Technology assessment, impacts and public policies: A review on electric vehicles in Brazil

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Rafael Ayres Soares[1], Carlos Henriques Ventura do Rosário Oliveira[2] and Paulo Roberto Duailibe Monteiro[3]

ABSTRACT

This article addresses electric mobility in Brazil, highlighting the advances, perspectives, and impacts. The absence of detailed national regulations has been an obstacle to the advancement of the sector. The lack of standardization, standards and awareness also has an impact on the electric vehicle market in the country, as well as the dependence on imported components regarding the high cost of electric vehicles. One of the main challenges is the impact on the power grid from vehicle recharges. The growth of electric mobility has the potential to overwhelm existing infrastructure, especially during peak hours. The analysis of the scenario and perspectives not only drive the development of electric mobility in Brazil, but can also help manage the impact on the grid, ensuring a sustainable growth of the sector and positioning the country as a technology exporter.

Keywords: Electric Mobility, Electric vehicles, National regulations, Electric grid, Charging infrastructure.

[1] Master's student in Electrical Engineering
Universidade Federal Fluminense (UFF), Niterói, Brazil
E-mail: rafaelayres@id.uff.br
ORCID: orcid.org/0000-0001-6239-9705
[2] Master in Management Systems
Universidade Federal Fluminense (UFF), Niterói, Brazil
E-mail: carloshenriques@id.uff.br
ORCID: orcid.org/0000-0002-6729-9209
[3] Doctor in Civil Engineering
Universidade Federal Fluminense (UFF), Niterói, Brazil
E-mail: pauloduailibe@id.uff.br
ORCID: orcid.org/0000-0002-7376-9115

INTRODUCTION

The growth of the global population coupled with the ever-increasing demand for goods and services increases the need for energy. As a result, innovative ideas and applications are being promoted to be implemented based on renewable energy sources. The Sustainable Development Goals (SDGs) defined by all United Nations Member States seek to promote people's living conditions while protecting the environment, now and in the future. There are 17 SDGs, which need to be urgently addressed by all member countries. The 17 identified SDGs include, but are not limited to, poverty eradication, hunger eradication, healthy conditions and well-being, quality education, clean water and sanitation; affordable and sustainable energy, as well as responsible consumption and production [1]. Electric vehicles are being used in many countries and therefore, to facilitate the charging of these vehicles, point-to-point charging stations are required in different establishments. Globally, in 2021, road transport accounted for approximately 16% of total CO2 emissions [2]. In the Brazilian scenario, for the same year, about 46% of the total CO2 emissions in the country were caused by land transport, of which 53% were related to passenger transport (including buses) [2].

With the increase of electric vehicles (EV's) some of the issues related to their charging need special attention, especially regarding the possible impact on the quality of the power of the electric system, including voltage drop and fluctuations, grid overload, harmonics and losses, however their implementation can still bring a new look to the electric grid. Another important aspect of EVs is the possibility of energy storage. It should also be considered that high nonlinear loading can be a cause of nonlinear voltage drop and therefore the voltage waveform can be distorted. On the other hand, non-linear load can affect the performance of the distribution transformer by increasing energy losses in the winding and thus reducing its output power. [3] Thus, EV chargers when integrated into the power grid or distribution network can impair power quality [3].

In the general context of electromobility, Brazil had 131,007 electric vehicles at the end of January 2023. In addition, at the end of 2022, the share of electric and hybrid vehicles in sales was 2.5% [4]. However, it is estimated that by 2030, they will represent between 12% and 22% of registrations in Brazil, or even between 32% and 62%, depending on the regulatory path the country will follow. In terms of electric vehicle charging infrastructure, the country has seen the increasing implementation of charging stations and electric corridors in the national territory. [4]

In light of this, this study aims to address the electric vehicle scenario, technologies, possibilities and future impacts. This study is organized as follows: In Section II, Electric Vehicles and the Technologies Involved are presented. In section III, Charging Systems are presented. Section IV deals with Public Policies in Brazil. Section V will deal with the Impacts on the Distribution Network from vehicle charging. The conclusion is presented in the last section (Section VI).

