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Security and Energy Consumption Considerations of Electric Vehicles Integration in Smart Grids

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Abstract

Over the past years, electric vehicles (EVs) have attracted great attention worldwide. Using EVs helps reduce CO2 emissions and the use of fossil fuels and motivates the nations toward a more sustainable future where the consumed energy matters. EVs are the main part of E-mobility; therefore, the EV integration problem is very important. This paper discusses the importance of EV integration in smart grids, and challenges toward the electrification of future cars are investigated. The two main categories for challenges are security and utility-related challenges. Security challenges deal with the communication means in the e-mobility, while grid-related challenges correspond to the energy that must be supplied and delivered to the vehicles. Security challenges come from the devastating actions from outside threats such as hacks, but the grid-related challenges come from the system's nature and can be dealt with using physical and software-based methods. While the challenges of security and grid are investigated, since our future work focuses on energy and cost optimization, the solution of grid-related challenges will be covered.

Author Keywords. Charging, Electric Vehicle, e-mobility, Optimization, Security, Smart Grid.

Type: Review Article

1. Introduction

In recent years, one of the most significant transitions in the transportation sector has been the electrification of vehicles. It is crucial for reducing CO2 emissions from private automobile transport to replace conventional cars with electric ones. Today, 30% of greenhouse gas emissions are generated by transport, approximately 80 % of which are generated by road transport (Axsen, Plötz, and Wolinetz 2020). As a result, governments have encouraged the electrification of traffic by offering monetary incentives and investing in charging infrastructure. In the past few years, plug-in electric vehicles (PEVs), battery electric vehicles (BEVs), and plug-in hybrid electric vehicles (PHEVs) have been receiving support. For such policies, it is important to understand the impact incentives may have on consumers, including on their choice between different kinds of vehicles and fuel types.

In 2020, Europe had the second share of EVs after China, and there are more EVs in Europe than in the USA. As of 2021, there are approximately 800,000 electric vehicles of various types on the California market only, while there are approximately 1.8 million in the United States (Lewis 2021). An important reason for this growth in EVs number is new CO_2 emission standards introduced by the world leaders and infrastructure investments across the regions ("Road Transport: Reducing CO2 Emissions from Vehicles," 2020). Besides, there are still some economic and environmental problems related to fossil fuel-based transportation that will keep motivating the electrocution of vehicles worldwide. By 2022, the number of EVs worldwide is expected to surpass 35 million (Liu et al. 2015).

It is now known that vehicles are responsible for about 30% of CO2 emissions worldwide, while personal transportation systems account for 10% of this pollution. On the other hand, only less than 5% of the cars are compatible with corporate average fuel economy (CAFE) standards in the US ("CO2 EMISSIONS FROM CARS: The Facts," 2018). Regarding the European Union standards, vehicles must produce 95 g of CO2 emissions per kg in 2020 to be considered clean, when only 5% of existing cars comply with this standard. Although some claims are indicating that EVs may not be as clean as they are believed to be (Biello 2016), recently authors in (Choma et al. 2020) indicated that electrification of transportation systems would eventually lead to many environmental benefits, even if they are powered by fossil fuels plant and not green energies. It is also noted that by using EVs instead of conventional vehicles, the level of harmful emissions would decrease, which will be regarded as more healthy for citizens.

As it is targeted for global EVs number to approach a 30% share by 2030, it is expected to see an exponential increase in the number every year (IEA 2020). For example, in Hungary, EVs' share was 1.9% in 2019, 50% more than its 2018 share. This shows the growing interest among casual users toward EVs. In some other European countries, the share is higher. For example, the EV market share has already reached 28.8% in Norway and 6.4% in the Netherlands. Also, while the number of EVs compared to conventional vehicles in China is 1.4%, many countries have targeted 100% EV usage in a not-so-far future (Meyer and Wang 2018).

As stated in the literature, although EVs are beneficial to urban society by reducing air pollution, their challenges must be understood and addressed to clear the path for electrification of such devices. These challenges, as shown in **Figure 1**, correspond to grid and information security. In this paper, the main focus is on introducing challenges and vulnerabilities regarding the integration of EVs in the grid. While security and grid challenges will be introduced, as our future work focuses on smart charging plans, only possible solutions for the grid-related challenges will be proposed in this paper. The rest of the paper is as follows: in section 2, challenges related to the security of the EVs will be investigated, while in chapter 3, grid-related challenges will be analyzed. In chapter 4, possible solutions for the grid-related problems are introduced, and finally, chapter 5 will give a conclusion, and insight into our future work will be specified.

