Fundamentals of Electric Vehicles
Technology and Economics
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Lecture 69
Public Charges Part-I

Greetings to everyone, so far you have already covered basics of chargers, chargers or definition, their categorization and also the structure what comprises of a charger, what resides inside the charger, the purpose of electric vehicle chargers and how they are different from the chargers that we use for batteries for other applications. So whole of this part actually has been covered by Professor Ashok.

And he also touched upon the standardization; why do we need standardization? What we are going to discuss today in this class is basic definitions, categorization of the chargers as far as the real implementation is concerned, how do we deploy them, where do we deploy them and what are various standards that are existing, how are they different from each other and we are going to cover it very broadly.

So, basically not much concepts to understand the working principles and all that we are not going to talk all that is already covered. We would only focus on what are different standards and how do we pick and choose different standards for our own applications.

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So, if we talk about public chargers there are different categories like we have standalone chargers. These are the one where when we buy the vehicle we get the charger along with the

vehicle. Whenever we are getting a charger along with the vehicle as a two wheeler, three wheeler application basically where the battery is installed inside the vehicle itself we call them as standalone chargers.

Second category is the slow charging station where we use such kind of charging stations at our homes or public station, but the purpose is that it would charge a fixed battery at a very, very slow rate. Now one part that is important is whenever we listen or hear about slow charging or fast charging it is very relative, it has nothing to do with the C rate of the charger. It is basically dependent upon the battery.

So, if the battery supports the charging at more than let us say 1C rate we say that we are able to charge the battery at a fast rate, but it also depends upon whether my charger is able to charge that battery at that rate or not. If my charger does not provide that kind of a current in that case we call it as a slow charger. So any charger that is able to supply or match the battery rating lower than the 0.5 C or we can also say for reference 1C we call them as slow chargers.

And if it can provide the current may be more than 1C or whatever is the highest rated capacity of that battery more than that we call them as or categorize them as fast chargers. There are chargers which can charge a battery in 1 minute, in 10 minutes, in half an hour, but all depends upon the matching between the two. Overall, just to say that what is the slow charger, fast charger there is no one particular definition.

But we can say that if we are able to charge a battery with the charger faster than 1C rate it is a fast charger lower than 1C rate it is a slow charger. Now when we talk about slow charging stations that we are talking about homes or public these are essentially the slow chargers and whenever we are buying a vehicle with the battery pack which is fixed inside. So, whenever we are using a charger to charge a battery pack at our homes that we have gone at our homes.

We park the vehicle at our parking station it takes about 5-6 hours, 7 hours sometimes to charge the whole battery in a cars or two wheelers. We are essentially using slow charging stations and if the similar charging station we use at public we would want that whatever the user is consuming that energy the person as an operator who has installed that charger he recovers that cost.

So there has to be an energy meter inbuilt into that charger so that it can generate a bill. So the difference between a home charger and public charger in this category is only about billing nothing more, nothing less and we will also come about the standardization with specify how do you build that and what are the different ways to identify user and will a particular user itself.

The second category that we talk about is the fast charging stations, essentially DC chargers. So, whenever we are talking about fast charging stations though there are AC fast chargers also and we will come to that definition as well, but these are both AC and DC, but largely when we talk about fast charging stations we are talking about DC stations which can give you a power of about 30 kilowatt, 50 kilowatt, 100 kilowatt and can charge your vehicle directly in DC form.

The last category is actually bulk charging stations. So, in your previous classes you would have touched about swapping as a concept. Whenever we are using swapping we take out the battery from the vehicle and there is a service provider who is giving you the batteries on lease or rent or paper used model right. In that case you cannot charge each battery with a separate charger.

All these batteries have to be clubbed together, grouped together and put it into a rack wherein we use this kind of a bulk charging station. So, a bulk charging station is nothing, but it is actually a rack where you can put in all number of different batteries that you have taken out of the swapping applications and charge them simultaneously and these are developed in a way that these have the intelligence to know that which battery is charged at what level.

