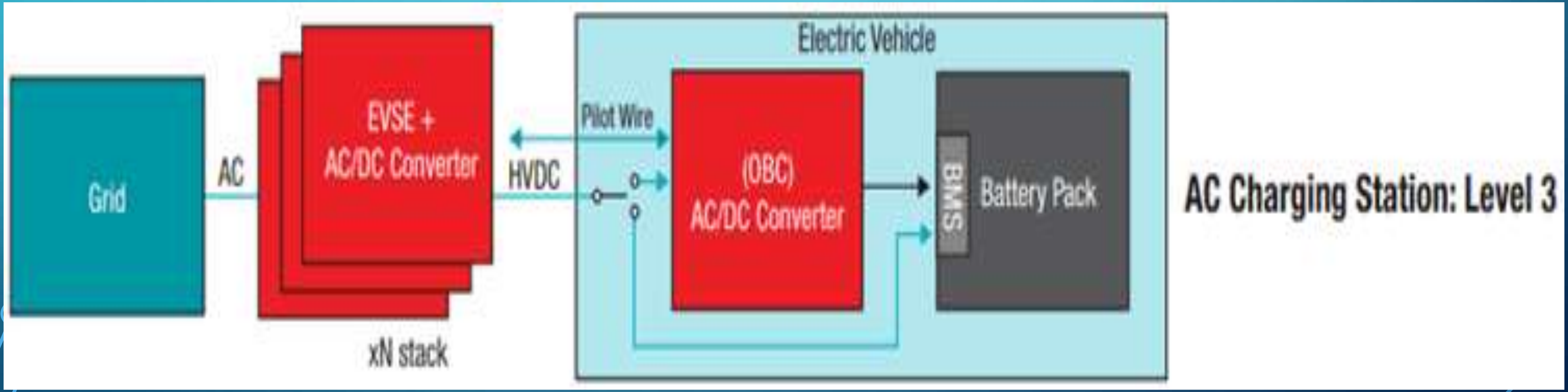
ONBOARD CHARGER IN DIFFERENT CHARGING STATIONS

ESVE	Charging level	AC Supply specification	Power rating	Time taken to charge a 24kWh battery pack (approx.)
AC charging station	Level 1 – residential applications	Single Phase- 120/230 V and 12 to 16 A	1.44 kW to 1.92 kW	17 hrs
AC charging station	Level 2- Commercial applications	Split Phase – 208/240 V and 15 to 80 A	3.1 kW to 19.2 kW	8 hrs
DC charging station	Level 3- Fast charging	Single Phase- 300/600 V and approx. 400 A	120 kW to 240 kW	30 min

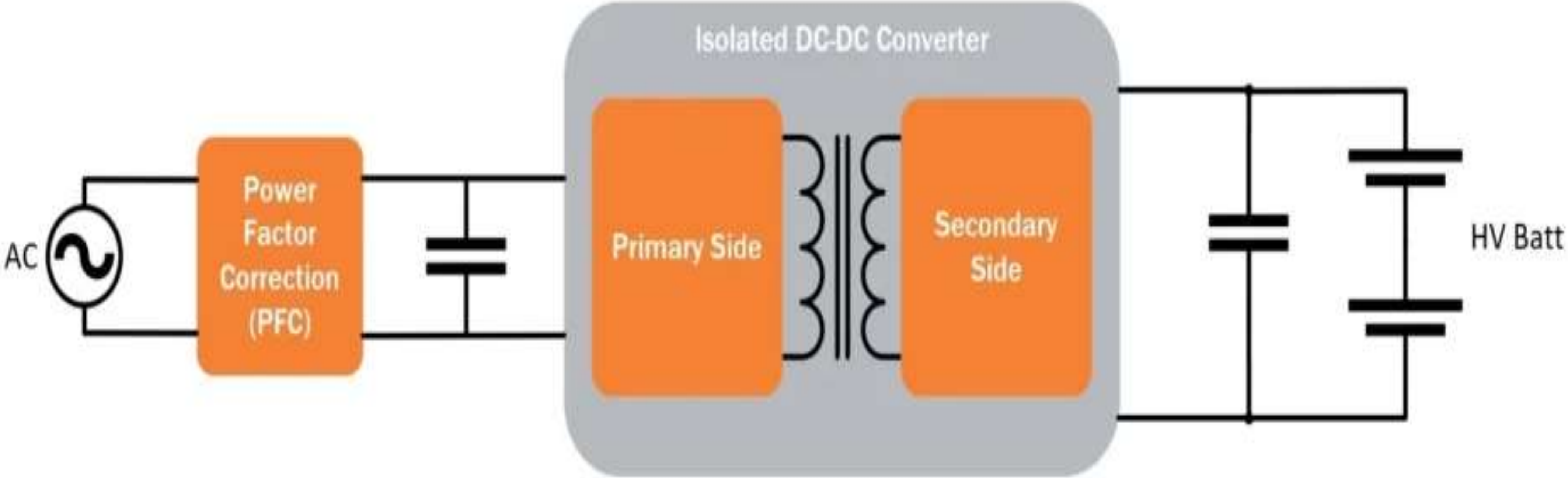
ROLE OF OBC IN AC CHARGING



ROLE OF OBC IN DC CHARGING



Working of an Onboard Charger

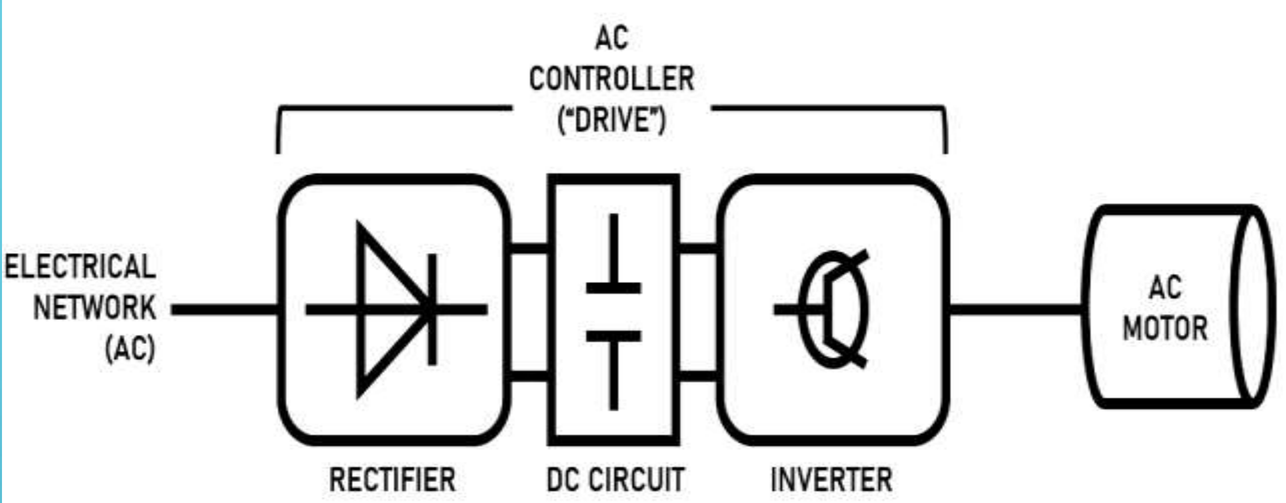


7. CONTROLLER

Two Type of Controller are:

A) AC Motor Controller
B) DC Motor Controller

A) AC Motor Controller



BASIC CIRCUIT DIAGRAM FOR MOST AC MOTOR CONTROLLERS.

Three Type of AC Inverters

A1)Variable Voltage Inversion

In this method, the AC frequency of the power source is rectified to a DC current, which is then increased and decreased in discrete steps to imitate a sine wave (or how a true AC current oscillates). This way, operators can regulate these steps to effectively change the motor speed, and these are commonly referred to as six-step inverters (though different steps exist). Figure 2 below shows an example of how a VVI controller sends stepwise power to a motor, simulating a true sine wave:

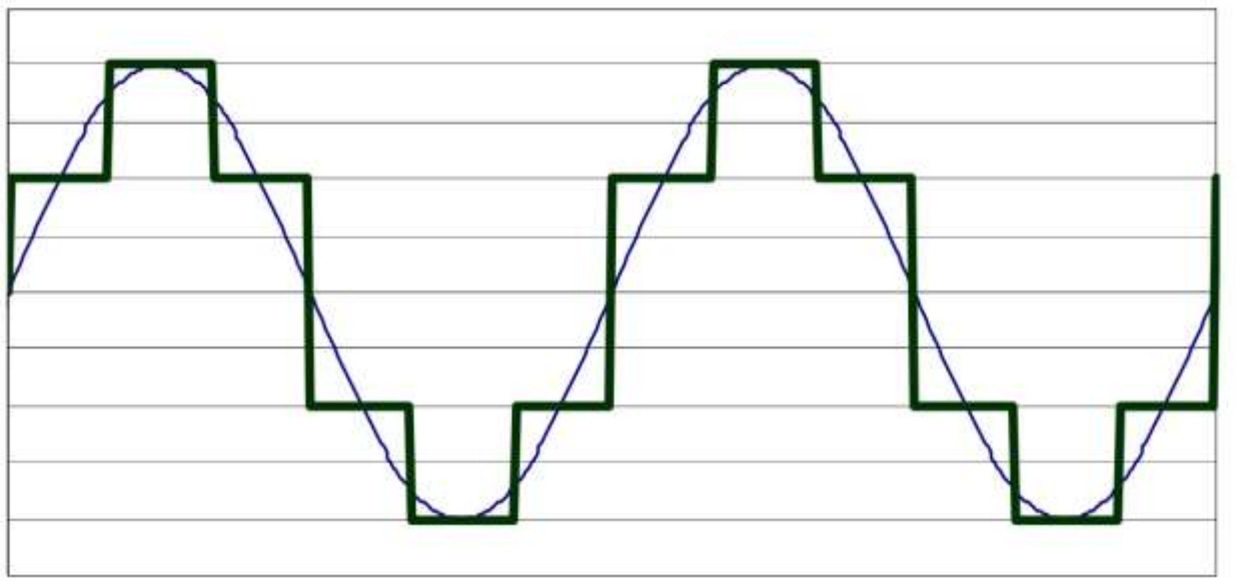
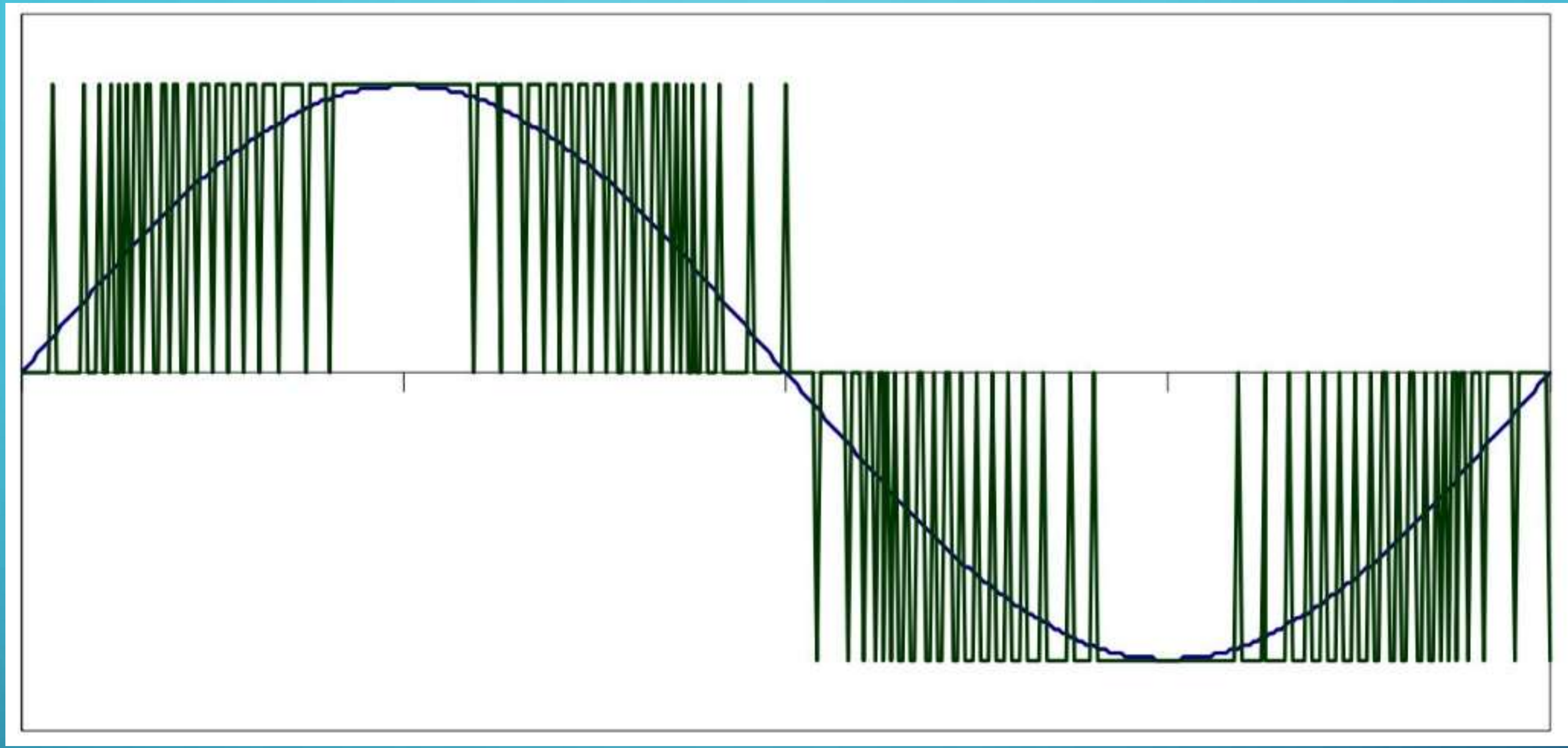


Figure 2: Voltage over time graph representing how VVIs allow speed control in AC motors. Notice that, if more steps were added, it would give a better approximation to the true sine wave.

- *Image credit:* https://www.me.ua.edu

A2)Pulse-Width-Modulation

Pulse width modulator circuits, or PWMs, are a popular method to simulate AC oscillations, as they often provide more precise control than variable voltage inverters. They do so by rapidly switching the current (or “pulsing” it) to match the area under the curve of the true sine wave. Recall from calculus that the integrals of any two continuous graphs are equal if their areas under their curves are equal; the goal of PWM is to more accurately approximate the area of a sine wave using many pulses of voltage, and the density of these pulses will dictate the size of the simulated sine wave (and thus change the motor speed). Figure 3 visualizes these spikes on a voltage over time graph:



- ***Figure 3: PWM graph compared to a true sine wave. Notice how the pulses change frequency as they move along the sine wave, but do so in an orderly, equidistant fashion.***
- *Image credit:* https://www.me.ua.edu

Different EV charging states

- State A
  - EVSE is ready to accept a charge
- State B
  - Vehicle is connected
- State C
  - Vehicle is charging but doesn’t require ventilation
- State D
  - Vehicle is charging and required ventilation
- State E
  - External problem with the charger (e.g. pilot short to ground, no grid power)
- State F
  - Problem with the charger itself (charger not available)

The control pilot **(CP)** pin provides bi-directional communications between the electric vehicle and charging system. This checks the maximum amount of current that the EV is able to take at any one time.

Electric vehicle supply equipment

Electric vehicle supply equipment **(EVSE)** supplies electricity to an electric vehicle (EV). Commonly called charging stations or charging docks, they provide electric power to the vehicle and use that to recharge the vehicle's batteries.

The EVSE sets the duty cycle, which is defined as the ratio between the high state and the low state. The EV must comply with this setting or change the duty cycle. For example, a 10% duty cycle relates to a maximum current of 10A, a 30% duty cycle is equivalent to 18A, and a 90% duty cycle flags fast charging at 65A.

State A

- CP at +12V
- Vehicle is not connected
- Charging is not possible

State B

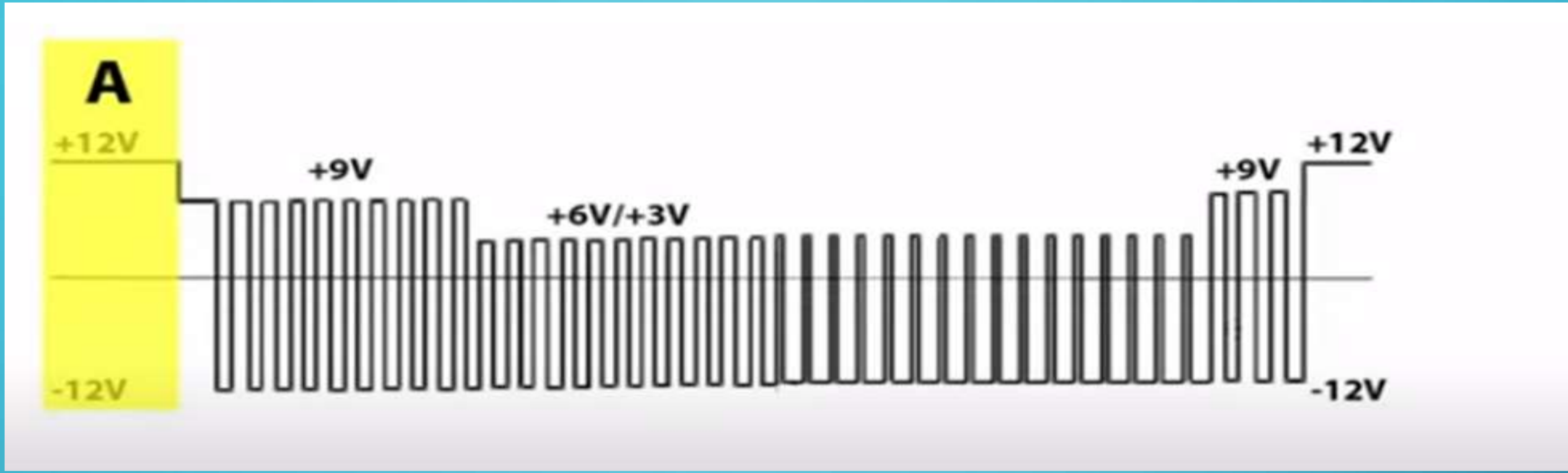
- 2.74kΩ resistor is switched in
- CP drops to +9V
- Vehicle is connected
- Charging is not possible

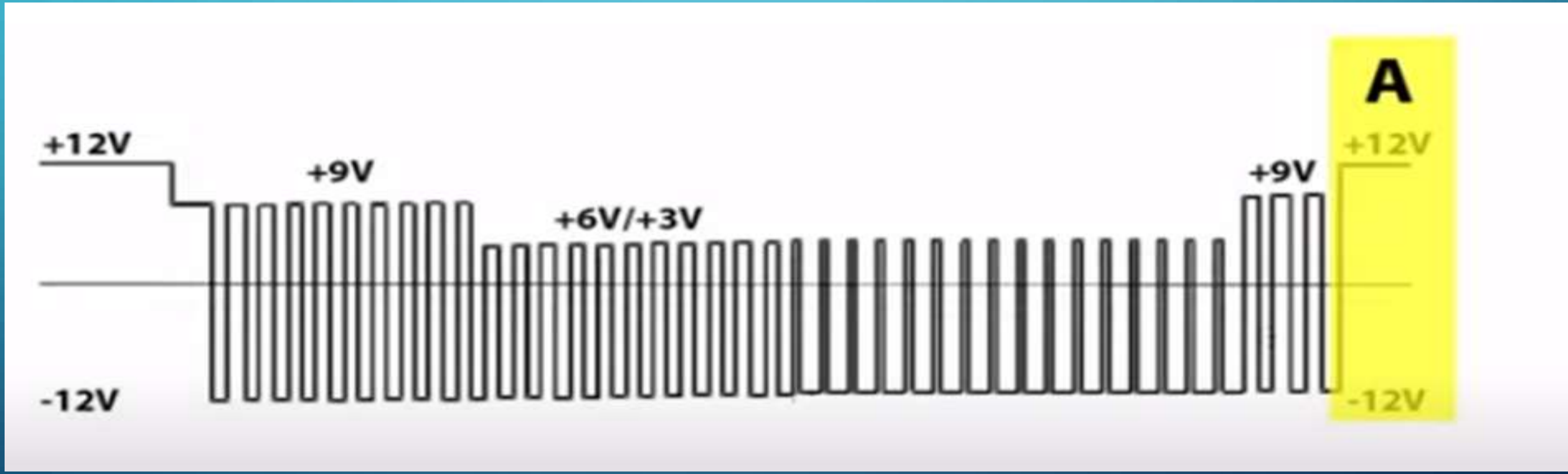
State C/D

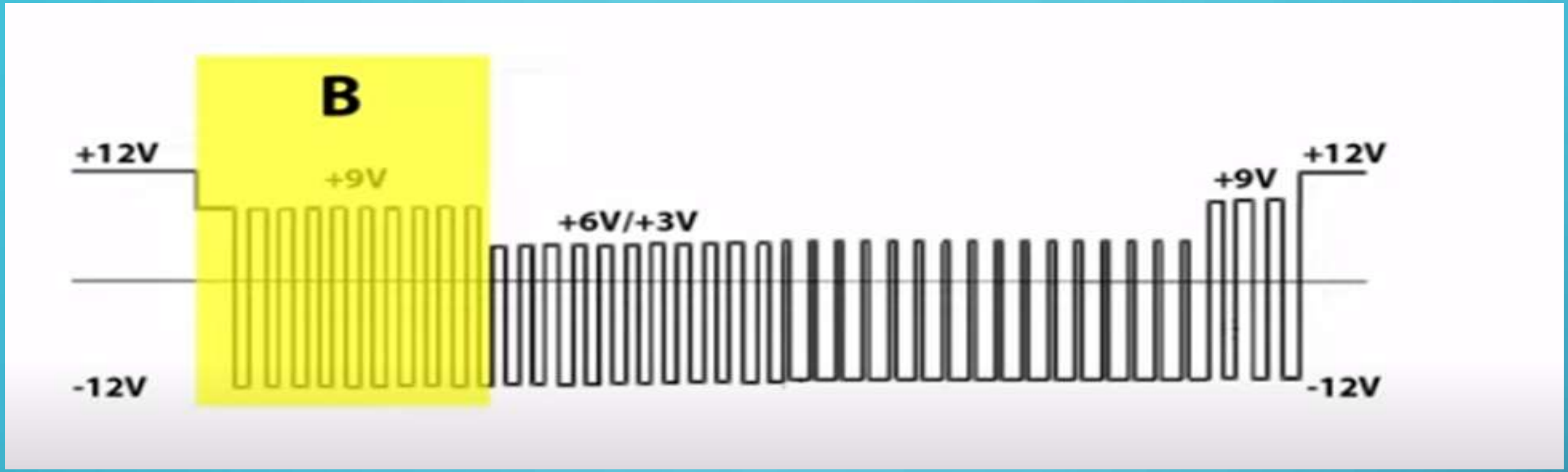
- State C
  - 1.3kΩ
  - CP drops to +6V (measured in function of total resistance of 882Ω)
  - Vehicle is connected
  - Vehicle is ready to charge, no ventilation required
- State D
  - 270Ω
  - CP drops to +3V (measured in function of total resistance of 246Ω)
  - Vehicle is connected
  - Vehicle is ready to charge, ventilation required

