



Government Policies and Economic Impact on Electric Vehicles (EVs) and Fast Charging Systems: A Review

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ABSTRACT

Conventional internal combustion engine (ICE) vehicles emit many types of pollutants. The list includes carbon dioxide (CO₂), nitrogen oxides (NO_x), particulate matter (PM), and volatile organic compounds (VOCs). They add much to air pollution, making it unhealthy to breathe. It results in various diseases related to respiration and the cardiovascular system. Moreover, conventional vehicles generate large amounts of greenhouse gases that are known to expedite global warming and changes in climate; mostly CO₂. EVs have several advantages over conventional automobiles in helping to solve environmental problems. Tailpipe emission from an EV is zero, thereby significantly reducing urban air pollution and associated health hazards. EVs clean the air and make people's lives healthier by removing NO_x and particulate matter (PM) pollutants; they also help in combating climate change by reducing GHG emissions. Government policies and activities drive the exponential growth in electric vehicles and fast-charging infrastructure. It incentivizes EV manufacturing and imports with subsidies, tax breaks, and lower registration costs, primarily to reduce the dependency on imported petroleum and lower resultant environmental pollution, apart from encouraging EV adoption.

1. INTRODUCTION

At the global level, there is fast growth in EVs and fast charging infrastructural setup for the same. Government policies and actions at times play a very crucial role in this proliferation. The Electric Vehicle Policy 2020 aims at encouraging the EV market through incentives on the manufacture and import of EVs in the form of taxation, subsidy, and reduced registration fees. Most of these policies target reduced dependency on imported petroleum, reducing environmental pollution, and encouraging the use of EVs.

The growing need to reduce emissions will particularly influence the mobility market. The European Commission approved the sale of automobiles with Zero-emission and hybrid vehicles with low emissions (less than 50 g CO₂/100 km) are expected to account for 20% of

sales by 2025 and 35% by 2035, respectively [1]. A similar trend can be seen with public transportation. These developments compel new technologies and advanced solutions from both electric vehicle manufacturers and charging infrastructure providers. The development of power networks is necessary to lower grid load during peak hours, charging services in high-demand areas may require energy storage [2]. The use of electric vehicles is becoming more and more influenced by environmental concerns, particularly since urban air pollution is a major issue in many places. Since they don't emit exhaust emissions, electric vehicles can be very helpful in reducing this problem [3]. This pattern is consistent with international efforts to mitigate climate change and reduce carbon emissions.

Furthermore, electric cars have significant financial benefits. Reducing imports of fossil fuels can result in significant foreign exchange savings, and developing a domestic EV manufacturing industry could promote economic expansion and employment creation [4].

The automobile industry is undergoing significant changes as a result of the introduction of autonomous cars (AVs) and battery electric vehicles (BEVs) to the worldwide market. On the one hand, the novel features of the BEV powertrain in comparison to the combustion type have led to the creation of new central parameters, including vehicle range, which subsequently serves as a key point of differentiation. However, the cost structure of vehicles is altered since electric components are still not optimized and because the sensors required for autonomous driving are still costly. It's not only a change in the car itself but also in how it moves and what type of infrastructure it demands. Novel usages and scenarios are impacted by new user activities. The latter is impacted by the BEV powertrain, which is dependent on the charging and energy supply infrastructure.

Electric vehicles diffusion can cut down significantly on expenditure related to oil imports, which are more often than not among the main import commodities. It can also result in creating new enterprises, hence job opportunities, and improving the socio-economic landscape. EVs offer great promise with fast-charging facilities. There is, therefore, the requirement to create a large and reliable network of charging stations, especially those enabling fast charging, for the ever-increasing EVs. The infrastructure to support this would need to be sustainably developed through a public-private partnership that provided wide geographical spread and easy accessibility to all EV customers.

Prospects for markets to be flooded with electric vehicles and quick-charging networks are excellent in the future. A portion of infrastructure development is huge in our future. Developing an extensive and reliable network of charging stations—especially fast chargers—will sustain the rising number of EVs. Public-private partnerships can work towards bringing in this kind of infrastructure and make sure that these charging stations are appropriately located and accessible to every user of EVs.

