CHARGING INFRASTRUCTURE

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Week-11

Lecture-55

Lec 55: DC Charging System (BEVC-DC001)-I

Hello everyone, welcome to lecture number 55 of this NPTEL lecture series on charging infrastructure. Today, we will study the topic related to the DC charging system, particularly corresponding to the DC001 standard, which is also called the Bharat electric vehicle charging standard DC001. So far, we have discussed the CCS2 DC charging systems, where we have understood different charging states A, B, C, D, E, and F as well. We have understood what the proximity pilot does. As we have understood, the proximity pilot is the one which, once detected appropriately, will immobilize the vehicle because once the charger plug gets connected to the vehicle, the vehicle should not move.

So, that's a task primarily done by the proximity pilot pin in the CCS2 charger. Then we have the meaning of the control pilot. What is the—I mean—how the control pilot voltage level, frequency, and duty ratio indicate some critical charging parameters in the case of AC charging. And in the case of DC charging, we have understood that the duty ratio is cut between 3% to 7%. However, the voltage level on the positive side indicates different charging states, whether the EV and EVSE are ready or not.

Then we have seen different charging sequences related to CCS2 charging systems. I mean, one by one, how that process happens. Then we have understood things related to PLC, which is power line communication. We have understood how power line communication takes place in CCS2 charging. In the DC charging system, the power line communication happens over the CP and PE lines. After that, we have seen how the PLC modem gets initialized, logically connected, and once logically connected, the high-level communication takes place over the CCS2 charging systems.

and we have seen in the low level communication which is particularly for AC type 2 charger that low level communication which is PWM based communication which was just to indicate the status of EV and EV AC however in high level communication a lot of parameters are exchanged during the charging system and primarily because The DC chargers have the power conversion unit outside the vehicle. So a lot of information related to batteries, related to charging or related to the charging states have to be shared with the charger unit so that accordingly the electric vehicle supply equipment will respond to it and will put the output at its power pins or you can say DC plus and DC minus pin as per the requirement of the BMS of the vehicle. So that's how you know the CCS to DC charging system takes place. Now let us move ahead and see another charging system which is BEVC DC001.

Now in this thing we have already seen that it has the input which is nothing but three phase AC which is 415 volt line to line and it has the five wire connection three phase wires and one neutral wire and one earth wire which is been there. However, it has the output which supports a maximum of 10kW for 48V system which corresponds to roughly 200A. And it will also be supported for 72 volt up to the 15 kilowatt because it will again make the maximum current going up to 200 ampere. So, for the 48 volt system, it supports up to 10 kilowatt because maximum current can support is nearly 200 ampere. So, for 200 ampere, it can support maximum up to 10 kilowatt.

If the battery voltage is 72 volt, it is roughly supporting the 200 ampere. And this particular standard has been introduced by the Department of Highway Industry Government of India in 2017 and it is one of the initial standard which has been adopted in India. However, this particular charging standard still exists in India and still we have charging stations which have this EVSCs which have BEVCDC001 EVSCs which have been present. And it primarily supports the low voltage

powertrain that means for the three wheelers for the early stage four wheelers for two wheeler system it can support the fast charging of the evs with the low voltage powertrain now in this the communication is actually been derived from 6185-24b which is also been included in ais 138 part 2 and mostly in NXG it is been present it is been included all the communication related aspects like different CAN databases different messages are been included in AIS 138 part 2 NXG and it is been derived from GBT 27930 mostly the application layer part how the messages can be represented what all messages which are been there the can database again there will be several messages which have also been included which is also reasonably specific especially for india and it actually uses the dedicated can channel to do the communication so since in this case as it is a dc charging system we have the power conversion unit placed in the evse so continuous Information has to be shared between EV and EVAC and in this case it has been done using the CAN communication. And it uses the GBT20234.3 connector with the standard 5 meter cable.

And you can see in this charger plug what we have is we have the DC plus line, DC minus line. Obviously this DC plus and DC minus line are the pins through which the actual power is being transferred. So that's why they are quite thicker pins. We have the charging confirmation pin number 1. We have charging confirmation pin number 2 to confirm the plugging of the charger plug into the EV.

And then the actual CAN communication is taking place using the S plus and S minus line. So S plus corresponds to the CAN high line and S minus corresponds to the CAN low line. And it is this S plus and S minus pins through which the actual CAN communication will be taken place. Actually the data is being shared between the EV and EVSE. And it also has the auxiliary plus and auxiliary minus pins basically to power up the auxiliary system for charging primarily the controllers and sensor related aspects and it also has the protective earth.

