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OVERVIEW OF EUROPEAN TRENDS IN ELECTRIC VEHICLE IMPLEMENTATION AND THE INFLUENCE ON THE POWER SYSTEM

Abstract. *An overview of the trends in the development of electric transport in European countries is presented, including the state and tax policy of supporting electric transport owners, the dynamics of the growth of the European fleet of electric vehicles, the development of charging infrastructure and the main principles of the interaction between electric vehicles and power system. The experience of countries that have successfully developed electric transport was reviewed, and it was found that the demand for electric cars mostly depends on the price of electric cars for the end user, infrastructure development and government incentive programs. The review also showed that, in practice, the wide spread of electric vehicles should occur simultaneously with the development of the corresponding infrastructure, as well as the development of systems for their interaction with the energy system and compliance with global environmental standards. The growing number of electric vehicles certainly requires special attention from network and power system operators, because the appearance of charging stations of various manufactures and capacities, installed in residential areas, private and apartment buildings, can lead to the number of problems, the emergence of which is associated with electromagnetic compatibility, overloading of electric cables and distribution transformers, safety of operation, that as a result can negatively affect the reliability and quality of power supply. There is also the potential risk that with a certain number of EVs, there will not be enough existing generation capacity and capacity of the electricity grid to charge EV batteries. The analysis of the principles of interaction between electric vehicles and power system in Europe showed that they are based on the concept of Smart Grid - smart or intelligent power supply networks, by means of which the electric vehicle charging system can be managed by the energy supplying company in order to solve a number of energy system tasks: increasing the efficiency of network infrastructure using, peak load shift and the development of smart grid infrastructure.*

Keywords: electric vehicle, electric charging station, charging infrastructure, power system, environmental requirements, the Smart Grid concept.

1. Introduction

In order to reduce emissions of greenhouse gases into the atmosphere, the problem of decarbonization of the sectors of the economy with the largest emissions of pollutants is increasingly relevant for Europe. In recent years, the transport and energy sectors have been the biggest polluters of the environment in the EU. Thus, according to European Environment Agency data on greenhouse gas emissions in 2020, the share of the energy sector was 13% of the total emissions, the share of private transport was 11%, and the share of communal and commercial transport was about 6.5% [1]. In order to reduce the negative impact of motor vehicles on the environment, as well as to reduce the use of fossil fuels, in many European countries, the implementation of programs for the mass electrification of transport has begun. Naturally, with the growth of the share of electric transport in the total fleet of vehicles, the consumption of electricity, necessary for charging batteries of electric transport, increases significantly. At the same time, the process of unregulated charging of electric vehicles can cause serious problems in the distribution network and in the energy system as a whole.

The purpose of this work is a comprehensive study of the current state, main trends and prospects for the development of electric transport in Europe, a comprehensive analysis of the impact of the electric transport charging process on the operation of

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the power system, as well as a study of the main methods and means of mitigating this impact, developed and implemented in the EU.

2. Methods and materials

As part of the European Green Deal [2] adopted in 2019, the European Commission presented a new package of proposals for strengthening environmental requirements, including a separate scenario and a number of requirements for the decarbonization of transport, and as a result, for the electrification of the transport sector. Thus, from 2030, CO_2 emissions from new passenger cars should be decreased by 37.5% compared to 2021, for vans by 31%. In addition, it is expected to provide more than 1 million charging points for electric vehicles by 2025 and approximately 3.5 million by 2030 [2].

At the EU level, a set of current legislative instruments that directly or indirectly regulate greenhouse gas emissions from road transport is comprehensively analyzed and taken into account in the position paper of the European Network of Electricity Transmission System Operators ENTSO-E on the integration of electric vehicles into electric networks [3]. Thus, the requirements for the level of CO_2 emissions of new cars are regulated by Regulation (EU) 2019/631 setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles [4] and Regulation (EU) 2019/1242 setting CO_2 emission performance standards for new heavy-duty vehicles [5], and stimulate the replacement of cars with internal combustion engines (ICE) by cars with zero CO_2 emissions by means of restrictions on the specific CO_2 emissions of a new car. Restrictions on the size of the fleet of vehicles with internal combustion engines for state needs are regulated by Directive (EU) 2019/1161 "On the promotion of clean and energy-efficient road transport vehicles" [6], which stimulates the replacement of vehicles with internal combustion engines operated by state structures of EU member states with cars with zero CO_2 emissions by establishing a minimum share of "clean" vehicles in the total volume of transport purchases by state structures, individually for each EU country. Greenhouse gas emissions from road transport are regulated by Regulation (EU) 2018/842 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement [7]. The possibility of establishing tax benefits related to the stimulation of the use of electric vehicles is regulated by Art. 19 of Directive 2003/96/EU "on the restructuring the Community framework for the taxation of energy products and electricity" [8]. Directive 2014/94/EU "On the deployment of alternative fuel infrastructure" establishes a set of measures for the creation of alternative fuel infrastructure in order to minimize dependence on oil and mitigate the impact of transport on the environment [9].

