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Research Paper

Analysis of renewable energy sources and electrical vehicles integration into microgrid with fuzzy logic control system

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Abstract *The rise in pollution levels, leading to the emission of greenhouse gas emissions and the subsequent phenomenon of global warming, is anticipated to stimulate the expansion of Electrical Vehicles (EVs). Consequently, EVs will establish a connection with the electrical grid within this timeframe. The implementation of this technology will significantly influence the voltage profiles and loads of grid components. The study centered on the modeling and analysis of the integration of renewable energy sources and EVs into a micro grid. The micro grid comprises four essential elements: a diesel generator functioning as the primary power supply, a combination of a Photovoltaic (PV) farm and a wind farm for generating electricity, and a Vehicle-to Grid (V2G) system positioned near the micro grid's load. The continuous increase in their energy production rate makes micro grids important. Micro grids can be designed to meet the energy needs of different establishments, including hospitals, universities, and EVs charging stations, as well as the energy demands of a district, town, or industrial site. Charging stations are essential for the purpose of replenishing the battery of an EVs. This paper investigates the influence of EVs on the micro grid network. EVs integrate non-linear circuit components into their structures In addition, the modeling and analysis of the renewable energy sources and EVs integration into the micro grid has been presented. Also, this paper reviews the analysis of the micro grid with EVs using Matlab/Simulink.*

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1. Introduction

The transport sector is responsible for a significant proportion of greenhouse gas emissions, as it accounts for 25% of energy-related emissions generated. The most viable solution is Electrical Vehicles (EVs). EVs are classified as clean and environmentally friendly because they do not emit any pollutants from their tailpipes. Several nations are actively promoting EVs through the provision of incentives and laws aimed at facilitating their widespread adoption. The implementation of this technology also has an impact on the electrical grid itself. If there is a large adoption of EVs and unregulated charging, allowing consumers to charge their vehicles at their convenience, this would have a detrimental impact by amplifying the daily maximum electricity demand. Uncontrolled EV charging would exacerbate power losses, overload equipment, and disrupt power quality. Nevertheless, the beneficial impacts of EV adoption would become apparent through the regulation of EV charging or by utilising EVs as tiny distributed generators, particularly when operating in V2G mode.

EVs represent the future of our world, encompassing more than just mobility. These vehicles are linked to a low-voltage charging station, they are emission free. EVs will undeniably play a crucial role in attaining this objective, to a certain degree. Internal Combustion Engines (ICE) or fossil fuel-powered vehicles have emitted significant amounts of carbon dioxide into the environment. The usual sources of energy, such as petrol and diesel, that are needed for

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EVs can be substituted with other options, such as batteries, fuel cells, and ultra-capacitors. These sources can be utilized independently or in conjunction with traditional sources to achieve optimal efficiency. Therefore, EVs can be categorized into three types: pure battery electrical vehicles (BEVs), Hybrid Electrical Vehicles (HEVs), and Fuel Cell Electrical Vehicles (FCEVs).

The primary issue with electrical vehicles is the battery. However, current studies indicate that the issue of battery life is no longer a significant concern. An electrical car is an alternative to a diesel or gasoline engine, designed to mitigate environmental pollution. Grid-to-Vehicle (G2V) and V2G are two crucial terms in the field of electrical cars. The G2V, or grid-to-vehicle, is the standard method of charging electrical automobiles. V2G technology refers to the process by which a vehicle serves as a power source [5]. EVs discharge their energy into the supply grid while in V2G mode. V2G technology serves multiple purposes, such as maintaining stable frequency and voltage levels, optimizing costs, reducing peak energy use, integrating renewable energy sources, and balancing electrical loads. The utilization of the V2G optimum logic control approach is highly advantageous in attaining load profile flattening.

An aggregator is utilized to ensure the efficient functioning of the V2G process. An aggregator is a digital platform that facilitates the provision of services by service providers to consumers in a digital format. V2G technology offers a practical solution to address the issue of peak demand placed on the power system or distribution network. The implementation of effective strategies helps to mitigate numerous issues related to distribution networks. An analysis is conducted on the influence of electrical vehicles on the profile of power demand. The primary obstacle to vehicle-to grid technology lies in the erratic nature of travel patterns. By manipulating the charging patterns of electric vehicles, the costs associated with battery cycle life regulation are reduced, thereby minimising the expenses associated with battery wear in electric vehicles.

