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EV Charging Standards and V2X: Which Standard Is Leading Toward V2X Penetration?

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Introduction

Battery electric vehicles (EV) are gaining great attention globally from the environmental perspective. As the access and functions of EV chargers are directly linked to the convenience for EV users, fierce competitions are under way in Japan, Europe and the United States to develop a de-facto fast-charging standard. Each standard largely differs in various aspects, including the connector inlet and communication protocol between charging stations and EVs, as explained in various articles written to date; however, there have been few articles comparing their V2X functions. This paper therefore overviews major fast-charging standards with a focus on V2X.

What are the V2X functions? V2X stands for “Vehicle to X” meaning power supply from EVs to power grids or end-users. V2X includes power supply to other EVs (V2V: Vehicle to Vehicle), to electrical appliances (V2L: Vehicle to Load), to homes and office buildings (V2H: Vehicle to Home and V2B: Vehicle to Building) and to the power grid (V2G: Vehicle to Grid). V2X can potentially contribute to realizing a smart energy system, providing demand response (DR) and virtual power plant (VPP) opportunities and integrating variable renewables. V2X functions are also expected to enhance the resilience of energy systems as emergency power sources. When Typhoon No.15 hit Japan in September 2019, EVs were sent to damaged regions to provide electricity to electrical appliances, such as smartphones[1].

Overview of existing fast-charging standards

There are five major fast-charging systems (Table 1): CHAdeMO initiated by Japanese companies, CCS1 (U.S. standard) and CCS2 (European standard) developed by European and U.S. automakers, the GB/T standard in China, and Supercharger developed by Tesla Corporation[2]. The

[1] Sankei Shimbun, “Running batteries useful in disaster-hit areas – Automakers lease EVs,” September 23, 2019 https://www.sankei.com/economy/news/190923/ecn1909230006-n1.html (Access date: October 2, 2019)

[2] CHAdeMO was named after “charging for moving” and “drinking cha (tea) during charging.” CCS stands for

CHAdeMO standard was developed by the CHAdeMO Association, the CCS1-2 standards by CharIN and the GB/T standard by the China Electricity Council[3]. The CHAdeMO, CCS1, CCS2 and GB/T systems have been standardized regionally or internationally.

Table 1 Overview of major EV fast-charging systems

		CHAdeMO	CCS1 (U.S.)	CCS2 (Europe)	GB/T	Supercharger
Developer		CHAdeMO Association	CharIN		China Electricity Council	Tesla Corporation
Standardization	IEC	✓	✓	✓	✓	
	U.S.	IEEE	SAE			
	EN (Europe)	✓		✓		
	JIS (Japan)	✓	✓	✓	✓	
	GB (China)				✓	
Communications protocol		CAN	PLC		CAN	CAN
Number of charging stations		18,000	7,000		220,000	8,500
Region		69 countries	U.S., Europe, Korea, Australia, etc.		China	World
V2X functions		Commercialized	Under development		Not available. To be commercialized in the next generation (Chaoji)	Not available

(Sources) CHAdeMO Association document [1], CharIN document (Grid Integration Levels version 4)

(Note) IEC for International Electrotechnical Commission, IEEE for Institute of Electrical and Electronics Engineers, SAE for Society of Automotive Engineers, EN for European Norm, JIS for Japanese Industrial Standards, GB for China's national standard. The numbers of installed fast chargers and regions are as of 2018.

These standards differ in various aspects, such as the connector inlet, communication protocols and safety measures. A key difference among them is the communication protocol between

Combined Charging System. GB/T represents Guo jia (national), Biao zhun (standard) and Tuijiang (recommended).

[3] The CHAdeMO Association was founded in 2010, led by Toyota Motor Corp., Nissan Motor Co., Mitsubishi Motor Corp., Fuji Heavy Industries Ltd. and Tokyo Electric Power Co. CCS has been developed since 2012 mainly by eight U.S. and German automakers (Audi, BMW, Chrysler, Daimler, Ford, GM, Porsche and Volkswagen).

