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Electric Vehicles within the Distributed Generation

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Abstract

The development of electric vehicle (EV) technologies are seen as a solution to current and future energy and environmental crises. Likewise, the electrification of transportation systems is a promising approach to alleviate and reduce the problems of climate change. This is why the implementation of EV in distributed generation (DG), especially in photovoltaic and wind systems together with energy storage systems (ESS), aims to be an energy solution and at the same time environmental. This document investigates unidirectional and bidirectional electrical grids, smart grids, distributed generation, photovoltaic and wind generation, EV, the concepts of V2G, V2V and V2H, charging stations and ESS to show that EV is in the center of the solution.

Keywords: DG, EV, station charged, V2G, photovoltaic, wind, storage, generation.

I. INTRODUCTION

There are multiple scenarios that the world of EVs can have, from the areas of the environment [1]–[3], the social [3], infrastructure [4], the economic [5]–[8], the investigative[9], [10] among others, that may exist in the midst of the vastness of knowledge.

The increase in energy demand experienced by all countries, due to population growth and fossil fuel reserves, is increasingly limited [2]; along with global warming and climate change [1]–[3], [6], [11], the transport sector being pointed out as the main cause and producer of carbon dioxide (CO2) [3], this by referring to article [6] in which it is mentioned that vehicles with an internal combustion, are one of the main causes of air pollution and climate change.

According to what is stated in articles [3] and [12] electric vehicles are an attractive possibility to replace the majority of conventional transport vehicles in general. However, EVs use electricity generated from the electricity grid and the electricity generation process can produce indirect pollution emissions such as coal-based thermal generation).

Therefore, the environmental impact of the use of EVs depends on the electricity sources [1]. The battery-powered vehicle (BEV) and the plug-in hybrid vehicle (PHEV) are implicit in EVs. But, the large-scale use of EV is not without problems for electrical distribution networks, such as: generation of harmonics, losses of electrical energy in the system, voltage drop, phase imbalance, increased demand for electrical energy, equipment overloads, among others [1].

However, conventional power generation (hydroelectric and thermoelectric), is very distant from the end users, so that they generate considerable losses of electrical energy in the system. Therefore, distributed generation (DG) based on renewable energy sources (RES), especially photovoltaic generation and wind generation, are ideal to be close to urbanizations.

DG in some distribution networks has caused an important change in the traditional model of electricity supply [13]. However, RES has two difficulties, the first is that it has a very limited space for its implementation [14], and the second difficulty is intermittence, therefore, it is unpredictable to determine its meteorological condition, causing generation of harmonics, variations in frequency and voltage level [4],[7],[9],[10],[15],[16], [17].

The intermittencies that are evident in the RES can be solved with the integration of an energy storage system (ESS) which provide quality and backup of the energy, helping the stability of the electrical system [1], [2], [4]. Not to mention that the batteries are exposed to thermal leaks caused by manufacturing defects, changes in the chemical components of the batteries or misuse of the battery due to overcharging or over discharge.[18]

The ESS integrate the concept of V2G, due to their compatibility with EVs, both have batteries in common. On the other hand, when a high number of EVs are connected to the electricity grid, the energy storage characteristics of their batteries can be gradually highlighted to improve the stability of the electrical system[16]. Meanwhile, EVs are recharged from distribution systems at EV charging stations. Therefore, charging stations are considered emergent electric charges, therefore, they have an impact on distribution systems[11], [19].

In **Fig. 1** a summary of what has been said above is observed. Environmental problems can be solved with DG and EV, since

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DG have photovoltaic and wind generation. On the other hand, the problems of the electrical network can be solved by the DGs and ESS, where the ESS will help the intermittency of the DGs, improve the stability of the electrical system and give support to the charging stations.

