Analysis of the possibilities for implementation of charging columns of electric cars at gas stations

Todor Yonov
Department of Electrical Supply, Electrical Equipment and Electrical Transport
Technical University of Sofia
Sofia, Bulgaria
todyon@tu-sofia.bg

Yavor Lozanov
Department of Electrical Supply, Electrical Equipment and Electrical Transport
Technical University of Sofia
Sofia, Bulgaria
ylozanov@tu-sofia.bg

***Abstract* — Nowadays, transport plays an extremely important role in the social and economic life of a country. The movement of people, goods and services is an integral part of the modern way of life, but at the same time it is one of the main causes of polluted air, climate change and its negative impact on humans. That is why the electric car stands out as a vehicle that can replace the traditional car with an internal combustion engine and at the same time be environmentally friendly. Every driver knows the convenience of refueling his car at a gas station, and no matter what the car is - electric or with a classic internal combustion engine, he is looking for refueling, as he always did. Specifically, the article seeks answers to the questions of how much it will cost and what are the possibilities for installing charging stations in gas stations in Bulgaria, or at least on the main roads connecting Sofia with major cities and for how long such an investment will pay off.**

Keywords — charges of electric cars, charging columns

I. INTRODUCTION

Nowadays, transport plays an extremely important role in the social and economic life of a country. The movement of people, goods and services is an integral part of the modern way of life, but at the same time it is one of the main causes of polluted air, climate change and its negative impact on humans. That is why the electric car stands out as a vehicle that can replace the traditional car with an internal combustion engine and at the same time be environmentally friendly. Every driver knows the convenience of refueling his car at a gas station, and no matter what the car is - electric or with a classic internal combustion engine, he is looking for refueling, as he always did. Specifically, the article seeks answers to the questions of how much it will cost and what are the possibilities for installing charging stations in gas stations in Bulgaria, or at least on the main roads connecting Sofia with major cities and for how long such an investment will pay off.

In order to answer the questions asked, it is necessary to study the prospects for the development of the electric car fleet in the country and to make a forecast for the growth in the coming years.

II. CHARGING INFRASTRUCTURE

One of the main factors deterring the wider use of electric vehicles is the understanding that they cannot cover the desired distance without the need for charging. This may be due to either a real lack of charging infrastructure or a lack of information that it exists. Although the network of charging stations is growing at different rates throughout the EU, similar to the use of electric vehicles, it is still insufficient in some countries, and there is a lack of centralized information on all existing charging points. Most publicly available charging stations in the EU are located in urban areas of countries such as the Netherlands, Germany, and France. In 2017 for example, in the Netherlands, there are over 32,000 charging points and more than 119,000 registered electric vehicles, while in Greece there are 40 charging points and just over 300 electric vehicles respectively. Nowadays, there is one fast-charging station every 60 km on the main EU highways. The EU is taking various measures to encourage an increase in the number of charging points, spread information about their existence, and optimize standardization and interoperability. One of the steps is the adoption of the directive on the deployment of infrastructure for 14 alternative fuels, which recommends giving a minimum level of infrastructure - one publicly available charging point for every 10 electric cars.

According to the latest data, there is currently one public charging point for every 5 electric cars. Given the expected growth in the number of electric vehicles, it is expected that the EU will need nearly 2 million charging points by 2025. The document also recommends the use of intelligent metering systems that allow charging to be carried out from the electricity grid at times when there is low consumption. This document also presents the long-term perspective for implementing charging points that allow electric vehicles to supply energy to the grid. Measures are also being taken to improve the charging infrastructure in households and workplaces, due to the fact that most electric cars are charged in these places. The Directive on the energy performance of buildings from 2018 requires the presence of at least one charging point in each new non-residential building (eg shopping malls) and in existing buildings with more than ten parking spaces undergoing a major renovation.

A. Types and modes of charging

The template is used to format your paper and style the text. All margins, column widths, line spaces, and text fonts are prescribed; please do not alter them. You may note peculiarities. For example, the head margin in this template measures proportionately more than is customary. This measurement and others are deliberate, using specifications that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

In this work, the charging of electric vehicles is categorized into two main groups according to the mode and type of charging.

The charging mode describes the speed at which the electric vehicle is charged, defines the required voltage, current, and speed that the charging cables must provide, as

978-1-6654-4192-6/21/$31.00 ©2021 IEEE

well as the level of communication between the vehicle and the charging station. The charging modes are defined in the international standard IEC 61851 and are as follows:

- Mode 1 - slow AC charging from a standard household socket, in which the charger is integrated into the vehicle (230V single-phase or 400V three-phase; max. 16A; 3.7 - 11 kW).
- Mode 2 - slow AC charging with semi-active communication connection with the vehicle for safety purposes (230 V single-phase or 400 V three-phase; max. 32 A; 7.4 - 22 kW).
- Mode 3 - AC charging with an active connection between the charging station and the electric car to ensure safety and provide the possibility for intelligent charging (250V single-phase or 480V three-phase; max. 32 A; 14.5 - 43.5 kW).
- Mode 4 - DC fast charging, an active connection between the charging station and the vehicle (600 V DC, max. 400 A; 38 - 170 kW).

