Implementation of Charging Standards and Communication Protocols for Electric Vehicle DC Fast Charging Station

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***Abstract*— Electric vehicles has been introduced as another method of transportation to assist reduce carbon emissions and fuel consumption, caused by ICE engines. The implementation of effective EV charging systems is important to motivate mass adoption of EV. The main downside in electrical vehicle charging, however, is that the time consumed to charge a vehicle. The fast charging of electric vehicles solves this problem thus making it a productive technology. The optimal planning of Electric Vehicle Charging Stations (EVSE) with advanced communication control algorithms is very important for development of fast charging technology. The paper proposes an implementation of communication charging standards and protocols to ensure the interoperability between EV and EVSE for DC Fast Charging Station.**

Keywords—EV, EVSE, Power Line Communication, CAN

I. Introduction

The transition from the ICE engines to electric mobility will help in decarbonizing the transport sector. As the world is trying to shift to reliable source of energy, electric vehicle turns out to be the best option. Electric vehicles (EVs) have already been implemented but in order to increase the speed of adoption the implementation of EVSE standards are goingto play an important role, and with all these efforts India willbe able to transform the transportation sector completely.

International Electrotechnical Council (IEC) is responsible for issuing Standards for all electrical & electronic industries. The standards for the electrical industry in India completely follow's the IEC International Standards. The development of reference standard is important to ensure interoperability between EV and EVSE. IEC 61851-24 defines in detail the sequence of digital communication that has to be carried between EVSE and EV for control of DC charging.[8] IEC 61851-23 along with IEC 61851-24, are used in order to carry out the digital communication between the EVSE and EV for the control of DC charging, with output power of 350 KW for the conductive charging procedure.

In this paper, we propose the implementation of charging standards and communication protocols for DC Fast charging station which ensures the interoperability between EV and EVSE. The proposed system is designed to achieve the communication with EMI aspects and timing constraints while charging the two vehicles simultaneously. This is accomplished by running multiple processes and libraries synchronously for each of the charging sessions while maintaining the timing constants as mentioned in the standards.

The remainder of the paper is organized as follows. Section II describes the EV charging system standards and protocols. Section III elaborates the proposed system . Section IV interprets the Implementation of the proposed system. Section V illustrate Results of the implementation. Conclusion is covered in Section VI.

II. Standards and Protocols in EV Charging System

The EVSE (Electric Vehicle Supply Equipment) consists of two main communication interfaces. One is between the ac-dc power converter and the application board and another is between SECC (Supply Equipment Communication Controller) and EV (Electric Vehicle). CAN protocol is used to communicate between the power converter and the application board and IEC 61851 standard implementation over power line communication is used between SECC and EV as described in Fig 1.[9] The charging process involve some of the important standards and protocols mentioned below.

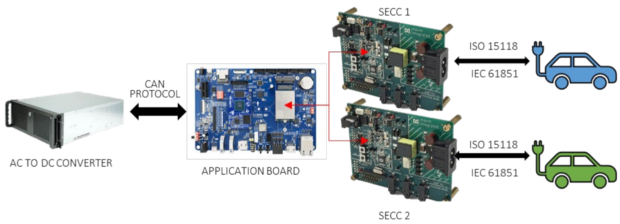

Fig. 1. EVSE Charging Communication Interface.

The Society of Automotive Engineering (SAE) categorizes charging stations into 3 levels. Level 1 and Level2 only supports AC power transfer whereas Level 3 is based on DC power transfer which supports DC charging and takesless time to charge EV's. AC and DC charging has been classified into four charging modes, as mentioned in IEC 61851 standard for electric vehicle conductive charging with Modes 1-3 pertaining to AC charging and Mode 4 pertaining to DC charging.[6] Mode 4 is the fastest way to charge the electric vehicle due to the use of off-board charger with DC output, allowing to bypass the EV on-board charger and delivering the DC output directly to the battery. This mode canprovide 1000v DC with current up to 400A and power of 50 kW to 250 kW. Due to the use of high-power this mode requires stricter safety features and higher level of communication.

