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NPTEL ONLINE CERTIFICATION COURSE

Video Course on

Electric Vehicles Part 1

By
Prof. Amit Kumar Jain
Department of Electrical Engineering
IIT Delhi

Lecture # 9

Intro HEV Subsystems and Configurations

Hello everyone, welcome to the NPTEL online course and electric vehicles.
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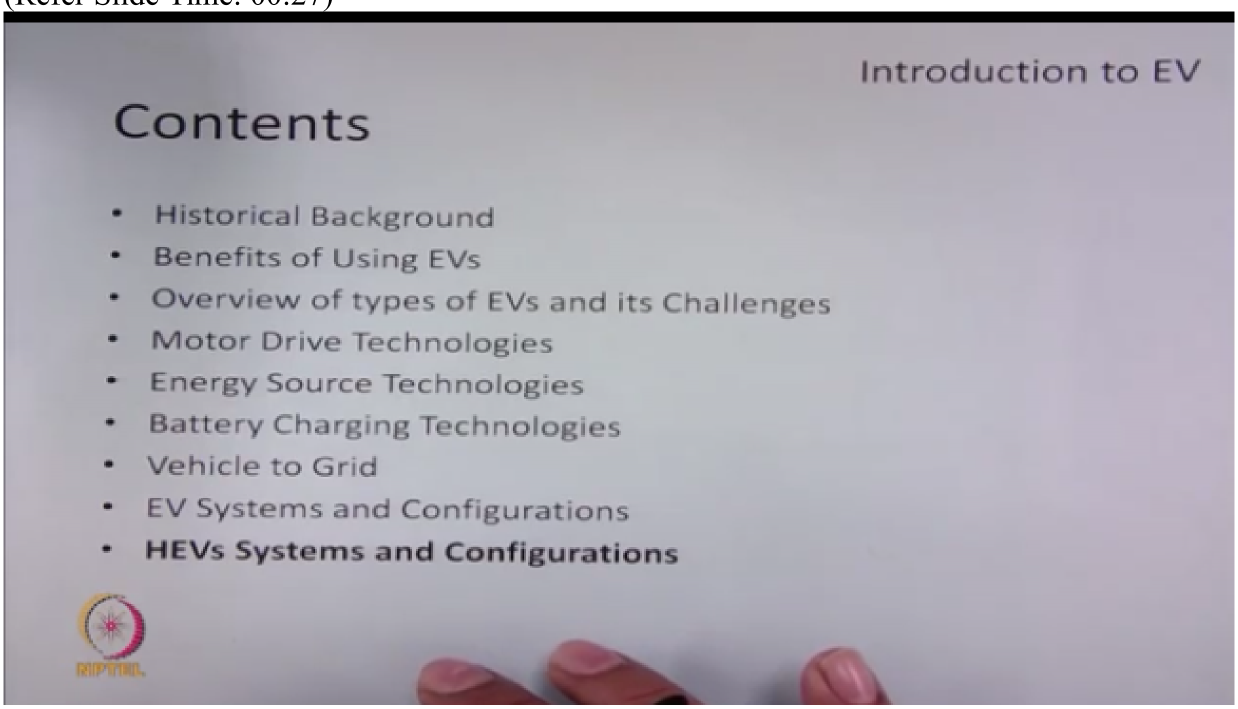

Let us discuss the next topic under introduction to EV which is hybrid electric vehicle systems and their configurations.
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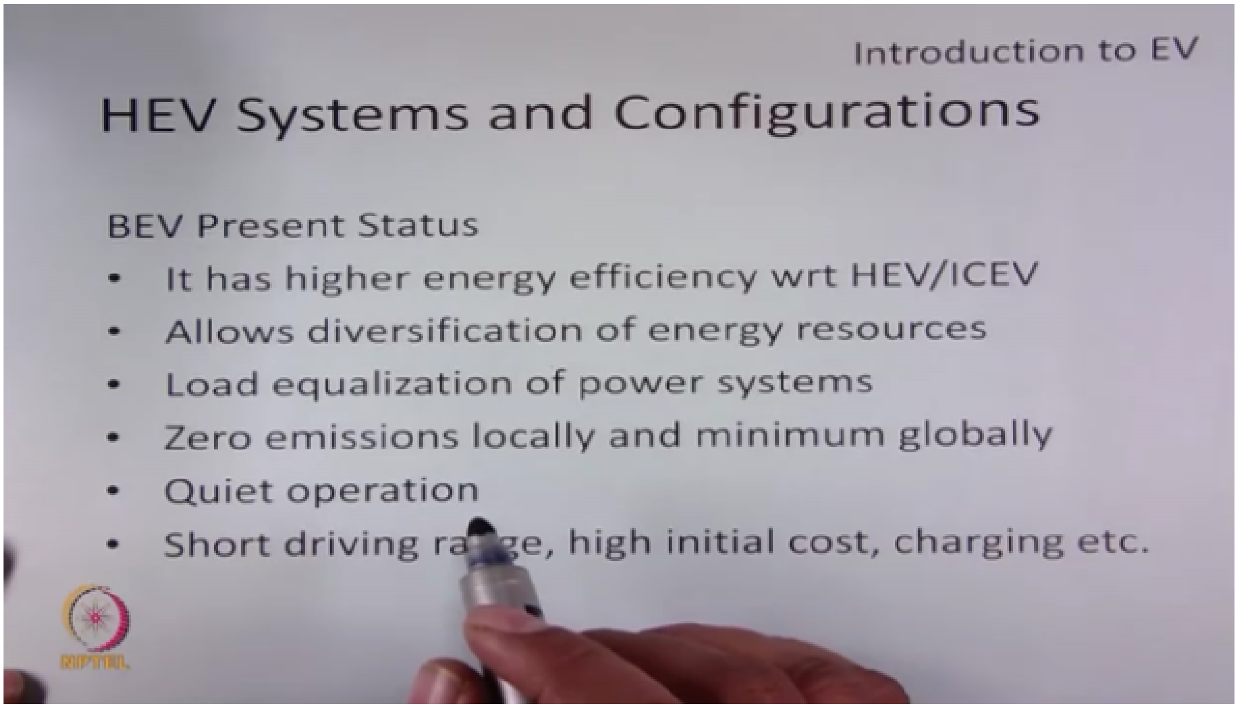

So that electric vehicle is one of the most promising technology for road transport, it is due to many reasons, it has higher energy efficiency compare to hybrid electric vehicle or IC engine based vehicles, it allows diversification of energy resources, means the electricity needed to charge the batteries can be obtained by oil, gas, coal, and all the renewable sources such as solar, wind etcetera.

Under V2G operation it supports power system for load equalization, so it can support peak shaving during peak load demand or it can support coordinating charging during night hours or light load, so it has a zero emission vehicle, and it creates very less emissions even globally, so when the electricity used for charging the battery it drive from thermal power plants, then there is a possibility of SO2 gas emissions, but otherwise if large part of charging energy is drive from renewable energy then it is totally a zero emission vehicle.

So it's a very quiet operation possibly in BEV, so IC engine based vehicles are typically noisy, so the main drawback which is hindering the success of BEV or short driving range, so we all know that the energy content that can be stored in a vehicle using batteries and other resources is very low, so you cannot drive a very high driving range using a BEV, so the battery cost is high and if you use a large energy content using lot of batteries, then it is also costly.

Secondly we require a battery replacement after cycle life of maybe 5 years, which is again adding to the cost of electric vehicles. Charging as we have seen is a another very important thing for a BEV, so battery needs charging and that also causes you know charging time to be available to the customer, secondly the requirement of charging infrastructure which is not there at present in the large scale as compared to the filling stations for IC engine based vehicles, so all these limitations are hindering the growth of BEV as a mass electric vehicle.

So what is the solution? So hybridization of resources is one of the key element which is generally looked in to,
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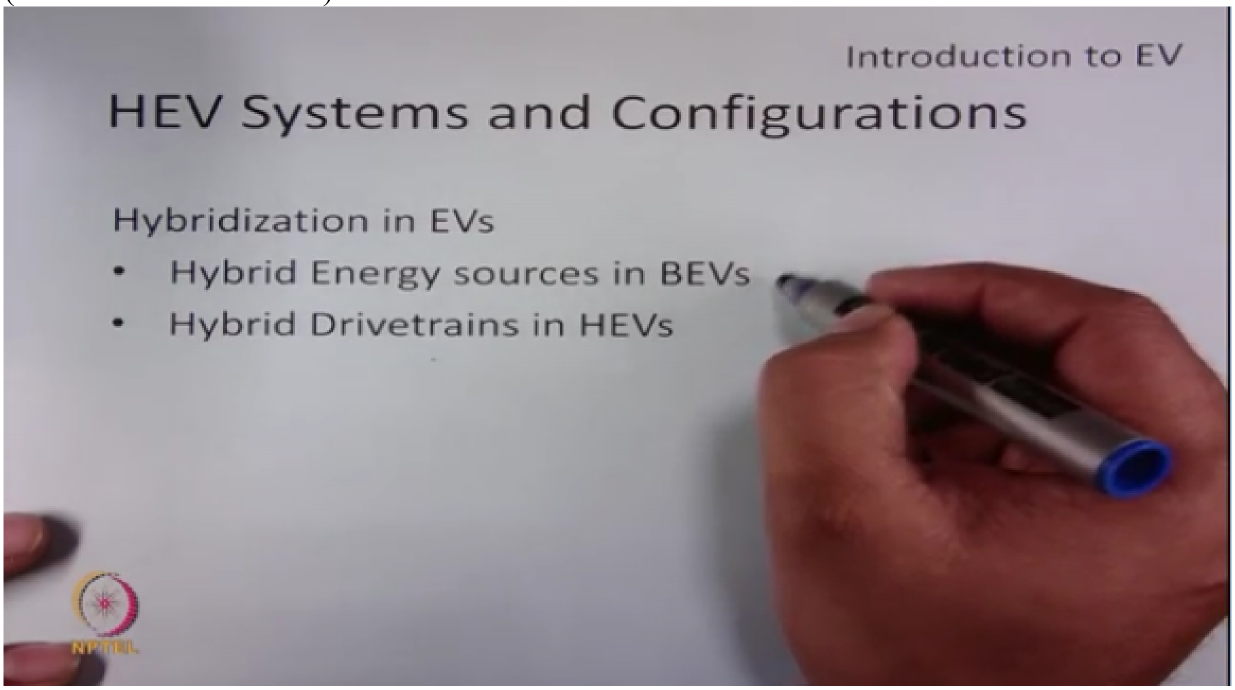

so we have already seen that there is a possibility of using one or more energy resources within a BEV, so we have explored that if you use fuel cell which is high specific energy and ultra-flywheel which is high specific power or other things together is possible to increase the driving range, and even get a performance similar to IC engine based vehicle.

