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Innovative Aidriven Strategies For Seamless Integration Of Electric Vehicle Charging With Residential Solar Systems

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Abstract

The recent increase in the need for electric energy in mobility is increasing the market of electric vehicles with a consequent increase of electrical load and because of their internal and often bidirectional battery they can be electric energy producers. The dissemination of electric energy trading in distribution systems among consumers equipped with renewable energy sources represents a promising tool in enhancing the benefits for prosumers. Energy systems represent the beating heart of the future society. The global energy demand should be satisfied targeting the transition toward a more sustainable system, favoring the adoption of renewable energy sources. In this framework, power systems become more complex because of the increasing installed capacity of geographically dispersed non-programmable power sources. In prospective future scenarios, the advent of electric vehicles (EVs) in the market will play a key role because they will represent a bridge between the electrical and transportation systems thus enabling a higher sustainability. Innovative methodologies have to be developed in order to make a new technology work harmonically with older infrastructures and in the trade of energy as well. Infections dynamics is a research area able to model the propagation of "diseases" in a "population".

The methodologies have been tested on a model, demonstrating that, properly controlling the quantity of vehicles trading the diseases, it is possible to significantly attenuate the contagion. If the issue should become an outbreak, engineering aspects have been deeply investigated in order to properly design the vehicles trading energy. The new design would partially increase the energy needed to exchange power and distribute the charging and discharging among the lines would help in reducing the overload. This paper focuses on the innovative application of energy sharing focusing on the dissemination among residential prosumers equipped with both a residential system and an EV, taking into account the novel advances in AI. Moreover, the aim of the manuscript is to demonstrate how combining these technologies is possible to obtain a solution to the optimization model that allows obtaining profits that are lower than 1% in comparison to the optimal.

Keywords: *Electric vehicles, solar systems, artificial intelligence, smart grids, renewable energy, machine learning, electric vehicle integration to the grid, excess solar generation_Scene Setter.*

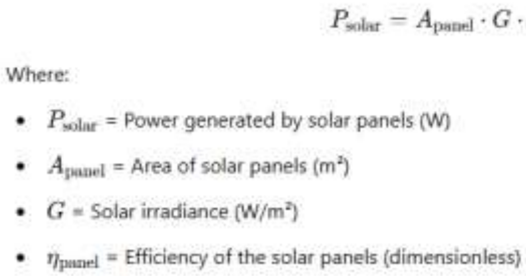
1. Introduction

The 21st century finds modern society at an important crossroads embracing both technological advancements and a frontrunning conscientiousness for the protection of the environment. Growing carbon emissions have become a global issue straining the world's ecosystems and resulting in climate change and global warming. Contemporary civilization turns to technology in an effort to address environmental challenges that have emerged as a direct consequence of industrial growth. On the other hand, growing technological achievements in the area of electronics and energy management systems have led to the development of new grids, which are viewed as the smart energy systems. Electric energy becomes a commodity, and all technological means available are used to produce, deliver and consume it efficiently, with minimum losses, costs, and negative impacts on the environment. Intermittently, distributed energy components emerge, exerting an impact on the way electric energy is managed throughout a microgrid. Promotional politics for cleaner means of transportation grows and an increased demand for residential photovoltaic installation is witnessed. These installations are, by rule, connected to the low-voltage grid. The sum of all the above results in a plethora of challenging energy management problems that need to be addressed to ensure uninterrupted service at low cost, high efficiency and greater penetration of green technologies. The purpose of this study is the development and testing of advanced and innovative methodologies that assist in the analysis and the optimization of the operation of the microgrid components over a wide range of time scales. Artificial Intelligence techniques have been widely used in similar cases and proven capable of providing valuable insight. In the context of the nowadays so-called big data, the sophisticated algorithms commonly employed in these cases are also considered further. Moreover, transformers may also be used, to a lesser extent, to analyze and compare the performance of the algorithms used. The importance of the various technological aspects concerning a microgrid and the necessity for the development of innovative strategies for the seamless integration of the distributed energy components are also highlighted. Finally, an indicative method for the implementation and testing of the developed approaches in real-life environments is presented and discussed.

