EVTeC 2025
7th International Electric Vehicle Technology Conference 2025
20259048

# Multi-port EV Charger Conducive to EV Society

## - Report on Large-scale Charging with Efficient Conversion System -

**Kimihisa Furukawa [1)] Yuichi Mabuchi [1)] Daisuke Matsumoto [1)] Hiroaki Miyata [2)] Masaya Ichinose [2)]**

*1) Research & Development Group, Hitachi, Ltd., Hitachi-city, Ibaraki, Japan*

*E-mail: kimihisa.furukawa.jz@hitachi.com, yuichi.mabuchi.wz@hitachi.com, daisuke.matsumoto.af@hitachi.com*

*2) Electrical Systems Division, Hitachi Industrial Products, Ltd., Hitachi-city, Ibaraki, Japan*

*E-mail: hiroaki.miyata.jz@hitachi.com, masaya.ichinose.yk@hitachi.com*

**ABSTRACT**: Various solutions are proposed to solve the issues for EVs society. We developed and released a multi-port EV charger that can be applied for EV charging infrastructure to enable the effective use of energy in EV-based societies. In this paper, we will introduce features of the multi-port charger and an overview of the large-scale multi-port charging system that is currently being tested as one form of the multi-port EV charger, and also report on a technology for a high-efficiency isolated DC/DC converter, which is a core technology of the multi-port EV charger.

**KEY WORDS**: EV charger, DC/DC converter.

## 1. INTRODUCTION

As various efforts to achieve carbon neutrality progress, the roles of electric vehicles (EVs) are becoming increasingly important. In terms of EV fast-charging infrastructure, various solutions are being devised to make more effective use of energy, in addition to the conventional charging-only functions.

In order to solve social issues associated with the increase in an adoption rate of EVs, we developed and commercialized a multi-port EV charger suitable for EV fast charging infrastructure and new solutions that utilize EV battery charging and discharging.

The multi-port EV charger, which features a multi-port configuration, large-capacity outputs, and vehicle-to-X (V2X) functions, is expected to be used in a variety of ways, such as a step-by-step installation of equipment according to needs, a flexible output capacity changes from a normal charging to an ultra-fast charging, a high-efficiency operation over a wide operating range, and an energy management with a building, a factory, and a grid using EV battery charging and discharging.

Currently, we are conducting multiple demonstrative operations, and we are expanding EV fast charging infrastructures while gradually adding functions necessary according to solutions.

In Chapter 2, this paper provides an overview of the multi-port EV charger, including their characteristics, utilization policies, and specific examples. Chapter 3 describes a high-efficiency modulation scheme for DC/DC converters, which are the core elements of the multi-port EV charger.

## 2. OVERVIEW OF MULTI-PORT EV CHARGERS

The multi-port EV charger consists of a power conversion cabinet with one AC/DC converter, up to twenty isolated DC/DC converters, DC output switches, and up to 20 charge dispensers. EV charging and discharging including power management functions are possible. In this chapter, we introduce features of the multi-port EV charger, the utilization policy of this charging system, and a specific case study of Workplace E-Powering (WEP): assuming a large number of EVs parked for a relatively long time in an office, etc., as a form of this charging system.

### 2.1. Features of multi-port EV charger

The multi-port EV charger has three features: a multi-port configuration with multiple charging outlets, a high-capacity output such as an ultra-fast charging, and a V2X function that supplies power to various things from the EV battery.

In a multi-port configuration, up to twenty isolated DC/DC converters can be installed each of which can be independently controlled as a single EV charging converter. In an initial stage of EV introduction, the number of DC/DC converter units can be gradually increased according to needs of customers, without all DC/DC converter units being implemented. In addition, it is possible to change the number of DC/DC converter units in parallel according to charging speed required by an EV to be charged, and charging power can be changed.

In order to increase the capacity of EV batteries and realize


Fig. 1 500 kW multi-port EV charger.

ultra-fast charging of EVs, the need for high-capacity output of chargers is increasing. In addition to increasing the output current by expansion of DC/DC converters in parallel, the multi-port EV charger is designed to output a high voltage covering the existent 450 V DC class EV to the 850 V DC class EV that will become popular in the future, and can output DC power up to 500 kW with a single multi-port EV charger.