A. IEC 61851-24

These part covers the digital communication between the EV and EVSE for control of DC fast charging station. IEC 61851-23 along with IEC 61851-24, are used to carry out the digital communication between the EVSE and EV for the control of DC charging.[12] Homeplug Green PHY protocol over the control pilot can be used to carry out the digital communication. The charging control process use the following signals and information to synchronize control process between DC EV charging station and the vehicle.[2]

- CP (Control Pilot) PWM signals.
- Monitoring the protective earth.

B. ISO/IEC 15118:

IEC 15118-1 forms the basis for further parts of the ISO 15118 series, specifies the general necessities and use-cases for High Level Communication between EVSE and EV. It provides general information of aspects like identification, optimization, payment, load levelling, cybersecurity privacy,association and charge or discharge control. It offers all e-mobilities an interoperable EV-EVSE interface.[7]

C. CAN Protocol

CAN bus is a widely used protocol for communication it is used in industrial vehicles and machines due to its robustness, simplicity, and operating flexibility. The CAN busis constitutes of twisted-wire pair wires, CAN low and CAN high, with a terminal resistance of 120 Ω. without complex dedicated wiring. The communication baud rate used is 125K and the message format used is CAN 2.0 B: 29-bit Extended Identifier. Linux provides support for CAN through the networking subsystem and Socket CAN, which is a hardware independent CAN API and can be used to control CAN devices.[11]

III. Proposed System

This section covers the hardware design for Mode 4 30KW Dc Fast Charging Station with 2 charging guns.

A. Hardware Setup

The DC Fast charger is composed of four maincomponents listed below:

1. Application Board

It's a central controller which controls the communication of the power converter and the SECC. It acts as a mediator to achieve the communication flow of the EVSE. The Table I describe the technical details of the selected processor.

HIGHLIGHTS	DETAILS
Processor	Imx8m Mini
Architecture	ARM Cortex-A53
Ram	2 GB
CAN	1xCAN FD
Power Supply	24V
Frequency	4x1.6GHz
Serial	1xRS485 , 1xRS232
OS	Linux(Yocto Distribution)

TABLE I Application Board Technical Details.

2. Supply Equipment Communication Controller (SECC)

This module is used to achieve the ISO 15118 V2G communication with is based on Homeplug Green PHY (*IEEE* 1901) over the control pilot line. The SECC module communicates with the Electric Vehicle Communication Controller EVCC (on the EV side) over the power line communication.

3. Power Converter Module

The power converter module consists of AC/DC power stage and DC/DC power stages which converts the three phase AC input to DC output with power rating of 30KW. Output Voltage range is 150-1000V and current range is 0-100A. The power converter module is equipped with CAN bus to communicate with the application board for the power transfer.

4. CCS Connectors

The charging gun used is Type 2 CCS (Combo 2) which is widely used in Europe. The CCS connector uses the J1772 charging inlet with added two more pins below. It simply combines the J1772 connector with two dc high speed pins. In case of DC charging only the lower two pins are used to transfer the DC power and the upper pins are utilized for communication and other protection signalling. The CCS connectors supports power transfer of up to 350 kW and is the most widely accepted type of DC connector.

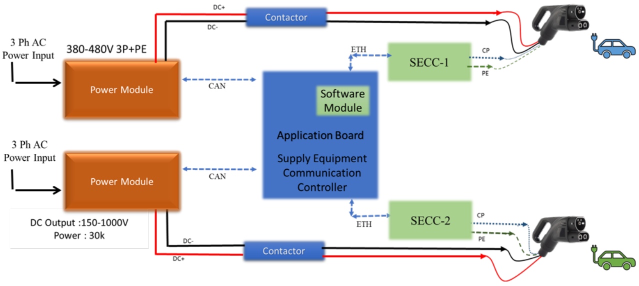

Fig. 2 Hardware Setup for the DC Fast Charging

The AC-DC power converter is supplied with the 3 phase 380-415V from the grid. The CAN communication interface is used between the Power Converter Module and AB (Application Board) while SECCs communicates vie Power Line Communication (PLC) with the EV. Control Pilot (CP) and Protective Earth (PE) are the two lines going from SECC to the Type 2 CCS Connector while the DC (+) and DC (-) from the Power Converter Module connect to the CCS Connecter vie DC Contactor for the isolation purpose.

