

CHARGING INFRASTRUCTURE

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Week-12

Lecture-60

Lec 60: Charging Stations-III

Hello everyone, welcome to lecture number 60 of this NPT lecture series on charging infrastructure. Today, we will continue our discussion on charging stations and different methods of communication, which we covered in the last lecture. So, we have discussed what components are present in the charging stations. We know there is a central management system implemented by the charging station service provider, then we have different EVSEs, which you can say are the various chargers placed in a charging station.

They communicate with the central management system using a protocol defined by OCPP, and the message exchange is also defined by the OCPP protocol. This helps the charging station service provider ensure interoperability between different EVSEs from various manufacturers and the central management system, which may be provided by another company. So, with that, interoperability is maintained, and data standardization is achieved. Simplicity in implementation is ensured. Scalability is made possible.

For this purpose, the OCPP protocol has been adopted worldwide for communication between EVSEs and the central management system. We have also seen the implementation of OCPP. Here, we have seen two types of OCPP implementation. One is SOAP-based OCPP implementation, and the second is JSON-based OCPP implementation. SOAP uses XML-based data representation, while JSON itself is a data representation, and they use WebSocket-based communication for interaction between these.

CMS and the EVSE now this XML based data representation are quite heavy duty communication due to its architecture while the JSON based implementation which is the data

representation uses web socket connection or HTTP can be also be used And these JSON are compact, lightweight and that's when it can be implemented faster as a result of which JSON is being adopted across various manufacturers. This is heavy duty implementation. This is lightweight. So because it is lightweight, they are quite faster and easy implementable because the messages are human readable and can be easily understood by the user.

And we have seen some of the examples of OCPP 1.6J indicate the JSON message formats. It has three kinds of messages. You have call, which is like a request. You have call result, which is like a response to that request. And then you have the call error in case if there are error.

then it need to be intimidated there are some errors which has happened so these are the three different kinds of messages which are being done all the three messages are of given format it has the message type id which indicate what kind of messages are there it has the message id that particular message has a unique id you can say call id as well as message id this is been done for the receiver to understand what message id it has to respond to and once the receiver respond to the corresponding message having given a message id so it has to respond it with having the same message id so that means call result will have the same message id which is again the unique message id and then you have the call error which includes error codes message id message type number so it has the message type number the first part is message type number then message id or you can say message unique id now this message id for every call messages are unique it should not be same as that of the previous call messages otherwise it will not communicate or they it will report an error so it has to be unique for that message type number for call is two for call result is three for call error is four so different message type number is there now why message type number it is for the receiver to understand what kind of message it is being sent then after message id you have action Again, this action is like the name of the action which has to be performed.

Generally, for call messages, the actions have been defined. For call results, generally those actions need not to be there. then you have the payload payload is like the data part of the message that carries the specific information which is been exchanged between the EVAC or charge point and the central management system or central system via messages in call result you have message type number you have message ID which is same as that of the call message and then you have the payload for that because action is not necessary to be reported to so that

can be there in call error we have message type number we have message id which is the same message id as that of the call message because the receiver once it receives the message id it will decide whether to respond to that message or whether to report an error to the sender so whenever it has to report an error it has to include the number corresponding to the same call message which is being received from the sender then after message id you have error codes you have error description and then you have the error details so this has to be included in that particular message whenever that particular kind of message is being sent we can see one example in last class also we have seen one example where we will define for the boot notification

boot notification request we can say now in the boot notification request message or you can say call message so it will start from message type number which is which is been defined as a 2 then you have the unique message ID which is again maximum 36 character string we can let's say define this is the message type ID this is the you can say message ID unique ID message unique ID and again this has to be maximum 36 character here we have defined just 8 characters for our simplicity implementation then comes your action so again the action is nothing but the name of the action which you would like to do after sending this message so that action is nothing but let's say if it is a boot notification we will define it's a boot notification and then after defining this action so this is the nothing but the action field of the call message you can say this is a call message and then after boot notification you have to define the payload so In this payload which is nothing but the data part of the message it has specific fields defined against that the data has to be sent.

