The 18-th International Conference on Electrical Machines, Drives and Power Systems ELMA 2023
June 29 - July 1 2023, Varna, Bulgaria

Charging Station Infrastructure and Standards for Electric Vehicles - State, Problems and Future Trends

Andrei Borisov
Department of Power Electronics
Technical University of Sofia
Sofia, Bulgaria
a.borisov@elsys-bg.com

Gergana Vacheva
Department of Power Electronics
Techniical University of Sofia
Sofia, Bulgaria
gergana_vacheva@tu-sofia.bg

Nikolay Hinov
Department of Power Electronics
Technical University of Sofia
Sofia, Bulgaria
hinov@tu-sofia.bg

***Abstract*— In the current paper a review of state problems and future trends in charging stations and the different types of standards and connector type for supplying EVs are presented. Three main types of infrastructure for building charging stations in the home, in public buildings and in offices are reviewed. Optimal methods for managing energy flows to use more green energy are also presented. The main advantages and disadvantages of the presented infrastructures are also presented.**

***Keywords*— electric vehicle, charging station, photovoltaic.**

I. INTRODUCTION

There are many companies that are rushing to come up with new products to ensure sustainability in protecting the environment and reducing harmful emissions. Several of the main trends in company management are the requirements for a lower value of carbon dioxide in the production of electric cars and charging stations. With the development of new technologies, improved efficiency is ensured throughout the life cycle of the individual components that make up a charging station. They include the efficient use of energy from natural resources. Also, various IoT-based solutions are offered to optimize costs in the construction of charging station infrastructures. Their main goal is to modernize the current equipment, following European and global environmental norms[1-4].

When building charging stations, it is necessary to take into account all the components that make it up. It would be useful to include a complete system connected to homes, public buildings and car parks in the EV charging structure. Also, various renewable energy sources and energy storage elements that could provide independent power from the distribution grid and other conventional energy sources can be added quite easily when building charging stations. This solution would provide convenient and economical charging of electric vehicles, and would also prioritize renewable energy for a clean future without harmful emissions.

Of course, the charging time of electric cars depends on many factors. Some of them are the type and power of the electric vehicle, the presence of external influences such as rain or wind, the state of charge of the battery and/or supercapacitor, the driver's driving style, and others. In order to ensure a minimum charging time for the electric vehicle, it is necessary to select an optimal way of management with minimal losses from electricity transmission to the charging station. There are various strategies for managing energy flows to ensure safe charging and maximum efficiency. Also, unidirectional or bidirectional power transfer can be used depending on the type of power electronic converters selected. Of course, the main mass and dimensions parameters of the charging station, such as dimensions, weight, etc., must also be taken into account.

II. AC AND DC CHARGING AND CONNECTORS TYPES

In Table 1 all the standards, charging level and basic characteristics of the charging station are presented.

TABLE I. IEC 62196, SAE J1772 AND CHADEMO STANDARDS [1]

Standard	Charging Level	Voltage (V)	Maximum Current (A)	Maximum Power Rating (kW)
IEC 62196	AC Level 1 (Mode 1)	230–240 VAC (Single-Phase) 480 VAC (Three-Phase)	16	3.8 7.6
	AC Level 2 (Mode 2)	230–240 VAC (Single-Phase) 480 VAC (Three-Phase)	32	7.6 15.3
	AC Level 3 (Mode 3)	230–240 VAC (Single-Phase) 480 VAC (Three-Phase)	32–250	60 120
	DC (Mode 4)	600–1000 VDC	250–400	400
SAE J1772	AC Level 1	120 VAC (Single-Phase)	16	1.9
	AC Level 2	240 VAC (Single-Phase)	80	19.2
	DC Level 1	200–500 VDC	80	40
	DC Level 2	200–500 VDC	200	100
CHAdeMO (Japanese standard)	DC Fast Charging	1000 VDC	400	400

The carried-out research is realized in the frames of the project “Research on charging stations powered by decentralized energy sources”, № 232ПД0014-03, Scientific Research Sector of Technical University of Sofia.