Fig 1: Incorporation of Electric Vehicles and Renewable Energy Distributed

1.1. Background and Motivation The rising concerns about the depletion of fossil fuels, environmental hazards, and exponential growth in energy requirements have directed the concentration of many countries around the globe towards renewable energy resources. As a final consumer of energy, the residential sector should focus on the expansion of solar energy for catering to its own energy requirements as well as contributing to the national grid. Since public power networks are designed for unidirectional power flow, the connection of distributed generators like solar power and biogas producing generators raises many technical problems that need to be addressed. Hybrid power systems can be utilized as distributed generations since they are able to feed the surplus power to the existing lines rather than local line congestion, which is a possible risk in off-grid stand-alone systems due to reverse power flow. Furthermore, the combination of passive filters and active power filters integrated with the grid connection of three-phase three-level inverters also needs to be investigated, which improves the power quality of the connected line through standardized control. It is clear that adequate planning and coordination of the power utilities and the system consumers of a country, looking to the utilization of renewable energies as distributed generations together, could improve grid power quality and mitigate possible problems. PV panels convert sunlight directly into electricity and form residential solar power generation systems that are safe and environmentally friendly with low operation maintenance costs. By adding energy storage facilities, it can be used as backup power with continuous power development during grid power shedding. Many methods are presented where EV charging methods are integrated with solar power. But still, more innovative techniques should be invented for the maximum integration of EV charging with residential solar systems. So, the seamlessly innovative strategy of integration of EV power to charge residential solar power is explored, which seamlessly overcomes the electric consumption from the public power grid on peak sunny days. This is a cutting-edge ongoing research of theoretical formulations.

Equ 1: Solar Power Generation Equation



$$P_{\text{solar}} = A_{\text{panel}} \cdot G \cdot \eta_{\text{panel}}$$

Where:

- P_{solar} = Power generated by solar panels (W)
- A_{panel} = Area of solar panels (m²)
- G = Solar irradiance (W/m²)
- η_{panel} = Efficiency of the solar panels (dimensionless)

1.2. Research Objectives The research work described in this paper is about the seamless integration of electric vehicle (EV) charging with residential solar systems and will prove to be beneficial for higher efficiency electricity use. Own electricity generation from solar power will be preferred over the conventional grid electricity and a maximum amount of electricity will be used from the solar PV system. The proposed work will contribute by developing novel artificial intelligence (AI)-driven strategies for the seamless integration of EV charging with residential PV systems. In this research work, it is assumed that the residential solar systems are already installed and the problems are related to the best usage of available electricity. However, the same concept may also be applied to the seamless integration of EV charging cum solar power systems. AI-driven strategies will be developed to automatically switch to the very less conventional electricity use when such electricity is generated by solar PVs. Uniform distribution of own electricity is preferred among different appliances using electricity and by using the developed strategies no appliance will dominate the usage of own electricity.

It has been observed that the use of electricity generated from solar power is generally liked by electric vehicles (EVs). Generation from solar panels and the use of EV cars has incrementally increased worldwide manifold. Like EV systems, solar systems are also being sold along with the offer of the "installation and do nothing else" for the better "customer experience." Goals of the proposed work are to investigate the operating load profile of PV (photovoltaic) equipped residences and EV (Electric vehicle) loads. Develop heuristic-based different strategies to intelligently match EV charging with solar generation by considering the user comfort level. Evaluate the reliability and economic efficiency perspectives of the appliances being charged by intelligent charging strategies. Assumption and the associated research direction will be highlighted. Both the challenges of the energy system, and opportunities resulting from these challenges will be detailed. There is also a focus on AI-driven strategies with the expectation of enhancing efficiency and energy likeliness within the system using EVs. Develop a comprehensive framework that turns the potential challenges into opportunities by proposing AI-driven charging strategies for EV integration within the RESs. Considering the assumptions, the research direction starts with a proposed framework, and its systematic components. Subsequently, the research focus moves on the strategies providing an exhaustive review of the state of the art. The challenge and opportunity are addressed via the AI-driven EV charging strategies.

2. Electric Vehicle Charging Infrastructure

The market for electric vehicles is set to grow significantly. In the United States, the Biden Administration has rolled out a plan that envisions half of all new cars to be electric by 2030. The UK's announcement to ban the sale of new petrol and diesel cars by 2030 is equally impactful. As internal combustion engine vehicles are phased out, electric vehicles are being introduced, which would necessitate a radical revamp of the existing fuel supply infrastructure. The electric vehicle charging infrastructure is in its infancy, with an environment reminiscent of the oil drilling 'wild west' of over a century ago. The road to a resilient future-proof telematics-based charging network is fraught with technical, organizational, and geo-political tensions. A variety of infrastructure models are emerging, each with pros and cons depending on a specific scenario: faster chargers being more expensive; home installations requiring a compatible off-road parking space; and Embassy building temporary chargers can irk local residents. The current infrastructure is very much at the embryonic stage, spanning the funky visual magnetic inductive chargers on Westminster Bridge or the 7-kW heavy-duty EV chargers next to the headquarters of Royal Dutch Shell. As an EV driver, these perplexing arrays of gunmetal gray-frosted pantographic arms induce trepidation rather than relief. The exponential growth of the fleet cannot guarantee that a charging sea will rise beneath EV drivers. Embarking on an analysis of some of these inadequacies starkly reveals the wilderness awaiting the nascent EV market. It elucidates how malfunctioning infrastructure breeds veiled contempt for EVs and stalls widespread adoption in its tracks before a drivetrain expands its last joule of energy from an 80-kW module. The charging infrastructure is central to electric vehicle adoption, tantamount to the roll of railhead junctions in railway network development. Addressing the myriad factors inhibiting its seamless proliferation is the first step in its eradication, kickstarting the zero-carbon transition to sustainable transport. Ultimately, recharging the telematics-based grid is not about the number of gunmetal-gray networks but the integration of an adaptive, ubiquitous, cosecant-resilient nexus that anticipates, tracks, and manages the always-on demand for electricity whenever and wherever it may occur.