2. Security Related Challenges

Integrating EVs into the grid has many benefits; however, since most of such vehicles are connected to an information network several IT security concerns must be addressed. The IoT paradigm has consistently demonstrated benefits in a wide range of areas of our lives. However, its inherent insecurity and the wide range of vulnerabilities among IoT devices have caused security and management concerns for users and network operators. The extended remote functionalities of Internet-connected EV charging stations (EVCS) might also open the door to various cyber-attacks on deployed EVCS, their users, and directly connected critical infrastructures such as the power grid. EVCS is vulnerable to cyber-attacks that aim to affect the operation of the EVCS or transferable data from the structure; therefore, finding an appropriate solution to this problem is essential. EVCS consists of two main parts: physical and software-based infrastructures. Furthermore, as EVs are connected to the internet today, a new concept called the Internet of Electric Vehicle (IoEV) has been introduced, where EVs are also vulnerable to attacks in the connection via the internet. The following section will investigate the risks and vulnerabilities corresponding to EVCS physical infrastructures, EVCS software-based infrastructures, and IoEV.

Figure 1: Summary of security and energy-related challenges of EV integration

2.1. Cyber-Physical Threats

When information systems are integrated with the power grid, it becomes a colossal cyber-physical system. The grid's unique nature poses new security challenges. Modern cyber threats pose a serious threat to the power grid components. The EV charging system is made up of many physical elements, such as charging pools, EVCSs, and electricity distribution networks, including power plants and transmission lines. EVCSs can be classified in different manners. Depending on the location, they can be categorized as public or private, or according to the power they supply to EV batteries from the grid into different power categories or a combination of both previously mentioned methods. Depending on the location, EVCSs are categorized into three levels as follows (Khayyamim et all. 2020):

- Level 1: Home and workplace
- Level 2: Public residential or commercial chargers
- Level 3: Public charging stations

Depending on the power EVCSs are classified into 5 groups, and they can be used for both G2V and V2G modes (Khayyamim et all. 2020):

- Group 1: lower than 20 kW, supplied by the local low-voltage grid
- Group 2: between 20-200 KW, supplied by a low or medium voltage grid
- Group 3: between 200-1000 kW, supplied by a medium voltage grid
- Group 4: between 1-7 MW, supplied by a medium voltage grid or the secondary of sub-transmission substation
- Group 5: between 7-25 MW, supplied by secondary or primary of transmission substation

Manipulation of the mentioned injected powers through the network can be devastating for all actors. Therefore, by looking at the powers within the EVCSs, it is obvious that considering security and safety plans for the equipment has the highest priority. While discussing protection plans for the EVCS facilities is out of the scope of this paper, it is just worth mentioning that besides taking IT security solutions, using proper protectives such as overcurrent and overvoltage relays, surge arresters, circuit breakers, etc. is necessary because, in case of outside attacks on the EVCS, these devices will prevent additional damage.

2.2. Software-based Threats

EVCS consists of a management system known as EVCS management system (EVCSMS). EVCSMS, which is connected to the internet, acts as regulating powers exchanging between the grid and EVCS. With an EVCSMS, operators can remotely control and manage platform operations, including scheduling, charging, user authentication, and controlling administrator access, and since it carries a huge amount of data, it is vulnerable to cyber-attacks and hacking.

EVCSMS can be connected to a local area network or internet, both exposed to attacks. To analyze the possible attacks against EVCSM, the authors of (Nasr et al. 2022) conducted an analysis on the internet-connected EVCSs and found 13 possible attacks that may take place on the station. The discovered vulnerabilities include Cross-Site Scripting (XSS), SQL Injection (SQLi), Information Disclosure, Missing Authentication, Embedded Secrets, Cross-Site Request Forgery (CSRF), Forced Browsing, Hard-Coded Credentials, Missing Rate Limit, Server-Side Request Forgery (SSRF), CORS Misconfiguration, FCDP Misconfiguration, and CSV Injection (CSVi). The consequent attack may occur on the EVCS, EV user, or the grid. The possible attacks resulting from the vulnerabilities of the EVCSMS are summarized in **Table 1** (Nasr et al. 2022).

