Fundamentals of Electric Vehicles: Technology and Economics
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Lecture 32
Battery Charging and Swapping

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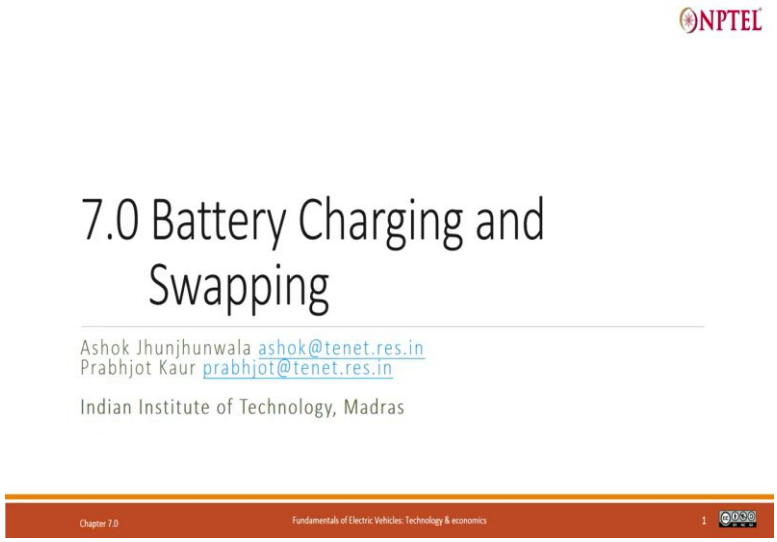

You learn more about charging and constant current, constant voltage the life in chapter 7, which will be on battery charging and swapping. I hope you have gone through chapters 5 which will be on battery pack design, mechanical thermal aspect and electrical and BMS, hope you have learnt motors and controllers.

So, you know what is the requirement from a battery and we will come to nearly the last chapter, chapter 7, chapter 8 is a small chapter on managing the charging infrastructure managing and analytics managing the infrastructure analytics, but here we will be discussing Battery Charging and this Swapping. Remember, swapping that we had introduced right in the beginning of the first chapter, we will look at more detail of what is involved in swapping also out here.

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This chapter is also a little bit older, bigger chapter we are going to do introduction of EV charger will define what is called slow charger and fast charger will define swapping, we will talk about why standardization required chargers, charging standards you call charging standards, why charging standards required. Then I will define what is called on-board chargers, a charger which is with the vehicle.

There is a public charger which is sitting outside. I will define what is called bulk chargers which is used in swapping and then just like I did a economics of battery will do economics of public charges in Indian context again taking into account the interest rates. Once again, you will find that if you do not take the interest rate you get one result you take the interest rate results have changes completely.

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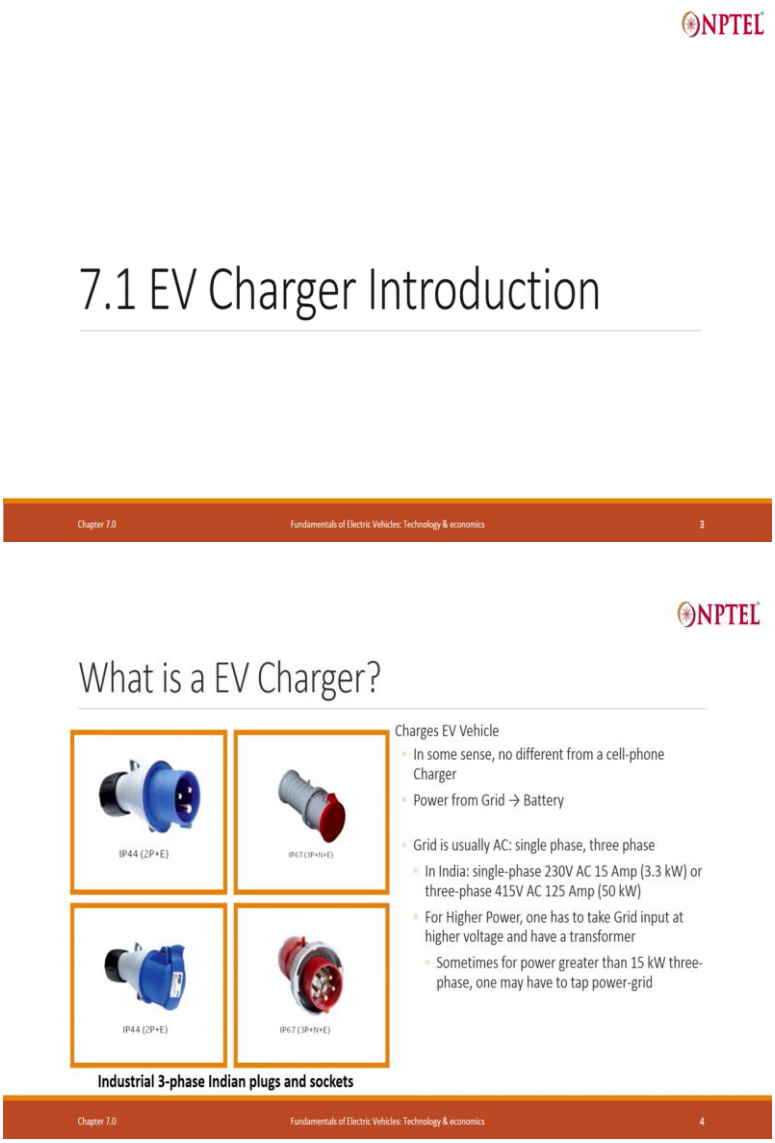

