

ELECTRIC VEHICLE DESIGN USING MATLAB

Submitted in partial fulfilment of the requirements for the
Professional training – I of Bachelor of
Engineering Degree in
Electrical and Electronics Engineering

BY

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**DEPARTMENT OF ELECTRICAL AND
ELECTRONICS**

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Certificate No PS-APSSDC-INTERN.EV2.0-1079



CERTIFICATE OF INTERNSHIP



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COLLEGE SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY

has Successfully Completed
MASTER CLASS ON EV DESIGN USING MATLAB(30 DAYS)

at Pantech e Learning Pvt Ltd, Chennai

From AUG 23,2021 To SEP 21,2021

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MATLAB MATRIX LABORATORY

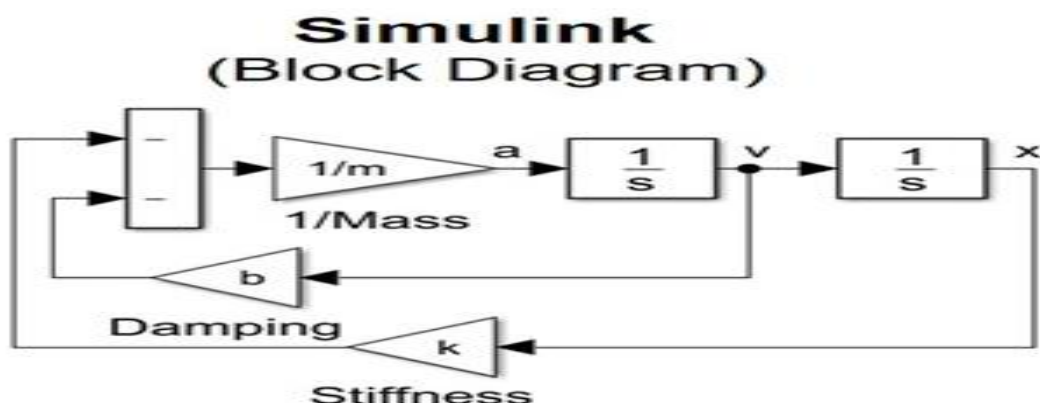
- MATLAB is a multi-paradigm programming language and numeric computing environment Tool
MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages.
- MATLAB combines a desktop environment tuned for iterative analysis and design processes with a programming language that expresses matrix and array mathematics directly. It includes the Live Editor for creating scripts that combine code, output, and formatted text in an executable notebook.

What Can we Do With MATLAB?

- Analyze data
- Develop algorithms
- Create models and application.

SIMSCAPE AND SIMULINK

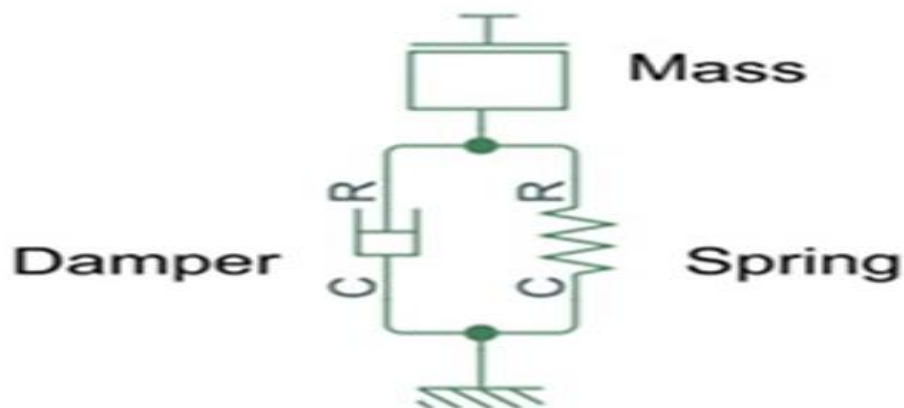
- To create models of physical systems within the Simulink environment.
- Modeling and simulating multi-domain physical systems
- Elements for various physical domains
- Unit manager, data logging etc.,
- Simscape helps you develop control systems and test system-level performance.
- You can create custom component models using the MATLAB based Simscape language, which enables text based authoring of physical modelling components, domains, and libraries.
- You can parameterize your models using MATLAB variables and expressions, and design control systems for your physical system in Simulink.



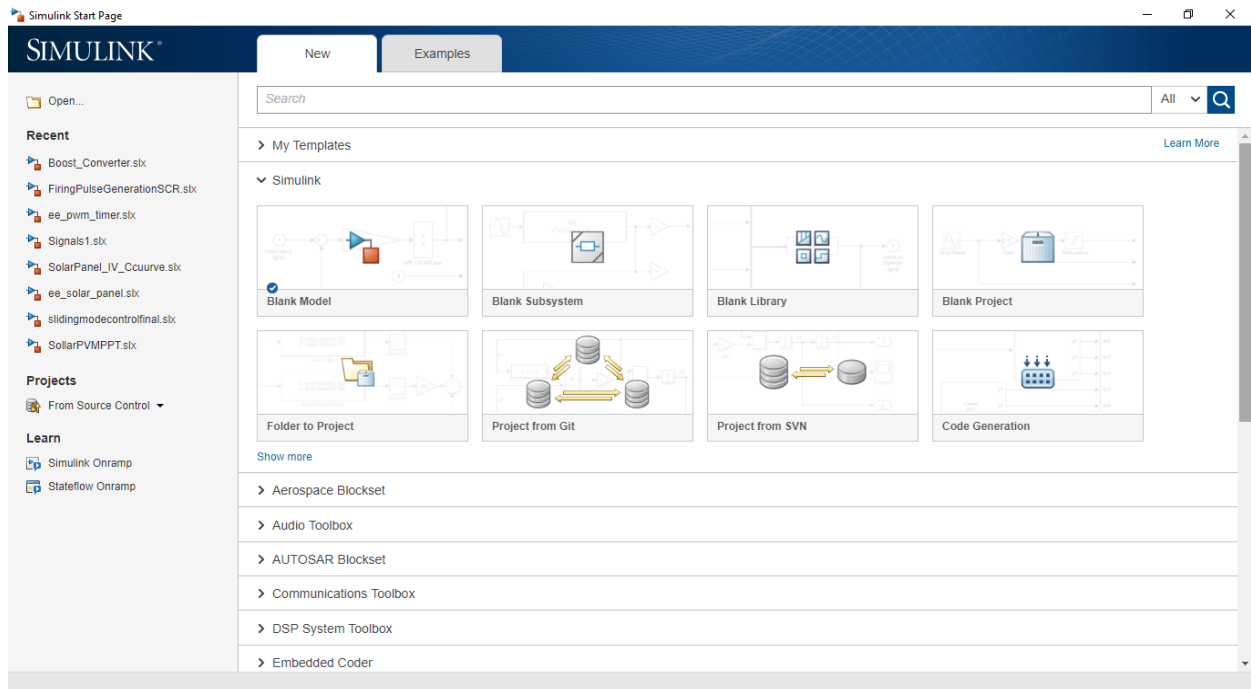
SIMULINK :-

- Simscape helps you to develop control systems and test system-level performance.
- We can create custom component models using the MATLAB based on Simscape language, which enables text-based authoring of physical modelling components, domains, and libraries.