At what rate, what is happening with the battery and how to build that battery. So each port or each battery is controllable, each battery is monitorable and you also get the records updated to the cloud. So, in all these categories actually you can have a connect to the cloud also. So, if we see for the first category standalone chargers these are essentially personal charges the rest of these three are categorized under public chargers. So as far as utilization or application is concerned these are the two categories of chargers personal and public.

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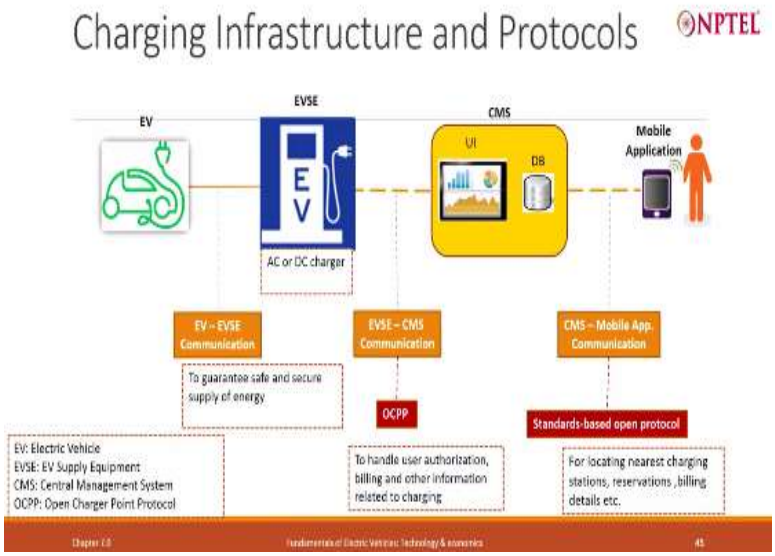

We would focus more on the public chargers because that is where the infrastructure comes into picture at homes we do not require an infrastructure it is just plug and play and you get those chargers from the OEMs or distributors that you are buying your vehicles from. So, when we have to talk about infrastructure that is where we are talking about public chargers. So, henceforth our communication or our talk discussion would be focused on pubic chargers.

Coming on to public charger if you look at the whole infrastructure architecture it is divided into four basic segments or we would say that it comprises of four basic actors that comprises of this whole architecture. The very first is the EV the electric vehicle itself. Second is the EVSE that stands for electric vehicle supply equipment, so EVSE is a supply equipment. Third is a CMS which is nothing, but a server central server which is connecting all these actors together and monitoring that what is happening where and how to control all this.

And CMS stands for central management system then the fourth is the user itself where he has an app which he is using for all different types of communications and as a user he becomes the basic interface to the kind of infrastructure that is required, the kind of whole of the communication that needs to happen. So, he is the person who is using the entire infrastructure.

And hence the CMS interacts with the EVSE the EV or different types of the chargers that are installed in that infrastructure and provides that information to the user. So, what does the user get? User needs to understand what is my nearest charger? He needs to ensure that if I

need a nearest charger can I book that charger. If I do not need or my mind changes can I cancel that charger and the billing amount would not be accrued into account or you want to see your history that what has been happening into your things for charging.

You charged at such and such date, this was your update on the energy, this is what you consumed and this is how it has been behaving. So all those things are all aligned together, linked together to form this whole architecture. Now when we talk about an architecture what is important is how do each of these sub segment or actors communicate to each other and that is where standardization come into picture.

And the importance of standardization you guys already know that interoperability and every system that new or old comes into an architecture should be able to fit into the existing stream of things. So if we talk about EV to EVSE there is one set of communication that we defined and their standards that define this kind of communication. Second interface is EVSE to CMS.

So EVSE to CMS largely there is one standard that is OCPP that we follow globally. So there is no largely no conflict though there are other standards also, but people usually follow OCPP that stands for open charge point protocol. When we talk about this interface EV to EVSE communication there are several standards and will focus on one stream of standard that exist here in a while.

Coming to the interface between CMS and mobile this is the standard based open protocol people usually may follow OCPP guidelines that are there between CMS to EVSE to map those all existing streams of functionalities into the user app also or they may have their own proprietary information flowing or proprietary standardization that they would follow for this kind of a communication.

