INDIAN INSTITUTE OF TECHNOLOGY DELHI

NPTEL

NPTEL ONLINE CERTIFICATION COURSE

Video Course on

Electric Vehicles Part 1

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Lecture # 10

Intro HEV Subsystems and Modes of Operation

Hello everyone, welcome to NPTEL online course and electric vehicles. So we were discussing the topic of Hybrid Electric Vehicle Systems and their configurations which is a last topic under introduction to EV.
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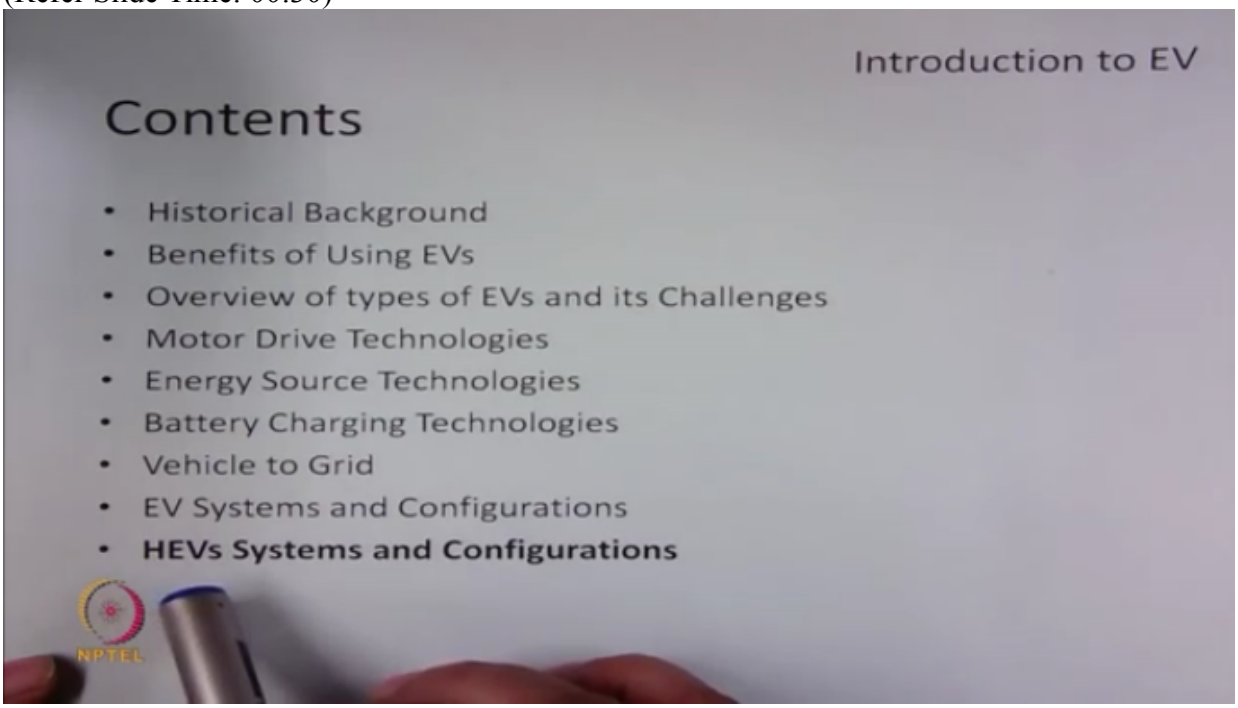

So in our previous interaction we were discussing the different advantages of HEV system and the different types of HEV configurations combining the IC Indian system and the electric motor system.

So in today's interaction let us discuss the different modes of operation of this HEV configuration, so when the HEV is used for driving a vehicle,
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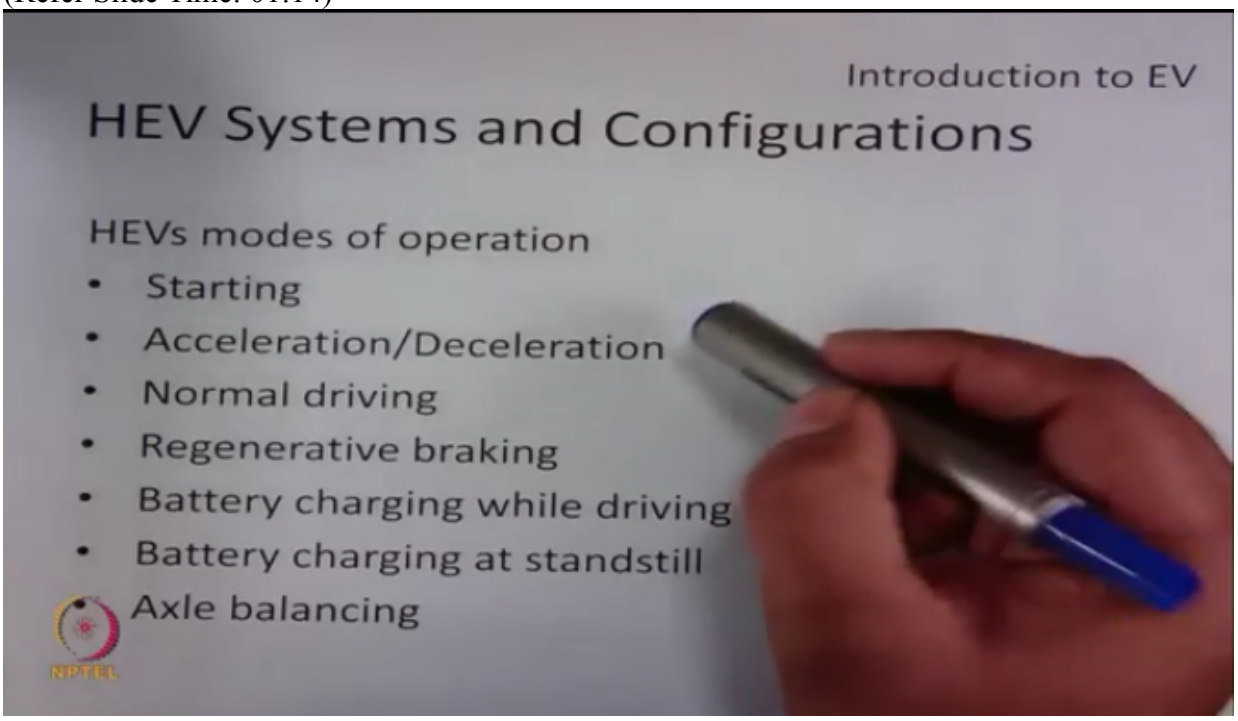

it needs to operate in various modes like starting the system, acceleration and deceleration of the system, normal driving, regenerative braking, the charging of the battery when the vehicle is in motion or when the vehicle is at rest, there is a mode which is known as axle balancing, so this mode is possible in complex HEV's.
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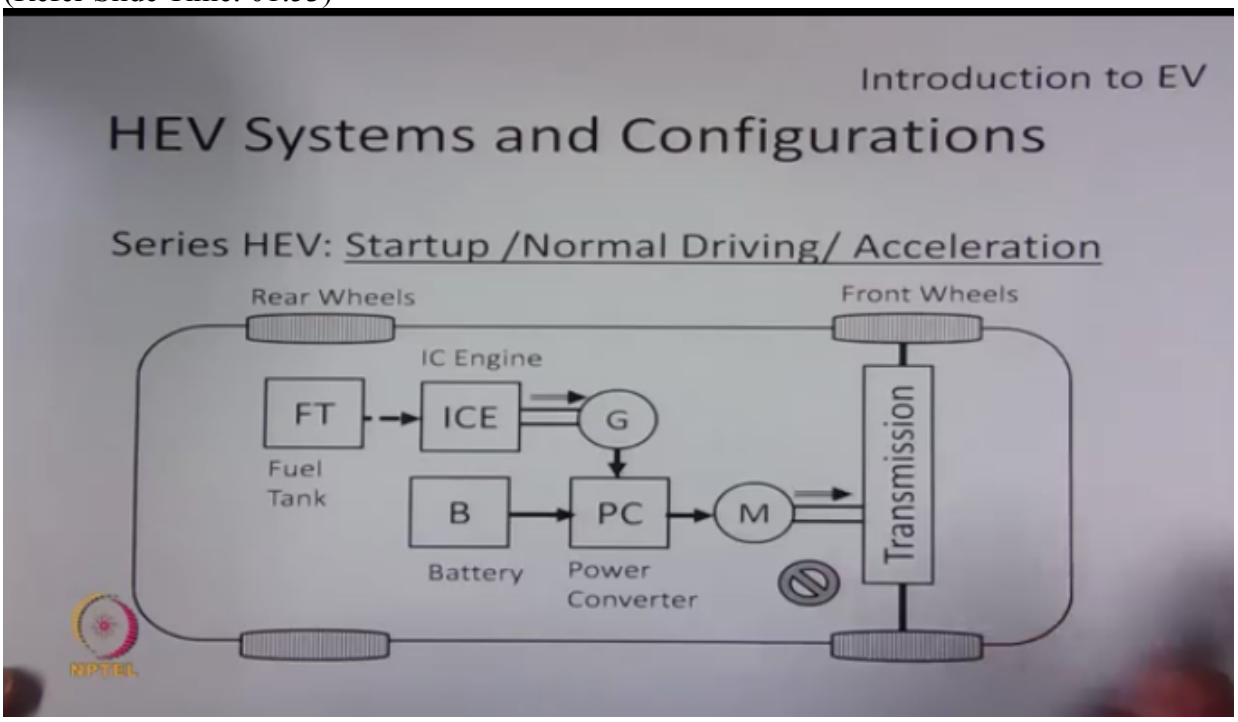

So let us start with the discussion of series HEV configuration, so when, we have to use the series HEV for starting the system and during normal driving and acceleration, the full system is active, so mechanical energy is transferred from IC engine to the motor wire, electrical generator together with the energy stored in the battery to the electrical motor, so the whole system is active during this mode of operation.

During light load on the transmission system not only the mechanical energy is transferred from the IC engine to the electrical motor, a part of it will be used to charge the battery, so in series HEV configuration the attempt is made to always operate IC engine at maximum efficiency, so if there is a light load it is always advisable to transferred part of that energy to the battery for charging requirements, during deceleration requirement and during observing of regenerative energy, during braking operation the energy is recovered from the wheels and the motor is operated at generator and mechanical energy is transferred to the battery via power converter mode, so this power converter has to be a bidirectional AC to DC converter if we are looking at AC motor.

It is possible to charge the battery when the vehicle is at rest, so this can be done by transferring the mechanical energy available from the IC engine to the battery, the operating, this motor at generator, so these were the different motion of operation of a series HEV.
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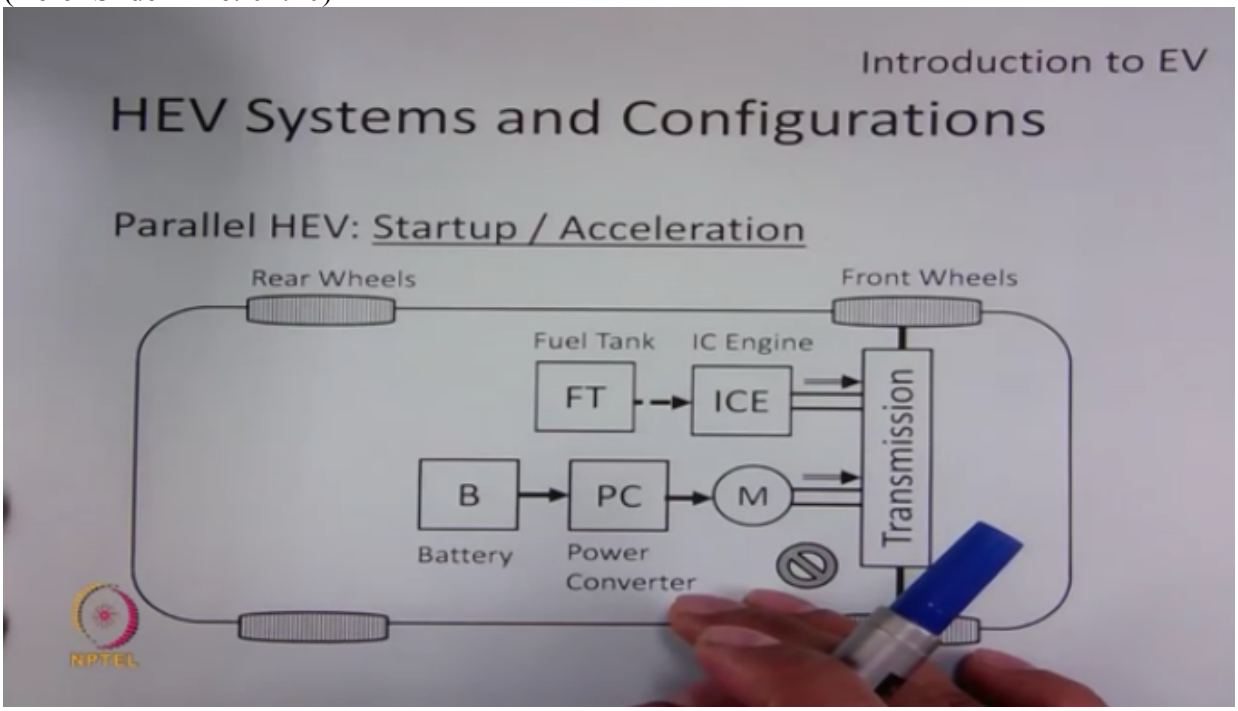

Now let us discuss the operation modes of a parallel HEV, so in a parallel HEV the mechanical system based on IC engine is also connected to the transmission, in addition to this electrical motor based battery device system, so both this drivetrains are connected individually to the transmission using different clutch, so during startup or acceleration both the systems will be on and maximum power can be transferred for both startup and acceleration,
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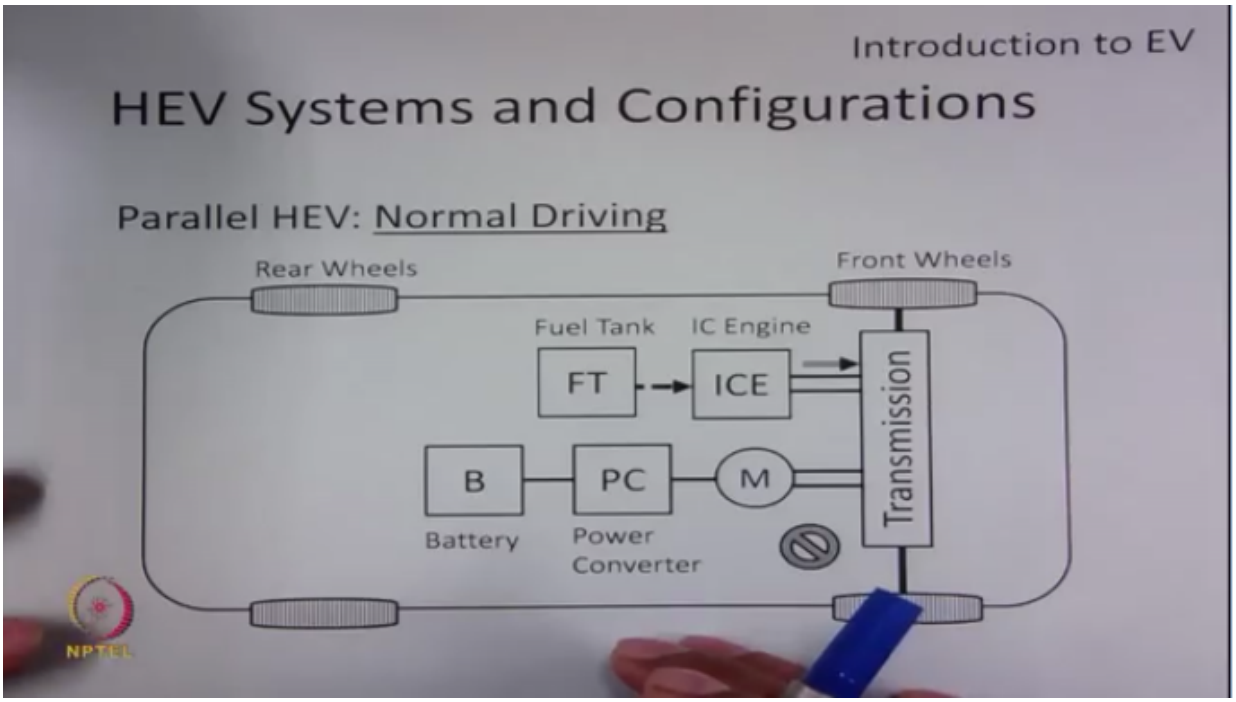

however during normal driving mode of a parallel HEV only IC engine based drivetrain is active and mechanical energy is transferred from the IC engine to the transmission, during this mode the electrical drivetrain is in off mode.