Let me start with simply charger introduction, if you remember we had started talking about charging in chapter four. Review that last small section it will help you. But basically we will get into details of that in this chapter.

What is a EV charger? Now basically something that chargers electric vehicles, actually it charges battery of the EV, it is not does not charge EV it is charging the battery of the EV, it is very similar to that way a cell phone charger that I use all the time or a laptop charger it charges this, you say charges a cell phone its actually charging the battery of the cell phone, we say it is charging laptop it is actually charging the battery of a laptop.

Similarly, EV charger will charge the battery of electric vehicle, basically power will be taken from grid electrical grid and put into the battery. What is the difference? The primary

difference is much larger battery, therefore much larger charging currents could be even charging voltage, grid pretty much all over the world is usually AC and typically in most countries is a single phase and three-phase. I am going to primarily talk about India there may be small variations, Europe has very similar small voltage difference.

In India, for example, single volt phase is 230 volt AC and you can get 15 ampere current or 3.3 kilowatt, so you have this plug points that are bigger plug points the kind of plug points that you can see even in things like this place the bigger plug points, thicker bigger connector that is a 15 ampere socket that is used when you are going to use a Refrigerator where your air conditioner is a must for your washing machine it is must, for your electric heater it is a must, for the mixer you can actually use both, low. Now the motors are becoming smaller for a mixer, for a grinder again it coms somewhere between in, so three-phase is commonly used.

So single phase is 230 volt AC 3 point 3 kilowatt. So, typically under 3 kilowatt charging, whereas if you want higher you go for three-phase 415 volt AC, up to 50 kilowatt in fact higher also you can go 200 kilowatt also, but the standard definition is 125 amperes.

So, for even higher power for more than 50 kilowatt, one has to take grid input at a higher voltage and would require a transformer, this is something single phase and three-phase comes to every home, every office, every factory, but if you want even higher voltage, higher power than 50 kilowatt you normally have to get a higher voltage line directly from the grid and probably use a transformer and do things like that.

Sometime even if you go over 15 kilowatt the electric, electric grid company the disk power distribution company may say no, you need to hire to tap the power, power grid, but otherwise single phase, three-phase is commonly available.

So, you have this one difference will be unlike the sockets that we use at home for a single phase and three phase we will actually use what is called Industrial Sockets and industrial sockets are also available on different rating IP-44. IP-44 for example is a socket where this pin is inserted the socket is, I think is this a socket well I do not know. I think socket may be given in the next slide no. So, it actually gets connected similar 3 pin, similar 3 pin it gets locked.

So, this is the socket and so this is a plug and a socket will come I think this is a socket probably I did not show you this is a socket and 3 pin the two together and these are normally industrial plugs, these are single phase but then there are three-phase sockets also the three-

phase, there are three-phase socket, so this is 2-phase plus electrical, so 2-phase plus, so this is a socket, plug and the socket, this is for three-phase plus neutral plus earth and this is IP-67.

IP-67 basically is industrial grade, but also can handle things like a water comes in it is a waterproof connector, so this is a waterproof connector and this has a 5 pin three-phase plus n plus e this is the sockets that are available this can do up to 50 kilowatt quite easily. So, for a smaller vehicle will almost always use something like this.

