

Basics of Mechanical Engineering-3

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Lecture 28: Basics of Electric and Hybrid Vehicles

Friends, this lecture we are going to talk about Electric and Hybrid Vehicles. The next topic will be very interesting, which is on Electric Vehicles. What happens to all the mechanical parts? Here, the combustion, compression, and whatever we were talking about are completely converted. You have a battery.

From a battery, we try to drive or derive energy so that other things can happen. So, electric vehicles are the new entry into the market, which has been there for the last 10 years. So here, we are going to use only a battery for energy. No petrol or diesel is used. And from the battery, what we do is try to run motors.

And from this motor, we try to take it to the transmission system, whatever we want. And finally, we try to connect it to the wheels. What used to happen earlier is you had an engine. In the engine, you used to pour petrol or diesel. And then there used to be a mechanical system that tried to do all those things.

And there used to be, after the combustion, there used to exhaust. They used to throw out the combust gas, which can be rich in fuel, which can be lean in fuel, and which created a lot of pollution. So now that system itself is gone. It just operates by a battery. Of course, the battery whatever we use here has to have very high torque, very high torque means very high current, very high current means the number of batteries have to be more.

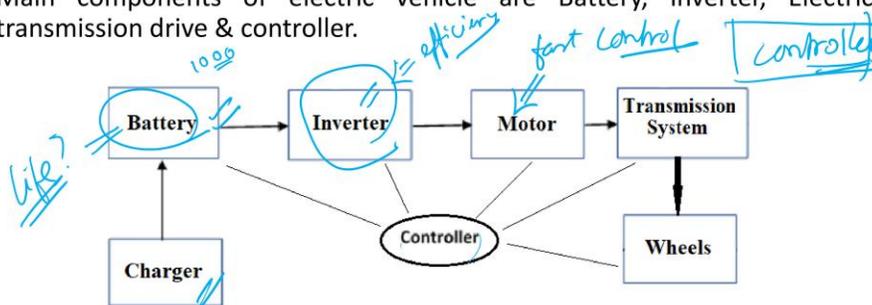
And here the battery will be charged frequently. So the life of the battery is always a challenge. So nowadays when you buy any scooter, they used to say the battery is given a warranty for three years. So that means to say you can try to do. Friends, it is not the three year matters.

They try to fix a specification for thousand times you try, you are allowed to charge the battery. Moment this 1000 hits faster or slower, the battery has to be changed. So the battery plays a very important role in EV vehicle. The rest is not a big deal. This battery is a bigger deal.

Electric Vehicle



- An electric vehicle (EV) is a vehicle that uses one or more electric motor for propulsion.
- The electric motors are the replacement of Internal Combustion Engine (ICE).
- Main components of electric vehicle are Battery, Inverter, Electric motor, transmission drive & controller.



An electric vehicle is a vehicle that uses one or more electric motors for propulsion. So, what is the advantage? The electric motors mean you can have very fast control. It's like your fan switching off and on. It's a motor.

You switch off, you switch on. If you want to switch on and then off, you can rotate in one direction. When you try to reverse it, it immediately stops. So motor can be easily controlled and there are lot of controllers, which are available for motor, which can do lot of wonderful things. They can have sinusoidal control, sawtooth control, and many other things can be done.

So, the motor is going to be attached to the transmission system. The engine output will be attached to the transmission system. Electric motors are the replacement for IC engines. The main components of an electric vehicle are battery which will be charged. Battery is like your UPS battery, your cell phone battery, your laptop battery. It is almost the same. And then you have an inverter. Why do you have an inverter? You convert DC into AC or whatever it is. So you have an inverter.

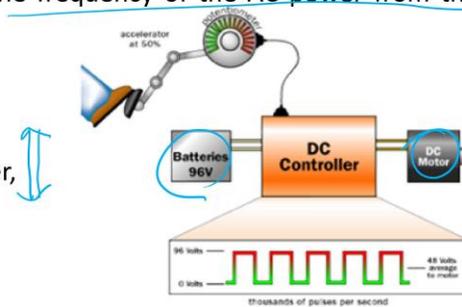
So generally in the inverter, we lose lot of efficiency. Now we are trying to improve the efficiency of the inverter and the controller. So inverter is again controlled by a controller. Motor is controlled by a controller. Transmission system, yes. And vehicle, yes. So here you can also go without gears.