Basically it is the data content sent inside the messages. As we have discussed in the last class for boot notification request message what are the fields similarly for every messages too the payload is being defined with specific fields which you can obtain by going through the ocpp 1.6d document or other version documents so in that we have let us say first required field is nothing but the charge point vendor now charge point indicates the evac vendor so you can just define that vendor name let's say you know vendor x we can say then we have the second required field which has to be sent with this message is nothing but your charge point model now this too has to be sent so let's say if we define you know single charger anything you can define this you can write down you can close the payloads this is nothing but your payload and that's

when you can close down your message so this is one way by which you will send the boot notification request now to respond to this if after once the receiver receives this call they will respond to that call so let us define boot notification confirmation

confirm if you see so it is nothing but a call result a message nothing but a kind of a call result so again since it is a call result or it is a response to that request about notification confirmation or you can say a response to that request so we have to go and implement the call result message we have to see the call result message format now it is started with the message type id which is 3 since it is a response or you can say call result message so it is a message type id then again since it is a response to that particular request so we must include the message id which is a unique id for the call message or you can say for the request message we must write down the same message id that's how when this message reaches to vendor which has initiated the call message they will come to know that it is the response to that particular message so again so the message id will be the same message id which was there for the call message so this is a message id same as call message id it is necessary one has to keep the same message id and then after that since here it is a response to a call message which was both notifications so we did not to write any action we have to just define the payload which include the data which has to be sent by the receiver to the sender which has initiated the both notification request so we will only write the required field in that payload so that is nothing but first is our status now this status is accepted

now if it is not accepted what thing to be given that particular thing you can see from the ocpp document i am just giving you the thing for this particular message and then comes here the next field which is the required field in the payload which is the current time it is a case sensitive so we should write current time now that current time it is the date time format so let's say it's 2025 assume it's the August month so it is 08 assume it is the 15th of August so it is 15 8 2025 and then followed by the time so this date and then you can define the time assume it is morning 10 a.m so it is 10 10 minutes seconds assume it is 30 seconds and then we have let's say 4 second here at that time so this is the next field we have sent in the payload and then the last field is nothing but your heartbeat interval now this heartbeat interval you can give any let us give after every 10 seconds there should be some heartbeat signal to be coming in so we will define let's say 10 or you can just define 100 as well so with that the payload gets over and that's when we

can close down this message so once you receive the call messages everything is fine so you will send this particular message everything is not fine the status is not accepted then you have to write not accepted and So, these are the messages which has to be sent between the CMS and the EVSEs and whenever you are saying that my EVSE is compliant to this OCPP and the CMS is compliant to OCPP, they have to follow this procedure.

message format while defining the messages and scheduling of those messages all those things will be defined accordingly now this you can use different server frameworks already available you can use python languages to define these messages and the structuring of the messages can be defined in order to do different functionalities in the messages So this is how one can implement the OCPP and one can easily go through OCPP document and can able to understand what all different messages are there, what all the payload fields are there which can be sent, what are required fields that you can define and then they can implement those messages step by step in their controllers which are actually doing the communications between CMS and the EDS. now we have discussed only one message which is a boot notification request message the other messages like start transaction message stop transaction message so that message has to be defined in this particular format only and they need to be structured such that after boot notification the configuration key has to be signed then several steps has to be followed before going to start transition and then after start transition before ending the session the logging all those things step by step that procedure has to be structured while developing this communication between the CMS and the EAC now let us discuss the OCPP profile so what I mean by OCPP profile OCPP profiles are the one which will define what different things one has to do once they incorporate that OCPP profile so one can introduce different profiles so for example one profile could be core certification profile One profile could be security profile, one profile could be smart charging profile, different profiles can be incorporated in that OCPP implementation.

However, the core certification profile must be present, which includes basic authentication, different security event notifications, booting, configuring, resetting of charging stations, stop transaction, local start transaction, check transaction status, remote start, and stop transaction. Remote unlock connector, remote trigger, change availability, charging station EVSE connector, clock-aligned meters, sample meter values, retrieve log information, get clear customer

information, secure firmware updates, clear authorization data in cache. So, the moment you say core certification profile, in the core certification profile, the basic authentication has to be there. So, you need to define that authentication message and write it down. Then, in that certification, you will have remote start and stop.

So, remote start and stop request, remote start and stop confirmation or response message, you have to structure while doing the implementation. Similarly, there are other profiles one can include, advanced feature profiles one can include, different profiles one can make by including different messages and can perform required functionality. Now, that was the thing we were discussing for OCPP 1.6J. Now, in OCPP 2.0.1, they come up with new security features, they come up with the provision for ISO 15118 implementation for vehicle-to-grid functionality. They come up with features that make it easily scalable, so all those things are there. However, this 2.0.1 is actually dividing the different functionalities of this communication between the CMS and the EVSE into 16 functional blocks, and the messages will be defined for implementing those 16 functional blocks. So for example, one functional block is the security functional block. You have a provisioning functional block, which includes boot notifications and configuration of the EVSE, so that will be there in provisioning. Then you have authorization, then you have local authorization list management.

