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# Research on Electric Vehicle Charging Communication Protocol Framework and the Application in ChaoJi Charging System

Xuling Li
State Grid Electric Power Research Institute
Nanjing, China
lixuling@sgepri.sgcc.com.cn

Bin Wu
State Grid Corporation of China
Beijing, China

Feng Ni
State Grid Electric Power Research Institute
Nanjing, China
nifeng@sgepri.sgcc.com.cn

Heng Song
State Grid Taizhou Power Supply Company
Taizhou, China
songhengyanxu@foxmail.com

***Abstract*—This paper compares the characteristics of the mainstream international electric vehicle charging communication protocols and proposes a new communication protocol framework, specifying the function modules that make up the charging process and the mandatory/optional, fixed/reloadable attributes of the function modules. The communication protocol based on the framework can realize personalized charging services through flexible configuration of the function modules and specific instances according to application requirements. This framework meets the requirements of compatibility, scalability, and flexibility of charging communication protocols. The charging communication protocol designed based on this framework has been adopted by the Chinese national standard GB/T27930 which is being upgraded, and has been applied in the new direct current charging system ChaoJi. In addition to basic charging, some new functions are being developed to validate its scalability and flexibility.**

***Keywords—Electric Vehicle (EV),Protocol framework, function module, ChaoJi***

## I. Introduction

The digital communication protocol between the electric vehicle and the DC charger plays an important part in charging. During the charging process, the electric vehicle and the charger interact the information of charging capacity, charging demand, charging status information, etc. in accordance with the communication protocol to ensure an orderly charging process. The booming development of the electric vehicle industry has brought more and more new scenarios and new application requirements, such as high-power charging, reservation charging, bi-directional charging etc. And the existing charging communication protocols for single charging service and charging mode have gradually exposed much more inadequacies in terms of compatibility, scalability, and flexibility.

This paper compares the characteristics of the communication protocols of three mainstream international DC charging systems, and proposes a new charging communication protocol framework in response to the current needs of rapid industrial change and strong adaptability. The framework has been adopted by Chinese national standard and used in ChaoJi charging system.

## II. Charging communication protocols

There are three international DC charging systems: the CHAdeMO system in Japan, the GB/T system in China , the CCS system in Europe and the US, which are defined as System A, System B and System C respectively in IEC 61851-23"Electric vehicle conductive charging system – Part 23: DC electric vehicle charging station"[1]. Each of these systems has different characteristics in terms of physical interfaces, control pilot circuits, sequence, and communication protocols. In terms of communication protocols, the transmission media, framework, and transmission parameters are different due to the industrial development backgrounds [2].

### *A. System A: CHAdeMO system*

The communication protocol of System A is based on CAN 2.0 with standard frame format and 500kbps of baud rate. As a lightweight communication protocol, there are only 5 messages are defined without layered architecture. Moreover, all messages are sent in a fixed cyclic time of 100ms throughout the charging process. Due to this simple design, new functions can be supported only by adding new messages or parameters to the original messages. This solution is not suitable for the increasingly complex information interaction process because of the limited expansion space, it is a big challenge to charging compatibility as well.

### *B. System B: GB/T system*

Like System A, the System B is based on CAN2.0 as well. But the frame format uses a more complex extended frame and the baud rate is 250kpbs.There are 22 communication messages are defined between the charger and the vehicle, and both sides process the communication messages through event-driven and cyclic transmission mode. However, due to the limitation of application requirements in 2011 when the initial version of this communication protocol was designed, the protocol framework lacked systematic design and adaptability to new scenarios and functions. In addition, the GB/T communication protocol lacks an effective version negotiation mechanism, the version cannot identify the protocol version of charger, which leads to difficulties in upgrading.