The largest challenge that electric vehicles face is

the cost of batteries. A battery is normally the most expensive element in an EV and often could make up a large portion of the total EV cost. Given the high EV battery cost, at markets where affordability would turn into a critical factor for vehicle adoption, this becomes one of the huge manufacturing and utilization barriers for EVs.

Another barrier is the lack of economies of scale in many markets. Since EV adoption is so new, few EVs and batteries are actually made. The lower the volume of the manufacturing process, the higher the cost per unit tends to be. That cost probably will fall once the industry has developed and grown, but that will take time.

In a bid to address these challenges, markets need to employ a wide array of techniques. First, a low cost can be attained by drastically reducing it through investment in R&D, constructing production facilities, and training qualified workers in local EV battery-making skills. Public-private partnerships and international collaborations could help speed this process up.

2. LITERATURE REVIEW

EVs have increasingly become famous with the developing technology and environmental concerns. The challenging issues of EV adaptation are the time consumed and demand for charging. This paper espouses a dynamic energy management system and DC rapid charging technology to overcome the difficulties. In order to shorten the charging time, DC fast chargers require high power demand times. This can negatively impact the grid's stability, resilience, and efficiency. This study aims to analyze a hybrid DC fast charging station to reduce peak consumption during charging [5]. The proposed energy management method, along with dynamic data, yields more trustworthy outcomes for such system operations. The suggested control technique reduces grid peak demand by 45% and improves battery life through better charge/discharge coordination [6].

Electrified transportation is seen as a possible solution to address climate change. To commercialize and widely use electrified transportation, an affordable, dependable, and quick-charging infrastructure is necessary. Integrating EV rapid charging infrastructure into the smart grid can provide chances for V2G technology and address renewable energy

intermittency issues. The article provides a complete analysis of rapid charging technology for electric vehicles, including studies on obstacles and roadblocks to deployment. It also compares conductive and inductive charging systems, provides an overview of charging standards, and discusses topologies used in fast charging stations [7].

Many countries have set objectives to replace fossil fuel vehicles with electric ones due to environmental concerns and energy supply security concerns. The use of electric vehicles is expected to increase significantly in the future years. Fast charging stations, in addition to home chargers, are necessary to increase charging speed and reduce energy costs for owners [8]. This reduces the disruptive impacts of home chargers on the electricity grid. In recent years, several concepts and technologies have been presented to model charging stations, including energy management, infrastructure, and optimal charging plans with integrated energy and technology. The key requirements for this field include enhancing charging station efficiency, regulating charging and discharging, incorporating renewable sources, and implementing Energy Storage Systems (ESS) [9]. Researchers have estimated that, at high power rates, 150 kW, the future demand for public fast-charging infrastructure can be met with one fast-charging port per 1000 vehicles. Moreover, the extra electricity price for payback is projected at 0.05-0.15 €/kWh per charging point, while requirements would differ depending on growing battery size and power rate [10]. A novel battery-supported quick-charging method was developed to reduce grid stress, maintaining the EV charging rates. The result of the study was that actually the ambient temperature showed the high impact on the charging behavior, with higher charging rates and shorter time frames during the summer period. This new technique will allow fast charging without queues in winter and summer compared to the conventional system. This solution solves fluctuations in electricity demand and enhances charging efficiency [11].

EVs are a potential and practical solution to high fuel consumption and related GHG emissions of conventional vehicles. In the presence of two main constraints—rather strong, long recharging times and range anxiety—this paper presents the performance evaluation of an FCS from two

important perspectives: that of the operator's earnings and customer waiting time. The FCS is connected to both DC and AC outlets and serves a variety of EV models, depending on their battery capacity and the type of charging process applied [12]. In this respect, flat-rate pricing policy is applied to calculate daily profit and line waiting times. For the reduction of queue build-up, a new Scheduled Pricing Policy (SPP) is proposed which encourages the customer to charge within the agreed energy threshold to lower the demand and hence the wait time [13].

These are challenged by electric vehicles, resulting in voltage fluctuations, power losses, and transformer overload conditions. This work presents an EV charging management system that reduces load variance, power losses, voltage fluctuation, and cost of charging in the presence of conventional, rapid charging, and Vehicle to Grid technologies using machine learning-based solutions. After trying out different machine learning algorithms, it turns out that the LSTM model is optimal for power loss and voltage swing minimization, peak shaving, and reduction of charging cost while demonstrating robustness to load data uncertainties [14].