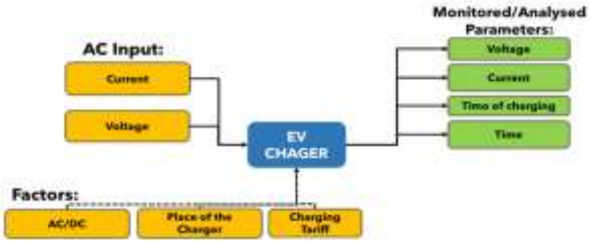


Fig 2: Artificial Intelligence-Based Electric Vehicle Smart Charging System

2.1. Current Challenges Electric vehicles (EVs) are a key mitigant in global efforts to reduce atmospheric emissions from transportation. Due to the increasing popularity of EVs, charging infrastructure is an important issue in cities and residential areas. Energy management systems (EMS) that serve to optimize energy use can operate by exchanging data over the internet. EVs can be related to smart grids/cloud/V2G/V2H/V2X systems through communications networks. In the case of cities, the management of energy of EVs has possible impacts on different infrastructures and operators. Low income urban areas and the marginalization of EV communities existing EMS models often have the limitation of being unidirectional when implementing applications with V2G or V2H. Here, a new model is proposed, in which the energy management based on the EM data of EVs is bi-directional, taking into account the parameters of various communication protocols. The electrical grid is responsible for the delivery of energy to meet the load requirement of the users at a designated point. Similarly, the employment of modern technology in the generation of electricity is popularized by the grid, categorized as a smart grid, and numerous desired results are reported. This was crucial to effective two-way communication between the utility and the consumer, demand side management (DSM), integration of renewables, and increased load control.

Electric vehicle (EV) technology has shown significant growth in recent years and with it, interest in infrastructure for EV charging has increased. New generation batteries offer longer battery life and better acceleration speeds. In addition, because the environmental impact caused by carbon emissions is an increasingly important topic, EVs, which produce zero tail-pipe emissions, started to become more preferable. However, the environmental impact of the vehicle throughout its lifecycle is equally important. Electrical power is a significant part of energy consumption in the world. In 2020, the global electricity generation was 21,504.6 Twh and, of this, 16,384.4 Twh was generated from non-renewable sources (the remaining 5,120.2 Twh generated from renewable sources, which led to 23.8% of total generation). In this context, renewable energy sources, such as hydroelectric, solar, and wind are mostly used in the generation of electrical power for zero carbon emissions. The global electricity generation had risen 40.3% in the period from 2000 to 2020. To benefit the environment, the electricity used in the other sectors should instead come from renewable sources. The system of integrating an Electric Vehicle (EV) from a customer's source to distribution networks, then to the electricity grid, to the energy market, to the substation, and finally to the utility ESCO is shown. To achieve the objectives of the integration system, a high penetration of EVs and a deep integration of smart devices were used.

2.2. Importance of Integration with Solar Systems One of the cornerstones of a successful energy management system for Electric Vehicles (EVs) is in the seamless integration with Distributed Energy Resources (DERs). With recent advancements in technology, it is vital that EV charging can be aligned with renewable and sustainable charging options. Thus, there is significant ongoing research on utilizing solar energy as an optimal charging option for EVs, with various strategies being tested.

In the seamless integration of EV charging with residential solar systems, energy efficiency is enhanced whilst overall costs are reduced. This has led to the design of novel strategies and algorithms that optimize the use of solar DERs in EV charging schedules, with the overall objective of maximizing the utilization of solar energy when charging the vehicles. Moreover, several countries have now legislated that all new or refurbished dwellings need to have a certain percentage of renewable energy sources, with solar systems being the most common. The resultant rapid increase in installed solar systems highlights the importance of strategies to utilize this energy resource. In addition to their energy benefits, solar systems also have environmental advantages. The use of solar energy as the main charging mechanism for EVs is an emissions free option. This not only improves the overall well-to-wheel efficiency of the vehicles but also vastly decreases the greenhouse gas emissions released from transport operations.

Aligned solar systems charging applications and EV systems have the potential to offer multiple grid services that can increase the overall resilience of electrical networks. As grid stability and security are major concerns in present era electricity networks, this type of grid service represents an economic benefit for the prosumers that use these combined charging systems. As a result, EV and solar systems owners can expect financial incentives to shift the power consumption/injections of their ‘assets’ from/to the electrical network in order to offer such grid services.