But the limitations what you've seen in a battery driven vehicle still remains, so therefore we have to look for another alternative which can solve those drawbacks, so another option is why can't we go for hybridization of drivetrains, means is possible to connect the IC engine based vehicle and is drivetrain to the drivetrain of an EV such that we can get better performance for IC engine based vehicle together with solving the limitations of battery electric vehicle, so this is interim solution and it maybe a quick solution to solve for fuel economy of IC engine based vehicle together with less emissions causing pollution and health hazards.

So what an hybrid electric vehicle can do?
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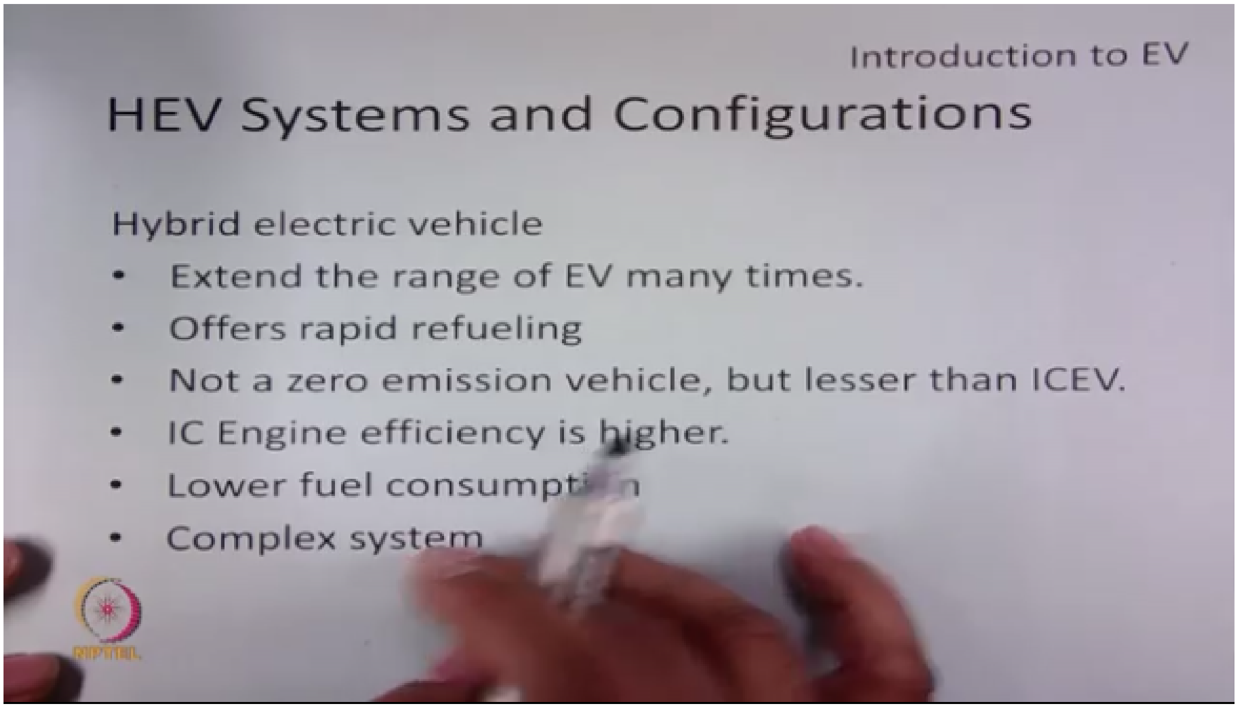

A hybrid electric vehicle which is a hybrid vehicle that utilizes both the IC engine and electric motor within a same vehicle, so since the IC engine based propulsion is attached to the hybrid electric vehicle, the range excelity will not exist anymore.

Secondly since we have filling stations which can readily give petrol or diesel for the vehicle, so the fueling infrastructure is also taken care of, and we need limited resources for battery charging, so it is not a zero emission vehicle, but the emissions are lesser than a fuel IC engine based vehicle.

In addition we can see that now the IC engine efficiency maybe better, and it may be taking less fuel for driving the total vehicle, so the only price we have to pay is now the system will be complex and it has to be handled properly such that all this benefits can be obtained, so in a hybrid electric vehicle we are combining the efficiencies of a IC engine based vehicle and a battery electric vehicle.

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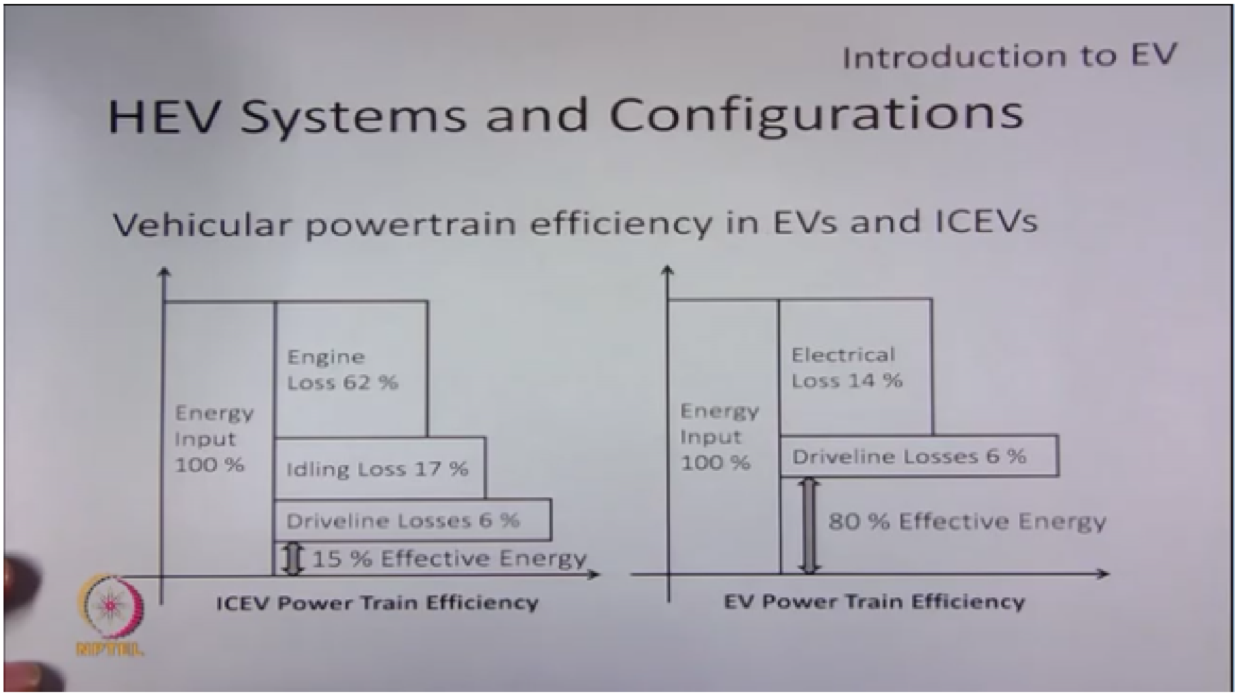

So let us see the powertrain efficiency of individual IC engine based vehicle and electric vehicle, so in a IC engine based vehicle if we assume a energy input of 100%, the major loss happens as heat energy, so 62% of the energy input to IC engine is wasted as heat energy.

Secondly a good amount of loss which is 17% happens when the IC engine is left idling, so this is required because the IC engine is not able to start and stop at very frequent times, so that the efficiency is best, so we have a mechanical losses which are known as driveline losses of 6% in a IC engine based vehicle, so in totality we can see that the effective energy which is available in the shaft is only 15%.

If we see the similar thing in a EV powertrain and if we start with energy input of 100%, a EV powertrain generally faces a electrical loss of around 14%, and a driveway line losses which is 6%, so it can be even lesser or if we use a you know very high performance EV which doesn't have gears or which doesn't have a differential, so it can be even lesser, so typically we get the effective energy utilization of 80% which is very high compared to a IC engine based vehicle.

So when we combine this two things in a common vehicle or a same vehicle which we are not terming as a hybrid electric vehicle, we have to see that how the losses of the IC engine based powertrain can be minimized, so there is a scope of improving the engine efficiency because it is not alone now, there is a support of EV motor.

Secondly can we do something for decreasing the loss due to idling operation,
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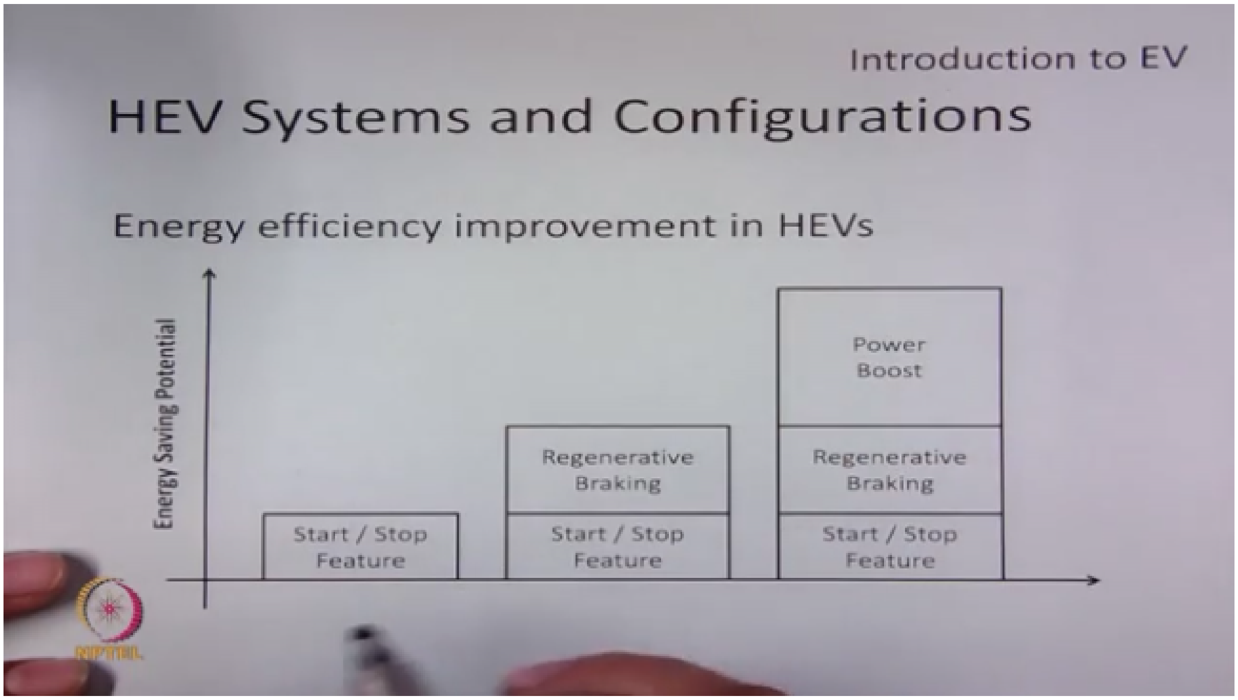

so the energy efficiency improvement is possible in a IC engine based powertrain by incorporating a feature which is known as start stop feature, so the engine is no longer needed to occupied link, and it can be stopped whenever supposed to, so this feature enables 6% saving an energy, in a hybrid electric vehicle there is also a possibility to store the regenerative braking energy, so this can add another 6% to the energy savings and we can say that if we have this two features, roughly we are saving 12% of the energy.

