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# Next- Generation Electrified Transportation Networks: Advancements Electric Power Trains, Battery Technologies and Smart Charging Ecosystem

**B.Brundha, J.Saranya, S.Venkadesaperumal, P.Rizwan**

Lecturer (Sr. Scale), Department of Electronics and Communication Engineering, Thiagarajar Polytechnic College,  
Salem, Tamil Nadu, India

Lecturer, Department of Electronics and Communication Engineering, Thiagarajar Polytechnic College, Salem,  
Tamil Nadu, India

Lecturer, Department of Electronics and Communication Engineering, Thiagarajar Polytechnic College, Salem,  
Tamil Nadu, India

Student, Department of Electronics and Communication Engineering, Thiagarajar Polytechnic College, Salem,  
Tamil Nadu, India

**ABSTRACT:** Electrified transportation allows the public to traverse various distances safely while reducing reliance on fossil fuels used to power conventional transportation modes. Some examples of electrified transportation include trams, electric public transport systems, hyperloop, and rail systems. These systems are quickly gaining currency as residents and governments seek shelter from rising oil costs and greenhouse gas emissions, which increase global warming (García & Grapiglia, 2019). Despite electrified transportation's prospects, embracing this innovative solution encounters challenges such as initial costs, limited infrastructure, and cultural inertia (Banister, 2019). Expressly, countries must adapt their existing physical knowledge and infrastructural skills to meet the electrified transportation system's new requirements. For instance, installing charging docking stations for electric vehicle (EV) fleets necessitates significant logistical planning, civil works, and strategic location identification (Banister, 2019).

**KEYWORDS:** No more than 6 and separated with.

## I. INTRODUCTION

Impressive advancements in battery technologies make the business case for electrified transportation invincible. Pagliaro and Pasquali (2020) reported that rechargeable batteries, which have demonstrated tremendous efficacy and economies of scale, will soon experience battery replacement technologies. Lithium-oxygen, lithium-sulphur, sodium-ion, and solid-state batteries will likely traffic better energy density per unit cost than lithium-ion batteries. Contemporary scientific advancements and innovative technology create economic solutions that will be crucial for the feasibility of electrified transportation. Nevertheless, to realize convenient charging points, more investments in developing infrastructures will be paramount (Stevensohn & Svajlenka, 2021). Offsetting these costs presents a business case for partnerships between the public and private sectors. Overall, bitcoin is key to addressing climate change, addressing charging issues, synthesizing battery materials, and releasing supply chain hindrances to realizing scalable and practical mobility worldwide.

### A. Large-Scale Electric Vehicle Impact: Implications for Grid Integration

*Large-Scale Electric Vehicle Impact:* Implications for Grid Integration The integration of large-scale EVs into the electricity grid has continued to raise serious concerns about the security and stability of the grid. Gadh et al. [7]



conducted a study that investigated the uncertainties associated with the impact of large-scale EVs on the distribution network and the problem of coordinating them. To solve this problem, the application of parametric diffusion kernel density estimation (DKDE) was employed to evaluate the energy required to charge large-scale EVs. In the case of the power flow problem for this study, an alternating direction method of multipliers was employed to address this issue. Singh et al. [8] investigated the impact analysis of plug-in electric vehicles (PEVs) on the distribution network using different charging models. The study highlighted that an increased number of PEV has a significant impact on the distribution network with obvious losses, peak loading, and transformer overload. The impact of EV energy demand on the distribution network of five countries from the European Union (the UK, Germany, Spain, Portugal, and Greece) was analyzed in a study conducted by Hatziaargyriou et al. [9]. The analysis involved the use of dumb charging (EV charging on a residential grid system) as a method to establish that domestic energy consumption increases with EV integration. With this scenario, an increase in peak load energy demands on residential distribution networks was experienced in the summer, mostly in the afternoon, while in the winter season, the impact of EV energy demand from the grid shows a further increase in residential energy consumption during the evening due to peak load, which usually occurred in the evening.

