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RESEARCH ARTICLE

Analysis of Renewable Energy Sources and Electrical Vehicles Integration Into Microgrid

MONTASER ABDELSATTAR[1], MOHAMED A. ISMEIL[2], (Member, IEEE), MOHAMED M. ALY[3], AND SALAH SABER ABU-ELWFA[3]

[1]Electrical Engineering Department, Faculty of Engineering, South Valley University, Qena 83523, Egypt
[2]Electrical Engineering Department, Faculty of Engineering, King Khalid University, Abha 61411, Saudi Arabia
[3]Electrical Engineering Department, Faculty of Engineering, Aswan University, Aswan 81542, Egypt

Corresponding author: Montaser Abdelsattar (Montaser.A.Elsattar@eng.svu.edu.eg)

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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 microgrid. The microgrid 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 microgrid's load. The continuous increase in their energy production rate makes microgrids important. Microgrids 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 microgrid 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 microgrid has been presented. Also, this paper reviews the analysis of the microgrid with EVs using Matlab/Simulink.

INDEX TERMS Vehicle-to-grid, electrical vehicles, charging infrastructure, sustainability, renewable energy, grid-to-vehicle.

I. 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 [1], [2]. 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 [2]. EVs represent the future of our world, encompassing more than just mobility. These vehicles are

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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 [3]. The usual sources of energy, such as petrol and diesel, that are needed for 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 categorised into three types: pure battery electrical vehicles (BEVs), Hybrid Electrical Vehicles (HEVs), and Fuel Cell Electrical Vehicles (FCEVs) [4]. 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, optimising costs, reducing peak energy use, integrating renewable energy sources, and balancing electrical loads. The utilisation of the V2G optimum logic control approach is highly advantageous in attaining load profile flattening [6]. An aggregator is utilized to ensure the efficient functioning of the V2G process [7]. 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 [8]. 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 [9]. 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. Additionally, enhancing the calibre, steadfastness, and dependability of power provision [10]. 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 [11]. Figs. 1 and 2 illustrate the objective functions of maximising and minimising the integration of electrical vehicles into an electrical distribution system.

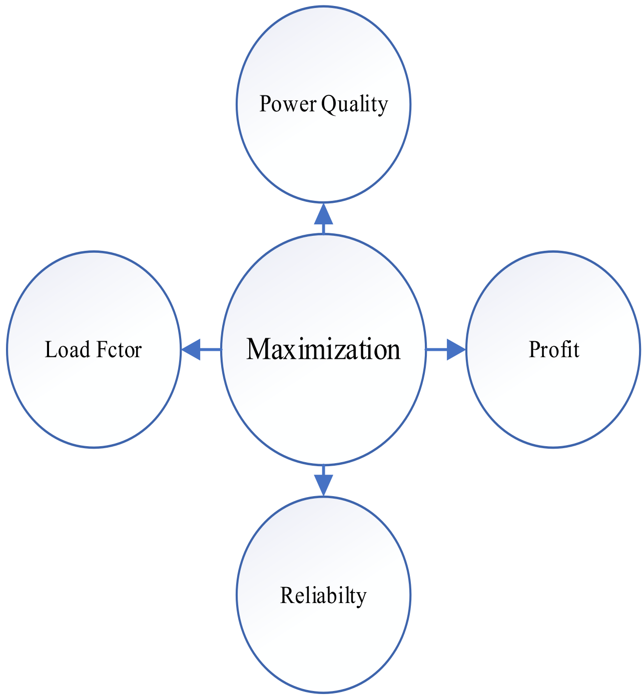

FIGURE 1. Maximization objective functions of electrical vehicle integration into the distribution system.

