

CHARGING INFRASTRUCTURE

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Week-10

Lecture-50

Lec 50: DC Charging (CCS2)-I

Hello everyone, welcome to the lecture number 15 of this NPTEL lecture series on charging infrastructure. we will be talking about a dc charging how it takes place particularly for the case of ccs2 charging system which is again a combined charging system with type 2 ac connector so we will discuss in detail about this dc charging system particularly related to dcs2 If we do the recap, we did the AC type 2 charging. We understood what are the communication which is taking place. It is happening through PWM of 1 kHz frequency cycle.

And we have also seen different charging sequence which goes from A to B1. to B2 then goes to C2 if the PWM is deactivated then it will be in C1 then in case if there is the ventilation is required in the EV so you have the state D and after that you know when it is returning to turn off it goes from C2 to again to B2 then B1 then A This is the different states of charging and we have seen that in this the first thing what the charger does whenever it gets plugged into the EV using its PP pin it detects whether the connector which gets plugged into the EV is correct or not so it's a EV which first recognizes whether the plug which is being plugged into the vehicle inlet connector is correct or not now that is through the R6 resistance because for different values for different current ratings and for AC or DC this resistance value will be differ and because of this resistance value the voltage which will be coming at this point or you can say at the PP pin which goes into the in point of the vehicle controller with respect to P will be changing that voltage will be different and depending upon the value of that voltage the vehicle identifies or able to recognize that this particular connector can able to sustain this much amount of current.

So, that is the way by which vehicle understand and once that recognition is done, the vehicle, the connector gets logged into the vehicle and then over the CP line, which is on this line, your communication takes place via PWM signal where the EVAC changes the duty ratio of the PWM. This PWM goes from plus 12 volt to minus 12 volt. The EVSE will change the duty ratio which indicates what is the maximum current which can be drawn from the EVSE at that particular instant of time. However, it is the vehicle which changes the voltage level of the PWM and that's when it will tell to the EVSE that whether it is ready or not ready. so this type of communication is low level communication where not much information is being shared between the vehicle and EVAC only the maximum current which the EVAC can sustain and what is the status or you can say what is the charging status that means whether the EV is ready or not or whether the EVAC is ready or not that communication only will be sent it's primarily because while doing the AC charging the power conversion takes place inside the vehicle

that means depending upon the battery conditions the BMS can define the power conversion unit controller inside the EV that this much voltage and current has to be made available at the output of the power conversion unit so that information need not to be sent to EVAC And thus EVSE has to just send what is the maximum current which can be drawn at that particular instant of time and at the same time the status whether both whether the EV as well as EVSE are ready or not that has to be exchanged between the EVSE and vehicle. So, that is what is all about the low level communication. So, if we see there are different states. We have state A where VDC voltage which is the positive voltage level of the PWM which is being sensed inside the EVSE is actually 12 volt and it indicates the EV is not connected to EVSE and the resistance between CP and PE pin will not be defined because since they are not connected.

And at this point, my S1 switch is connected to the constant plus 12 volts. then when the charger gets plugged into the EV the voltage which will be measured by the EV will goes to 9V however the S1 switch is still connected to the fixed 12V the PWM is deactivated and since the PWM is deactivated it indicates that EVSC is not ready and since it is 9V it indicates that EV is connected and since it is 9V the EV is also not ready for energy transfer so neither EV or EVSC is ready for energy transfer at that point the resistance between cp and pe pin is nothing but equal to 2740 ohm and during this time the vdc voltage is kept at plus 9 volt then once you plug the charger plug into the vehicle the charging will go into the state b1 from there it goes to

state b2 where the positive voltage level of the pwm is not changed it is still at 9 volt and that means the PWM is going between plus 9 volt and minus 12 volt however the S1 switch in the EVSE will now be connected to oscillator since it is now being connected to oscillator the PWM is activated between the CP and PE pin and that indicates that EVSE is ready And since there is 9 volt and the EV does not change its S2 switch position, that indicates that the EV is not ready for charging and switch S2 is still not connected to R2 resistance.