Main attacks related to EVCSMS	Type of attack
Attacks Against the EVCS	Charging Process and Settings Manipulation. Firmware Manipulation Billing Manipulation Bot Recruitment and Network Proxy Denial of Service (DoS)
Attacks Against the User	Charging Data/Record Theft. Payment Fraud Personally Identifiable Information Leakage
Attacks Against the Power Grid	frequency instability attacks Increase in Charging Demand

Table 1: possible attacks resulting from the vulnerabilities of the EVCSMs

2.3. Internet of Electric Vehicle (IoEV) Threats

With the growth of EVs and to mitigate the lack of required electric energy to supply all the vehicles inside the network, the importance of coordinated charging or smart charging became more obvious, where the interconnection between all vehicles or system's different actors is inevitable. In order to provide this connection, the concept of IoEV was introduced, which corresponds to the communications between the vehicles and other actors and facilities inside the grid via internet. IoEV helps the EV networks to be supported, controlled, and managed by both time and space-varying information and communication technologies.

IoEVs are considered intelligent entities because they are equipped with multiple sensors and actuators capable of exchanging and sharing information and controlling drive and charging while managing energy and traffic flow (Bayram and Papapanagiotou 2014). Connected entities are a wide network of vehicles, humans, sensors, etc., that are part of the Internet of Vehicles. It is possible for these sectors to have a communication with each other to collect, store or transfer traffic or vehicle's information. In the IoEV framework, a huge amount of data is transferred between entities to create a better experience for all traffic partners, including EV drivers, operators and helps to have less traffic dense on the roads. This data may include the drivers' personal information and their locations. Also, the vehicle consumption data or drivers' choices can be found in the IoEV communication links. While this data can help have a more optimized traffic service, since there is a communication link, the risk for cyber-attacks exists. **Figure 2** demonstrates a smart city with the concept of IoEV (ElGhanam et al. 2021).

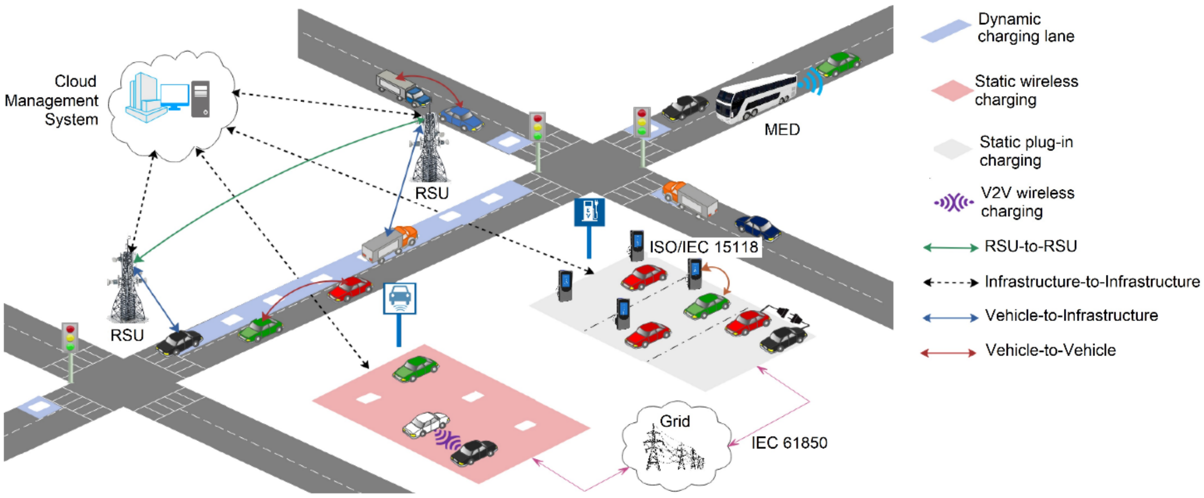

Figure 2: a smart city with IoEV interconnections (ElGhanam et al. 2021)

IoEV includes four main communication links that are vulnerable to cyber-attacks, including Vehicle to Sensor (V2S) communication attacks, Vehicle-to-Vehicle (V2V) communication attacks, Vehicle to Infrastructure (V2I) communication attacks, Vehicle to Network (V2N) communication attacks (Fraiji et al. 2018). To handle the challenges regarding communication security, the article (Bayram and Papapanagiotou 2014) proposes three main communication standards that must be observed while designing the system. These standards are related to

