NPTEL

National Programme on
Technology Enhanced Learning

Video Course on

Electric Vehicles Part 1

by

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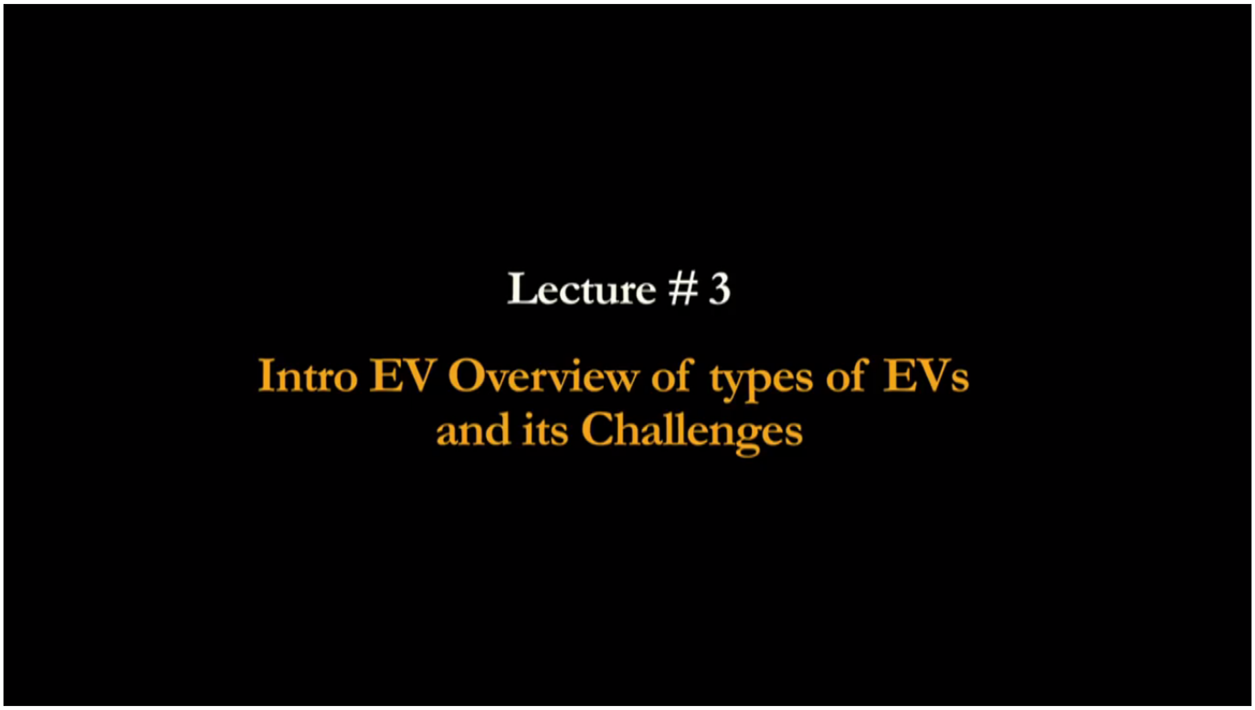
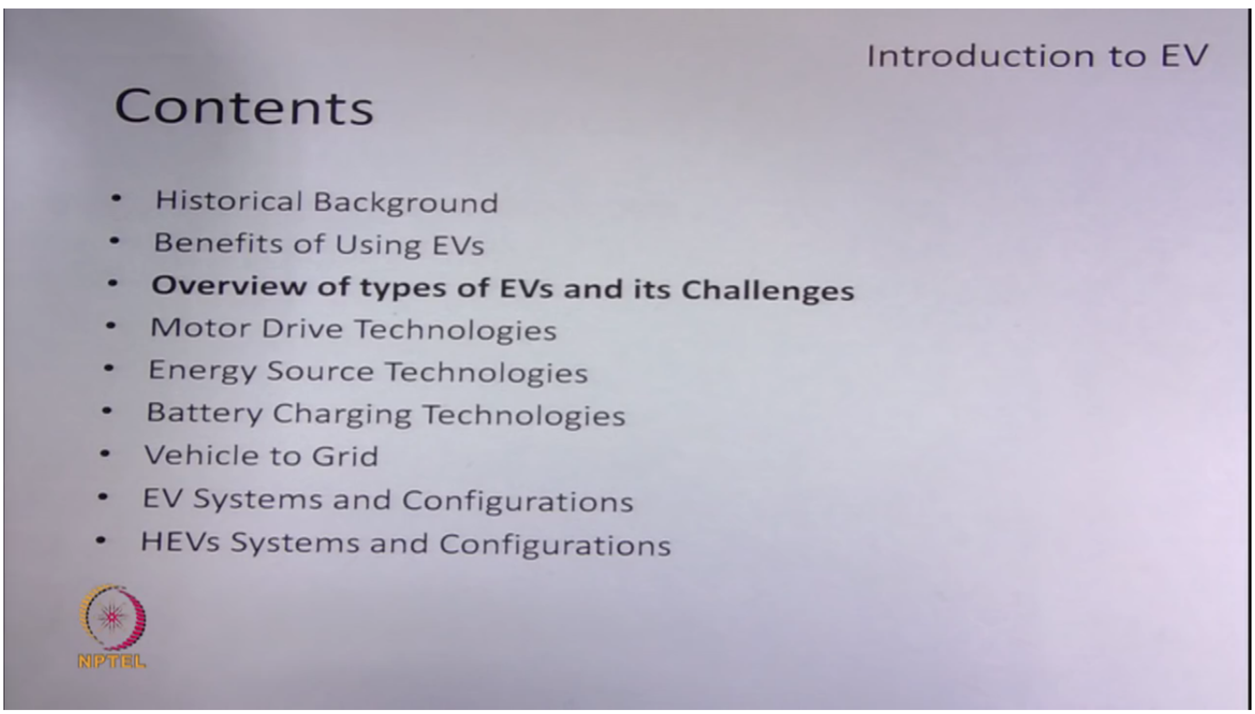
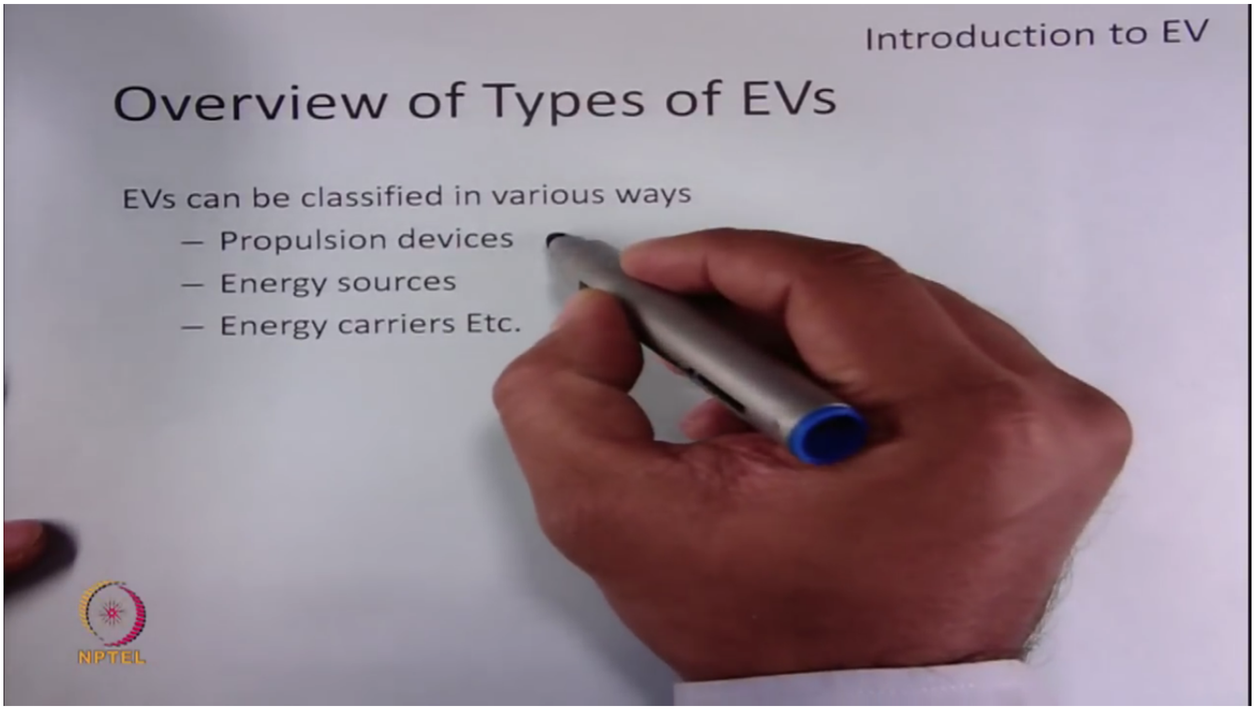
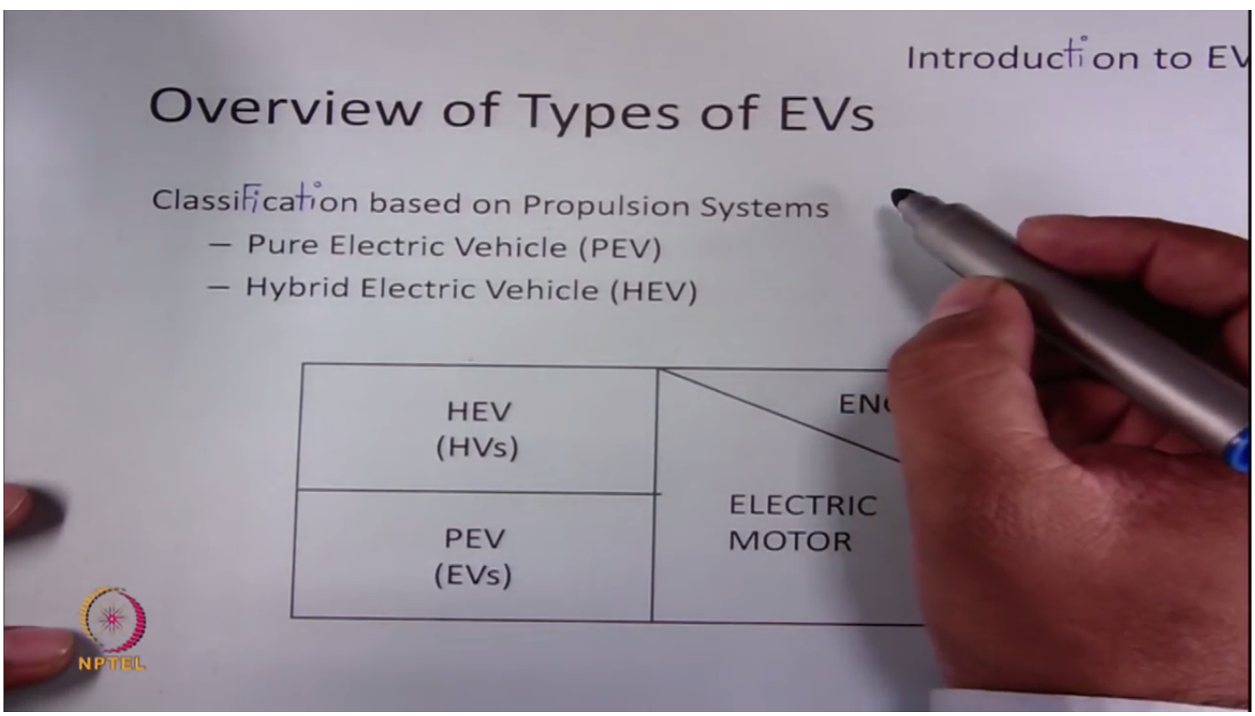