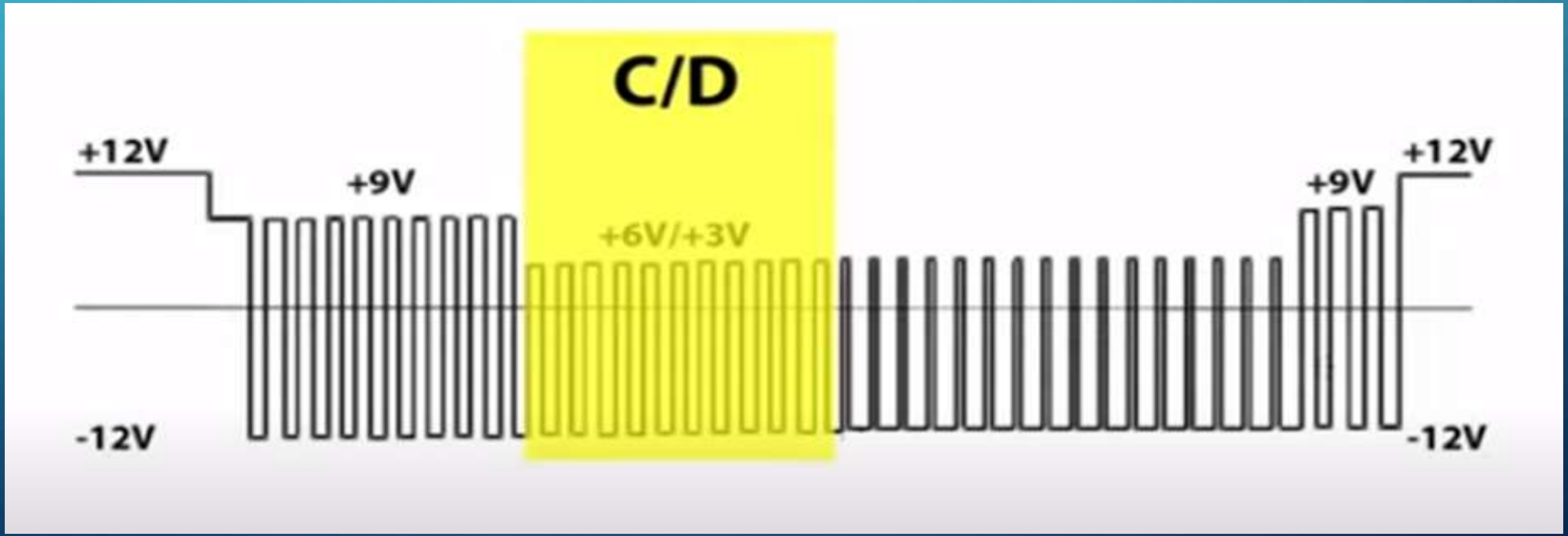
State E/F

- State E
  - CP drops to 0V
  - Error in external factor to EVSE
    - No grid power
    - CP short to ground
- State F
  - CP drops to -12V
  - EVSE itself is not available
    - Broken internal component
    - Faulty communication


A
+12V
+9V
+6V/+3V
+9V
+12V
-12V
-12V


+12V
+9V
+6V/+3V
+9V
A
+12V
-12V
-12V


B
+12V
+9V
+6V/+3V
+9V
+12V
-12V
-12V


C/D
+12V
+9V
+6V/+3V
+9V
+12V
-12V
-12V

A3) Vector flux

Flux vector drives not only vary the frequency of the current to change the speed of the motor but can also change the motor's torque as well. They can do this by taking advantage of the motor's magnetic flux (the number of magnetic field lines passing through a surface, in this case, the coils) as a portion of the current in all induction motors must generate the magnetic coupling between the rotor and stator. The remaining current is the portion that generates torque, and flux vector drives hold the coupling current to a minimum while allowing operators to adjust this torque-producing current. This is easier said than done, as controlling both torque and flux current is analytically intensive, and requires continuous transformations between coordinate systems. Flux vector drives, therefore, require microprocessor-based controllers, software, and oftentimes encoded sensors to precisely tune the independent currents. These drives typically provide speed accuracy of up to 0.3%, and while more impressive than the other two options, comes at a heavier installation and operational cost.

B) DC MOTOR CONTROLLER

24～ 48 BLDC CONTROLLER 2 KW

Working responsibilities of Motor Controller

Control the Motor torque and speed

- Start/Stop the Motor
- Prevent from electrical faults
- Provide overload protection
- Change the motor rotation direction
- Regenerative Braking

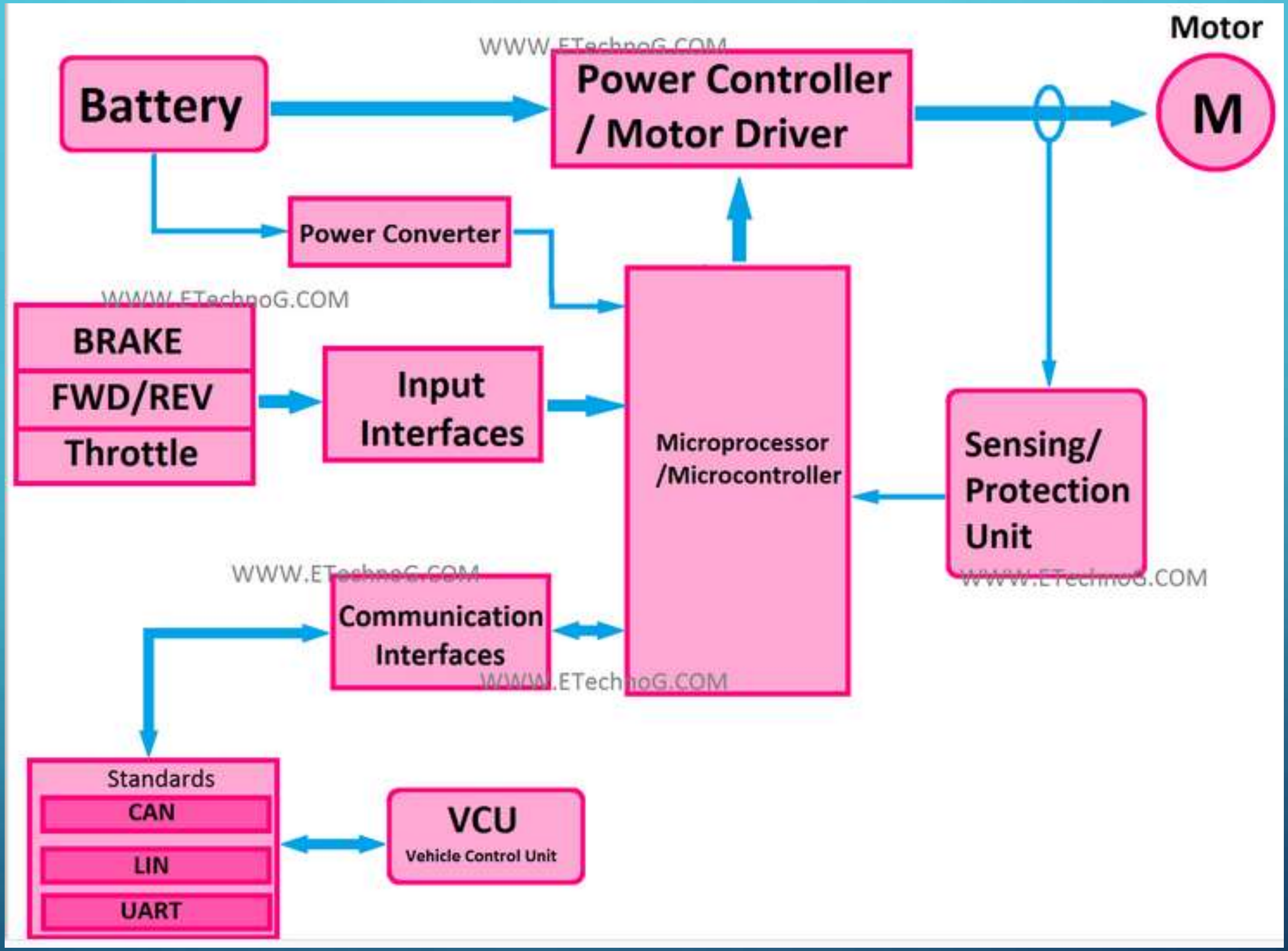
The **Local Interconnect Network** (LIN) is an extension of the CAN data bus, exchanging digital data between actuators or sensors and the corresponding control units. One example of LIN bus application is the electric glass sunroof whose servomotor receives its commands from the comfort control unit via the LIN bus.

The **Controller Area Network** (CAN bus) is the nervous system, enabling communication. In turn, 'nodes' or 'electronic control units' (ECUs) are like parts of the body, interconnected via the CAN bus. Information sensed by one part can be shared with another.

Universal Asynchronous Receiver Transmitter (UART) is one of the Embedded Communication Protocol used the RS232 an Electrical Standard. It has its own limitation to our Standard of Communication.

In telecommunications, RS-232 or Recommended Standard 232 is a standard originally introduced in 1960 for serial communication transmission of data. It formally defines signals connecting between a DTE such as a computer terminal, and a DCE, such as a modem.

Officially, RS-232 is defined as the "Interface between data terminal equipment and data communications equipment using serial binary data exchange." This definition defines data terminal equipment (DTE) as the computer, while data communications equipment (DCE) is the modem.


Motor
WWW.ETechnoG.COM
Battery
Power Controller / Motor Driver
M
Power Converter
WWW.ETechnoG.COM
BRAKE
FWD/REV
Throttle
Input Interfaces
Microprocessor /Microcontroller
Sensing/ Protection Unit
WWW.ETechnoG.COM
WWW.ETechnoG.COM
Communication Interfaces
WWW.ETechnoG.COM
Standards
CAN
LIN
UART
VCU
Vehicle Control Unit

MOTOR CONTROL UNIT BLOCK DIAGRAM DESCRIPTION

Following are the description for each block of MCU.

1. Microcontroller: The main function of microcontroller is to control the electrical energy received from battery using VSI and sensing signals. While the controller itself gets the main control signal/input from the throttle signal that can be controlled by the vehicle driver. This throttle signal will determine how the duty cycle of PWM pulses vary to obtain the desired speed and torque. To achieve efficient and fast control, FOC control is implemented in the microcontroller.

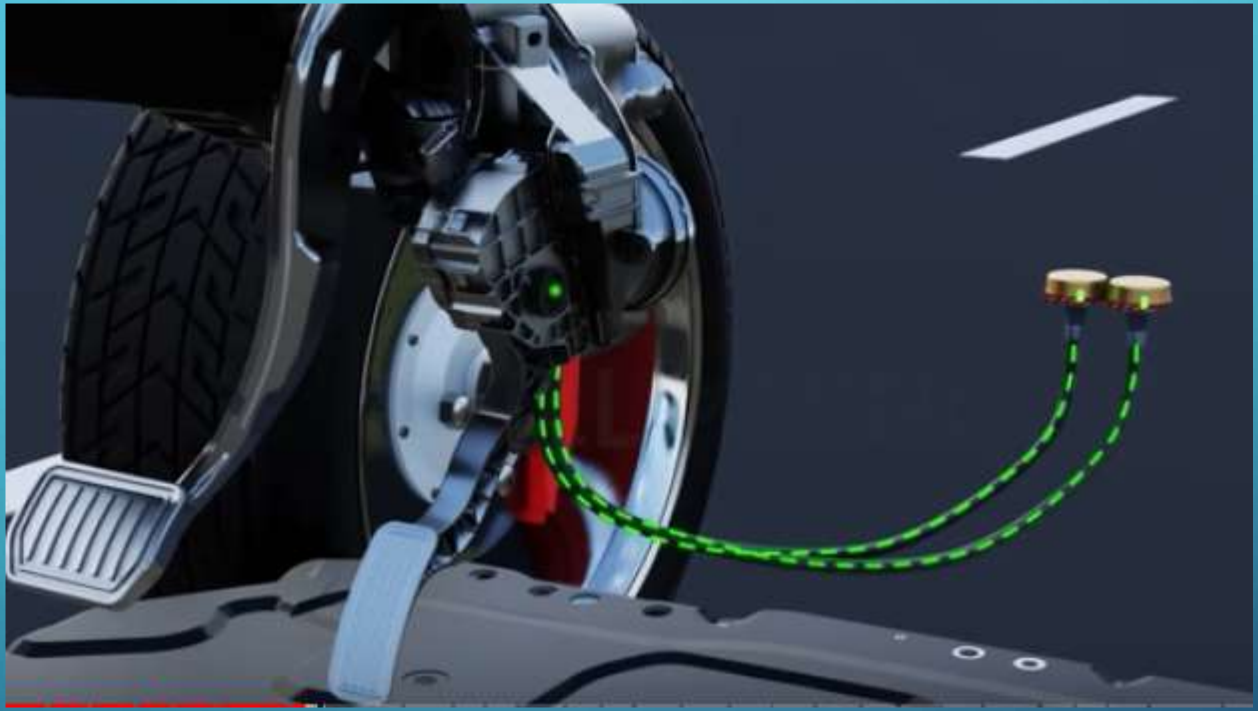
2. VSI: The main function of VSI is to convert DC to AC by using position feedback from the Motor. Generally, six MOSFETs are used to implement a VSI. However, to increase the current capacity of the MCU, parallel combination of MOSFETs is also used.

3. Phase Current Sensing: To sense the motor phase current, Hall Effect based current sensors are used. Generally, two current sensors are utilized to sense the two phase currents and the third phase current is derived from these two.

4. Power Supply: As MCUs have inbuilt sensors, therefore, to properly bias these sensors, power supply is required. Also, to provide the supply to microcontroller, motor temperature sensor and position feedback sensors, different level supply is required. To fulfill these requirement a power supply section converts a fixed DC voltage into different level of voltages according to the requirement.

5. Gate Driver: A gate driver circuit is used to amplify the PWM pulses voltage level generated by the microcontroller.

6. CAN Transceiver: The role of the CAN transceiver is basically to drive and detect data to and from the CAN bus. It converts the single ended logic used by the controller for the differential signal transmitted over the CAN bus.



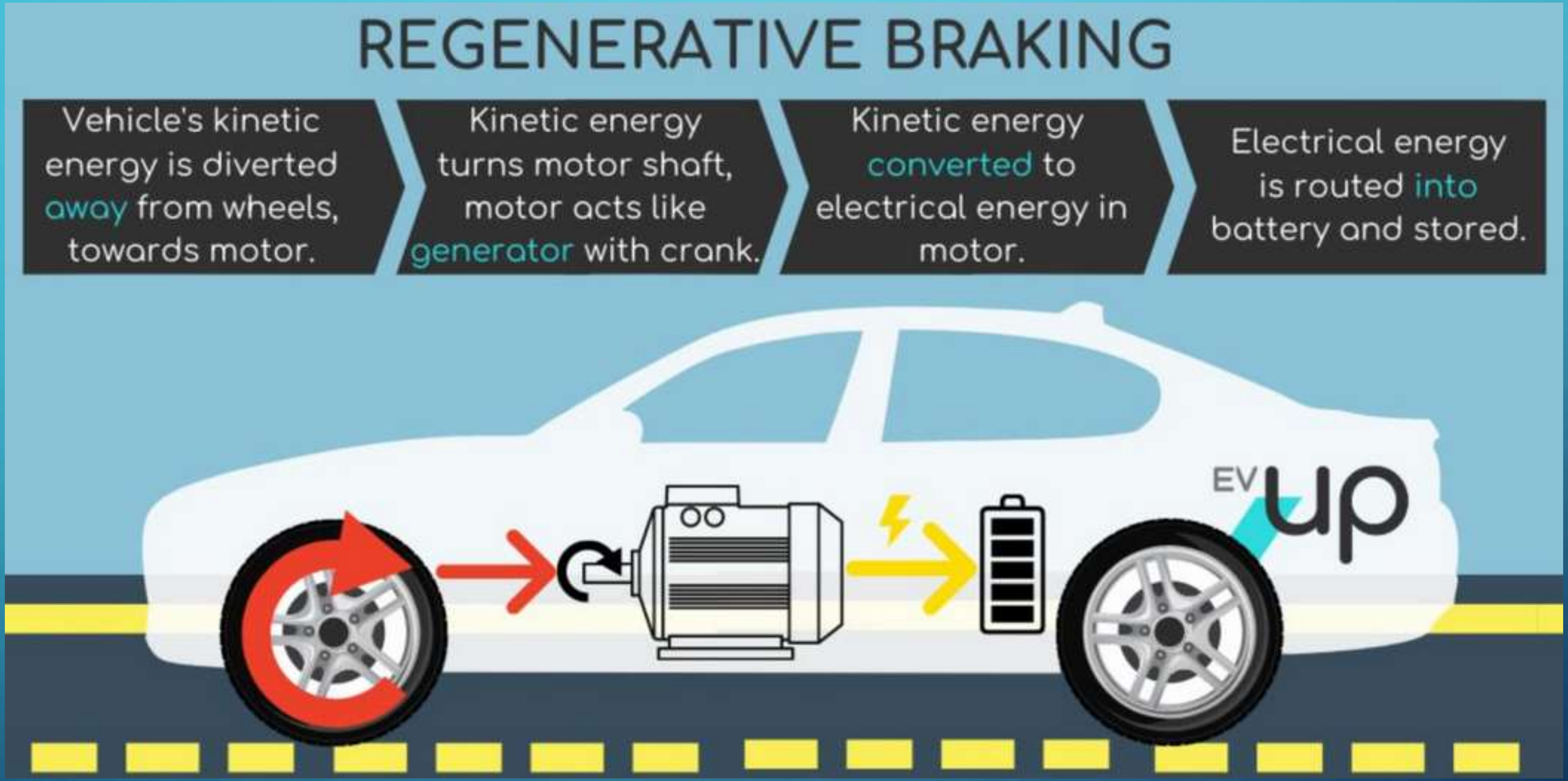
TWO POTENTIO METERS

TWO POTENTIO METERS

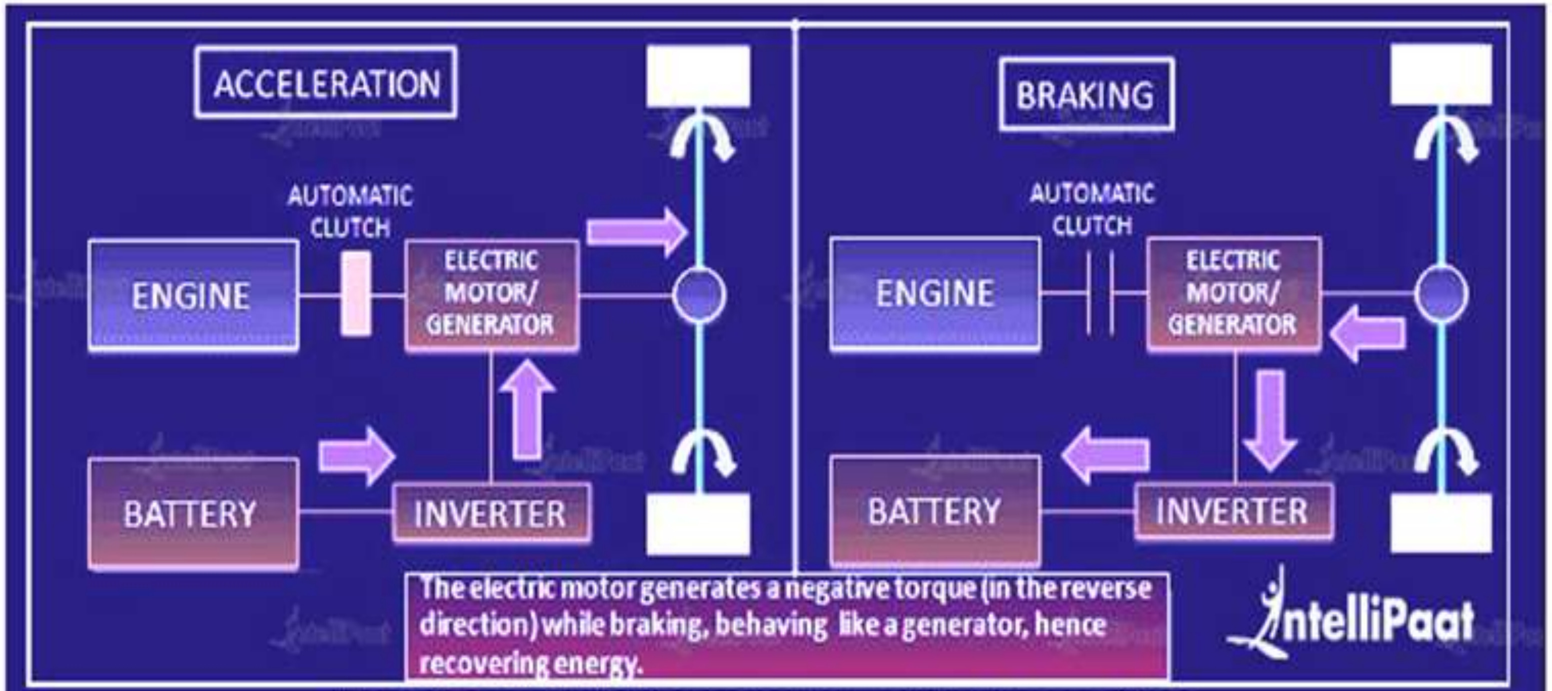

DC
MOTOR CONTROLLER
AC


DC
MOTOR CONTROLLER
DC

CURRENT ,MOTOR SPEED AND VOLTAGE


REGENERATIVE BRAKING
Vehicle's kinetic energy is diverted away from wheels, towards motor.
Kinetic energy turns motor shaft, motor acts like generator with crank.
Kinetic energy converted to electrical energy in motor.
Electrical energy is routed into battery and stored.
EV up

A typical regenerative braking system project consists of several key components, including



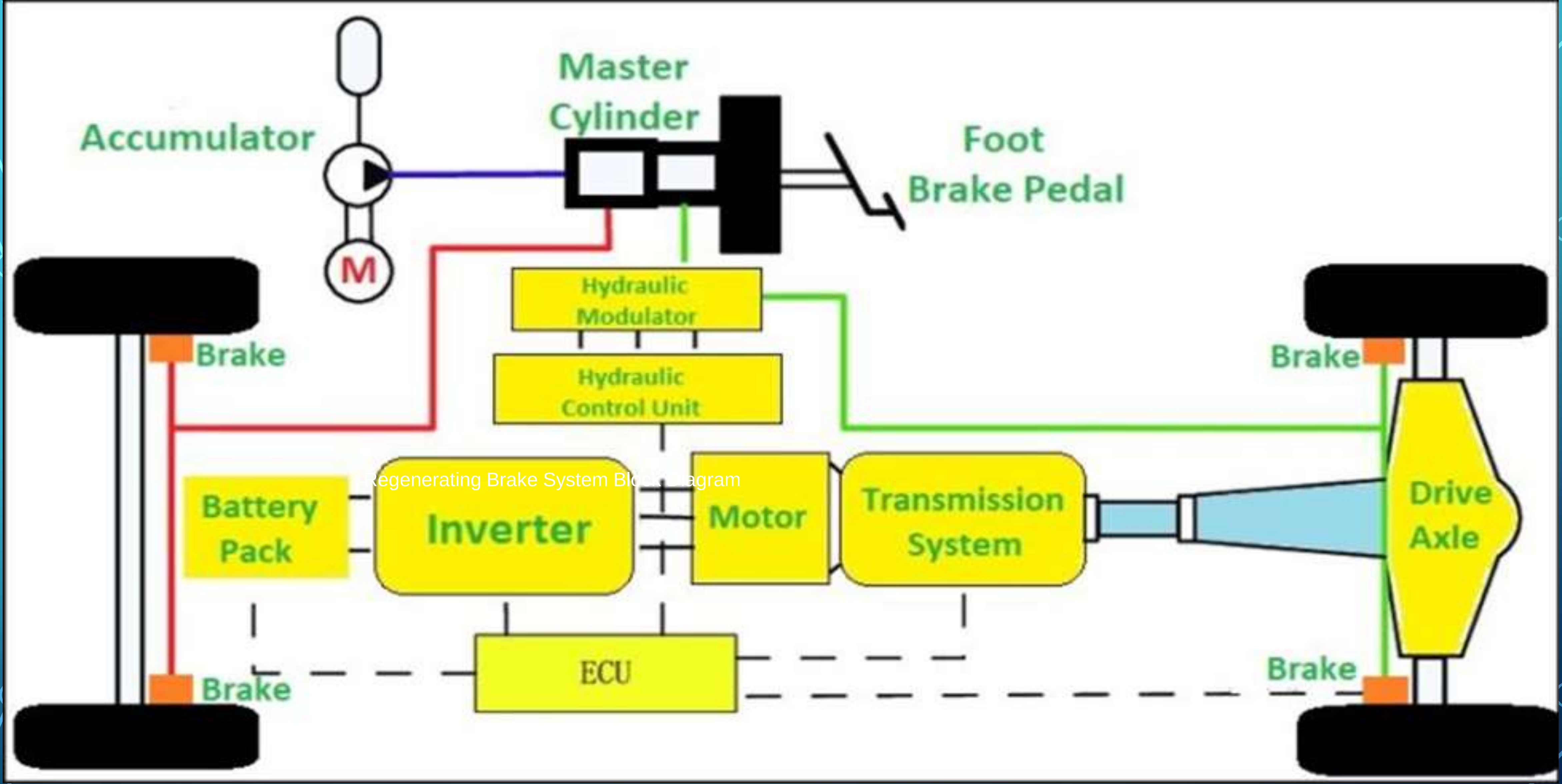
Flow of energy in both acceleration and braking conditions

- <u>**Electric motor/ generator**</u> – This part offers two purposes: it powers the car and produces electricity during regenerative braking.
- **Controller** – The controller manages the energy transfer between the battery and the generator/motor.
- **Brake pedal sensor** – This sensor recognizes when you push the brake pedal and alerts the controller to activate the regenerative braking system.
- **Battery** – The battery stores energy generated during regenerative braking for future use.