The V2X function is the ability to supply power from the EV's battery to other things such as buildings, factory equipment, and grids via an EV charger. By designing AC/DC and DC/DC converters as bidirectional specifications, it is also possible to discharge power from an EV battery. When discharging from an EV to the power grid, it is necessary to have a function such as grid-connection protection, and for this, we have applied the technology developed in grid-connected inverters for renewable energy power generation and storage battery systems. By linking the V2X function with the charge/discharge management function, the multi-port EV charger can realize effective use of energy, such as power demand shift, peak power cutting of consumer facilities, and stabilization of the power system for renewable energy generation. In addition to functions built into the multi-port EV charger, a controller installed outside the multi-port EV charger can also realize advanced energy management functions.

**2.2. Utilization of multi-port EV charger**

The multi-port EV charger can be applied to a variety of system solutions. It is possible to construct a large number of large-scale EV fast charging infrastructures at a lower cost and more compactly, such as route charging for highways, roadside stations, etc., and destination charging for large-scale offices, which are expected to be introduced in the future. In addition, it will be possible to expand and change flexibly  a capacity according to EV charging needs. In EV fast charging infrastructure for charging destinations and bases such as buildings, shopping malls, and offices, it is possible to optimize an energy use by combining energy information of the entire facilities with EV charging/discharging management functions.

The issues of introducing EVs and EV fast charging infrastructures differ depending on business fields in which they are introduced, and various novel solutions are expected to emerge in the EV-oriented society in the future. The multi-port EV charger is a product that can be applied to these solutions as standard. Depending on the issues and solutions for the introduction of EVs, the operation method and required functions of the multi-port EV charger will increase, so we plan to add functions and configurations sequentially.

In expanding the introduction of multi-port EV chargers, it is also important to operate them in actual facilities and provide feedback, and we are currently conducting and planning several demonstration operations. As a way to take advantage of the features of the large capacity of the multi-port EV charger, a demonstration site for the next-generation ultra-high-power charging standard applying this product has been built and is currently in operation at Omika Works, Hitachi Industrial Products, Ltd. In addition, Tsuchiura Works, Hitachi Industrial Products, Ltd. has started operation of "Workplace E-Powering (WEP)," an initiative to reduce $CO_2$ emissions during commuting by installing EV fast charging infrastructure in the commuting parking lot of the office and converting commuter vehicles to EVs, from FY2024. In the next section, we will introduce specific initiatives of WEP.

**2.2. Workplace E-Powering (WEP)**

As one of the application forms of the multi-port EV charger, Workplace E-Powering (WEP) was developed. The WEP is a $CO_2$ reduction model using commuter EVs, and it assumed to be a charging infrastructure for a large number of EVs parked for prolonged periods of time at offices and other locations. The first WEP system was introduced at Tsuchiura Works, Hitachi Industrial Products Ltd. Fig. 2 shows a charging scenery of the WEP. Fig. 3 shows the system configuration. In the charging system for the WEP, a power conversion cabinet contains an AC/DC converter and 10 DC/DC converter units, and five multi-connector type charging dispensers with each dispenser equipped with 4-port charging connectors. The multi-connector charging dispenser is equipped with a built-in switch that allows time-division charging of 4 EVs. The EV charging is operated under time-sharing control using multi-connector charging dispensers, in which the charging of connectors 1 to 4 (connected to a DC/DC converter) is switched every hour. The EV charging is operated in

Fig. 2  Scenery of a Workplace E-Powering (WEP).

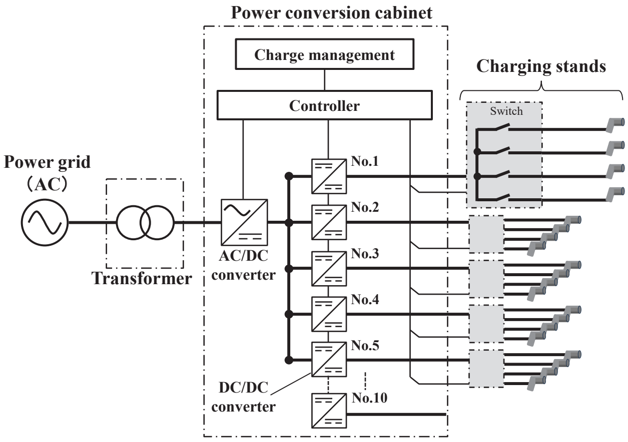



Fig. 3  System configuration of a Workplace E-Powering (WEP).

