

CHARGING INFRASTRUCTURE

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Week-10

Lecture-49

Lec 49: AC Type-2 Charging - II

Hello everyone, welcome to lecture number 49 of this NPTEL lecture series on charging infrastructure. In today's lecture, we will continue our discussion from the previous lecture, where we were discussing how AC charging takes place when we connect a Type 2 AC charger plug. Let us recap: we have understood what is there in the PP circuit (Proximity Pilot pin circuit). We know that in AC charging, all power conversion takes place inside the vehicle using the onboard charger. However, the EVAC (Electric Vehicle Supply Equipment) only performs metering, monitoring, and protective functionalities and provides AC at its output, which will be directly plugged into the vehicle. Then, we have seen what is there in the PP circuit. We understood that the PP circuit helps the EV identify whether the plug connected to the EV is the correct plug or not—or, in other words, whether it is among the charging plugs in the ecosystem. There is one resistance named R6, which varies for different current levels and different types of charging (AC or DC).

The value of R6 will change, and accordingly, the vehicle will determine—using the PP circuit—whether a charging plug of 63 ampere, 32 ampere, or CCS2 charging plug has been connected. Here, we have taken one example where we used a 1500-ohm resistor. Using just the voltage divider circuit, we could see that the voltage at the PP pin (when R6 is present) with respect to the protective earth is equal to 3.87 volts. Accordingly, tables can be made that indicate if the resistance between PP and PE (which is the R6 resistance) is greater than 4500 ohms, then it indicates no plug has been connected, or it is an error condition, or the plug has been disconnected. If it is 1500 ohms, then it indicates a 13-ampere plug. The vehicle's control system senses the voltage at the PP pin with respect to the protective earth pin. When it detects

3.87 volts, it recognizes that the R6 value is 1500 ohms, which corresponds to a 13-ampere AC plug with a wire cross-section of 1.5 square mm. Similarly, for other resistances, different values will be obtained at the PP pin, allowing you to back-calculate and identify which charging plug has been connected.

This is how the vehicle identifies whether the correct charging plug has been connected. Once it confirms the correct plug, the vehicle will immobilize (meaning it will not move further). After that, communication takes place between the EVLC and the EV, using the control pilot. Again, we have already discussed that in AC charging, power conversion (AC to DC and then isolated DC-DC power conversion) takes place inside the vehicle. Since power conversion happens inside the vehicle, the BMS of the vehicle does not need to share much information about the battery status with the EVAC, as the control can be managed inside the vehicle using the onboard charger. In this case, they use a simple PWM-based communication, also called low-level communication. If you observe the PWM pulses, the PWM period is nothing but 1 divided by the PWM frequency. The PWM pulses repeat themselves. You have the voltage level of PWM (the positive and negative voltage levels). Here, you can define the time during which the positive voltage level is applied as the 'on' time (t_{on}).

the time during which the pwm has the non-zero positive value so for that we can define a term called as the duty ratio d which is nothing but t_{on} by t_{now} this duty ratio indicates the fraction of the time in the pwm cycle when the voltage level of pwm is positive non-zero value and depending upon different voltage levels the vehicle and the EVAC detects what will be the state of charging and depending upon the duty ratio the EVAC tells the EV what will be the maximum value of current it can deliver at that moment so let us see what is the meaning of each and individual thing one by one So in this we know that once the proximity polar identifies the correct plug and that's when the communication will start between the EVLC and EV using the PWM pulse of 1000 Hz which is nothing but 1 kHz PWM signal. And this 1 kHz PWM signal is generated nothing but by the EVAC or the electric breaker supply equipment. That means the electric breaker supply equipment will have the oscillator which will actually generate the PWM of 1 kHz.

And on the vehicle side, vehicle actually measures the duty ratio. I mean duty ratio of the PWM pulse which is being sent over the CP pin from the EVSE to vehicle side. And along with duty

ratio, it also measures the frequency. However, in this communication as per SAE J1772 or IEC 61850, we are not actually changing the frequency. We are keeping the frequency at 1 kHz.

so the ev measures this frequency and duty cycle the frequency is not within the required range and they will stop doing the communication between them and charging gets stopped then it's ev which actually changes the voltage level so i have mentioned the voltage level or you can say amplitude of pwm this in a voltage level or amplitude and that's when The EVSC comes to know whether the EV is ready for charging or not. So, on the EVSC side, the EVSC measures the voltage between the control pallet and protective earth. So, in the communication over the CP line, the pulse width modulator signal of 1 kHz is being sent and the EV measures those duty ratio and frequency. Then EV changes its state by changing the S2 switch and that's when it changes the voltage level of the PWM pulses which will tell EVSE whether the EV is ready or not to do the charging or is ready for energy transfer or not.

