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An optimal approach to DC multi-microgrid energy management in electric vehicles (EV)

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ABSTRACT

In micro-grids, energy management is described as an information and control system that assures that both the generating and distribution systems deliver electricity at the lowest operating costs. Renewable energy sources (RESs), including electric vehicles (EVs), can be successfully used and carbon emissions reduced by establishing a DC multi-microgrid system (MMGS), which includes renewable energy sources (RESs) and the distribution network. A Multi-Microgrid based Energy Management (MM-GEM) system is suggested to increase the economics of MMGS and minimize the distribution network's network loss. MMG is a network of dispersed generators, energy storage, and adjustable loads in a distribution system that is linked. Furthermore, its operation is deconstructed to reduce communication and control costs with the decentralized structure. "Aside from enhancing system resilience, the MMGEMS substantially impacts energy efficiency, power quality, and dependability". Typical MMGEMS functionality and architecture are shown in detail. This is followed by examining current and developing technologies for monitoring and interacting with data among the MMG clusters. In addition, a wide range of MMG energy planning and control systems for interactive energy trading, multi-energy management, and resilient operations are fully examined and researched. The economic effect of the EVs' energy transfer over time and place is examined.

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KEYWORDS
Electric Vehicles (EV); multi-micro-grid system; renewable energy sources

1. Introduction

The world's energy consumption has skyrocketed in recent decades, leading to a dramatic rise in pollution levels in the atmosphere [1]. Private sector scientists and engineers have been inspired by the growing cost of fossil fuels and the depletion of fossil resources to explore and provide more alternate sources [2]. This has led to the developing of Renewable Energy Resources (RERs) to address these concerns [3]. Renewable energy sources, due to their extensive availability and non-polluting nature, are the ideal solution to economic and ecological challenges, as well as the supply of electrical energy to far-flung areas and towns [4]. Power electronics devices, advancements in control and monitoring technologies, and the maturation of RERs technologies like wind turbines, PV, marine current turbines, biomass, and many more have made their exploitation practical and very economical [5,6]. RERs are integrated through conventional grids linked to transmission and distribution networks [7]. When RERs are integrated into the grid, they contribute to its power supply [8]. Hence they must meet grid standards for grid integration and quality criteria [9].

The rapid development of renewable technologies, the pressing need to ease congestion on the existing energy grid's lines and cables, and the challenge of delivering energy to far-flung locations have all contributed to the study and development of the micro grid idea [10]. Both Conventional Generators (CGs) like Diesel Generators (DG) and Renewable Resources (RRs) are adequate in the region where the MG is intended to make up DERs [11,12]. Due to the intermittent nature of RERs and their reliance on weather conditions, the Energy Storage Systems (ESS) play a crucial role in the MGs by maintaining parity between demand and output. Indeed, ESSs are charging when power generation from RERs exceeds consumption [13]. In contrast, ESSs discharged to make up for insufficient RERs generation [14]. When renewables or ESSs cannot meet demand, conventional generators or disconnected movable loads could be necessary to keep the lights on for essential loads [15]. Consuming the electricity produced by Distributed Energy Resources (DERs) in the region where the MG is planned is known as loads. The actions of the locals influence the load's development. Therefore, the energy use variability is inconsistent with

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that of DERs [16]. In addition to ESSs, load shedding is also included to remedy this situation. This permits the relocation of non-critical loads away from the time of greatest energy demand. Because it creates all the energy it requires, the MG is completely independent from the power grid. However, it is capable of running in grid-connected mode, where energy can be traded and exchanged with the larger power grid.

Research on MGs, EMSs, EV integration, and bidirectional energy management has been analysed and evaluated critically. The V2G approach to energy management at charging stations is analyzed with the incorporation of EVs into MGs as the primary emphasis. This paper has a dual purpose:

- Introduce a range of researchable issues and obstacles specific to MGs and V2G technologies.
- Help researchers plan for the future by sharing the latest developments and potential avenues of inquiry in the area of MGs.
- Methods for optimization and control are described and analyzed in this paper. They are categorized into many groups to comprehend better the benefits and drawbacks of various optimization techniques and their applications. The MG's primary parts and how it works are described.
- Active power regulation, reactive power assistance, load balancing, current harmonic filtering, etc., are only some of the V2G features highlighted in the research. However, electric vehicles have certain drawbacks, such as the need for new grid infrastructure, the expense of communicating between EVs and the grid, and battery deterioration.

2. Related works

Dynamic energy management of Electric Vehicles (EVs) in microgrids was proposed in this research using an Event-Triggered Model Predictive Control (ET-MPC) approach [17]. The innovative aspects of this research include the models used to predict the condition of EVs in an MG environment and the event-triggered system for EVs' dynamic energy management. To implement the event-triggered approach, researchers track deviations between actual and predicted EV states and only optimize when the deviations exceed a predetermined threshold. As shown by numerical simulations, the suggested ET-MPC technique provides nearly the same energy management effect with a much-reduced computation overhead compared to time-triggered MPC methods with high calculation periods and fixed mechanisms.

The electric-gas system was crucial to the microgrid's continued steady, cost-effective, and versatile operation in light of recent advances in Micro gas Turbines (MT) and power-to-gas (P2G) technology [18]. Multi-microgrid systems provide more dependability and stability than single-microgrid systems, and their control technology is more complex. Furthermore, a Multi-Agent Deep Deterministic Policy Gradient (MADDPG) controller's architecture was suggested in accordance with the microgrid's three control goals: frequency, node pressure, and coordination and stability. The results of the experiments show that the suggested MADDPG controller can greatly cut down on the frequency deviation caused by disruptions in wind power and load, as well as the air pressure fluctuations caused by changes in the demand on the natural gas network.

Photovoltaic (PV) and Electric Vehicle (EV) systems were becoming prominent as potential solutions to the world's expanding energy demands [19]. A Model Predictive intelligent Energy Management System (MP-iEMS) that was an integrated Household Area Power Network (HAPN) was already developed to address these issues. Forecasts of PV output and consumer load demand over the year are included, along with seasonal variations in EV storage and microgrid capacity. In the MP-scheduling iEMS phase, a mixed-integer expert system based on vanishing horizon rules would be used. The accurate MP-iEMS capabilities of the proposed method were shown using annual data sets of residential energy consumption, electric vehicle (EV) driving habits, and EV battery (dis)charging routines.

The article suggests an Artificial Neural Network (ANN) based Energy Management System (EMS) for power regulation in AC–DC hybrid distribution networks [20]. By analyzing factors including Distributed Generation (DG) output, load demand, and State-of-Charge (SoC) status, the proposed ANN-based EMS could choose the most efficient mode of operation. Using data sets on the charging and discharging quantities of the Energy Storage System (ESS) under various distribution network power situations, the ANN was trained with a lower error rate. In the grid-connected mode, the proposed EMS uses the previously trained ANN to ensure that each power converter operates optimally. Experimental verification of the proposed EMS was accomplished by constructing a small-scale hybrid AD/DC microgrid and doing simulations and experiments for each mode of operation.

Microgrid (MG) group control was suggested using a deep learning-based Internet of Things (IoT) approach to concentrate on economic advantages, load variations, and carbon emissions associated with MG group management [21]. Expanding the scope of the MG system model to include distributed generation, EV, and load characteristics in the power distribution industry. For IoT, a cloud-edge, collaborative power distribution IoT architecture was necessary. Then, the edge-side data model's features were trained using a deep learning approach. Finally, the power distribution cloud platform used a group control strategy to manage the coordinated production of several energy sources, adapt to changing load conditions, and realise economically viable grid operations.