3. Artificial Intelligence in Energy Management

Under the current scenario, with the integration of electric vehicles (EVs) and various renewable distributed energy resources (DERs), artificial intelligence (AI) technologies have come to play an important role in optimizing management. Recently, AI-driven methodologies have been developed, including data analytics and machine learning. These faculties can be employed to forecast and make decisions in case of an energy demand and production in balancing it, leading the grid users to an enhanced use of EV chargers and solar systems spread across the domestic network. Predictive analytics can be used to foresee some events related to a possible energy misuse in order to anticipate accurate scheduling strategies. Additionally, machine learning approaches can be applied to analyze data related to energy use, possibly leading to new behavior strategies on appliances to improve both consumption and energy efficiency. In this context, it is aimed to understand the impact of these kinds of methodologies in order to open up an analysis to the future sustainable energy practices and possible strategies to embrace.

Fig 3: Artificial Intelligence into Energy Management Systems

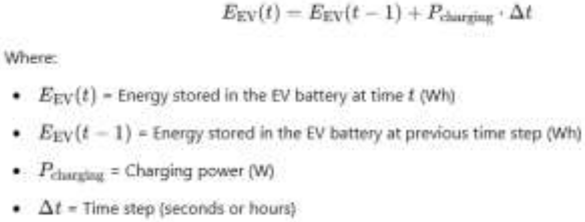
3.1. Overview of AI Technologies A foundational understanding of AI technologies is presented, including various techniques specifically designed for non-specialists and those not yet engaged with AI technologies in their research activities. It is shown how AI technologies can leverage vast amounts of data that may be generated by energy systems to uncover patterns of potential value to the research community. A key focus is on predictive modeling, given the usefulness of predictive models in both understanding energy use and the subsequent implementation of energy use interventions. Finally, the scalability and adaptive nature of AI systems are discussed. A potential avenue for smarter houses, in particular the integration of electric vehicle charging with residential solar systems, is detailed to identify the capabilities offered by AI technologies. With the growth of renewable energy sources, a challenge of increasing relevance is now developing scalable strategies for appropriately managing energy distribution networks. Using an Interactive Artificial Intelligence agent-based approach, it is shown how, in comparison to existing techniques, a scalable solution can be designed that significantly reduces the likelihood of power outages and manages energy storage devices more efficiently. This is a provocative perspective on the transformative potential of AI, for a wider audience beyond AI, in engaging with complex adaptive systems, with potential implications for how AI researchers articulate the value of their technologies to other domains.

3.2. Applications in Energy Sector Artificial Intelligence (AI) technologies have found numerous applications in various sectors including the energy industry. The broad applications of AI in the energy sector include, but are not limited to: smart meter readings, grid management, demand response, energy forecasting, analysis and optimization of operational system efficiency gains such as predictive maintenance, and optimization of variable resource allocation.

A case study was conducted in an office building with batteries and solar panels as well as a residential solar system to demonstrate the advantages of AI in the field of energy management systems. AI significantly reduced building energy consumption. A business model for the hassle-free implementation of AI as an energy management system is also presented and discussed. Despite these advantages, the large-scale deployment of AI remains a challenge, particularly data security and the empirical lack of confidence in these technologies.

In general, the important factors for the successful integration of AI as support for the energy industry are discussed, including regulatory measures, information dissemination about the benefits and potential of AI, and the importance of technological collaboration between AI solution providers and energy sector stakeholders. In the context of high-tech solutions to new renewable energy sources, AI can be the innovation that will support an increase in the share of these energy sources in the final energy consumption. By exchanging products/services based on AI solutions, companies tend to produce or consume energy more efficiently by fully recognizing the potential of AI technologies.

Equ 2: EV Charging Demand Equation



$$E_{\mathrm{EV}}(t) = E_{\mathrm{EV}}(t-1) + P_{\mathrm{charging}} \cdot \Delta t$$

Where:

- $E_{\mathrm{EV}}(t)$ = Energy stored in the EV battery at time t (Wh)
- $E_{\mathrm{EV}}(t-1)$ = Energy stored in the EV battery at previous time step (Wh)
- P_{charging} = Charging power (W)
- Δt = Time step (seconds or hours)