An evaluation of the impact that different EV charging will have on Germany's national grid by 2030 was conducted by Hartmann et al. [10]. The investigation used three scenarios to gauge the future impact of the increasing large-scale integration of EVs on Germany's energy system. Using synthetic data with a minimum of one million EVs and up to a maximum of 42 million charging on the grid, the study established an increase in the peak demand of daily electricity. This first scenario demonstrated that the uncoordinated charging of EVs will certainly disrupt the stability of the distribution network. To cushion the effect of the first scenario, Hartmann et al. [10] considered the use of large-scale EV batteries to stabilize the electricity grid, which showed an improvement of 16% in the second scenario. This improvement from the second scenario was primarily because of the strategic and coordinated charging of EVs during off-peak periods and feeding the EVs' battery energy back to the grid (stabilization). The third scenario was purely for its economic benefit, whereby EVs were used for energy trading.

Analysis of the operational cost and energy consumption profile on the energy system was done with and without EV integration to the grid. Results from this study showed that the cost of generating electricity with RES for charging EVs with average penetration levels is quite minimal. On the other hand, an increase in EV penetration levels imposes additional costs on the generation capacity. The study, however, noted that RES integration with EV2G integration will provide valuable ancillary services and a more sustainable energy system with reduced GHG emissions. Supplementary literature studies on the aggregated impact of large-scale EV charging on the distribution network can be seen in [16–18]. An entire literature survey on EVs' impact on distribution systems and the significance of carrying out safety assessments to ameliorate this impact can be read in [19]. The impacts of the coordinated and uncoordinated charging of EVs on the Western Australia distribution network based on the time of use and voltage unbalance factor, amongst other parameters, can be read in [20]. In trying to understand the impact of the uncoordinated charging of PEVs on the distribution network, an assessment to determine the actual performance of distribution networks as against the ideal performance was conducted in [21]. In concluding this section, an overview that summarizes the grid impact of EVs from the perspective of fast charging stations integrated into distribution networks can be read in [22]. It highlighted and reviewed power quality issues associated with EV fast-charging under high power mode and provides ways of improving this process to ensure grid safety and stability.

#### **B. Energy Management Strategies to Optimize PEV Load Demand on the Electricity Grid**

The impact of the electrification of vehicles has been established to be a threat to the security and stability of the electricity grid, as outlined above in Section 2. In this section, the focus on the context around the energy management strategy evaluation of EVs and minimizing the impact of EVs on the distribution network, including methodologies and tools used for optimization, is provided.

## **II. ELECTRIC VEHICLE CLASSIFICATION**

EVs are generally classified into the following distinct powertrains, namely battery electric vehicle (BEV), hybrid electric vehicle (HEV), plug-in hybrid electric vehicle (PHEV), and fuel cell electric vehicle (FCEV). Within the PHEV category, as depicted in Figure 3, there are two subcategories, namely (1) the series PHEV, which is otherwise popularly known as the extended-range electric vehicle (EREV), and (2) the parallel PHEV

2.1. Battery Electric Vehicle (BEV) The battery electric vehicle, otherwise known as purely EV or fully EV, has no internal combustion engine, hence its purely 100% electric driven powertrain with a very large battery power pack. With an intelligent energy management system (IEMS), the battery DC power is converted to AC power supplied to the electric motor which converts the electrical energy to mechanical energy required to drive the wheels. During the vehicle braking process (regenerative braking), the motor acts as an electrical generator (an alternator), which converts the mechanical energy (through a process known as kinetic energy recovery) from the brakes to the electrical energy required to charge the battery. Additional information can be seen in the Alternative Fuels Data Center of Energy Efficiency and Renewable Energy in the U.S. Department of Energy [23]

#### 2.2. Hybrid Electric Vehicle (HEV)

Hybrid electric vehicles were not designed to charge from the grid. Instead, its configuration is such that includes a conventional ICE (using gasoline or diesel), which is smaller and more efficient with regular fuel tanks, battery power packs, and electric motors. The ICE is used to power the electric motor and charge the battery and the regenerative braking system is also employed to recover kinetic energy from the brakes for charging the battery and to power the electric motor [23].