A. LITERATURE REVIEW

An alternative avenue of investigation was centred on the reduction of energy expenditure. The techniques employed in references [12] and [13] utilise model predictive control and stochastic mixed integer linear programming methodologies, respectively, in order to determine the most advantageous EV charging procedures that will maximise the revenues of the aggregator. Nevertheless, the aforementioned studies have conducted simulations without taking into account the distribution system, microgrid performance, peak load, and voltage dips. The technique in [14] minimises the electrical energy cost and load fluctuations by using genetic algorithms in conjunction with sequential quadratic programming. However, this technique did not address the overall losses and voltage dips in the distribution networks. Ant colony optimisation is used in [15] to minimise waiting times and charging expenses without considering the efficiency of the distribution grid. One important finding from the reviews in [16] and [17] is that, regardless of the other difficulties, the majority of EV charging techniques concentrated on one or two of the following power grid problems: severe voltage dips, load/frequency variations, overall power losses, or peak shaving. For example, the authors of [18] made an effort to reduce voltage regulation and active power losses, particularly in MV networks. In [19], the focus was solely on peak shaving and valley lling, whereas in [20], the focus was solely on energy cost reduction. Some studies concentrate on EVs' capacity to offer control that can enhance the grid's efficiency. For instance, [21] outlines a number of advantages of EVs, including their capacity to make the integration of renewable energy sources easier. Concerning brief time intervals, in [22]. Additionally, [23] demonstrates how advanced centralized PEV charging schemes can both raise the potential benefits of EVs as system ancillary services providers and lessen the negative effects of electrical mobility penetration, such as congestion concerns on distribution grids. Reference [24] offers a power management plan for Secondary Frequency Regulation (SFR) with an integrated fleet of EVs, taking longer time horizons into consideration.

B. THE CONTRIBUTIONS OF THIS PAPER

EVs may be electrical loads and may be also a source of electricity. In this paper, studying a microgrid with the seizure of renewable and non-renewable energy, electrical loads, and EVs is presented. Also, showing the energy generated from each source, studying of EVs as a load and as an energy source, and the influence of EVs on the performance of the grid and its role in supporting the grid at peak times. This study focuses on the modeling and analysis of the renewable energy sources and EVs integration in the microgrid. This study reviews the analysis of the microgrid with EVs, the results have been validated using Matlab/Simulink.

C. THIS MANUSCRIPT IS STRUCTURED AS FOLLOWS

Section II provides a brief technical background on the impact of EV. Section III describes the charging infrastructure. Section IV summarizes harmonic components produced by EV. Section V describes the technology and challenges involved in EVs. Finally, the simulation and results (analysis of the microgrid with electrical vehicle) are shown and discussed in Section VI, Section VIII represents the conclusion.

II. 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 [26] 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 optimisation 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 [27]. 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 [28]. 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.

B. IMPACT ON THE DISTRIBUTION NETWORK

1) 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 [29].

a: 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 [29].

b: 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].

c: 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 [30], [31].

2) 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 [32].

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 [32].

b: CABLES

The high harmonic currents have a detrimental effect on the cable. Consequently, this leads to diminished efficiency and a shorter lifespan [32].

C. 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 [33]. 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 [34]. 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 [35]:

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 [36]. Nevertheless, recent technological developments and the implementation of highly efficient manufacturing procedures have led to a significant reduction in emissions produced during battery production.

1) 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 [37].

2) 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 [38].

3) 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 change-related effects. However, they do contribute to an increase in particulate pollution, resulting in a net overall higher environmental impact compared to existing conventional methods [39].

III. CHARGING INFRASTRUCTURE

Following usage, it is necessary to recharge the electrical vehicle's battery. As the individual battery rating and number of EVs increase, it is crucial to consider the charging demand from the perspective of the power grid. The EV/PHEV charging techniques can be categorized into three distinct groups, as outlined in Table 1 according to the established standards [40].

A. STANDARD CHARGING (MODE 1, 6 h < CHARGING TIME < 8 h)

The conventional charging method for an electrical vehicle with a power of 3.3 kW involves using a socket outlet with a voltage of 230 V and a current of 16 A. Europe primarily uses this charging method, which requires a single-phase AC charger. The charging process for a car typically requires a duration of approximately 6 to 8 hours. Additionally, it

TABLE 1. Charging modes of EV/PHEV.

