NPTEL

National Programme on
Technology Enhanced Learning

Video Course on

Electric Vehicles Part 1

by

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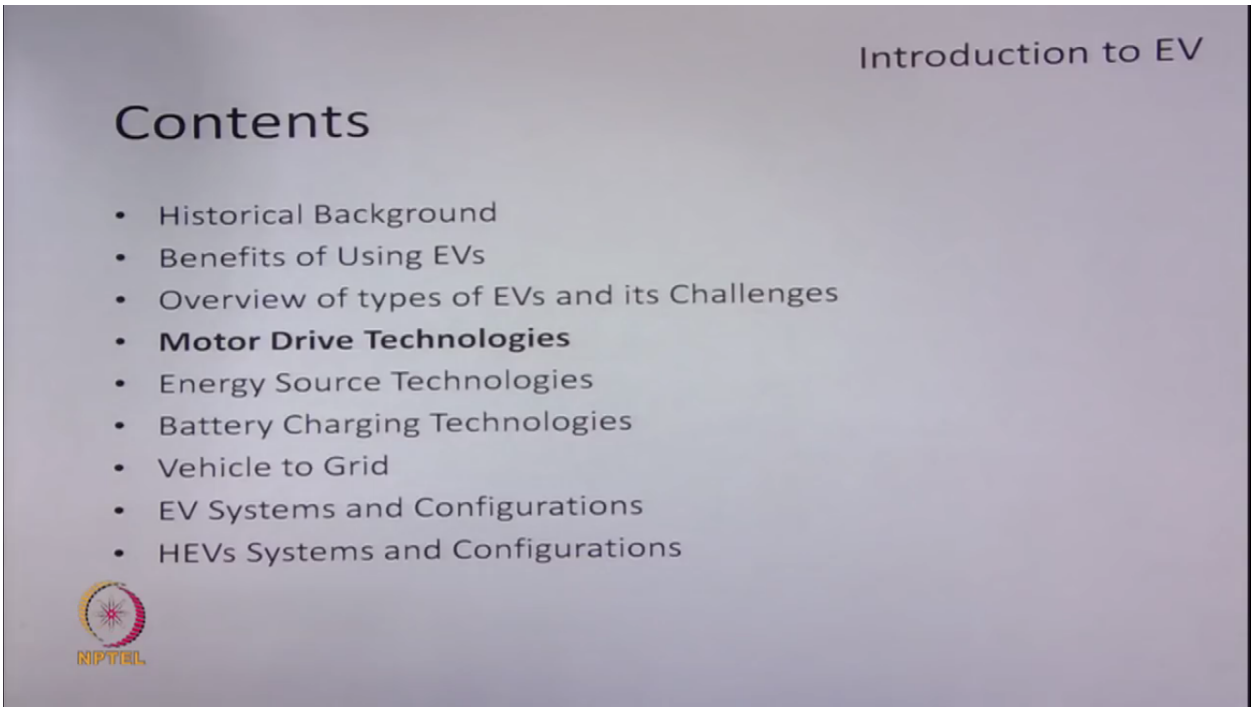
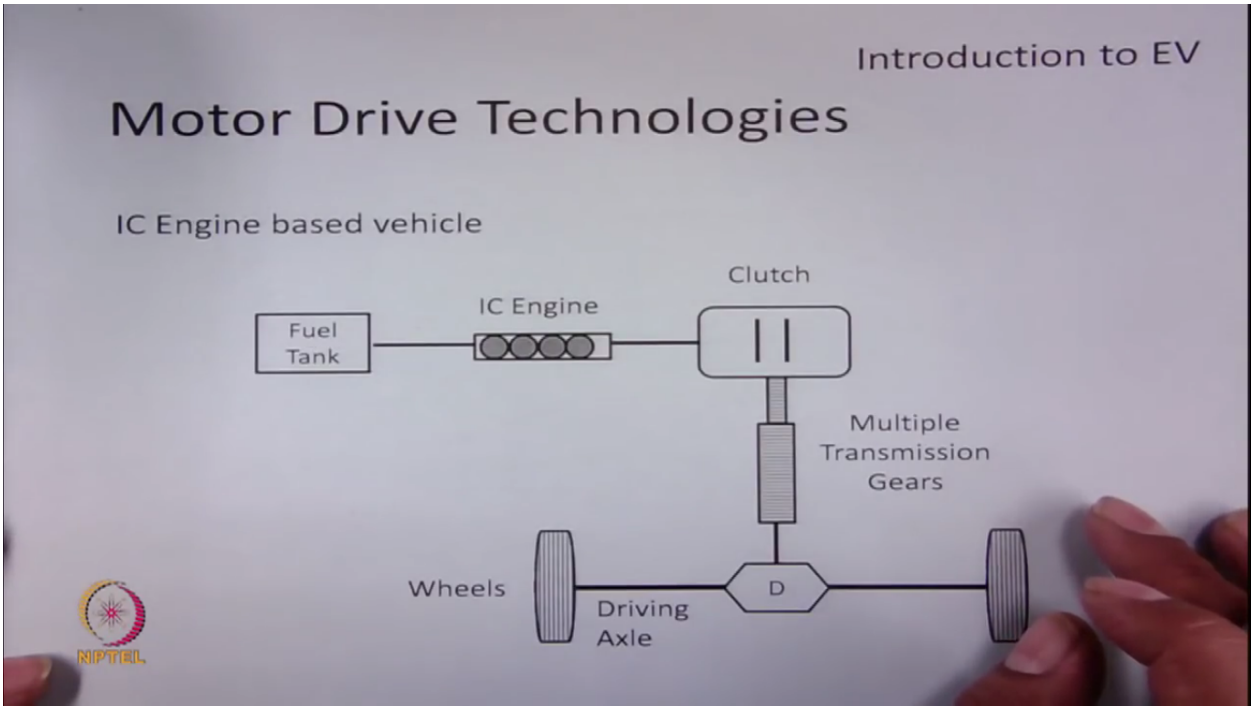
Lecture # 4

