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Energy Support Options for Charging Station with Photovoltaic System

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Abstract : Current developments in energy policies around the world and the associated challenges of future sustainability in relation to climate change and the requirement to achieve a minimal to neutral carbon footprint pose serious challenges to solutions for modern transport and mobility infrastructures. The alarming state of fossil fuel depletion and the increasing awareness of worsening climate conditions is clearly leading to the adoption of alternative energy technologies. Among the technologies developed are mass and individual means of transport for people and goods, such as the electric vehicle (EV), which is fast becoming part of the modern transport system. This paper deals in a focused and clear way with the outlined topic mainly with the sources of electrical energy for EVs and their devices - charging stations and especially with the issue of current and planned development, implementation and characteristics of these charging stations in the under-construction user network of the Slovak Republic.

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1 Introduction

However, the crucial fact in this issue is that every EV also has to recharge its batteries somewhere. That is why the term charging station is becoming more and more widely used and will come to the fore in time, just like petrol stations. EV charging infrastructure is a new type of consumer in the electricity grid. The popularization of electric vehicles has brought a stronger push for the development of charging facilities, The demand for charging stations is steadily increasing due to the growing interest in electric vehicles. In the context of rising electricity prices as well as social pressure on the environmental impacts of electromobility, EV owners are also becoming more interested in a green source of electricity. If we wanted to provide electricity for EVs using RES, we could consider solar, hydro or wind power. However, hydropower is not suitable because of the availability of the water source. Wind power could theoretically be useful, but it is still unrealistic in the long term in Slovak conditions. So for the time being we will choose solar, which is the most practical and inexpensive in terms of usability [1] .

2 Current and planned status of charging stations in Slovakia

The public opinion that electromobility is an unrealistic transport option in Slovakia is no longer valid. In professional publications and discussions, the question of the availability of areas for PV systems that could be used for EV charging is often raised. Opponents of PV argue, among other things, that there is not enough suitable land in Slovakia to cover the electricity needs of EV chargers [2] .

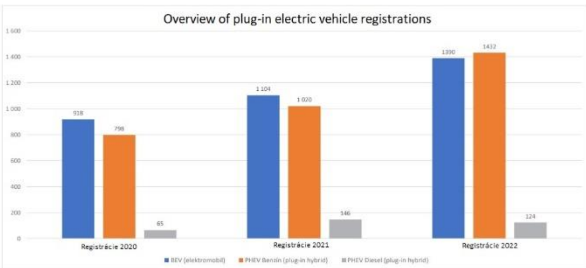

Figure 1 Overview of plug-in electric vehicle registrations

Table 1 M1 vehicles registrations overview 2020-2022

Year	Registration 2020	Registration 2021	Registration 2022
Plug-in electric vehicles			
BEV (battery electric vehicle)	917	1104	1390
PHEV petrol (plug-in hybrid)	798	1020	1432
PHEV diesel	65	146	124
Total BEV + PHEV	1781	2270	2946
Hybrid vehicles			
HEV petrol	6 246	12 185	14 588
HEV diesel	987	2 963	2 767
Total HEV	7 233	15 148	17 355
Hydrogen fuel-cell vehicles			
Hydrogen	0	1	1
Total FCEV	0	1	1
Internal combustion engine (ICE) vehicles			
Petrol	47 263	42 184	43 903
Petrol+LPG	540	953	1 407
CNG	404	234	291
Diesel	19 082	14 909	12 937
Total ICE	67 289	58 280	58 539
All fuel types – total for the year	76 303	75 699	78 841

In total, 90074 vehicles in all categories were registered in Slovakia in 2022, an increase of 3.1% year-on-year. In the category of new M1 passenger cars, registrations reached 78841 vehicles, an increase of 4.15% year-on-year. On the contrary, light commercial vehicles did not fare well, with a year-on-year decline of almost 7%, mirroring the situation in the trade and business environment in Slovakia. The total number of vehicles in the N1 category was 7679. The M1 segments again recorded growth in SUVs (+4.0%) and a decline in the small and compact vehicles segment (-4.3%). Registrations of passenger cars for legal and natural persons recorded year-on-year growth. Interest from individuals was more dynamic.

