*Journal of Basic and Environmental Sciences*

*ISSN*
*Online:2356-6388*
*Print:2536-9202*

Research Paper Open Access

# A Survey Study on Optimization of Solar Power Systems Used in Charging Electric Vehicles Based on Artificial Intelligence Techniques.

**Heba Makhlouf Mohamed [a*], Mostafa Eltokhy [a], Reda Hendy Juma Massoud[b], Ayman Haggag [a]**

[a] Department of Electronics Technology, Faculty of Technology and Eduction, Helwan University, Cairo, Egypt.

[b] Department of Education, Faculty of Education- Banha university

## Abstract

This survey study investigates the current state of research on the optimization of solar power systems used in charging electric vehicles (EVs) through the application of artificial intelligence (AI) techniques. Despite significant advancements, a critical research gap remains: the lack of a comprehensive mathematical model designed to minimize the surface area of photovoltaic panels while ensuring sufficient energy to charge EV batteries. This survey aims to address this gap by reviewing existing optimization methods and their application to solar-powered EV charging systems. The primary research questions posed are: "Which AI-based optimization techniques are most effective in minimizing the solar panel surface area required for EV charging?" and "What are the key factors and constraints that need to be considered in developing such a mathematical model?" Key hypotheses include the potential superiority of certain metaheuristic algorithms over others in achieving these objectives. Findings are systematically presented in tables, comparing various algorithms and highlighting their respective strengths and limitations. This study sets the stage for future research focused on developing a precise mathematical model to optimize solar panel usage for EV charging.

**Keywords:** Electrical Vehicles (EVs); Sizing panel; Metaheuristic Algorithms; battery storage.

**Submit Date** **2025-04-30**
**Accept Date** **2025-06-21**
**Published Date** **2025-07-07**
**Doi:** 10.21608/jbes.2025.380575.1018

## 1-Introduction

In recent years, global awareness of climate change and sustainability has significantly increased. Between 1990 and 2014[1], Global carbon emissions have significantly increased, rising from 6 billion to 10 billion metric tons annually, driving widespread efforts to mitigate the effects The global scale of climate change necessitates immediate and comprehensive mitigation strategies .efforts culminated in the Paris Agreement in 2015, although transitioning to a carbon-neutral and sustainable economy has become a vital goal. remains challenging, This is especially challenging for industries with a deep reliance on fossil fuels for over a century, emphasizing the need for renewable energy alternatives has spurred interest in solar energy systems, aiming to reduce the use of oil derivatives, which negatively impact the environment, public health, and economies, particularly in developing countries[2,3].Fossil fuels remain the leading cause of carbon emissions globally, leading to a growing focus on solar energy systems that concentrate solar radiation on panels made of sensitive materials to absorb radiation and convert it into electricity[4]. Since their inception in the mid-20th century, solar energy systems have evolved significantly, driven by advancements in materials, from silicon panels[5] to gallium [6], and, more recently, polymeric panels[7], Despite their contribution to generating clean, low-cost electricity, obstacles such as inconsistent solar radiation, seasonal and climate variations, and insufficient radiation in some regions have hindered their rapid development and widespread adoption. Solar energy storage systems[8], which operate through frequent charging and discharging of batteries, offer a solution by providing stable energy output, making batteries a crucial component in solar energy systems[9].

Traditional The majority of power generation and vehicles still depend heavily on the combustion of fossil fuels. [10], contributing to CO2 emissions[11]. Renewable energy sources, electric vehicles (EVs), and plug-in hybrid electric vehicles (PHEVs) are promising solutions to mitigate CO2 emissions and reduce fossil fuel dependence fuel dependency, shaping These advancements symbolize a pivotal shift towards the future of energy and transportation. [12,14]. Smart grids play a critical role in this transition, improving energy management efficiency, lowering costs, boosting reliability, and integrating renewable energy sources such as photovoltaic (PV) systems and electric mobility[13]. Over the last decade, significant technological advancements have been made, particularly in smart grid infrastructure, real-time communication, and pricing—such as smart meters and advanced information/communication technologies. Efficiently organizing and Recent developments in smart grid infrastructure, including real-time communication and advanced metering technologies, have revolutionized energy systems and could set a new standard for modern power systems [15] Solar-powered vehicles leverage photovoltaic panels to capture and convert solar energy into usable power, are pollution-free and eco-friendly, reducing reliance on fossil fuels and addressing global warming concerns (Dasolar, (n.d.), (Shukla et al., 2019). As solar panel technology becomes Enhanced efficiency and cost reductions have increased, and the accessibility and feasibility of solar-powered EVs are becoming more accessible to the public. Research by Massar et al. (2021) investigated the intricate relationship between autonomous vehicles (AVs) and greenhouse gas emissions, influenced by factors like vehicle economy, travel demand, energy sources, and driving behavior. Their analysis suggests that integrating AVs into sustainable transportation networks could significantly impact greenhouse gas emissions. They also emphasize the need for Further research is needed to develop advanced tools and methodologies to address these complexities effectively and understand these impacts better[16]. The EV market is anticipated to grow by 800% by 2030, primarily due to its potential to cut emissions, reduce transportation costs, and act as distributed energy resources. The concept of Vehicle-to-grid (V2G) systems allows EVs to return excess stored energy back to the grid, improving overall system efficiency and, allowing EVs to transfer stored energy back to the grid, though current infrastructure requires upgrades to support this idea. Transportation electrification (TE) offers EVs that present innovative solutions to challenges such as climate change, fuel economy, and energy security, despite the challenges posed by power quality and grid control issues, necessitating innovative technologies to address these issues. While energy storage units have reduced carbon emissions, the reliance on fossil fuel-generated electricity for charging them remains a concern. Solar energy systems, when integrated with energy storage units, offer an environmentally friendly alternative. The optimal design of these storage units in solar energy systems is critical, considering factors such as capacity, efficiency, and charging/discharging time. Some studies suggest that solar panel designs should align with these factors and the technical specifications of batteries suitable for generating electricity from solar radiation.

Achieving optimal calibration of these factors using traditional statistical models is challenging, leading to inefficiencies in time, effort, and cost without guaranteeing an optimal solution)[18,19].

Recent studies have explored solar energy optimization for various applications. For instance, researchers proposed a mixed random model  Optimization studies often aim to determine the ideal number of solar panels and storage systems for efficiency and cost-effectiveness for residential and non-residential buildings[5], reducing material costs and enhancing performance. Similarly, researchers examined energy source sizes in integrated solar cell systems, proposing different panel and battery configurations to maximize system effectiveness. Their findings indicate that optimal panel area ratios can achieve the highest efficiency at the lowest cost. Another study focused on using stored electric energy in residential buildings, demonstrating that optimizing solar cell systems and electricity pricing can significantly increase energy production. In South Africa, researchers identified the optimal size of energy storage units relative to solar radiation, providing electric energy to residential buildings with satisfactory cost-effectiveness. Additionally, a study explored capacity loss in iron phosphate batteries for EVs, proposing a mathematical model with constraints representing actual manufacturing parameters. The model increased battery operating hours fivefold compared to the factory-designed model[20-21]. Electric vehicles are categorized into Battery Electric Vehicles (BEVs), Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs), and Fuel Cell Electric Vehicles (FCEVs). Each type serves different energy and operational needs [22]

