

# **CHARGING INFRASTRUCTURE**

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**Week-11**

**Lecture-52**

**Lec 52: DC Charging (CCS2)-III**

Hello everyone, welcome to the lecture number 52 of this NPTEL lecture series on charging infrastructure and today we will continue our discussion on DC charging of CCS2 charger. So, in the last class if you recall we have studied about the charging sequence which is being documented in detail in IEC 61851-23 standard and also been included in AIS 138 standard. Broadly, the charging sequence included the mating of the connector.

After that, it's an initialization where the PLC modem gets actually logically connected and then the high-level communication is started. Then the system will do cable check that means they will continuously monitor the insulation between the DC plus and DC minus line and then after that there will be pre-charging which will be taking place in order to avoid the huge amount of inrush current which can be drawn from the DC VSE considering the voltage differences between the output of the DCC converter and the a battery pack so they will limit the amount of current which can be drawn from the DC VAC and that is what constitutes the pre-charging stage and after that whenever the voltage level is less than 20 voltage difference the actual charging will start taking place and during that time it's the BMS of the vehicle which keeps on demanding the required magnitude of current and voltage and the DC supply will respond to that change by ensuring that the output at the DC plus and DC minus will be at the requested current and the voltage level. and then after that once the battery SOC reaches to its required level the BMS of the EV will tell to the EVSC that now the battery does not needed to be charged and that's when the slowly the power down stays taking place and then finally the charging will come to the state B1 and then finally it gets unlocked and then it will be unmated I mean the charger plug can be unmated from the vehicle inlet connector so this is the entire procedure we have discussed in detail

in the previous lecture and let us see the actual scenario which we can get during the DC charging using the CCS2 charging systems so if you see as we have discussed we go from A state to B1 state then to B2 state and then to C you know C or you know D state I mean again in that C2 state or D state so this continuous and from here we go to back to B I mean B2 then B1 And then finally B1 to A. A means the connector is actually unmuted. So here if you look the different stages. So here we have state A where the voltage or positive voltage level of the CP pin is at 12 volt. Again this voltage is between CP and PE.

Between CP and PE protective earth. so you can see there you have a 12 volt which is coming over here again this waveform we have obtained it while doing the charging of the actual ev using the charging discovery system provided by this key side so if we look very carefully at the this state it is state a where our voltage level positive voltage level of the cp pin will be at 12 volt and then after that once the connector get mated then the system will go from A state to B1 state And in B1 state, you will see the voltage level will be, you know, 8.78 or you can say roughly 9 volt. And then after going to B1 state, the EVAC will then change its S1 switch connection from the constant 12 volt to the PWM based 12 volts.

And that's when PWM gets activated. And here, it's here, it's the B2 stage has arrived. And then after that all the PLC get logically connected, high level communication get started, the EVSC will go into the state C2 where seeing the positive voltage level on the CP versus PEP into be nearly 6 volts. If you look very carefully, the moment you plugged in your charger plug into the vehicle inlet connector, you will see that PP pin, resistance between PP and CC pin, if you look very carefully, as we have generally on the PP versus PE pin on the connector, we have 1500 ohm for the DC CCS2 charger. And again, this resistance may vary from 1100 to 2460 ohm.

And this particular resistance will be coming in parallel with 4700 ohm. And this will give a value nothing but 891.379 ohm to 1588.732 ohm. And this is what we have seen over here. It is 1.385. kilo ohm resistance which is showing over here.

So we can say that this 1.385 kilo ohm is within this particular range. and that is when our voltage level will be this will come to recall our proximity pilot connection it is 1385 divided by 1385 plus 330 ohm which is coming and this will be multiplied by 5 volt and this will be roughly

around 4.03 volt which is we can see over here it is nothing but 4.06 to 2286 volt Since we are taking it from the real CC2 connector, the resistance range could be between 1100 to 2460 ohm and that will give us the value nothing but equal to 1385 which is shown over here and that is when the voltage of the PP versus across the PP pin with respect to PE is nothing but 4.03 volt which is shown over here. so first the pp pin through the pp pin the vehicle will come to know that okay it's a valid connector and that's when it will immobilize itself and apparently in the cp pin the charging state is going from a to b1 to b2 stage now let us see how the duty cycle and frequency of the pwm over the cp line looks like so as we see here we have a state and during the state you can see it is 100 100 means In the EVSE side, the S1 switch is still connected to fixed 12V and that's when the duty ratio is 100%.