In addition, the European Commission presented the REPowerEU plan on May 18, 2022, designed to end the EU's dependence on Russian fossil fuels, as well as to overcome the climate crisis. One of the points of this plan [10] is to accelerate the transition to zero-emission vehicles, for which a legislative initiative is being introduced to increase the share of zero-emission cars in state and corporate fleets in greater amount than were previously determined.

Thus, the influence of environmental factors led to the fact that many European countries developed and adopted plans to completely ban the sale of cars with internal combustion engines. For example, Norway and the Netherlands intend to ban the sale of new cars and light commercial vehicles, as well as city buses with internal combustion engines as early as 2025. From 2030, Sweden, Germany and Denmark plan to introduce similar initiatives, and from 2035–2040 – Great Britain, France and Spain [11].

It should be noted that greenhouse gas emissions during the entire life cycle of electric transport – from the production of all components (including batteries), operation and to their disposal – are not zero. The amount of these emissions depends primarily on the structure of power production in each country. Therefore, the carbon footprint for road transport (including electric vehicles) is calculated separately for each country, its value differs significantly in different countries, and the term of operation or mileage in thousand km is also calculated, after which compensation for harmful emissions occurs.

Research conducted in 2021 showed that during the entire life cycle (in particular, because of the higher efficiency of the electric motor), electric cars produce on average about 22% less CO_2 emissions than cars with internal combustion engines, and in countries with fully decarbonized energy, this figure can reach 70–80% [12]. In addition, in a 2020 study on determining the environmental impact of traditional and alternative fuel vehicles using life cycle assessment [13], taking into account specific emissions during electricity production in different countries, it was found that CO_2 emissions during the life cycle (per 250,000 km mileage) of mid-segment electric cars are 33% (Great Britain), 30% (Germany), 35% (France) lower than for similar cars with internal combustion engines. In France, CO_2 emissions during the life cycle of electric cars are compensated much earlier due to the low carbon capacity of France's electricity, associated with a high share of nuclear generation (about 75%), – after 25,000 km of mileage compared to almost 100,000 km for cars with internal combustion engines. According to forecasts for 2030, due to rapid changes in the structure of electricity generation in European countries, the moment when the emissions during the life cycle of electric vehicles become lower than the CO_2 emissions of cars with internal combustion engines will come much earlier [13].

Steady growth of the electric vehicle market has been noted in European countries since 2020, according to EV-Volumes [14], which indicates a trend towards mass distribution of electric transport. As shown in Tab.1, formed according to the data of the leading European media platform in transport Fleet Europe [15], in 2020–2021 already more than 20% of new passenger cars sold in many EU member states were fully electric or hybrid. At the same time, according to the data of the Association of European Automobile Manufacturers ACEA [16], the share of cars with internal combustion engines dropped significantly (from 89% to 75%).

By 2030, in Europe, according to various scenarios for the development of electric transport, the growth of the fleet of electric vehicles is predicted from 33 to 44 million units, that is, more than 10 times compared to the current state [16]. Today, the number of electric vehicles in European countries is growing rapidly not only due to the general climate policy, but primarily due to the implementation of state assistance programs (tax reductions and benefits, as well as subsidies for buyers of electric vehicles [16]. Therefore, the planned development of the electric vehicle fleet requires further strengthening of support and assistance programs at the legislative, economic and political levels.

It should be noted that success in the development and diffusion of electric transport largely depends on incentives at the state and local levels. Electrification of transport in Europe has acquired a stable character, however, this process occurs at different speeds in different countries. And it can be noted that the most significant indicators in this matter are developed incentive programs at the state level and the GDP indicator.

In general, there are three groups of countries divided by these characteristics:

1. Countries with a high share of EV in the total fleet of cars (>33%) are Norway, Sweden and the Netherlands. This group is characterized by a high level of GDP, a highly developed and generous program to stimulate the purchase of electric vehicles and business programs in charging infrastructure for electric vehicles. As evidenced by the practice of these countries, the best way to stimulate the development of electric transport is exemption from taxes and fees.

2. Countries with average indicators (between 20% and 33%) – Germany, Belgium, Great Britain, Switzerland and France. This group is characterized by a high or average level of GDP, average development and implementation of only some of the possible programs to stimulate the purchase of electric vehicles and development in electric transport charging infrastructure.