The objective is achieved by utilizing electric vehicles to provide frequency regulation services. An analysis is conducted on the impact of EV charging time and the efficiency of EV batteries on the total load profile. The goal is to optimise the operation of V2G systems with the aim of minimising environmental pollution and decreasing the cost of operating both transportation and electricity supply systems.

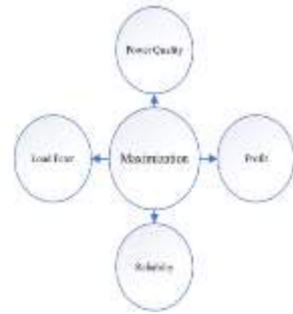


Fig 1.1: Maximization objective functions of electrical vehicle integration into the distribution system.

Additionally, enhancing the calibre, steadfastness, and dependability of power provision. The upcoming EVs will not only impose a burden on the electrical grid, but they will also serve as a type of decentralised power generation in the future. Additionally, they will play a significant role in distributing the load through the system. The plug-in hybrid electrical vehicle (PHEV) can both supply and consume power, making it capable of acting as both a load and a source for the grid. Hence, investigating the impact of EV charging on the distribution network holds immense theoretical importance and practical relevance. Figs. 1 and 2 illustrate the objective functions of maximising and minimising the integration of electrical vehicles into an electrical distribution system.

Fig 1.2: Minimization objective functions of electrical vehicle integration into the distribution system.

2. Renewable energy sources

The demand for renewable energy has increased significantly over the years because of shortage of fossil fuels and greenhouse effect. Among various types of renewable energy sources, solar energy and wind energy have become very popular and demanding due to advancement in power electronics techniques. Photovoltaic sources are used today in many applications as they have the advantages of being maintenance and pollution free. Solar-electric-energy demand has grown consistently by 20%–25% per annum over the past 20 years, which is mainly due to the decreasing costs and prices.

This decline has been driven by the following factors:

1) An increasing efficiency of solar cells
2) Manufacturing technology improvements and
3) Economies of scale.

PV inverter, which is the heart of a PV system, is used to convert dc power obtained from PV modules into ac power to be fed into the grid. Improving the output waveform of the inverter reduces its respective harmonic content and hence, the size of the filter used and the level of electromagnetic interference generated by switching operation of the inverter.

The increasing energy demand, increasing costs and exhaustible nature of fossil fuels and global environment pollution have generated huge interest in renewable energy resources. Other than hydroelectric power, wind and solar are the most useful energy sources to satisfy our power requirements. Wind energy is capable of producing huge amounts of power, but its availability can't be predicted. Solar power is available during the whole day but the solar irradiance levels change because of the changes in the sun's intensity and shadows caused by many reasons.

Generally solar and wind power are complementary in nature. Therefore the hybrid photovoltaic and wind energy system has higher dependability to give steady power than each of them operating individually. Other benefit of the hybrid system is that the amount of the battery storage can be decreased as hybrid system is more reliable compared to their independent operation.

3. Modeling of case study

3.1 Impact of electrical vehicle

a. Effects of electrical vehicle charging and discharging

EVs have both advantageous and detrimental impacts on the power delivery system [25]. The charging and discharging procedure of EVs is crucial in minimising the peak demand on the power system network and reducing battery degradation costs. A cost-minimization billing plan that excludes the transmission and distribution infrastructure may not be viable. Various optimization strategies are employed to enhance the load profile, thus decreasing peak demand and ultimately reducing the overall charging expenses of EVs. The simultaneous reduction of battery degradation cost and peak demand on the load profile is achieved. Multiple methods exist for charging electric automobiles. Charging electric vehicles during non-peak hours is more cost-effective. Conversely, charging during times of highest demand incurs more costs. The primary goal of any approach is to minimise the expenses associated with EV charging and enhance the entire system's efficiency. Maintaining a greater level of charge in a charging scheme is considered desirable. There are both static and dynamic pricing plans that offer advantages to both power utility companies and electric vehicle customers.