- home charging applications and data exchange between the EV and charging equipment
- mobile EV communication technologies
- 'inter-control center' communication

For the first group, some standards introduced by The Society of Automotive Engineers (SAE) have been proposed to follow while charging an EV includes SAE J2293, SAE J2836/1, J2847/1, SAE J2836/2, J2847/2, SAE J2836/3, J2847/3, SAE J2931, SAE J2931/2. Furthermore, (Bayram and Papapanagiotou 2014) investigates different means for communications in the mobility systems and suggests available solutions and challenges and benefits of each one.

3. Grid Related Challenges

EV integration into the electricity grid has many positive effects, such as power management and V/f regulation; however, since this paper deals with the solutions to compensate for EV's negative impacts, only adverse effects are noted and investigated. Electric charging stations must supply the load with continuous power at the desired time and in the dispersed locations; therefore, they are not favorable for utility companies as utilities try to have a homogenous load profile, and otherwise, they will face future issues implied on the grid, such as local power shortages. The effect of EV charging stations on load profile in transmission systems has been investigated in (Khodayar, Wu, and Li 2013; Xi and Sioshansi 2014; Alizadeh et al. 2019; Wei et al. 2018), and the effects of EV charging stations on load profile in distribution systems have been investigated in (Wang et al. 2013; Hu et al. 2014). Also, charging stations can imply some impacts on the grid's power quality, such as injecting harmonics and changing the grid's power factor (Karmaker, Roy, and Ahmed 2019; Guoliang et al. 2013; Giri and Isha 2017; Aiqiang Pan et al. 2016; Li et al. 2017; Sharma et al. 2020).(**Table 2**)shows the different challenges of EV charging in the grid, divided by power quality, energy-related and pricing issues.

Power quality	Energy issues	Pricing issues
• Harmonics • Sag/Swell • Flicker • Notches • Voltage Imbalance	• Inhomogeneous load profile • Transformer overloading • Shortage of energy • Need for new electricity infrastructures	• Trade-off between actors' profits • Determining optimum price

Table 2: Different challenges of EV charging in the grid

3.1. Grid's Energy Challenges

EV charging occurs most frequently between 4 and 9 PM when most drivers return home from work. Multiple EVs charging together increases the grid's peak demand during these times, potentially increasing grid congestion and overloading distribution components and requiring additional distribution infrastructure investment. So, it is pervasive that peak electricity consumption coincides with the peak charging demand if charging of most vehicles is carried out uncontrolled ("IEA" 2020).

Figure 3 illustrates a sample daily load curve in the residential distribution grid with large share EVs. As observed, In the baseload scenario, the load follows its normal trends, while adding EVs into the grid in an unscheduled charging manner will increase the load significantly during specific hours, something that must be tackled. There is also a PV integration scenario that compensates for the effect of EVs to a good scale; however, using PVs is not cost-effective, and implementing them is not possible in all areas (Faghihi, Sabzi, and Vajta 2022).

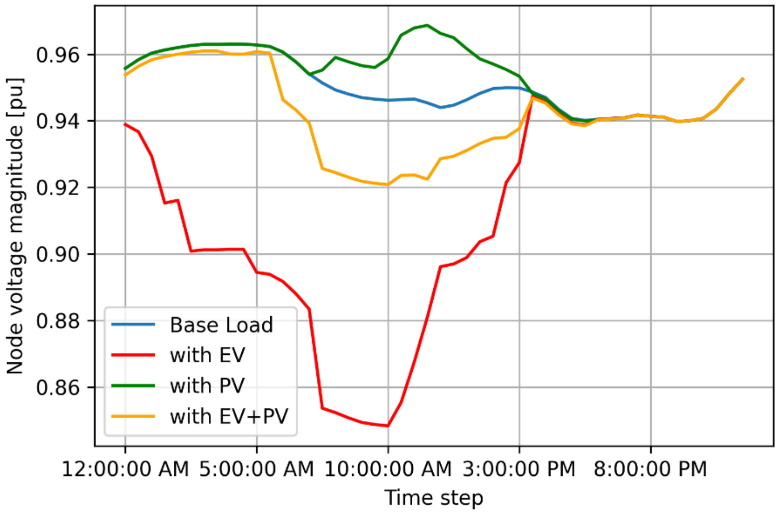

Figure 3: Load curves in different cases
in a residential distribution grid (Faghihi, Sabzi, and Vajta 2022)

