Fundamentals of Automotive Systems
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Module No # 15
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Introduction to Electric and Hybrid Powertrain Part 01

Greetings welcome to today's lecture. So today we are going to have a brief and broad overview of electric powertrains. So we have looked at in great details about conventional IC engine-based powertrains. How IC engine works? What are the characteristics? Why do they need a multi spread geared box? We have also learned how do we calculate the gear ratio of a multi speed gear box based on certain vehicle performance requirements.

So those are topics that we have already discussed in detail. So in today's lecture you know we are just going to learn from a powertrain's perspective what are the features of an electrified powertrain? What do I mean by electrified powertrain? One the where the traction to drive the wheels is provided by an electric motor as opposed to an internal combustion engine in fact if you look back at the history of electric vehicles, electric vehicle technology is not new.

But interest in electric vehicle technology has essentially increased greatly in the recent years due to multiple reasons. What to say main among them being environmental concerns we looked at engine emission right. So if we want to reduce IC engine based emissions and that is also becomes serious with the increasing number of road vehicles. So emissions are a concerned the corresponding environmental impact is also a concern.

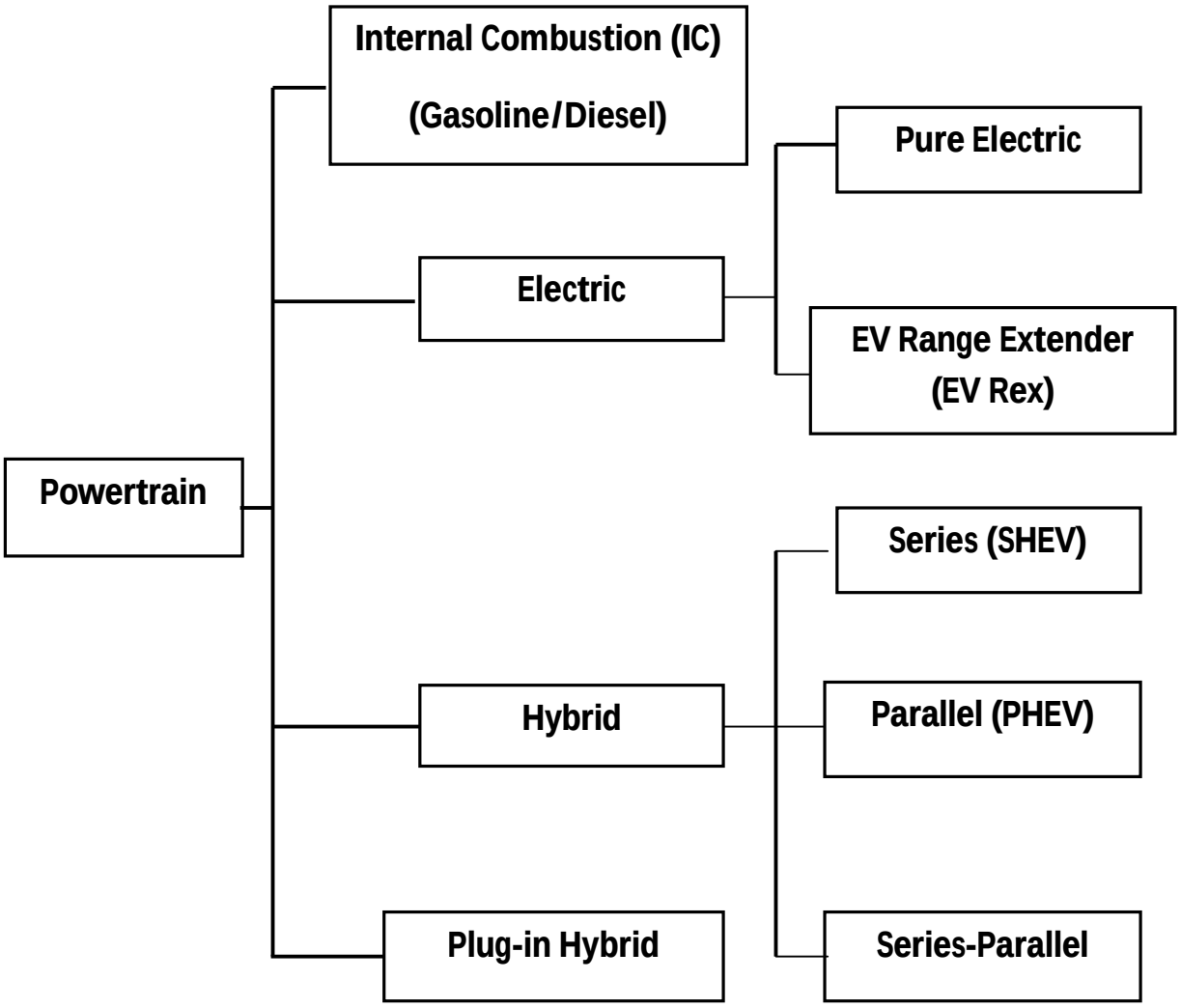
So given those concerns you know like development activities into electric vehicles and hybrid vehicles electric vehicles as accelerated in the recent years. And in today's class we are going to only look at the powertrain perspective. So an electric vehicle today you know like needs to be designed from scratch you know like it is not just simply about replacing the internal combustion engine and transmission by an electric motor drive.