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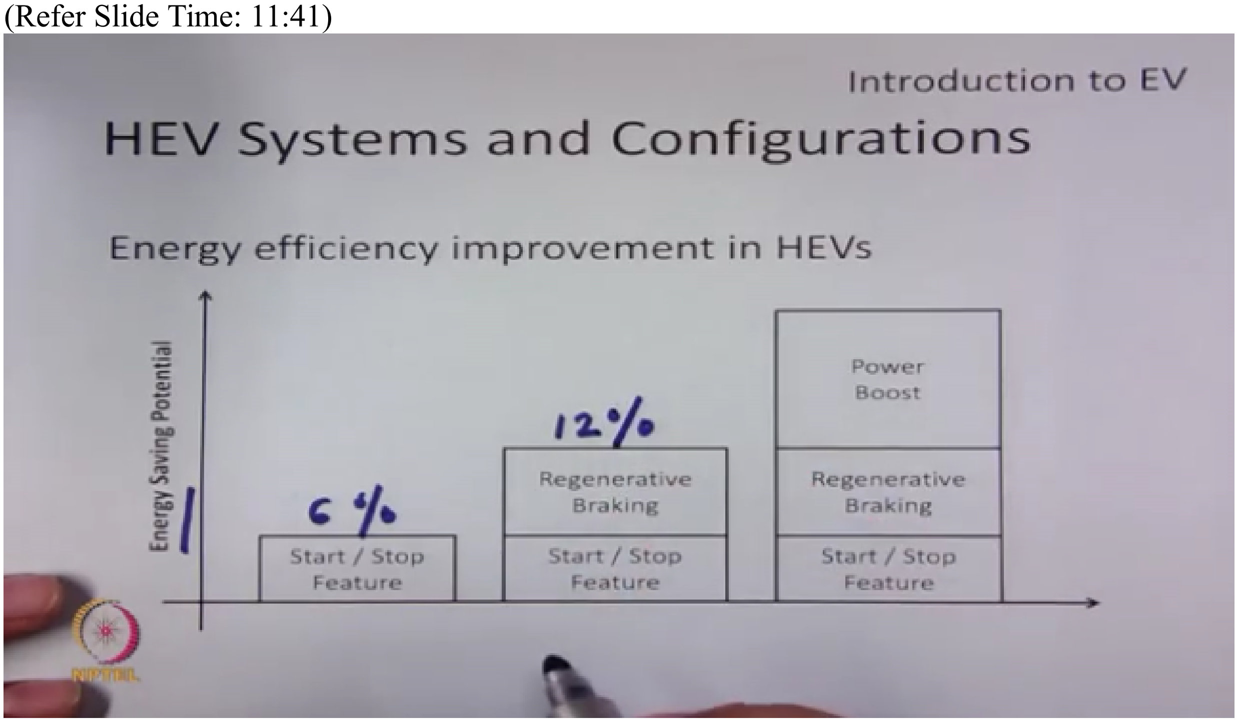

As we have said earlier the IC engine has a major loss component as heat energy, this is due to the inefficient operation of IC engine, so this can be improved by operating the electric motor such that the IC engine can now operate at its best efficiency, so there is also possibility to increase another 15 to 20% and it's possible to get energy saving in the range of 25 to 30%,

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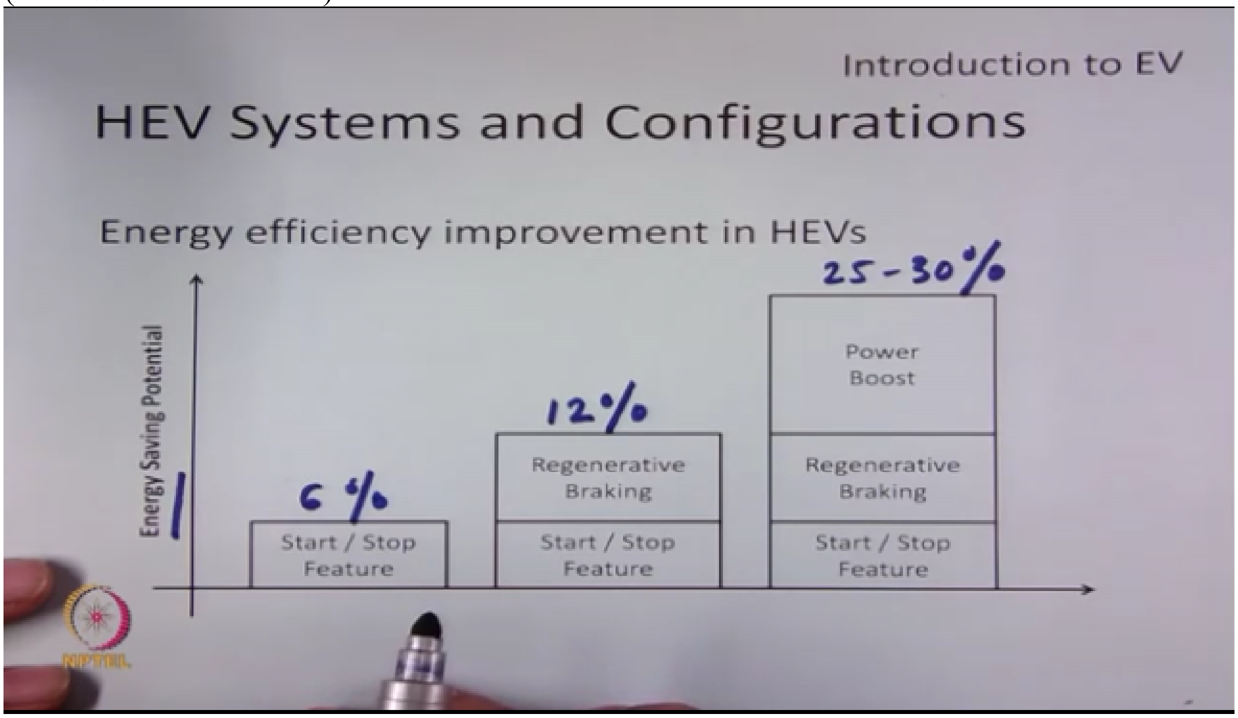

so we can say that incorporating EV powertrain with a IC engine based powertrain improve the energy sprint the vehicle by around 30%, so as a data shows this kind of energy saving is even better for a urban driving compared to a highway driving.

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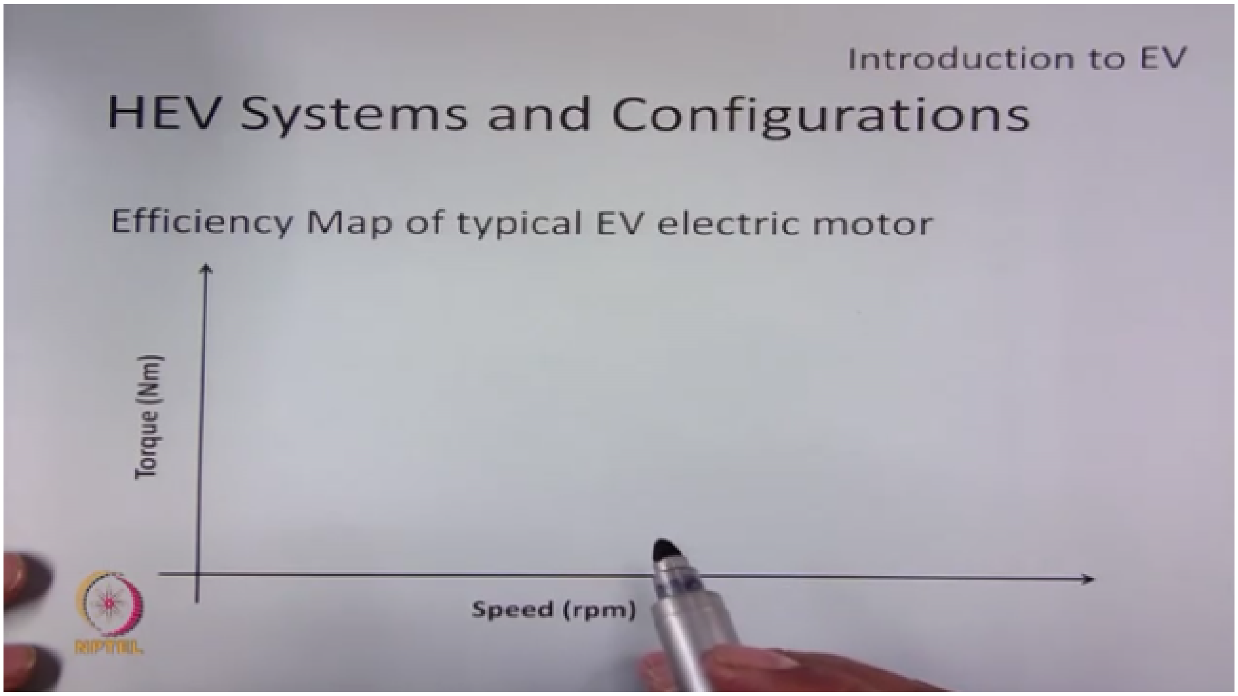

So let us see the energy map of a typical EV electric motor, so if a electrical machine is a sole propulsion device in a, let's say in a battery electric vehicle, it has to support all the modes of operation, so it has to support constant torque region and also has to support constant power region, so let us assume that 250 newton meter torque is required and a speed of around 600 or 6000 RPM is required,