Can you use the standard 15 ampere socket that is used at homes? Single phase? Well yes and no. You know number of times that socket can be charged removed and connected again and is limited, so if you are going to have a EV and you are going to do it about thousand-two thousand times that no longer remains reliable, so you generally prefer to use something like this. So, if you do use something like this then you have to be prepared to replace that.

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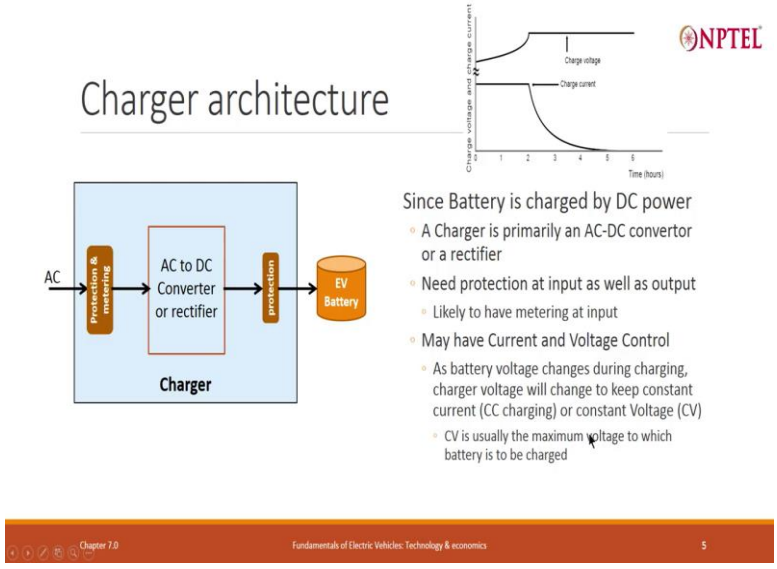

What is a charger consist of? It basically is AC charger, always AC will have the protection and metering here, it will invariably protection and metering. Then there is AC to DC converter essentially, rectifier to the right voltage and the voltage is controllable, there will be normally a processor which will be communicating with the vehicle and based on that it will control the voltage the DC voltage, DC voltage is controllable. You will then put some DC voltage protection, because you do not want anything to go wrong if something goes wrong here and then you will get it to the EV battery.

Since, battery is charged by DC power a charger is not normally AC to DC converter it has a protection at the input as well as output, it will invariably have metering at input, it may have current and voltage control, because depending on what the battery require you normally will have current and voltage control, a battery voltage charges changes during charging continuously, so you should have a voltage controller and you should have a current controller, CV is usually the maximum voltage to which battery is charged. So, that is what it is.

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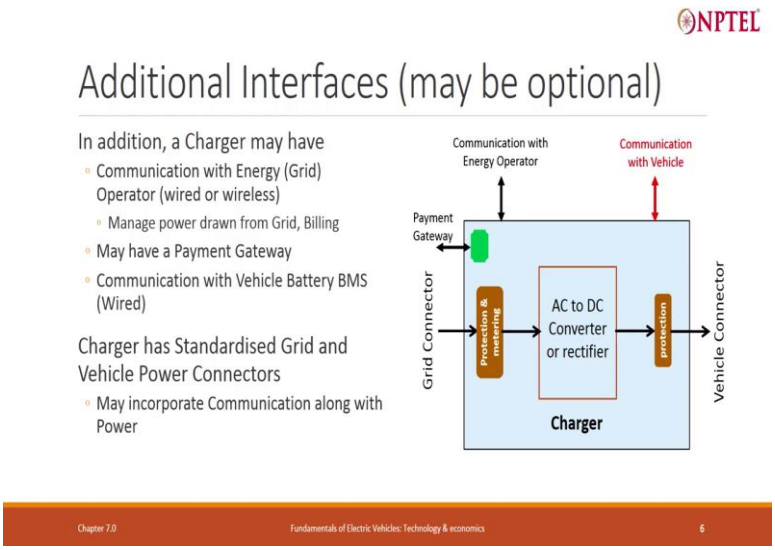

Additional interfaces this was a simple charger, a charger may be optional for a simple, very simple charger this all that is there, but as the charger becomes more sophisticated you will see there is a communication interface to energy operator, whose energy or DISCOM, you want to tell them that so much power I am taking not just from metering, but actually it helps this energy operator if it gets from every charger, the charger is a large load could be a 30 kilowatts load, 50 kilowatts load and this can be turned on turned off depending on whether it is used or not.