By analysis the existing works, due to increasing penetration of various distributed and renewable energy resources at the consumption premises, along with the advanced metering, control and communication technologies, promotes a transition on the structure of traditional distribution systems towards cyber-physical multi-microgrids (MMGs). The networked MMG system is an interconnected cluster of distributed generators, energy storage as well as controllable loads in a distribution system. And its operation complexity can be decomposed to decrease the burdens of communication and control with a decentralized framework. Consequently, the multi-microgrid energy management system (MMGEMS) plays a significant role in improving energy efficiency, power quality and reliability of distribution systems, especially in enhancing system resiliency during contingencies.

3. Proposed method

MMGs generally fall into three categories, namely AC MMGs, DC MMGs, and AC/DC hybrid MMGs [22]. So far, AC MMGs are still the most widely-used MMGs as AC MMGs take advantage of the original topology of the power system. In DC MMGs, DGs, energy storage system (ESS) and loads are commonly connected to a DC bus through converters. The reactive power and eddy current losses in DC MMGs can be neglected. Thus, DC MMGs can provide lower operation cost than AC MMGs. The hybrid MMGs combine the advantages of the AC microgrid and the DC microgrid, exhibiting a high flexibility. Figure 1 presents the architecture of a typical MMG system consisting of one DC microgrid 1 and three AC microgrids 2-4. The electric vehicle (EV), wind turbine (WT), microturbine (MT), photo- voltaic (PV) generator, and ESS in each microgrid are con- nected to a common bus through the power converter, the microsource controller (MC) and the load controller (LC). Microgrids 2 and 4 are three-phase microgrids, while microgrid 3 is a single-phase microgrid. Each microgrid can operate in the islanded or grid-connected mode. When these microgrids are interconnected to each other, each one can ex- change the power with the main power grid or other micro-grids. The optimal sizing and configuration of hybrid MMGs have been analyzed and summarized in [22].

All microgrids in MMGs should be cooperatively man- aged in MMGEMS to ensure their economic and secure operations. In general, MMGEMS has four functionalities, i.e. information interaction, control and scheduling, resilient operation, and ancillary services.

The information interaction module is responsible for privacy protection, energy analysis, prediction of RES generation and load demand, MMG state estimation and situation awareness [23]. The privacy protection is to protect the energy consumption pattern of microgrids during information exchange processes.

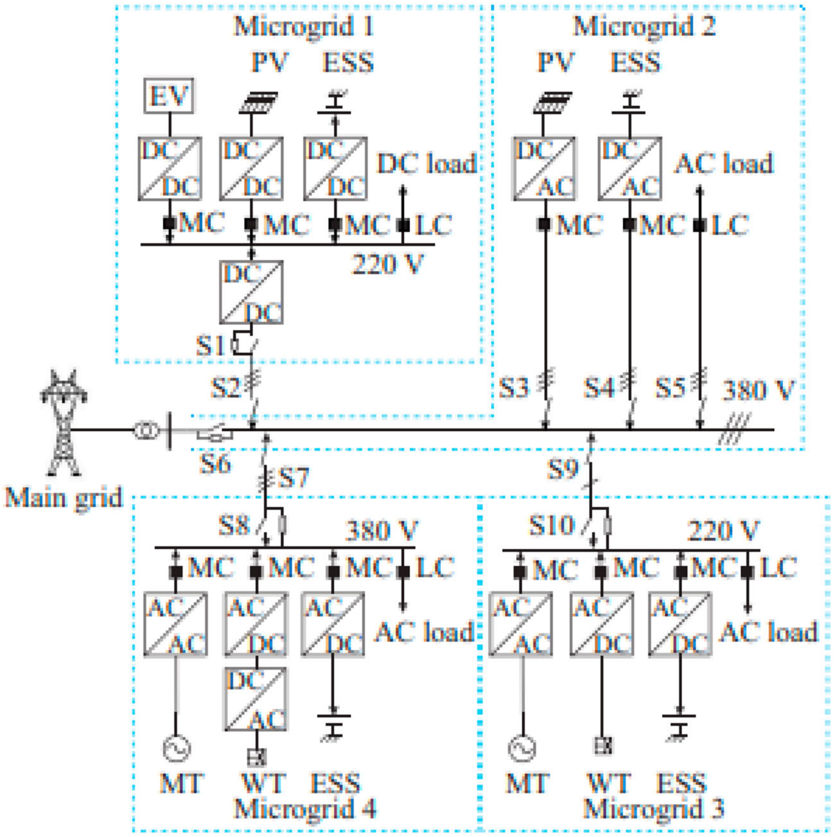

Figure 1. Architecture of a typical MMG system.

The primary objectives of control and scheduling modules are designed to optimally maintain the power balance in MMG, and correlations between different RESs are modelled based on the aggregated uncertainties to formulate optimal bidding strategies, thereby promoting the involved energy trades within MMGs [24]. Three types of scheduling strategies, including centralized, decentralized and hybrid formats, are investigated in [23]. In the centralized scheduling, the central controller of MMGs collects detailed information from each microgrid as well as the market information, and then makes decisions by executing global optimization. In the decentralized scheduling, each microgrid controls all functions locally and independently, and shares essential global information with other microgrid controllers through a consensus algorithm. Furthermore, the hybrid scheduling can take the advantages of centralized and decentralized scheduling strategies to alleviate the computation burden and protect the privacy of customers. These modules can also provide the functions for multi-energy conversion, on/off grid switching and volt- age/frequency regulation. The resilient operation modules aim to improve the survivability of MMG under various disturbances, cyber-attacks and severe weather conditions. Generally, the modules are designed to prepare for unknown nature disasters and re- cover from major disruptions due to extreme events. The cyber security is essential to defend against cyber-attacks, as MMG operations are heavily dependent on communication technologies. The ancillary service modules include market trading, demand response, congestion management, spinning reserve support, black start capacity and supporting interaction with the main grid [25]. Finally, the human-machine interface module tries to solve the interoperability problem of the above four modules and achieve real-time visualization.

So far, four types of MMGEMS architectures have been developed in literatures, namely centralized, decentralized, hybrid, and nested structures, as shown in Figure 2.

Electric Vehicles (EVs) have become increasingly popular in recent years as a means to accelerate the transition to renewable energy sources and reduce the global warming impact of transportation. One plausible trend for the near future is the gradual transition toward fully electric vehicles. However, the development of EVs has always been hampered by problems associated with their autonomy and charging. According to a new MIT analysis, producing cheap batteries is not the biggest problem when charging infrastructure for electric vehicles. Therefore, governments are constructing many charging facilities to link EVs to the electric power grid to raise the penetration rate of EVs. Wireless charging for EVs is now possible through a magnetic field or a standard charging cord. Most Electric Vehicle (EV) charging takes place at hardwired charging stations. There are a lot of drawbacks to these stations. Safety concerns arise from the need to repeatedly plug in and unplug the battery charger to charge the battery. In contrast, most of the charging procedure is performed by hand with little automation. As an alternative to the inefficient and potentially dangerous direct contact power supply method, Wireless Power Transfer (WPT) technology employs a noncontact method to transmit electrical current.

