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INCREASING THE ENERGY EFFICIENCY OF THE CHARGING STATION FOR ELECTRIC VEHICLES WITH SINGLE-STAGE CONVERSION OF ELECTRIC ENERGY

ПІДВИЩЕННЯ ЕНЕРГОЕФЕКТИВНОСТІ ЗАРЯДНОЇ СТАНЦІЇ ДЛЯ ЕЛЕКТРОМОБІЛІВ З ОДНОЕТАПНИМ ПЕРЕТВОРЕННЯМ ЕЛЕКТРИЧНОЇ ЕНЕРГІЇ

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The relevance of the issue of increasing the energy efficiency of charging stations for electric vehicles is considered. Types of charges according to international standards are presented. The topology of a charging station for electric vehicles with one-stage conversion of electrical energy is proposed.

In the last few decades, there has been a steady transition from vehicles with internal combustion engines to electric motors. Electrification of road transport is one of the main trends in the development of the global automotive industry [1, 2].

The expansion of the use of electric vehicles is very promising in view of the possible reduction of atmospheric air pollution by vehicles, primarily in large cities. Another advantage of using electric cars is a significant reduction in energy costs, as well as a possible reduction in repair and maintenance costs compared to conventional cars [3, 4].

Currently, there is a tendency to strengthen the requirements for standards for the quality of electrical energy. In power systems built on the basis of rectifiers, there is a problem associated with increasing the power factor due to reducing the non-sinusoidal nature of the consumed current [5].

An electric vehicles charging station appears as a DC load to the electrical distribution system, and the nature of the AC to DC conversion process through rectification can introduce unwanted current harmonics into the grid distribution system, resulting in a negative impact on grid power quality [6, 7].

Manufacturers and researchers pay considerable attention to the development of electric vehicles. At the same time, an important issue is the creation of energy-efficient charging stations with the highest parameters of efficiency, power factor. Also, a rather important parameter of charging stations is the time and method of charging electric vehicle batteries [8].

In the standards IEC-62196, IEC-61851 and others, which are valid in Europe, five charging modes of electric vehicles are distinguished. The last type of charge cannot be classified on the same level as the other types – it is an inductive wireless charge. The first to fourth types can be classified according to the Table 1.

Table 1 – Types of electric vehicle charges according to international standards

Type	Number of phases	Charge voltage, V	Type of current	Charge current, A	Disposition	Location of the charging station
Mode 1	1	up to 250	AC	up to 16	onboard	homely
	3	up to 480				
Mode 2	1	up to 250		up to 32		
	3	up to 480				
Mode 3	1	up to 250		up to 32		private / public
	1	up to 250		up to 70		
	3	up to 480		up to 63		
Mode 4	3	up to 1000	DC	up to 500	outboard	public

A traditional fast charging charging station usually consists of two stages, namely an AC/DC converter and an output DC/DC converter (Fig. 1). Therefore, the output voltage can be adjusted according to a wide range of battery voltage (280...400 V) for different electric vehicles.

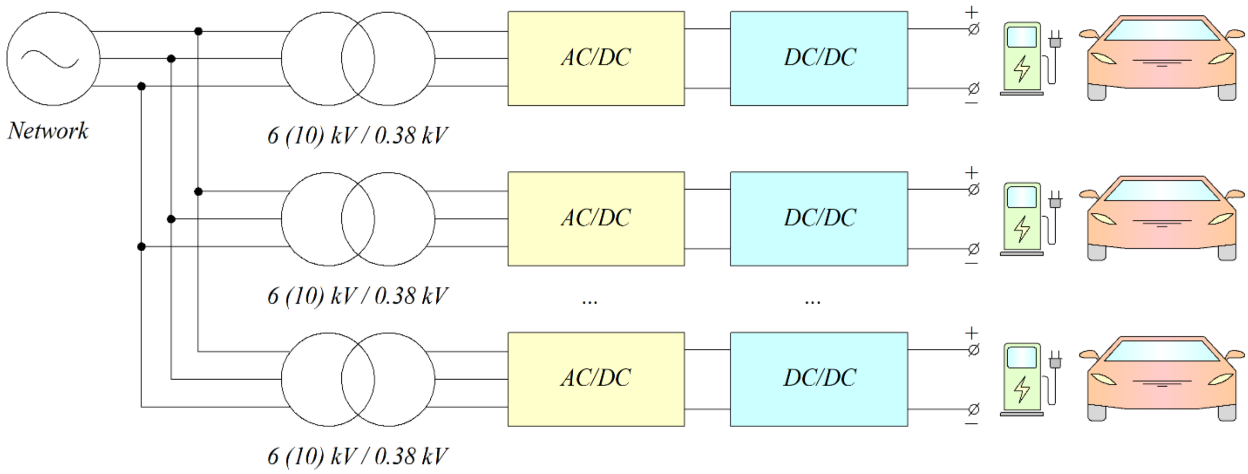

Fig. 1. Structural diagram of a traditional charging station for electric vehicles