The positive news, however, is that according to SEVA (Slovak Electric Vehicle Asotiation) data, the building of charging infrastructure has moved forward, with an increase of up to 45% last year and a total of 1,483 public charging points in operation by the end of January 2023. Even better news is that the number of locations with a charging station has increased by 46% year-on-year. There are now a total of 629 sites, of which 331 are fast or ultra-fast charging sites, i.e. with a capacity of 50-350 kW. In fact, 100-150 kW chargers are becoming standard. The largest charging station networks in Slovakia are operated by Greenway with 425 charging points at 152 locations and ZSE Drive with 391 charging points at 137 locations. The third major player is ejoin GO, which expanded its network significantly last year and now has 314 charging points in 126 locations. Unlike the first two, who mainly focus on DC charging, ejoin GO has as many as 238 AC charging points and 76 with DC chargers.

In the near future, it will be necessary to start building a network of slow (AC) chargers, of which there are so far only a few in Slovakia. The Ministry of Economy of the Slovak Republic has supported the elaboration of a map with suitable locations near motorways and first-class roads, where more vehicle traffic is expected and therefore the need to recharge batteries in the future.

3 Technological charging of electric vehicles

3.1 DC charging

DC charging, or so-called fast charging, is carried out using a DC charging station that can convert alternating current (AC) to direct current (DC), then "bypass" the EV's on-board charger and send this DC current through the battery management system (BMS) to the battery as instructed by the vehicle's charge management system.

A DC charging station is technologically much more complex and many times more expensive than an AC charger, plus it requires a powerful power supply. In addition, the DC charger must be able to communicate with the car in order to be able to adjust the output power parameters according to the state and capacity of the battery.

3.2 AC charging

Charging an electric car with alternating current uses the car's onboard system (also called an on-board charger), which converts the AC voltage from the mains to the DC voltage needed to charge the batteries. The main difference between AC and DC charging is that in AC charging, the AC current is converted to DC by an On-Board Charger (on-board charger). The main function of the AC station is to mediate the necessary communication with the vehicle control system and ensure the safety of the vehicle and crew. In addition, the charger informs the vehicle of the maximum current it can draw at that time, depending on how busy the grid is. The AC charging station thus regulates the charging according to the current capabilities of the house or charging point to avoid overloading the grid.

4 Charging methods of Electric Vehicles

There are currently three main charging methods: conductive charging, inductive charging, and battery swapping [3] .

4.1 Conductive charging

Conductive charging uses direct contact between the EV charging cable connector and the charging input. The cable can be powered from a standard electrical outlet or charging station. A minor disadvantage of this solution is that the conductor must plug into the cable.

4.2 Inductive charging

Inductive charging uses an electromagnetic field to transfer energy between two objects. This is done by means of a charging station. The energy is sent through an inductive link to an electrical device, which can then use this energy to charge batteries or run the device.

5 Analysis of the energy needs of charging stations in Slovakia

From the users' perspective, charging availability is still top of mind. Charging must therefore be easily accessible from a location perspective. Customers in countries where electromobility is already more developed have the same view. The cost of charging comes second, but this does not mean that users are not concerned about it. So what are the prices in Slovakia? Due to the wide range of not only provider but also their individual programs, we will look at the price differences separately for AC and DC charging. However, the price summaries should be taken as information, as prices are constantly changing and may not be up-to-date at the time of reading. We have not included some operators due to unclear and frequently changing conditions. The price comparisons depending on the monthly usage of users are summarised in the following charts. When converting kWh per kilometer travelled, an average consumption of 20 kWh per 100 km is taken into account. The graph shows that the most cost-effective charging is at ZSE Drive's charging stations when using their Partner programme, where the programme is already the cheapest for electric car users when the mileage is above 20 km on weekdays. It is not worthwhile for customers to charge through so-called ad hoc schemes, i.e. charging when they are not registered with individual operators. Differences can reach levels of 200 to 300 % [4] .