Together, these elements provide an effective and environmentally sustainable braking system for electric cars.

Electric vehicle regenerative braking systems offer a myriad of advantages, including

- **Eco-friendliness** – Regenerative braking may reduce the carbon footprint of electric and hybrid vehicles by lowering the amount of energy required to power the vehicle, which leads to fewer greenhouse gas emissions and a decreased reliance on fossil fuels.
- **Increased Energy Efficiency** – Regenerative braking systems smoothly increase the driving range of electric cars by collecting the kinetic energy that is generally wasted while braking. This implies that one charge will allow you to travel further!
- **Reduced Brake Wear** – The requirement for conventional friction brakes is reduced because the electric motor performs most of the braking. As a result, you'll spend less on maintenance because your brake pads and rotors will last longer.



Regenerating Brake System Block Diagram

As the Regenerative Braking is a type of Electric Braking System; mostly it consists electrical and electronic devices or parts. So, the parts of Regenerative Braking System are

- Electric Traction Motor
- Battery Pack
- Hydraulic Pump
- Accumulator
- Hydraulic Circuit
- Reservoir
- Hydraulic Valves
- Electronic Control Unit (ECU)

Two Type of Regenerative Braking System

- Series Regenerative Braking System
- Parallel Regenerative Braking System (Kinetic Energy convert to Electric Energy)

TYPE OF ELECTRIC VEHICLES

There are four types of electric Vehicles

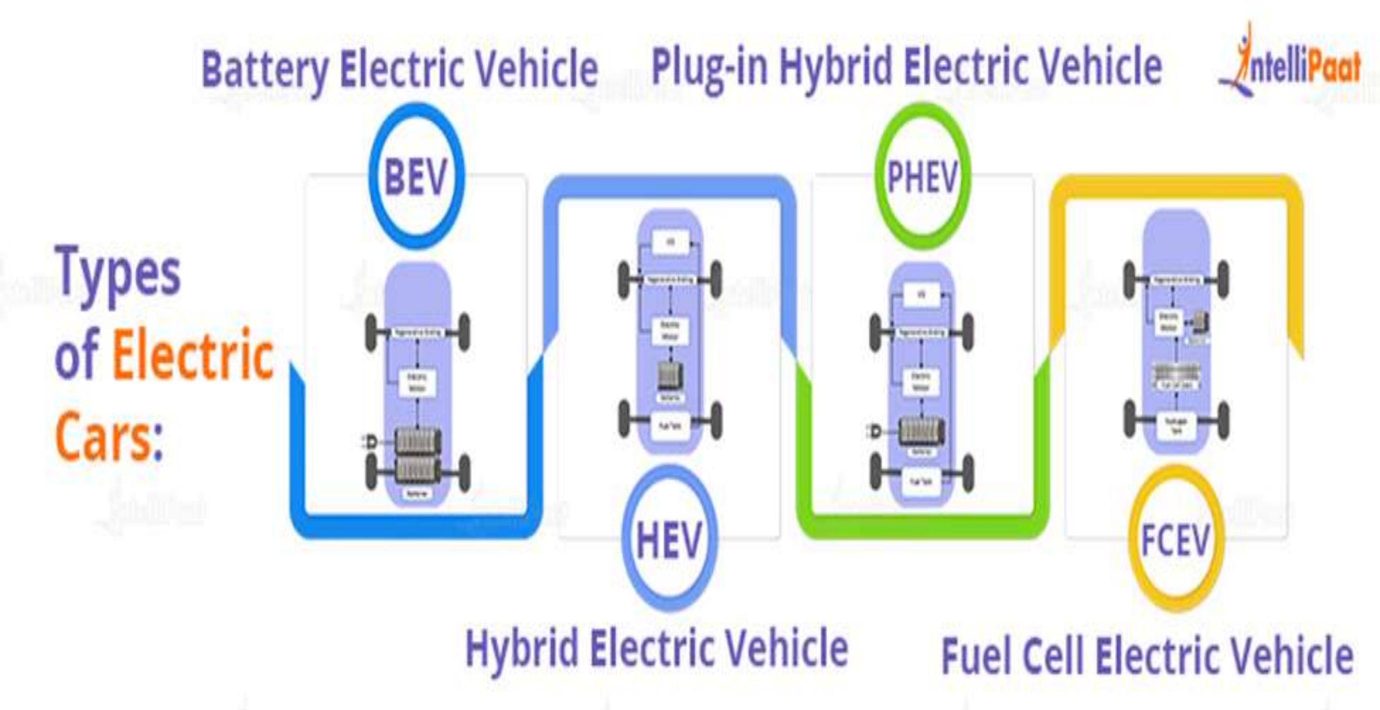
Introduction of type of EV

1)BEV

2)HEV

3)PHEV

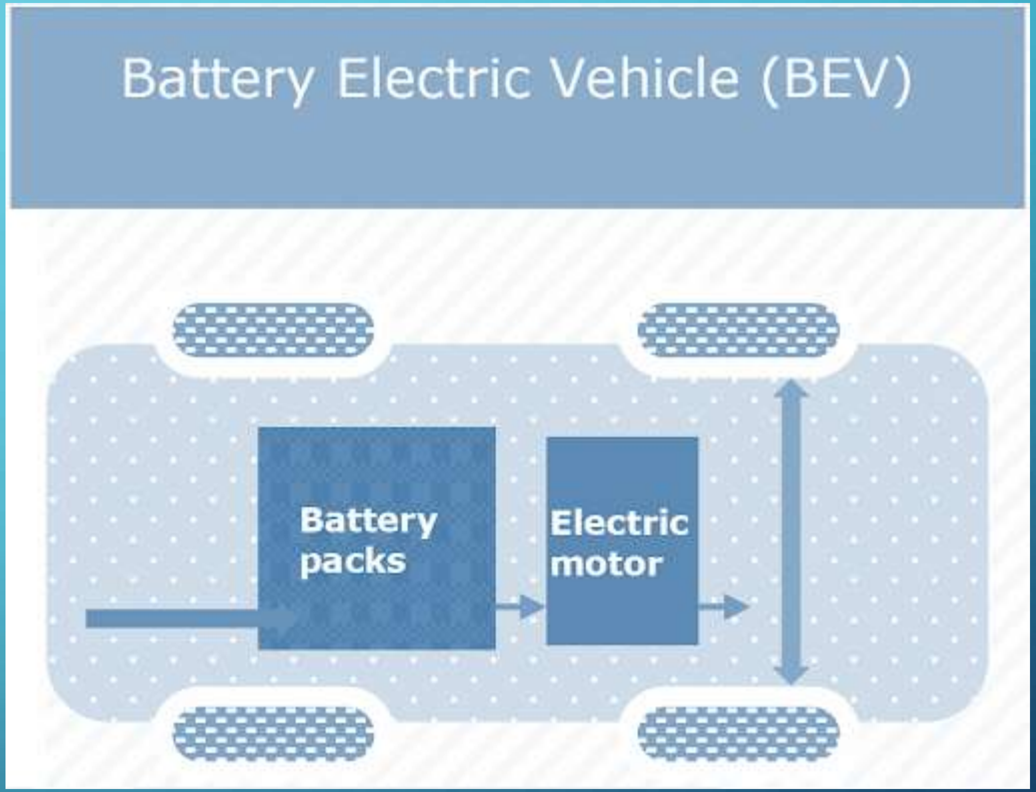
4)FCEV



Solar Roof Type Vehicles

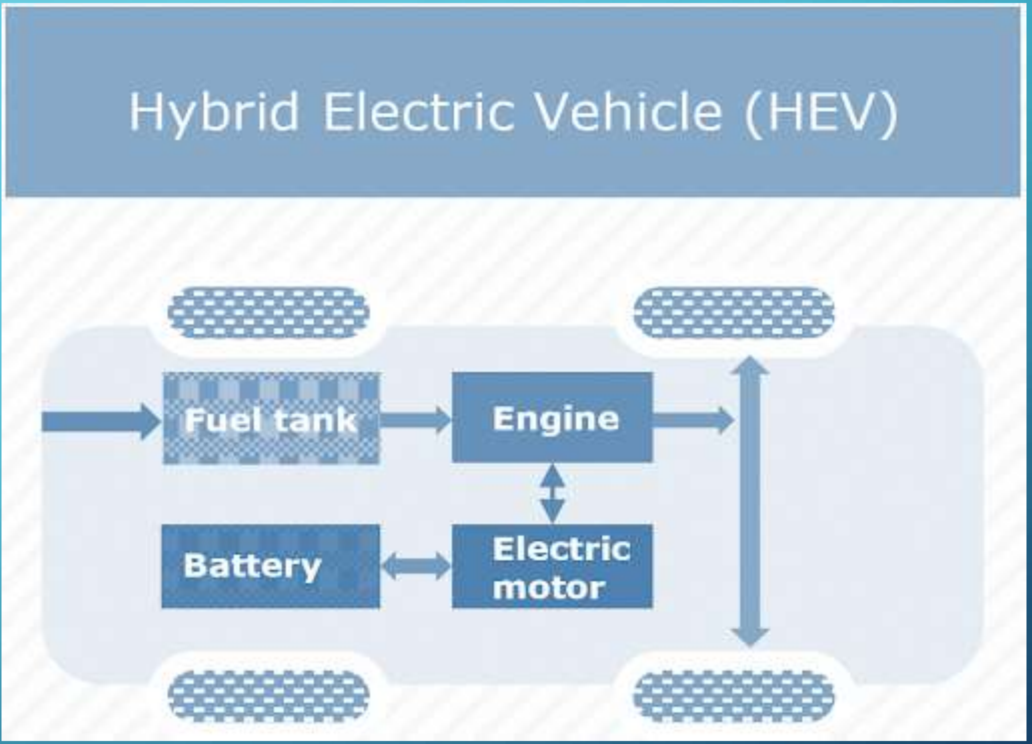
1)BATTERY ELECTRIC VEHICLES (BEV'S)

BEVs are also known as All-Electric Vehicles (AEV). Electric Vehicles using BEV technology run entirely on a battery-powered electric drivetrain. The electricity used to drive the vehicle is stored in a large battery pack which can be charged by plugging into the electricity grid. The charged battery pack then provides power to one or more electric motors to run the electric car.



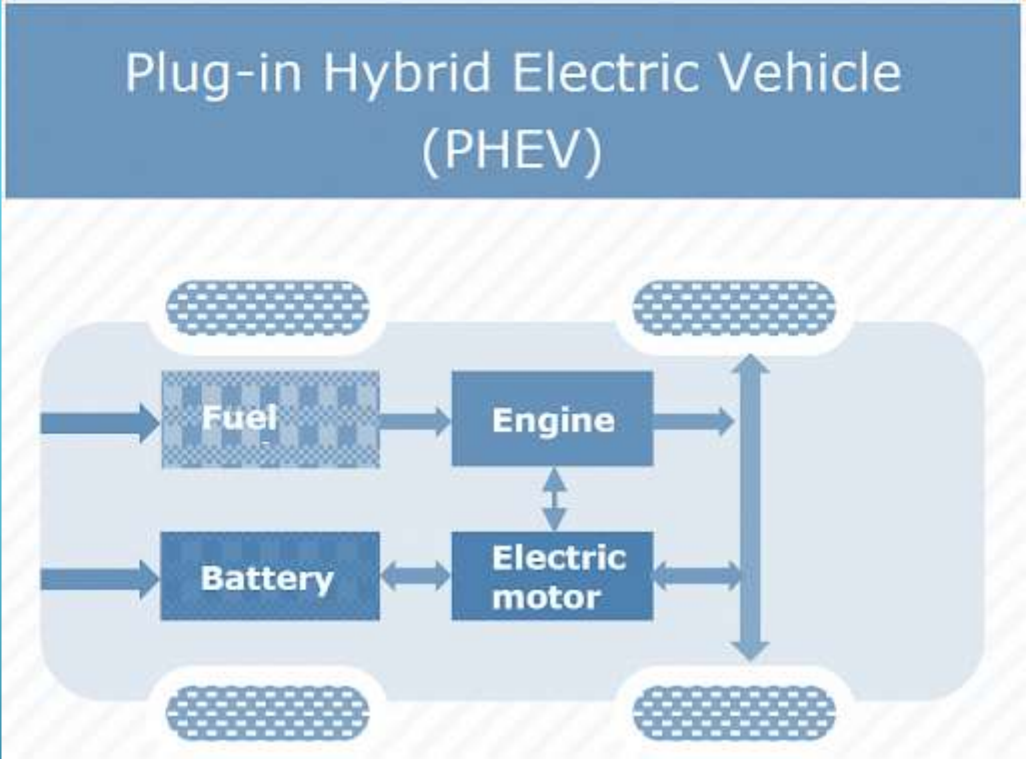
2)HYBRID ELECTRIC VEHICLE (HEV):

HEVs are also known as series hybrid or parallel hybrid. HEVs have both engine and electric motor. The engine gets energy from fuel, and the motor gets electricity from batteries. The transmission is rotated simultaneously by both engine and electric motor. This then drives the wheels. To find out more about HEVs, click below.



3)PLUG-IN HYBRID ELECTRIC VEHICLE (PHEV):

The PHEVs are also known as series hybrids. They have both engine and a motor. You can choose among the fuels, conventional fuel (such as petrol) or alternative fuel (such as bio-diesel). It can also be powered by a rechargeable battery pack. The battery can be charged externally.