Intro EV Motor Drive Technologies

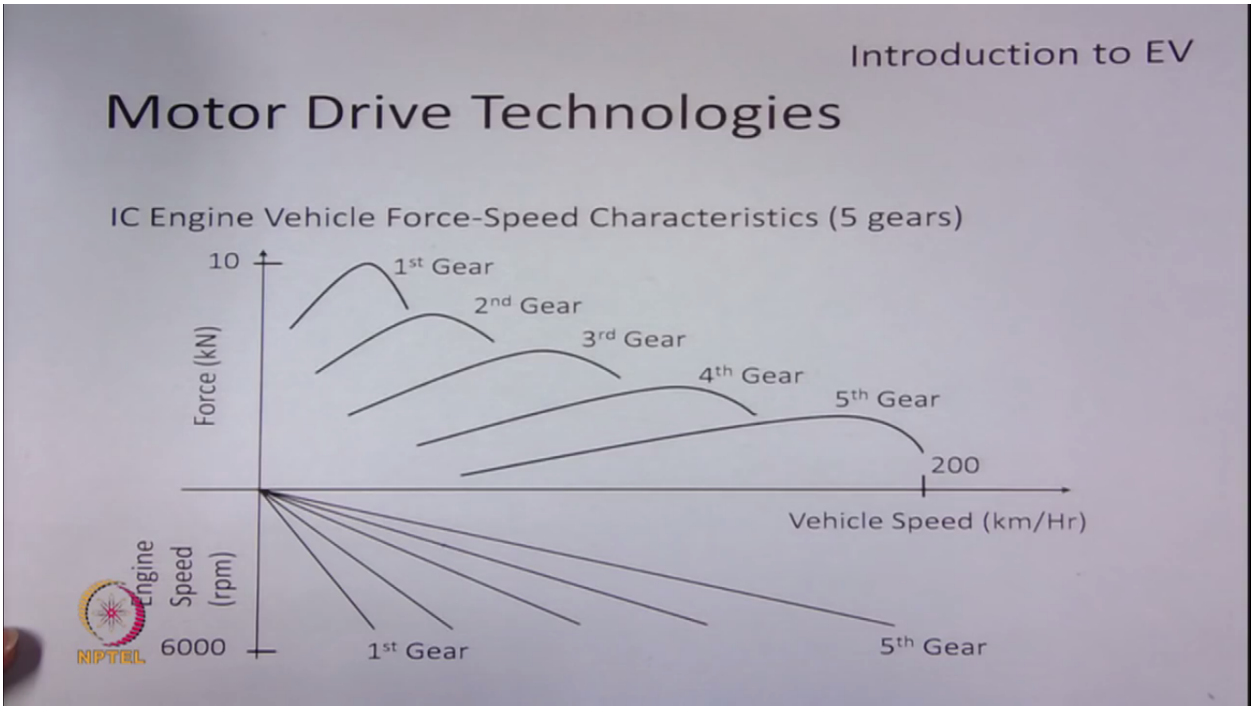




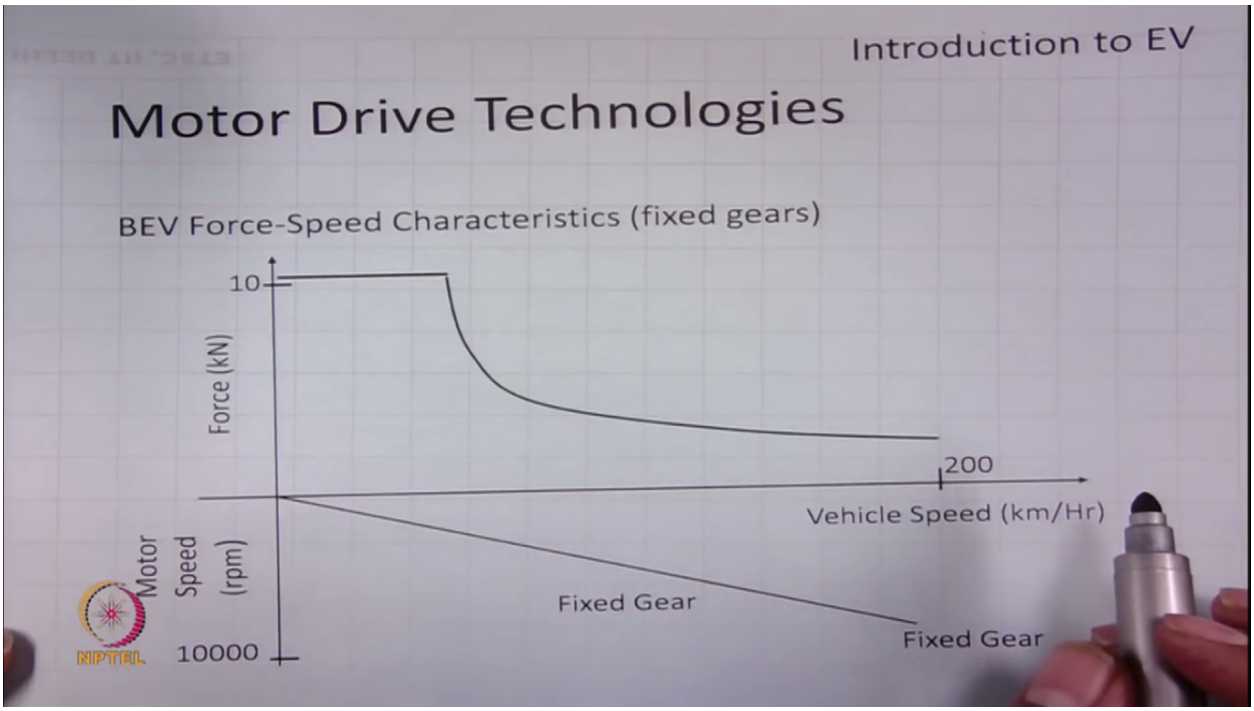
Hello everyone. Welcome to the online MOC course on electric vehicles. Let us discuss the next topic under introduction to EV which is motor drive technologies. In order to appreciate the features of electric motor for EV application let us first discuss the principle of transmission of mechanical energy used in a typical IC engine based vehicle. IC engine cannot operate in wide

[00:01:01] regions on its own. Therefore it requires the support of clutch and multiple transmission gears to achieve multiple speed and multiple torque profiles required in a vehicle application.

