The Large-Capacity EV Fast Charger “TQVC500M3” and the CHAdeMO Protocol Supporting the Charging Infrastructures

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Abstract

Preparation of battery charging infrastructures is the key to the dissemination of electric vehicles. Some types of EV chargers are already available according to applications. We would like to introduce the need for the CHAdeMO protocol that allows any vehicle to be charged optimally and the functional specifications and technologies applied to the large-capacity EV Fast Charger “TQVC500M3” that features battery recharging at the most rapid rate.

Keywords

electric vehicle (EV), low carbon society, large-capacity quick charger, CHAdeMO

1. Introduction

The recent development of high-performance lithium-ion batteries has led to the commercial release of new electric vehicles (EVs) by the automobile manufacturers.

The EV can utilize electrical energy that is easily converted from natural resources. As the EV has a high conversion efficiency of electrical energy to mechanical energy thanks to the use of its high-performance motor, it is regarded as the key to a low carbon society that will support the reduced consumption of fossil fuels such as oil and coal. In spite of its environmental friendliness, the EV requires a long time for a full charge and its cruising distance is shorter than for gasoline vehicles. These issues make it necessary to deal with the fear of battery run-out before the technology can really achieve popularity.

In order to promote acceptance by the market, it is necessary to prepare charging facilities capable of “anywhere”, “anytime” and “immediate” recharging as an inherent part of the new social infrastructures.

Below, we report on the CHAdeMO protocol for an electric vehicle quick charging system, and also introduce the functions of the large-capacity EV Fast Charger “TQVC500M3” (**Photo**).

Photo EV Fast Charger “TQVC500M3”.

2. Types of Chargers

The EV chargers can roughly be classified in the following three categories (**Fig. 1**).

- Normal charger
- Double-speed charger
- Large-capacity quick charger

(1) Normal charger

This charger uses a 100 V single-phase AC power outlet, which is identical to the power outlets used typically in Japanese households. The EV is charged via a charger mounted on the vehicle (AC-DC converter). Charging takes about 14 hours so it should be conducted during the period the EV is not used, which is typically in the nighttime.

(2) Double-speed charger

This charger uses a 200 V single-phase AC power out-

let, which is usually installed as a stand at a parking location or garage. The EV is also charged by a charger mounted on the vehicle just like a normal charger.

The charge time of about 7 hours is half that of the normal charger. It is called the double-speed charger because it is capable of charging at twice the speed of the normal charger. However, drivers might not feel that the charging time seems to be as fast as the name implies.

(3) Large-capacity quick charger

This charger has an output power of about 50 kW and charges the car-mount battery directly. It is usually equipped with a user authentication function.

The charging time is as short as 15 to 30 minutes, which means that, if the charger is installed at a commercial facility, the EVs of the customers can be charged while they are doing shopping. The charger communicates with the EV using the CHAdeMO protocol and controls the charge current to complete charging in the shortest period. As the Japanese regulations require a high-voltage reception agreement for an input power of 50 kW or more and makes it mandatory to select qualified personnel (licensed electrician etc.) for installation and maintenance of the power receiving equipment, this charger is suitable for installation in large-scale buildings and large commercial facilities.

3. CHAdeMO

The "CHAdeMO" is named from the three puns "CHArge de MOve = 'de' meaning 'for' in Japanese", "de = first syllable of Japanese word ' *denki* ' meaning electricity" and "CHAdeMO = part of Japanese sentence ' *Kuruma no juden-chu ni o-CHA demo ikaga desuka?* ' which means 'Let's have tea while charging'".

The following subsections describe the needs and functions of CHAdeMO.

3.1 Specifications of the CHAdeMO

The specifications of the CHAdeMO are formulated by the CHAdeMO Association. This association was established in March 2010 aiming at the enhancement of charging infrastructures required to support the dissemination of the EV, which aims to contribute to a reduction in emissions from vehicles and to the stabilization of energy supplies. The association is composed of secretary members that include the automobile manufacturers and power companies, the regular members including the charger and parts manufacturers, the supporting members and the observer organizations.