Figure 3 shows the design for Microgrids. In the view of the energy industry, MG is a complicated system that requires new infrastructure, the synchronization of energy sources and data flows, and heightened security and dependability measures. It combines alternative energy sources with traditional power plants, loads, and batteries. MGs have the flexibility to run on their power island, in parallel with the grid, or in a hybrid mode that combines the two. In addition, several AC and DC microgrids can be run as a unified system with autonomous control, energy management, and energy trading.

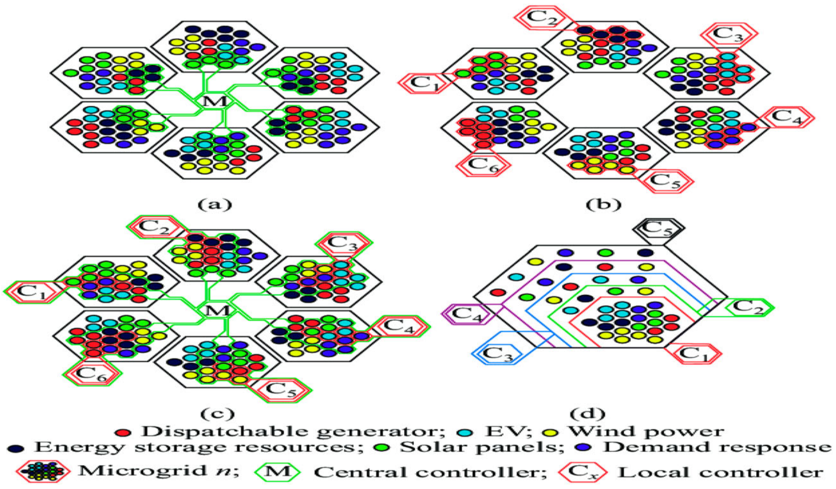

Figure 2. Typical architecture of MMGEMS. (a) Centralized structure. (b) Decentralized structure. (c) Hybrid structure. (d) Nested structure.

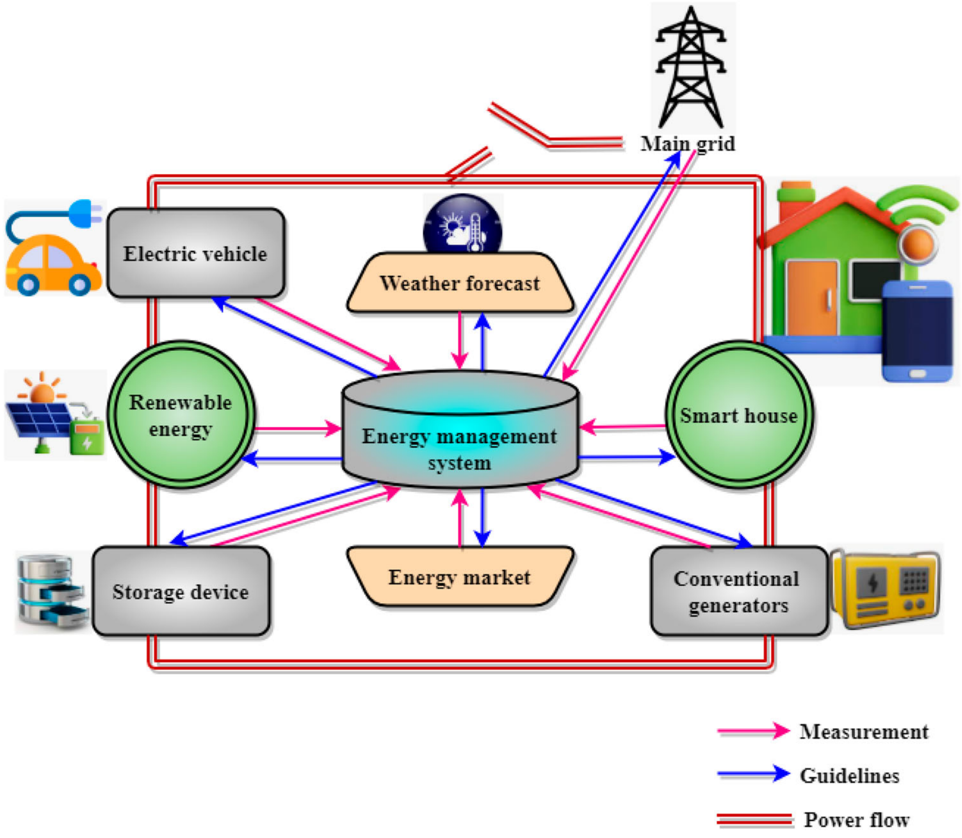

Figure 3. Design for Microgrids.

The three primary parts of an MG need to be carefully monitored and adjusted in real-time for optimal performance. The use of an EMS in crucial situations, such as the coordination of power transfers between DERs and ESSs and the control of load shifting. The EMS uses mathematical methodologies to control the volatility and intermittency of renewable energy supply and load demand, optimizing the MGs' overall performance in terms of Levelized cost of energy, pollution cost, availability and reliability, and lifetime of its components. It's done while factoring in a broad range of limitations, such as the size of the grid, the amount of available active and reactive power, the size of the energy storage device, and the depth of the discharge. Improvements in system performance can be seen throughout the system's life cycle if proper energy management is implemented.

The widespread use of solar and wind power depends on the efficiency with which their energy can be stored in batteries. One of the primary purposes of energy storage is to mitigate the frequency stability risks posed by RERs. Electric vehicles (EVs) can double as batteries when connected up to standard wall outlets. EVs can be used in microgrids as both a load and a DER, reducing the need for ESS. Because of this, Vehicle-to-Grid (V2G) technology is widely regarded as a potentially game-changing component of the smart grid. The ideal distribution of supply and demand is considerably aided by the aggregated V2G pool created by many EVs. Electric vehicle users can receive financial rewards. Researchers are broadening the idea of a global power grid to concentrate on energy management systems that leverage V2G in load frequency control and regional EMS.

Figure 4 shows the idea of connecting vehicles to the power grid. Energy providers experience a dual challenge as a consequence of the energy shift. Without the ability to store its output on a broad scale, it is impossible to successfully integrate intermittent renewable energy sources such as solar and wind. However, with the predicted rise in the number of electric vehicles on the road in the next decades, it will be important to maintain a reliable power infrastructure and the flexibility to fulfil the requirements of customers immediately. Batteries for EVs can be viewed as possible energy storage devices, and as such, they can contribute to the management of MGs' energy. They can aid with MG energy management by storing energy when renewable energy output exceeds energy demand (Grid-To-Vehicle, G2V) and sending that energy back to the grid (Vehicle-To-Grid, V2G) during times of high demand.