In (Nour et al. 2018; Ramadan, Ali, and Farkas 2018), in a case study by the EU project Microgrids, the charging of a low voltage network was studied in two different scenarios (uncontrolled and indirect controlled), and it was shown that the detrimental effect of the uncontrolled charging on the grid is much larger than the indirect controller scenario. It was concluded that a high share of EVs that use indirect controlled charging method (smart) could be acceptable in the network. However, the network could not be responsible for uncontrolled charging, and in this case, other solutions such as upgrading the network must be implemented.

In (Hashemi, Baboli, and Moghaddam 2018) technical challenges resulted from uncoordinated in-home and public charging stations are investigated in a wide area in the capital city of Iran, Tehran. It is noted that the charging of EVs has the most impact on the distribution grid, and it can also negatively affect the reliability of the network. As a solution, the authors propose a controlled charging strategy for EVs to minimize the network's daily power losses considering operation constraints. Also, a stochastic algorithm based on the Monte Carlo simulation is presented considering the uncertainty of EV owners' commuting behavior. The proposed algorithm eventually helps the utility to achieve a smooth load profile.

3.2. Energy Pricing

E-mobility is a setting where different actors participate in a multi-dimensional market where each actor seeks to maximize its own profit. The problem becomes an optimization issue where the cost of energy must be minimized, and at the same time, different actors such as EV users and utility operator benefits from the solution. Since there is a contrast of interest among the actors' goals, finding the most optimum solution is considered a challenging job. In such a complicated market that each EV attempts to charge on its own, the optimal point seems impossible to achieve; therefore, the aggregator concept was introduced as a solution. Aggregator considers all possibilities for electricity price (and other network parameters) and suggests best charging offers to EV users.

Aggregator acts as an interface between the utility operator and the end-users to achieve a goal for participants in the market. Their most usual responsibility is to achieve demand response while reducing the operational cost of the whole system. In a traditional definition, aggregators pay compensation to end-users, allowing them to control their consumption (Gkatzikis, Koutsopoulos, and Salonidis 2013). They mainly represent the end-users and negotiate with the grid operator on behalf of the users to improve the efficiency of the operation.

In the case of EV fleet charging, the aggregator's role can benefit utility operators, EV users, and the aggregator itself. Hence, aggregators propose some offers regarding the charging time (or/and location) to the EVs to achieve the optimal point. The aggregator can consider the charging pattern of an EV and decide that if the charging process is moved to another time of the day, it will be financially beneficial for the EV user and operationally beneficial for the utility company. **Figure 4** demonstrates the role of aggregator in a market framework with EV fleet. As seen, the aggregator is connected with EVs and utility operators through data lines, while EVs are directly connected to utility in terms of energy flow.