If the user is already registered, that management is there. The different transactions which are done, remote control of EVSEs are there. Availability: CMS can change the availability of the charging station, so once that availability is changed, one can see in their apps that chargers are busy, and accordingly, scheduling can be done. Then reservation: that function block will enable the reservation of the charging station beforehand. Different tariffs and cost implementation different metering information, like what are the voltage level, current level, for basically maintaining the EVSEs. One can implement smart charging features, basically optimally utilizing the EVSEs such that EV demand can be intelligently managed centrally, so that features can be provided. For example, in a charging station, let's say if there are 10 EVs which are there to charge from those EVSEs, but if let's say the grid is heavily loaded, so the intelligent features can be implemented where the proper scheduling of those EVs which are coming in can be done, such that overcrowding or the difficulty for the user can be avoided. Then you have firmware management, where one can easily update the firmwares which are there. Certificate

management: that means whenever the communication gets set up, so certificates are being exchanged between the EVAC and CMS, that management has been done. Diagnostic: what display message has to be there in the human-machine interface of the EVACs and also in the app, that functionality has been there. Then the data transfer.

in this enables you know actually the exchange of data between the cms and the evse basically to perform different customized functionalities like different services one can provide for the user different charging station operator can provide then by direct power transfer functionality that means from the vehicle to the grid then you have distributed energy resource control so let's say if in the charging station you have some renewable energy sources also so you can use that and you can control that via using this ocpp 2.0.1 protocol and also they have defined battery swapping functionality block as well right that means whenever you have battery swapping stations what all messages need to be exchanged between the battery swapping point to the center management system So all those different functionalities have been incorporated and to implement each functionality there are different messages which has to be implemented which has to be structured accordingly while doing the implementation of this OCPV protocol. So as of now what we have discussed we have discussed how the EVACs different EVACs which are present in the charging station 1 EVAC 2 EVAC EVSE 3 EVSE 4 and this you have central management system they will be communicating with different EVSEs how they are communicating using what protocols what kind of messages are being exchanged between these all those things we have seen and they are done following this OCPP protocols

Now, in this EVAC, if you look very carefully, we have not discussed how the power distributions will be taking place. So, let us discuss that how the power distributions will be taking place. Now, broadly, if you look very carefully, we have different chargers. We have home chargers, which are generally AC chargers. AC chargers, you can say.

And whenever we have AC chargers, we have onboard chargers as well with us. And then we have the DC fast chargers. having power level going more than 25 kilowatt and they are also the off-board charger because power conversion is placed outside the ev and then you have extreme fast chargers you can say extreme fast charger now this extreme fast charger is things greater than 350 kilowatt and all with a single EVSE or you can say single charger supporting that 350 kilowatt so in all the things if you look very carefully generally these things can be done

by using our low voltage ac distribution system either using single phase distribution or a three phase with 400 or 440 volt ac distribution can be done

However, for the fast charger it is again it is the low voltage AC distribution three phase low voltage AC distribution line which is there which will be sent to the DC fast charger for doing the conversion from AC to DC. And then you have extreme fast chargers where generally they could be done using medium voltage AC distribution from medium voltage AC distribution they can be done. using three-phase medium voltage ac distribution it can be done now whenever you are doing this extreme fast charger or very high power charging will be taking place you will be needing a dedicated transformer you will require a dedicated switch gear to support that particular charging station so for example if a charging station has extreme fast charger or you can say very high power dc chargers so directly the mvac which is 11 kb which will be directly coming to the charging station and then you will provide the dedicated transformer and switch gear to take out the power and give it to that particular different supply equipment which are being placed in the charging station.

