CHARGING INFRASTRUCTURE

Prof. Apurv Kumar Yadav

Department of Electrical Engineering

Indian Institute of Technology Roorkee

Week-10

Lecture-48

Lec 48: AC Type-2 Charging - I

Hello everyone, welcome to the lecture number 48 of this NPTEL lecture series on charging infrastructure and today we will discuss about AC charging systems, primarily the type 2 or you know one can also do using the CCS2 vehicle inlet connector as well. So, we will see how the different charging sequences takes place, what are the communication systems which are used to facilitate this AC charging systems. So, as we have studied in our previous, you know, we have been discussing a lot in detail about the power conversion unit which comprises of AC to DC converter and isolated DC-DC converter. And if you look very carefully, our charger is actually comprises of not just the power conversion unit, it will also have several communication aspect also involved in that in order to facilitate the safe charging of the battery.

Now if you look very carefully we have power conversion unit here we are showing you the AC charging system because first we will discuss the AC charging system and then going ahead we will discuss the one of the commonly used AC charging system and using the AC type to charging generally the AC charging of the vehicle takes place. So, here what we are going to do is we are going to see in detail how the AC charging systems are there and I mean how the AC charging takes place whenever the vehicle is connected with the AC charging gun from the ACVAC. So, we have if you recall I know in lecture number 2 we have discussed about basic building block of the AC charging which is comprises of ACVAC which actually has the controller has the sensor part has the safety interlocks and then from the grid which could be single phase ac or three phase ac it is directly you can say the the ac which is getting plugged into the vehicle and that's why it is called as the ac charging since we are actually plugging in the direct ac into the vehicle and in the vehicle we have the onboard charger which is comprises of the power conversion unit, which is comprises of AC to DC converter here, AC to DC

converter followed by isolated DC to DC converter, which ensures there is the isolation between the battery pack and the AC grid as well as the required value of DC or the required value of DC voltage and current will be coming or will be used to charge the EV battery.

And then the BMS of the EV battery which is there inside the vehicle will actually be sensing the voltage, current and temperatures of the battery cells and then continuously they will be finding out what is the status of the battery pack and that BMS will be actually will be sending the information to the ACVSE like whether the vehicle is ready or not ready and what is the possibility and what the ACVSE has to do. While the ACVAC on one hand is doing the communication with the battery management system, on the other hand, they will be doing communication with the central management system of the charging station service provider and for actually doing the metering and billing purposes. So, the ACVSE what we have here is comprises of basically only the controller which actually do the communication on either side, the sensor part which actually senses the voltage and current and that is when which can be used to do the monitoring and protection systems. And then we have safety interlock comprises of relays, contactors to ensure that in case whenever there is fault on the EV side or on the EVSE side, these safety interlocks come into place and then ensures that vehicle gets cut off from the grid. So, this is the entire AC charging systems which comprises of some portion inside the vehicle and some portion in the EVSE side.

And if you recall EVSE means electric vehicle supply equipment we are talking about. So when we have AC charging system, we have the AC electric vehicle supply equipment. Now, if you look very carefully since the power conversion is taking place inside the vehicle itself using this onboard charger. So, they can control the whatever the voltage and current which is been coming at the output of the isolated DC-DC converter. So, in this particular charging system AC charging system since the power conversion is taking place inside the vehicle and this power conversion unit is the only thing which is actually controlling

the required voltage and current at its output. So that's when you do not have to send a lot of information to the EVSE. You just have to send maybe the shutdown indicator or maybe the start indicator depending upon how much amount of current the ACVSE can allow at that particular moment of time. So, since the power conversion is taking place inside the vehicle, so

that means a lot of controlling is taking place inside the vehicle. So, not too much of a data need to be sent from the vehicle to the EVSE.

So, that's when we did not require high level communication. It can be done using the low level communication, which is done using the, which is primarily done using the PWM based, PWM based low level communication and this communication takes place over the this takes place over the cp pin called as a control palette pin now we have already discussed these things i mean some of the things in the lecture number four but still we it is good to recap those things so that for us to have the smooth understanding of the concept Now an AC type 2 charger if you look very carefully we have the charger plug in the when you go to a charging station or mostly generally people are putting this AC type 2 charger in their home.