Various type of hybrid vehicle

- SERIES HYBRID VEHICLE
- PARALLEL HYBRID VEHICLE
- SERIES PARALLEL HYBRID VEHIC

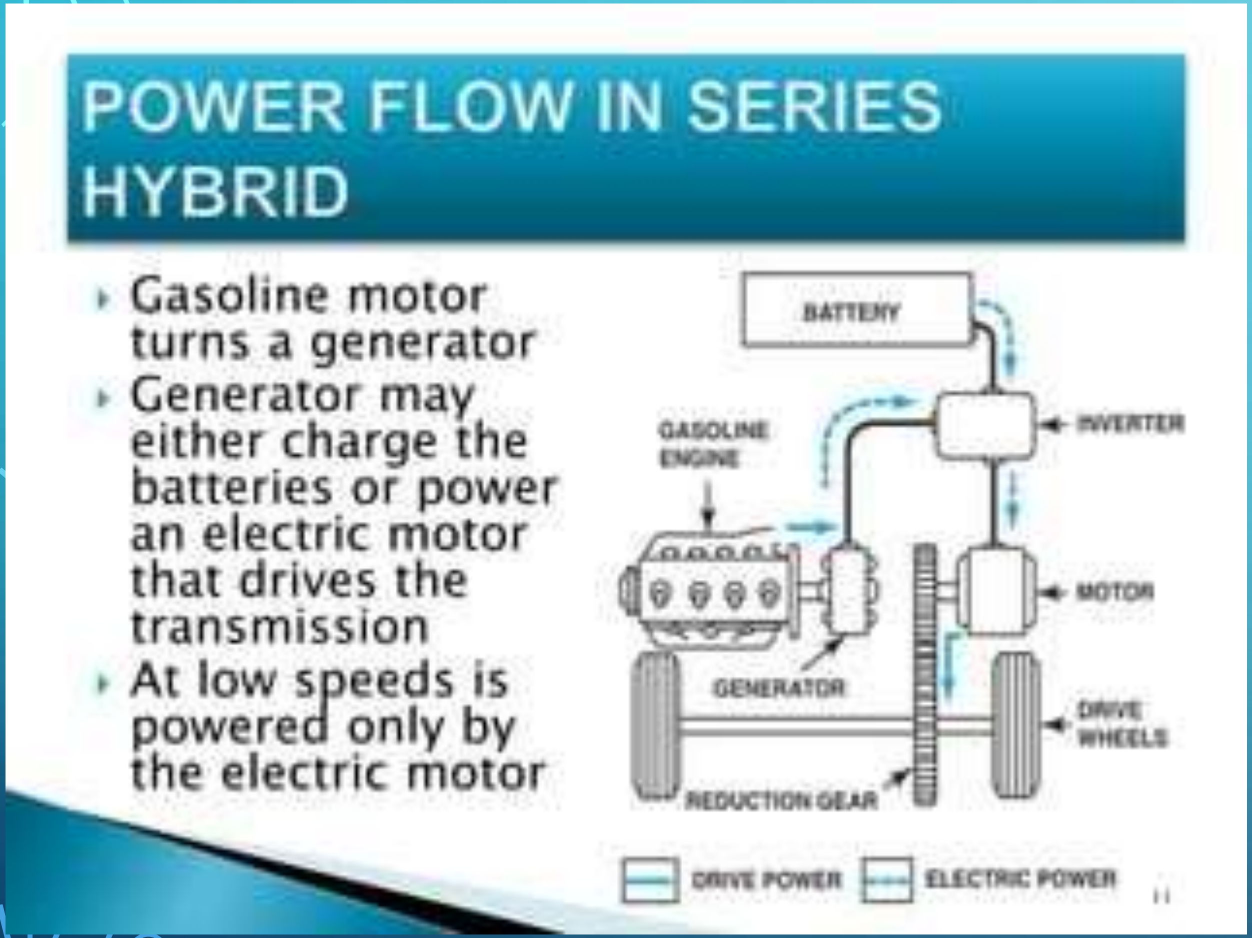
Chevrolet Volt -Series Hybrid

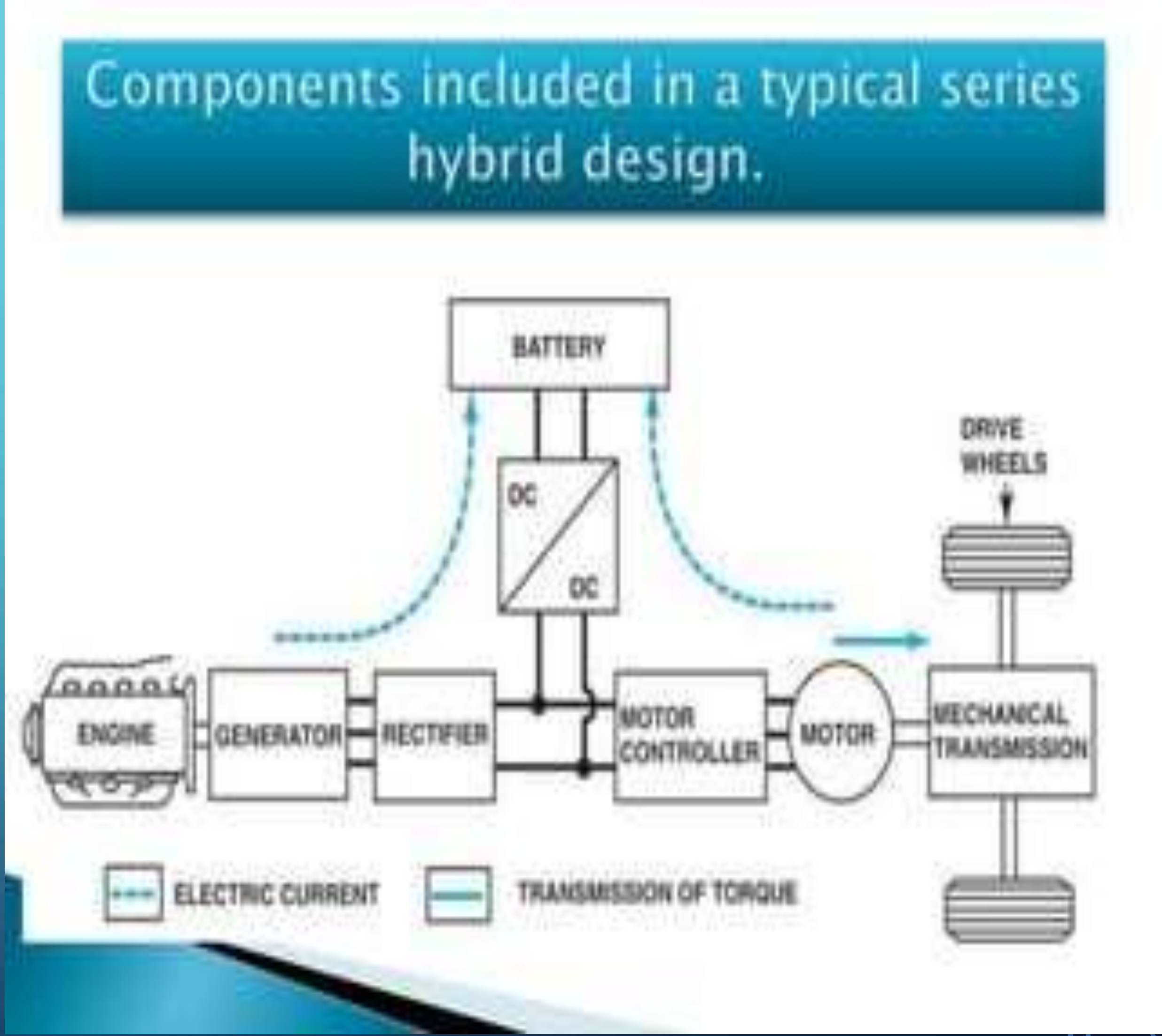
Honda Insight-Parallel Hybrid

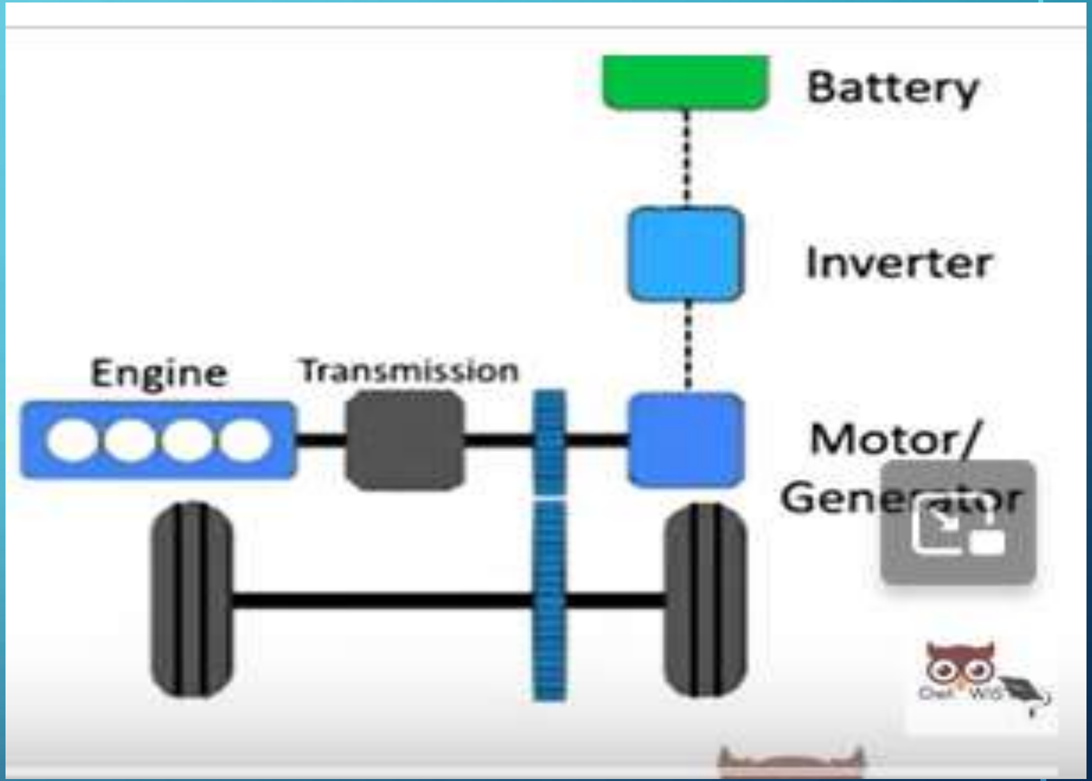
Ford Escape-Series Parallel Hybrid

Series Hybrid

- Simplest hybrid configuration.
- Electric motor is the only means of providing power .
- Engine size is smaller
- The battery pack more powerful .
- Series hybrids more expensive .
- Engine in a series hybrid is not coupled to the wheels.
- Series drivetrains perform best in stop-and-go driving .


POWER FLOW IN SERIES HYBRID
Gasoline motor turns a generator
Generator may either charge the batteries or power an electric motor that drives the transmission
At low speeds is powered only by the electric motor
BATTERY
INVERTER
GASOLINE ENGINE
MOTOR
GENERATOR
DRIVE WHEELS
REDUCTION GEAR
DRIVE POWER
ELECTRIC POWER

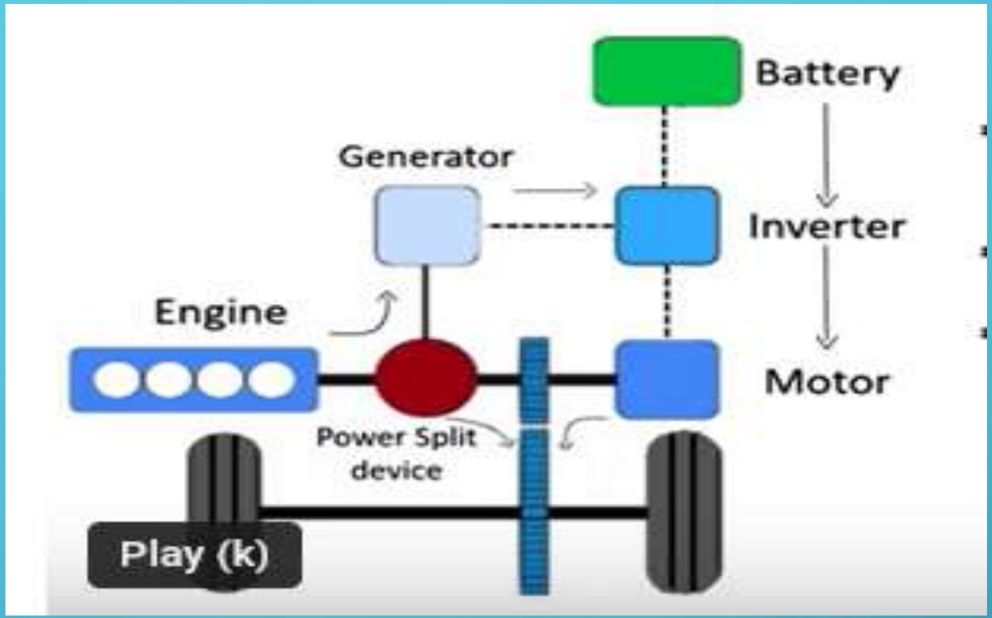

Components included in a typical series hybrid design.
BATTERY
DC
DC
DRIVE WHEELS
ENGINE
GENERATOR
RECTIFIER
MOTOR CONTROLLER
MOTOR
MECHANICAL TRANSMISSION
ELECTRIC CURRENT
TRANSMISSION OF TORQUE



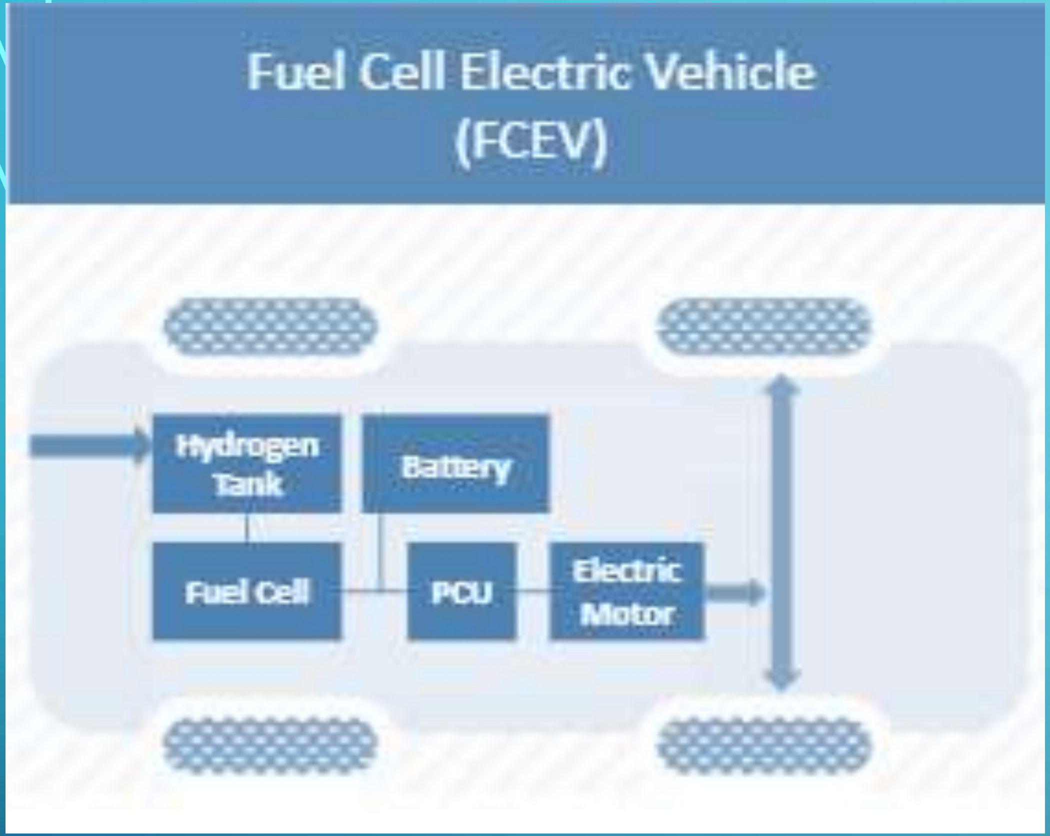
Picture of Series Hybrid Cadillac ELR MY 2014 to 2016

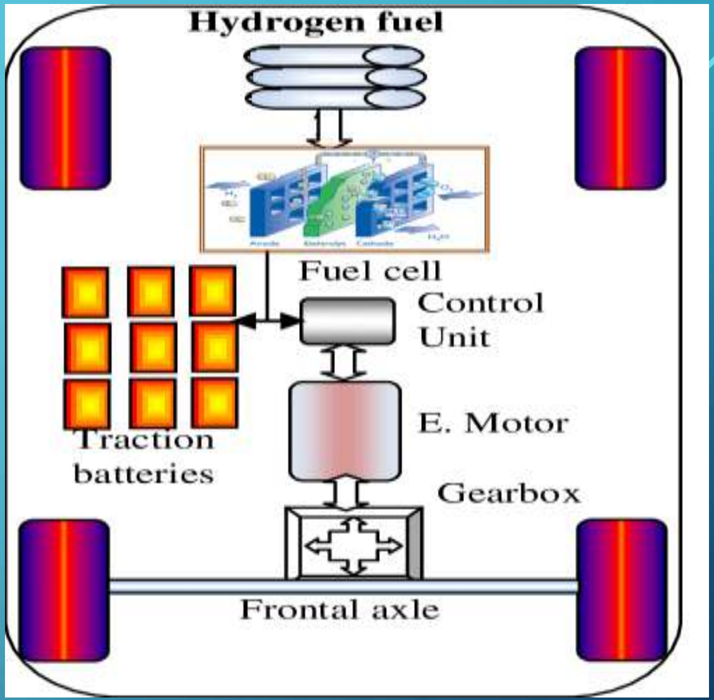
Parrel Hybrid Vehicles

Series Parrel Hybrid



4)FUEL CELL ELECTRIC VEHICLE (FCEV):





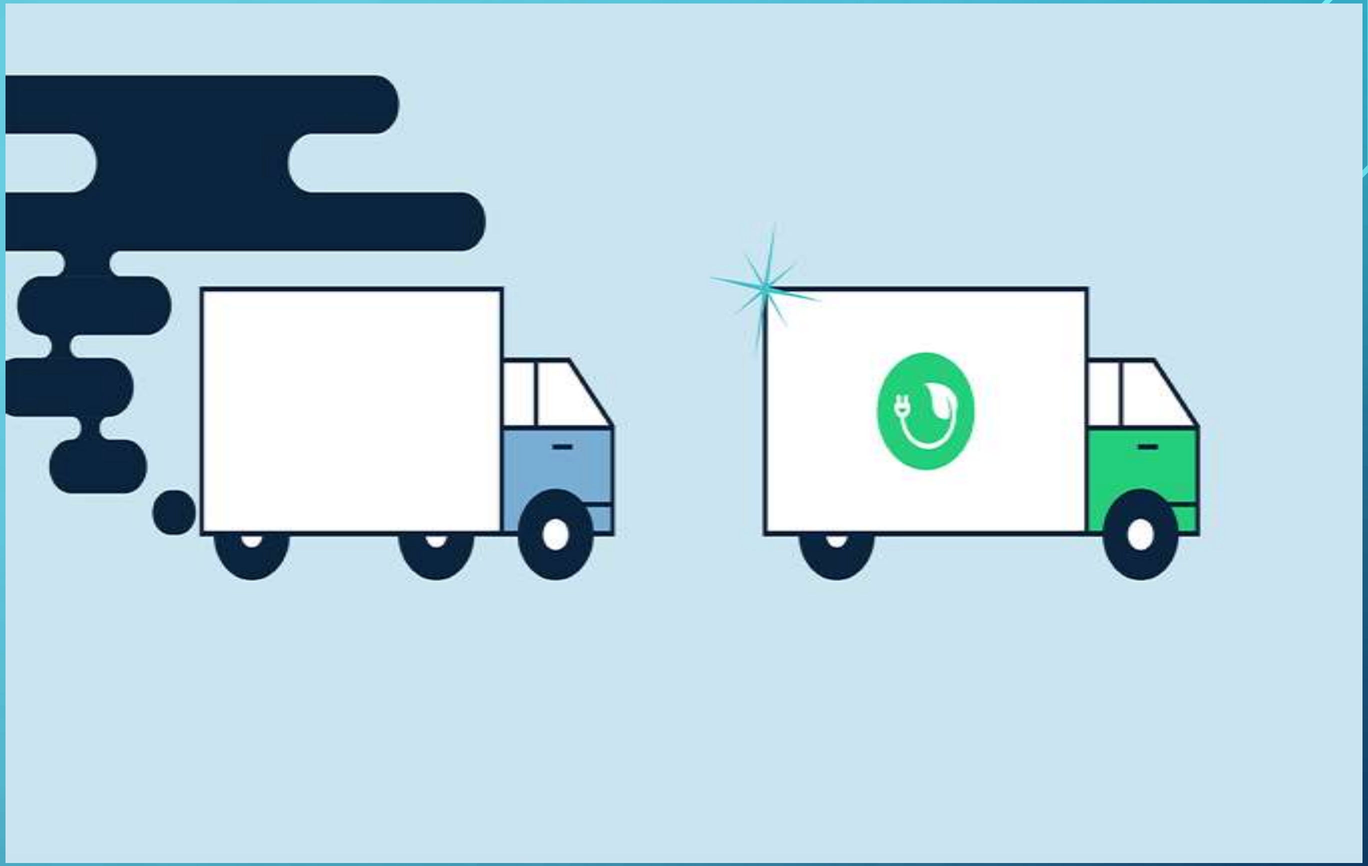
FCEVs are also known as Zero-Emission Vehicles. They employ 'fuel cell technology' to generate the electricity required to run the vehicle. The chemical energy of the fuel is converted directly into electric energy.

Benefit for Electric Vehicles

1. Easy to drive
2. Charge at our homes itself
3. Low maintenance costs
4. Zero noise pollution
5. Independent of fuel price hikes
6. Low running costs
7. Eco-friendly
8. Government Incentives and Tax benefits
9. More spacious than conventional cars
10. **Electric Vehicle are more stable and safe for driving curve of road.**
11. Electric cars are future proof

Electric Vehicles are good for environment

1. EVs can produce zero tailpipe emissions.
2. Even when using fossil fuels, EVs contribute fewer emissions than Internal Combustion Engine(ICE) vehicles.
3. EV battery production can be clean.
4. ICE (Internal Combustion Engine) used vehicles pollute manufacturers use eco-friendly materials.



On average, a gasoline-powered passenger vehicle produces between 5 to 6 metric tons of CO_2 per year. A study by the Union of Concerned Scientists found that the Internal Combustion Engine (ICE) emissions surpass the EVs' well-to-wheel emissions in just 6-18 months of operation.

EVs is safer than conversional Vehicles when driving curve of road because CG of EV is Lower than Conversional Vehicles.

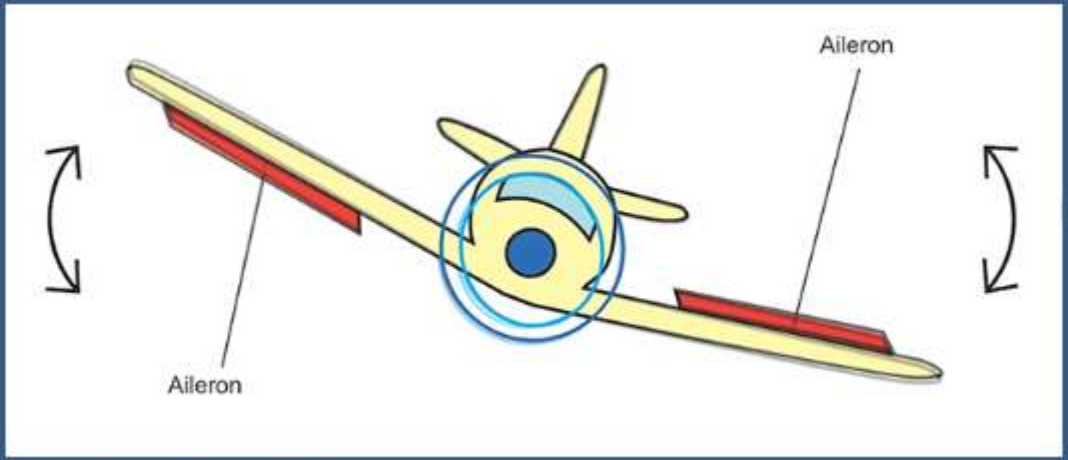
Three accidences are:

1)Rolling

2)Yawling

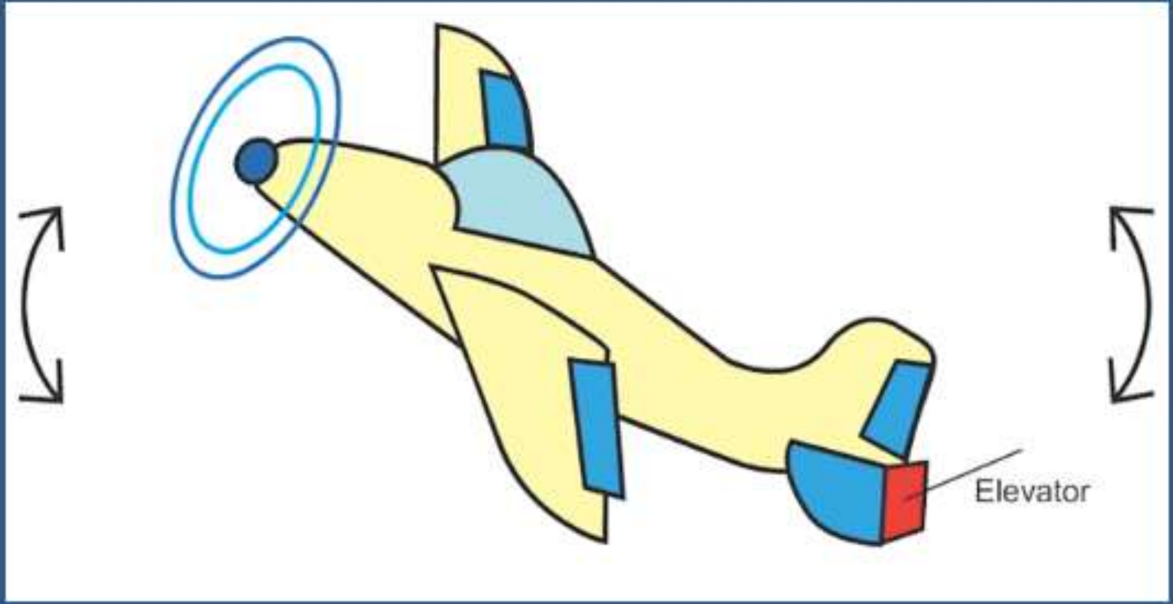
3)Pitching

ROLL



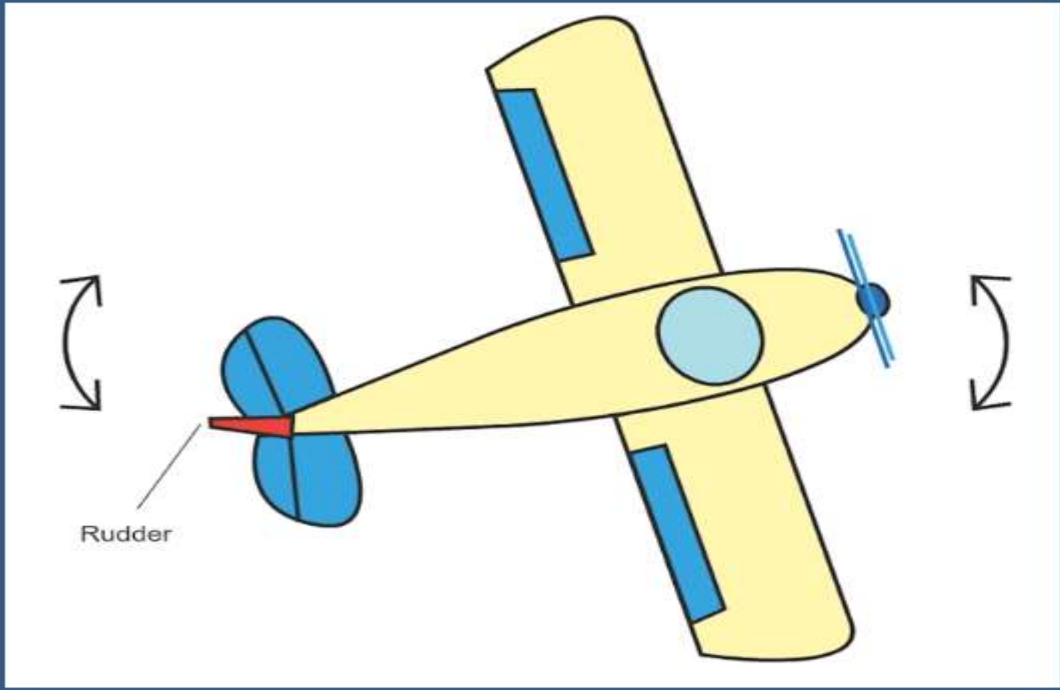
The Ailerons Control *Roll*

PITCH



The Elevator Controls *Pitch*

YAW



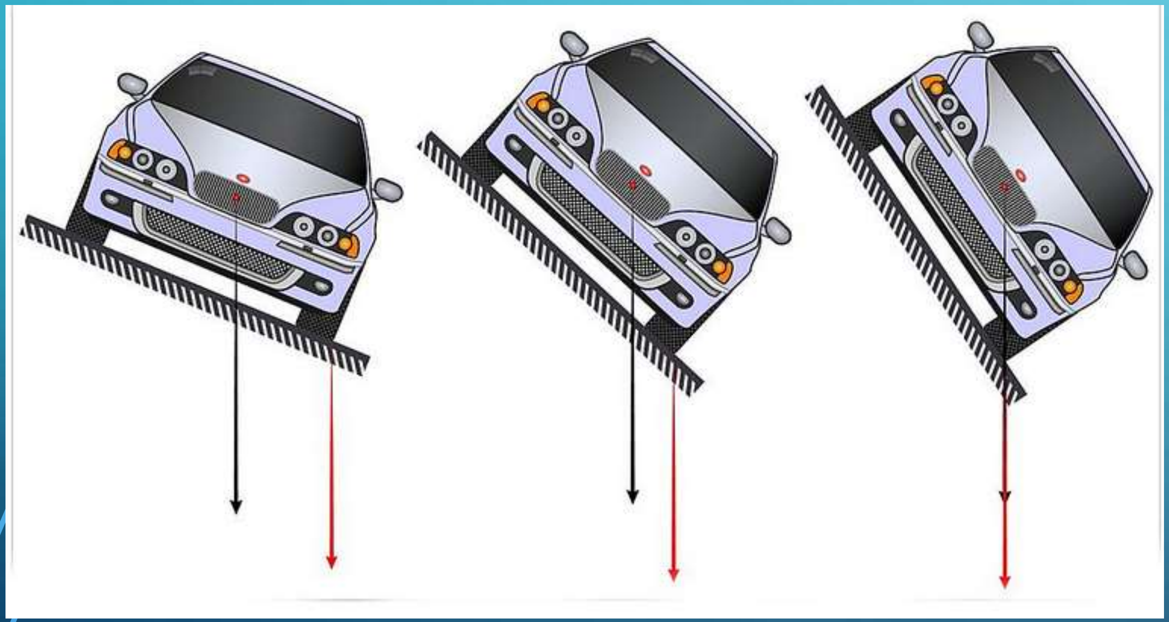
The Rudder Controls *Yaw*

CONVERSIONAL VEHICLES CG

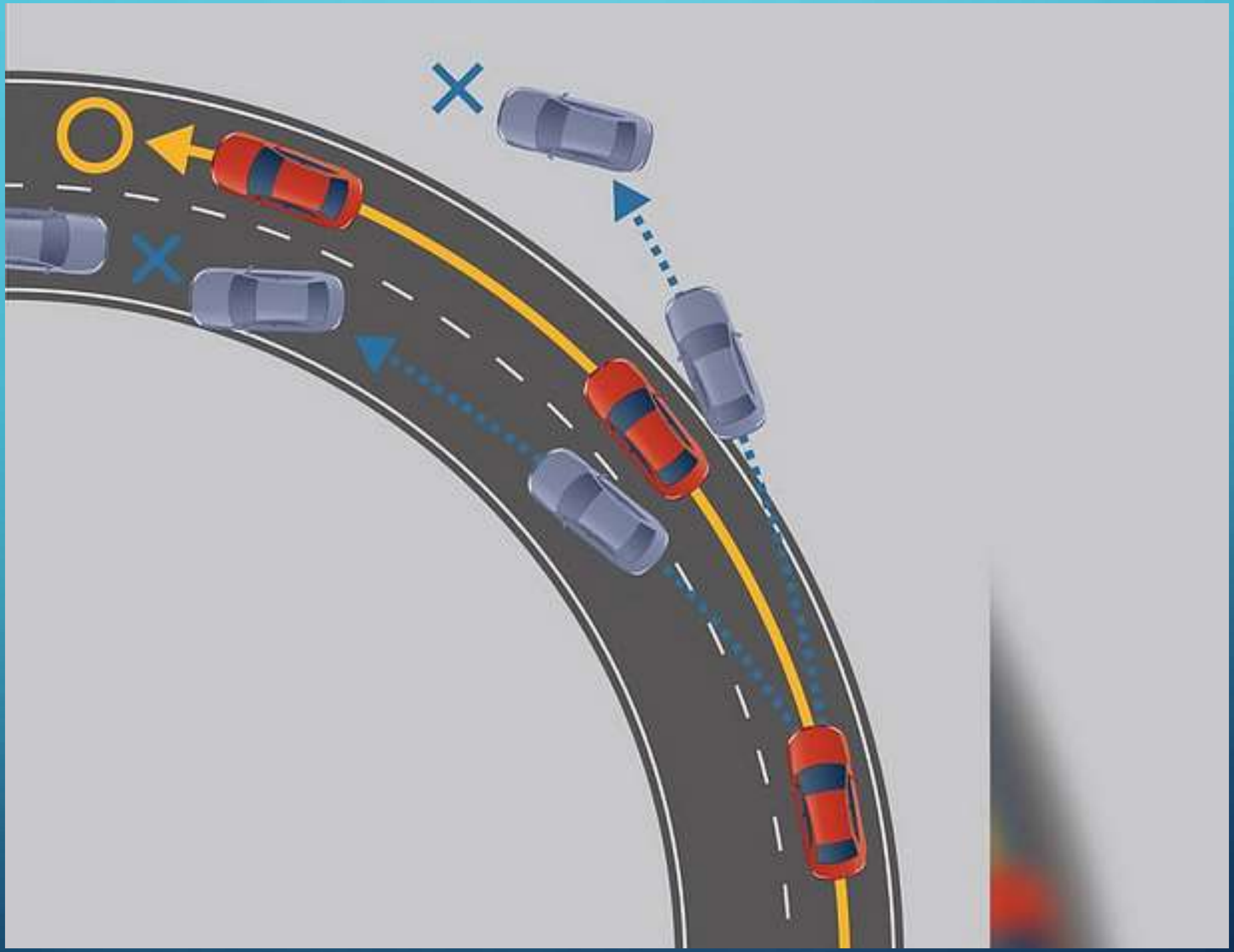
ELECTRIC VEHICLES CG


CG
CG

ROLLING OF EV



YAWLING

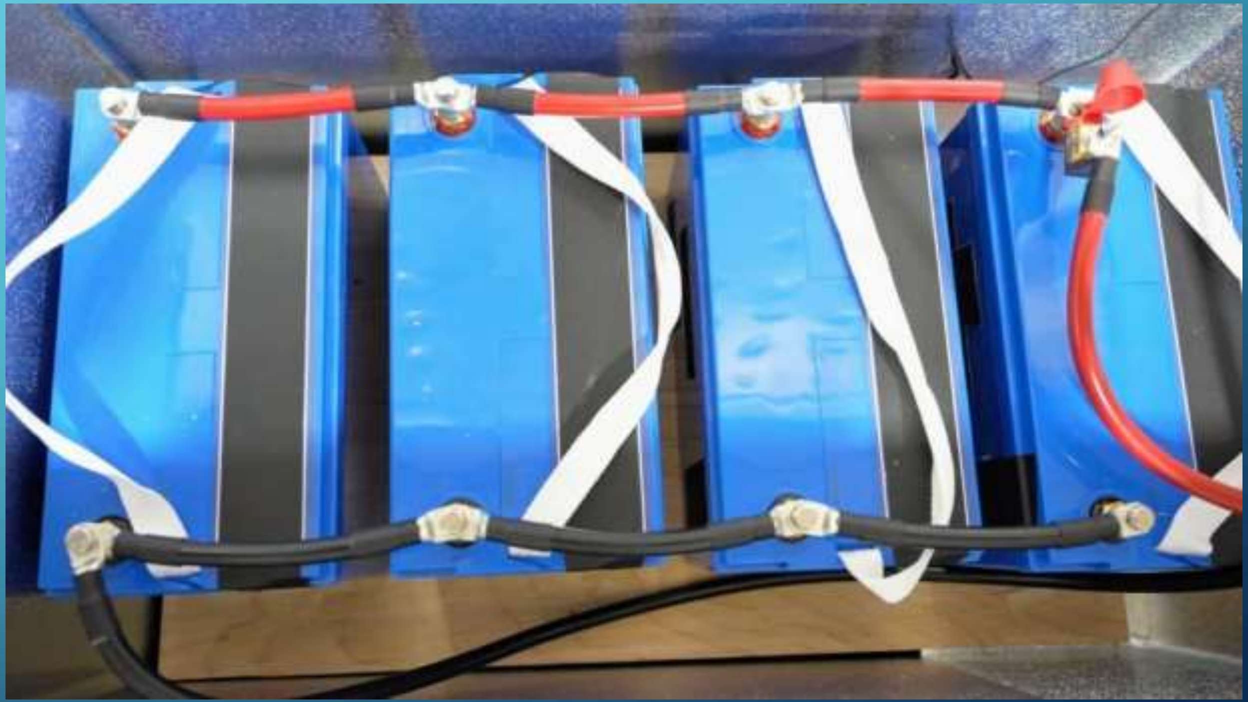


8.AUXILARY BATTERY

Most auxiliary 12-volt systems use an Absorbent Glass Mat (AGM) or a Valve Regulated Lead Acid (VRLA) battery. It's **the main battery's backup** and is used to run the car's electrical components like lights, audio systems, and air conditioners. In some models, the auxiliary battery is only a capacitor to store electricity. The auxiliary battery is charged by the inbuilt charging system like the main battery. Common locations include: In the trunk.

Advantage of AGM Battery

So why would someone consider an AGM battery instead of the flooded versions you've likely been using for years or decades.



You must open up flooded lead-acid batteries to top off their fluids periodically to maintain the correct balance of electrolytes and water. Without this necessary maintenance, your batteries won't operate as efficiently as possible and eventually become damaged. There's no similar requirement for AGM batteries, as they're sealed by design. This means they're virtually maintenance-free.

Can Install Non-Vented

You can also install an AGM battery in a non-vented way. You often must vent traditional batteries, as they release gases as part of their normal operation. These can build up with corrosive or even potentially explosive consequences without proper ventilation. This lack of venting requirements means more flexibility for you in installation.

Can Install in Different Positions

The installation benefits of an AGM battery go far beyond helping with venting. While you must install traditional flooded lead-acid batteries right-side-up to prevent fluid leaks, AGM batteries have no such restrictions because they're sealed. That means you can install them upside down, on their side, or in any other position without significant effect on battery operation. In a crowded engine compartment or small RV battery space, this can be incredibly helpful in freeing up additional space.

Drawbacks of AGM Batteries VS Flooded Lead Acid

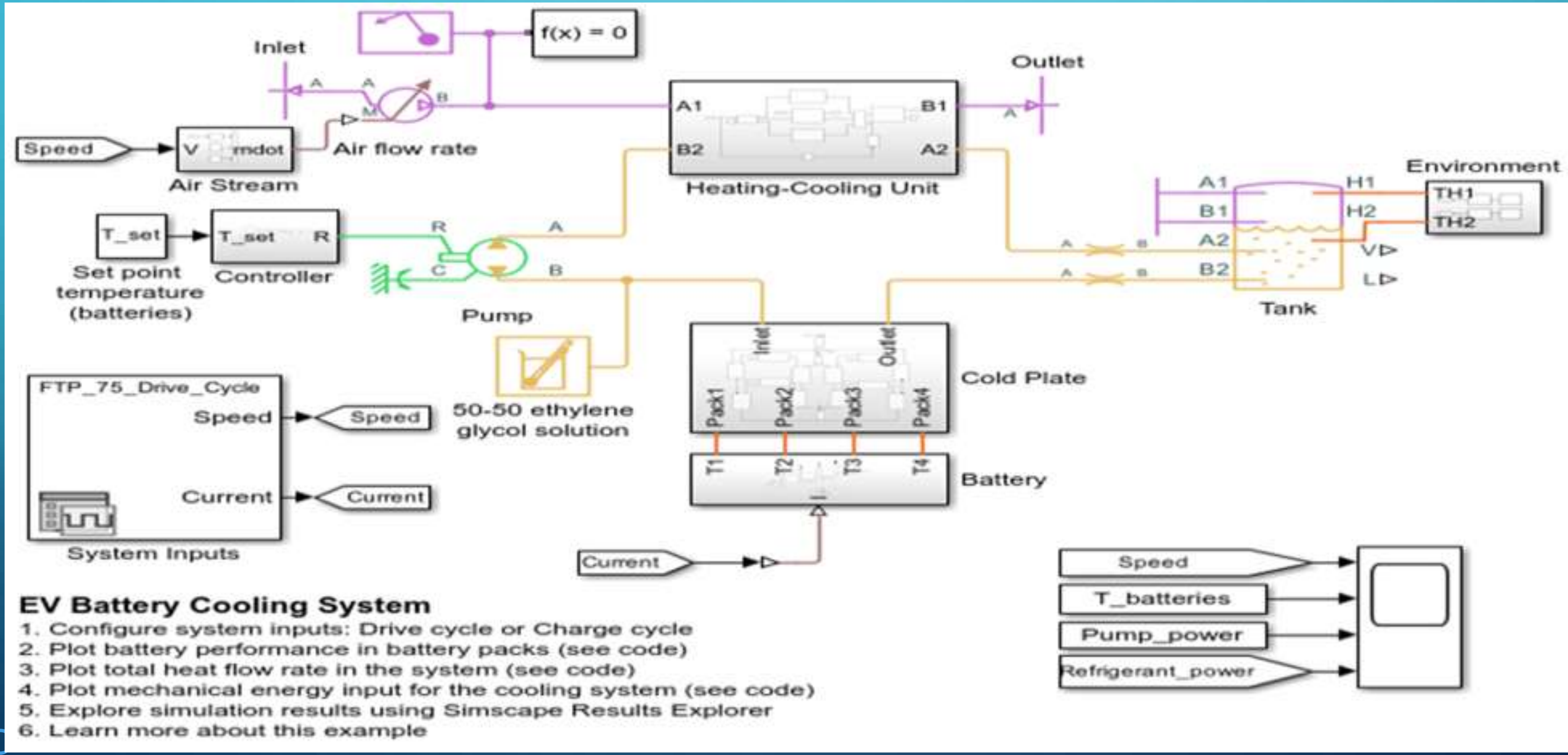
While AGM batteries have many benefits, their main drawback is cost.

AGM batteries tend to cost quite a bit more than flooded lead-acid. This price differential may be worth it if you are using it for the correct application. As a starting battery, this could be very beneficial, but for energy storage, the price increase compared to their performance is not worth it.

In the below video, Mortons on the Move test AGM batteries against flooded lead-acid and lithium-ion (LiFePO4) batteries. The results show that AGM is not worth its price for storage applications.