Now, if you look very carefully in medium voltage AC distribution system, generally, these are very high voltages. So, we require either the multi-level converters or you can say the stacked kind of converters because the voltage levels are higher. So, you require the switches which can able to block those high voltages. So, in that case, one modular approach one can take. however there are different approaches one can take one can take the low frequency AC transformer and step it down and then convert it to the low voltage AC and then give it to the different EVAC but however in that particular case cable thickness will go up and that's when the cost becomes higher and also the implementation becomes quite difficult

So, one can take modular approach where one can take three base connection and can give AC to DC or using the rectifier one can use and then can generate a DC and then one can take DC to AC high frequency AC and then having the isolation. and then followed by AC to DC conversion and that's when one can step it down using this transformer and that's when one can actually come up with the your DC plus and DC minus low voltage DC line low voltage DC distribution you can one can create similarly you one can connect one can have three phase module and one can take this is let's say this is the A phase one can take the B phase form B phase one can again make the same module modular approach one can take generating the DC

then DC to AC followed by high frequency transformer one can operate this at mostly if IGBTs are there it will be somewhere in 5 to 10 kilohertz range if it is SiCs it will go up to 10 to 50 kilohertz range as well and then again this is also connected to DC bus and then finally this will go and connect here from here similarly one can take the C phase and then again put the AC to DC

and one can do that since this voltage is so high that one could not able to get the devices one can connect so many modules in series and that's when it goes up and then this module it will come from here three things will come out and that's when it will get sorted so with this particular approach what you can get is for a phase if you look very carefully a phase you have this converter and then you have this different three phase module there are so many modules like this this module there could be several modules like this in so many are connected in series and this will go from a phase terminal and neutral terminal and this is again will go and connect it to the dc bus so this is the modular approach one can take and then can directly connect this to this mvac line and using this high frequency transformer one can implement modularity approach and can able to achieve the extreme fast charger at very high power so these are all modules one can make and step by step the modules can be connected in series to take care of that medium voltage ac distribution and per phase wise they can connect it into the series fashion and a lot of researchers are working on this to come up with the different optimization scheme to optimally design this high frequency transformer optimally choose those switches such that the power losses and those things can be reduced and they can be modular and with modularity you can also do a lot of redundant operations as well in case something fails out fault right through schemes can also be implemented now with this approach one can do several things one can easily control output

a customer side voltage levels customer side demand one can easily control the grid side requirements like power factor and power quality one can maintain at the same time one can also facilitate the bi-directional power functionality from this dc bus to the ac butt and now from this dc bus which has been generated this one so we have a dc minus 9 DC minus line and from the DC minus line one can have the small DC-DC converters connected to the EV and several DC-DC converters can be connected and they can be connected to EVs like that several things can be there. and evs can be there and this is way one can create that the low voltage dc line

and from the dc line individually one can have dc dc converter and then connect it to the ev and this dcc converter controls the voltage and current which the ev demands at the charger output so this is one modular approach one can follow there could be several other modular approaches which could be there so high frequency transformer provides the isolation which is a galvanic isolation which is one of the requirement between the EV and the grid and at the same time it is the power dense solution because our transformer is actually seeing the high frequency AC so DC-DC creates a DC link then DC-AC will convert the DC link into the high frequency AC which is seen by the transformer.

Because of the transformer action at the output secondary, you will have the high frequency AC, which gets converted into DC and then connected to the low voltage DC bus. And from the low voltage DC bus, individual EVACs will have the DC-DC converters. So, you can have the low voltage distribution line and then you can have a dedicated DC-DC converter, which will be connected to the ev and that's when ev can be charged and this can be one of the modular approaches so like this one can also look for different multi-level based ac dc converters then multi-level based high frequency dc ac converters then high frequency ac dc converters and that's when one can do several modular approaches while implementing the extreme fast charger for the ev charging However it requires a dedicated transformer that's when directly from the MVAC grid which is coming it has a dedicated transformer unit.

In case if this is not there then one has to provide the low frequency transformer such a big transformer. So imagine if you have 350 kilowatt per charger and let's say if you have 10 chargers you will have 3.5 megawatt peak power demand and that's when the transformer size will be huge. So, one need to see the modular approach while implementing extreme fast charger having more than 350 kW power level at the output it can support. This is a scenario which we have at present where we have this kind of different charging systems which are available. This home charger, AC charger, on-board charger does not require a dedicated transformer.