Type	KVA	Charging time	Charging method
Slow/Normal	1–5	6 h	AC: 1 phase, 230 V, 16/32 A
Semi-fast/Medium	10–25	1–3 h	AC: 3 phase, 230 V, 32/63 A
Fast	180–400	5–15 min	Undetermined, DC off-board charging

features an integrated charger within the car, commonly referred to as an on-board charger. Mode 1 charging is a practical option for charging automobiles at one's own residence or workplace. However, this method raises some safety concerns due to its reliance on the residual current circuit breaker's breaking capacity on the supply side. This safety requirement is compulsory in numerous nations that enforce the adoption of such a device [41].

B. SEMI-FAST CHARGING (MODE 2, 1 h < Charging Time < 3 h)

Semi-fast charging is used for power levels ranging from 7 to 22 kW. This is equivalent to a single phase current of 32 A or a three-phase current of 16 A for a 30 kWh battery. It provides the advantage of obtaining double the available power. It enables a modest charging speed of around two to six hours. This is equivalent to Mode 2 charging. In this mode, the vehicle is directly connected to an AC power supply. The control pilot conductor ensures both equipment and user safety by providing the necessary protection [42].

C. FAST CHARGING (MODE 3, CHARGING TIME < 1 h)

Mode 3 charging refers to the process of charging a car using an external charger that operates on a DC power supply. This mode has the advantage of rapid charging, but it necessitates the use of mature and deployable technology [43].

The following are the available fast chargers:

1) Fast charger
2) Super-fast charger
3) High AC charger.

A fast charger is a charging mechanism that operates using power electronics. It transforms AC into regulated DC to replenish the EV battery. In Europe, quick charger stations are classified under Mode 3. This method is the costliest. Its application is restricted solely to public charging stations. At a rapid charging station, the vehicle's charging speed is comparatively slower than at a gasoline station. The battery requires approximately 25–35 minutes to reach full charge. The power peak of this charging station is approximately 50–75 kilowatts. A super-fast charger aims to recharge a battery in the same amount of time as it takes to refuel a typical car. The recharge period of this component is similar to the "battery swapping" method implemented by the Renault project Better Place. Due to the substantial magnitude of the peak power, a specialized component is necessary to handle the high power. The Mode 3 high AC charger is capable of providing high-power AC charging of up to 250 A. Currently, high-capacity AC sources are employed to recharge a traction battery by means of the traction inverter. In this scenario, voltage adaptation is carried out using an external mains transformer [44].

IV. HARMONIC COMPONENT PRODUCED BY EV

Charging modern EVs introduces harmonic components to the microgrid. The current waveforms have higher harmonic components compared to the voltage waveforms. The level of Total Harmonic Distortion (THD) can have an impact on the electrical system of a microgrid. Furthermore, the THD value will influence the microgrid's power quality. The assessment of THD is crucial in the context of the charging station. The growing utilisation of non-linear loads in electrical cars has led to disturbances in the sinusoidal characteristics of current and voltage signals. Non-linear waveforms consist of harmonic components.

Electric cars utilise AC/DC and DC/AC converters in their charging systems. They are the primary sources of harmonics. Below is a list of the electrical components of an electrical automobile. A battery pack energizes the electrical motor in electric cars. EVs offer a significant benefit in that they produce no emissions and are highly eco-friendly. In addition, they do not utilise any fossil fuels, thereby relying on a sustainable source of energy to propel the vehicle.

The aforementioned harmonics are generated as integer multiples of the primary harmonics at 50 Hz, namely 150 Hz, 250 Hz, 350 Hz, and 750 Hz, representing the 3rd, 5th, 7th, ..., and 15th harmonics, respectively. THD typically arises from the presence of a non-linear waveform within a smart microgrid. Harmonics in the electrical system pose various risks in a smart microgrid. Thermal overload in electrical power transmission lines [45].

1) Excessive heat in power distribution lines.
2) Harmonics manifest as resonance phenomena in the smart microgrid.
3) Lifespan of transformers and electronic gadgets.
4) Disruption of the reactive capacitors.
5) The inclusion of protective switches in a microgrid allows for the timely opening of circuits.
6) Disturbances arise in communication facilities.