Table 2 AC charging prices, source – official price lists of individual operators [3]

Provider	Program	Rate per kWh [€]	Lump sum monthly [€]	Free kWh within a month
e-join	GO1	0.29	-	0
GreenWay	Single use	0.42	-	0
	Energia Standard	0.42	-	0
	Energia Plus	0.32	7.90	30
	Energia Max	0.26	24.90	100
ZSE Drive	Guest	0.39	-	0
	Eco	0.39	-	0
	Partner	0.29	11.90	40
	Flat	0.29	89.00	400
Slovnaft	No registration	0.32	-	0
	Registration	0.27	-	0

5.1 DC charging

Compared to AC charging, fast-charging price lists are a bit more complicated. IONITY, e-join GO, and Slovnaft have a uniform price per kWh. GreenWay and ZSE Drive set DC charging prices depending on the charging speed. In order to compare comparables, we divided DC charging into two categories. DC charging stations with a capacity of 50 - 60 kW are the most common in Slovakia, so we focused on this charging speed. The second charging comparison is when using charging stations with power ranging from 75 to 350 kW.

Table 3 DC charging prices, source – official price lists of individual operators [3]

Provider	Program	Rate per kWh [€]	Lump sum monthly [€]	Free kWh within a month
e-join	GO1	0.29	-	0
IONITY	Public	0.49	-	0
	Partners	0.36	13.00	0

Provider	Program	≤ 25 kWh [€]	25-100 kWh [€]	>100 kWh [€]	Lump sum monthly [€]
GreenWay	Single use	0.42	0.65	0.78	-
	Energia Standard	0.42	0.65	0.78	-
	Energia Plus	0.32	0.54	0.66	9.90
	Energia Max	0.26	0.46	0.52	29.90

Provider	Program	DC > 50 kWh [€]	Ultra DC > 50 kWh [€]	Lump sum monthly [€]	Free kWh within a month
ZSE Drive	Guest	0.16	0.59	-	-
	Eco	0.49	0.59	-	-
	Partner	0.29	0.39	11.90	40
	Flat	0.29	0.29	89.00	400

Provider	Program	DC > 50 kWh [€]	Ultra DC > 62 kWh [€]	Lump sum monthly [€]	Free kWh within a month
Slovnaft	No registration	0.50	0.50	-	0
	Registration	0.45	0.45	-	0

6 Potential PV systems for charging stations

Photovoltaics, also called solar cells, are electronic devices that convert sunlight directly into electricity. The energy can be harnessed directly from the sun, even in cloudy weather, but with lower efficiency. Solar energy is used all over the world and is increasingly popular for generating electricity or for heating and desalination of water. In many countries, photovoltaics have become central to reducing carbon emissions and mitigating climate change. Currently, there are two basic types of PV panels: amorphous and crystalline. Crystalline is divided into polycrystalline and monocrystalline. Amorphous ones are less temperature dependent, do not reduce performance when overheated, and absorb more diffuse radiation. The efficiency is in the range of 12-15 % [5,6] .

Monocrystalline ones require direct radiation. Efficiency ranges from 15 - 22%, higher yield from the installed area. Disadvantages may include cost and uniform coloration of panels.

Polycrystalline also absorbs diffuse radiation, which is very common in our geological conditions. The efficiency is around 14-20%, which is not that big a difference compared to monocrystalline. The disadvantages of these panels can be e.g.: price, lower stability of the silicon layer.

6.1 PV installation possibilities

Between 2009 and 2011 it was possible to implement PV on arable land in Slovakia. But since 2011, it is only allowed to install on roofs, building facades, and private land.