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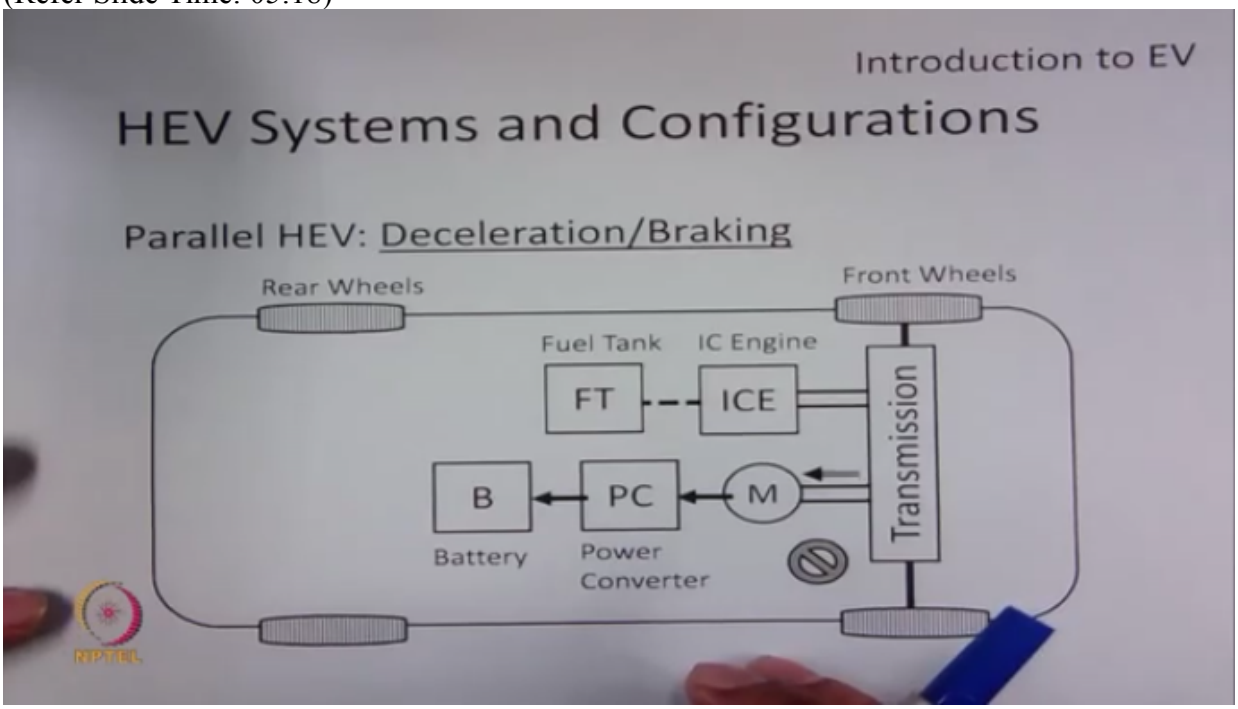

On the other hand during deceleration of braking the electrical drivetrain is only active and power is recovered from the base, and the recovered energy stored in the battery by operating the motor is the generator.

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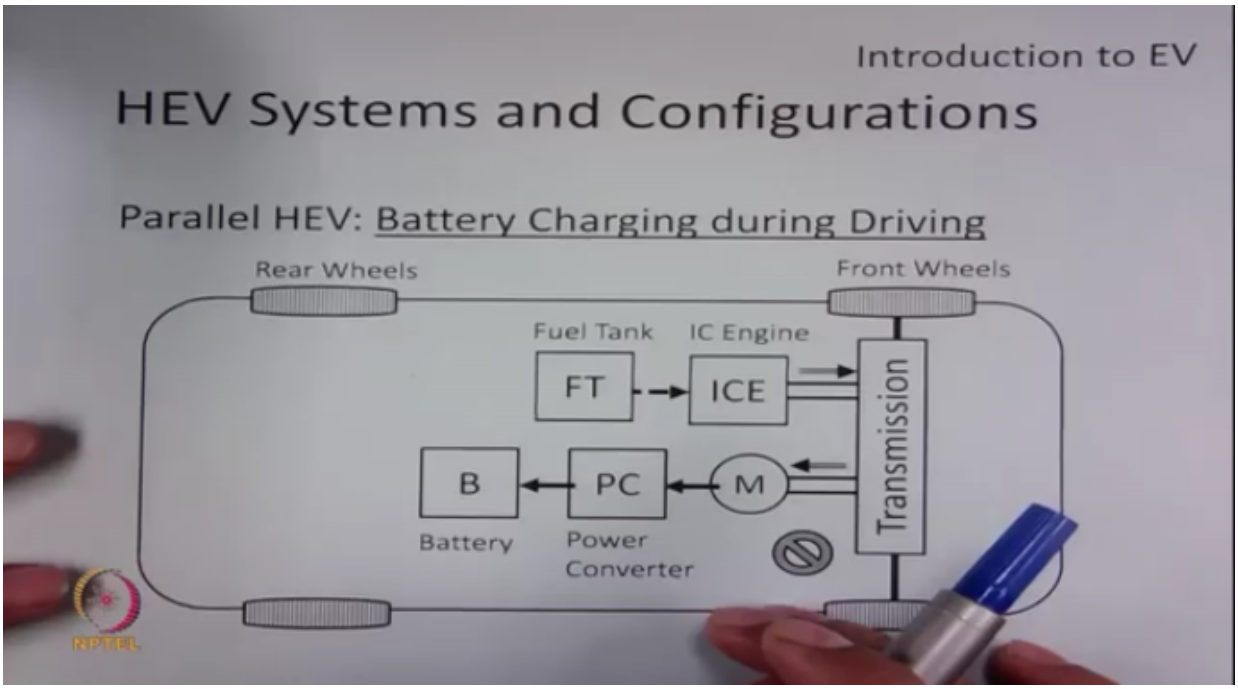

In parallel HEV if this requirement of battery charging while the system is in motion or when the vehicle is moving it has to be done via transmission, so the mechanical energy required for the transmission has to come from IC engine base system, and a part of it will be transferred to the battery by operating the motor is generator, so the power flow happens through transmission in this case,

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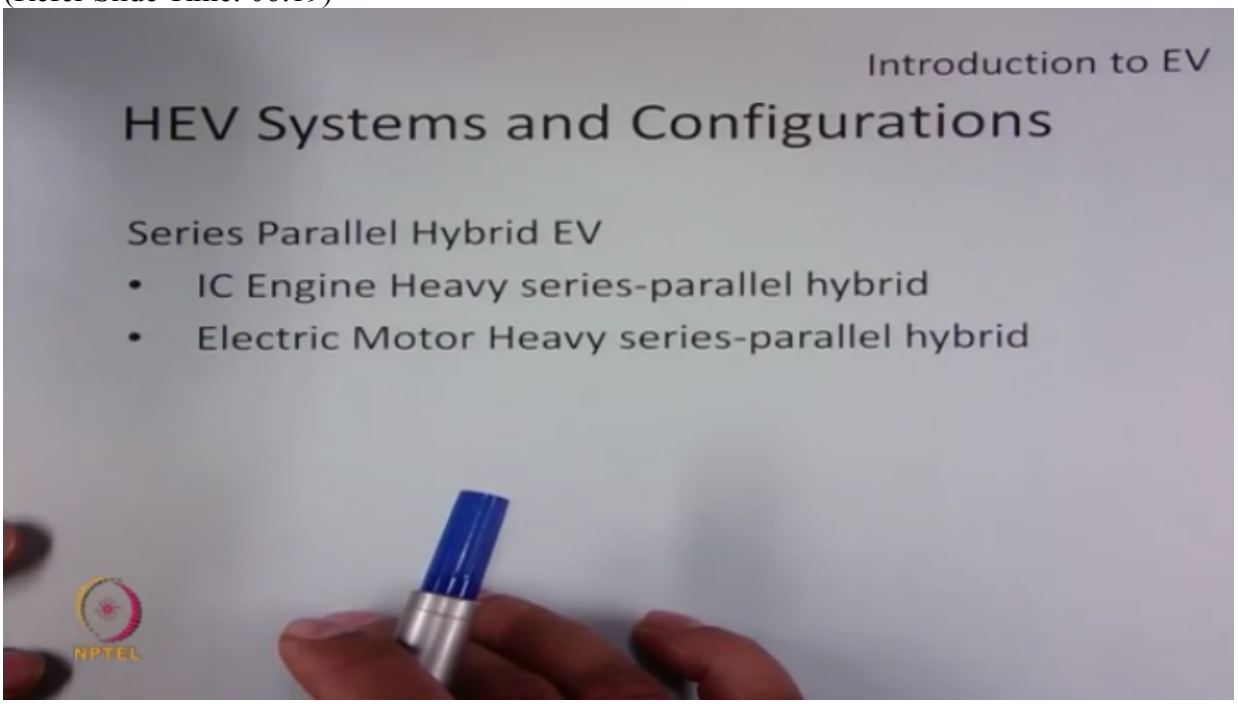

so we all know that there is complex in parallel HEV subsystems where both the series configuration and parallel configurations are combined together such that both the advantages

of series hybrid and parallel hybrid can be obtained together, the system is complex but there are lot of advantages and various kind of mode of operation is possible in the systems.

So depending on whether the IC engine is more active or the electrical motor is more active there are two types of series parallel HEV configurations, one is known as engine heavy series parallel HEV, and second is electrical motor heavy series parallel HEV.

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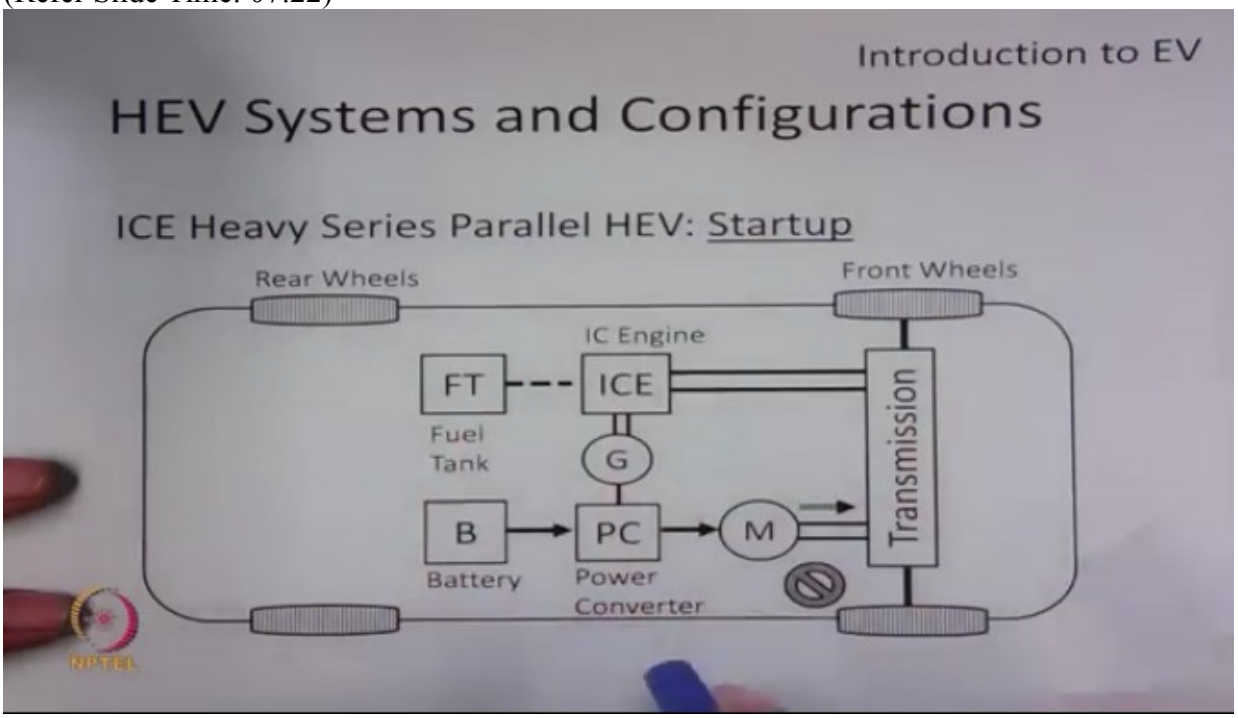

So let us see the modes of operation of this configurations, so let us start with IC engine heavy series parallel HEV, so during startup the system only uses the electrical drivetrain for starting the system, so this system as we have discussed earlier has both the parallel and series connection of IC engine to the electrical drivetrain, so mechanical system is also connected, mechanical to the transmission and also electrically to the electrical drivetrain using electrical generator, so during startup only the electric drivetrain is used and is all electric mode type of startup.

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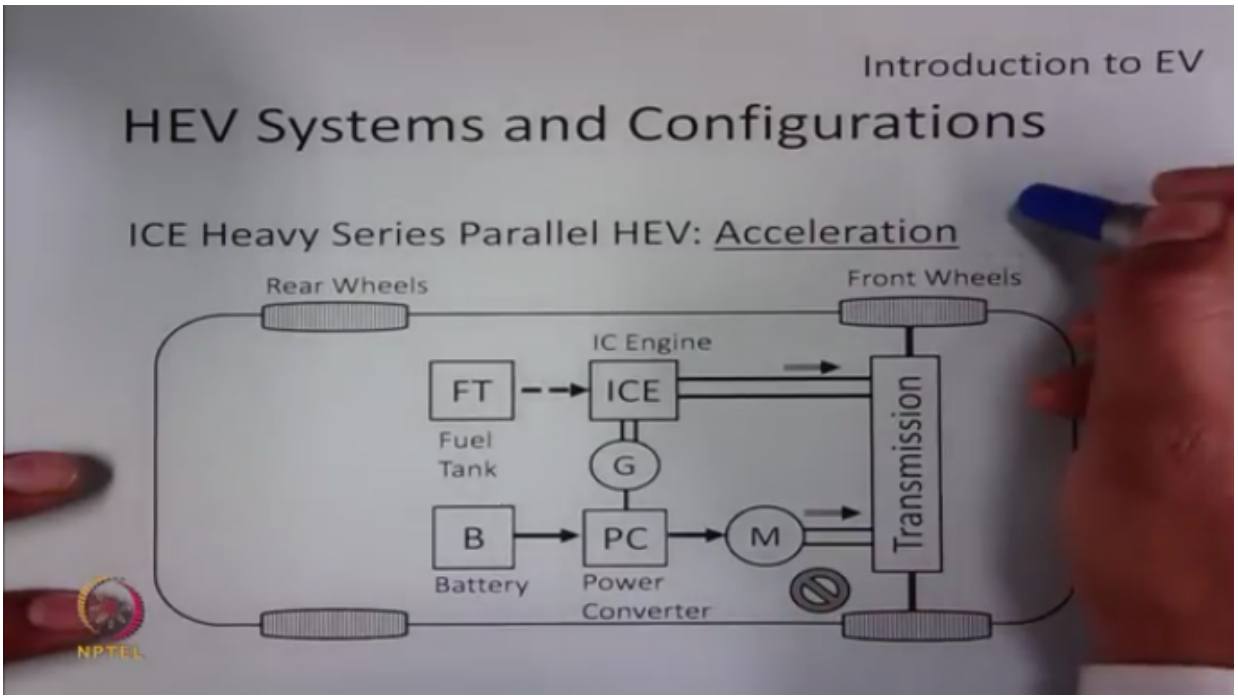

During acceleration this system works similar to a parallel HEV, so the mechanical energy is transferred from the IC engine to the transmission in parallel to the electrical drivetrain based battery driven electrical motor type of propulsion, so this generator is non-active in this mode.