### *C. System C: CCS system*

The current communication protocol of System C adopts the ISO 15118 series standards [3], which consists of 9 parts. Part 1 specifies general information and use cases, Part 2 specifies network layer and application layer requirements; Part 3 specifies physical layer and data link layer requirements, Parts 4 and 5 specify testing requirements, Parts 6-9 are for wireless charging system. And the newly released Part 20 is currently a supplement and update to Part 2. As the 15118 series starts with use cases analysis, adequate consideration has been given to the charging modes and needs that may be available at the time and in the future, such as AC charging, DC charging, plug-and-charge charging and external identification modes (e.g., NFC, SMS, etc.), wireless charging, automatic charging device, etc. It's an adaptable framework with too much flexibility, to achieve which the version negotiation strategy supports charging for different protocol versions of vehicles and chargers, and it leads to lots of protocol compatibility issues [4].

Based on the above analysis, when designing a new communication protocol framework, it is important to consider the compatibility, scalability, and flexibility. In addition, it is also necessary to stipulate version negotiation principles and give certain restrictions to flexibility, which can avoid confusion and compatibility issues caused by different versions of vehicle and charger.

## III. Communication protocol framework

### A. Function Modules

Unlike the use case elements defined in ISO 15118-1, the framework proposed in this paper logically divides the communication process into a few sequentially executed business function called function module (the serial number assigned to a function module is called Function Code, or FC for short). The function modules that make up the communication process include version negotiation, function negotiation, authentication, parameter configuration, reservation, self-check, supply mode, pre-charge and energy transfer, end-of-charge, service idle.

At the same time, in order to reduce coupling, that is, the layers are only concerned with the bottom layer providing services (interfaces) between them to ensure the scalability of the framework, a layered network design is used. The relationship between the function modules and the layers is shown in Fig. 1.

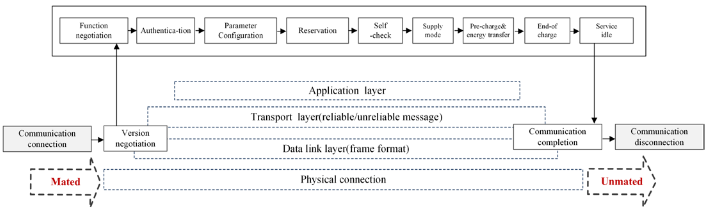


Fig. 1. Function Modules

### B. Function module attributes

In order to be scalable and flexible, each function module has two attributes: mandatory/optional and fixed/reloadable.

In the charging communication protocol, some function modules are mandatory and some are optional, and a charging communication process consists of all mandatory function modules and zero or more optional function modules. The mandatory function modules include version negotiation, function negotiation, parameter configuration, self-check, pre-charge and energy transfer. The rest function modules are optional ones.

Another attribute is fixed or reloadable. Fixed function modules have unique information interaction principles, message definitions and information interaction processes in the framework, reloadable function modules support re-definition of which, the instance of reloadable function modules can be replaced in different versions of communication protocols. A specific charging communication protocol can support one or more application instances of a function module.

Fixed function modules include version negotiation, function negotiation, parameter configuration, all the rest are reloadable function modules.

To distinguish different application instance of reloadable function modules, the Function Description Code (FDC for short) is involved in the framework, e.g., for the authentication function module, there are different ways: NFC or QR (FDC1), vehicle VIN authentication (FDC2), digital signature (FDC3) etc. Each FDC is for authentication, but it takes a different approach, supporting different parameters and interaction process. The attributes of function modules are shown in Fig.2.