The infrastructure considered in this paper is related to the charging of electric vehicles: it provides an overview of the advantages of smart chargers, types and power levels of chargers, communication protocols, and standards in the area of charging [15]. The integrated EV charging navigation framework proposed in this research uses a hierarchical game strategy to lead EVs to charging stations while tying in with the electricity and transportation systems. The framework encourages off-peak charging and offers real-time navigation, which increases grid reliability and financial profits [16].

The primary benefit of DC fast charging stations (FCS) over regular AC charging stations is their low charging times. However, an EV's charging time increases dramatically if its charging request is close to the full state of charge (SoC) due to the internal resistance characteristics of EV batteries. In this study, we offer an operation analysis of FCS, wherein operators can establish a restriction on the required SoC of EVs in order to optimize revenue, considering the influence of SoC requests on charging time. We model the FCS operation as an M/G/S/K queue and include both the FCS

revenue model and the DC fast-charging model in the queuing analysis. Simulation results show that FCS can increase total charged energy and revenue and reduce the likelihood of blocking arriving EVs by restricting the desired SoC in an overloaded scenario [17].

Typically, electric vehicle systems are built around a number of modules that work together to ensure the car's power and stability on the track. The majority of these components are connected to the charging mechanism. In this regard, dynamic wireless power transfer is a useful way for alleviating electric car range anxiety and lowering the cost of onboard batteries. Wireless recharging has long been prevalent in pure electric vehicles, and it is intended to allow charging even while the vehicle is in motion. However, this method is tough to assess because its working philosophy is complex, especially given the presence of multiple variables and factors [18].

Insufficient fast-charging infrastructure and limited driving ranges due to energy storage technology continue to hinder consumer adoption of electric vehicles. This article focuses on designing, developing, and testing a multi-port sustainable fast-charging station that includes solar photovoltaics, an in-house battery electric vehicle, the utility grid, multiple power electronic converters, and proper control for various charging modes. Such a charging station would allow for quick and traditional charging at a reduced power level using sustainable power, if available, decreasing the impact on the grid and the energy costs of system operation [19].

The MDIBC topology is ideal for high-power BEVs and PHEVs (>10 kW) due to its low input current and output voltage ripples, low electromagnetic interference, bidirectionality, high efficiency, and reliability. For low-power electric vehicles (<10 kW), it's difficult to recommend a single contender who excels in all criteria. The Sinusoidal Amplitude Converter, Z-Source DC-DC Converter, and Boost DC-DC Converter with Resonant Circuit are ideal for low-power BEVs and PHEVs because of their soft switching, noise-free operation, low switching loss, and high efficiency [20].

3. METHODOLOGY

3.1 System Modeling

Electric vehicle system modeling implies developing mathematical and computational

models of electric vehicles describing numerous elements and their interactions. As such, the method allows to understand, analyse, and optimise electric vehicle performance, efficiency, and reliability. The modeling generally encompasses some of the following primary needs: battery system, electric motor, power electronics, vehicle dynamics, and control strategies. The battery system modeling tries to approximate the features and behavior of the EV's battery pack. These include electrochemical processes, state of charge (SOC), state of health (SOH), and thermal control. The battery modeling must be accurate as it plays a very crucial role in predicting EV range, longevity, and efficiency. Differential equations usually are part of the models to describe the voltage, current, and temperature responses of batteries under various operating conditions. Advanced battery models may additionally include aging effects and degradation mechanisms to provide information about the battery system's long-term performance. An internal combustion engine (ICE) car has 90% more moving components than an electric vehicle (EV). An EV's component parts are broken down as follows:

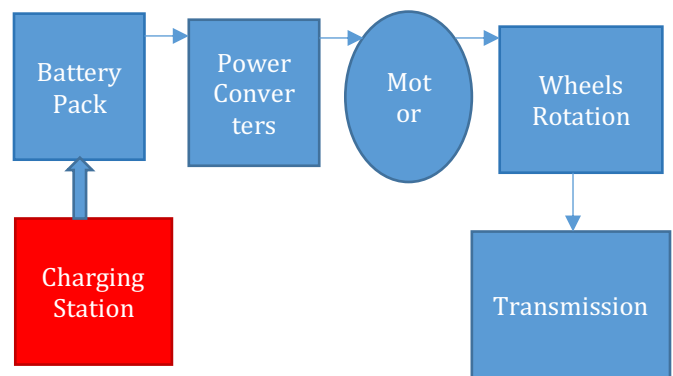


Figure 1: Proposed Block Diagram of EV Components

To charge your battery, plug it into an electrical outlet or an EV charging station. Batteries hold the electricity needed to power an electric vehicle. The battery's range increases with its kW rating. A power converter is a device that changes direct current (DC) electric current into alternating current (AC) and vice versa. Although they can be either DC or AC, AC motors are more widely used. The power from the motor is transferred to the wheels by an EV's single-speed transmission.

As soon as the car's pedal is pressed, batteries and inverters provide electrical energy, which the

controller receives and controls. After the controller is configured, the inverter supplies the motor with a specific amount of electrical energy (based on the pedal's depth of pressure). Electrical energy is transformed into mechanical energy (rotation) by an electric motor. The car drives when the wheels turn due to the transmission's rotation caused by the motor rotor.

3.2 Charging Mechanism of EVs Battery

Electrical Vehicle Supply Equipment (EVSE): The EVSE, also known as a charging station, connects the electric grid to the electric vehicle (EV). The EVSE's connector plugs into the vehicle's charging input. Different locations and manufacturers may employ different connector types (e.g., Type 1,

Type 2, CCS, CHAdeMO, Tesla Supercharger) [21]. The onboard charger converts the EVSE's AC electricity into DC electricity that can be stored in the battery. This component is often integrated into the EV and varies in capacity according to the car model. Battery Management System (BMS) controls the charging and draining of the battery to guarantee safety, efficiency, and long life. The BMS monitors voltage, temperature, and current to prevent overcharging and overheating. The battery pack stores the electrical energy. It is made up of several cells grouped into modules and packs, the most popular of which is lithium-ion. The charging mechanism of EVs is broken down into different blocks:



Figure 2: Block Diagram for the Charging Mechanism of EVs

The grid normally supplies high-voltage alternating current (AC). A transformer converts this high voltage into a smaller level appropriate for charging EVs. The transformer guarantees that the voltage levels are safe and appropriate for the remaining phases of the charging process. An RL filter is used to smooth out any high-frequency noise and ripple in the AC power supplied by the transformer. The resistor (R) and inductor (L) work together to remove undesirable frequencies, resulting in a cleaner AC signal. This protects downstream components while also improving system efficiency and lifespan. The DC-DC converter adjusts the voltage level of DC power to meet the needs of the EV battery. Depending on the design, it can increase (boost) or decrease (buck) the voltage [22]. The DC-DC converter guarantees that the voltage delivered to the battery is within permissible limits for safe and efficient charging. It also has isolation and protective measures for the battery and other components. The final stage is the EV battery, which stores the regulated DC power. The EV's Battery Management System (BMS) monitors and manages the charging process to ensure battery health and performance. It guarantees that the battery is charged within safe voltage and temperature limitations, and it distributes the charge evenly among individual cells to enhance efficiency and lifespan [23].

3.3 Types of Batteries for EVs:

The batteries used for charging EVs are as follows:

3.3.1 Lithium-Ion Batteries:

Lithium-ion batteries dominate the market for portable consumer electronics, such as smartphones and laptops, due to their superior energy density by mass and volume compared to other storage technologies. These batteries boast a high power-to-weight ratio, excellent energy efficiency, robust high-temperature performance, long lifespan, and minimal self-discharge rates. While many components of lithium-ion batteries are recyclable, the cost of recovering these materials poses a significant challenge. Most modern electric vehicles and plug-in hybrid electric vehicles (PHEVs) rely on lithium-ion batteries, although their specific chemistries often differ from those used in consumer electronics. Ongoing research and development aim to lower costs, extend battery life, reduce cobalt usage, and address safety issues associated with various fault scenarios [24].