So, if we see overall we have talked about two different standards. So we will leave aside CMS and the user because that is something that the operator would define as the app interface. What are different standard is EV to EVSE one set of standard and second standard is EVSE to CMS. EVSE to CMS since it is only one standard that is defined there is no conflict we just pick it up that all different chargers have to communicate in such and such language standard is nothing, but the language right.

Set of protocols or rules that they have to follow, the message on the structuring that they need to follow and they need to communicate to CMS. So there is no conflict on that part also. So what is the focus is actually EV to EVSE communication. So, broadly we would be focusing on this category that why is there a conflict, how to select that and where and how to apply which kind of standard.

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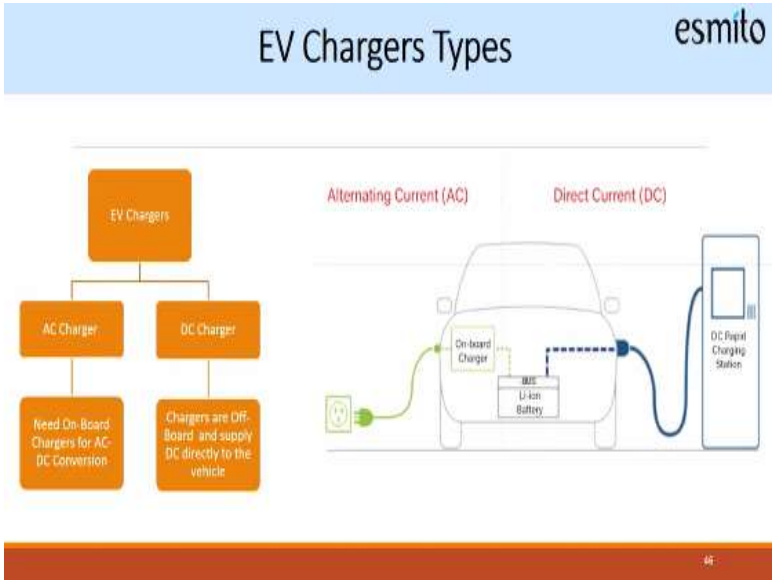

Before that there are different types of chargers that we need to understand. We said there are two different categories. One is AC chargers, DC chargers. So, what is the logical difference between AC and DC and how would we select that we would need my car would need an AC charger or my car would need a DC charger. If I own an EV and something like Tesla, BMW or something why to think of anything lower than that.

So, if you have any such vehicle if in the vehicle I have an onboard charger and I just need an AC plug to do that I would actually search for an AC charger. If I do not have an onboard charger in the vehicle most of the times what happens is that two wheelers and three wheelers do not come with an onboard charger. They have something like we use all our laptops, we have that adaptor, that adaptor is nothing, but a charger because it converts that AC to DC to charge the vehicle to charge the laptop.

Similar is the concept when we use it for vehicle so the vehicles also come with essentially a separate charger. The charger is nothing, but which is converting AC to DC because it is finally need to charge the battery inside the vehicle and battery is DC. So it comes with an off-board charger. Whenever we have that charger in hand also we are given by the OEM and

we have that charger in that case also we look in for an AC charger we do not need a DC charger.

In case I do not have this portable AC charger with me I do not have an onboard charger also that is there with me then I would need a DC charger because in that case this DC supply should be directly charging the battery which is there inside the vehicle this difference is clear. Now if I look in for the DC charger the very first thing that comes into picture is that my vehicle, your vehicle, his vehicle, her vehicle all these vehicles could be all different in nature.

All the vehicles might need different kind of a power supply because all of them are working at a different capacity. So, if they are working at different capacities, they have different batteries, their chemistries are different, they would certainly need different voltage and current and largely even when we try to distinguish them from these segment point of view or two wheeler would require a different kind of supply, three wheeler would require a different kind of supply kind of supply means different voltage, current and the C rate.