Electric Vehicle



Working of an Electric Vehicle:

- Power is converted from the Direct Current (DC) battery to Alternating Current (AC) for the electric motor.
- When the accelerator pedal is pressed, it sends a signal to the controller which adjusts the vehicle's speed by changing the frequency of the AC power from the inverter to the motor.
- The motor connects and turns the wheels through a transmission system.
- When the brakes are pressed, the motor becomes an alternator and produces power, which is sent back to the battery.
- **This is known as regenerative braking.**



So working of an electric vehicle, the power is converted from a DC battery to an AC for the electric motor. DC motors are there, but DC motors are not very efficient. So AC motors are a little lighter in weight and can be better controlled.

So people get attached to AC motors. So from an AC motor, it gets attached to a transmission system. So the power is converted from a DC battery to an AC electric motor. When the accelerator pedal is pressed, it sends a signal to the controller, which adjusts the vehicle speed by changing the frequency of the AC power from the inverter to the motor. So when we press the accelerator, okay friends, we missed a point in the previous discussion.

When we press the accelerator, this accelerator in SI engine tries to improve the air mixing ratio. When you do the same in a CI engine, when you keep pressing the accelerator, the metered quantity of fuel entering the system is also changed. Here, what happens in an electric vehicle is that when the accelerator pedal is pressed, it sends a signal to the controller. Where is the controller? It is here.

The controller adjusts the vehicle speed by changing the frequency of the AC power from the inverter to the motor. The motor connects and turns the wheel through a transmission system. When the brakes are pressed, the motor becomes an alternator and produces power, which is sent back to the battery. So this is called as Regenerative braking system. So, you remember in the power plant we saw regenerative cycles.

So in the same way, in automobile also, you have when the brakes are pressed, accelerator brake, when the brakes are pressed, the motor becomes an alternator and produces power. This power is sent back to the battery. So, DC controller, batteries, and then you have a DC motor. When the brakes are pressed, the motor becomes an alternator and produces power, which is given back to the battery.

Electric Vehicle



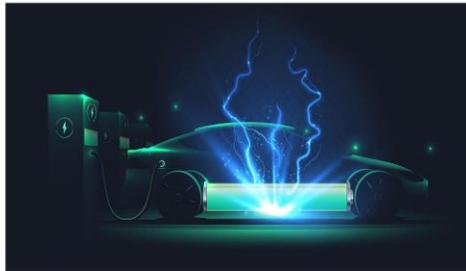
Advantages and Disadvantages of EVs

Advantages:

- Better for the environment.
- Electricity is less expensive than fuels.
- Less maintenance at a lower cost.
- Produce less noise.

Disadvantages:

- EVs have short ranges for driving. (100 to 400 km)
- Charging can take a lot of time.
- Initial investment is high.
- Charging stations are not available everywhere.



The advantages and disadvantages of an EV vehicle: it is better for the environment, no combustion occurs, electricity is less expensive than fuel, maintenance cost is lower because it is fully electric, and though these parts are largely improved, and the maintenance cost remains high. The noise is very low.

The only biggest challenge up till now is it can travel from 100 kilometers to 400 kilometers, it has to be recharged. Charging takes a long time, but nowadays, fast chargers are coming into action. The initial investment is high when we try to buy a four-wheeler. Yes, it is. For a two-wheeler, it is almost comparable.

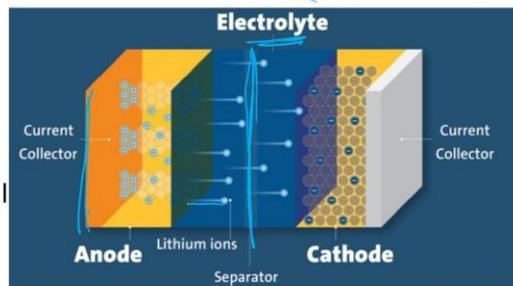
The charging stations are not available everywhere. The network and supply chain management of electric charging stations are improving in this country. So there are different types because, as you know, the battery is the heart.

Types of Batteries

1 Lithium-ion Batteries:

- Li-ion batteries are most commonly used in electric light motor vehicles because of their high power-to-weight ratio, good high-temperature performance, excellent specific energy, and low self-discharge rate.
- Lithium-ion batteries are better than other batteries at maintaining the ability to hold a full charge over time.
- These battery parts are recyclable so it is a good option regarding the environmental aspect.
- They have long cycle life even they support higher energy costs, exceptional power efficiency, longer service life and eco-friendliness.

