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# Comparison of Electric Motors for EVs & HEVs Applications

Presented By
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# Outlines

- Introduction: Electric Drives
- Major Components of EVs and HEVs
- Types of Electrical Motors
- Effects of EVs and HEVs
- Major Challenges of EVs and HEVs

# What is an Electric Drives

Definition of electric drive

- ❖ "Systems employed for motion control are called **drives**"
- ❖ "Drives employing electric motors are known as **electrical drives**"

Why its required

- ❖ To control the speed and torque of the electric motors

Applications of electric drives

Electric Vehicles

Celling fan

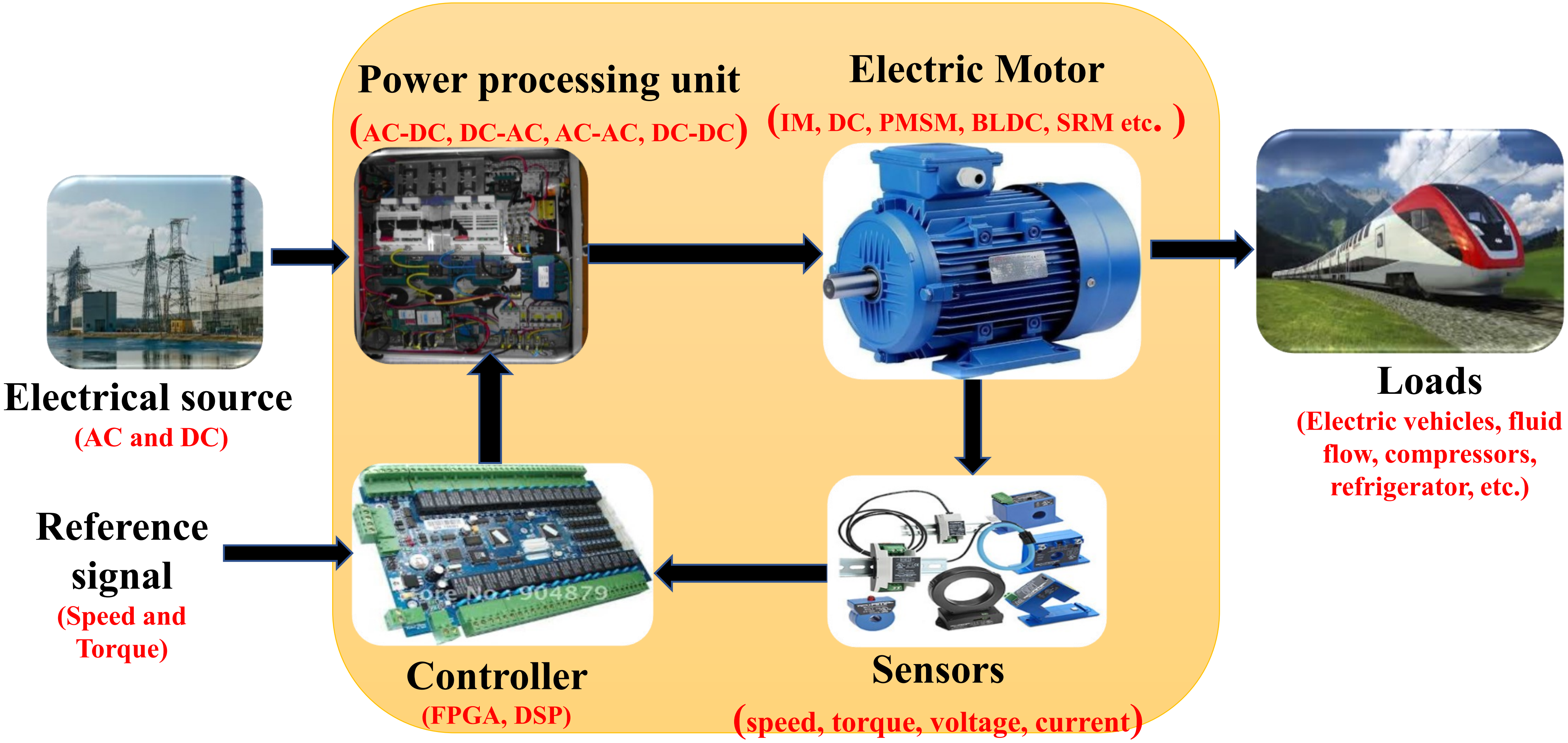
Refrigerator

Lift

Vacuumed cleaner

Ship

# Introduction: Electric Drives

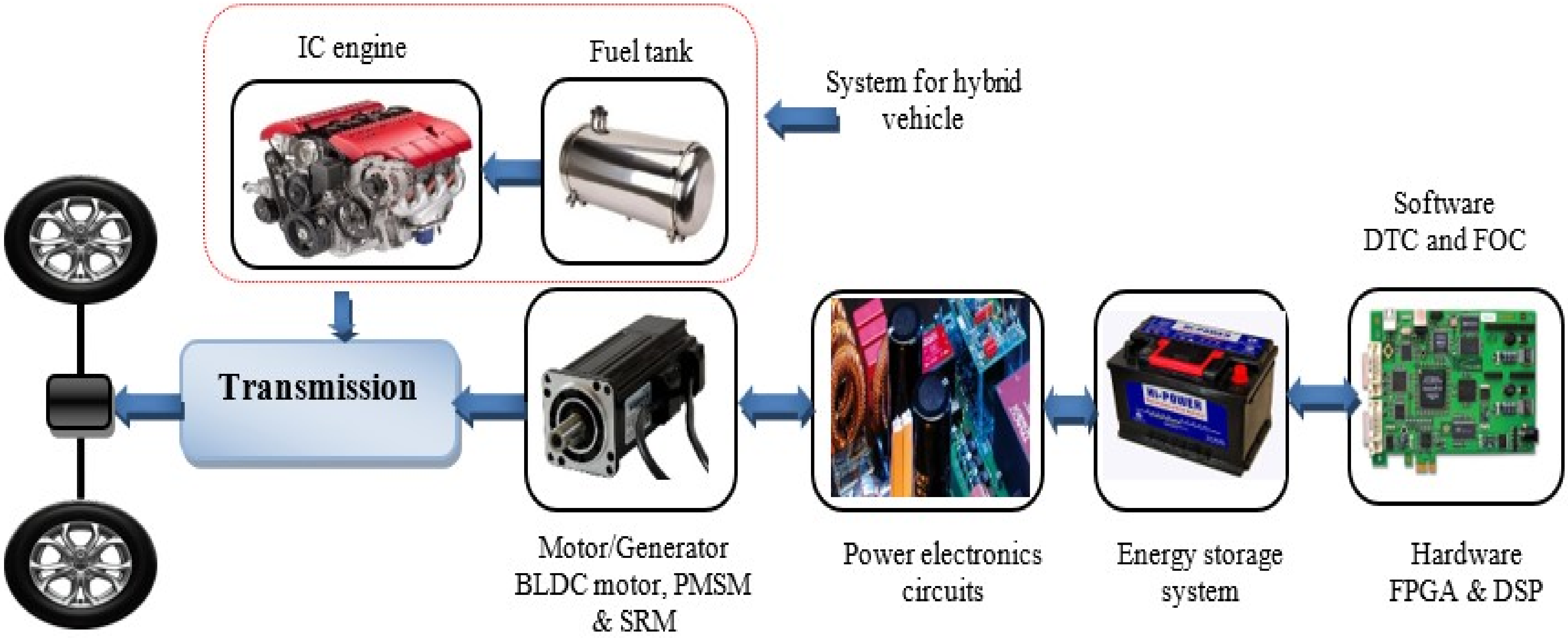


# Introduction to Electric Vehicles

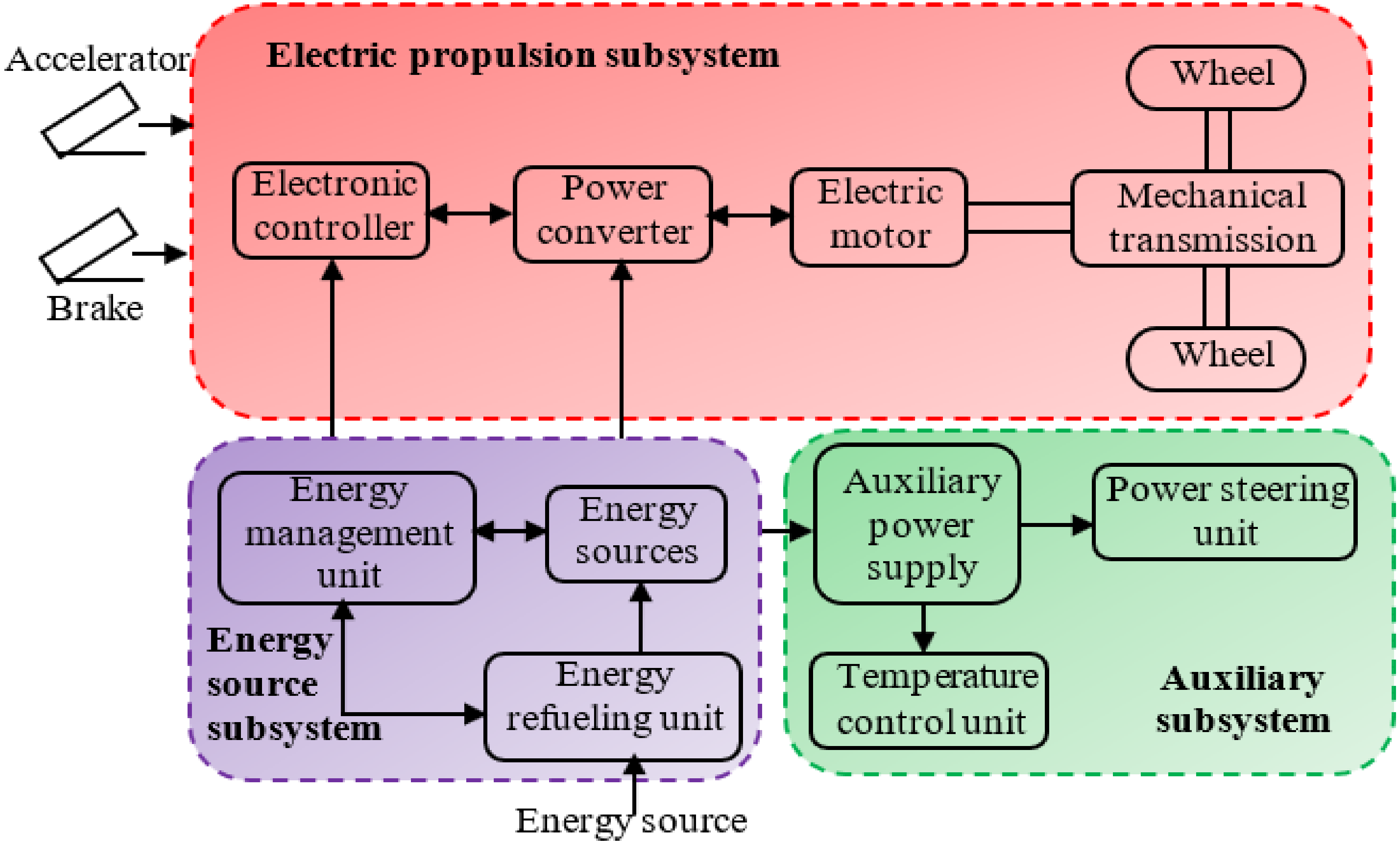
- An **Electric Vehicles (EVs),** uses one or more electric motors or traction motors for propulsion.
- An EVs may be powered through a collector system by ***electricity from off-vehicle sources, or may be self-contained with a battery, solar panels or a generator to convert fuel to electricity***