9. THERMAL SYSTEM

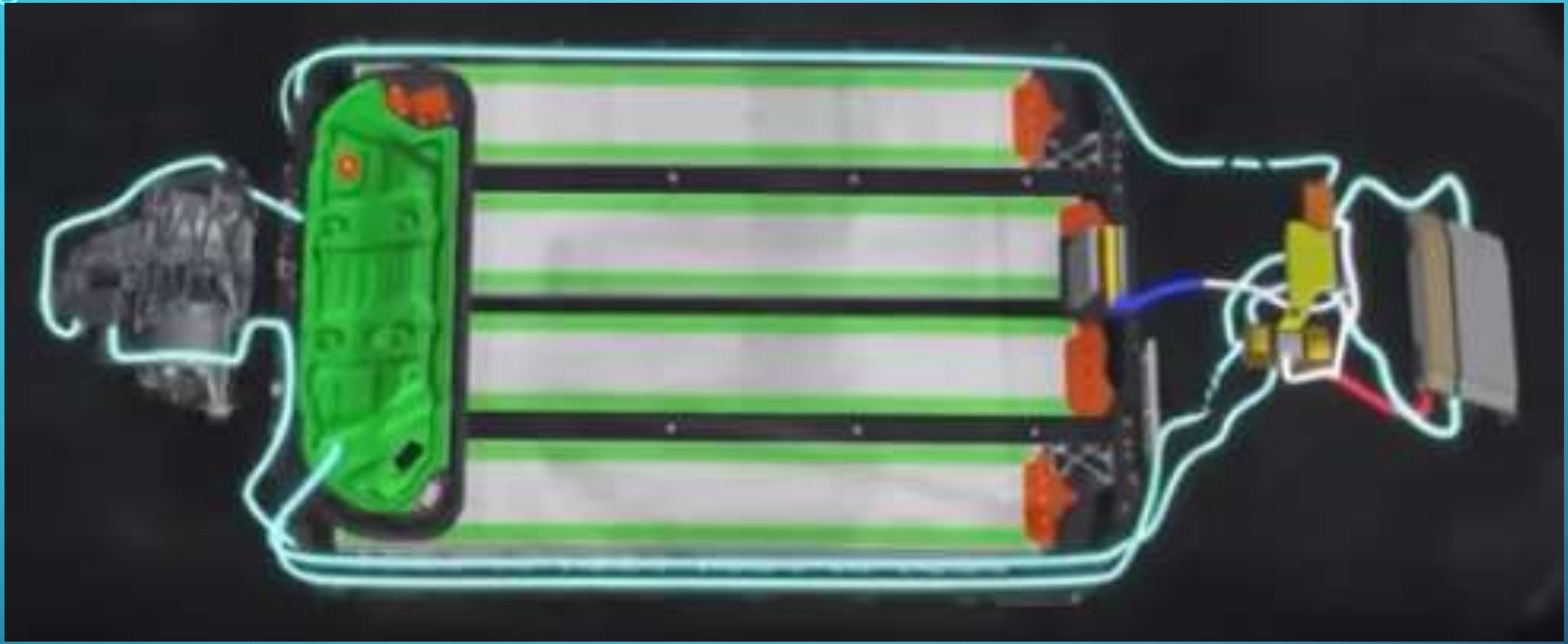
BATTERY COOLING SYSTEM



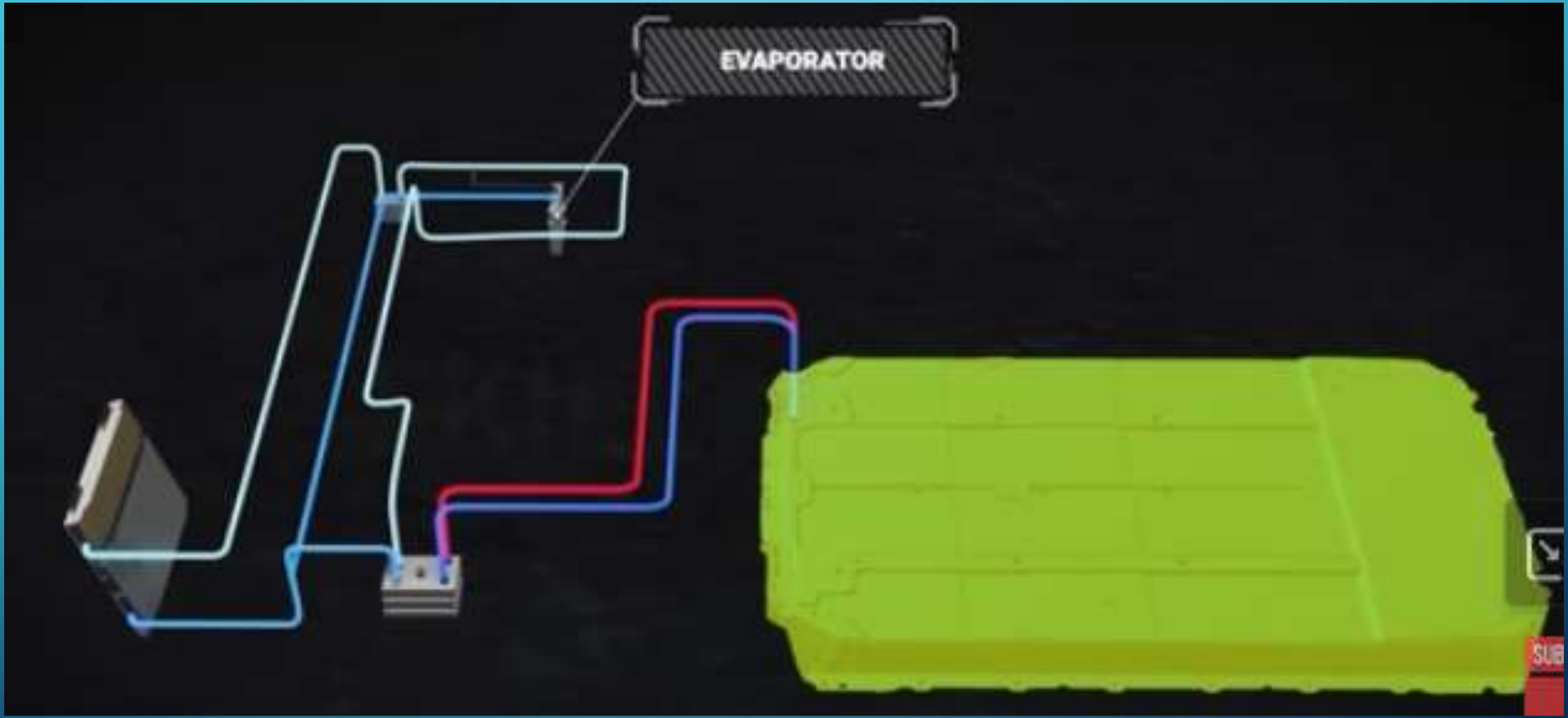
Ethylene glycol = $C_2H_6O_2$

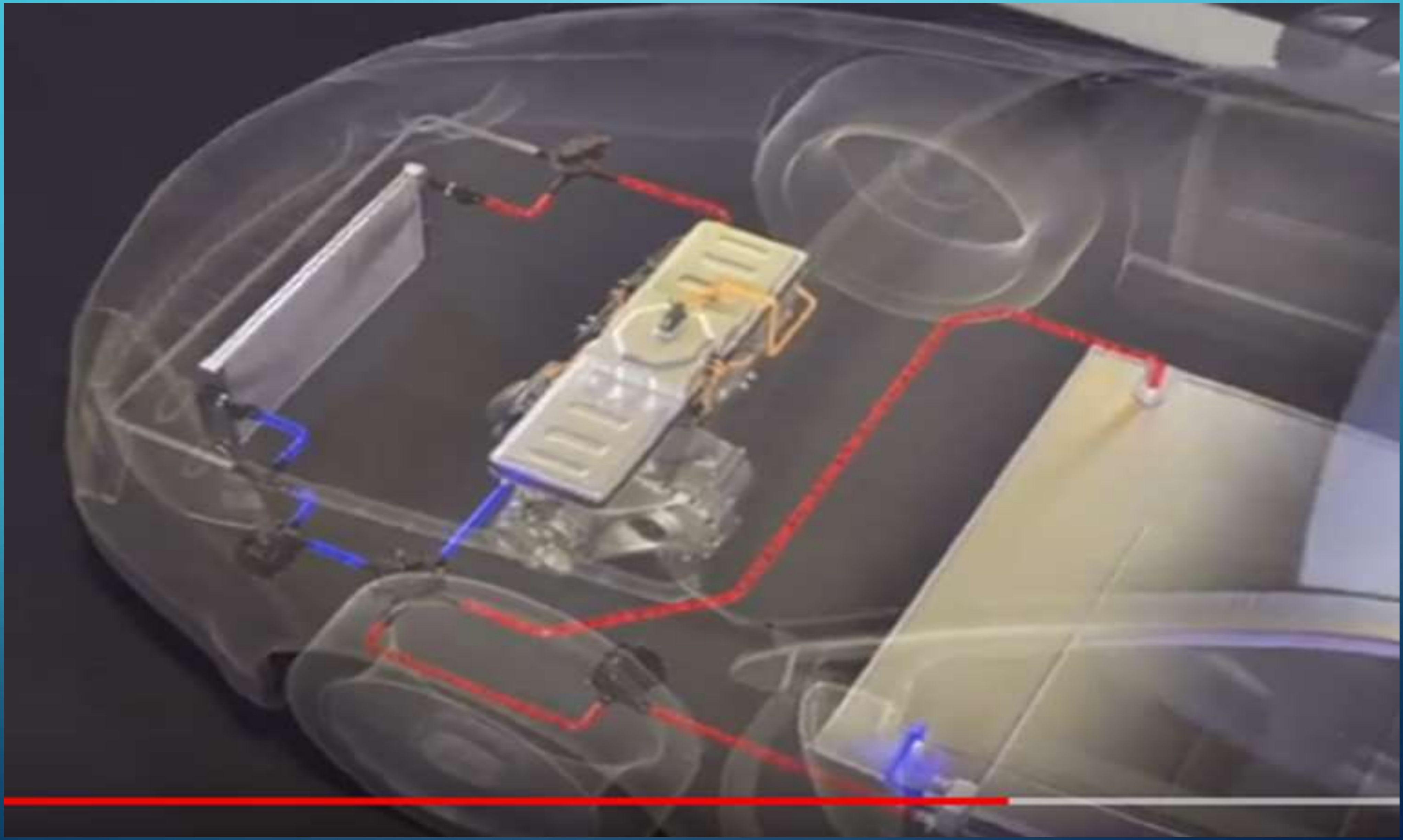
Charles Adolphe Wurtz

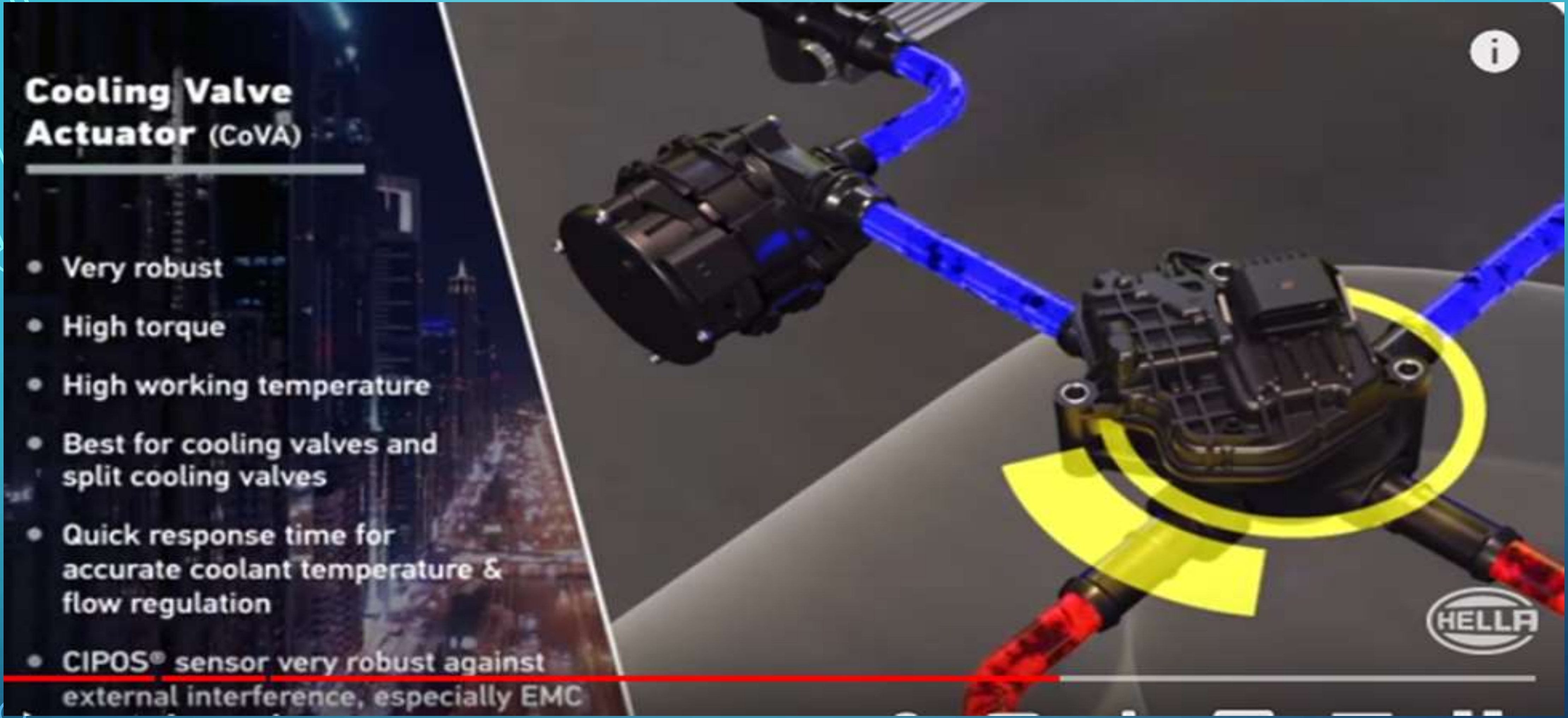
Invented Ethylene glycol



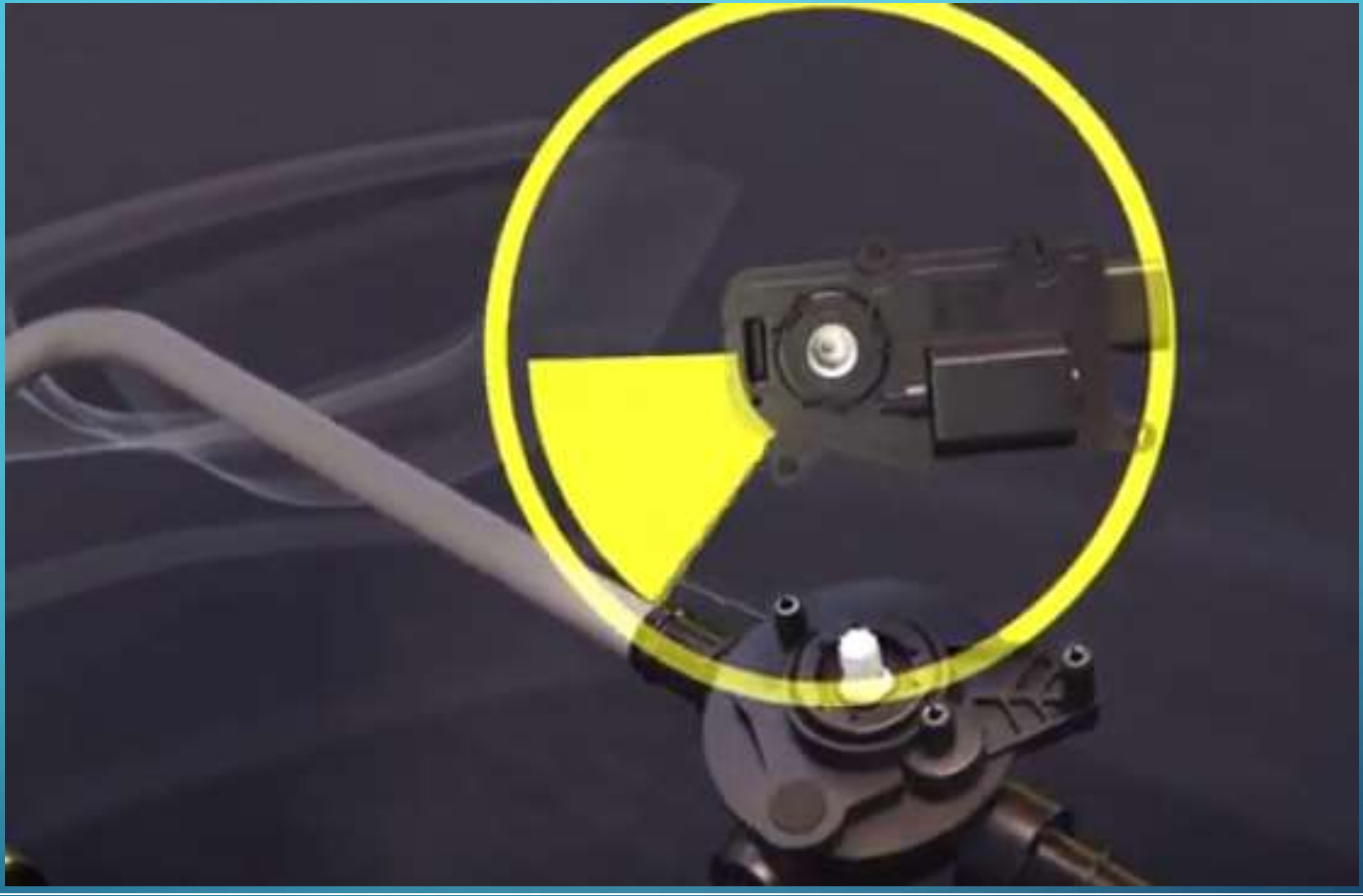
Traction Battery and traction Motor Thermo Management System Path Way


EVAPORATOR





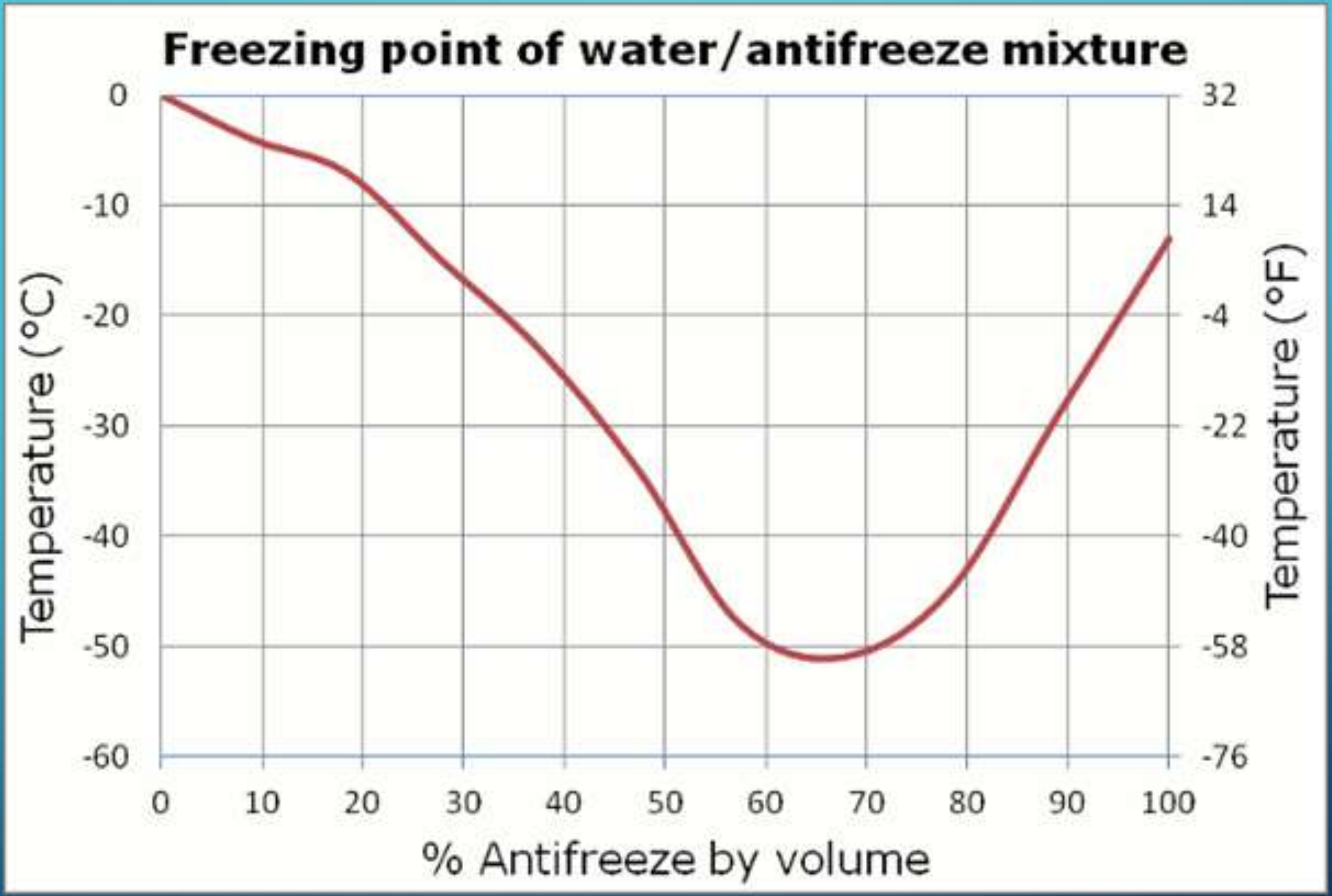
Contactless Inductive Position Sensor **electromagnetic compatibility**(EMC)



Variable Coolant Flow(Siphon Sensor)

4:16 / 4:58 · Cooling system
+ 180°
0°
- 180°

CHEMICAL STRUCTURE OF ETHYLENE GLYCOL



Freezing point of water/antifreeze mixture
Temperature (°C)
0
-10
-20
-30
-40
-50
-60
Temperature (°F)
32
14
-4
-22
-40
-58
-76
0
10
20
30
40
50
60
70
80
90
100
% Antifreeze by volume

SAMPLE OF TUBE AND PLATE COOL

Figure 2: This Press-Lock™ cold plate uses counterflow through two different layers of tube for averaging of temperatures

STANDARD INSULATED HAND TOOLS, MEASURING INSTRUMENT AND EQUIPMENT

STANDARD INSULATED HAND TOOLS

1000V INSULATED HAND TOOLS

INSTRUMENT FOR ELECTRIC VEHICLE

- Insulation tester.


In this test, we verify that there are no flaws in the insulation between the high-voltage (HV) system and the ground. For reference, the locations of the measurements are labeled as follows:

- A: Inverter, motor, etc.
- B: Chassis
- C: HV cable
- D: HV batteries

The flow of insulation testing is as follows:

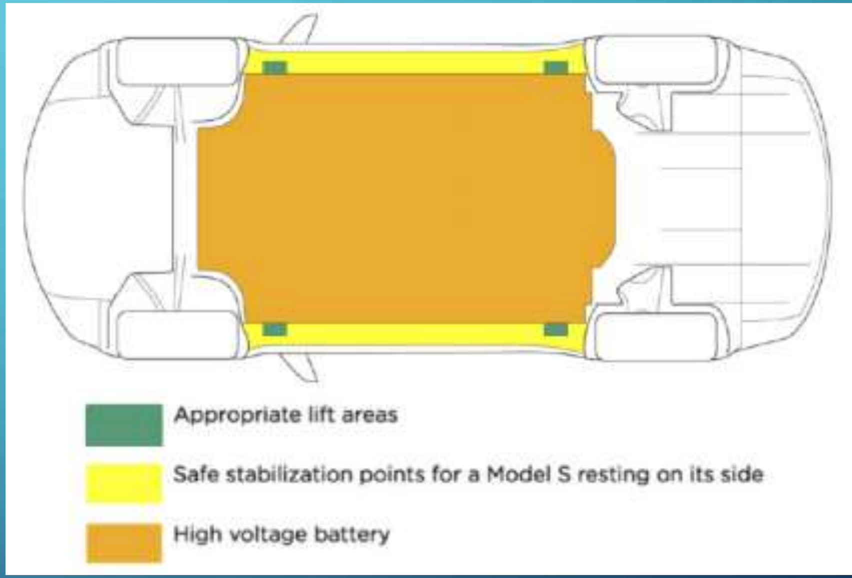
(LHS), Insulation Test for HV Battery Side (RHS),Insulation Test for Inverter Side

- Milliohm meter.

Two Pole Tester for EV

EQUIPMENT FOR ELECTRIC VEHICLES

HIGH VOLTAGE BATTERY LIFT



LOCATION SHOWING TO LIFT ELECTRIC VEHICLES

LIFT POINTS FOR ELECTRIC VEHICLE

FOOT PAD KIT OR (PUCK) FOR ELECTRIC VEHICLE LIFT

EV GLOVE

DIELECTRIC OVER BOOTS

CLASS 00 ELECTRICAL SAFETY GLOVES

CLASS 0 SAFETY GLOVES

STEERING WHEEL LOCKOUT

INTRO TO HIGH-VOLTAGE BATTERY DISCONNECT SWITCHES

This article introduces high-voltage battery disconnect switches, where transistors have replaced the old-fashioned relays.

Electric vehicles currently on the market use 400 V and 800 V batteries with nominal currents above 200 amperes, which could be lethal if this high voltage and current were connected to the chassis or any conductive part of the vehicle. To prevent such a scenario, manufacturers use high voltage and high current direct-current contactor relays, disconnecting the battery plus and minus rail from the high-voltage-board net shown in Figure 1.

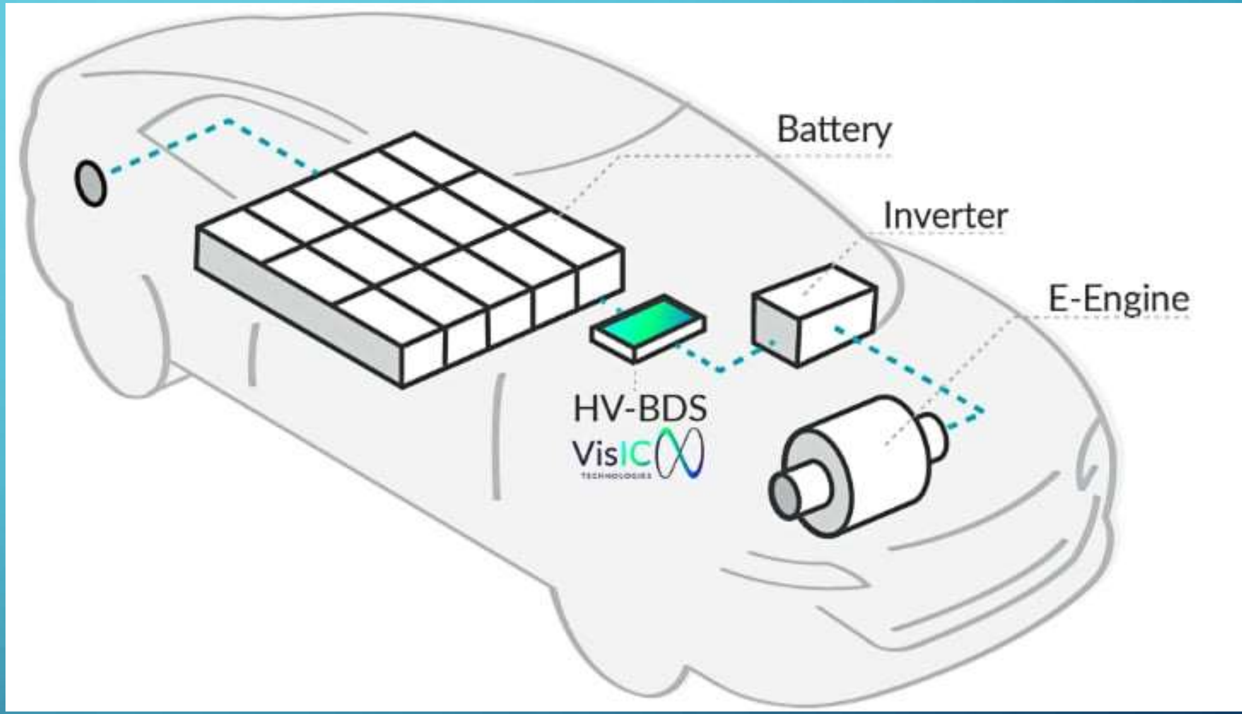


Figure 1. *Battery disconnect switch. Image used courtesy of Bodo's Power Systems [PDF]*

