Fundamentals of Electric Vehicles:
Technology and Economics
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Lecture 5
Charging and Swapping Infrastructure

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So far I have introduced battery and even gave you a mechanism to compute cost. So, the introduce the battery, battery life cycle is very important because without the life cycle, it is not just a capital, cost capital cost plus life cycle plus how many times we charge-discharge per day, these 3 things are required to figure out the actual cost of battery per kilo watt hour per year and then for per kilowatt hour and then per kilometre, we can do this.

So this is the problem that I am assigning to you, please try to solve this, we will get back to this in more detail later on. But the life cycle I pointed out depends on a number of things. One is what is the depth of discharge, charging rate, discharge rate and it also depends on the temperature, details of this battery we will get into later in a separate chapter.

The next part of the introduction is if we either going to charge or discharge, what is the infrastructure required? And again, we will be talking from India point of view.

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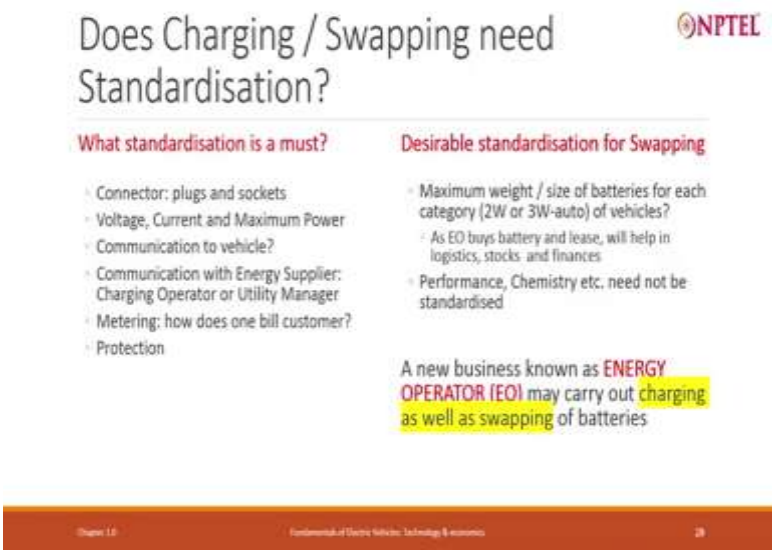

The first question is, should these charges be standardized? Now, what does it mean by standardized? Opposite of standardize is that it is proprietary that my vehicle requires a special charger. Now if my vehicle requires a special charger I have to (buy) purchase it along with the vehicle. And wherever I installed that I can charge only there.

But if I want a public charger, a charger to place in a public place and go and charge it, that public charger should be able to charge my vehicle battery, which basically means standardization. So what standardization is a must? First what is the connector and socket that I use? Because if I do not have a standard connector and socket, I take the car then I cannot even plug it in so that is the first standardization that is required.

The voltage current and maximum power, what is the maximum? If my charger gives me a certain amount of power I can always use less power, it gives me a certain voltage I can always use lower voltage, but if my vehicle requires a higher power or higher voltage then I cannot charge. So the maximum voltage, current and power needs to be standardised specified.

You know when vehicle is charged, vehicle battery charged by a charger, the charger needs to talk to the battery, to the vehicle, without talking he does not know how to charge. We later on look into detail what does it have to talk, it has to talk what voltage should I apply? How much current should I give? Are you full? How full you are?

Should I stop charging or should I continue charging? This much communication must take place between vehicle, vehicle battery and the charger and this needs to be standardized.

Similarly, there may be a communication requirement to energy suppliers, the electricity supplier in this case, because you know charger, a battery is large and you may actually try to draw a lot of power in one place, suddenly you have turned it on, you are drawing a lot of power.

The energy supplier, the electricity provider will suddenly see a spike. A single spike is not a problem but if there are a large number of charges and they certainly see all the time spike, is the electricity supplier ready to cable or supplying this extra power? So there has to be a communication between the charger and the electricity supplier, what I call energy operator, energy supplier.

Now I am going to draw so much power, make sure that your grid does not collapse. We will get into some details later on. We then need metering, how much do I pay? How much power have I consumed and how do I pay? And I also need protection, this must be also standardized, because any vehicle can go and connect to a charger, it should provide protection, this is a must, other things are desirable but not a must.

What is the maximum weight or size of the battery? Now, you may not bother because by way it is there in the vehicle, vehicle has come, size and weight may not matter. In the other hand if you are swapping battery, the size and weight will matter, this is a desirable but not a must.

For example, energy operator when he buys battery and leases it is important that maximum size and weight is specified. Do you need to specify some performance, chemistry, etc? Actually no need. So, there is a must for standardization, there is something that are not required. We will remember that we talked about that when we will do the swapping we will have a new business called energy operator who will buy a battery and lease out the battery.