And once it goes from the A state to B1 state to B2 state, at that point, you can see that at this point, the CP duty ratio is 5% and which is in the range of 3 to 7%. which indicates that we are now having the high level communication over the CP line using PLC based communication so this is what is the indication of that similarly if you see the frequency it is at 1 kilohertz or you can say 1000 hertz and again the CP goes from 12V to 8.78V and it goes finally to 6V where it is C2 state which is showing over here and if you look very carefully the frequency it starts only after reaches to the B1 stage there is some small time period is there when the switch in the EVAC goes from constant 12V to the oscillator voltage and at the same time if you look very carefully when the CP goes into the C2 state it's only after that if you look here it has not started charging while the charging starts at this point where our charging will start and you know after certain point it has reached after you know the time if you take it is somewhere around the time of charging is 3.257 out of 35 seconds only the three seconds has been started we have you know 32 seconds where we are being used to actually you know to connect and ensure the communication got set up and then all the EV and EVSE both are ready and that's on that's when the things will start you know actually the powering stage will start conducting

At the same time, if you look very carefully, only after C2 reaches to 6V, Only after the charging reaches to C2 state, it's the DC contactor which gets closed after this. So, you can see that there is some small time period between this and this point. This point is near to this dotted line 24 second and this is somewhere around near to 23 point, some near to that. So, there is some small time between this point and this point.

After this point, only the charging state goes into the C2 state. The DC contactor gets closed, ensuring that now the system is ready to do the pre-charging. So now, if you look very carefully, if you consider our pre-charging and insulation monitoring. So you see, it is continuously monitoring the insulation, which is somewhere in mega ohms. You know, obviously, we must ensure that it should be greater than 100 kilo ohms.

This insulation between the DC plus and DC minus line, the resistance of insulation has to be greater than 100 kilo ohms. And you can see here, we have 42 mega ohms here and 40 mega ohms, which is very much greater than the 100 kilo ohms value. Again, here the A state, B1, B2, and then the C2 stage, which has arrived. And here, if you look very carefully, in the charging state, there is no charging taking place up to this point. After this point, there is a 2 ampere charge.

Pre-charging after the cable check stage, it has reached the pre-charging stage where the demand is 1.95. This is real data which is showing over here; it is 1.95, which is less than 2 amperes. And if you look very carefully, then after the pre-charging stage, the vehicle will go into the charging stage, and that's when the vehicle is demanding the 15 amperes. Current from the EVSE, and that's when, after a certain time in the pre-charge stage, it enters into the charging stage where the vehicle will demand the current as per the SOC level and the maximum current level communicated by the EVSE. And if you look over here, it is the time where the actual charging starts roughly after two seconds from here. So this is what is making initialization cable check. After that, it goes to the pre-charging state. From the pre-charging state, it goes to the charging state, and then charging will keep on happening depending upon how much the vehicle will demand the current within that maximum current limit. So this is how the charging sequence will be taking place. However, if you look very carefully, this We have just understood how the charging stages take place. But in the charging stages, if you recall, once the 3 to 7 percent duty ratio has been detected on the CP line, the EV will come to know that now it is the high-level communication which will be taking place over the power line communication on the CP pin. And the EVSE will now start that high-level communication using certain handshaking methods; they will do that. And a lot of information needs to be shared before the PLC communication gets set up. Obviously, they have the PLC modems at the front end between the PLC modems of EV and EVSE.

And we know that the IEC 61851-23 standard details the requirements for DC charging stations, specifically mentioning the use of PLC for high-level communication. There, we have HomePlug Green PHY-based PLC, which is being used for CCS to DC charging of the system, and it has a data transmission rate operating between 2 to 28 megahertz in the wideband range. So that means, by using the wideband frequency range, the data is being communicated between the EV and EVSE, and the digital data rate achieved is somewhere between 4.5 to 10 Mbps. Again, these are the values incorporated in the HomePlug Green PHY-based PLC standard, which is a subset of the HomePlug AV standard. Now, here again, the problem arises. We must look very carefully when we see the DC-VSC. If we see the DC-VSC, what we have is the AC plug coming in.

