CHARGING INFRASTRUCTURE

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Week-11

Lecture-51

Lec 51: DC Charging (CCS2)-II

Hello everyone welcome to the lecture number 51 of this NPTEL lecture series or charging infrastructure and today we will continue our discussion on dc charging system particularly first using the ccs2 you know charger plug so now as we have discussed in ccs2 we have discussed that when we are doing the dc charging that time since a lot of information need to be exchanged between the vehicle and the supply equipment or you can say since it is a dc charges the dcvac so a train of information or is continuously information need to be shared so we require a dedicated communication channel and that is happening through the plc communication over cp control pilot and protective earth line And this will already have the 1 kHz in this PLC communication. The high frequency signals will be superimposed on the 1 kHz signal having PWM of 5 to 7%.

So over that having 3 to 7 PWM with a duty ratio of 3 to 7%. So over that, that high frequency signals are actually being superimposed and that's when the informations are continuously shared over the CP line. However, the protocols which has been followed are structured in the form of seven OSI layer and that that's why it is also called as the high level communication called as HLC. Since in this case, a lot of informations are shared, the communication are happening using a protocol which is structured in the form of seven OSI layers. So that's why this communication is named as a high level communication where a lot of informations are in exchange between the EVSC and EV.

So, now we were discussing about the charging sequences. Now, when we are doing the charging sequences, these charging sequences are detailed in IEC 6185123 standard and it has

also been included in AIS 138 which was introduced by the ARAI in association with the Ministry of Road, Transport and Highway Government of India. so now this detail sequence are been included over here however for our better understanding we are just mentioning those things in concise manner so in this case supply station means it is nothing but is the EVSE and on the other side we have the vehicle and this is the place where you know the connector comes out of the EVSE and on this side it gets plugged into the vehicle So these are different pins of this charger plug and the vehicle inlet connector. Now at the initial stage whenever the charger plug is not been plugged it is in the state A having the voltage level is at 12 volt and the charging is in the state A.

now afterwards the charger plug gets plugged into the EV and that's when what happens is that a proximity pilot in the vehicle detects that it is the valid connector which gets plugged into it and that's when the moment it gets plugged into it the way charging will go into the B1 state instantaneously and since the PP pin or proximity pilot indicates that there is the connector which gets plugged into the EV it will give signal to the ECU and that's when vehicle gets immobilized that means the high voltage battery gets cut off from the proportional system and that's when our vehicle gets immobilized so that is also one of the you know advantage of using the proximity pilot because the moment the proximity pilot detects that there is a correct connector or the valid connector which gets plugged into the vehicle the vehicle has to get immobilized and that is the work done by the pp pin and we know how it will done that we have already discussed in the ac type 2 connector then After this, the EVSE will change its S1 switch from the fixed 12V to the oscillator and that's when the pulses will start coming and since it is the DC charging which is happening and the high level communication which will take place over the CP line through the PLC based communication. So here they will keep the duty ratio between 3 to 7%.

And since the PWM gets activated, the vehicle will enter into the state V2 and where the PWM pulses have the voltage level plus 9 volt and minus 12 volt. So during this time, what happens is that the high level communication starts and handshaking with different exchange of charging parameters will be taking place. and this voltage sensor which is sensing the voltage between dc plus and dc minus if it sees if it is greater than 60 volt then it will send the message for shutdown and in case if the charger plug is incompatible with ev so that's when the system must disengage

itself and that's when the system must go to shutdown mode now during this period it's the initialization period and during this period ev will send its maximum limits that means what is the maximum DC supply voltage and current which is being needed from the DC EVAC and that's when the supply station or you can say the EVAC will come to know whether it is compatible with this EV or not and if it is not compatible then they will go for shutdown after this once the compatibility is confirmed that okay this much maximum voltage and maximum current this supply station can support that's when ev will then lock you know if you look very carefully here the ev is not doing the locking of the charger plug once they confirm the compatibility the ev will then put the lock