And then EV actually measures that the voltage level of the PWM pulses which is been defined by the EV and then accordingly EVSE also comes to know what is the status at which the vehicle is. So we will see one by one how this communication takes place. Remember this is the PWM pulses which is taking place over the CP line between the EVSE and vehicle. This is not the pulse width modulation which is being used to control the power in the power conversion unit. So, in the power conversion unit the pulse width modulation of the gate pulses are taking place using a dedicated controller which is being used to control the power flow of the power conversion unit.

This is just to do the communication between the EV and EVSE that means to send some vital information from the EVSE to the EV or to check what is the status whether the EV is accepting the charge or not or whether the EVSE is ready to transfer the energy or not. So, it is for that purpose only the CP pin is being used and over the CP pin it is the PWM which is being activated so that to ensure that information is being sent. so if you look at the circuit parameters of a control pilot circuit it actually has as I mentioned the oscillator which is being put in the pulse with modulated signal which is been put in has the peak value or you can say the positive voltage of 12 volt it has the negative voltage of minus 12 volt so it is a PWM pulse going from plus 12 volt to minus 12 volt it is not the zero volt it is a plus 12 volt or the minus 12 volt so the pulses will be like minus 12 volt then again plus 12 volt and the t on period is the time during

which the positive voltage is been applied where duty ratio is the fraction of the period of the PWM cycle in during which the positive voltage pulse is been applied. then the frequency as i mentioned is 1 kilohertz plus minus 0.5 hertz the maximum value of rise time so see this pwm will have some rise time it will not be straight line it will have some rise time and it will have some fall time so the maximum rise time it can afford to be 2 microsecond

because you know if we take one kilohertz it means in one millisecond the two microseconds is nothing but just 0.2 percent so it is very less as compared to the duty ratios which one can achieve then the maximum value of falling time is again 2 microsecond which is again 0.25% maximum value so it is very less as compared to the overall PWM cycle then minimum value of settling time is nothing but 3 microsecond that means sometimes you know this PWM pulse will have also sometimes this kind of oscillation so it will settle down maximum value is 3 microsecond so it is nothing but 0.3% which is very less as compared to the 1 millisecond PWM cycle Then resistance of the source. So here we have the resistance of the source which is nothing but 1 kilo ohm. plus minus three percent so one k means one kilo ohm plus minus three percent and the cs value this capacity there will always be capacitance between between different pins so between cp and ground they the maximum recommended capacitance for the suppression of this interference is nothing but 300 picofarad however the maximum value of total line capacitance which is corresponding to the capacitance between control pilot and ground and the cable capacitance of the cable should be less than

So, these are some of the CP circuit parameters. Now, let us see how the different states takes place or how the charging takes place so in initially whenever the vehicle whenever the charger plug is not connected with the vehicle so this is a portion in the evsc side and this is a portion on ev side and whenever the the connector is not get connected to the ev so that means there is no physical connection between the control pilot and ground to ev or you can say the protective earth this is a protective earth pin this is the control pilot pin or pilot signal you can say So, during this time, you know, we know that on the vehicle side, we are measuring the frequency and duty cycle. On the EVSE side, we are measuring the maximum voltage which these PWM pulses we have at this point.

So, during this point, what happens is that if you look very carefully, the S1 switch is this s1 switch is actually gets controlled by the evsc and we have another switch which is s2 switch

which is on the vehicle and which gets controlled by the vehicle controller so in this the first state takes place which is nothing but called as a state a in state a the charger is i mean the evsc is not being connected to ev so you can say ev is not connected to evsc And since EVAC is not connected to EV, the PWM or the oscillator you can say is turned off or you can say that PWM is deactivated. And this S1 switch is connected to the fixed 12 volt, the constant 12 volt. Since it is been connected to the constant 12 volt, there is no connection on this side.