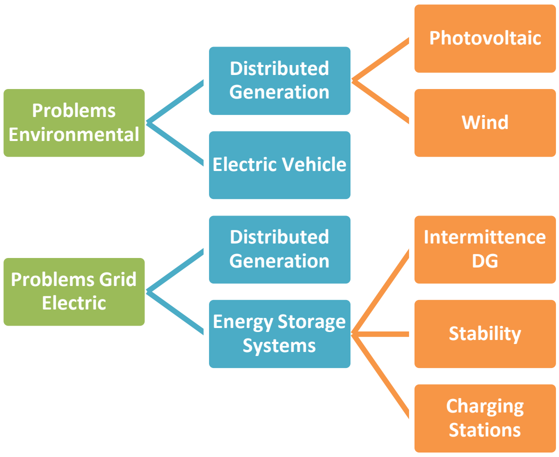

Fig. 1. Compendium.

Consequently, we emphasize that the objective of this document is to understand and place EV within DG, the scope of EV with the V2G concept and ESS. The article is organized in several sections. Section 1 presents the introduction. Section 2 describes the electrical network together with the concept of unidirectional and bidirectional. Section 3 introduces SMARTGRID, Section 4 mentions distributed generation with photovoltaic and wind generation. In Section 5 EV types are described as well as the V2G concept. Section 6 presents the charging stations; Section 7 mentions ESS; section 8 develops the results of the investigation; section 9 presents the discussions and section 10 describes the conclusions.

II. ELECTRICAL GRID

The electrical network is an interconnected network for the supply of electricity that goes from generation to the consumer (Generation, Transmission, Distribution and Marketing). In general, the flow of traditional electrical energy is characterized by being a unidirectional flow (from generation to demand) [8]; On the other hand, the evolution of RES together with the DG and the EVs, have allowed the development of a bidirectional energy flow.

II.I. UNIDIRECTIONAL

Unidirectional electrical networks are those where their energy flow goes in only one direction. In **Fig. 2** the path of the energy flow is observed, which begins in the generation, passes to the transmission, then reaches the distribution and later, is marketed to the end user.

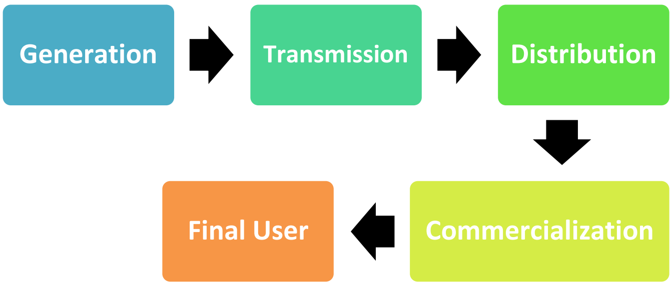

Fig. 2. Unidirectional Diagram.

II.II. BIDIRECTIONAL

Bidirectional electrical networks are those where their energy flow can go in two directions. The presence of smart grids is characterized by being able to transmit, in two directions, the flow of energy, allowing the end user to have the possibility of generating their own energy through the use of DG and / or EV (within the V2G concept). In addition, they can market their surpluses to the distribution network.

In **Fig. 3**, the flow of electrical energy that comes from conventional generation is observed, passes to the transmission, then reaches the distribution and, in the commercialization process together with the smart grids and the end user, the bidirectionality.

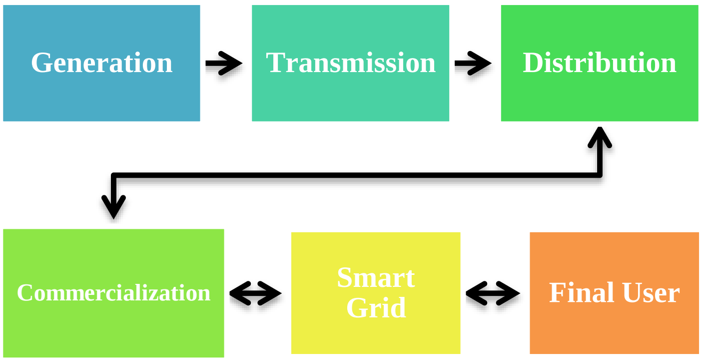

Fig. 3. Bidirectional Diagram.

It is important to mention the existence of another type of bidirectionality, and it is the internal bidirectionality of plug-in hybrid electric vehicles (PHEV) and non-plug-in (HEV), referring to the change from internal combustion propulsion to an electric motor. The issue of internal bidirectionality of EVs is focused on short-circuit faults of batteries as studied in articles [18], [20] and [21].