and that's when your charger plug gets locked with the EV and you cannot remove the charger plug until this lock gets open up by the EV or in case if there is some problem happens during the charging some communication error or something then one has to go and manually unlock the charger plug which you can find it near to your vehicle inlet connector there will be the switch kind of arrangement will be there you have to just pull it up that's when the lock becomes unlocked So, the moment the compatibility is verified or the vehicle will lock the connector in the vehicle inlet connector. and that's when the maximum values of the supply station are responded to the ev so the dc evsc will then tell to the ev that what is its maximum value it can support the voltage and current and then the dc supply it will start checking its internal insulation as long as you know this there is no voltage is applied at the connector Now in case if the EV and DC supply are not compatible then the vehicle will not go to the ready state and it will move from the charging state to the shutdown state or you can say it goes into the shutdown sequence if the plugs are not compatible or you can say that if the EV and the DCVST is not compatible. now what happens after that now once the compatibility test is done the charger plug gets locked into the ev the s2 switch in the ev will move to 1300 ohm and that's when or it gets connected to 1300 ohm and that's when the positive voltage level of the pwm will go from plus 9 volt to plus 6 volt and that will show that the vehicle is now ready

In previous case if you look very carefully in previous case the vehicle was not ready because still the charging state is in B2 which indicates that EVSE is ready but EV is still not ready. Now afterwards if compatibility test is done the EV will then change the CP state from the B to either C2 or D depending upon if ventilation is required or not required and which sets the EV status

to ready. that EV is ready, which indicates the EV is ready. And during this time, there is also parallelly the DC EVSE will actually be doing the isolation check and it will self-certify that there is sufficient isolation between the DC plus and DC minus. And also the EV request the cable and insulation check

once the connector gets locked i mean once the connector gets locked and the lock has been confirmed so after this the dc supply start checking the high voltage isolation and it will continuously report the isolation state to the ev and then afterwards the dc supply will determine that the isolation resistance is above 100 kilo ohm if it is above 100 kilo ohm then that will do the isolation check okay and then after successful isolation the dc supply will indicate valid status and then changes the status to ready with the cable check response So, although the EVSC was ready, but only after the insulation check only or the cable check only, the DC supply will then go into the ready state. So, vehicle was ready. Now, the supply, DC supply will also get ready.

Now, after this, the pre-charging starts. From here, the pre-charging will start. And in this pre-charging, the EV will send the pre-charge request to So it's EV remember whenever there is a communication between EV and EVSE EV is the master and inside EV means the BMS of the EV is the master which is actually communicating with the supply equipment communication controller via PLC modems on either side on both the vehicle and the EVSE side. So now the EV will send the pre-charge request.

So this will indicate the start of pre-charge state. So EV will then send the pre-charge request which contains both the DC current I mean or you can say the maximum how much maximum current to be put or to be allowed to be allowed during pre-charging and along with the current they will also request the required DC voltage. or the requested DC voltage. Both the things EV will then send the information to the EVAC that this much limit on the current one should keep at the DC plus and DC minus line and the required DC voltage need to be maintained. now why this 2 ampere is limited because if there is a some mismatch between the output of the evsc and the high voltage battery huge interest current will flow between the dc evsc and the high voltage battery so to limit that the current this request has to be made and that maximum current limit on the maximum current will be determined by the power conversion unit

you know you can control the phase shift or your frequency accordingly and so that your required voltage and the current gets limited. Now once the message is been received from the EV that this much p charge current and this much voltage to be kept at the output of dc plus and dc minus now the dc supply or you can say the dc vse will adopt to that request or will respond to that request and that respond in such a way that at the dc plus and dc minus within the required tolerances current is emitted at 2 ampere And the DC voltage will reach to the requested voltage within the tolerances up to let us say a T6 time instance. Now, this T6 and T5 time instances are the same time instances which are mentioned in detail in IEC 61851.

2, 3 standard and which are also been included in AIS 138 standard. So, still the pre-charge state is continuing where before that it was the request it was sent by the EV and now the DC supply will respond to that request by making sure that at the output the required voltage and the required limit on the current is been made. And also if you look very carefully, once the isolation check is done, the contactors in the DCVAC will also get closed. So that has also happened parallelly. Now after this, what happens is that once contactor gets closed and the required voltage has been achieved at this point, now what happens is that if necessary, EV adopts requested

dc voltage you know with the cyclic messages in order to limit you know deviation of dc output voltage from the ev battery to less than 20 volt that means see this side we have some voltage this dc bus battery has some voltage and on this side the voltage got build up by the power conversion unit to the requested voltage So now this disconnecting device will only get closed if the deviation between this voltage and this voltage is within the 20 volt. That means if I say this V1 and this is V2 voltage if the deviation that means if V1 minus V2 is less than 20 volt then only this disconnecting device will close. actually closed so only if the input voltage monitoring so at this place monitoring is happening so if the input voltage monitoring v in detects correct dc voltage and deviation should be less than 20 volts then only this disconnecting device gets closed in and see here also the contactor gets closed in here also the disconnecting device gets closed in the power will start flowing from the dc vsu to the high voltage battery Now once the pre-charging is taking place where the currents are limited to 2 ampere and the disconnecting device gets closed in and the current is still under 2 ampere.