Let us take a three-phase AC plug. We have AC to DC. Then we have DC to DC. Isolated DC to DC. And then, following the use of protective devices like contactors, protective devices, and relays.

And after that, you have the DC plus and DC minus lines, which come out of the DC VSC. Similarly, we also have a controller, which we can define as the SECC (Supply Equipment Communication Controller). This communicates using the CP and PE lines via PLC to our model of the EV. After the SECC, we have a PLC modem, and over the CP and PE lines, it will handle the communication. However, the power supply for the Supply Equipment Communication Controller will come from the same supply sources. They have a small AC-to-DC converter, which will provide power to this supply. We can say this is the power supply to the SECC.

Now, since the power supply is generated from the same source, there could be possibility of crosstalks when we have several DC EVAC connected in the charging station. So, what I am trying to say is that whenever the vehicle gets connected to that particular EVAC in the charging station, we must ensure that the PLC modem of the EV and EVAC which are physically connected must be connected logically which we use to perform the high level communications. what I mean by that is if I have let's say public charging station and let us assume in this particular public charging station we have two EVACs now in one charging station there could be many EVACs which are present but in this case let us assume that we have just two EVACs so let us draw our EVAC we have EVSE1 and we have EVSE2 and let us assume that both the

EVSE are of CCS2 charging systems that means they have a CCS2 charger plug so let us also assume we have two EVs let's say here we have EV number 1 and here we have EV number 2 this is what we are trying to see the real scenario which can occur now in the EV we have EVCC which is called as the electric vehicle communication controller

and it will be going through the PLC modem through the PLC modem through the CP and PE line it will be going and get using the cable it will getting connected with the EVSE so this is your CP and PE line on the other side assume we have this kind of thing is there similarly on the EV2 also we have same EVCC we have PLC modem and it is now getting connected via the CCS2 charger plug and cable to the EVSE so EV2 is getting connected with the EVSE2 and in this case let us say that PLC means our PLC modems so this kind of thing is there in the EVSE what we have is we have again at the front we have PLC we have PLC modem and then after that it will be connected to the SECC which is nothing but supply equipment communication controller and it is now connected with the CP and PE line this is nothing but your CP and PE line which is coming from the PLC modem and along with that you know this we will also have DC plus and DC minus line so assume we have AC supply from where our EVSE's are getting powered up mostly 3 phase AC supply now this AC supply which is there is being used to actually power the EVSE1 as well as EVSE2 so let us assume that we have our power line which are laid down in this manner so here let's say we have a again a power supply to actually power the SECC and we have the power line which is coming

in such a manner that from the same power line the power supply for the SECC is being generated so this is nothing but PS is nothing but power supply for SECC so this is there which is actually powering up the SECC and then we have the our nothing but piece power conversion unit which is actually getting power from the AC supply and then converting it into the is DC plus and DC minus line so this is my DC plus and DC minus line similarly on the other EVAC also we have the same thing we have the PLC modem and we have the SECC again we can say that SECC is nothing but supply equipment communication controller so on this side again the same line from the AC supply is coming they will be coming and giving input to the power conversion unit which is actually going and giving it to the DC plus and DC minus line and this is you know nothing but our CP and PE line and this is coming from this side more precisely like

this similarly our power supply for sccc will also be generated from the same ac line which is coming from this power supply

So this is the real scenario which can happen where we have assumed we have a public charging station and in the public charging station we have assumed that it has just two EVSEs. There could be many EVSEs but here in this example we assume that we have just two EVSEs which have been there. And in this public charging station what we have is we have two EVs which are coming in and simultaneously they are connected to EVSE1 and EVSE2. So EV1 is connected to EVSE1 and EV2 is connected to EVSE2. Now in this what you will see is that both the EVACs are getting powered from the same AC supply and in the AC supply it is used to give the input to the power conversion unit to actually convert that AC into the DC on both the EVACs.