3. Countries with low indicators (<20%) – Italy, Ireland, Spain and Poland. This group is characterized by an average or low level of GDP, low or completely absent development of stimulation programs and low development of EV charging infrastructure.

Table 1. The dynamics of the development of the electric vehicles fleet in European countries, unit [15]

Country	EV sales in 2021	% compare to 2020	HEV sales in 2021	% compare to 2020	Total car sales in 2021	% compare to 2020	EV part, %
Norway	22410	+36,0	20846	+46,4	52147	+8,0	83%
Sweden	21060	+74,3	33615	+4,6	98782	+1,1	55%
Netherlands	38894	–12,8	12564	+80,8	138196	–12,7	37%
Germany	104775	+104,3	141658	+53,7	768175	–6,5	31%
Belgium	16560	+72,3	38887	+54,9	178632	–3,2	31%
Great Britain	105949	+71,6	64890	+66,7	622661	+3,4	27%
Swizerland	7062	+70,6	4388	+42,7	51210	+1,0	22%
France	32196	+41,8	66601	+107,1	483503	+7,8	20%
Italy	22588	+64,3	35218	+202,0	328265	+16,5	18%
Ireland	3136	+120,7	1754	+388,6	36356	+36,9	13%
Spain	8229	+14,5	21212	+74,8	250406	+0,3	12%
Poland	3817	+131,5	5057	+121,4	253605	+13,2	3%

In Germany, at the current stage, about 570,000 electric cars are registered, and this is only about 1% of the country's car fleet. At the same time, it is planned to cancel the registration of cars with internal combustion engines by 2030, which should stimulate the demand for electric cars and increase the production and sale of electric cars by 33% annually, expecting to reach 15 million electric cars in 2030 [17].

In France, they use all methods that allow to update the existing car fleet of citizens, significantly increasing the share of electric cars and hybrids. In addition, the French government announced a competition to create a French electric car costing less than €7,000, in order to stimulate private companies to create environmentally friendly public vehicles [18].

Stimulation policies for electric transport introduced in the Netherlands in 2009 were aimed at increasing the number of electric vehicles to 200,000 units by 2020, up to 1 million units by 2025 and a complete refusal to sell new cars with internal combustion engines by 2030 [18]. In the Netherlands, each underground parking lot has specially marked and equipped spaces designated for electric vehicles. In addition, cities are equipped with a large number of charging stations located on the streets. For example, in The Hague – a city with a population about 500,000 people – there are about 500 charging stations, and the local government plans to install another 500 in the coming years [19].

In Norway, a broad program of state subsidies for electric car owners, launched back in the 1990s (tax benefits, no tolls on toll roads, free parking, etc.) is planned and implemented. Norway has one of the most developed incentive systems for the purchase of electric vehicles in the world: electric cars are exempt from VAT and purchase tax, road tolls and tolls for traveling through tunnels and using ferries. As a result of all current tax incentives in Norway, the Volkswagen eGolf electric car, due to the support system for electric cars and the tax burden on cars with an internal combustion engine, costs less than the variant of the Volkswagen Golf with an internal combustion engine [20].

Thus, as a result of government programs to stimulate and support the spread of electric cars, initially much more expensive electric cars after taxation become cheaper or equal in price to cars with internal combustion engines of similar characteristics. The share of tax on CO_2 emissions in the final price of a gasoline car is from 10 to 17%, the share of tax on nitrogen oxide emissions is from 0.2 to 0.75%, the share of tax on car weight is 15% – 20% [20]. In general, the amount of taxes levied on gasoline cars can be considered as an indirect subsidy for the purchase of an electric car.

Despite the rapid growth of sales of electric vehicles in European countries, the development of charging infrastructure for electric vehicles also differs significantly depending on the country. According to research by the Association of European Automobile Manufacturers ASEA [21], 70% of all charging stations in the EU (both high-speed and conventional) are concentrated in only three countries of Western Europe: the Netherlands, France and Germany. At the same time, these countries make up only 23% of the total area of the EU. On the contrary, the remaining 30% of the charging infrastructure is distributed over the remaining 77% of the EU area. For example, Romania is about six times the size of the Netherlands, but has only 493 charging stations, or 0.2% of the total in the EU.

According to the European Federation of Transport and Environment (Transport & Environment), on average, as of 2021, in the EU, there are 5 high-speed public chargers for every 100 km [22], despite the fact that most modern electric vehicles can travel more than 400 km on a full battery charge . However, if we consider the entire European territory, the charging infrastructure for electric vehicles is very unevenly developed across countries (see Fig. 1).