- A **Hybrid Electric Vehicles (HEVs)** combines any two power (energy) sources.
- Possible combinations include d***iesel/electric, gasoline/fly wheel, and fuel cell (FC)/battery***.
- Typically, one energy source is storage, and the other is conversion of a fuel to energy.

# Schematic Layout of EVs and HEVs



# Components of Electric Vehicles [1]






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

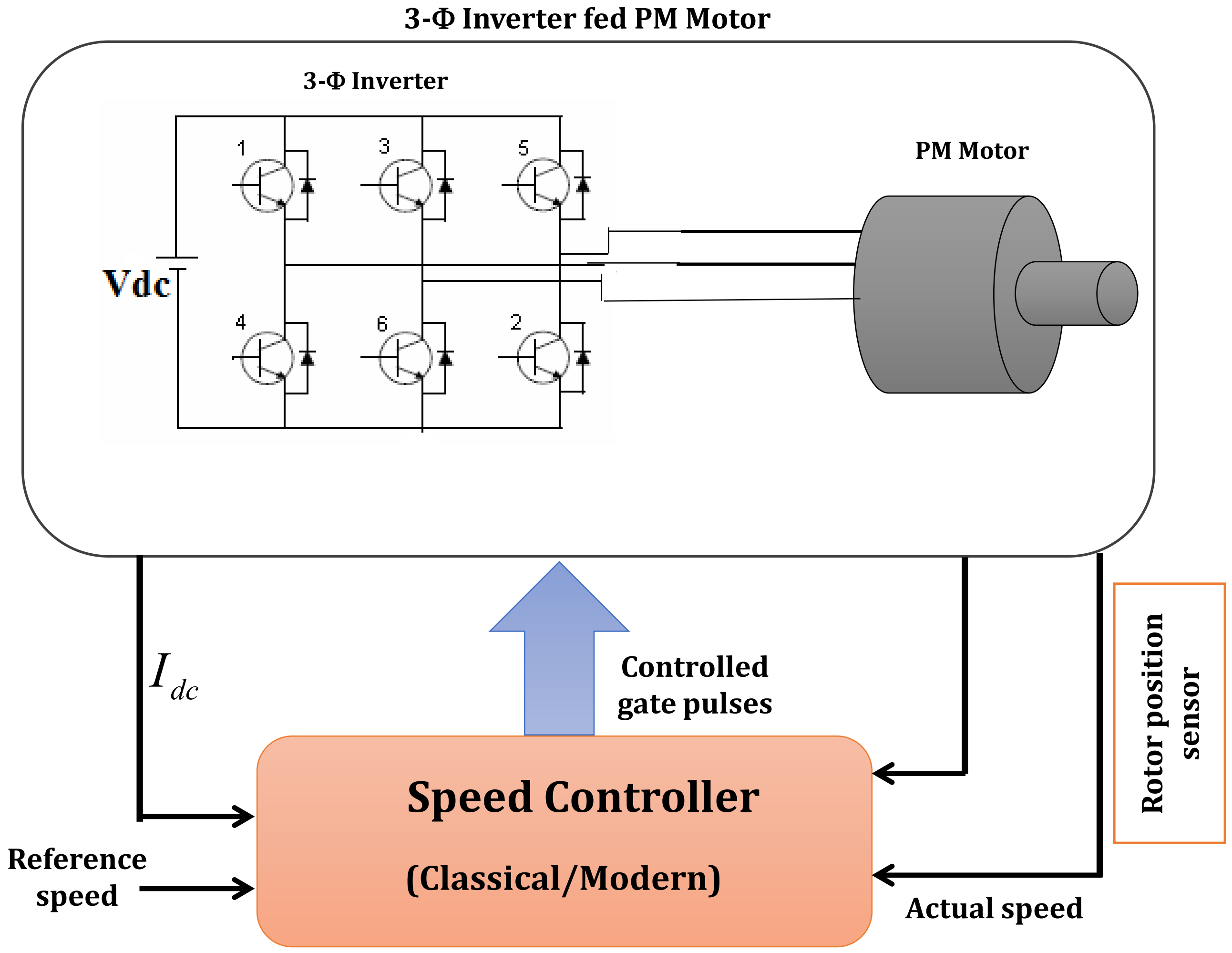
# Electric Machines in EVs are Expected to be [1]

- High Power, High Rated Torque, High Starting Torque, High Efficiency
- Wide Speed Range, High Overload Capacity
- Fast Dynamic Response, Good Flux Weakening Capability at High Speed
- Reliability, Robustness, Reasonable Cost
- Low Noise and Small Size

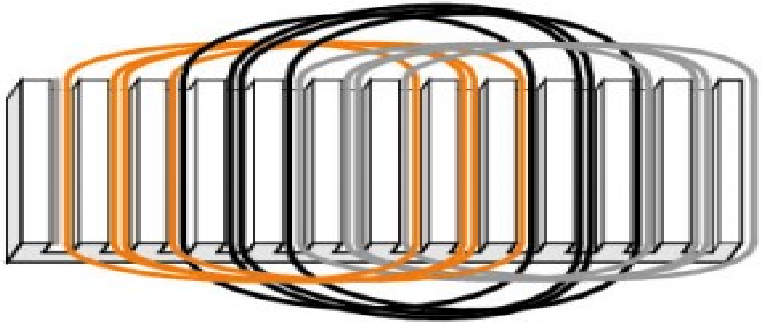
# Types of Motors

- Induction Motors
- DC Motors
- Permanent Magnet Synchronous Motors
- SRMs

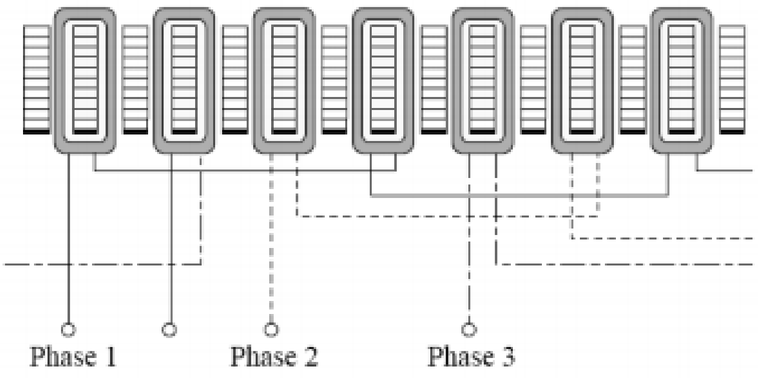
# Basic Understanding about PM Motor Drives



# Classifications of PM Motors



(a)




(b)

Fig. 1. The three-phase stator winding of PM motors: (a) distribution winding and (b) concentrated winding.