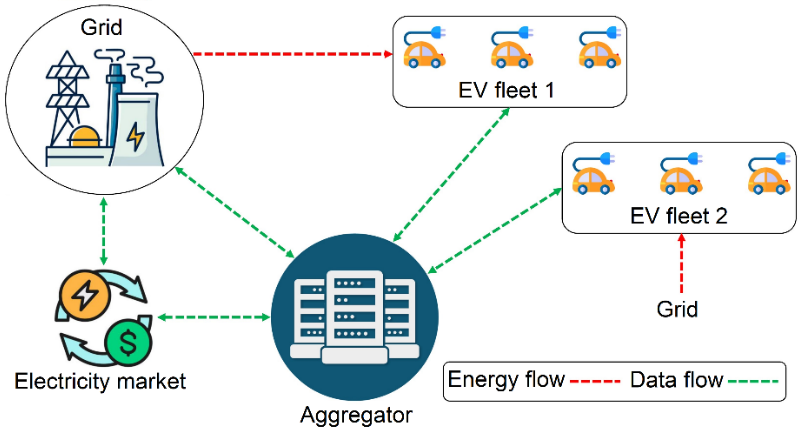

Figure 4: Market framework with the aggregator

3.3. Power Quality Challenges

Power quality becomes a major concern as the number of fast chargers for EVs on utility grids increases, and meeting the IEEE-519 becomes a challenging task ("IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems" 2014). Due to EVs dynamic characteristics, they have a natural effect on the grid's e power quality, such as harmonics, sag, swell, voltage, and phase imbalance, etc. However, companies follow power quality standards while manufacturing EVs to prevent devastating impacts on the grid. As indicated in the literature, power electronics devices are sources of harmonics and other power quality issues in the grid. Therefore, since EV chargers use power electronics devices that include switching semiconductor-based elements, harmonics are produced when converting power is carried out ("IEEE Draft Guide for Applying Harmonic Limits on Power Systems" 2004).

Unwanted sequence components in the load currents are also produced in EV charging stations, which impact the converter's performance. There is an interference distortion in grid load currents due to these second-order harmonic components (Sharma et al. 2020).

4. Mitigation of Grid's Related Challenges

As illustrated in **Figure 3**, the integration of EVs into the grid can significantly increase demand, and therefore, utilities should find proper solutions to deal with this incoming demand. While there are software-based and hardware-based solutions, utilities usually install new electric energy storage systems at different locations to get charged in off-peak hours and charge the EVs in peak hours or PVs to cover the peak demand, invest in building new infrastructures such as new charging stations, parallel lines, new transformers, etc. They can also concentrate on smart charging solutions that rely mostly on planning the charging of EVs, dynamic pricing, offering different charging patterns, etc. Solutions to compensate for the adverse effects of EV charging stations are summarized in **Figure 5**.

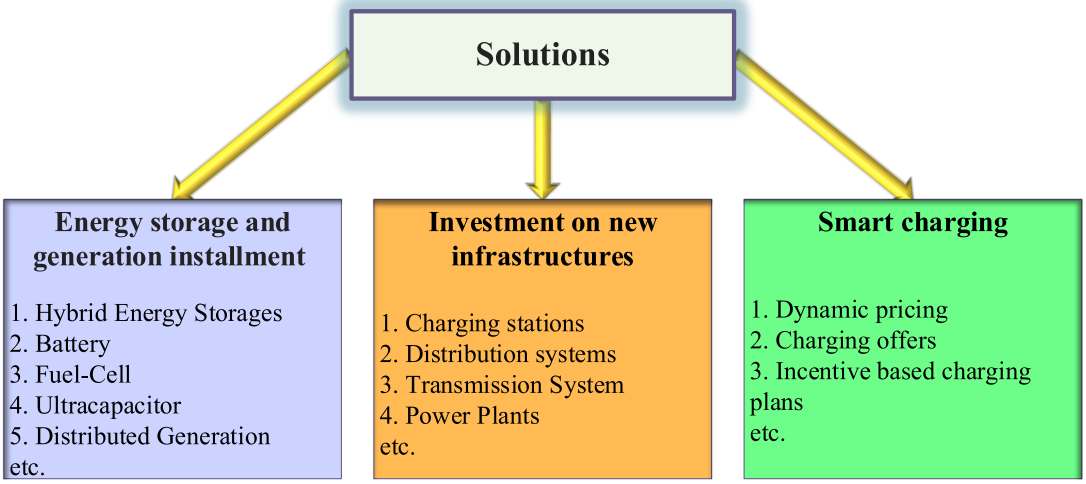

Figure 5: Solutions to compensate the effects of EV charging stations on the grid's energy

4.1. Energy storage and generation installment

One method that has been utilized for charging EV batteries is the installation of stationary energy storage systems. Sometimes, this energy storage system comes with a renewable energy source or another energy storage device to increase the charging system's reliability (Sabzi, Asadi, and Moghbeli 2019; Sabzi, Asadi, and Moghbelli 2017; Sabzi, Asadi, and Moghbelli 2016; Moghbelli and Sabzi 2015). **Figure 6** shows a simple diagram of such a system. While there is an ordinary charging station to charge the vehicle in the off-peak period, the battery can also be charged during off-peak hours and consequently charge the electric vehicle during peak hours. While this method will help the utility to control the demand to an acceptable range, there is still the need for installing new devices that will increase the costs of the systems. Also, there is a problem related to the sizing and placement of the battery (Hussain et al. 2019), making the system not optimum.