The main difference found in different vehicles is the charging voltage - AC and DC. Although both types are used, the energy that can be stored in batteries or supercapacitors is DC. For this reason, the use of a DC charge can significantly reduce the charge time, the lack of conversion of energy from AC to DC, which allows energy flows to flow directly to the batteries. Also, the DC charger can allow the charging of EVs with capacities up to 350 kW and a minimum charging time of 15 min.

Despite the stated advantages of DC charging, there are still a significant number of charging stations that use AC voltage. With it, the charge time is longer and in the structure of the charging stations it is necessary to have a greater number of converters, which also leads to a more complex control system. On the other hand, their use is easier since we can draw the necessary energy for a charge directly from the distribution network.

III. Types of Electric Mobility

There are several solutions for connecting a charging station to existing residential buildings, to single-user public buildings and to office and industrial buildings. Figure 1 presents a general load schedule of user usage and an assumed load balancing curve with the addition of one or more charging stations.

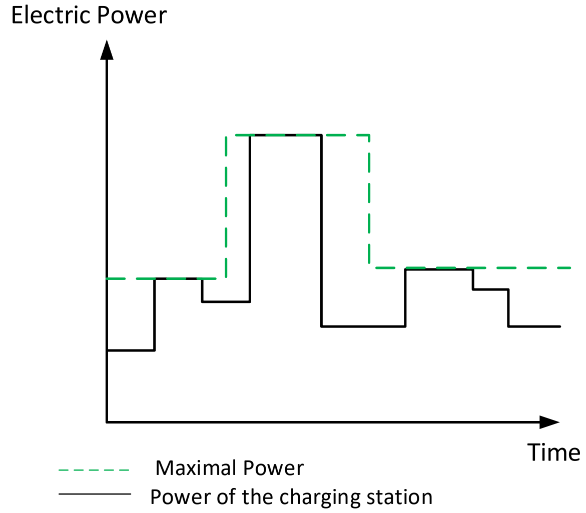

Fig. 1. Balance of the power

A. *Electric mobility for residential buildings*

Electromobility for buildings is the connection of charging stations to existing residential buildings with multiple users. This allows owners or tenants of multi-family buildings to have fast and optimized charging of their electric vehicles. With the addition of smart electricity meters and a load management system, each user will have a correct allocation of electricity costs. Also, optimal load management allows us to distribute power between charging stations, regulate the charge of electric vehicles in different time ranges in the presence of peak energy consumption. Figure 2 shows a block diagram of connecting charging stations to multi-family residential buildings[9].

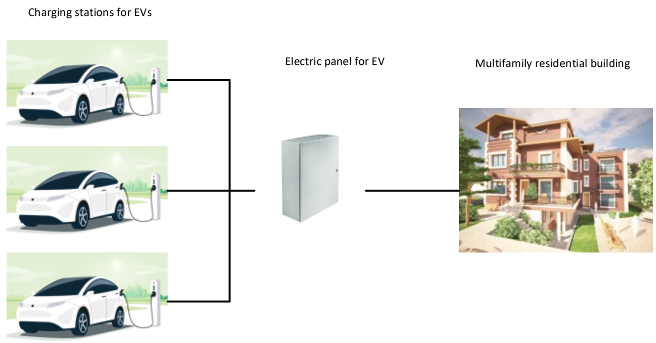

Fig. 2. Electric mobility for residential buildings[10]

B. *Electric mobility for public buildings*

Electric mobility in public buildings with one owner is an initial and easy step for entrepreneurs who want to orient their business towards the production and use of green energy. By adding charging stations and building one or more parking lots for electric cars, owners could significantly optimize their investments and electricity costs. In this way, they have the opportunity to orient their companies to the use of electric vehicles, with the aim of reducing harmful emissions and meeting European requirements. Figure 3 shows a load management system for public buildings with one owner. These approaches allow us to dynamically monitor and distribute capacities between charging stations. Also, the possibility of communication between individual charging stations based on open protocols.