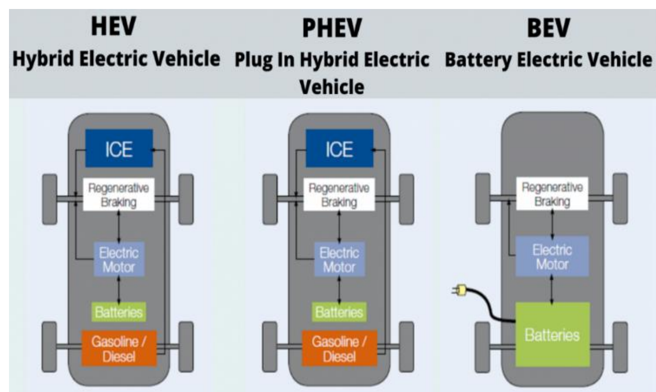


**FIGURE 1**: TYPES OF EV POWERTRAIN[54]

In [23], the researchers also provided examples of the size of energy sources in an integrated solar cell system, and a set of panels and batteries with different configurations were proposed depending on an objective function to determine the effectiveness of the system. Research has shown that optimal configurations of solar panels and batteries significantly enhance system efficiency ratios of the area of the panels used to ensure obtaining the highest efficiency at the lowest cost. In [24], the electric energy stored in residential buildings was used, and examples of Proper sizing of solar panels and batteries is critical to achieving optimal energy performance used in the system were given in terms of cost and return. Energy storage systems are pivotal for the scalability and reliability of renewable energy solutions units and appropriate pricing of electricity, which in turn can increase the volume of energy production of solar units in the construction sector. In [25], the study aimed to determine the best Accurately sizing storage units based on solar energy inputs to optimize energy capture and storage capacity radiation projected onto the solar energy receiving panels of a solar energy system in South Africa to provide residential buildings with electric energy. The study concluded by identifying satisfactory results in terms of cost. On the other hand, the researchers. In [26] examples of capacity loss in iron phosphate batteries are used in electric vehicles, and a mathematical model was proposed with an observable objective and an Optimization model incorporating constraints to reflect realistic parameter values used in manufacturing the battery. The results showed the accuracy of the proposed model in increasing the number of battery operating hours five times that of the factory-designed model.

This research aims to study various solar energy systems for EV operation and explore optimization algorithms to address challenges facing photovoltaic-powered EVs, with the goal of identifying potential solutions for future implementation.

## 2. Methods

Literature and prior experience inform optimization strategies for integrating solar panels and batteries, Studies were surveyed methods of optimization reviewed and their application to solar-powered EV charging systems.

### 2.1 Optimal Sizing of Panel and Battery Storage.

Solar PV benefits from no rotating parts, being on rooftops, and having low maintenance costs. [27]. The total installed solar PV power generation capacity worldwide exceeded 625 GW at the end of 2019 compared to just 23 GW 10 years ago [28]. The annual addition of solar PV capacity exceeded 115 GW in 2019 compared to just 8 GW in 2009. According to estimates, solar PV power generation will provide 3,518 TWh and 7,208 TWh by 2030 and 2040 on the bank [29]. For PV-BES in grid-connected households, an adaptive resilient optimal planning and operation approach was put out in [30]. Uncertainty of solar PV generation and load consumption were modeled using polyhedral sets. Reliability and tractability are the primary advantages of robust optimization for PV and BES sizing over traditional techniques like scenario creation, Monte Carlo simulation, K-means data clustering, and probability distribution functions An overview of current developments of PV battery systems for grid-connected buildings is given in [31]. PV battery architectures for residential sectors are examined in [32]. The economic feasibility of PV battery systems for residential buildings is surveyed in [33]. The economic aspects of integrating solar PV and batteries in the residential sector are reviewed in [34]. In [35], an economic analysis of residential solar PV systems with batteries in the United States is given. A review of the application of distributed solar PV with batteries is given in [36]. The energy management of small-scale PV battery systems in residential homes is reviewed. Batteries can be subject to different operation strategies and bring in different economic benefits. In the first place, batteries increase the self-consumed electricity by storing excess PV generation and discharging to supply consumption later.

A grid-connected photovoltaic battery system for a residential neighborhood is designed in Paper [37]. The PV and BESS systems are sized using a genetic algorithm. The battery time-of-use tariff for electricity. "A group battery offers more value for cost saving, especially for groups with sufficient diversity in their demand," is one conclusion drawn from the simulations. A similar system concept for a 692-home neighborhood is covered in Paper [38]. Software optimization is used. One key finding is that "the most financially attractive solution to RES integration into the SG" is to lower BESS costs.

### 2.2 Electrical Vehicles (EVs)

In [39] highlighted the EVs, technologies demand quick charging to shorten the charging time and enhance range anxiety. Also, describe the system for the fast charging of EVs, which offers constant feedback to the DC-DC converter considering the battery SOC by employing a battery pack control module and tuning the PI controller.

[40] Through an analysis of actual EVs, the study aims to determine the best practices for battery, DC-DC converter, and motor usage from the standpoint of an EV application.

In research [41], the study identifies A stochastic mixed-integer programming model that incorporates variables such as load, solar radiation, and grid pricing to identify optimal configurations, and electricity grid prices as random factors. The findings reveal that The study found that operating under a net metering program requires a higher number of panels and batteries compared to other setups compared to a scenario without net metering. Reference [42] proposes a hybrid operation strategy that integrates multiple approaches. The study compares three distinct operation strategies through a multi-objective optimization process, successfully achieving both a high Net Present Value (NPV) and a high Self-Sufficiency Ratio concurrently. This involves optimizing battery sizing and implementing rule-based operations. In [43] they focus on the development of Intelligent microgrids with commercially available inverters to address the challenges of integrating EV charging infrastructure grids. Extensive experimental tests were conducted to validate new operational modes and the novel charger design for the EV charging station. In [44], the paper introduces Combining Genetic Algorithm-based optimization with load flow analysis offers multipurpose solutions for EV systems anticipates the rise in electric vehicles on the road. Simulation results indicate that this approach optimizes voltage levels and minimizes power loss when installing EV charging stations. The authors in [45] investigate the challenges and limitations associated with solar-powered vehicles, with the aim of proposing solutions for their broader adoption. The study highlights areas for further research, including the development of vehicles capable of harnessing Integrating solar irradiation with various energy sources, including wind and nuclear, strengthens system resilience and reliability. In [46], the research details a controller designed to charge electric cars using the fluctuating power generated by photovoltaic panels. This controller allows homeowners to utilize locally produced energy, dynamically regulating charging power based on available grid capacity when solar power is insufficient. Reference [47] provides a Recent review of Hosting Capacity (HC) methodologies highlighting deterministic, stochastic, and streamlined approaches for EV and PV integration studies and extensive studies to estimate HC efficiently. The review observes that most HC studies on PV and EV charging in low-voltage distribution networks consider performance indices such as voltage magnitude, line loading, and transformer loading. [48] discusses solutions for home-based EV charging using smart home energy management systems to reduce dependency on the grid through renewable integration, software optimization, and government incentives, supported by case studies of particular interest. In [49], the paper examines Metaheuristic techniques such as MSSA, SSA, and Gray Wolf Optimization are employed to optimize hybrid systems in EV charging station applications and identify the best methods for sizing energy system components. Finally, [50] discusses the current challenges and solutions in constructing reliable hybrid fast-charging stations for EVs. The study Strategic power management strategies enhance hybrid charging station efficiency, particularly in highway locations along with optimized control via an improved Snake algorithm to ensure optimal facility operation.