3.3.2 Nickel-Metal Hydride Batteries:

Nickel-metal hydride (NiMH) batteries, commonly used in computers and medical devices, offer a balance of specific energy and power capacity. They have a significantly longer life cycle compared to lead-acid batteries and are known for their safety and resistance to abuse. NiMH batteries are

extensively utilized in hybrid electric vehicles (HEVs). However, their drawbacks include high costs, a high self-discharge rate, heat generation at elevated temperatures, and the necessity to manage hydrogen loss.

3.3.3 Lead-Acid Batteries:

Lead-acid batteries are cost-effective, safe, recyclable, and reliable, with the capability to deliver high power output. However, their use is limited by low specific energy, poor performance in cold temperatures, and a relatively short lifespan. Efforts are underway to develop advanced high-power lead-acid batteries, which are intended primarily for auxiliary loads in electric vehicles. Additionally, they are used in internal combustion engine vehicles for stop-start systems to reduce idling and improve fuel efficiency.

3.3.4 Ultracapacitors:

When voltage is applied to an ultracapacitor, energy is stored at the interface between the electrode and the electrolyte. The energy storage capacity increases with the surface area of this interface. Although ultracapacitors have a lower energy density compared to other storage devices, they excel in power density, enabling them to deliver substantial power quickly. This makes them beneficial for providing additional power during vehicle acceleration and hill climbing, as well as for recovering energy during braking. Ultracapacitors are also used as secondary energy storage in electric vehicles, supporting electrochemical batteries in maintaining consistent load power.

Table 1: Different EVs Charging Stations

Levels	AC Level 1	AC Level 2	DC Fast Charger
Location	Basic home installation	Home and public installation	Public and commercial installation
Current Rating	12-16A	12-30A	DC output up to 400A
Charging Time	8-12 hours	4-6 hours	15-30 mins
Voltage	120V, 250V AC, 1-phase	208-240V AC, 1-phase	300-600V AC, 3-phase
	480V AC, 3-phase	480V AC, 3-phase	
Power Rating	1.4-1.9kW	2.5-19.2kW	50kW

- **AC Level 1 Charging:** This is the most basic type of EV charging, which requires a typical household outlet (120 volts in North America). It has a charging rate of approximately 2 to 5 miles of range per hour. Because of its modest speed, level 1 charging is most commonly utilized for overnight charging at home.
- **AC Level 2 Charging:** This type of charging uses a 240-volt outlet, much like many residential appliances, including dryers, and it delivers a faster charging rate of 10 to 60 miles of range per hour, depending on both the vehicle and charger capacity. They are combinedly installed in homes, businesses, and public stations and offer the best balance between convenience and speed.
- **DC Fast Charging:** This will be the fastest mode of charging. Contrary to the AC

chargers, the DC chargers do not utilize an onboard charger; rather, they have one inside the station itself, and they charge at higher voltages of normally 400-800 volts. DC fast chargers provide 60-80 miles of range in 20 minutes, and so they are pretty good for quick recharges if somebody needs to cover a large distance. These are normally put along highways and busy spots in order to cater to the fast charging demands [25].

6. CONCLUSION

In this paper, the review of the adoption of electric vehicles and their fast charging systems is discussed. The type of battery used in EVs remains the same, which is often lithium-ion. However, the impact on battery health varies according to charging pace. AC Level 1 is mild on the battery, making it ideal for overnight charging. AC Level 2

strikes an excellent mix between speed and battery health, making it ideal for regular usage. DC rapid charging, while useful for speedy recharges, should be used sparingly to prevent battery degeneration. This article also covers a variety of charging techniques because the battery is the primary part of an electric vehicle that must be charged effectively to prevent internal damage. One of the key elements that significantly influences a nation's development is its transportation infrastructure. Thus, in order to implement EV infrastructure, a number of policies and regulations are being considered, which could lead to a radical shift in the auto industry. Using just electric vehicles has resulted in a significant improvement in the environment. It will make a tremendous contribution to a sustainable future. However, before implementing them, the government must build additional charging stations that use renewable energy sources and can charge batteries more quickly. Many studies are now being conducted to increase the overall system's reliability.

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