And during that time, the resistance between CP and PEP was 2740 ohm. then after the B2 state when the EVSC is ready then the EV will change the S2 switch position and connect that R2 in parallel to the 2740 ohm resistance which will give the resistance between CP and PE pin to be 882 ohm and since it is 882 ohm the VDC voltage which is coming over there will now be just 6 volt and the S2 switch is actually is on and connected to R2 Again, in state C, there are two states, C1 and C2. There could be possibility that PWM is deactivated because of some problem in EVSE. So, if the PWM is deactivated, it indicates EVSE is not ready.

But however, since the VDC voltage is 6 volt, it indicates that EV is ready for energy transfer. Then in case if the EVSC does not have any problem from state B2 it will directly go into state C2. In state C2 the same thing S1 is connected to the oscillator PWM is activated S2 is on and connected to R2 that indicates the EV is also ready and since the PWM is activated EVSC is also ready. And the PWM is having the positive voltage level of plus 6 volts and negative voltage level of minus 12 volts. And the resistance between CP and PE is nothing but 882 ohm.

It's because the 2740 ohm resistance comes in parallel to that of your 1.3 kilo ohm resistance. So because of that, our resistance between CP and PE pin will be 882 ohm. Then after that let's say if the battery pack in the vehicle require ventilation so during that time what happens is that the vehicle changes the R2 value which was at 1.3 kilo ohm it changes that value to 270 ohm and that's when the 270 ohm comes in parallel to that of 2740 ohm and that will give the resistance between CP and PE to be 246 ohm. and since it is 246 ohm the positive voltage level of the PWM will be plus 3 volt and negative voltage will still be at minus 12 volt so during this time what happens is that since the PWM is activated EVS is ready Since we have VDC equal to 3 volt, it also indicates that the EV is ready, but EV requires ventilation.

Then in case if there is some fault, there could be some fault, could be short circuit fault between CP and PE line, could be some communication fault. Because of that, the VDC voltage goes to 0. And at that point, since the VDC voltage goes to 0, the PWM will be 0. And that indicates that there is a fault and the EVSE will stop operational and also the EV will stop accepting the energy. Then there could be another possibility where VDC goes to minus 12 volt.

This is again an error condition. It could also be possible that EVAC is not available and at that point the voltage level is maintained at minus 12 volt. so if we look very carefully the waveform we goes from a state to b state from b state to c state it could be either in d state and from d state it goes to b state and then again move to a state we have seen here the negative voltage will still be minus 12 because of diode which is present in the cp line which actually does not allow the negative voltage because during that time it actually gets a reverse bias so the negative voltage will not change however the positive voltage will change because during that time the diode D1 gets forward bias and as a result of which different resistances will come into picture and because of the resistor divider circuit the positive voltage level at the CP line will be different. Now in this if you look very carefully there is some duty ratio.

The duty ratio indicates that the maximum current which has to be drawn by the vehicle and that is according to IEC 61851 standard. here we know that when it is the duty ratio is between 0 to 3 volts the charging is not allowed whenever it is between 3 to 7 volt it indicates that it is a dc charging and during that time you require the communication which supports the dc charging which is nothing but called as the high level communication which we will discuss as we go along And then you have a duty ratio between 7 to 8% which indicates that the EVSE is not ready to actually allow any current to be drawn from it. So that's why that is there between 8 to 10% duty ratio only 6 amperes maximum current is allowed by the vehicle to be drawn from the EVSE. And then the vehicle BMS will decide how much current to be actually drawn within the limit of the maximum current which can be allowed by the EVSE.

Then between 10 to 85% it is 0.6 times duty ratio between 85 to 96 it is D minus 64 into 2.5 between 96 to 97% duty ratio it is 80 ampere and between 97 to 100 it is not allowed. The maximum current which can be drawn by the vehicle as per the IEC 61851 it is nothing but the 80 ampere which can be drawn whenever the duty ratio of the PWM is between 96 and 97% and only the EVSC controller can able to change the duty ratio of the PWM. So if we see how

our maximum charging current with respect to duty ratio if we see that you know with respect to duty ratio and this is the maximum current let us define in ampere so we will see that whenever it is between let's say it is three from starting from zero again it is in percentage so it goes from zero to hundred percent so at three then we have at seven then we have another point as 8 then we have another point as 10 then we have at 85 and after 85 we have 96 97 and 100 so when it is a 0 to 3 we can say that charging not allowed during that time charging not allowed

Between 3 to 7%, we can just say that between 3 to 7% is nothing but it is the zone for DC charging. So, whenever the charger goes for DC charging at the CP, the PWM will be having the duty ratio of pulse width modulation between 3 to 7%. After that, from 7 to 8%, again it is not allowed, charging not allowed. And after 8 to 10, if you look very carefully, it is just the 6 ampere. So it is just the 6 ampere.

