Hello everyone. Welcome to the NPTEL online course on electric vehicles. So let us begin our next topic, introduction to EV, which is battery charging technologies. The development of chargers is a very important area under battery charging technologies.

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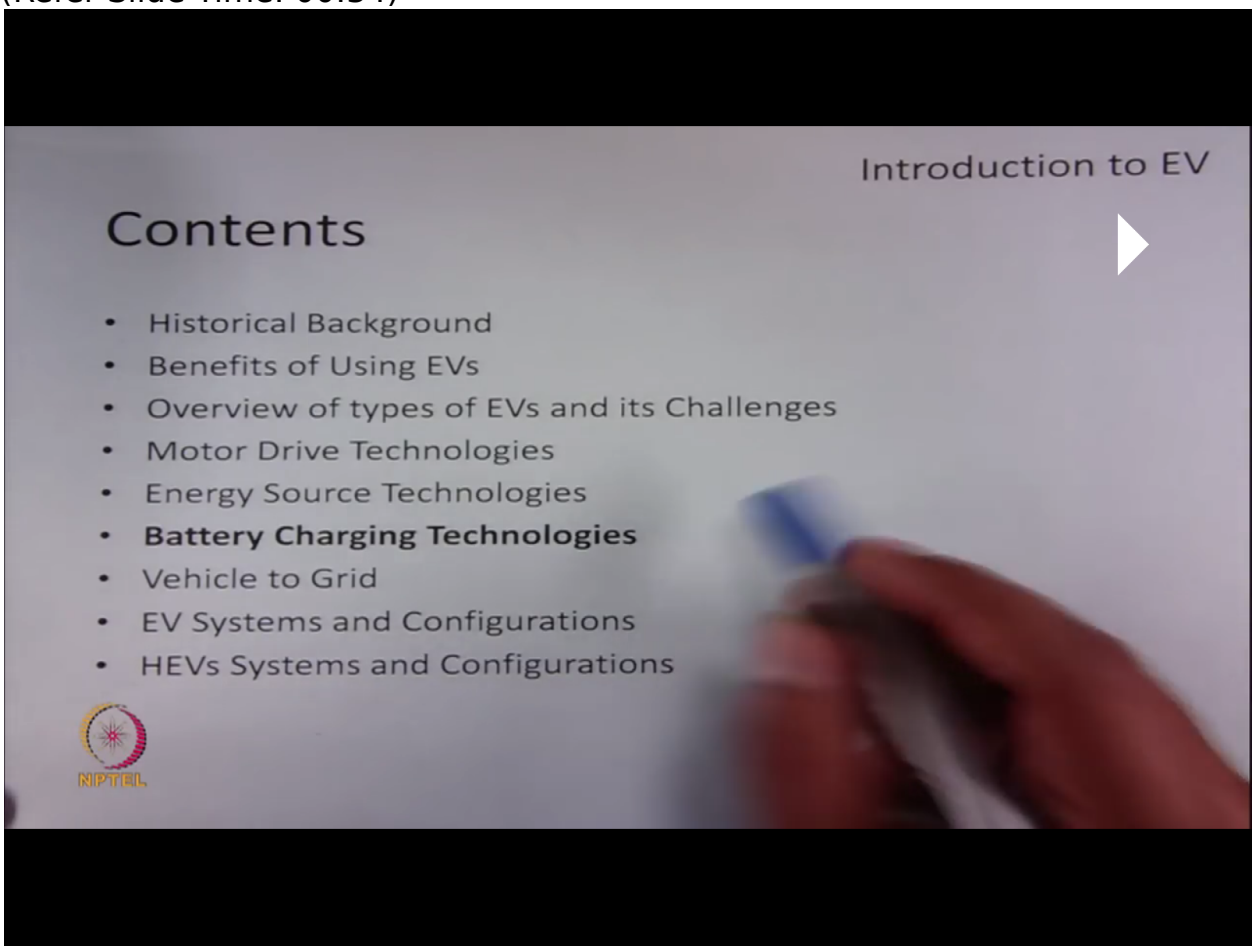

So basically there are four major charging schemes used for charging the EVs. So they are based on level voltage, current, power level, and the time of charging. So in normal charging, we use a system, which is single phase AC system with the available voltage varying from 110 to 240 volts. Currents varying anywhere between 13 Amps to 20 Amps with the power level of 2 to 4 KW. So this type of charging is used in homes, garages, and residential car parking. So this type of charging takes a longer time, typically 5 to 8 hours and it is done mostly in the night time. Since the current is less and also it is done in night time, it does not burden the power system, on the other hand it helps the power system for load leveling, since the other loads are very less on the power system during that time. But this type of charging is not very popular among customers, since most of them wants quick charging and they want to use the vehicle all around the day. There is another type of charging, which is known as opportunity charging. So this system uses 3 phase AC with the system of voltage of 110 to 240 volts with

the with the current varying anywhere between 30 to 280 Amps and the power range of 8 to 20 KW. So as the name suggests, it charges the vehicle whenever the opportunity comes or whenever it is possible to charge the system or the vehicle, it does so. So this type of charging system is used in public charging places or public parking places. So it doesn't care how many charge you do in a day or what is the duration of each charge. The only condition is that, that the battery should be ready to take charge. So this kind of charging does not put significant stress on power systems, since it is intermittent throughout the day. Fast charging uses the DC system with system voltage of 200 volts to 450 volts and current ranging from 80 to 200 Amps with the power level of 36 to 90 KW. As the name suggest, it is a fast charging algorithm and it charges the battery by direct DC voltage. So this kind of charging system charges the battery in 20 to 30 minutes and the battery reaches typically 80% of its full charge capacity in the 30 minutes. But since it's a... this involves heavy charging platform, it requires a dedicated charging stations and dedicated hardware and safety protections in place. Also since this is a heavy system, it puts burden on the power system and it has to be designed and installed in concentration with the utility. There is another type of charging on is battery swapping. So it is not actual charging, basically it is swapping the batteries to charging station. So the vehicle owner can go to the battery swapping station and replace his battery, which will take typically 5 to 10 minutes, that is very convenient for a vehicle owner. Secondly the discharged batteries, which were taken by the charging stations can charge those battery during off peak hours, means during the night time. So in some way this kind of charging scheme also doesn't put any stress on power system, rather it helps it. The drawback of this kind of scheme is, it requires a very large space for the charging starting to mechanically swap the batteries and it also requires standardization of the battery packs, to enable this kind of scheme to be successful.