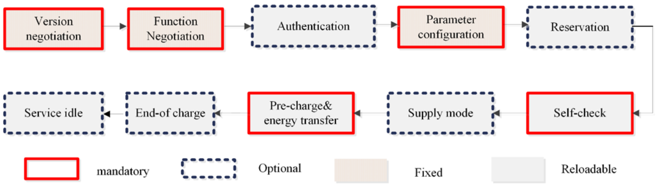


Fig. 2. Attributes of function modules

- The version negotiation occurs after the communication is established, the protocol version number is exchanged between the charger and the vehicle, the vehicle compares the version number sent by the charger with its own supported version number and returns the negotiation result, if the negotiation is successful, it enters the function negotiation function module, or it exits the charging process.
- The function negotiation is after the successful version negotiation, the charger and the vehicle negotiate the reloadable function module and its supported FDCs. The vehicle returns the negotiation result in accordance with a certain priority strategy according to the function modules and instances it supports, and each function module can only return one instance: if the negotiation is successful, it enters the parameter configuration function module, or it exits the charging process.
- The authentication is used for the vehicle and/or charger to interact and confirm the identity, if the authentication is successful it goes to the next function module, otherwise it exits the charging process.
- The parameter configuration is after authentication (if any) or successful function negotiation, the charger and the vehicle are for basic charging parameters matching, if the parameters are successfully matched, it enters the next function module, otherwise it exits the charging process.

- The reservation is used to negotiate the start time of charging. If the reservation is successful it will proceed to the next function module, otherwise it exits the charging process.
- The self-check is for information interaction during some operations such as insulation detection, short-circuit detection and welding detection of the charger, if the self-check is successful it will proceed to the next function module, otherwise it exits the charging process
- The supply mode is for information interaction of some scenario such as heating the traction battery in constant voltage mode without the battery being connected.
- The pre-charge and energy transfer includes 2 parts: the pre-charge is for the relevant operations performed by the charger to avoid surge to the battery, the energy transfer comprises the entire process of charging after charging contactors closed; if charging finishes (including normal end and abnormal situation), the charging process will exit or enter next function module.
- The end-of-charge is for the interaction of relevant information such as statistics data (e.g., final soc, amount of electricity) after energy transfer.
- The service idle is a reserved function mode, which is used for exchanging information other than energy transfer after charging.

### *C. Version negotiation principle*

When charging communication protocol is upgraded, the protocol version numbers is updated incrementally. The optional function modules and application instances of reloadable function modules can be different depending on the version numbers. To improve the charging compatibility in practice, multiple versions of communication protocols can be installed in chargers and vehicles. In order to ensure a certain range of flexibility, the version negotiation principle proposed in this paper is that charging is possible only if vehicle and charger both support the same version of the communication protocol.

The vehicle/charger following a particular version of the communication protocol can implement all/partial functions supported by the communication protocol according to its own operating conditions and needs. The requirements for compatibility, scalability and flexibility of the charging communication protocol are realized through version negotiation, function negotiation, and flexible configuration of optional and reloadable function modules. The version negotiation process is shown in Fig.3.