EV chargers and vehicles[4]. CHAdeMO, GB/T and Supercharger adopt the CAN (Controller Area Network) protocol. The CAN protocol was originally developed as an on-board network for vehicle controllers, featuring excellent communication reliability (high noise resistance and error-detection capabilities). This protocol ensures an accurate, safe and secure charging sequence; accuracy is crucial for commercializing the V2X functions in CHAdeMO, which is the only enabler of V2X as mentioned below. In contrast, CCS employs a communication protocol based on PLC (Power Line Communication)[5]. To manage the charging process in a cost-efficient manner while leveling electricity load, this protocol is designed for EVs to communicate with power grids to obtain grid operation and electricity price information [2]. Compared with CAN, however, PLC features less communication reliability due to relatively low noise resistance, posing technical challenges for realizing V2X functions.

Among the five major charging systems, GB/T boasts the largest share due to the vast Chinese market. As of 2018, the number of GB/T fast-charging stations amounts to 220,000, mainly in China, accounting for 87% in the world, followed by CHAdeMO (18,000 stations=7%), CCS (3%) and Supercharger (3%). In August 2018, the CHAdeMO Association and the China Electricity Council announced that they will jointly develop a next-generation Japan-China standard “Chaoji,” targeting the year 2020.The Japanese and Chinese groups together account for 94% based on the current global number of installed fast charging stations, indicating the potential de-facto standardization and future cost reduction through mass production. The CHAdeMO Association is negotiating cooperation with German automakers on the CCS side, although no announcement has been made as of this writing; the future international market may shift to a competition between Chaoji (Japan-China joint standard) and CCS.

Availability of V2X functions

V2X functions are not necessarily commercialized for all the major standards; as of 2019, these functions are available only in the CHAdeMO standard (Table 1). The CHAdeMO Association began developing V2X specifications around 2012 (Figure 1), and various V2X products have already been released around the world, including in Japan, Europe and the United States. To guarantee the safe and secure operation of CHAdeMO chargers as well as V2H and V2L products, the CHAdeMO Association has developed a third-party certification system. No serious incidents have been reported regarding the CHAdeMO infrastructure; this would be one of the technical advantages of CHAdeMO compared to other major standards.

[4] During fast charging, chargers and EVs communicate various data, such as the remaining battery level and maximum allowable current.

[5] This communication protocol is standardized as ISO/IEC 15118.

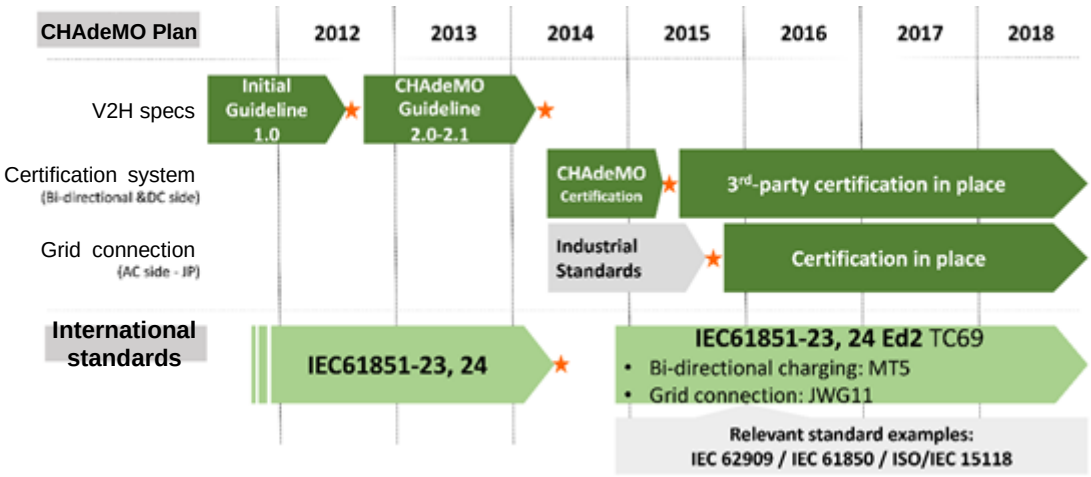

Figure 1 Timeline of CHAdeMO V2X specification and certification system development

(Source) CHAdeMO Association document [3]

V2X functions are under development in the GB/T and CCS standards. GB/T plans to incorporate V2X functions in the next-generation Japan-China joint standard (Chaoji) [3], implying that V2X functions are to be technically available in China in the near future. The vast Chinese market would be attractive for V2X product manufacturers.