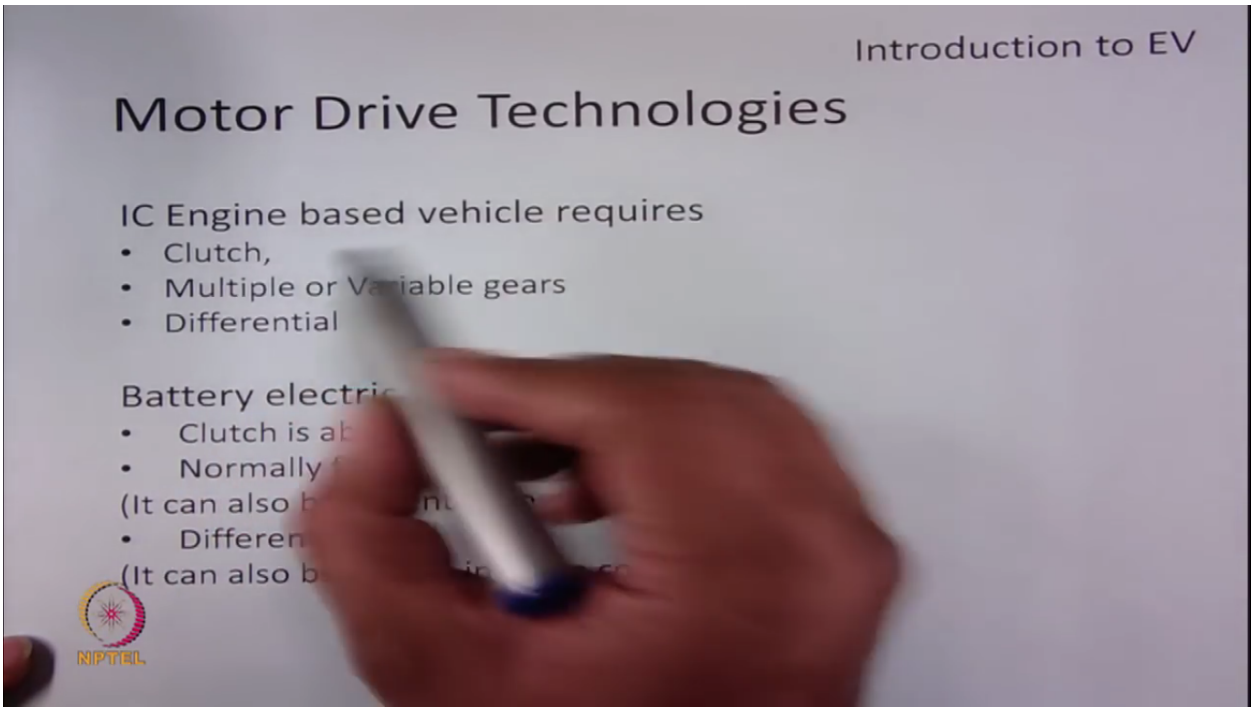
So when the clutch is engaged the IC engine is coupled to the gear box and energy is transferred from the IC engine to the wheels using gearbox. So when a different torque and speed requirement needs to be delivered from IC engine the clutch is disengaged and a different gear is used to meet the requirement such that the required torque and speed is achieved at the wheels. So a typical IC engine based vehicle uses multiple gear systems. So it can be around five gears for a typical car and it is around 16 gears for a big trucks or buses.