3.2 Impact on the distribution network

a. Effect on power quality

The incorporation of EVs into the power grid presents many power quality issues, such as harmonic contamination, increased power dissipation, diminished voltage, and unbalanced three-phase voltage.

b. Harmonic distortion

Increasing the accessibility of EVs will result in higher usage of the charging infrastructure. This infrastructure comprises several intricate power electronic devices and a Direct Current (DC) link that connects the three-phase Alternating Current (AC) power source. This DC link can produce harmonic distortion, which has the potential to contaminate the electrical grid and impact the performance of distribution system components, thereby affecting power quality.

c. Voltage drop

The technology of EVs is steadily advancing and being implemented on a global basis. This leads to an increase in local load on the power grid. The charging of large-scale EVs will have an impact on the voltage at specific points in the network, particularly causing a decrease in voltage at the end nodes. This, in turn, affects the power demand of users [30].

d. Three-phase imbalance

A lower number of EVs charging at a specific location for a specific duration decreases the charging process. Consequently, this leads to an increase in the magnitude of unevenly distributed three-phase currents. However, the charging of a significant quantity of electrical vehicles results in an imbalanced current condition.

3.3 Effect on operation

Regarding the economic functioning of the distribution network, it mostly manifests in terms of net loss, decreased lifespan of cables, and lifespan of distribution transformers.

a. Net loss

Elevated permeability results in a higher rate of charging load for EVs, which in turn leads to an increased rate of load loss.

b. Cables

The high harmonic currents have a detrimental effect on the cable. Consequently, this leads to diminished efficiency and a shorter lifespan

3.4 Environmental impact

If the current trend persists in the upcoming years, it will result in a rise in temperature and have an impact on the global climate. In order for the efforts of smaller countries to effectively mitigate emissions and utilize renewable technologies, it is imperative that high-energy consumers likewise take measures to decrease their own emissions. Ever since the introduction of the Tesla Roadster, there has been a significant surge in interest in the EV business. The factors contributing to the increase in emissions are as follows:

1) Population growth.
2) Rise in production capacity.
3) Rise in energy use.
4) Rise in transportation.

The production of electrical automobiles entails significant energy usage. The production of electrical automobiles emits a greater amount of dangerous pollutants compared to conventional fuel-powered vehicles. This is due to the fact that the manufacturing process entails the creation of lithium-ion batteries, which are a crucial component of electric vehicles. According to statistics, the emissions produced during the production of an EVs account for almost 33% of the total Carbon dioxide (CO_2) emissions released over the vehicle's full life cycle. Nevertheless, recent technological developments and the implementation of highly efficient manufacturing procedures have led to a significant reduction in emissions produced during battery production.

a. Positive impact

EVs are indisputably proven to produce less pollution compared to conventional fuel-powered vehicles. Nevertheless, the manner in which the vehicle is controlled is contingent upon the user's anticipated advantages. When aiming for zero emissions and sustainable energy, it is important to recognise that not all sources of electricity are alike. Alternatively, it is prudent to power the car using sustainable energy sources such as solar and wind power. The installation of a solar panel eliminates the need for gasoline and allows the car to be powered by the electricity generated by the panels, free of charge. Additionally, it could be necessary to enlarge the dimensions of the solar panel in order to accommodate the heightened demand for charging the electrical vehicle. The number of extra solar panels needed to provide power for the electric car is contingent upon the vehicle's efficiency, frequency of usage, and the solar potential of the specific area. If it is not feasible to produce the necessary electrical power from solar resources on one's own property, an alternative option is to enrol in a communal solar charging system that operates on a sharing model. This trend is quickly gaining popularity nationwide, and the majority of utility organisations opt to procure electricity from these renewable energy sources .

b. Direct impact

EVs possess the remarkable attribute of producing fewer tailpipe emissions. They utilise the stored energy in their batteries to propel their wheels and facilitate locomotion. Empirical research has proven that this transformation displays remarkable efficacy, as it experiences negligible thermal dissipation during the procedure. Considering the environmental repercussions resulting from the extraction of battery materials and their subsequent processing, this is of utmost importance. The primary cause of these emissions is mostly the result of coal mining and the extraction and refining of raw materials for battery production. However, the impacts of these influences are significantly less significant when compared to those induced by the operation of a gasoline engine.

c. Indirect impact

While EVs offer numerous benefits, there are also a few areas of concern to consider. The most detrimental consequence of electric automobiles becomes apparent when we examine the supply chain. It has been discovered that the concentration of particulate matter significantly rises. This is the outcome of coal-based electricity generation. Recent studies indicate that there has been a fluctuation in the typical grid composition, with a notable transition towards renewable energy sources and natural gas. Nevertheless, this transition will not occur instantaneously. When examining the impact of EVs on climate change, research has shown that EVs powered by the current grid generally decrease climate changerelated effects. However, they do contribute to an increase in particulate pollution, resulting in a net overall higher environmental impact compared to existing conventional methods.