So that has the ACVAC which is the wall mounted unit and then from the wall mounted unit you have the standard 5 meter cable which is coming out and the end of that will have the charger plug which actually goes into the vehicle inlet connector and that vehicle inlet connector has to be the you can say the shape which is the similar as that of the charger plug so that the form factor of the charger plug and the ac vehicle inlet connector must be such that they both get easily connected to each other this charger plug gets easily goes into the vehicle inlet connector so for the type 2 charger plug for the type 2 ac charger plug you require the ac type 2 vehicle inlet connector or vehicle inlet port where you will put the plug now in this case as i mentioned since most of the power conversion is taking place inside the vehicle the communication is actually be doing using the pwm based communication and that too it is happening over the control pilot pin So if you look very carefully it has the control pilot pin, it has the proximity pilot pin, it has L1, L2, L3 and neutral which is actually this L1, L2, L3 and N are the pins which actually carries the power or you can say that actually carries the AC power which is actually plugged into the vehicle. Corrective earth is for the protection systems.

and for the protection of the you know if there is some fault happens or there is some earth related fault so this protective earth will become very handy for the safety of the user who is using it and then we have the control palette where the communication takes place as the name suggests control palette it is the pin through which the communication is actually taking place and then we have the another pin which is the proximity palette as the name suggests is the pin which actually detect whether the correct ac charger plug gets plugged in or not on the other side on

the vehicle side we have the vehicle inlet connector which is having the form factor similar to that of the type 2 ac charger plug so the communication is taking place using the pwm based communication this is not the pwm which is actually controlling the ac dc and dc dc converter it is the communication which is dedicatedly taking place over the CP pin. However, the power part is coming through the L1, L2, L3 and N and which will be connected to the converters after that. And there again, the pulse pin modulation is taking place to ensure the proper operation of those AC, DC and DC-DC converter.

So, here it is not, this PWM is not there to control the power conversion unit. However, it is just there to do the communication between the AC, VLC and the E. Now, if you see the PWM, any generalized PWM has some time where you have some non-zero value, which is let's say defined as the, you know, T on and for some time it is off. So, this is if you define this as TS period, this is a PWM. I mean, using this communication taking place.

So, what we have? We have the TS. We have this T on period, which is nothing but D times TS. And then we have the T off period, which is nothing but 1 minus D TS period. and then we have the amplitude you know let's say define as the let's say v amplitude so the evac and ev is doing this communication by changing this amplitude so v amplitude is changed you know is either is changed to actually send the information required information similarly you one can also change the duty ratio

to actually send some other information if let's say if they wanted to send some information they can either change the duty ratio or they can either change the v amplitude and that will be detected on the other side and then depending upon the magnitude of those v amplitude and duty ratio they can then extract that data what actually that data means so what happens so the communication is taking place using the pwm based communication which has varying amplitude level which has the varying duty ratio level so that they will change and then the informations will be sent between the ev and evsc and in this case whenever the charger plug gets plugged into the ev so it's a ev which recognizes the plug-in via proximity pilot It's the EV which will first determine whether the charger plug which is gets plugged into the EV is correct or not or is it the valid charger plug or not. Then after that after that once that check is done then what happens the EVSE will then tell the vehicle that what is the maximum possible charging current it can support and depending upon that the vehicle react to it and then vehicle will send the

information about whether the vehicle is ready or not so then after doing vehicle receives the information from the EVSE about the maximum possible charging current

the vehicle will send the information to the charger and the charger receives the vehicle ready status and then the charging takes place and in all this process it's the vehicle who is the master who will say when to stop the charging when to start the charging so vehicle whenever the evac is communicating with ev it's the ev who is the master and primarily it's the bms in the ev which is actually communicating so it's the bms in EV who is the master. That means EVSE will receive that message from the BMS of the EV and then decide and or take the appropriate action. similarly if you look very carefully we can also do ac charging with the dc ccs to vehicle inlet connector as well that means we can just use the top portion of that and ac type 2 vehicle inlet connector is then the form factor of that is similar to that of the top portion of the vehicle in that connector so that's when it is this place where the ac charge ac type 2 charger plug gets plugged in and then just by using the single Vehicle inlet connector one can do the AC charging just by using the top portion of it and they can also do the DC charging by using just this control pilot, proximity pilot, protective earth and the DC plus and DC minus pins from the CCS2 charger plug.