There have been limited updates from the CCS-side regarding the commercialization of V2X functions since the establishment of the CharIN in 2012. Given that they put continuous efforts into research and development of the PLC protocol, the Initiative might have been focusing on a unidirectional optimal charging system, rather than bi-directional charging (V2X). In response to growing interests in V2X functions, however, CharIN recently released a position paper about V2X functions in December 2018, expressing their interests in this technology [4]. They also updated a roadmap for V2H and V2G (hereinafter "V2H/G") functions [5]. The roadmap has five phases from the present to the commercialization of V2H/G functions. Version 4 of the roadmap, released in November 2018, scheduled to realize V2H/G by around 2025 (Figure 2a), but the timeframe is excluded in the latest version 5, indicating that CCS is ready for V2G (Figure 2b). This update implies accelerated research and development in the CharIN initiative, while we also need to continue watching future updates from the CCS side, especially, how they will overcome technical challenges including communication reliability.

Conclusion

This paper overviewed major EV charging standards and the availability of V2X functions. One of the highlights of this paper is that the CHAdeMO standard is the only enabler of V2X functions as of 2019; selection of charging standards would be a key factor for accelerating V2X businesses.

EVs are gaining great attention in developing countries and regions, such as India and Southeast Asia, providing large opportunities for each standard to widely spread as a national standard. From Japan's technology export perspective, smart and resilient energy management by V2X would be a great advantage.

Reference

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[2] Junichi Takemoto, "European EV Charging Standard 'Combo' Developed with Consideration Given to Leveling Power Output and Billing," https//monoist.atmarkit.co.jp/mn/articles/1407/02/new014_2.html (July 2, 2014) (Access date: October 1, 2019)

[3] Tomoko Yamabe, "European EV Market Trend and V2X," http://www.nihonjinkai.be/file/jetro/seminar2018_2_shiryo4.pdf (Access date: October 2, 2019)

[4] CharIN, "Mission Statement: Grid Integration," released on December 11, 2018 https://www.charinev.org/fileadmin/Downloads/Papers_and_Regulations/Grid_Integration_Mission_Paper.pdf (Access date: October 2, 2019)

[5] CharIN, "Grid Integration 2019-05-23-Version 05," https://www.charinev.org/fileadmin/Downloads/Papers_and_Regulations/CharIN_Levels__Grid_Integration_v5.pdf (Access date: October 2, 2019)