(a)

(b)

Fig. 2. Pictorial view of a stator of PM motors: (a) distributed winding (PMSM) and (b) concentrated winding (BLDC).

# Construction and Operating Principle

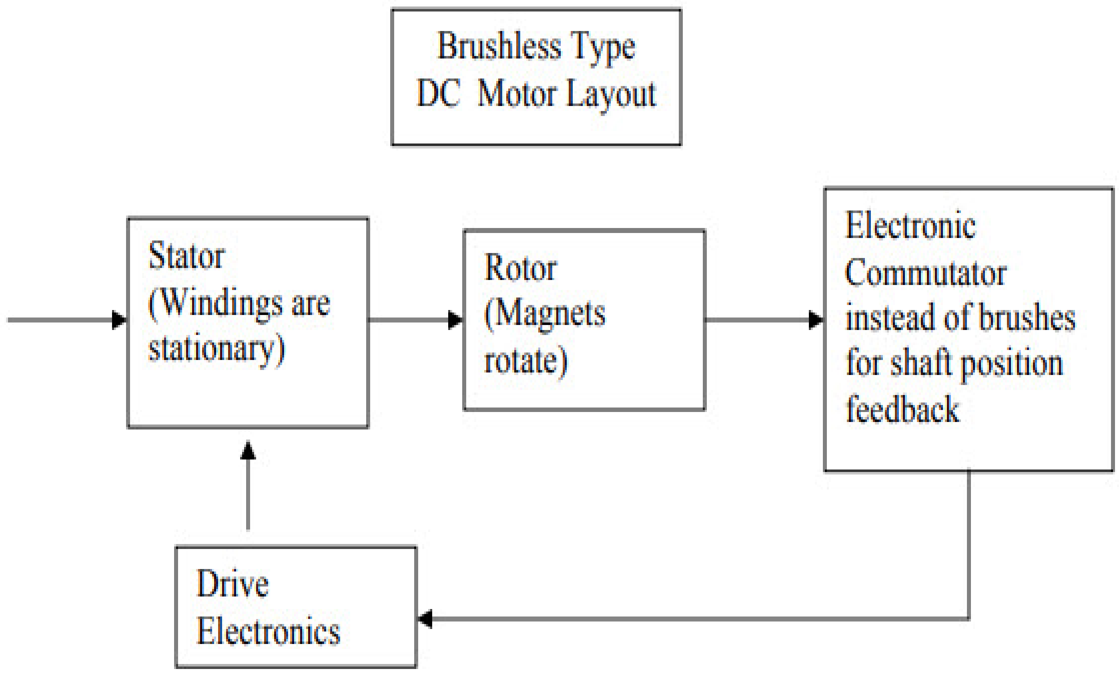



Fig. 3. Block diagram of PM Motor Drive

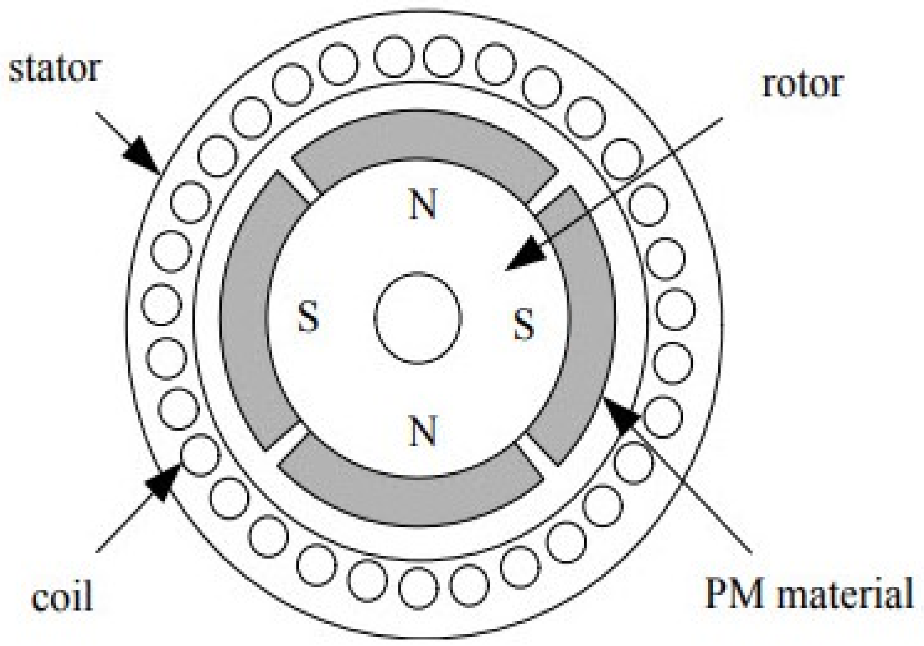
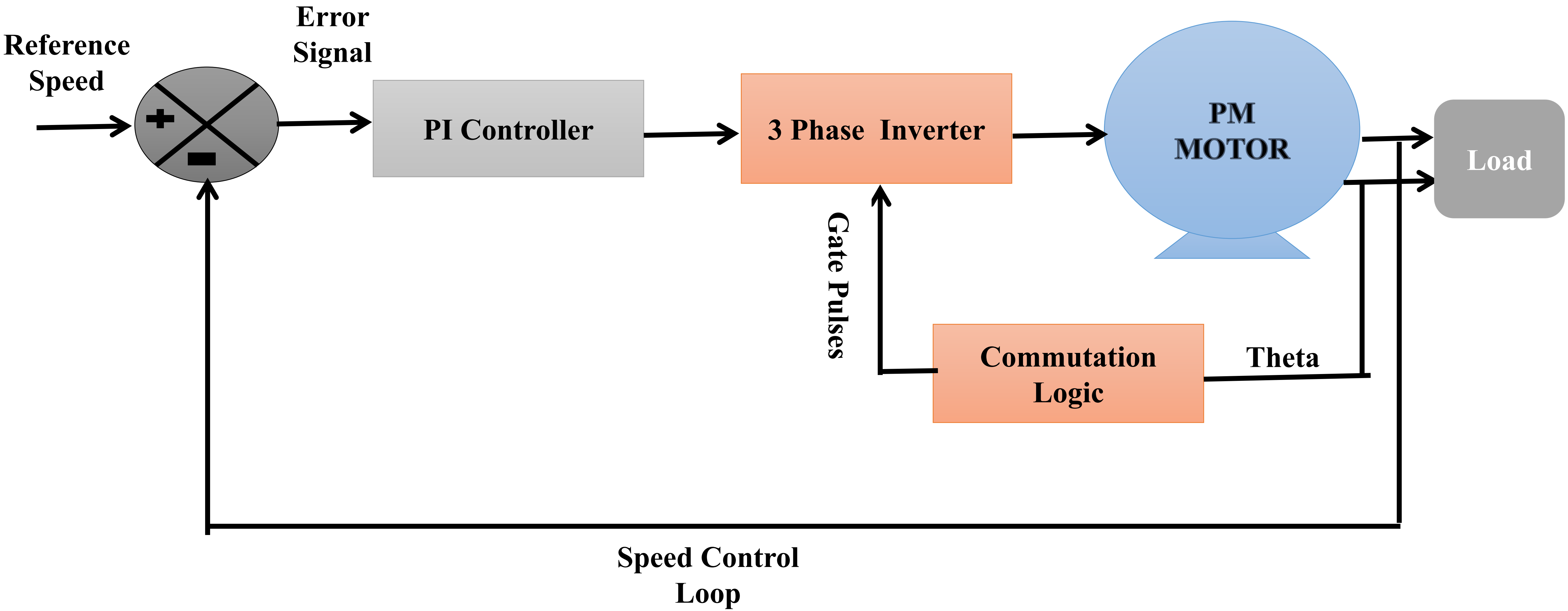



Fig. 4. Pictorial view of PM Motor Drive

# Flow Chart of Controller



# Basic about Switched Reluctance Motor (SRM)

- The **switched reluctance motor (SRM)** is an electric motor that runs by reluctance torque. Unlike common brushed DC motor types, power is delivered to windings in the stator (case) rather than the rotor. Switched Reluctance Motor (SRM) is also known as **Variable Reluctance Motor**.