Battery → Cost
→ Life time
→ Shape/size



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Now we have to see what different types of batteries are available for us. There are batteries used in laptops, batteries used in smartphones, batteries used in wall clocks, and batteries used in cars as well. So all of them are not the same.

There are different types of batteries. So predominantly, the batteries used in EV vehicles are lithium-ion batteries. Lithium is not a freely available material. So this dictates the cost of the battery. So batteries have two major challenges.

One is the cost. The other one is the lifetime. People are working on the third one is their shape and size. Because the majority of the batteries available are cuboidal in nature. And if we could make this cuboidal shape into a curved, flexible one, it would help reduce the space.

So people are working on all three. Lithium-ion batteries are most commonly used in electric light motor vehicles because of their high power-to-weight ratio, good high-temperature performance, excellent specific energy, and low self-discharge rate. Okay. So the lithium-ion battery—this is a schematic diagram. You will have a current collector

on one side, current collector on the other side. You will have an electrolyte which is there.

So the lithium ions—this is the anode and cathode. The lithium ions move from here to here, and then they are separated by a separator. These are electrolytes which are in between. Okay. The electrolytes can be solid electrolytes or liquid electrolytes. Today we are talking about solid electrolytes.

Lithium-ion batteries are better than other batteries at maintaining their ability to hold a full charge over time. These batteries are recyclable and are a good option regarding environmental aspects. They have a long cycle life. Even they support higher energy costs. Yes. So exceptional power efficiency, longer shelf life, and eco-friendliness are the basic advantages of going for lithium-ion batteries.

Types of Batteries



2 Lead-acid Batteries

- Lead-acid battery technology is still in the development phase.
- These batteries have a comparatively wide operating temperature range and have low energy density.
- They are easier to recycle. About 95% of the content of the battery can be reused, which is better for the environment.
- Lead-acid batteries have a relatively low depth of discharge so it directly impacts their cycle life.
- These batteries tend to be expensive because they don't last as long so they often need to be replaced within 4 to 15 years depending on their type.



You have lead-acid batteries, which are the conventional batteries. So here you have an electrolyte, which is a liquid electrolyte, and this has been in the market for a long time. If you go back to this figure, you saw an alternator. This alternator is attached to a battery, I said. So this battery, which is commonly used now in the market, is the lead-acid battery.

The lead-acid battery technology is still in the development stage. These batteries have a comparatively wide operating temperature range and low energy density. This has high—

lithium-ion batteries have high—this has low. They are easier to recycle. 95% of the content of the battery can be reused, which is better for the environment.

Lead-acid batteries. But lead is toxic. The lead acid batteries have a relatively low depth of discharge. So it directly impacts their cycle life. These batteries tend to be expensive because they don't last as long as they often need to be. Replaces within 4 to 15 years depending upon the type. Lead acid batteries are the second type.

Types of Batteries



3 Nickel-Metal Hydride Batteries:

- In a Nickel-Metal Hydride battery, one pole has Nickel alloy whereas another pole has Nickel oxy hydroxide with the electrolyte of Potassium hydroxide.
- It is usually slower to charge and discharge this battery. It contains less power per weight so it takes a longer time to charge the battery.
- These batteries have a wide operating temperature range. **But in extreme heat Ni-MH batteries can deteriorate faster.**
- They are also reliable and safe. Ni-MH batteries have a typical cycle life of over 3000 cycles.
- These batteries are widely used in automotive batteries, computers, medical instruments as well as equipments and electric razors.



The third one is nickel metal hydride batteries. These batteries have one pole has nickel alloy whereas the other pole has nickel oxygen hydroxide with the electrolyte of potassium hydroxide. So, nickel metal hydride batteries are there.

So, you have nickel at one end and the other pole is nickel oxy hydroxide with the electrolyte of KOH. It is usually slower to charge and discharge this battery. So, charging is also very slow. Discharging is also very slow. It contains less power per weight.

So, the power densities are low. So, it takes a longer time for charging of these batteries. These batteries are operated wide temperatures, but whereas lithium ion batteries does not operate at wider temperature zones. The second and third operates at a wider range, but in extreme heat, nickel, metal, hydrate, batteries can discharge faster. So, typically the lifetime is 3000 cycles.