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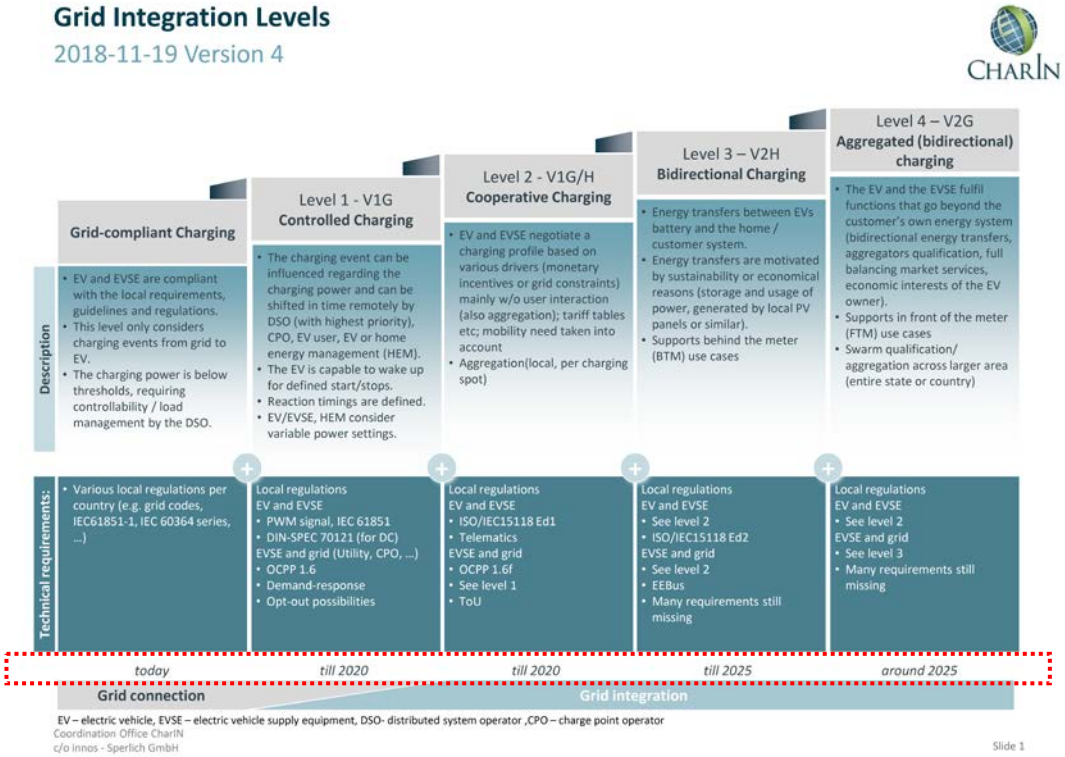
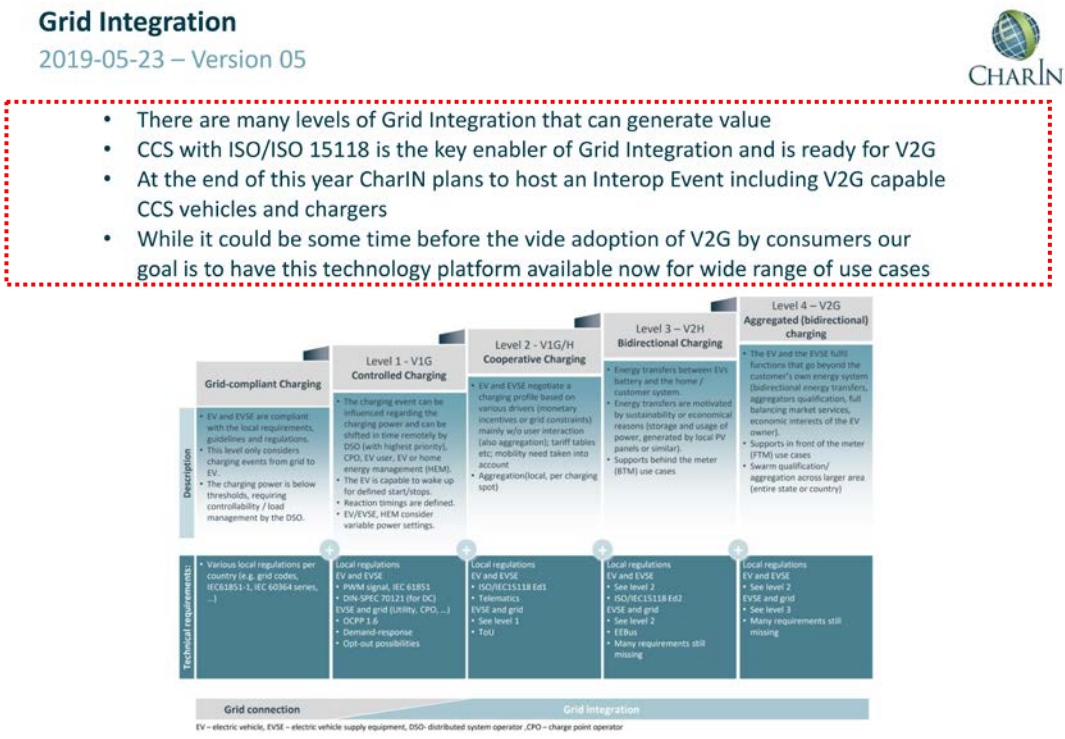


(a) Version 4 (Released on November 19, 2018)



(b) Version 5 (released on May 23, 2019) [5]

Figure 2 CharIN V2H/G realization plan

(Note) Red dotted lines were added by the authors