So we need to look at various other aspects. So there are lot of aspect to it because even like the design of a suspension design of the, what to say other components like brake systems you know like also get affected by electrification of the powertrain. But in this lecture we are only going to look at the critical feature of an electric powertrain ok. So that is going to be scope of this particular lecture.

So if you look at it from a powertrain's perspective what are the benefits that we get visa-vis an internal combustion engine right. So in order to identify those benefits please recall that an internal combustion engine typically has a lower efficiency you know like when compared to in its what to day range of operations comparatively an electric motor is going to have a higher range of operating efficiencies ok.

This is going to be a positive attribute from the perspective of energy consumption. So, lower efficiency of internal combustion engine is a one motivating factor. Another motivating factor you know like behind an electric powertrain is the fact that there is a big gap between the torque speed characteristics of an engine visa-vis the ideal traction hyperbola and that was the reason why we need a multi speed gear box to try and reduce that gap right.

So larger gap of the internal combustion engine's powertrain from the ideal traction hyperbola right or requirements ideal traction or requirements and that imply we needed to use a multi speed gearbox. So the question is what happens with an electric powertrain? Ok so before looking at the pure electric powertrain let us understand the classes of various powertrain choices that are available and their configurations you know. So let us look at what we can refer to as a classification of electrified powertrains ok.



CLASSIFICATION OF POWERTRAIN

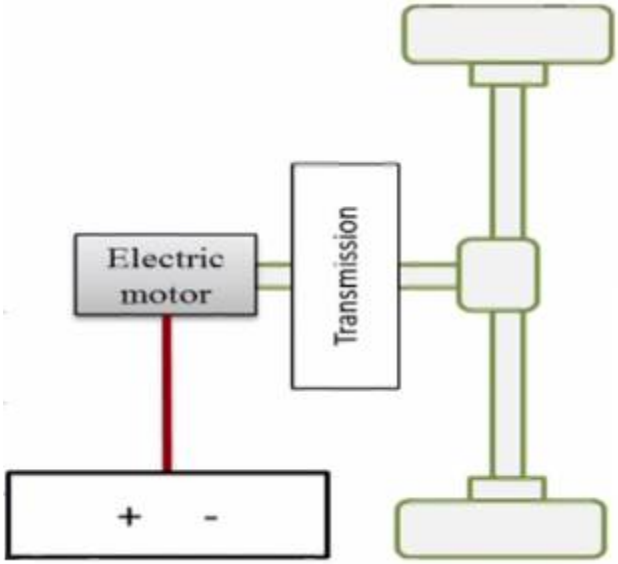
So based on the components and used and their configuration you know like one can essentially have a broad category of powertrains. So if we look at this schematic right so we have you know the conventional internal combustion engine you know like which are gasoline engines and diesel engines right and powertrain based up on them or something which we already discussed. If you consider the pure electric powertrain of course the electric powertrain can be divided into two broad categories what is called as a pure electric that is only an electric motor drives the wheels.