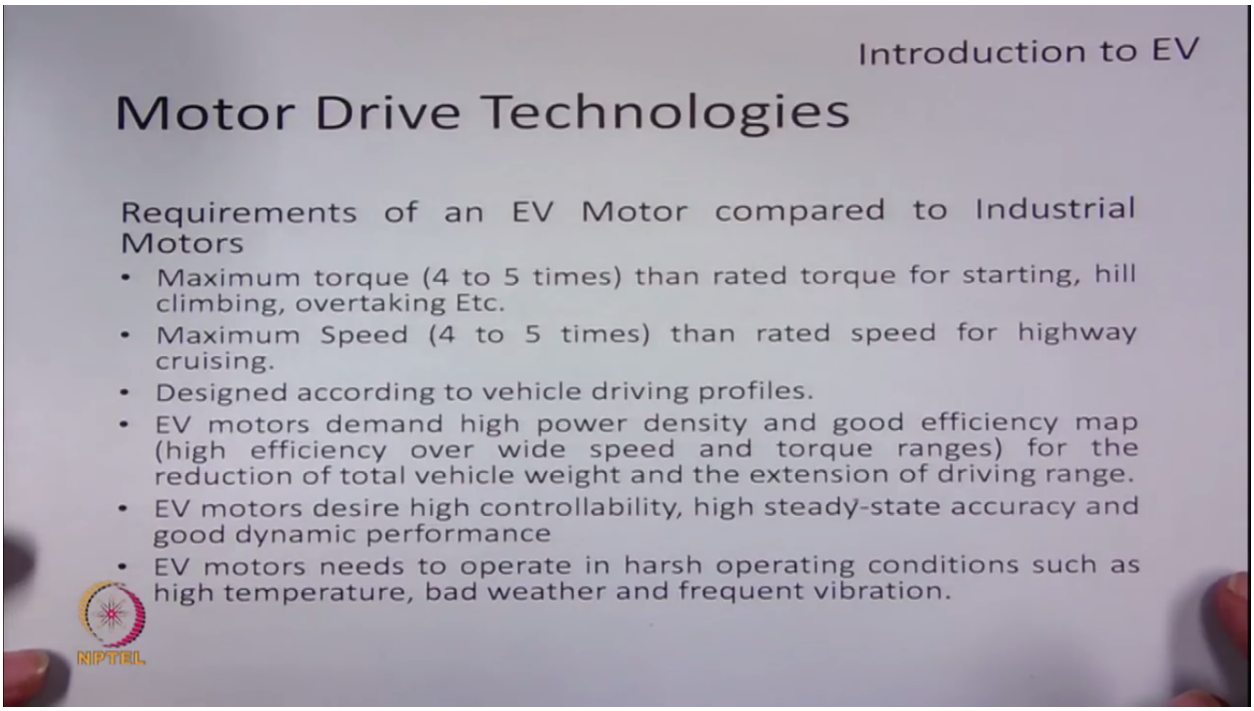
So this figure shows the force-speed characteristics of IC engine based vehicle which has five gears means it can operate at five different speeds. So in first gear the IC engine can deliver a very torque in the shaft and enable low speed operation. So this mode is required for starting and acceleration. So when the vehicle is required to go at high speeds the gear needs to be changed such that high speed operation is possible but now the torque that is available on the shaft is very low.



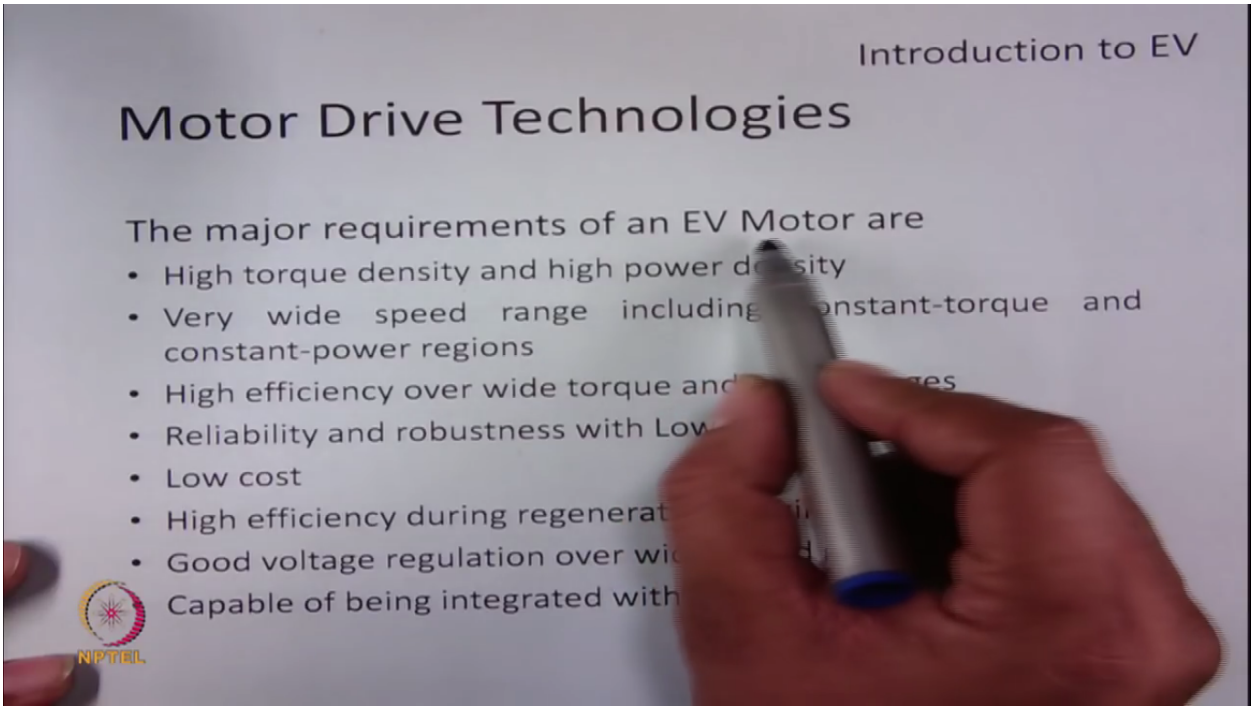
So what does the gear do? So gear enables increase in speed together with decrease in torque such that the power input from the IC engine remains constant. On the other hand, if this is the force-speed characteristics offered by a electric motor with fixed gearing it can be seen that in electric motor readily provides a high torque at starting and also enables high speed operation at reduced torque. So this operation can be achieved without the necessity of clutch or variable gears. Therefore, the battery electric vehicle does not require the complex gearing and transmission systems required in a IC engine based vehicle. It also enables smooth driving experience and the transmission efficiency of a BEV is higher compared to a IC engine based vehicle.