Now after certain time the EV will now send the power delivery request such that that limit on the current which was 2 ampere should be removed from the DC plus and DC minus terminals. now after this the dc supply will give feedback that it is ready for energy transfer and ev sets the dc current request to start the energy transfer phase at at time t8 so what happens the ev will send that request the dc supply will give feedback that it is ready okay it can start so now ev will then set the you know the required dc current request to start the energy transfer now at this instant the charging state will take place so previously it was pre-charging stage how the pre-charging state is defined the limit on the current was maintained at 2 ampere and the requested voltages were come on the dc plus and dc minus line now afterwards the ev will send the message to the evsc or the dc supply that we require this much output current from the dc supply so the dc supply will then respond to it saying that it is ready for energy transfer and once the ev will get that feedback the ev will then request the required dc current to start the energy transfer state now in this state you know the charging state, what happens?

The DC supply will then adopt its output current and voltage to the requested values from the EV. And the DC supply will respond with the required output current and voltage, its current limit and voltage limit and its present status to the EV. And at T equal to T9 the DC output current reaches to the DC current request which was done by the EV obviously there will be some delay time which goes from you know T delay you can put it from T9 minus T8 after certain time only the DC power supply will respond to that and from T9 onwards that means from that instance when the DC current reaches to the requested current value the EV will now initiate the message cycles by requesting required voltage and currents and the DC supply will be responding to those messages by adjusting its output voltage and current as well as their limits and the status values and continuously the supply station will be informing the EV that they have set up to that particular output voltage and current now

Similarly, there will be continuous monitoring of the lock, the isolation because the isolation with the isolation resistance of greater than 100 kilo must be there between DC plus and DC minus line. Also, continuous monitoring of the voltage at the output of the DCVSE, the current which is been flowing from the DCVSE to the battery pack and the temperature of the contacts which is been there, you know, used to make the connections between EVSE and the vehicle. So, that

continuous monitoring will be keep on happening. After this what happens? This continues until the vehicle battery does not reaches to its required SOC level.

Let us say after it reaches to the required SOC level, let us say it reaches to 95% or 100% SOC. Now, during that time, the EV will then reduce the current request to complete the energy transfer. So, now once the required SOC has reached, So, EV has to now you have to go to shutdown stage that means you have to stop charging. So, now to do the stop charging what happens is that first the EV reduces the current request.

For example, if the EV was demanding 30 amperes and DC supply was adjusting its output to 30 amperes. Now, after reaching to required as you see they may reduce the demand to 5 ampere or 6 ampere I mean the low current level. So, the EV reduces the current request which actually completes the energy transfer and the DC supply will now follow the current request from the EV obviously with a time delay and it reduces the output current to less than 1 ampere before disabling its output so ev will continuously reducing is its current request i mean the amount of current it needs at the output and the dc supply will follow that current request and it keeps on going until the output current request goes below 1 ampere which actually indicates to this evse that it has to now disable its output Now finally, once the output goes below 1 ampere, the EV will then send a message to DC supply or DC VSE, you must disable your power output.

And after the current reaches below 1 ampere, the EV will now open its disconnecting device. so first what will happen is that ev will be sending the messages for required current to be coming out then ev reduces the current value which it is required to charge the battery it reduces it keeps on reducing until the current the output current reduces less than one ampere And once it loses less than 1 ampere, the EV will then send a message to DC EVSE that you disable your power output. And once the current level at this DC plus and DC minor become less than 1 ampere, it is first EV which will open its disconnecting device. It could be contactors on the EV side.