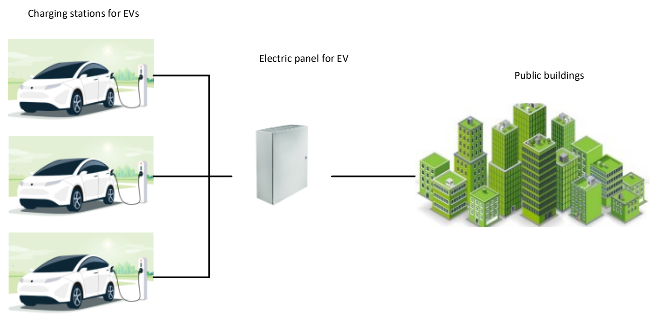

Fig. 3. Electric mobility for public buildings with one owner[10]

C. *Electric mobility for office buildings*

Electromobility for business buildings is a complete solution for charging electric vehicles by optimizing energy flows in multiple sites. In this case shown in Figure 4, several control technologies are presented. To ensure an intelligent monitoring system and optimal energy distribution, we have the option of adding a remote monitoring system. This type of system would provide us with the ability to remotely control and debug if necessary, the ability to analyze and monitor charge systems.

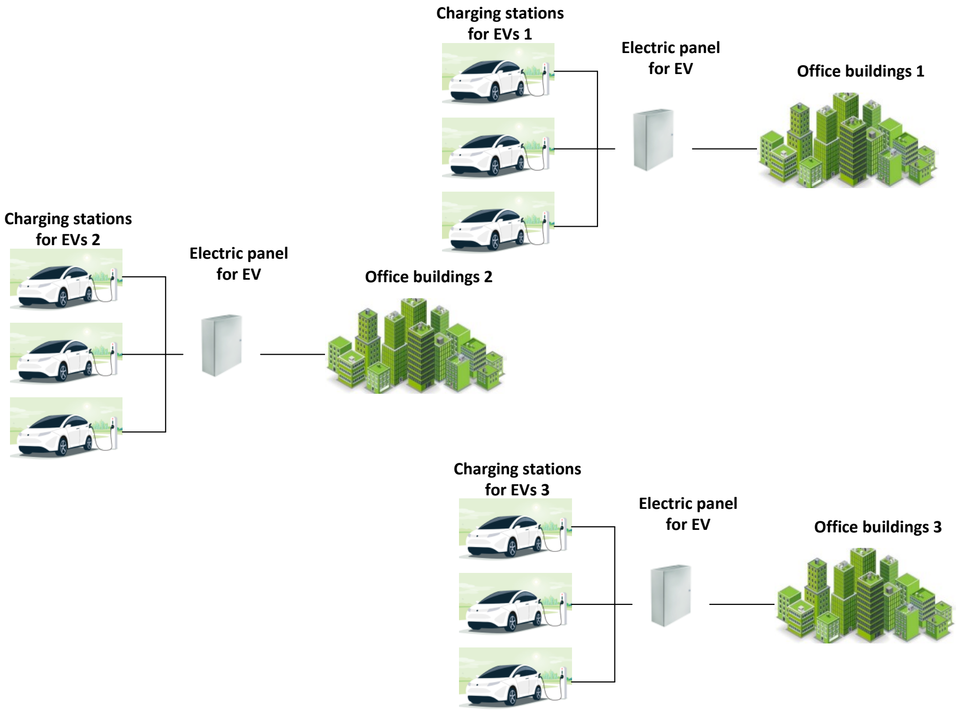

Fig. 4. Electric mobility for office buildings[10]

IV. Control of Charging Modes

With the increased use of electric vehicles on a global scale, power distribution networks are expected to fail to meet the demands during charging. This would lead to the mandatory renewal and increase of the capacities of the existing networks. At the moment, the majority of charging stations charge simultaneously with maximum power all plugged-in electric vehicles. This consumption, together with the normal consumption of a business building, would result in overloading and penalties by the distribution company. For this reason, it is necessary to design a control system suitable for intelligent power distribution.

Of course, from the point of view of intelligent load management of charging stations, there are two ways to categorize load balancing: cluster load balancing and dynamic load balancing [2-3]. With Cluster load balancing, the distribution of power from the charging stations is determined. In this case, the setting of a certain power for charging the electric vehicles is set manually in the control and communication systems of the charging stations. When using dynamic load balancing, the control systems are set up in such a way that the power with which the electric vehicle is charged can be automatically changed depending on the state of charge it has reached. In this way, by building the charging stations according to the required charging power, the demand on the distribution network can be reduced and thus the electricity costs can be reduced. Figure 5 and 6 schematically presents the power distribution in intelligent load balancing.