There is a very wide gap in the density of charging infrastructure between richer EU member states in Western Europe and countries with lower GDP in Eastern, Central and Southern Europe. Some countries with a large territory and lower GDP, such as Poland (0.8% of EU charging stations) and Spain (3.3%), have underdeveloped charging infrastructure [22].

The most developed and flexible system for the development of charging infrastructure for electric cars is currently in the Netherlands, where every owner of an electric car can request the installation of a charging station near their place of residence. In addition, local experts analyze how and when charging stations are most actively used in order to optimize the infrastructure and as a result, electric charging stations (EPS) are installed in places where it is most convenient for users.

At the moment, there are about 374,000 public electric power stations in Europe. At the same time, only 12% of them are "high-speed" (with a power of 22 kW and above). At the current stage, the electric charging infrastructure in Europe is developing by increasing the number of powerful or so-called high-speed EVs (with a capacity of more than 22 kW) of fast charging. So, for example, the fastest charging station in the world "Terra 360" with a capacity of 360 kW has been installed in Norway, which allows you to fully charge the battery of an

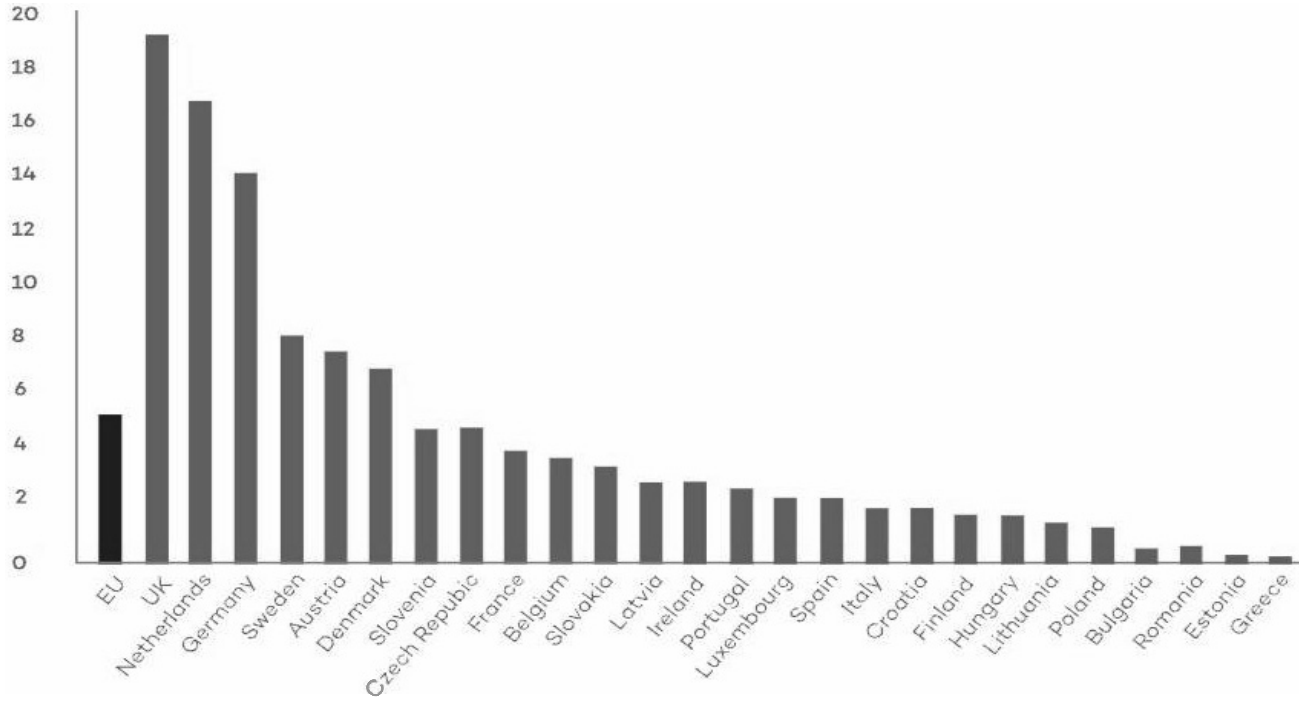

Fig. 1. Number of high-speed charging stations per 100 km in European countries [22]

electric car in 15 minutes. In the future, Terra 360 terminals are planned to be installed throughout Norway and Switzerland [23].

Energy companies, primarily those directly involved in the distribution of electricity, participate in the creation of the EHS infrastructure in Europe. Thus, the pan-European G4V project on the creation of a universal infrastructure for electric transport unites the companies ENEL, ENDESA, VATTENFALL, EDF, EDP and RWE, i.e. the largest European participants in the electricity distribution market.