And we have what is called as an electric vehicle with the range extender ok. So we will shortly see what that is. Then we can have what are called as hybrid. So what is a hybrid powertrain? A hybrid powertrain is powered by two or more prime movers ok. See for example an electric motor and internal combustion engine right. So that is a hybrid powertrain. So a hybrid electric powertrain or a hybrid electric vehicle has typically an electric motor and an internal combustion engine as the two prime movers ok driving the wheels.

Then there are various configuration of this hybrid electric powertrain ok we will shortly look at the configuration what is called as a series hybrid, a parallel hybrid and a series parallel hybrid ok. So one also has what is called as a plug in hybrid where the battery is also recharged by connecting to the electric grid ok in addition to other features that we will shortly see about the remaining hybrid configuration ok.

So the question then becomes you know like what are the aspects or what are the characteristic of these various configurations and under what scenarios and under what requirement would one choose these various configurations right. To understand that let us look at these configurations to begin with.

So let us consider a pure electric powertrain ok. So what is the pure electric powertrain if we look at a simple schematic of a pure electric powertrain.



PURE ELECTRIC

So it essentially has an electric motor driving the wheels you know like through a transmission you know like so let say so we can observe that there is an track what is called as a traction motor. So, typically when the electric motor is utilized to provide the energy required for driving the vehicle.

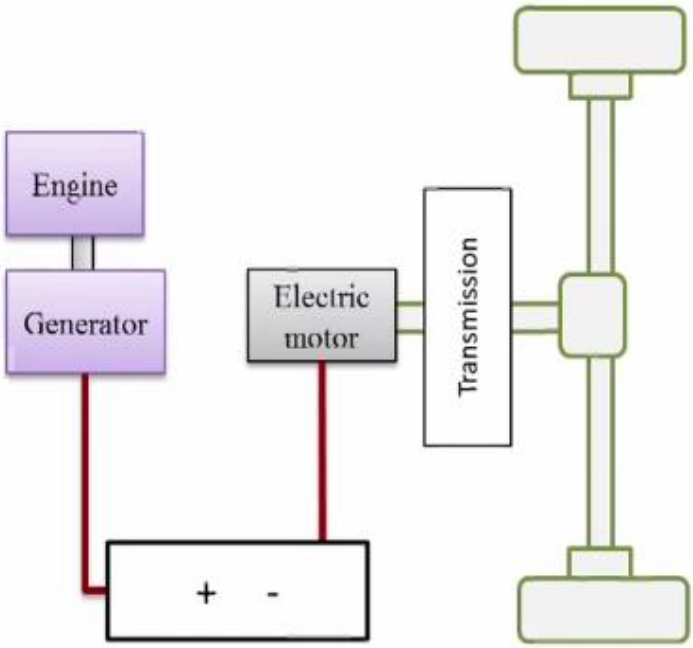
We referred to those motors as traction motors. So we can observe that the battery is the energy source and that provides energy to the traction motor and the traction motor then uses the mechanical transmission and then drives the wheels. So, a few important characteristics of pure electric vehicle is that like we do not use any fossil fuel right, it implies that there is no tail pipe emission. So that is an important feature and we will shortly observe that electric motors can provide the higher torque at lower speeds and during starting.

So that is going to result in higher accelerations ok higher vehicle longitudinal accelerations. So; faster acceleration of the vehicle due to higher starting torque so that is another advantage. So what are issues? So such pure electrics are suitable for you know vehicles you know where the energy consumption is also low.

So that like we can have a reasonable size of the battery but however with increasing vehicles sizes we need to have a correspondingly larger energy source which in this case is a battery ok. So there is a tradeoff you know like in having a pure electric vehicle for all classes of vehicles ok. So the main issue that one needs to consider is the range of the electric vehicle. So what do I mean by range? Range is the distance travel between two successive charging cycles right.