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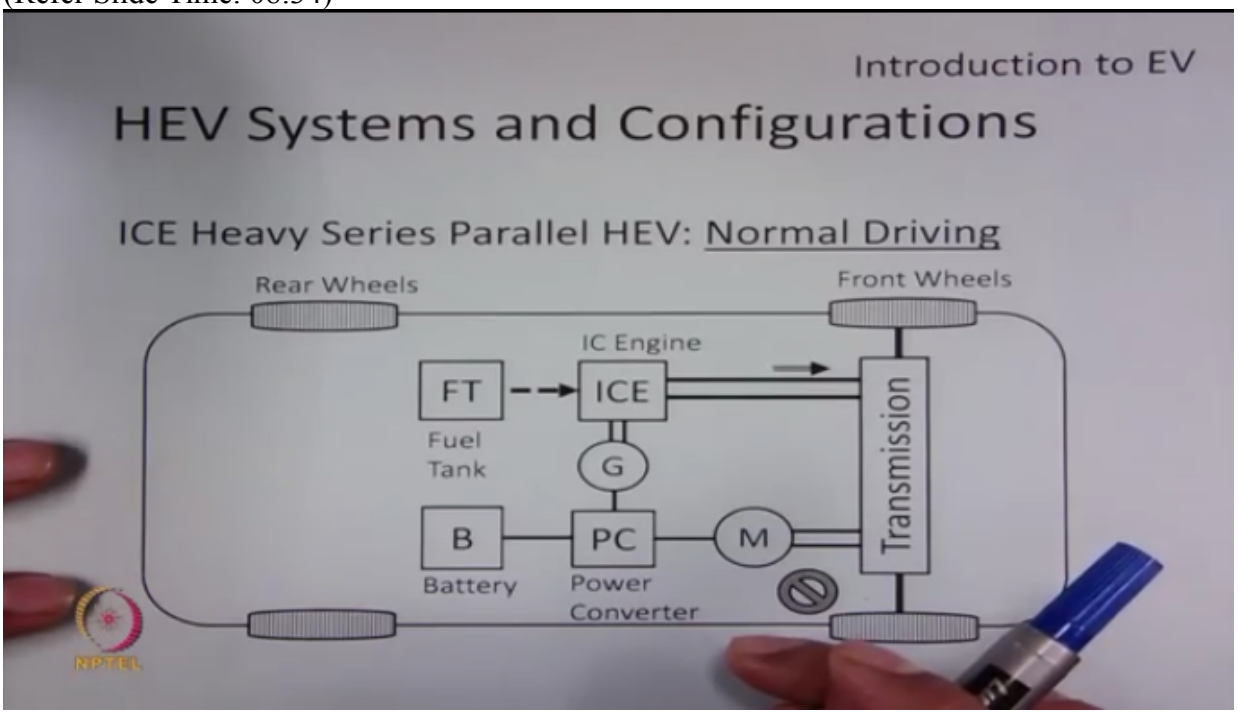

During normal driving only the IC engine based drivetrain is active, and the mechanical energy is transferred from the IC engine to the transmission, and the rest of the system is inactive, so the electrical drivetrain in the generator is turned off at that time.

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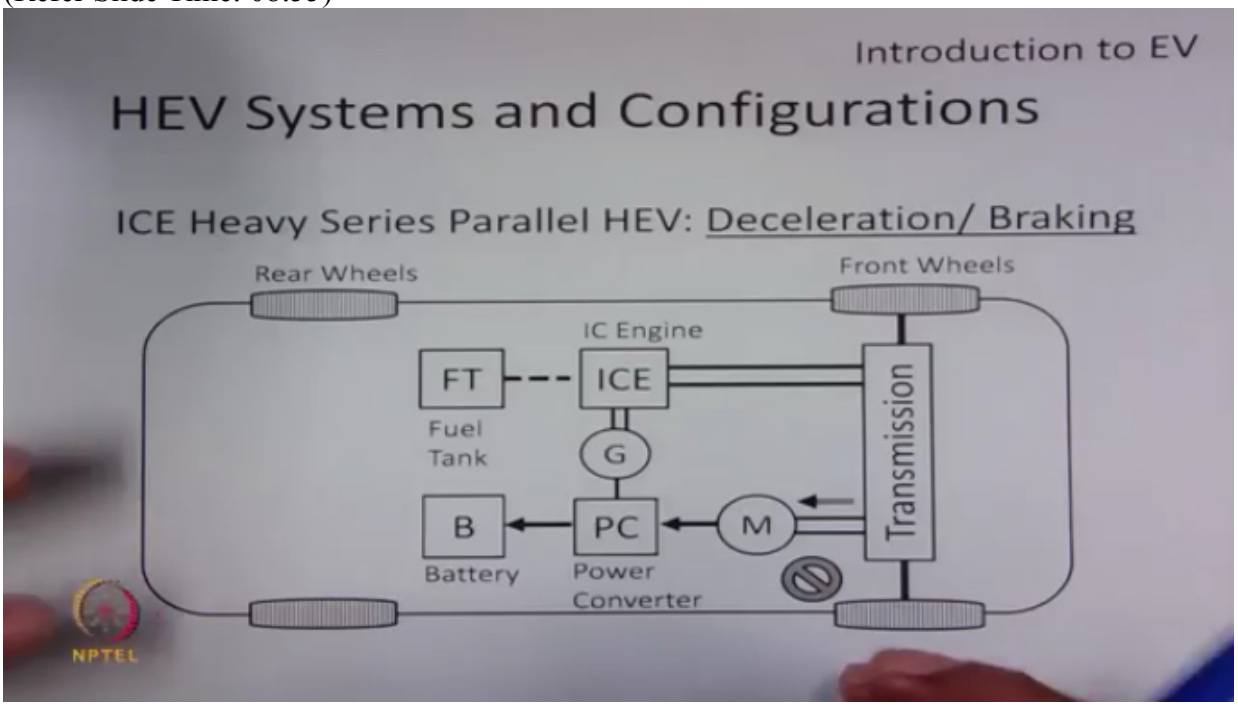

During deceleration or braking only the electrical drivetrain active and the mechanical energy is the wheels is extracted by motor operating at generator and the battery is charged by the energy recovered from the wheels.

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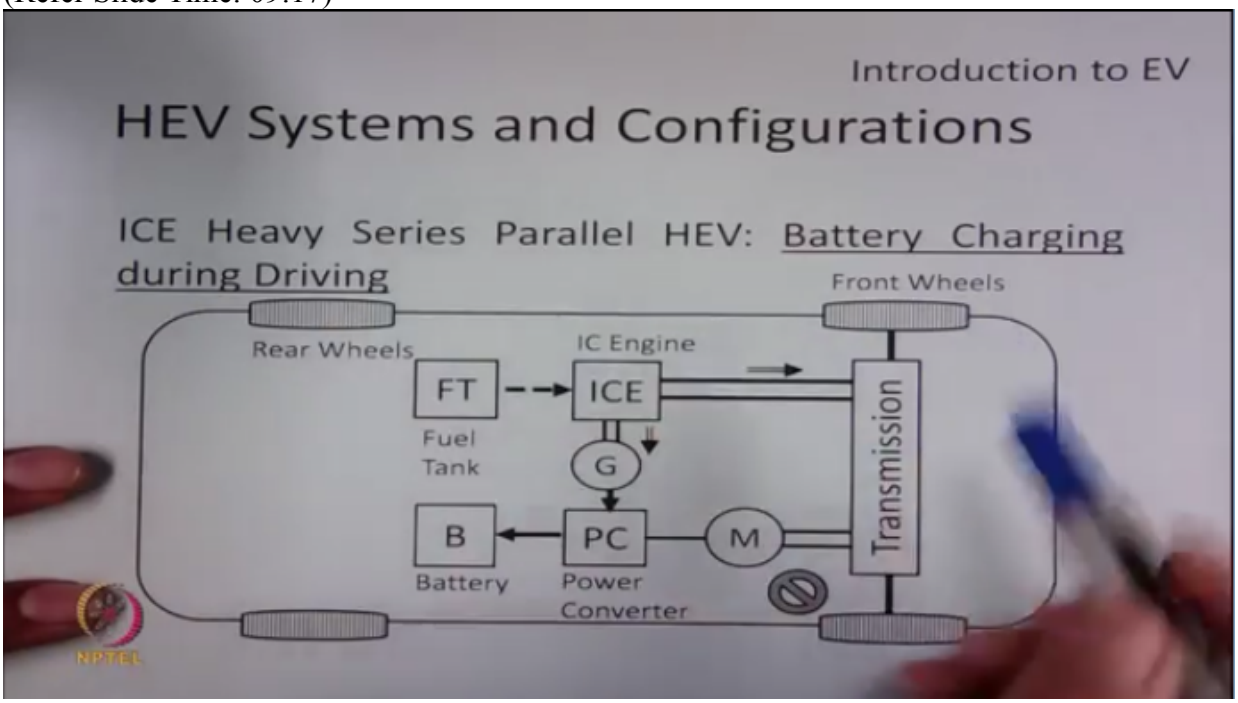

In this system, when we want to charge the battery while driving we don't need to operate the transmission system for doing that, since we have a series connection up here, so while driving the IC engine drive the transmission and a part of it can be used to charge the battery by

operating the electrical generator, so the IC engine is generated and connected by a complex planetary gear which enables connection and disconnection of electrical generator during driving operation, so when the vehicle is not moving or when it is at rest, it's possible to charge the battery by operating the generator while the mechanical propulsions are off.

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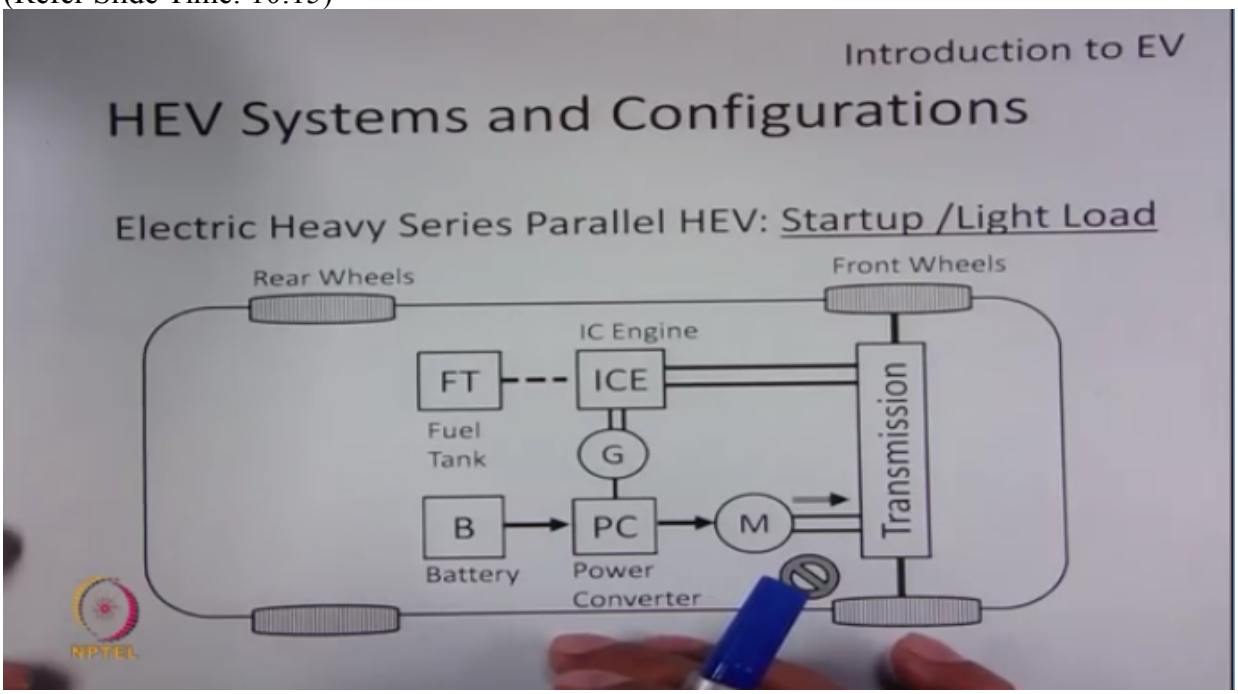

Now let us discuss the electric heavy type of series parallel HEV, so again during startup or at light load conditions, the system is started in all electric mode, so the electric drivetrain is only used to start the system or also for driving the vehicle at light loads,

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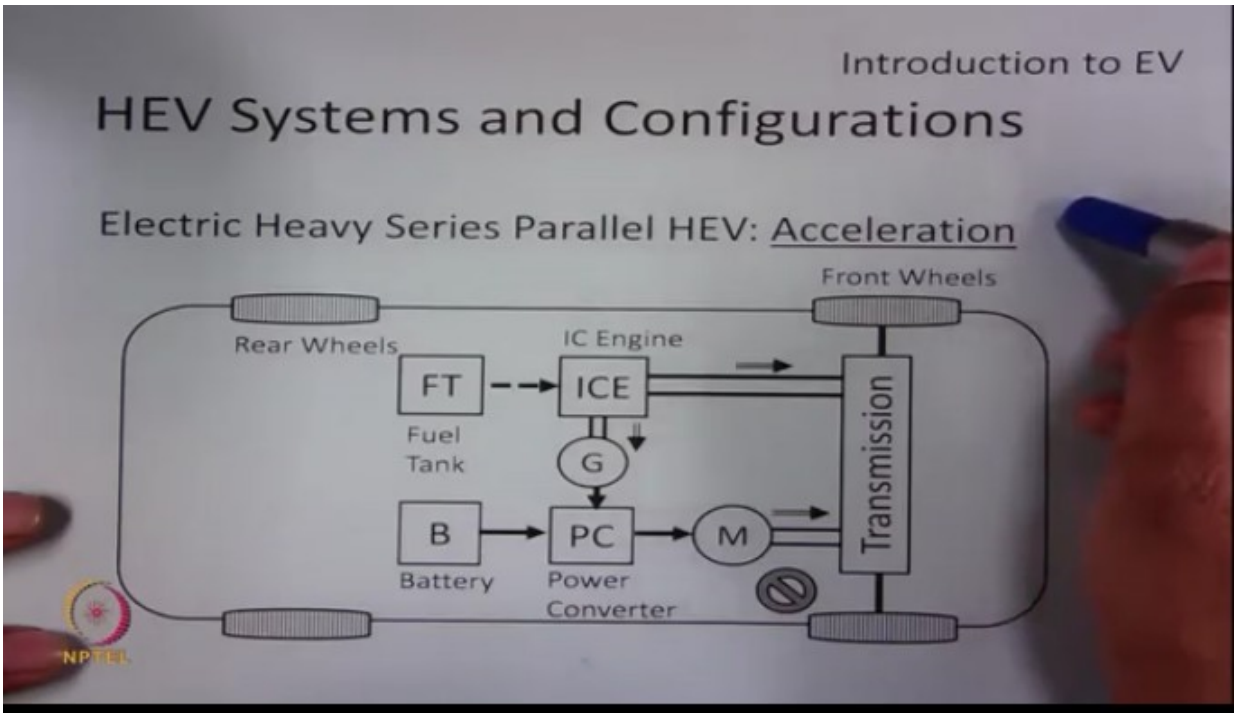

but during acceleration all the three propulsion devices or mechanical devices are used to accelerate the system, so the system uses full torque availability of the system, so mechanical energy is transferred from IC engine to the transmission, and a part of it is transferred via generator to the motor, and third is from the battery to the motor, so this is different from the IC engine heavy series at parallel HEV rear, only the system acceleration is achieved by a parallel HEV mode, and this generator was off at that time.