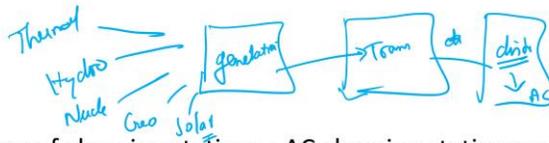
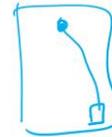
These batteries are widely used in automobile, computer, medical equipments and henceforth. So, these are the different types of batteries which are now thought of. Lithium ion is most exhaustively used. It is expensive, but it is exhaustively used. We have lead acid batteries. We also have nickel, metal, hydride batteries.

Charger

On-board Charger

- There are two main types of charging stations : AC charging stations and DC charging stations.
- Batteries can only be charged with DC electric power, while most electricity is delivered from the power grid as AC. For this reason, most electric vehicles have a built-in AC-to-DC converter, commonly known as the "onboard charger".
- **At an AC charging station, AC power from the grid is supplied to this onboard charger, which produces DC power to charge the battery.**
- EV's Charger are of three types:

- 1 Rapid Charger
- 2 Fast Charger
- 3 Slow charger



Charger: they are called as onboard charger. There are two types of charging stations today, AC charging station and DC charging station. The batteries can only be charged in DC electric power, while most electricity is delivered from the power grid as AC. So for this reason, the electric vehicles have built-in AC to DC converter, commonly known as on-board chargers.

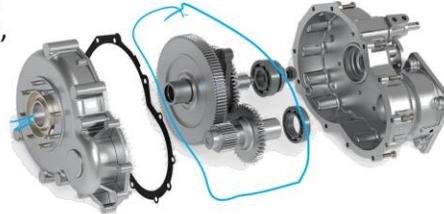
What comes through electricity transmission? Generally what happens, friends, you have three boxes in the electricity. So one is generation. Where we saw it can be through hydro, thermal, nuclear, it can be geo, it can be solar. So all these things are generation.

EV Transmission



- **Single-speed transmission:**

This is the most common type, consisting of a fixed gear ratio. It simplifies the drivetrain, reduces weight and complexity, and still delivers instant torque for acceleration. Examples include Tesla Model S and Chevrolet Bolt.



- **Multi-speed transmission:**

Some high-performance EVs (like Porsche Taycan, Audi e-tron GT) use two-speed or multi-speed transmissions to improve acceleration, top speed, and overall efficiency by keeping the motor operating in its optimal power range at different speeds.



Next is transmission. I have to transmit from the generation station across the country, that is transmission. The third one is the distribution, which comes from the transmission. For example, to your city, it will come here. Your house will be here.

So from here to here, it is distribution. So the power, the transformer will step down or step up and then transmit to your house through a wire. So, generally what comes in the entire cycle is AC. In solar what happens, they are trying to make standalone systems. So, the solar will be standalone.

So, directly you get a DC. So, you do not put this onboard charger. Moment you put a converter, it is, the efficiency is lost or the power is lost. At the AC charging station, AC power from a grid is supplied to its onboard charge while producing DC power to produce the battery. So, there are three types of chargers which are there.

One is rapid charger, slow charger and fast charger. Rapid charger are very high currents are passed, right. Fast charger is slightly lower and then the slow charger are used in nickel metal hydrides. So, single speed transmission is there, multiple speed transmission is there. So, it is the most common type single speed transmission consisting of a fixed gear ratio. So single speed: from a motor you have a gear, a fixed gear ratio.

So then it is called as a single speed. It simplifies the drivetrain, reduces weight and complexity and still delivers instant torque for acceleration. So this include Tesla Model

S and Chevrolet Bolt. So they use a single speed transmission. Multi speed transmission is some high performance EV vehicles like Porsche take can.

And then, the Audi e-tron GT uses a two-speed or multi-speed transmission to improve acceleration. One speed means the motor is given. After the motor, you have a gearbox. So, this gearbox tries to give you the torque, right? The speed and torque are adjusted by this, right?