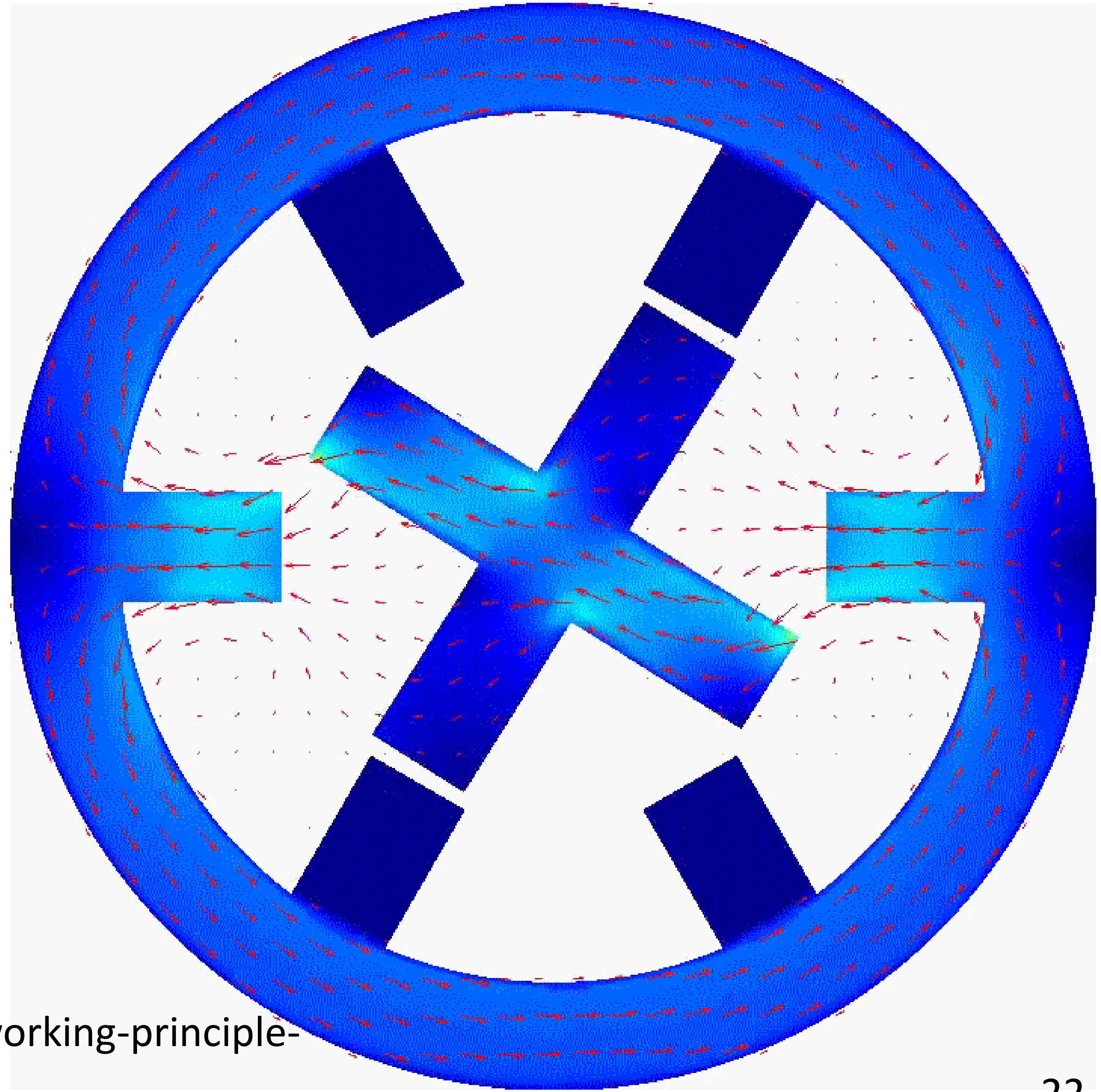
- Due to higher efficiency, magnet-less operation, and simple mechanical structure, SRM becomes the most preferable electric motor for latest electric vehicle applications.

- A recently advanced version of SR technology has been used to power **Tesla Model 3 electric car and claimed a significant increase in range (efficiency) compared to the induction motor used in Model S.**


https://www.aarohies.com/construction-and-working-principle-of-switched-reluctance-motor-srm/

# Working Principle of SRM

- This motor works on the **principle of variable reluctance.**
- This means, the rotor always tries to align along the lowest reluctance path.
- As we know that magnetic flux have a tendency to flow through lowest reluctance path, therefore rotor always tends to align along the minimum reluctance path.



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# Electric Motors for EVs and HEVs

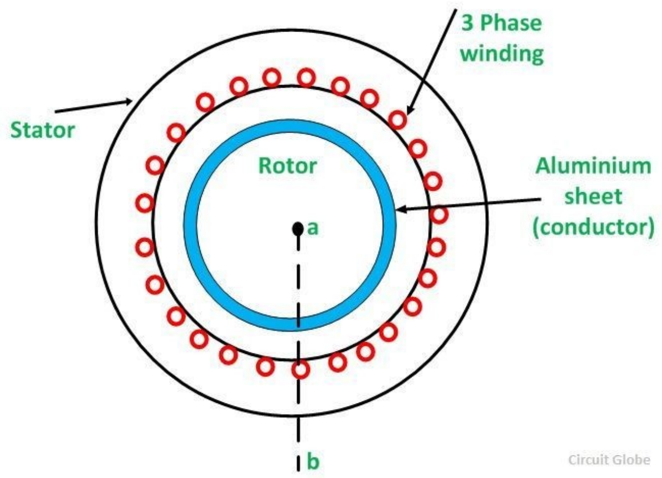



Fig. 8. IM

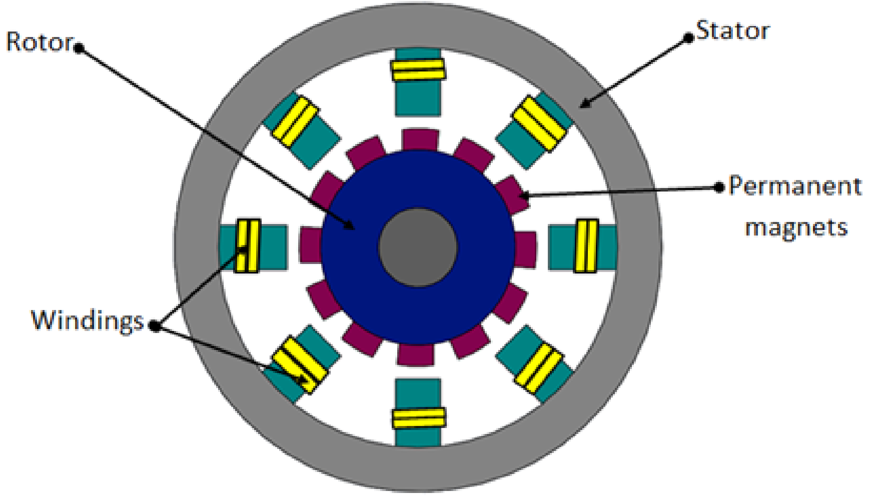



Fig. 9. PMSM/BLDC Motor

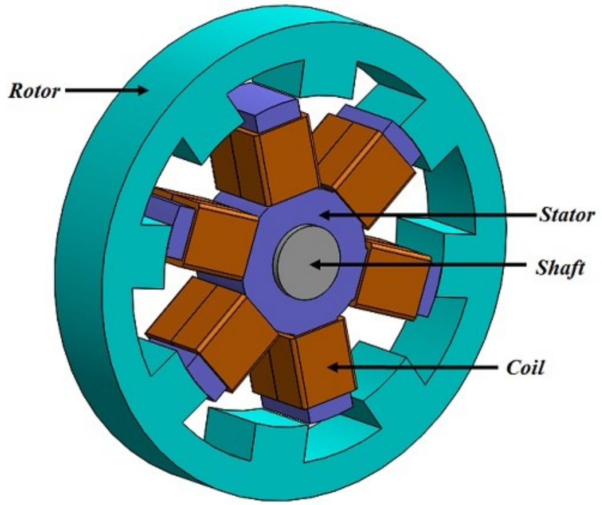



Fig. 10. SRM

Stator: Three phase winding
Rotor: Aluminium sheet/Bar

Stator: Three phase winding
Rotor: Permanent Magnets

Stator: Three phase winding
Rotor: piece of (laminated) steel

# Torque Speed Characteristic of IM, PM and SRM

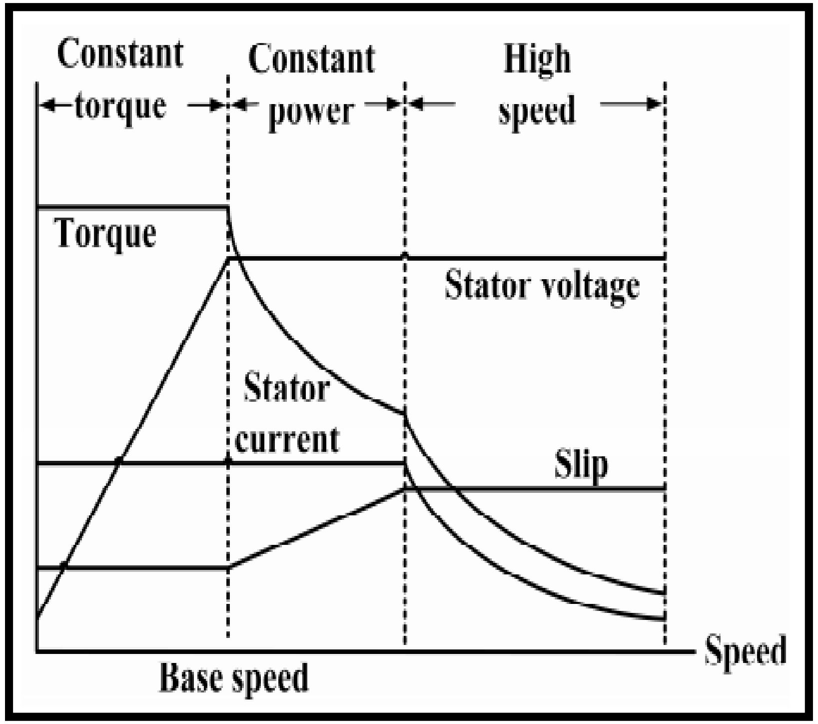



Fig. 11. Induction Motor (IM)