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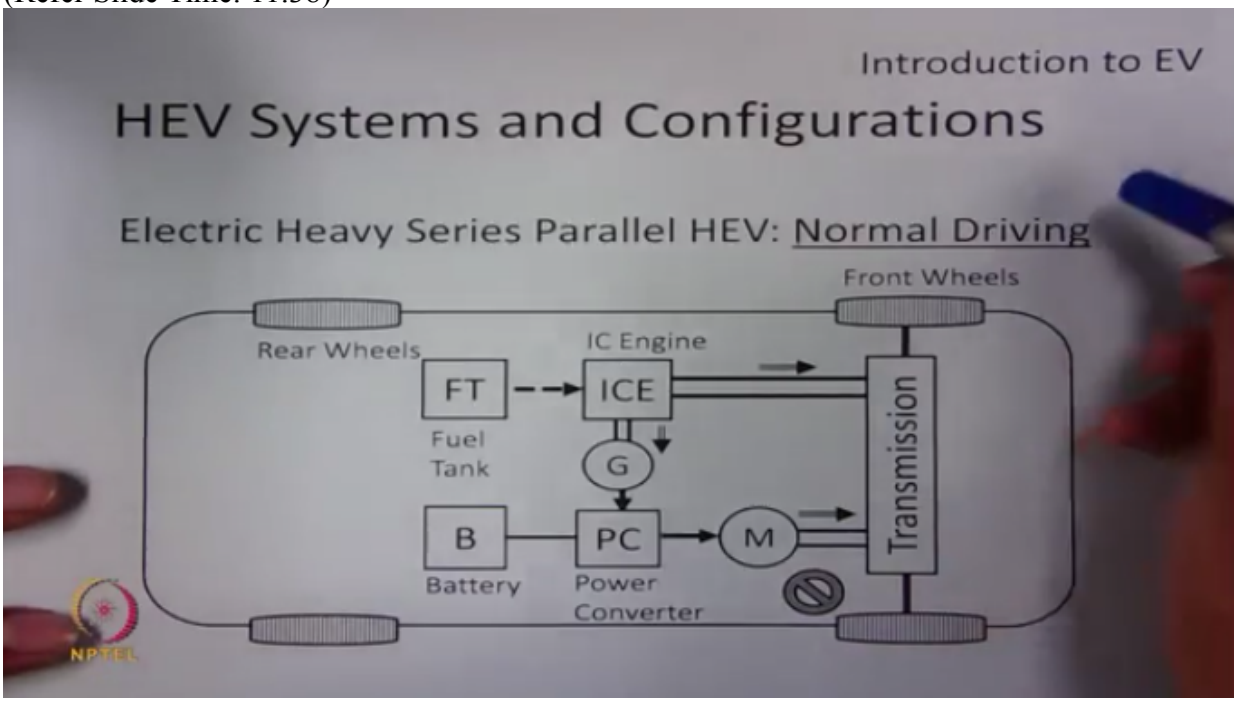

During normal driving, not only the IC engine is used to drive the transmission, a part of that mechanizes also transferred from generator to the motor or propulsion, so in this mode of operation the battery is not used, so this mode is again different from the IC engine heavy series parallel HEV where only the IC engine is propulsion, so here this mode is also active,
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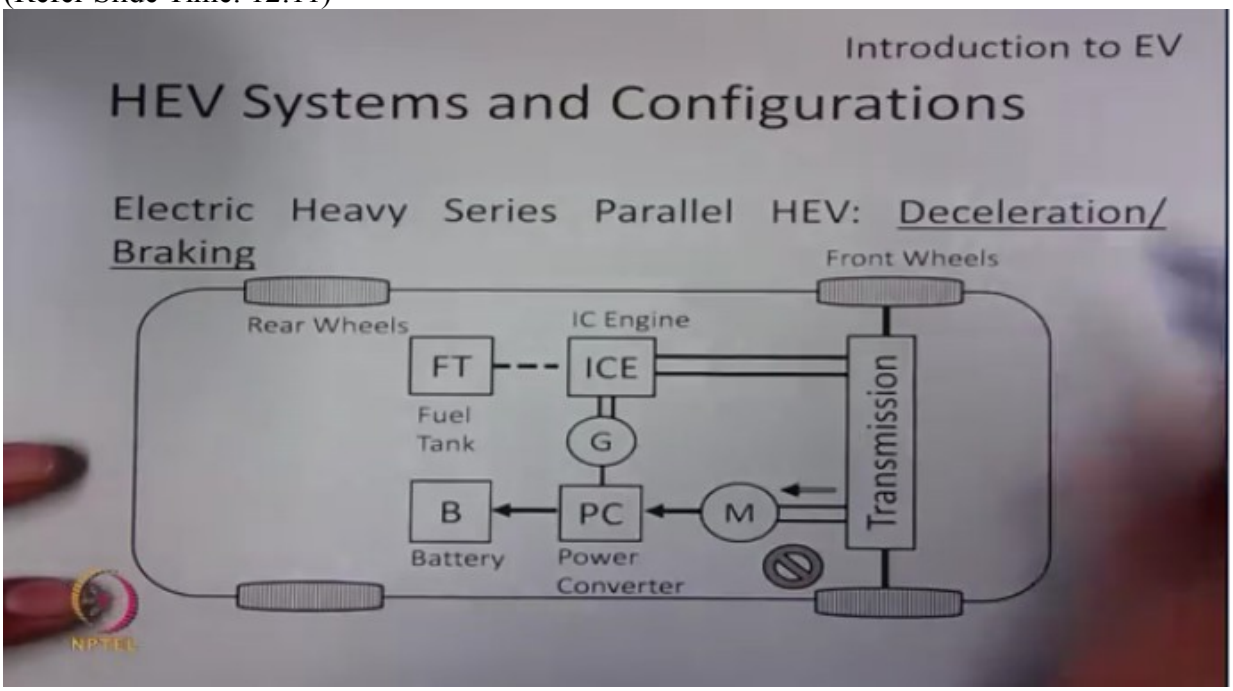

so deceleration and braking is similar to IC engine heavy series parallel HEV where the power is recovered only from the electrical drivetrain.
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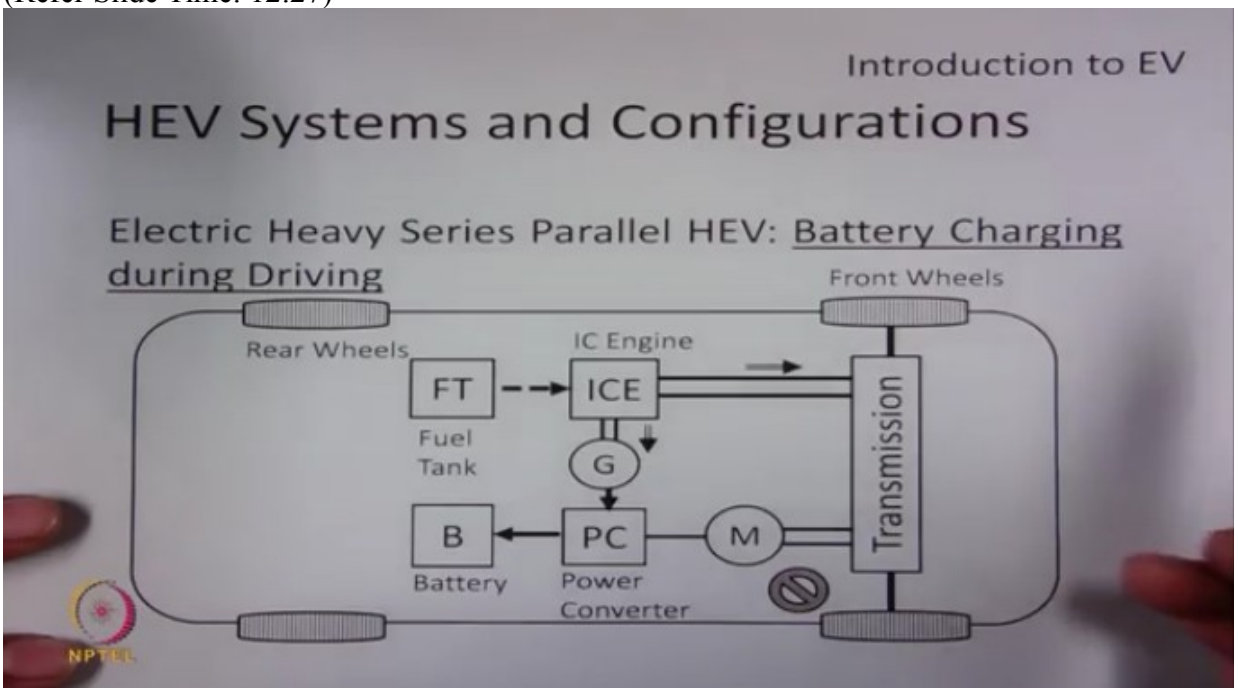

So again similar to IC engine heavy series parallel HEV, in electrical heavy series parallel HEV also battery can be charged when the vehicle is in motion, and when the mechanic power is transferred from the IC engine to the transmission.
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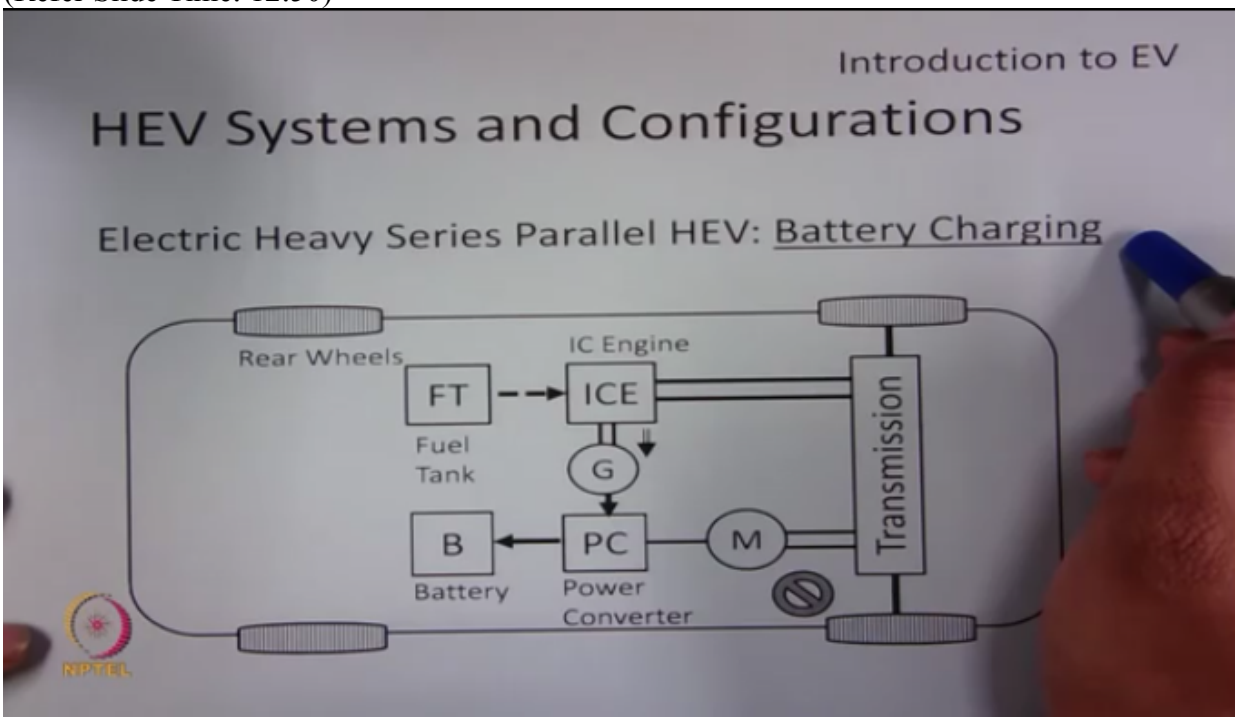

The battery charging at stand still also similar to the IC engine heavy series parallel HEV and it is done by a charging the battery via electrical generator from mechanical power obtained from IC engine.

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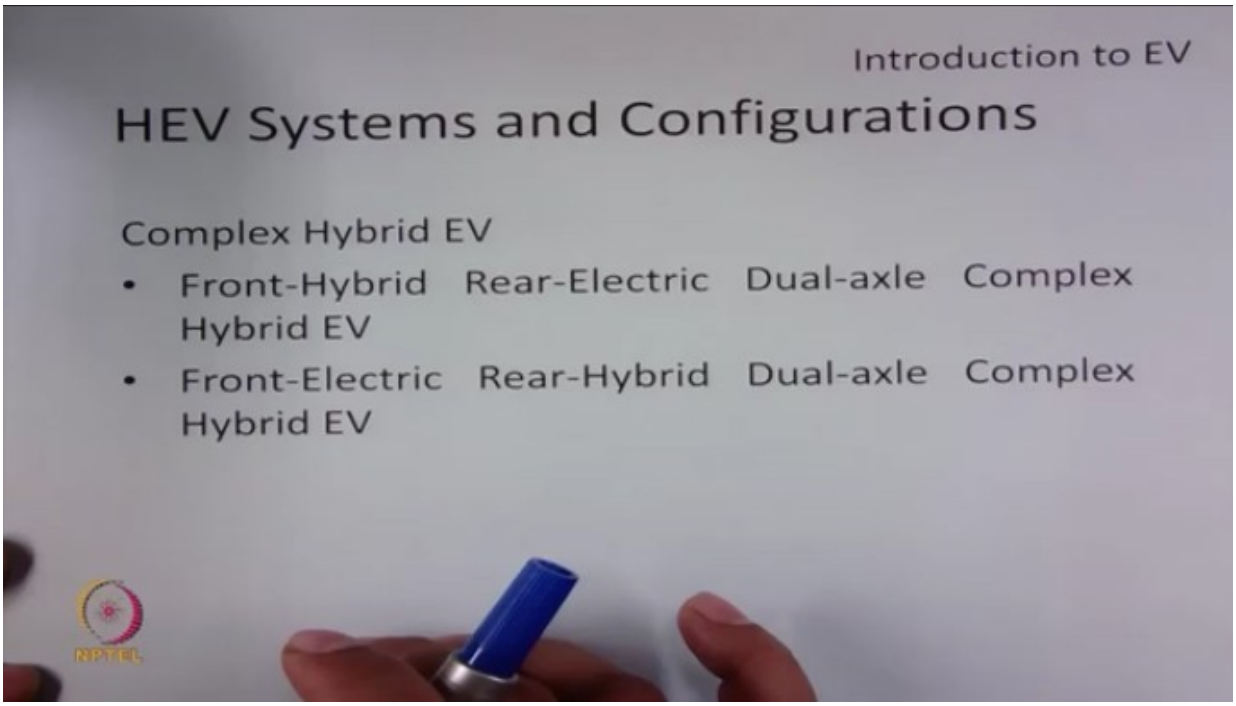

So in addition to series HEV, parallel HEV and series parallel HEV there is a configuration which is known as complex HEV, so this is a complex system and it's a superset of series parallel configuration, so based on how the devices are placed within the configuration, there are two types of complex HEV's, one is front hybrid real electric dual axle complex hybrid, and front electric rear hybrid dual axle complex HEV.

So in complex HEV generally dual axle transmission is used, so both the front wheels and the rear wheels are driven, and two types of subsystems are used, one is front hybrid, front hybrid means it's a hybrid of IC engine and electric motor, and rear electric means it's another motor to drive the rear transmission.