III. SMART GRID

The smart grid is the renewal of the electricity grid. Uses data and information processing for remote control and automation of processes, in order to improve the reliability, efficiency and sustainability of the energy supply [1].

A particularity of the intelligent network is the intervention of consumers in the operation of the network. Users have the possibility to access information at any time they want, inquire about electricity use, rates and incentives through the smart meter infrastructure. They can decide their own electricity usage patterns and preferences. Also, smart grids use widely dispersed DG units. Even if a network problem occurs, the network can recover on its own, and it will immediately take corrective action to restore itself from the outage.

Table 1 presents the characteristics of the smart grid compared to the conventional electrical grid [1].

Table 1. Comparison of conventional grid and smart grid [1]

Characteristics	Conventional Grid	Smart Grid
Communication	Uni-directional	Bi-directional
Monitoring control	Manual	Autonomous and intelligent
Inclusion of smart sensors and meters	Limited	Throughout
Consumer participation	Passive	Active
Power generation	Centralized	Distributed
Recovery	Manual	Self-healing

IV. DISTRIBUTED GENERATION

The RES-based DG, in some distribution networks, has caused an important change in the traditional model of electricity supply (bidirectionality). The tendency of DGs is the possibility that the user has to be close to the generation of electrical energy, as opposed to the traditional generation in centralized plants [13].

In the DG there are several sources of anergy that can be considered, but photovoltaic and wind generation (on a small scale) are suitable for this document, because they are the ones that have recently had the greatest growth [4].

IV.I. PHOTOVOLTAIC GENERATION

Photovoltaic solar energy has received increasing attention, since it allows a 100% renewable electricity production and without emissions [10], where it is part of the RES. Considering it as a clean, silent and ecological electrical energy.

This energy is appropriate for smart grids within the DG, because its costs are accessible and energy independent, but photovoltaic generation depends on the climate and makes it difficult to forecast its generation. [7]. The difficult generation forecast leads to the nature of intermittency which can generate the following problems [10]:

- Fluctuation in voltage.
- Fluctuation in frequency.
- Increase in the level of failure.
- Voltage rise problem

IV.II. WIND GENERATION

Wind energy is becoming increasingly important, allowing the generation of 100% renewable and emission-free electricity[10].

This energy is suitable for smart grids within the DG, because they can be used at small scales and close to consumer loads, but, like photovoltaic power generation, wind power is climate dependent and makes it difficult to forecast generation. The problem of intermittence is also generated where the same problems of photovoltaic energy are generated [10]:

- Fluctuation in voltage.
- Fluctuation in frequency.
- Increase in the level of failure.
- Voltage rise problem

V. ELECTRIC VEHICLE

An EV is a vehicle that uses electrical energy and converts it into mechanical energy to be used to transport people or goods. "Traction can be provided by wheels or propellers driven by rotary motors, or in other cases, use other types of non-rotating motors, such as linear motors, inertial motors or applications of magnetism as a source of propulsion, as is the case. of magnetic levitation trains. "[22]

The types of electric vehicles can be classified according to two characteristics: if they are plug-in or non-plug-in or in their effect by a combination in the propulsion systems. According to **Table 2** you can see the type of vehicle, its abbreviation and a brief description.

Table 2. VE Types [20]

Type	Abbreviation	Description
Electric Vehicle	**BEV o VE**	Battery-powered vehicle, called pure electric. It only uses one or more electric motors and does not have a combustion engine of any kind. Electric motors are powered by batteries that are fed mainly from the electrical network. (Pluggable)
Hybrid Electric Vehicle	**HEV**	It has a combustion engine and one or more electric motors. Both the combustion engine and the electric motor are used to move the wheels of the vehicle, and depending on the manufacturer, it can work in 100% electric mode, while in others it always works as a back-up electric motor. It has batteries that are self-recharging thanks to the heat engine and the energy recovery system during braking. (Not pluggable)
Plug-in Hybrid Electric Vehicle	**PHEV**	It combines a combustion engine with a battery and an electric motor, unlike HEVs, they have larger capacity batteries that have to be charged by connecting them to the electrical network. (Pluggable)
Range Extended Electric Vehicle	**REEV o EREV**	They have a combustion engine that is not used to power the vehicle, but is used as a generator when the charge of the batteries runs out. (Pluggable and non-pluggable)
Fuel Cell Electric Vehicle	**FCEV**	They only have electric motors and the energy is not obtained from batteries, but from a fuel cell that uses hydrogen. (Not pluggable)