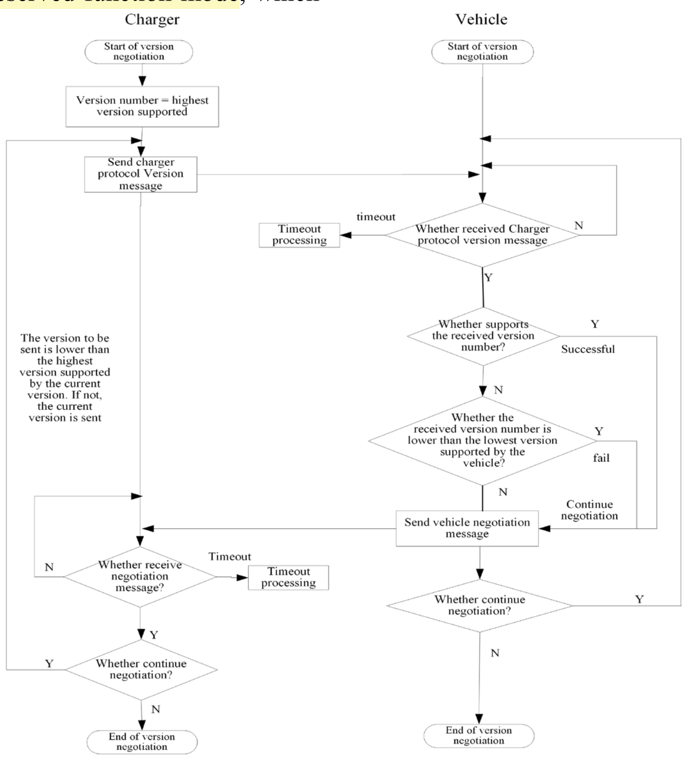


Fig. 3. Version negotiation process

## IV. Communication protocol of ChaoJi charging system

### *A. ChaoJi charging system*

ChaoJi. is a new charging system proposed by China and promoted worldwide currently [5-7]. ChaoJi draws on the advantages of the international DC charging systems and fills in the gaps that are difficult to overcome in current systems. It meets the fast, safe, and compatible charging requirements and is compatible with existing DC charging systems. More importantly, it can be smoothly upgraded with full consideration of future industrial development needs. Compared to the advantages of ChaoJi in terms of hardware, if the existing GB/T communication protocol architecture is still adopted in terms of software, the advantages of ChaoJi cannot be fully utilized and it is difficult to win international recognition. As a result, the protocol framework proposed in this paper is adopted when developing the ChaoJi communication protocol in national standard GB/T27930 [8].

### *B. ChaoJi communication protocol*

Based on the framework in chapter III, this paper proposes a concrete implementation of the ChaoJi communication protocol with the following steps.

*1) Step1:* After the vehicle and charger establish the communication link, the version negotiation function module information interaction is carried out. The charger firstly sends the highest protocol version number it supports to the vehicle, and the negotiation principles are as follows.

- If the vehicle supports the version and determines to communicate in that version, a "negotiation successful" message is returned to the charger.
- If the vehicle does not support the version and the version is lower than the lowest version supported by the vehicle, a "Negotiation Failed" message is returned to the charger.
- If the vehicle does not support the version and the version is higher than the minimum version supported by the vehicle, a "continue negotiation" message will be returned to the charger, along with the desired version number.

When the charger has received the "continue negotiation" message:

- If the current version sent is the minimum version supported by the charger, continue to send the current version, and wait for the negotiation to fail to time out.
- If the charger supports the desired version of the vehicle, the version number is sent and the negotiation is successful.
- If the charger does not support the vehicle's desired version, send the highest version lower than the current version and continue negotiation.

If the version negotiation is successful, go to Step2, and if the negotiation fails or times out, enter Step8.

*2) Step2:* The vehicle and charger enter function negotiation information interaction, the charger sends the function codes (FC) and application instance code (FDC) of all reloadable function modules it implements to the vehicle, the vehicle receives and then checks and determines the final negotiation result.

- If the same FDC can be implemented by both sides on all mandatory FCs, the negotiation is successful on that FC.
- If there is no mutually supported FDC on a particular FC, the negotiation fails on that FC.
- If multiple common FDCs are supported on a particular FC, the vehicle selects an FDC according to its own priority policy and returns the negotiation result.

If the function negotiation is successful, go to Step3 and if the negotiation fails or times out, enter Step8.

*3) Step3:* Through the above function negotiation, if the result of the negotiation between charger and vehicle is authentication with specific FDC, it will enter into corresponding information exchange of authentication.

There are currently 3 instances of authentication in ChaoJi, FDC1, FDC2 and FDC3 respectively.

if the authentication is successful, go to Step4 and if the negotiation fails or times out, enter Step8.

*4) Step4:* In the parameter configuration process the charger sends basic charging parameters (e.g. maximum/maximum output voltage, maximum/minimum output current) to the vehicle, and the vehicle receives and replies to the charging protection threshold, checking whether the charging parameters match with each other according to the following principles:

- The current voltage of the vehicle charging system is lower than the minimum output voltage of the charger.
- The current voltage of the vehicle charging system is higher than the maximum output voltage of the charger.