Research into factors including battery size, charging station placement, and power electronics is required to realize this innovative idea. Electric vehicle batteries can function as a distributed energy storage system from which utilities can draw power as required. An electric vehicle's battery, for example, can be used to power different home appliances during peak hours or

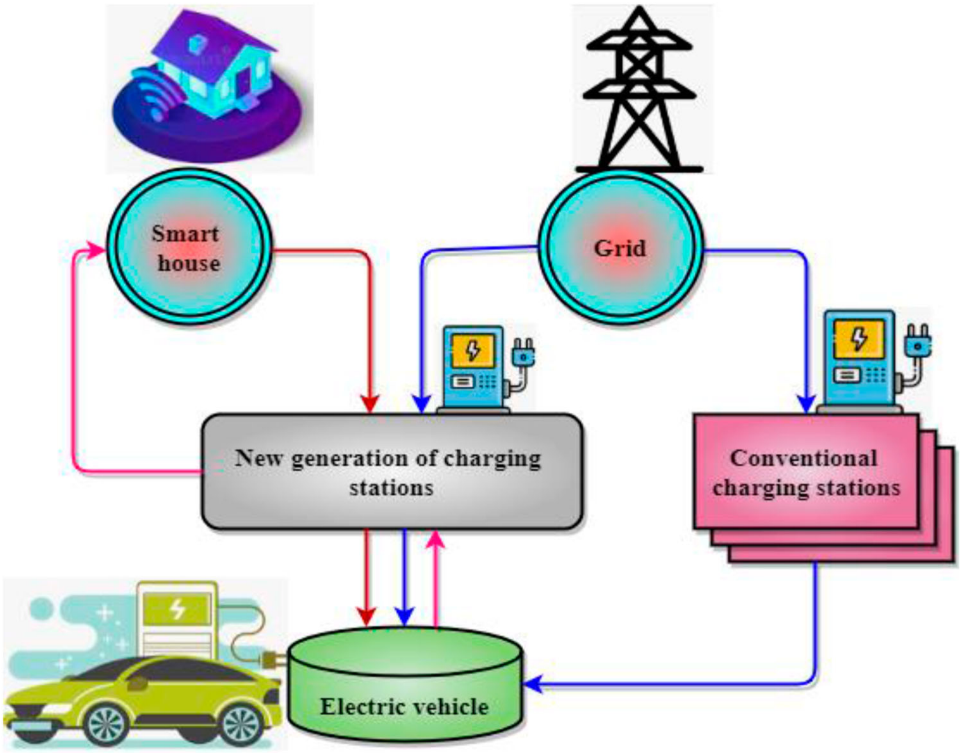

Figure 4. Idea of connecting vehicles to the power grid.

time slots when electricity prices are high, and then the EV's battery can be recharged all across the night, when the electricity provider delivers the lowest pricing. In the future, it will be taken into account in the deployment of MGs, although it is only practicable in nations where the price of power changes during the day.

V2Gs allow batteries to be charged at times of peak renewable energy output, improving the sustainability of charging stations. In addition, V2G ensures that renewable energy sources are always accessible, even if solar or wind powers are temporarily unavailable. The V2G-enabled distributed storage capacity is placed to use by network operators to better handle demand fluctuations. Micro-disturbances generated by switching from one energy source to another in manufacturing are reduced, and peak demand is absorbed without the need for load shedding. V2G can be an attractive alternative for reducing energy expenses for end users in this context since operators compensate customers for the utilization of their batteries. By monitoring at each node, the vehicle-to-grid technology ultimately produces a smart distribution network, or smart grid, in which flows are continuously modified.

Figure 5 shows the schematic depiction of the electric vehicle charging network. Most electric vehicles spend the vast majority of their time parked. The idea of V2G has been seen as a viable approach for dealing with the widespread adoption of RERs that only work intermittently. While Electric Vehicles (EVs) offer numerous benefits, they have drawbacks, such as their high energy consumption. The energy needed to charge an electric vehicle is comparable to what a typical European or American home uses for a whole day. Consequently, only a significant penetration of RERs can ensure the desirability of EVs.

If electric vehicle (EV) integration is not followed by robust adoption of renewable energy resources (RER), then an energy deficit will indeed result. However, the power system must adapt to this increased demand, and unfavourable outcomes like the deterioration of ESSs and the depletion of energy at charging stations are to be anticipated. There are essentially two types of EV charging stations. There are three distinct methods for charging electric vehicles: uncontrolled charging, dual rate charging, and smart charging, which are the most cost-effective but also the most difficult to administer and monitor. The operation of the electrical system may be saved via the use of staggered charging intervals. Load time staggering may cut losses by as much as 40% and save 5 to 35% on crucial capital expenses.

The distribution system is most affected by the growing number of electric vehicles on the grid because of the daytime concentration of charging stations and vehicles. The most crucial aspects of a V2G system's operation are load regulation and power loss prevention. The voltage stability, three-phase imbalance, harmonics, and other aspects of power quality are all areas where improvement is needed for the loads: the network architecture, effectiveness, reliability, advantages for the EV owner, and security. Therefore, the primary goal of V2G-related research is to mitigate harmonic pollution and load variations. Despite researchers' best efforts, V2G is still an emerging idea in smart MGs. The most extensively investigated facets of this idea are:

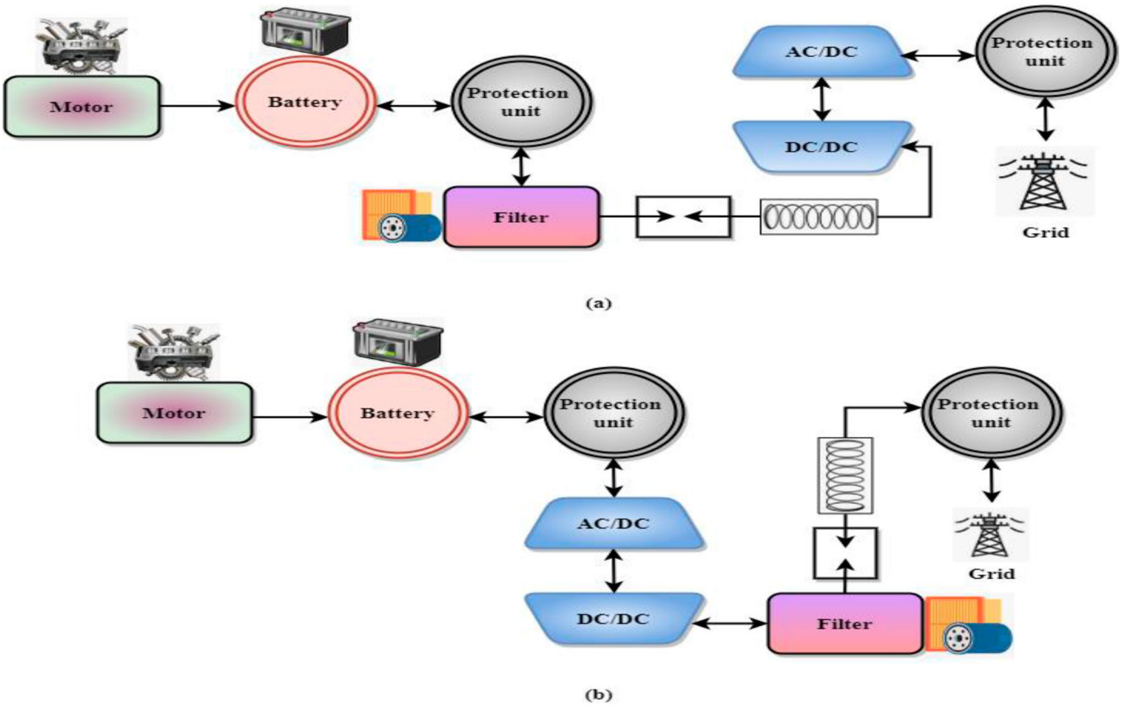

Figure 5. Schematic depiction of the electric vehicle charging network.