So, as per the standard document shared by the Ministry of Heavy Industries, Government of India, we see that they mentioned the EVAC has two outputs. And obviously, since we have the DC EVSE, we are actually doing Mode 4 charging. We have already understood the meaning of Mode 4, where we have a dedicated DC EVSE to perform DC charging of the vehicle. Now, in this document, they have defined two types of EVSEs, where the first is Type 1. In Type 1, you can have two outputs.

Output 1 and Output 2. Now, for Output 1, the power is limited to 10 kilowatts for 48 or 72-volt systems, and Output 2 is limited to the 48-volt system with a maximum power rating of 3.3 kilowatts. It is primarily used for two-wheelers with a 48-volt battery pack. They have also defined another type of EVSE, which is Type 2, where they have the Output 1, which provides 10 kilowatts for a 48-volt system and another power rating of 15 kilowatts for a 72-volt battery system. If the battery system is 72 volts, they can use up to 15 kilowatts because the maximum current draw is 200 amperes. If the battery pack is 48 volts, the maximum power it can take is 10 kilowatts. The second output is the same as before, specifically for two-wheelers at 48 volts, with a maximum of 3.3 kilowatts.

So, these are the two types of EVSEs defined in the standard document. They have specifically stated that Output 1 uses a charger plug derived from the GBT20234.3 standard. All the information, such as the dimensions of the pin, the form factor of the charger plug, and the proximity detection registers, must be derived from the GBT20234.3 standard. They have also defined some functional requirements, stating that voltage measurements must be performed such that the variation is within ±0.5%. They have also defined current measurement as ±1 ampere, especially for current levels ≤50 amperes. The sensors used must meet these measuring accuracies. Additionally, they have defined protection against overvoltage. They stated that the EVSE shall reduce the DC output current to less than 5 amperes within 2 seconds to prevent battery overvoltage if the output voltage exceeds the maximum voltage limit for 1 second.

So they have also defined the protection against over voltage which they tell that once the output voltage exceeds the maximum voltage rating of the battery for 1 second then they must reduce the output current value to be less than 5 ampere within the 2 seconds if voltage exceeds the maximum limit of battery voltage and here they have also defined that there will be dedicated communication which will be there between the EV and EVAC which is been done using CAN communication and all the properties related to the digital communication is incorporated in IEC 61851-24 and GBT 27930 which is also been included in AIS 138 part 2 an extra G of that. Then they have also defined that there is a communication between the EVAC and central management system which is done using the OCPP protocol which is open charge point protocol. open charge point protocol so they have also defined that that facility must also be there with the EVSE so that it can facilitate the metering the logging and the maintenance functionality for the EVSE by the charging station service provider

And they have also defined the regulation method which be the combination of constant voltage and constant current control methods. They have also mentioned some of the key characteristics of power conversion unit which is nothing but that overall efficiency must be greater than 92% at nominal power output. And at the same time, they have also mentioned that the power factor which has been there, this is the efficiency, and power factor which is there must be greater than 0.9 during the full load case. So, these are some of the key things they have defined. Further, they have also defined the maximum current

limit is nothing but 200 ampere and we have already discussed what are the voltage levels and the power levels which can be supported by this particular charging system similarly they have also defined that the tolerances for the regulation the voltage and current regulation at the output at the output what they have mentioned is that the tolerances will be plus minus 2.5 ampere for the current level less than 50 ampere and plus minus 5 percent for the current level greater than 50 ampere and this is the case when you are at constant current charging Similarly, they have also defined the tolerance level when the system is in the constant voltage charging. So, constant voltage charging CV mode. In the CV mode, they have defined that the voltage tolerance must be maximum 2% for the maximum rated voltage of EVSE.

So that has to be there. So these are some of the key pieces of information which will be useful for us while going ahead and discussing BEVC DC001. However, one can go and see the details of that using the document which has been shared by the Ministry of Heavy Industry, Government of India. In that, they have defined each and everything, but here I am only including some of the key information which will help us in understanding other aspects of this charging system. Further, in this particular charging system, as we have mentioned, the digital communication happens over the control area network, and it uses the dedicated CAN bus lines, that means CAN high and CAN low lines.