**TABLE I.** Comparative studies highlight the strengths and weaknesses of Lead-Acid, Li-Ion, and LFP batteries for EV applications.

| TYPE / SPEC | Iron Phosphate Batteries | Lithium-ion Batteries | Lead-acid Batteries |
|---|---|---|---|
| **Overcharge Tolerance** | Low. Cannot tolerate trickle charge | Low. Cannot tolerate trickle charge | High |
| **Internal Resistance** | High | Less than phosphate | Relatively weak |
| **Energy Density, Wh/liter** | Moderate | High | LOW |
| **Volt** | 24v | 24v | 24v |
| **Ampere** | 20A | 20A | 20A |
| **Watt** | 500W | 500W | 500W |
| **Weight** | 20 kg | 10kg | 12kg |
| **Price** | 4000L.E | 3500 L.E | 1200L.E |
| **Capital cost ($/kWh)** | 168 / kWh | 700/ 3000 | 300/ 600 |
| **Charging Cycles** | 6000:10000 | 1000:3000 | 300 |
| **Temperature** | 50CO:60 CO | 40O:50O | 40CO |
| **Life Span** | 12 years | 5 years | 2 years |
| **Charging Time** | 3 hours | 4 hours | 7 hours |
| Discharging Time | 15 hours | 5 hours | 4 hours |
| Battery Capacity | 20A-50A-100A - 200A | 3A-6A-9A-12A-20-26A | 12A - 18A -20A-25A- 60A |

These battery energy storage technologies are lead-acid (LA) batteries, lithium-ion batteries (LIB), and Iron Phosphate Batteries, As illustrated in Table I, the LIBs have higher efficiency and lifetime compared to other technologies. However, the LA batteries are traditionally used in electrical systems and their cost is low. It is notable that the LA and LIB are generally used in residential systems.

[51] These studies focused on Smart charging stations and also used the

Technique of PV and V2G power supply Solved Problems by Improving grid stability during peak load hours, [52] the study explores real-time energy management, including optimization problems that are phrased as mixed-integer linear programming. Photovoltaic (PV) sources, stationary storage, a power grid connection, and EV batteries as a load are all components of the DC microgrid. The optimization problem's objective is to reduce the overall cost of energy. The viability of the suggested control and its superiority over the storage priority method is shown by real-time modeling and experimental results under various weather circumstances.[53] suggested an energy management plan that takes into account the varying states of charge of home AC loads, EVs, ESSs, and rooftop PV arrays in order to regulate the power flow between them. A battery as an energy storage system (ESS) and a rooftop photovoltaic solar system are used in a multi-scenario assessment of a grid-connected residential EV charging station.

The optimal search program for the case of a photovoltaic power system in 2018 was presented in the paper [54] After discussing the optimization criteria, the authors came to the conclusion that the best compromise between power reliability and system cost leads to the optimal solution for any photovoltaic power system (hence RES+BESS). For reliability analysis, the relationships between loss of load probability (LOLP) and loss of power supply probability (LPSP) are presented, and for cost issues, the formulas of net current cost (NPC), levelized cost of energy (LCOE), and life cycle cost (LCC) are presented. The following methods are summarized: numerical methods and computer-aided.

[55]A grid-connected MG-based PV/battery/EV hybrid system erected at the Mulhouse campus in France was the subject of this study's functional analysis and performance evaluation. Two PV generators, two inverters, batteries, and an EV make up the two subsystems that make up the entire system. All of them have direct feed-in power or solar self-consumption connections to the power grid. The system installation goals are outlined, one of which is to maximize self-consumption of the generated energy in order to manage demand on-site. It presents and analyzes the behavior of the system's components, particularly the storage batteries and inverters. Two randomly chosen days were used to evaluate the system, both with and without an EV

connection. PV output power, energy efficiency, feed-in power, and self-consumed power were the factors that were examined. Considering the outcomes and performance evaluation,[56] article discusses the importance of EVs while coming on the road and facing many challenges of charging time, range covers, and energy storage system issues. All these issues can be overcome by improving the technological development of BMS in terms of various parameters, including battery sizing, the life cycle of the battery, and battery capacity demand with proper calculations and examples, In,[57] a new configuration of a double-switch step-down converter was proposed. It was experimentally demonstrated that the converter could effectively track the maximum power point for PV application and maintain optimum efficiency during load fluctuation conditions. In [ 59 ], a hybrid fuel cell-based power generation system containing an inductor-coupled step-down converter was used. The converter achieved higher efficiency, non-inverting output, and low input and output ripples. Apart from renewable energy applications, step-down converters are well-established in industries and have a wide range of applications. Buck-boost, SEPIC, Zeta, and Cuk DC-DC converters are preferable for photovoltaic energy generation systems as their performance is better in maximum power point tracking (MPPT) algorithms.[59]These conventional converters can make sure that the system operates with optimum efficiency in varying solar irradiation and load conditions. However, to reduce the output ripples the filter capacitance must be larger than the maximum value of boundary capacitance for buck-boost and Cuk DC-DC converters.[60] To improvise the voltage gain, apply a voltage lift approach. Increasing the voltage lift will result in additional losses that will impact the converter's overall performance. A Z-source with a nominal voltage gain and duty cycle ratio is equipped with an impedance network of inductors. For DC-DC converters, a variety of control strategies have already been developed based on the needs of the application. These include fuzzy logic control, state-space modeling (SSM), modern predictive control (MPC), proportional integral derivative (PID), and slide mode control (SMC).

### 2.3 Applications of the meta-heuristic searching algorithm in EVs.

Optimization techniques play a crucial role in enhancing the performance of EV charging systems. The choice of method depends on the specific application, system complexity, and computational requirements. With ongoing advancements in AI and computational tools, hybrid approaches combining traditional and intelligent optimization methods are expected to become more prevalent in future EV charging infrastructure.

**TABLE 2.** Review of Current Optimization Methods and Their Applications in Electric Vehicle Charging Systems

| Optimization Method | Description | Typical Applications |
|---|---|---|
| **Linear Programming (LP)** | Solves problems with linear relationships between variables. | Cost minimization under time-of-use electricity tariffs. |
| **Nonlinear Programming (NLP)** | Handles nonlinear constraints and objectives. | Battery degradation modeling, non-linear grid constraints. |
| **Dynamic Programming (DP)** | Breaks problems into stages and solves recursively. | Real-time charging control, uncertain pricing scenarios. |
| **Genetic Algorithms (GA)** | Evolution-inspired search algorithm for global optimization. | Charging schedule optimization, and station placement. |
| **Particle Swarm Optimization (PSO)** | Swarm-based optimization method. | Energy management in smart grids with EVs. |
| **Ant Colony Optimization (ACO)** | Path-finding inspired by ant behavior. | Optimal routing and scheduling of EV fleets. |
| **Simulated Annealing (SA)** | A probabilistic method for approximating global optimum. | Multi-objective optimization (e.g., cost vs. time trade-offs). |
| **Game Theory** | Analyzes strategic interactions among multiple agents. | Pricing schemes, and resource allocation among EV users. |
| **Model Predictive Control (MPC)** | Predicts future states and optimizes control actions accordingly. | Real-time adaptive charging, demand response participation. |
| **Reinforcement Learning (RL)** | Learns optimal strategies via environment interaction. | Smart adaptive charging strategies, user behavior prediction. |

The existing studies of metaheuristic methods are classified based on single- and multi-objective optimization studies. In some studies, the applied method was compared with other methodologies.