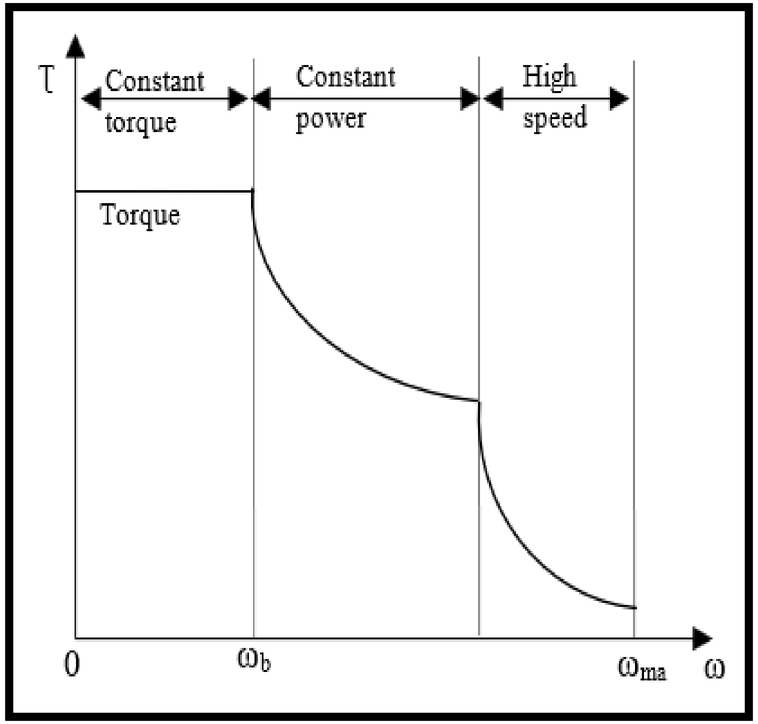



Fig. 12. Permanent Magnet (PM)

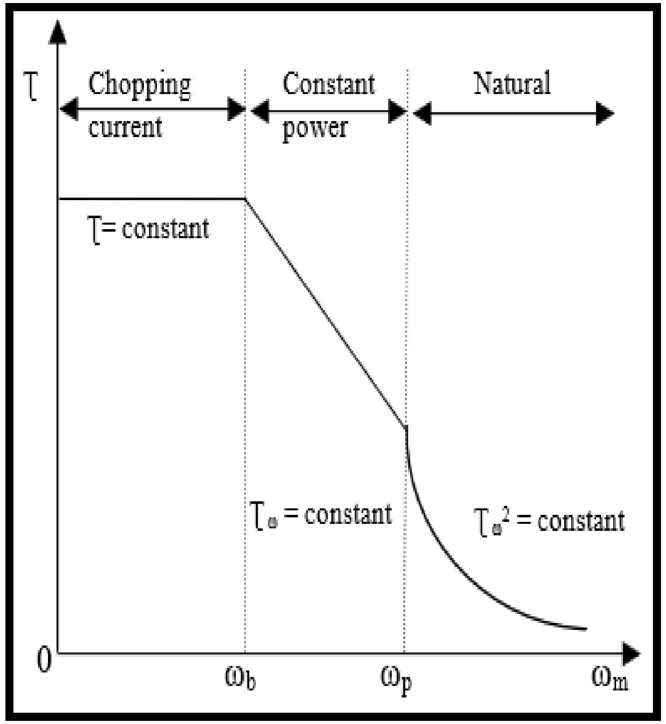



Fig. 13. Switched Reluctance Motor (SRM)

# Advantages and Disadvantages of Induction Motors

| Sr. No. | Advantages | Disadvantages |
|---|---|---|
| 1 | High max. speed, high range of field weaking | Small torque density |
| 2 | Low current at no load and part load operation | Higher weight |
| 3 | Robust design | High current at constant torque |
| 4 | No hazardous material | High power losses in the rotor |
| 5 | Low production cost | Bigger volume |

It is used by Tesla Model S, Tesla Model X, Toyota RAV4, GM EV1 [2]



2. Available [online]: https://electricvehicles.in/advantages-disadvantages-of-diff-types-of-evs-motors/

# Advantages and Disadvantages of DC Motors

| Sr. No. | Advantages | Disadvantages |
|---|---|---|
| 1 | Ease of control due to linearity | Brush wear that leads to high maintance |
| 2 | Capability for independent torque and flux control | Low maximum speed |
| 3 | Established manufacturing technology | EMI due to commutator action |

It is used by the Fiat Panda Elettra [2].

# Advantages and Disadvantages of PM Motors

| Sr. No. | Advantages | Disadvantages |
|---|---|---|
| 1 | High torque density | High cost due to rare earth magnets on the rotor |
| 2 | High continuous torque | Efforts in field weakening necessary |
| 3 | High efficiency | High induced voltage when operating as a generator |
| 4 | Low power losses | Safety aspects of hazardous material |
| 5 | Wide range of constant power | Identification of the rotor position necessary |

BLDC: This type of motor is used in the Toyota Prius (2005) [2]
PMSM: Toyota Prius, Nissan Leaf, Soul EV

# Advantages of SRM

1. It does not require an external ventilation system as the stator and rotor slots projected. The airflow maintained between the slots.
2. The rotor does not have winding since therefore no need to keep the carbon brush and slip ring assembly.
3. Since the absence of a permanent magnet, such motors are available at a cheaper price.
4. A simple three or two-phase pulse generator is enough to drive the motor.
5. The direction of the motor can be reversed by changing the phase sequence.
6. Self-starting and does not require external arrangements.
7. Starting torque can be very high without excessive inrush currents.
8. High Fault Tolerance.
9. Phase losses do not affect motor operations.
10. High torque/inertia ratio.
11. High starting torque can be achieved.

https://www.aarohies.com/construction-and-working-principle-of-switched-reluctance-motor-srm/

# Disadvantages of SRM

1. Creates Torque ripple at high-speed operation.

2. The external rotor position sensor is required.

3. Noise level is high.

4. At a higher speed, the motor generates harmonics, to reduce this, we need to install larger size capacitors.

5. Since the absence of a Permanent Magnet, the motor has to designed to carry a high input current. It increases the converter kVA requirement.

https://www.aarohies.com/construction-and-working-principle-of-switched-reluctance-motor-srm/

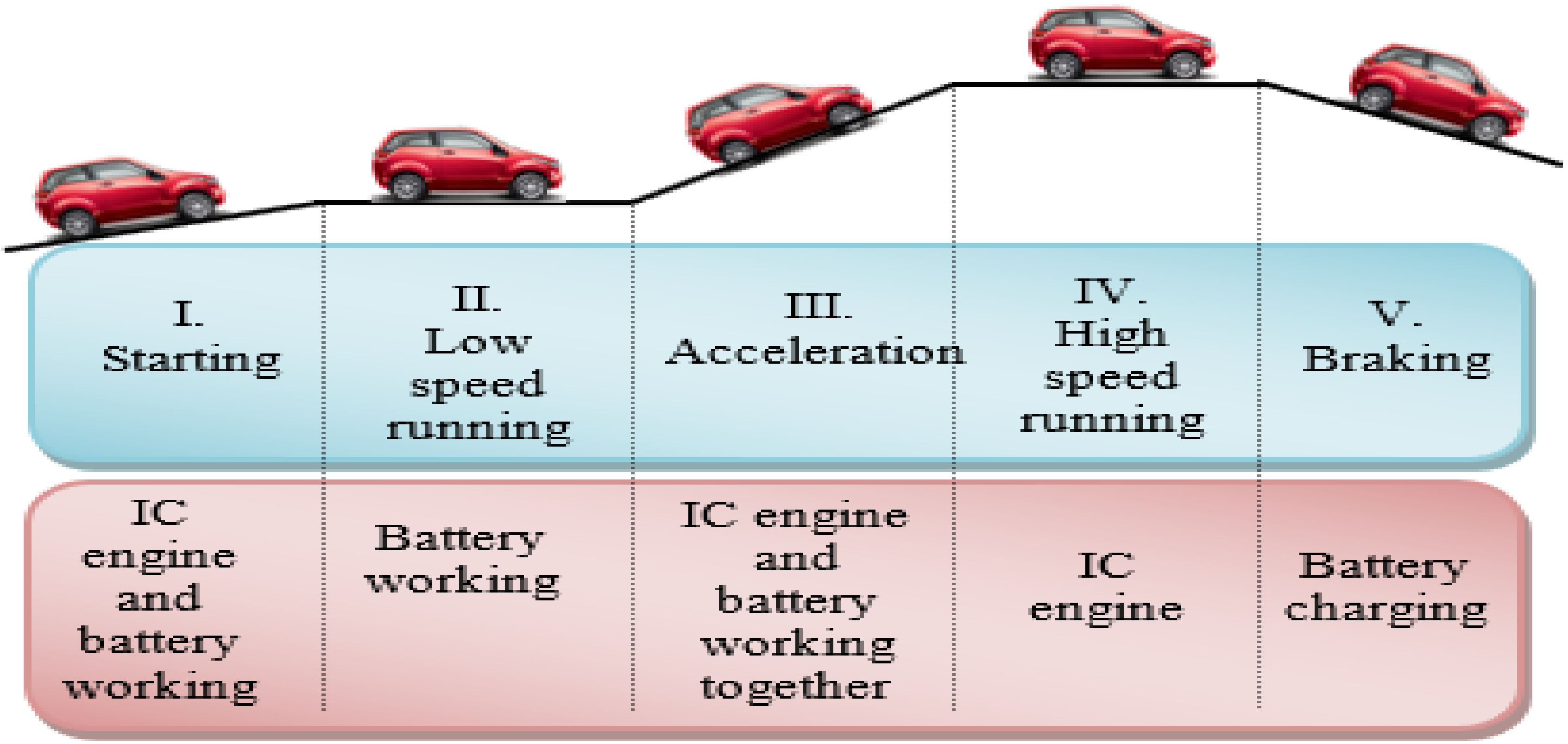
# Traction Motor Specifications [3]