Similarly battery a car would need a different rate, bus would need a different rate and truck would need a different rate. How would the same charger be supplying the charge or the current to all these batteries this depends upon the communication that is where again the standards comes in place. So the charger needs to ask the vehicle kaun ho aap? What are you and what is it the type of the battery that you are asking for?

And that battery or the vehicle needs to communicate to the charger that I am such and such battery, I would need such and such voltage, such and such current and for such and such duration and these are my cutoff limits. If I cross a current total AH that has gone into my battery by whatever amount x, x amount then you cut me off. So these things are also inbuilt into the BMS.

But these are also communicated to the charger such that the charger does not damage the battery. Why is it important is because we do not want that whatever thresholds that battery can tolerate the charger should exceed that, that is why the whole of these communication become very, very important.

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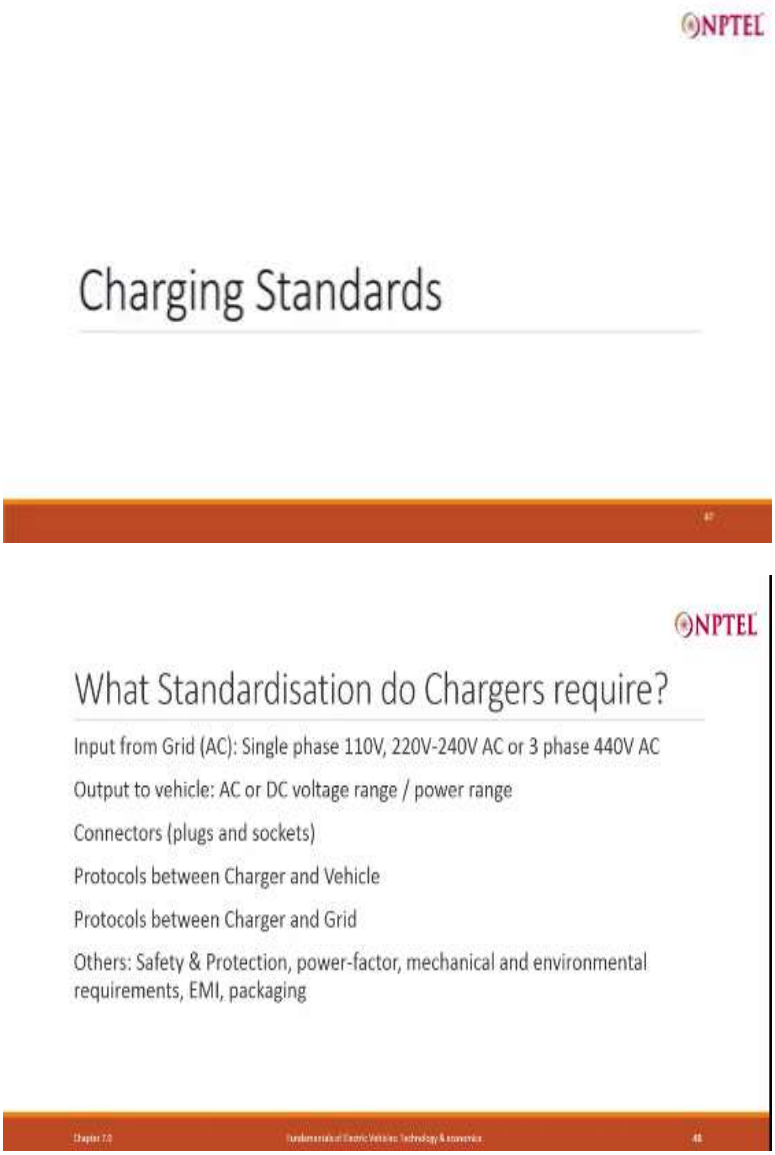

So when we talk about different standards, what do the charger require a charger is nothing but you need to have some input power, it need some output power inside it has some intelligence apart from the electronics. Now this intelligence is what makes that standard apart from that standard what all different safety requirements, what all different protection requirements have to be there, what different environmental things that it needs to tolerate and comply to.