So, that business will require something little more about the batteries, the batteries that the energy operator purchases can be used by different vehicles otherwise their operation will not work.

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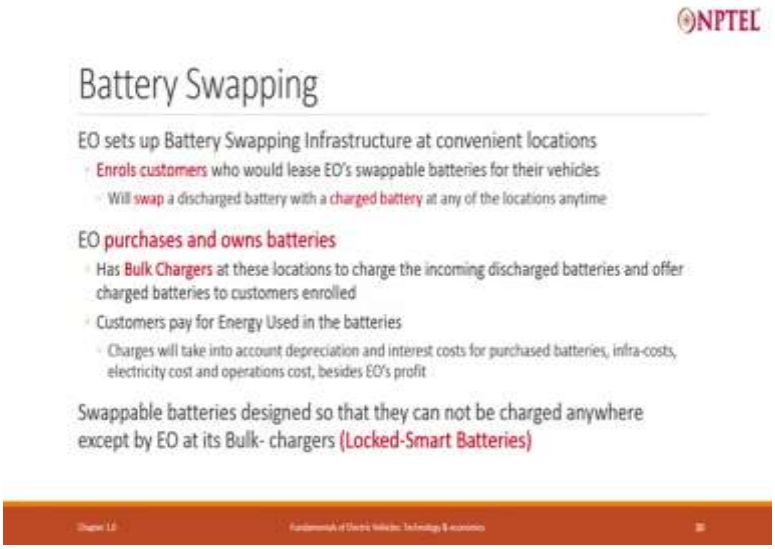

So I come to this concept of battery swapping. We talked about that battery swapping is a mechanism. Energy operator sets up battery swapping infrastructure at a convenient location as appointed on every third street corner, so you go there when your battery is discharged, you give away the discharged battery, take a charged one that the.

Energy operator has to enrol a customer who will regularly take battery from them, give the discharged one, keep taking the new battery and we will actually set up multiple locations for doing this. For this the energy operator has to purchase the battery and will typically use what is called bulk charger.

Normally a energy operator will have large number of battery, maybe he may have 100 batteries, they even have 300 batteries. So they have to charge multiple batteries at the same time. So they have to what is called bulk charger, it is not a single battery charger. Most chargers are single vehicle charger, single battery charger.

You need a bulk charger which actually in parallel charging 20 batteries so that is called bulk charger and this has to be put at multiple places. Remember that in swapping customers pay for the energy used in the battery plus also the charging will take into account that the every time the battery is used, its life goes down to that extent.

So, to that extent interest and depreciation charges has to be incorporated in the hiring cost, in the renting cost of the batteries including the cost of the bulk charger, the infrastructure charge, operation costs, all of that energy operator has to take that into account and therefore

sort of say, okay for this 1 kilowatt hour battery, pay me 20 rupees every time you come to swap a battery.

That 20 rupees should include, ofcourse, the electricity cost, which is the one thing that you will use, it should take into account the swapping operation cost, it should take into account the bulk charger and infrastructure cost, it should take into account that the battery life has been partially used, so it will have to take into account depreciation and interest cost.

Finally, energy operator has to make some money so to that extent some profit also has to be included. We will learn how to compute things like this. So, a question sometimes asked and again we will get into details. I have given a battery to you, and suppose you run away with this battery or you have taking this battery once, I am supposed to give you a charged battery and discharged battery you are supposed to bring it back.

But instead of bringing back the discharge battery, you keep on charging yourself and using it. So you keep on charging, discharging, charging, discharging yourself. So you are not paying me the cost. I am taking the cost only when a discharged battery comes to the amount of electricity that you have consumed. But you may have done it 5 times charged, discharged, I would not even know about it.

The battery would have deteriorated, it would have been with you for a long time and I have paid for the battery, I only take it for 1 cycle of charge-discharge. So very often these batteries will be designed what is called locked smart batteries. We later on talk about what is a locked smart batteries.

These batteries will be designed in such a manner that it cannot be charged by any charger other than the under authorized charge, it is locked. It cannot be discharged by any vehicle except the vehicle to which it is assigned to. How do you do it, we will learn later but that is what makes the swapping works. If you open up, person will just take and do whatever they want.

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Charging strategy for the best battery life, it is important to understand and I have repeated it several times that best is so charged at homes in the nights, why slow charge? Why nights? Why home? In the night, temperature is lower, charge is better in the night. Night will give you 5-6 hours to charge probably more so that is good for the battery slow charge.