ELECTRIC VEHICLES & TECHNOLOGIES

There are mainly three types of electric vehicles available worldwide, i.e., plug-in hybrid electric vehicle (PHEV), hybrid electric vehicle (HEV), and battery electric vehicle (BEV). According to data from ABVE (Brazilian Electric Vehicle Association), of the 128 electrified light vehicle models registered in Brazil in 2022, 44.5% are BEVs (57 models), sold by 27 automakers, and 28% are PHEVs (36 models), sold by 21 automakers. The figures indicate that 72.6% of the models registered in Brazil are plug-in electric vehicles, following the trend in Europe and China. Throughout 2022, Volvo, BMW and CAOA Chery were the automakers that stood out the most in the sales of plug-in electric vehicles (BEV and PHEV) in Brazil. The largest share was held by Volvo, due to both the offer of BEV and PHEV models.

Hybrid electric vehicles with external charging also had a notable performance in electrified vehicle sales in April 2023. A total of 1,304 PHEV registrations were registered, which represents an increase of 106% compared to April 2022, when 634 vehicles of this type were registered. On the other hand, all-electric battery vehicles (BEV) totaled 564 registrations in April, an increase of 22% compared to the same month of the previous year, which recorded 461 registrations. Hybrid electric vehicles without external charging (HEV) also showed significant growth. A total of 2,925 HEV vehicles were registered in April, which represents an increase of 44% compared to the 2,028 registrations in April 2022. [5]

Among the 2,925 hybrid electric vehicles registered, 2,229 are ethanol-fueled HEV flex-fueled vehicles, while 696 are gasoline-powered HEVs. These figures represent a growth of 33% and 96%, respectively, in relation to the registrations of ethanol flex HEV and gasoline HEV vehicles registered in April 2022.[6]. Table 1 shows the sales classification of electric vehicles.

Table 1 - Electric Vehicles - Sale Ranking 2023 [6]

Ranking	Model	Manufacturer	Technology	April 2023
1º	Corolla Cross	Toyota	HEV	1037
2º	Corolla Altis	Toyota	HEV	529
3º	Tiggo 5X	Caoa Chery	HEV	429
4º	Tiggo 7	Caoa Chery	HEV	234
5º	Tiggo 8	Caoa Chery	PHEV	209
6º	XC60	Volvo	PHEV	157
7º	XC40	Volvo	PHEV/BEV	140
8º	Q5	Audi	PHEV	139
9º	Cayenne	Porsche	PHEV	132
10º	Defender	Land Rover	PHEV	131

As far as the vehicle model is concerned, there is a considerable arrangement of PHEV vehicles on the best-seller list. Among them, the models *Tiggo 8* as the best seller and models *XC40* and *XC60* made by Volvo. Then the models *Q5, Cayenne e Defender*.[6] Therefore, based on this information, it is possible to highlight that the Electric Vehicle market is evolving.

PHEVs have proven to be an attractive option for consumers who are not yet ready to fully embrace BEVs but want a low-emission technology. This alternative offers consumers the ability to take advantage of the efficiency of electric motors, combined with the flexibility and range provided by internal combustion engines. By opting for a PHEV vehicle, consumers can enjoy environmental and economic benefits by reducing their carbon footprint and decreasing their reliance on fossil fuels. In addition, the ability to recharge the vehicle at home or at public charging stations makes it easier to transition to a more sustainable mobility option. In the current context, PHEVs represent a promising solution, meeting the needs of those who want a low-emission option without compromising convenience or range.[5]

The battery range of a BEV can vary from a limited-range vehicle (*Nissan Leaf-24 kWh*) to a long-range vehicle (*Rimac C II-120 kWh*), while the HEV battery has a capacity of 0,9 kWh (*Toyota Yaris Hybrid*) a 1,78 kWh (*Toyota Pirus I*). The battery capacity of PHEVs ranges from 4.4 kWh (*Toyota Prius III*) to a maximum of 34 kWh (*Polestar 1*) [3].