Along with that the same AC power supply is being used to actually generate the power supply for the SECC at its required voltage and current level whatever the requirement from the SECC it is there. Let me also define the PCU which is the power conversion unit. So, a PLC signal if we see it is nothing but a high frequency signal which is been superimposed on a 1 kHz PWM signal and which is coming over the CP and PE line. So, a very high frequency signal are being superimposed on this 1 kHz PWM signal. So, because of that what happens is that this high frequency signal, let us assume from the EV1 it is starting and from the PLC modem of EV1 it is starting and from there it will reach to the PLC modem of

EVAC1 from the PLC modem of EVAC1 it will go through the supply equipment communication controller and from the supply equipment communication controller of EVAC1 it goes to the power supply which is being used to generate the required voltage and current level for SCCC it will go through the power supply and since the power supply for this SCCC is using the same input which is coming from the grid what happens is this high frequency signal will navigate through the AC line and it will start to go to the EVSE2 and in the EVSE2 it will navigate to the power supply which is being used to power up the SECC of EVSE2 through that it reaches to the SECC of EVSE2 and then through that it will reach to the PLC modem of EVSE2. So what happens is that this high frequency signal which has been there because of this high frequency signal they may navigate through the copper wires which are being used to power up the EVSEs as well as power up the power supply for the SECCs and what happens

is that the high frequency signal which starts from EV1 may go and end up with the PLC modem of EVSE2 may navigate through that point because of this high frequency signal and this high frequency signal is nothing but called as the crosstalk which is actually linked from EV1 to the which is going through the other EVSEs. Further the high frequency signal may get radiated and coupled to DC plus and DC minus lines and as they are very much close to CP and PE lines and bundle together in a cable and which then gets radiated and coupled through the isolation transformer in the power conversion unit to the supply line and then can follow the same path as shown over here.

Also in case when the EVSEs have two charging guns then the control wires of one PLC modem are routed nearby or bundled together with other PLC modem control wires and they are placed inside the same cabinet which also lead to the crosstalks. Further the crosstalks also occurs due to the shared ground loops in case the cables are laid down very much near to each other in case of space constraints, further poor EMI design of boards and unfiltered power supplies. So in summary this crosstalks happens due to insufficient galvanic isolation in the power supplies in the power conversion unit as we have already shown over here. It also occurs due to the close proximity of control wires especially in case when we have EVSEs with multiple charging guns. It also occurs due to the shared ground loops over EMI design of boards and filter power supplies.

So what happens is that now here if you see there are several possibilities which can happen. So the possibilities which are possible are generally you will see that when the EV modems get trying to get connected with the EVAC modem they actually start sending the broadcasting messages. So what happens is that there is a possibility that the PLC modem of EV1 can get logically connected to PLC modem of EVSE1. That is one possibility is there.

Second possibility, the PLC modem of EV1 can get logically connected with PLC modem of EVAC2 that can also be possibility is there then other possibility could be the PLC modem of EV2 because when EV2 is trying to get connected so EV2 can get logically connected with PLC modem of EVAC1 and similarly the PLC modem of the PLC modem of EV2 can get logically connected with PLC modem of EVSE two now so these are the different possibilities and why this possibility happens because generally before starting the communication between ev and evsc the plc modems of ev and evsc are get logically connected and that logical

connection happens when the ev initiates the broadcasting message using the plc communication over the cp and pe line that means the high frequency signal is been initiated by the evs so what happens is that ideally what we wanted that the physically connected EV and EVSE must be logically connected the physically connection means the connection which is which are been made by plugging in the charger plug so we ideally wanted that PLC modem of EV1 must be connected with PLC modem of EVSE1 but because this high frequency signal is there we have the copper wires they may navigate through those copper wire and reach to the PLC modems of other EVSEs so that is why

what we see is that in this particular example there are four possibilities which can happen the plc modem of ev1 can get logically connected with plc modem of evsc2 the plc modem of ev1 can get logically connected with plc modem of evsc1 similarly the plc modem of ev2 can get logically connected with plc modem of evsc2 or it can logically get connected with the evsc1 However, out of these four possibilities, we wanted that only this possibility and this possibility should exist. We do not want that these two possibilities should occur. Otherwise, what happens is that the PLC modem of EV1 will be communicating different messages of EV1 to the PLC modem of EVSE2 and ideally it should have been communicating with EVSE1 because it is the EVSE1 which is physically connected with the So, several possibilities which have been possible and these possibilities are arises primarily because the high frequency signal will navigate through the copper wires and reach to the PLC modems of other EVSEs.