So, all these things actually formulate a standard. Apart from that the protocols that you need to have the set of rules that we need to follow for communicating between the charger and the vehicle and on the other side charger and the cloud and that is why charger becomes the

focus. So in an infrastructure where we want to put up things in a very standardized way there what we do need to focus more on is actually the charger.

Because charger is what has all the interfaces, so once we define that these are the standards to be followed by the charger we are eventually telling that this is the standard on the battery, this is standard on the CMS, this is the standard on the app. So one standard when we pick up for a charger it actually sets up the base to define that what kind of infrastructure or standardization we are going to follow.

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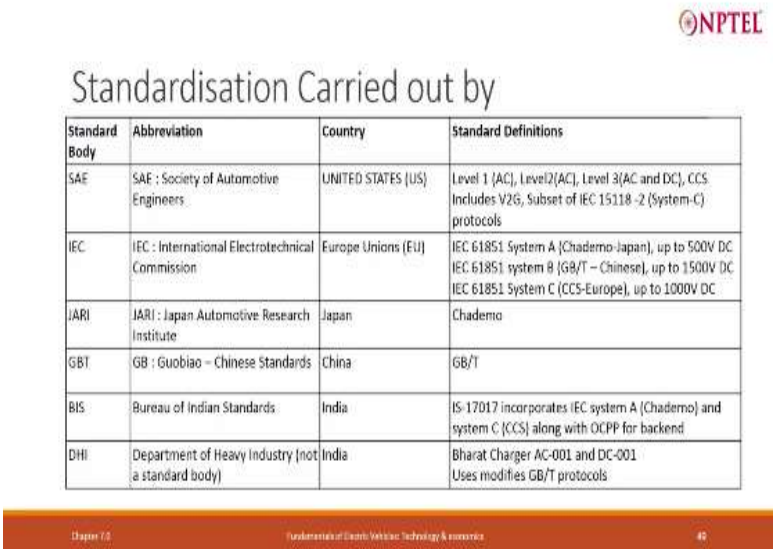

Just to give you an overview of what are different types of standardizations that are carried out by different organizations there are few bodies that have specified the standard. The first that you see is the SAE that is society of automotive engineers and that is where they specify their standards in different levels; level 1, level 2, level 3 and so on and so forth. They also do follow or take some subsets of IEC standards which are actually European standard.

So, these also here this is the most important part worldwide IEC standards are one that are getting adopted by all different organizations. So here this is an important part to understand because the rest of the organizations be it the SAE, JARI, GBT, BIS or DHI all these organizations derive their standards from this basic definition. So IEC 61851 this is one standard where it specifies that how things should be picked up.

How things should be used and what all different standards exist. So, if we talk about system A that follows mind it that whenever we are talking about IEC 61851 as a standard we are

essentially talking about all the DC standards we are not talking about AC standards here. AC standards as far as the standardization is concerned is specified in SAE standardization and also given by BIS and DHI that something are there will come back to that.

Because that is important from our point of view to understand where we are as far as standards are concerned in India and what is it that we have some guidelines available on standardization for chargers, but overall IEC 61851 specifies only DC standards. System A goes up to about 500 volt DC and this is the standard that Japan follows or Japan framed and then it is adopted here as a comprehensive standard.

So this Chademo came from actually JARI standard. System B is GB by T which is a Chinese standard and defined by GBT standardization body in China and it goes till about 1500 volt DC. System C is a European standard again specified by IEC and it goes till about 1000 volt DC. Now BIS in India is the standardization body that is Bureau of Indian Standard and that is what specifies all standards for India.

In BIS we are not specifying any standards from scratch. So, here what it also does it like other standardization body we pick up what is good in which standard and which applies to the standardization in India it is not that it always does it why it is doing for automobile or EV segment is that unfortunately we are much behind the countries where EV and standardization has happened.

And since the wheels have been invented there, people have the infrastructure, they understood what has to be done, there is no use to redefine that and rediscover that wheel. So, essentially what we are doing at BIS is picking up what is good in mid standard and what should be applicable in different segments of the automobile sector that we want to pick up. So one of these things is what we are trying to pick up in BIS.