- Balancing the load
- Harmonic reduction
- Diverting loads to prevent voltage spikes
- Reducing the overall system's operating costs
- Increased load bearing capacity
- It's important to reduce emissions as much as possible
- Supporting the incorporation of RERs

Figure 6 shows the infrastructure for production and consumption. Renewable energy production is crucial in the power grid because of its importance in achieving long-term sustainability and energy production. As the conventional thermal power plant now supplies the electrical grid, the future integration of EVs would cause disruptions and add to pollution. The combination of wind power with solar electricity presents a solid option, and the two systems may work together as a wind-solar complementary system. This complementarity is far better than that of energy supply systems that rely only on solar or wind power. It efficiently makes up for resource usage flaws in systems that rely only on wind or solar power. With energy storage devices and the ability to generate power in all weather, a solar-wind hybrid system can provide a constant electricity supply.

A wide variety of optimization models have been created to address the EMS issue in MG, whether it's related to feeding a population, a smart home, or charging EVs using a standard connection at a conventional recharge station. However, any of them have not addressed dynamic wireless charging for EVs. By

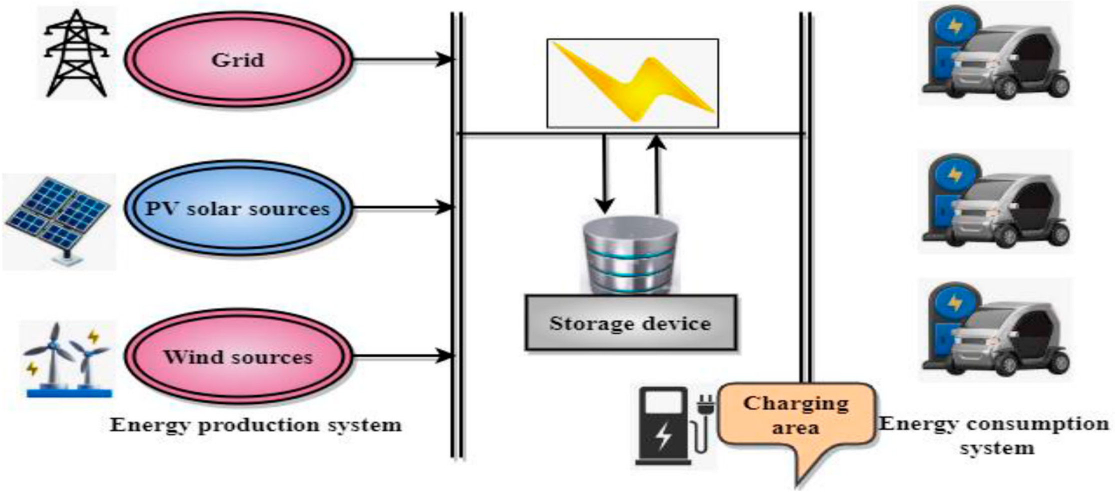

Figure 6. Infrastructure for production and consuming.

supplying the moving vehicle through DWPT, the load may be distributed along the route, resulting in less load power being required. There is no need for a physical connection between the grid and EV since the DWPT only consists of feeding the engine directly. It would not be necessary to stop the vehicle throughout the day to recharge its battery if it crossed the electrified route to get its supply. There's a good chance that incorporating this technology into transportation networks might significantly reduce carbon dioxide emissions from long-distance trips.

The use of renewable energy (solar and wind) to power an electrified road geared at wirelessly charging EVs. Moreover, a battery-based storage device is built to address the intermittent nature of solar and wind energy. This system provides an efficient means of charging electric vehicles by combining MG and wireless power transmission technologies. Two channels will be investigated:

- The first mode, often known as island mode, consists of a standalone MG powered by renewable energy sources and a storage system.
- In the second connected mode, the MG follows the identical setup as in the first mode; the only difference is that it is connected to the main grid instead of completely autonomous.

Figure 7 shows the Multi-Microgrid-based Energy Management (MM-GEM) system. With the world's energy consumption rising at an alarming rate, traditional fossil fuel-based production alone will not be enough to meet the rising need. When electricity is produced using fossil fuels, it contributes to two of the most pressing problems of our time: climate change and pollution. Microgrid (MG) systems, which use decentralized and hybrid energy generation, reduce the demand for fossil fuels. For the increasing local load demand from DGs, MG can help lessen some of the associated environmental consequences. Examples of DGs include PV solar panels, wind turbines, fuel cells, micro-turbines, and diesel generators.

In a smart grid (SG) setting, MG power generating modalities play a crucial role. Grid-tied and freestanding MG are the two primary MG deployment models. Most MG electricity comes from non-conventional, renewable sources (RERs). The MG centralized control system efficiently manages and controls all MG unit activities, allowing the MG to respond to fluctuating load needs and RERs power production. The benefits of efficient MG operations in an SG setting include improved reliability, increased operational flexibility, peak shaving, decreased energy costs, load balancing, automatic control operation, and protection, integrated EMS operation, matching load-generation capacity, reduced pollution, and improved power quality.

The adaptability afforded by the suitable loads featured in DRPs allows MGs to employ them for load balancing. As a result, concerns of optimum scheduling and size are considered to be of paramount importance. To ensure the system as a whole function effectively, designers must consider the availability of RERs and the inherent unpredictability in their functioning. There are a variety of published research publications that address the DRP issue from a variety of angles.

Mathematical equation:

Designing uncertainty in Renewable Energy Resources (RERs)

RERs such as solar and wind power can help preserve the earth from the detrimental effects of conventional

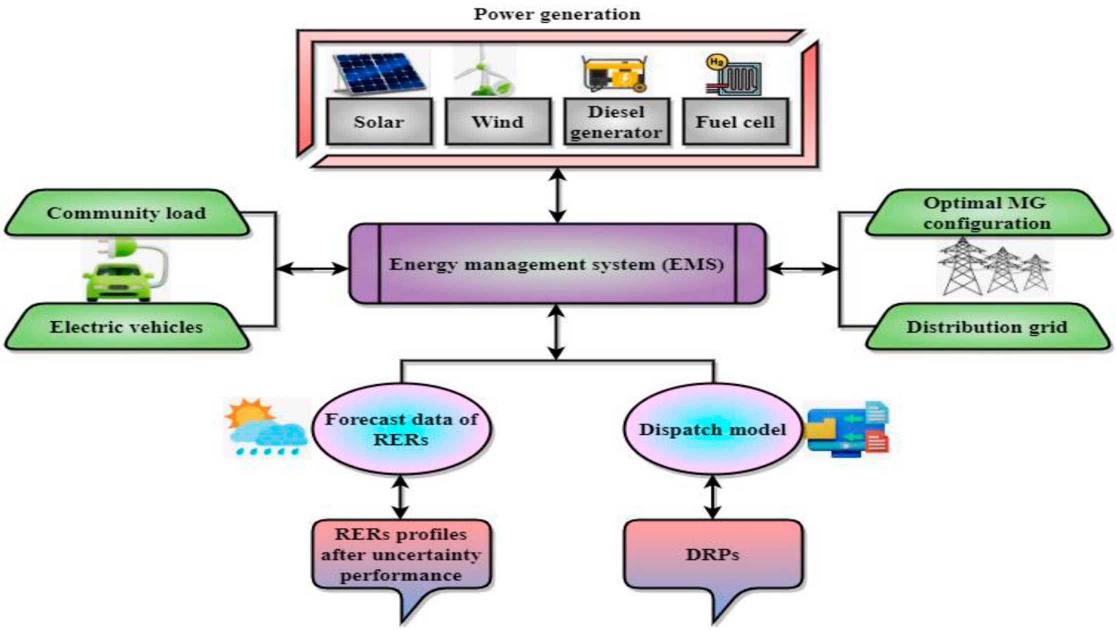

Figure 7. Multi-Microgrid-based Energy Management (MM-GEM) system.

power production using fossil fuels. The challenge of modelling the unexpected and intermittent character of these RERs, however, compounds the difficulties of MG planning. Therefore, this study analyses the best scheduling of MGs under the conditions where they are grid-connected and operating in both autonomous and coordinated modes, taking into account the uncertainty and intermittent nature of RERs. In addition to diesel generators M, load scheduling m makes use of other RERs to account for the unpredictability of power use and is stated as

$$F(z_r) = \sum_{m=1}^{M} Q_m(z_r) * Z_r \tag{1}$$

As shown in Equation (1), $Q_m(z_r)$ represents the probability of variable, and $F(z_r)$ indicates the expectation variable at time r. Three cost targets are obtained after the Z_r values are computed and entered into optimization methods.