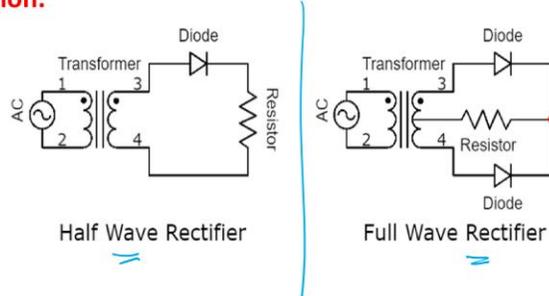
Uses a two-speed, multi-speed transmission to improve the acceleration, top speed and overall efficiency by keeping the motor operating in an optimum power range. Multi-speed transmission is also there, and single-speed is also there.

EV Power Devices



Rectifiers:

- A rectifier is an electronic device that converts an alternating current into a direct current by using one or more P-N junction diodes.
- A diode behaves as a oneway valve that allows current to flow in a single direction.
- **This process is known as rectification.**
- The rectifiers are used in AC-DC conversion stages of Plug-in EVs, where the grid electricity is firstly met with this device.



Rectifiers: these are rectifiers which you would have studied in your electrical course, basic electrical. Half-wave rectifier and full-wave rectifier. Rectifier is an electronic device that converts an alternative current into a direct current by using a PN junction one or more PN junctions, which converts an AC into a DC because motor can operate in the battery is DC, so what comes to the to your home is AC, then DC.

The diode behaves as a one-way valve that allows control of flow in a single direction. This process is called rectification. The rectifiers are used in AC-DC converters, a conversion stage of plugs in EVs where the grid electricity is first met with a device.

EV Power Devices



~ 50 Hz → rpm / torque

Power Converters

- Power converters are classified according to their input and output types namely DC-DC Converters and AC-AC Cycloconverters.
- DC-DC Converters are designed to increase or decrease the input voltage stage to desired value at the output.
- Therefore, a device known as Buck Converter or stepdown converter decreases the output value according to a high input voltage while Boost Converter or step-up converter generates an increased output voltage.
- The cyclo-converters are used to convert input power at one frequency to output power at a different frequency. → VFD
- This can also be achieved by an inverter.



Then power converter: the power converter are classified according to the input-output type of power: DC-DC converter, AC-AC cycloconverter. So there are two things. So, DC-DC converter and AC-AC cycloconverter.

DC-DC converters are designed to increase or decrease the input voltage to the desired output. Therefore, a device known as buck converter or a step-down converter decreases the output value according to the input voltage, while booster converter or step-up converter generates the increased output voltage. So, a booster converter and a buck converter—two things are there. Friends, these are just for information and for you to know, because mechanically you understand many things, but on the electric side, what happens you should understand. So, what we saw till now was the battery,

then we saw the onboard charger, then we saw speed mechanisms, and now the rectifier—finally, the power converter. The cycloconverter is used to convert high input power at one frequency to an output of different frequencies—this is the boost cycloconverter. DC-DC converters increase or decrease input voltage. AC-AC converter cycloconverter converts one frequency to multiple frequencies. So, this is nothing but a variable frequency drive (VFD).

Variable frequency drive—variable because what comes in AC is a single frequency, 50 hertz. Now, the cycloconverter will convert it into a variable frequency. With variable

frequency, you can adjust the RPM or the torque accordingly. So that is what is the advantage, which can be achieved by an inverter.

EV Power Devices

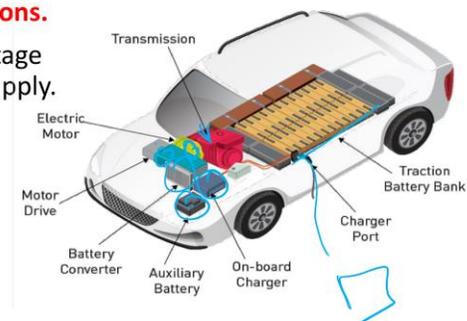


Controller and Sensors:

- The required control signals are generated by Microcontrollers and commutate power electronic devices with switches to provide fixed speed or torque.

Inverters:

- **In EVs, Inverters are used for DC-AC conversions.**
- They are used to provide the required AC voltage and current for AC motors from DC battery supply.



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The controller, which is the heart of the EV vehicle. And today, onboard sensors, there are a lot of things which are getting incorporated in SI engine as well as CI engine. So controller: they require control signals are generated by microcontroller and commutate power electronic devices with switches to provide the required speed and torque. This is done by this. Inverter: in EVs, inverters are used for AC-DC conversion. They provide the required AC voltage and current for AC motors from a DC battery power supply.