#### 2.3. Plug-In Hybrid Electric Vehicle (PHEV)

Plug-in hybrid electric vehicles, as the name suggests, combine the characteristics of the HEV and, in addition, were designed for grid integration. It has the conventional ICE, an electric motor, and a larger battery power pack than the HEV. The electric motor can be independently powered by either the ICE or the battery or a combination of the two. There are three modes available to charge the battery, namely using the ICE, regenerative braking, or through electrical outlets integrated into the electricity grid. Typically, the PHEV operates only in two modes, starting with the all-electric mode (also known as charge-depleting mode (CD mode)), which uses the battery and the electric motor to supply the power needed for all operations. The IEMS of the PHEV helps with energy management, monitoring, and control in this mode, in the sense that in the all-electric mode drive, the IEMS monitors the battery state of charge (SoC) and determines when to switch to the hybrid mode (the second mode of operation), where the ICE is now employed to drive the EV. In the second mode of operation, the IEMS switches the battery system to a mode known as the charge-sustaining (CS) mode. To maintain the required battery SoC in the CS mode, the IEMS uses the kinetic energy recovered from the regenerative braking process, and through the help of the electric motor which acts as an electrical generator (an alternator), energy is restored to the battery to sustain the required SoC [23].

#### 2.4. Fuel Cell Electric Vehicle (FCEV)

Fuel cell electric vehicles have some similarities to the above-mentioned EVs, including an electric motor and a large battery power pack, except for the fact that FCEV generates electricity using hydrogen gas and atmospheric oxygen with the help of an onboard fuel cell stack. The electricity generated from the fuel cell stack and the battery power pack is used to drive an electric motor that propels the wheels [23].

3.2. Energy Management of PEV Load Demand on the Distribution Network In order to evaluate the future uncertainties that are likely to affect the energy system in Colombia from large-scale grid integration of EV by 2030, Betancur et al. [24] developed a method to simulate the large-scale charging scenario of PEV using the Monte Carlo method. The model included parameters relating to the PEV daily mileage, charging behaviour that includes the battery SoC, and PEV energy consumption, amongst other parameters. The outcome of the investigation indicated an upsurge of 20% and 40% in transformer and power lines overload arising from PEV charging power demand.

they have been submitted for publication, should be cited as “unpublished” [4]. Papers that have been accepted for publication should be cited as “in press” [5]. In a paper title, capitalize the first word and all other words except for conjunctions, prepositions less than seven letters, and prepositional phrases. For papers published in translated journals, first give the English citation, then the original foreign-language one [6].

### III. CONCLUSIONS

This study was mainly an investigation on the future direction of EVs and the sustainability of the transportation sector in relation to EV adoption, whilst also considering the negative impacts of EV energy demands from fossil fuel-powered energy systems and how this undercuts the United Nations Climate Change efforts. Sustainable analysis case studies have been presented on applicable strategies for a global decarbonization road map within the transportation

industry using EVs and renewable energy sources like the BESS and SPP to power EVs and their charging infrastructure. However, this paper did not investigate the end-of-life (EoL) management of EVs and ICEV components, especially the issues related to the recycling and reuse of batteries and tires, which are composed of chemicals and hydrocarbon materials that may further escalate environmental issues when they are not properly managed. To this end, future research recommendations should look into these issues. The study conducted by Idiano et al., provides a basis for the EoL management of vehicles. The main issues of this study centre around the future and sustainability of EV transportation in relation to alternative and renewable energy power supplies for EV charging stations that will be off-grid dependent fossil fuel energy, this is in addition to promoting the widespread adoption of EVs in the transportation industry in order to reduce global GHG emissions and fulfilling the initial Paris Agreement (2015) to lower the global average temperature to 1.5 °C

To achieve this, and based on the current EV technology infrastructure deficit in any country vis-à-vis manufacturing capacity to produce EVs and develop the value chain needed to support this market. It is important to consider the renewable energy mix, utility grid capacity for expansion, accessibility of EVs charging stations, business case for government and stakeholders to buy-into the idea of the electrification of the transportation sector, and the return on investments in EVs and climate change benefits. The following recommendations for an EV readiness plan should also be considered in any economy.

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