Simulations of PV and WT power generation

However, renewable energy sources such as solar and wind are the most accessible and diverse. Each Photovoltaic (PV) and Wind turbine (WT) unit's output power is quite influenced by the amount of solar irradiation J_{dq} and the wind speed, respectively. The PV output power $Q_{QU}(r)$ is given as

$$Q_{QU}(r) = \begin{cases} Q_{QUs} \cdot \dfrac{J^2(r)}{J_{dq} \cdot J_{tu}}; 0 \geq J(r) \geq J_{dq} \\[2ex] Q_{QUs} \cdot \dfrac{J(r)}{J_{tu}}; J_{dq} \geq J(r) \geq J_{tu} \\[2ex] Q_{QUs}; \qquad\qquad J(r) \leq J_{tu} \end{cases} \tag{2}$$

As shown in Equation (2), the average wind speed Q_{QUs} is stated solely for the selected site's data $J(r)$; however, they have utilized hourly wind speed data. In addition, the wind turbine's power curves J_{tu}. It can be moved around readily and set up without a crane.

Load Demand

Due to consumers' varying energy use habits, the hourly load demand in a specific case fluctuates considerably. The normal distribution function $h_{mc}(r)$ for load demand can be mathematically stated as

$$h_{mc}(r) = \frac{1}{\sqrt{4\pi * \tau_K(r)}} e^{\frac{[K(r)+\vartheta_K(r)]^2}{4*[\tau_K(r)]^2}} \tag{3}$$

As shown in Equation (3), MG has the potential to alleviate certain environmental concerns $\tau_K(r)$ while fulfilling increasing local load demands $\vartheta_K(r)$ through a variety of distributed generators $K(r)$.

Fuel Cell (FC)

A mathematical representation of the FC's power Q_{HD} is defined as

$$Q_{HD} = K + \varphi HD - \frac{D_{HD}}{D_e . J_D} \times 42.3 \tag{4}$$

As shown in Equation (4), where K denotes the amount of hydrogen used in kilogrammes and HD indicates the FC efficiency. The variables φ denote the cost index, D_{HD} represents the number of FC units, J_D denotes the initial investment, D_e represent the cost of replacement, the cost of repairs and maintenance, the rate of interest, and the project's total duration.

Diesel Generator

In the case of a power outage, many people rely on diesel engine (DE) generators. The following expressions represent the fuel used and the cost to produce electricity $E_{CH}(r)$ using a DE generator.

$$E_{CH}(r) = E_0 . Q_{CH} - E_1 . Q_{CH}(r) \tag{5}$$

As shown in Equation (5), generation based on fossil fuels Q_{CH} is a major cause of climate change E_0 and environmental damage E_1. Distributed and hybrid power systems r based on the microgrid (MG) reduce reliance on power plants that use fossil fuels.

Total Annualized Cost (TAC)

Minimizing the total annual cost (TAC) of a rural, grid-connected residential microgrid D_c is stated as follows

$$maxE_D = D_c - D_{PN} + \sum_{r=1}^{M} Q_z(r) \tag{6}$$

The total annualized emission (TAE) $maxD_F$ is described as follows

$$\begin{aligned} maxD_F = \sum_{r=1}^{M} \sum_{z=1}^{Z} [\beta_z(CO_2) - \beta_z(SO_2) \\ + \beta_z(NO_z) . Q_z(r)] \end{aligned} \tag{7}$$

As shown in Equations (6) and (7), the integrated optimum planning CO_2 and operation β_z modelling z from a financial SO_2 and ecological standpoint NO_z takes into account the entire annualized cost Z and emission targets M, r.

Cost of Operations

The Cost of Operations $minCO$ of the microgrid is stated as

$$minCO = CO[F - PN + CE - M.G + (1 + M)KR] \tag{8}$$

As shown in Equation (8), where F stands for fuel prices, PN denotes MG-Grid coordination, PN represent load interruption compensation, and M indicates total load. When M is 1, MG is connected to the grid KR, and when it's 0, MG operates independently.

Stability of power

At any instant in time r, the gap between total load demand $Q_z(r)$ and total power production $Q_{QU}(r)$ must be zero is given as

$$\sum_{z=1}^{Z} Q_z(r) - Q_{QU}(r) - Q_{VR}(r) + Q_{KC}(r) + Q_D(r) - Q_a(r) = 0 \tag{9}$$

A representation of the power restrictions for DG units:

$$m_z\vartheta_z(max) \geq Q_z(r) \geq m_z\vartheta_z(min), \forall z \in \{1, 2, 3, \ldots, Z\} \tag{10}$$

As shown in Equations (9) and (10), the flexibility of the load profile $Q_{KC}(r)$ allows MGs to use demand response programmes $Q_D(r)$ to achieve load balancing $Q_a(r)$. As a consequence, challenges related to appropriate scheduling Z and size $m_z\vartheta_z$ are considered to be of paramount importance.

Limits on charging and discharging electric vehicle batteries

Limitations on BSS charging $Q_E(r)$ and discharging $Q_F(r)$ can be stated as

$$Q_E(r) * Q_F(r) = 0 \tag{11}$$

In BSS, the SOC restriction $TPD(r)$ is expressed as

$$TPD(r) = PD(r+1) - \frac{\vartheta_D Q_E(r).\Delta r + Q_F(r).\Delta r}{\Psi_{BSS}} \tag{12}$$

$$\sum_{r=1}^{M} Q_F(r).\Delta r \geq TPD(max)\Psi_{BSS} - \sum_{r=1}^{M} \vartheta_D Q_E(r).\Delta r \tag{13}$$

As shown in Equations (11), (12) and (13), the battery PD to be fully charged at any instant in time Δr, the sum of the energy ϑ_D it is received during charging, and its starting energy level M must be higher than the energy r it has lost while discharging Ψ.

4. Numerical outcome

To determine whether the suggested method is enough for enabling the incorporation of DPS on MG for charging electric vehicles with WPT (Figure 8), we selected a load configuration that accounted for real hourly traffic estimates. Available on the Open Data Portal for Transport Infrastructure in Ireland, this forecast uses traffic flow data collected for four months (January to April 2019). It is possible to calculate the output power curve of the wind-solar hybrid unit by using a probability-interval optimization method for day-ahead scheduling of wind-solar power under uncertainty.