And in the second mode where there is a front electric where one motor will be used to drive the front wheel. And in rear hybrid a combination of IC engine and electric motor are used for driving the rear wheels.

So let us see this configurations and there modes of operation,
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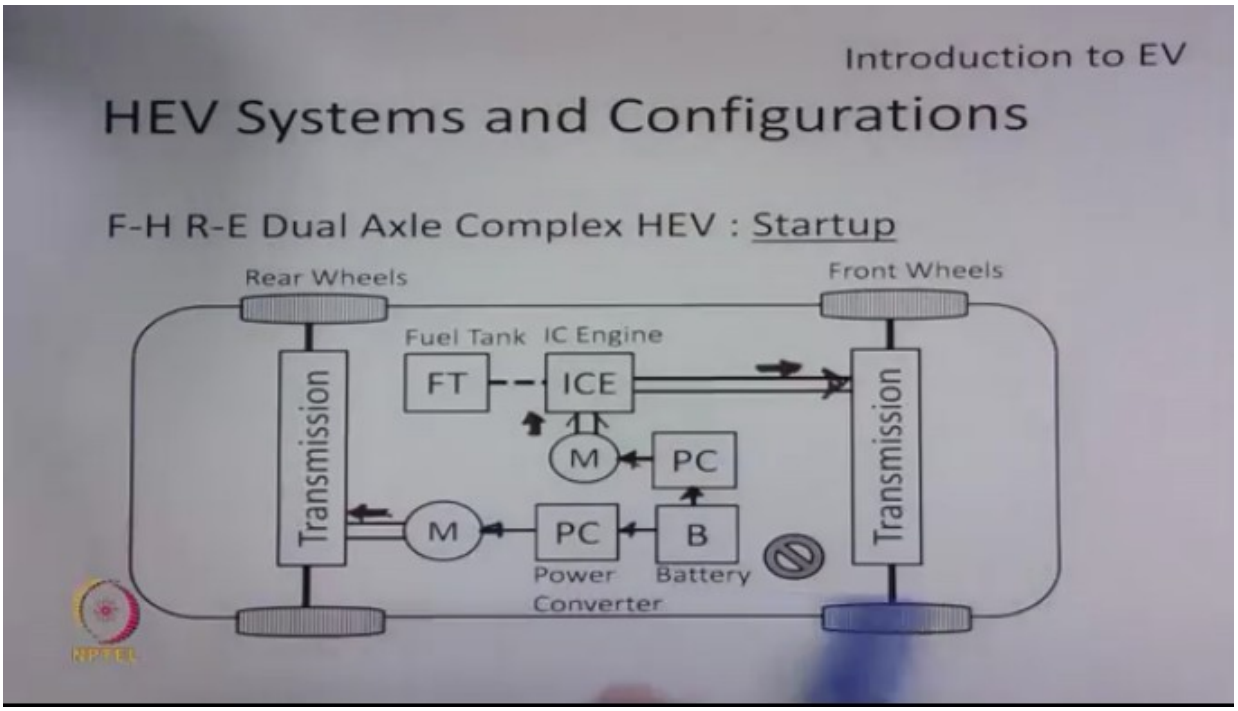

so in a front hybrid rear electric dual axle complex HEV, so there is a hybrid system of IC engine and motor connected to the front wheel transmission, and there is another system which is pure electric drivetrain which is connected to rear wheels or rear transmission.

So now compare to series parallel HEV the machine here is able to operate both as generator and motor, so when you want to operate this machine as generator it can be used to extract power from IC engine to charge the battery, and when it is used as a motor this power converter can be used to extract power from the battery and operate this as a motor, so this is a hybrid of IC engine and electrical motor, and since this is connected to front transmission it is called front hybrid, and since only electrical system or electrical drivetrains connected to rear transmission it is called rear electric. And since both the transmissions are used, I mean both front transmission and rear transmission are used it is called dual axle HEV.

So during startup of such kind of configuration again it is all electric mode, so both the motors are used to drive the front transmission and rear transmission, so one is battery power converter in one motor, second is battery power converter this motor and front transmission.

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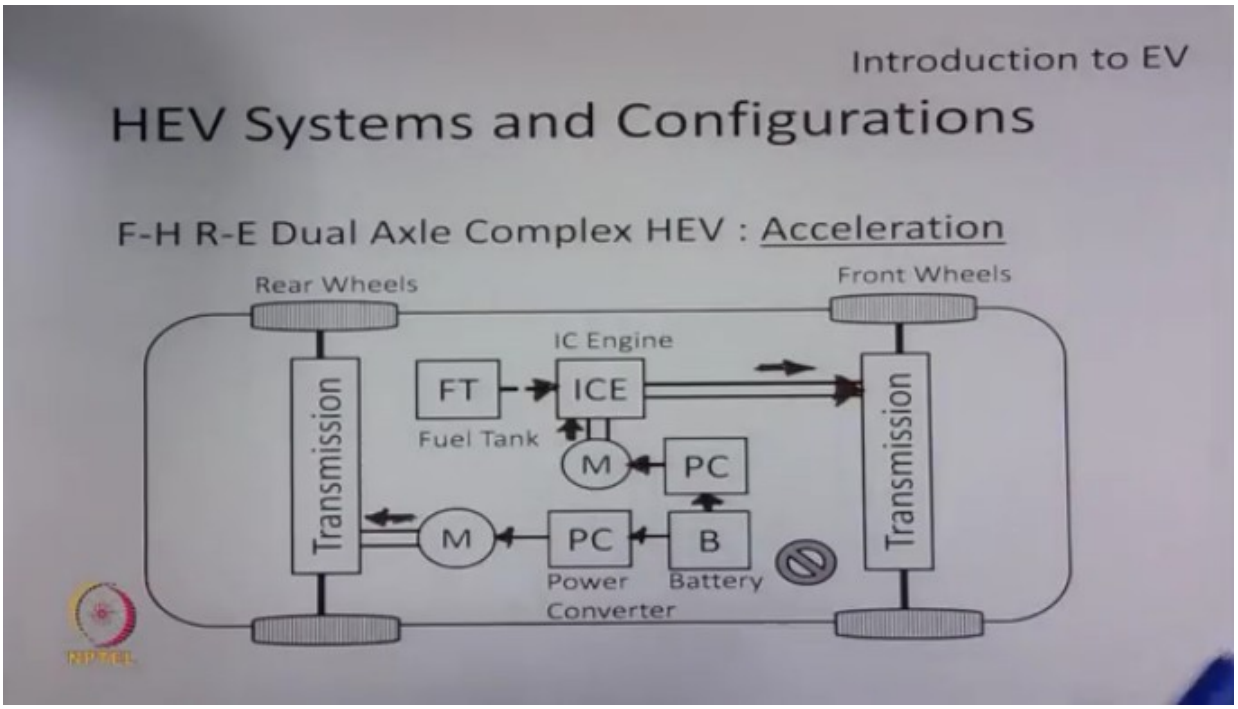

However during acceleration mode the power is also delivered from the IC engine, so both IC engine and front motor drives the front wheels, while the rear motor drives the rear transmission or rear wheels, the whole system is active and it's able to accelerate very quickly.

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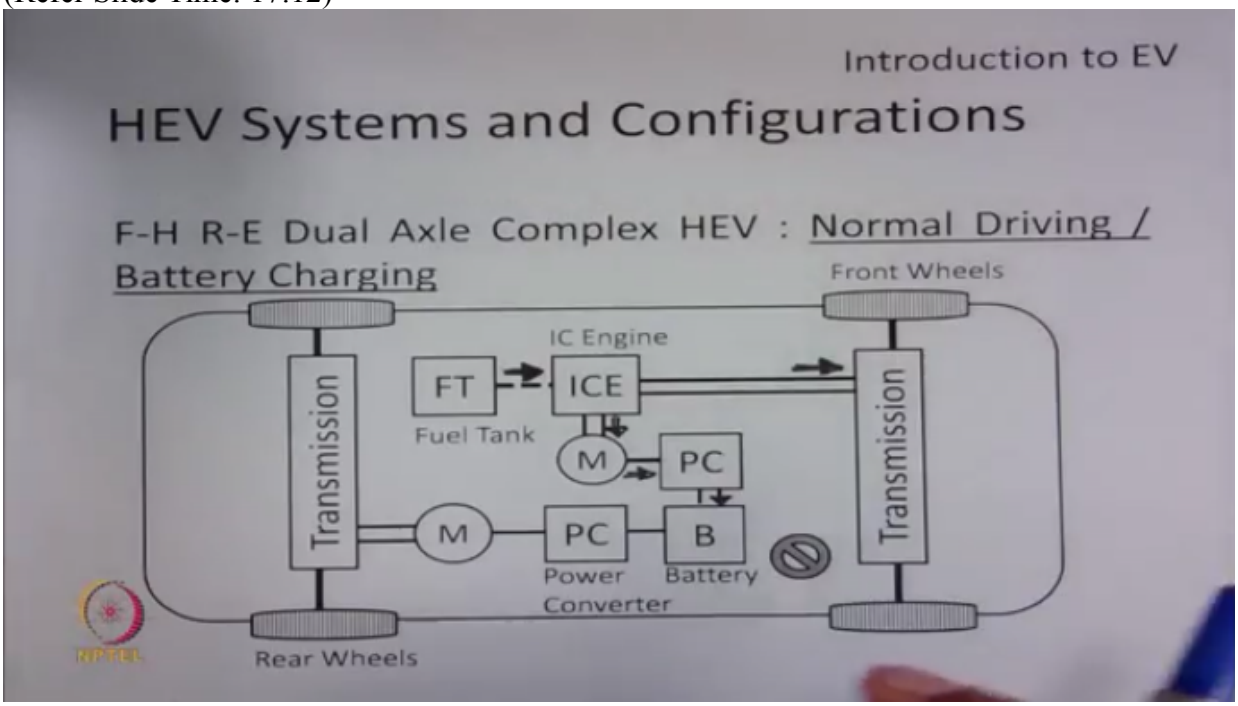

During normal driving or battery charging mode, the mechanical energy is from the IC engine is used to drive the front wheels and a part of it is used to charge the battery, so in normal driving only front wheels are used for driving the system, and the rear transmission is not used and the electrical drivetrain connected to a rear system is inactive.

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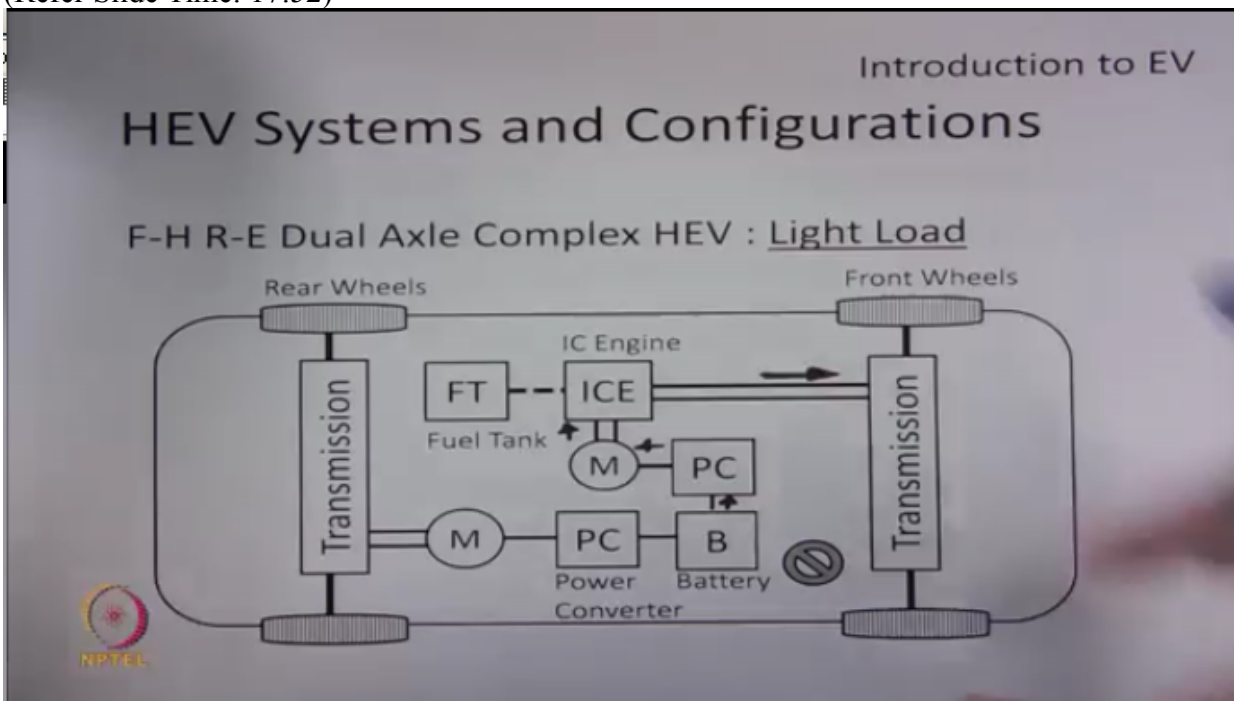

Again during light load condition the wheel connected to front transmissions are only used for supporting the light load, and the motor is connected to IC engine is used for driving the propulsion, so IC engine by itself is not active and the rear wheel connected electric drivetrains also not active, so only power is flowing from battery power converter electrical motor and front transmission, so which is again all electric mode with only front wheel transmission.

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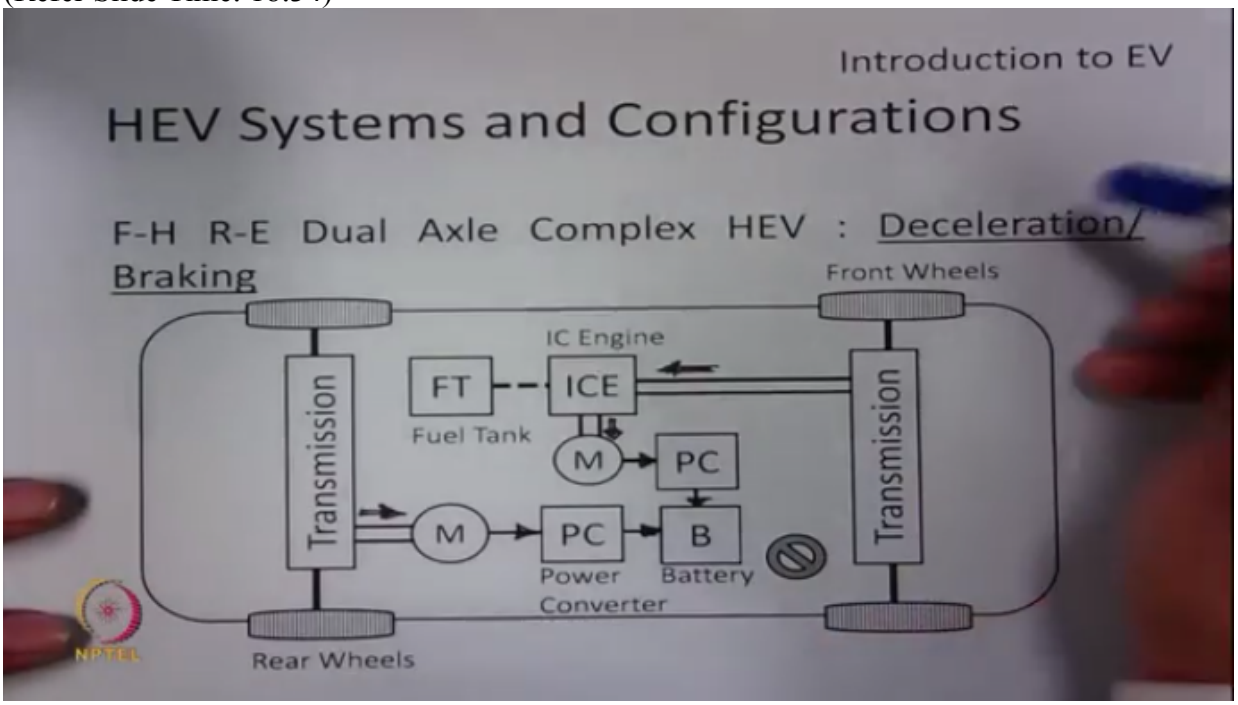

During deceleration or braking it is again all electric and the power is attracted both from the front wheels and the rear wheels using this electric drivetrain, and this electric drivetrain, so both front and rear electric drivetrains are active, and the power is extracted from all the wheels, therefore it is also possible to generate good amount of degenerative braking energy which is higher compared to other configurations.