The growing number of electric vehicles that already interact and will interact with the energy system in the coming years certainly requires special attention from network and energy system operators, because the appearance of charging stations of various designs and capacities installed in residential areas, private and multi-apartment buildings can lead to the emergence of a number of problems, the list of which is presented in Tab. 2 [24], the occurrence of which is associated with electromagnetic compatibility and deterioration of the quality of the power supply voltage, overloading of electric cables and distribution transformers, operational safety, etc. If the rapid growth of the fleet of electric vehicles takes place without the active participation of energy companies in the creation of infrastructure, then this infrastructure and new types of unplanned loads may negatively affect the reliability and quality of electricity supply. There is also the potential risk that with a certain number of EVs, there will not be enough existing generating capacity and capacity of the electricity grid to charge EV batteries.

In order to avoid all the above-mentioned negative effects in networks and the power system, the European principles of designing and launching the infrastructure for electric vehicles are based on the principles of Smart Grid – smart or intelligent power supply networks, where charging stations, the charging management system and the electric vehicles themselves can be controlled by the energy company to solve the following tasks power systems: increasing the efficiency of the use of network infrastructure; load shift; development of the appropriate smart grids infrastructure. In the power industry, smart grids are necessary for optimizing the operation of power supply systems and ensuring energy efficiency, their application allows controlling and optimizing the charging process and allows regulating the amount of energy consumed by the vehicle, depending on the state of grids during charging. In order to create a single technical policy when solving the mentioned problems in Europe, a set of standards was developed to regulate various aspects of charging stations and devices operation.

To date, several modifications of the concepts of smart grids for electric vehicles have been developed, depending on the number and type of active elements and their interaction and charging schemes. These include the concepts of V1G (Unidirectional Smart Charging, vehicle – grids, unidirectional charging) and V2G (Vehicle-to-Grid,

Table 2. The impact of uncontrolled EV charging on grid stability and power quality [24]

Parameter	Remarks
I. Grid stability parameters	
Voltage Stability	EV charging presents different load characteristics as compared to conventional loads. Integration of EVs can negatively affect voltage stability of the grid, which depends on the location, penetration level, EV charging time.
Frequency Stability	The uncertainty of EV connection point, level of penetration, and the period of connection and disconnection causes increased level of load demand. This may have detrimental impact on frequency stability of the grid. However, EV can be operated as controlled load and with faster ramp rate can participate in grid frequency regulation.
Oscillatory Stability	The characteristics of EV load is significantly different from conventional loads. The negative exponential EV load characteristics have more impact to the power system oscillatory stability compared to conventional systemloads.
II. Power quality parameters	
Fluctuation in voltage	The effect on voltage fluctuations depends on the level of integration and the charging speed of electric vehicles. If the charging speed and power increases, so does the impact.
Voltage Unbalance	The effect on the voltage imbalance increases with the increase in the charge of the electric vehicle with a single-phase charge.
Grid Losses	Power losses increase with the large number of uncontrolled and single-phase EV charging systems. Overload and losses in the distribution transformer increase with the increase in the number of electric vehicles.
Harmonics	The impact on harmonics due to the proliferation of electric vehicles increases with penetration levels and increasing charging rates. Harmonics increase with random unregulated charging of electric vehicles.

vehicle – grids, bidirectional charging) and V2B/V2H/V2X (Vehicle-to-Building, vehicle – building/ Vehicle-to-Home, vehicle – private house/ Vehicle-to-Everything, car – anything, bidirectional charging) [25]. The V1G system allows you to control the charging of electric vehicles in such a way that, if necessary, the charging power is increased or decreased. Unlike the V1G concept, the V2G and V2B/V2H/V2X concepts need several elements to work, such as a bidirectional charger, a communication protocol for the interaction between the charger and the car, a vehicle with all V2G capabilities, and an efficient system control (see Fig. 2).

Among these technologies, only V1G is unidirectional, but it is the base for the rest. Compared to V1G, battery capacity with V2G can be used 10 times more efficiently. Given that the number of electric vehicles in Europe is predicted to increase by 50% in 2030 and by 80% in 2050, it is important that their charging infrastructure is used efficiently, which requires the development of principles and methods for managing the load of electric vehicle batteries from the side of electrical grids and the power system as a whole.

It should be noted that an electric car is not only an active consumer of electricity, but also a potential element of its temporary storage. Electric vehicles become both an additional load and a resource of new opportunities for the energy system. Due to the optimal management of the charging process potential problems of the energy system can be solved and all potential opportunities can be taken advantage of.