Table 1. Specification.

| Item | Values and details |
|---|---|
| System total capacity | 250 kW |
| DC/DC capacity | 25 kW |
| Number of DC/DCs | 10 units |
| Charging dispenser capacity | 25 kW / connector |
| Number of dispensers | 5 (maximum 10) |
| Number of connecters | 4 /stands |
| Charge management | Time-sharing control between 4 connectors |

turn by changing over the output connectors based on the charging schedule, the connection status of each port, and the remaining charge level of each EV. The specification of the multi-port EV charger for WEP is shown in Table 1.

## 3. HIGHLY EFFICIENT ISOLATED DC/DC CONVERTER

### 3.1. Proposed control for DC/DC converter

In the multi-port EV charger, different EVs are connected to each DC/DC converter. To separate the DC systems of the EVs from each other and ensure safety, the DC/DC converters should be applied galvanic isolations. In addition, to support EVs and use

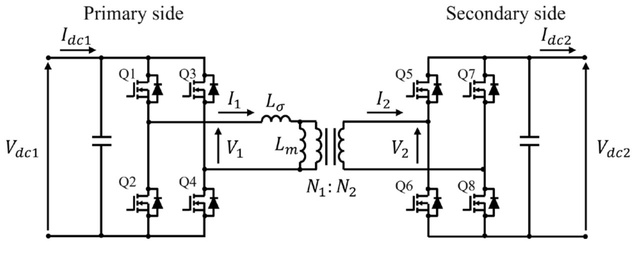
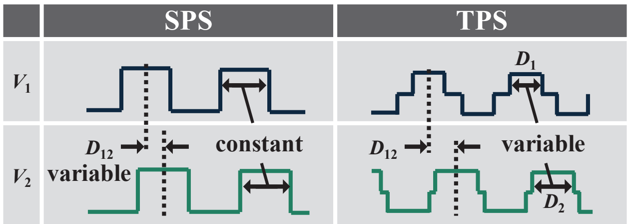



Fig. 4  Circuit configuration of DAB.

Table 2. Comparison of control methods: SPS and TPS.




cases of various specifications, the DC/DC converter is necessary to be designed for wide voltage and current operation range and bi-directional power conversion in a single circuit. Under these requirements, a dual active bridge (DAB) converter circuit with SiC power semiconductor devices and a high-frequency transformer is selected as the DC/DC converter, as shown in Fig. 4. Although DAB converter modulation schemes are classified according to degrees of freedom in controlling phase angles: single-phase shift (SPS), dual-phase shift (DPS), and triple-phase shift (TPS). The SPS modulation, which is traditionally the most used method of DAB converters, is a simple control algorithm but has a narrow operating range with high efficiency. To overcome this drawback, The DPS and the TPS are effective. In particular, the TPS is the most complex to design and algorithm, but it maximizes the DAB performance by controlling three phase angles. Table 2 briefly compares voltage waveforms of the TPS and the SPS. The TPS has been studied in the past, but there has not been enough research to minimize the total loss of semiconductor devices and a high-frequency transformer. The TPS control proposed in this development is an unprecedented novel modulation method in terms of minimizing the total loss of power semiconductor devices and a high-frequency transformer. The TPS control achieves high conversion efficiency over an unconventional wide voltage and current range.

The proposed TPS achieves high efficiency by skillfully switching between zero voltage switching and zero current switching according to voltage and current operation range.

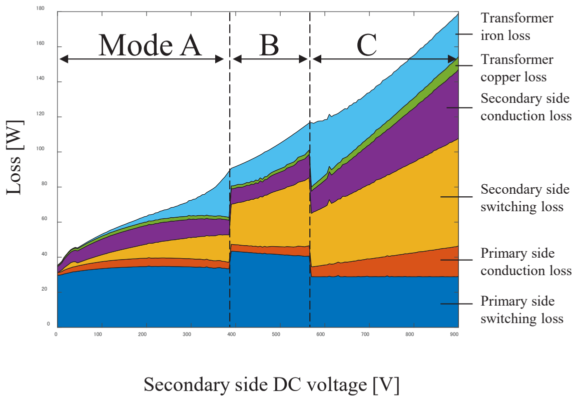
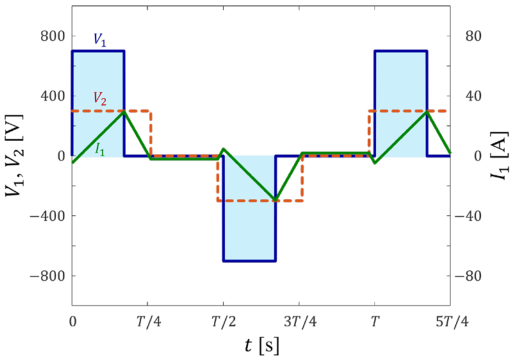
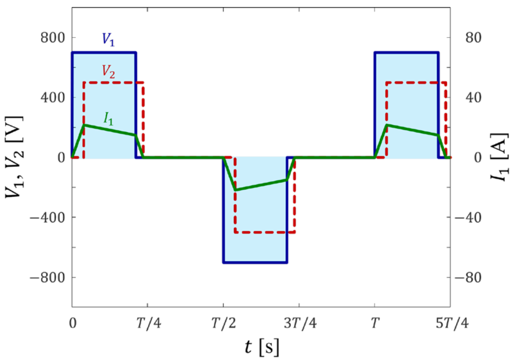