This is why inverters exist. The controller is very important, and there are multiple sensors. These include pressure sensors, air-fuel sensors, torque sensors, and more. There are many sensors present. The number of moving parts in an electric vehicle is reduced.

So you can see here, the traction battery bank is here. There is also a charging point connected to the external power source. Additionally, there is an onboard charger and an auxiliary battery. Then it is battery converter. Then motor drives here.

Electric motor which is here. Then transmission systems. So transmission systems is what we saw here. You will get a variable frequency drive. So the last part is a mixture of these two.

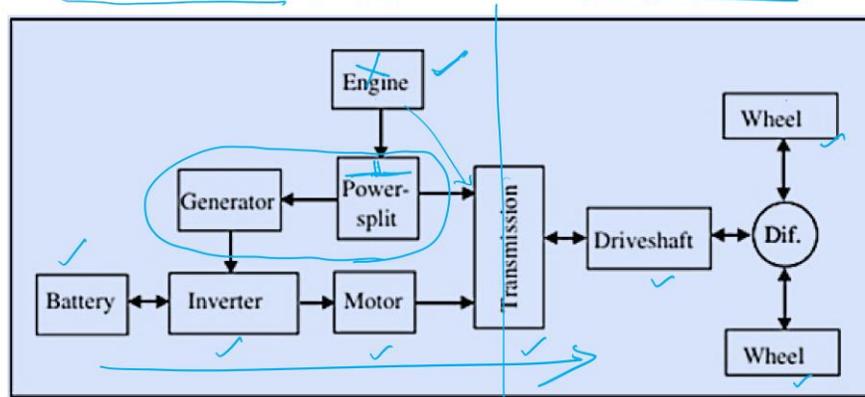
Because initially when the electric vehicle came, people were not ready to accept electric vehicle. And people also felt that the battery is very difficult for a long drive. So then people decided let us have a mixture of both, where in which you will have your normal vehicle where the starting will be done by petrol or diesel.

After a threshold value it switches to electric. So the initial start will be done by it and the battery gets charged, and then you get into the electric, so electric can be used for control and then you can have a pollution reduction.

Hybrid Vehicle



- A hybrid electric vehicle (HEV) is a type of vehicle that combines a conventional internal combustion engine (ICE) system with an electric propulsion system.



A Hybrid Energy Vehicle is a type of vehicle that combines a conventional internal combustion engine with the electric power propulsion system. So this is a typical hybrid engine. So you can hybrid vehicle, you can see here the battery, inverter, motor, transmission system. Then you have a driving shaft, differential, both wheels are given control. Right. So now the other thing what we will see is engine, which is attached to the transmission system, then driveshafts, differential wheels, right?

But here, there is a difference. So, where is the difference? It has a difference here. So, the engine, what it does is it sends its power to a power split. So, from the power split, it gets divided into two parts.

One part gets into the transmission drive shaft and goes away. The other part gets into the generator. Why a generator? This generator is, in turn, going to generate power and give it to the inverter. From the inverter, it gets into the motor.

So here, the power is split into two parts. Initially, when you try to give the starting torque, it is very high, and it goes from the engine. When it goes from the engine, the generator inverter is also getting power. It gets a generator and that is given to an inverter. The inverter sends it to a motor. After a certain speed, this part is removed and this one gets into action. It happens automatically through a controller.

Hybrid Vehicle



Modern vehicles (HEVs) make use of efficiency-improving technologies such as regenerative brakes which convert the vehicle's kinetic energy to electric energy, which is stored in a battery or super-capacitor.

Advantages of Hybrid Cars

- Cleaner Emission
- Less Fuel Dependency
- Smaller and Efficient Engine

Disadvantages of Hybrid Cars

- Lower Performance
- Expensive to Buy
- High Maintenance Cost



So the hybrid modern vehicles (HEVs) may use the efficiency improving technologies such as regenerative bricks, which convert the vehicle kinetic energy to electric energy which is stored in the battery or a supercapacitor. So we saw how regeneration happens when you apply brakes and how it gets stored as energy. So the advantages are cleaner emissions, less fuel dependency, and small, efficient engines in hybrids.