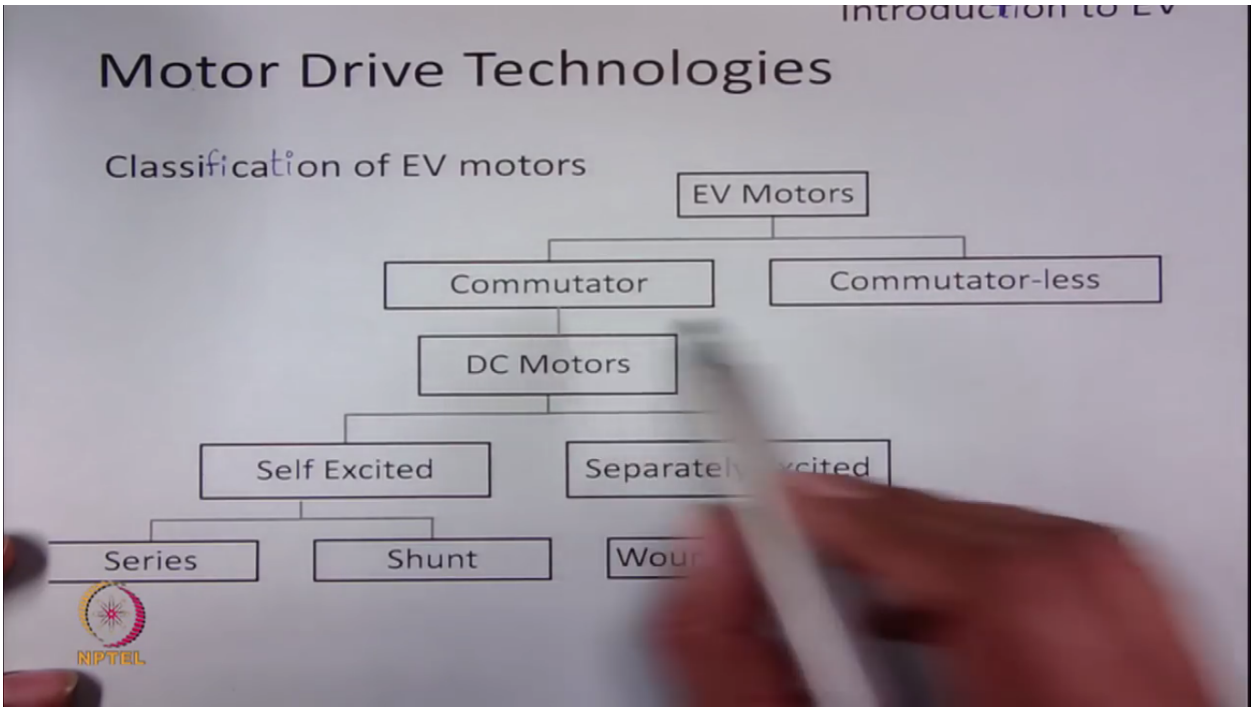
So summarizing what we have discussed now so IC engine based vehicle requires clutch, multiple gears and a differential. On the other hand the battery electric vehicle does not require clutch and only fixed gears are used. This requirement is also absent in some of the recent configurations. We will discuss that in our next interactions. It's also possible to remove differential.