The modes of operation of the EVs refer to who is going to exchange the electrical energy. Three modes are described below

Vehicle To Vehicle o V2V

It allows several EVs (such as vehicles in a neighborhood or in a public parking lot), to transfer their energy through bidirectional chargers to the local grid. The difference with the V2H configuration is that the control of the energy that is delivered to the network is carried out by means of a controller or also called an aggregator. [23]

A V2V network is made up of several V2H systems, such as several vehicles in a parking lot, whose charging points are linked to the aggregator. The latter allows all vehicles to interact with each other, as well as executing the energy dispatch control, either to the grid or to other vehicles that require it. Under this configuration it is possible to establish priorities, such as, for example, that first all connected vehicles are recharged and the surplus is delivered to the network.[23]

Vehicle To Home o V2H

It allows an EV to connect to the existing electrical network of the user's home to recharge or discharge its energy by means of a bidirectional charger. When an EV needs to be charged, the most convenient way for the vehicle owner is to drive home and simply plug the vehicle into the outlet prepared for that purpose. [23]

In general, V2H is made up of an EV connected to a domestic electrical network by means of a bidirectional charger. The energy source can come from the local electricity utility supply network or through small-scale renewable generation installed at the recharge site. An electrical network operator is also required, who will manage the energy resource if required through communication links that connect the EV with the electrical network. [23]

Vehicle To Grid o V2G

The concepts of V2H and V2V made it possible to evolve to a configuration that was completely integrated into the network, such as the Vehicle to Grid or V2G network. V2G technology is one in which EVs can absorb and store energy from the electricity grid in addition to having the possibility of returning it to it when required. An observation, V2Gs must have the ISO 15118 standard, since it is an international standard that defines the communication of the vehicle to the network for EV charging and discharging. [23]

Fig. 4 shows the different configurations that have an EV within bidirectionality.

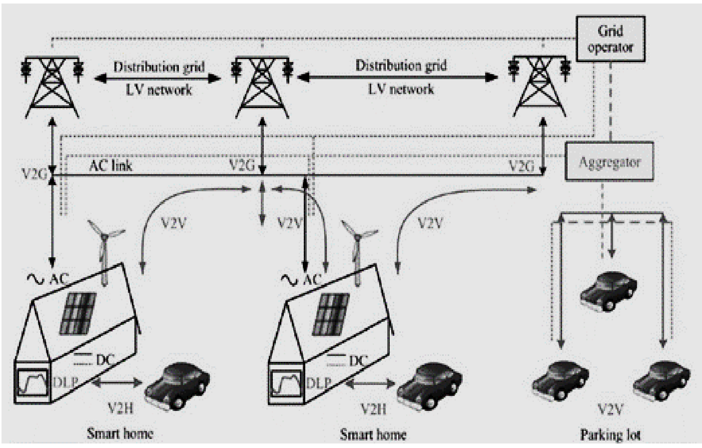

Fig. 4. Bi-directional EV settings (V2G, V2V y V2H). [23]

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VI. CHARGING STATIONS

A charging station is identified as a place that supplies electricity to recharge EV batteries. In several types of EV, the process of charging the batteries is done through the use of a device called a "battery charger", which is connected to the external electrical network. The battery charger is characterized by having the process of transforming alternating current (AC) from the electrical network and converting it into direct current (DC) for EV batteries. Usually, the battery charger is designed to be an AC-DC converter, in case of being a fast charging station, a DC-DC converter is added. Finally, electric vehicle chargers are classified into three levels. Level 1 is located in homes and small offices, Level 2 is located in public and private entities, and Level 3 is located in commercial areas. [1], [3].