Electric vehicles (EVs) are universally recognized as an incredibly effective method of lowering gas emissions and dependence on oil for transportation. Electricity, rather than more traditional fuels like gasoline or diesel, is used as the main source of energy to recharge the batteries in EVs, Augmented "-constraint method and Lexicographic optimization Integrating solar energy with EV charging enhances home energy management by balancing multiple objectives efficiently. In [61], research identified the potential for using solar energy Data-driven strategies inform the development of solar-powered EV charging systems for university campus transportation networks located on campus was analyzed, and approaches included installing solar panels on bus stop shelters roofs, utilizing underutilized university Utilizing open spaces and developing solar roads offers innovative PV deployment opportunities made of photovoltaic (PV) materials. The findings revealed variations in capital costs and anticipated energy generation based on siting flexibility. In [62], the authors presented grid-grid-connected EV charging stations equipped with Fuzzy Logic Controllers (FLCs) to efficiently manage energy flow during charging and discharging cycles. A decentralized energy management system was developed to regulate energy flow between the PV system, battery, and grid, with the controller's efficacy verified through MATLAB simulations under several microgrid scenarios. [63] provides a comprehensive analysis of various power management and control techniques, considering the effects of EVs on the electric system. The authors thoroughly examined different EV classes, and their corresponding Detailed analysis of charging infrastructure highlights the technological and operational requirements for widespread EV integration strategies to evaluate the impact of EV adoption on grid infrastructure.In [64], the authors conducted Markov-Chain Monte Carlo simulations to provide insights into mobility and charging load profiles, improving predictive accuracy and deriving charging load profiles. The study also integrated an hourly flexibility Flexibility potentials are incorporated into optimization models for cost-effective energy dispatch solutions over an extended period. The research described in [65] focused on building a solar-powered two-wheeler. The vehicle's permanent magnet DC motor, powering the rear wheel, is driven by voltage generated from a solar panel, which is then stored in a battery. The vehicle's power system achieved enhanced efficiency with the integration of a charge controller and speed controller. The Vehicle Charging Simulation (VeCS) model is explored in [66] to support improved system performance by focusing on employee satisfaction, CO2 emissions, and operating costs. The VeCS model was designed to simulate a smart charging system that combines local photovoltaic input with existing charging infrastructure. Applying the model in a real-world scenario reduced fuel costs by 65% and CO2 emissions by 55% compared to an all-ICEV scenario. [67] discusses user experiences in charging electric vehicles using both independent and grid-connected solar systems, providing an overview of various operational modes. The study suggests that subsequent research should focus on advanced charging management systems. In [68], the research proposes maximizing surface area by extending or bending the panel surfaces using the concept of a topological surface manifold, with shapes such as hemispherical, sinusoidal wavy curves, pyramids, or cones. The findings indicate that geometrical design could increase panel surface area by more than 20%, although curved surfaces present certain disadvantages. The study in [69] computes the Advanced power management strategies to evaluate the impact of EV adoption on grid infrastructure. Finally, in [70], Enhanced Energy Management Systems (EMS) leverage blended modes of operation to improve PHEV efficiency through intelligent transportation systems and cloud technologies. [71] discusses Genetic Algorithm-based EV charging schemes to optimize vehicle-to-grid interactions, improving system usability. In [72], Advanced optimization of EV Fast Charging Stations (EVFCS) using algorithms like PSO, SSA, and AOA delivers efficient designs and management systems. EVFCS structures and manages energy flows between PV systems, Battery Energy Storage Systems (BESS), EVFCS, and the grid. The results showed that PSO provided the best Net Present Value (NPV), followed by AOA and SSA. In [73], alternative Orientation-specific PV panel designs aim to maximize energy generation while minimizing associated costs.using these techniques. [74] introduces a new algorithm, The SW-OBLCSO algorithm improves efficiency and convergence for large-scale EV grid scenarios algorithm was applied in a scenario involving large-scale EVs connected to the power grid, considering economic, environmental, and safety factors. The results showed improvements in Machine learning models that offer robust frameworks for optimizing renewable microgrid operations, including smart charging of HEVs. The simulation results on a test renewable microgrid confirmed the proposed method's high accuracy. Finally, reference [52] presents a multi-objective Pareto-based PSO algorithm that effectively enhances PV hosting capacity and reduces distribution losses simultaneously. While this approach increased PV hosting capacity and lowered losses, it required additional investment compared to other approaches.

[75]The heuristic algorithm suggested in [22] establishes upper and lower limits for the capacity of a battery storage system while

reducing the consumer's energy and storage expenses. The lower limit is the necessary capacity to meet the load when harvested power is inadequate, resulting in the load needing to reduce its consumption. The upper limit represents the essential capacity for holding excess harvested energy and the need for load reduction. The two-layer heuristic method.[76]A renewable hybrid system of photovoltaic, wind power, and batteries, which takes into account the work on electric vehicles, the main search space is improved in optimizing the system size to determine the optimal capacity of the universe and efficient energy utilization. Zhang Shannon, A mixture design of experiments (MDOE) methodology is employed in [77] to define the objective function model. The optimization problem's Pareto-optimal front is produced using normal boundary intersection (NBI). Choose between the best non-dominated outcomes, data envelopment analysis (DEA) is then used.

[78] designed an integrated light storage and charging station using the multi-intelligent particle swarm optimization (MAPOS) algorithm. Determining the charging station's ideal capacity layout and reducing operational expenses and carbon emissions were the goals [79] The charging station study company is based on the combination of photovoltaic power generation and electric energy storage systems with an improved photovoltaic power configuration algorithm. The sustainable energy and charging goals of electric vehicles have been achieved. Used the discriminant algorithm to solve the computer speculation optimization problem in multi-energy capacity allocation with hydrogen production coupled with wind photovoltaic. The superiority of the independent algorithm and the hybrid electricity swarm algorithm has been verified. Badia et al.

[80-81-82-83-84-85-86-87] These studies focused on (AC PV charging station - Electric vehicles and photovoltaic energy - Distribution networks for generating photovoltaic energy for electric vehicles - Renewable energy and renewable energy systems and DC microgrids for electric vehicles - Electric vehicles and mobile self-sustaining systems - Solar energy and energy storage systems and electric vehicles - Electric vehicle charging process - Mobile energy for electric vehicles - Electric vehicles) and used some methods and algorithms to solve some problems related to electric vehicles] The modified stability criterion of MION (one-base infinity) based on the impedance method to evaluate the stability of AC bus electric vehicle charging stations with photovoltaic energy - It also used electric vehicle charging strategies to reduce the peak power demand and solar energy storage - It focused on the alternative-assisted multi-objective probabilistic optimal power flow (POPF) to achieve improved reliability and sustainability of the power system - It also used the hierarchical control method to stabilize frequency fluctuations and regulate the DC bus voltage - A multi-scenario and multi-objective joint optimization approach for distributed power networks to increase energy consumption capacity Photovoltaic and voltage limit optimization – It also improved the decision tree algorithm to reduce the demand on the distribution network at peak times – It used the coordinated control strategy of flexible DC systems to ensure the stability of the network frequency and voltage; – It also used the Peak Load Management Model (PLM) to maintain the stability of the smart grid – It also used charging management and control methods to reduce the negative impact of charging on the network.