The type of charging describes the connector that connects the electric vehicle and the charging point. The following standards exist:

- Type 1 - allows slow charging, common in North America;
- Type 2 - standard for slow charging in the EU;
- Type 3 - allows slow charging, common in Italy and France, not installed since 2012;
- Type4 - allows for slow and fast charging, common in Japan and Europe;
- CCS (combined charging system, Type 2 and Combo 2) - standard EU for Type 2 slow charging and Combo 2 fast charging;
- Tesla Charger and Tesla Supercharger - international slow and fast charging for Tesla electric cars.

B. Charging at normal power (<22 kW)

All all-electric vehicles come with a portable charging cable that allows direct connection to an accessible AC power source. The onboard charger of the electric car converts the energy to DC for charging the batteries. However, all-electric vehicles usually also use charging stations that are equipped with safety, control, and stability functions and allow daily charging. The charging speed of the electric car depends on its capacity, as well as on the rated power of the charging station. Modern electric vehicles typically have a charging capacity at home from an AC power source from 3.3 kW to 11 kW, with a trend of gradual shift to higher power options due to the increase in battery capacity and the desire of vehicle makers to meet customer needs for faster charging.

Home wall charging points are designed to provide the required power to a specific electric vehicle, while publicly available charging stations can offer several power levels to meet the needs of many different electric vehicles.

For commercial AC charging applications that use Mode 2 a 400 V three-phase industrial socket can also be used for even faster charging. In this case, it is possible to achieve charging levels up to about 19 to 22 kW, and the station can be mounted on a wall or pole. AC Mode 2 charging is a good option when the electric car is parked for several hours during the day or at night. It can also be applied entirely to plug-in hybrids (PHEV), whose batteries have a much smaller capacity. The cost of these stations varies widely depending on whether they are designed for home or commercial use, the power level, and many other features such as network connections.

C. High power charging (> 22 kW)

There are two main options for fast charging - AC and DC. A charging station using a three-phase alternating current can provide power levels up to 43 kW. This type of charging is faster than other AC charging stations, and at the same time, the price is lower than that of the DC charging technologies.

DC fast charging offers higher power than most AC solutions. This type of charger converts AC power to DC, which is needed to directly charge the battery. This is more typical of battery-powered electric vehicles (BEVs) than PHEVs, as higher power from DC equipment is required to fully charge a high-capacity battery within a reasonable period of time.

The cost of a DC station is significantly higher than that of an AC, but on the other hand this is compensated by the fact that charging is done many times faster. Most DC charging stations today offer 50 kW of power, but there are also those with lower levels - about 20 - 25 kW.

There is currently a need to move to levels of 100 - 150 kW, even up to 400 kW, to service the next generation of electric vehicles with batteries with much higher capacity (80 kWh and more). The purpose of DC charging stations is to provide up to 80% of the charge of the electric vehicle in 20 minutes or less. Experts believe that levels above 150 kW, at least in the short and medium term, will only be applicable to a very small segment of vehicles. Such capacities represent a technological challenge for the battery, which is why the availability of station models that charge to such levels will remain quite limited.

D. Charging in households

Charging electric cars in households is often the most convenient and cost-effective option for consumers. Most home chargers have a rated power of 3 or 7 kW. The cost of higher power wall mount stations is usually slightly higher than the slower charging options, but they halve the time to fully charge the battery of the electric vehicle. Many electric car manufacturers work with charging station suppliers, and in some cases a free home charger is offered when buying a new car. Most often, this type of charging requires parking the car off the streets to avoid cables passing through sidewalks and other public areas. Although less common, there are also chargers for home use that are installed on the street.

E. Charging at the workplace

It is becoming increasingly common for companies to install charging stations for electric vehicles for use by employees and visitors. In some cases, this is even seen as an opportunity to attract customers, for example in shopping malls. Although charging stations for electric vehicles at the workplace are similar to those for home use, they usually have a higher rated power of 7 and 22 kW. Many of these devices have dual charging contacts, allowing the charging of two electric vehicles simultaneously.

In some countries, grants are provided for the availability of charging stations for electric vehicles in the workplace. Business owners can choose whether to provide the service for free or for a fee, but many prefer the free option to encourage the use of electric vehicles within the company and among customers and visitors.

Often the electric cars of customers and visitors have different charging needs, which is why it is important to install a charging point that is compatible with the maximum number of electric cars. The most common are the Type 2 wall-mounted chargers with a power of 7 kW, which are compatible with most of the best-selling electric vehicles and can fully charge a battery within about 3-7 hours, depending on the model.