3.5 Fuzzy logic controller

In recent years, the number and variety of applications of fuzzy logic have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection.

To understand why use of fuzzy logic has grown, you must first understand what is meant by fuzzy logic.

Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multivalve logic. However, in a wider sense fuzzy logic (FL) is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects with unsharp boundaries in which membership is a matter of degree. In this perspective, fuzzy logic in its narrow sense is a branch of fl. Even in its more narrow definition, fuzzy logic differs both in concept and substance from traditional multivalve logical systems.

In fuzzy Logic Toolbox software, fuzzy logic should be interpreted as FL, that is, fuzzy logic in its wide sense. The basic ideas underlying FL are explained very clearly and insightfully in Foundations of Fuzzy Logic. What might be added is that the basic concept underlying FL is that of a linguistic variable, that is, a variable whose values are words rather than numbers. In effect, much of FL may be viewed as a methodology for computing with words rather than numbers. Although words are inherently less precise than numbers, their use is closer to human intuition. Furthermore, computing with words exploits the tolerance for imprecision and thereby lowers the cost of solution.

4. Simulation results

Electrical cars consist of two components. An internal energy source powers the batteries of electric vehicles, while an electric motor facilitates the vehicle’s propulsion. Electrical vehicles require external energy sources to charge their batteries. Under these circumstances, it is necessary to charge the cars. EVs utilise several forms of charging. Charging stations can be classify into various categories based on their charging speed and voltage. The challenges facing the development of EVs involve enhancing their range and reducing the time required for charging. Currently, researchers are conducting ongoing, rigorous investigations to address these issues. To expedite the charging process of an electric car, it is advisable to charge the vehicle using DC. We enhance the power output of the charging stations to reduce the duration of charging for EVs. Consequently, the quantity of charging stations with a power exceeding 350 kW is progressively growing. Several charging plugs equip the charging stations, enabling simultaneous charging for multiple automobiles. Simultaneously charging numerous automobiles can lead to significant issues within the microgrid. The escalating load demand on the grid poses a significant issue. The integration of renewable energy sources and EVs into a microgrid is modelled in Fig. 4.1

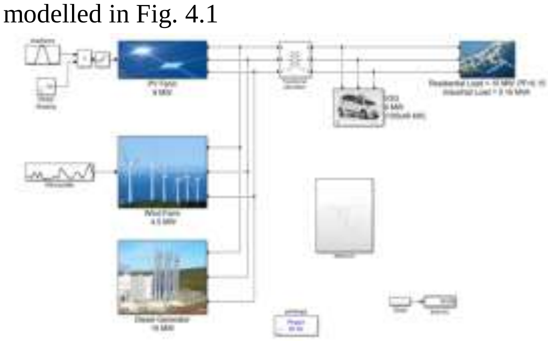


Fig 4.1: MATLAB/SIMULINK circuit of the proposed system

Microgrid systems rely on the precise management of fundamental quantities like current and voltage, which are represented by sinusoidal waveforms with a frequency of 50 Hz.However, these fundamental variables lose their sinusoidal features due to various factors, resulting in the presence of undesired harmonic components in the microgrid system. The exponential growth of EVs results in a surge in power demand, posing an additional burden on the microgrid. Consequently, there is an increase in the variability of the microgrid. The diesel generator within the microgrid maintains equilibrium between the electricity consumed and the power generated. You can determine the discrepancy in the grid frequency by comparing it to the rotor speed of the synchronous machine. Figure 4.2 presents the total energy output of the diesel generator over the course of the day. The drawbacks of diesel generators are their exorbitant cost and their detrimental impact on the environment. Nevertheless, when renewable energy sources are unable to meet the energy demand, the utilization of a diesel generator becomes necessary to generate the required energy. The microgrid consists of two renewable energy sources. First and foremost, the PV plant generates energy in direct proportion to the level of irradiation present in the surrounding environment. Figure 4.3 presents the diurnal energy output of solar panels. The solar farm in the microgrid generates direct current by harnessing solar irradiation. The material composition of the panels, the amount of solar irradiation they absorb, and the prevailing climatic conditions all influence the energy output. The wind farm produces electrical power in direct proportion to the strength of the wind. The turbine produces its maximum power output once the wind speed reaches its designated value. The microgrid deactivates the wind power when the wind speed exceeds its maximum threshold, until it returns to its standard level. Figure 4.4 displays the daily energy production of the wind farm in the microgrid.The use of wind power plants in microgrids is steadily rising owing to their status as a renewable energy source, uncomplicated design, and notable efficacy. Wind farms, in contrast to other conventional power facilities, exhibit distinct characteristics. The primary benefit of EVs is their ability to utilise V2G applications. This application is exclusively applicable to electric cars. Essentially, it enables the car to directly supply electricity to the distribution microgrid.