4. Integration of Solar Systems with EV Charging

Several methodologies and technologies of integrating residential solar systems with electric vehicle charging infrastructure are available. Existing solar panels have fixed angle mounts and as solar panels need to be oriented toward the south or have a sun-tracking system, it is quite difficult in residential premises due to space constraint and cost. Bifacial solar panels can be used which are capable of converting both direct and scattered sunlight by absorbing light on one surface of the panel and by using a transparent backsheet to capture light on the backside as well. However, there exists little research on using bifacial solar panels for integration with EV charging. To overcome these difficult installations, solar windows or solar balcony railing can be installed. Solar windows can provide a substantial electricity generation opportunity for many residential premises where standard solar panels are not feasible, offsetting the environmental impact caused by the electricity usage. It is a cutting-edge, yet efficient way to produce green energy by exploiting sunlight and to provide sun shading for privacy and leave a free rooftop space for other applications. Photovoltaic curtain wall is a PV panel integrated in the curtain wall system and it can complement the generating power of conventional flat PV by utilizing the direct sun and resisting higher surface temperature offering a double-skin façade. The angle of the solar panel in the solar balcony railing and planar photovoltaic curtain wall can be adjusted to track the sun elevation lower or higher, which is generally uncommon in current solar installations. Roofs with photovoltaic (PV) panels can be used as a smart generation system for solar energy, providing electricity both for the charging of an electric vehicle (EV) and for the requirements of the house. It can also support the electricity grid services and reduce financial expenditures on home energy usage. Ev smart applications can control EV charging based on optimized matching with the electricity generation thanks to the smart meter data. Thus, power flow is optimized and it improves the use of solar PV power, increasing the self-sufficiency rate increasing from 0% to over 85%, decreased costs 1.5 to 3 times, and lower CO2 emissions reduced by 1.7 to 7.2 times compared to base peak ANN.

Typically, a solar system generates more electricity than can be consumed by the house, particularly in some specific time slots. The excess electricity is transferred to the public grid. Conversely, it needs to charge the EV from the public grid like extra cost and poor self-sufficiency rate if the solar energy cannot meet the charging need. The better way specializes matching the energy flow between the solar generation and the EV charging charge the EV "sufficiently" only when the surplus electricity is high). Thus, to mitigate the power loss from storage and work in a more sustainable manner, the storage capacity and power-writing schedule have to be elegantly designed for the storage and EV system simultaneously. The grey wolf optimizer (GWO) algorithm combined with a mixture probabilistic/internal dissipative/ potential (LP-IDP-P) framework is utilized. To handle the shortcomings and difficulty of an in-depth understanding of the existing new methodologies like simulation-based EMTP-ATP and hardware-in-the-loop technologies and novel optimization techniques such as whale optimization algorithm and big bang-big crunch technique can be created. Several governments have dedicated financial incentives and investments in R&D to further promote renewable energy, and particularly photovoltaic technology, as a way to decarbonize the environment, diversify the energy source, and reduce its dependence on fossil fuels. discuss the development of utility rate schedules and the impacts of rate designs for electric vehicles on the grid distribution. They propose to prefer dynamic pricing schemes to encourage users to optimize the load. describe channel policies and behaviors to promote electric vehicles (EVs) and study the influencing factors in facilitating integration of solar energy generation systems (SEGS) and EV charging systems. The results are useful for policy makers and strategists to promote the SEM (sustainable electricity market) in residential areas. focus on the impact of co-optimized placement of residential solar panels and energy storage with controlled loads. Furthermore, SCADA-integrated blockchain IoT platform for the stakeholders involved in residential energy sharing system (RESS) arrangements is also being discussed. It is a fact that electric vehicles (EVs) because their battery-operated engine isn't free of CO2 emissions have a certain environmental impact in case the electricity comes from highly polluting fossil fuel power plants. But their use can be helpful to reduce the overall emissions of the transport sector, enhancing effectiveness and efficiency with respect to internal combustion engine vehicles. This policy, together with specific subsidies and incentives like tax advantage, free parking and green zones, are promoting the diffusion of EVs in several countries.

Fig 4: Solar Energy - Powering the Future of EV Charging

4.1. Existing Approaches Frameworks in terms of both technological and policy directed to improve comprehension on the strategies development and policy supports required to finish such integrations have to be discussed in the subsequent work. Technologically driven frameworks extend from nascent scheduling of residential solar system generation cantered EV charging, extension of EV charging infrastructure, to mature aggregation of integrated services provided within virtual power plants along with decentralized energy trading banes. As divided within leading dynamic and forecasting capabilities of each energy vector component across sections, policy supports subsequently required to nurture formerly separated power and mobility sectors through mapping the development paths of such AI driven integrations are deliberated after. In an effort to facilitate introduction, a comprehensive literature review covering both technical and policy frameworks influencing the integrations for both EV charging and household level photovoltaic plants is provided beforehand. Thereafter, enabled by an optimization algorithm developed ahead, the comprehensive systems modelling of such smart energy systems enabled integrations are conducted to evaluate the technical feasibility and economic costs that can be incurred. The work is eventually then extended to perform a scenario based model analysis to unravel the impacts in terms of financial benefits and energy exchange behaviours induced across participants involved in the integrations.