For businesses planning to install charging points in publicly accessible locations, it is important to consider access requirements. Most charging station manufacturers offer devices that can be accessed with a key or RFID card to prevent unauthorized use. Workplace chargers are often available in a package with solutions for monitoring energy consumption, charging point usage and calculating carbon savings.

III. ANALYSIS OF THE POSSIBILITIES FOR PLACING CHARGING COLUMNS

A. Suggestion - select a column

The paper discusses the installation of a column for charging electric cars, based on the assumption that the owners will charge mainly at home and will need a charging station only for long-distance travel. This determines the need for columns with a combined charging system, Type 2 and Combo 2. For comparison, two columns were selected - with power up to 24kW Schneider Electric EVD1S24THB2DC [1] and up to 150 kW - DELTA UFC 150DC [2]. Both columns meet the requirement for fast charging. Their data are given in the cited literature. The data for the construction of a column in a gas station are given in the Table.1.

TABLE I. PRICES FOR INSTALING OF CHARGING COLUMN

Price	**Schneider Electric EVD1S24THB2DC**	**DELTA UFC 150DC**
Value of the charging station, BGN	27 883	67183
Installation, connection and grounding of the station	Included in the price	Included in the price
Materials not included in the price, BGN	1374	1903
Labor not included in the price, BGN	632	2052
Total, BGN	29889	71138

B. Assumption for charged electric vehicles

Two electric cars were chosen for comparison - Nissan Leaf - 40 kWh and Tesla Model S (100D) - 100 kWh. These two models were chosen because of the different classes. A small city car, such as the main class of cars in our country and a family car of a higher class. The prices are 0.48 BGN/kWh for charging AC / slow / and 0.68 BGN/kWh for charging DC / fast /. The data are given in Table. 2.

TABLE II. ECONOMIC COMPARISON OF CHARGING METHODS

Nissan Leaf - 40 kWh							
Car power		AC Charging			DC Charging		
usable	real	power	time	price	power	time	price
kWh	kWh	kW	h	BNG	kW	h	BNG
40	38	6,6	6	19	46	0,67	21
Tesla Model S (100D)							
Car power		AC Charging			DC Charging		
usable	real	power	time	price	power	time	price
kWh	kWh	kW	h	BNG	kW	h	BNG
100	95	17	6	49	200	0,67	91,1

It can be seen that if we assume that most owners will prefer to charge their vehicles at home or at work, only a small part of them will charge their cars at gas stations, the latter can count on long distance travels by the owners of such cars. By taking into account the following data:

- Not only electric cars are charged, but also hybrids, so the total number of charged cars is significantly increased;
- Cars from the class of Tesla Model S (100D) are not more than 10% of the total number of cars;
- The difference in price between the selling price of a gas station and the price of a column reduced by costs by 30% is the real profit;
- Only 25% of the electric cars pass through the gas station in question once a year;
- Fast charging is mainly used, the difference between slow and fast - charging is accepted 20/80% in favor of fast - this is due to the assumption that the owners move mainly in the city.

The results obtained under these conditions are shown in Table 3.

TABLE III. ECONOMIC COMPARISON OF CHARGING METHODS

	EV with battery capacity				HPEV	
	100 kW	Amount BNG	40 kW	Amount BNG		Amount BNG
From them	118	-	1067	-	7735	-
charged	30	-	276	-	1934	-
Slow	6	139	54	486	-	-
Fast	24	1222	213	2502	1547	10966
Amount BNG	-	1361	-	2988	-	10966
Total BNG	EVs 4349		EVs and HPEVs 15315			

IV. CONCLUSIONS

It should be borne in mind that to charge cars of the class of Tesla Model S (100D) it is necessary to mount DELTA UFC 150DC columns. Electric cars in our country have rechargeable batteries with less power and can be charged without problems from columns with a capacity of 24 kW.

With the assumptions presented above, the following conclusions are valid:

- If you rely only on electric cars, a column with a capacity of 24 kW will pay off after 10 years, with a capacity of 150 kW after 17 years;
- If they charge hybrids - the column with a power of 24 kW will pay off in 2.2 years, the other - 4.6.

It can be seen that the return of investment period of the columns with the relatively few electric cars makes the investment at the current stage risky. If you also rely on charging hybrids, the buying time becomes quite bearable. On the other hand, most gas station owners are large companies with financial capacity and can afford such a risk. Our country is relatively small. A very reasonable solution to the problem is to choose 2-3 gas stations at a distance of approximately 130-180 km and place columns in them to ensure the longer sections from Sofia to Bourgas, Varna, etc .. this, as mentioned above, the trend of increasing the number of electric cars will make such an investment return faster.

ACKNOWLEDGMENT

The authors would like to thank the Research and Development Sector at the Technical University of Sofia for the financial support.

REFERENCES

[1] https://www.se.com/ww/en/product/EVD1S24THB

[2] https://emobility.delta-emea.com/en/Ultra-Fast-Charger.htm