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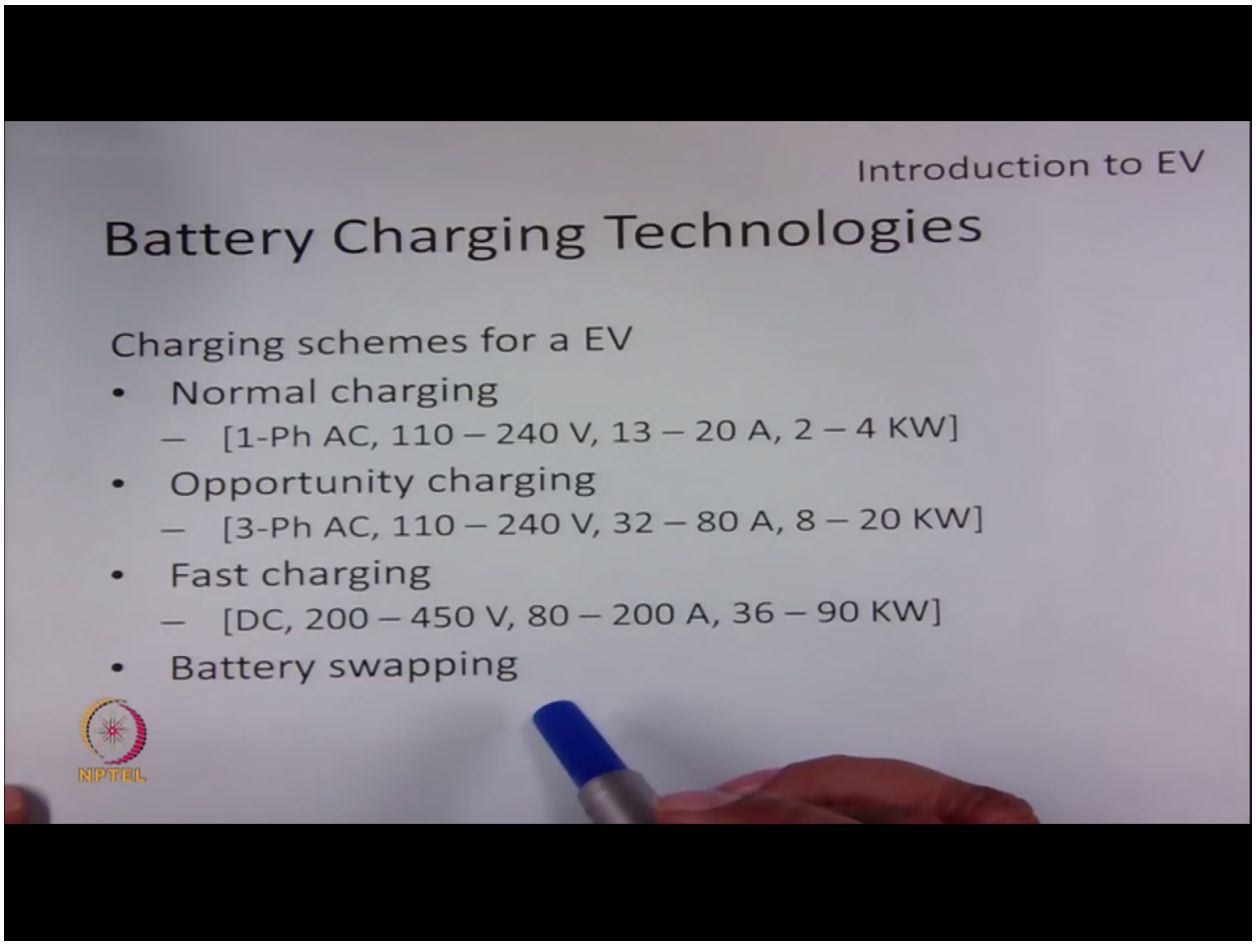

To implement the charging schemes, there are various charging algorithms, which are developed. So this charging algorithms are designed such that it improves the charging efficiency. It sees that the charging time is less, it also sees that the battery life is enhanced, and it's not affected by the charging process, secondly, it protects the battery against any kind of faults. But you can see that this requirements are conflicting to each other. Means if you want to increase the charging time, definitely there are chances that battery life is reduced and also the charging efficiency will be decreased. So the charging algorithm has to come with the optimization algorithm such that the requirement of the charging scheme is implemented.
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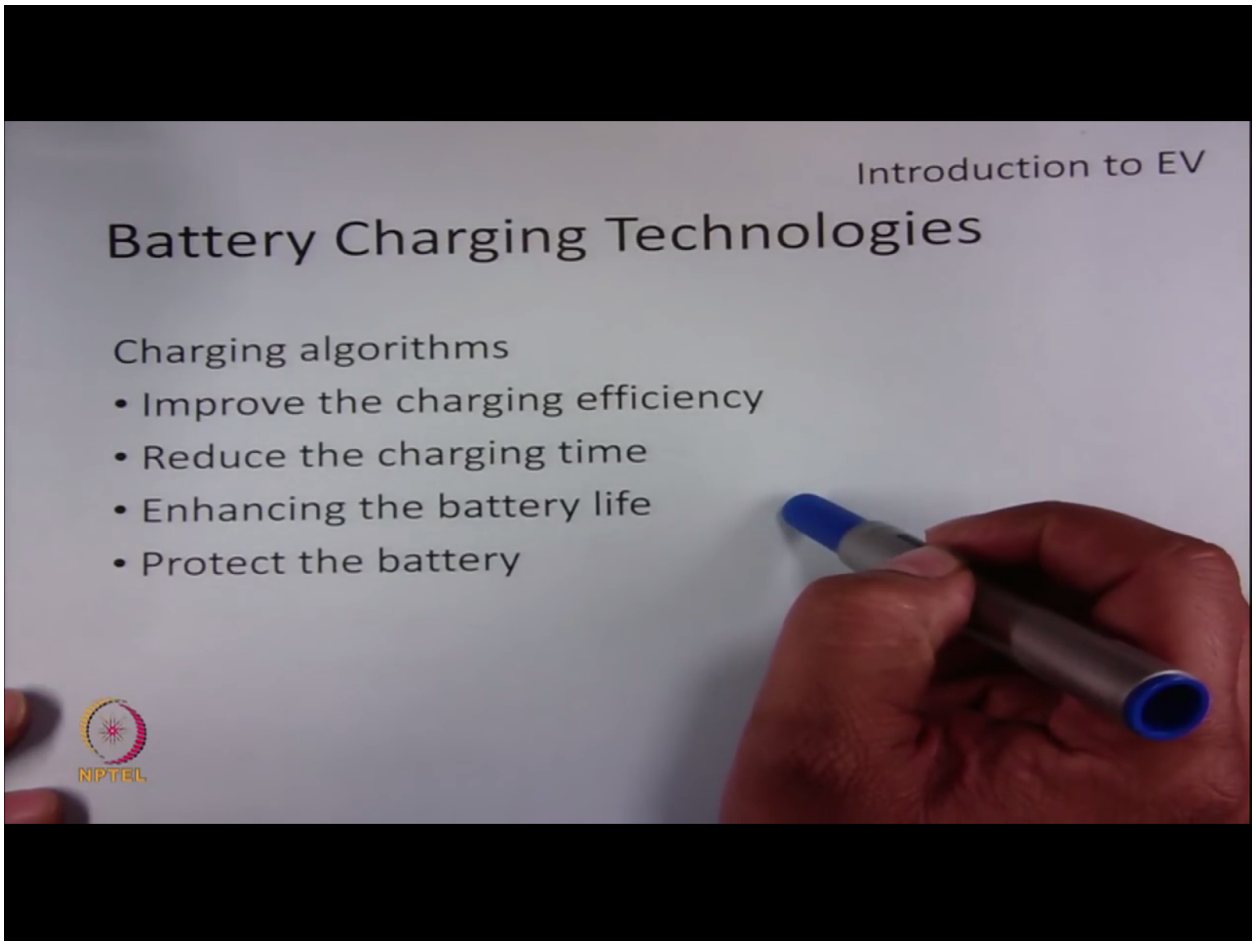