So the first thing is the EV will now get disengaged from the DC EVSE. because it is first open its disconnecting device Now, the moment the DC supply sees that the disconnecting device is open and EV has already requested the DC supply to disable its output, that the DC supply will

now act upon that request and DC supply will now disable its output and open its contactor. So, if you see in the previous case, the DC contactor, I mean the contactors on the EVSE is still closed. However, on this side, once the request has been received, the DC EVSE will open its contactor.

and during that time the DC supply will not cause any current flow on the EV input during the discharging phase because the power conversion unit of the DCVAC have output capacitors which has to be discharged so during this period EVAC must ensure that there is no current flow towards the EV that means at this place so this again comes under the power down stage or you can say the shutdown stage which is there And then after that, what happens is that after certain point of time, the DC supply will report the status that it is not ready with a message to indicate that it has disabled its output. So EV has sent the request and the DC supply has acted upon it by first disabling its output and then make the status goes to not ready. so although the communication channel is there but it is not ready it is operational but it is not ready now after this what happens is that once the ev receives that the evs is not ready and it has disabled its output the ev will then change the state of s2 switch and that's when the 1300 ohm resistance get disconnected and that's when the cp state will go to b state from c2 or d stage and this is happening only after receiving the message from the DCVSE or after a certain timeout now during this time the vehicle will also perform the welded contactor check whether this contactors are still in connection or not that check is done and it will indicate to the DC supply that if it is everything is okay

and then finally what happens is that since the shutdown state is been done once the contactor gets open up the isolation monitoring can be avoided however after certain point the EV will now start the EV isolation monitoring and now EV will unlock the connector you know this connector because it will unlock the connector only after doing the isolation monitoring and now the EV unlocks the connector you see previously the connector was still locked afterwards once the ev changes the cp state to b2 state and also perform the welded contactor check as well as the isolation check then after that the ev will unlock this particular connector and this unlocking will only happen since the output of the power conversion unit is now being disabled so this will only happen if the voltage at this point if the voltage at this point this particular voltage becomes less than 60 volt and during this time the DC supply continuously monitoring the isolation and

finally once this connector gets unlocked also parallelly the session stop request with a message to terminate the digital PLC based communication so when the unlocking happens At the same time your session stop request will also be made and that's when it will terminate the PLC communication which was set up between the PLC modem of EV and PLC modem of the supply station.

so at this point the communication also got stopped and the contactors on both the ev side as well as evac side gets opened up and the connector gets also unlocked and before doing that they will check that if the voltage is less than 60 volt or not and now afterwards Since it is unlocked, now the plug is free to move out from the vehicle inlet connector and that's when EV and the supply gets unmuted and the supply disables the DC output. The lock is disabled and you can say that the disconnecting of vehicle connector will lead to the CP state or you can say the charging state goes back to state A. and obviously since the request was sent to stop the PLC communication the PLC communication gets terminated so this is the overall the charging sequence of DC CCS2 charging system where it starts from initialization from initialization it goes to the cable check from cable check it goes to the pre-charge state from pre-charge state goes to the charging state and then from charging state it goes to the power down stage or you can say the shutdown stage so first the EV will demand the lesser current output at the output of DC plus and DC minus and once the current value goes below 1 ampere the first the EV will open its disconnecting device

and then afterwards the request is being sent to the DC supply to disable its output then DC power supply will open its contactor and after the isolation check the unlocking will take place and after the unlocking the request to stop the PLC communication will go and then the PLC will get terminated and that's when the charger plug gets unmuted Obviously, it starts with the mating stage where the charger plug gets connected into the vehicle inlet connector. so this is the overall charging sequence however there are many things which are there because whenever the during the charging the messages are sent over the PLC communication and that messages how the messages are being shared what is the rate transmission rate how the authentication takes place how the protection takes place all those things is being taken care by the seven OSI layer which we will discuss in the coming lectures And if you recall, in the initial stage, whenever the EV will initialize, then during this time, the high-level communication starts. Once the PLC gets

started, before that, there is also the attenuation check one has to do in order to ensure the signal-level attenuation is within the prescribed limit between the EV and EVSE.

So, those things are also important. However, this is how the charging sequence takes place in DC CCS2 charging. System, which we have discussed briefly in this lecture. However, one can go through and read this charging sequence in detail from the IEC 61851F123 standard and also see it in the AIS 138 standard as well. In the next lecture, we will discuss how the PLC modem gets logically connected, and before the EV and EVSE start sharing messages, one should also ensure that the correct PLC modem of the correct EV is getting logically connected to the correct PLC modem of the EVSE.

So, those things we will see in the next class—how that procedure takes place—and then from there, we will go into detail and see how the high-level communication takes place in the DC-CCS2 charging system. Thank you very much for patiently listening to this lecture.