So, for the CAN bus lines, they have defined that it uses shielded twisted pair wires with a termination resistance of 120 ohms. Now, that's a dedicated communication channel between the EV and EVAC we are talking about. That means between the vehicle and the charger which is being used to charge the vehicle. Similarly, the proximity detection is done via the charging confirmation pins, which actually provide a simple hardware-based confirmation indicating that the physical connection is being done, and it also ensures the locking of the charger plug into the vehicle. This is actually done using a simple register device circuit, so once the confirmation of the charging plug is done, the charger plug gets locked into the vehicle inlet connector, and after that, the digital communication starts. In the digital communication, BEVC GC001 is derived from GBT27930, which is primarily the GBT27930-2015 standard. In that particular thing, it actually defines the rules for implementing the physical layer, data link layer, and specifically the application layer. Primarily, the physical layer and data link layer are derived from the SAEJ1939 standard, which is also incorporated in GBT27930 and BEVCDC001. So here, the physical layer defines the termination conditions, the voltage levels of the signals, the differential signaling, and the speed with which the signaling can be done. While the data link layer, which is there in SAEJ1939 and also incorporated in GBT27930, defines the addressing for the communication nodes, which is nothing but the BMS of the EV and the charger controller.

while it also indicates what will be the can data frame formats how the can data frame has to be arranged how the messages has to be arranged now in this case the application layer which is being taken from the gbt 2793 hyphen 2015 it actually defines the representation of the parameters and their parameter group numbers so it includes all the messages and in the messages what all the different data units which are been there the parameter corresponds to this the resolution corresponds to this and their specific parameter group numbers for easy identification of the messages which are been received and they also defines the canned data frames which are been transmitted which is in the form of protocol data unit format which is been derived from the gbt 27930 And using this protocol data unit format, the controller is able to identify the messages and then can decide whether that message belongs to them or not. And in this particular thing, the speed with which it can do communication is 250 kbps and it actually uses CAN 2.0b protocol which is nothing but having the 29-bit identifier. This we will study, which we will understand once we discuss the CAN communication.

So they use this CAN 2.0b based data frame, which has nothing but 29-bit identifier. So in summary, what we can see is that here we only have three layers. We have the physical layer which is been incorporated from SEJ1939 or ISO 11898 which is been included in the GBT27930 and which is been again derived in BEVCDC001. Then we have data link layer which is also taken from the SEJ1939 which actually defines the addresses for the communicating node and also the data frame with which the CAN messages has to be sent from one side to another side. And finally the application layer has been derived from

GBT27930-2015 and some of the things have been added in those messages so that it can be used in particularly in Indian region.

now up till this point we have seen that it uses the can communication now in this communication we only have two participants at a time that means we have the charger on one side and we have the bms on the vehicle side that means whenever the communication is taking place between ev and evac it is taking place between the charger controller on one side and the BMS on the vehicle side and they have the fixed addresses since only two communicating nodes are there they have already defined the fixed addresses which is 86 in decimal number and 56 in hexadecimal number for charger and 244 in decimal number and F4 in hexadecimal number for the BMS So, the moment the vehicle says that they are BEVC DC001 compliant, the BMS must have the address of 244 and the moment the charger says that they are BEVC DC001 compliant, then they must have the address which is nothing but 86. This is the dedicated communication channel which is been there between the charger and the EV while on the other hand if we see in the vehicle we also have the other CAN communication network which is been there and there is no direct connection to other CAN systems which is there in the vehicle such as powertrain CAN or the CAN bus which is been there between the different controllers inside the vehicle. so this is a dedicated communication channel which is there only between the BMS and between the charger and using this particular CAN channel the BMS and the charger controller communicates the information within itself generally the communication is done over the CAN high and CAN low line the two

CAN bus lines which are been there using the differential signaling and with a speed of 250 kbps and here they use the CAN 2.0b message format that means they have the 29-bit identifier so since we are using the CAN communication here so let us first deep dive and understand what is the CAN communication how it is useful why it has been adopted in vehicle systems and why it is being incorporated in this particular system since Here if you see one more thing that there is no in between layers. Here we only have just the three layers of the open source interconnection layer system. However, the most important thing is it's the CAN communication over which the data are being transmitted between the charger and the EAM. So, let us also understand and let us also build our understanding related to CAN communication briefly.