| Model | Year | Motor Type | Peak Power kWp | Peak Torque N.m | Max Speed RPM | Poles | Peak Specific Power kW/kg | Peak Power Density kW/L |
|---|---|---|---|---|---|---|---|---|
| Roadster | 2008 | IM | 215 | 370 | 14,000 | 4 | 4.05 | - |
| Tesla S60 | 2013 | IM | 225 | 430 | 14,800 | 4 | - | - |
| Model 3 | 2017 | PM | 192 | 410 | 18,000 | 6 | - | - |
| Prius | 2004 | PM | 50 | 400 | 6000 | 8 | 1.1 | 3 |
| Prius | 2010 | PM | 60 | 207 | 13,500 | 8 | 1.6 | 4.8 |
| Prius | 2017 | PM | 53 | 163 | 17,000 | 8 | 1.7 | 3.35 |
| Accord | 2006 | PM | 12 | 136 | 6000 | 16 | 0.53 | 2.83 |
| Accord | 2014 | PM | 124 | - | 14,000 | 8 | 2.9 | 2.93 |
| Spark | 2014 | PM | 105 | 540 | 4500 | 12 | - | - |
| Volt | 2016 | PM | 111 | 370 | 12,000 | 12 | - | - |
| Bolt | 2017 | PM | 150 | 360 | 8810 | 8 | - | - |
| Leaf | 2012 | PM | 80 | 280 | 10,390 | 8 | 1.4 | 4.2 |
| Leaf | 2017 | PM | 80 | 280 | 10,390 | 8 | 1.4 | 4.2 |
| Camry | 2007 | PM | 70 | 270 | 14,000 | 8 | 1.7 | 5.9 |
| Camry | 2013 | PM | 70 | 270 | 14,000 | 8 | 1.7 | 5.9 |
| Lexus | 2008 | PM | 110 | 300 | 10,230 | 8 | 2.5 | 6.6 |
| Sonata | 2011 | PM | 30 | 205 | 6000 | 16 | 1.1 | 3.0 |
| BMW i3 | 2016 | PM | 125 | 250 | 11,400 | 12 | 3 | 9.1 |

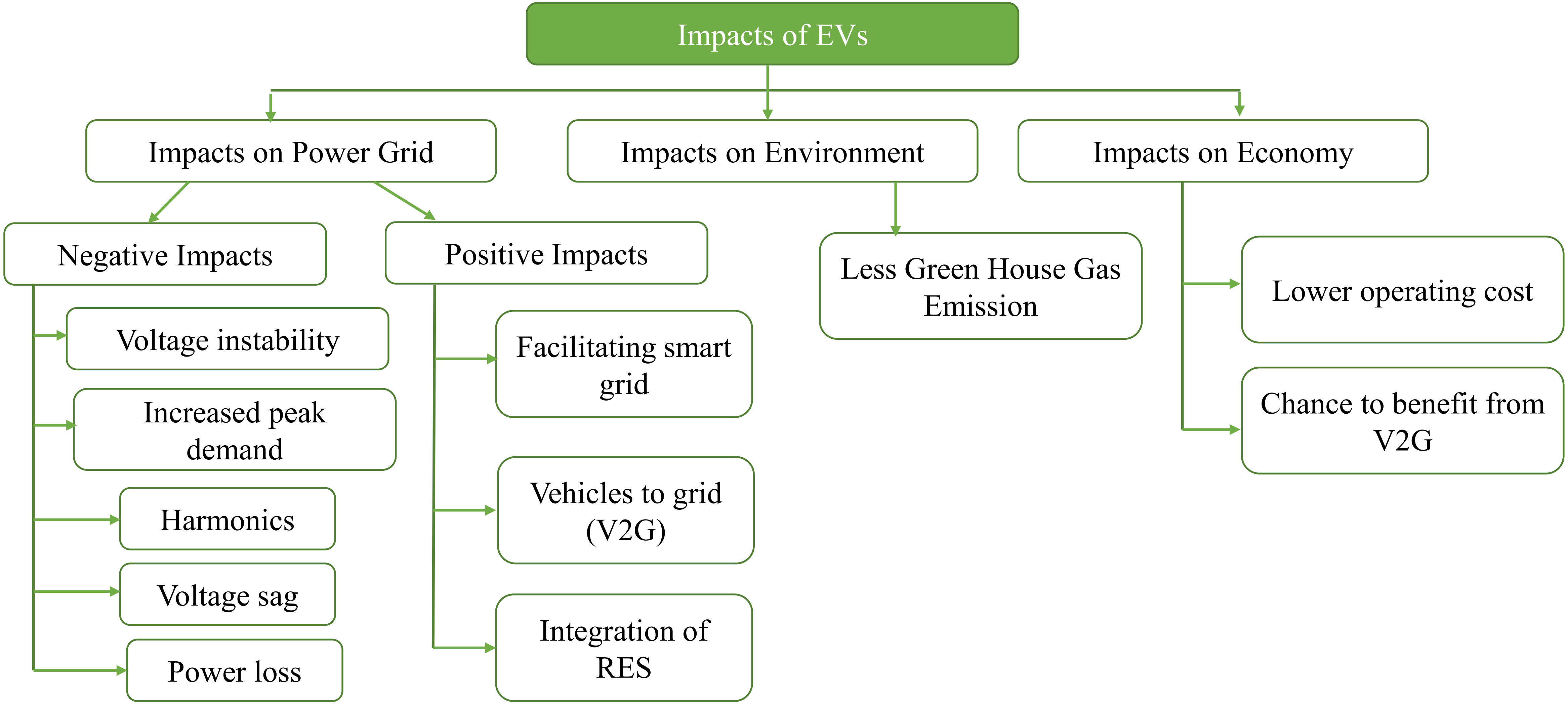


3. Agamloh, E.; von Jouanne, A.; Yokochi, A. An Overview of Electric Machine Trends in Modern Electric Vehicles. *Machines* 2020, *8*, 20, pp. 1-16, 2020.