So at this point, the value of voltage is nothing but plus 12 volt. So at this point, which is been measured by the EVAC, this point, this value is been measured by 12. EVSE controller the EVSE controller identifies it is a 12 volt and which indicates that vehicle is in state a state a means the charger plug is not connected to the EV and at this point your EVSE controller has plus 12 volt which is been actually measured by the EVSE controller then Afterwards the next state comes when the charger plug gets plugged into the EV. Now the moment the charger plug gets plugged into the EV what happens is that the vehicle enters into the state B1.

This is the state B1. In state B1 what happens is that you know this diode is nothing but a diode D1. now in state B1 what happens is that if you look very carefully in state B1 in this circuit if you look very carefully this circuit which goes from here to here so in this figure if you look very carefully we have plus 12 volt after plus 12 volt it is connected through S1 switch through S1 switch S1 switch is engaged with the fixed plus 12 volt to the R1 resistance and this is nothing but 1000 ohm we can neglect for now the tolerance level then after this what happens is that since plus 12 volt is there your D1 gets forward biased D1 get forward biased and then finally you have nothing but R3 which is nothing but 2740 ohm and then it is connected to protective earth and at this point which is nothing but this point is actually been measured by which is nothing but VDC, which is being measured by EVAC controller.

Measured by EVAC controller. Now, at this state, what happens is that, let us calculate what will be the VDC value will be nothing but your 2740, which is coming over here, divided by 2740 plus 1000 ohm. This is actual register divider multiplied by this 12 volt is coming and this will value will give you nothing but equal to 8.79 volt which is roughly nothing but equal to 9 volt. So what happens at this point the EVAC measure is said plus 9 volt which indicates the EV is getting connected but it is not ready for charging. The moment the 9 volt comes here, I mean at this point since it is been measured by EVSE controller, at this point the moment plus 9 volt

comes over there, it indicates that some EV is been connected but the EV is not ready for charging.

And here since the S1 switch is connected to fixed 12 volt, the vehicle identifies that, the EV identifies that the PWM is deactivated which means EVSE is not ready for charging. So, in this state B1, the EV gets connected and the EVSC recognizes the vehicle is being connected. However, in the EVSC side, the oscillator is still off, that means PWM is still deactivated, which is understood by EV that the EVSC is not ready for charging. So, in this case, they are plugged in, but they both are not ready for charging. Now comes another state which is called as a state B2 at this state what happens is that the S1 switch changes its position to the oscillator and that's when you can say that at this point whenever the S1 switch is getting connected to the oscillator so what you can say at this state PWM is activated which indicates that EVSC is ready for energy transfer but still EV is not been ready for charging because

EV still does not changes the state of the S2 switch. so at this stage what happens is that the s1 switch is connected to the oscillator that indicates evs is now ready for energy transfer but now ev has to tell that okay i am also ready to accept the charge so at this point again if you look very carefully here you have plus 12 volt coming in and minus 12 volt coming in so when you take the maximum voltage which is been coming out at this point so if you can put here this of plus 12 minus 12 volt comes over here and that's when you know it is going through R1 switch as you know and the diode D1 gets forward bias again diode D1 gets forward bias only during whenever we have the positive voltage during the negative voltage the D1 gets reversed bias so that means we have only have the positive voltage which is being then apply through the R3 resistance to the ground protective earth so at this point what is there is that we have VDC which is only you know going up to plus 9 volt plus 8.79 volt coming in and that is nothing but equal to nearly equal to 9 volt because only positive side is only positive polarity is been used or is been activated

due to the presence of D1 diode now because of this at this state B2 it indicates that the EVSC is ready but EV is still not ready so we move from A to B1 where our charger gets plugged in then goes to B2 where the voltage level of PWM remains the same But because of the PWM which is coming over here, the EV detects that frequency and duty cycle and it understood that now the EVSC is ready. So at this place EVSC is ready for charging for energy transfer. Then

comes the next state. now the evs is ready now vehicle has to get ready so then vehicle gets ready by changing the state of s2 switch by controlling this s2 switch the vehicle controller is tells to the EVAC that they are also ready by moving from the off state to the on state where the R2 which is 1.3 kilo ohm gets connected in parallel to this R3 resistance and that's when the circuit will be you know this PWM will be coming in over here plus 12 volt minus 12 volt like this will be coming over here then we have R1 which is nothing but 1000 ohm then going to diode D1 this is diode D1 diode D1 because of diode D1 the negative polarity voltage will cut off and that's when we only have the positive polarity voltage and then after this point we have the R3 which is nothing but 2740 ohm in parallel to that we have R2 which is 1300 ohm and then it is connected to protective earth and at this point we are actually measuring the VLC voltage so the VLC voltage will be nothing but equal to if we do the basic you know resistor divider if we do so what we will get is 2740 in parallel to 1300 ohm divided by 2740 in parallel to 1300 ohm plus 1000 And this multiplied by 12V because negative will not come into picture because of the diode D1.