If we do that, it is 6 ampere. From 10 to 85, it is just the rising, linearly rising. It is linearly rising, reaches to this point. And this point is nothing but equal to We just put this one, nothing but equal to 52 ampere.

And then from here to, you know, there is between 85 to 96, it is nothing but D minus 64 into 2.5. So there you will have some dark zone, which is, you know, or some non-oppositional zone, which is, which is start from 52.5. And then again, it goes linearly. And beyond this point, it reaches to 82. this is the 80 ampere so which after this it becomes settle down okay this is 52 ampere this is 52.5 and this is 80 and after this from between 96 to 97 it is 80 ampere which can be allowed and between 97 to this one you can say that it is not allowed no charging is been allowed sorry it's 51

So, this is with respect to duty ratio, our maximum current will look like. For better understanding, we can draw it using this one. It is 6 ampere, then it goes up to 51, then 52.5, it goes up to 80 and then it settles down at 80. So, this depending upon the duty ratio, the EVSE will tell the EV that this is the maximum current I can allow and that is when the vehicle BMS will decide what should be the current within that maximum current limit we should demand from the EVSE. So, similarly if you see here the current which is been demanded over here must be less than the maximum current which is allowed by the vehicle to be drawn from the EVSE that information is sent by the duty ratio of the PWM signal which is at the CP line and this

frequency cycle of this is nothing but one kilohertz or you can say the time period is time period of that pwn cycle will be one by thousand hertz which is nothing but one millisecond So, this is how the charging of the AC charging system takes place. Now, let us see how the charging with the DC charging system takes place. Now, if you recall our previous discussion about the DC charging system, what are the building blocks of DC charging system, what we realize is in the DCVSE, we have the controller, we have the power conversion unit and it is directly the DC which actually gets plugged into the vehicle. And since the DC is plugged into the vehicle through the protective devices, it is going into the directly EV battery.

So there is no power conversion which is taking place inside the vehicle. all the power conversion is taking place outside the electric vehicle that's why the a lot of information of related to battery status related to temperature current soc level voltage level of the battery has to be shared by the bms to the controller or you can say the supply equipment communication controller secc and on this side you have vehicle controller so the BMS has to communicate a lot of series of information need to be shared and at different instance of time between the BMS and the controller that's why you require a dedicated communication channel and you require a high level communication and that is taking place in case of CCS2 that is taking place using the PLC based dedicated communication channel using the 7 OSI layers which is open system interconnection layers so in this case this particular things are there now if you look very carefully in this thing we have drawn the control however this controller is not that straightforward generally what we have is in this case controller what we have is this particular DCVAC what we have is we have we have you know one controller which is actually communicating again I am drawing for CCS2 charging which is actually using the PLC modem it is actually connected to the BMS of the it is going into the BMS so what happens is that on the vehicle side also you have PLC modem and on the charger side also EVSE side also you have PLC modem so these two will be communicating using the power line communication over the CP line

Now this controller will be communicating with PLC that communication could be using SPI or you know in other cases could be SCI or could I mean serial communication. Generally these are the two communication which is there sometimes CAN can also be used CAN communication. And this controller will be actually on the other side through the dedicated

channel will be communicating with the CMS Central Management System of the charging station provider. and this controller will then be communicating with another controller local controller which is actually controlling the rectifier or you can say ac to dc converter and isolated dc to dc converter and through the this controller is actually controlling the safety interlocks which will be there this safety interlocks could be Relays, contactors could be RCD device which is residual current detection device many things could be there for protection and safety and which will be actually you are sending you know control DC or control or regulated DC you are directly feeding into the vehicle.

