36th International Electric Vehicle Symposium and Exhibition (EVS36)
Sacramento, California, USA, June 11-14, 2023

CHAdeMO EPAC Project: DC charging standard for Electrically Power Assisted Cycles (EPACs)

Daisuke Takahashi

CHAdeMO Association, Tokyo, Japan, ebike@chademo.org

Executive Summary

In the last 10 years, sales of EPACs (Electrically Power Assisted Cycles) have grown significantly in Europe, Japan the U.S., and other regions. While conventional EPACs have been designed to be charged at home using a proprietary charger, as the market for EPACs grows and their applications expand, there is an increasing need for a faster, 'standardised' charging infrastructure. In response to such growing needs, CHAdeMO Association decided to establish a new DC charging standard for EPACs. This paper shall describe backgrounds, key features, current project status and future prospects of CHAdeMO EPAC project.

Keywords: bicycle, DC Fast Charging, lithium battery, PAS, standardization

1 Introduction

EPACs (Electrically Power Assisted Cycles) have grown significantly in Europe, Japan the U.S., and other regions in the last decade. Given this rapid expansion and demands from the industry, CHAdeMO Association started in September 2021 its new project to develop its charging standard for EPACs.

The CHAdeMO EPAC project is unique and important because there had been few initiatives to develop a charging standard for EPACs.

This paper will describe the background, key specifications, and future prospects of the CHAdeMO EPAC standardisation project.

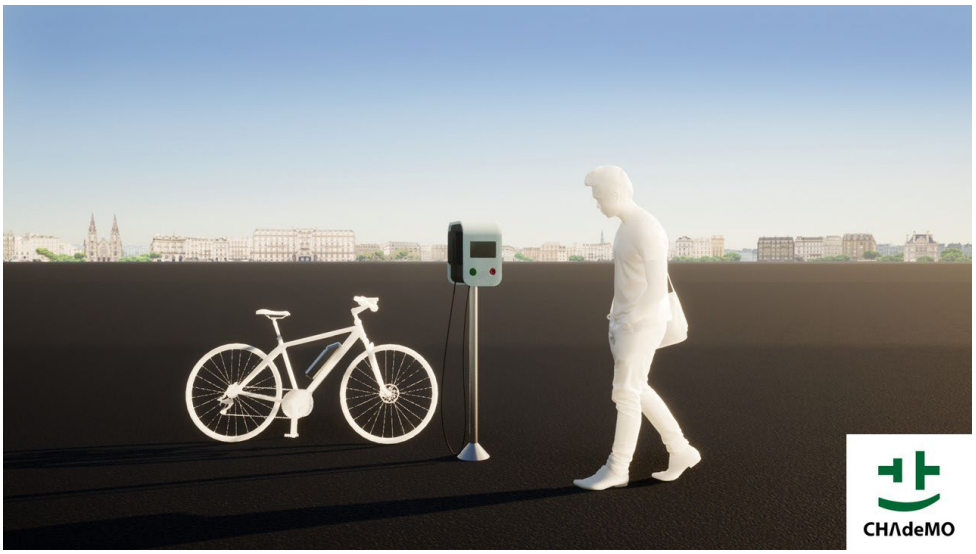

Figure 1: Image of CHAdeMO EPAC charger & EPAC

2 Backgrounds

2.1 Definition of EPAC

An 'EPAC' stands for Electrically Power Assisted Cycle and is generally defined as follows:

> *cycle, equipped with pedals and an auxiliary electric motor, which cannot be propelled exclusively by means of this auxiliary electric motor, except in the walk assistance mode* [1]

In Europe, the U.S., and Japan, as far as EPACs are in conformity with certain requirements, the same rules as conventional bicycles are applied, and no driver's license or license plate is required.

Table 1 is a summary of EPAC regulations for these regions.

With the acceleration of the market growth, the international safety standard ISO/TS 4210-10[1] was released in 2020, and is expected to become more widely used in the future.