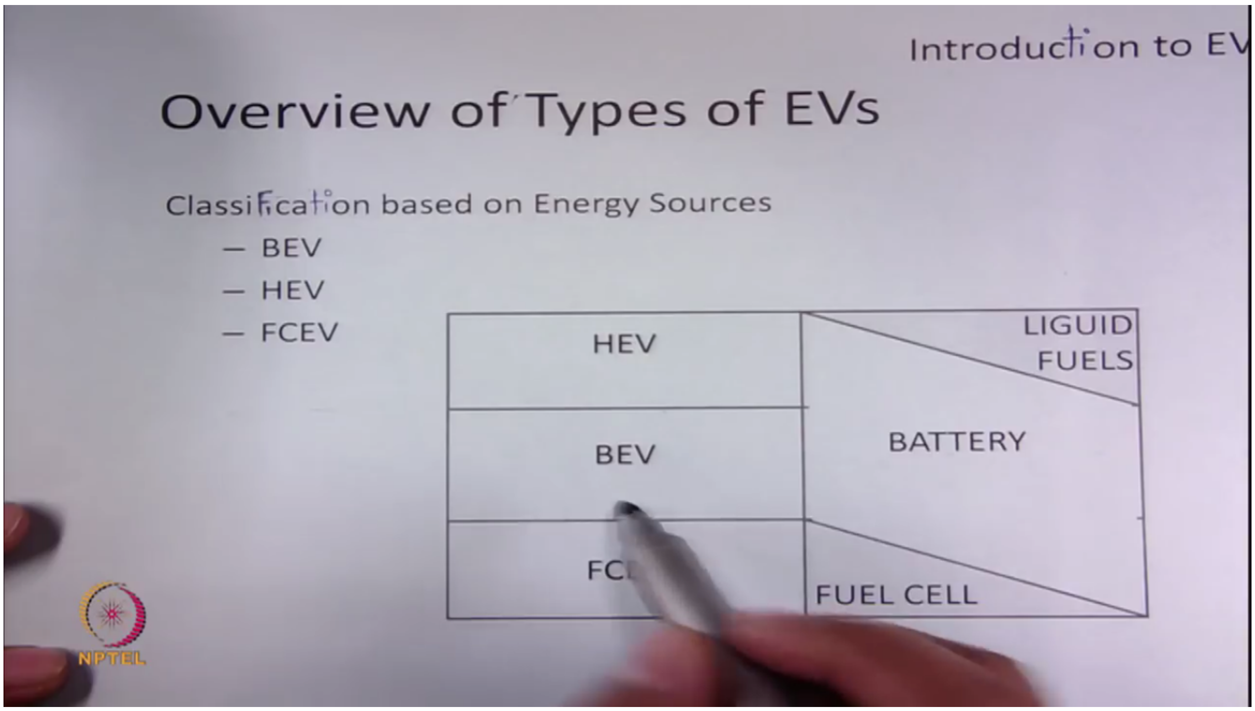
Hello everyone. Welcome to the NPTEL online course on electric vehicles. In our previous interaction we have covered the topic benefits of using EVs compared to other modes of transport. Now let us discuss the next topic which is overview of types of EVs and their challenges.



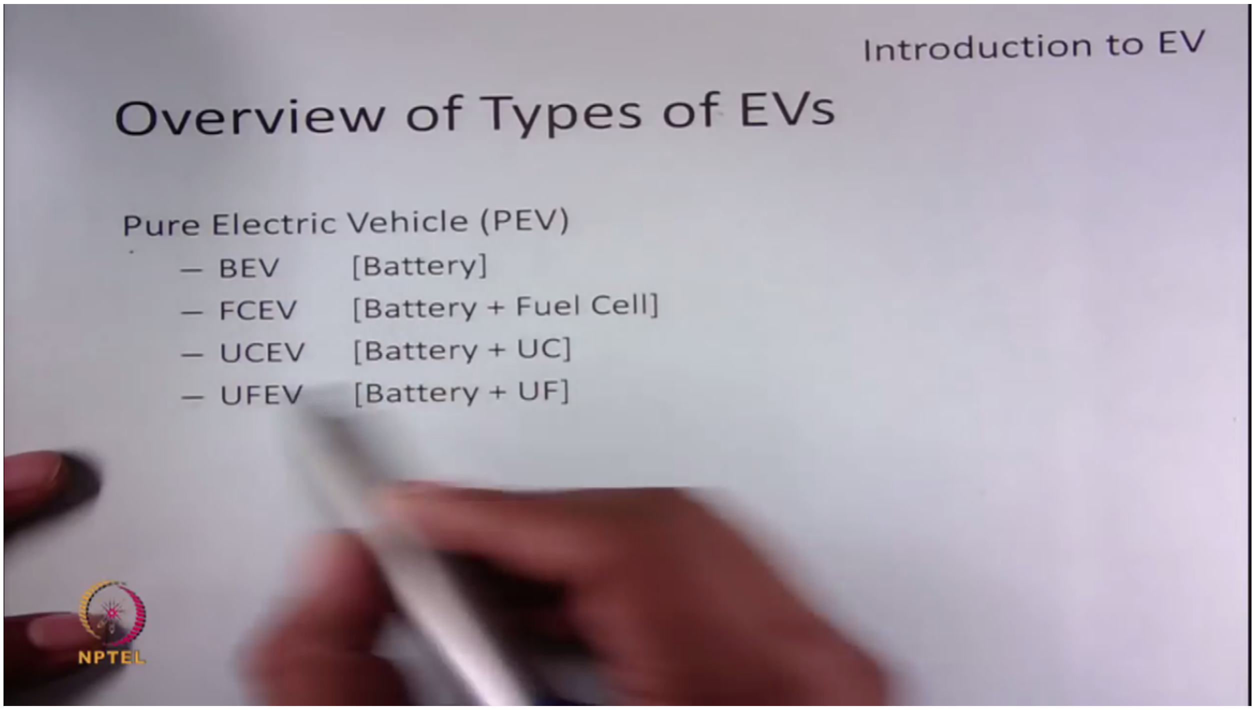
So EVs can be classified in various phase. It can be classified in terms of propulsion devices, or energy sources, or even the energy carriers which are used as medium to transfer energy from energy sources to propulsion devices.