So there are various types of charging algorithms, which are in use. The first one is constant current charging. So as the name says, it charges the battery at constant current. It is a very simple algorithm. So this kind of charging scheme or algorithm is used mostly in nickel cadmium and nickel metal hydride batteries. So the higher the amount of current used to charge the battery, the charging time will be correspondingly less. But this comes at a cost of charging efficiency. Similarly if the current method is reduced, the charging time will increase, but the charging efficiency will be more. So a optimum current level is maintained such that the charging efficiency is optimum, together with not allowing the battery temperature to go up. So the end of this charging process is decided based on the voltage level. So the... once the battery is charged to its full capacity, the battery voltage will start dropping rather than increasing, so that decides that this charging step needs to be stopped. So this charging algorithm requires current sensor for controlling the current, voltage sensor for stopping the charging, and the temperature sensor for thermal protection. There is another scheme, which is known as constant voltage charging, which is very popular and is normally used for charging led acid batteries. Since the name says, it is a constant voltage system discharging, but it has to be current limited. So in this charging scheme, there is a current limit, which tells the maximum amount

of current that can be allowed to charge the battery, while this kind of charging. So as the battery charges and it attends its full capacity, it is noticed that the current taken by the battery becomes lesser and lesser and it becomes almost constant and very low magnitude current flows when battery reaches its full capacity. So the constant small current will last for around three hours before the system can be stopped. There is another scheme, which is very popular now a days is constant current, constant volt charging. So this is hybrid charging algorithm, which takes advantage of constant current and constant voltage charging schemes. So it is understood that if you want to charge the battery quickly, you should start charging process with constant current based method. So in this scheme the charging starts in constant current mode and when the voltage or the charge level reaches a threshold, it moves to constant voltage charging. So under constant voltage charging, the current magnitude is subjectively less and it will charge from 80% to the full capacity at very small current magnitude. So this kind of charging scheme is used in led acid batteries and lithium ion batteries. Another type of charging scheme is developed, which is multistage charging scheme. So this charging gives variable magnitude of current at different stages of charging. It starts with high current magnitude and the magnitude of current decreases as the charge of the battery increases. So we know that when the battery is reaching its full capacity, the requirement of current becomes less. So it's a kind of variable current magnitude, which is progressively decreasing from starting towards the end of charging. So this is popular in lithium ion batteries. Pulse charging is very similar to multistage charging, but this is done in pulses. So it gives pulses of current in decreasing fashion. So it starts with a high current pulse followed by a current pulse of lower magnitude. Trickle charging is basically a charging done to keep the battery in charged condition. So once the battery is fully charged and if let it unattended, it will discharge because of self charging and other losses. Therefore this kind of charging enables keeping the battery in fully charge condition and supplying only the losses, which occur due to self discharge.

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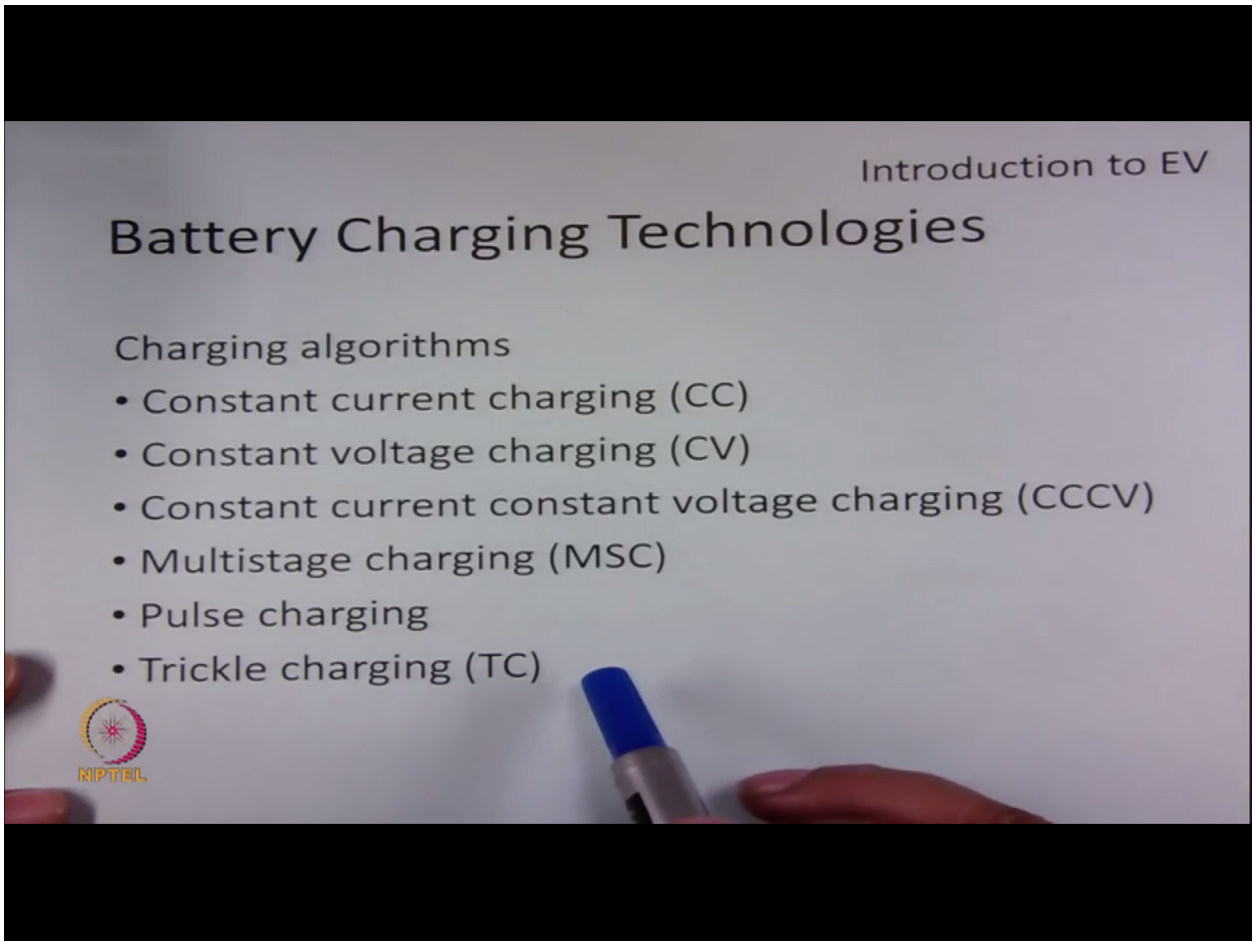