Figure 2: Image of EPAC (Trek FX+ 2 Stagger) [10]

2.2 The EPAC market

The EPACs were originally introduced to the market by a Japanese company Yamaha Motor Cooperation in 1992.

Table 1: Summary of EPAC regulation

	Max Power	Max. Speed	Max Assistance ratio
EU Nations [2]	250 [W]	25 [km/h]	N.A.
USA(Class #1) [3]	750 [W]	20 [mph] (32 [km/h])	N.A.
Japan [4]	N.A.	24 [km/h]	200 [%]

Since then, the EPAC market has steadily grown and it is estimated at 5 million units in the EU [5], 1.1 million units in United States [6] and 800 thousand units in Japan in terms of new vehicle sold per year [7] (as of 2021).

During the Covid-19 pandemic, the general concept of public transportation has changed, and the importance of personal small vehicles like EPACs was reconsidered. In fact, the two-year comparison from 2019 to 2021 shows strong growth rates of +50% in EU, +60% in the U.S., and +13% in Japan.

2.3 Backgrounds of the growing EPAC market

As mentioned above, the EPAC market has shown steadily growth over the past decade, EU, Japan and United States. The background to this growth can be briefly considered for several reasons.

First of all, the fact that EPAC is a clean vehicle that do not use fossil fuels is no doubt the reason for support among many end-consumers and other stake holders.

In addition, EPACs can be used just as easily as (normal) bicycles, but they require less power because of the motor assist. As a result, our study have indicated that EPAC users ride their EPACs more frequently and longer distances than that of "normal bicycles". In other words, the higher convenience of EPACs compared to "normal bicycles" is one of the main reasons behind the popularization of EPACs.

On the other hand, compared to regular passenger (4-wheels) EVs, EPACs have an advantage that they are less affected by the traffic problems found in many large cities, such as chronic traffic jams and lack of parking spaces. In addition, a large part of residents in such large cities are sufficient to travel short distances, making the choice of EPACs over passenger EVs more reasonable decision.

2.4 Market demand for 'standardised' charging infrastructure

Since the majority of EPACs are privately owned at the moment, the current EPACs are designed to be charged at home using a proprietary charger, just like many other consumer electronic devices. As home charging typically takes place at night, charging time is usually set at 2 to 5 hours.

However, as the market for EPACs grows and their use expands, there is an increasing need for a faster 'standardised' charging infrastructure, enabling charging in a short time. According to our research, the following use cases are envisaged:

1. For shared cycle operators or delivery service providers who need to charge EPACs frequently and rapidly
2. For restaurants and shops who wish to offer chargers as an incentive to encourage customers to visit more frequently
3. For large companies who wish to incentivise their employees to switch their cars to EPACs for commuting

In response to such growing and diversified needs, CHAdeMO Association decided to establish a new DC charging standard for EPACs in February 2021 by inviting participation from inside and outside of the Association, which resulted in the official launched of the project in April 2021. [8]

Figure 3: Image of a bicycle parking with multiple CHAdeMO EPAC chargers

2.5 Market demand for ‘standardised’ charging infrastructure

EPACs are designed to be charged at home using a proprietary charger, just like many other consumer electronic devices. As home charging typically takes place at night, charging time is usually set at 2 to 5 hours.

However, as the market for EPACs grows and their use expands, there is an increasing need for a faster ‘standardised’ charging infrastructure, enabling charging in a short time. According to our research, the following use cases are envisaged:

2.6 Wide variation of CHAdeMO DC charging standard

By adding the new DC charging standard for EPAC, CHAdeMO Association will provide four charging standards in total.

These consist of “CHAdeMO” for passenger EVs, “ChaoJi” for higher output such as EV buses, e-PTW CHAdeMO for e-Power-Two-Wheels, and EPAC CHAdeMO, and can cover a range from a very low charging output of 800W to a high-power output of over 1MW.

It may seem inefficient to have these four charging standards at first glance, however, each of these four categories has very different safety requirements and acceptable costs.