The association is deploying activities aimed at establishing international standards for EVs from Japan, by advocating "recommending and standardizing the CHAdeMO Protocol enabling optimum quick charging for any vehicle as a global standard".

3.2 CHAdeMO Protocol

If automobile manufacturers adopt different charging methods for different models, the quick charger should be compatible with all of the charging methods.

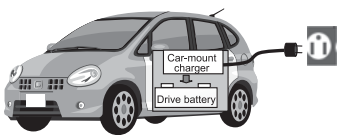
Type	Large-capacity quick charger	Double-speed charger	**Normal charger**
Specifications	Voltage: 500 V DC Current: 125 A Power: 50 kW Charging time: Approx. 15 to 30 min. (Charging rate 0 to 80%)	Voltage: 200 V single-phase AC Current: 20 A Power: 4 kW Charging time: Approx. 7 hours. (Charging rate 0 to 80%)	Voltage: 100 V single-phase AC Current: 15 A Power: 1.5 kW Charging time: Approx. 14 hours. (Charging rate 0 to 80%)
Charge method			

Fig. 1 Types of chargers.

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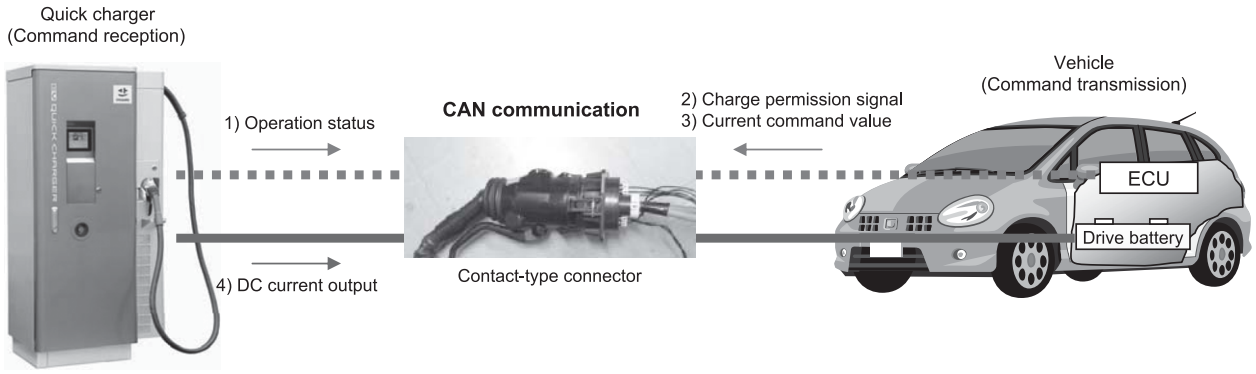

Fig. 2 CHAdeMO protocol operations.

Such a situation would necessitate complication of the charging function and hinders enhancement of the installation of charging infrastructures. On the other hand, if all EVs are forced to use the same charging pattern, the EV manufacturers cannot employ their original charging technologies, so that the overall performance would be unable to improve. To solve this issue, CHAdeMO proposed, which defines a common charging protocol so that the EV and charger communicate with each other to charge the battery under the best conditions for both.

One of the biggest features of the CHAdeMO Protocol is that the EV determines the optimum charge current according to the status of the mounted battery while the charger performs charging by following instructions from the EV that are sent from moment to moment. This feature makes the protocol compatible with any combination of vehicle models and quick charger types. The operations of the CHAdeMO Protocol are performed as shown below (**Fig. 2**).