The nascent models constrain the random consumption behaviour of EVs and the deterministic dispatching of residential solar systems, leaving the unbalanced cost and neighbouring current at the medium voltage level as linearity constraints. The day-ahead scheduling can be divided into two steps. The day-ahead fixed dispatch of residential solar systems is first determined. Then, aiming at minimizing the user cost, the charging profile of EVs is planned with the assistance of the scheduled residential solar systems. This approach is employed finding the day-ahead scheduling solution of the integrated residential solar system and EV system is NP-hard. The random variables in the mathematical model. The chance constraint is used to deal with the probabilistic constraint. Finally, the performance of the proposed algorithm is analysed through a comprehensive Monte Carlo simulation. The integration of electric vehicles and renewable energy sources has gained a growing interest during these last years. Smart charging of EVs can help reduce the costs associated with the energy demand increase in a renewable electric grid. In this scenario, the mobility and energy sectors become intertwined and their operation should be jointly analysed. However, most of the knowledge found in literature only considers behavioural models of these services separately, without considering market actors playing in both fields. This chapter performs a review of the state-of-the-art on the integration of EVs and renewable energy sources, as well as their state-of-the-art related modelling and simulation tools. Also, the first models developed from the pre-study of the distribution and application of these energy vectors in the specific case studies are presented.

4.2. Benefits and Opportunities Integration of electric vehicle (EV) charging with residential solar systems can have a multitude of benefits, for consumers, dealers and the wider community. It can also present opportunities for new businesses and local energy markets. • The existing bidirectional inverter in the solar system can be shared as a two-way charging point, essentially providing 100% cheaper than installing a new charging point, which would take up unnecessary extra space and potentially put pressure on existing main supplies. In this case, the rated power of the solar system inverter should be taken into consideration when designing the inverter of the solar / battery / vehicle connection, given that excess power from the solar system is typically exported to the grid. • Solar-battery-vehicle connections take full advantage of renewable energy sources to reduce carbon emissions, increase energy independence and aspire to environmentally cleaner air. • A setup supporting DC and higher power AC chargers and also potentially introducing an energy management system / smart charger and load management, so that charging is coordinated in a grid-friendly way is preferable. • An experimental demonstration of the TAMU EV to home scheduling algorithm on the scaled test set through standard hardware in real time, coupled with environmental variables captured by the Low-cost Open-source Electricity Monitor. Integrating residential solar systems with EV charging is a fundamental part of domestic level power electronics and their enormous potential in changing how the electrical networks and markets function at the residential level. This can also form a magnitude of devices, such as EVs, battery storage, electric vehicles (EV) charging, network interface controllers (NIC), smart grid and electric energy supply systems.

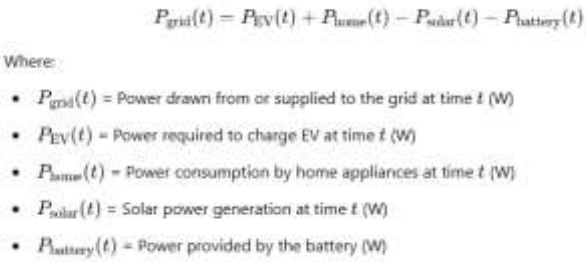
5. AI-Driven Strategies for Seamless Integration

Electric vehicles (EVs) and solar residential systems (SRSs) are essential components of a sustainable energy ecosystem. Harnessing solar energy with SRSs can allow residential buildings to achieve energy self-sufficiency by generating solar energy to fulfill their energy requirements. EVs offer eco-friendly mobility, and the potential of complementing SRSs with enhanced eco-friendliness is being realized. The interdisciplinary expertise of renewable energy communities, smart grid engineers, data scientists, and domain specialists is essential for wide-scope electric mobility in the renewable power-efficient buildings sector, using artificial intelligence (AI) and data mining as central enablers to provision data-driven insights, analytics, and real-time forecast data. It is expected that timely movement predictions will enable economic benefits and efficiencies . Forty percent of greenhouse gas emissions in the world can be attributed to buildings. In underdeveloped countries, buildings consume more than 40% of the electricity generated. In comparison to other places, Pakistan has the 6th largest population in the world. Pakistan is currently facing a serious energy crisis, with a shortfall of 4.4 GW and 12 GW per day.