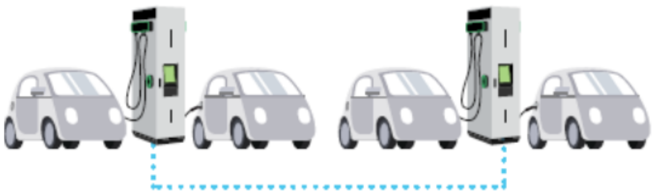

Fig. 5. Cluster load balancing[4-5]

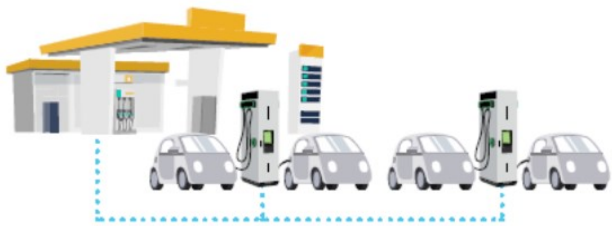

Fig. 6. Dynamic load balancing[4-5]

In this way, each electric vehicle connected to the charging station can be charged in a specific way. Of course, in this case, both the needs and specifics of the vehicle driver and the power limitations imposed by the distribution network are taken into account. Also, the use of intelligent charging leads to an increase in the operational life of the infrastructure and a reduction in operating costs. In this case, an additional energy source such as additional batteries or a photovoltaic system can be used. These additional energy sources would contribute to the optimization of the renewable energy used. The proposed solution has many advantages such as:

- reliability of the built infrastructure - does not have a significant impact when connecting a charging station to low and medium voltage networks;

- intelligent use of electricity tariffs - balancing of electricity supplies;
- use of renewable energy – optimization of energy consumption using additional energy sources.

There are also various platforms for control the energy flows, when charging the electric vehicles to ensure trouble-free charging in the home, public buildings and large parking. Some of the manufacturers [10] use software as a service, which can be used significantly easily. They have the ability to remotely monitor, operate and store data in cloud spaces. With the help of these innovative management methods, flexible access and reduced cost of electricity are enabled.

V. Conclusion

In the presented paper an infrastructure for charging station and standards for charging electric vehicle are presented. An overview of different types of connectors used for power from charging stations has been made. Also, the current article presents three main infrastructures that are used in the construction of charging stations. Their main advantages and disadvantages are also described. Two main types of EV charge management are also added to the overview.

The main purpose of the current article is to present existing solutions and methodologies for the intelligent management of energy flows when charging electric vehicles. These innovative methods enable intelligent real time control without system interruption through remote monitoring. Also, peaks in load schedules can be eliminated in this way. The benefits of using smart charging are also presented, such as reliability and infrastructure of the built facility, dynamic electricity tariffs to reduce operating costs, power and load balancing, optimization of energy produced locally by photovoltaic and wind power plants.

Acknowledgment

The carried-out research is realized in the frames of the project " Research on charging stations powered by decentralized energy sources", № 232ПД0014-03, Scientific Research Sector of Technical University of Sofia.

References

[1] K. Dimitriadou, N. Rigogiannis, S. Fountoukidis, F. Kotarela, A. Kyritsis, N. Papanikolaou, Current Trends in Electric Vehicle Charging Infrastructure; Opportunities and Challenges in Wireless Charging Integration. Energies. 2023; 16(4):2057. https://doi.org/10.3390/en16042057.

[2] Sanguesa, J.A.; Torres-Sanz, V.; Garrido, P.; Martinez, F.J.; Marquez-Barja, J.M. A Review on Electric Vehicles: Technologies and Challenges. Smart Cities 2021, 4, 372–404.

[3] Funkea, S.A.; Spreib, F.; Gnanna, T.; Plötza, P. How much charging infrastructure do electric vehicles need? A review of the evidence and international comparison. Transp. Res. Part D Transp. Environ. 2019, 77, 224–242.