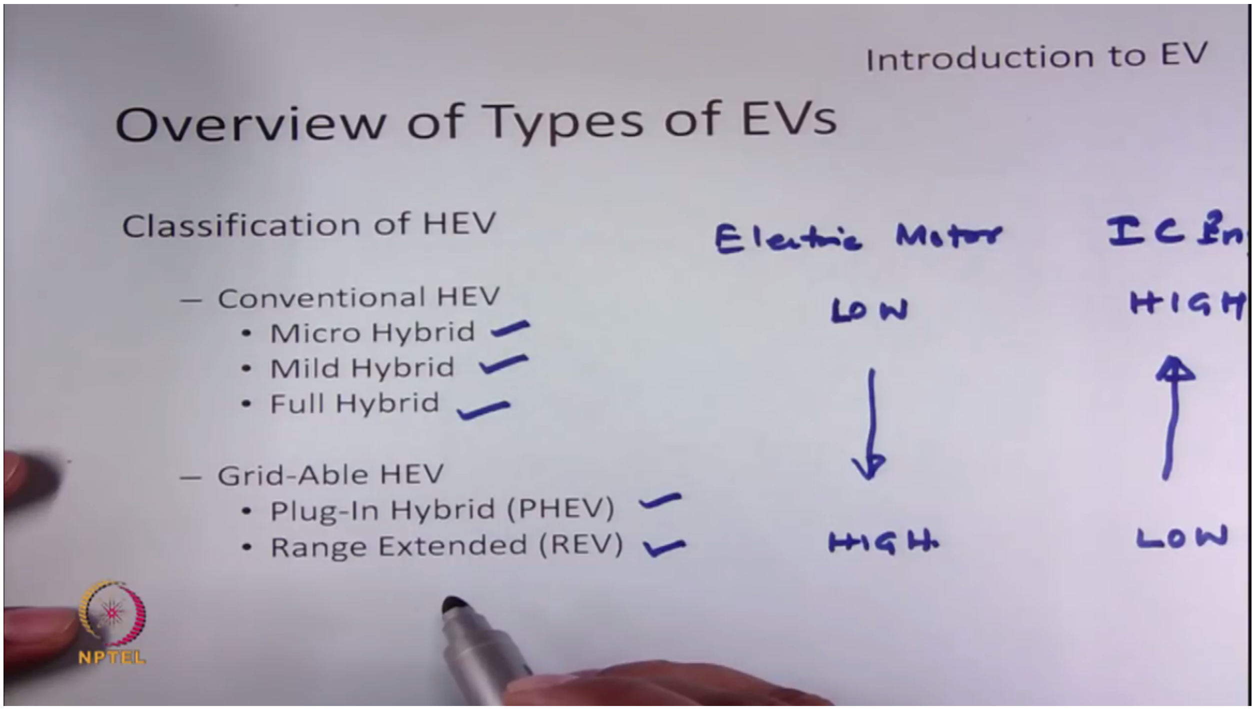
So based on propulsion systems, EVs can be classified as pure electric vehicle or hybrid electric vehicle. A pure electric vehicle uses electric motor as a sole device for propulsion. While in HEV uses both electric motor and IC engine for propulsion. Popularly pure electric vehicles are also known as EVs while HEVs are known as HVs. If we classify the EVs on the basis of energy sources pure electric vehicle will be further classified into battery electric vehicle and fuels electric vehicle. For HEV usage both liquid fuel and energy source while a battery electric vehicle uses battery as a sole energy source.



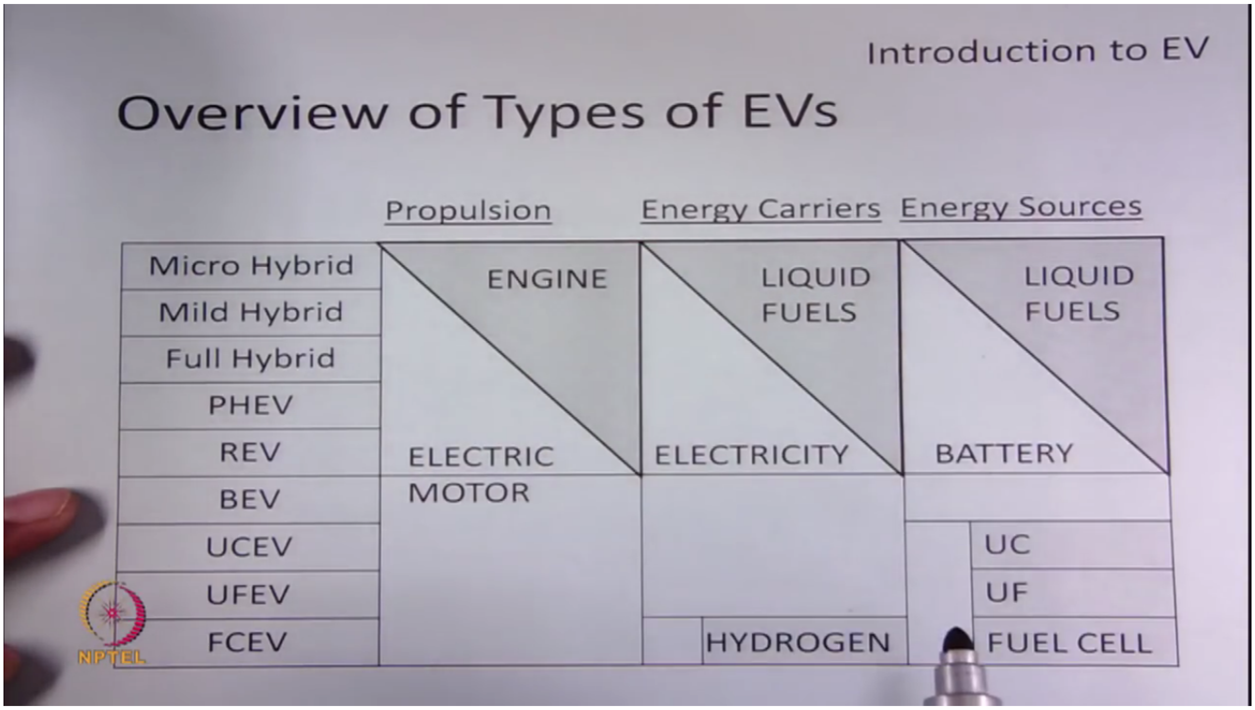
On the other hand a fuel cell electric vehicle uses both battery and fuel cell as energy sources. A similar classification can be done on the basis of energy carriers where the energy carrier for battery is electricity while the energy carrier for a fuel cell is hydrogen.



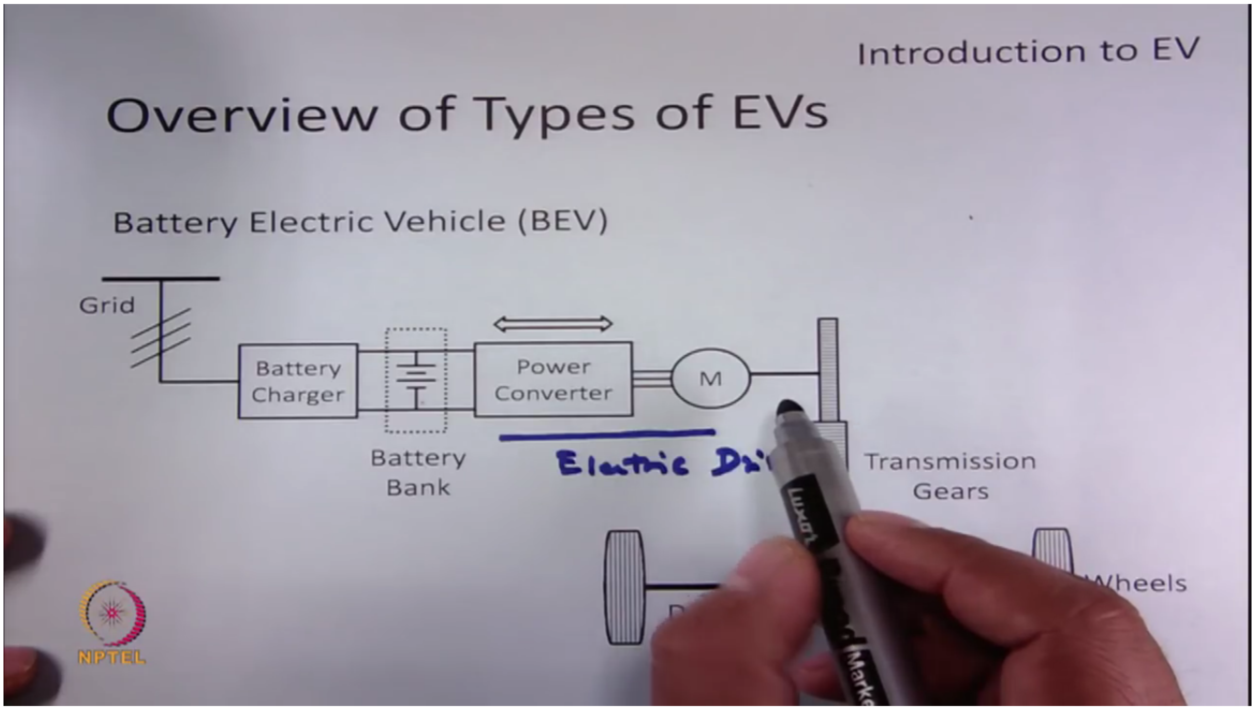
So four types of EVs come under the family of pure electric vehicle. They are battery electric vehicle, fuel cell electric vehicle, ultra-capacitors electric vehicle and ultra-flywheel electric vehicle. In all these vehicles the battery is a common energy source. While a BEV uses battery as sole energy source, Fuel cell electric vehicle, ultra-capacitor electric vehicle and ultra-flywheel electric vehicle uses battery as a hybrid energy source. In a fuel cell electric vehicle battery is primarily used for observing the regenerative power. Since fuel cell is incapable of storing the renewable energy. While in ultra-capacitor and ultra-flywheel based EVs batteries are required for storing energy since ultra-capacitor and ultra-flywheel have very low specific energy. So as we know a hybrid electric vehicle uses both motor and IC engine for propulsion.