The charging stations can have two functionalities, the first is responsible for supplying power to the EV batteries (unidirectional) and the second, can supply and extract power from the ESS (bidirectional) [3], Additionally, V2G, V2V, and V2H are important applications of EVs for bi-directional power flow.

Fig. *5* a mind map is observed where a charging station is characterized by having battery chargers that convert power from AC to DC, and in case of a fast charge a DC to DC converter is needed, where unidirectional charging can be implemented in levels 1, 2 and 3, while bi-directional loading can be implemented at levels 2 and 3.

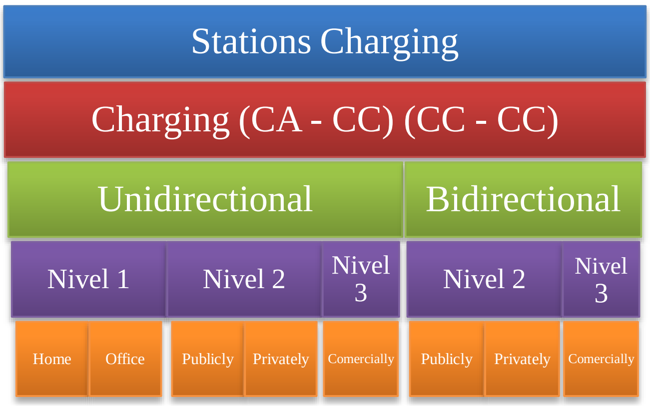

Fig. 5. Mind map

VII. ENERGY STORAGE SYSTEM

The ESS are the most important element for the smart grid, for DG RES (photovoltaic and wind), for charging stations, for EVs and for the V2G concept. In the papers [4], [6], [10], [15], [24], indicate that a large penetration of RES requires a huge ESS to support electrical networks. Meanwhile, documents [10], [15], [17], mention that large-scale EVs can be used as a large energy storage to reduce the required size required by RES and to respond to the intermittence of the DG. ESS can smooth DG power generation fluctuations, improve power quality, power imbalance, frequency variations and system stability [7], [15], [16].

The intention of **Fig. 6** is to see the ESS interacting with the conventional electrical network, the EVs and the DG. It can also be observed that the ESS serve as a bridge between the electrical network, the EVs and the DG.

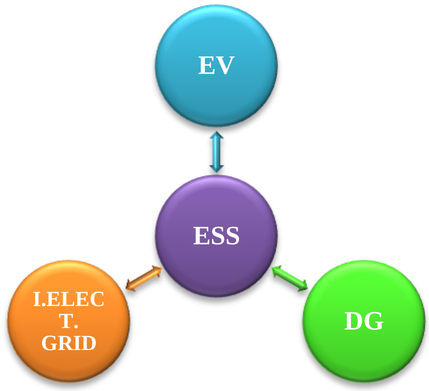

Fig. 6. Interaction of ESS as multipurpose.

VIII. RESULT

Of the articles reviewed, 55% evaluate the variables of voltage and active power, 35% the energy and state of charge of the batteries (SOC), 30%, 25%, 20%, 15% evaluate reactive power, efficiency, EV penetration and frequency, respectively (see **Fig. 7**).

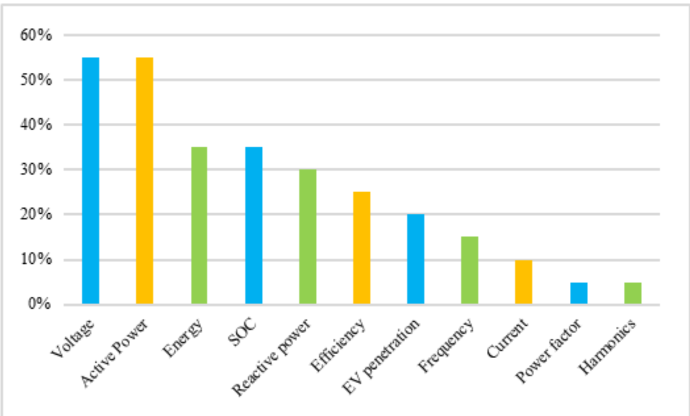

Fig. 7. Bar chart, metric evaluation.