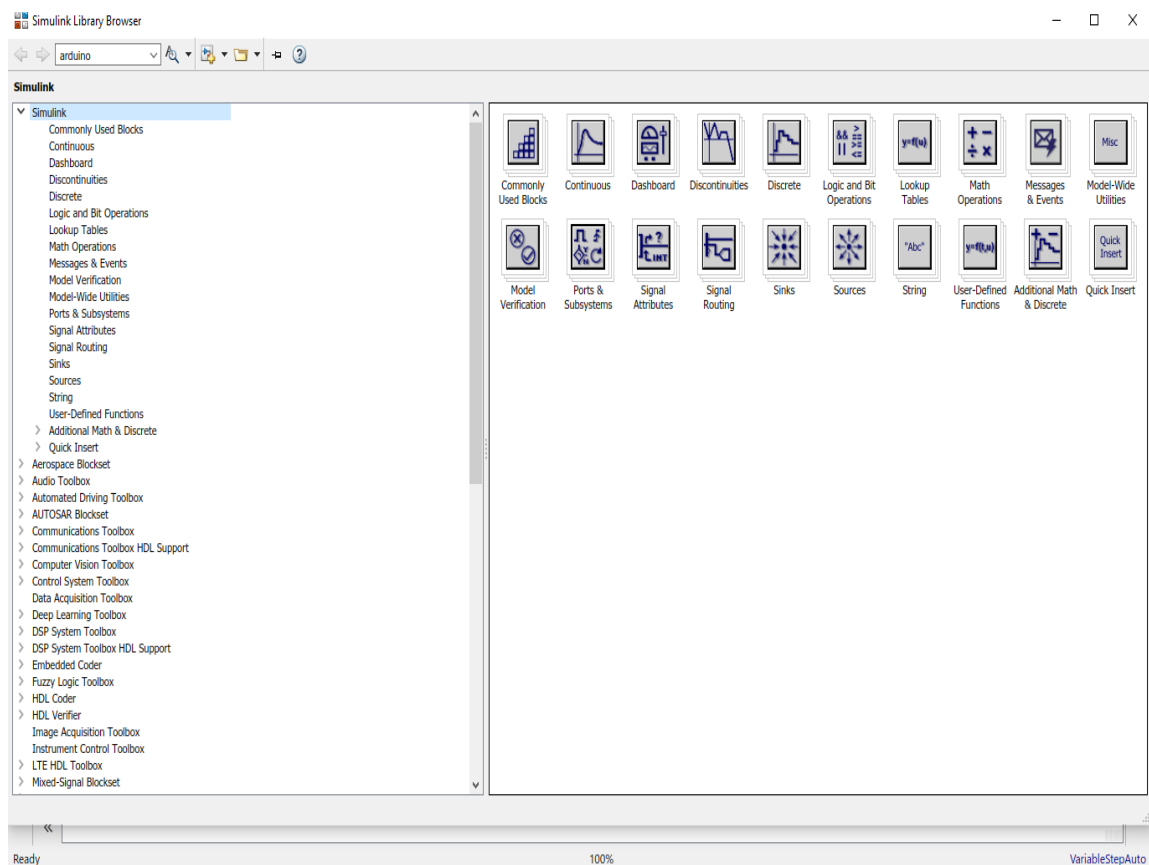
Simscape (Schematic)



SIMULINK



PROJECT WINDOW



ELECTRIC VEHICLE (EV)

✓ An EV is a shortened acronym for an electric vehicle.

EVs are vehicles that are either partially or fully powered on electric power.

✓ Electric vehicles have low running costs as they have fewer moving parts for maintaining and also very environmentally friendly as they use little or no fossil fuels (petrol or diesel).

✓ There are 4 (four) types of electric cars, with the following outline:

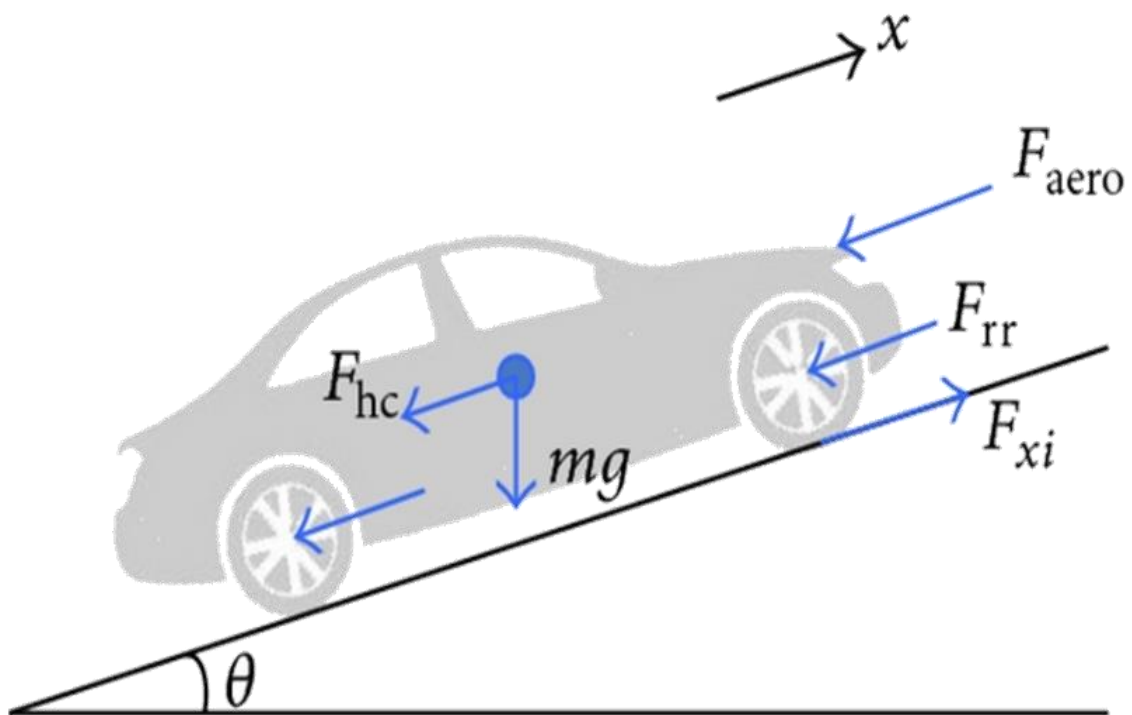
- Battery Electric Vehicle (BEV)
- Hybrid Electric Vehicle (HEV)
- Plug-in Hybrid Electric Vehicle (PHEV)
- Fuel Cell Electric Vehicle (FCEV)



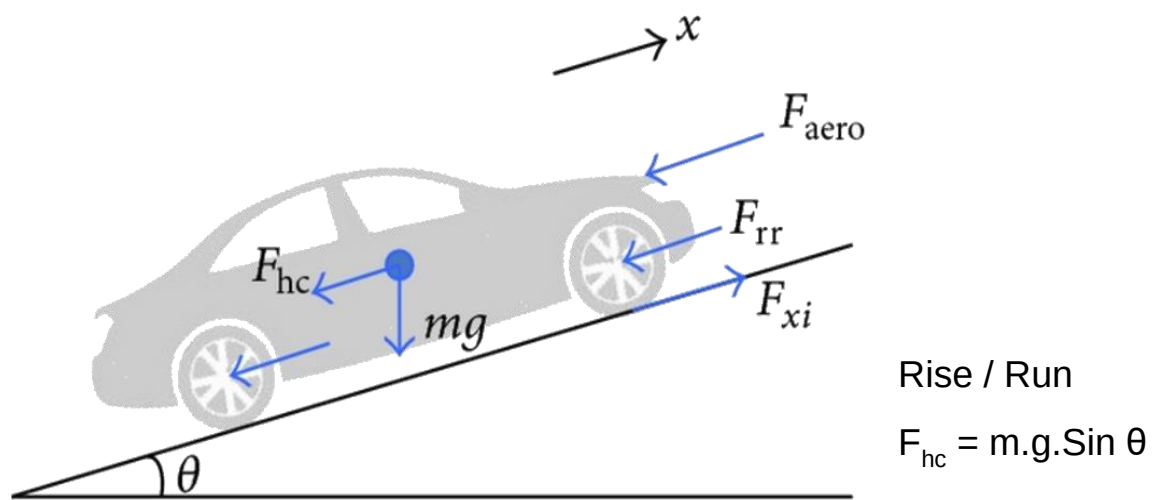
FORCES ON EV

Total Tractive Force

- ❖ Rolling Resistance Force (F_{rr})
- ❖ Aerodynamic drag Force (F_{aero})
- ❖ Hill climbing Force (F_{hc})
- ❖ Acceleration Force (F_{xi})
 - Linear Acceleration Force
 - Angular acceleration force