So, in order to ensure that the correct PLC modem of EV and EVSE are connected, especially those PLC modem, must be logically connected which has direct physical connection that means the plc modem of ev must be logically connected to the plc modem of evac through which it is being plugged in via the charger plug here the logically connected means the two plc modems can communicate with each other different messages can be exchanged between them so it could be possible that physically it's the EV1 and EVSE1 is connected but the PLC modem of EV1 is actually communicating with the PLC modem of EVSE2 and that is a very serious problem because the stages and the information which is shared between ev1 and evsc1 is actually being shared between ev1 and evsc2 so this is a problem when we have so many evscs put together in the charging station and that's why we must ensure that the correct plc modem of ev which is the plc modem of ev1 must be connected to the correct plc modem of

the EVAC which is EVAC1 so here what we want exactly the PLC modem of EV1 must be connected to PLC modem of EVAC1 but because of the cross talks because of the high frequency signals in the PLC communication it may possible that the PLC modem of EV1 is connected to the PLC modem of EVAC2 and that will lead to catastrophic failure or it may lead to the wrong operational of the EVACs in the charging station

So, in order to ensure that the correct PLC modem of EV and EV-LC is connected, mostly it is between those modems which are actually physically connected to each other. In order to ensure that, there is a procedure which is being followed and that procedure is called as the SLAC procedure. Now, if you see this select procedure whose full form is signal level attenuation characterization as the name suggests, it's the protocol which measures or characterize the attenuation between the different PLC modem which are detected in that particular charging station and then the correct PLC modems will be connected by following that particular procedure. So, as the name suggests the signal level attenuation characterization is basically it basically characterizes the attenuation between the PLC modems of EV and EVLC which are been detected in a given charging station. So, it is basically a protocol which actually ensures that the logical connection of PLC modems of EV and EVLC are made and particularly those

PLC modems where the EV and EVLC are physically connected to each other. Where the physical connection between EV and EVLC are made, only those PLC modems are actually being connected. So, it is the protocol which ensures that there must be a logical connection of PLC modems of EV and EVLC which are actually physically connected to each other. now this slack procedure is actually defined in the home plug green phi v 1.1.1 specification in that standard is being mentioned and this slack is basically as i mentioned is a protocol which measures the attenuation between the two power line communication modules or you can say modems so it basically measures the attenuation between the two plc modems and then take a decision which plc modems to be logically connected and this slack procedure is performed only after the charging state reaches to the b2 state that means once the three to seven percent pwm pulses is actually been ensured only after that the slack procedure is been done to ensure the plc modems are logically connected

So PLC modem of EV and EVSE after the slack procedure are logically connected to actually perform the high level communication over the PLC line or over the CP and PE line which are using PLC based communication. Now it is in the data link a layer of the 7 OSI layer. So once the EV and EVSE gets plugged in, the slack procedure is being called upon which is basically it measures the attenuation between all the available PLC modems in the vicinity and then the PLC modems of that EV and EVLC which are physically connected together are then been logically connected so that the correct PLC modems of EV and EVLC are connected and they do the communication with each other. Now particularly if there are several EVs which are being connected to the charging station which are very much nearby to each other there can be some cross talk in between them as we have seen in this figure where we have two EVSEs in a charging station which are being kept nearby and it is being connected with the AC grid and that's when we see that the communication has to be done between EV1 and EVSE1 but because of the power line communication which consists of a very high frequency signal between 2 to 20 megahertz will actually take a path and then goes to the PLC modem of the EVSE2 and there could be possibility that although the EV1 is connected to EVSE1 but the PLC modem of EV1 will be communicating with the PLC modem of EVSE2. So that particular condition should be avoided and that is happening just because there is a possibility of crosstalk between them.

So, we must ensure that the communication must be taking place only between the physically connected EV and EVSE. So, this is important thing which has to be ensured that the communication must be happening between the physically connected EV and EVSE and that's why the slack procedure is being performed. So, generally the PLC modem which shows the lowest attenuation to each other are actually the physically connected to each other and that's when they get logically connected to each other and then perform high level communication between them. So, in this lag procedure it is nothing but it's a protocol which is been used to set up the communication between the EV and EVAC. And primarily it is used to ensure that correct PLC modems of EV and EVSE are being connected to each other.