However, this DC fast charger may require a simplicity in that way it is like you have three-phase charger. 400 volt line coming in then you can provide the low frequency transformer and then from the low frequency transformer you can directly take it to the power conversion unit of EVAC or you can say EVAC1 and then it is to the EV similarly you can take EVAC2

power conversion unit we know what is power conversion unit our AC-DC and then DC-DC then we have another power converter EV-AC3 to EV this could be a standard DC fast charging station power architecture and this is the power architecture of extreme fast charging stations or you can say extreme fast charging stations you can say so these are the things which are there in both the cases charging station require dedicated transformers in this case it is a low frequency transformer in this case it is the high frequency transformer so this is nothing but this particular thing and this is nothing but the power architecture for this particular extreme fast charging station now if you look very carefully as of now charging station is been developed they are taking power directly from the grid and that grid could be obtained either from thermal power stations or some renewable energy based power stations either solar power stations or using wind power stations but majority if you look in this case and in this one they are taking directly power from the grid

However, in case of extreme fast charging stations or in case of DC fast charging stations, one can easily integrate the renewable energy sources and one can make sure that one has the sustainable solution towards that charging system. So, one of the example of the power architecture of the, you know, Power architecture of renewable energy integration with the charging station. So, here one example is using the AC coupling. So, power architecture of renewable energy integration using AC coupling.

Now, in this thing, what we generally do is From the MVAC grid, it could be an 11 kV three-phase grid. We are providing the low-frequency transformer; however, this transformer becomes very bulky, so this one needs to be seen. Then, from here, they will generate the low-voltage AC distribution, which could be a 400-volt three-phase AC distribution. They can generate and Then, what one can do is use different energy storage. For example, one can implement this energy storage using batteries, one can use a fuel cell stack, or anything else. One can also integrate PV panels or wind power stations. However, from a windmill, one can create AC to DC, and then from DC to AC, and then connect. So, one can integrate wind power, wind power, you know, battery power and one can also integrate solar power as well. So, every renewable energy storage will have this dedicated power conversion, which converts the output of that renewable energy source to the required output, which can be connected to the

low-voltage AC distribution system. Then, from this low-voltage distribution system, one can do it for different EVACs. One can

let's say EVSC1, EVSC2, which is there. Again, this is I'm talking about the power conversion unit because we are only talking about power architecture. Again, either it could be battery power or it could be a green hydrogen-based fuel cell. That thing one can say. So, with this thing, different EVSCs can be integrated. Now, one can also do the bi-directional functionality of this bi-directional functionality of this EVSC power conversion unit. So, one can use EV effectively as the energy resource and can create the microgrid and can support this low-voltage AC distribution bus and can support some of the different loads of the charging station as well. So, basically, one can provide the back-to-back power flow through that. Similarly, since we have the battery power, we can also, with this particular approach, support the islanding mode. Let's say the grid is not there. One can easily island this particular charging station, and that's when the grid is not there. The EV can be charged because we have the battery sources that one can do in islanding mode.

One can also do standalone mode. In case we have good wind power, we can just eliminate this grid and we can still supply power to the vehicle. Similarly, in the daytime, one can use this power from the solar panels as well. Similarly, one can use this power from the solar panel and can charge the battery for providing the support to charge the vehicle in the nighttime, and that's when we reduce the loading from the conventional grid which is coming over here. So, this is one way by which the low-voltage distribution bus one can provide and connect different renewable energy sources or different energy storage with these low-voltage AC distribution via the required power conversion unit or required AC-DC or DC-AC converters. So, this is the one configuration one can integrate. So, with this, the charging station service provider.

can also support grid because this different distributed energy resources can also support reactive power and the active power or you can say real power to support the peak load demand since they are supporting the reactive power and the real power one can do the voltage control one can provide the frequency control and one can also do the optimal scheduling of these different energy resources such that optimally we can use them and ensure the power distribution is quite efficient so they can provide different ancillary services as well using this thing and this is possible only when they support both the reactive and real power because if

these are bidirectional in nature they can support the reactive power as well by doing the appropriate controlling of this individual power converters and that's when charging station service provider can also provide this functionality as well that means integration of this renewable energy can also provide different sensory services as well like voltage control frequency control and optimal scheduling of this charging stations or energy resources then comes another type of coupling again it's a power architecture coupling Again a power architecture where you can integrate the PV, you can integrate the energy storage.