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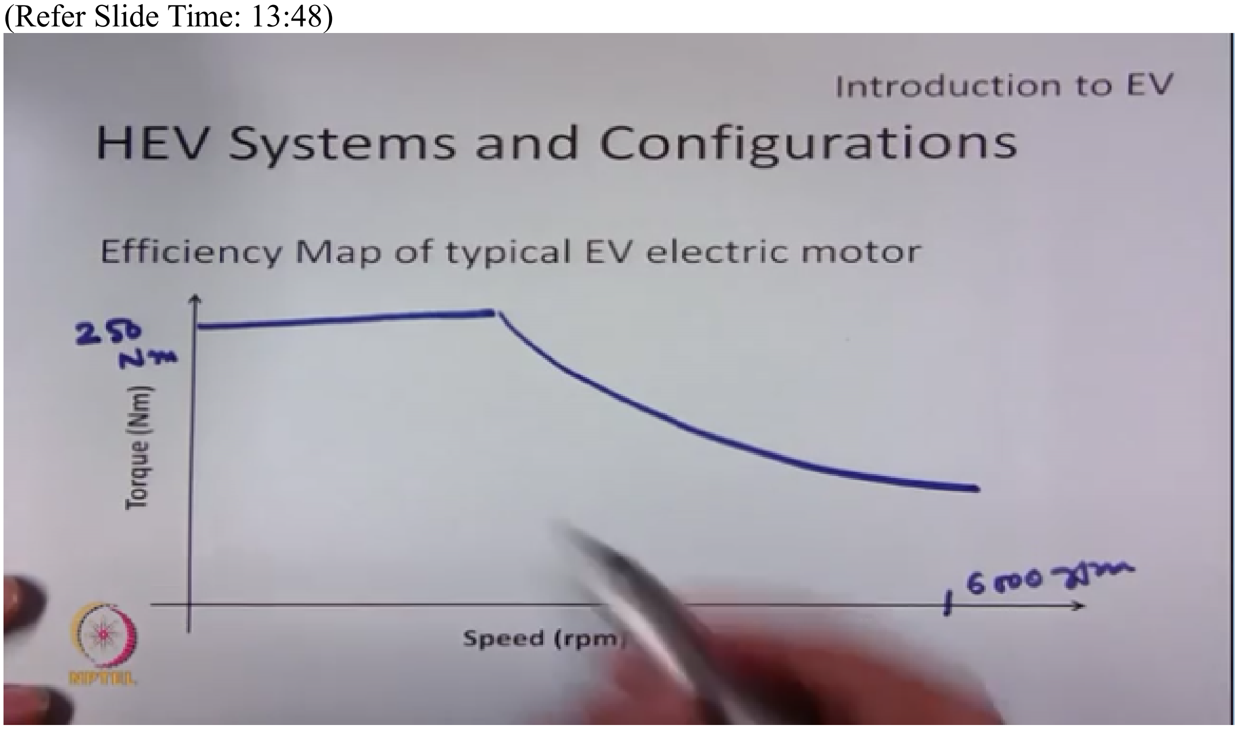

and let say we start the constant power region somewhere around 2500 RPM, so the efficiency map has to be designed such that the electric motor operates at maxim efficiency in most of the

regions, so this is a important research area and so that typical energy map is something like that, so we generally get the highest efficiency around this region which is let's say 92%,
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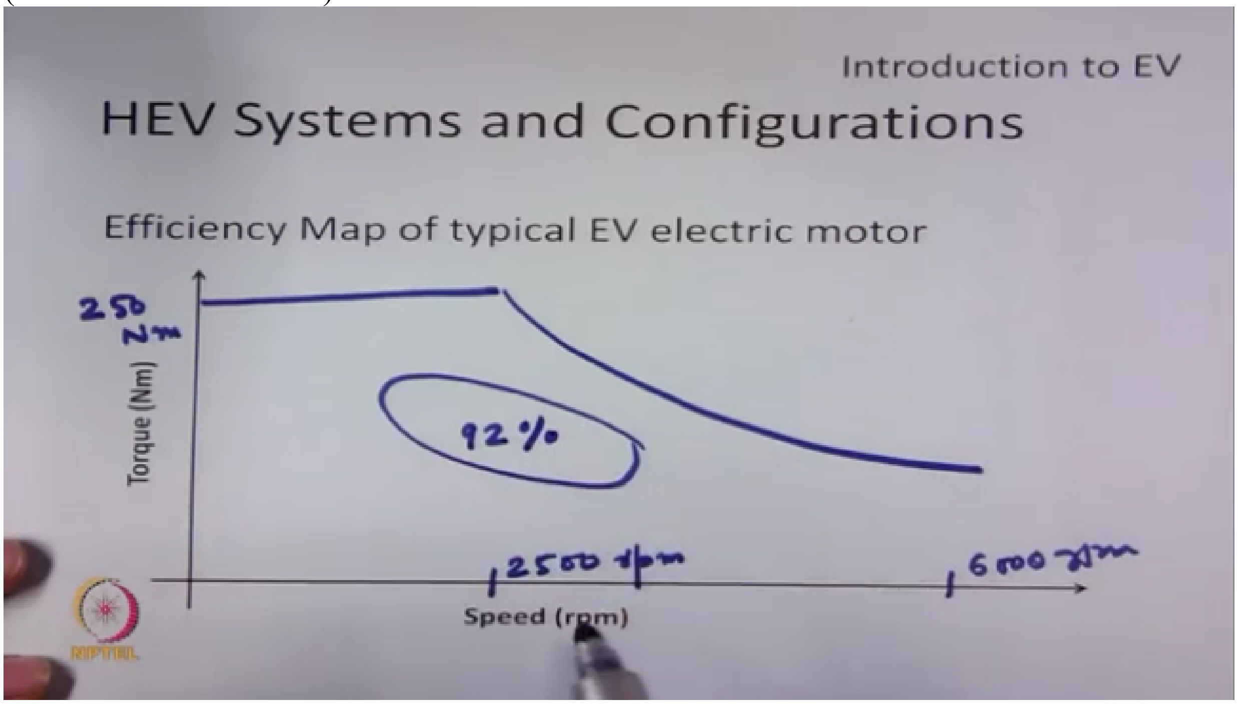

then we will get another region which has let's say efficiency of 90%.
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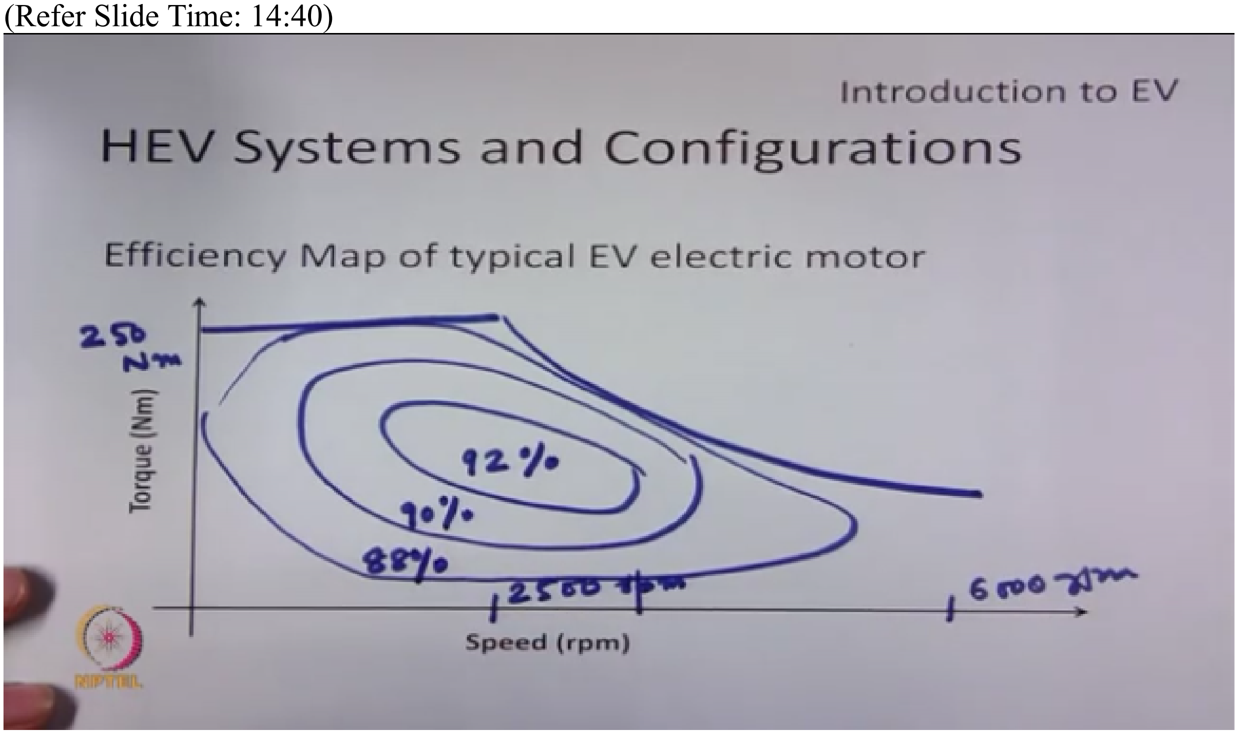