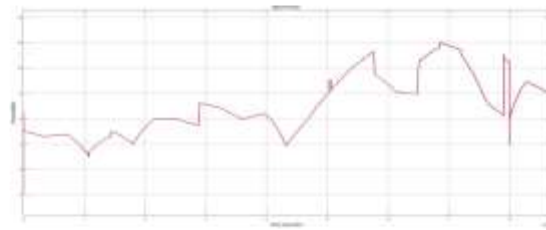


Fig 4.2: Power generated by the generator throughout the day.

Fig 4.3: Power generated by the solar throughout the day.

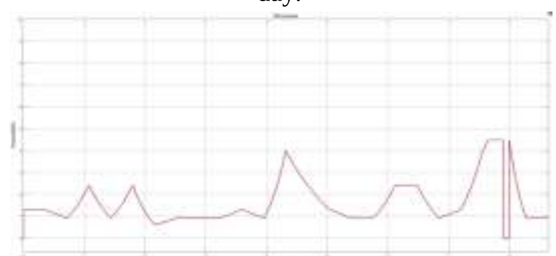


Fig 4.4: Power generated by the wind throughout the day.

Figure 4.5 shows the power value that the EV transmits and controls to the microgrid throughout the day. V2G refers to the process of transferring electrical energy from the battery systems of EVs to the microgrid. Within the electrical system, the batteries of EVs function as a means of storing energy. Car-to-grid technology enables the charging and discharging of a car battery based on various signals, such as energy output or consumption. The utilisation of electric vehicle charging results in a rise in the electrical demandper transformer during periods of high energy consumption inside the microgrid. This poses significant challenges to achieving energy equilibrium. Charging many EVs in the same phase leads to a phase imbalance in the microgrid. Spontaneous charging of EVs poses significant issues within the microgrid. Charging many EVs at the same time can result in a decrease in voltage at the connectors of the chargers. EVs draw a significant amount of active power from the network during charging, leading to power losses within the microgrid. V2G technology serves two primary objectives. It manages the battery charge and utilises the available power to stabilise the grid during transient events. V2G technology guarantees the immediate accessibility of current decentralised energy storage systems. A multitude of battery types are introduced into the market.

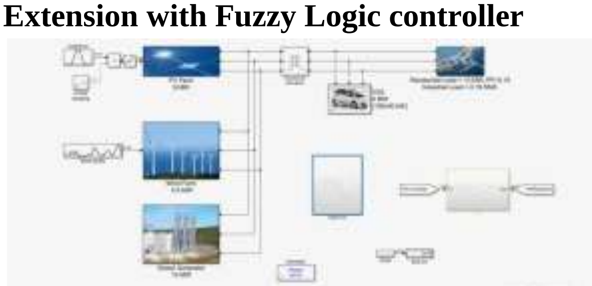
Charged and regulated into the micro grid throughout the day.

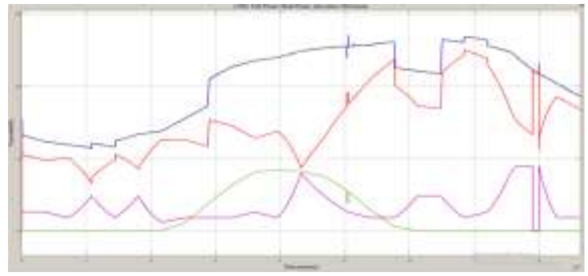
The residential load is represented by the active power drawn at a specified power factor, as illustrated in Fig. 4.6 The total power generated is represented by the active power generated from the microgrid, and the power generated is equal to or more than the load. That means there is an equilibrium between demand and generation, as shown in Fig. 4.7

Load drawn power from the micro grid during the day.

Total power generation from micro grid during the day.