So this is the thing which is there which is a charger plug for CCS2 and if you look this is the vehicle inlet connector where the top portion is actually same having the same form factor as that of ac type 2 vehicle inlet connector and when someone wants to the dc it has they have to use the entire connector however when someone wants to just do the ac charging they will be only using the top portion of the ccs2 vehicle inlet connector so here with this we can do ac type 2 charging and with this we one can do the dc charging and we have seen ac charging generally people do for slow charging i mean generally ac charging is being installed in the homes and over the night you can one can charge the vehicle using ac charging so ac charging is actually a kind of you can say actually a slow rate of charging which takes the overnight charging overnight to actually charge the vehicle battery Similarly the DC charging is actually the you know using the DC charging one can do the charging at a faster rate can do charging at faster rate is primary because the power level of DC charging is DC charges are quite high. DC charging can do charging at higher power level it is primary because the DC charging systems have the higher

power levels and that's why the power conversion is taking place outside the vehicle because the size of power converters will be huge which cannot be put it on the vehicle

So, this is what you know we can use the top portion of the CCS to vehicle inlet connector and can do the AC type 2 charging. They also follow the same thing the same PWM based communication and proximity pilot to detect the correct charger plug which gets connected to the vehicle inlet connector. So, let us try to see how the real charger gun works. And we will show you how the CCS2 vehicle inlet connector looks like and how the AC charging can be done using the DC CCS2 vehicle inlet connector. So if you see here we are showing you the actual AC type 2 charging gun along with that here we are showing you the vehicle inlet connector for CCS2 charging system.

Now if you look very carefully this charging gun comprises of this standard 5 meter cable from the EVAC and it comprises of the charging plug which is the charger plug which is the AC type 2 charger plug. Now if you look very carefully it comprises of several pins going from PP proximity pilot L1 L2 L3 neutral protective earth and our control pilot if you look very carefully this L1 L2 L3 neutral and protective earth these are pins which are bigger in size primarily because these are the pins from where the actual power is actually being flown from the EVAC to the EV However, if you look the proximity pilot pin and control pilot pins, they are smaller in size because they are responsible for the communication between the EV and EVAC. That's why it is not to be of or very larger in size.

I mean, so that's why they are of a smaller size. Now, if you look very carefully in the vehicle inlet connector of let's say CCS2 charger, because this is the vehicle inlet connector which will be placed in your vehicle. Most of the four wheelers will have the CCS2 because using just single vehicle inlet connector, we can do the AC charging just by using the top part of it. And we can also do the DC charging by just using our proximity pilot, control pilot, our protective earth and DC minus and DC plus pins. So here if you look very carefully the shape of this AC type to charger plug and the top part of the CCS2 vehicle inlet connector is actually the same kind of shape is there and so this can go and insert in this top part of the CCS2 vehicle inlet connector and that's when we can also just by using single vehicle inlet connector we can do AC charging as well as the DC charging.

so we are showing you here if you look very carefully here the charger gun goes with the AC type 2 charger plug goes into the CCS to vehicle inlet connector the top portion of the CCS to vehicle inlet connector and It goes in and gets connected with the vehicle inlet connector and that's when you can do the AC charging with the CCS2 vehicle inlet connector as well. And if you have to use the DC charging, you will be using the entire portion of the vehicle inlet connector where the top portion will actually be doing the CP, PP, productive earth, DC minus and DC plus connection. So this is the actually the charging gun which we will have with us and now we will see how this charging gun will actually help you to do the communication between the EV AC and EV and this is primarily be done using this charger plug using the charger plug which has the control pilot and proximity pilot since we can do the AC charging using the type 2 AC charger plug or just by using the top portion or of the CCS2 vehicle inlet connector or the dedicated type 2 vehicle inlet connector mostly the vehicles have you know just one CCS2 vehicle inlet connector using the top portion of that you can do AC charging and using the overall vehicle inlet connector you can do the DC charging so we can say that the AC charging using the CCS2 vehicle inlet connector and using the type 2 charger plug

so in that we have the pp circuit we have the proximity pilot pin which has the circuit corresponds to that let us try to see how the ev detects whether the charger plug which gets plugged into it is correct or not you can say is the charger plug which can do the ac charging so the proximity pilot is actually detecting the adapter or you can say the charger plug in the ev and ensure that the charger plug is that plugged in is the is correct charger plug which can do the ac charging or not now in this particular system if you look very carefully just see the proximity pilot part which is this part We are just seeing this part because control pilot part is different. We will see what is those control pilot part looks like. But first we will just see the proximity pilot part.