So, this is the multi-layer controller structures one can have. However, for the CCS in order to ensure we have the CCS2 charging system, we must have PLC at the front end, PLC modem at the front end on both the EV side as well as the EVAC side. such that the supply equipment communication controller will be sending information to PLC modem and PLC modem will then be following certain standard put those high frequency signal superimposed on the low frequency signal of 1 kilohertz on the CP line and then send it to the EV side and then on the other side using the PLC modem the information will be extracted and it will be shared with the BMS that communication between the PLC modem on the vehicle to the BMS could be done using CAN or SPI or serial communication depending upon the speed which you wanted to achieve so let us see our DC charging system since we are focusing only on CCS2 so what we have in CCS2 we have the charger plug it is called a CCS2 because if you see the top portion of that it is simply as that of AC type 2 however the bottom portion will be there for DC connections DC connections so whenever you are plugging in AC type 2 connector you will be plugging in only on the top portion of the CCS2 vehicle inlet connector but whenever you are actually plugging in the overall CCS charger plug you will be plugging in the entire CCS2 vehicle inlet connector now in that what you have is you have the you know the DC plus and DC minus line DC plus and DC minus line which is actually on the other side will be connected to DC minus and DC plus line

and you have just the cp you have just the proximity pilot and this is nothing but the protective earth so these are the terminals of the ccs2 charger plug which actually gets plugged into the vehicle inlet connector having the same form factor such that the charger plug gets plugged into the vehicle inlet connector now here in case of dc charging system which is done using ccs2 We

will also have control pilot and proximity pilot. And as in case of AC type 2 connector, we have the PWM based communication which is happening over the control pilot and protective earth. Here also we will be doing the communication between the control pilot and protective earth line. However, the duty ratio is maintained between 3 to 7%.

So, the moment the EVSC put the duty ratio between 3 to 7 percent, the EV recognizes that it is nothing but it is the DC. CCS2 charger which gets plugged into its vehicle inlet connector so it has to then enable that the high level communication or you can say it has to then superimpose the high frequency signals over the 1 kilohertz PWM signal which is coming between the control pilot and the protective earth so here we are showing you the charging gun for the DC CCS2 charging system now it has you know this standard 5 meter cable which is coming from the DC VSC now if you see in this one what we have is we have in total five number of pins we have control pilot at this place we have proximity pilot at this place we have protective earth and along with that we have DC plus and DC minus pins which is there in the charger plug and if you see this CP and PP are smaller in size because they are responsible for doing the communication while DC plus and DC minus pins are thicker in size or you can say are larger in size because it is actually carrying the current which is actually going to charge the battery that means in the range of upwards of 100 ampere 200 amperes like that so that is why this DC plus and DC minus pins are thicker similarly on the vehicle inlet connector for this DC CCS2 charging system we have also discussed this in in case of AC type 2 what we have is we have proximity pilot we have control pilot we have L1 L2 L3 neutral protective earth

and for the DC side what we have is we have DC minus and DC plus pins so you know using this part we can do the AC type 2 charging while when we are doing a DC charging we will be using this DC minus and this DC plus pins so let us see our charger plug once again we don't have any L1, L2, L3 and neutral pins we only have our control pilot, proximity pilot, protective earth and DC plus and DC minus pins so let us try to plug in this charger plug into the vehicle inlet connector so this charger plug will go and gets plugged in into the vehicle inlet connector like this and once it gets plugged in the vehicle reorganizes that the charger plug gets plugged in using the proximity pilot pin and that's when they immobilize the vehicle and that's when the next level of communication will start So this is how your DC CCS2 charging system works especially we are showing you here the vehicle inlet connector and the charger plug for DC

CCS2 charging system So in DC CCS2 charging system what we have is we have the PP circuit which is same as that of the AC type 2 so which consists of R6 resistance onto the charger plug and depending upon the value of R6 resistance the EV will come to know what will be the charging plug which gets plugged into it and whether the charging plug is correct charging plug or not

