OCPP 1.6
Smart Charging Implementation Overview

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Revisions

Revision	Description	Date	Author
1.0	First issue	21 February 2020	Mikhail Kireev
1.1	Chapter on charging profile and schedule validity added Chapter on known issues added	26 July 2021	Mikhail Kireev
1.2	Added chapter on stacking charging profiles of the same purpose for different connectors	10 august 2021	Mikhail Kireev

Overview

This document describes how Smart Charging feature profile for OCPP 1.6-J is implemented in ABB fast chargers.

For more information on general OCPP functionality, dual-uplink setup and versions of software per charger model which supports Smart Charging please refer to OCPP Implementation Overview document [1].

Target audience for this document

This document is intended for a person who has at least basic knowledge of OCPP 1.6 protocol (advanced knowledge is preferred).

Who should read this document and why:

- ABB Service personnel to understand specifics of ABB implementation and to be able to properly diagnose questionable situations and provide more elaborative explanation and help to the customers
- ABB Application engineers to understand specifics of ABB implementation and to be able to explain to customers specific details during initial setup phase and answer their technical questions. And after initial stage to be able to help customers to operate and maintain connection to their OCPP central system with Smart Charging functionality
- ABB Technical Sales specialists or Technical Product managers, who interacts with customer's technical personnel to be able to answer detailed technical questions about ABB implementation
- Customer technical personnel who is responsible for implementing Smart Charging on Central System side where ABB chargers connected (or connecting ABB chargers to OCPP Central System with existing Smart Charging implementation)

Who does not need to read this document (but still encouraged to do so):

- ABB General sales specialists
- ABB Commercial product manager
- Anyone else

Smart Charging in Open Charge Point Protocol 1.6 (OCPP) specification

OCPP 1.6 has defined a Feature Profile for Smart Charging. The OCPP specification document [2] contains information about the Smart Charging Feature Profile in the following sections:

- 3.3 Feature profiles (to see the messages of the smart charging profile)
- 3.13 Smart charging (overview of the concept and use cases)

Details of the messages related to Smart Charging:

- 5.5 Clear Charging profile
- 5.7 Get Composite schedule
- 5.11 Remote start transaction

- 5.16 Set charging profile

Configuration keys for Smart Charging:

- 9.4. Smart Charging Profile

NOTE: Smart Charging profile is not enabled by default on ABB charger. To enable Smart Charging please contact ABB Service. If Smart Charging is enabled, the OCPP Configuration key Supported-FeatureProfiles will include “SmartCharging”

Charging profile

OCPP uses concept of charging profile. Charging profile defines current or power limits at specific points in time. A charging profile consists of a charging schedule, which is a list of time intervals with their maximum charging power or current, and some values to specify the time period and re-currence of the schedule ([2] 3.13.1 “Charging Profile Purposes”).

The figure below is from OCPP 1.6 specification contains an overview of data structure for the ChargingProfile type. A ChargingProfile consists of a ChargingSchedule, describing the amount of power or current that can be delivered per time interval. ([2] 7.8 “ChargingProfile”).