In commercial fast chargers, the DC output converter is intended for use as a galvanically isolated converter where a high-frequency transformer is required for isolation. However, the efficiency of such a charging station is lower due to the presence of a DC/DC converter link.

The proposed single-stage AC/DC structure replaces the two-stage structure with lower cost and higher efficiency (Fig. 2). It is suggested to use an active rectifier as an AC/DC converter. It is assumed that the single-stage structure has a 2 % higher efficiency compared to the traditional two-stage structure.

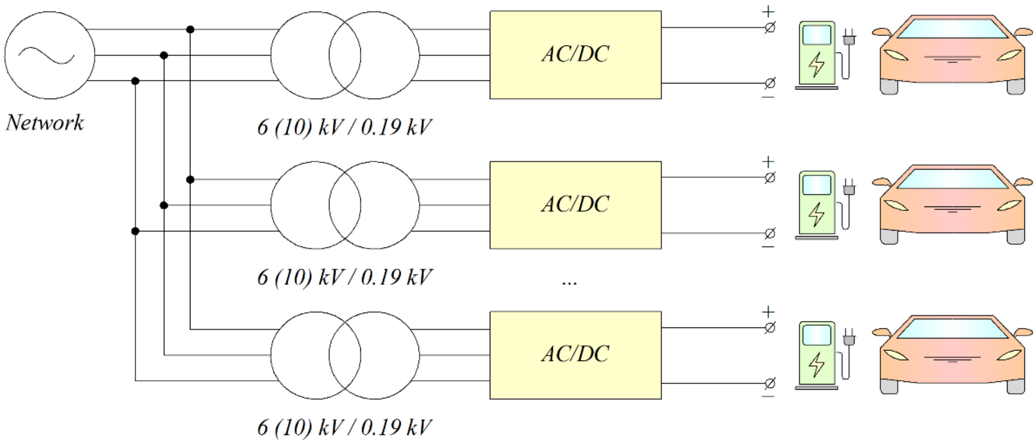

Fig. 2. Structural diagram of a charging station for electric vehicles with one-stage energy conversion

The advantages of the proposed charging station with an active rectifier include:
– high power factor, close to unity;
– low coefficient of harmonic distortion of the consumed current (*THD* < 5 %);
– higher efficiency relative to two-stage charging stations of the AC/DC – DC/DC type;
– the possibility of providing two-way energy transfer.

In addition, unlike the previously discussed topologies, the proposed charging station does not contain an additional energy conversion link – a DC/DC converter, which results in a smaller number of energy conversion stages and better efficiency indicators.

The schematic diagram of the proposed topology of the charging station for electric vehicles is shown in Fig. 3. The charging station consists of an input transformer, a three-level active rectifier and a load.