1) When the start button on the charger is pressed, the charger notifies the EV of the operation status.
2) The EV confirms the operation status of the charger and sends the charge permission signal.
3) The EV sends the current command to the charger (the EV requests the optimum charge current according to the battery status).
4) The charger outputs current according to the current command from the EV. Hereafter, steps 3) and 4) are repeated.
5) Charging is completed when the stop button on the quick charger is pressed or the EV sends the charge completion notification.

4. Specifications and Functions of the Large–Capacity Quick Charger

This section describes the specifications and functions of the TQVC500M3 large-capacity quick charger.

4.1 Design Specifications

The input voltage of the charger is rated at 200 V three-phase, three-wire AC assuming the use of a typical motive power supply. The input voltage range is set to 170 to 230 V considering the voltage drop that may result from the distribution of cables in the installation.

The frequency variation range is rated at 47 to 63 Hz considering the use of a power supply with poor frequency stability such as a diesel power generator. The power factor is 0.95% or more thanks to the PFC (Power Factor Correction) circuit.

With regard to the higher harmonic current, this is considered to be equivalent to equipment incorporating an inverter and is set identically to the grid interconnection code of "total current distortion less than 5%, individual current distortion less than 3%". The operation location requires procedures equivalent to IP45 for outdoor installations in parking lots and roadsides. The ambient operating temperatures are specified at -10 to +40°C assuming the use in Japanese territories other than cold regions (**Table**).

4.2 Function Blocks

The quick charger is composed of two blocks, including the

Table System specifications.

	Item	Specifications
Input	AC voltage	170 to 230 V three-phase AC
	Frequency range	47 to 63 Hz
	Power factor	0.95% (*1)
	High-frequency outflow current	Total current distortion: ≤5%
		Individual current distortion: ≤3%
Output	DC voltage output range	50 to 500 V
	Max. power	50 kW
	Ripple voltage	≤5% (*2)
	Ripple current	≤5% (*2)
Other	Efficiency	≥90% (*1)
	External Interface	LAN (10BASE-T, 100BASE-TX) port × 1
		Serial (RS-232C) port × 1
	Structure	Outdoor installation (IP45 equivalent)
	Ambient temperature/humidity	-10 to +40°C/ 30 to 90%
	External dimensions	830 mm(W) × 1,650 mm(H) × 550 mm(D)
	Weight	Approx. 380 kg

*1 Input: 200 V AC, Output: 400 V DC - 125 A
*2 Output: 400 V DC - 125 A

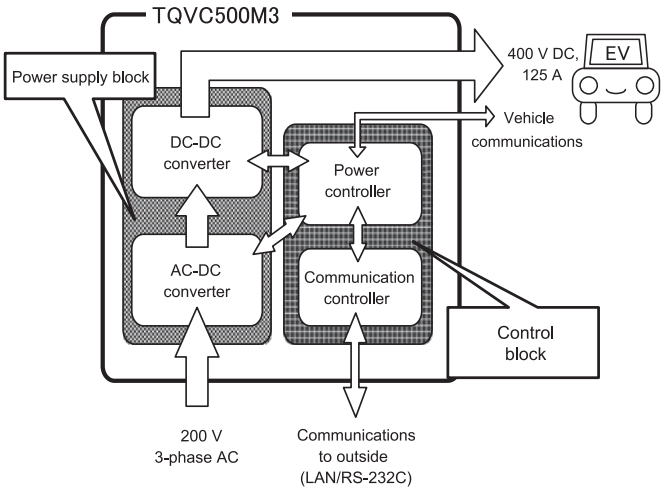

Fig. 3 Function blocks.

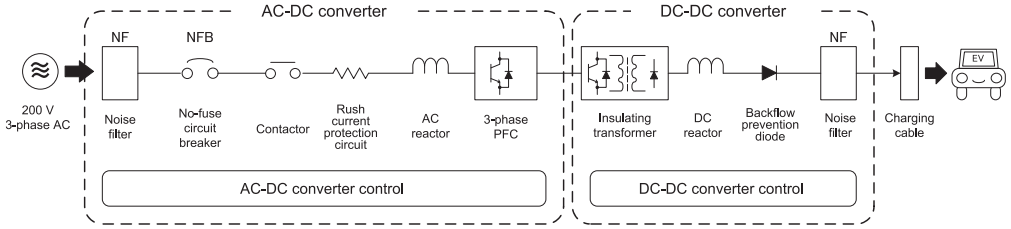

Fig. 4 Details of power supply block.