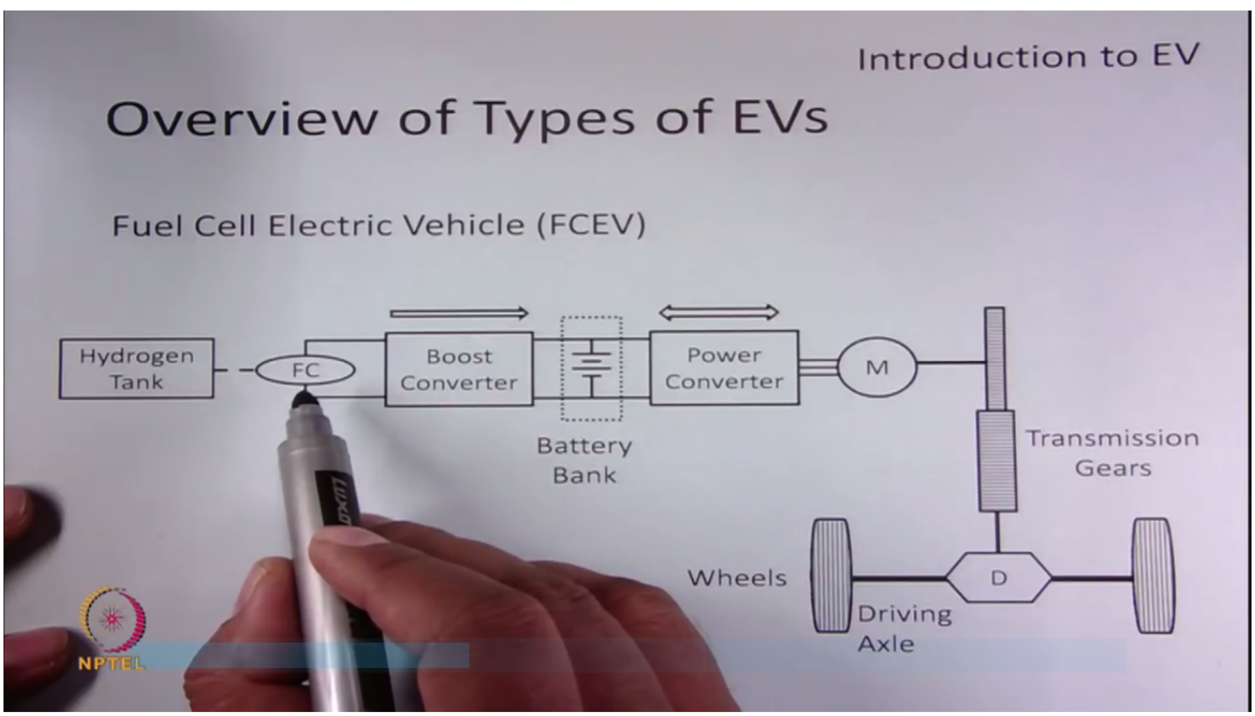
So on the basis of ratio of hybridization between electric motor and IC engine it is classified into five types. Micro hybrid, mild hybrid, full hybrid, plugin hybrid and range extended hybrid electric vehicle. So the rating of electric motor is very low in micro hybrid vehicle and is high in REVs. On the other hand, the rating of IC engine is high in a micro hybrid while it is low in a REV. So micro hybrid, mild hybrid and full hybrid are clubbed and known as conventional hybrid electric vehicle. While plugin hybrid or PHEVs and range extended hybrid which is known as REV are clubbed under grid-able HEVs. So the difference between these two types is that the conventional HEVs can be refueled only at the filling stations or petrol buns. While grid-able HEV can be refueled both electrically and at the filling stations. So a grid-able HEV enables direct charging of battery using charging ports in addition to refueling by liquid fuels at a filling station. So the classification of all types of electric vehicles in terms of propulsion devices energy carries and energy sources is elaborated here.



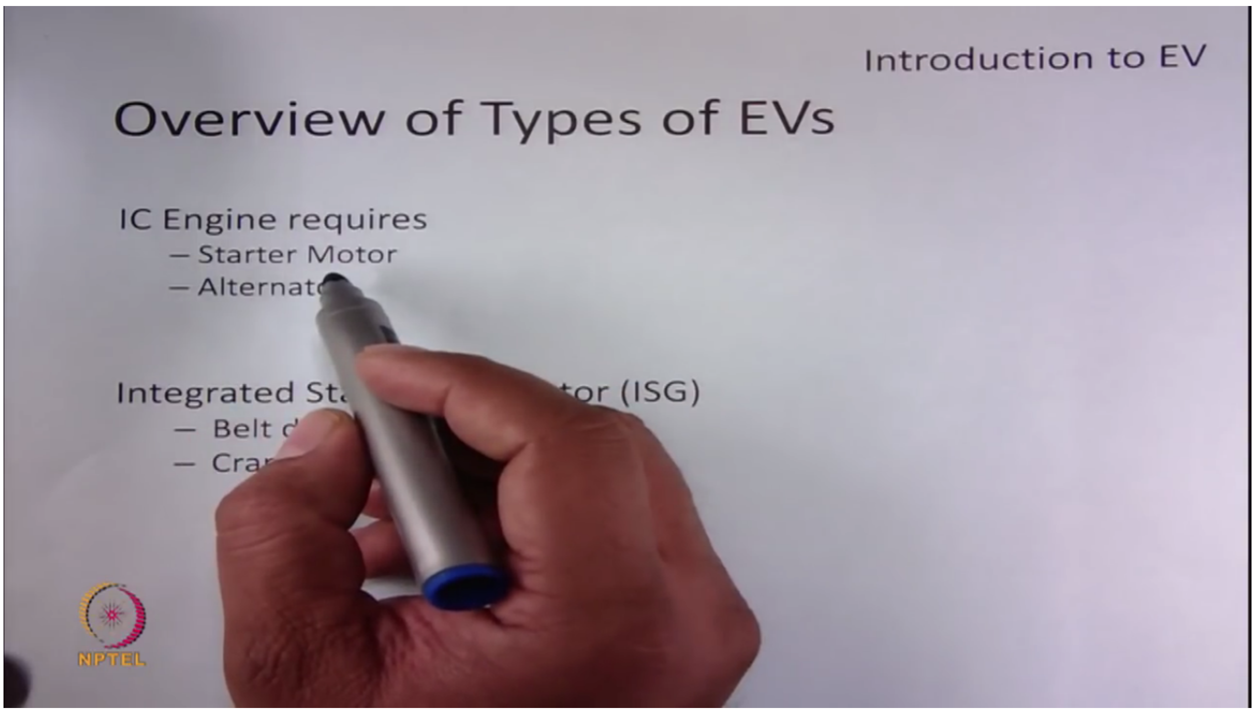
So in terms of propulsion systems a hybrid electric vehicle primarily use an engine and electric motor while a pure electric vehicle uses solely electric motors for propulsion. On the other hand if we classify the EVs on the basis of energy carriers hybrid vehicles uses either liquid fuel electricity as carriers while a pure electric vehicle uses either battery or hydrogen as energy carriers. If we classify the EVs on the basis of energy sources you will see that hybrid vehicles use either liquid fuels or battery as an energy source. While the pure EV uses battery and other types of energy sources alternative are ultra-flywheel fuel cells as energy sources.



The vehicle configuration of a typical battery electric vehicle is elaborated here. So we can see that the battery bank in a BEV is normally charged directly from the grid using a battery charger and the electrical energy stored in the battery is transferred to the wheels using a electric drive consisting of a power converter and electrical machine via transmission gears and driving axle. This power converter has to be designed to carry bidirectional power flow since it can also be used to regenerate the power coming from the wheels during breaking.

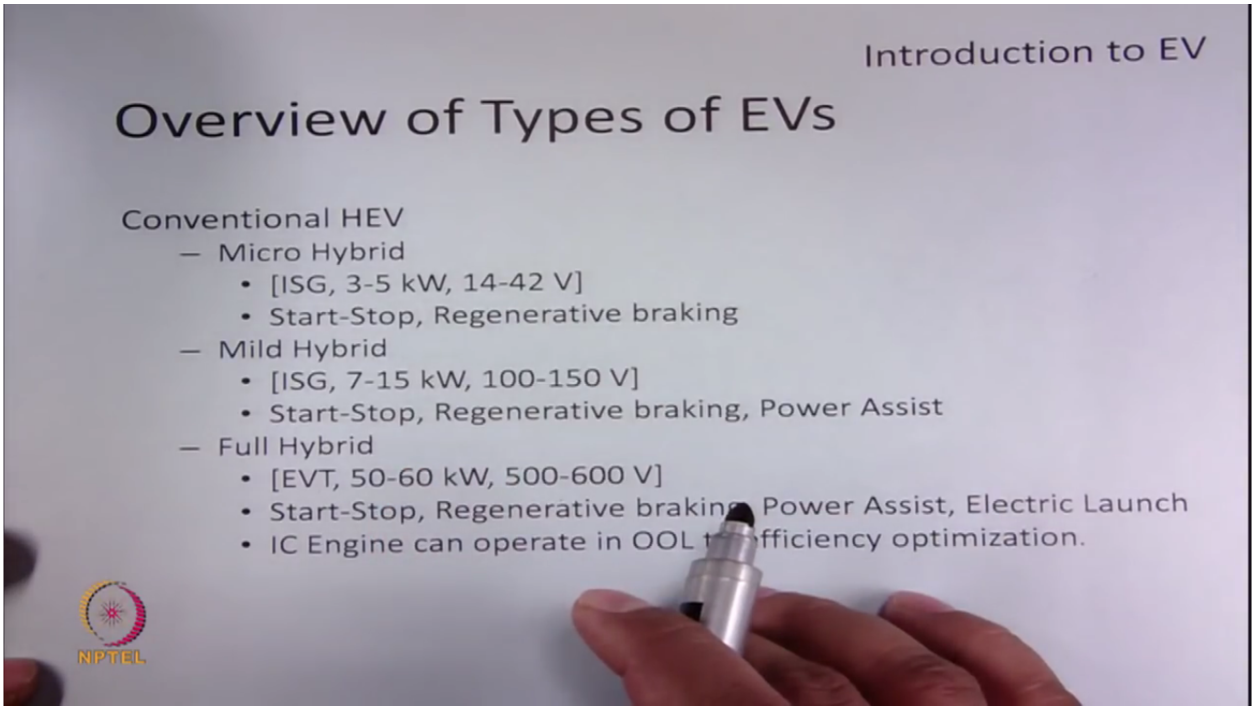


You can also see that the clutch is normally not required in a battery electric vehicle as in conventional IC engine based vehicle. This is the configuration of a typical fuel cell electric vehicle. So it uses fuel cell as a source of energy which is connected to hydrogen tank. A boost converter is required to step up the voltage of the fuel cell to charge the battery and store the energy. And electric drive and the mechanical propulsion system similar to battery electric vehicle. Battery bank enables two purposes. First it allows fuel cell to operate at optimum efficiency. Secondly it can support the transient mechanical energy requirements in the wheels. It can also help to store the regenerative energy coming during breaking since fuel cell is incapable of storing the regenerative energy. As we all know an IC engine requires a starter motor for starting IC engine, an alternator to recharge the battery once the IC engine started functioning. So these two functions can be kept together in a device called integrated starter generator or ISG in short form.