So, the charging the grid will know that this is what is being drawn and it can adjust its supply demand in such a, supply in such a manner that you can service this. It manages power drawn from the grid. It can also do billing, billing, billing metering is done here, billing it can do saying no, this you charge at a special rate or this time of the day I have a shortage and he is trying to draw too much power charge them heavily, all this can be done by communication with energy operator.

What kind of communication interface it is there today it is invariably wireless 2G, 3G, 4G is used for this communication. There is a typically a payment gateway in the charger, you go to a charger you put a, your vehicle for charging you can swipe your card or use mobile phone for sort of saying, well finish charging and my payment can be done from this this account.

So, invariably there is a payment gateway. Public charger is very important, if it is a private charger which is you just use it for yourself that is not important. There is a communication with a vehicle, this is important, particularly when you are charging fast, it tells you well charge slow, charge fast do not put so much current, now I have reached you go to constant voltage all the, what is my peak voltage, all this is done plus different vehicles may have different peak voltage.

All this is done with communication with the vehicle, this is invariably wired just like the charger is always be wired in, so there is going to be the sockets the cables for charging, power cables plus communication cables together both of them can be a single socket and so there is a grid connector and there is a vehicle connector. Normally this communication with the vehicle and vehicle connector, this is the power, this is not for communication the two can be integrated.

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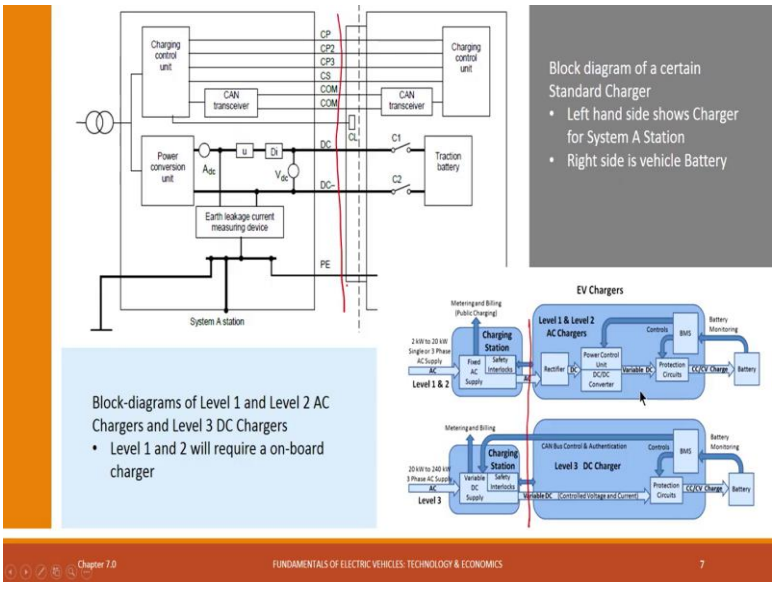

This is what a full charger looks like, well this is a block diagram showing the same charger if I look at it typically there is a, this part is vehicle, this part is vehicle battery, this part is the charger. If you look at it this is communication, it is a communication unit, charging control unit and charging control unit in the battery could be your BMS and the two will be exchanging messages and this is the commonly method that is used for exchanging messages

is a CAN messages, CAN is a protocol controller network physical cables are defined and messages go back and forth on to this.

So, messages will go plus it will also have some individual cp2, cp3 which will, which will also be used for charging. This is where the power conversion unit from, from the input and the power is converted to DC and the DC is brought into battery there is invariably relay which can be switched off at any time. So this is, this gives you protection also, then for some reason what happens if this is shorted, so you have various earth leakage and there is a earth point also brought in.

So this is a typical AC charger, AC charger, this is a typical AC charger and this is how it connects to the battery, this is showing the same level-1 and level-2, AC charger this is a AC charger which will come in and it has 2 kilowatt to 20 kilowatt single phase or three-phase AC supply. This is a fixed AC supply.

This is a simple, it does metering, billing and some safety interlocks and then gives you out that is all the same AC out and actually charger in the AC charger charging conversion is not done in this part this is a public part this is your private vehicle charger the vehicle takes in the AC it does the rectification to DC the level-1 charger or AC charger level-1 and 2 charger it does conversion to DC and then, this is the DC charger DC-DC converter and then it communicate with the protection unit.