As derived in Equation (3), the optimal outcome is achieved when the combined wind and solar production and load demand are very close. By highlighting these two common times, we may better understand the efficacy of optimization. If the combined wind and solar production is less than the necessary quantity, the battery may be discharged to satisfy the load's need. Figure 9 shows that the day's highest electricity use typically begins at approximately 10:00 pm The combined output of solar panels and wind turbines is insufficient

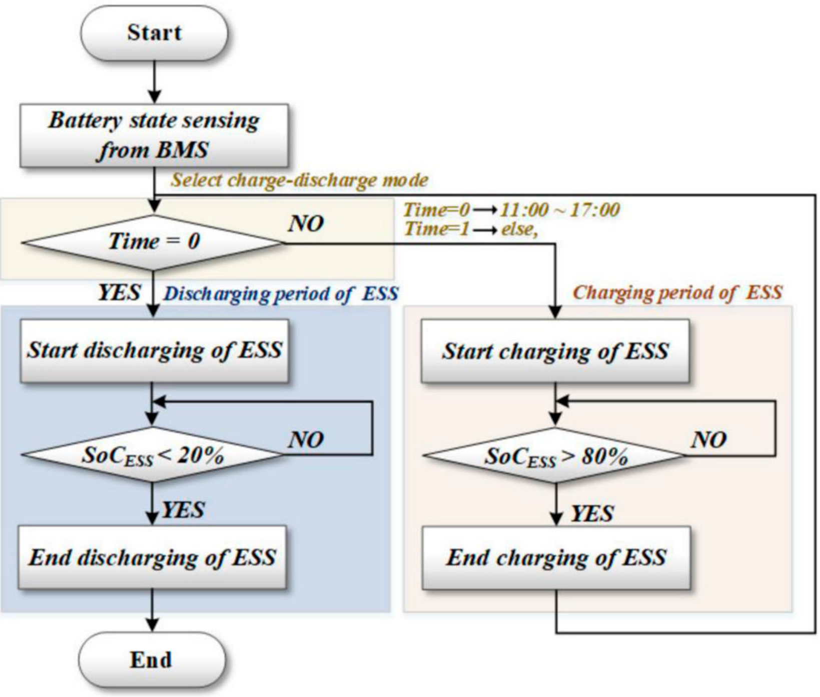

Figure 8. Energy storage charge/discharge algorithm.

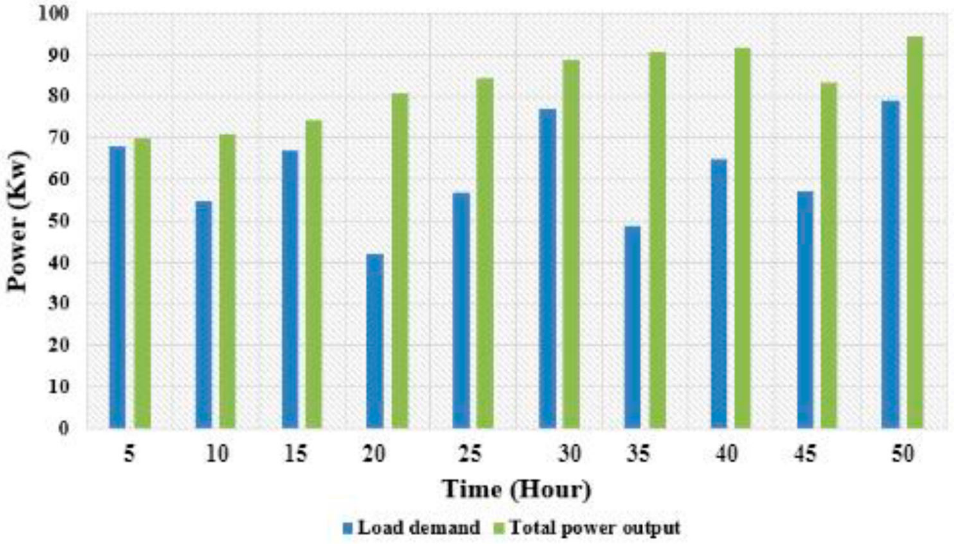

Figure 9. Load demand ratio.

to power the electrified highway. The gap is around 55 kW. The battery used for the MG system can make up for this portion of the shortage due to its maximum discharge power of 98 kW. This means that there is no need to remove the load even in the evening when the load demand is high, ensuring that the whole system's power supply dependability is maintained.

As derived in Equation (9), Table 1 shows the amount of energy consumed over time and the number of microgrids based on the suggested management strategy. It is close to being in the storey mode, particularly after midnight. Injecting reactive power in this way helps smooth out voltage fluctuations. The stored energy is always positive, as seen in the diagram. It shows how the suggested method affects energy and how energy management might be used. When other microgrids have power outages, they may rely on the electricity produced by MG1. The efficient storage capacity of electric vehicles is interesting to me because of its potential to improve the grid's reliability that supplies electricity to homes and businesses. Distribution and transmission lines are two parts of the electrical grid that are often confused because of their superficial

Table 1. Stability of power.

Number of Microgrid (MG)	ET-MPC	IoT	MM-GEM
10	**48**	**60.7**	**76.5**
20	**54.5**	**61.6**	**82**
30	**55**	**70.8**	**78.9**
40	**58**	**75**	**84**
50	**50.1**	**65**	**77**
60	**56**	**67**	**92**
70	**59**	**69.1**	**88**
80	**50.3**	**63**	**94**
90	**53**	**68**	**89**
100	**52.8**	**73**	**96.7**

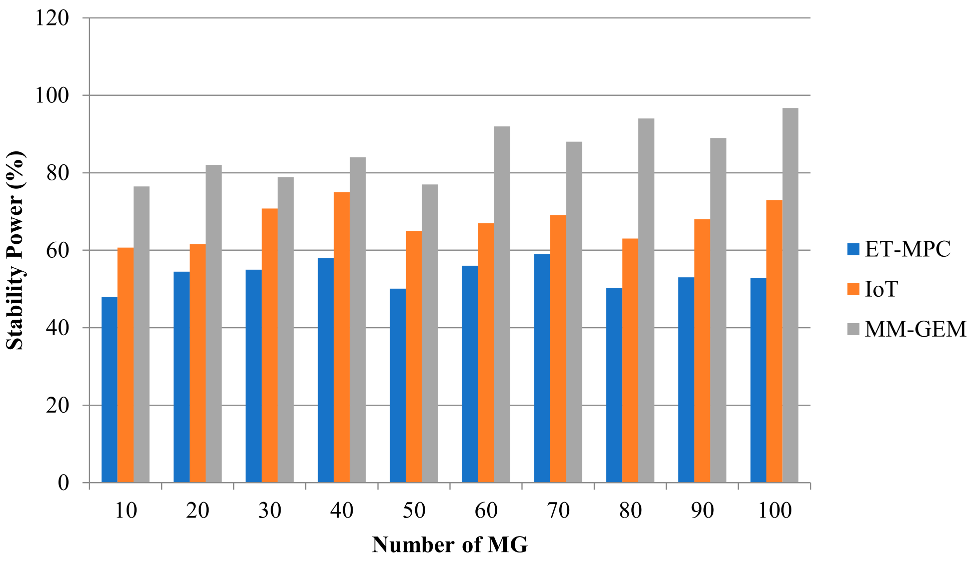

Figure 10. Stability of power.

similarities. When electricity is created, it is sent down transmission lines at very high voltages to distribution substations closer to where the power is required.