B. System Architecture.

To achieve communication between the Ac-Dc power converter and application board CAN protocol is used and the power converter can be controlled by the application board with the help of CAN frames to turn on/off the module, set module output voltage and current, read module AC input voltage information and read module error information. Linux provides support for CAN through the networking subsystem and Socket CAN, which is a hardware independent CAN API and can be used to control CAN devices. Linux socket CAN is used to transmit and receive can frames. The CAN library is written in C with the separate functions to set the module voltage/current, set module on/off which is called from the charger application code.

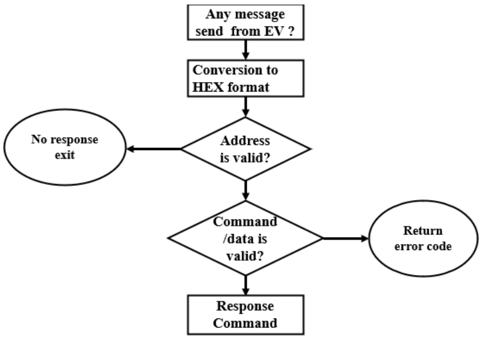

Fig 3: CAN Library Flow Chart.

Fig .3 elaborates the CAN library code flow. The charger application code runs on the application board to achieve the high-level communication between the SECC and EV. In charger application code, an object of EVSE class is created where the SECC IDs associated with the SECCs, and Application Board ID is passed to it. For two charger connectors two instances are created named EVSE Connector-1 and EVSE Connector-2 which are being passed with the respective SECC ID and other parameters. With-in the respective EVSE connector two more objects of Charger class and SECC class are defined, where the charger class is responsible for the charging voltage, current and power calculation and SECC class handles getting or setting status associated with the high-level communication. Fig.4 shows the code flow for the charger application code.

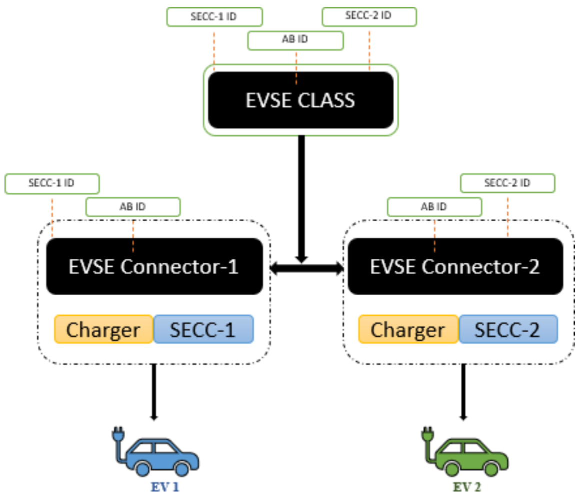

Fig. 4. Charger Application code flow.

The process of supplying energy to the electric vehicle by the EVSE is initiated and controlled by the messages sent over High Level Communication (HLC). Before the exchange of information over the HLC the initialization takes place, which covers the SLAC Matching process and Low-Level Communication over Pulse Width Modulation (PWM) where the duty cycle is controlled by the EVSE, and the voltage of the signal is controlled by the EV. On running the Charge-Loop code the CP Duty Cycle get set to 100% and waits for the charger gun to be connected to the EV, on connecting, causes the voltage to drop thus allowing the EVSE to start the SLAC matching process by setting the Duty Cycle to 5%. SLAC is a Protocol to Ensure that Communication takes place only between the physically connected EV and EVSE.

IV. Implementation

This section covers the implementation of the proposed system.