Extension with Fuzzy Logic controller





Load, Total Power, Diesel power, Solar Power and Wind Power

As shown in the figure, the electric vehicle's power value is controlled and sent to the microgrid throughout the day by use of a fuzzy logic controller. Bringing power from electric vehicles' battery systems to the local grid is known as vehicle-to-grid (V2G) technology. Using a fuzzy logic controller, the batteries in EVs store energy inside the electrical system. Thanks to developments in car-to-grid technology, indications like energy consumption or output may trigger the charging or draining of a vehicle's battery. Using a fuzzy logic controller to charge electric vehicles causes the electrical demand per transformer to go up when the microgrid is using a lot of power. Reaching an energy balance becomes much more difficult because of this. An imbalance in the microgrid's phase might occur when a large number of electric vehicles are charged simultaneously utilising a fuzzy logic controller. There are major problems with the microgrid caused by EVs charging themselves. The voltage at the charger connections can drop if a large number of EVs are being charged simultaneously. There are power losses in the microgrid since EV charging uses a lot of network active power. There are two main purposes for vehicle-to-grid technology. In order to stabilise the grid during transient occurrences, it uses a fuzzy logic controller to regulate the battery charge and make use of the available electricity. Present decentralised energy storage systems are immediately accessible using V2G technology. The market is flooded with a myriad of battery kinds.

5. Conclusions

The incorporation of Electrical Vehicles (EVs) has become an unavoidable trend in the expansion of distribution networks. The rising utilisation of EVs will amplify possible issues for the distribution system. The reduction of reactive power is employed to ensure voltage regulation in the microgrid. Reactive power support enhances the power factor and diminishes power losses in power transmission lines. Furthermore, it results in heightened efficiency. EVs that are linked to the microgrid have the ability to offer reactive power adjustments. The study focuses on analysing the operation of a standalone microgrid, specifically examining various EV charging procedures. The effects of uncertainty relate to predicted values of load demand, solar irradiation, and wind. In considering the growing prevalence of EVs, it is imperative to conduct thorough investigations on their power quality, with a particular focus on harmonic components, and implement appropriate solutions accordingly. The number of charging stations is growing steadily in direct correlation with the rising prevalence of EVs. The rapid transformation of the transportation industry in the present day necessitates the swift development of EVs, which will significantly influence both the power system and the environment.

REFERENCES

[1] R. K. Beniwal, M. K. Saini, A. Nayyar, B. Qureshi, and A. Aggarwal, ‘‘A critical analysis of methodologies for detection and classification of power quality events in smart grid,’’ IEEE Access, vol. 9, pp. 83507–83534, 2021.

[2] 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.

[3] Y. Qi, G. Mai, R. Zhu, and M. Zhang, ‘‘EVKG: An interlinked and interoperable electric vehicle knowledge graph for smart transportation system,’’ Trans. GIS, vol. 27, no. 4, pp. 949–974, Jun. 2023.

[4] M. H. Nikkhah and M. Samadi, ‘‘Evaluating the effect of electric vehicle charging station locations on line flows: An analytical approach,’’ in Proc. 30th Int. Conf. Electr. Eng. (ICEE), May 2022, pp. 287–291.

[5] S. Habib, M. Kamran, and U. Rashid, ‘‘Impact analysis of vehicle-togrid technology and charging strategies of electric vehicles on distribution networks—A review,’’ J. Power Sources, vol. 277, pp. 205–214, Mar. 2015.

[6] F. Garcia-Torres, D. G. Vilaplana, C. Bordons, P. Roncero-Sánchez, and M. A. Ridao, ‘‘Optimal management of microgrids with external agents including battery/fuel cell electric vehicles,’’ IEEE Trans. Smart Grid, vol. 10, no. 4, pp. 4299–4308, Jul. 2019.

[7] S.-A. Amamra and J. Marco, ‘‘Vehicle-to-grid aggregator to support power grid and reduce electric vehicle charging cost,’’ IEEE Access, vol. 7, pp. 178528–178538, 2019.

[8] C. Liu, K. T. Chau, D. Wu, and S. Gao, ‘‘Opportunities and challenges of vehicle-to-home, vehicle-to-vehicle, and vehicle-to-grid technologies,’’ Proc. IEEE, vol. 101, no. 11, pp. 2409–2427, Nov. 2013.

[9] S. Shahriar, A. R. Al-Ali, A. H. Osman, S. Dhou, and M. Nijim, ‘‘Machine learning approaches for EV charging behavior: A review,’’ IEEE Access, vol. 8, pp. 168980–168993, 2020.