Some publications consider the effect of EV charging stations along with other elements on the grid. In (Turan et al. 2019), distribution generators are combined with EVs, and an existing network is analyzed. Although the method is implemented on a small network (YTU Davutpasa Campus), the results show that using a solar power plant, and the voltage levels can be restored and regulated as planned. The result is that EV charging stations can operate at full capacity without affecting the network and that solar power plants can be sized appropriately based on solar radiation variations without risking the network. Authors in (Zeb et al. 2020) and (Cheng and Gao 2018) presented a method for optimal placement of charging stations to help the load profile's homogeneity. While in (Zeb et al. 2020) the effect of installing the PV is also included in the network, particle swarm optimization (PSO) is used to solve the constrained nonlinear stochastic problem, and the designed system is claimed to reduce the costs effectively.

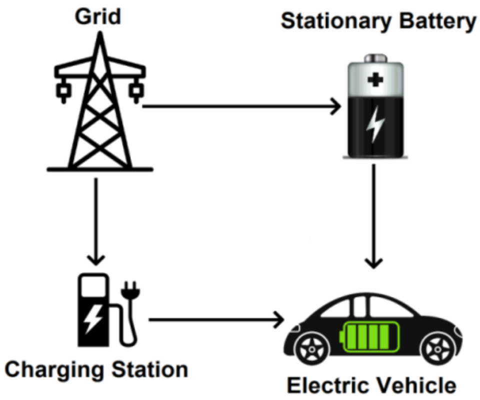

Figure 6: Using a stationary battery to charge EVs

4.2. Deployment of new infrastructures

The need for charging stations is more evident as the number of EVs is increasing, and they require electric energy. Increasing the number of charging stations will also lead to market acceptance of EVs ("Developing Infrastructure to Charge Plug-In Electric Vehicles,"). Some EU projects participated in this concept to grow the charging infrastructures and introduce the new transportation fleet in the grid ("Electrified L-Category Vehicles Integrated into Transport and Electricity Networks"; "Matrix Charging: Novel, Automated Charging Infrastructure for Electric Vehicles"; "Novel, Automated Charging Infrastructure for Electric Vehicles"; "ZAPINAMO – Affordable, Future-Proof Rapid Charging Infrastructure for Electric Vehicles from Stored[Clean and Economical] Energy" 2018). In ("Matrix Charging: Novel, Automated Charging Infrastructure for Electric Vehicles"; "Novel, Automated Charging Infrastructure for Electric Vehicles"), which is brought as an EU project in Austria, Matrix charging stations' concept is introduced, where no moving parts are placed outside the vehicle. It was found that this method increased efficiency by 9% while reducing costs by 30% in BMW cars. EV fast-charging infrastructure developed by ZPN is able to easily rolled out, requiring only a small amount of stored energy. Just like a mobile phone power bank, but much bigger and faster ("ZAPINAMO – Affordable, Future-Proof Rapid Charging Infrastructure for Electric Vehicles from Stored[Clean and Economical] Energy" 2018).

If EV owners charge the vehicle whenever and wherever they wish, utilities will have no choice but to expand the charging capacity and grow the number of charging stations (Cannon 2020). Since this usually comes with uncontrolled charging, the energy will not be optimized, and the load profile will not be flattened, leading to many issues brought on the grid; this is why it is suggested for the utilities to invest more in smart charging rather than investing new infrastructures. Developing new charging stations may be required for areas facing a few numbers of charging stations. However, the grid's capacity must be accounted for if a new station is planned to be developed. Besides, developing a new charging station requires financial support. Therefore, there must be a trade-off between developing new charging stations and energy optimization.

4.3. Smart Charging Scheduling

The best possible way to optimize electrical energy in a grid with the integration of EVs is the utilization of smart charging methods. Smart charging can be carried out pursuing several goals, such as technical and financial objectives. Technical objectives can include balancing load power, V2G scheme realization, frequency, and voltage regulation reducing losses, and financial objectives can contain reducing energy cost and increasing profits for charging providers (Fachrizal et al. 2020). In this paper, any possible solution that does not require additional energy storage devices or developing charging stations will be considered smart charging and will be included in this section, which is the main focus of this survey.