We believe that optimizing for each use case is consequently the way to optimize the cost of social deployment.

Table 2: CHAdeMO DC charging standards and their intended applications

Application	Output Power	Specification
EV Bus, and more...	> 1 MW	ChaoJi
Commercial EV, Passenger EV	10 to 400 kW (150V to 1,000V)	CHAdeMO (IEC 61851-23)
eMotorcycle, LEV	1 to 10 kW (20V to 120V)	e-PTW CHAdeMO (IEC 61851-25)
eBike (EPAC), eScooter	< 800 W (max 42 V)	EPAC CHAdeMO (Based on ISO/TS 4210-10) Electrically Power Assisted Cycles

3 Key features of the e CHAdeMO EPAC charging standard

A DC charging standard for EPACs, unlike passenger vehicle charging standards, requires the following features:

1. Low-power and low-voltage charger suited to EPAC batteries
2. Small size and lightweight outlet / inlet to go with EPACs’ small body size and weight
3. Compatibility with existing EPAC batteries which were originally designed for charging by proprietary chargers
4. ‘Pluggability’ into household electrical outlets requiring no specific electrical installation

5. Communication protocol and principle design of control sequences are identical with other CHAdeMO standards.。

The following chapter explains further each of the above requirements.

3.1 Output

Using the lithium-ion technology, a typical EPAC battery has a capacity of around 500 Wh and a rated voltage of 24 V to 36 V (7 series to 10 series).

The output of the EPAC fast charger was designed as indicated in Table 2, based on the assumption that the above battery would be charged 80% of SOC in 30 minutes.

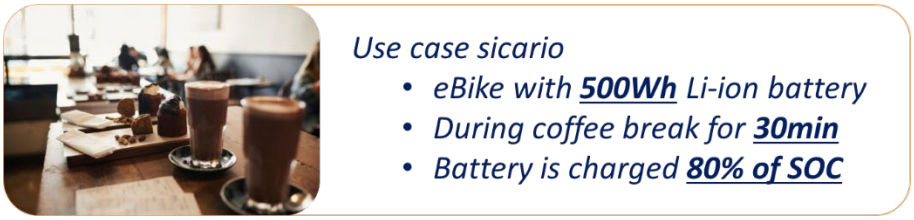

Figure 4: Use case scenario of CHAdeMO EPAC charger

Table 3: Output specifications

	Voltage	Current	Power	Charging mode
Output	14V to 45V	0.1A to 20 A	Max 800 W	Constant current

3.2 Small size and lightweight outlet / inlet

As EPACs are smaller and lighter than EVs, a small size and lightweight connector (outlet & inlet), compliant with the ISO/TS 4210-10 standard has been applied.

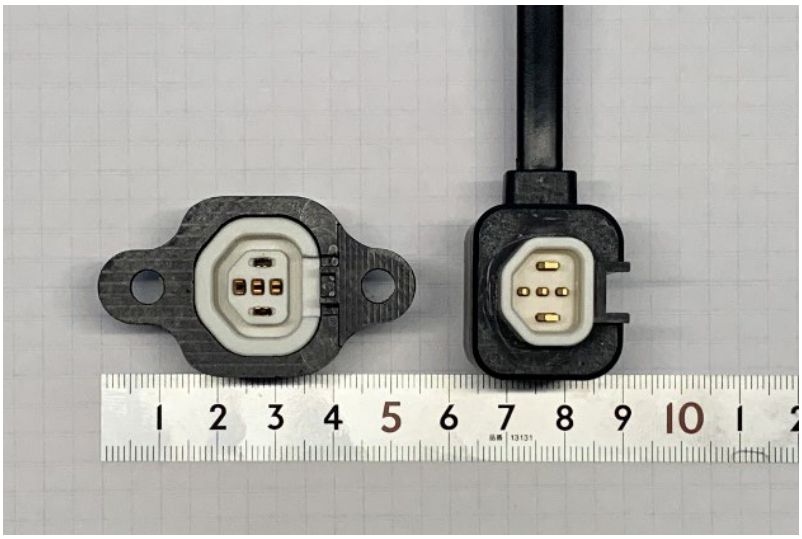

Figure 5: outlet & inlet of CHAdeMO EPAC charger (cm)

3.3 Compatibility

Considering the number of EPACs with their proprietary chargers already in the market, the CHAdeMO EPAC charger is designed to be easily compatible with existing EPACs thanks to the “connection adapter”.