So an ISG in an electrical machine which have been – which can be connected to the IC engine either using a belt driven system or it can be directly mounted to the crankshaft. So what is the role of an ISG?

So it can assist IC engine in various ways. Among the different types of conventional HEVs the micro hybrid, mild hybrid and full hybrid provides and offers different types of capabilities to the system. In a micro hybrid. And ISG of around 3 to 5 kilowatt with a system voltage of 14 to 42 volts is used.



So the ISG supports not only the starting of ICEV engines it can also support the stopping of ISG engine when the vehicle is at rest. So this is known as start, stop feature. So this feature enable fuel economy in each vehicles. Energy can also help in recovery of regenerative power able during braking. Generally this is a low power ISG and they are connected using belt driven systems. In a mild hybrid an ISG if slightly higher rating is used typically 7 to 15 kilowatts with a system voltage of 100 to 150 volts.

So this ISG enables not only start stop feature and regenerative braking but it can also support the IC engine in power sharing during normal operation which means the IC engine rating can be reduced to a little extent.

In a mild hybrid the ISG cannot support a pure electric motor based launching or starting of the vehicle. Different from the operations of micro and mild hybrids a full hybrid offers more versatile operation. The vehicle will operate in IC engine mode along an electric motor, along or in combination of both the IC engine and water together. It requires a complicated transmission system which is known as electronic variable transmission which is generally a high power device of 50 to 60 kilowatt. The system voltage of 500 to 600 volts.

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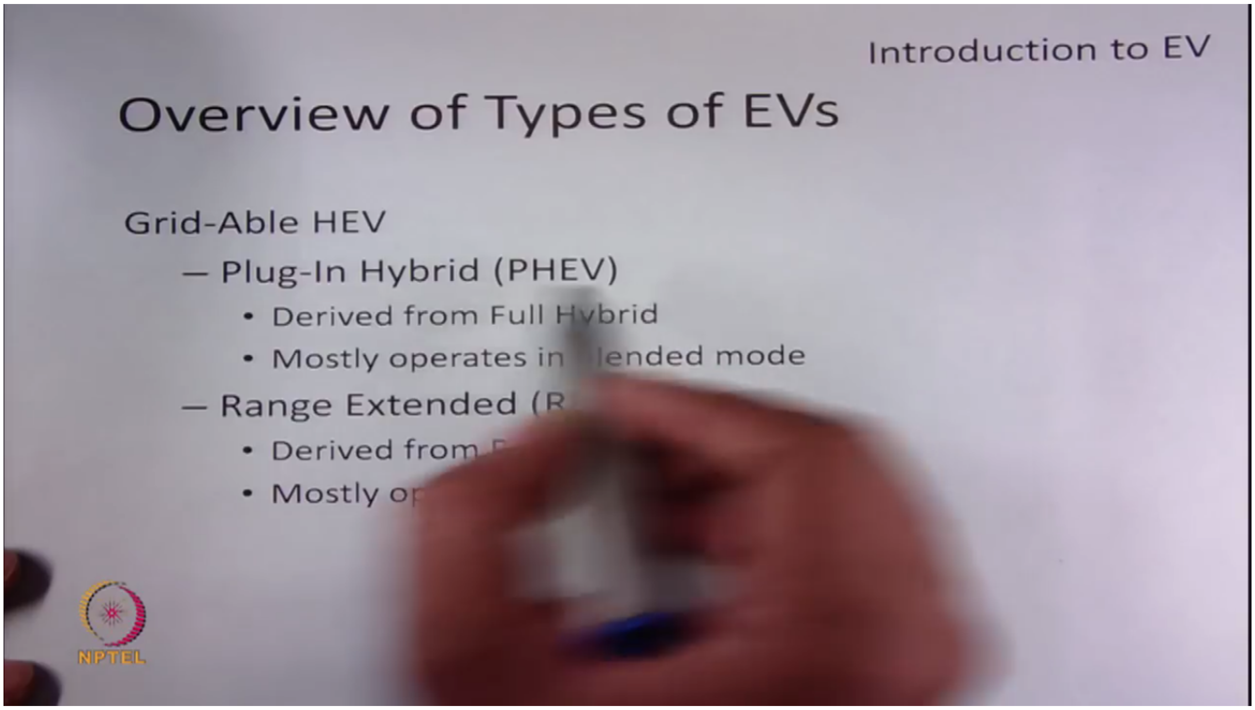
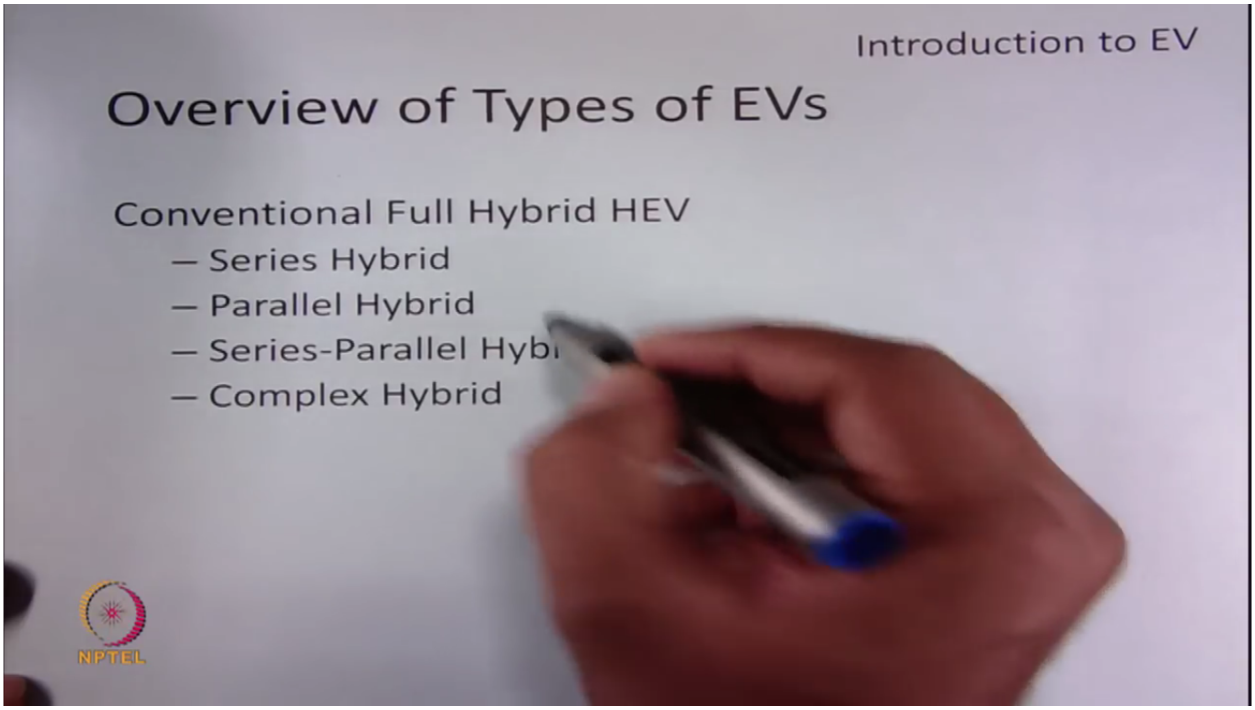
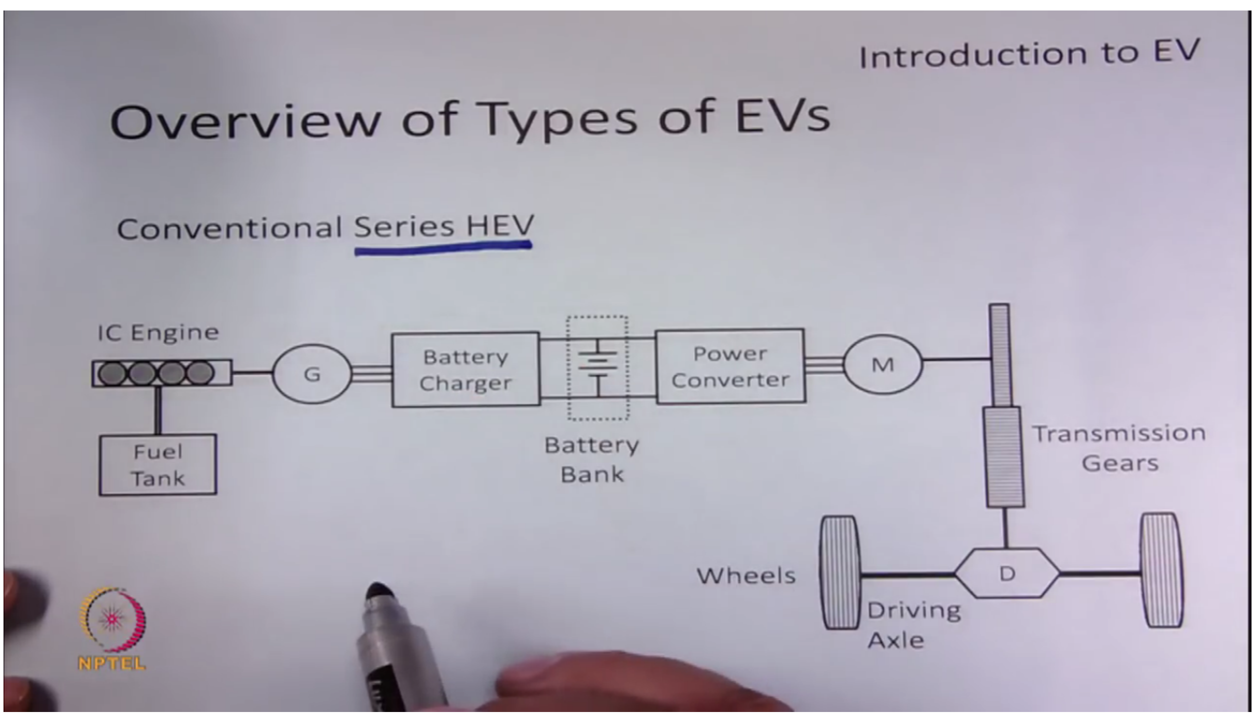
It requires a complicated transmission system which is known as electronic variable transmission which is generally a high power device of 50 to 60 kilowatt with the system voltage of 500 to 600 volts. So this device allow us a connection of IC engine and motor together or in its sole way to the wheels and that allows various kinds of operations possible such as start-stop, regenerative braking, power assist and also electrical launch means a full hybrid can start an all electric board using an electric motor alone.