Now if you look very carefully, this is my vehicle inlet connector and this is my connector coming from the EVSE or you can say that charger plug. In the charger plug, we know that we have L1, L2, L3 neutral and protective earth control pilot, proximity pilot and we also have DC plus and DC minus. Since we are just doing AC charging, this part has no connection to be there or there is no circuit associated with this part. So, this part can be avoided. Since this is for the CCS2, that is why we are just showing this DC plus and DC minus as well.

Now, if you look very carefully, this particular part This particular part on one side, it is the EVSE side. On the other side, it is the vehicle side. On the EVSE side, it has the R6 resistance. On the vehicle side, it has the R5 resistance and R4 resistance.

And they are actually getting powered from plus 5 volt. And it is this R6 value which tells us that whether this particular you know this charging gun which has the charger plug which go comes in and gets plugged into the vehicle inlet connector is the correct one or not and it also determine what will be the maximum current rating of the plugged cable or the cable which gets plugged into the EV now it is this R6 value so we look very carefully if R6 is having 100 ohm that means it is the AC charging plug which can carry 63 ampere if the R6 is 220 ohm then it is basically the AC charger plug which can do 32 ampere if it is having 680 ohm then it can do AC charging with 20 ampere and if it is the 1.5 kilo ohm or 1500 ohm, then it can do AC of 13 ampere or it can do the CCS to DC charging.

If it depends upon this R6 value, which R6 will be there? Suppose if I am using the AC charger plug with the 32 ampere charging gun, then it will have the R6 value to be equal to 220 ohm. Just a 220 ohm will be there. So, let us see how the vehicle comes to know that it gets plugged in with the AC charger plug of 32 ampere or with the AC charger plug of 20 ampere having 680 ohm or the AC 13 ampere plug or DC CCS to DC plug with 1500 ohm. Similarly, we can just write down here this particular tolerance ranges which tells the resistance between PP and PE which is this.

This is the PP and this ground is actually protective earth. So, this we can say this is nothing but R6 value. generally resistances have tolerance range and if the resistance is within this tolerance range then it will also define what will be the maximum current this particular charging gun can able to withstand and indirectly it will define the conductor size or the dimensional cross section of the wire what will be the cross section area of the wire conductor or the conductor through which the power flow is taking place and then it will also define You know because we have different R6 value because of this R6 value the value at this point the value at this point will be different for different charger plug which gets plugged into the AC type to vehicle inlet connector. and these are the rated voltage which is being put that means if you look very carefully for R6 if it is greater than 4500 ohm then that means it is error condition that could be possible that your charger plug is not correct or you can say it has some fault in that

or it is disconnected or there is no charger plug which is actually connected which indicate the voltage at this point the voltage at this point with respect to ground so if this is the voltage at PP with respect to ground is greater than 4.37 volt if let's say resistance is 1500 ohm and it has the tolerance sense going from 1100 to 2460 ohm then it means that the charger the ac charger plug which gets plugged in would be able to carry the 13 ampere ac or it is the dc ccs2 charging plug which gets plugged into it and then the vehicle will need to do the dc charging so this 1500 ohm which indicates this thing this 13 ampere for the ac current and this and this will lead to the conductor size of 1.5 mm square this is i am talking about conductor size of l1 l2 and l3 for l1 l2 l3 pin not the dc plus and dc minus pin only for l1 l2 l3 pin And that will correspond to the rated voltage at the PP pin, I mean at this pin, you can say at this pin to be equal to nothing but 3.87. Now let us see how this thing will take place.

How do we get this particular voltage? So, let us take an example where we have R6 equal to, let us say, 1500 ohm. These are not there; only the R6 value equal to 1500 ohm is there, which means the charging gun can support up to a maximum of 13 ampere current. Now, if you see in this circuit, if you see thus the PP part. So, if you see this circuit, what does it look like?