Articles that evaluate voltage level do so in terms of overvoltage and undervoltage, in most studies looking at ESSs as a solution to problems associated with voltage. However, ESS are closely associated with SOC (State of Charged) and energy.

The high incidence of EV penetration can address the problems associated with reactive power and voltage. But it can generate harmonics, a problem associated with the electronics of the internal component with EVs.

DG, ESS, EV, the concept of V2G and bidirectionality within an intelligent grid concept, turn out to be a multipurpose gear, where they can improve the variables of voltage, active power, reactive power, power factor, frequency and energy.

IX. DISCUSSION

From the article [1], it was evidenced that the environmental impacts of EV can be observed from two points of view, the first is a comparison of direct emissions with respect to a conventional vehicle, where EV is too environmentally friendly, which, It is a point of view shared by most of the articles consulted within the research. Instead, the second point of view is the origin of the energy supplied by the conventional network to charge the EV. Sometimes, the generation of energy is produced with the use of coal and other polluting fuels, therefore, the use of EV would have indirect emissions, a point of view that most of the articles consulted do not take into account.

From the articles[11], [15], [17], [19], the integration of EV in the wind and photovoltaic generation systems was identified together with the ESS, considering it as a complete and friendly system with the environment, in which energy benefits are revealed, where the EV as an ESS can solve the intermittency of photovoltaic and wind generation, improve stability and correct electrical variables such as voltage and frequency.

Articles [1] and [3] show a conflict regarding EVs with the V2G concept, unidirectionality and bidirectionality, in which the SAE J1772 standard mentions certain levels of charges for EV electric chargers. Likewise, it was mentioned that, in public, private (level 2) and commercial entities (level 3) the V2G concept can be implemented, leaving out the offices and homes (level 1), which leads to think that the concept V2G is designed for large amounts of EV (Fleet of VE).

From the research [3], the requirement for bidirectionality in the V2G concept, is the charging and discharging of EVs, where the batteries are exposed to degradation, in this way the useful life of the batteries is shortened faster. Therefore, it is a problematic idea that should be taken into account in other investigations where it is not mentioned as problems of EVs, as is the case in the articles [5], [6], [24] and among others.

X. CONCLUSION

The environmental problems produced mainly by the transport sector that uses internal combustion as an energy means are in terms of the energy transition towards the electrification of transport. This transition has several phases, the first is the change from conventional vehicles to the use of hybrid electric vehicles, the second is the improvement of batteries in terms of energy storage. The third is the repowering or improvement of the infrastructure of the electricity distribution system with the inclusion of smart grids, relying on the participation of the DG (especially photovoltaic and wind generation). The fourth is the inclusion of the ESS as a multipurpose interaction system that functions as a support and that serves as a bridge for the electricity grid, the DG and the EVs. The fifth is to generate social policies and economic incentives. The bidirectional charging is compatible with V2G technology, allowing to increase the flexibility and potential of the electrical networks in order to improve the energy crisis. The main advantages that V2G technology offers in terms of electrical variables are the following:

- Active and reactive power.
- Power factor and frequency control.
- Load balance.
- Voltage regulation.

In addition, the V2G together with an ESS, allows a better integration of the RES towards the conventional electrical networks.

Wind and solar photovoltaic energy are RES where their generation of electrical energy is unpredictable and inconsistent in nature, which makes them classify as intermittent, however, EV and ESS, make them an ideal solution to correct the problem of nature of intermittence.

The V2G concept is considered if there is a high EV penetration involved, this indicates, consider a charging station that includes a fleet of EVs. It can also be considered V2G, if the EV is included in a complete system with some RES and an ESS. Otherwise, when talking about low EV penetration, in the V2G concept it becomes V2H, which groups together the supply characteristics required by small households.

A high penetration of DG would imply a very large ESS, which makes it unfeasible in economic and infrastructure terms; but with the massive involvement of EV and with the inclusion of V2G, it makes it viable and useful.