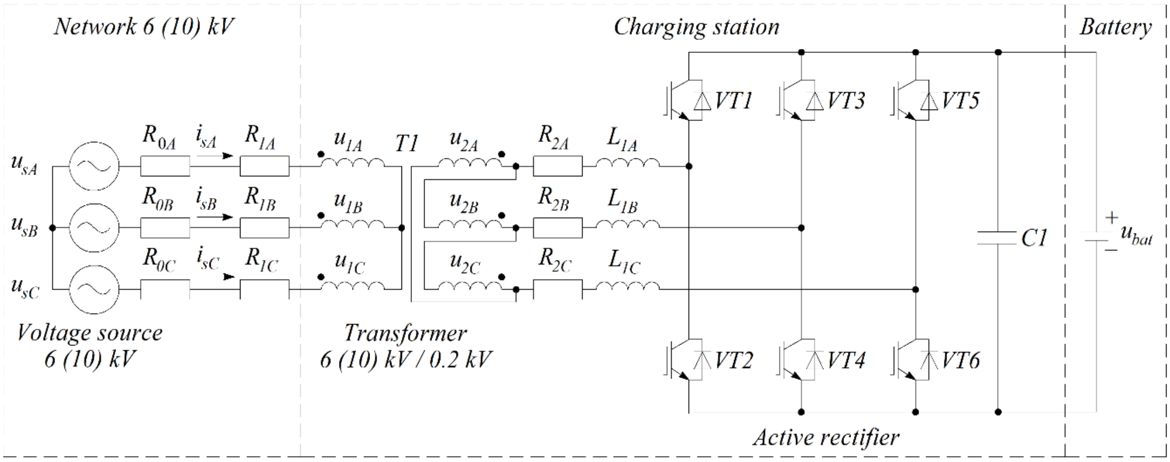

Fig. 3. Schematic diagram of the proposed topology of a charging station for electric vehicles

The 6 (10) kV network is represented by a three-phase symmetrical system of sinusoidal voltages u_{sA}, u_{sB}, u_{sC}. Network parameters are taken into account by active resistances R_0 and inductance L_0. The parameters of the line connecting the traction substation and the converting three-phase transformer 6 (10) kV / 0.31 kV are determined by the active resistance R_2 and the inductance L_1. The supply windings of the transformer *T1* are connected to the 6 (10) kV network, and the valve windings are connected to the active rectifier, which consists of chokes $L_{1A}…L_{1C}$, transistors *VT1…VT6* and capacitor *C1*. The parameters of the line from the transformer *T1* to the chokes of the active rectifiers correspond to the active resistance R_2. The load is represented by a DC battery.

Conclusions. The structure of a charging station for electric vehicles is proposed, which realizes a single-stage conversion of electricity in an active rectifier. At the same time, it is expected to improve the parameters of efficiency, power factor and harmonic distortion factor.

1. Ivanchev J., Fonseca J., Knoll A. Electrification and Automation of Road Transport: Impact Analysis of Heat and Carbon Emissions for Singapore. 2020 IEEE 23rd International Conference on Intelligent Transportation Systems (ITSC). 2020. P. 1–8. DOI: 10.1109/ITSC45102.2020.9294274.

2. El Bakkari F., Mounir H., El Marjani A. Electric Vehicle Progress and Challenges on the Road to Sustainable Transportation. 2021 9th International Renewable and Sustainable Energy Conference (IRSEC). 2021. P. 1–6. DOI: 10.1109/IRSEC53969.2021.9741163.

3. Weiss M., Zerfass A., Helmersb E. Fully electric and plug-in hybrid cars. An analysis of learning rates, user costs, and costs for mitigating CO_2 and air pollutant emissions. Clean Prod. 2019. Vol. 212. P. 1478–1489. DOI: 10.1016/j.jclepro.2018.12.019.

4. Wilberforce T., El-Hassan Z., Khatib F. N., Al Makky A., Baroutaji A., Carton J. G. Developments of electric cars and fuel cell hydrogen electric cars. International Journal of Hydrogen Energy. 2017. Vol. 42, No. 40. P. 25695–25734.

5. Haq G., Weiss M. Time preference and consumer discount rates – insights for accelerating the adoption of efficient energy and transport technologies. Technol. Forecast. Soc. Change. 2018. Vol. 137. P. 76–88. DOI: 10.1016/j.techfore.2018.06.045.

6. Plakhtii O., Nerubatskyi V., Mashura A., Hordiienko D. The analysis of mathematical models of charge-discharge characteristics in lithium-ion batteries. 2020 IEEE 40th International Conference on Electronics and Nanotechnology (ELNANO). 2020. P. 635–640. DOI: 10.1109/ELNANO50318.2020.9088827.

7. Jog P., Shete S., Kumawat R. K., Palwalia D. K. Electric Vehicle Charging Station Infrastructure: A Review. 2021 6th IEEE International Conference on Recent Advances and Innovations in Engineering (ICRAIE). 2021. P. 1–7. DOI: 10.1109/ICRAIE52900.2021.9703969.

8. Plakhtii O., Nerubatskyi V., Mashura A., Hordiienko D., Khoruzhevskyi H. Improving energy indicators of the charging station for electric vehicles based on a three-level active rectifier. Eastern-European Journal of Enterprise Technologies. 2020. Vol. 3, No. 8 (105). P. 46–55. DOI: 10.15587/1729-4061.2020.204068.