Otherwise you are in a hurry, you would like to charge it fast. So 2 to 3 hours alternatively if you cannot do that home charging, you try to charge it either fully or partly in 2 to 3 hours that is also slow charging at parking lots. You have come to your office and your vehicle is parked for 4 hours, charge in that time.

Or it is going to a shopping centre, you have gone and you will probably take one and a half, two hour partially charge, slow charge always slow charge. And for the slow charge in India the best plug is this 15 ampere plug point that you use for a whole lot of different things, 15 ampere plug point is used for example, for your mixer, actually used for your washing machine, used for your refrigerator.

This kind of plugs are very commonly used, it can draw up to 3 kilowatts of power, on a single phase 3 kilowatt power. So, that is a slow charging that you can use and it will be widely available those kind of plug. Alternatively if the battery is large, then even if you slow charge the battery may be 20 kilowatt hour. So, you may like to charge in 4 hours so you like to put 5 kilowatt.

Now that is not possible with the 15 ampere plug point, you will have to do what is called 3-phase charging. And 3-phase charging 6 to 20 kilowatts, 25 kilowatts is quite common, we

will get into that also later on. You ofcourse may have to occasionally fast charge, and remember every time you first charge it will hurt the battery.

Then there are batteries which can be charged fast often and there are batteries which cannot be charged fast often. So you will have to keep that in mind. You are driving a vehicle, going in a long distance, going on vacation, you should be able to do fast charging, but that time you may not have time to wait.

For example you have gone to a restaurant, 1 hour you will be at the restaurant. Ideally you will be able to do fast charge. Fast charge will be less than an hour, hour or less. There are super-fast charging where one can try to do it in 10-15 minutes. There are normally fast charging is 45-50 minutes, 55 minutes, 1 hour, this is where you like to charge very often, occasionally.

Why occasionally because if you do that regularly, battery life will get impacted. On the other hand, buses and taxis, they run all throughout the day and may even late in the evening night, you may want to do more fast charging, and therefore, the battery that you would like to put there should be capable of taking fast charging, or you replace the battery more often. So all these are things that you need to keep in mind for charging.

Another question that is asked, where do you charge? A year and a half back government of India came up with a notification; we will make all our petrol pumps into fast charging stations. They probably never consulted anybody. A petrol pump is designed for somebody to come in, fill up the petrol and get out in 5 minutes. So it is designed to handle so much traffic.

Every 5 minutes it has to get out, just come in and get out. If you do slow charge, you are going to take 2-3 hours, 4 hours, it will not have space, it is not a parking lot. A parking lot is a place where you can do slow charge. You need to get out in 5 hours you cannot 5 minutes, you cannot do 2 to 3 hours charging.

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Even if you do fast charge let us say 45 minutes to an hour. A vehicle cannot go and park in a in a petrol pump for 45 minutes, if we start doing that the parking, the complete petrol pump will be full in no time and the vehicles which come for 5 minutes to get the petrol will not be able to do.

On the other hand swapping is possible at petrol pumps, as swapping takes about 5 minutes. So this simple thinking very often is not done. An announcement is made, all BPCL petrol pumps, all IOCL Petrol pumps will install fast charger, and IOCL, BPCL board says we do not know what to do. We know if we do that will destroy our petrol pumps.

So, petrol pump is not the right place, it needs vehicle to get out every 3 to 5 minutes. The right place is parking lots, office parking, street parking, shopping food complex, multi-story parking lot and immediately the question will be okay, that is where you can do, should we put slow charger or fast charger? You will put public chargers which can charge any vehicle.

How many chargers should we put? How many fast chargers should we put? And you probably can choose a right mix of slow and fast charger. People will always prefer slow charger if they are going to wait, park for long enough. If they are going to wait for park for 2 hours, 3 hours, 4 hours, you will do slow charge, you will not for charging, you will not hurt your battery.

If you have to get out in 30-45 minutes then you may do fast charging. So you have to figure out what kind of traffic will come and then decide how many slow charger, how many fast

charger, you must figure out how many electric vehicles are going to come, not just today but even 2 years down the line and then install the number of slow chargers and fast chargers.

So this is what the slow chargers and fast charger infrastructure that will be required, more detail of what is a slow charger, what is a fast charger, what kind of standards are there we will get into details. What we have learned that yes, there are public chargers, there are slow chargers and they are fast chargers. It requires limited standardization, for chargers largely it has been done. We will get into the standardization also later.

And the right place to put it is parking lots, office buildings, place where you keep the car for 1 hour plus, and not the petrol pumps. Same thing we have discussed in terms of swapping, the whole concept of swapping where people buy battery and are able to swap it that can be done in 3 to 5 minutes. That can be done in places like petrol pumps. We will get into more detail of charging infrastructure. Full chapter is there on that towards the end.