Currently, renewable energies play a significant role in smart microgrid systems. These systems are environmentally benign. On the other hand, they are environmentally friendly. THD is a common measurement of the level of harmonic distortion present in smart microgrids. THDv can be defined from Eq. (1) as follows:

$$THD_v = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \cdots + V_n^2}}{V_1^2} \tag{1}$$

If the harmonics are equal to the "0", THD_v will be equal to the "0". Where, V_n, is the RMS voltage of nth harmonic and n = 1 is the voltage of fundamental frequency. THDI can be defined from Eq. (2) as follows:

$$THD_i = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \cdots + I_n^2}}{I_1^2} \quad (2)$$

where, In is the effective current of nth harmonic, and n = 1 is the fundamental of current. When the harmonic components are equal to zero, THD_i will be "0". THD_i value is bigger than THD_v value in microgrids that charging station is located. A controversial situation for PV inverter is the harmonics level. The IEEE 929 standard permits a limit of 5% for the current total harmonic distortion [46].

V. TECHNOLOGY AND CHALLENGE INVOLVED IN EV

A. PROBLEM FORMULATION

The main objective of the proposed study is to reduce losses in the distribution system by implementing the V2G strategy, which is based on the fluctuating load demand.

The power equations for the distribution system are based on the below one:

1) G2V
2) V2G.

Equation (3) gives the operation of G2V [47].

$$PG = \sum_{i=1}^{24} PBL + PEV + PL \quad (3)$$

Here, *PG* is Total power generation *P*BL is base load, *P*EV is the EV load, and *PL* is the Losses.

Equation (4) gives the operation of V2G [47].

$$PG + \sum_{i=1}^{24} PEVDG = \sum_{i=1}^{24} PBL + PL \quad (4)$$

where:

*P*EVDG is the power generated by EV acting as DG.

EVs Power charging, discharging limits [47].

B. V2G TECHNOLOGY

The EV and the grid are mutually beneficial systems for managing both energy and electricity. The electricity grid typically lacks provisions for energy storage. The pumped storage plant's overall capacity does not exceed 2.2%. Ensuring effective control and ongoing management of energy generation and transmission is crucial in order to align with fluctuating consumer demand. EVs are defined as vehicles that are propelled by electrical drives fueled by batteries or hybrid sources. Therefore, they are often compared to traditional vehicles with internal combustion engines. Electrical automobiles have the potential to generate or store electrical energy even when they are stationary, which is a notable advantage. If they possess robust interconnections with several auxiliary components within the system, they are capable of providing electricity to the grid. The term used to describe this type of link is a V2G connection [48]. An EV can be powered exclusively by a battery or fuel cell, or it can have a hybrid structure that includes both of these energy sources. Nevertheless, the main duty is to provide electricity to the power system while it is not in motion or parked. The most vital attributes in power markets are regulation, spinning reserves, and peak power [49]. Batteries exhibit a sluggish rate of charging and discharging, which is why EVs powered by batteries are charged when there is low power demand and discharged when there is high power demand, such as during acceleration or motoring mode. Fuel cell-powered cars derive energy from either liquid or gaseous fuel. PHEV has the capability to operate in either of these modes.

C. CHARGING CONTROL

1) HARMONIC CONTROL

Converters are crucial elements in battery charging systems as they contribute to the accumulation of harmonics in the system. In order to regulate or reduce the presence of harmonics, one can utilize the pulse width modulation technique or utilize a multilayer operation of the converter [50]. Augmenting the quantity of pulses will lead to a significant decrease in harmonics in the Root Mean Square (RMS) current. In addition, techniques for mitigating reactive power can be employed to maintain the undesired harmonics. Harmonics might ultimately result in further power quality complications inside the system, necessitating ongoing monitoring to promptly address unforeseen concerns.