## 3. Discussion

With the extensive advancements in optimizing solar power systems for charging electric vehicles (EVs) using artificial intelligence (AI) techniques, a significant research gap persists. This gap lies in the absence of a comprehensive mathematical model specifically designed to minimize the surface area of photovoltaic panels while ensuring they provide sufficient energy to charge EV batteries effectively. Most existing studies have focused on optimizing energy storage and generation separately, but few have addressed the integrated approach needed to achieve both objectives simultaneously. To address this gap, we hypothesize that a mathematical model integrating metaheuristic algorithms can effectively minimize the surface area of photovoltaic panels required for EV charging. The hypothesis is based on the premise that AI-based optimization techniques, particularly metaheuristic algorithms such as the Bees Algorithm, have the potential to balance multiple objectives efficiently. These objectives include minimizing the surface area of solar panels, maximizing energy efficiency, and ensuring sufficient power to charge EV batteries fully. Path Forward for Future Research The findings from this survey indicate the need for a targeted approach to develop and validate a mathematical model for optimizing solar panel usage in EV charging systems. Future research should focus on the following areas:

1. Development of a Mathematical Model:

Formulate an objective function that

integrates both the minimization of the solar panel surface area and the maximization of energy output. Define constraints that encompass technical specifications, environmental conditions, and practical limitations of photovoltaic panels and EV batteries.

2. Application of Metaheuristic Algorithms: Implementing and comparing various metaheuristic algorithms, such as the Bees Algorithm, Genetic Algorithms, and Particle Swarm Optimization provide innovative solutions for addressing the challenges of EV system design. These algorithms are in terms of convergence speed, solution accuracy, and computational efficiency.

3. Simulation and Validation: Conduct extensive simulations to test the proposed model under different scenarios, including varying solar irradiance, battery capacities, and environmental conditions. Validate the model using real-world data to ensure its practical applicability and reliability.

4. Integration with Real-Time Data: Develop mechanisms to integrate real-time data on solar irradiance and EV battery status into the optimization model. Ensure the model can dynamically adjust solar panel configurations based on real-time data to maintain optimal performance. This discussion highlights the critical research gap in the current literature regarding the optimization of solar power systems for EV charging. By proposing a hypothesis and outlining a clear path forward, this study paves the way for future research aimed at developing a precise and practical mathematical model. The anticipated outcome is an optimized solution that minimizes the surface area of photovoltaic panels while ensuring sufficient energy to charge EV batteries, thereby supporting the transition to sustainable and efficient solar-powered EV charging systems.

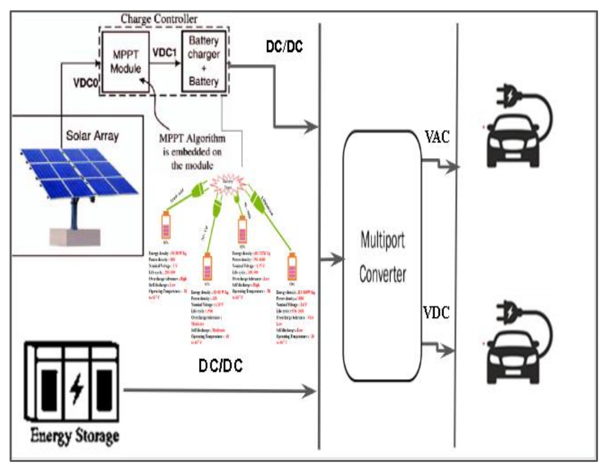


**FIGURE 2:** EVCS MODEL INPUTS AND OUTPUTS

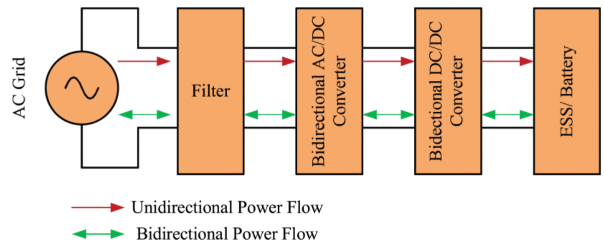


**FIGURE 3:** UNIDIRECTIONAL AND BIDIRECTIONAL CHARGER TOPOLOGY [70].

## 4. Conclusion

This survey highlights the critical gap in the current research on optimizing solar power systems for EV charging: the absence of a mathematical model specifically aimed at minimizing the surface area of photovoltaic panels while ensuring adequate battery charging. By reviewing and comparing various AI-based Bridging gaps in solar-powered EV research requires advanced optimization techniques and validation, and Bees Algorithm, this study identifies effective strategies and key challenges. The findings, organized in detailed tables, underscore the need for a targeted mathematical model Future studies will test the scalability and adaptability of proposed models under real-world scenarios, contributing to advancements in sustainable energy systems.

## 4. Conflicts of Interest

The authors declare no conflict of interest.

## 5. Funding

All work was independently conducted by the authors, without external funding from organizations.

## 6. Author contributions

Prof. Mostafa Ali AlRifai AlToukhy oversaw supervision, conceptualization, and validation, ensuring rigorous methodological standards and Editing Prof. Reda Hendy Juma Massoud contributed significantly to the methodology, review, and refinement of the research Prof. Ayman ElSayed ElSayed Haggag: Supervision, Methodology, Validation, Reviewing. This collaborative effort has produced a comprehensive study aimed at advancing EV technology and renewable energy integration.

## References


[1] Tiseo, I. Annual Greenhouse Gas Emissions Worldwide from 1970 to 2022. Statista. 23 October 2023.Available online:https://www.statista.com/statistics/1285502/annual-global-greenhouse-gas-emissions (accessed on 7 December (2023).

[2] W. U. Rehman et al., "The Penetration of Renewable and Sustainable Energy in Asia: A State-of-the-Art Review on Net-Metering, " in IEEE Access, vol. 8, pp. 170364-170388, 2020, doi: 10.1109/ACCESS.2020.3022738.

[3] Y.L. Zhukovskiy, D.E. Batueva, A.D. Buldysko, B. Gil, and V.V. Starshaia, "Fossil Energy in the Framework of Sustainable Development: Analysis of Prospects and Development of Forecast Scenarios." Energies 2021, 14, 5268

[4] Francisco Javier Gómez-Gil, Xiaoting Wang, Allen Barnett, Energy production of photovoltaic systems: Fixed, tracking, and concentrating, Renewable and Sustainable Energy Reviews, Volume 16, Issue 1, 2012.

[5] Li, C. (2013). Silicon-Based Photovoltaic Materials. In: Zhou, Y. (eds) Eco- and Renewable Energy Materials. Springer, Berlin, Heidelberg.

[6] Andreev, V.M., Sorokina, S.V., Timoshina, N.K. et al. Solar cells based on gallium antimonide. Semiconductors 43, 668–671 (2009).