And BIS has just rolled out one standard that is called IS 17017 that incorporate system A and system C for standardization between EV and EVSE. So mind it for a charger we are calling it as EVSE and this standard is between EV to EVSE. So, between EV to EVSE they say that you follow either system A or system C or to say Chademo or CCS respectively where Chademo is system A and CCS is system C.

So, here what they say is that since we know that these are for voltages 500 volt or 1500 or 1000 volt DC this means that essentially this is for a segment where we are talking about cars

or buses that is the category we call them as mid segment EV wherein we categorize all the vehicles all the electric vehicles in three way we call it as low EV, mid EV and high EV. So if it is low EV we are essentially talking about two wheelers and three wheelers where the voltage range of operation is about 48 volt to about 100 volt.

So, whenever we are talking about low voltage of electric vehicles we are talking about LEV. Whenever we are talking about buses small buses or cars we are talking about mid segment and these are the standard that are specified for mid segment, when we talk about high voltages let us say loaders high loaders, big buses or we are talking about trucks.

They fall under a category of HEV that is high segment of electric vehicles wherein the voltages may go up to 1500 volts. Now very interestingly before the standardization came in picture since we needed some guidelines in place in India and we did not have any standardization in place DHI which is department of heavy industries so this is the only body which actually is not a standard body.

But this is the body that actually introduce the guidelines in place for introducing FAME subsidies. You would have all heard of FAME subsidies when we buy the electric vehicle government is subsidizing our electric vehicles and all those subsidies come from FAME scheme which is introduced by DHI. Now how to provide that FAME subsidy on charges or electric vehicles to be given to anyone and everyone without knowing that which standard they are following and whether this is apt for India or not?

So it was not there, but they wanted to give it a push to EV as an important segment for the country and since that was not happening and we had huge fuel imports that were there. So to combat that what DHI did was they framed a guideline for AC charger and DC charger to introduce and since most of our vehicles lie in LEV segment we do not see much of the I would electric vehicles in MEV or HEV segment.

DHI kind of realize that is the need and why not to introduce our own guidelines for AC and DC charger and that is where they introduced two chargers one is called Bharat Charger AC-001 and the second is called Bharat Charger DC-001. We will talk about that in a while.

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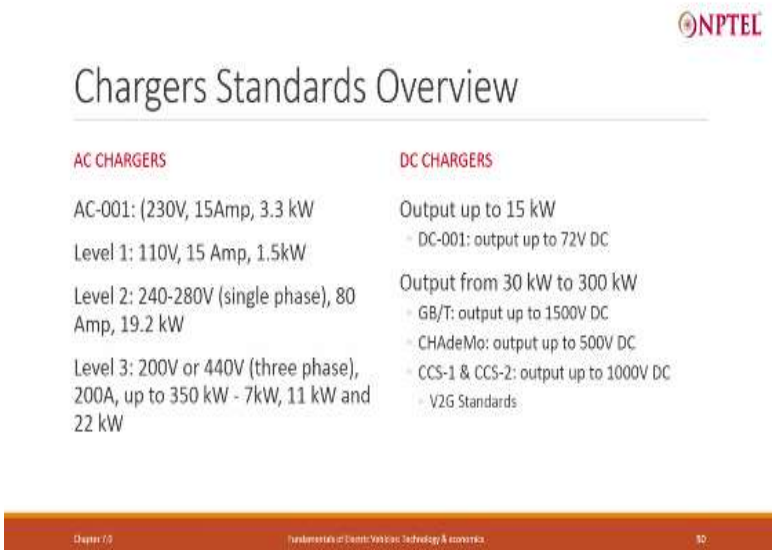

Overview, if we talk about AC chargers AC-001 230 volt, 15 amps, 3.3 kilowatt and that is essentially if you can see that is something that we use at our home 230 volt supply then we talked about SAE the standard that is given by US. They specified three different levels level 1, level 2 and level 3. Level 1 is 110 volt, 15 amps, 1.5 kilowatt. Level 2 goes to about 80 amps and it is again a single phase with a capacity of about 19.2 kilowatt.