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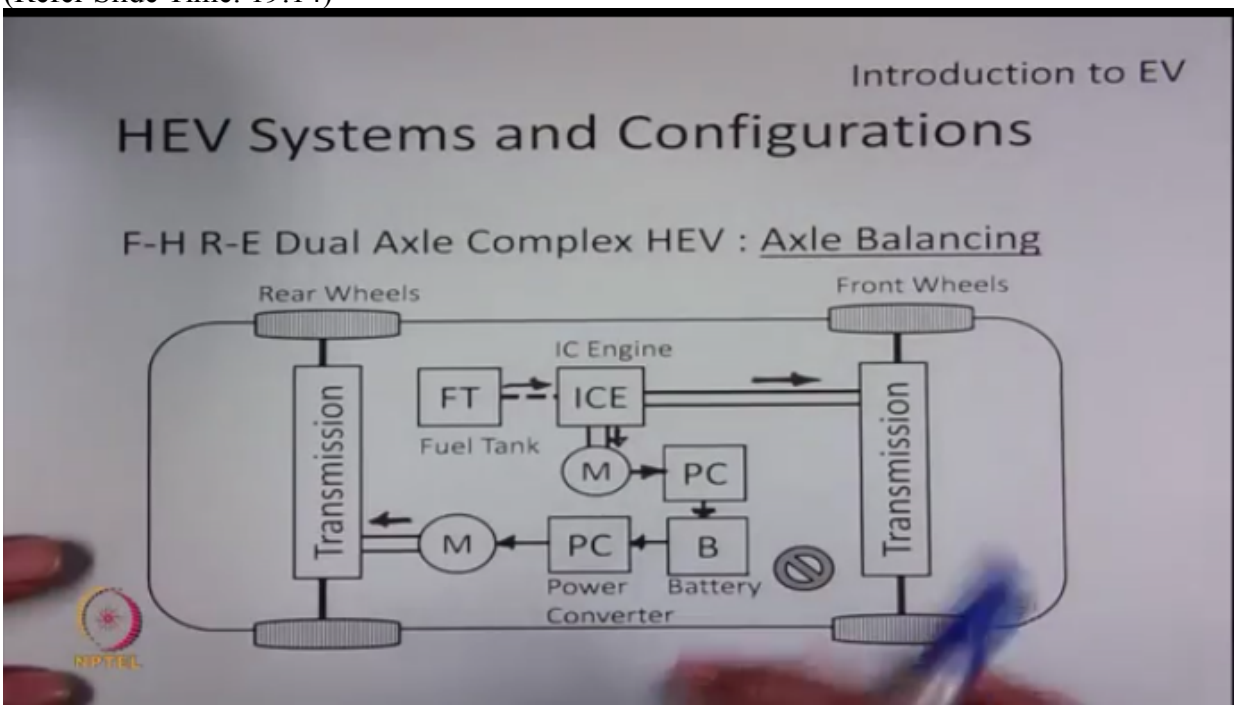

This type of complex HEV's where the transmission can happen both from front wheel and rear wheels picked has a tremendous capacity for axle balancing, means when, let's say the front wheels see a condition where this wheels are sliding, it's possible to control the sliding by operating the rear wheels, how it is done? Let's say the system is under normal driving mode, and engine is used to support the front wheel transmission and then the system is undergoing a sliding condition or due to bad condition of the road, so to oppose this sliding force, a equal and opposite driving force can be extracted or put in the rear wheel, so it's a kind of power balancing, so how much power is you know getting taken by the sliding force, the equal amount of power is given to the rear transmission, such that a system is able to balance itself, so this is the tremendous capacity and this type of vehicle can go in different tarring's with ease.

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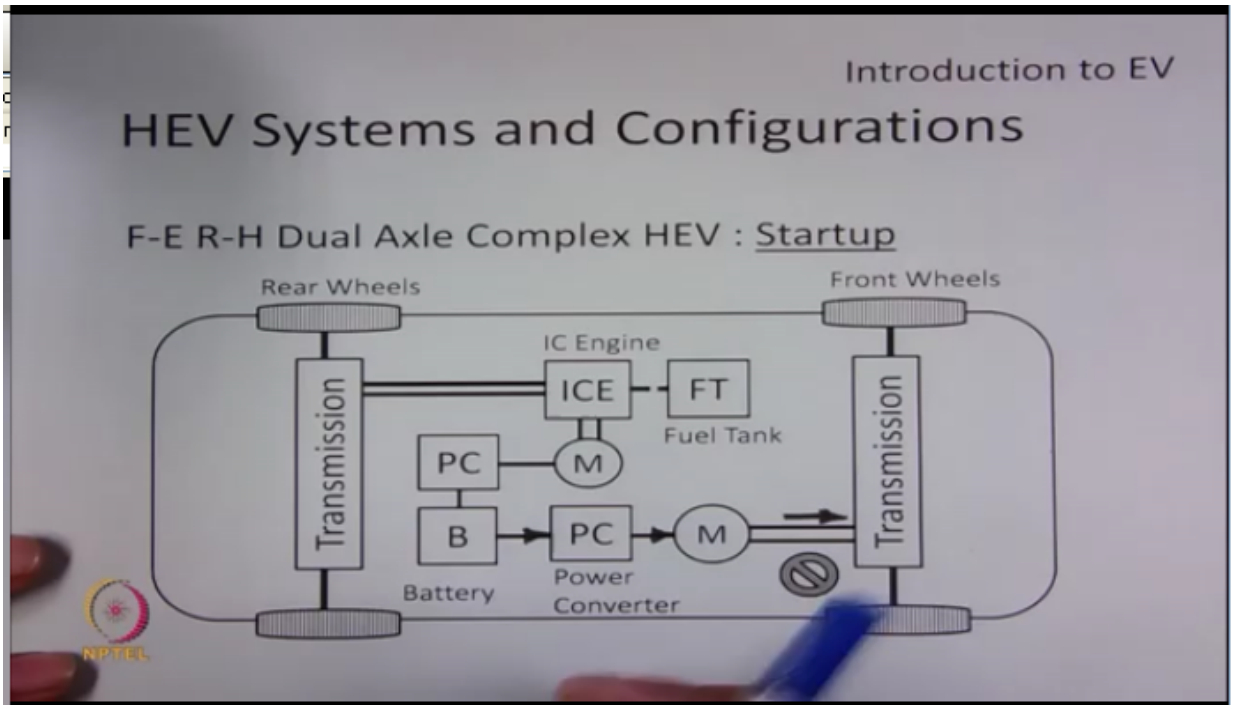

So let us not see the configuration of the another dual axle complex HEV which is front electric and rear hybrid, so you can see that the system is now reversed, the IC engine and the motor is connected to a rear wheels while the second electric drivetrain is connected to the front transmission, so during startup only the front electric drivetrain is only active for supporting the startup operation, while the rest of the system is not active.

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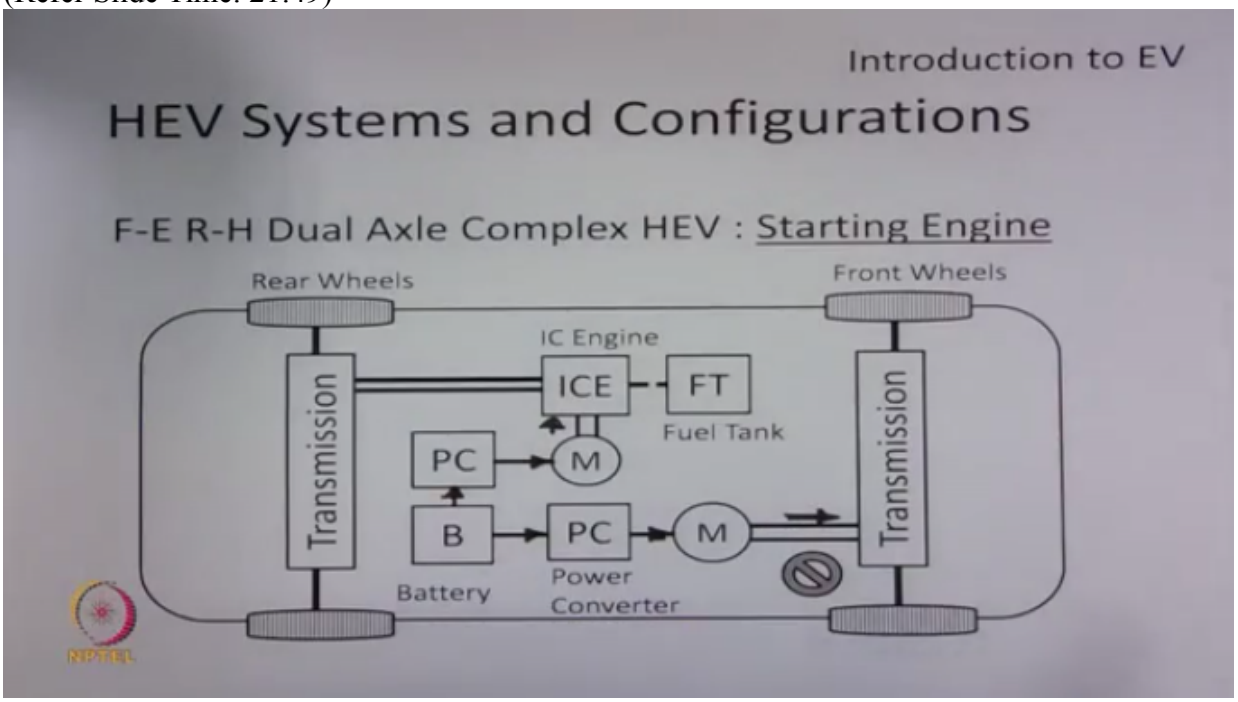

So if the engine has to be started, after startup of the system the second motor can be used to start the IC engine as cranking, so this system has very similar to the starting of the IC engine where this motor is working as a integrated starter generator.

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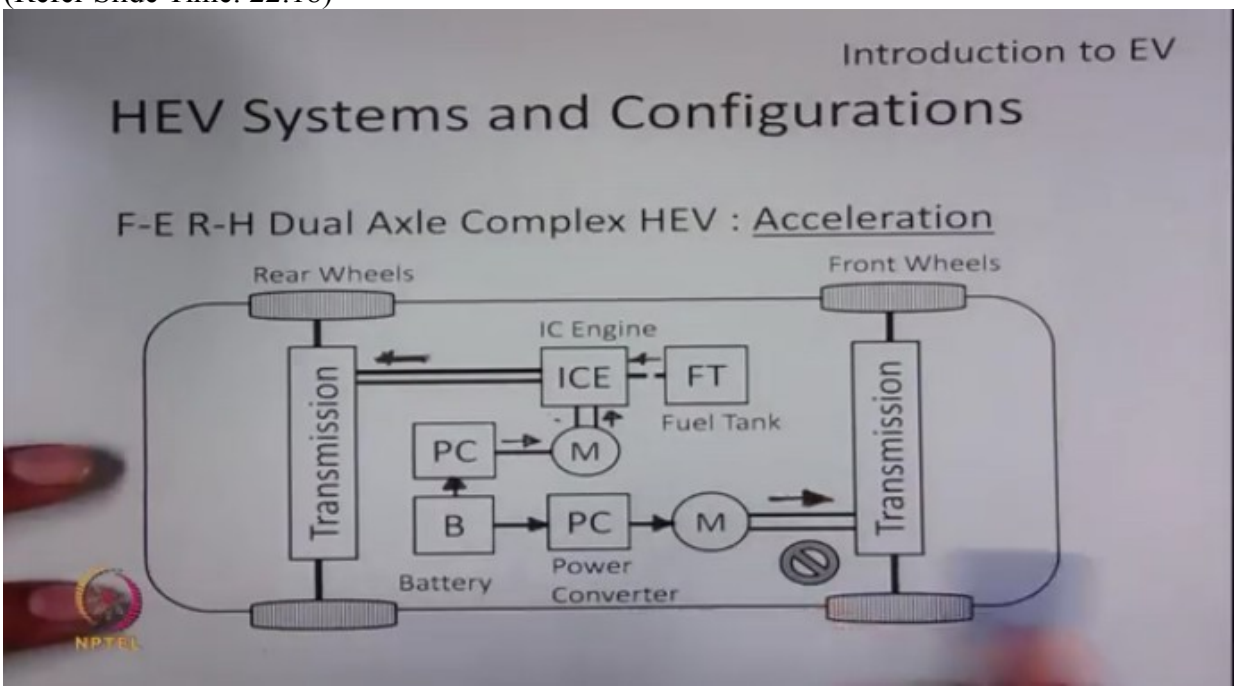

During acceleration all the propulsion device are active and both front electric drivetrain and rear hybrid drivetrain is active, it's very similar to the previous complex HEV configuration.

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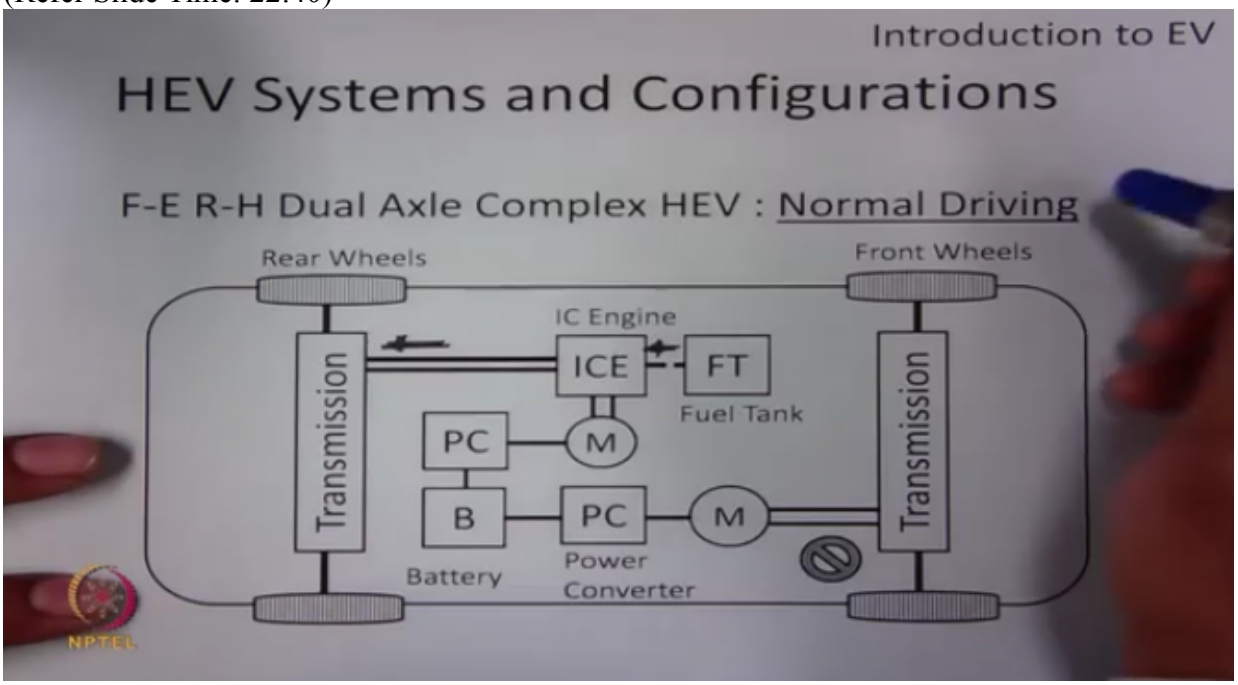

During normal driving only the IC engine drivetrain is active while the both the electric motors are inactive, so this is very similar to other counterpart, but you can see that in a rear hybrid type of complex HEV during normal driving only the rear wheels are used to drive the vehicle, and the front wheels are idle.