Diode D1 gets reversed bias. So this we can just do 2740 into 1300 parallel. 2740 parallel 1300 is nothing but 2740 times 1300. 2740 plus 1300. is nothing but 882 near about 882 ohm and that indicates this is nothing but 882 divided by 882 plus 1000 into 12 which gives you value to be nothing but 5.79 volt which is roughly equal to 6 volt so at the control pilot this is control pilot pin

on the EVAC side it will measure the 6 volt and the moment the EVAC comes to know that the 6 volt is coming in at the maximum voltage level of the PWM pulses PWM signals that's when EVAC comes to know that the EV is also ready to accept the charge so that means the moment the vehicle enters into state C2 See we are not talking about C1 state I will discuss. Here at this state it is called as a C2 state. At this state the EVSC is already ready to do the energy transfer by activating its PWM. Now EV is also been ready by changing the state of S2 switch.

Ready for charging by changing the state of S2 switch. And that is being detected by EVSE as EVSE is measuring the voltage level of the PWM. Since the S2 switch status got changed, that's when these 2740 ohm comes in parallel to 1300 ohm. And that is when your voltage level at this

point goes to near about 6 volt, which is 5.79 volt. And that is when the EVSE also know that the EV is ready for charging.

And when EV will change this S2 switch? When EV is ready for charging. So now we have moved from A state where vehicle is not being plugged in to B1 state where vehicle gets plugged in then to B2 state where EVSC is ready by activating the PWM and which is being detected by EV and after detecting that PWM EV will change its state of switch S2 to indicate to EVSC that it is also ready to charge which makes the state of charging to go into the state C2. Now, you will be wondering why C2, why not C1? So, C1 is the state.

EV is ready for charging that means the plus 6 volt is coming over here in the same manner what we have discussed that we have this PWM from the PWM this thing there however in this case what happens is that the EVAC could have got some failure or some error and because of that its PWM gets deactivated and it will connect its S1 switch to plus 12 volt so in this case the plus 12 volt comes here through R1 which is 1000 ohm through the D1 diode to the resistance which is in parallel to each other which is 2740 and 1300 goes into P protective earth and here we are measuring the VDC which is nothing but 5.79 volt same as what we have seen in the previous state so the voltage level since the S1 switch is moved from the oscillator to the plus 12 volt that's when the VDC value will remain be the same So what happens in this case the EV enters into the charging state may be EVSE would have got some error and because of that EVSE quickly tells the EV that it is not ready by changing its switch S1 from the oscillator to the fixed 12V and that's when on the vehicle side it detects the frequency and duty ratio to be 0 to be 00 and that's when it the EV comes to know that okay although I am ready but EVSE is not ready for charging and that's why PWM is deactivated and that's when accordingly EV will change its state if it feels that it has to change the state sometimes it could also happen that EVSE may return back or the that error may go and the EVSE will again activate its PWM and that's when again since EV is ready so the charging will take place So, we go from A to B1 to B2 and then we enter to C2 and if there is some problem, then it can also enter into C1 state.

If there is some problem in EVSE, so EVSE will change this S1 switch from the oscillator to the fixed 12 volt and that is why EVSE will change its status that it is not ready for energy transfer. Now, there is another state which can take place. In this state, what happens is that sometimes while charging the EV, the EV requires a ventilation. So, in this state, what happens is that the

EV will then change the R2 value from 1300 ohm to the 270 ohm. ohm and that's when ev will tell the evse that it requires the ev requires the ventilation especially for evs with vented batteries which emit gases so thus require ventilation it is requested by the ev and evse will then detects it and changes the state if evse does not support ventilation it will not allow charging in d state however it is for

older evs where the vented batteries are used now modern day evs does not require this state mostly it is in the state c so in this case what happens is that you have again the pwm which is coming over here plus 12 volt minus 12 volt pwm is coming over here and from here we have this r1 which is 1000 ohm then we have this diode D1 and then we have R3 which is 2740 ohm in parallel to 270 ohm in place of 1300 ohm it is now 270 ohm and then it is connected to protective work so at this place if we see the VLC because of the diode it's only the positive positive voltage will be appearing so at this point VLC will become nothing but 2740 in parallel to 270 ohm divided by 2740 in parallel to 270 ohm plus 1000 ohm multiplied by 12 volt and this we know that 2740 multiplied by 270 which is divided by 2740 plus 270 it will be somewhere on 246 so that's when we can write 246 by 246 plus 1000 into 12 which is becoming equal to be 37 volt is roughly equal to the 3 volt.