now apart from PP circuit we also have CP pin where the communication is taking place so in case of AC type 2 charging we know that we have 1 kilohertz PWM which is been employed over the CP and PE line and since in the AC charging system our power conversion is taking place inside the vehicle itself so the status of battery pack like the SOC or the voltage current temperature will be sent by the BMS to the local power conversion unit controller However, in case of DC charging system, since our power conversion unit is kept outside the vehicle and we are actually plugging in directly DC into the vehicle, we need to ensure that a lot of information related to the battery like voltage, current, temperature has to be shared from the BMS to the EVSE and that's when we require a dedicated communication channel which is happening over the CP line. So, in the communication, the communication is actually you can say indirectly happening over the cp and and p line it is using you know plc based communication power line based communication where the cp signal width is kept between three to seven percent range of one kilohertz pwf signal which is nothing but looks like something like this so this is one millisecond Time period corresponds to 1 kHz and this value T on value will be between 0.03 millisecond to 0.07 millisecond.

That's when we are keeping the duty ratio between 3 to 7% range. And the moment the EVSE keep the 3 to 7% duty ratio within 3 to 7% range, it tells the EV that it is the DC charging which is been taking place. And thus EV will also understand that it's the DC charging accordingly take required actions. Now in case of CP line since a lot of information has to share between the vehicle and the EVSE so we require a dedicated communication channel and that communication is happening through the power line communication. Now that power line communication is happening over the CP line that means the PWM pulse which is there between the CP and PE line will also have a very high frequency modulated signal which is being superimposed

onto this 1kHz PWM that means you also have a lot of high frequency signal which is being superimposed over the PWM which is going between plus 12V and minus 12V. Over the plus 12V and minus 12V you have a very high frequency modulated signal superimposed over it and that carries all the information, all the messages which has to be shared between EV and EVSE. Now, this modulating signal which is high frequency modulating signal which is being superimposed over the CP line between CP and PE line Since it is the high frequency signal which is being superimposed on the 1 kW PWM, this is similar to that of the power line communication which takes place in the transmission system where the high frequency signals are superimposed onto the power lines. Here, we are having the high frequency modulated signal superimposed onto the

1 kHz PWM which is happening over the CP and PE line. Here one thing to be note that it is the power line communication taking place over the CP line or the control pilot line not the DC plus and DC minus line. It is happening over the CP line that means over the PWM which is employed over the CP and PE line to send the required information between the EV and EVSE. so when the DC charging system takes place in the communication first the duty ratio of the PWM pulse is kept between 3 to 7 percent and the high frequency modulator signal is superimposed onto that 1 kilohertz PWM signal over the CP and PE signals which enables the power line communication and in the power line communication a lot of multiplexing can be done to send a lot of information in required time now the required parameters the communication methods are actually very in detail are specified in ISO 1158 standard and DIN spec 70121 standard now these are the two standards which actually defines

All the communication methods, all the parameters like when information needs to be sent, how the information needs to be sent, what the message type will be, how the message looks like—all that information will be presented and detailed in this standard. So, whenever someone wants to develop this particular charging system, one must read the ISO 15118 standard and DIN SPEC 70121 standard to implement this communication, this high-level communication. Over the CP line—now it is called high-level communication because we are sending a lot of information—and that particular communication is actually happening using power line communication. The structure of communication protocols, the different protocols, will be defined and used to define the different parameters of the communication, so those particular

protocols are being structured in the form of the seven-layer network model, which is also called the OSI seven-layer OSI model, which is nothing but the Open Systems Interconnection reference model. Just like two computers get connected over the internet, in the same manner, the EV and EVSE system also get connected to each other, and they will be determined by certain communication protocols which are arranged in seven OSI layers. So, we will discuss some details of those seven OSI layers in the subsequent lecture. But before that, let us see some of the things related to the PLC power line communication.

Now, as we know, our IEC 61851-based communication protocol indicates a 1 kHz PWM with the required voltage levels and a duty ratio between 3% to 7% for DC charging. That is imposed by the IEC 61851. The moment your duty ratio is between 3% to 7%, it indicates that it is nothing but DC charging. Now, in this case, the power line communication signal is actually modulated onto the control pilot, having a 3% to 7% PWM signal of 1 kHz. Now, this PLC signal, which is there, contains the high-level protocol messages. Why is it called high-level? Because it follows seven OSI layers and has several sets of messages which have to be exchanged between the EV and EVSE, because those messages have a lot of information which has to be sent at the required time or at every interval between the EV and EVSE.