So, if you see this circuit, what it looks like, we have this EVSE side. Let us draw the EVSE side. It has, you know, from here it is coming, which is actually nothing but the in pin, which is coming over here. We have the in point, and from the in point, we have the R6, which is coming over here, which is nothing but 1500 ohm. And this is going, and it is the PP pin, which is at this point we have used.

On the other side, we have the PP pin, and what we have is here we will connect it to 5 volt plus 5 volt through the resistance R4 equal to 330 ohm. And we have, you know, on the bottom side, we will be having through the R4, we will be having R5, which is 4700 ohm, and this is actually going into the in of the controller inside the vehicle. So, if you see, this is my, this is the controller for EVSE; this side is my EV, and this is the controller. For EV now, when you plug this charger plug, you know, this is for, let us say, AC 13 ampere charger plug. When you plug it in, you make this connection over here between these two PP pins. As a result, when we try to see the voltage which is coming over here, let us define this voltage to be VPP. So, we can then write. My VPP, we can just do a simple, you know, resistor divider, which is nothing but 5 volt voltage, which is coming over here. And this will be the parallel of 1500 and 4700.

Parallel 4700. divided by 1500 parallel 4700 ohm plus 330 ohm. Now this will be actually equal to 5 volt into 4700 divided by 1500 plus 4700 divided by 1500 into 4700 divided by 1500 plus 4700 plus 330 now when you solve this thing what we are going to get is which is nothing but nearly about 3.87 volt So this is what we will get at VPP pin that is the same thing which is shown in this one which is nothing but equal to 3.87 volt.

Similarly when you are plugging the vehicle with the 20 ampere AC plug there the resistance R6 will be 680 ohm and in real world I mean in the real case scenario it is going between 400 to 936 ohm and the voltage which you get at proximity pilot pin is somewhere around 3.21 volt. Similarly, when you are using the charger plug with 32 ampere maximum current capacity, then you are having the R6 value, this value to be equal to or this value to be equal to 220 ohm and where the actual resistance will be within the tolerance level going between 164 to 308 and that will correspond to the voltage at PP pin to be 1.94 volt. And the corresponding wire dimension will be 6 mm square. I mean, we are talking about L1, L2, L3 wires where actually the power is flowing through it. I mean, sometimes you can also say if you are using the same size connector for neutral as well, you can use the same cross section conductor size of the wire.

Then you can also have the 63 ampere three phase, you know, when you are using all L1, L2, L3, which can do up to 63 ampere. That's when the resistance R6 value will be 100 ohm and which has the tolerance going between 80 to 140 ohm. ohm and the conductor sizes between L1, L2, L3 and neutral will be 16 mm square cable and how the EV will come to know? EV will come to know when they saw the voltage at PP pin to be equal to 1.14 volt and finally whenever the R6 is less than 60 ohm then that is the error condition that means whenever the voltage at PP pin is less than 0.76 volt it is the error condition that means there is some problem with the charger plug which gets plugged in so this is by just changing the r6 value in the charger plug the vehicle can able to identify that there is correct charger plug which gets plugged in and they will also come to know what is the maximum current the those charger plug can carry that means they know what are their conductor sizes of l1 l2 l3 and n

So what we have understood in this is that we have recapped our understanding about the AC charging system. We have understood how the vehicle identifies that the correct charger plug is plugged in, and that's when the vehicle will then go and set up the PWM-based communication over the CP line and then can allow AC charging through the power pins. So, this is the first

thing that happens whenever the charger gets plugged in: through the PP pin, the vehicle identifies or, as you can say, understands that the correct charger plug is plugged in. And once that information is confirmed—that is, just by sensing this voltage at the PP pin—if it is within those voltage limits (I mean, you can easily put that in the lookup table on the controller side), then the vehicle will get immobilized, meaning it will not move further, and that's when the communication gets set up through the CP pin. Then, once the communication is set up, the power flow will take place through the L1, L2, L3, and N pins. So, we will see how the PWM-based communication gets set up through the CP pin in the next lecture.

Thank you very much for your patience and for listening to this lecture.