REFERENCES

[1] J. Y. Yong, V. K. Ramachandaramurthy, K. M. Tan, and N. Mithulananthan, “A review on the state-of-the-art technologies of electric vehicle, its impacts and prospects,” *Renew. Sustain. Energy Rev.*, vol. 49, pp. 365–385, Sep. 2015, doi: 10.1016/J.RSER.2015.04.130.

[2] W. Enang and C. Bannister, “Modelling and control of hybrid electric vehicles (A comprehensive review),”

Renew. Sustain. Energy Rev., vol. 74, pp. 1210–1239, Jul. 2017, doi: 10.1016/J.RSER.2017.01.075.

[3] S. Habib, M. M. Khan, F. Abbas, and H. Tang, "Assessment of electric vehicles concerning impacts, charging infrastructure with unidirectional and bidirectional chargers, and power flow comparisons," *Int. J. Energy Res.*, vol. 42, no. 11, pp. 3416–3441, Sep. 2018, doi: 10.1002/ER.4033.

[4] F. Mwasilu, J. J. Justo, E. K. Kim, T. D. Do, and J. W. Jung, "Electric vehicles and smart grid interaction: A review on vehicle to grid and renewable energy sources integration," *Renew. Sustain. Energy Rev.*, vol. 34, pp. 501–516, Jun. 2014, doi: 10.1016/J.RSER.2014.03.031.

[5] D. Liu, W. Wang, L. Wang, H. Jia, and M. Shi, "Dynamic Pricing Strategy of Electric Vehicle Aggregators Based on DDPG Reinforcement Learning Algorithm," *IEEE Access*, vol. 9, pp. 21556–21566, 2021, doi: 10.1109/ACCESS.2021.3055517.

[6] H. Patil and V. N. Kalkhambkar, "Grid Integration of Electric Vehicles for Economic Benefits: A Review," *J. Mod. Power Syst. Clean Energy*, vol. 9, no. 1, pp. 13–26, Jan. 2021, doi: 10.35833/MPCE.2019.000326.

[7] L. Tong, S. Zhao, H. Jiang, J. Zhou, and B. Xu, "Multi-Scenario and Multi-Objective Collaborative Optimization of Distribution Network Considering Electric Vehicles and Mobile Energy Storage Systems," *IEEE Access*, vol. 9, pp. 55690–55697, 2021, doi: 10.1109/ACCESS.2020.3026204.

[8] W. Alharbi and A. Almutairi, "Planning Flexibility with Non-Deferrable Loads Considering Distribution Grid Limitations," *IEEE Access*, vol. 9, pp. 25140–25147, 2021, doi: 10.1109/ACCESS.2021.3057553.

[9] S. Debbarma and R. Shrivastwa, "Inertia emulation from HVDC links for LFC in the presence of smart V2G networks," *Smart Power Distrib. Syst. Control. Commun. Optim.*, pp. 251–265, Jan. 2019, doi: 10.1016/B978-0-12-812154-2.00012-2.

[10] K. N. Kumar, B. Sivaneasan, K. T. Tan, J. S. Ren, and P. L. So, "Electric Vehicles as Energy Storage: V2G Capacity Estimation," in *Energy Storage for Smart Grids: Planning and Operation for Renewable and Variable Energy Resources (VERs)*, Academic Press, 2015, pp. 249–275.

[11] X. Zhang, Y. Xu, S. Lu, C. Lu, and Y. Guo, "Joint Planning of Distributed PV Stations and EV Charging Stations in the Distribution Systems Based on Chance-Constrained Programming," *IEEE Access*, vol. 9, pp. 6756–6768, 2021, doi: 10.1109/ACCESS.2021.3049568.

[12] L. Hua, J. Wang, and C. Zhou, "Adaptive electric vehicle charging coordination on distribution network," *IEEE Trans. Smart Grid*, vol. 5, no. 6, pp. 2666–2675, Nov. 2014, doi: 10.1109/TSG.2014.2336623.