[7] Feng Liu, et al., On the Morphology of Polymer-Based Photovoltaic, Journal Of Polymer Science Part B: Polymer Physics 2012, 50, 1018–1044.

[8] Yaduvir Singh, Nitai Pal, Obstacles and comparative analysis in the advancement of photovoltaic power stations in India, Sustainable Computing: Informatics and Systems, Volume 25,( 2020).

[9] Mohammad Reza Maghami, Hashim Hizam, Chandima Gomes, Mohd Amran Radzi, Mohammad Ismael Rezadad, Shahrooz Hajighorbani, Power loss due to soiling on solar panel: A review, Renewable and Sustainable Energy Reviews, Volume 59, 2016.

[10] Sandile Phillip Koko, Optimal battery sizing for a grid-tied solar photovoltaic system supplying a residential load: A case study under South African solar irradiance, Energy Reports, Volume 8, Supplement 5, 2022, Pages 410-418

[11] H. Jin, S. Lee, S.H. Nengroo, and D. Har, "Development of Charging/Discharging Scheduling Algorithm for Economical and Energy-Efficient Operation of Multi-EV Charging Station," Appl. Sci.2022, 12, 4786.

[12] Shaukat, N.; Khan, B.; Ali, S.M.; Mehmood, C.A.; Khan, J.; Farid, U.; Majid,

M.; Anwar, S.M.; Jawad, M.; Ullah, Z. A Survey on Electric Vehicle Transportation within Smart Grid System. Renew. Sustain. Energy Rev. 2018, 81, 1329-1349.

[13] Badin, F.; Scordia, J.; Trigui, R.; Vinot, E.; Jeanneret, B. Hybrid Electric Vehicles Energy Consumption Decrease According to Drive Train Architecture, Energy Management and Vehicle Use. In IET Hybrid Vehicle; IET Digital Library: Coventry, UK, 2006; Volume 11, pp. 213-223.

[14] Narayan, A. The Electrification of Transport Could Transform our Future- If We Are Prepared for It. Available online: https://www.weforum.org/agenda/2018/08/we-must-get-it-right-with-electric-vehicles-for-the-sake-of-our-planet/ (accessed on 6 May 2020).

[15] Mwasilu, F.; Justo, J.J.; Kim, E.-K.; Do, T.D.; Jung, J.-W. Electric Vehicles and Smart Grid Interaction: A Review on Vehicle to Grid and Renewable Energy Sources Integration. Renew. Sustain. Energy Rev. 2014, 34, 501-516.

[16] Massar, M., Reza, I., Rahman, S. M., Abdullah, S. M. H., Jamal, A., & Al-Ismail, F. S. (2021). Impacts of autonomous vehicles on greenhouse gas emissions—positive or negative? International Journal of Environmental Research and Public Health, 18(11), 5567.

[17] Markets And Markets. Electric Vehicle Market by Vehicle (Passenger Cars & Commercial Vehicles), Vehicle Class (Mid-Priced & Luxury), Propulsion (BEV, PHEV & FCEV), EV Sales (OEMs/Models) Charging Station (Normal & Super) & Region-Global Forecast to 2030. 2019. Available online: https://www.marketsandmarkets.com/Market-Reports/electric-vehicle-market-209371461.html (accessed on 19 July 2020).

[18] Berthold, F. Integration of Plug-In Hybrid Electric Vehicle with the Grid Using Vehicle-to-Home and Home-to-Vehicle Capabilities. Ph.D. Thesis, Concordia University, Montréal, QC, Canada, 2014.

[19] Fathabadi, H. Novel Solar Powered Electric Vehicle Charging Station with the Capability of Vehicle-to-Grid. Sol. Energy 2017, 142, 136-143.

[20] H. Jin, S. Lee, S.H. Nengroo, and D. Har,"Development of Charging/Discharging Scheduling Algorithm for Economical and Energy-Efficient Operation of Multi-EV Charging Station," Appl. Sci.2022, 12, 4786.

[21] W. Chen, Y. Liu, F. Shi, Q. An, C. Dai, and X. Fu, "Review: Efficiency factors and optimization of Lithium-Ion Battery," 2019 14th IEEE Conference on Industrial Electronics and Applications (ICIEA), 2019, pp. 644-649, doi:

10.1109/ICIEA.2019.8833816.

[22]F. Un-Noor, S. Padmanaban, L. Mihet Popa, M.N. Mollah, E. Hossain A comprehensive study of key electric vehicle (EV) components, technologies, challenges, impacts, and future direction of development. Energies, 10 (8) (2017), pp. 1-82, [10.3390/en10081217](10.3390/en10081217)

View at publisher Google Scholar.

[23] Ibrahim Anwar Ibrahim a, * Tamer Khatib b, Azah Mohamed, Optimal sizing of a standalone photovoltaic system for remote housing electrification using a numerical algorithm and improved system models, Energy 126 (2017) 392e403.

[24] Juha Koskela*, Antti Rautiainen, Pertti Järventausta," Using electrical energy storage in residential buildings – Sizing of battery and photovoltaic panels based on electricity cost optimization, Applied Energy 239 (2019) 1175–1189.

[25] A. ATALLA, et al., "A Mathematical Model for Capacity Optimization of Electrical Vehicles Iron-Phosphate-Based Supercharged Batteries Using Bees Algorithm". To be cited.

[26] Sandile Phillip Koko, Optimal battery sizing for a grid-tied solar photovoltaic system supplying a residential load: A case study under South African solar irradiance, Energy Reports, Volume 8, Supplement 5, 2022, Pages 410-418.

[27] Renewables 2020 Global Status Report, [Online], Available: https://www.ren21.net/reports/global-status-report/?gclid=CjwKCAjw1K75BRAEEiwAd41h1Dxzm8phSkeMwiySxt38eWF7g0Zo5GzfooKdq3f70lAU6Fd5PzeymhoCYRoQAvD_BwE

[28] A. Jäger-Waldau, A. PV Status Report 2019; Publications Office of the European Union: Luxembourg, 2019.

[29] A. Jäger-Waldau, “Snapshot of Photovoltaics—February 2020,” Energies, vol. 13, pp. 930, Feb. 2020.

[30] M. Aghamohamadi, A. Mahmoudi, and M. H. Haque “Two-stage Robust Sizing and Operation Co-optimization for Residential PV-battery Systems Considering the Uncertainty of PV Generation and Load,” IEEE Transactions on Industrial Informatics, Early Access, Apr. 2020.

[31] J. Liu, X. Chen, S. Cao, and H. Yang, “Overview on hybrid solar photovoltaic - electrical energy storage technologies for power supply to buildings,” Energy conversion and management, vol. 187, pp. 103-121, 2019.

[32] V. Vega-Garita, L. Ramirez-Elizondo, G. R. C. Mouli, and P. Bauer, “Review of

residential PV-storage architectures," In 2016 IEEE International Energy Conference (ENERGYCON), pp. 1-6. IEEE, 2016.

[33] J. Hoppmann, J. Volland, T. S. Schmidt, and V. H. Hoffmann, "The economic viability of battery storage for residential solar photovoltaic systems–A review and a simulation model," Renewable and Sustainable Energy Reviews, vol. 39, pp. 1101-1118, 2014.

[34] E. O'Shaughnessy, D. Cutler, K. Ardani, and R. Margolis, "Solar plus: A review of the end-user economics of solar PV integration with storage and load control in residential buildings," Applied Energy, vol. 228, pp. 2165-2175., 2018.