2) COORDINATED CHARGING

The charging of EVs on a wide scale can result in concentrated charging, which has the potential to impact the regulation of the power grid. Therefore, we classify coordinated charging as a regulated load and use it to regulate the grid. The primary objective of this strategy is to optimise economic efficiency while minimising its impact on the grid. We primarily manage the charging process by considering the grid's condition, battery performance characteristics, and consumer requirements. Additionally, it serves to stabilise undesired fluctuations in load demand and prevent the generation of new peak loads. This approach can enhance the dependability, power consistency, and economic efficiency of the distribution network [51].

In order to effectively execute coordinated charging, it is necessary to schedule the charging process and ensure that the distribution of electric vehicles is coordinated with the grid. The concept of a middleman emerged because it was challenging for the grid to directly manage the charging process. Additionally, this objective can be achieved by employing multi-agent technology [52]. The integration of electric vehicles with smart grid systems inherently decreases the duration of the charging process during peak times.

D. FREQUENCY CONTROL AND V2G CHARGER

The purpose of frequency control is to adjust the active power output in order to maintain the frequency within the allowed range, which is defined as $f_0 \pm \Delta f$.

Specifically, metrics for adjusting frequency are categorized into three sub-controls [53]. Primary control is a rapid regulatory mechanism that activates when a frequency deviation exceeds the allowed threshold, with the goal of minimising both the transient frequency and the Rate of Change of Frequency (RoCoF). Secondary control is a regulatory mechanism that acts with a delayed reaction, intervening after the primary control.

The goal is to keep the frequency at a consistent value, even if it falls outside the allowed range. Ultimately, tertiary control occurs subsequent to the secondary control in order to rectify the frequency and bring it back within the acceptable range. The provision of tertiary control is presently fulfilled by high-inertia, high-capacity power plants, such as nuclear or coal-fired facilities. In upcoming power grids, the management of tertiary control is anticipated to be handled by durable, high-capacity storage or demand response systems [54].

Therefore, based on extensive evidence from the literature [55], [56], it is justifiable to believe that V2G chargers primarily and particularly contribute to secondary frequency regulation. The electricity and energy supplied by a V2G fleet for primary and secondary regulation must adhere to legislation and market mechanisms. Secondary frequency regulation is compensated for capacity reserve and activation through a market auction process, which incentivizes EV fleets to offer this service [57].

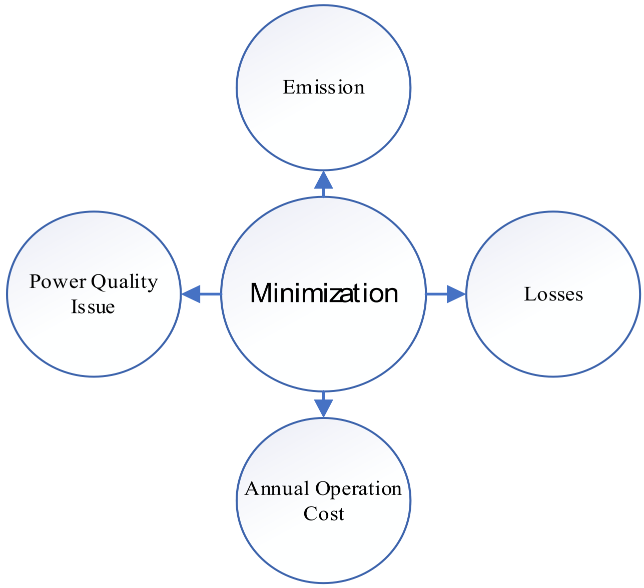

FIGURE 2. Minimization objective functions of electrical vehicle integration into the distribution system.