That means setting up the communication means the logical connection. So the select procedure is the one which ensures that the communication between the EV and EVSE must be correctly done. Now, it is given in detail in ISO 15118-3 and DIN spec 70121 standard and which is

actually been derived from Home Plug Green 5 standard. Now in this what happens is that it's the EV which initiates the select procedure by sending the broadcast messages to all the EVSEs which are present in the charging station. So we have seen in our public charging station example case what we have seen.

Here we have two EVSEs. So let's say the EV1 has to be logically connected with the EVSE. So what happens is that the EV1 will send the broadcast messages to And that broadcast message will go to all the EVACs which have been there in the charging station. So here it will go to EVAC1 as well as EVAC2.

Then after that what happens is that it actually follows several steps. The first step is parameter exchange or you can say the parameter setup step. Then after that there will be discovery of PLC nodes. It will discover all the PLC nodes which are trying to communicate with the PLC modem of EV which is actually sending the broadcast message. After that, they will make the matching decision.

In case if the matching decision is not been achieved, what they will do is they will do the validation which is again an optional step in case if the correct matching is not been obtained. After that, they will exchange the key and that's when the logical connection will be set up. So in this case the first and foremost thing is parameter exchange and setup step. In this step there is a message which is cm underscore slack underscore parameter dot request message which is being sent by the EV and this is in the form of broadcast message. This is the request message from the EV and all the EVACs which are listening to this request

Obviously, the EVACs which are there in that particular public charging station, all those EVACs which are actually listening to this request will then send a confirmation message which is nothing but cm underscore slack underscore parm.cnf message and the confirm message contains the number of sounding or attenuation indication signals so they will send certain sounding signals which is actually been sent by the EV so in the confirmation message they will say that what will be the number of sounding messages or these signals which has to be sent by the EV while they are doing the attenuation characterization. So, after receiving the confirmation message from the EVACs, the slack parameters got set up, that means the run ID, the allowed frequency, that means the range of frequency within which those sounding messages are being sent, then the

timing after how much time those sounding messages should be sent one after the other. the number of sounding messages and nothing but the attenuation thresholds which are been there that means what will be the maximum attenuation or the signal strength we can expect from the connection. So those things will be determined in this particular step, step number 1.

After that the discovery of PLC node will take place. So after receiving the confirmation message from all the EVSEs which are actually responding to the broadcast message which was sent by the EV what happens is that the EV will now broadcast three times the message which is cm underscore start underscore attenuation underscore characterization dot ind message now this particular message it is been sent for three times and it acts as the wake-up call for all the EVSEs which sends the confirmation message So, for example, in a charging station there could be 10 EVACs and out of those 10 EVACs only 4 EVACs would have responded with the confirmation messages. So, now they should be ready to receive those sounding messages to do the attenuation characterization.

Hence, the EV will send the wake-up call to the EVACs who have sent the confirmation messages that they are now going to send the sounding messages. And after receiving that particular wake-up call, the EVSEs will be ready to receive those sounding or the attenuation messages. Now, after this, the ev broadcast the preferred amount of sounding messages generally it is 10 so ev sends 10 times those sounding messages and those sounding messages is actually comprises of 58 different frequency group and each frequency group corresponds to the narrow band of frequency within the plc frequency band so in in our case our plc band is between 2 to 28 megahertz So what they will do is they will divide them into 58 different frequency group which generally corresponds to a narrow band of frequency within that 2 to 28 megahertz frequency band.

So you can say that those 58 frequency group signals will be sent 10 times and what happens is that for each sounding message so which is and we know that there are 10 number of sounding messages number of them. So, each sounding messages which is defined as a CM underscore MNBC underscore sound dot IND message. The PLC modem on the EVSE side will actually produce the CM profile. That means it's the EVAC modem which actually measures the attenuations for each sounding message. So in each sounding message we have 58 frequency group.

So you will see that there will be 58 different attenuation values for 58 different frequency groups will be there. And those attenuation will be measured by the PLC modem on the EVAC side and they will produce the attenuation profile messages. And then after receiving all these 10 messages from the EV, the PLC modem of EVAC is actually sends those attenuation characterization message which contains the average attenuation value for 58 frequency groups. So that means the first sounding message would have come for 58 different frequencies. They would have calculated 58 different attenuation values.