Now, this physical interface, which uses PLC-based communication, follows the HomePlug Green PHY standard, which is one of the standards for power line communication and is again a subset of the HomePlug AV standards, which defines some of the features of the HomePlug AV standards. Some of these features are taken and defined in the HomePlug Green PHY standard. Along with that, there is something called signal level attenuation characterization. So, whenever the EV gets connected to the EVSE, the first step that takes place is nothing but the signal level attenuation characterization, in order to ensure that the correct modem of the EVSE and the modem of the EV actually get logically connected. After the slack, only then the HomePlug Green PHY standard will determine the different physical aspects of the communication, like the voltage levels, the band of frequencies, the subcarrier frequency, how far the bands are arranged—those things will be determined by the HomePlug PHY standard, the physical property of the communication. However, before that, the signal level attenuation characterization has to be done. So, the correct digital data, which is appropriately modulated, is actually applied via the PLC modem, which is connected to the CP line.

So, on the CP line on the EVLC as well as on the EV you have the PLC modem which is being connected and that will convert that the information from the supply equipment communication controller into the PLC signals whose properties are been defined by the Home plug, Green PHY, Now, if we see some of the key properties of home plug green phi standard, so home plug green phi base PLC, it uses actually OFDM amplitude phase modulation, which is nothing but called as the orthogonal frequency division multiplexing. again we are not going too much in detail what is OFDM because it is a very one of the concept which is been used in communication systems particularly those who study electronic communication background they must be knowing what is the OFDM which is orthogonal frequency division multiplexing so in this what happens is that there are a lot of signals at different frequencies are actually been multiplexed together So you can say that the entire band or entire frequency band, it has a wide frequency band of 2 to 28 megahertz. Wide band is there.

In that wide band, a lot of sub-carriers are there. That means a lot of carriers with the defined frequencies are there. And those carriers are used to send information and they are multiplexed together, which forms the PLC signals. So, in this if we see there since there are 2 to 28 megahertz wide band OFDM which is present OFDM means all the frequencies are multiplied using the orthogonal frequency division method and it has total of 1155 subcarriers with 917 of them will be used while the others are not being used that means that many frequency bands are not being used. and each subcarrier frequency signal is generated with a 24.414 kilohertz interval that means the subcarrier signals are separated from each other with the frequency interval of 24.414 kilohertz and the each subcarrier is actually modulated using the quadrature phase shift keying so quadrature

using the quadrature phase shift key. Again, it's the concept. which has been used in the communication system. So, each subcarriers are actually getting modulated using QPSK method and the overall, you know, the different subcarriers are combined together will be multiplexed using OFDM method and that signal will be actually superimposed onto the 1 kilohertz PWM. now in home plug green pi they also define the digital data transmission which has to be between 4.5 to 10 mbps that means in one second maximum of 10 mb data can be shared then one important thing is you know the peak to peak plc signal is in the range between 0.3 volt to 1.3 volt that means you know if we see our pwm pulse

see our PWM pulse will be going between 12 volt to minus 12 volt and over this the high frequency modulated signal are superimposed so in this a lot of high frequency signals are being superimposed using the PLC modem so you know in this way if you see look very carefully this particular signal high frequency signal will be put over there And if you look very carefully, the distance or the peak or the value of this and this is actually be between 0.3 volt to 1.3 volt peak to peak. And this is again 0.3 volt peak. to 1.3 volt peak to peak that's why since this amplitude of this high frequency signal is very small that's why whenever the ev is getting connected with evac one must ensure the attenuation between the ev and evac is as minimal as possible and for that one has to do The slack procedure, which is signal level attenuation characterization before EV is actually doing the charging or converting from the state B to C1, C2, D state, different states.

So, we have around 1155 subcarriers or you can say 1155 channels we have. you know we have 1155 channels that means parallelly we can send 1155 informations by doing the proper multiplexing further if you look very carefully out of 1155 there are only 917 subcarriers are used that means only 917 channels are being used now if you look very carefully Whenever that DC-CCS2 charging plug gets connected into the EV, let us see the different charging sequence which takes place. And after that, we will see how the communication is taking place. So, let us see how the charging sequence takes place.