Building-integrated solar installations have gained popularity due to their potential to reduce electricity production costs and carbon footprints. The total facade area, rooftops, and windows of residential buildings contribute to sustainable mobility and energy self-sufficiency. Both facilities have become essential necessities for a smart city framework. It is very important to discuss the combined operation of an electric vehicle charging system linked to SRS systems with residential buildings in the form of a microgrid in light of the current energy shortfall scenario. Recent advancements in many methodologies improve the importance of sustainable energy. It is proposed that a residential wall with different situations, such as higher pollution and low power. The EV parking area is built of Li-Ion technology. Upgraded vehicles offer a convenient and modern method of electrical charging. Residents can charge their vehicles in the car parking facility. In the context of existing systems, solar systems are proposed on the walls of buildings for tapping unutilized resources. Buildings have also surrounded many well-known hazardous environments. Mobile alerts are the solution, but the proposed mobile charging system at the top of the vehicle is an updated electronic charging alert system (i.e., home device). Residential SRSs harvesting solar energy, electric charging facilities for EVs, and additional grid resources in the form of a microgrid with a structure consisting of a building, SRS, EV, loads, and a charging facility. Initially, the electricity requirement load is fulfilled by grid resources; only the excess power is exported to reduce its electricity bill. So, to analyze the feasibility of the charging schedule optimization algorithm for the simultaneous operation of EV with SRS systems prediction with smart operations, it assumes that the microgrid is connected to the main grid. A transformation process is proposed in which the power flows between on-site generations (SRS), load, and a facility for intelligent EV charging (FIEVC). This transformation is improved through recent advances in intelligence in the form of data analytics and clean-line transport. Since the combination of EV and SRS systems can yield a complex problem, heuristic, analytical, or conventional methods are overwhelmed to produce the optimal solution. However, this work is proposed as an evolutionary meta-heuristic optimization solution. Therefore, the novelty of this work lies in its ability to propose the impact of improving the SRS system for charging EV systems with analytics and machine learning support.

5.1. Data Analytics and Predictive Modeling Data collected through smart energy meters not only provide insights into consumption patterns but could also help inform a range of interesting energy management practices. Hourly consumption data, for example, can be used to assess the effects of policies or testing interventions by way of experimental evaluations. Moreover, real-time data could be aggregated to finer time resolutions and fed into accurate forecasting models to anticipate the need for, possibly storage trades, with energy. Such forecasting systems would be particularly valuable in urban settings where most of the electricity is used and wasted, by industry, and lead to a re-shaping of the electricity demand curve around available energy slots. Similarly, models based on real-time data analytics are used to inform the assignment of the current energy slot in the short run (time to EV plug) or to the assignment of the available energy slot in the medium-long run (charge system cycling), i.e., in under-capacitated systems only some of the amount of available energy can be harvested. However, several barriers prevent the uptake of data-driven strategies in the wide range of existing electricity charging systems, limiting the sector benefits that could be derived by their use. In part, this can be due to external conditions with large buildings not always able to connect with the very few electricity providers that are given access to the market. However, there are system-specific constraints posed by a lack of compatibility of the existing systems with the cutting-edge technology that should govern energy allocation, therefore they are disposed of vast capability to process data in real time, avoid glitches and allocate energy through advanced learning algorithms. Given a time window for the event, it will be crucial to develop a viable solution that allows such systems to be updated cheaply and maximize the potential of their large size and storage capacity. Advanced algorithms that take full advantage of big data are clearly required to effectively optimize the allocation of energy in charging systems where the provision of electric vehicle charging interfaces, rooftop photovoltaic systems, and physical or virtual storage devices are integrated. To this end, case studies are used to design quick-to-implement mechanisms capable of enhancing the solar energy into EV charging. In the light of this, the cleaning of complex experimental data systems is taken as a priority, suggesting the necessity of uniform data collection processes or outputs. The discussion underlines that equally challenging is the development of an algorithm that combines the accurate scheduling of energy demands, on the basis of real-time forecasting systems, while being able to respond quickly to sudden changes in parameters. Obviously, constraints breed opportunities.

Equ 3: Grid Interaction and Load Balancing Equation



$$P_{\text{grid}}(t) = P_{\text{EV}}(t) + P_{\text{home}}(t) - P_{\text{solar}}(t) - P_{\text{battery}}(t)$$

Where:

- $P_{\text{grid}}(t)$ = Power drawn from or supplied to the grid at time t (W)
- $P_{\text{EV}}(t)$ = Power required to charge EV at time t (W)
- $P_{\text{home}}(t)$ = Power consumption by home appliances at time t (W)
- $P_{\text{solar}}(t)$ = Solar power generation at time t (W)
- $P_{\text{battery}}(t)$ = Power provided by the battery (W)

5.2. Optimization Algorithms Home energy generation systems play a pivotal role in lessening the impact of EV charging on wider energy systems, thereby helping to integrate both technologies into the larger energy grid. For individual homeowners, a potentially profitable use of private energy generation systems may be the coordination of charging timers in accordance with the times of peak solar energy generation. Even with a minimal feed into larger grids, or an interconnected set of home systems, the seamless matching of generation and charging can contribute to developmental goals for local energy grids. For instance, properly managed home and residential systems can reduce the costs of investment in larger energy systems in order to mitigate the impact of an increasing number of EVs on commercial grids.

Optimization algorithms geared toward a smarter charge management can take into account charging demand forecasts and energy flow models for home energy generation systems. In such parameter sets, the interaction with larger energy grids can be either minimal or remedial, such as mechanisms to affect local battery storage costs or to offload charging in the case of grid congestion. In situations where energy delivery into larger systems is permitted, the participant’s energy availability over a defined time period and forecasts of energy generation can be important parameters for grid operators looking to take advantage of locally injected energy.