Then all those 10 messages have come. So for each frequency group, they will do the averaging of the attenuation values and then they finally send one average attenuation value for those 58 frequency groups so then the EV acknowledges the attenuation profile result and then start analysis for the matching decision so what happens is the first the EV broadcast the message after EV broadcast the message the EVAC send the confirmation message after sending confirmation message EV sends the wake up call to all the EVSE who have responded to a confirmation message after that EV sends those 10 sounding messages which are nothing but consist of 58 frequency group and for each sounding messages the EVSE modem or the PLC modem on the EVSE side will measure the attenuation values and then they do the average attenuation values corresponding to 58 frequency group and they will send back to the EV and then the EV acknowledges those attenuation profile result and they will start doing the analysis for So, in this case, what happens is that if more than one EVSEs have answered the request of the EV, primary due to the crosstalks as we have discussed in the example, then the PLC modem of EV has to decide to which PLC modem of EVSE it should be connected to.

Now in this case what happens is that the PLC modem of EVAC which has the least attenuation value will be chosen for logical connection. Now this is the case when the results are well defined. That means, let us say for example, if only one EVSE has responded, so the EV will know that it has to be logically connected to that particular PLC modem of EVSE only. If there are only one EVSE which has responded, if in case more than one PLC modems of EVSE would have responded and the attenuation values are very much nearby each other, so it is very difficult for the EV to decide to which PLC modem of EVSE to be connected to. So, in that case, if the result is undecided, then the validation process is required.

Otherwise, the EV can advance with the matching process by sending the message cm underscore attention under this particular message to the chosen EVSE. that means if the results are well defined then the EV will send the matching decision to the chosen EVSE if the results are not well defined or they are undecided then we require the validation process now in the validation process what happens is that the EV sends a request message to start the validation process now that particular request message is confirmed by EVSE by sending the confirmation message Now after receiving that confirmation message, the EV toggles the charging state by closing and reopening of the S2 switch. That means they open and they close the S2 switch. That means they go from state B to state C to state B again.

So that is nothing but the BCB toggle they do. So for example here if you see this is an example and if you see here there are toggling which is happening. So this is plus 9 volt. So this is a B2 state. It is 6 volt.

This is C2 state. Again it is a B2 state and again it is a C2 state and again it is a B2 state. So there are B2, C2, B2 then again C2, B2. So if you see here there are two BCB toggles which are happening. And so the EV actually does the BCB toggle by closing and opening its S2 switch.

And after this what happens is that after EV toggles the charging state, EV again sends the request message to the EVACs who are actually being communicating with EV. And then the EVAC will send the confirmation messages. And in that confirmation messages they will include the number of detected BCB toggles. Now that particular thing is the one which actually decides to which EVAC is to be connected to. Because you know if you see this BCP toggle is happening with 1 kHz signal, the low frequency signal.

And this particular state which is happening, it is happening over the CP and PE line. That means it is only been there for the EVACs which is actually physically connected by the charger plug. Because then only it is not the high frequency signal which are being superimposed. It is the actual signal which is happening between the CP and PE line and which is being seen by the EV and EVSE on either side of that charger plug. So, once the EV sends that BCV toggle, only that EVSE will send the confirmation message with correct number of BCV toggle which is been physically connected.

And that is how EV will come to know that to which EVSE should be connected to and it will be that EVSE which is actually been physically connected. to the EV via the charger plug and that is how if in case the matching decision is undefined that is how EV will able to recognize to which EVSE it should be connected to and after this thing what happens is that once that particular thing is completed the correct EVAC is been chosen what happens is that the EV will then informs EVAC by sending a request messages which is the slack match request messages to the EVAC and after that particular chosen EVAC receives that matching request the EVAC confirms that matching request by the match confirmation message which actually contains the logical network membership key NM key and the network ID which is the NID short form is NID and once the EV receives that matching confirmation message from the chosen EVAC the EV will then set that particular received key in its PLC modem using the set key request message to its PLC modem and that will be confirmed by the PLC modem And after that, what happens is that the PLC modem gets automatically rebooted after receiving this key request message.