And let's say we have another region which has a efficiency of 80%, so this is energy map, so when electric motor is designed it has to be taken care that the efficiency is maximum in wide speed and torque ranges.
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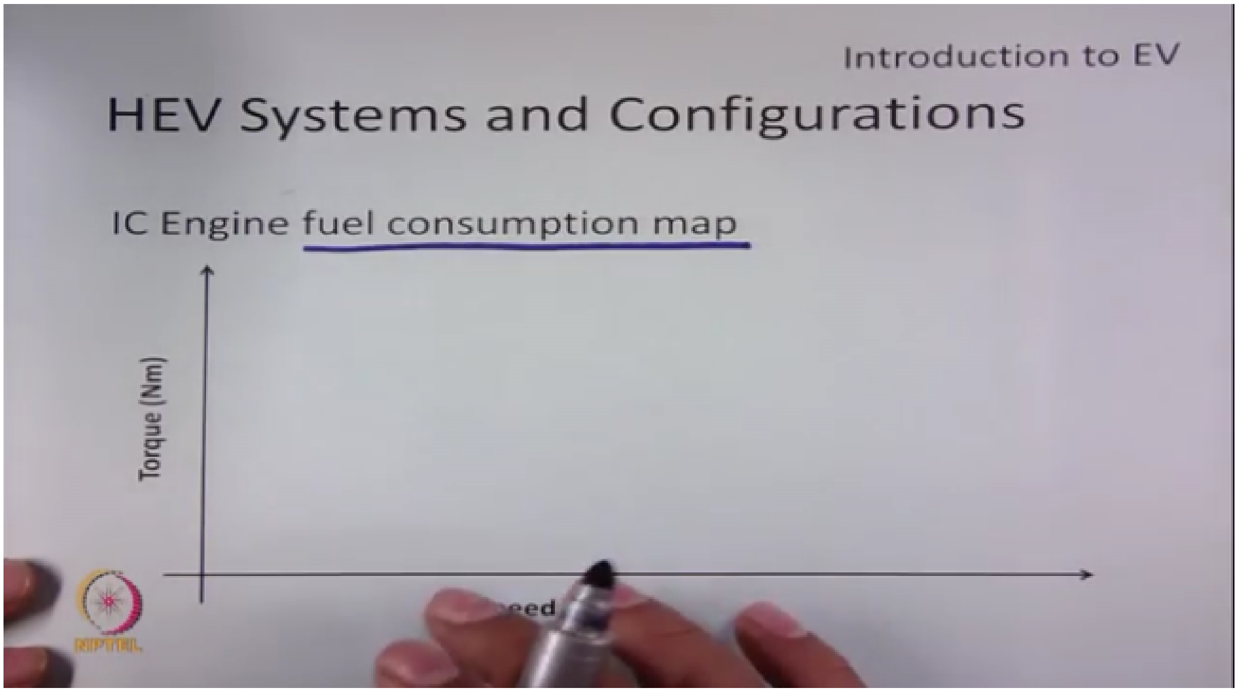

Similarly in a IC engine based vehicle there is a fuel consumption map which gives an indication of the fuel economy or fuel consumption, so let us say it's a highest 60 newton meter torque that can be obtained from a IC engine based vehicle and we are operating the maximum speed of again 6000 RPM, so typically this is the region of operation and we have pockets similar to the efficiency thing,

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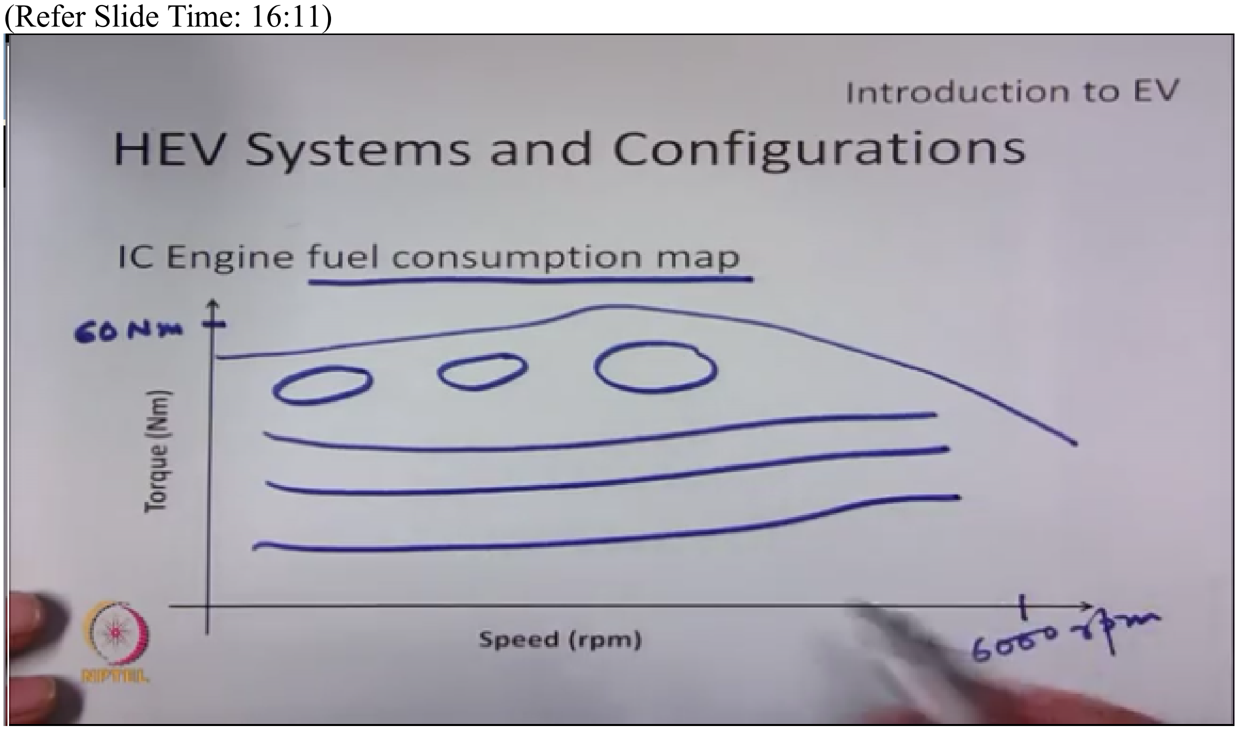

and this regions tell the fuel consumption, so let's say it is 210, 220, 210, this is 240, 270, 350, so this is basically energy consumption in gallons per kilowatt hour,

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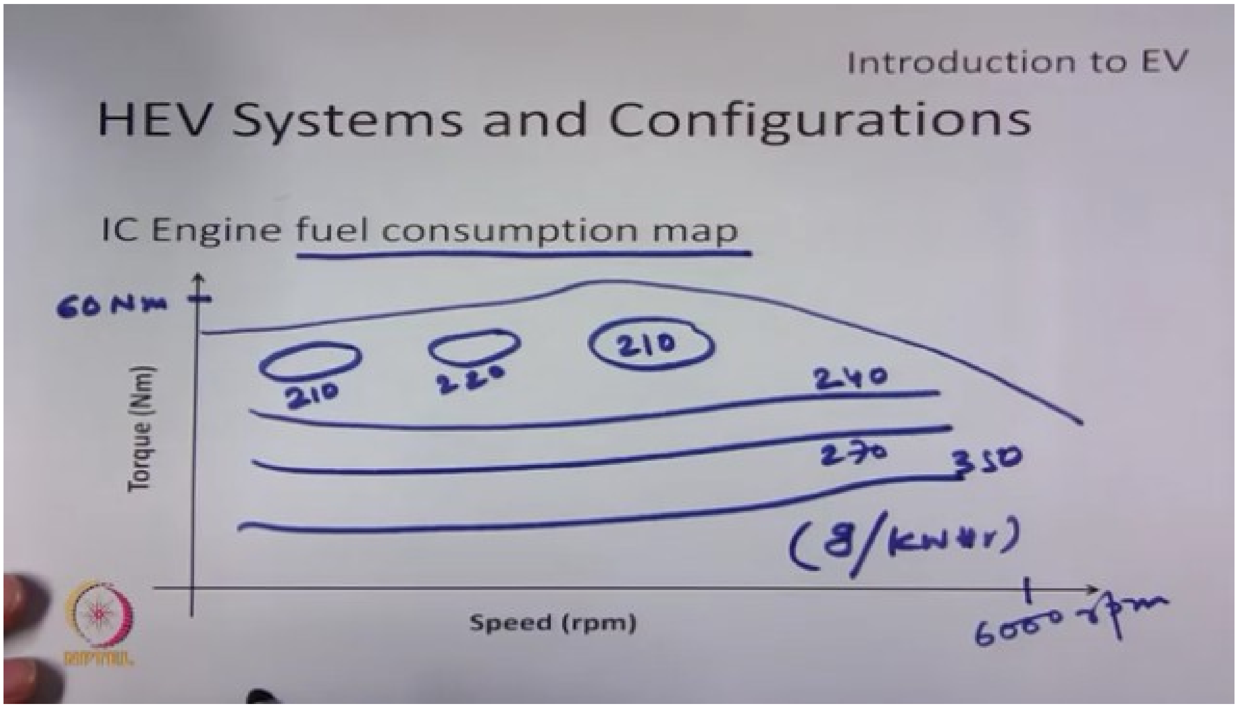

so the best fuel economy or the least fuel consumption is possible when we operate the system in a region or line which is known as OOL or optimal operation line,

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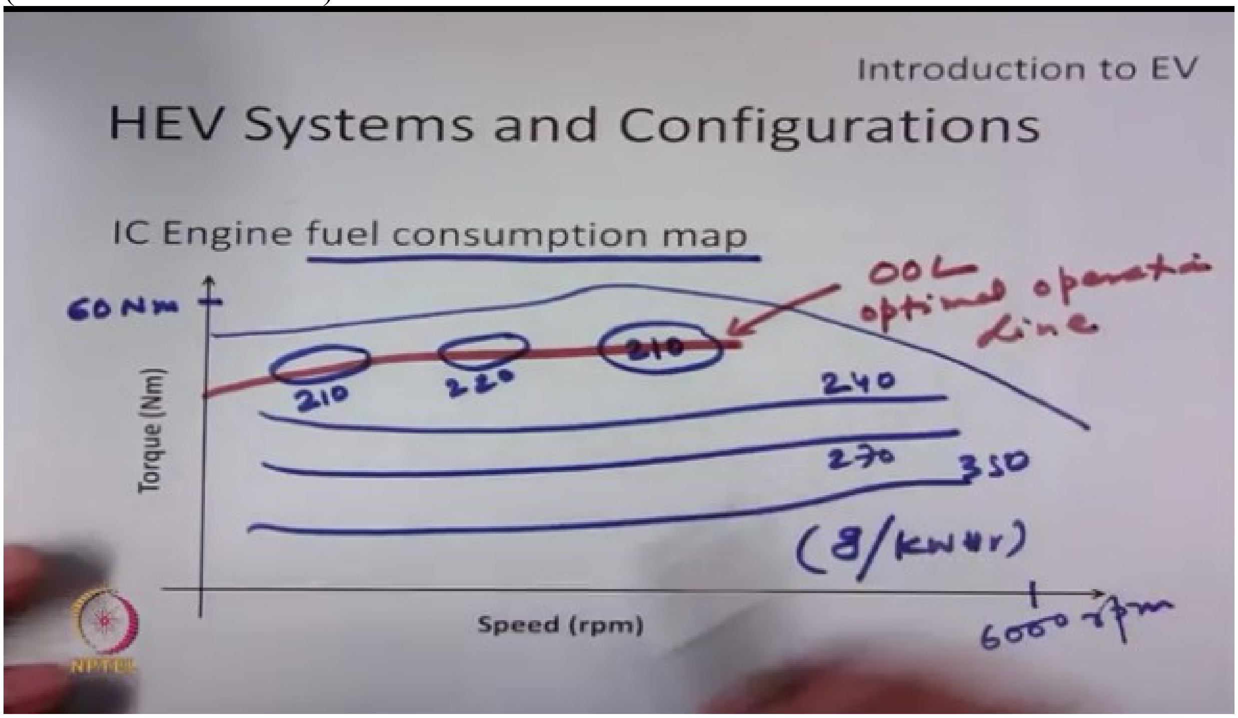

so in a hybrid electric vehicle the power flow between a IC engine and electric motor is designed such that we obtain maximum fuel economy for the IC engine, minimum system cost and good driving performance,