In the last decade, many hybrid vehicles have come into use. The disadvantage is that sometimes it delivers low performance. These vehicles are expensive because they use both combinations, and they have higher maintenance costs due to the engine's mechanical parts and the battery.

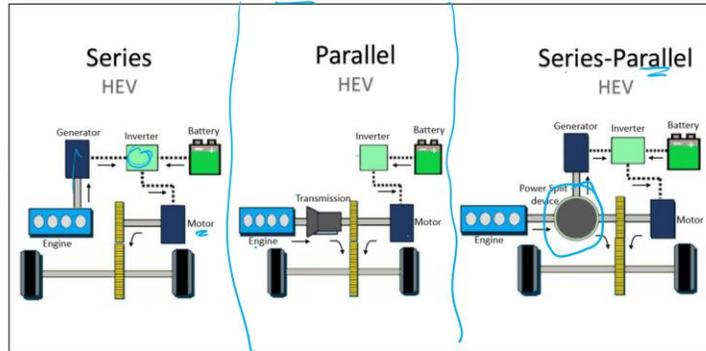
Hybrid Vehicle

HEV Drivetrains

• Drivetrain or Powertrain refers to the set of components that generate the power required to move the vehicle and deliver it to the wheels.

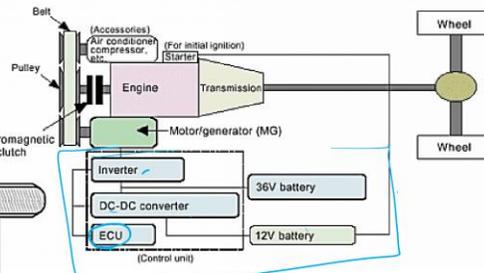
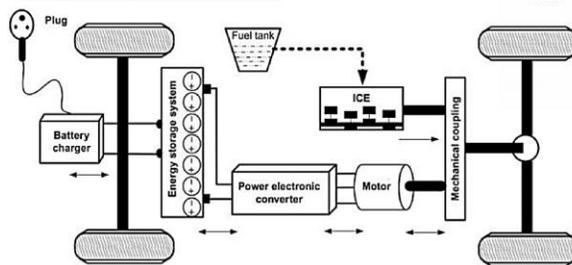
• Based on the HEV drivetrains, an HEV are categorized as:

- ✓ 1 Series Hybrid Vehicle
- ✓ 2 Parallel Hybrid Vehicle
- ✓ 3 Plug-in Hybrid Vehicle
- ✓ 4 Mild-Hybrid Vehicle



Hybrid Vehicle

Plug-in Hybrid Vehicle



Mild Hybrid Vehicle

So there is a drivetrain. The drivetrain or parallel system refers to a set of components that generate the power required to move the vehicle and deliver it to the wheels. So this is a serial style, this is a parallel style, and this is a blend of serial and parallel styles. The serial style has an engine, a generator, and an inverter attached, so it is in series.

This goes to the inverter, and then from the battery, it also comes to the inverter before going to a motor transmission system. When you take it parallel, what happens is you have battery which is given, motor and that goes to the transmission system, the engine

also gives it to the transmission system. So serial and parallel is half of them is serial and half is parallel.

So you have a power splitter device. So based on the hybrid electric vehicle, the drivetrains can be categorized as serial type, parallel type, mild hybrid type or hybrid. Plug-in hybrid type. So plug-in hybrid type and mild hybrid vehicle, these two are almost falling in the serial type. So plug-in and mild, you can see here plug-in hybrid is you have the energy storage system.

So if you go back and look into this, this is the traction of battery bank. So that's what is told here, the energy storage system. So from there, you will have a power electronic converter which goes to your motor and the mechanical coupling happens here. This is plug-in hybrid. You charge the battery and then use it.

The other one is mild hybrid vehicle. You will have engine which everything is there and then you have a small support which is given by the engine. battery type. So, you will have 36 volt battery, 12 volt battery. So, this 36 volt also is sent to the DC-DC converter, 12 is also given here. This is engine control unit and you have the inverter which is placed. So, these are the four types.