On smaller scales, it might be more difficult to accurately model energy flows for the purpose of generating charging schedules. However, non-comprehensive models applied to individual participants can still work in order to reduce charging costs. This would require further study, owing to the challenges of forecasting solar energy availability, energy consumption, and residential unit feed/power loss. Nevertheless, the field of energy management algorithms is still developing, and there is potential for the continuous improvement of charging schedules through learning-based algorithms.

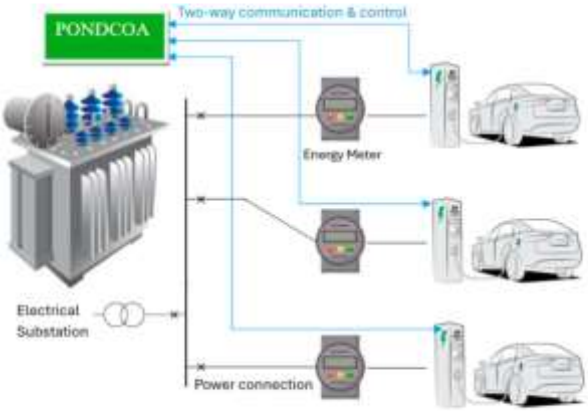


Fig 5: Dynamic Charging Optimization Algorithm for Electric Vehicles

6. Conclusion

Energy consumption has continuously been growing globally, contributing to a significant boost in greenhouse gas emissions, leading to an unsustainable environment and climate change. The increasing trend of power generation based on renewable energy sources has emerged as a sustainable solution to address the environmental challenges posed. However, renewable energy generation is uncertain due to climate variations, increasing the power grid's complexities. Appropriate energy management of the coupled residential solar photovoltaics systems and the electric vehicles is essential. The existing electric vehicle user preferences indicate the sporadically different charging power trends among the users. The innovative artificial intelligence based approach utilizing long short-term memory neural networks offers precise EV charging power forecasts.

An innovative AI-driven strategy is developed using long short-term memory neural networks for the seamless integration of the optimal residential solar system and EV charging to offer specific charging recommendations for the EV users. The insightful capability of the neural network is involved to train the proposed AI-driven strategy. Multiple case studies are examined to evaluate the beneficial effects of the proposed AI strategy for the different exemplary EV users. The economic impact of the photovoltaic system combined with the EV system is also studied. Several innovative and challenging research directions could be explored, which include the optimization of the inverter power limit and the integration of bidirectional power flow into the developed AI approach. Offering the proposed AI framework consisting of a neural network model to offer the optimal EV charging power integrated with the residential solar system can benefit the consumers, grid communities, and also the utility companies by empowering the automotive transportation with green solar energy.

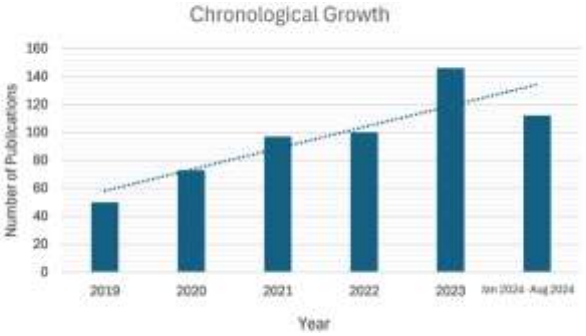


Fig : Electric Vehicle Adoption

6.1. Future Trends In the upcoming years, considerable focus will be placed on the integration of electric vehicle charging with solar systems. Solar energy systems are already a popular renewable energy source for households. However, a smarter approach should involve electric vehicle charging to mitigate external shocks to the grid. Additionally, explorations into the integration of energy management and the prediction of energy demand have been unexplored. It is anticipated that the rise of AI will help with the optimization of the domestic production and exchange of energy. Decision-making should be device-based and appraised in terms of the amount of energy used. As such, the management system might work to buy and sell energy, autonomously turn devices on and off, and use energy-intensive devices during cheaper blocks of time. Future grid systems will necessitate more vehicles with greater energy storage and a bidirectional power exchange system. In that case, buildings could purchase energy from cars during peaks of the solar cycle. Strategies that encompass solar sharing networks and car batteries as energy stores were not developed in this case study. As the technology of electric vehicles advances, it is possible they will become bi-directional too, allowing for cars with more capacity and long-range batteries. That said, several important concepts were broached, such as the impact of weather and daylight in charging, and the costly way vehicles are recharged.

There will be a marked increase in the number of electric vehicles, which will necessitate precision in the planning of charging sessions, so as to reduce drains on the electricity network. Public places like shopping centers, restaurants, or offices that can offer chargers will receive benefits, including enhanced attractiveness to potential consumers or as a way to make energy savings. Home charging may be granted a time frame, to curb unnecessary nights' energy usage or to better harness solar energy systems. Moreover, car batteries could also be used as an emergency energy supply, transferring energy to the building when surplus energy exists.

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