So this charging schemes can be implemented using wired means or wireless means. So wired power transfer or charge transfer is conductive in nature, it's very simple, low cost, and is... It has high efficiency, but it is very inconvenient and you require to carry the charging cables and there is also a risk of electrical shock to the operator. So therefore various wireless based power transfer schemes were developed, which is known as WPT, which is very convenient and the operator is also free from electrical shock, but this requires you know, high installation cost, because of the hardware involved, secondly, there is chances of high power loss, which will decrease the charging efficiency.

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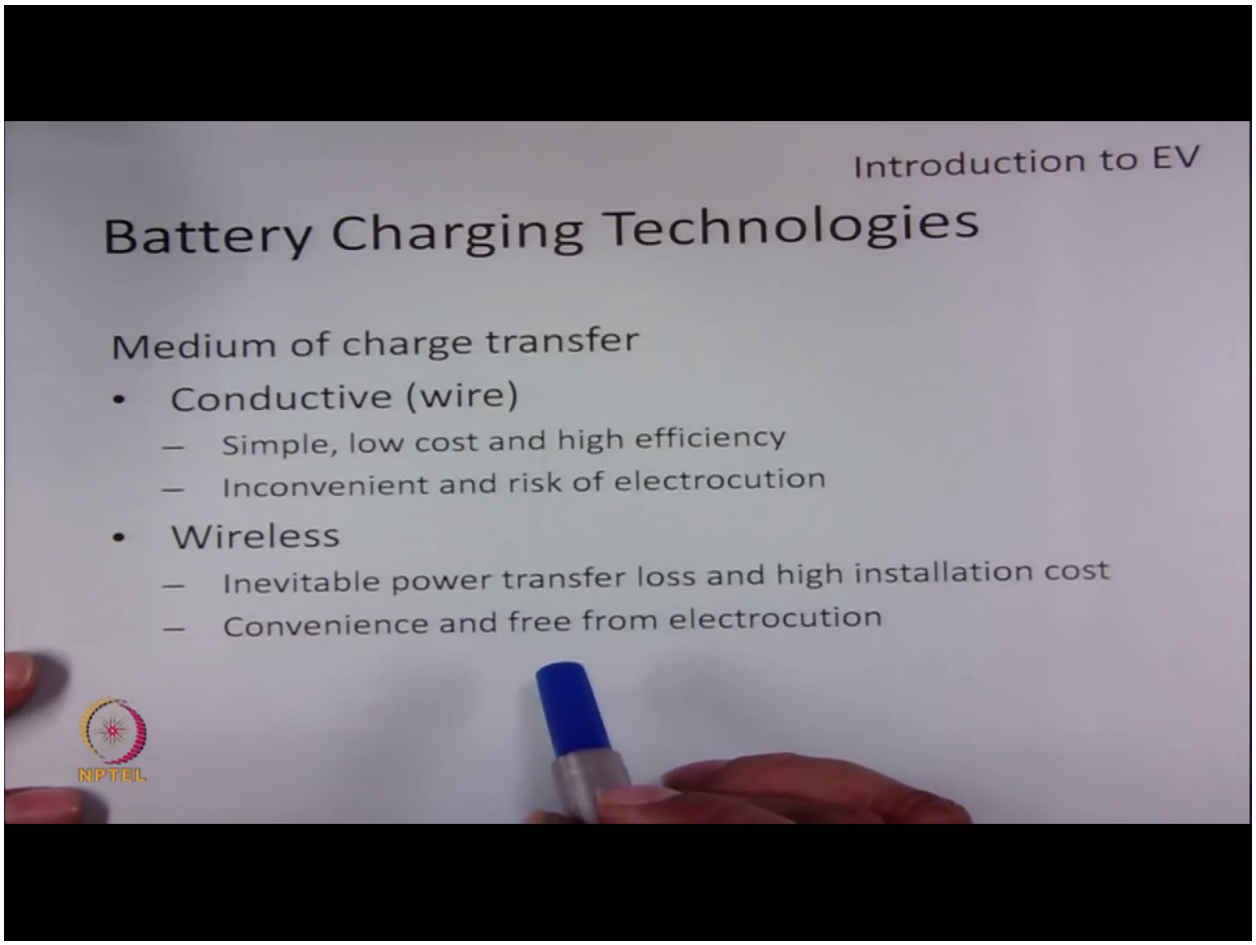

So there are different methods of implementing wireless power transfer. So there are far-field strategies and near-field strategies. So far-field strategies uses high frequency and it can transfer high power at long distances. It is based on microwave or laser type of technology. This technology is not suitable for EV, because it involves tracking strategies, antinas, and it's also prone to human health. So therefore near-field strategies are developed. So these strategies use either capacitive or inductive medium to transfer the power to the vehicle. So capacitive method uses electric field to transfer the charge to the battery. So this kind of technology is unaffected by metal barriers and it also does not emitted any EMI problems, which is there in magnetic based inductive systems. But this technology is very sensitive to air gap and the displacement of the charging plates. So it was seen that his capacitive type of wireless power transfer is suitable for low power application and it is not suitable for a typical EV application. On the other side inductive based mechanically covered wireless product also promises a very good technology for wireless power transfer. So it uses a phenomenon known as magnetic resonant coupling or MRC such that the high power can be transferred in the range of you know, 10s of KW or 10s of cm, but as evitable, the inductive schemes may suffer EMI issues and it also suffers from energy loss due to leakage inductances.