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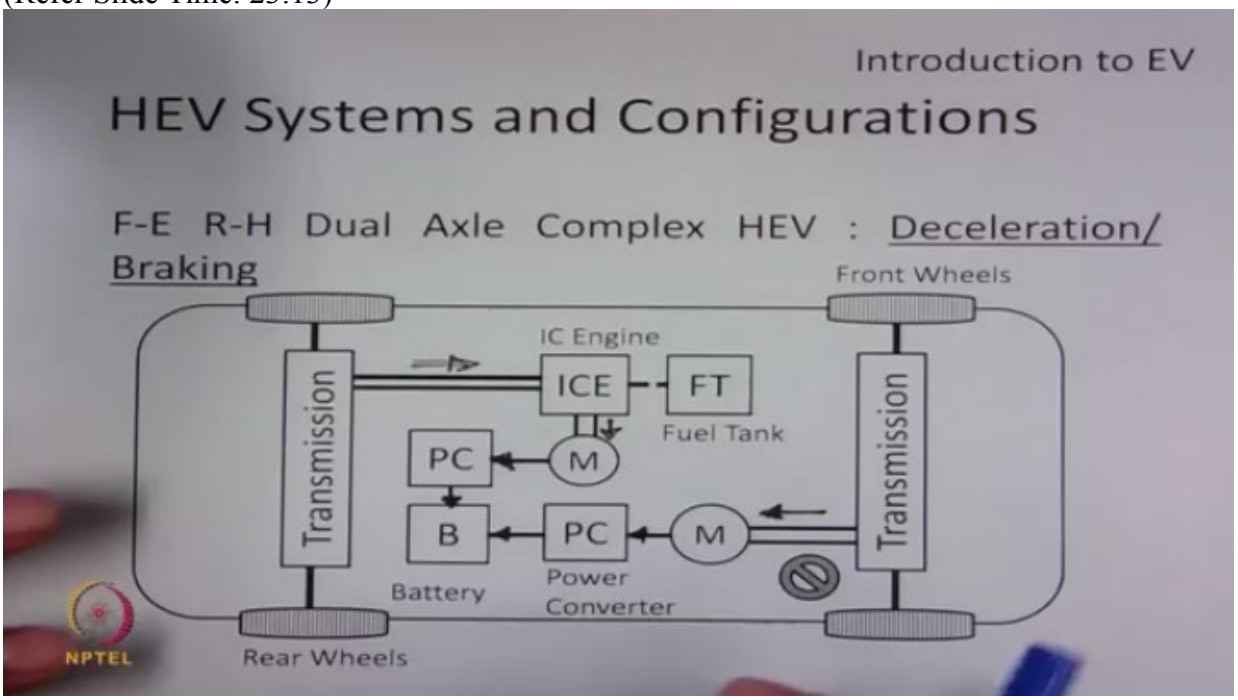

Similar to the previous configuration during deceleration or braking operation both the motors will operate at generators and extract the power from both rear and front wheels, so the IC engine is off because cannot regenerate any energy.

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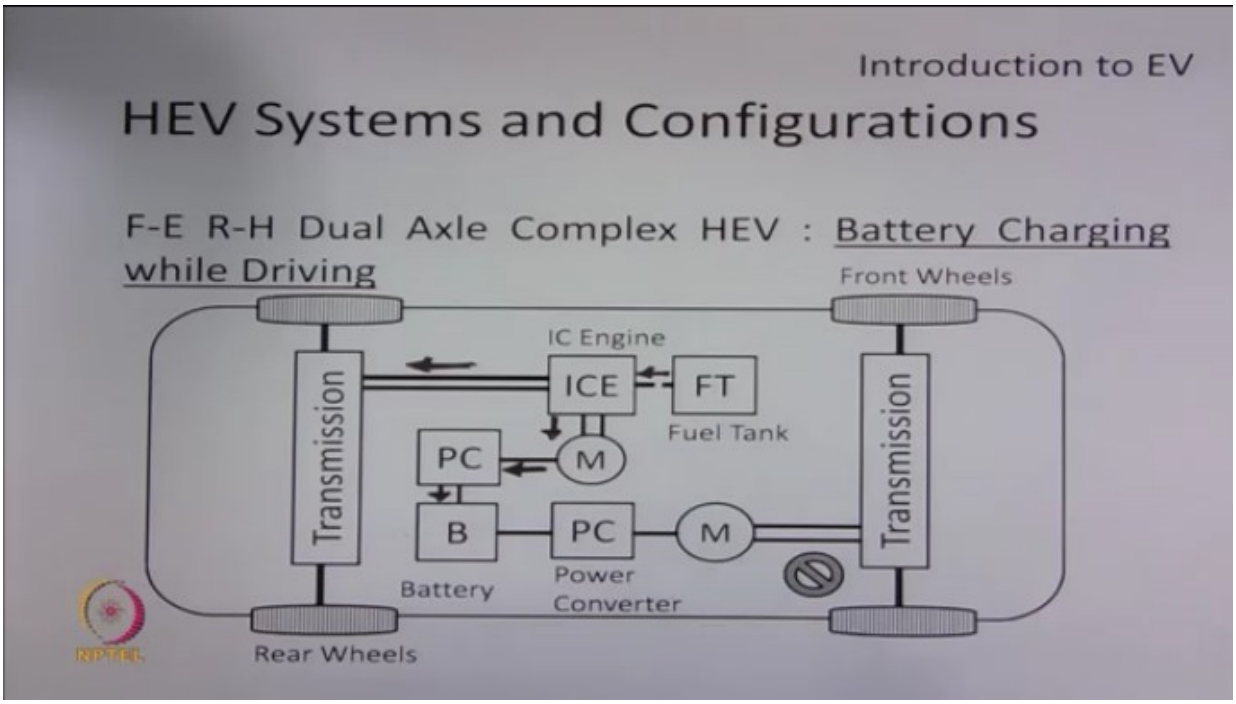

So similar to the previous counterpart, if you want to charge the battery during driving, the part of the IC engine energy is transferred to the battery via operating the second motor as generator.

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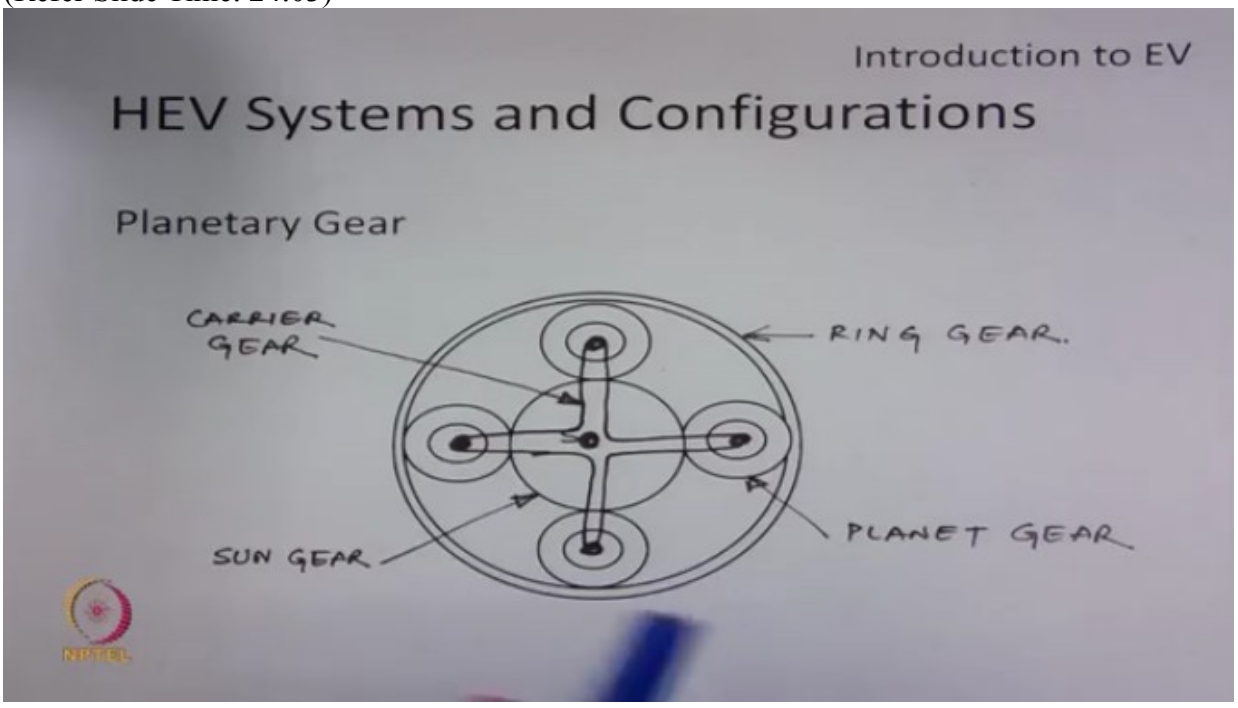

So that's all the discussion or different modes of operation of different types of HEV configuration, so we've discussed series hybrid configurations, parallel hybrid configuration, series parallel HEV configuration, complex HEV configuration and there all modes of operation.

So as discussed in our discussion to obtain all this modes of operation, we require special gearing system at the hybrid mode of IC engine and electric motor. So IC engine should be able to connect both to the transmission and to the electrical machine, and should also able to operates alone, so all this modes of operation is possible by having a special gearing system which is known as planetary gear system, so as can be seen from this diagram so there are various kind of gears connected together, so the outmost gear is known as ring gear, and the inner most gear is known as sun gear, and this small, small gears which connects the sun gear to the ring gear are called planet gears, so there are three gears, ring gear, sun gear and planet gear, so sun gears are connected to electrical machine, ring gear is connected to transmission, and it's possible to transfer energy from ring gear to sun gear using planet gears, and there is a link between sun gear and planet gear by this kind of connection, so this is called carrier gear or carriers, so this carrier is actually connected to IC engine, and it can decide based on the speed of operation, how to transfer power from either IC engine to electrical motor or electrical motor to IC engine, or IC engine to the transmission.

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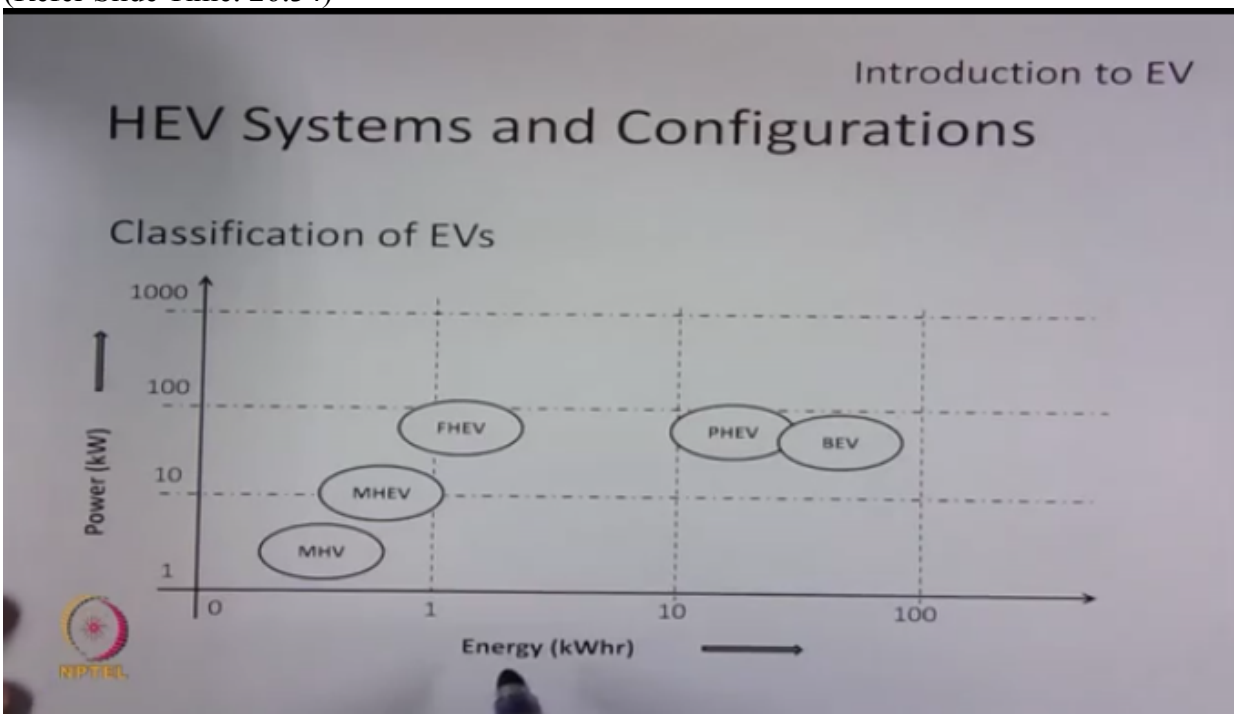

So let us quickly see on the power and energy graph where this different types of EV stand, so different types of this systems are decided based on the power rating of the vehicle, so this is the micro HEV, this is mild HEV, this is full HEV,

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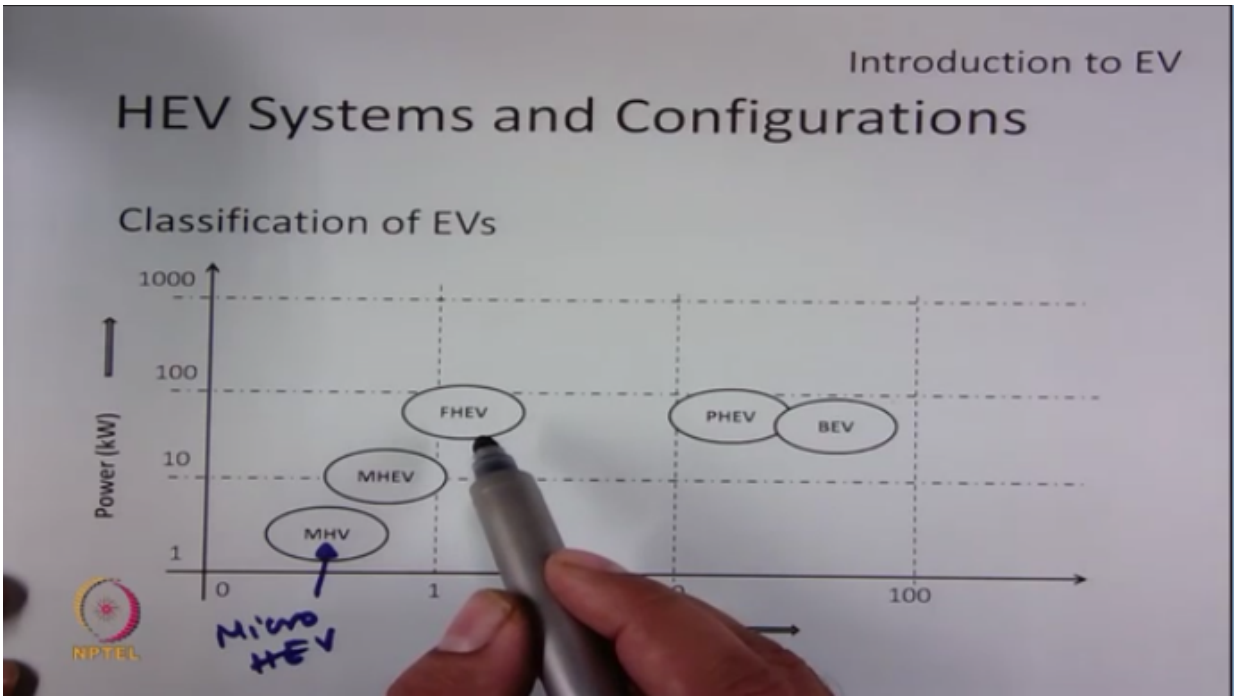

so here you know you have all series parallel and type of full hybrid vehicles and also, so PHEV stats here so in PHEV the energy storage requirement is high, and therefore it needs to have lot of batteries, while this systems doesn't require much battery because it has very high capacity IC engine with it. A BEV uses more battery when compared to PHEV, since it has only batteries for supporting the transmission.