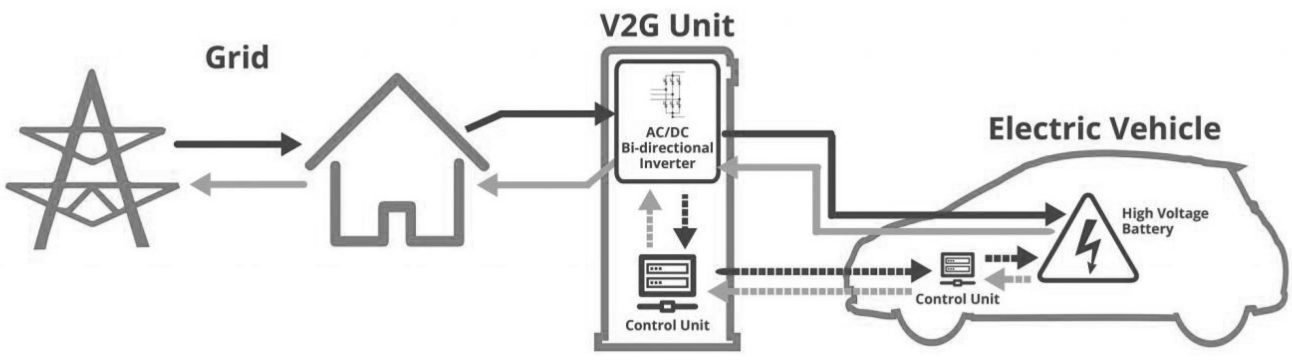

Fig. 2. The scheme of bidirectional V2G charging

Optimal management of electric vehicle charging leads to the following positive effects in the energy system:

– changing the electrical load schedule (load shift);

– provision of auxiliary services for operation of the power grid;

– grid congestion management;

– avoiding overloading of distribution grids;

– voltage control in distribution grids;

– reduction of excess RES generation;

– services "over the counter" (from the consumer's side).

It should be noted that these advantages and effects with smart charging can be achieved simultaneously. The most relevant example is the transfer of electric vehicle charging from the evening hours to the daytime hours. In this case, a decrease in the cost of electricity for end consumers will be achieved, overloading of distribution networks will be reduced, the electricity production curve will be favorably changed, and overproduction will be limited. The development and use of this system can allow for the regulation of power flow and the integration of renewable energy sources into the grid by increasing the reserve capacity of the national grid operator and enabling the long-term phase-out of peak generating capacities that produce electricity with a high carbon content. (Fig. 3) shows the impact of smart charging on the forecasted load profile in Germany, together with a histogram of RES generation [26], which visually shows the shift in peak demand to the time slot when more electricity is produced.

Similarly, several advantages can be gained by controlling the charging process in real time. Peak load on charging infrastructure can be reduced, voltage can be controlled by distribution system operators, ancillary services can be provided to the transmission network and network congestion can be managed. Unlike the previous example, in this case the four objectives cannot be achieved simultaneously, as different control strategies will be required.

The European network of electricity transmission system operators ENTSO-E assigns electric vehicles the role of a powerful resource not only for the decarbonization of the transport sector, but also for the creation of a significant potential operational reserve in the energy system [3]. This allows to believe that the optimal interaction of the charging structure and electric vehicles with the power system will provide important environmental and economic benefits for consumers and all involved entities. At the same time, the process of charging electric vehicles represents a real place of interaction between the transport and power sectors and is an important element for ensuring the successful development of both sides.

The European Association of the Electric Power Industry Eurelectric released a study on the development of the electric vehicle market and related infrastructure [27]. According to this study, the number of electric vehicles in Europe is expected to increase from 3 to 130 million over the next 13 years, resulting in an increase in demand for electricity. The peak load on networks will increase by 21–90%, and therefore the transition to electric mobility will be accompanied by frequent voltage spikes, power loss and rising energy prices.

If the current rate of spread of electric transport in Europe is maintained, the number of electric vehicles will increase to 65 by 2030, and to 130 million units by 2035. For this reason rapid development of infrastructure will be required to charge future electric vehicles: 34 million EVs by 2030 and 65 million EVs by 2035, with most of them (56 million) to be installed in residential buildings. According to Eurelectric's calculations, 115 billion EUR will be needed to deploy such an infrastructure [27].