HILL CLIMBING FORCE



ACCELERATION FORCE:-

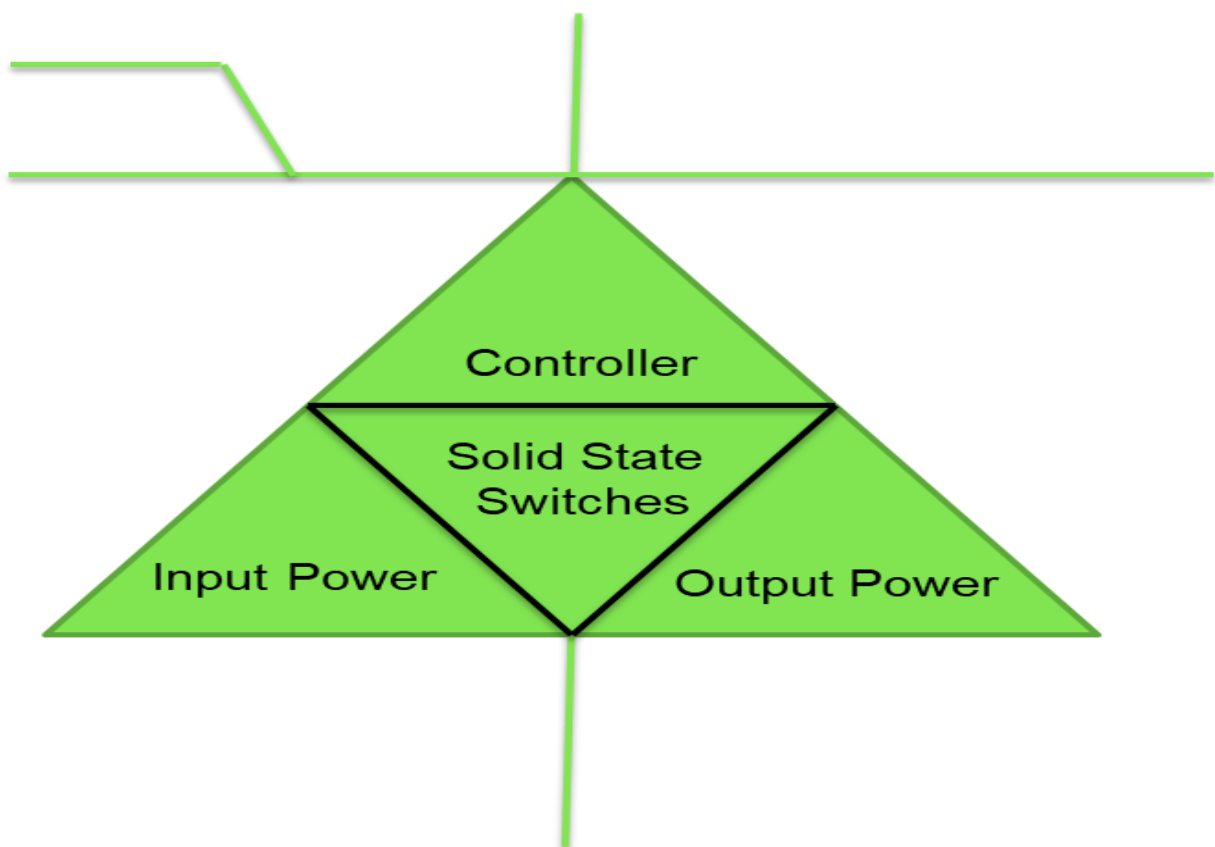
Linear Acceleration Force (F_{la}) = $m.a$

Angular Acceleration Force (F_{wa})

$$F_{wa} = \frac{IG^2 a}{r^2 \eta_q}$$

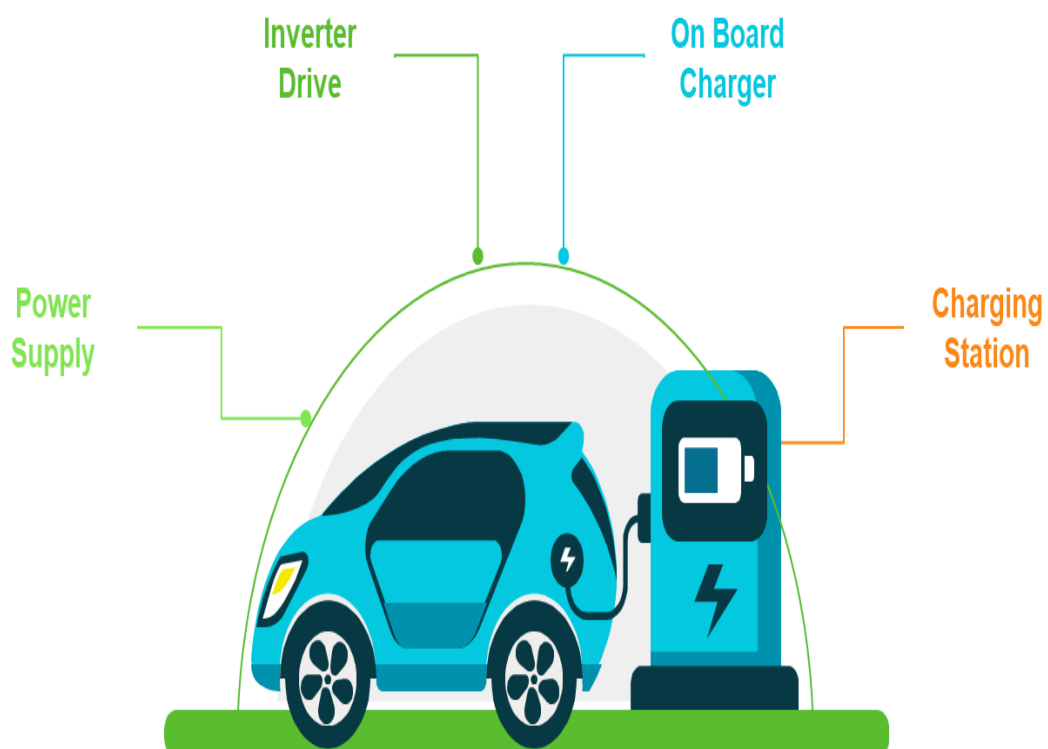
POWER ELECTRONICS

- Power electronics is the application of solid-state electronics to the control and conversion of electric power.
- Power electronics can be defined as the use of electronic devices to control and convert electric power.

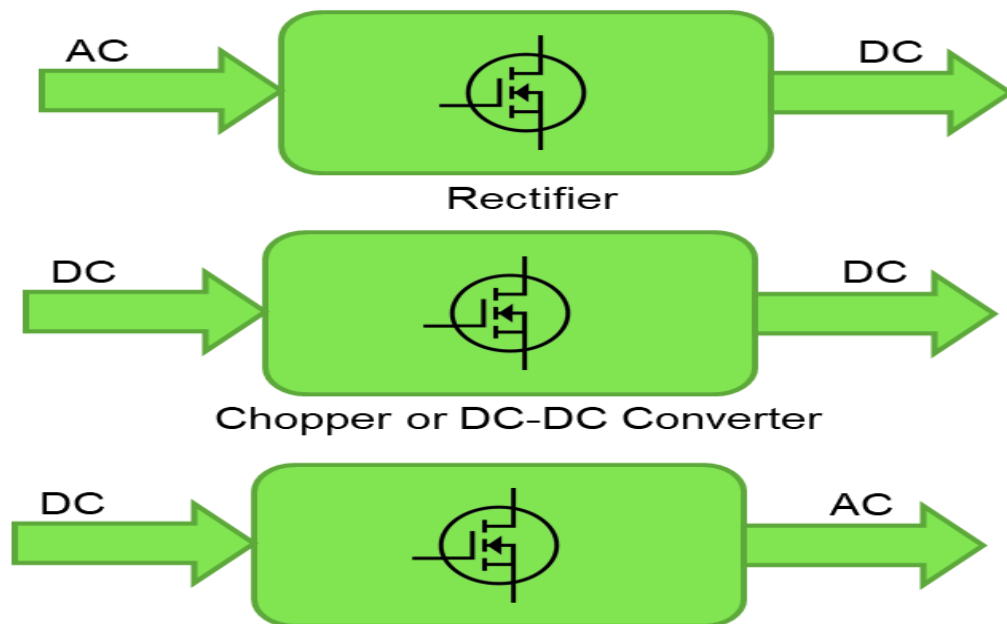


APPLICATION OF POWER ELECTRONICS IN EV: -

- ❖ Bidirectional Converter Topologies for Plug-In Electric Vehicles
- ❖ Bidirectional DC–DC Converter for Ultra-Capacitor Applications
- ❖ Direct Conversion of an AC–DC Converter for Plug-In Hybrid Vehicles
- ❖ Isolated Bidirectional AC–DC Converter for a DC Distribution System
- ❖ Bidirectional T-Type Converter Topology for EV Applications
- ❖ Multiphase Integrated On-board Charger for Electric Vehicle.