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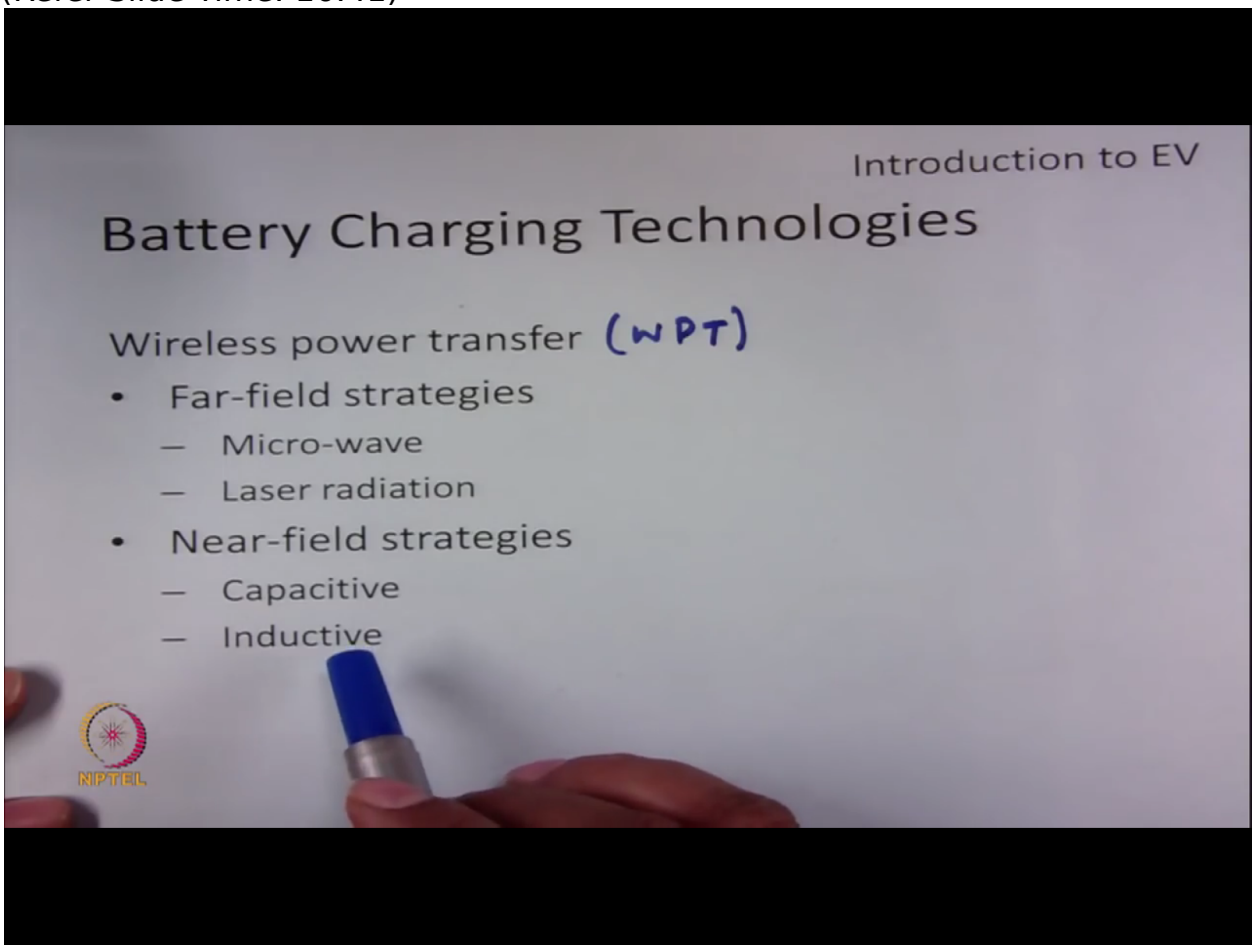

So what is the typical circuitry of a inductive power transfer system. So it transfers energy through inductive coupling. So basically there will be two coils, one on the charging coupler and one inside the vehicle. So the power is taken from the grid, which will be 50 to 60 Hz, it is rectified and converted to DC voltage. After that it is inverted using a inverter and AC voltage of... is generated at very high frequency in the range of 60 to 80 KHz. So this high frequency enables a very small inductive coupler and the size of the coils can be reduced at this high frequency. So the power will be transferred using inductive BDM and it is available on the secondary site, which is again rectified and converted to regulated DC. This DC voltage is used to charge the battery using DC-DC power converter. So this is the scheme of inductive power transfer.

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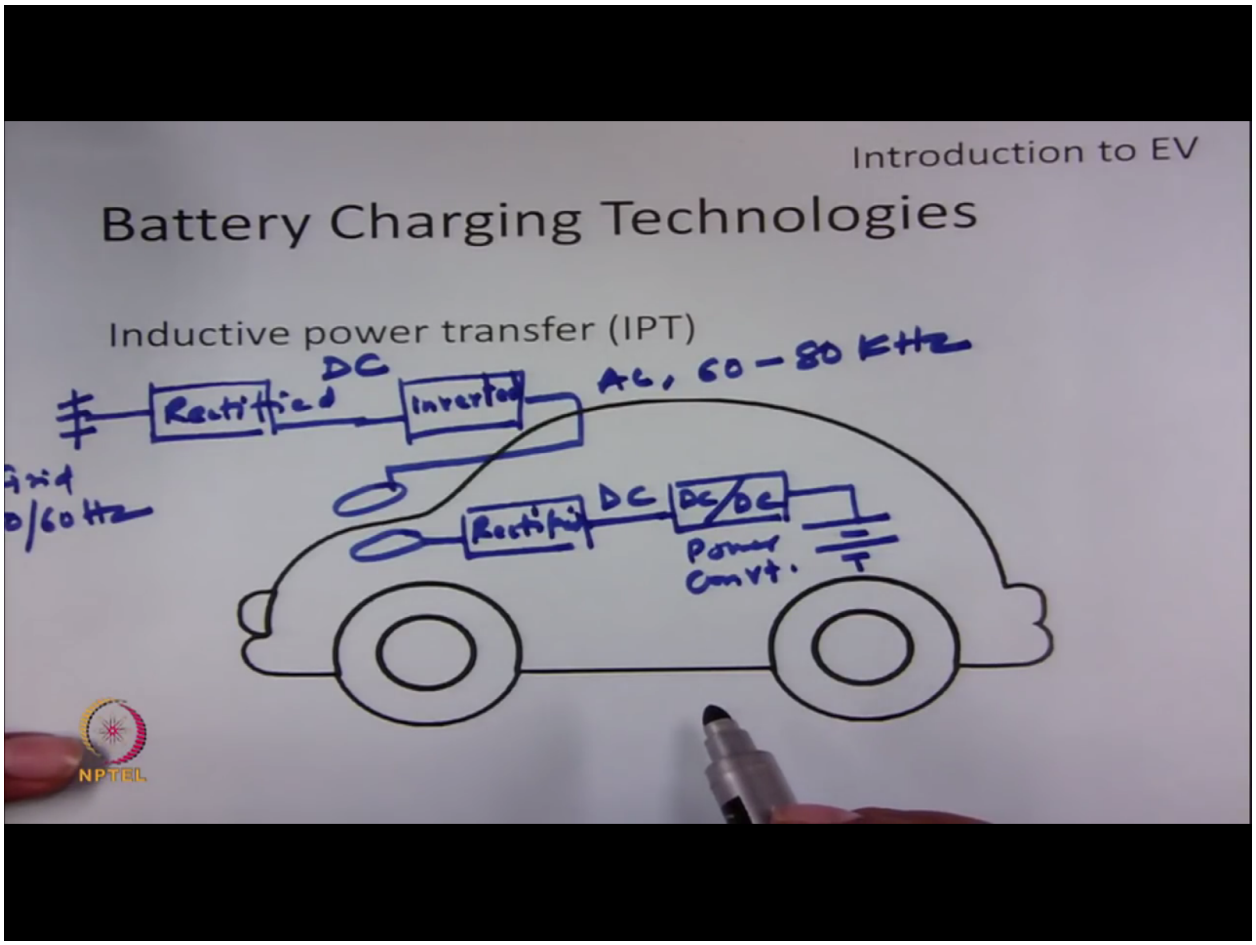