So, this value will be measured by the EVAC controller. It will see the voltage nothing but equal to 3 volt. So, in this case, EV is ready for charging, but it requires ventilation. Since the PWM is activated, the EVAC is ready for energy transfer. So, in this case, both the EV and EVAC both are ready for energy transfer, but EV requires the ventilation.

Then comes the next state, So we went from A to B1 to B2 to C1 or C2 state or D state in case the ventilation is needed. After this what happens at this state the EV both are ready for charging and the contactor gets closed and that's when what happens is that in the L1, L2, L3 and N pin of AC type 2 connector the AC voltage starts appearing. and that actually goes to the AC to DC converter to do the AC to DC conversion and then this is the isolated state and then going to the battery. However, during the operation there could be possibility that this control pilot pin gets short circuited with the protective earth may be because of some external entity or because of loose connections or due to the sudden jerk or sudden removing or closing.

some error could have happened so there is short circuit and that's when the vdc value at this point becomes zero this vdc is the voltage which is measured with respect to protective work so this will become zero and that is when the problems like short circuited of control pilot pin of cp and ppe pin may take place there could be error from the EVSC side some error could have occurred because during the operation of the this thing so this is the state E which is nothing but the state where the short circuit or some fault occurs between the control pilot and protective earth and that's when both the EV and EVSC comes to know that there is some problem and they have to stop do the energy transfer. Then comes another state which is nothing but state F where the VDC voltage is nothing but minus 12 volt and sometimes it may occur because of some error or sometimes the charging station is not available or you can say the EVAC is not available. So this is again the error condition. And previous one is also the communication error conditions.

The state E also arises due to fault in the control pilot and protective earth pins. In this case, it's an error condition or EVAC gets plugged out and the measuring circuit may have some error. Or you can say the EVAC gets plugged out or unavailable. So, this could be one problem. and the state at which the vehicle and EVS are called as the state F so finally when we do the overall charging sequence or you can say when we try to summarize everything so we can have first state A now in state A let us define different states in state A our VDC value is nothing but 12 volt EVSE is measuring the 12 volt it indicates EV is not connected

to EVAC and the resistance between CP and PE pin is not defined resistance between CP and PP pin is R CP PE pin is not defined then comes our next state which is state B1 In state B1, we have VDC nothing but equal to 9V we were getting. VDC which has been measured by the EVSE controller is 9V. And you can say that S1 is still connected to fixed 12V, fixed plus 12V. PWM is deactivated.

So, it indicates that EV is connected and we can say that neither EV or EVSE is ready for energy transfer. and the resistance between CP and PE pin is nothing but 2740 ohm you know you can see in state B1 in state B1 between CP pin this is the control pilot pin between CP and PE pin it is nothing but 2740 ohm resistance which is coming in similarly in state B2 next state is state B2 In state B2, what we are doing is our VDC value is nothing but 9V. Our S1 is connected to oscillator. That's when PWM is activated.

And our EVSE is ready. However, our EV is not ready and S2 is still not connected to, we can just take not connected to R2. and here what we get value is nothing but we will get value is plus 9 volt and in the negative side it is minus 12 volt here it we were just having plus 12 volt because constant is connected to constant thing it is connected to constant thing so it is just the plus 9 volt here on the cpn and protective earth we are getting plus 9 volt and minus 12 volt and we can just write our cpn pe is nothing but equal to 2740 ohm but still S2 is not connected to R2 then comes our state C1 in state C1 we have VDC equal to plus 6 volt S1 is actually you know this is the state when the EV is ready but EVS is not ready so it is connected to fix the 12 volt S2 is on and connected to R2 PWM is deactivated that indicate EV is ready but EVAC is not ready because our PWM is not activated or deactivated