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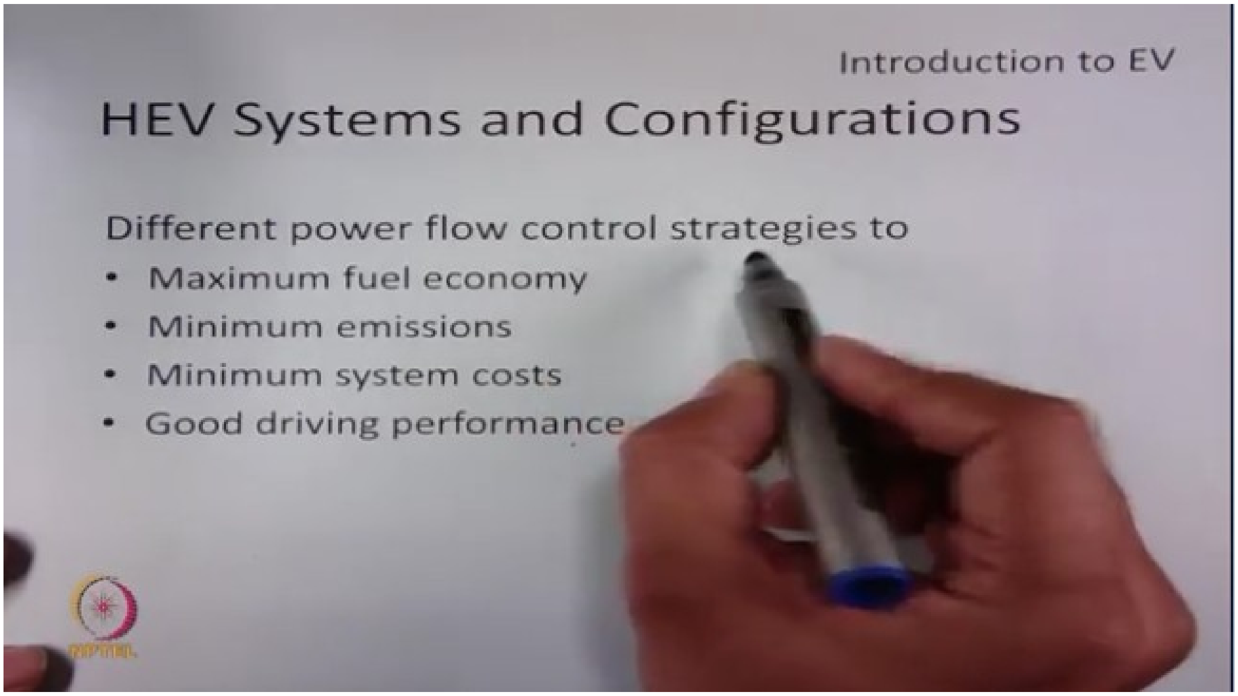

so all these things are considered while deciding a control strategy.

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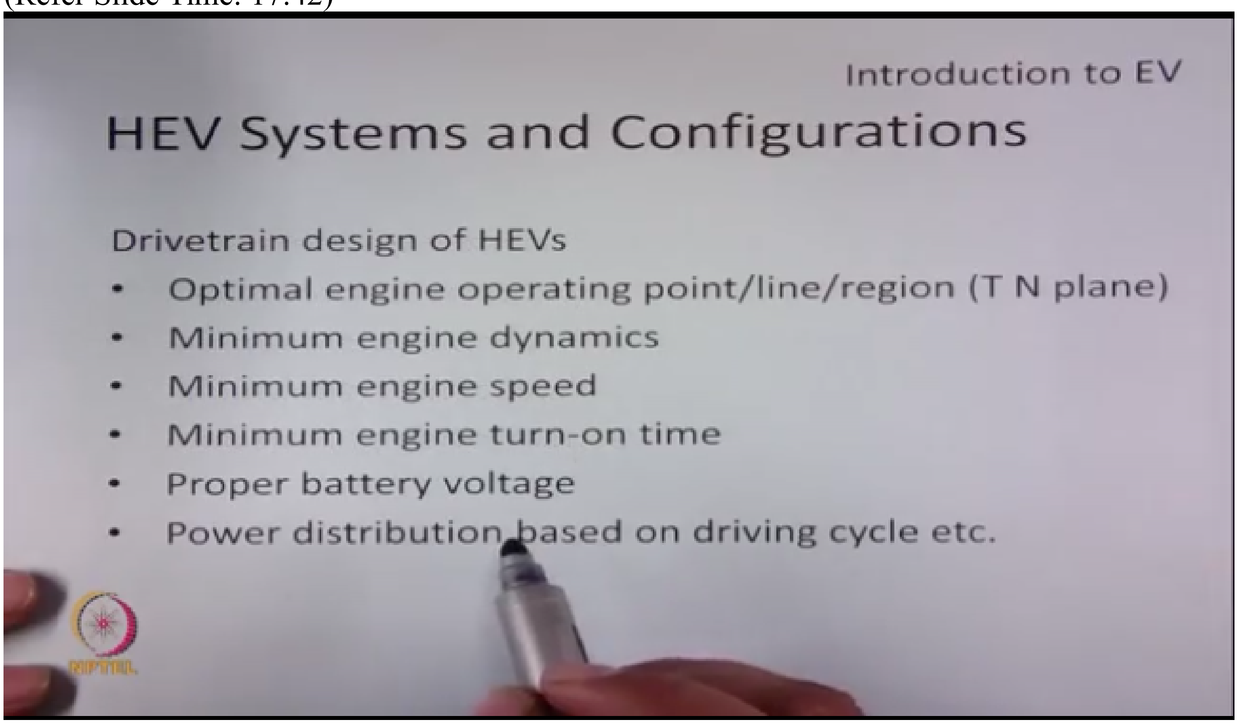

So when we design the drivetrain of a typical HEV we see that the system always operates such that the fuel economies maximum and the emissions are also minimum, so we always operate in OL line such that each operating point in the region, in a torque speed plane enables that operation, so we also should look at minimum engine dynamics, a typical IC engine based system doesn't give good fuel economy and we also lead to higher emissions if the load fluctuations are maximum, so we should see that the high dynamic operation should not be obtained from a IC engine, rather it should be supported from a electric motor.

Similarly the engine should not be operated at very low speeds, so at very low speeds again the emissions are very high and the fuel consumption is also very high, so when the engine speed is below the certain speed it is better to stop the engine, so engine needs a minimum turn-on time rather it is set so that once you start turn-on operation, the user should not give a turn-off command until the turn-off processes complete, if we don't do that there is a possibility of heavy machines and carbon formations in the engine which is not good for the health of an IC engine, so the battery voltage has to be kept in a good condition, so we need a battery and a integrated starter generator or you know the coupled motor for starting the IC engine, so the battery has to be kept in a good condition such that it enables starting of the IC engine properly, and the required acceleration, it's a power distribution between the IC engine and the electric motor should be designed to suit the driving cycle of the vehicle.

So what are the different types of hybrid electric vehicles?
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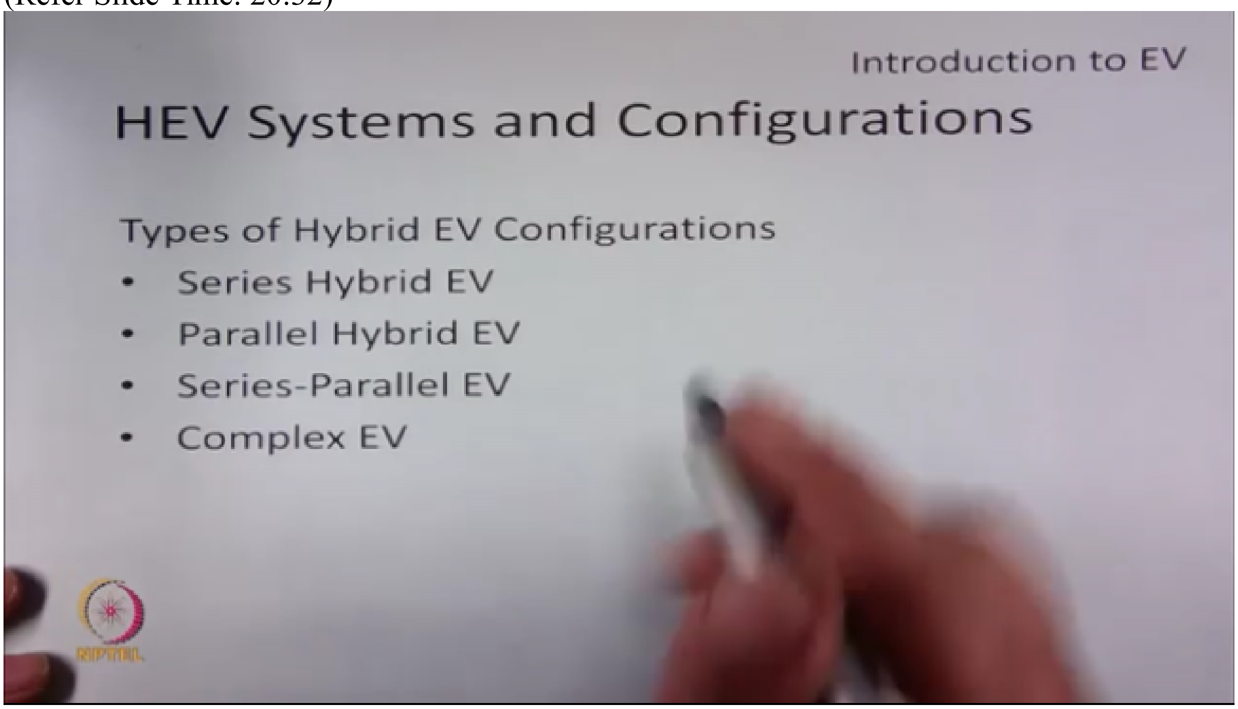

So conventionally all the series hybrid and parallel hybrid type of HEV's were designed, but later more advanced HEV such that series parallel operation and complex operation is possible with the newest technologies, and these are very popular in high-end electric vehicles, specially the hybrid electric vehicle.