IC Engine Vs Electric Vs Hybrid Vehicles



Category	Electric Vehicles	Hybrid Electric Vehicles	I.C. Engines
Power/Fuel Source	Electricity through Battery Pack (DC)	Electricity and Fossil Fuel (Petrol and Diesel etc.)	Fossil Fuel (Petrol and Diesel etc.)
Engine	Electric Motor(s)	Internal Combustion Engine and Electric Motor(s)	Internal Combustion Engine
Fuel Efficiency	Depends on Battery Range	Combination of ICE and Battery Range	Internal Combustion Engine
Emission Levels	Lower compared to ICE and Hybrid vehicles	Higher compared to Electric Vehicles	High
Price Range	High	Similar to Conventional ICE Vehicles	Low as compared to EVs
Charging	Required	Not required	Not required

So, finally, when we try to compare the IC engine versus electric, pure electric versus hybrid, you will see three parts, right. So the power fuel source in electric vehicle it is

from the battery pack which is DC battery pack. The hybrid will have electricity plus fossil fuel will be used here.

In IC it will be only fossil fuel used here. The engine will have electric motor. So here hybrid will have internal combustion engine and electric motor will be there. When we talk about IC, it will be internal combustion engine only. Then the fuel efficiency will depend on the battery range.

So it is a combined, so it depends on IC as well as battery. Then IC combustion engine will be only the fuel whatever is there. The emission levels are low compared to IC. It is a very low hybrid vehicle; it is the lowest. So the next one, since some amount of IC is involved, is slightly higher compared to electric vehicles.

Here, the fuel efficiency level is very high because it is only combustion-based. The range of electric vehicles is high. This is similar to conventional vehicles, and this is comparatively lesser. Out of these three, it is lesser. But today, electric vehicles are also coming close in comparison with IC engines.

Charging is required here in hybrids, but here it is not required because whatever charging happens will occur by the first part of the IC when it is running; it will try to charge the battery from there and then use it. So here, it is not required.

To Recapitulate



- What is an IC Engine? How does it differ from the steam powered engines?
- What do you understand by 4 stroke and 2 stroke in terms of and IC engine?
- Describe the features and differences of SI and CI Engine.
- How do Electrical Vehicles (EVs) operate?
- What is the elementary difference between and EV and IC engine operated vehicle?
- What are various types of Batteries? State with a brief description.
- Name and describe various transmission devices in an electric vehicle.
- What do you understand by a Hybrid Vehicle?
- Compare and Contrast the IC Engine, Electric and Hybrid Vehicles.

Friends, I think this lecture would have given you a lot of insight about IC engines, two-stroke engines, four-stroke engines, hybrid engines, and electric engines. So, you will be able to appreciate how does all these things happen from the science of thermodynamics. There are few exercise which I wanted you to try if you have a bike, or a scooter, or a TVS 50, or a moped.

What I would like you to do is try to pour one liter of petrol or whatever fuel is available. You pour it inside. And then what you do as a single operator, you try to drive it to the fullest extent. Then you try to repeat the same experiment with two people. Try to see what is the difference in performance and the efficiency of the engine.

So then try to browse through in net and try to figure out if two people sit in the car or four people sit in a car, how is the efficiency going to change? The next question is, if I am going to drive a car at low speed, high torque, what will be the mileage? High speed, low torque, what will be the mileage? If I try to load or switch on an AC in the car and drive, look at the mileage, without an AC, look at the mileage. And sometimes when you start the scooter or car, you see here, gut, gut, gut, gut, gut, there will be a sound.

So where is this sound coming from? And when you start an EV vehicle, there is no sound. Why? The difference is coming. And when you try to look into an EV vehicle, you can go in the forward direction and reverse direction just by switching a small switch towards left and right.

How does it happen? So, these are some of the things which I want you to browse or experience so that you can try to enjoy this lecture. To recap what we saw in this lecture, we learned what an IC engine is, the difference between a steam power engine and an IC engine—that is, external combustion and internal combustion—and what 4-stroke and 2-stroke engines are. What is the difference between an SI engine and a CI engine? What are electric vehicles?

And in electric vehicles, what are the elements of an electric vehicle that we saw? What is the difference between an EV vehicle and an IC engine vehicle? What are the various types of batteries? We saw three different types of batteries. Then we saw the different types of transmission drive systems—parallel, serial, serial-parallel, plug-in type, and mild—all these things we covered.

Then, what do we understand by hybrid? And hybrid is in the initial phase; you try to run it on fuel mode, and then you switch to battery. That is hybrid. And finally, we saw the comparison between IC, electric, and hybrid engines.

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So, these are the references which we have used in making these slides.

Thank you.