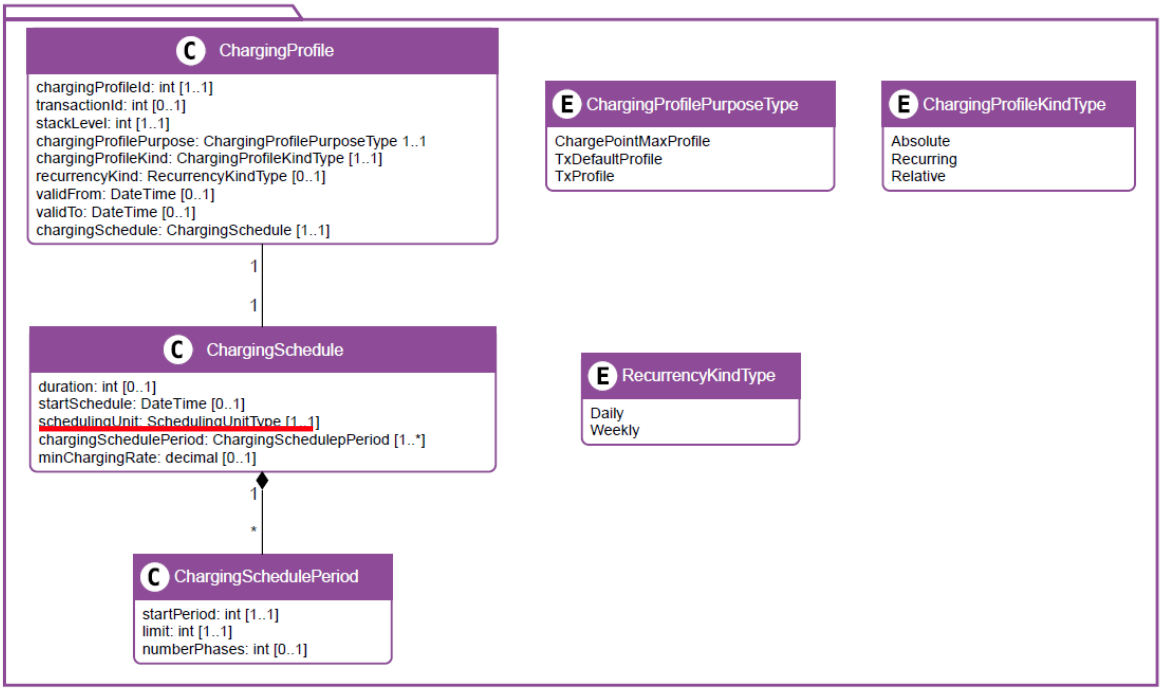

Figure 42. Class Diagram: ChargingProfile

***NOTE**: There is a mistake in OCPP document in diagram above. In ChargingSchedule there should be chargingRateUnit, but not schedulingUnit (underlined in red above). It is properly described in 7.13 “ChargingSchedule” of [2].

Supported functionality

Messages

The following OCPP messages of Smart Charging Feature Profile are supported:

- SetChargingProfile
- ClearChargingProfile
- RemoteStartTransaction with (optional) ChargingProfile

The remaining OCPP message GetCompositeSchedule is not yet implemented. ABB intends to provide this functionality in the future software versions.

Smart Charging Configuration keys

Smart charging configuration keys are defined in section 9.4 “Smart Charging Profile” of [2].

Name	Supported in ABB implementation	value
ChargeProfileMaxStackLevel	yes	10 (default)
ChargingScheduleAllowedChargingRateUnit	yes	Current, Power
ChargingScheduleMaxPeriods	yes	24 (default)
ConnectorSwitch3to1PhaseSupported	no	-
MaxChargingProfilesInstalled	yes	10 (default)

Please take into account, that according to OCPP specifications all Smart Charging keys are read-only and cannot be changed via command ChangeConfiguration. However, values for these keys could be chnaged by ABB Service personnel by adjusting charger configuration

Persistency

The smart charging profiles that were sent to the charger are persistent across chargers reboots. This is required to support profiles with purposes ChargePointMaxProfile and TxDefaultProfile.

Charging profile and schedule validity

ChargingProfile data structure specifies optional fields *validFrom* and *validTo* to define validity of ChargingProfile. If these fields are left empty, profile becomes active as soon as received by charge point and until replaced by another profile

Further, every profile may have *startSchedule* to define when schedule will become active. If not defined, start of schedule will be relative to start of charging. Another optional field *duration* defines how long schedule will be valid.

It is important to realize that if there is no active schedule with an limit inside active charging profile, it means that there is no active limit. Which means charging will not be limited and would go with maximum charging power.

Let's consider following profile as example. For simplicity we assume there is one profile active specified below:

```
{
  "chargingProfile" : {
    "chargingProfileId" : 1,
    "chargingProfileKind" : "Absolute",
    "chargingProfilePurpose" : "TxDefaultProfile",
    "chargingSchedule" : {
      "chargingRateUnit" : "W",
      "chargingSchedulePeriod" : [ {
        "limit" : 5000.0,
        "startPeriod" : 0
      } ],
      "duration" : 900,
      "minChargingRate" : null,
      "startSchedule" : "2021-04-14T18:03:50Z"
    },
    "recurrencyKind" : null,
    "stackLevel" : 1,
    "transactionId" : null,
    "validFrom" : "2021-04-14T17:03:50Z",
    "validTo" : "2021-04-14T19:03:50Z"
  },
```

In this example Absolute profile will become active for every new charging session. However, schedule starts at **2021-04-14T18:03:50,** so shall any session start before that time, even though there is active profile for that session this session will run without any limit until that time.

At **2021-04-14T18:03:50** limit of 5000 W (5kW) will become active and will last 900 seconds (15 minutes). After that there will be no any active schedule again and limit will be lifted. Because profile itself is still valid until **2021-04-14T19:03:50**, charging session will run until that time, or another 45 minutes, without any limit. Even if there is another profile with e.g. another stack level and active schedules.

It is also important to realize that if validTo field is left empty, this charging profile with ended schedule (and therefore without limit) will be active until actively replaced by another profile according to OCPP.