We charge the battery completely and then we discharge it completely you know like then what is the range you know like or what is the distance in kilometer or miles that the vehicle has travelled ok. So that is the range. So charging time is another issue that one needs to look at. And of course battery life and cost are other issue that the people need to consider. You know while choosing an pure electric ok.

So to address a pure electric vehicle limitations we have electric powertrains or electric vehicle with what are called as range extender. So what is range a extender or a EV with a range extender. So here we can observe that in the wheels are still driven by the electric motor. You know like one could observe from the schematic that the electric motor still drives the wheel. So that is the traction motor ok. So the electric motor obtains its energy from the battery and that is used for driving wheels as before.

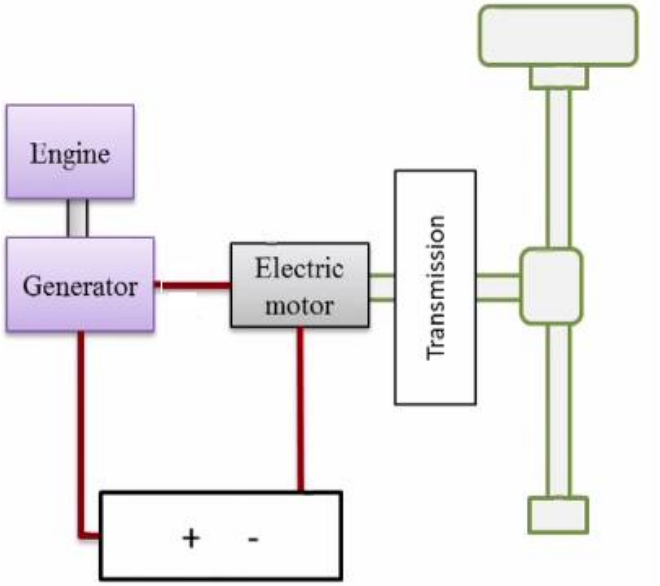


EV WITH RANGE EXTENDER – EV Rex

But the only difference now is that like the batteries is also charged by using an engine through a generator ok. So the purpose of this engine you know like it is essentially to charge a battery. And typically, these engines you know like are not going we have as high rating as they would have if they were power the vehicle. So they are downsized engine whose specific objective is only to powering the, or recharge the battery through the generator.

And the way also they are controlled is since their only task is to recharge the battery not to drive the vehicle they can be operated under condition where the engine gives its peak efficiency. So that like the energy is utilized properly right. So that is an electric vehicle with a range extender. So, essentially an engine driven generator recharges the battery when required ok. So consequently, range is better when compare to the pure electric ok and recharging time is reduced.

But what is the limitation here we can observe that due to the presence of an internal combustion engine tail pipe emission is present and of course the cost is more right when compare to a pure electric vehicle because of the present of the engine and the generator ok. So the initial cost is more. So we have tail pipe emission here ok in the electric vehicle with range extender.



SERIES HYBRID ELECTRIC VEHICLE – (SHEV)

So consequently, you know like one can also consider hybrid electric powertrains ok those are available options. Wherein you know like we try to match the positive aspects of both the internal combustion engine and the electric motor. Rather than using them separately you know that is the idea. So if you look at various configuration of hybrid electric vehicle so the first one is what is called as a series hybrid powertrain. So what is this a series hybrid powertrain or electric vehicle.

So we can observe from the schematic that in a series hybrid electric vehicle typically abbreviated as SHEV ok. So there is an engine which can do two things right it can drive the wheels through this traction motor when required or it can recharge the battery when required or do both ok depending on the scenario ok. So

that is the purpose of the engine. The engine does not drive the wheels directly the traction motor is the one which drives the wheel through the transmission ok.