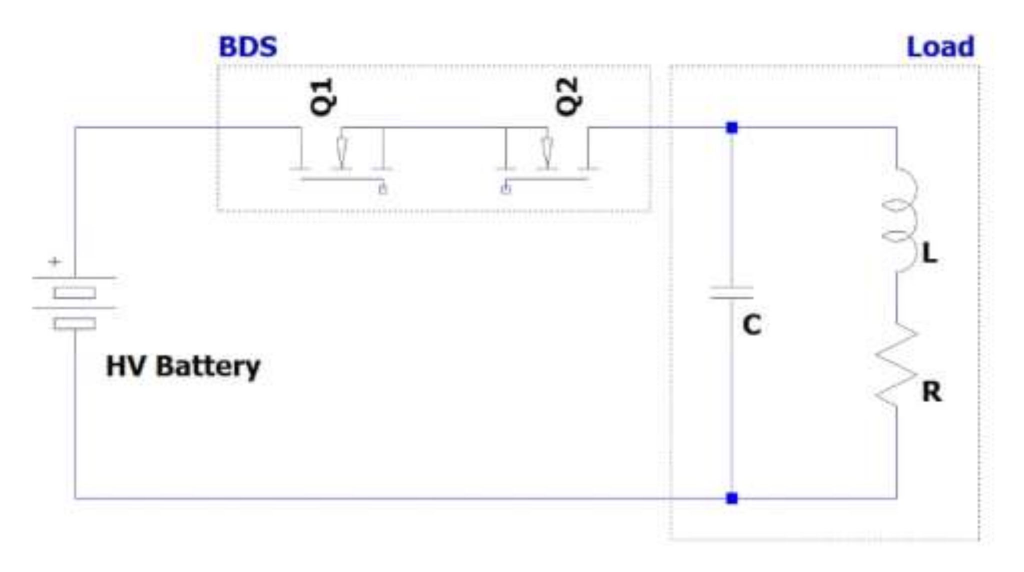


FIGURE 2. BLOCK SCHEMATIC. IMAGE USED COURTESY OF BODO'S POWER SYSTEMS

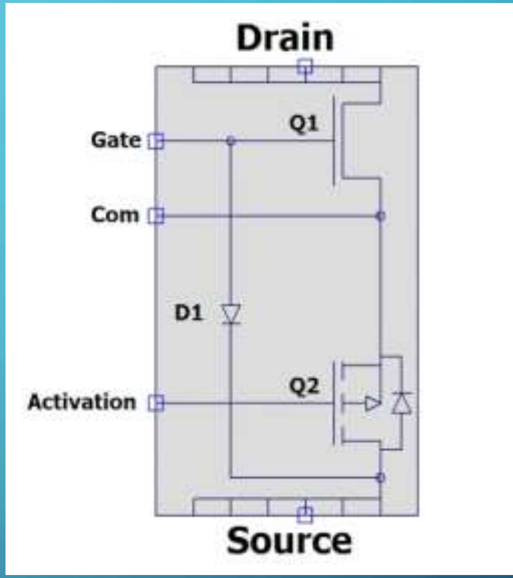
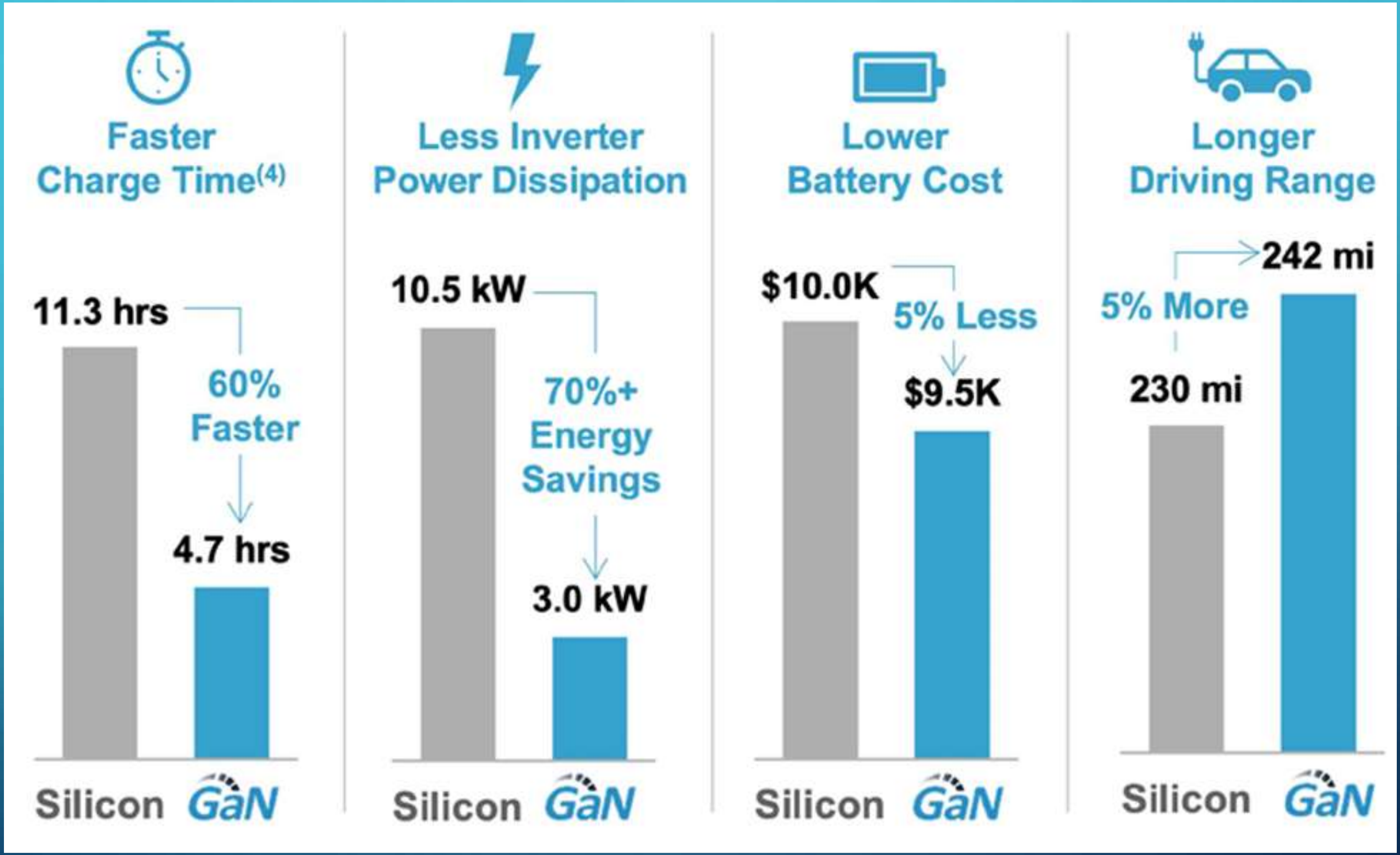
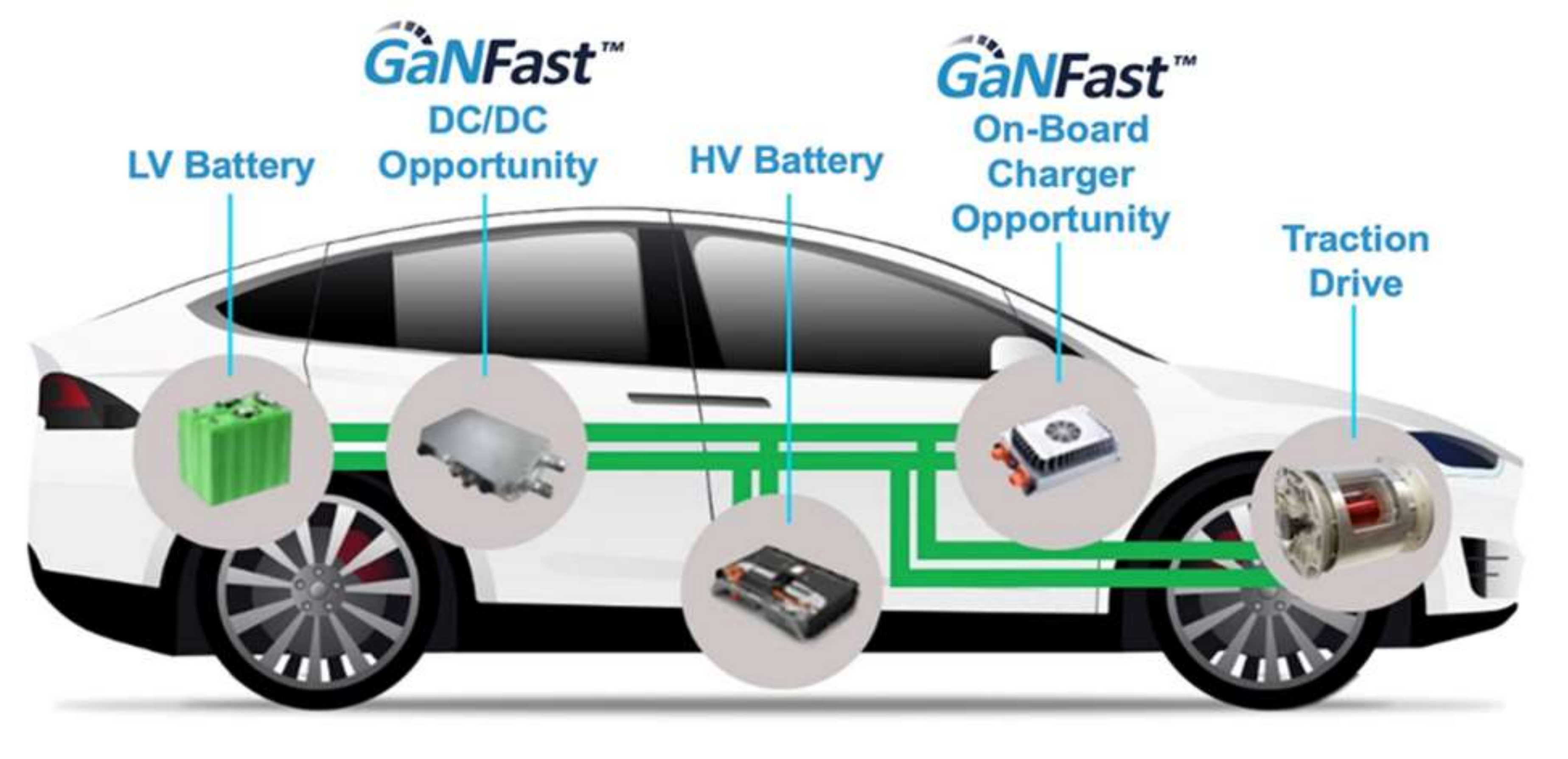


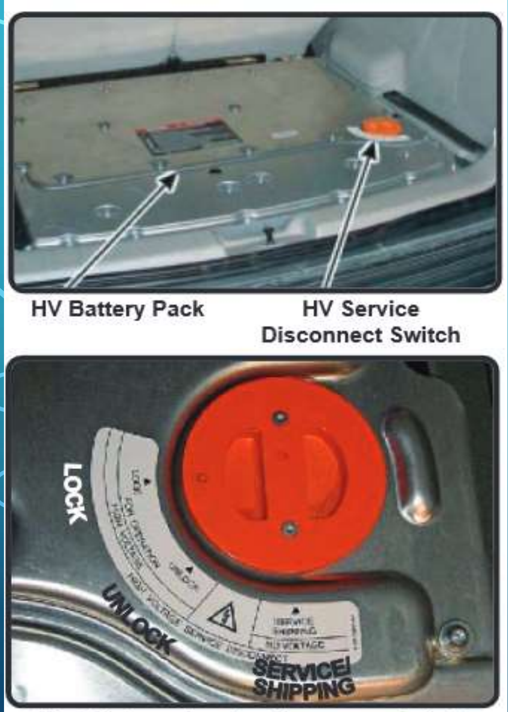
FIGURE 3. DIRECT DRIVE GAN. IMAGE USED COURTESY OF BODO'S POWER SYSTEMS [PDF]


Faster
Charge Time(4)
11.3 hrs
60%
Faster
4.7 hrs
Silicon
GaN
Less Inverter
Power Dissipation
10.5 kW
70%+
Energy
Savings
3.0 kW
Silicon
GaN
Lower
Battery Cost
$10.0K
5% Less
$9.5K
Silicon
GaN
Longer
Driving Range
242 mi
5% More
230 mi
Silicon
GaN

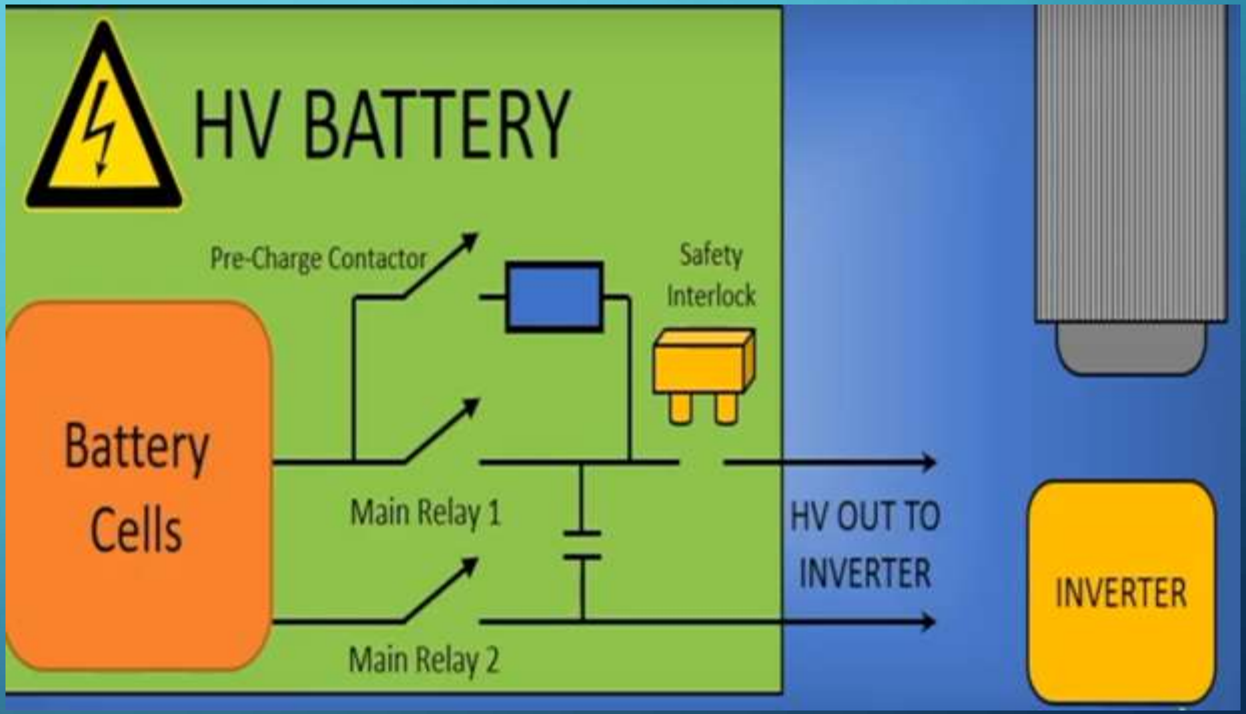


- **References:**
- 1. Baliga (2016): Gallium Nitride and Silicon Carbide Power Devices, World Scientific
- 2. VisIC Technologies Short Circuit Protection Application Note APN-01650-0003 Rev1.0
- 3. **Q. Song et al.**, "Evaluation of 650V, 100A Direct-Drive GaN Power Switch for Electric Vehicle Powertrain Applications," 2021 IEEE 8th Workshop on Wide Bandgap Power Devices and Applications (WiPDA), 2021, pp. 28-33, doi: 10.1109/ WiPDA49284.2021.9645143.

DISCONNECTING HIGH VOLTAGES FOR ELECTRIC VEHICLES



High-Voltage Service Disconnect Switch Shown in LOCK position.



Safety Precautions and Before You Start Working on the EV

- Make sure to wear your personal safety equipment and that it fits properly, is worn correctly and is not damaged in any way.
- Consult the common and manufacturer specific instructions where available
- On receiving an EV first examine the high voltage battery visually for physical, mechanical damage, intrusion and leakage. The inspection of the vehicle should be done by a person with a requisite qualification.
- If the high voltage battery is identified as damaged handle in accordance with manufacturer specific instruction and applicable national legislation and guidelines.
- Before removal of high voltage battery, ensure the area around the EV is restricted and marked.
- Place a “High voltage” sign on the vehicle, incl. the name of the person in charge for the treatment of the EV.
- It is forbidden to carry out operations or electrical checks on the electrical network when it is power up.

Signal of Defective Battery

- The removed battery must be classified as damaged when ONE of the following criteria is met:
- Mechanical or physical damage of the battery, e.g. dents, cracks, exposed contacts or conductors
- Leakage and / or suspicion of fluids in battery System
- Vented gas
- Smoke, steam
- Fire, sparks
- Noises (hissing, crackling)
- High Voltage Battery Storage

The following provides a guideline to store high voltage batteries after removal from the vehicle:

- Store the battery where it will be kept dry and not exposed to high temperatures, fire and/or direct sunlight.
- Protect the battery from mechanical loads and damage (punctured or crushed).
- Batteries should be stored by battery type (i.e. NiMH), according to applicable legislation.
- Keep the battery away from water and rain.
- Never place directly on the floor. Lay a High Voltage rubber insulation mat underneath the battery.
- Always store the battery in its normally installed orientation, never invert.
- Store the battery in well ventilated areas in accordance with applicable legislation.
- Only store batteries which are sufficient insulated against short circuiting.
- Cover the battery with a high voltage rubber insulation mat.
- Mark the storage with a warning sign.
- Please refer to manufacturer specific information where available and national legislation on storage of high voltage batteries.

Zero-Voltage Measurement of Electrical Vehicles

Measurement purpose

The purpose of this measurement is to prevent electric shock and make sure that the vehicle is shut down. In this measurement, we verify that the measurement points where high voltage may be generated is at zero volts (0 V). The zero-voltage test is carried out between the HV battery and the inverter. It is performed three times: once before disconnecting the HV cable, once after disconnecting the HV cable, and once before reconnecting the HV cable. The measurement can be performed with a multimeter

Measurement timing	Purpose
1. Before disconnecting the HV cable between the HV battery and the inverter	To measure the zero-voltage on surfaces that are likely to be touched when unplugging the HV connector
2. After disconnecting the HV cable between the HV battery and the inverter	To safely repair or inspect the BEV, ensure that the vehicle is free of hazardous voltage
3. Before reconnecting the HV cable between the HV battery and the inverter	To check that the HV cable can be connected safely after the BEV has been repair

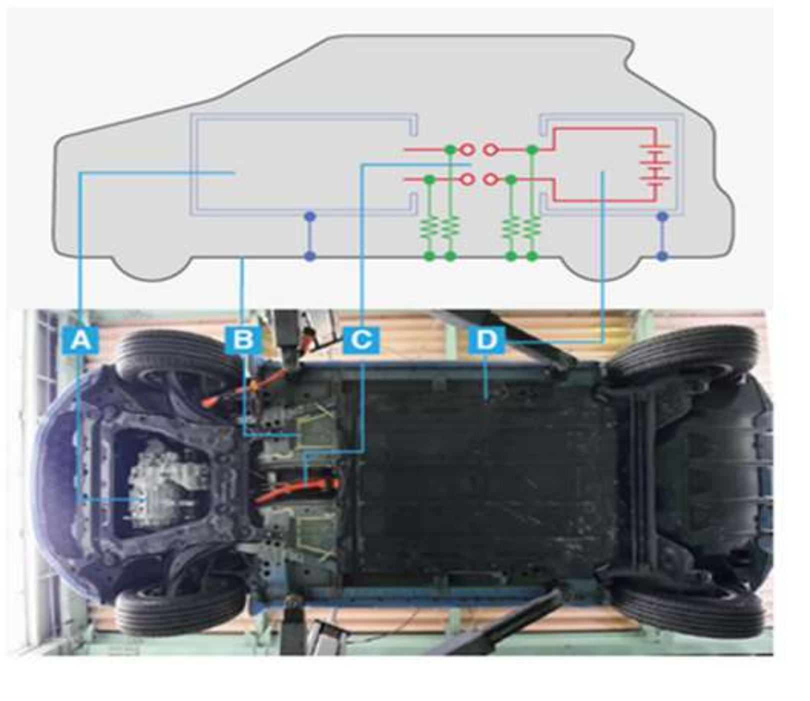
MEASUREMENT PROCESS

Preparation before measurement: Shutting down the vehicle's HV system

The locations of the measurements are labeled as follows:

The removal of high-voltage components is hazardous work. Ensure that qualified personnel specified by the laws and regulations with professional training perform the work. For details, please follow the operation manual of each vehicle manufacturer.

Be sure to shut down[*1] the vehicle's HV system by disconnecting the service plug or switch before carrying out any electrical tests or measurements.



A= Inverter, Motor, etc:

B= Chassis

C= HV Cable

D= HV Battery

Measurement 1: Before disconnecting the HV cable after vehicle shutdown

After shutting down the vehicle's HV system, zero-measurement is performed on surfaces that are likely to be touched when disconnecting the HV cable connector. Table 1 shows examples of the measurement points.

Table 1: Examples of the measurement points.

Measurement point	Multimeter terminal (+)	Multimeter terminal (−)
HV battery side	Places likely to be touched when disconnecting the HV connector	Chassis ground (GND)

Measurement 2: After disconnecting the HV cable

After disconnecting the HV cable, wait for at least 10 minutes for the HV system to discharge, then conduct the zero-voltage measurement again.

As shown in Table 2, measurements are done at the HV battery-side connector and the inverter-side connector. To avoid serious accidents, it is necessary to wait for a certain period of time. Take note that the discharge time may vary, so make sure to check with the vehicle manufacturer.

Table 2: Examples of the measurement points.

Measurement point	Multimeter terminal (+)	Multimeter terminal (−)
HV battery side	Positive terminal of the connector (+)	Chassis ground (GND)
	Negative terminal of the connector (−)	Chassis ground (GND)
	Positive terminal of the connector (+)	Negative terminal of the connector (−)
Inverter side	Positive terminal of the connector (+)	Chassis ground (GND)
	Negative terminal of the connector (−)	Chassis ground (GND)
	Positive terminal of the connector (+)	Negative terminal of the connector (−)

ZERO-VOLTAGE MEASUREMENT ON THE HV BATTERY SIDE (LEFT FIGURE) AND INVERTER SIDE (RIGHT FIGURE)

Measurement 3: Before reconnecting the HV cable after the inspection

After completing the repair or inspection, do a zero-voltage measurement on the inverter and battery sides before safely reconnecting the HV system. Table 3 shows the measurement points for the HV battery side and inverter side. Since there is a diode on the inverter side, it is necessary to switch the polarity, so the test is performed twice.

Table 3: Examples of the measurement points.

Measurement point	Multimeter terminal (+)	Multimeter terminal (−)
HV battery side	Positive terminal of the connector (+)	Chassis ground (GND)
	Negative terminal of the connector (−)	Chassis ground (GND)
Inverter side	Positive terminal of the connector (+)	Chassis ground (GND)
	Negative terminal of the connector (−)	Chassis ground (GND)
	Chassis ground (GND)	Positive terminal of the connector (+)
	Chassis ground (GND)	Negative terminal of the connector (−)

ZERO VOLTAGE MEASUREMENT ON THE HV BATTERY SIDE (LEFT PICTURE) INVERTER SIDE (RIGHT PICTURE)

FT3701 is an **infrared thermometer** with a two-point laser marker that measures the average surface temperature inside a circle formed by the two points.

Deactivate the High Voltage Electrical System

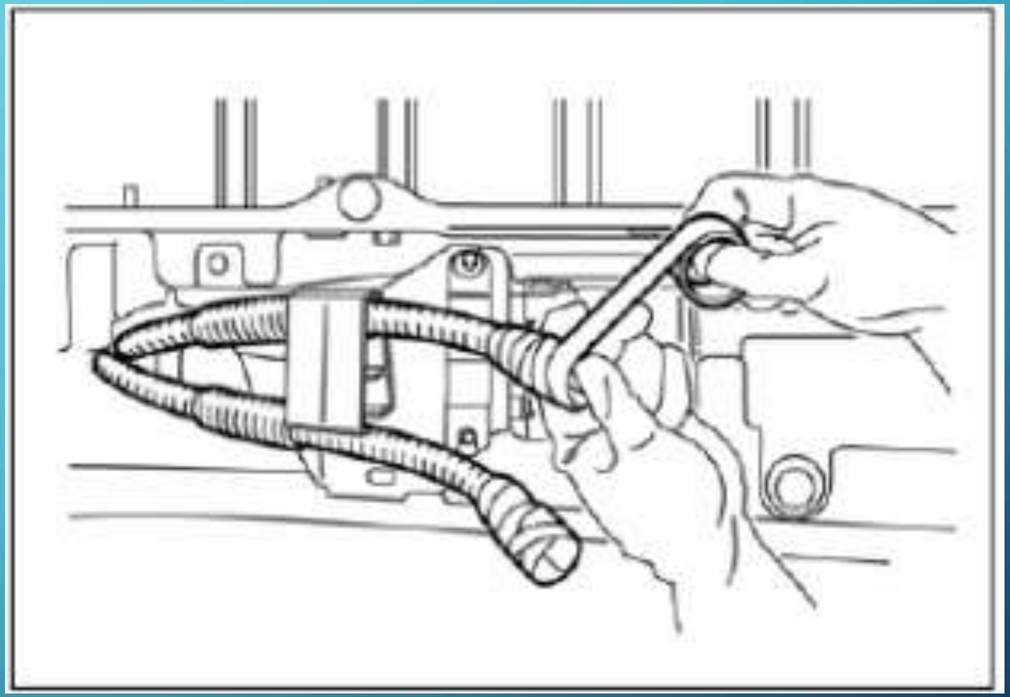
- EV must NOT be connected to the charging cable!
- Position of the electric vehicle on a suitable lifting platform.
- Check manufacturer specific information if it is necessary to open bonnet and luggage

compartment before disconnecting the starter battery.