and we are having plus 6V and R, CP and PE is nothing but 8882 Ohm then comes our state C2 where our VDC is nothing but 6V S1 is connected to oscillator S2 is on and connected to R2 PWM is activated This indicate my EVSE is ready and my EV is also ready both are ready and ready to do the energy transfer and here we were getting the PWM to be plus 6 volt and minus 12 volt and R, CP and PE is nothing but same as previous C1 state which is 882 ohm then comes your state D there our VDC is nothing but 3 volt our S1 is connected to oscillator S2 is actually connected to 270 ohm or you can say S2 is off and there could be another switch which is connected to 270 ohm we have represented in that way so you can say that S2 is connected to this one it indicates that EVSC is ready also EV is ready but EV require some kind of ventilation so here we have plus 3 volt and minus 12 volt which comes over here and our CPPE is nothing but having 246 ohm then we have quickly we will write state E as well here we have VDC equal to zero fault condition which has occurred

You can say communication, some communication fault here. We have just 0 volts coming in. There is no PWM which is coming there, and we have now finally a state F. In state F, our VDC is equal to minus 12 volts, which is the error condition. The error condition could be the sudden removal of the EVSE. You can see the EVSE is not available. And here we will not have any PWM; we just have minus 12V. Here in state A, we have plus 12V. In state B1, our PWM will be plus 9V.

Our state B2 is plus 9V minus 12V. In state C1, we have plus 6V. In state C2, our PWM has plus 6 minus 12V. In state D, we have plus 3 minus 12V. In state E, we have 0V.

And in state F, we have minus 12V. This minus 12 volts is still there because our diode D1 does not get turned on. It gets turned on only with the positive voltage. Now, till now, we have seen we are only talking about the voltage levels. So the voltage levels of the PWM move between plus 12 volts and minus 12 volts.

The voltage levels we are only talking about the voltage level of the PWM which indicates whether the EV and EVSC are ready or not. Or primarily we can say that the voltage level tells whether EV is ready for energy transfer or not. And EV comes to know whether EVSC is ready by detecting the duty ratio and the frequency of the PWM. So this is where we will indicate just whether they are ready to do the power transfer or not.

But how much amount of current which the EVSC can provide because in the communication between EVSC and EV it's the EV or you can say the BMS of the EV is the master. That means it's the BMS which tells the onboard charger that you make sure that this much voltage and current should come at the output of the isolated DC-DC converter. To make the decision by the BMS, BMS must also know what could be the maximum value which can be drawn from the EVAC and that is obtained by defining the duty ratio. Till now, we are only talking about the voltage level, but now we will also see what is the meaning of duty ratio. So, duty ratio indicates the maximum current which can be demanded by the BMS of the EV.

And this duty ratio will be defined by the EVAC. This duty ratio is defined by EVAC. because the PWM is generated inside the EVSE is the EVSE controller which tells to the EV that this is the maximum current which I can allow and now EV must demand the current is lower than the maximum value of the current which the EVSE can support how it indicates if the duty ratio is between 0 and 3 percent it indicates there is no current which can be demanded by the EV If it is between 3% to 7%, it indicates that it is the DC charging and there again the high level communication will take place which we will discuss when we discuss about the DC charging. So, between 3% to 7% is the point which is being blocked by the DC charging.

and then if the duty ratio is between seven to eight percent the ev cannot demand the maximum current if the duty ratio is between eight to ten percent it's just the six ampere which can be maximum current which can be demanded by the ev if the duty ratio is between 10 to 85 percent it's 0.6 times of the duty ratio so for example the duty ratio is let's say 20 20 that

indicates my maximum current I_{max} which can be demanded by the vehicle is nothing but 0.6×20 which is nothing but 12 ampere. Similarly, if the duty ratio is between 85 to 96, it is $D - 64 \times 2.5$. If the duty ratio is between 96 and 97, it is the maximum current nothing but equal to 80 ampere which can be demanded by the electric vehicle or demanded by the BMS of the EV. And if the duty ratio is between 97 and 100, the EVSE cannot support the charging and then the BMS is not being allowed to demand any current from the EVSE.

this is how the EVSE tells the EV that this is the maximum current at present EV can draw and it depends upon the temperature different things inside the EVSE which can be told to the EV sometimes because of variable pricing the EVSE can change the that maximum current which they can support when it is demanded by the bms of the ev so the voltage level tells whether the ev is ready the pwm tell whether the evsc is ready the duty ratio tells how much maximum current the evsc can support now if we look overall the waveform how the waveform at the control pilot looks like So if you look very carefully in this particular system, so first it was the plus 12 volt which is appearing. So the charger plug is not connected to the vehicle. Then the charger plug gets connected.