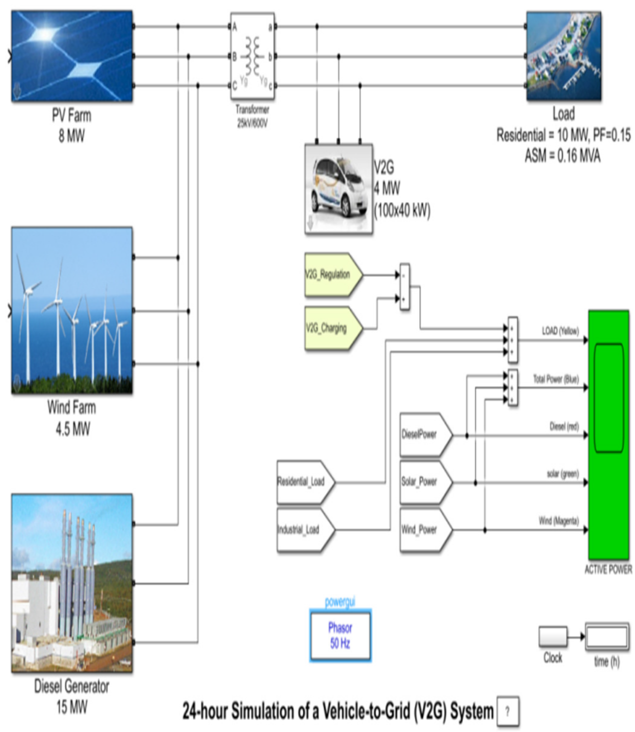

FIGURE 3. Microgrid and electrical vehicles.

VI. ANALYSIS OF THE MICROGRID WITH EV

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. 3.

The microgrid under analysis comprises four components. The main power source is the diesel generators, while a PV facility with wind turbines generates renewable energy. We also employ the V2G system as a load on the network. The microgrid load of this neighbourhood comprises one thousand residences with minimal consumption, along with 100 EVs. The ratio of EVs to households is 1:10. Augmenting the generation of renewable energy contributes to the preservation of the environment. However, the energy generation from renewable energy sources is heavily reliant on environmental conditions.

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.

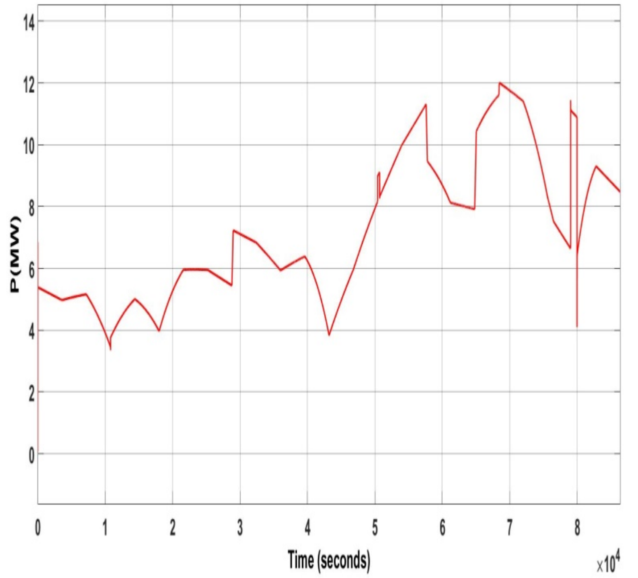

FIGURE 4. Power generated by the generator throughout the day.

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 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 5 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 6 displays the daily energy production of the wind farm in the microgrid.

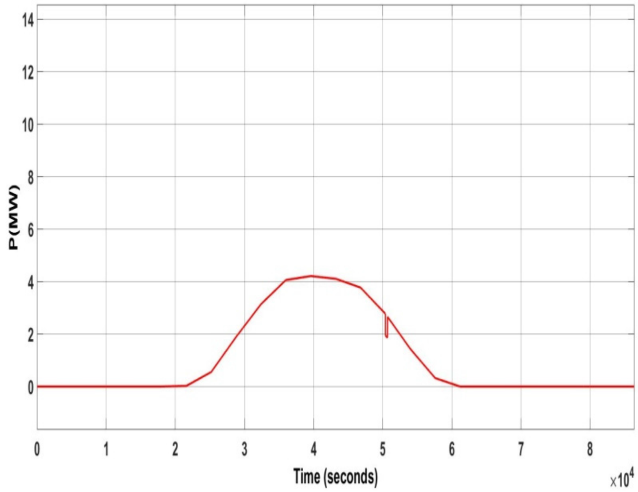

FIGURE 5. Power generated by the solar throughout the day.