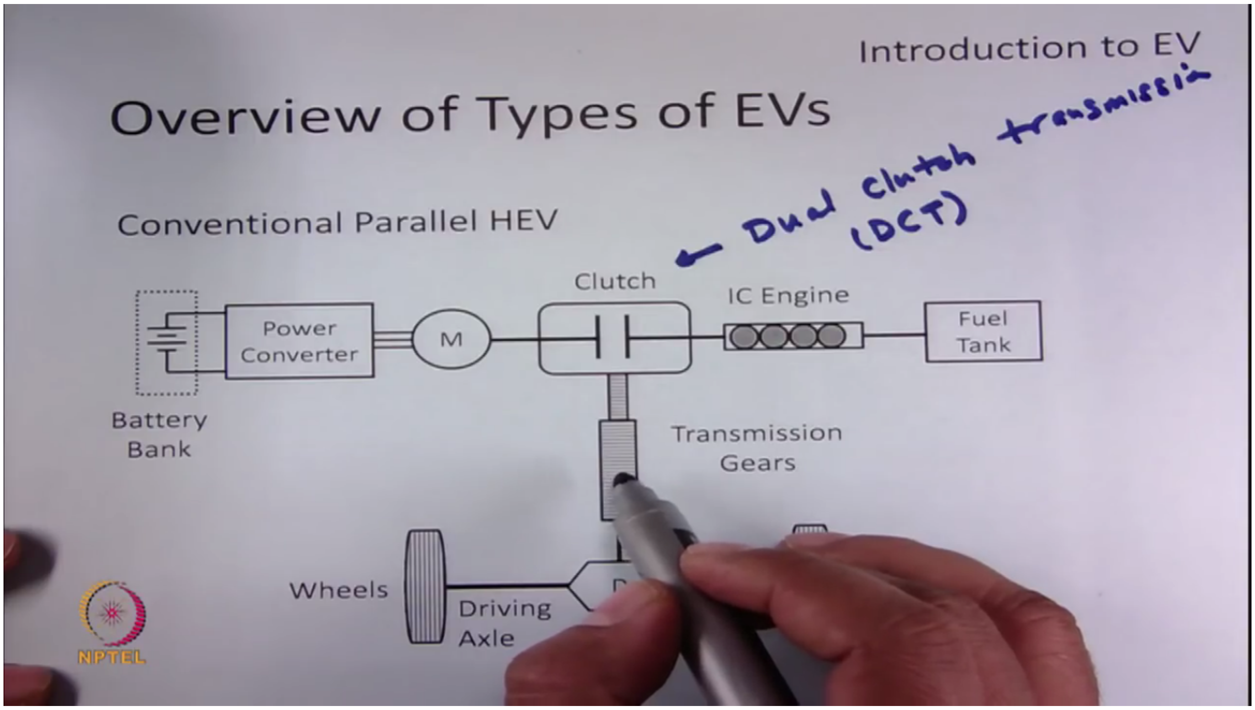
Since full hybrid can work in various modes the IC engine can now operate in high efficiency mode in optimum operation line which is known as OOL in IC engine terminology. So among grid-able HEVs the PHEV Or plugin hybrid vehicle is derived from the configuration of full hybrid. For this system mostly operates in the blended mode the electric motor and IC engine complements each other such a way that the fuel economy is maximum. A PHEV requires a higher battery bank compared to a full hybrid and it can also be charged using charging ports. On the other hand REV or range extended vehicle is derived from a battery electric vehicle. So it mostly operates in pure electric mode with electric motor alone as propulsion device. So it operates in pure electric mode until a threshold of battery pack voltage is reached where it starts the smaller rated IC engine to charge the battery to support the electric motor. A full hybrid HEVs can be further classified into four types series hybrid, parallel hybrid, series-parallel hybrid and a complex hybrid.



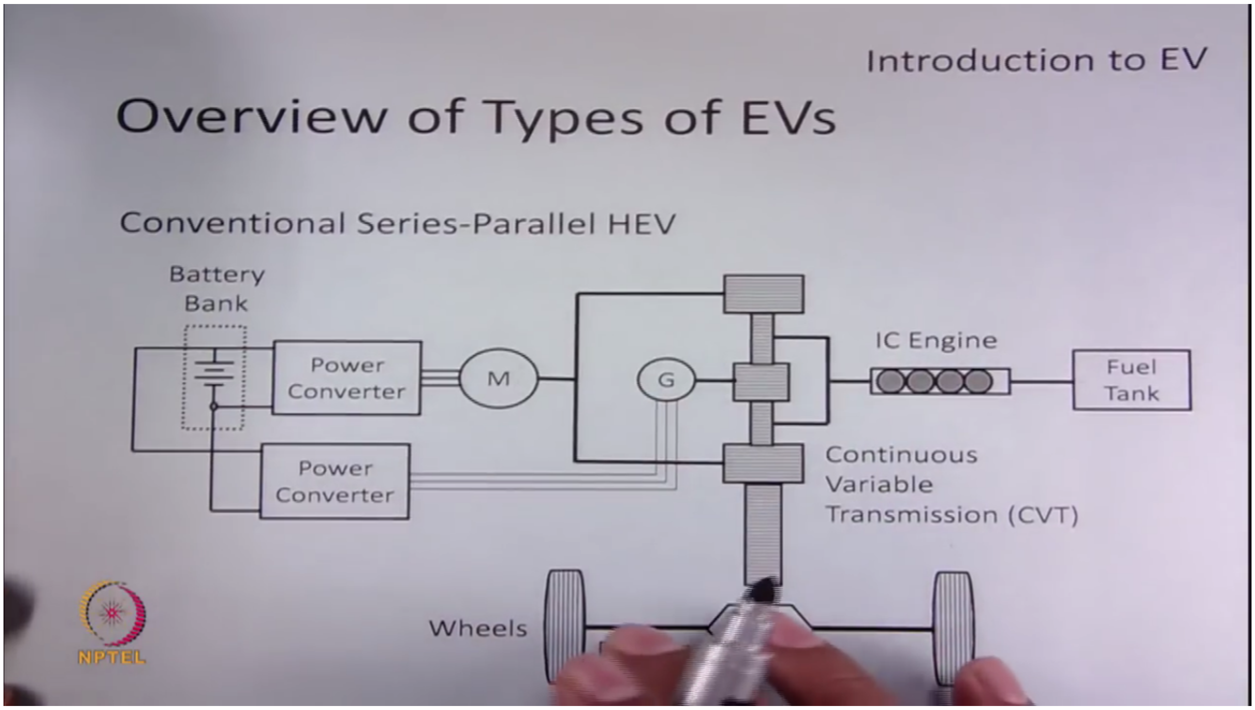
So let us see the configurations of few of them. So this is the configuration of a typical series hybrid electric vehicles where an IC engine is connected to a typical electric drive using a electric generator and a battery charger. So this configuration allows high efficiency operation of IC engine.