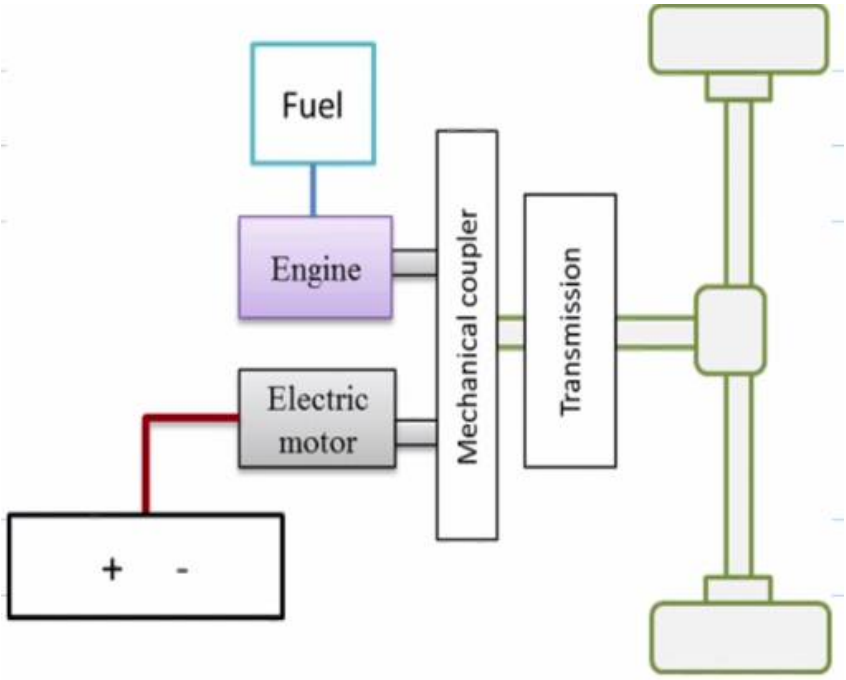
But the traction motor can get its energy by either from the battery or from the internal combustion engine through the generator ok. So those are the critical aspects of the series hybrid electric vehicle. So in a series hybrid electric vehicle the electric motor or the traction motor drives the wheels and the engine driven generator can charge the battery or power the electric motor ok or do both. So that is the role of the engine driven generator.

And if you look at other hybrid electric vehicle configurations you know compared with other HEV configurations ok. So SHEV has a simpler transmission and controller ok. So that is the one advantage and also this is well suited for frequent start-stop driving. So like one that we encounter in urban traffic right. So essentially, we stop at signals and then start you know like there are traffic jams you know like we need to stop the vehicle and then restart and so on right. So in those conditions this SHEV is relatively better.

So there are a few limitations so one major limitation is the larger and heavier traction motor which is used because please note that the vehicle is still what to say driven by the traction motor. So consequently, the traction motor needs to be of sufficiently high rating to drive the vehicle ok. So that is an issue with a series hybrid electric vehicle ok.

So now the next configuration that we would be looking at is what is called as the parallel hybrid electric vehicle. So in this series hybrid electric vehicle only the motor directly drives the wheel ok. So but in a parallel hybrid electric vehicle; both the motor and the internal combustion engine can be used to drive the wheels. So

that is kind wheel one of the main attributes or features of the parallel hybrid electric vehicle.