[35] E. Tervo, K. Agbim, F. DeAngelis, J. Hernandez, H. K. Kim, and A. Odukomaiya, "An economic analysis of residential photovoltaic systems with lithium-ion battery storage in the United States," Renewable and Sustainable Energy Reviews, vol. 94, pp. 1057-1066, 2018.

[36] O. M. Toledo, D. Oliveira Filho, and A. S. A. C. Diniz, "Distributed photovoltaic generation and energy storage systems: A review," Renewable and Sustainable Energy Reviews, vol. 14, Iss. 1, pp. 506-511, 2010.

[37] Li J. Optimal sizing of grid-connected photovoltaic battery systems for residential houses in Australia. *Renew. Energy* 2019, *136*, 1245–1254.

[38] Zafar, U.; Bayhan , S.; Sanfilippo, A. Home Energy Management System Concepts, Configurations, and Technologies for the Smart Grid. *IEEE Access* 2020, *8*, 119271–119286.

[39] M. A. Hannan, M. Hoque, S. E. Peng, and M. N. Uddin, "Lithium-ion battery charge equalization algorithm for electric vehicle applications", *IEEE Trans. Ind. Appl.*, vol. 53, no. 3, pp. 2541-2549, May/Jun. 2017.

[40] D. Mohanraj, J. Gopalakrishnan, B. Chokkalingam and L. Mihet-Popa, "Critical aspects of electric motor drive controllers and mitigation of torque ripple—Review", IEEE Access, vol. 10, pp. 73635-73674, 2022

[41] Cervantes, J., & Choobineh, F. (2018). Optimal sizing of a nonutility-scale solar power system and its battery storage. Applied Energy, 216, 105-115.

[42] Zhang, Y., Lundblad, A., Campana, P. E., Benavente, F., & Yan, J. (2017). Battery sizing and rule-based operation of grid-connected photovoltaic-battery system: A case study in Sweden. Energy conversion and management, 133, 249-263.

[43] Petreus, D., Patarau, T., Szilagyi, E., & Cirstea, M. (2023). Electrical Vehicle Battery Charger Based on Smart

Microgrid. Energies, 16(9), 3853.

[44] Deeum, S., Charoenchan, T., Janjamraj, N., Romphochai, S., Baum, S., Ohgaki, H.,.& Bhumkittipich, K. (2023). Optimal Placement of Electric Vehicle Charging Stations in an Active Distribution Grid with Photovoltaic and Battery Energy Storage System Integration. Energies, 16(22), 7628.

[45] Nayak, Ravi, "SOLAR-POWERED MOBILITY: CHARTING THE COURSE FOR A BRIGHTER FUTURE WITH SOLAR VEHICLES" (2023). Electronic Theses, Projects, and Dissertations.1773. https://scholarworks.lib.csusb.edu/etd/1773.

[46] Bakolas, B. V., Bauer, P., & Prins, D. (2014, June). Testing of Smart Charging Controller for dynamic charging from solar panels. In 2014 IEEE Transportation Electrification Conference and Expo (ITEC) (pp. 1-4). IEEE.

[47] Umoh, V., Davidson, I., Adebiyi, A., & Ekpe, U. (2023). Methods and tools for PV and EV hosting capacity determination in low voltage distribution networks—A review. Energies, 16(8), 3609.

[48] Marinescu, C. (2022). Progress in the development and implementation of residential EV charging stations based on renewable energy sources. Energies, 16(1), 179.

[49] Bilal, M., Alsaidan, I., Alaraj, M., Almasoudi, F. M., & Rizwan, M. (2022). Techno-economic and environmental analysis of grid-connected electric vehicle charging station using ai-based algorithm. Mathematics, 10(6), 924.

[50] Elsanabary, A., Khairullah, K., Ab Aziz, N. F., & Mekhilef, S. (2024). Power management and optimized control of hybrid PV-BESS-grid integrated fast EV charging stations. Journal of Energy Storage, 90, 111802.

[51] Ul-Haq, A.; Cecati, C.; Al-Ammar, E.A. Modeling of a Photovoltaic-Powered Electric Vehicle Charging Station with Vehicle-to-Grid Implementation. Energies; 2017; 10,4 [DOI:https://dx.doi.org/10.3390/en10010004]

[52] Cheikh-Mohamad, S.; Sechilariu, M.; Locment, F. Real-Time Power Management Including an Optimization Problem for PV-Powered Electric Vehicle Charging Stations. Appl. Sci.; 2022; 12, 4323. [DOI: https://dx.doi.org/10.3390/app12094323].

[53] Chandra, I.; Singh, N.K.; Samuel, P. A Rule-based Energy Management Scheme for Grid-Integrated PV-Battery-powered EV Charging Station. *Proceedings of the 2022 IEEE Students Conference on Engineering and Systems (SCES)*; Prayagraj, India, 1–3 July 2022; pp. 1-6.

[54] Alsadi, S.; Khatib, T. Photovoltaic Power Systems Optimization Research Status: A Review of Criteria, constraints, Models, Techniques, and Software Tools. Appl.Sci2018,8,1761. https://doi.org/10.3390/app8101761.

[55] Haffaf, A.; Lakdja, F.; Ould Abdeslam, D. Experimental performance analysis of an installed microgrid-based PV/battery/EV grid-connected system. *Clean Energy* 2022, *6*, 599–618.

[56] M. Khalid, F. Ahmad, B. K. Panigrahi and L. Al-Fagih, "A comprehensive review on advanced charging topologies and methodologies for electric vehicle battery", J. Energy Storage, vol. 53, Sep. 2022.

[57]M. Kaouane, A. Boukhelifa, A. Cheriti

Regulated output voltage double switch Buck-Boost converter for photovoltaic energy application.Int J Hydrogen Energy, 41 (45) (2016), pp. 20847-20857

[58] H. Ramírez-Murillo, *et al.*

An efficiency comparison of fuel-cell hybrid systems based on the versatile buck-boost converter

IEEE Trans Power Electron, 33 (2) (2018), pp. 1237-1246.

[59]S. Sivakumar, M.J. Sathik, P.S. Manoj, G. Sundararajan An assessment on the performance of DC-DC converters for renewable energy applications, Renew Sustain Energy Rev, 58 (2016), pp. 1475-1485

[60]P.K. Maroti, S. Padmanaban, M.S. Bhaskar, M. Meraj, A. Iqbal, R. Al-Ammari High gain three-state switching hybrid boost converter for DC microgrid applications, IET Power Electron, 12 (14) (2019)

[61] Ioannidis, R., Iliopoulou, T., Iliopoulou, C., Katikas, L., Petsou, A., Merakou, M. E., ... & Koutsoyannis, D. (2019). Solar-powered bus route: introducing renewable energy into a university campus transport system. Advances in Geosciences, 49, 215-224.

[62] Zhang, Y., Lundblad, A., Campana, P. E., Benavente, F., & Yan, J. (2017). Battery sizing and rule-based operation of grid-connected photovoltaic-battery system: A case study in Sweden. Energy conversion and management, 133, 249-263.