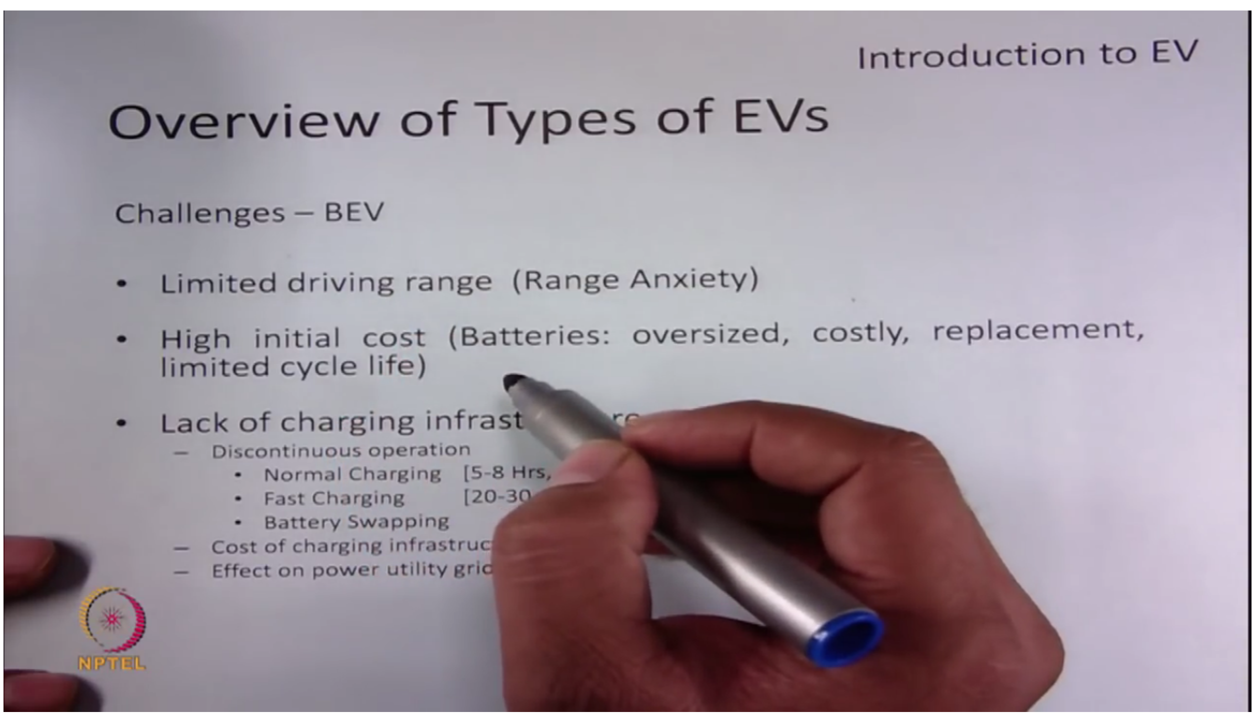
This is the configuration of the conventional parallel HEV where both the IC engine and battery based electric drive is coupled to the transmission system using a clutch known as dual clutch transmission or DCT. So the system offers three modes; an IC engine mode alone. An electric motor mode alone or a combined IC engine and electric motor mode. So the electric motor can not only be used to operate the vehicle it can also be used to recharge the battery during regenerative braking.



This motor can also be used as generator to recharge the battery when the power required at the wheels is less than the power available from the IC engine.



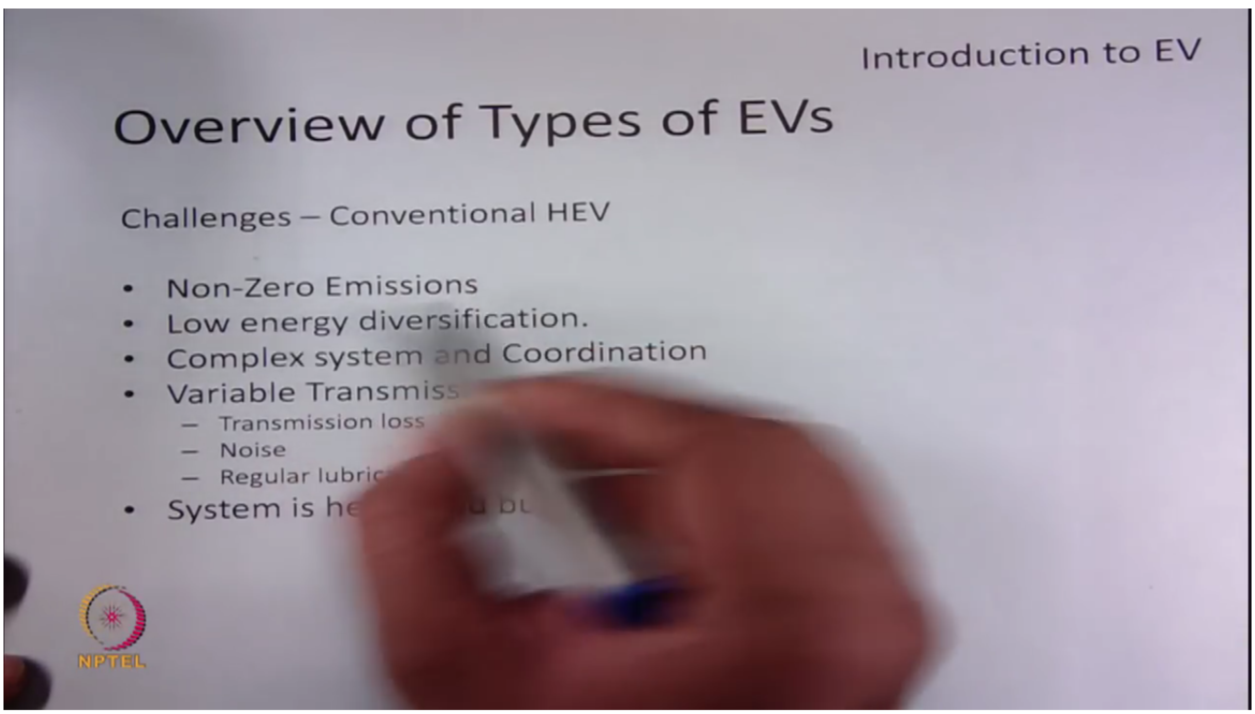
This is a configuration of a typical series-parallel HEV which combines both the features of a series hybrid and a parallel hybrid. Such a configuration is possible only because of a special gearing system which is known as continuously variable transmission system or CVT which allows all the modes of a series hybrid and parallel hybrid together.



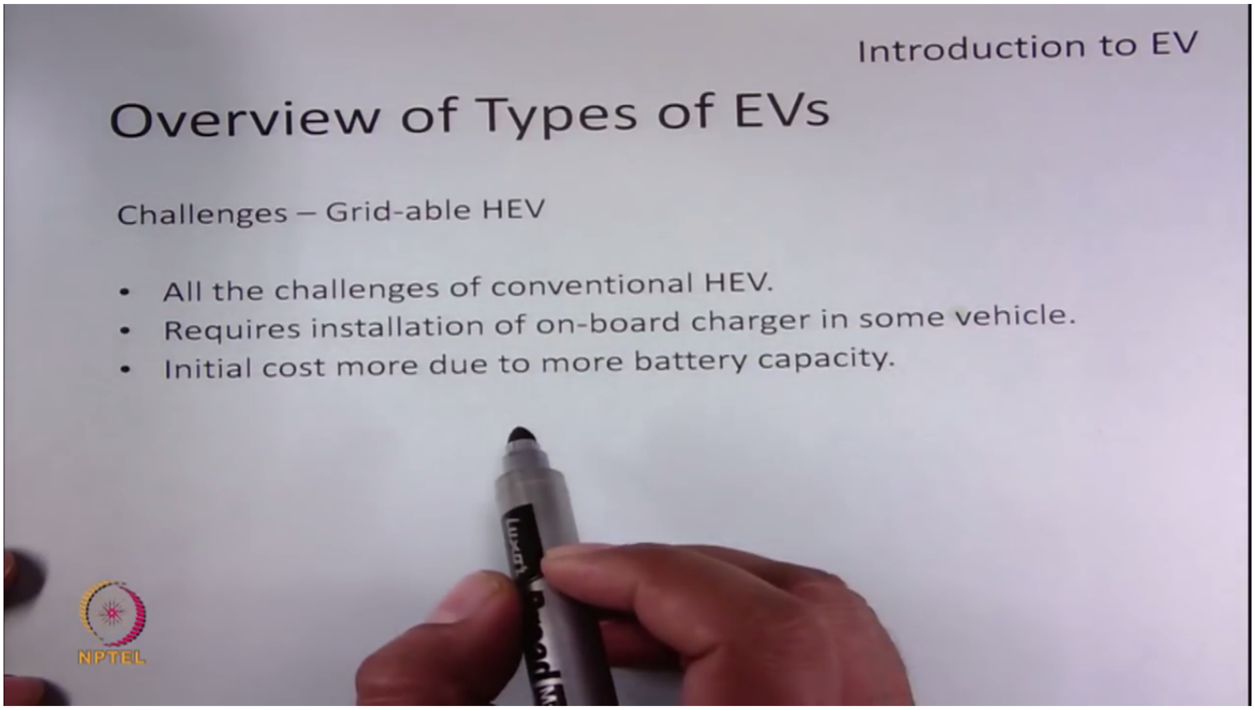
So what are the challenges of a typical battery electric vehicle.? The energy storage capacity of a battery electric vehicle is lower compared to a IC engine based vehicle because of low specific energy and low energy density of battery compared to a liquid fuel. Therefore it offers a limited driving range. For similar conditions it is around 120 kilometers per charge for BEV compared to around 500 kilometres per charge for a IC engine based vehicle. PEV suffers from the problem of range anxiety among customers.

So what is done is more battery banks are used to match the operation of IC engine based vehicles. Therefore it is not only oversized, it is very costly. Also since the battery have a limited cycle life of around 1500 which means four to five years it requires replacement of battery bank in around five years which again increases the cost of battery electric vehicle. The battery electric vehicle also faces the challenge of lack of charging infrastructure compared to a IC engine based vehicles. Charging requirements of BEV lead to this continuous operation of the vehicle. In normal charging it takes around five to eight hours for a typical 110-240 volt 13 to 40 amphers and 2 to 4 kilowatt system but it can be reduced to less than half an hour if you the system which is 200 to 400 volt, 100-200 amps and 50 kilowatt system which is also known as fast charging. These systems put a lot of pressure on the power grid since it is drawing very high currents from the utility grid and it requires a costly charging infrastructure.