Most of the time energy storage is basically a DC energy storage. So you can have the MVAC grid at 11 kV or more than 11 kV. three phase then one can provide the low frequency transformer and then low frequency transformer will convert into the low voltage AC and then from this one can provide the AC DC converter and then create the DC distribution and since most of our renewable energy sources are DC voltage sources so we can just have DC DC converter we can actually connect to the DC bus and then on the power conversion unit of the different EVACs also we can have just the dc dc converter so if you look very carefully here we have the ecac at the integration of different renewable energy storage systems and acdc for different ebcs we have at the front end by just doing the dc distribution we can eliminate eliminate different different

AC-DC converters and that's when we can actually reuse our power component in the charging station having integrated the renewable energy sources and energy storage systems. So we can say that this is the power architecture of integrating renewables and energy sources. storage system using DC coupling so one can do that way as well and again you can make this one as a bi-directional in nature so in this way you can provide the optimal loading of different EVSEs can be provided and that's when one can implement different features since here we have a low frequency transformer which are bulkier in size bulkier voluminous in size because we have already discussed in our course that the low frequencies transformer will be bulkier in size so one can implement power architecture which has the high frequency transformer so again it is greater than 11 kV three-phase system we can convert that low frequency which is 50 Hertz or 60 Hertz line to the high frequency AC it is the high frequency AC which is been seen by the transformer and from this one you will again convert into you know high frequency AC and from high frequency AC one can easily convert into DC and then create the low voltage DC

distribution and then you can integrate this energy storage as well as PV just by putting the DC-DC converter into the low voltage distribution bus

This can do bi-directional energy transfer. This can do single direction, and also you can provide just the DC-DC converter in the power conversion unit of different EVSEs (EVSE1, EVSE2) to actually charge the vehicle using DC again. It will provide the power-dense solution, a power-dense and high-efficiency solution it provides. So, both things can be done with this, and that is another power architecture with DC coupling where you can integrate different energy storage and different renewables with the charging station, and where you can have different EVSEs and also support this LVDC distribution bus. Now, if we provide the bi-directional functionality, the bi-directional functionality of— If we can provide the bi-directional functionality of the power conversion unit of EVSE, we can actually do vehicle-to-grid operation, vehicle-to-home operation, vehicle-to-vehicle power transfer, and grid-to-vehicle operation. We have only studied grid-to-vehicle operation.

One can do vehicle-to-grid power transfer, vehicle-to-home power transfer, and vehicle-to-vehicle power transfer, provided— We have the bi-directional functionality of the power conversion unit of the different EVSEs we have discussed in the previous lectures. So, if we can provide this V2G, V2H, V2V functionality in the charger, then we can easily create the microgrid with the EV. So, each EV with the EVACs connecting to the grid in the home or in the charging station will actually form the microgrid, and one can implement hierarchical control, one can do— So, now with the microgrid created by EV, created by different EVs, will be one of the—

Research problems which a lot of researchers are working on, primarily because if we have V2G operation, if we have V2H operation, if we have vehicle-to-vehicle operation, then you are actually creating a microgrid where different EVs, which have the distributed energy resources, are actually connecting to the grid. So, in that case, you require coordinated control. Across different distributed energy resources, such that the power grid with which it is connected to these different distributed energy resources, which are being connected, are actually operated in a coordinated function. So, there are researches which are happening using the hierarchical control— Providing the tertiary control, secondary control, then followed by primary control. A lot of researchers are working on solving the problems when a lot of EVs are

connected to the grid with bi-directional power transfer capabilities. That means the power conversion unit can allow the power to flow from the battery to the grid. That's when different EVs potentially act as distributed energy resources, energy resources, and this—

Distributed energy resources need to be controlled so that the grid to which they are connected does not get into trouble. So, those things are being considered by many researchers who are working in power system areas, implementing different levels of hierarchical controls. So, in this course, we have started by understanding the different ecosystems related to charging energy. Then we studied the components in AC chargers and DC chargers, and what EVACs mean. We have discussed in detail the different power conversion units that are available.

At present, in different DC chargers, ECU chargers, and on-board chargers. Then we have seen in detail some of the charging systems, the different communications happening, the exchange of messages, how it occurs, how connections are made, how EVSEs and EVs are logically connected, and how they communicate with each other following different protocols. And then, briefly, we have seen some of the key components of charging stations. And what goes into a charging station. So, with this course, we have tried to introduce the different aspects of EV charging systems, from the power conversion unit to some discussions related to communications.

However, this is quite an evolving field. Every day, new standards are emerging. Different governments and countries are introducing features in chargers, proposing new standards, and defining different features within those standards. This course will help you understand what exists as of now at the current stage. So, thank you very much for listening.

I hope you have enjoyed these lectures. Thank you.