CHARGING SYSTEM

As EV loads are increasing day by day in a rapid manner, the impacts of EVs must be analyzed. There are several charging standards for electric vehicles in the world, which requires the user to know different charging points.

a) Level 1: The vehicle is charged using on-board charger (which is built into the EV). Here, the domestic power supply is directly connected to the charging point. The management and control of the energy flow is supervised by the control system available on board. In this method, the current power supply is small and the power injected into the battery is restricted according to the existing converter in the vehicle and the installation conditions of the local grid. [7]

b) Level II: Level 2 charging mode is the most suitable option for private charging facilities. For private installation, this mode assigns a 240 V single-phase AC with a current handling capacity of 40 A and 80 A for a 400 V (three-phase) AC supply. [3]

c) Level III: During charging, it can be achieved in 20 – 30 min due to the DC terminals, regardless of the converter in the vehicle model. This level of charging is dedicated to higher powers, such as 130kW, and relies on a robust infrastructure. [8]

Loading levels can be seen in Table 2.

Table 2 - Charging Levels

Level	Typical use	Voltage and type of current	autonomy per hour of recharging
Level 1	Homes and workplaces	127 V AC	3km a 8km
Level 2	Homes, workplaces and public places	220 - 240 V AC	10km a 96km
Level 3	Public places	can reach up to 600 V AC or DC	96km a 160km

Table 2 shows that there are three levels of loading, depending on the power involved: the load with low power (levels 1 and 2). For those with higher capacity, called fast chargers (level 3), it is common for the power converter to be outside the vehicle. [8]

Another important point regarding the charging system is the charging connector. For the Brazilian market, ABNT (Brazilian Association of Technical Standardization) has recommended these plugs for direct current recharges: (IEC 62196-2) Type 2, CCS Combo 2 and CHAdeMO (IEC 62196-3). However, the most widely used plug today in Brazil is Type 2 (Mennekes) containing almost 90% of all recharges. [9]

IMPACTS ON THE DISTRIBUTION GRID

Electric vehicle charging stations are manufactured using non-linear electronic components that inject energy and successively harmonics. As a result, distribution networks tend to receive these disturbances, which can have an impact on the quality of the network's energy. The following are some of these disturbances:

a) Harmonics: Harmonics are characterized by the presence of a high frequency component of voltage and current when compared to the fundamental frequency. Total harmonic distortion (THD) can be calculated using a mathematical formula. [10]

b) Voltage: Another important impact on the distribution network can be associated with the voltage profile. Through rapid charging, an imbalance and distortion in the voltage waveform occurs. Since the power demanded during charging is high, it affects the stability of the voltage waveform, resulting in grid instability. This situation can be improved by integrating renewable energy sources into the charging station. Renewable resources, such as solar PV, provide grid support and prevent waveform instability.[11]

c) Distribution Transformer Overload: Overloading the charging station puts pressure on the transformer's windings, reducing their ability to deliver power. The presence of harmonic current and harmonic voltage results in pressure loss and absence of charge loss, respectively. These harmonics must be within the transformer's bearable capacity, known as the K-factor. [12]

$$K_{factor} = \sum_{n=1}^{N} n^2 \left[\frac{I_n}{I_R}\right]^2 \quad (1)$$

PUBLIC POLICIES – NATIONAL SCENARIO

The commercialization of electric vehicles in Brazil should follow the global growth trend in the coming years, as a result of technological evolution, but which must be followed by public policies that regulate the issues of polluting gas emissions and decarbonization, and mainly, that create tools to encourage the use and popularization of EVs. The evolution of electric vehicles in Brazil, whether in cargo or utility transport, seems obvious, but there are barriers, as they are not accompanied by regulation [13].