The first parameter that is exchanged between EV and SECC is ChargeParameterDiscovery_Req<3a> which carries the information of electric vehicle maximum voltage and current limit for which the SECC responds with ChargeParameterDiscoveryRes<3b> carrying information of maximum and minimum values of voltage and current supported by EVSE. Before the actual transfer of power the cable and insulation check is performed with the CableCheck<4a> <4b> and once the cable check is successful the PreCharge_Req<5a> is send by the EV to start the initial power transfer with current less than 2A. On getting the PreCharge_Req the AB triggers the CAN communication with the PreCharge voltage and current parameters and on getting response from the power converter the SECC sends the corresponding PreCharge_Res <5b>.The EV sends the PowerDelivery_Req <6a> to enable the power transfer and EVSE communicates its readiness for energy transfer with PowerDelivery_Res<6b>.The cyclic current demand request is sent by the EV with the charging current parameters and theAB forward those parameters to the power converter to set thedemanded voltage and current while continuing these process till the EV is being charged. Fig 5 shows the complete communication sequence diagram.

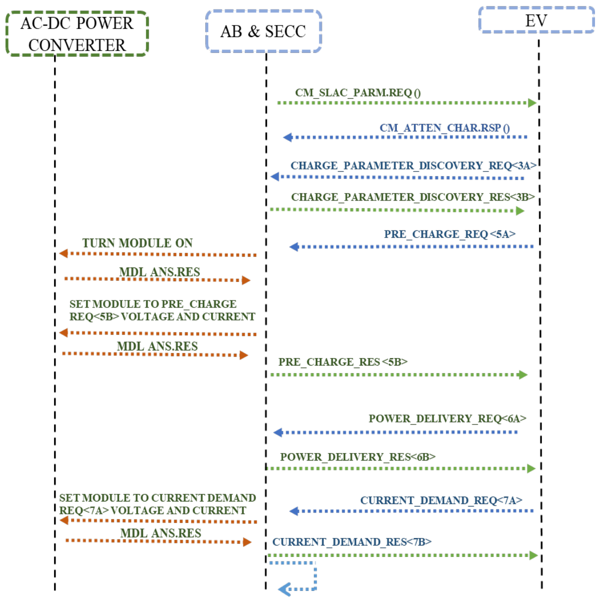

Fig. 5. EVSE Complete Communication Sequence diagram.

V. Results

On plugging into the EV. The Low-Level Communication(LLC) initiates and on successful mating and SLAC matching the High-level communication sequence flow originates. The generated LLC logs are shown in Fig 6.

```
Set the CP mode to EVSE
Set the CP duty cycle to 100%
Start the CP service
Start SLAC in EVSE mode
Wait until an EV connects
EV connected
Start SLAC matching
Set duty cycle to 5%
SLAC matching successful
```

Fig. 6. Generated LLC logs.