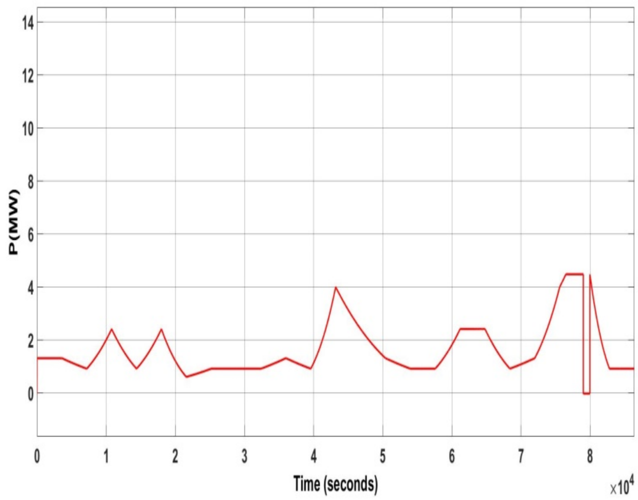

FIGURE 6. Power generated by the wind throughout the day.

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. Figure 7 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 demand

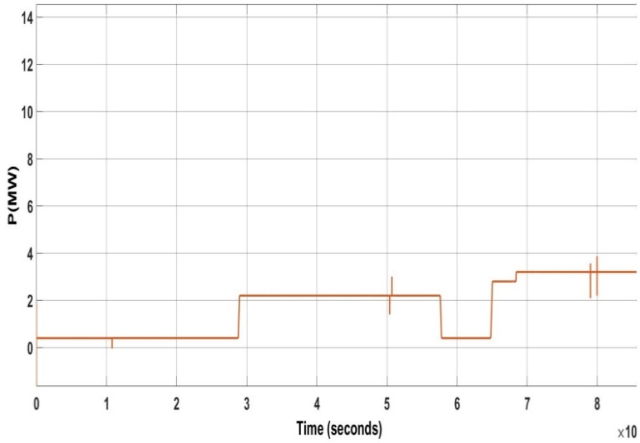

FIGURE 7. Charged and regulated into the microgrid throughout the day.

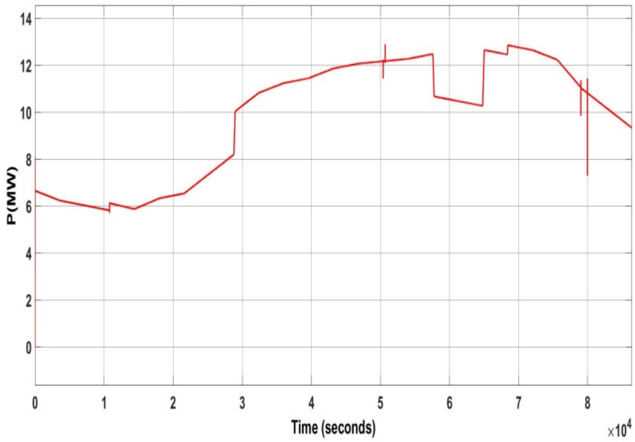

FIGURE 8. Load drawn power from the microgrid during the day.

per 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.

The residential load is represented by the active power drawn at a specified power factor, as illustrated in Fig. 8.

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. 9.

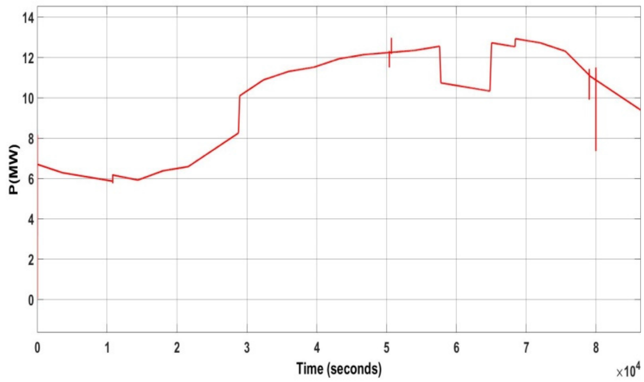

FIGURE 9. Total power generation from microgrid during the day.