Level 3 is a 3-phase supply and goes till about 11 kilowatt to 22 kilowatt in AC and 350 kilowatt up for DC. So, if we talk about level 1 and level 2 these are purely AC levels. So by definition these are AC standards level 3 is both AC and DC and if we talk about our standards that we just said Chademo, GB by T and CCS. Chademo and GB by T these are two standards which are purely DC CCS is also DC.

But CCS connector also comes with DC as well AC supply. The only connector or the only standard which supports both AC and DC otherwise there are AC standards and there are DC standards. So only standard that only support AC and DC is CCS standard and the only standard wherein it specifies that what is the kind of communication even if we go in for AC charging.

Mind it when we go in for AC charging we are saying that the battery has an onboard charger or it has a portable charger. Whenever you have a portable charger or an onboard charger for an AC supply like our homes there is no communication happening. So the standalone chargers or public charges which are AC in nature there is no communication that happens between EV and EVSE or charger and EV.

But whenever we are talking about DC charger there is a communication that happens between EV and EVSE and apart from that if we use a high rated, higher capacity chargers in level 3 then the communication between EV and EVSE on AC supply as well becomes mandatory and that is where it is specified only in CCS standard and CCS connectors and we cannot choose any other connectors it has to be typed-2 or say CCS connector.

DC charger; if we talk about the Bharat charger it was specified till 15 kilowatt and serving LEV category of vehicles DC-001 output up to 72 volt DC. So you can select 48 volt battery, 60 volt battery and 72 volt battery. So the categories that we have in the market you pick up any vehicle two wheeler, three wheeler and a small car like Verito or Tigor or let us say whatever vehicles that we have they are all till 72 volt.

Now we have an introductory I mean this year that we are seeing MG Motor and couple of others that have introduced their cars at higher voltage. So their voltage goes till about 350 volts or 400 volts as well 350, 380, 400 volts. So those are not covered by the Bharat DC-001, Bharat DC-001 covers only two wheelers, three wheelers and all those cars whose batteries are rated at 72 volt.

Then the other category that the other standards had GB by T Chademo and CCS they are all from 30 kilowatt to 300 kilowatt at higher voltages. So you see why was the need for defining the Bharat charger? The very first thing our vehicles are mix is very different from what is existing in Western countries or where the standardization happened and if you see for the standardization rating 1000 volt, 500 volt, 1500 volt all the segment is not there in India largely.

So, whatever we have in India the standardization was not existing for that, that is why we needed to define another standard for that actually suits the segment that we are wanting to target and that is why there was a new standard formulated Bharat charger DC-001.

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Let us have a look at what are different levels that we specify when we talk about Level 1 of AC charger this is nothing, but actually the plug point that we have. So in US it started that yeah you can procure your car and you can use your standard plug that you have at home. Level 2 also a standard plug at your home or any other public place, but with this thing that it can go for a higher current rating.

The difference between Level 1 and Level 2 is only with the current rating and as far as regulations or permissions are concerned Level 1 does not ask for any permission from any discom or a grid people that you are connected to. As far as Level 2 is concerned there is a specialized metering that US says that if you want to install that you need to have permission for installing a Level 2 charger.

Now Level 3 this goes till about 200 amps, but typical current that these guys use is about 60 amps and the charging load is from 50 to 350 kilowatt and this is the 3-phase supply. Broadly, the difference is I mean all these ratings you can derive from it is a single phase or a 3-phase charger.