So in order to facilitate charging during parking hours, a system is developed where the inductive coils will be installed on the floor of the parking area. So primary coil will be installed in the basement of the parking area and secondary coil will be installed on the chassis of the vehicle. So whenever vehicle is parked a automatic charging can be enabled, such that there is no inconvenience to the driver or the operator. So this kind of charging scheme uses magnetic resonant coupling phenomenon, such that power will be transferred efficiently and during power transfer the non resonant object such as metal body or the driver is unaffected by it. So the protection is kind of in-built in this kind of scheme.

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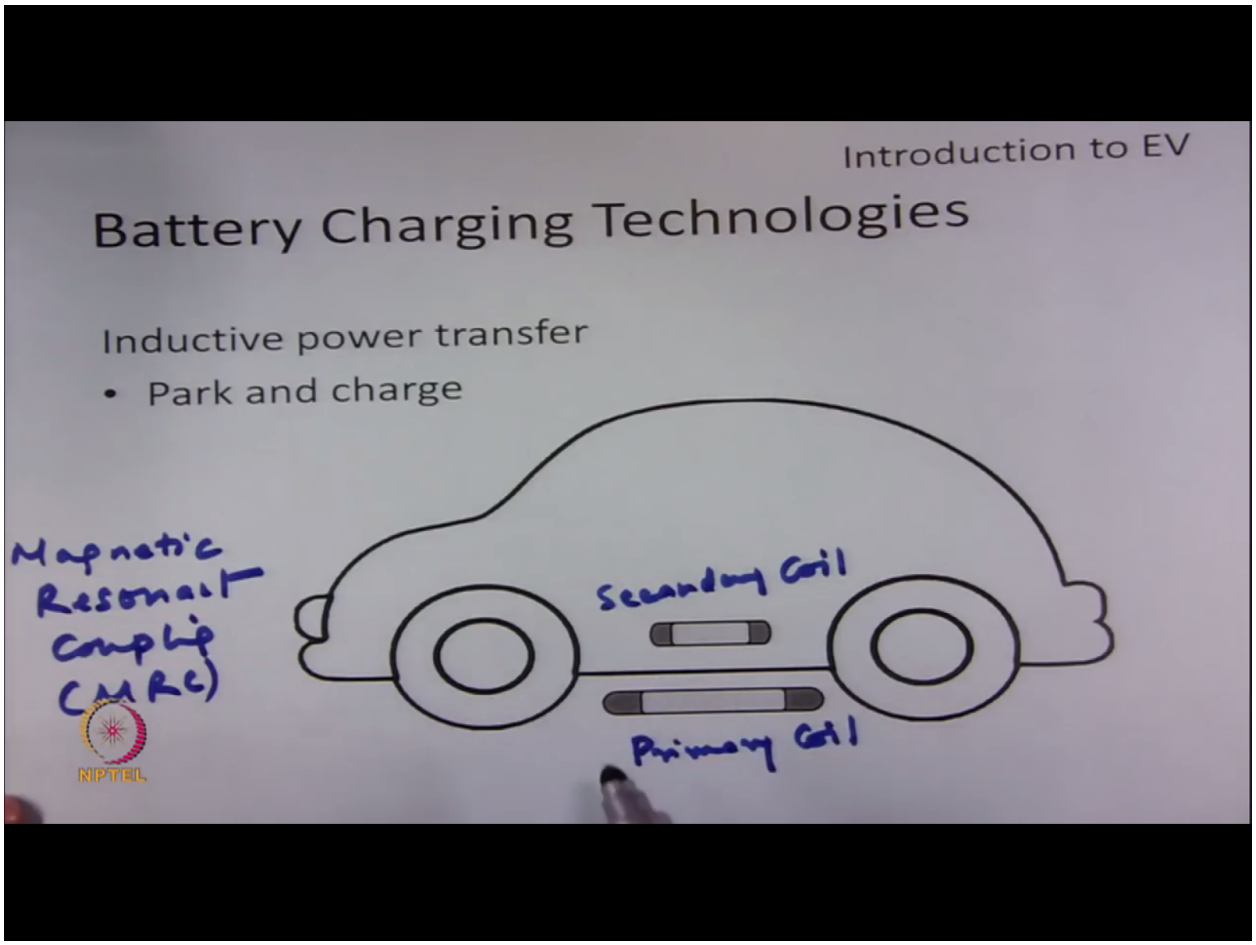

So there is also a thinking to charge this vehicle when they are plying on the road. So this can be done by you know, having a charging zones or... or lanes in some areas of the city, where lot of primary coils will be installed over half a km or 1 km. So when the vehicle moves on this kind of lanes the power will be transferred to the vehicle using inductive phenomenon. So this kind of scheme enables various advantages, such as since the vehicle can be charged on the go. Now the requirement of the battery size can be less. Because the user is able to charge the batteries multiple times during moving. Secondly the anxiety of driving range will also be minimized, but implementation of the schemes requires multiple things. Firstly, the charging scheme may observe different resonant frequencies because of the vertical distance and the horizontal distance. This primary and secondary or the transmitter receiver observes, when the vehicle is moving. Therefore the power transmitters should be able to be configured dynamically such that the coupling can be maximum and the power transfer can be maximum. Secondly, when such a charging zone or lanes were developed, they should consider a uniformity in the magnetic field all around the road, such that the coupling can be same and charging can be done properly with high efficiency.