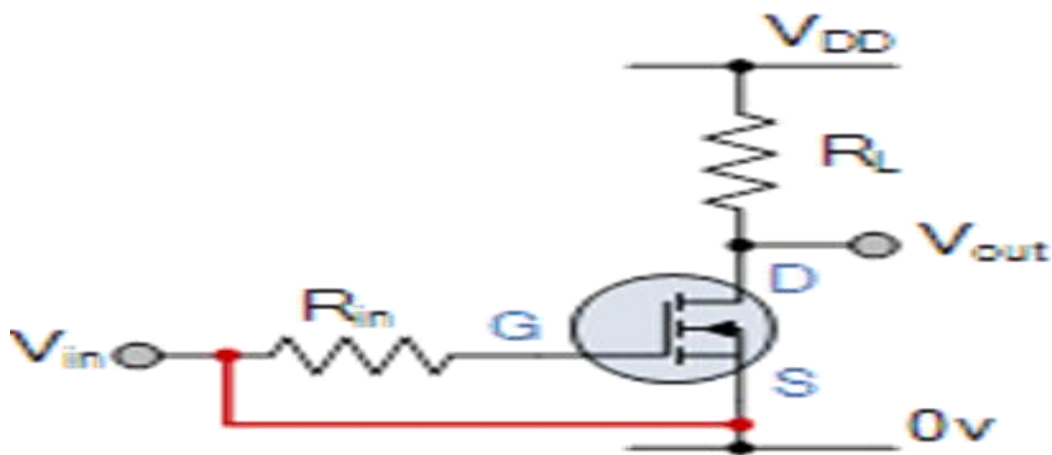


Power Electronics Converters



Solid State Switches

- Diode
- SCR – Thyristor
- MOSFET, IGBT, GTO
- Sic-MOSFET



POWER CONVERTER DESIGN: -

- Power Converters for Electric Vehicles gives an overview, topology, design, and simulation of different types of converters used in electric vehicles (EV).
- It covers a wide range of topics ranging from the fundamentals of EV, Hybrid EV and its stepwise approach, simulation of the proposed converters for real-time applications.

Power Factor Correction (PFC): -

- Power Factor Correction (PFC) shapes the input current of the power supply to be in synchronization with the mains voltage, in order to maximize the real power drawn from the mains.
- In a perfect PFC circuit, the input current follows the input voltage as a pure resistor, without any input current harmonics.

OBSERVATIONS: -

- Power factor correction is essential to minimizing the total apparent power consumed from the grid.
- Regions around the world recognize this need and have implemented voluntary or mandatory requirements depending on the class of electronic equipment.

Design Procedure

- Specifications
- Efficiency
- Range of Input
- % Of Accuracy

Specifications:

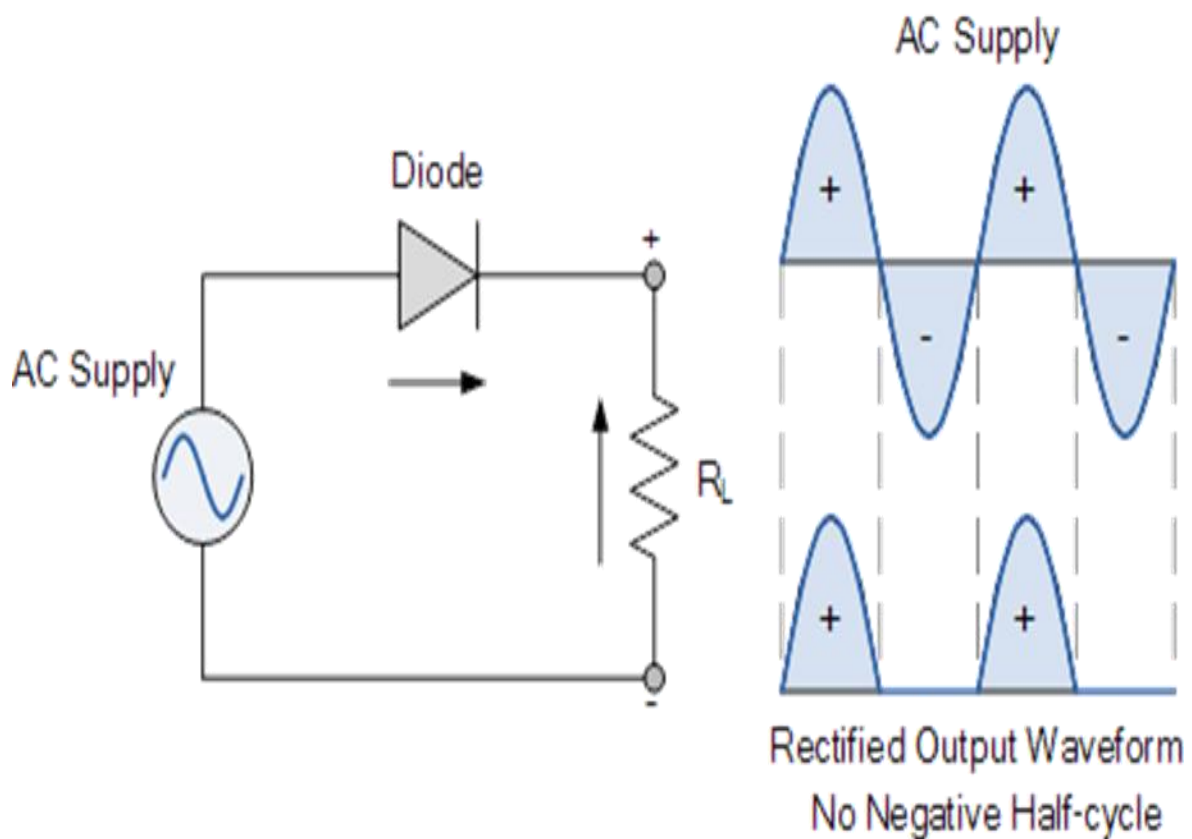
- Power: 2KW
- Output Voltage: 400V/5A
- Efficiency: 90%
- Input Voltage regulation 15% of Input
- Op Voltage ripple 20%