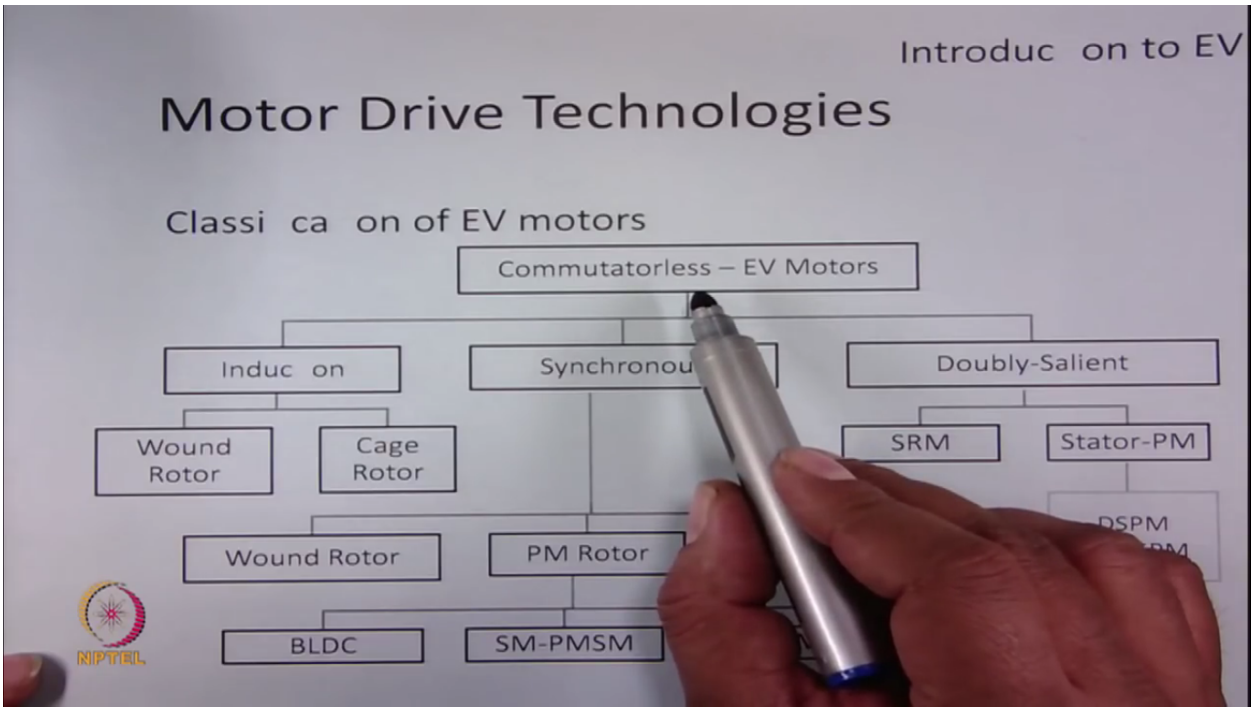
So what are the design requirements of a typical EV motor? It can thought that we can use the on the shelf industrial motors for this application. But that is not true. A typical industrial motor gives a maximum torque equal to twice the rated torque of the machine. But the maximum torque requirement of a EV motor is four to five times the rated torque of the motor for starting, hill climbing, overtaking, etc. Similarly, the maximum speed required in a industrial motor is around two times the rated speed. While this requirement is very high in a EV application it is also around four to five times the rated speed for high speed highway cruising. The EV motor has to be designed considering the vehicle driving profiles which means that it should have a good efficiency map in wide range of speed operation. If possible the motor has to be high power density so that the total vehicle weight is less and it will enable extension of driving range. Since the motors directly control the wheel it is decided that they should have high controllability and good steady-state and dynamic performance.