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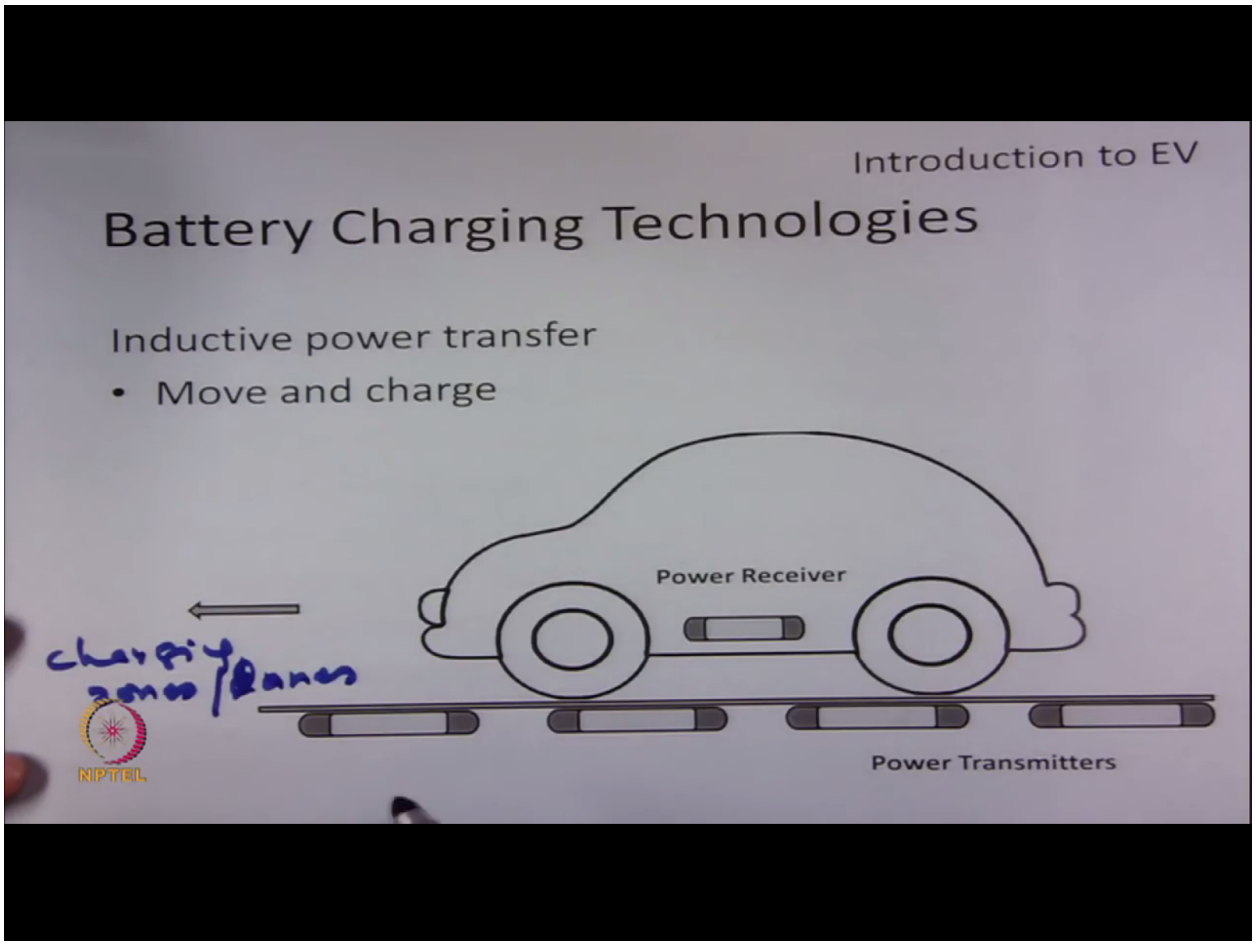

Another important thing which has to be done is a communication protocol has to be developed such that the vehicle that are meant to be charged are only charged and not all the vehicles applying on the road. Since the battery energy storage capacity is limited, it is always a important aspect to manage the battery and energy associated with the battery. So therefore battery management systems are developed. So these systems measure voltage, current, and temperature data of the battery in real time and log it for different estimations. First thing is this kind of measurement can help for cell balancing. So since there are different cells in a battery pack, they may not be charged equally during charging and discharging cycle. So there are some passive and active cell balancing techniques, which needs to be enabled to achieve cell balancing. And thermal management is important for thermal protection... other protection such as over voltage and over current also. So using the charging and discharging data the BMS can estimate the state of charge of the battery. It means it can estimate the ratio of the present charge to the full charge capacity. This will enable the driver to take decisions about the range it can... the vehicle can go, similarly the state of health is very important for the driver to know, with respect to vehicle performance and lifecycle. So when battery is charged and discharged many times, it loses the capacity of charging to its full capacity, which is designed

originally. So over many cycles of charge and discharge, the battery cannot be charged fully. So if there is a estimate on the present full charge capacity to the original full charge capacity, the health of the battery is normal. So when the state of the health reaches to some definite thrash hold, the driver knows that the battery needs to be replaced and this battery cannot be used for further vehicle driving. Another important parameter is state of power. So state of power decides the, you know, power transfer capability of the battery. So when the voltage is less or the current discharging capacity is less, it tells the driver, how much acceleration this battery can afford during starting or hill climbing or overtaking. So this kind of parameters estimation is very important for the driver or the vehicle to decide it's next course of action in real time. So that is all under battery charging algorithms and technologies.