RECTIFIERS: -

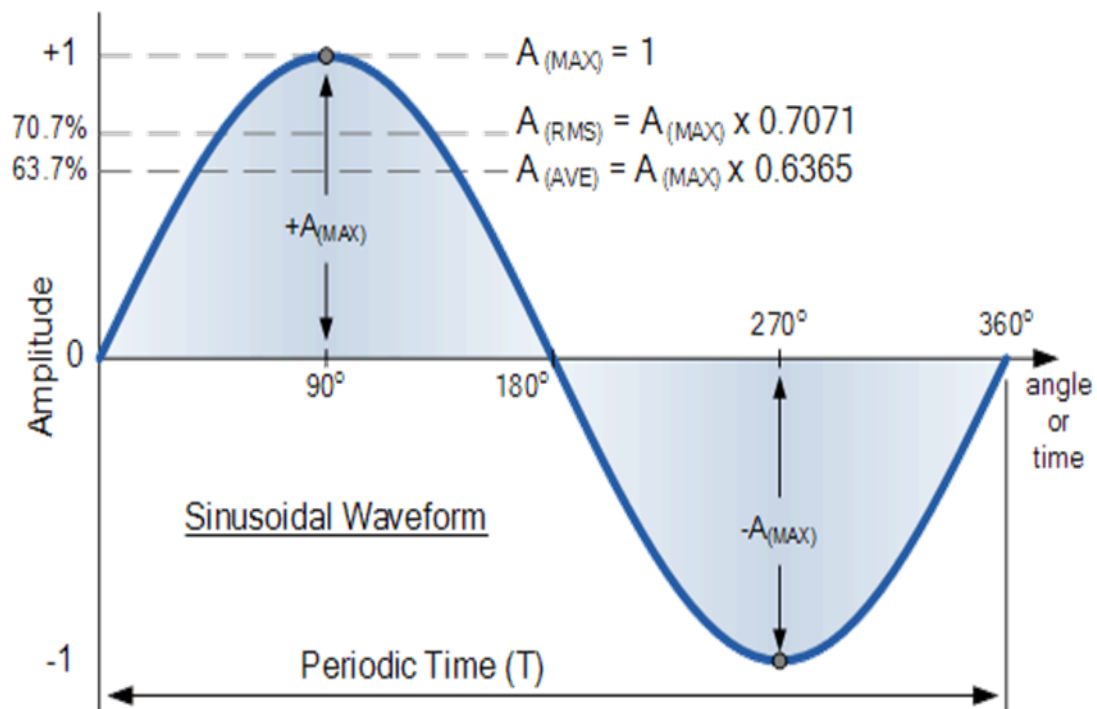
✓ Uncontrolled Rectifier

✓ Controlled Rectifier

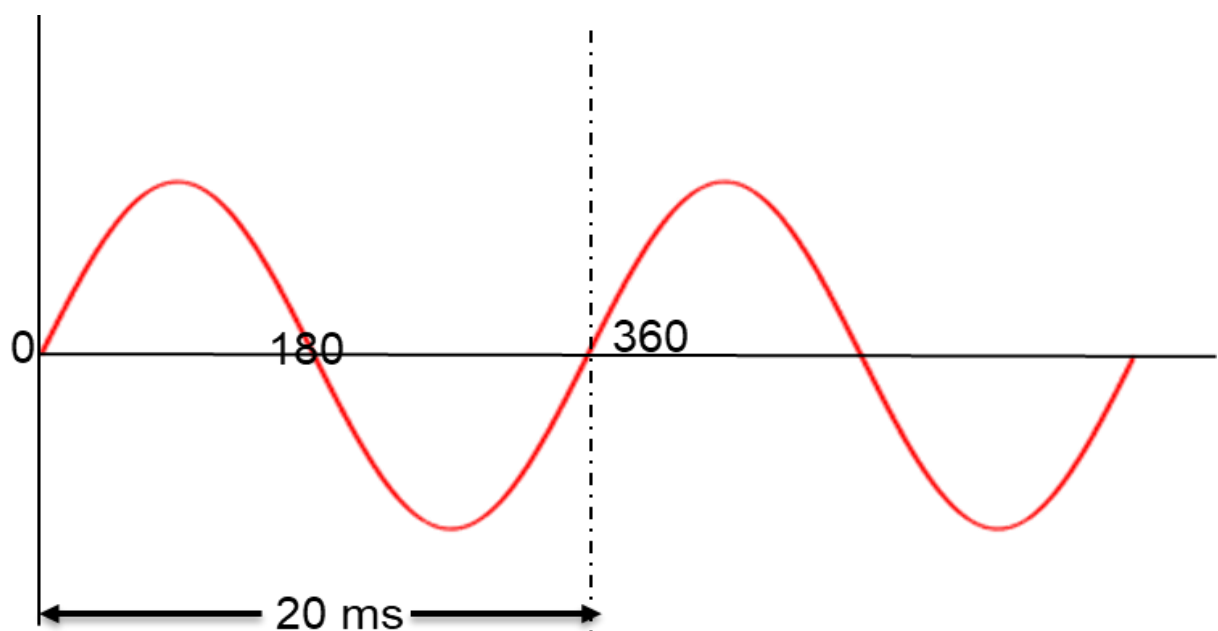
- Half wave-controlled Converter
- Full wave-controlled Converter
- Single Phase/Three Phase Converter



Sin wave Analysis



Time Period



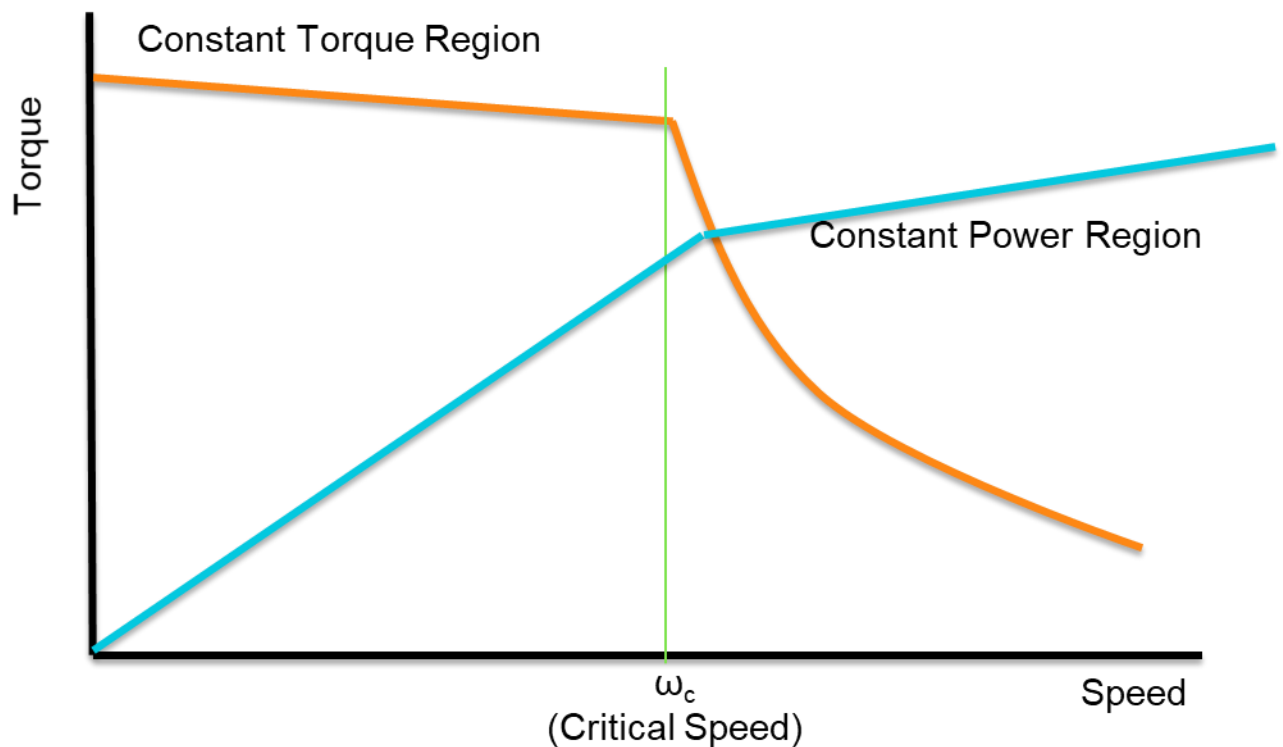
Time for 1 Degree : $20\text{ms}/360: 5.55\text{e-}5$

Intro to Electric Motor for EV Application

Motors required Specification

- ✓ High efficiency
- ✓ High instant power
- ✓ Fast torque response
- ✓ High power density
- ✓ Low cost
- ✓ High acceleration
- ✓ Robustness

Motor Performance



TYPES OF MOTORS: -

- DC Motor
- Permanent Magnet Brushless DC Motors (PMBLDC)
- Induction Motors
- Permanent Magnet Motor
- Switched Reluctance Motor (SRM)

SPEED CONTROL: -

DC SPEED CONTROL

- ✓ When a wire carrying electric current is placed in a magnetic field, a magnetic force acting on the wire is produced.
- ✓ The force is perpendicular to the wire and the magnetic field.
- ✓ The magnetic force is proportional to the wire length, magnitude of the electric current, and the density of the magnetic field.
- ✓ Magnetic Force $F = BIL$
- ✓ Torque $T = BIL \cos\alpha$
- ✓ α – angle between the coil plane and magnetic field
- ✓ F = Force, B = magnetic flux density, I = current

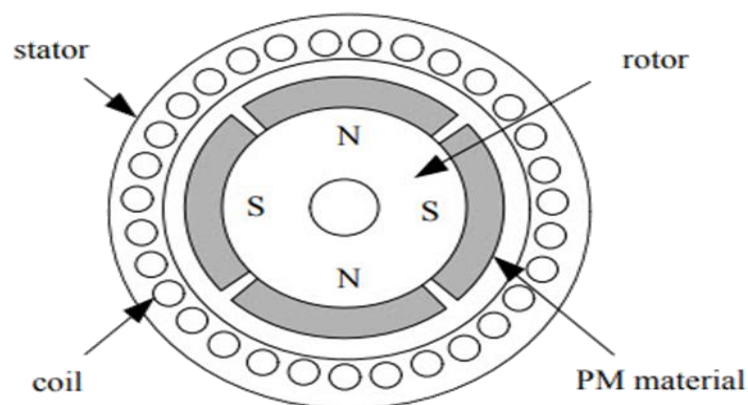
ADVANTAGE OF SPEED CONTROL: -

- ✓ High Torque
- ✓ Simple Control
- ✓ Low Cost

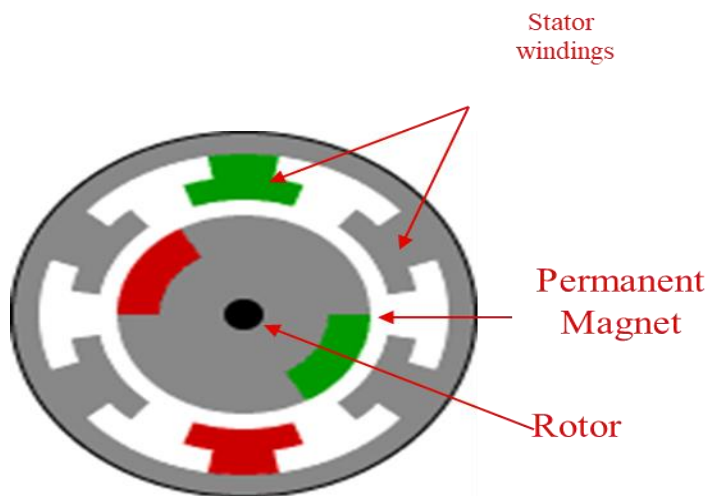
DIS-ADVANTAGE OF SPEED CONTROL: -

- ✓ High Maintenance cost
- ✓ Poor Efficiency.