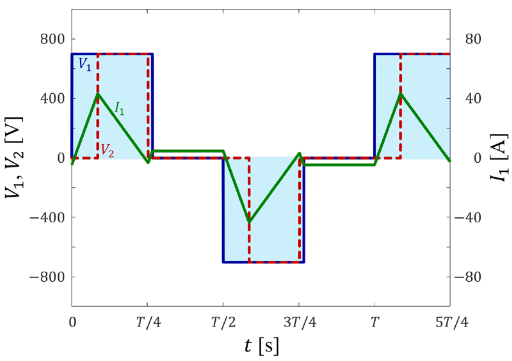

Fig. 5. Break down of losses at $I_{dc2} = 10$ A.




(a) Mode A




(b) Mode B




(c) Mode C

Fig. 6. Typical voltage and current waveforms for three modes.

As an example, Fig. 5 shows the analytical results of the breakdown of loss at the condition of the secondary side (output side) DC voltage from 0 V to 900 V and the secondary side DC current with 10A. From the breakdown figure, the switching method is changed for each of the three operating modes A, B and C, and the tendency of loss is different. In the region of operation mode B, the core loss of the high-frequency transformer is small and the switching loss of the semiconductor devices is relatively large, whereas in the operating modes A and C, the transformer core loss is large and the switching losses of the semiconductor devices are small, which tends to be the opposite of that of mode B. By changing the operating modes for each area in this way, the overall losses can be minimized.

Fig. 6 shows typical voltage and current waveforms for modes A, B, and C. Modes A and C minimize switching losses by switching the semiconductor devices under a condition called a zero-voltage switching (ZVS) at every switching moment. On the other hand, the mode B uses both a condition called a zero-current switching (ZCS) in which the current is 0 A and a condition that switches with a ZVS, which increases the switching loss, but the core loss is reduced because the current is suppressed.

By extending the above modulation concept to the operating range of all currents and voltages and determining the optimal switching mode, it is possible to realize the DC/DC converter with high efficiency over a wide operating range.

### 3.1. Experimental evaluation of proposed DAB modulation

The newly proposed modulation scheme for the DAB shown in the previous section was implemented in a 25kW converter for the multi-port EV charger. Fig. 7 shows the appearance of the DAB DC/DC converter unit using the proposed modulation scheme. The DAB circuit of Fig. 4 is mounted on this converter unit. SiC MOSFETs were applied as switching devices. For a high-frequency transformers, ferrite core was applied as a magnetic material, and Litz wires were applied to windings to improve high-frequency wire loss characteristics.

In order to demonstrate the effectiveness of the proposed TPS modulation scheme for the DAB, the efficiency of the SPS and the TPS were compared analytically, and the efficiency was measured experimentally by implementing the TPS in the developed DC/DC converter under the same operating conditions.

As shown in Fig. 8, the conversion efficiency of the DC/DC converter is experimentally confirmed, experimental maximum efficiency showed 98.8 %.

Fig. 9 shows an example of experimental waveforms controlled

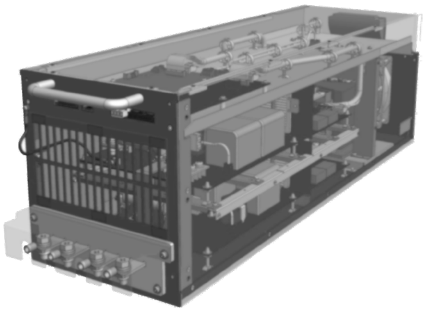


Fig. 7. Appearance of 25 kW DAB DC/DC converter using the proposed modulation scheme.