The adapter does not have a switch and hence does not require any contactors or semiconductor-switches. This makes CHAdeMO EPAC charger to be small and affordable.

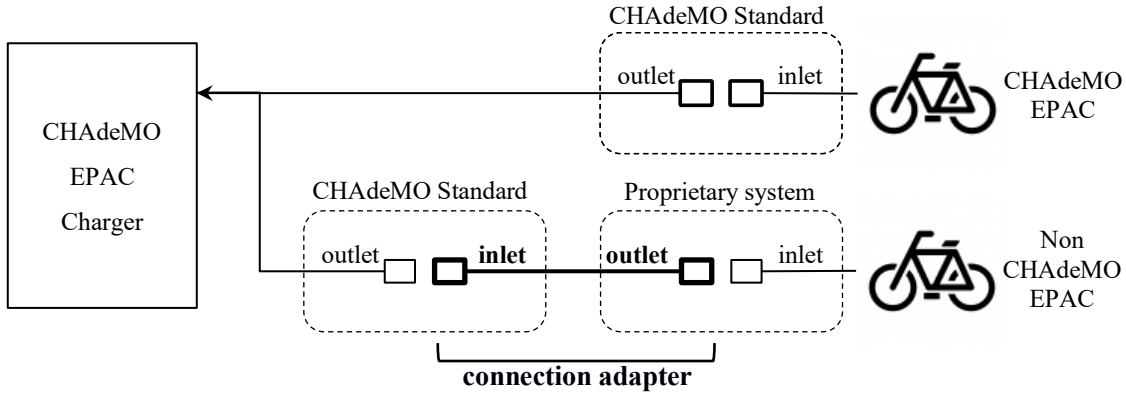

Figure 6: compatibility by “connection adapter”

3.4 Pluggability into household electrical outlets

CHAdeMO EPAC charging is intended not only for public usage but also for small businesses such as restaurants. The charger is therefore designed to be plugged into household electrical outlets, and in conformity with product safety as defined under IEC 62368-1, which is a widely used global standard.[9]

3.5 Communication protocol & control sequence

While the above four items were modified to suit EPAC specific requirements, the communication protocol is used CAN communication, which is identical to other CHAdeMO standards. Table 4 is the main requirements the CAN communication.

In addition, its principle design of control sequence (= the procedure from “start to charging” to “end of charging”) is also identical with other CHAdeMO standards.

Table 4: CAN communication requirements

Item	requirements
Communication standard	ISO 11898-1:2015 and ISO 11898-2:2016
Protocol	CAN 2.0B active
Applicable format	Classical base frame format ・ Standard format: ID length 11 bits ・ Extended format: not used
Communication speed	500kbps
Bit sample point	72.5% -87.5%

This makes it possible to develop safe and reliable specifications in a shorter period of time, utilizing the knowledge of CHAdeMO accumulated over the decade. Similarly, for member companies developing products, it contributes to reducing development cost and resources.

4 CHAdeMO EPAC Project

The CHAdeMO EPAC project is proceeding as follows.

4.1 Standard development

The biggest outcome of this project is the development of the standard (document), which shall cover product specifications, safety requirements as well as the charging sequences. The first version of the standard was released to the CHAdeMO Association members in March 2022. It will be reviewed according to the results of validation tests with prototypes.

4.2 Verification by test-prototypes

Some member companies have already started product development based on the first version of the standard. To support their efforts and accelerate the development process, CHAdeMO Association is making working prototypes and conducting verifications.