BLDC MOTOR SPEED CONTROL



Brushless DC Motors



Brushed DC Commutation

- The windings in the armature are switched to the DC power by the brushes and armature.
- Each winding sees a positive voltage, then a disconnect, then a negative voltage.

DC Motor Bridge

- The DC motor needs four transistors to operate the DC motor.
- The combination of transistor is called an H-Bridge, due to the obvious shape.
- Transistors are switched diagonally to allow DC current to flow in the motor in either direction.

Three-Phase Bridge to Drive BLDC Motor: -

- Six-step Commutation
- The Brushless DC motor is really a DC motor constructed inside-out, but without the Brushes and Commutators
- The mechanical switches are replaced with transistors

Types of BLDC Motor based on Magnet Arrangement

- I. One Pole Pair
- II. Two Pole Pair
- III. Four Pole Pair

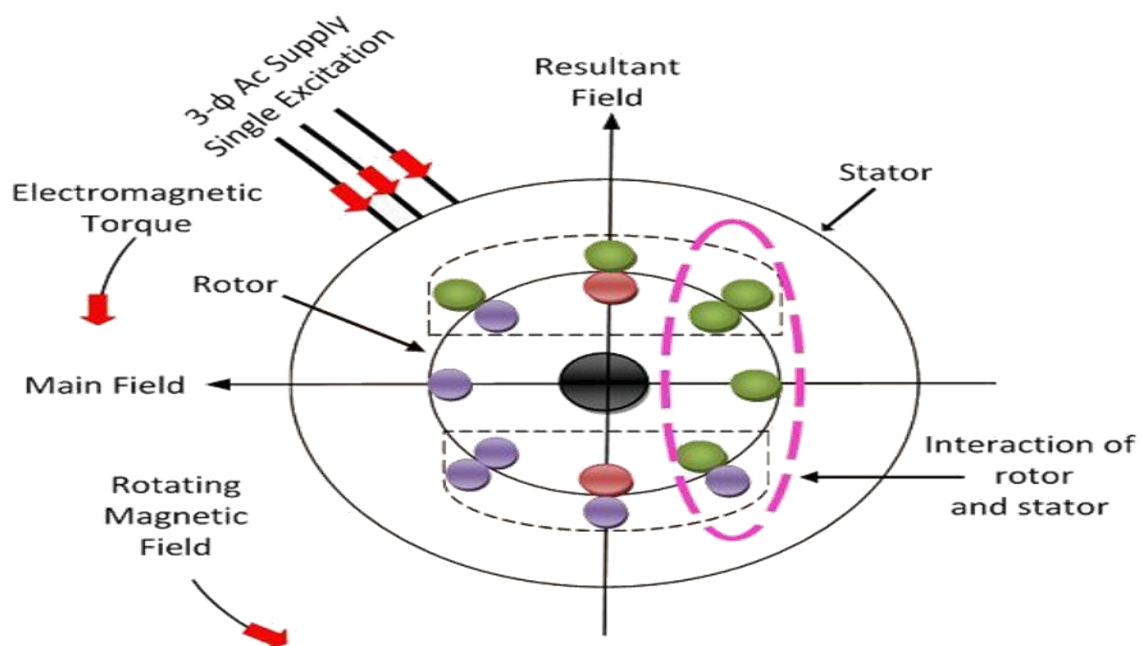
Advantages:

- Simple and rough construction
- Affordable and low maintenance
- High reliability and highly proficient
- No requirement of additional starting motor and necessity not be synchronized.

Applications:

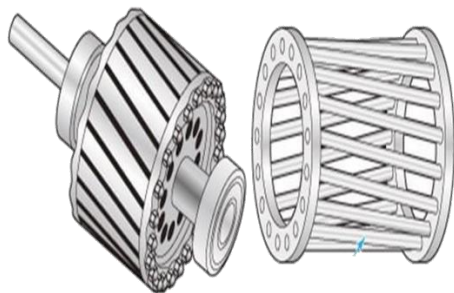
- Large capacity exhaust fans
- Driving lathe machines
- Oil extracting mills
- Electric Sewing Machine
- Drilling machines

INDUCTION MOTOR SPEED CONTROL

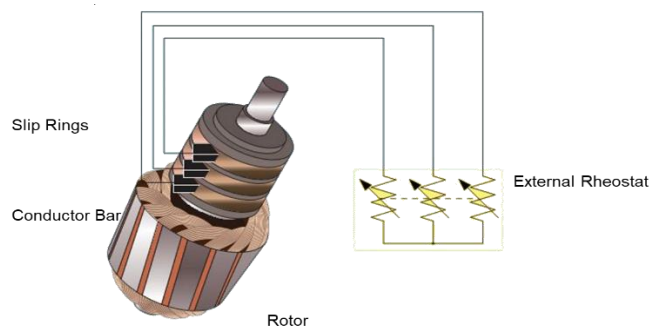


Types

- AC Motor
- Asynchronous Motor
- Synchronous Motor
- Three Phase
- Single Phase
- Wound Rotor
- Squirrel Cage
- Speed Control Methods



Squirrel Cage



Wound Rotor

AC Motor

Asynchronous Motor & Synchronous Motor

Three Phase

Single Phase

Wound Rotor

Squirrel Cage

Speed Control Methods

(Note: For Squirrel Cage Motors)

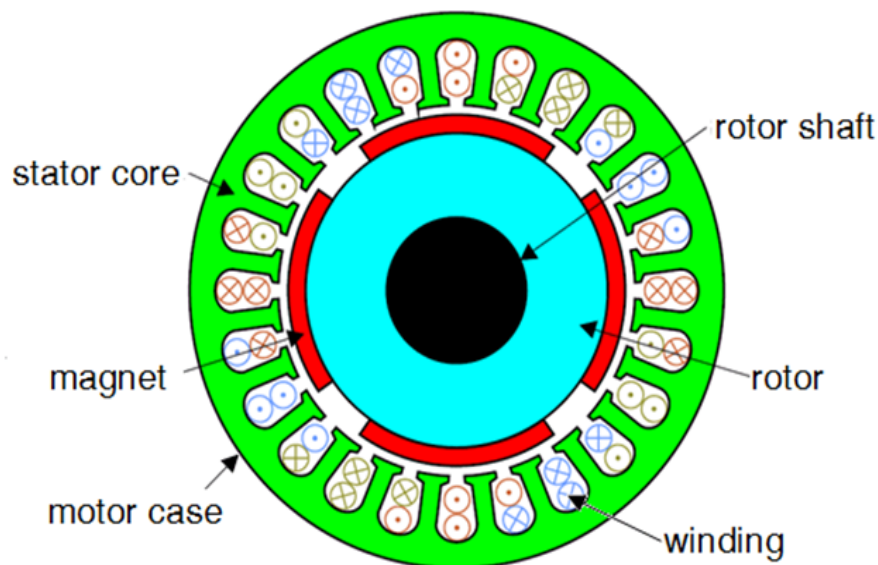
$$N_s = \frac{120f}{P} \qquad E \text{ or } V = 4.44\phi K.T.f \text{ or } \phi = \frac{V}{4.44KTf}$$

Variable frequency

Variable voltage

PMSM SPEED CONTROL

- Permanent Magnet Synchronous Motors (PMSM) are similar to Brushless DC motors (BLDC).
- PMSM are rotating electrical machines that have a wound stator and permanent magnet rotors that provide sinusoidal flux distribution in the air gap making the BEMF inform a sinusoidal shape.