Again, we are not going too deep into the concepts of CAN communication, but some portion we will understand and that will help us to determine how the CAN communication will be taking place in the DC001 charging system. So, in the CAN communication, the full form of the CAN communication is nothing but called as a controlled area network. Now this control area network is basically a communication network between the devices. So between the devices having controllers you can say or having some controller or you can say that let's say in your vehicle for example in your vehicle you have several systems several intelligent systems are there in your vehicle you have infotainment system you have anti-braking systems you have electronic control unit. You have several sensor systems you have in a vehicle.

You have HVAC system. Then you have powertrain system. So all those systems will have the individual controllers. And those controllers will be actually communicating with each other via a network which is nothing but CAN communication network. In 1991 SAE conference the Bosch has introduced this CAN communication systems that will be taken up by all the manufacturers around the world to do the communication within the different controllers in the vehicle.

That will help the different OEMs and different companies to share the information over the single communication channel because once they follow the CAN communication protocol, those controllers can be easily interpreted from one vehicle to another. They can be connected once they have the CAN communication. Now, the CAN communication is done with the network comprising several nodes. There are more than one node; there could be 10 controllers communicating with each other, or there could be 100 controllers communicating with each other. It is a message-based protocol. What I mean by a message-based protocol is that in the message itself, in the data itself, the priority of the messages will be defined. Since the priority of the message is defined in the data itself, these CAN networks or CAN communication networks can be easily extended and are very flexible. One can easily add other nodes or remove nodes in the future just by doing software changes. One can easily add or remove any nodes in the future. So that's why it is a message-based protocol.

It is just the messages that are defining the priority. It's just the message that will define which node will be sending and which other nodes will be the receiving nodes. It is basically a two-wire system defined by CAN high and CAN low channels. And it is a serial bus communication, which means the messages are sent one by one. So, if let's say one CAN message has 100 bits, it will go one by one, each bit will be transmitted, and it is just via a two-wire network, which is CAN high and CAN low. Originally, CAN was developed to reduce cable wiring so that separate control units inside the vehicle could communicate with just a single pair of wires. They did not need to send several data among different controllers. Now, it is a message-based protocol that also allows for several features to be added just via software alone.

So, no need to change the hardware; you just have to program it in a new manner such that you can increase or reduce the amount of data being shared among different units. It has originally been widely used in the automotive industry, avionics industry, medical industries, medical systems, and escalators. How does it reduce the wiring? Let us see one example. Let us say you have an ECU unit.

You have a propulsion unit. And you have, let us say, anti-breaking system. It helps in avoiding the sliding of the vehicle whenever sudden brakes are being applied. And let's say you also have an infotainment system. So four systems you have.

Infotainment system means things related to entertainment as well as information comes under infotainment system. Now, in this case, what happens is that you have different controllers which has been there employing in your vehicle. And let us say you have a sensor. Let us say you have a speed sensor which has been placed on the wheels or near to the wheels to understand what is the speed of the vehicle. And since all the systems needed the information related to speed, let us say there is no CAN communication.

This speed sensor has to give signal to ECU. The separate wire should run to give indication to proportional system. The separate wire should run and indicate the speed to the anti-braking systems in order to take the required action to avoid sliding of the vehicle. Then the same thing two wire will go into the infotainment system to showcase what is the vehicle current speed in the dashboard or let's say it can be used for future purposes storing it somewhere from the same speed sensor since we have four controllers you are sending nearly eight copper wires and this issue could be at one point in the vehicle proportional system will be at some other place in the vehicle abs will be some other place in the vehicle infotainment system will be at near to the driver's seat

So, there are several things which are there and they are fully distributed in a vehicle and 8 wire has to run inside the vehicle and take the information and inform all the different controller what is the speed of the vehicle. However, in case of CAN communication, let us take we have a CAN communication. So, same units we have let us say ECU, we have proportional system. we have ABS we have infotainment system again they are at different places in the vehicle however they are now getting connected to the CAN communication which has the CAN high line and CAN low line so this ECU is connected this proportional system is connected this ABS is connected this infotainment system is connected you have one CAN high CAN low wire which is running around the vehicle only two wire system and let's say you have a speed sensor through the speed sensor the speed sensor will give through the CAN trans receiver in the CAN trans receiver it will then connect it to the CAN bus so in this case if you look around