[4] Das, H.S.; Rahman, M.M.; Li, S.; Tan, C.W. Electric vehicles standards, charging infrastructure, and impact on grid integration: A technological review. Renew. Sustain. Energy Rev. 2020, 120, 109618.

[5] F. Mwasilu, et al. Electric vehicles and smart grid interaction: a review on vehicle to grid and renewable energy sources integration, Renew Sustain Energy Rev, 34 (2014), pp. 501-516

[6] P. Franzese *et al.*, "Fast DC Charging Infrastructures for Electric Vehicles: Overview of Technologies, Standards, and Challenges," in *IEEE Transactions on Transportation Electrification*, doi: 10.1109/TTE.2023.3239224.

[7] S. Rivera *et al.*, "Charging Infrastructure and Grid Integration for Electromobility," in *Proceedings of the IEEE*, vol. 111, no. 4, pp. 371-396, April 2023, doi: 10.1109/JPROC.2022.3216362.

[8] S. M. Deshmukh, V. Biradar and S. P. Gawande, "Design and Development of Charging Station for Electric Vehicles," *2022 International Conference on Smart Generation Computing, Communication and Networking (SMART GENCON)*, Bangalore, India, 2022, pp. 1-4, doi: 10.1109/SMARTGENCON56628.2022.10084136.

[9] https://tehnopol.bg

[10] https://www.se.com

[11] S. Pal, A. Kurchania, N. L. Shah, P. N. Tiwari, A. Soni and K. P. Tiwari, "Multiple Sources Off-Board Electric Vehicles Charging Station, Different Techniques, Standards and Challenges," *2022 IEEE International Conference on Current Development in Engineering and Technology (CCET)*, Bhopal, India, 2022, pp. 1-7, doi: 10.1109/CCET56606.2022.10080262.

[12] S. Tyagi and B. Singh, "A Solar PV-Small Hydro Energy Conversion System Powered Charging Infrastructure," *2022 IEEE IAS Global Conference on Emerging Technologies (GlobConET)*, Arad, Romania, 2022, pp. 503-508, doi: 10.1109/GlobConET53749.2022.9872340.

[13] M. Almeida, M. Chaves, S. Morgado and M. Louro, "Effects of EV ultra-fast chargers in power quality," *CIRED Porto Workshop 2022: E-mobility and power distribution systems*, Hybrid Conference, Porto, Portugal, 2022, pp. 1178-1181, doi: 10.1049/icp.2022.0901.

[14] R. Jovanovic, S. Bayhan and I. S. Bayram, "Capacity Optimization of EV Charging Networks: A Greedy Algorithmic Approach," *2022 3rd International Conference on Smart Grid and Renewable Energy (SGRE)*, Doha, Qatar, 2022, pp. 1-6, doi: 10.1109/SGRE53517.2022.9774066.

[15] A. N. Morab, S. Marchand and B. Wille-Haußmann, "Electric vehicle modelling for function testing of charging infrastructures using power hardware-in-the-loop simulations," *5th E-Mobility Power System Integration Symposium (EMOB 2021)*, Hybrid Conference, Germany, 2021, pp. 90-96, doi: 10.1049/icp.2021.2510.

[16] B. Al-Hanahi, I. Ahmad, D. Habibi and M. A. S. Masoum, "Charging Infrastructure for Commercial Electric Vehicles: Challenges and Future Works," in *IEEE Access*, vol. 9, pp. 121476-121492, 2021, doi: 10.1109/ACCESS.2021.3108817.

[17] L. Wang, Z. Qin, T. Slangen, P. Bauer and T. van Wijk, "Grid Impact of Electric Vehicle Fast Charging Stations: Trends, Standards, Issues and Mitigation Measures - An Overview," in *IEEE Open Journal of Power Electronics*, vol. 2, pp. 56-74, 2021, doi: 10.1109/OJPEL.2021.3054601.

[18] S. Vignesh, S. Nihith Koundinya, K. Narayanan, G. Sharma and T. Senjyu, "Investigation on Reliability and Cost in the Presence of Electric Vehicle Charging Station," *2020 International Conference on Smart Grids and Energy Systems (SGES)*, Perth, Australia, 2020, pp. 465-469, doi: 10.1109/SGES51519.2020.00088.