Advantages and disadvantages of placing PV on roofs and building facades:
Advantages:

- Saving arable land for agricultural purposes
- Better thermal insulation of roofs
- Less maintenance
- Less likelihood of the panel being covered by leaves
- PV is less accessible to vandals and thieves

Disadvantages:

- Possible damage to the quality of roofs and facades
- Facades may be more difficult to install PV at high heights
- Damage to panels may occur in high wind conditions
- Deterioration of building appearance

Advantages and disadvantages of placing PV on arable land and meadows:

Advantages:
- Easily accessible installation
- Possibilities of building large areas
- Non-interference by construction in residential areas
- Greater electricity generation when large areas are developed

Disadvantages:
- Land take
- Damage to panels by vandals
- Theft of panels
- More difficult to connect to the grid with large PV systems compared to PV on buildings

6.2 Photovoltaics in Slovakia

Photovoltaics in Slovakia is making very big progress. In many cases, this is due to the energy price situation last year. However, more and more people are considering or currently already using photovoltaics as an ideal complement to an electric car. Such a tandem makes great economic and ecological sense in case of a sensible setup and the use of the right technology or the right type of the whole system. Being able to charge at least your daily mileage for a couple of hours a day from the sun on the roof of your house is, in short, something that makes sense.

7 Symbiosis of battery storage, photovoltaics and electric vehicle

This system is developed and manufactured in Slovakia, where it is also sold and provides complete technical consulting for the end customer.

7.1 IQ SMART HOME kit

The basis of the set-up is photovoltaic panels with outputs from 5 kWp to 30 kWp and a powerful hybrid inverter with an EPS output and an output of up to 20 kW. The most essential part of this system is the EV-GP LPF HV battery storage in 23 kWh or 31 kWh version, which consists of LiFePo 4 type batteries, where the manufacturer declares a lifetime of more than 15 years (6000 cycles/DOD 80%). There is also a charging station for electric vehicles (EVs) and hybrid cars (PHEVs), represented by the EV-GP home 22 kW IQ Smart model. Charging can be implemented in two ways - IQ charging from surplus. In this case, the control unit continuously manages the power to the charger and does not terminate charging even in the event of a lack of energy from the sun, but only interrupts it. In case of surpluses, hot water heating, heat pump and/or other options can also be triggered where the energy from the sun is used. At lower battery charge levels - lack of solar power - automatic power from an electric vehicle that supports V2L, i.e. has a single-phase output socket, is possible. So you can have a complete three-phase power supply in the house from an electric car. As well as the electric car, an external power source can be connected, whether LPG, petrol, diesel, or hydrogen generator.

Figure 2 EV-GP LPF HV

8 Conclusions

Infinite, inexpensive and clean, that's what we can call solar energy, which is nowadays advantageous as a supplementary source for EV charging, mainly for two reasons:

1. PV panels are easier to install and more efficient than other RES such as wind power. The cost of producing solar panels has dropped significantly over the last decade, making them not only affordable but often the cheapest form of electricity.
2. The future looks very promising for electromobility.

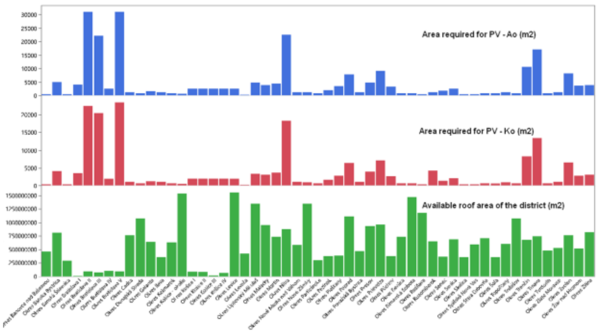

Figure 3 Required area for PV installation in districts

The required installation area for PV is also shown in Fig. 3 For amorphous panels (Ao), the Bratislava I - Bratislava V and Košice I - Košice IV districts would need the most area. The same is certainly true for crystalline technology (Ko).

Dependence on petroleum-based fossil fuels may change the growing interest in electric vehicles. In addition to the environmental impact and fossil fuel needs, electric cars are easier and more efficient to design and manufacture. As EVs become part of our daily lives, implementing and optimizing charging infrastructure will have new challenges. The future of PV charging station support is a viable option to harness the potential of solar radiation. In developed countries like China, Japan, and Germany, the concept of PV has long been a foreign concept. How our country will deal with it is not yet known. But thanks to the growing demand for EVs, we can hope that the charging infrastructure will also start to expand. We cannot predict how long it may take before we start to see more use of electricity generated from PV.

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