So let us see the configuration of a series hybrid electric vehicle,
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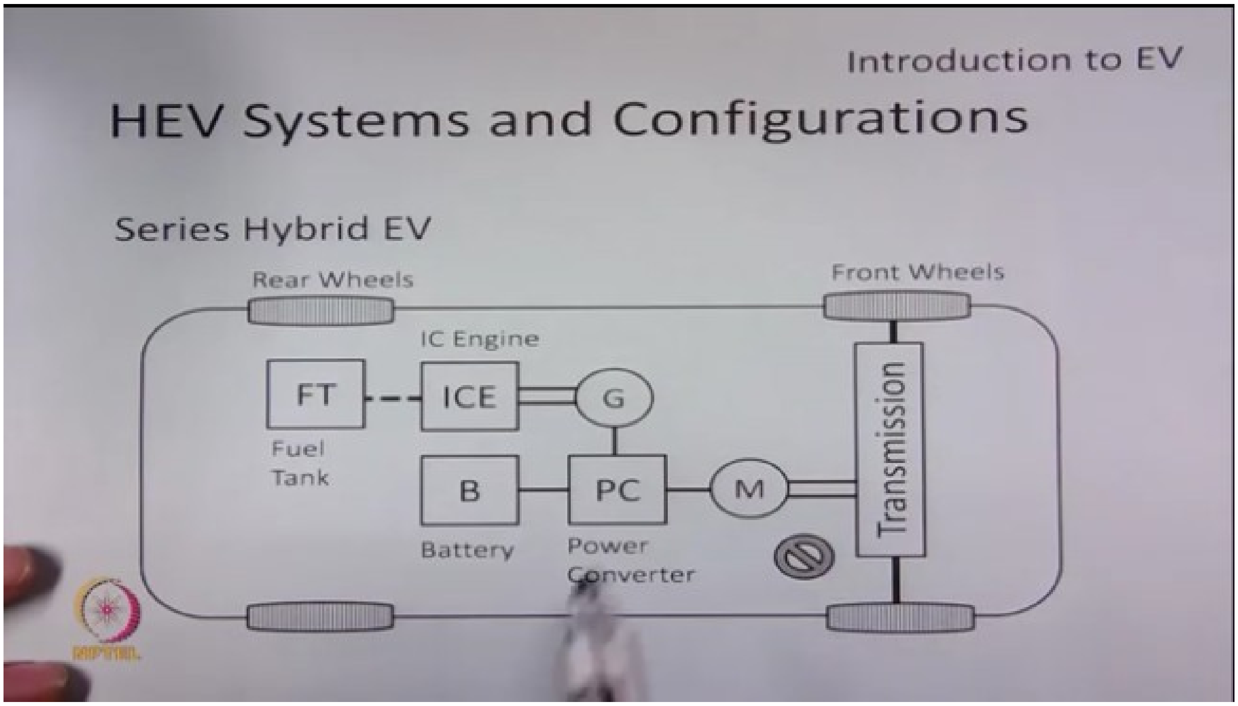

so we can see that a IC engine based system is connected to the battery electric system using a electric generator, so the power for the battery is generated by running the IC engine and the mechanical energy obtained by the IC engine is converted to electrical using electrical generator and it's used for charging the battery and driving the electric motor for propulsion, so as the propulsion device is electrical we don't need any clutches which is typically required in IC engine based vehicle, therefore the placement of the IC engine and the generator is flexible, and it can be placed anywhere, so this system is very simple to make, but it has few drawbacks such that it now needs three mechanical systems, and the sizing of them has to be high when you a demanding a high climbing operation or high acceleration, so this is known as a IC engine assisted electric vehicle,

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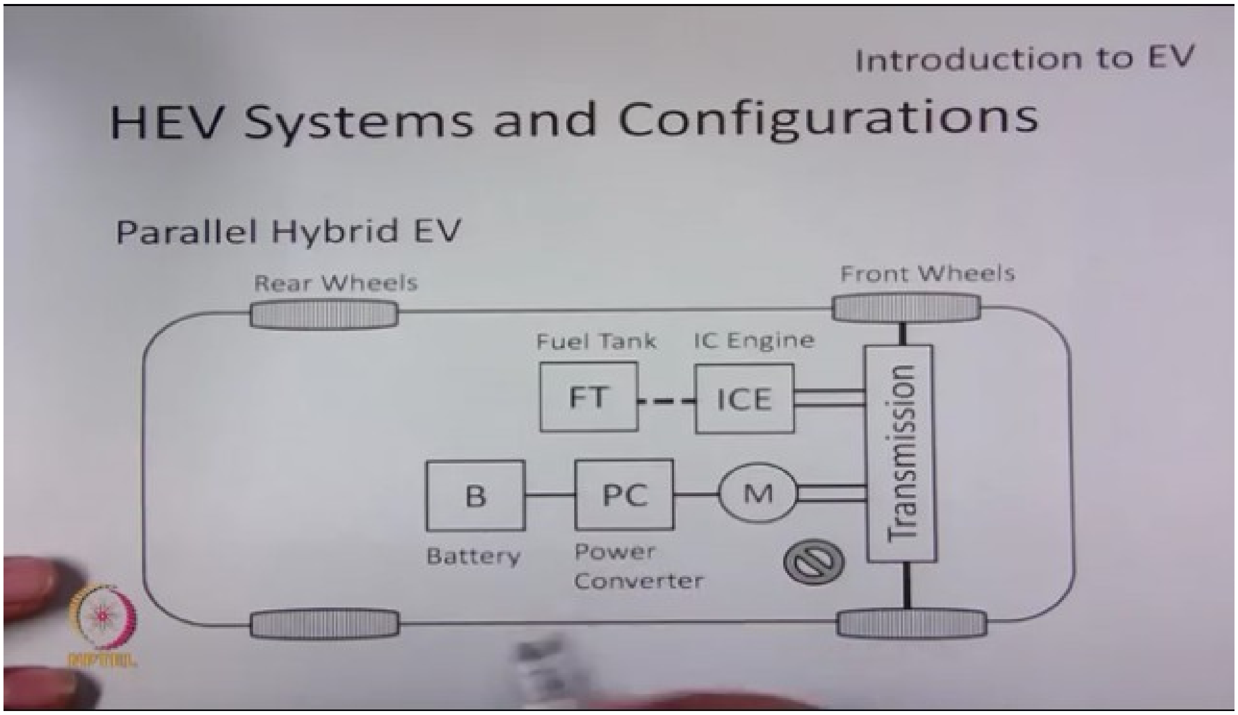

so it is also possible to have another configuration which is known as parallel HEV where both the IC engine and the electric motor or used for propelling the system or the transmission, so in this system we need to have two clutches, one for connecting IC engine to the transmission, another for connecting motor to the transmission, so this system is called dual clutch mechanism.

Here the advantage is that the sizing of each of the propulsion system is lesser compare to the series system, also the size of the battery can be also less but now the system is slightly more complex to obtain the features of both the series and parallel hybrid in the same HEV, a new configuration known as series parallel HEV was developed,
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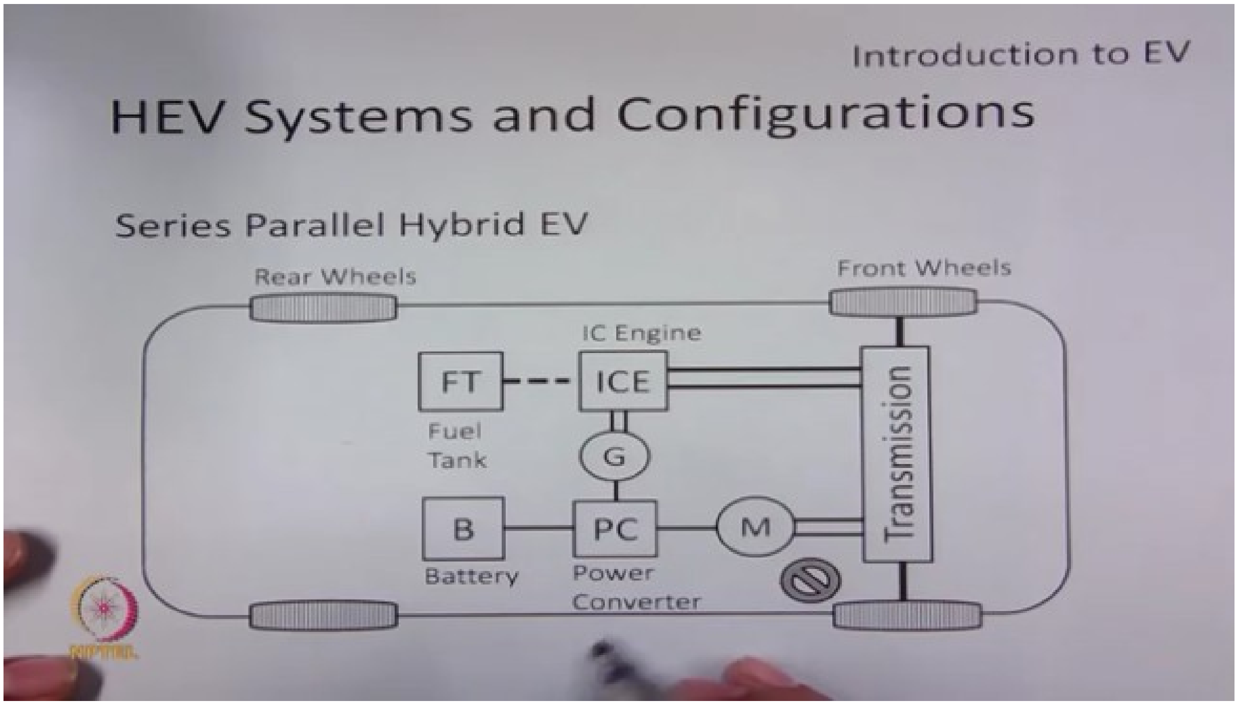

so compared to a series HEV now a mechanical link is also added between the IC engine and the transmission, and compared to a parallel HEV a electric generator is connected between the IC engine and the power converter, so this system can obtain all the operation that is possible in a series HEV or a parallel HEV such that the more better performance and the fuel economy of idle engine can be obtained.