In a smart charging scheme, EVs cannot be connected to chargers anytime or anywhere the driver wishes; instead, some mechanisms should be realized for the EVs fleet's charging action. EVs are also viewed as mobile energy storage devices that can reduce load fluctuations as they are linked to the distribution network in a centralized manner (Csonka 2020). Considering the mobility needs of EV users, the share of renewable energy sources has been maximized in order to coordinate the flexible charging demand with the varying renewable energy capacity. Also, EVs are charged during the day using PV energy, concluding that there will be no additional generation with a specific share of the flexible load. In paper (Yu et al. 2019), charging is carried out using a smart real-time charging scheduling to reduce grid peak demand. For the optimization problem, dynamic programming is used to balance the energy in the grid. Although the authors succeeded in reducing the annual grid demand by 24%, they did not witness any significant shift in the hourly demand.

According to (Rodrigues et al. 2019), in many utilities, time-based prices determine EV charging fees, so random and uncontrolled charging can result in a significant negative impact on costs and network load. Therefore, the authors presented a regulated charging scheme that incorporates the transformer loading and the time-of-day tariff at the utility level. In (Ramadan et al. 2018), the authors mentioned that EVs could bring issues regarding power system components overloading and power quality. As a result, to solve these problems, they utilized EVs to fulfill peak-shaving in peak hours and solved the optimization problem using Particle Swarm Optimization (PSO) algorithm.

Some articles use a more sophisticated algorithm for the optimization problem. For example, in (Moradipari and Alizadeh 2020) a network operator that owns multiple public charging stations presents various options to its customers. These options include optimal pricing and routing protocols. This algorithm somehow includes the driver's preference, where he cannot determine his charging station; instead, he can put a priority level and amount of energy request from the presented menu. Afterward, the operator suggests a charging station on his way compatible with his needs. This algorithm lets the operator manage the approach time to charging stations based on the user's priority. This algorithm considers the effect of EVs on the grid and tries to maximize the profit earned by the charging station's owner, where the drivers' profit is not included in the cost function.

Participants of the EU project ("Artificial Intelligence Based Smart Charging Assistant for Electric Light Commercial Vehicle Fleets,") proposed a smart AI-based charging assistant for Light Commercial Vehicle fleets. First, vehicle charging data from the electric LCVs is analyzed, and then it is combined with consumption data from public, home, and office chargers to ensure business continuity of e-LCV fleets, save money on charging, and reduce idle time. A control framework has been developed for EVs' energy management based on transportation information and drivers' habits in ("Hierarchical Optimal Energy Management of Electric Vehicles,").

While slow chargers take a long time to fully charge an EV battery (about 9 hours or more), implementing fast chargers is difficult and costly; however, it reduces the time of charging (Shao et al. 2020). Consequently, the task of fast charging is usually fulfilled in the battery charger's power electronics topology and the designed controller and not in the optimization algorithm, so it is out of the scope of this paper.

5. Conclusions

As stated in the previous sections, integration of EVs into smart grids brings several challenges related to information security and required energy for them. In this paper, the main security challenges were briefly investigated, which included cyber-physical challenges, issues related to the charging stations management system and threats corresponding to internet of EVs. Also, the main challenges related to the energy required by EVs were analysed. These challenges that mainly affect the grid, undermines power quality, energy and pricing of energy. As an optimum solution, smart charging has been proposed, where charging offers are developed and presented to drivers that can benefit various actors in the platform including, EV users, utility operator and aggregators.

Also, as smart charging requires new mobile applications, new security problems may appear which will attempt to steal the users' information. Currently there are many mobile applications for EV users to find EVCSs and routes to reach them, but the lack of a comprehensive research on the security aspects of these applications is apparent.

Furthermore, a research gap on prosumer cells security is evident, which includes a local charging station, energy storage and a renewable energy source such as photovoltaic arrays. Prosumer cells include management systems and other telecommunication means that could be investigated.

In our future work, we will focus on the energy policies and the role of drivers on the energy consumption in such systems. The aim will be to consider driver's attributes on the charging offers that are made in smart charging plans. These attributes can include, but not limited to, age, gender, social level, income, occupation and etc., and the effect of each attribute on the decisions that drivers make in choosing the charging plans will be investigated. While considering these attributes is very important, a deep learning method can be used to predict the charging plan that will be offered to the drivers. Besides the drivers' attributes, other parameters such as SoC at the time of charging, the duration that a car can park in the EVCSs, the waiting time for the drivers, the charging fee can be considered.

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