And after the rebooting, the PLC modems of EV and EVSC are logically connected. So what we see is that the SAC procedure is initiated by the EV by sending the broadcasting message to all the EVSE which are being connected in a charging station and after that the EVSEs which are receiving that particular messages will send the confirmation messages and in that confirmation message they will send some of the parameters mostly it is the number of sounding messages and after receiving that confirmation messages the EV will then send the wake up call And after the EV sends a wake-up call, EV will then send the 10 sounding messages. Those wake-up calls are actually 3 in numbers. And here the sounding messages are nothing but 10 in number, 10 sounding messages.

And after that, those 10 sounding messages, what happens is that the EVAC will send the attenuation profile for frequency group. and after they are receiving the attenuation profile the matching will be taking place EV will take care of the matching sequences and if in case the matching is not been well defined then EV will do the validation process as well by doing the toggling BCB toggling and EVSE will respond to the number of BCB toggle which has happened and after this thing validation those things are confirmed the EVAC has been chosen to which it should be logically connected what happens is that EV will then send the matching

request and EV sends the matching request and after the matching request has been received EVAC will send the keys for matching and after the key is been received the ev will then set its plc modem to to that particular key and then after that the plc model once they receive that particular key they will get rebooted and after the rebooting the logical connection is being made So this is how the slack procedure takes place and following this slack procedure the correct modems of EV and EVAC are being connected.

Correct what I mean by that is those PLC modems of EV and EVAC are being connected which are actually being physically connected via the charger plug. And that is how the logical connection has been made. And after this thing, the high-level communication will be initiated using the PLC based communication. Mostly it will be those PLC modems of EV and EV-LC which are actually physically being connected because we have taken that particular point which has the least attenuation value. So, this is the way by which the PLC modem get logically connected following the slack procedure.

Now if you look very carefully you know one example I am showing over here. So, you can see there are total of 10 sounding messages which are being sent. by the EV and EVSCs will be receiving that and this is the average attenuation value they have done the calculation for 58 different frequencies the average attenuation of those 10 sounding messages are being calculated and then finally the total average attenuation is being obtained for that particular EVSC which has the MAC ID given over here so every EVACs will have its own PID which is Middle Axis Control ID so for that particular EVAC they will send that average attenuation which is shown over in the red color to the EV and then EV will decide whether it is okay or not to get it logically connected. Then if we see in the real system where the slack procedure has been taken place as we told here we are in state A, here we are in state B1 and here we have these two state B2 where our PWM has started.

Now if you look very carefully after that my slack procedure is starting this is by sending if you see this is different carrier number 1 to 58 so this is been sent between this and this point so after it reaches to b2 state these different sounding messages are being sent from the EV side and which is been received in the EVAC now after that only that EV and EVAC will be decided and then required PLC of the EVAC will get connected to so you know after the slack procedure is been done the PLC status or PLC link status will be then turned to 1 only after

certain point after it receives all these carrier signal and then do the attenuation and then finally decided by the EV so you can see after the slack procedure is done only after that the plc link status becomes one that means plc modems get logically connected to do the communication and once the slack procedure is been done the plc modems are logically connected Logically connected means they can now be ready to do the high level communication between them.

You know one can then do the high-level communication between them because they are logically connected. Now once they are logically connected there is another procedure which takes place which is nothing but called as SLAC which is nothing but called as a stateless address auto configuration which is nothing but it is defining the IP addresses ip addresses of ev and evac modems so once the you know they are logically connected they will now be given addresses that ev and evac will be given addresses and that is through stateless address auto configuration method and which actually follows internet protocol version 6 and which assigns the local address or you can say IP address to the EV and EVSE PLC modems now been logically connected as well as they will be ready to do the data transmission between them I mean obviously to and fro data transmission is been possible and at the same time their ip addresses are also defined and already once they have this thing they are already mac addresses will also be there we will study those things one will discuss how the high level communication takes place over the seven osls now this particular part the slack procedure is been con is constitutes of layer number three of

OSI layer which is nothing but your network layer that we will see in the next class where we will see how once the PLC modem gets logically connected how the high-level communication is been taking place following the seven open system interconnection layer model. So, this is how PLC modems are logically connected. In the last lecture, we have seen what is the charging sequences and then now we have seen how the PLC modems are logically connected. In the next class, we will see how once the PLC modems are logically connected, how they will do the high-level communication following those seven OSI layers. And then after that, we will summarize all the processes together.

And that's when we will proceed to other charging methods. Thank you very much for your patience in listening to this lecture.