[63] Kumar, M., Panda, K. P., Naayagi, R. T., Thakur, R., & Panda, G. (2023). A comprehensive review of electric vehicle technology and its impacts: Detailed investigation of charging infrastructure, power management, and control techniques. Applied Sciences, 13(15), 8919.

[64] Guthoff, F., Klempp, N., & Hufendiek,

K. (2021). Quantification of the flexibility potential through smart charging of battery electric vehicles and the effects on the future electricity supply system in Germany. Energies, 14(9), 2383.

[65] Arulious, J. A., Earlina, D., Harish, D., Priya, P. S., Rexy, A. I., & Mary, J. N. (2021, November). Design of solar-powered electric vehicle. In Journal of Physics: Conference Series (Vol. 2070, No. 1, p. 012105). IOP Publishing.

[66] Voss, M. F., Haveman, S. P., & Bonnema, G. M. (2021). In-Company Smart Charging: Development of a Simulation Model to Facilitate a Smart EV Charging System. Energies, 14(20), 6723.

[43] Jain, F., & Bhullar, S. (2024). Operating Modes of Grid Integrated PV-Solar Based Electric Vehicle Charging System-A Comprehensive Review. E-Prime-Advances in Electrical Engineering, Electronics and Energy, 100519.

[67] Okello, M. O. (2024). Panel Surface Area Maximization for Increasing PV Performance.

[68] Belany, P., Hrabovsky, P., & Florkova, Z. (2024). Probability Calculation for Utilization of Photovoltaic Energy in Electric Vehicle Charging Stations. Energies, 17(5), 1073.

[69] Martinez, C. M., Hu, X., Cao, D., Valencia, E., Gao, B., & Wellers, M. (2016). Energy management in plug-in hybrid electric vehicles: Recent progress and the perspective of a connected vehicle. IEEE Transactions on Vehicular Technology, 66(6), 4534-4549.

[47] Bibak, B.; Bai, L. An optimization approach for managing electric vehicle and reused battery charging in a vehicle to grid system under an electricity rate with a demand charge. Sustain. Energy Grids Netw. 2023, 36, 101145.

[70] Antarasee, P., Premrudeepreechacharn, S., Siritaratiwat, A., & Khunkitti, S. (2022). Optimal design of electric vehicle fast-charging station’s structure using metaheuristic algorithms. Sustainability, 15(1), 771.

[71] Mouli, G. R. C., & Bauer, P. (2018, June). Optimal system design for a solar-powered EV charging station. In 2018 IEEE Transportation Electrification Conference and Expo (ITEC) (pp. 1094-1099). IEEE.

[72] Yin, W. J., & Ming, Z. F. (2021). Electric vehicle charging and discharging scheduling strategy based on local search and competitive learning particle swarm optimization algorithm. Journal of Energy Storage, 42, 102966.

[73] Lan, T., Jermsittiparsert, K., T. Alrashood, S., Rezaei, M., Al-Ghussain, L., & A. Mohamed, M. (2021). An advanced machine learning-based energy management of renewable microgrids considering hybrid electric vehicles' charging demand. Energies, 14(3), 569.

[74] Lakshmi, S.; Ganguly, S. Simultaneous optimization of photovoltaic hosting capacity and energy loss of radial distribution networks with open unified power quality conditioner allocation. IET Renew. Power Gener.; 2018; 12, pp. 1382-1389. [DOI: https://dx.doi.org/10.1049/iet-rpg.2018.5389].

[75] Jain, F., & Bhullar, S. (2024). Operating Modes of Grid Integrated PV-Solar Based Electric Vehicle Charging System-A Comprehensive Review. E-Prime-Advances in Electrical Engineering, Electronics and Energy, 100519.

[76] Author: Vikrant Garud , (2023). Ev Charging Station Technician, Retrieved from https://sarepenergy.net/wp content/uploads/2023/07/EV-Technician-Handbook-SAREP.pdf

[ 77] M. N. Fonseca, E. D. Pamplona, A. R. Queiroz, V. E. M. Valerio, G. Aquila, and S. R. Silva, "Multi-objective optimization applied for designing hybrid power generation systems in isolated networks," *Solar Energy*, vol. 161, pp. 207-219, 2018.

[78] Dai, Q.; Liu, J.; Wei, Q. Optimal Photovoltaic/Battery Energy Storage/Electric Vehicle Charging Station Design Based on Multi-Agent Particle Swarm Optimization Algorithm. Sustainability; 2019; 11, 1973. [DOI:https://dx.doi.org/10.3390/su11071973]

[79] Khalid, M. R., Khan, I. A., Hameed, S., Asghar, M. S. J., & Ro, J. S. (2021). A comprehensive review of structural topologies, power levels, energy storage systems, and standards for electric vehicle charging stations and their impacts on the grid. IEEE Access, 9, 128069-128094.https://ieeexplore.ieee.org/abstract/document/9536577#:~:text=%5B59%5D.-

[80]. Wang, R.; Sun, Q.; Qin, D.; Li, Y.; Li, X.; Wang, P. Steady-state Stability Assessment of AC-busbar Plug-in Electric Vehicle Charging Station with Photovoltaic. J. Mod. Power Syst. Clean Energy; 2020; 8, pp. 884-894. [DOI: https://dx.doi.org/10.35833/MPCE.2020.000182]

[81] Needell, Z.; Wei, W.; Trancik, J.E. Strategies for beneficial electric vehicle charging to reduce peak electricity demand and store solar energy. Cell Rep. Phys. Sci.; 2023; 4,101287.[DOI:https://dx.doi.org/10.1016/j.xcrp.2023.101287]

[82]. Srithapon, C.; Fuangfoo, P.; Ghosh, P.K.; Siritaratiwat, A.; Chatthaworn, R. Surrogate-Assisted Multi-Objective Probabilistic Optimal Power Flow for Distribution Network with Photovoltaic Generation and Electric Vehicles. IEEE Access; 2021; 9, pp. 34395-34414.[DOI:https://dx.doi.org/10.1109/ACCESS.2021.3061471]

[83]. Tayebi, N.; Najafabadi, A.A.; Naderi, M.S.; Khorsandi, A.; Hosseinian, S.H. Voltage Regulation in a DC Microgrid with Renewable Energy Resources, Energy Storage Systems and Electric Vehicles Station using Hierarchical Control Method. Proceedings of the 2023 5th International Conference on Optimizing Electrical Energy Consumption (OEEC); Tehran, Iran, 28 February–1 March 2023; pp. 35-39.

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

[85]. Mahmud, K.; Hossain, M.J.; Town, G.E. Peak-Load Reduction by Coordinated Response of Photovoltaics, Battery Storage, and Electric Vehicles. IEEE Access; 2018; 6, pp.29353-29365

.[DOI:https://dx.doi.org/10.1109/ACCESS.2018.2837144]

[86]. Wang, T.; Chen, K.; Hu, X.; Liu, P.; Huang, Z.; Li, H. Research on the coordinated control strategy of photovoltaic energy storage system. Energy Rep.; 2023; 9, pp.224,233.[DOI:https://dx.doi.org/10.1016/j.egyr.2023.04.293]

[87]. Said, D.; Mouftah, H.T. A Novel Electric Vehicles Charging/Discharging Management Protocol Based on Queuing Model. IEEE Trans. Intell. Veh.; 2020; 5, pp. 100,111.[DOI:https://dx.doi.org/10.1109/TIV.2019.2955370]