So once the charger plug gets connected, it goes to plus 9 volt. on the positive side pwm is still deactivated so this is the place b1 state is there now after t_1 from there once the charging enters into the b1 state after t_1 after some time the pwm gets activated that is when the charging enters into the b2 state and once it is in b2 state it is the plus 9 volt and minus 12 volt pwm appears across the control pilot And the duty ratio will tell to the vehicle that what is the maximum current which they can demand. After TS_2 on period, S_2 switch is turned on by the EV. The S_2 switch gets turned on inside the vehicle.

As a result of this, if the PWM is activated, vehicle enters into the C2 state or D state. If the R_2 value is actually 270 ohm, then the vehicle demands the ventilation. So, it could be either plus 6 volt or plus 3 volt, but the negative will remain be the minus 12 volt. And then what happens is that now at this point, at this place, we can say vehicle is also ready and EVSC is also ready. So at this point after TAC on the alternating current will start appearing across L1, L2, L3 pins or those power pins and then after T on period the vehicle will then will start drawing current because after contactor gets turned on the BMS of the vehicle will take some time and then it will start drawing current from the AC source.

Now at this point The current demanded by the BMS at this point, this current magnitude must be less than the maximum value of the current which can be supported by EVAC and that EVAC will tell to the EV by the duty ratio of its PWM. So, this value is nothing but 1 kHz, you know the cycle time and this duty ratio will actually tell to the EV that this much is the maximum current which can be demanded and the vehicle must demand the current smaller than that maximum value of current which is this current has to be less than what the maximum value of current which the EVSE can support. After this point what happens is that at this point the EVAC will change its duty ratio and told the EV that this is the maximum current which they can demand and that's when the EV will respond to it and the current demanded by that will get reduced because the duty cycle here gets reduced. And then after certain point, once the vehicle understood that, you know, it gets fully charged, the vehicle will change its S2 switch.

That's when what happens is that the vehicle moves from either C2 or D state to the next state, which is B2 state, where the voltage we are getting is plus 9 volt and PWM is activated. That means EVSE is ready for charging, but the EV is not ready for charging. And then after certain point, the contactors gets open and that's when the alternative voltages which are appearing at the L1, L2, L3 pins will get removed and that's when what happens is that after this point your contactor gets opened and that's when the alternative voltage which was coming was gone to zero and that's when the vehicle will then enter into the state where you know this PW will get deactivated and after this point this Q2A point the charger gets actually plugged out. So this is how the AC charging takes place.

First it goes from A state to B1 state then to B2 state then C2 state and in C2 state when the voltage is either plus 6 volt or 3 volt it's during that time only the EV AC and both EV are ready for charging and the contactor gets closed and that's when you are having alternating voltage appearing at the L1, L2, L3 pins and that's when the using the duty ratio information of the PWM the EVAC tell to EV that this is the maximum current which it can draw and then BMS will do the calculation will look its its lookup table or its algorithms and then decide okay this much maximum current EVAC can support and let me demand this much current which is less than the maximum value of current which the EVSE can support and then the charging will take place and after that once the EVSE cannot support that much current it will change its duty ratio that's when vehicle will come to know okay now I have to demand less current so which is less

than the maximum value of current if the EVAC changes and then after certain period of time when the battery gets fully charged the vehicle S2 switch will get opened up and that's when the charging goes from the C2 DE stage to B2 stage and that's when the EVAC is ready but the vehicle is not ready and then after TAC off the contactor gets open up and that's when your voltage at L1, L2, L3 will no longer have the alternative voltage it will be going to zero and that's when after certain point the PWM gets deactivated and then finally plug is ready to get plugged out and then it gets plugged out and charging state will enter into the state A.

So this is how the AC charging takes place Since the entire power conversion is taking place inside the vehicle We don't have to exchange a lot of information We don't have to exchange the information related to battery to the vehicle Only some key information which has to be exchanged between EV and EVSE Which is being done using the PWM based communication which is also called as a low level communication Now, we will see in the next class how in the DC charging the communication takes place and what are the charging sequences we have in the DC charging because in DC charging the communication is quite complicated because we have to share a lot of information to EVSE since the power conversion is taking place inside the EVSE. So, we will discuss those things in the next class. Thank you very much for patiently listening to this lecture.