Now, first and foremost thing, whenever the supply station or you can say that EVSE, electric vehicle supply equipment or you can say supply station as well, is been is not been connected to ev what we have is between cp and pe line we have the voltage nothing but equal to plus 12 volt and we are in the charging state a and charger is not been plugged in here if you look very carefully this theta is is there to actually measure the temperature of the contacts which has been made between the charger plug and the vehicle inlet connector further we also have the lock Mechanism once the connector is been detected the lock will get closed up and that's when once the charging is taking place no one can remove the charger plug from the vehicle inner connector. just to ensure the proper charging which is been taking place now if you look very carefully we have low level control pilot signal which is again having 1 kilohertz and we also have a high level communication which is happening using the plc based communication where over the 1 kilohertz the high frequency signals are being superimposed and then we have dc plus

and dc minus line which is been connected to the vehicle Now, this is the charger plug which is been unmet during this point.

Now, at T equal to T_0 , the charger plug gets plugged into the EV. That means you can say the charger plug is mated. Now, during that time, what happens is that since the charger plug gets mated, the resistance between the CP and PE line will now change from an undefined value to 2740 ohms. And that's when the positive voltage level, since the PWM is deactivated, is connected directly to 12 volts. So, the voltage level of the CP line will be plus 9 volts, and that indicates a positive state.

We have the B1 state, so the charging enters into the B1 state instantaneously whenever the charger plug gets mated with the vehicle inlet connector. And since this has been mated, the vehicle is mobilized, and that mobilization takes place after detecting the PP line, after performing the detection in the PP line. So once the PP line is detected, the vehicle will now get immobilized. That means all the motor control and all the propulsion systems get deactivated from the battery pack. So that is important because, you know, the proximity pilot will determine that.

The moment the PP line is detected, the vehicle detects that there is a correct plug which gets plugged in via the PP line by detecting the voltage at the PP line, which is defined by the R_6 resistance. Depending upon that, if the vehicle sees a voltage which is within the specified limits, then the vehicle will immobilize itself. That means the propulsion system gets cut off from the battery system because the vehicle now identifies that the user is actually charging the battery pack. So that is where, at the B1 state, after detection over the PP line, the vehicle gets immobilized, and the charging system enters into the B1 state. So once the vehicle is mobilized and enters into stage B1, the next state is the start state, which is the initialization stage between T_0 and T_1 . During this time, what happens is that the S1 switch is actually connected to the oscillator, and that's when it goes into the B2 stage. And since the S1 switch is connected to the oscillator and since it is a DC charging system, the oscillator will have pulse width modulation with a 3 to 7% duty ratio. Since it is between a 3 to 7% duty ratio, the vehicle identifies that DC charging has to take place, and that's when it will start setting up the high-level communication using the PLC and the handshaking with the exchange of charging parameters will take place.

So, it is during this point the moment the PWM of 3 to 7 percent duty ratio is been imposed by the EVSE the vehicle identified it is a DC charging system and that's when it has to stabilize the high level communication and that's when a lot of handshaking must be taking place using the high level communication and that's when the PLC modems has to be activated between the vehicle and the EVSE. now during this time some voltage will start appearing at this place and during this time if the voltage is greater than 60 volt at this point if the voltage is greater than 60 volt or is there if there is any incompatibility with the ev and dc supply is detected So, during that time, the charger will immediately do the shutdown. If the voltage at this point, because the contactors on the supply side or the contactors on the EVAC side is still open, but however, because of some faulty condition, if the voltage is greater than 60 volt or if there is an incompatibility between the EV and DC supply is detected, that is when the charging system will actually be demanding for the shutdown. There will be sudden shutdown of the charging system which takes place.

And at this point, the EV sends its maximum limit, maximum value of output current and voltage which the EV is expecting to have. That means, let's say if the battery is there, some 400 volt battery is there, when it is charged, it will go up to 520 volt. So, that maximum limit has to be informed to the EV as the maximum voltage and current limit which the battery can support. So, that's what that EV will send during this initialization stage itself. That is happening after the high level communication is stabilized between the PLCs of EV and EVSC.