Stacking charging profiles of the same purpose for different connectors

It is mentioned in section 3.13.2 "Stacking charging profiles" of [2] that

" To avoid conflicts, the existence of multiple Charging Profiles with the same stackLevel and Purposes in a Charge Point is not allowed. Whenever a Charge Point receives a Charging Profile with a stackLevel and Purpose that already exists in the Charge Point, the Charge Point SHALL replace the existing profile."

This could be interpreted that even if profiles of the same stackLevel and Purpose are defined for different connectorIDs their existence is not allowed and if new profile of the same stackLevel and Purpose is received it would replace previous one.

To be on the safe side ABB followed this guideline in implementation and the existence of multiple Charging Profiles with the same stackLevel and Purposes in a Charge Point is not allowed even if profiles are defined for different connectorIDs.

Therefore if profile with the same stackLevel (e.g. 1) and purpose (e.g. txDefaultProfile) will be sent for another connector (e.g. there were profile stored for connectorID=1 and new profile is for connectorID=2) new profile will replace existing one. In this case connectorID=1 may NOT have active profile at all.

To avoid this potential issue of replacing profiles for different connectroIDs with the same stackLevel and purpose ABB recommends always use profiles of different stackLevel for the same purpose even if they are defined for different connectors.

Specifics of ABB implementation

The OCPP specification leaves some room for interpretation related to smart charging. In this chapter some of such questionable aspects are noted along with ABBs implementation and reasoning for it.

Charging Rate Unit

In 7.12 “ChargingRateUnitType” of [2], ChargingRateUnitType is defined as “Unit in which a charging schedule is defined”. It can have 2 values: "W" = Watts (power) and "A" = Amperes (current). Power and Current can be measured on the Inlet, on the Outlet, or on the Vehicle (see 7.43 “sampledValue” in [2]). However, OCPP does not specify where the limit in the charging profile applies.

This is the interpretation of Power and Current limits applications in different situations:

Purpose	chargeRateUnit A (Current)	chargeRateUnit W (Power)
ChargePointMaxProfile (connectorId = 0)	location = Inlet	location = Inlet
TxDefaultProfile / TxProfile (connectorId > 0)	location = Inlet	location = Outlet

- Outlet is defined by ABB as connector to the vehicle
- Inlet is defined by ABB as incoming power to a charging station from the grid before AC/DC conversion.

So if power is used on transaction related profile, such as txDefaultProfile or txProfile, it is the power delivered to the vehicle. This allows limiting power to the vehicle (outlet).

If current is used in any type of profile it is always AC current input from the grid connection per phase. The same is true for ChargePointMaxProfile even if it is specified in Watts: it is AC power from the grid.

Conversion Current to Power

IMPORTANT: Power/current management software component uses AC current per phase as unit to calculate and apply limits. DC power and AC power are calculated by formula and not yet measured directly. Measuring DC power and current directly in the outlet and using this as unit for calculation of limits is planned for later software versions.

To convert between Current I (per phase) and Power on Inlet (P_i) you need to know the Voltage V on the grid and the number of phases p

$$P_i = IV\sqrt{p}$$

To convert between Power on inlet (P_i) and Power on outlet (P_o) you need to know (an estimation of) the efficiency e of the Power modules.

$$P_o = P_i * e$$

From parameters above only current I (per phase) is measured and other are specified as configuration parameters of the charger. These parameters could be adjusted by ABB service.

Configuration parameters and default values:

name	description	default value
GridVoltage	voltage on the grid connection	230
GridPhaseNumber	number of phases on the grid connection	3
PowerConverterEfficiency	typical efficiency of the power converters	0.94

NOTE 1: Please pay attention that for other than European grid, e.g. North American or Japanese default parameters should always be adjusted for proper calculations. To avoid problems and customers dissatisfaction please ALWAYS pay attention how parameters above are configured!

NOTE 2: in the future these parameters may come from different sources, e.g. the GridVoltage can be measured.

Charging Profiles edge cases

Charging profiles have many parameters. Some combinations can be conflicting or ambiguous. An overview was made of these cases, and a decision how to interpret the Charging profile in that case.

Combining multiple charging profiles

The OCPP 1.6 specification has two sections that describe how to combine multiple charging profiles.

- 3.13.1. Charging profile purposes
- 3.13.2. Stacking charging profiles
- 3.13.3 Combining charging profile purposes

In some cases the order of combing charging profiles is open for interpretation, which could give unpredictable results. Some requirements from OCPP specification:

> "*If TxDefaultProfile is set to ConnectorId 0, the TxDefaultProfile is applicable to all Connectors. If ConnectorId is set >0, it only applies to that specific connector.*

In the event a TxDefaultProfile for connector 0 is installed, and the Central System sends a new profile with ConnectorId >0, the TxDefaultProfile SHALL be replaced only for that specific connector."