On successfully authorization by the user the HLC parameter, Request Discovery_Charge is sent by the EVSE as seen in the Fig.7.The detail logs are generated for each HLC parameter exchanged between EV and EVSE.

```
"Session started" received
Protocol: 2
Session ID: 8063fa9ac5ea9dcf
EVCC ID: fcd6bdffce1e
"Request EVSE ID" received
Set EVSE ID: DE*ABC*E*00001*01
"Request Authorization" received
Authorize the vehicle? Type "yes" or "no" in the next 59s:
yes
Vehicle was authorized by user!
"Request Schedules" received
Max entries: 128
Set the schedule: [{'id': 1, 'tuple': [{'start': 0, 'interval':
1800, 'max_power': 25000}, {'start': 1800, 'interval': 1800,
'max_power': 18750}, {'start': 3600, 'interval': 82800,
'max_power': 12500}]}]
"Request Discovery Charge Parameters" received
EV maximum current: 63.0A
EV maximum voltage: 370.0V
SOC: 78%
"Request Cable Check Status" received
"Request Cable Check Parameters" received
SOC: 78%
"Request Pre Charge Parameters" received
EV target voltage: 332.6V
EV target current: 2.0A
['0x00', '0x05', '0x10', '0xE0', '0x00', '0x00', '0x07', '0xD0']
SOC: 78%
"Request Pre Charge Parameters" received
EV target voltage: 332.6V
EV target current: 2.0A
['0x00', '0x05', '0x10', '0xE0', '0x00', '0x00', '0x07', '0xD0']
SOC: 78%
"Request Pre Charge Parameters" received
EV target voltage: 332.6V
EV target current: 2.0A
['0x00', '0x05', '0x10', '0xE0', '0x00', '0x00', '0x07', '0xD0']
SOC: 78%
"Request Start Charging" received
Schedule ID: 1
EV power profile: []
SOC: 78%
Charging complete: False
"Request Charge Loop Parameters" received
EV maximum current: 63.0A
EV maximum voltage: 370.0V
EV target voltage: 362.0V
EV target current: 19.0A
['0x00', '0x05', '0x86', '0x10', '0x00', '0x00', '0x4A', '0x38']
SOC: 78%
Charging complete: False
"Request Charge Loop Parameters" received
EV maximum current: 63.0A
EV maximum voltage: 370.0V
EV target voltage: 362.0V
EV target current: 21.0A
['0x00', '0x05', '0x86', '0x10', '0x00', '0x00', '0x52', '0x08']
SOC: 78%
Charging complete: False
"Request Charge Loop Parameters" received
EV maximum current: 63.0A
EV maximum voltage: 370.0V
EV target voltage: 362.0V
EV target current: 23.0A
['0x00', '0x05', '0x86', '0x10', '0x00', '0x00', '0x59', '0xD8']
SOC: 78%
Charging complete: False
"Request Charge Loop Parameters" received
EV maximum current: 63.0A
EV maximum voltage: 370.0V
EV target voltage: 362.0V
EV target current: 25.0A
['0x00', '0x05', '0x86', '0x10', '0x00', '0x00', '0x61', '0xA8']
SOC: 78%
"Request Stop Charging" received
SOC: 78%
Charging complete: 0
"Request Post Charge Parameters" received
SOC: 78%
"Request Post Charge Parameters" received
SOC: 78%
"Request Post Charge Parameters" received
SOC: 78%
"Request Post Charge Parameters" received
SOC: 78%
"Session stopped" received
EVSE loop finished
Goodbye!
```

Fig. 7. Generated HLC logs.

The Linux terminal of the application board displays the status of the HLC. Fig 8 shows the status of HLC parameters being successfully exchanged between the EV and EVSE. During the Pre-Charge stage the voltage and current that is being delivered to the EV is being showed and the SOC (State of Charge) data is shared by the EV indicating the battery charged percentage.

```
CONNECTOR 1
Start Transaction
Authorization
Cable Check                VOLTAGE  362.000000000000005
                           CURRENT  2.00
Pre-Charge                 SOC   54
Charging
Charging Stopped
Post Charging
```

Fig. 8. Linux terminal showing parameter exchanged status.

Fig 9 shows the charging process of two EVs being simultaneously charged without causing any EMI interface and timing constraints. The screen on the left shows the status of the Connector 1 and on the right status of the Connector 2 is updated.

```
CONNECTOR 1                                               CONNECTOR 2
Start Transaction                                         Start Transaction
Authorization                                             Authorization
Cable Check          VOLTAGE  362.000000000000005         Cable Check          VOLTAGE  387.0
                     CURRENT  2.00                                             CURRENT  2.0000000000000001
Pre-Charge           SOC  54                              Pre-Charge           SOC  70
Charging                                                  Charging
Charging Stopped                                          Charging Stopped
Post Charging                                             Post Charging
```

Fig. 9. Linux terminal showing parameter exchanged status for two vehicles.

Multiple charging session were done on the vehicles. Tata Nexon was used for testing. Simultaneous charging session were done with the help of Hyundai Kona and Tata Nexon.

VI .CONCLUSION

We have designed and implemented the communication charging standards and protocols for a DC fast charging station which ensures the interoperability between EV and EVSE. With this system we can charge two vehicles at the same time.

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