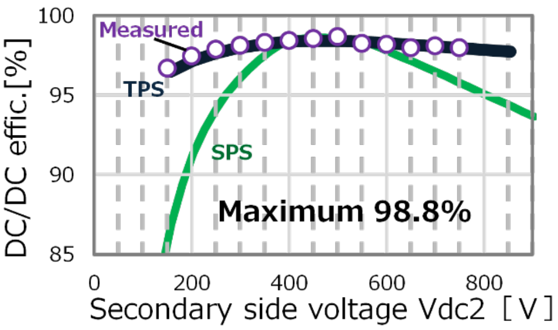



Fig. 8. DAB efficiency comparison: experimental TPS, analytical TPS and analytical SPS.

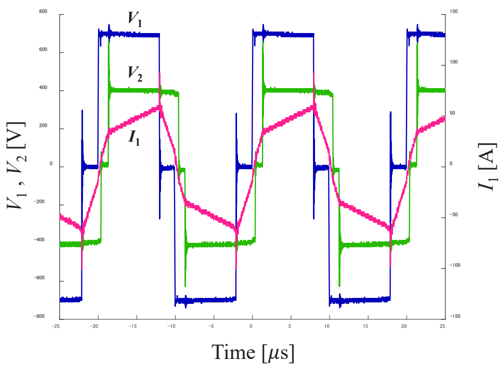



Fig. 9 Experimental waveforms of TPS at $V_{dc2} = 400$ V, $I_{dc2} = 59$ A.

by the TPS at $V_{dc2} = 400$ V, $I_{dc2} = 59$ A. The current $I_1$ is created by relations of the primary voltage $V_1$, the secondary voltage $V_2$ and the inductance of the middle frequency transformer.

### 3. CONCLUSIONS

This paper has presented the multi-port EV charger concepts and the large-scale charging system of WEP as an application example, and the bi-directional galvanic isolated DC/DC converter that is the core component of the multi-port EV charger. The developed DC/DC converter has been confirmed to have high efficiency over a wide voltage and current operation range by the newly proposed TPS modulation of the DAB converter. The maximum efficiency was 98.8% at Vdc2=450 V, and the average efficiency from Vdc2=200 to 800 V was 98.0%. In the future, we plan to add the EV charging/discharging energy management functions based on the multi-port EV charger equipped with the developed DC/DC converter, and to expand a series of the systems.

### REFERENCES

(1) Hitachi Industrial Products, Ltd., “EV Charger.” https://www.hitachi-ip.com/products/evcharger/

(2) Hitachi Industrial Products, Ltd. News Release, “Participation in the CHAdeMO3.0 (ChaoJi2) Demonstration Project for the Next-generation High Power EV Charging Standard” (Oct. 6, 2022). https://www.hitachi-ip.com/news/20221006.html

(3) Hitachi Industrial Products, Ltd. News Release, “Hitachi Industrial Products to Launch High-capacity Multi-port EV Charger that Contributes to the Expansion of Charging Infrastructure and Growth of EVs towards the Realization of a Decarbonized Society” (Sept. 19, 2023). https://www.hitachi-ip.com/news/20230919.html

(4) News Release from Hitachi Industrial Products, Ltd., “High-efficiency Multi-port EV Charger that Contributes to the Expansion of Charging Infrastructure Received a Judge Committee's special award at the 53rd Japan Industrial Technology Awards organized by The Nikkan Kogyo Shimbun” (Apr. 4, 2024) in Japanese. https://www.hitachi-ip.co.jp/information/20240404.html

(5) M. Ichinose, K. Gorai, H. Miyata, R. Gomi and K. Furukawa, “Multi-port EV Charger Contributes to Effective Energy Use Solutions in an EV Society,” in Hitachi Review, June. 2024.

(6) F. Krismer and J. W. Kolar, "Closed Form Solution for Minimum Conduction Loss Modulation of DAB Converters," in IEEE Transactions on Power Electronics, vol. 27, no. 1, pp. 174-188, Jan. 2012.

(7) M. Capó-Lliteras, G. G. Oggier, E. Bullich-Massagué, D. Heredero-Peris and D. Montesinos-Miracle, "Analytical and Normalized Equations to Implement the Optimized Triple Phase-Shift Modulation Strategy for DAB Converters," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 11, no. 3, pp. 3535-3546, June 2023.