[13] D. Alcala-Gonzalez, E. M. G. del Toro, M. I. Más-López, and S. Pindado, "Effect of Distributed Photovoltaic Generation on Short-Circuit Currents and Fault Detection in Distribution Networks: A Practical Case Study," *Appl. Sci. 2021, Vol. 11, Page 405*, vol. 11, no. 1, p. 405, Jan. 2021, doi: 10.3390/APP11010405.

[14] S. Rafique, M. J. Hossain, M. S. H. Nizami, U. Bin Irshad, and S. C. Mukhopadhyay, "Energy Management Systems for Residential Buildings with Electric Vehicles and Distributed Energy Resources," *IEEE Access*, vol. 9, pp. 46997–47007, 2021, doi: 10.1109/ACCESS.2021.3067950.

[15] W. Wang, L. Liu, J. Liu, and Z. Chen, "Energy management and optimization of vehicle-to-grid systems for wind power integration," *CSEE J. Power Energy Syst.*, vol. 7, no. 1, pp. 172–180, Jan. 2021, doi: 10.17775/CSEEJPES.2020.01610.

[16] E. M. Ahmed, E. A. Mohamed, A. Elmelegi, M. Aly, and O. Elbaksawi, "Optimum Modified Fractional Order Controller for Future Electric Vehicles and Renewable Energy-Based Interconnected Power Systems," *IEEE Access*, vol. 9, pp. 29993–30010, 2021, doi: 10.1109/ACCESS.2021.3058521.

[17] Y. Pan, W. Wang, Y. Li, F. Zhang, Y. Sun, and D. Liu, "Research on Cooperation between Wind Farm and Electric Vehicle Aggregator Based on A3C Algorithm," *IEEE Access*, vol. 9, pp. 55155–55164, 2021, doi: 10.1109/ACCESS.2021.3071803.

[18] M. Seo, M. Park, Y. Song, and S. W. Kim, "Online Detection of Soft Internal Short Circuit in Lithium-Ion Batteries at Various Standard Charging Ranges," *IEEE Access*, vol. 8, pp. 70947–70959, 2020, doi: 10.1109/ACCESS.2020.2987363.

[19] R. Wang, Q. Sun, D. Qin, Y. Li, X. Li, and P. Wang, "Steady-state stability assessment of ac-busbar plug-in electric vehicle charging station with photovoltaic," *J. Mod. Power Syst. Clean Energy*, vol. 8, no. 5, pp. 884–894, Sep. 2020, doi: 10.35833/MPCE.2020.000182.

[20] H. Al-Sheikh, O. Bennouna, G. Hoblos, and N. Moubayed, "Modeling, design and fault analysis of bidirectional DC-DC converter for hybrid electric vehicles," *IEEE Int. Symp. Ind. Electron.*, pp. 1689–1695, 2014, doi: 10.1109/ISIE.2014.6864869.

[21] I. Sefik, D. A. Asfani, and T. Hiyama, "Simulation-based analysis of short circuit fault in parallel-series type hybrid electric vehicle," *APAP 2011 - Proc. 2011 Int. Conf. Adv. Power Syst. Autom. Prot.*, vol. 3, pp. 2045–2049, 2011, doi: 10.1109/APAP.2011.6180687.

[22] J. Trashorras Montecelos, "Vehículos eléctricos : infraestructura para la recarga, componentes de electricidad y electrónica, esquemas eléctricos, seguridad eléctrica para la electromovilidad," 2019.

[23] M. Moreano Alvarado, Milton Ponce Jara and J. Cedeño Villaprado, "Capitulo 9: El esquema 'Vehicle to grid' y los desafios de su implementación en las

actuales redes eléctricas.," in *Estudios Estratégicos Del Sector Energético*, Primera ed., E. Martínez, Ed. Mexico: Febrero del 2017, 2017, pp. 331–358.

[24] M. Ghiasi, M. Dehghani, T. Niknam, A. Kavousi-Fard, P. Siano, and H. H. Alhelou, "Cyber-Attack Detection and Cyber-Security Enhancement in Smart DC-Microgrid Based on Blockchain Technology and Hilbert Huang Transform," *IEEE Access*, vol. 9, pp. 29429–29440, 2021, doi: 10.1109/ACCESS.2021.3059042.