# Coordination Operation of EVs and HEVs



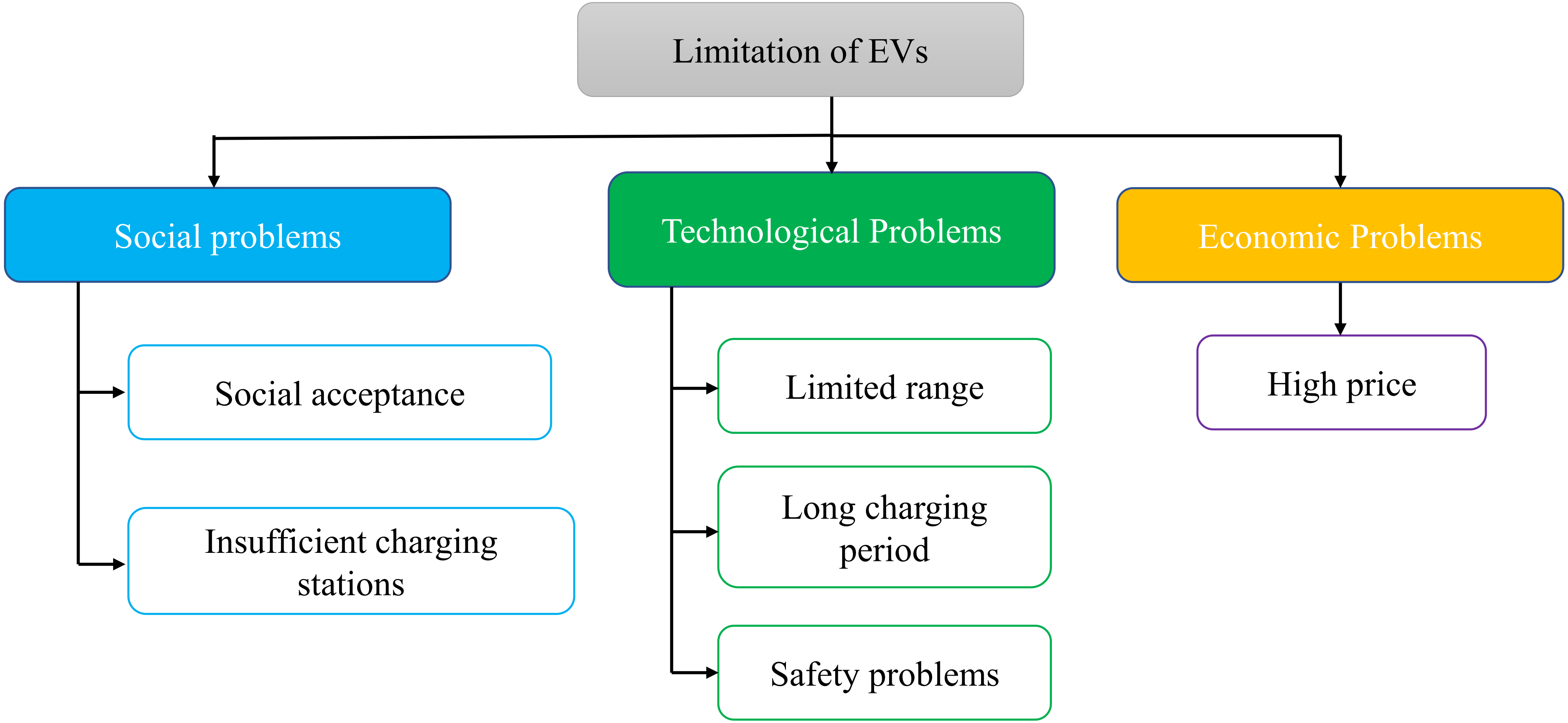
# Effects of EVs and HEVs [4]





4. Grunditz, E.A.Thiringer, T. “Performance Analysis of Current BEVs Based on a Comprehensive Review of Specifications,” IEEE Trans. Transp. Electr. 2016, 2, 270–289.

# Limitations of EVs [5]




5. F. U. Noor, S. Padmanaban,L. M. Popa, M. N. Mollah and E. Hossain, "A Comprehensive Study of Key Electric Vehicle (EV) Components, Technologies, Challenges, Impacts, and Future Direction of Development," Energies 2017, 10, 1217, pp. 1-84, 2017.

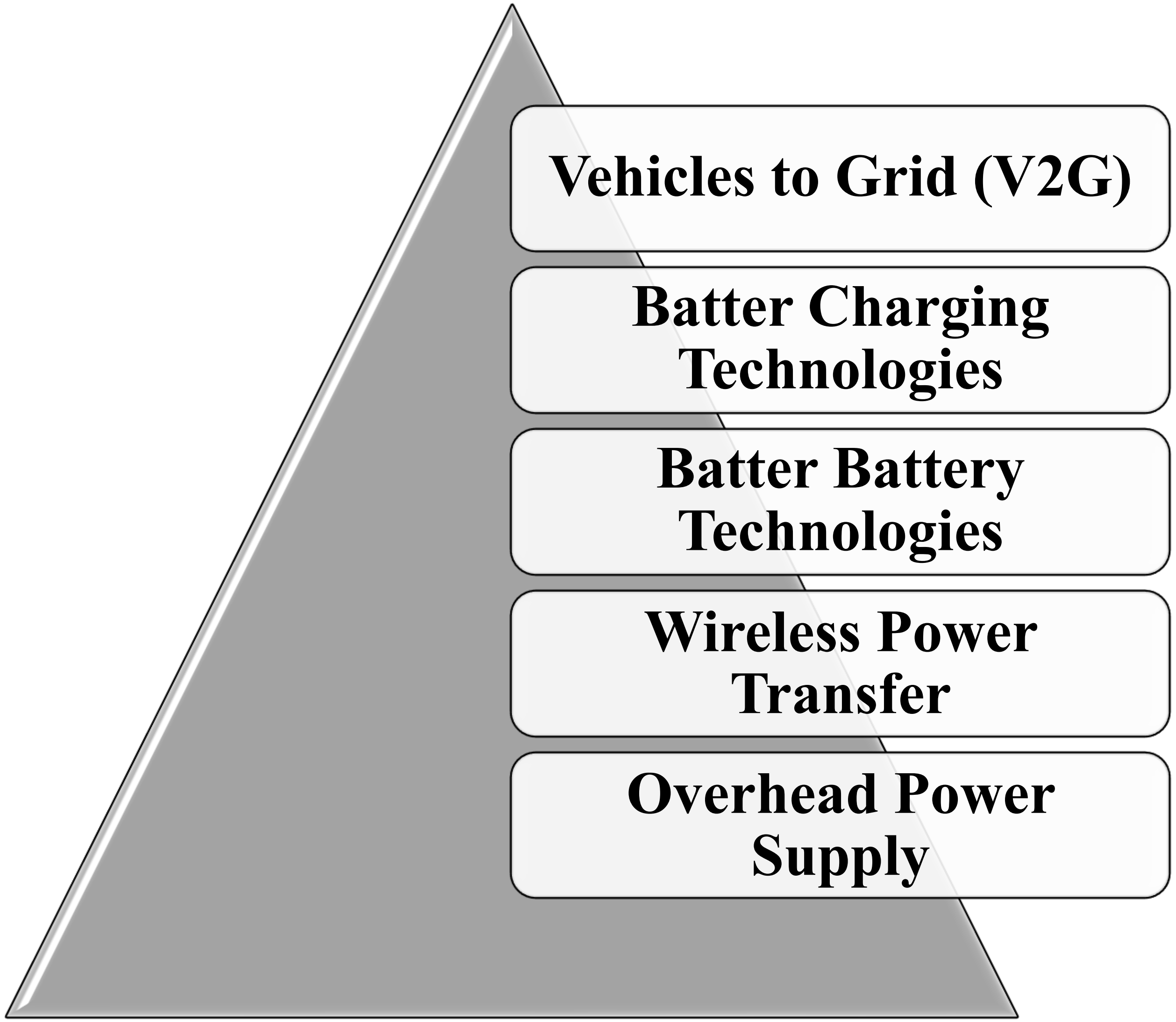
# Tentative Solutions of Current Limitations of EVs [5]

| Limitation | Probable solution |
| --- | --- |
| Limited range | Better energy source and energy management technology |
| Long charging period | Better charging technology |
| Safety problems | Advanced manufacturing scheme and build quality |
| Insufficient charging stations | Placement of sufficient stations capable of providing services to all kinds of vehicles |
| High price | Mass production, advanced technology, government incentives |

# Foot Race in Key EVs Factors

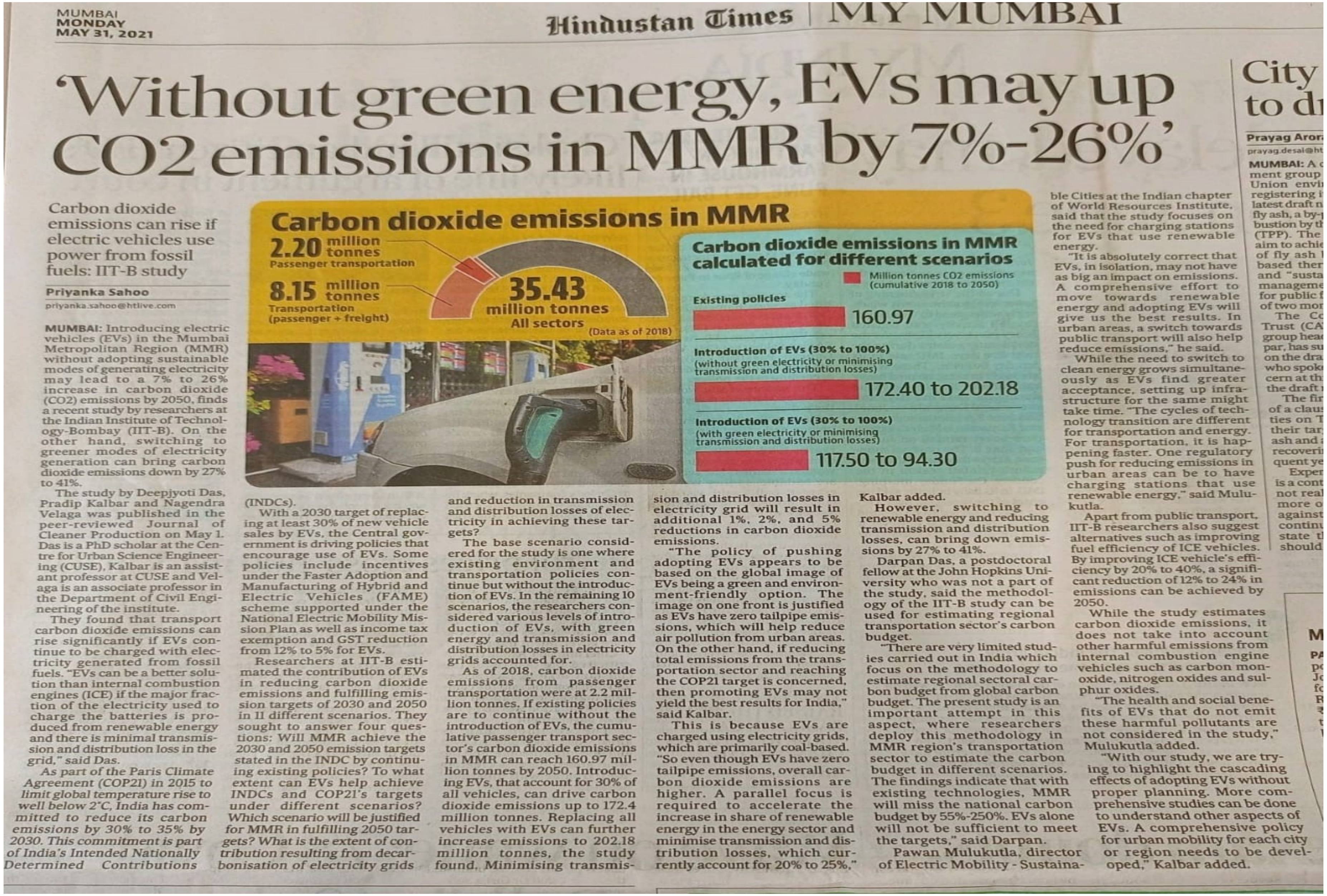
| Factor | Foot Race |
|---|---|
| Recharging | Weight of charger, durability, cost, recycling, size, charging time |
| Hybrid EV | Battery, durability, weight and cost |
| Hydrogen fuel cell | Cost, hydrogen production, infrastructure, storage, durability and reliability |
| Auxiliary power unit | Size, cost, weight, durability, safety, reliability, cooling and efficiency |