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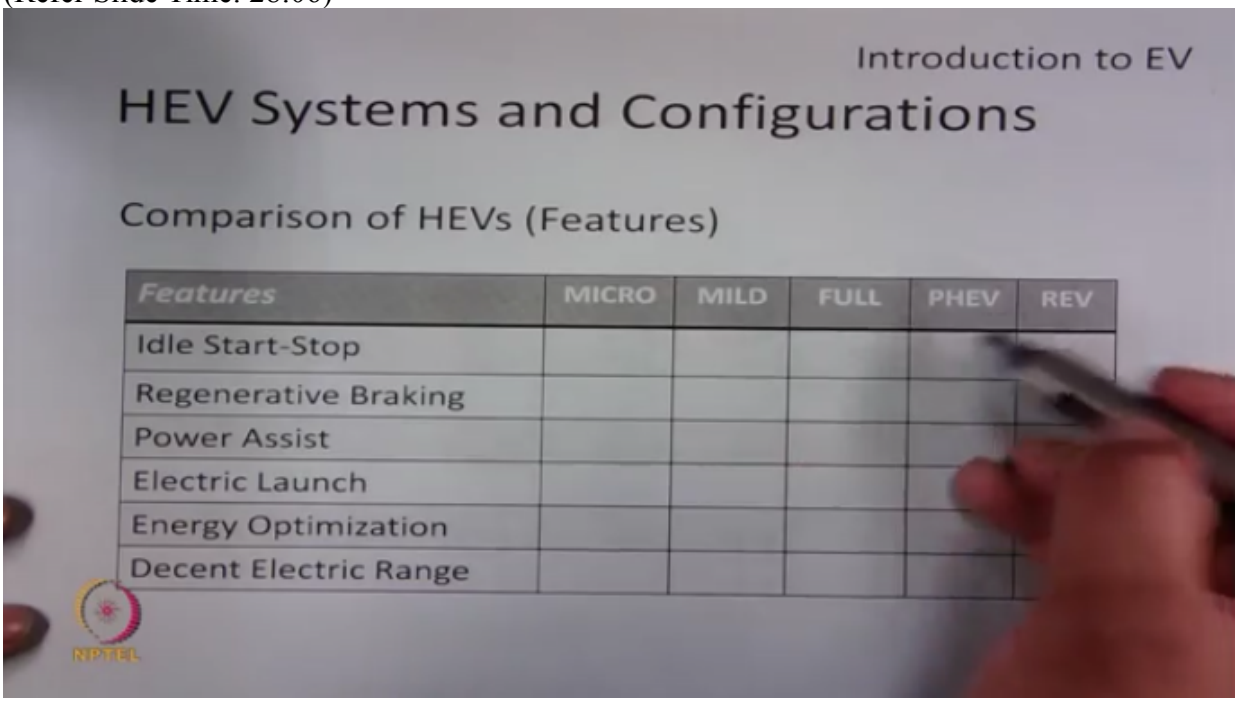

So if you want to have a quick comparison of the different features this kind of micro, mild, full, PHEV and REV type of HEV can offer, you can say that the micro HEV can only support

startup feature or idle startup feature, and regenerative braking, while they are in mild hybrid HEV can support start stop, regenerative braking, and also it can support the IC engine mechanically during acceleration and quick alignment.

In full HEV not only this modes are possible, it is also possible to start the engine in full electric mode which is known as electrical launch.
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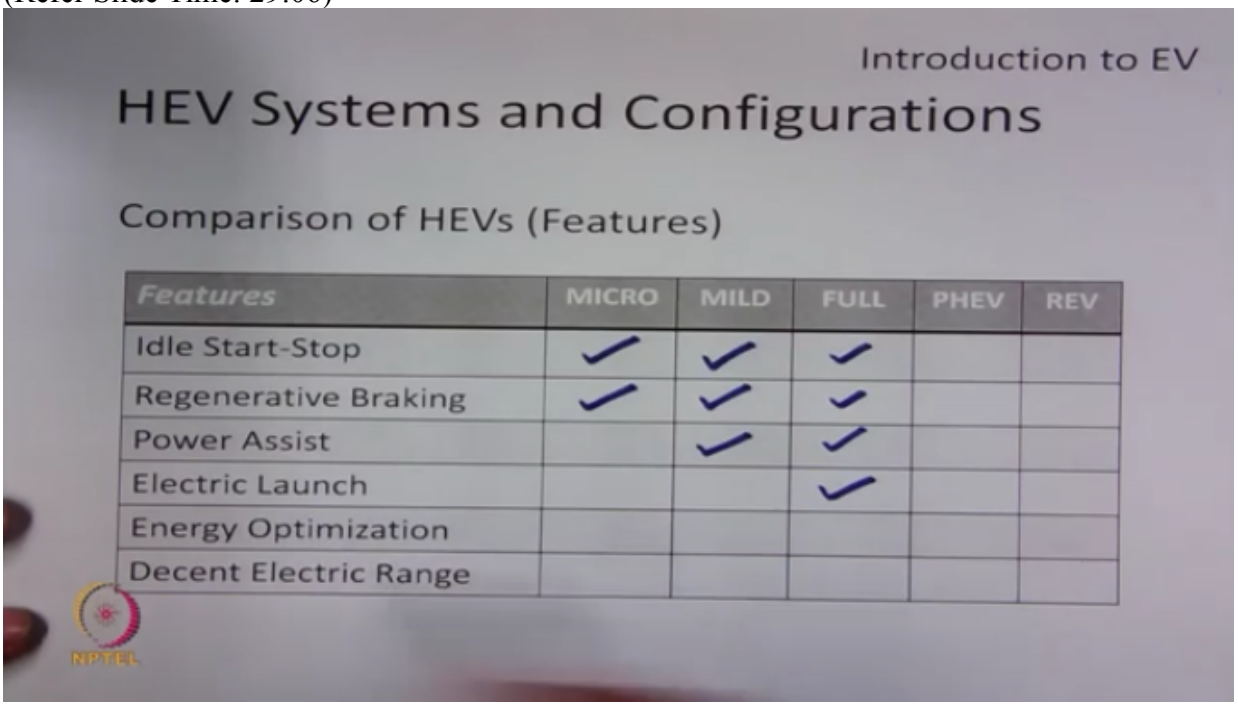

Since in full HEV there is a possible of optimizing the energy flow such that the energy is optimized is maximum, so this mode is also possible in a full HEV.

In PHEV and REV all this modes are possible,
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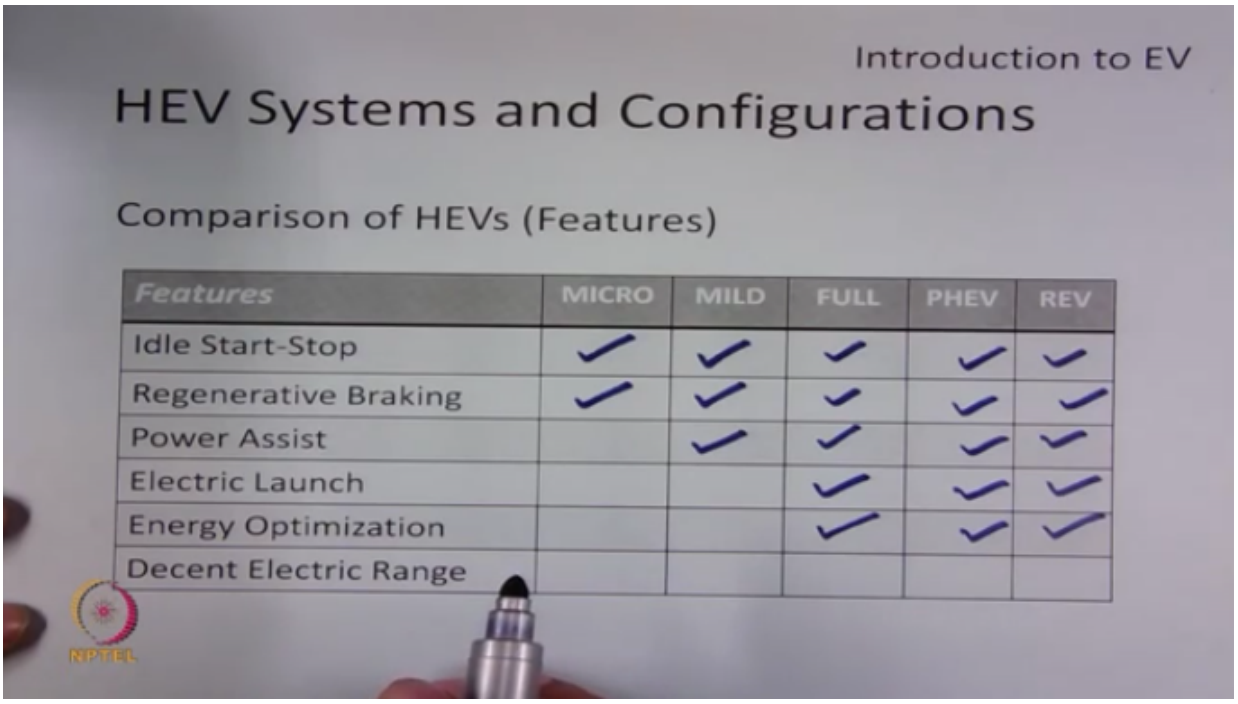

and in addition to that it is possible to operate this PHEV and REV in full electric mode for a lot of time, so it can offer descent electrical range in full electric mode,

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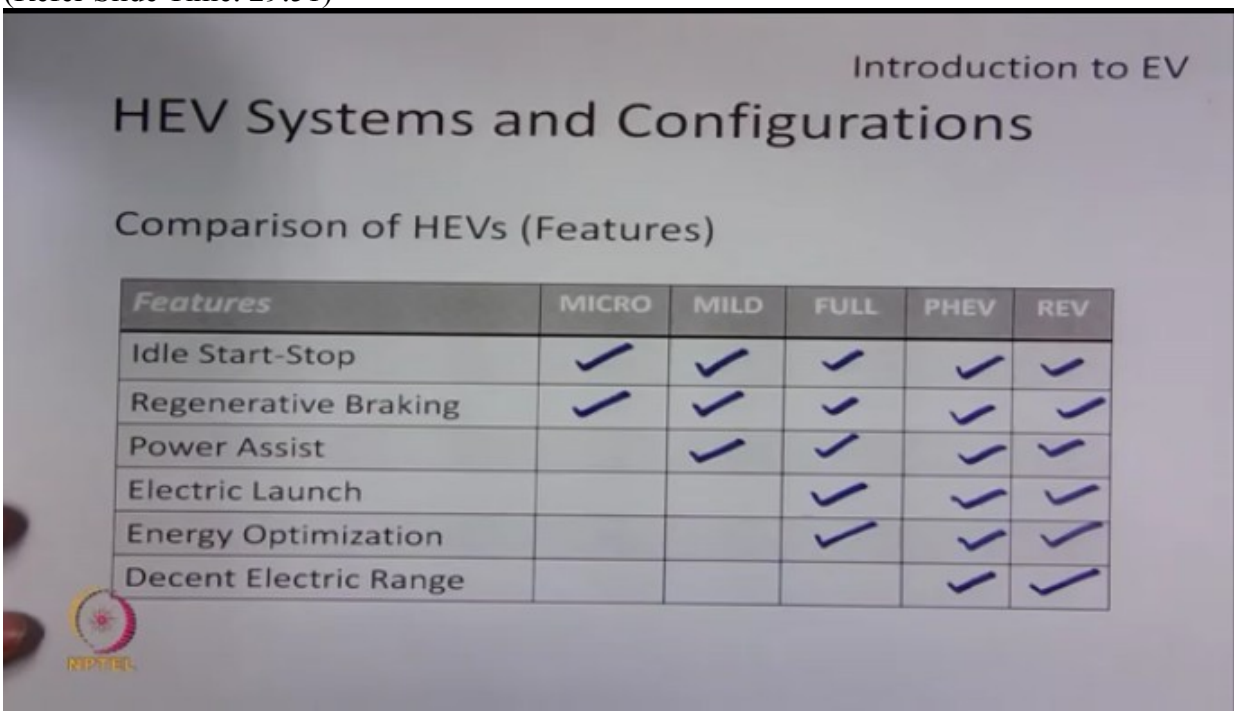

so that is all under the topic HEV systems and configurations, and we will start the topic of discussion known as vehicle dynamics and it's modeling and simulation in our next instructions,

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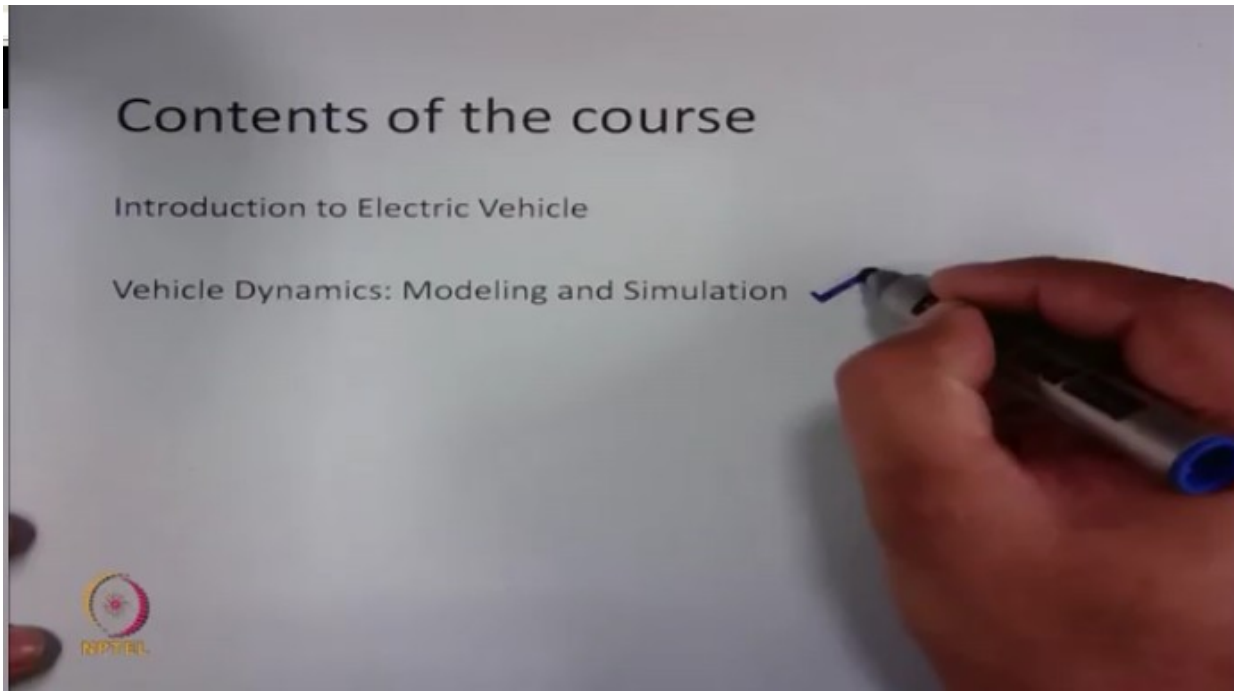

so introduction to HEV is kind of complete, and we will go ahead with vehicle dynamics, it's modeling and simulation in the coming interactions, so thank you for listening the lecture.

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