If the parameters are successfully matched, go to Step5, or it will go to Step8.

*5) Step5:* During the self-check function modules, the charger performs the operation of insulation monitoring detection, short circuit detection etc., the vehicle also sends the status information of its electronic lock to the charger.

If the self-check is successful and the electronic lock of the vehicle is intact, both sides move on to the next step, or it will go to Step8.

*6) Step6:* In the pre-charge and energy transfer process, the charger sends charging demand voltage, current during the energy transmission process, the charger delivers the charging output according to the demanded message, while the charger adjusts the dynamic output capacity and informs the vehicle, the vehicle will adjust the charging demand.

During the energy transfer process, when the charging is aborted normally (e.g., when the pre-set charging conditions are met) or abnormally (e.g. fault abort, artificial abort, etc.), it will go to Step7.

*7) Step7:* If the result of the function negotiation between the vehicle and the charger is “no end-of-charge", this function module will skip, or charging statistics information for both sides will interact. After that, the both sides will go to Step8.

*8) Step8:* The vehicle or charger sends the“Stop charging message”and exit charging process.

There is currently no FDC of reservation, supply model, service idle in ChaoJi. The ChaoJi communication protocol with basic charging function is shown in the Fig.4.

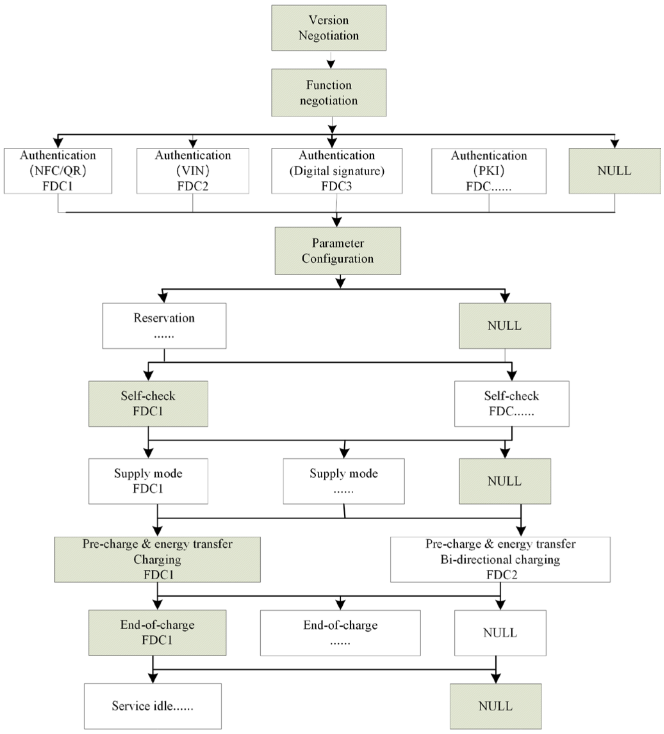


Fig. 4. ChaoJi communication protocol structure of basic charging

## V. CONCLUSION

This paper addresses a charging communication protocol framework and implementation method for electric vehicles and chargers in terms of compatibility, scalability, and flexibility of charging requirements. The framework has the following features:

- Support flexible protocol configuration: the communication protocol can be freely configured with different instances of optional function modules and reloadable function modules. vehicles and chargers supporting a particular version of the communication protocol do not need to implement all functions within the protocol, but all/partial functions according to operating conditions and needs.
- Support diverse charging scenarios: the reloadable attribution of the function modules makes different ways of solutions for the same function module possible.
- Support effective version negotiation: version negotiation is used as the first function module of the framework, both sides negotiate successfully only if the vehicle and charger support the same protocol version, which can ensure charging compatibility.

The communication protocol framework has been used in ChaoJi charging system, the Chinese national standard of which is currently being upgraded. In addition to basic charging, more new applications (such as high-power charging, bi-directional charging, plug-and-charge) based on the framework are being developed.

## ACKNOWLEDGMENT

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