This test-prototypes had made in two versions: “charger” and “dummy battery”.

Figure 7: test-prototype of charger (left) and dummy battery (right)

The test-prototypes make possible to support both the development of CHAdeMO charger as well as CHAdeMO-compatible battery. They also will be utilizes to ensure compatibility between chargers and batteries.

In addition, any potential improvements found through the test-prototypes verification will be reflected in the revised version of the standard to make it more complete.

4.3 Product certification

The process of product certification is also being developed in collaboration with certification bodies around the world. By having an independent third-party certification system in place, CHAdeMO Association ensures the safety and interoperability of its products, like they have done for EV chargers.

4.4 Schedule

The first version of the standard was released to the member companies in March 2022, and, at the time of writing (March 2023), verification by prototypes is in progress. The aim is to have the first ‘certified’ product on the market by the end of 2024.

5 Conclusion

As described above, the CHAdeMO EPAC project is progressing in a comprehensive manner, taking advantage of CHAdeMO's collaboration platform with a diverse range of member companies.

In the future, we would like to invite even more companies to the project and aim to expand the standard into EPACs around the world. In addition, in anticipation of global dissemination, measures against barbarism, integration with billing systems, international standardisation of the CHAdeMO industrial standard, etc. are some of the topics of the future discussions that shall be needed. We hope to gather knowledge from our various members and keep providing good solutions.

References

[1] ISO/TS 4210-10:2020, Cycles — Safety requirements for bicycles —Part 10: Safety requirements for electrically power assisted cycles (EPACs)

[2] REGULATION (EU) No 168/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 January 2013 on the approval and market surveillance of two- or three-wheel vehicles and quadricycles, https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32013R0168

[3] Bosch eBike Systems, https://www.bosch-ebike.com/us/everything-about-the-ebike/stories/three-class-ebike-system, accessed on 2022/11/01

[4] Road Traffic Act（Act No. 105 of 1960）, article 2-(xi)-2, https://www.japaneselawtranslation.go.jp/ja/laws/view/2962#je_ch1at2, accessed on 2022/11/01

[5] CONEBI, https://www.conebi.eu/bicycle-and-e-bike-sales-continue-to-grow-reaching-record-levels/, accessed on 2022/11/01

[6] Japan Bicycle Promotion Institute, U.S. Bicycle Import/Export Status-2021, http://www.jbpi.or.jp/report_pdf/rep_us_20220823.pdf, published on 2022/8/23, accessed on 2022/11/01

[7] Ministry of Economy, Trade and Industry Current Production Statistics, https://www.meti.go.jp/statistics/tyo/seidou/index.html, accessed on 2022/11/01

[8] CHAdeMO Association, News, https://www.chademo.com/new-e-bike-working-group-at-chademo, published on 2021/2/25, accessed on 2022/11/01

[9] IEC 62368-1:2018, Audio/video, information and communication technology equipment - Part 1: Safety requirements

[10] Trek Bicycle Corporation, https://www.trekbikes.com/jp/ja_JP/%E3%83%90%E3%82%A4%E3%82%AF/%E3%82%AF%E3%83%AD%E3%82%B9%E3%83%90%E3%82%A4%E3%82%AF/%E9%9B%BB%E5%8B%95%E3%82%A2%E3%82%B7%E3%82%B9%E3%83%88%E3%82%AF%E3%83%AD%E3%82%B9%E3%83%90%E3%82%A4%E3%82%AF/fx/fx-2-stagger/p/35849/?colorCode=black, accessed on 2023-03-01

Daisuke Takahashi is the project leader of EPAC Working-Group in CHAdeMO Association. He is the chief researcher of Takahashi eBike Laboratory LLC, after +20 years' experience in EPAC industry at Bosch eBike system & Yamaha Motor Corporation. He is specialized in product safety and standardiation related to EPAC and led the development of ISO/TS 4210-10 as the project leader.