It is assessed that charging an EV at a consumer's residence is 59-78% cheaper than at a public termi-

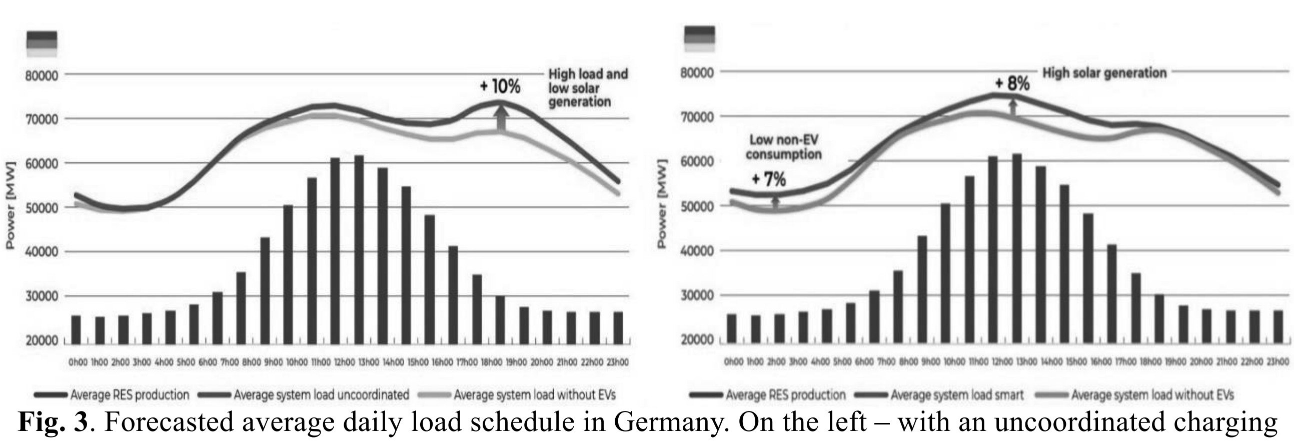

Fig. 3. Forecasted average daily load schedule in Germany. On the left – with an uncoordinated charging of electric vehicles. On the right – with the implementation of intelligent charging of electric vehicles [26]

nal, and predicts that by 2035, 85% of charging sessions will take place at home networks, with another 6% being on-site charging works, 5% – for public places such as parking lots, 4% – for expressways. It is clear that this increase in the number of electric vehicles will cause an increase in the demand for electricity, which is expected to increase by 1.8 percent each year and reach 3,530 TWh by 2030. Analysis of options for the use of chargers showed that the peak load would increase by 21–90 percent, and the load factor of transformers would increase by 19–80 percent [27].

Belgium's electric load graphs [27] clearly show the regulatory capacity of electric vehicles with smart grid concepts. The impact of V1G and V2G smart charging on the electric load schedule is presented in (Fig. 4), which shows the simulated average daily electric load from EV charging in Belgium for 2030.

One of the implemented Smart Grid projects adopted by other European countries is the EcoGrid EU project implemented in Denmark [28], which differs from most similar projects in Europe by using market instruments of consumers motivation to change their power consumption mode based on electricity prices. Thus, consumers, including owners of electric vehicles, participate in the provision of services for maintaining the balance and managing the load of the power system in real time.

In addition, a number of V2G projects were successfully implemented in practice in the Netherlands, Belgium, Germany, Great Britain, etc. [29]. The implementation of electric vehicle charging coordination strategies by power system transforms the traditional power system into a distributed system, in which a separate element (in this case, an electric vehicle or an electric vehicle aggregator) connected to the grid also has the ability to provide electricity to the grid, forming a separate distributed microgenerator. From the point of view of distribution networks, the charging infrastructure is the electricity sales channel, and the charger is the sales terminal. An electric service company can install the charger, operate it and make a profit.

For example, RWE (a German company for the maintenance of electric grids) created a charging network for electric vehicles separately from the gas station network [30]. While installing 11 charging stations in the city of Essen to attract consumers, the company developed and offered a tariff system for electric vehicles called "Autostrom". RWE has launched a pilot project in major German cities with ambitious plans to connect charging infrastructure for electric vehicles across Germany into a single network. However, it should be noted that with a distributed type of power grid, its operation is somewhat complicated by the fact that it is necessary to monitor and solve consumption patterns in real time.

It should be noted that with the development of technologies, the service time associated with charging an electric vehicle is significantly reduced, soon it will be possible to charge it almost instantly. From the point of view of electric vehicles, this provides an advantage that will accelerate the diffusion of electric vehicles.

3. Results

The performed review showed that the connection of a large number of electric vehicles to the distribution grid causes a corresponding technical