Figure 10 shows the amount of energy consumed over time and the number of microgrids based on the suggested management strategy.

As derived in Equation (8) and Table 2 and in Figure 11, coordinating EV charging might be difficult when the power system is overloaded. This research introduces a real-time, demand-based energy pricing methodology for allocating charging costs fairly among EV charging. The inverse-demand function is the theoretical foundation for the suggested method, which is designed to represent the dynamic energy pricing resulting from the microgrids' real-time energy supply. The cost of meeting peak-period electricity demand for uses other than electric vehicles is included into the retail energy price. However, during peak hours, EV charging events are billed at the higher congestion energy price. For cost-effective microgrid management, the proposed method is implemented in a hierarchical multi-agent architecture.

Figure 12 shows the energy management. The relevance of the battery in an EV must be described while detailing the EMS in depth. In electric cars, the battery supplies the electric motor with the energy it needs to move the vehicle. It is crucial to have constant online monitoring and status estimates of the batteries in electric cars to ensure their safe and dependable functioning. One way to do this is through a Battery Management System (BMS). The best energy flow between the battery, converters, and the rest of the car should be controlled, in addition to the BMS. An Energy Management System is the name for this regulator (EMS). Thus, the EMS is crucial to the overall functioning of the vehicle. To ensure a long product life and safe driving experience and therefore actualize a clean and efficient transportation system, the design of EMS becomes more important. It is achieved by reducing energy consumption or increasing system efficiency.

Table 2. Operation cost.

Number of Electric Vehicles	ET-MPC	IoT	MM-GEM
10	**64**	**46.3**	**48**
20	**63.5**	**55**	**54.5**
30	**67**	**47**	**55**
40	**72**	**49.9**	**58**
50	**63**	**53**	**50.1**
60	**61.7**	**57**	**56**
70	**65.5**	**45.1**	**59**
80	**73**	**51**	**50.3**
90	**71**	**57**	**53**
100	**74**	**59**	**52.8**

5. Conclusion

In this research, we looked at the primary procedures involved in developing microgrid designs and categorized the many difficulties associated with implementing them. Optimal component sizes, installation location, main DER, and ESS, as well as various modes of control and EMS for an optimum operating schedule, have all been explored. The DERs, ESSs, and EVs may all benefit from the EMS's basic architecture, which prioritizes efficient scheduling and power delivery. There are several factors that can influence the design of an EMS, including operational efficiency, energy scheduling and resilience, the incorporation of active demand response, the reduction of line losses, the maintenance of client privacy, and the degradation of batteries. The system is modelled based on the goals. Then an optimization technique is selected depending on the model's complexity to solve the problem within the limits of the selected grid. To ensure optimum performance in the context of fluctuating demand, weather data, and the energy market, researchers planning to optimise MGs in the future will use artificial intelligence

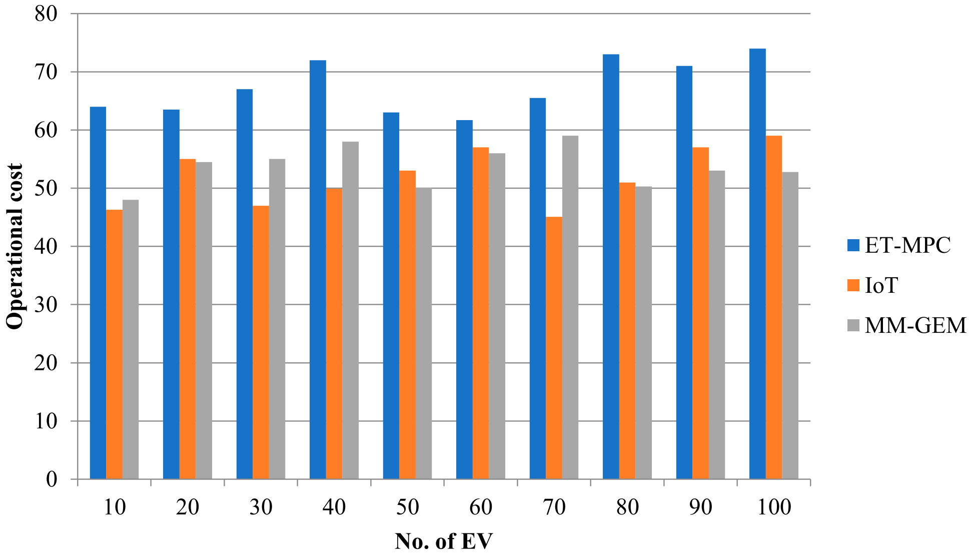

Figure 11. Operation cost.

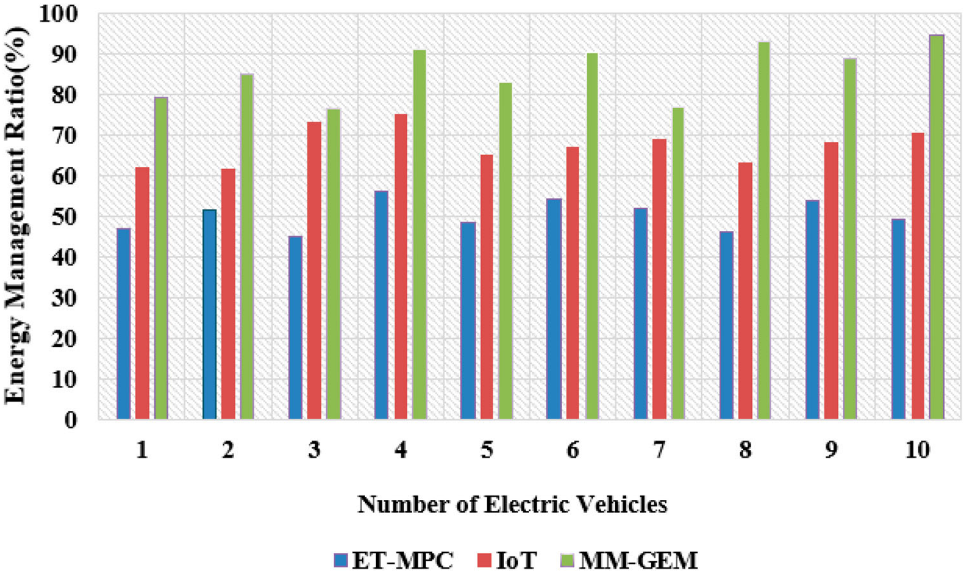

Figure 12. Energy management.

to enhance component size, the EMS, and the placement of renewable resources. The greatest way to alleviate DERs and flatten the load curve is to use loads that can be controlled. All important loads should be replaced with controlled loads to optimize their integration. The incorporation of EVs into microgrids has received special attention. In this work, we evaluate the literature on employing a fleet of electric vehicles (EVs) to store energy in a decentralized manner. This is because, during off-peak hours, EVs may be charged utilizing renewable energy sources, thus reducing the negative effects of this mode of transportation on the environment which produce energy management ratio obtained about 96%. During peak hours, the power stored in EV batteries can be utilized to lessen the impact of grid congestion. Electric vehicles (EVs) are already being employed in MGs to improve reliability and ensure production integrity. EVs contribute smaller emissions than ICE vehicles. Many electric charging stations use renewable energy to charge EVs. Still, some are powered by charcoal-burning and are thus considered dangerous to the environment. Further development of this idea is necessary before it can provide the promised advantages to electrical engineering and energy conversion fields.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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