"power supply block" that generates the DC output from the 200 V three-phase AC input and the "control block" that controls the vehicle communications and communications to outside as well as the power supply block (**Fig. 3**).

(1) Power supply block

The power supply block consists of two converters: the "AC/DC converter" including the PFC circuit and the "DC-DC converter" including the insulating transformer (**Fig. 4**).

The electricity flows in the order of: 200 V 3-phase AC input → Noise filter → No-fuse circuit breaker → Contactor → Rush current protection circuit → AC reactor → 3-phase PFC → transformer-insulated DC-DC converter → Backflow prevention diode → Output noise filter → Charging cable → EV.

1) AC-DC converter

The AC-DC converter rectifies the 200 V three-phase AC input by means of three-phase PFC control. During this procedure, it also reduces the harmonics of the input current, improves the power factor and stabilizes the DC bus.

The harmonics reduction function and power factor improvement function serve to reduce the burden on the system.

2) DC-DC converter

The DC-DC converter converts DC voltage into a high-frequency AC voltage and applies the voltage to the insulating transformer.

The insulating transformer is necessary for ensuring the safety of the operator and vehicle by insulating the power grid (200 V AC) and charger output.

The converter rectifies and smoothes the secondary voltage of the insulating transformer and generates a DC voltage.

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The output voltage range is as wide as 50 to 500 V in order to deal with the various EV batteries. The maximum current output is 125 A.

(2) Control block

The control block consists of two blocks; the "power controller" that commands the power supply block to start/stop the charge current and controls the charge current based on communications with the EV, and the "outside controller" that allows a remote party to control and maintain the charger.

1) Power controller

The power controller communicates with the EV using the CHAdeMO Protocol.

The communication interface applies the contact signal and CAN (Controller Area Network) communication. Rarity of malfunction thanks to high noise resistance and the fast communication rate allows the power controller to respond to the charge commands sent successively from the EV. The power controller controls the current of the power supply block linearly so that efficient charging is possible.

2) Outside controller

The outside controller has a high-brightness color display with a touchscreen on the front panel that is highly legible, even under direct sunlight outdoors.

The outside communication interfaces (LAN/RS-232C) are available for starting/stopping charging and managing operational situations remotely.

As the optional functions, it is possible to add an authentication function that uses an IC card or e-money for billing, and a contact input/output function that enables external control and monitoring.

5. Conclusion

The dissemination of EVs has made it necessary to install quick chargers at various locations. Quick chargers are also required to further reduce their size to deal with installation space issues when charging multiple vehicles simultaneously. The size reduction imposes a need for improvement of the power factor and reduction of the magnetic parts sizes by increasing the switching frequency.

Furthermore, the quick charger is expected to be used as a bidirectional converter for V2G (Vehicle to Grid) applications, with which the lithium-ion battery of the EV will be used as an energy storage device. In the future, we will advance development of more attractive products by adding various service features.

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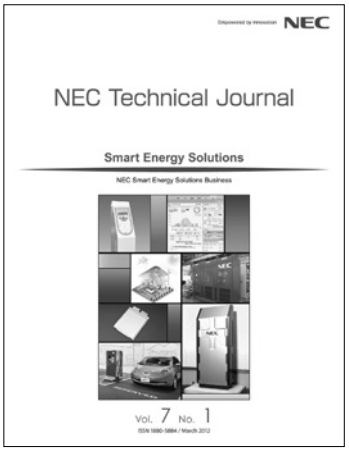

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