BLDC	PMSM
• DC Power • Square Flux Density • Trapezoidal Back EMF • Stator Current is Trapezoidal • Controlling is easy and Cheaper	• AC Power • Sinusoidal Flux Density • Sinusoidal Back EMF • Stator Current is Sinusoidal • Quite Complex and costly

Classification of PMSM with the Rotor Design

- Surface Mount PMSM
- Interior Mount PMSM

PMSM Characteristics

- No sparks, safer in explosive environments
- Clean, fast and efficient
- Designed for high-performance servo applications
- Runs with/without position encoders

Applications

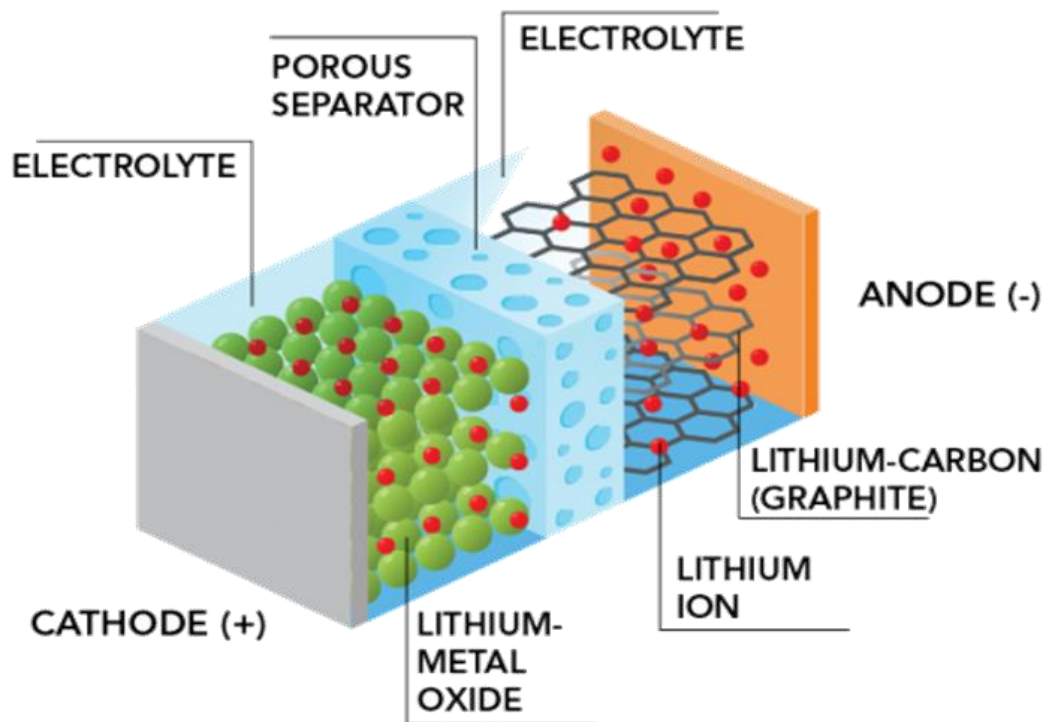
- AC Drives
- Automated Guided Vehicles
- Heating, ventilation and air conditioning
- Robots
- Servo drives

BATTERY MANAGEMENT SYSTEMS

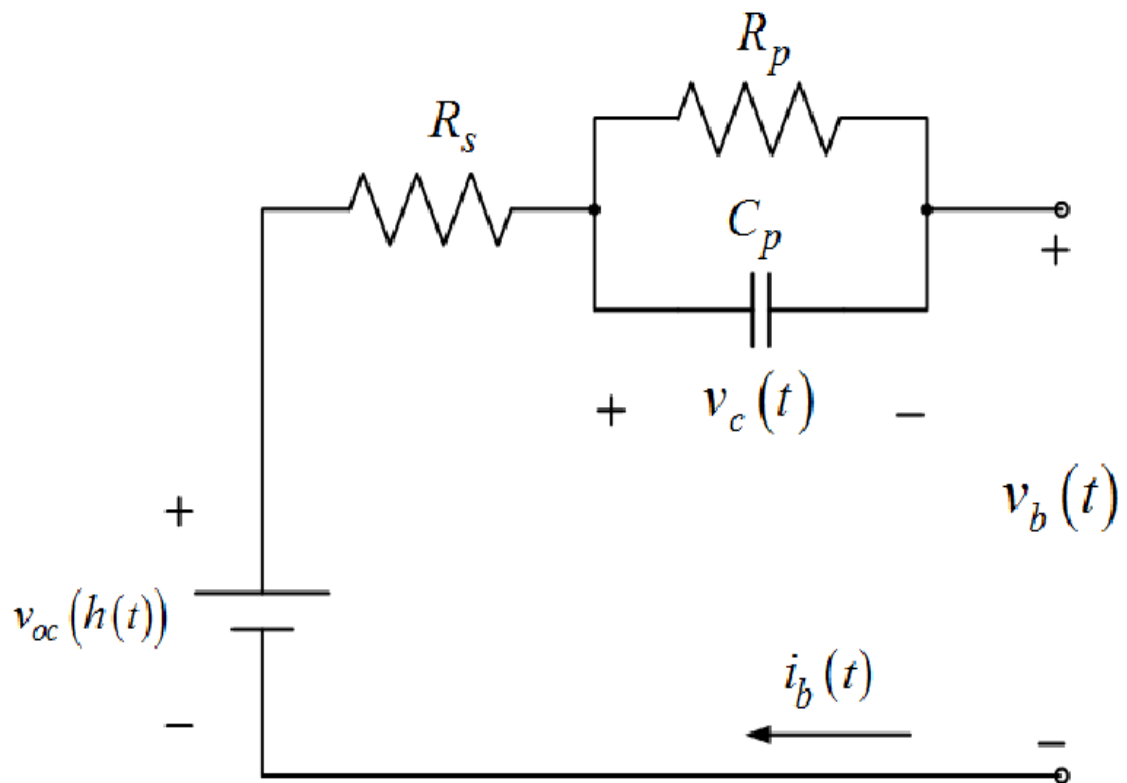
- It's a device to convert Chemical Energy to Electrical Energy.

Types of EV Battery

- Lithium-ion
- Lithium Phosphate
- Nickel-metal hydride batteries
- Lead-acid batteries



Battery Equivalent Circuit



Battery Parameters Battery SOC:

- The fraction of the total energy or battery capacity that has been used over the total available from the battery.

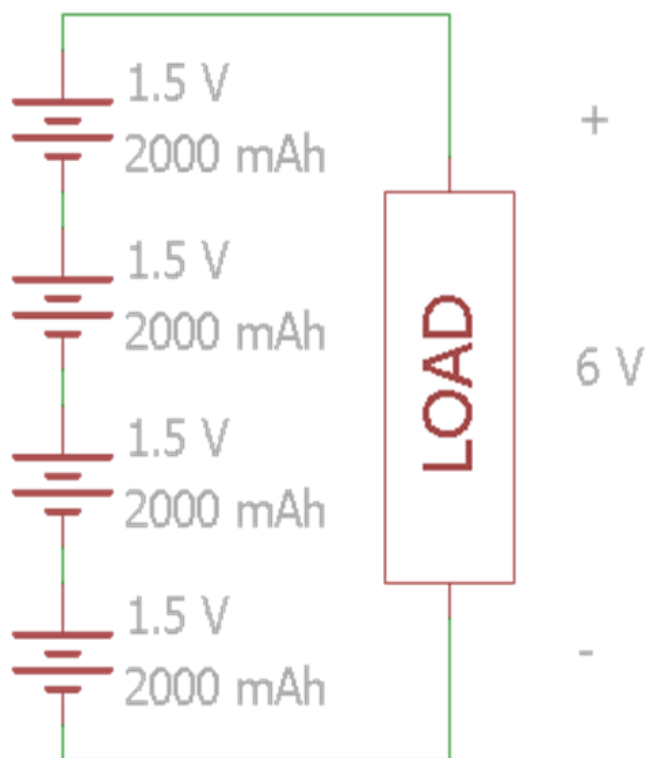
Shows the remaining capacity of the battery while in use.

Model	Battery	Charge Times
Toyota Prius PHEV	4.4kWh Li-ion, 18 km all electric range	1.5h at 230VAC 15A
Chevy Volt PHEV	16 kWh, Li-manganese/NMC, liquid cooled, 181 kg (400 lb), all electric range 64km	4h at 230VAC, 15A
Mitsubishi iMiEV	16 kWh; 88 cells, 4-cell modules; Li-ion; 109Wh/kg; 330V, range 128km	7h at 230VAC 15A
Smart Fortwo ED	16.5kWh; 18650 Li-ion, driving range 136km	3.5h at 230VAC, 15A
BMW i3 Curb 1,365kg	Since 2019: 42kWh, LMO/NMC, large 60A prismatic cells, battery weighs ~270kg (595 lb) driving range: EPA 246 (154 mi); NEDC 345km (215 mi); WLTP 285 (178 mi)	11kW on-board AC charger; ~4h charge; 50kW DC charge; 30 min charge.
Nissan Leaf*	30kWh; Li-manganese, 192 cells; air cooled; 272kg, driving range up to 250km	8h at 230VAC, 15A; 4h at 230VAC, 30A