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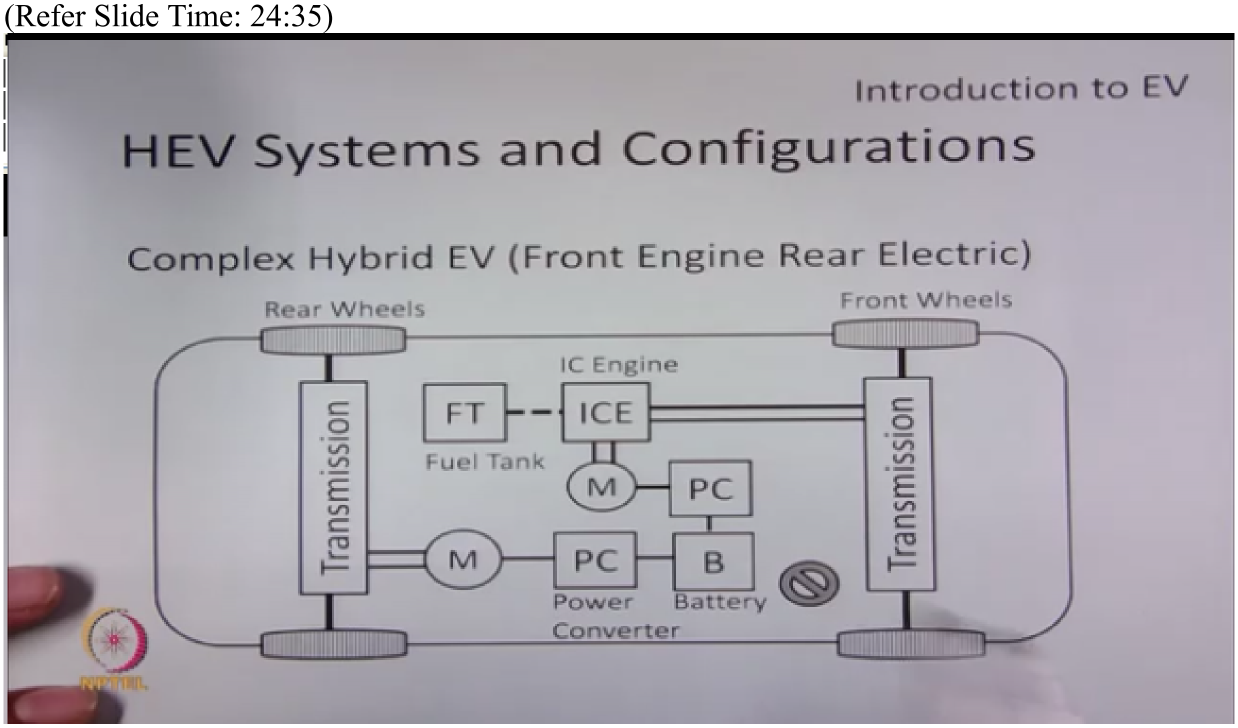

Nowadays complex hybrid EV configurations becoming popular for high-end HEV's where that two changes compared to series parallel configuration, first is now the motor operates both

as propulsion system and supporting the IC engine, secondly it can also work as a generator for charging the battery, so this machine now has a dual purpose. Secondly we need a power converter here, another power converter if we want to use this motor as propulsion device for supporting the IC engine, so as we can see now there are three propulsion devices, two motors and IC engine based, so it's possible to operate all this propulsion devices in tandem and we can operate in a very high torque mode during starting, this kind of configuration is generally used for dual axle transmission,
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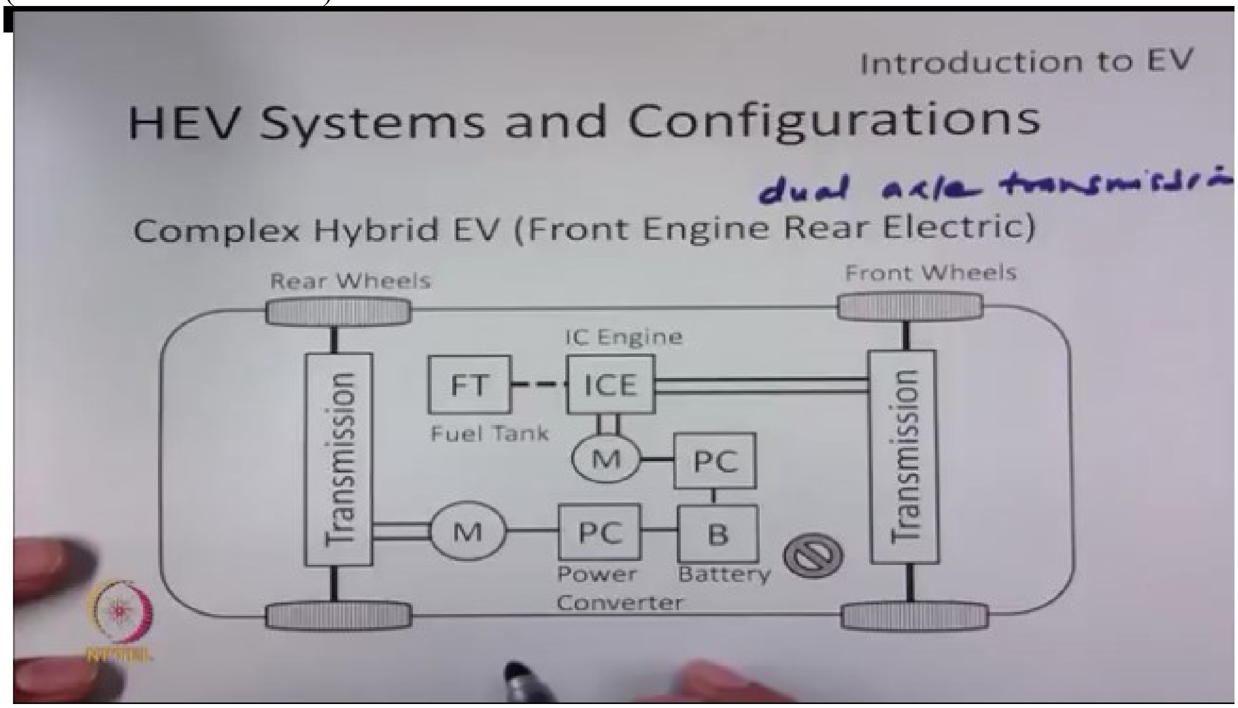

so the one of the propulsion devices such as IC engine is connected to the front wheel system and a electric motor is connected to the rear transmission system.

So another simplicity of the system is now the requirement of propeller system which shift the power from the front wheels to the rear wheel in a typical series or parallel system can be eliminated, so the system is less heavy, secondly the placement of the system is more flexible and the sizing of each component can also be introduced.

Another important thing is now the energy can be recovered from all the wheels during braking so there is also an increase in energy recovered during braking operation, so it's possible to connect either the system as front engine rear electric type or there is another configuration where the front wheel speed driven by electric and the rear transmission is driven by the IC engine.
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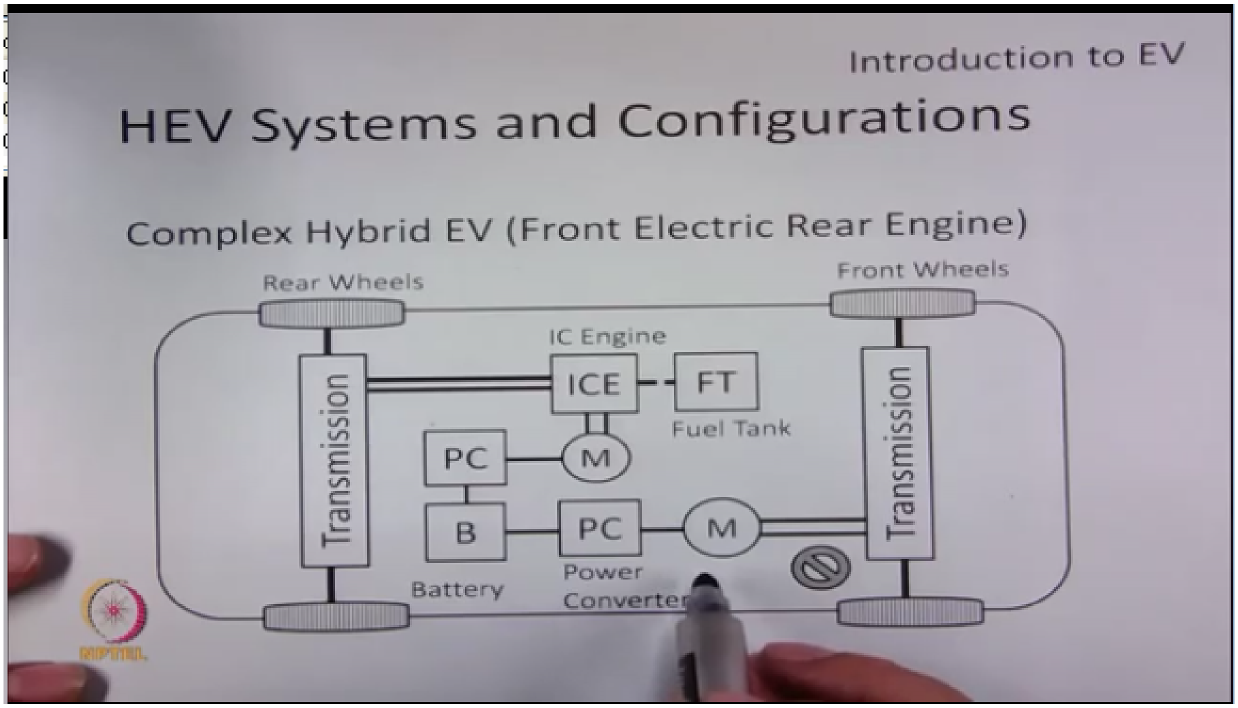

So let us stop the discussion for HEV subsystems here, so in this interaction we have seen the benefits of HEV compare to a BEV, and what are the different types of configurations we generally use to make a HEV which includes designing the control strategy for a IC engine based system and the placement of this individual propulsion system and their connection to each other.

So we will discuss the different modes of operation of each of this configuration such as series hybrid, parallel hybrid, series-parallel hybrid and complex hybrid in different modes of a electric vehicle such as starting, normal driving and acceleration, deceleration, battery charging etcetera in our next interaction. So thank you for listening.

INDIAN INSTITUTE OF TECHNOLOGY DELHI

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For Further Details/Information Contact:
Head
Educational Technology Service Centre
Indian Institute of Technology
Hauz Khas, New Delhi – 110016
Phone: 011-26591339, 6551, 6131
E-mail: npteliitd@gmail.com
Website: www.iitd.ac.in

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