EV motor also needs to operate in harsh conditions such as high temperature, bad weather and frequent vibrations. Therefore, there is need to provide thermal and IP protection together with good suspension. So summarizing the points we discussed an EV motor should be having high torque density and high power density. It should operate in a very wide speed range that is low speed constant torque region and high speed constant power region. It should be having high efficiency in all those regions. There is a requirement for high reliability and robustness. It should be less costly for mass vehicles. If the electric motor is used for HEV application it should also deliver high efficiency during regenerative braking. It should maintain good voltage regulation in wide speed generation. It should also be capable of being integrated with a IC engine.



So what are the different types of EV motors used for electric vehicle applications? So this motors are generally classified into two types, commutator motors and commutator-less motors. So commutator motors have commutator in them while it is absent in commutator-less motor. Typically all DC motors are commutator motors. For control purpose generally PM-excited separately excited DC motor is used since it offers high power density and it is smaller in size. DC motors also provide very simple control since its construction offers orthogonal control of the flux and torque.



So PMDC motors are used for low rated two wheeler applications. So commutator-less motor offers high efficiency high power density as well as maintenance free operation. Therefore this kind of motors are more preferred for EV applications. As all of you know the industrial machine is widely preferred in industry because of this long life and maintenance free operation. The highest efficiency of industrial machine ranges from 85% to 91%. This kind of efficiency can be achieved if rotor copper bars are used in cage rotor motors. So this kind of technology was used in early Tesla car models. On the other side wound rotor industrial machine although has higher weight [00:11:33] motors, it does offer high power density at higher speeds with complex control. So this configuration is also picking up slowly in the research domain.

The most widely used motor in EV application is synchronous machine. Out of the different types of synchronous machine the PM rotor type of synchronous machine is preferred for EV applications since it offers high torque density, high power density, and high efficiency which is the highest among all these motors. Brushless DC machine is very popular in two and three wheeler domain the operation is very simple similar to a DC machine. It is also known as commutator-less DC machine. Surface mounted permanent magnet synchronous machine is used at power rating greater than 15 kilowatt. So in this type of motors the stator is similar to the one used in industrial machine but the rotor is fitted with permanent magnets. So permanent magnets are rare earth magnets pasted on the surface of the rotor such that it offers characteristics very similar to cylindrical rotor synchronous machine without any [00:13:12].

So BLDC motors are used upto typical power rating of 15 kilowatt and above that surface mounted PMSM is preferred. These two motors are very similar. The difference is in terms of back [00:13:32] wave form in a BLDC the back [00:13:35] in nature while it is [00:13:40] in surface mounted PMSM.

There is another variety of motor which is called interior permanent magnet synchronous machine. In this motors the permanent magnets are embedded within the surface of the rotor

such that not only the electromagnetic torque is available in these machines but it also offers reluctant torque which is very handy specially in high speed operation or popularly known as the flux weakening region. Another motor which is upcoming in EV domain is synchronous reluctance motors. So in this motor the torque is achieved only by reluctance phenomena. There is no electromagnetic torque and no PM is used. It is very simpler in construction. The only disadvantage is it is not able to get high power for its value. There is another type of motor which is called doubly-salient motors which is upcoming in EV domain. So as you can note the saliency is inbuilt both in stator as well as rotor.

There is a machine known as Switch Reluctance Machine which falls under this category. This is a type of motor derived from reluctance machine. The construction of this machine is very simple but the design of this machines is complex and the control of this machine is also complex. This machine is disadvantage of high noise but slowly this machine is picking up and maybe available for EV applications in the near future.

There is a machine known as stator PM type doubly salient machine where the PM is embedded in the stator saliency where the rotor is salient structure without any PM. So these machines offer very simple rotor construction and this kind of machine is upcoming in EV application. So this is known as doubly salient PM machines. There is another configuration where a field winding is also embedded in stator in addition to PM such that we both have a constant flux and a variable flux operation possible from the stator side. This feature enables a good EV vehicle performance and this is an upcoming motor popularly known as FC-DSPM. The machine design for EV application is a very challenging area and lot of industries and academic circles are working on this side such that this kind of very high demanding EV motors can be developed which can deliver the performance required to make this a similar area.

So this is the end of the topic motor derived technologies. We will start discussing our next topic which is energy source technologies used in EV application in our next interaction. So thank you for listening.