MATLAB DEMO: -

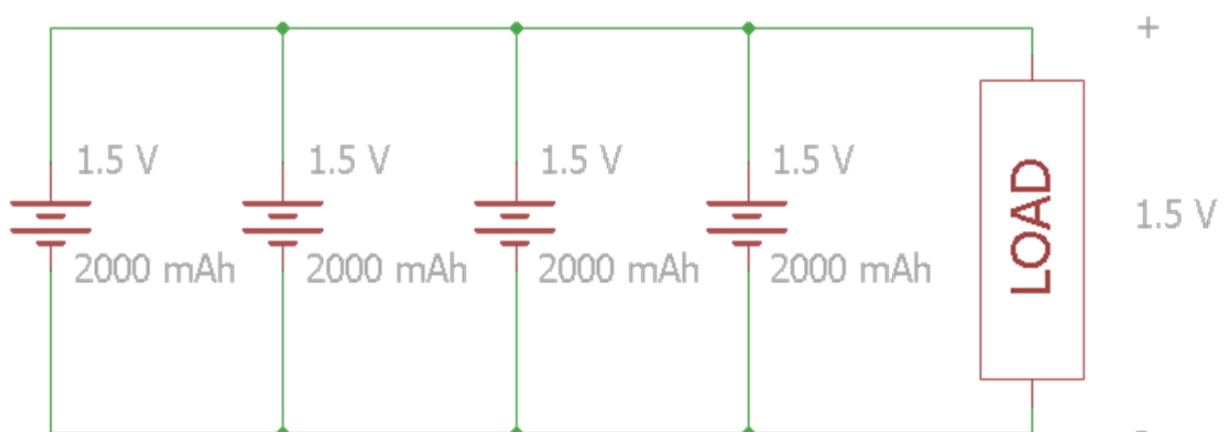
- Series
- Parallel
- Series-Parallel

SERIES CONFIGURATION: -



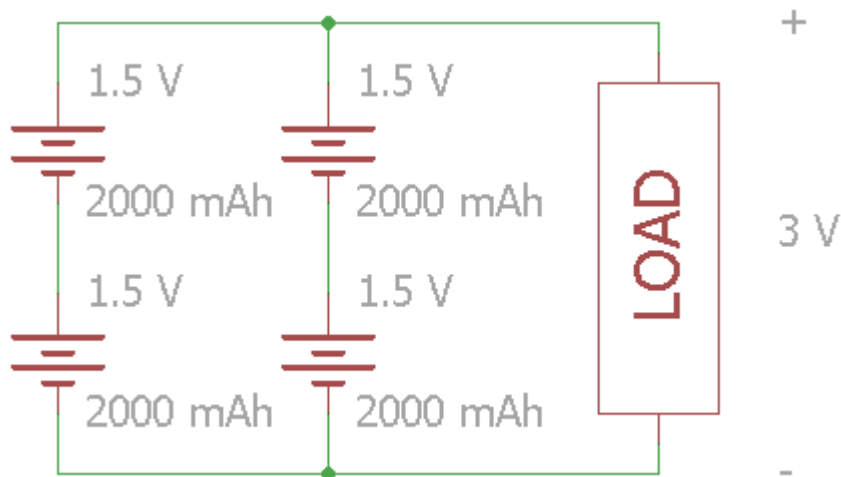
- $1.5 + 1.5 + 1.5 + 1.5 = 6\text{V}/2000\text{mA}$

PARALLEL CONFIGURATION: -



- $1.5\text{V} / (2000 + 2000 + 2000 + 2000)$
- $= 1.5\text{V}/8000\text{mA}$

SERIES PARALLEL CONFIGURATION:-



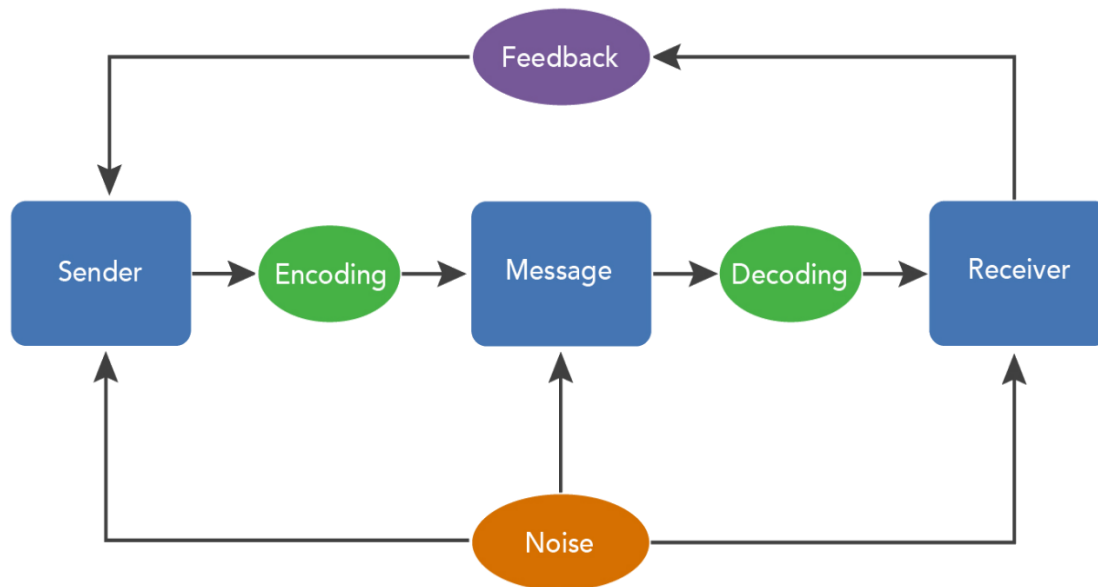
- $(1.5+1.5) / (2000+2000)$
- $= 3V/4000mA$

Protocols for EVs

PROTOCOL: It's an agreement about how to do Something

Communication:

- ❖ Fault tolerance
- ❖ Determinism
- ❖ Bandwidth
- ❖ Flexibility
- ❖ Security



Types of Protocols

- Data Link Protocols (UART/SPI/IIC/LIN/CAN)
- Application Protocols (UDS/J1939/CAN-Open/MOST)
- Others (Bluetooth/Wi-Fi/USB/4G/5G)

How to select new protocol for a new feature?

- Max Payload Size
- Network Bandwidth ex Max Speed of Data Transmission
- Max Bus Length Supported
- Architecture (Master/Slave Configuration Options)

- Transfer Model (Full/Half duplex & synchronous/asynchronous)
- Fault Tolerance
- Suitability for safety critical feature
- Ease of addition removal into/from the vehicle network design

Protocols for EV Charging Industry

EV charging industry standards and protocols which deliver the flexibility that is needed for the entire electric vehicle market and will be a key enabler of future EV charging infrastructure developments.

EV Charger Standards

Type	Connection	Power (kW)	Max current
Europe	1-Phase AC	3.7	16 to 20
	1 or 3 Phase AC	3.7 to 22	16 to 32
	3-Phase AC	>22	>32
	DC Fast	>22	>32
USA	AC Level-1	1.44	12
	AC Level-2	7.7	32
	DC Fast	240	400

SCOPE OF ELECTRIC VEHICLE

Automakers from all around the world are sighting a keen eye on Indian markets. With world's largest electric vehicle manufacturer, Tesla coming into to the Indian electric automotive spectrum, it is not futile to say that India got a new lease for becoming the future hub for electric vehicles. However, the pandemic has slowed the growth speed of India by leaps and bounds.

In April 2019, NITI Aayog, the federal think tank, published a report titled "India's Electric Mobility Transformation", which pegs EV sales penetration in India at **70 percent for commercial cars, 30 percent for private cars, 40 percent for buses**, and 80 percent for two- and three- wheelers by 2030.

As electric vehicle manufacturing is becoming popular every day, its market share is also expected to rise greatly. India's GDP is expected to grow by an amazing 25% by 2022. The best part is that, apart from reducing environmental pollution, EVs **can lower oil import by about \$60 Billion by 2030.**

CONCLUSION

The global electric vehicle market size is projected to grow from 4,093 thousand units in 2021 to 34,756 thousand units by 2030, at a CAGR of 26.8%. India has already shown its keen interest to be a major part of this automotive paradigm shift.

Countries like, The UK, France, Norway and Germany have even brought in legislation to ban the sales of non-electric vehicles as early as 2025.

India has already shown its keen interest to be a major part of this automotive paradigm shift. Adding to that, India has already put forward the desire to become the biggest hub for electric vehicles in the future.

Price of electricity as fuel could fall as low as Rs 1.1/km, helping an electric vehicle owner save up to Rs. 20,000 for every 5,000km traversed.

Finally, electrification will help reduce vehicular emissions, a key contributor to air pollution which causes an average 3% GDP loss every year, reports suggest.

Thank You