And that high level communication is stabilized once the PLC modems of the EV and EVSC gets logically connected. And that logical connection is happening using the slack operation. And that we will discuss in subsequent lectures what is a slack operation. So, here what is happening is that the high level communication PLC starts some of the charging parameters is being exchanged between the EV and EVAC. Then the next stage comes which takes place between T1 to T2 time instances.

During this time the EV locks the vehicle connector in its inlet. So, this locking will take place. If you look very carefully in the previous case there was no locking. Now, in this case, the lock takes place. So, now the charger plug gets fully locked into the vehicle inlet connector.

And after the EV sends the information to the DCVSE, the DCVSE will then respond to the EV that, okay, we have got this much information of the maximum voltage and current information. And then EV will see whether that maximum value which the DC supply is sending is correct or not. Then after that, the DC supply knows that it has to check the internal insulation between the DC plus and DC minus line as long as no voltage is applied at the connector. So that has to be done. And if the EV and DC supplies are not compatible, there could be possibility that both are not compatible to each other.

Let's say the vehicle told the EVSE that the maximum voltage is, let's say 900 volt from the battery pack. And if the EVSE cannot support that, then that shows there is incompatible. And that's when the vehicle will not go into the ready state and there will be transition towards the shutdown, which will take place. So, now it reaches to the state where the vehicle locks the vehicle connector and the maximum value of voltage which is being shared which is being sent by the vehicle is being responded by the DC supply or you can say the DC VSE that this much is the maximum voltage and then the DC supply or the DC VSE has to do the internal insulation check before the voltages are applied at the DC plus and DC minus line. then the cable check state takes place so now both the modem of the ev and evsc are logically connected that means they can do the high level communication using the power line communication and during this time what happens is that since they are logically connected the ev will change the cp state from the state b2 to either c2 or if let's say if the ventilation is required then state d

And that's when the EV status since the S2 switch in the EV will change its state. So the CP state will go from B2 to C2 state and that's when EV sends the information that EV is ready for charging or energy transfer. And the EV request the cable and insulation check after the connector locks has been confirmed. So now that DCVSE was actually doing the insulation check within itself. But now the vehicle request that cable and insulation check that you must do the insulation check of the cables or DC plus between DC plus and DC minus.

And the DC supply then start checking the high voltage isolation and it will continuously report that isolation state or what is the status of that isolation. It will continuously telling to the vehicle. So this was the case between T2 to T3 time period and then between T3 to T4 time period. the dc supply must determine that the isolation resistance of the system is above 100 kilo ohm so this isolation between the dc plus and dc minus must be more than 100 kilo ohm and if this

successful isolation check is done the ec supply will change its state to valid state that means it is also ready with these cable check response it will also tell to the EV that the EVSC is also ready and it has also checked its isolation between the DC plus and DC minus line and then after the isolation is been properly checked the vehicle modem and the EVSC modem are logically connected the pre-charging state will then start

because both are logically connected and isolation are properly met the pre-charging will start during the pre-charging the contactors in the dc plus and dc minus line of the evsc gets closed and then once the contactors are closed and they enter into the pre-charging state since the ev is the master ev will send the pre-charge request to the evse or or you consider to the supply station this pre-charging supply request has both the information of the maximum current limit it has the both the information which is the maximum current limit and the required DC voltage which has to be kept at the DC plus and DC minus line so the EV sends the pre-charging request contains requested DC current which you can say initially it has the inrush current because the voltage which is coming at this place will be different than the voltage which is coming at this place which is V_{out} will be different than the voltage of the battery so that's when one must provide the limit on the inrush current the moment the charger plug gets connected and the charger gets logically connected and the contactors get closed so that limit has to be kept and that limit is kept at less than 2 ampere and the required dc voltage which has to be kept at the dc plus and dc minus pins so that these are the two information which is being there in the in the pre-charging switch with the ev signs Now, the remaining stages we will discuss in the next lecture where we will see how the pre-charging stage gets completed and after pre-charging stage, the charging stage takes place and after charging stage, unmating of the connectors will be taking place.

Since DC charging operates at a very high power level and requires extensive communication between the vehicle and the EVSE, there are multiple stages of charging and shutdown that must be understood in detail, as discussed in this lecture. So, thank you very much for patiently listening to this lecture. We will discuss the remaining portion, including the remaining stages, in the next lecture. Thank you.