[10] K. Ginigeme and Z. Wang, ‘‘Distributed optimal vehicle-to-grid approaches with consideration of battery degradation cost under real-time pricing,’’ IEEE Access, vol. 8, pp. 5225–5235, 2020.

[11] P. Sinha, K. Paul, S. Deb, and S. Sachan, ‘‘Comprehensive review based on the impact of integrating electric vehicle and renewable energy sources to the grid,’’ Energies, vol. 16, no. 6, p. 2924, Mar. 2023.

[12] J. James, J. Lin, A. Y. Lam, and V. O. Li, ‘‘Maximizing aggregator profit through energy trading by coordinated electric vehicle charging,’’ in Proc. IEEE Int. Conf. Smart Grid Commun. (SmartGridComm), Sydney, NSW, Australia, May 2016, pp. 497–502.

[13] Y. Vardanyan, F. Banis, S. A. Pourmousavi, and H. Madsen, ‘‘Optimal coordinated bidding of a profit-maximizing EV aggregator under uncertainty,’’ in Proc. IEEE Int. Energy Conf. (ENERGYCON), Limassol, Cyprus, Jun. 2018, pp. 1–6.

[14] T. Mao, X. Zhang, and B. Zhou, ‘‘Intelligent energy management algorithms for EV-charging scheduling with consideration of multiple EV charging modes,’’ Energies, vol. 12, no. 2, p. 265, Jan. 2019.

[15] Z. Moghaddam, I. Ahmad, D. Habibi, and Q. V. Phung, ‘‘Smart charging strategy for electric vehicle charging stations,’’ IEEE Trans. Transport. Electrific., vol. 4, no. 1, pp. 76–88, Mar. 2018.

[16] M. T. Hussain, D. N. B. Sulaiman, M. S. Hussain, and M. Jabir, ‘‘Optimal management strategies to solve issues of grid having electric

vehicles (EV): A review,'' J. Energy Storage, vol. 33, Jan. 2021, Art. no. 102114.

[17] M. Amjad, A. Ahmad, M. H. Rehmani, and T. Umer, ''A review of EVs charging: From the perspective of energy optimization, optimization approaches, and charging techniques,'' Transp. Res. D, Transp. Environ., vol. 62, pp. 386–417, Jul. 2018.

[18] A. Amin, W. U. K. Tareen, M. Usman, K. A. Memon, B. Horan, A. Mahmood, and S. Mekhilef, ''An integrated approach to optimal charging scheduling of electric vehicles integrated with improved mediumvoltage network reconfiguration for power loss minimization,'' Sustainability, vol. 12, no. 21, p. 9211, Nov. 2020.

[19] K. Zhou, L. Cheng, L. Wen, X. Lu, and T. Ding, ''A coordinated charging scheduling method for electric vehicles considering different charging demands,'' Energy, vol. 213, Dec. 2020, Art. no. 118882.

[20] L. Gong, W. Cao, K. Liu, and J. Zhao, ''Optimal charging strategy for electric vehicles in residential charging station under dynamic spike pricing policy,'' Sustain. Cities Soc., vol. 63, Dec. 2020, Art. no. 102474.

[21] D. B. Richardson, ''Electric vehicles and the electric grid: A review of modeling approaches, impacts, and renewable energy integration,'' Renew. Sustain. Energy Rev., vol. 19, pp. 247–254, Mar. 2013.

[22] S. Izadkhast, P. Garcia-Gonzalez, P. Frìas, L. Ramìrez-Elizondo, and P. Bauer, ''An aggregate model of plug-in electric vehicles including distribution network characteristics for primary frequency control,'' IEEE Trans. Power Syst., vol. 31, no. 4, pp. 2987–2998, Jul. 2016.

[23] J. A. P. Lopes, F. J. Soares, and P. M. R. Almeida, ''Integration of electric vehicles in the electric power system,'' Proc. IEEE, vol. 99, no. 1, pp. 168–183, Jan. 2011. [24] Y. Shi, H. D. Tuan, A. V. Savkin, T. Q. Duong, and H. V. Poor, ''Model predictive control for smart grids with multiple electric-vehicle charging stations,'' IEEE Trans. Smart Grid, vol. 10, no. 2, pp. 2127–2136, Mar. 2019.

[25] S. Shafiee, M. Fotuhi-Firuzabad, and M. Rastegar, ''Investigating the impacts of plug-in hybrid electric vehicles on power distribution systems,'' IEEE Trans. Smart Grid, vol. 4, no. 3, pp. 1351–1360, Sep. 2013.