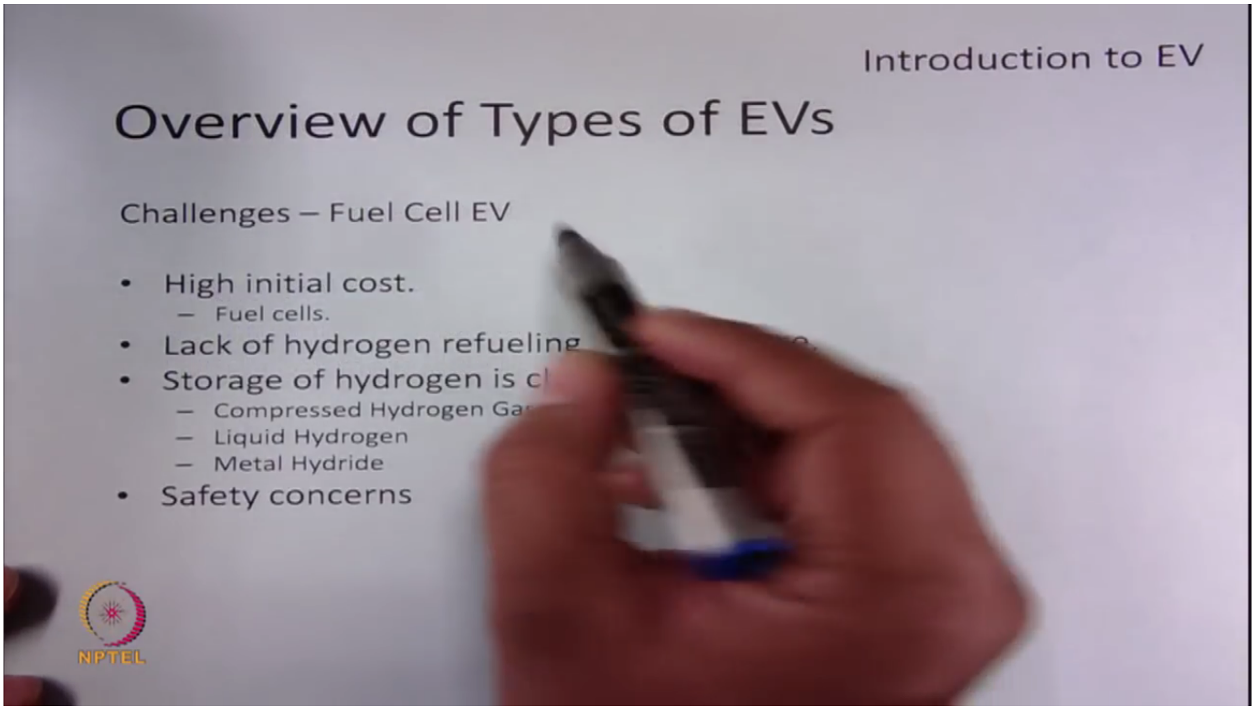
One of the solutions for this is battery swapping technique where the battery bank will be mechanically replaced at a battery swapping station but this solution requires standardization of battery packs and sizes.



A conventional HEV suffers from non-zero emissions, low energy diversification as we know that it can be only refilled using oil and natural gas. The system is very complex and it requires a lot of coordination to achieve fuel economy. It requires a device called variable transmission system which has its own losses. It creates a lot of noise and it requires regular lubrication. The system is quite heavy and also bulky.

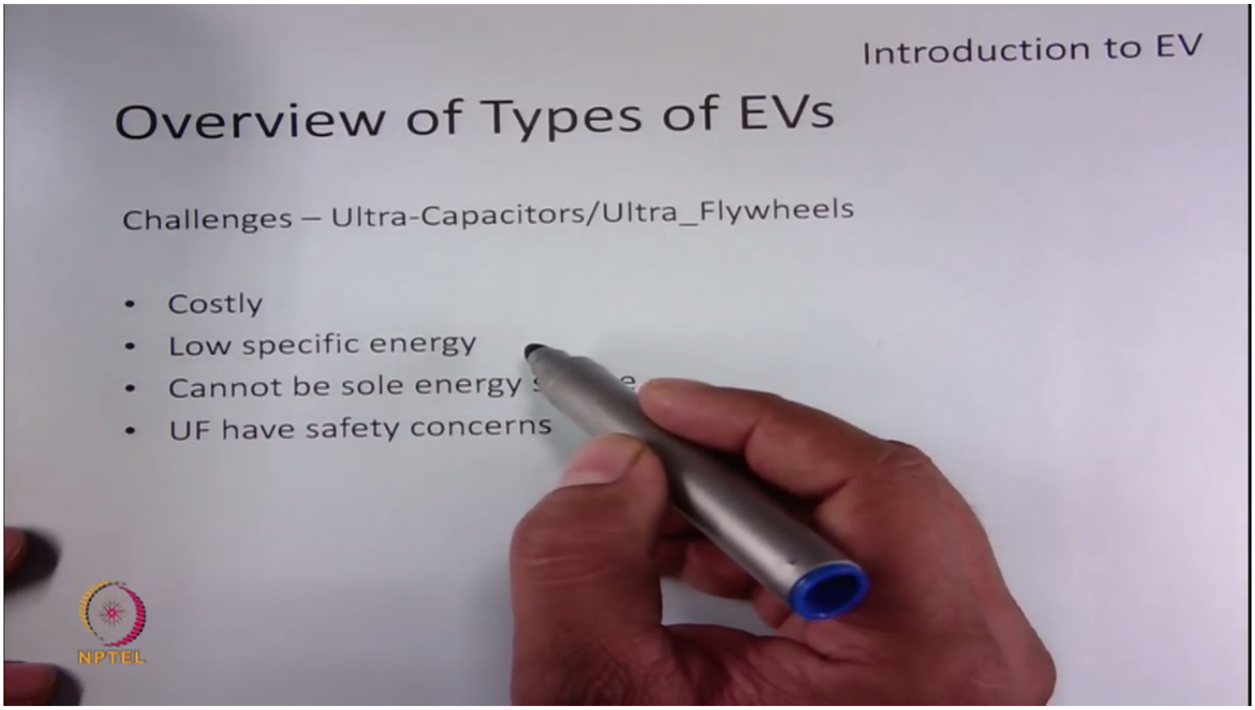


Grid-able HEVs faces all the challenges faced by a conventional HEV that we have seen. It is more costly since it requires more battery capacity. In some vehicles it requires installation of onboard charges also.

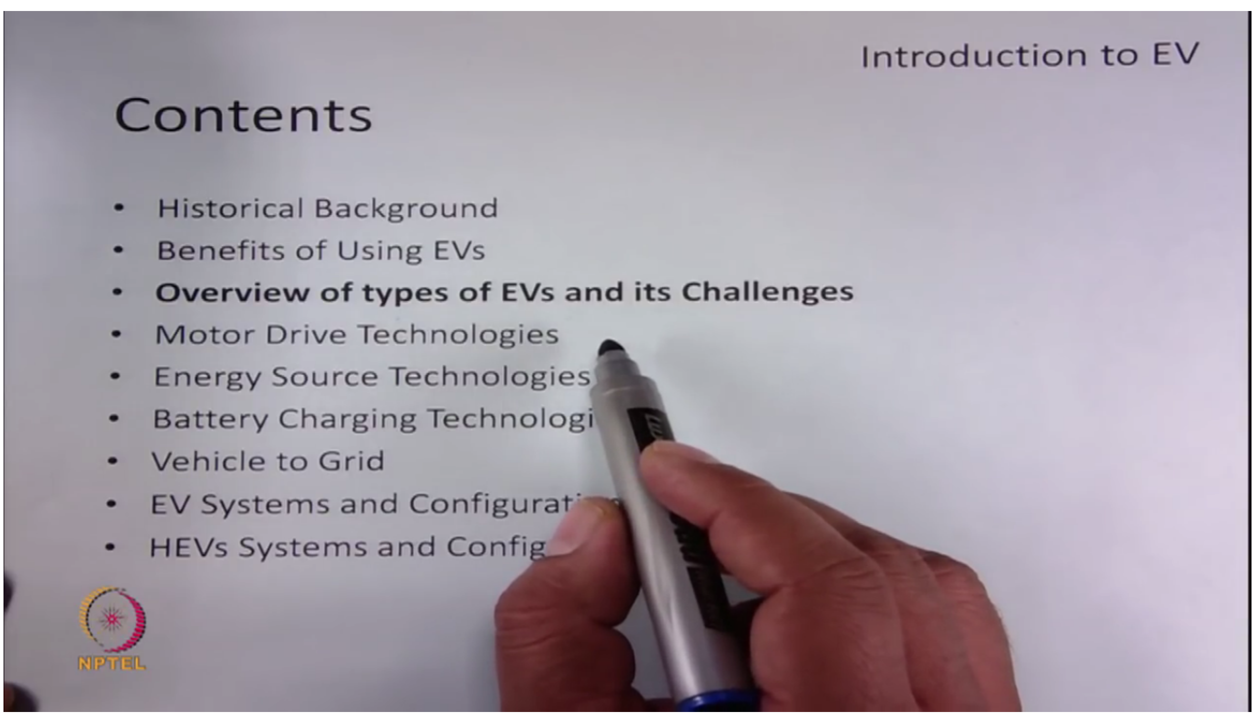


A fuel cell electric vehicle requires a very high initial cost since the cost of fuel cell is very high. It also suffers from a lack of hydrogen refueling infrastructure since it is not commonly available. The storage of hydrogen is is very challenging. There are three ways in which hydrogen can be stored. One is methods similar to CNG which is compressed hydrogen gas. Second is liquid hydrogen. It requires technology similar to cryogenic storage technology which is also costly. It can also be stored in a solid form as metal hydrides.

So this system is very similar to battery swapping. A hydrogen based vehicle has high safety concerns of explosion and therefore it requires lot of safety factors to be in place before it can be commercially viable.



Ultra-capacitor and ultra-flywheel based system are upcoming. The challenges they're facing are it is very costly. It has low specific energy. Therefore it cannot be used as a sole energy source and it requires battery as a hybrid energy source along with it. In addition ultra-flywheel which stores mechanical energy at high speed of flywheels often have safety concern and is less reliable.



So this is the end of session of our topic overview of types of EVs and we will start discussion on our next topic which is motor drive technologies used in EV in our next interaction.

So thank you for listening.