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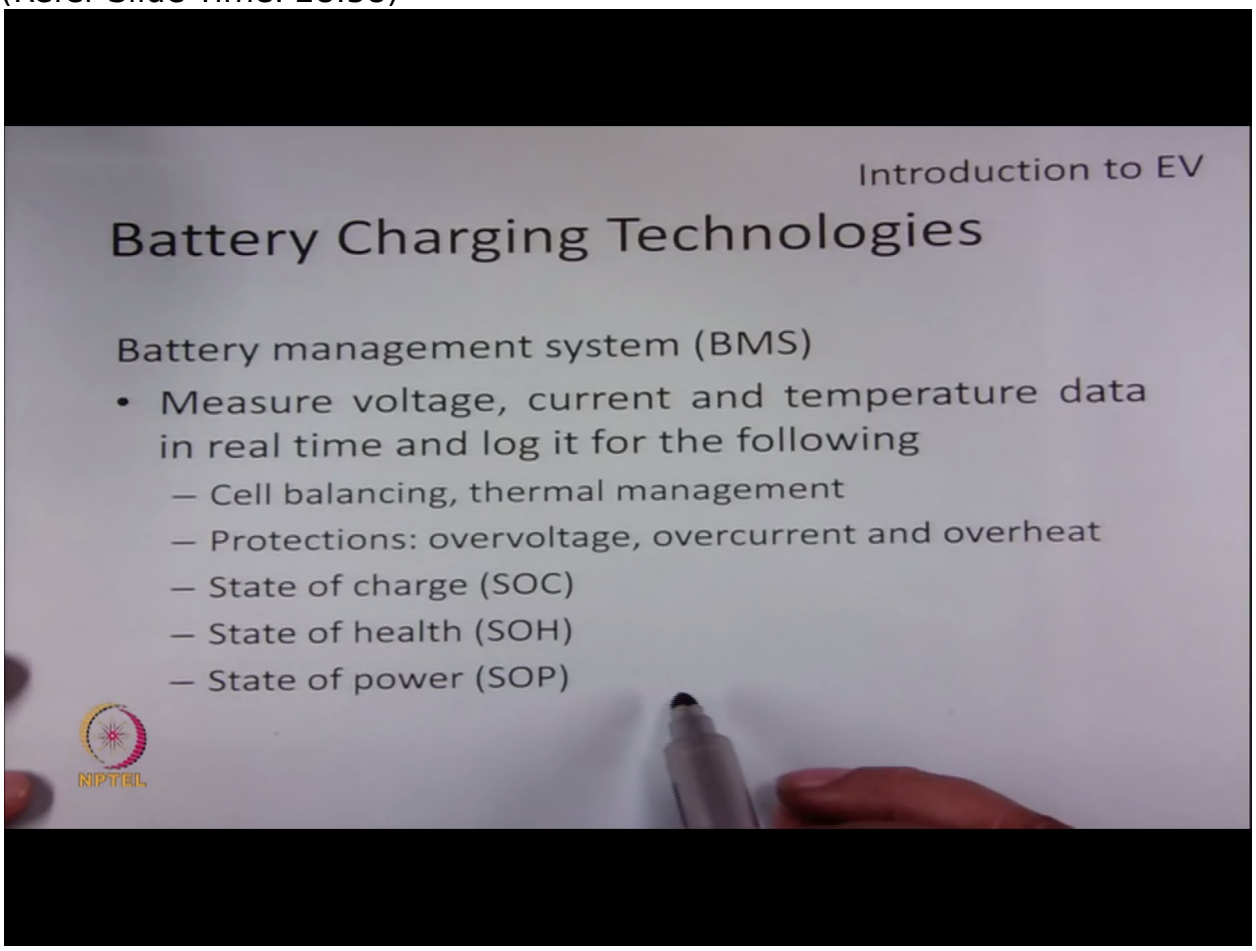

In our next instruction, we will discuss our next topic, which is vehicle to grid interface and the technologies associated with that. So thank you for listening.

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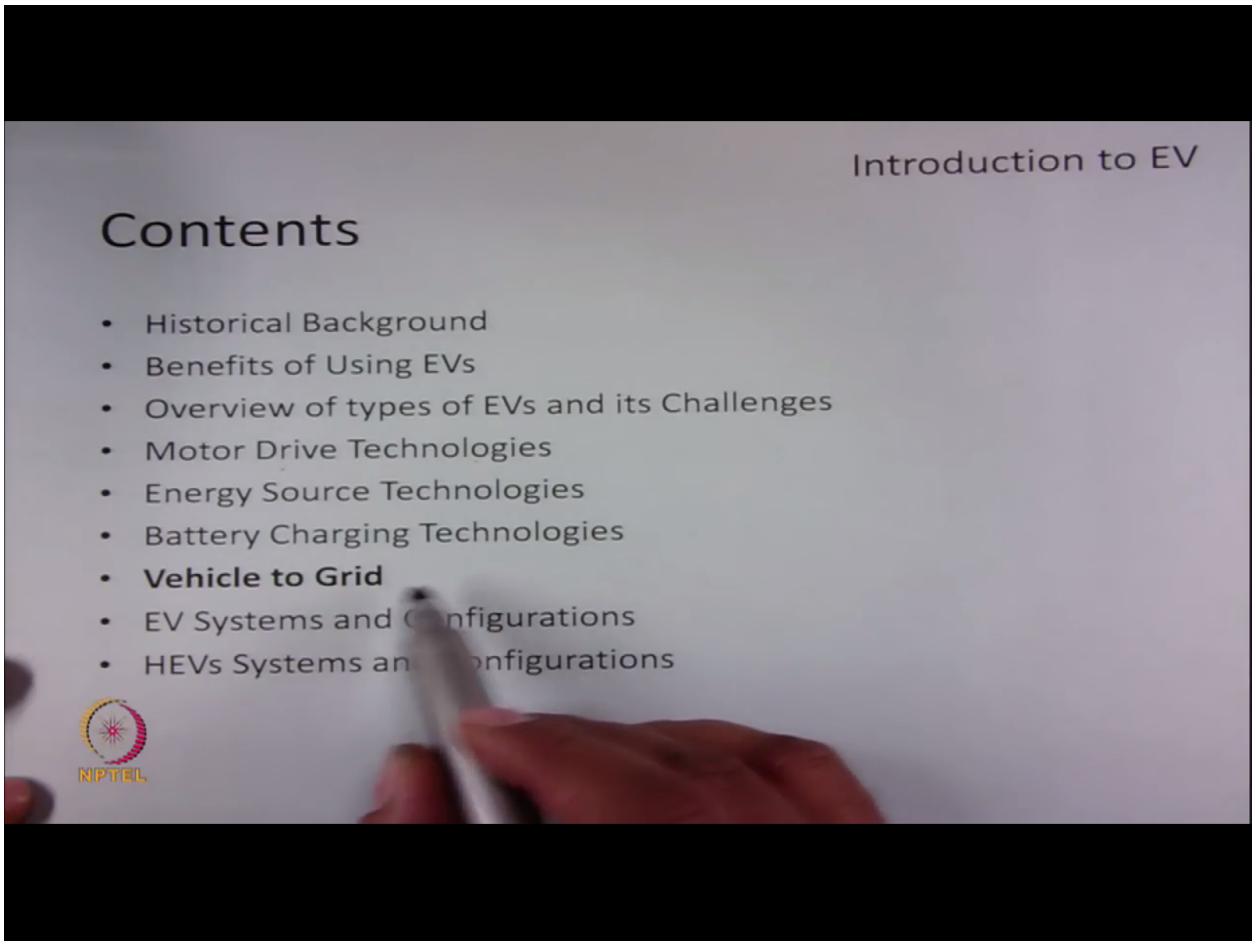
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