# Major Trends and Future Developments



# Current Areas of Research

- Reduce Mass
- Decrease material and manufacturing costs
- Improving the Hardware
- Battery – alternatives to/maximizing the nickel-metal hydride currently in use



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# 'Without green energy, EVs may up CO2 emissions in MMR by 7%-26%'

## Carbon dioxide emissions can rise if electric vehicles use power from fossil fuels: IIT-B study

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**MUMBAI:** Introducing electric vehicles (EVs) in the Mumbai Metropolitan Region (MMR) without adopting sustainable modes of generating electricity may lead to a 7% to 26% increase in carbon dioxide (CO2) emissions by 2050, finds a recent study by researchers at the Indian Institute of Technology-Bombay (IIT-B). On the other hand, switching to greener modes of electricity generation can bring carbon dioxide emissions down by 27% to 41%.

The study by Deepjyoti Das, Pradip Kalbar and Nagendra Velaga was published in the peer-reviewed Journal of Cleaner Production on May 1. Das is a PhD scholar at the Centre for Urban Science Engineering (CUSE), Kalbar is an assistant professor at CUSE and Velaga is an associate professor in the Department of Civil Engineering of the institute.

They found that transport carbon dioxide emissions can rise significantly if EVs continue to be charged with electricity generated from fossil fuels. "EVs can be a better solution than internal combustion engines (ICE) if the major fraction of the electricity used to charge the batteries is produced from renewable energy and there is minimal transmission and distribution loss in the grid," said Das.

*As part of the Paris Climate Agreement (COP21) in 2015 to limit global temperature rise to well below 2°C, India has committed to reduce its carbon emissions by 30% to 35% by 2030. This commitment is part of India's Intended Nationally Determined Contributions* (INDCs).

With a 2030 target of replacing at least 30% of new vehicle sales by EVs, the Central government is driving policies that encourage use of EVs. Some policies include incentives under the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme supported under the National Electric Mobility Mission Plan as well as income tax exemption and GST reduction from 12% to 5% for EVs.

Researchers at IIT-B estimated the contribution of EVs in reducing carbon dioxide emissions and fulfilling emission targets of 2030 and 2050 in 11 different scenarios. They sought to answer four questions: Will MMR achieve the 2030 and 2050 emission targets stated in the INDC by continuing existing policies? To what extent can EVs help achieve INDCs and COP21's targets under different scenarios? *Which scenario will be justified for MMR in fulfilling 2050 targets? What is the extent of contribution resulting from decarbonisation of electricity grids* and reduction in transmission and distribution losses of electricity in achieving these targets?

The base scenario considered for the study is one where existing environment and transportation policies continue but without the introduction of EVs. In the remaining 10 scenarios, the researchers considered various levels of introduction of EVs, with green energy and transmission and distribution losses in electricity grids accounted for.

As of 2018, carbon dioxide emissions from passenger transportation were at 2.2 million tonnes. If existing policies are to continue without the introduction of EVs, the cumulative passenger transport sector's carbon dioxide emissions in MMR can reach 160.97 million tonnes by 2050. Introducing EVs, that account for 30% of all vehicles, can drive carbon dioxide emissions up to 172.4 million tonnes. Replacing all vehicles with EVs can further increase emissions to 202.18 million tonnes, the study found. Minimising transmission and distribution losses in electricity grid will result in additional 1%, 2%, and 5% reductions in carbon dioxide emissions.

"The policy of pushing adopting EVs appears to be based on the global image of EVs being a green and environment-friendly option. The image on one front is justified as EVs have zero tailpipe emissions, which will help reduce air pollution from urban areas. On the other hand, if reducing total emissions from the transportation sector and reaching the COP21 target is concerned, then promoting EVs may not yield the best results for India," said Kalbar.

This is because EVs are charged using electricity grids, which are primarily coal-based. "So even though EVs have zero tailpipe emissions, overall carbon dioxide emissions are higher. A parallel focus is required to accelerate the increase in share of renewable energy in the energy sector and minimise transmission and distribution losses, which currently account for 20% to 25%," Kalbar added.

However, switching to renewable energy and reducing transmission and distribution losses, can bring down emissions by 27% to 41%.

Darpan Das, a postdoctoral fellow at the John Hopkins University who was not a part of the study, said the methodology of the IIT-B study can be used for estimating regional transportation sector's carbon budget.

"There are very limited studies carried out in India which focus on the methodology to estimate regional sectoral carbon budget from global carbon budget. The present study is an important attempt in this aspect, where researchers deploy this methodology in MMR region's transportation sector to estimate the carbon budget in different scenarios. The findings indicate that with existing technologies, MMR will miss the national carbon budget by 55%-250%. EVs alone will not be sufficient to meet the targets," said Darpan.

Pawan Mulukutla, director of Electric Mobility - Sustainable Cities at the Indian chapter of World Resources Institute, said that the study focuses on the need for charging stations for EVs that use renewable energy.

"It is absolutely correct that EVs, in isolation, may not have as big an impact on emissions. A comprehensive effort to move towards renewable energy and adopting EVs will give us the best results. In urban areas, a switch towards public transport will also help reduce emissions," he said.

While the need to switch to clean energy grows simultaneously as EVs find greater acceptance, setting up infrastructure for the same might take time. "The cycles of technology transition are different for transportation and energy. For transportation, it is happening faster. One regulatory push for reducing emissions in urban areas can be to have charging stations that use renewable energy," said Mulukutla.

Apart from public transport, IIT-B researchers also suggest alternatives such as improving fuel efficiency of ICE vehicles. By improving ICE vehicle's efficiency by 20% to 40%, a significant reduction of 12% to 24% in emissions can be achieved by 2050.

While the study estimates carbon dioxide emissions, it does not take into account other harmful emissions from internal combustion engine vehicles such as carbon monoxide, nitrogen oxides and sulphur oxides.

"The health and social benefits of EVs that do not emit these harmful pollutants are not considered in the study," Mulukutla added.

"With our study, we are trying to highlight the cascading effects of adopting EVs without proper planning. More comprehensive studies can be done to understand other aspects of EVs. A comprehensive policy for urban mobility for each city or region needs to be developed," Kalbar added.

# Key References

1. C. C. Chan, “The State of the Art of Electric and Hybrid Vehicles.” Proc. IEEE 2002, 90, 247–275, 2002.
2. Available [online]: https://electricvehicles.in/advantages-disadvantages-of-diff-types-of-evs-motors/
3. Agamloh, E.; von Jouanne, A.; Yokochi, A. An Overview of Electric Machine Trends in Modern Electric Vehicles. *Machines* 2020, *8*, 20, pp. 1-16, 2020.
4. Grunditz, E.A.Thiringer, T. “Performance Analysis of Current BEVs Based on a Comprehensive Review of Specifications,” IEEE Trans. Transp. Electr. 2016, 2, 270–289.
5. F. U. Noor, S. Padmanaban,L. M. Popa, M. N. Mollah and E. Hossain, “A Comprehensive Study of Key Electric Vehicle (EV) Components, Technologies, Challenges, Impacts, and Future Direction of Development,” Energies 2017, 10, 1217, pp. 1-84, 2017.

# Thank you for your attention

# Queries

**The future really is in our hands!**