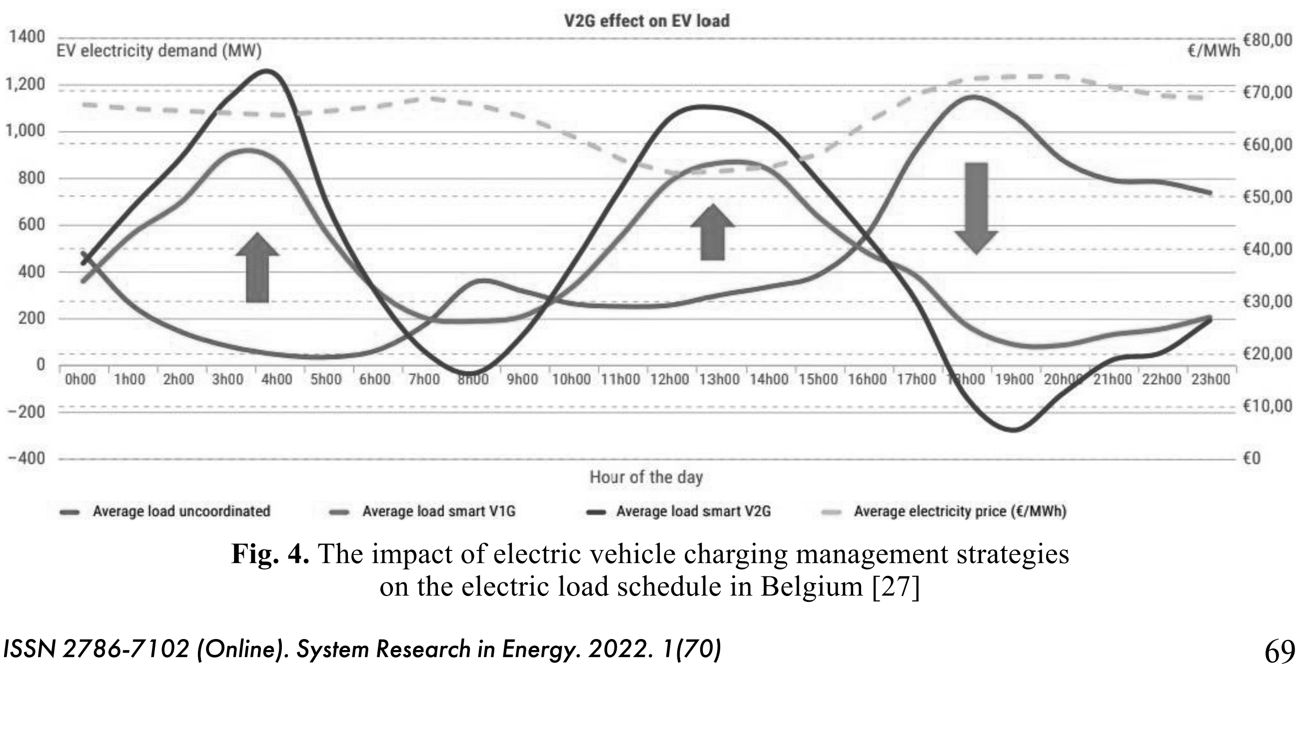

Fig. 4. The impact of electric vehicle charging management strategies on the electric load schedule in Belgium [27]

and economic impact on the power system. Studies of the impact of EV charging on the electricity sector have shown that it depends on when, where and how they are charged. When charging, electric cars consume between 15 and 30 kWh of electricity per charging session, which is equivalent to the daily electricity consumption of an average household. Although the demand for the charging service is not constant throughout the day, it can be managed, so the Smart Grid system is designed to avoid charging EVs during peak electric load hours, when energy demand is higher, and to facilitate recharging during hours when energy consumption is lower, thus using electric vehicles in particular and the charging infrastructure in general as a consumer-regulator of electric power.

4. Conclusions

The European car fleet has a steady trend towards an increase in the share of electric and hybrid cars, which will continue in the future due to the planned phase-out of cars with internal combustion engines. Having considered the experience of countries that have successfully developed electric transport, it was found that in general the demand for electric vehicles depends on the cost of electric vehicles for the end user, the development of the charging infrastructure for electric vehicles and government programs for preferential taxation and additional measures to stimulate using of electric transport.

In practice, the effective widespread introduction of electric vehicles must occur simultaneously with the development of the appropriate charging infrastructure for electric vehicles, as well as the development of systems for their interaction with the power system and compliance with global environmental standards. Despite the higher cost of electric transport, its operating costs could be significantly lower, and with the expected decrease in the cost of the battery in the future, the share of electric transport in the market will constantly grow.

The connection of an electric vehicle to the distribution grid determines the corresponding technical and economic impact on the power system. Determining the degree of impact of EV charging infrastructure on the power system depends on when, where and how they are charged. Although the electricity demand for electric vehicle charging is not constant throughout the day, it can be predicted, so the Smart Grid system is designed to manage the demand for the charging service and is designed to avoid charging electric vehicles during peak hours when the energy demand is greater and to facilitate recharging in hours when less energy is consumed.

The results of this work should be used for further research on the current state, studying the main trends and determining the prospects for the development of electric transport and charging infrastructure in Ukraine, and forecasting the volumes and modes of electric energy consumption by electric transport for the terms of Ukraine.

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