VII. LIMITATION AND FUTURE WORK

The lack of sufficient research on the full lifecycle emissions related to lithium-ion battery manufacturing significantly limited this study.

Future work will focus on improving battery performance and increasing their efficiency and life. In addition, reducing the emissions that result from EV manufacturing.

VIII. CONCLUSION

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.

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MONTASER ABDELSATTAR was born in Abu Tisht, Qena, Egypt, in 1983. He received the B.Sc. degree from the Electrical Engineering Department, Faculty of Engineering, Al-Azhar University, Egypt, in 2006, and the M.Sc. and Ph.D. degrees in electrical engineering from the Faculty of Engineering, Minia University, Egypt, in 2011 and 2015, respectively. From 2016 to October 2020, he was a Lecturer with the Department of Electrical and Computer Engineering, El-Minia High Institute of Engineering and Technology, El-Minia, Egypt. From November 2020 to September 2021, he was a Lecturer with the Electrical Engineering Department, Faculty of Engineering, South Valley University, Qena, Egypt, where he is currently an Associate Professor and the Head of the Department. His research interests include renewable energy sources, power electronics, power quality, power system protection and control, harmonics, and optimization algorithms. He has published more than 60 technical papers in international journals and conferences and has supervised and examined more than ten M.Sc. and Ph.D. theses at Minia University, Sohag University, and other Egyptian universities. He has published three international books in the field of renewable energy.

MOHAMED A. ISMEIL (Member, IEEE) was born in Qena, Egypt, in October 1977. He received the B.Sc. and M.Sc. degrees in electrical engineering from South Valley University, in 2002 and 2008, respectively, and the Ph.D. degree from the Channel System Program, Aswan University, in April 2014. From October 2010 to January 2013, he was a Ph.D. Student with the Department of Electrical Drive Systems and Power Electronics, Technical University of Munich, Germany. From April 2014 to September 2018, he was an Assistant Professor with the Faculty of Engineering, Aswan University. Since October 2018, he has been an Associate Professor with the Faculty of Engineering, South Valley University. From March 2020 to November 2022, he was the Head of the Electrical Department, Faculty of Engineering. He is currently an Associate Professor with the College of Engineering, King Khalid University, Saudi Arabia. His current research interests include power electronics applications in wind energy conversion systems, PV interface with the utility, smart grid technologies, digital control applications (PIC, FPGA, and DSP), and power inverter design for renewable applications.

MOHAMED M. ALY was born in Egypt, in January 1972. He received the B.Sc. degree (Hons.) from Assiut University, Egypt, in 1994, and the Ph.D. degree from Cardiff University, U.K., in 2003. From December 2003 to October 2013, he was an Assistant Professor with the Faculty of Engineering, South Valley University, Aswan, Egypt. From November 2011 to April 2012, he was a Postdoctoral Researcher with Faculté des Sciences et Technologies, Université de Lorraine–1. Since October 2013, he has been an Associate Professor with the Faculty of Engineering, Aswan University, Aswan. From March 2015 to September 2015, he was a Postdoctoral Researcher with the University of the Ryukyus, Okinawa, Japan. He is currently a Full Professor with the Faculty of Engineering, Aswan University. His research interests include applications of SFCLs and SMES on power systems, power systems stability, power systems quality and control, and modeling and control of wind turbines.

SALAH SABER ABU-ELWFA was born in Egypt, in January 1995. He received the B.Sc. degree in electrical engineering from the Faculty of Engineering, Al-Azhar University, Egypt, in 2018. He is currently pursuing the M.Sc. degree with the Faculty of Engineering, Aswan University, Egypt.

He was an Electromechanical and Energy Engineer. His current research interests include renewable energy sources, power quality, microgrids, and electrical vehicles.