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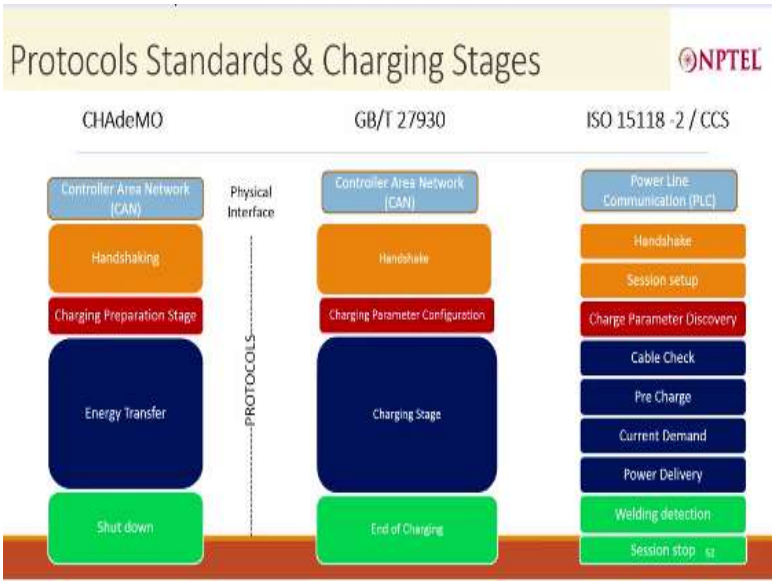

Protocols that we have discussed so far for DC standard that is Chademo, GB by T ISO-15118 which is actually CCS standard. At the protocol level the difference is between their physical media and their application layers that are divided into. As we are not covering every standard picked up into detail we just are laying out here the basic differences that are there. So if we talk about Chademo and GB by T both are the physical level use CAN interface.

CAN interface you understand so both of them have a CAN interface that is controller area network that is what they follow and if we talk about ISO standard which is CCS standard they follow power line communication. So, basically communication over power line itself little tedious to get that because of all the isolations and all the EMI and interfaces that happened during with the power as well as communication both.

But that is something people are seeing that this is a way forward. So PLC is one form of communication and CAN is another form of communication. Largely when we talk about vehicles do you know what is the kind of communication that we follow in vehicles in vehicle communication? It is CAN, so CAN is what our existing automobile people are also using for the communication inside the vehicles.

And that is where we are also seeing that probably Chademo and GB by T since people are aware of what is CAN and how to utilize CAN is an easier thing to adopt from standardization point of view for communicating outside of the EV also. Now as far as the

protocols are concerned all these protocols are similar. Protocols by definition may know this is the handshake signals over which the messaging structure is formulated.

Overall, all these three protocols are actually defined into 3 stages; one as handshake stage, second as charging stage, third as termination stage. Handshake stage basically is for understanding what is the kind of the battery that I am supposed to charge; if I am a charger I need to get to understand the battery that is the handshake stage where the battery and the charger get to know each other.

From what is the type of the battery, what is the type of the charger, what is my current, what is it that it can supply, what are my thresholds, can I limit it or not limit it. So that is something handshaking that happens to set up the parameters that you need to have. Second stage comes as a charging, so the charging starts happening and during the charging you keep on continuously monitoring what is happening at every point.

Now this every point there is a regular interval. So what is the interval is defined again as per the standard, at what interval you need to hand shake all those signals. Last is the termination stage where we tried to figure out how much of the battery has been charged and try to capture all that information. If we talk about the charging stage the handshaking stage there are usually two stages handshake and charging parameter configuration it sets that configuration.

Where is the difference between these three is both Chademo and GB / T energy transfer or charging stage similar, but names are different it is only one stage whereas for CCS it is divided into all different stages. We would say that makes CCS a little more complex that is one way to look at that, but if we want to compare it and say that what is the advantages or disadvantages between these two.

We would say that CCS also gives you better granularity, better resolution whatever you want to capture as result of finding out the energy or finding out what are the errors, finding out what is the faults. So though those parameters can be calculated, can be derived in GBT and Chademo CCS gives it directly so that is an advantage. Once you specify it more and more and more as far as the standardization is concerned that means you have less to think about on how would you calculate things.

How would you figure out what thresholds are there, how would you define that there is a fault that has occurred and if there is a fault that has occurred what are the actions that you have to take. So all those things becomes the responsibility of the operator if we choose Chademo and GB by T whereas there are lot of stages and lots of action items that are already given in CCS. So that is one of the ways to look at that.