There is a need to develop standardization, create business models, open lines of credit, and other legal instruments at the federal, state, and municipal levels. Incentives should also be created to enable the implementation of electric vehicle and battery industries, promoting the development of national technology. One positive factor is that many Brazilian public transport companies have electrified their fleets, and plan to increase the use of electric vehicles. A car rental company had 400 EVs in 2021, announced, with the aim of neutralizing carbon emissions by 2028, the purchase of 2000 electric vehicles. [14]

Even so, there is still a long way to go for the electrification of fleets. At the federal level, there are already some laws, programs, and bills that deal with electric mobility and electric vehicles. An important rule is Aneel's Normative Resolution 1000/2021, which establishes the rights and duties of consumers, and the rules for the provision of public service by Distribution Concessionaires. [15]

It defines various technical aspects relating to electric vehicles, and in Chapter V it deals with electric vehicle charging installations. Law 13,755 of 2018 establishes the mandatory requirements for the sale of vehicles in Brazil and establishes the Rota 2030 Mobility and Logistics Program, and also provides for the tax regime for non-produced auto parts. [16]

a) Through resolution no. 97 of the Chamber of Foreign Trade (CAMEX), import duties for electric vehicles were reduced from 35% to a range of 0% to 7%, depending on the characteristics of the EV [17]. In the industrial sphere, Decree 11,158/2020 regulated the IPI values on hybrid and electric vehicles. Considering the legal aspects of Brazil, it is necessary to evaluate and create specific public policies on several aspects, among them we can mention [18]:

b) Price and taxation of EV recharges: According to ANEEL's Normative Resolution No. 1000/2021 in its article 599, recharge prices can be freely negotiated, but it is necessary to detail how fees will be charged, whether as a service or as a product.

c) Electrification of Public Transport: Although the transition to electric bus transport is a necessity, there is still a barrier which is the high cost of vehicles. One option is to create incentive fees to make migration viable, and to create new concession contract models for public transport.

d) Incentives for the Battery Industry: Batteries account for 40% of the total price of the electric vehicle, and it is the main item that results in the high price compared to combustion vehicles. [G]. In this way, in addition to creating ways to reduce the price by reducing import duties or credit lines, the long-term solution is to encourage the installation of industries in Brazil.

e) Standardization of charging stations: Due to the variety of technical solutions for charging systems, it is necessary to standardize and standardize stations in Brazil, to become compatible with EVs manufactured abroad, including electronic systems, types of connectors and battery charge cycles.

CONCLUSIONS

The current scenario of electric mobility in Brazil presents both significant advances and challenges. Brazilian companies are already advancing in the electrification of their fleets, however, the lack of national regulation does not keep up with this development. The National Electric Energy Agency (ANEEL) has opted for a minimal regulatory approach to avoid disruptions to the electricity grid and ensure that consumers' tariffs are not impacted by the electric vehicle charging service.

This lack of standardization and regulatory frameworks, in addition to the scarcity of new business models, access to credit, and general knowledge of the population about the benefits of electrification have been limiting factors for the electric mobility market in the country. Unfortunately, the lack of awareness, interest and involvement of local authorities has also not provided public policies that encourage the development of national industry and technology in this sector.

The lack of a domestic electric vehicle industry results in a higher cost for battery vehicles compared to combustion vehicles. In addition, for the integration of the electric vehicle into the grid to be efficient, it is essential to discuss regulatory and normative issues, such as communication protocols between vehicles, charging stations, system operators, and electric power companies. Taxing the sale of energy for charging electric vehicles is also important. Defining whether the sale is considered a service or a product is relevant to stimulate investments and facilitate business development in electric mobility.

As for the impact of charging on the grid, dynamic pricing emerges as an essential tool to guide user behavior, allowing EV owners to respond to price incentives and recharge their vehicles at times that do not overload the grid.

Despite the challenges, Brazil already has some factories installed and other companies have shown interest in the Brazilian market. However, even Brazilian factories are dependent on imported components, which generates a significant tax burden on the sale of these buses in the country. Brazil should also exploit its already consolidated industrial capacity and promote the development of the local electric vehicle industry in all categories (light and heavy). This long-term action has the potential to generate jobs and position Brazil as an exporter of technology, just as it already happens with diesel vehicles.

Therefore, it is imperative that Brazil advances in the regulation and promotion of electric mobility, taking advantage of its competitive advantages and overcoming the present challenges. With joint efforts of the public and private sectors, a more sustainable and efficient future for mobility in the country can be built.

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