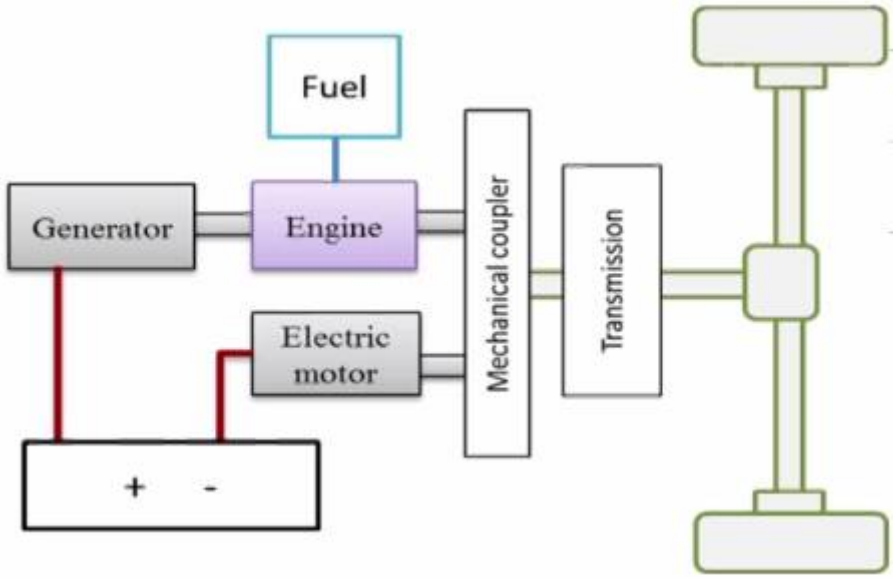
PARALLEL HYBRID VEHICLE – (PHEV)

So we can observe that in this vehicle both the engine and the traction motor can drive the wheels ok can power the wheels through this mechanical coupling system. So that is an advantage. But compared to a SHEV obviously the initial cost and complexity or more and the fact that the transmission also becomes a little bit complex than a SHEV because it has to accommodate 2 different prime movers ok.

So those are some features of a parallel hybrid electric vehicle. So the wheels are driven by both the engine and the traction motor ok. So, one advantage is that of course we need a smaller traction motor compared to a SHEV right. So we do not want because since the task of driving the vehicle is also shared by the engine we need a smaller traction motor compared with SHEV that is an advantage.

And this can work well in cruising also relative to SHEV right. And a limitation is a complex controller and transmission when compared with SHEV. So of course, all this we are comparing with the other hybrid electric vehicle configuration right. So those are some features of a parallel hybrid electric vehicle.

So, now if one wants to combine the features of both the series hybrid electric powertrain and the parallel hybrid so then one obtain what is called as a series parallel hybrid electric vehicle ok. What is this abbreviated as SPHEV ok so that is another configuration. So let us look at a simple schematic to understand what a series parallel hybrid electric vehicle is? So in this series parallel hybrid electric vehicle we could observe that the engine drives a wheels the motor also can be used to drive the wheels.



SERIES PARALLEL HYBRID ELECTRIC VEHICLE – (SPHEV)

But now we can immediately observe that there is one more attribute the engine can also recharge the battery through a generator ok. So, one can observe that in a certain sense it combines the desirable attributes of both a series hybrid powertrain and a parallel hybrid powertrain. Like in a parallel hybrid powertrain the engine

and the electric motor can drive the wheels like in a series hybrid the engine can charge the battery through a generator ok.

So the IC engine what to say essentially can be used to drive the wheels directly and charge the battery. If you recall in a series hybrid the IC engine could drive only through the electric motor ok not directly right. So that is the difference. Of course this results in increased flexibility of operation so we can have more modes of operation depending on the operating state of the vehicle. But however it is extremely complex and expensive right among the hybrid electric vehicle configuration obviously right.

So those are some limitations of a series parallel hybrid electric vehicle. So these are various hybrid electric vehicle configuration of course electrics and hybrid electric vehicle configurations and some features associated with them.

The next topic which I am going to discuss is about the electric powertrain ok. So let us now look at the electric powertrain and discuss some of its features relevant for powertrain application and perform some basic analysis ok so that is going to be the objective. So if we look at an electric powertrain there are, some major systems ok in an electric powertrain. So, one is obviously about the propulsion using the electric motor.

So this system has traction motor, the transmission, the driven wheels ok and the corresponding power electronics and controllers right as its components ok. That is what is called as a electric motor propulsion system and we have the energy source system. So the energy source essentially; consist of the energy storage let say in the form of batteries right and then we have an energy management unit which regulates the energy supply to the motor system.

And then like we have also components for recharging and refueling right the energy source ok. So those are important requirements ok important components ok of an energy source. So by and large you know like we are going to be using batteries but there are other choices like an ultra-capacitor fuel cell to power these powertrains also.