So, it is a part of the, part of the vehicle this is the part of the vehicle, this is put inside the vehicle. You just take a AC and connect it this is how I do, this is put inside the vehicle, this part is built into the vehicle. You can off course have separate AC charges and then you just put the battery monitoring and battery. But these two are finally integrated on the other hand, if you do DC. Here AC to DC supply is done in the charging station and the DC charger simply puts the protection circuit and BMS and charges the battery.

So, if I take a public AC charger, this is the public interface, this side is giving you AC, this is giving you DC, this is called level-3 DC charging, invariably there is a communication and safety interlock that is there in both AC and DC charging and here the difference is here the converter is here and here is no converter, this directly DC charging. Protection is invariably there in this.

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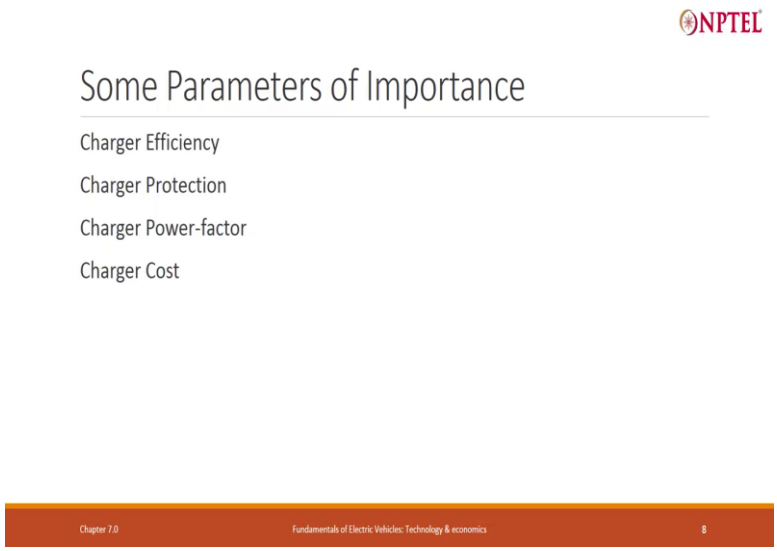

So, what are some of the parameters for importance, the first parameter that I keep on worrying about is I am taking this grid power and giving it to the vehicle, what is the charger efficiency? Why is that important? If I say it is 90 percent, well 10 percent of power is lost, not just losses converted to heat.

Now, I have to worry about heat dissipation. What if it is 85 percent, 15 percent it is a large power I may be doing drawing 20 kilowatts, 153 kilowatts will be lost, huge heat so I generally tend to have it higher efficiency. If it is a very low power charger like Hanna's designing then 87-88 percent will be okay, you lose 10 percent of 3 kilowatt or 10 percent of let us say 1 kilowatt or 2 kilowatt, 100-200 watt. But for larger charger, you will have to go 95, 96, 97 percent efficiency.

Charger protection is an important parameter both the charger, the grid has to be protected vehicle has to protect all three. Power factor is another very important thing, you are drawing power from the grid, grid does not want you take reluctance power, so if you have designed the charger particular converter, which tends to take a lot of reluctance power that is extra load on the grid without they are getting paid for it. So, the grid may say do not do anything less than power factor of 0.95, 96 and you have to comply with that of course charger cost is important parameter.

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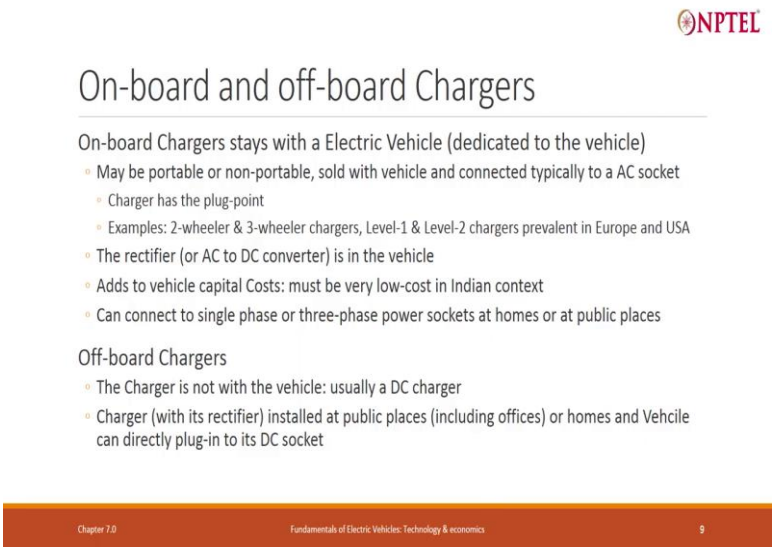

Then there are what is called on-board charger and off-board charger, what is on-board charger it is a built into the vehicle, dedicated to the vehicle either dedicated or in between the vehicle, even keep it separately or inside the vehicle, may be portable or non-portable that is what is saying, it can be portable means you can take it out non-portable means already fixed, is normally sold with the vehicle and correct typically to have AC socket.