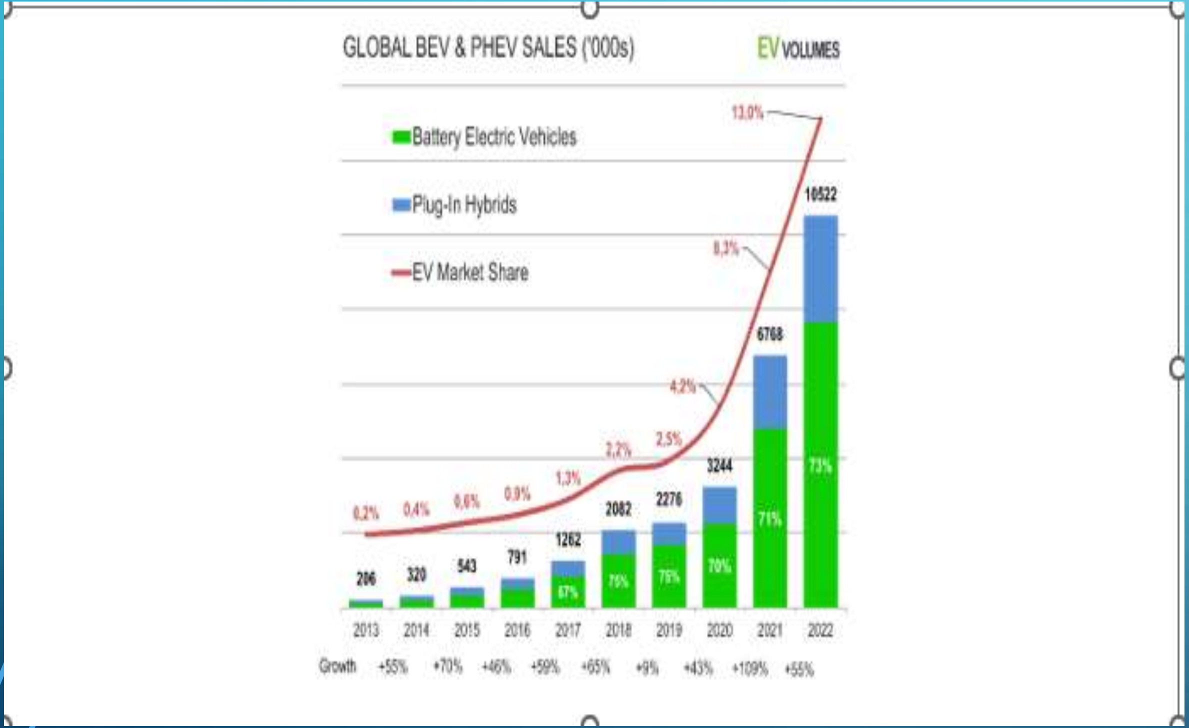
EVs must be deactivated at four separate steps:

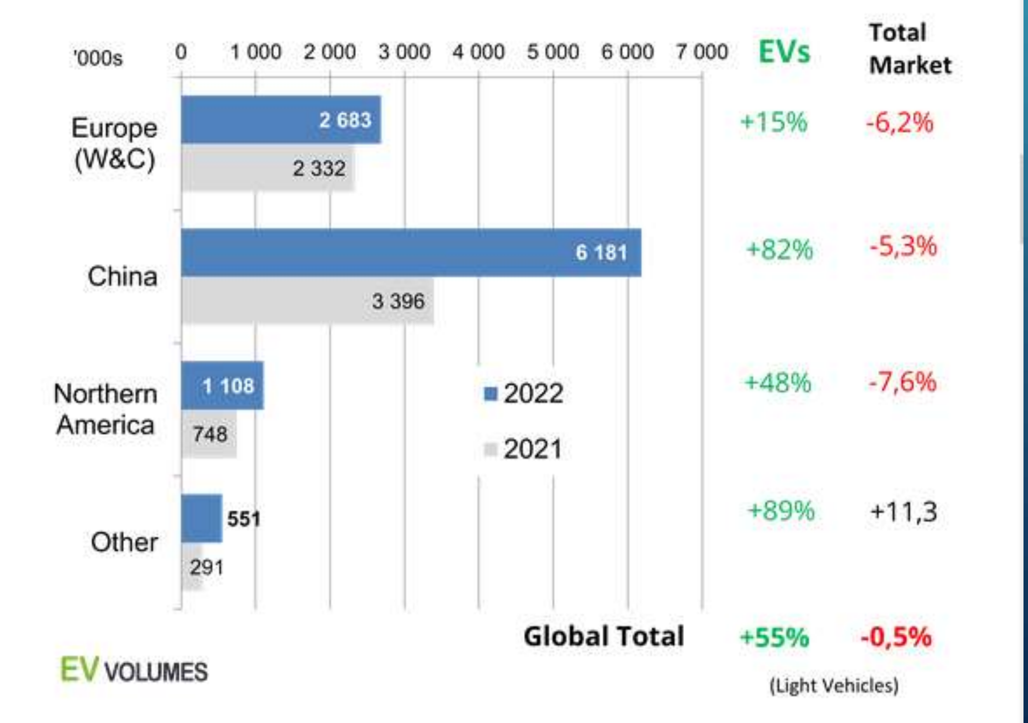
- 1.) Switch off the ignition and remove the key / store the key at least 3m away from the vehicle.
- 2.) Disconnect the starter battery and any other auxiliary batteries if available. Insulate all battery terminals. Ensure that no other internal or external power source, such as slave batteries, jump start or charging equipment is connected to the vehicle.
- 3.) Remove the service plug or turning off the isolation switch and secure against reconnection.
- If the service plug/ switch is not accessible, visible or available, please see manufacturer specific information.
- 4.) Ensure that the high voltage system is at zero potential by using a voltage absence verifier.
- Steps 2, 3 and 4 may be different for some vehicles. Please refer to the manufacturer specific documents.
- By waiting for 10 minutes after above battery deactivation process, the high voltage electrical system external to the battery is discharged and the battery isolated. However, the high voltage battery inside the battery housing still retains its state of charge.
- Disconnection and Removal of the High Voltage Battery
- Check the manufacturer specific manual for disconnection and removal of the high voltage battery.

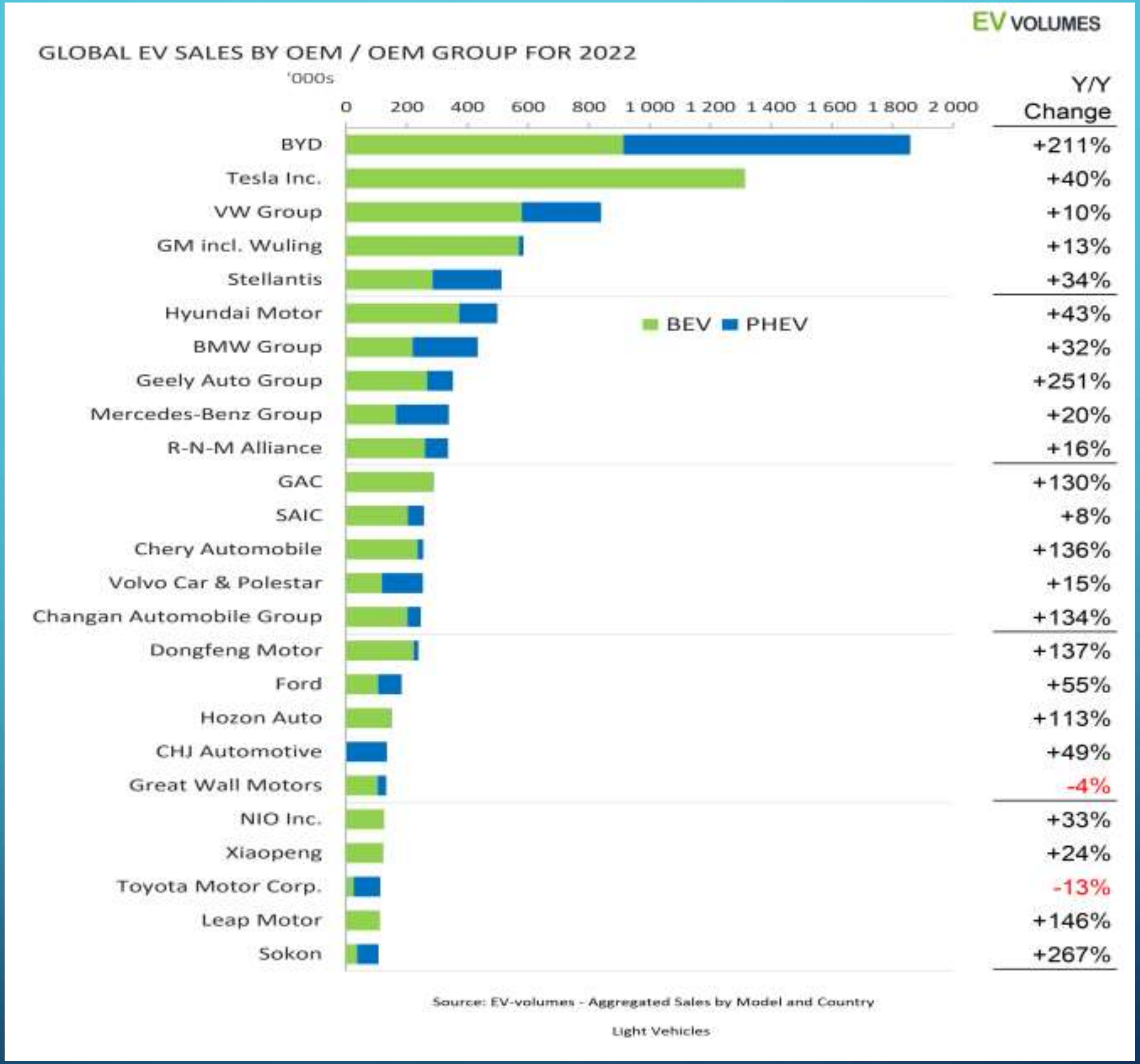
- Before taking any actions: Test the checking equipment e.g. the voltage absence verifier is working correctly.
- Before disconnecting the high voltage cable terminals, make sure that the voltage between the terminals is 0 V with a suitable tool.
- Wrap the high voltage battery terminals with electrical insulation tape (to prevent short circuiting)
- Certain vehicles may require fitment of an insulating protection cap to the battery cable socket, please see manufacturer specific information.
- Once the high voltage battery has been removed successfully, the vehicle can then be dismantled the usual way.



EV POPULATION GROWTH IN THE WORLD






EV VOLUMES
GLOBAL EV SALES BY OEM / OEM GROUP FOR 2022
'000s
0 200 400 600 800 1 000 1 200 1 400 1 600 1 800 2 000
Y/Y Change
BYD +211%
Tesla Inc. +40%
VW Group +10%
GM incl. Wuling +13%
Stellantis +34%
Hyundai Motor +43%
BMW Group +32%
Geely Auto Group +251%
Mercedes-Benz Group +20%
R-N-M Alliance +16%
GAC +130%
SAIC +8%
Chery Automobile +136%
Volvo Car & Polestar +15%
Changan Automobile Group +134%
Dongfeng Motor +137%
Ford +55%
Hozon Auto +113%
CHJ Automotive +49%
Great Wall Motors -4%
NIO Inc. +33%
Xiaopeng +24%
Toyota Motor Corp. -13%
Leap Motor +146%
Sokon +267%
BEV
PHEV
Source: EV-volumes - Aggregated Sales by Model and Country
Light Vehicles

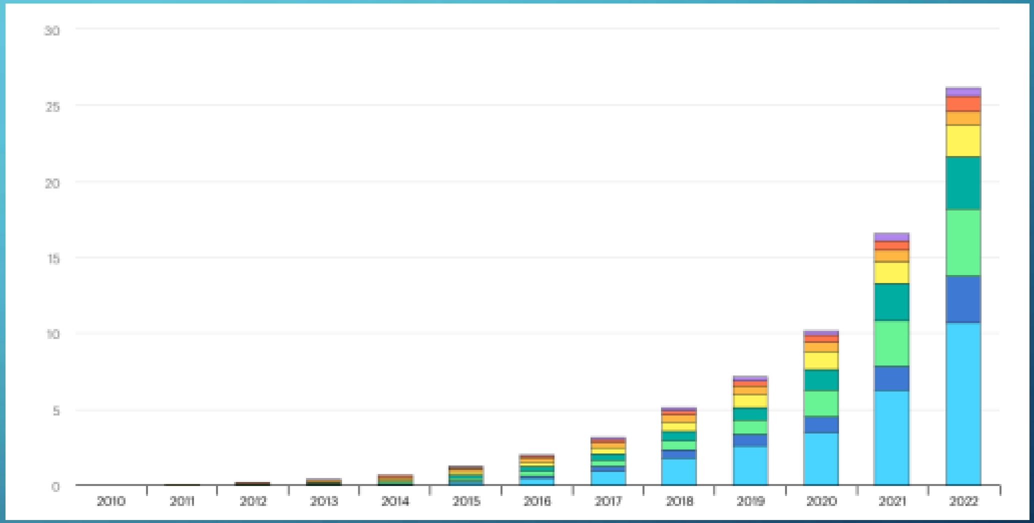
GLOBAL ELECTRIC CAR STOCK, 2010-2022

Norway is the country with the most electric car population. In this country, the share of plug-in electric vehicles (PHEVs) reaches 75 percent.

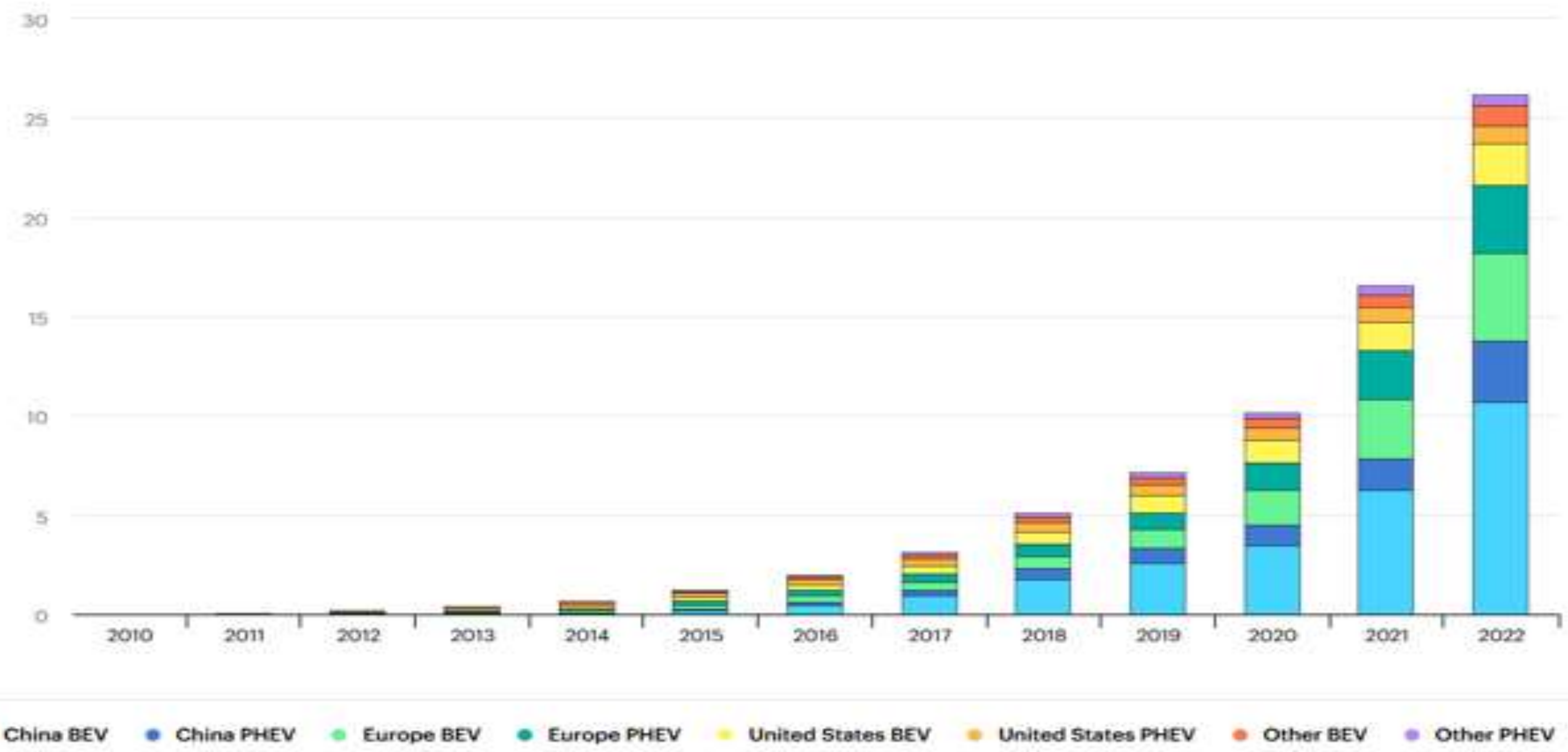
The country will end the sales of internal combustion engine cars in 2025. Norway's experience suggests that electric vehicles bring benefits without the dire consequences predicted by some critics. There are problems, of course, including unreliable chargers and long waits during periods of high demand.

Electric vehicles: U.S. market growth forecast 2030 & 2035

Electric vehicles are projected to account for 45 percent of the market in 2035, up from a forecast of **32 percent** in 2030.

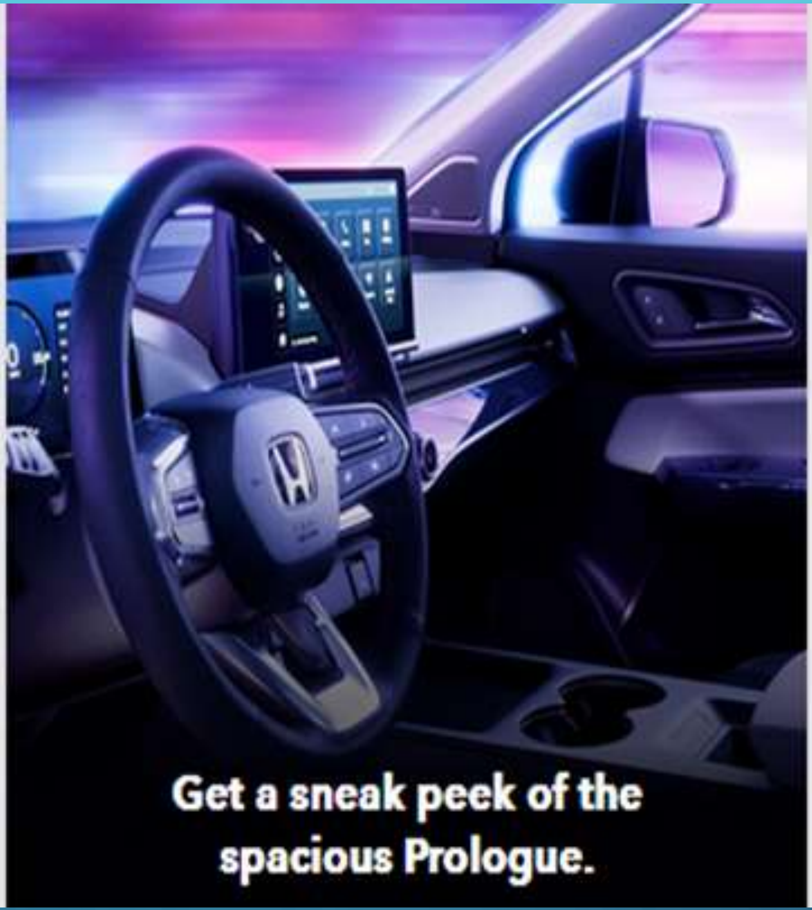


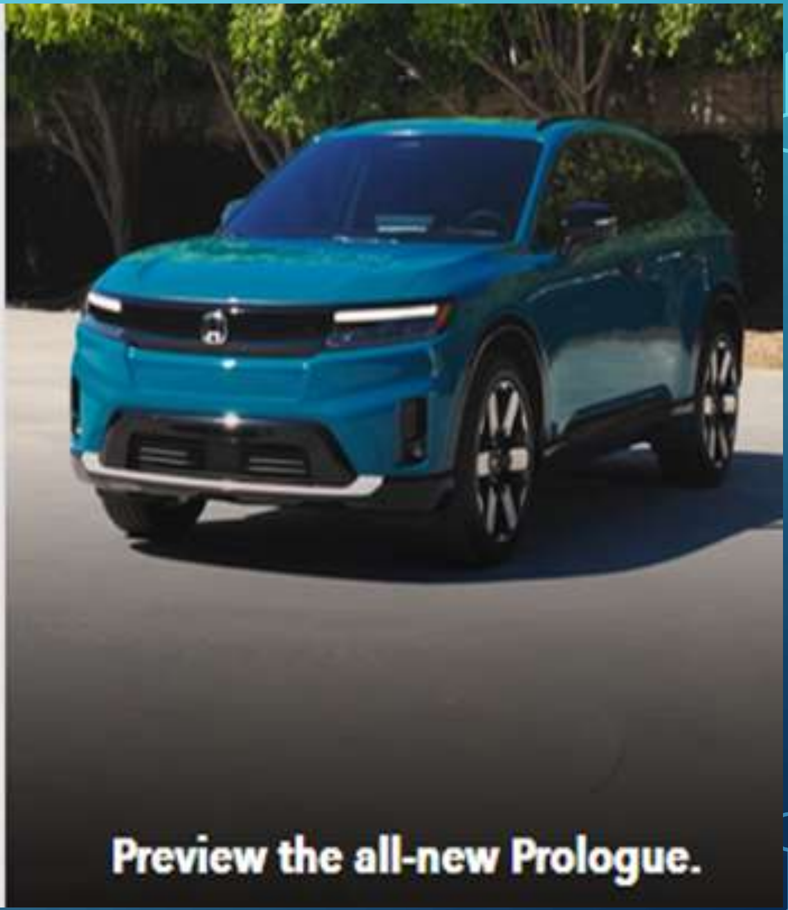
Global electric car stock, 2010-2022




The All-New, All-Electric Prologue
Arrives Early 2024


Modern appearance.


Get a sneak peek of the
spacious Prologue.


Preview the all-new Prologue.


Big on Space, Style, and Innovation
The spacious Prologue offers over 136.9 cubic feet of room inside the cabin. And with muscular 21-inch wheels and a wheelbase on par with our other rugged vehicles, this all-electric SUV is equipped with some sizeable capability.

THANK YOU FOR ATTENDING