you have only two wires which is running all throughout the vehicle instead of eight wires which were running when there was no CAN channel. Here we have a CAN channel and because of CAN channel what happens is that whenever the speed information has to be sent the speed controller in the speed sensor will through the CAN transceiver will put in the speed information on the CAN bus and then all the four nodes which are connected on to the CAN bus will receive that particular information at one go the moment the messages are put in on the CAN bus. and that is when you can avoid having the so many copper wire running throughout the vehicle you just require two copper wire which is CAN high and CAN low which will be running in the entire vehicle and will be connected to different nodes and that's when easily one node can be communicating to any node which can be placed at different place in the vehicle just by putting the message into the CAN channel which will reach to the other node and the other node will then use that data and perform certain functionality. So that is where you have reduced from 8 wires to just 2 wire system and it is case with just one sensor and just 4 controllers we have taken.

In vehicle you have hundreds of controllers, you have hundreds of sensors to make sure the vehicle perform appropriately. So there will be so many wires which will be running around the vehicle if you do not have used the CAN system. communication however with the CAN communication we have now just two copper wire which will running inside the vehicle and all the informations can be exchanged with different controllers which are connected over the CAN bus now this is where it reduces the cable wiring it reduces the copper component onto the vehicle and that's when the weight the cost of the overall system get reduced and that is why the CAN communication got adopted across all the automotive OEMs to actually communicate between different controllers now let us see what are the benefits and from the benefit we will then try to see different data frames related to CAN communication so the first benefit is the low cost obviously the controller unit communicate with just a single CAN interface reducing the copper content in the vehicle It has the centralized communication that means from one controller you can centrally diagnose and configure all the controller unit in the vehicle.

It is the robust communication system because the CAN signals are robust against the electromagnetic interferences or you can say from the nearby circuit and it is primarily because it uses a differential signaling and twisted pair cable. So, that is why using the twisted pair cable it reduces the electromagnetic interference to the circuit and because of the differential signal it can also avoid the electromagnetic interferences from the nearby circuit that means it has now become electromagnetic compatible in place where you have the huge amount of electromagnetic interferences. Then comes the efficient. It is highly efficient because in the CAN messages itself, the priorities are defined and along with the data, you have the message ID and that message ID defines the priority of the message and the top priority always gets the access to the CAN bus. That means the message which is actually having the top priority is actually owning that CAN bus to perform certain things.

Then we have the error compatibility. So CAN data frame has cycling redundancy check, which is to perform different error check onto each message frame, which is being received from the source to the receiver. And an error frame is actually transmitted to indicate the occurrence of an error and frames with error can be discarded by all the nodes. So in the CAN communication, you have the CRC, which is the cycling redundancy check code, which is incorporated in the CAN data frame. And that will help to avoid having the error or in case if their errors are persisting, it will tell to the other node that error is there.

now it is very flexible the can communication is very flexible because each can connected controller receives all the transmitted message for example in this canvas assume in this canvas there are node 1 node 2 node 3 are connected so let's say one of the node is a sender or is a transmitter so whenever it transmit the message it goes into the canvas And each node which is receiving that message from the sender, it will receive that particular message and decides its relevance. And how it decides the relevance? By comparing the message frame which is receiving, it has the message ID. By comparing the message ID in the frame using the CAN database,

of itself so every node will have the can database it will have can database it will have can database it will have can database and they will compare with that can database and they will understand if the message is correct message they will receive it if the message is not correct it they will just ignore it so the message will get received they will check the message with the can database if it is within the database it is okay if they will take it the message is not within the database they will reject the message And this will help us in easy modification or inclusion of additional nodes in future. Again, the speed, it supports the data rate of 1 Mbps up to 40 meter cable and 125 kbps up to 100 meter distance between the two nodes. And again, it is a multi-master configuration. So, all the nodes which are connected through the CAN bus, anyone could be master, anyone could be slave.

It depends upon the message which are being put on the CAN bus. The node which is actually putting the message having the highest priority will win the bus and it will be called as a sender node. And while the other nodes will be the receiver node and they will be receiving the message which is being put by the master node. And that sender node or you can say the master node will keep on changing depending upon the message id or the priority of that message which has been put on the CAN bus.

So, these are the some of the benefits of CAN communication. We will study more things related to CAN communication like the electrical properties, the CAN data frame and how the CAN communication can be used to do the communication between the EV and EVAC in case of DC001 which is actually following nothing but GBT27930-2015 standard. We will see those things in the next class. Thank you very much for patience listening to this lecture and we will continue our discussion in the next class.