The charger always has the plug point it goes and plugs into AC socket. Two-wheeler and three-wheeler chargers with level-1 and 2 chargers prevalent in Europe and United States. Then here since AC is the input rectifier is in the vehicle, in the on-board charger it adds to the vehicle cost. But, if it is a low kilowatt charger does not add not too much, it must be very low cost in Indian market, we will look at this in the end. Can correct to single phase or three-phase depending on amount of current that it is drawn or power sockets at homes and public places. So, this is on-board charger.

Off-board charger is a charger which is not with the vehicle, usually a DC charger, usually charger can be installed in public places sometimes all bigger DC charger can be installed even at your home. But there is a extra cost you have to pay if it is a home, so big charger cost and vehicle can plug directly into the DC socket. So, off-board chargers are typically DC. So, this is all that I want to do as a very quick introduction.

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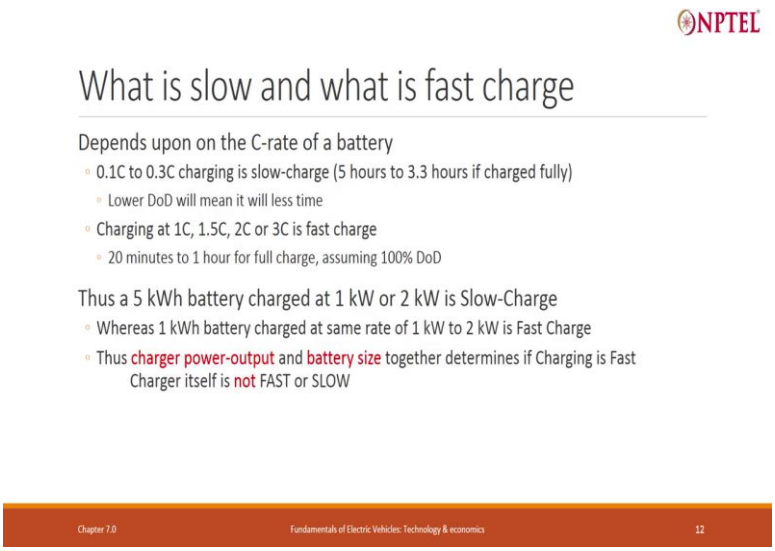

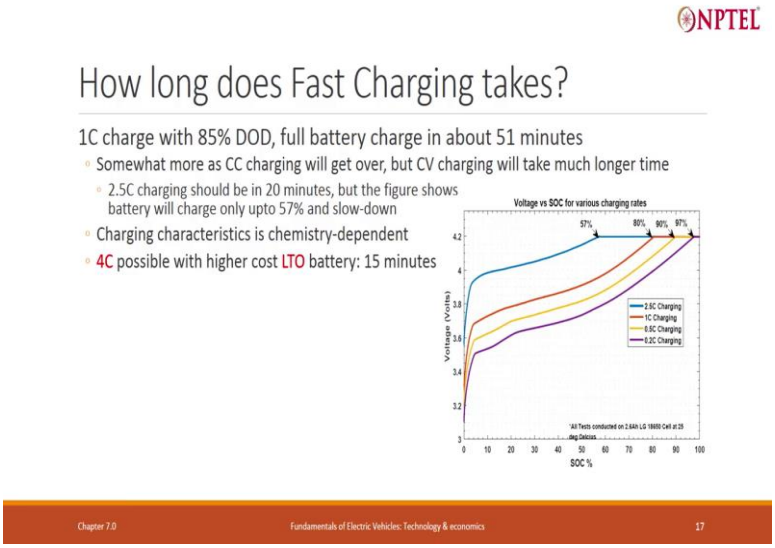

Later on I am going to look at what is a slow charger, what is a fast charger and what does it really mean and remember that this kind of picture I had shown you earlier, what happens when you try to fast charge, what happens try to charge slow this is what I will do in the next lecture. Thank you.