(3.13.1 "Charging profile purposes", Page 20 of [2])

And at the same time:

"Precedence of charging profiles is determined by the value of their StackLevel parameter. At any point in time the prevailing charging profile SHALL be the charging profile with the highest stackLevel among the profiles that are valid at that point in time, as determined by their validFrom and validTo parameters.

It is allowed to stack charging profiles of the same charging profile purpose in order to describe complex calendars"

(3.13.2 "Stacking charging profiles", Page 21 of [2])

When combining profiles with purpose TxDefaultProfile

- with different stacklevels
- for connectorId=0 and connectorId>0

Question: how to determine the active TxDefaultProfile for connectorId=c (c>0) (assuming there are no profiles with purpose TxProfile)?

We are using all profiles with purpose TxDefaultProfile:

- First you discard any profiles which are not valid (based on validFrom and validTo)
- Next you have following options to combine the remaining TxDefaultProfiles and select the active one:

    1. Search for all (valid) profiles for connectorId=c; either you find at least one, or you don't find any.
       And only if you did not find such profile(s), search for (valid) profiles with connectorId=0
       Then, if you have found multiple profiles for connectorId=0 , select the one with the highest stacklevel
    2. First order the (valid) TxDefaultProfiles on stacklevel for connectorID=c and connectorID=0
       Then, from high to low: Select the first one that has either connectorId=0 or connectorId=c
    3. Determine the TxDefaultProfile with the highest stacklevel for all connectors.
       See if it is applicable for this connectorId (either connectorId=0 or connectorId=c)
       If yes, select it, if not, there is no active profile (so there is no limit)

This can result in different profiles to be selected as active. Example with 3 (valid) profiles:

- Profile A: purpose TxDefaultProfile, connectorId = 0, stacklevel = 3
- Profile B: purpose TxDefaultProfile, connectorId = 2, stacklevel = 2
- Profile C: purpose TxDefaultProfile, connectorId = 1, stacklevel = 4

If we want to know the active profile for connectorId = 2:

- In case of option 1, profile B would be active (first check on matching connectorId>0)
- In case of option 2, profile A would be active (first take the highest stacklevel for 0 or 2))
- In case of option 3, profile C would be active: no limit for connector 2 (highest stacklevel only applies to connector 1)

Conclusion: ABB implementation is now according to option 1. If there is valid txDefaultProfile(s) for connectorId>0, the active profile will be selected from these profiles only without taking into account profile(s) for connectorId=0.

Charging schedule periods

A charging schedule has an array with one or more chargingSchedulePeriods, each period has a field startPeriod:

"*startPeriod: Start of the period, in seconds from the start of schedule. The value of StartPeriod also defines the stop time of the previous period.*"

(7.14 "ChargingSchedulePeriod", Page 81 of [2])

If the values of startPeriod in the array are monotonically increasing, the behavior is clear.

However, what if there are duplicates or the array is not sorted.

Looking at the definition of startPeriod, one interpretation is to ignore intervals where the stop time is equal to the start time. For instance (startPeriod,limit) sequence: (100,10), (200,20), (**300**,30), (**300**,40) would be the same as (100,10), (200,20), (300,40)

If the startPeriod values are decreasing, interpretation of the schedule will be ambiguous. In that case the ChargingProfile should be Rejected.

For instance (startPeriod,limit) sequence: (100,10), (**200**,20), (**150**,30), (300,40) would be Rejected.

Parameter minChargingRate

A charging schedule can contain an optional minChargingRate

"Minimum charging rate supported by the electric vehicle. The unit of measure is defined by the chargingRateUnit.

This parameter is intended to be used by a local smart charging algorithm to optimize the power allocation for in the case a charging process is inefficient at lower charging rates."

Both the active Charger related profile and the Connector related profile can have a minChargingRate. OCPP does not specify how to combine them if both have a value.

Parameter minChargingRate is not supported in ABB implementation.

Known issues

- In software versions before 1.5 (before 4.5 for Terra 54) there is issue that optional field startSchedule in ChargingSchedule can be defined only in the future. If startSchedue is defined in the past, profile would be rejected. This issue is fixed in 1.5/4.5 version.

Reference documentation

[1] OCPP 1.6 ABB Implementation Overview, version 1.2, 2020-01-06

[2] Open Charge Point Protocol 1.6, edition 2 FINAL, 2017-09-28