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BIDIRECTIONAL POWER MANAGEMENT SCHEME IN PLUG-IN ELETRIC VECHILE INTEGRATED WITH ELETRIC GRID

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Abstract: The Bidirectional power management scheme in Electric vehicles (EVs) are thought to be efficient means of reducing carbon emissions and the reliance of the transportation industry on fossil fuels. But the distribution infrastructure faces serious operational and planning challenges as EVs gain widespread. Vehicle-to-grid (V2G) technology is a research hotspot that has the potential to provide a variety of auxiliary services for the utility grid through appropriate charging and discharging schedules, in addition to mitigating the negative consequences of widespread uncoordinated EV charging. For the first time, EV-grid integration and V2G operation are considered from the perspective of a thorough analysis of distribution grid topologies, grid connection infrastructures and standards, and typical applications in this article. In this V2G operation we use a limitation condition like usage of power supply until half of the battery percentage, by this way the vehicle can also be used at emergency driving at minimum of fifty percent on it. We also suggest using solar energy for electrical vehicle (EVs) charging which leads to reduce the cost of electrical bill of charging of these electrical vehicles. Through this we use renewable source for electricity which is efficient and convenient for electrical vehicle battery which is used as bidirectional power for electrical appliance

Keywords: Electrical vehicles; Vehicle-to-grid(V2G); Solar power; Bidirectional power management: vehicle battery.

1. Introduction

Electricity in used in our day-to-day life for almost everything such as entertainment (tv, phone), for cooking and machinery use for cooking (mixer, grinder), etc more and every day. Day by day we are getting started to depend on electrical machinery more and more, electrical device that work on electricity which make a great deal. The cost of the electricity consume cost can be reduced by the help of renewable energy sources such as solar and wind energy and this energy can be stored and can be used for further future use. Now day since the fossil fuel cost is getting high due to the more demand on it less supply we got. Due to demand is higher than the supply the fossil fuel cost is sky rocketing compering to past experience, so company and people all over the world have changed the view of their eyes over Electrical Vehicles (EVs). Here is still an advantage for everyone which make it a win-win situation for both user and the manufactures. We can create an eco-system between the car battery and the home load. We create a bidirectional scheme which the supply can be given to home at peak hours or at emergency. For an additional advantage we can create a model that makes use of solar energy to charge the Electrical Vehicles (EVs) so the draining and charging at emergency is not a problem. The solar panel is used as an optional power source provider because in sometimes we will be unable to charge the battery if the power got shut down and it would take more power to charge to reduce more usage of the power and during emergency times we use this renewable source of energy. This power produced from the solar panel is stored in the battery of a car. Now we must make a proper Vehicle-to-grid (V2C). An inverter is used since most of the home appliances uses ac power supply Here Node MCU (ESP32) deals with the controlling part. It controls the amount of power we use from the battery. This battery percentage pay vital role in the project this project Here the power is generated from the solar energy which is directly given to the car battery without storing it in another battery. The limitation for the usage of power in battery will be up to fifty percentage. Why we set this limit is because when the power is down, and we need using the vehicle also we should have at least a minimum amount of power in the battery without draining it. It helps not only in this situation but also to reduce the electricity usage from the power station which reduces the electricity bill. Here is an important task that the user must be selective over the usage of electronic materials that he/she uses which do not exceed the usage of fifty percentage of power in battery. There is a relay which switches immediately once the threshold (that is the fifty percentage of power) has been reached. So that the remaining power can be used to run the vehicle**.**

2. OVERVIEW OF TECHNOLOGIES

A. Node MCU:

In a bi-directional power management scheme for plug-in electric vehicles (PEVs) integrated with the grid, a node MCU (microcontroller unit) is like a small computer bossing around how electricity flows between the car's battery, charger, and the grid. It keeps track of important things like battery health, and grid conditions using sensors. This data, coupled with pre-programmed instructions, empowers the node MCU to make intelligent decisions on power flow. During charging mode, it controls the on-board charger to draw power from the grid for PEV battery charging, while considering factors like battery health and grid demand. Conversely, in discharging mode, it manages the on-board inverter to send excess power from the PEV battery back to the grid during peak demand periods or when participating in demand response programs. The node MCU performs a critical function in ensuring extended lifespan of the PEV battery by implementing battery management strategies. These strategies involve real-time monitoring of battery health that could get handy while considering problems such as draining the battery and absence of power at required. For instance, the node MCU can regulate the charging current and voltage to prevent overcharging or excessive discharge, both of which can lead to lithium-ion battery degradation [1]. Additionally, the node MCU can implement thermal management strategies to maintain the battery within an optimal temperature range, as extreme temperatures can also accelerate battery degradation [2]. These preventive measures undertaken by the node MCU contribute to extending the usable life of the PEV battery, thereby enhancing the overall economic viability of the bi-directional power management scheme. To save the battery and make it last longer, the node MCU can turn off some things in the car that aren't being used, or it can even disconnect the car from the grid entirely, if the battery level gets too low. This is like how your phone switches to low power mode to save battery life.

Communication is another key function. The node MCU may communicate with a central control system (if present) using protocols like CAN (Controller Area Network) or Modbus to share data and receive control commands. The node MCU also facilitates communication with external entities (which may include the grid operator's system) using appropriate protocols. This enables functionalities such as participation in demand response programs or receiving real-time grid pricing information. In essence, the node MCU plays a critical role in transforming PEVs from passive consumers of electricity into active participants in grid management, contributing to a more stable and sustainable electric grid.

B. battery:

In a bi-directional power management scheme for plug-in electric vehicles (PEVs) integrated with the grid, the car battery technology must chose Lithium-ion (Li-ion). Li-ion batteries are very comfortable in this application for several compelling reasons.

Firstly, these Li-ion batteries have a very impressive energy capacity can be stored, meaning they can store a significant amount of energy into a very small and lightweight package which is used is in electrical vehicles most widely. This stands in very contrast to other battery technologies such as Sealed Lead Acid (SLA) batteries, which have a much lower energy density. This translates to a clear advantage for PEVs. With Li-ion batteries, PEVs we can achieve a maximum driving range, allowing them to fulfill their purpose of electric transportation. But that's not all. The high capacity of Li-ion batteries empowers PEVs also play a more important role in the grid by discharging excess stored energy during peak demand periods, contributing to grid stability, and potentially reducing less reliance over traditional power plants.

Secondly, bi-directional power management relies heavily on the battery's ability to not only be charged from the grid but also discharged back into the grid when needed. Li-ion batteries excel in this two-way flow. They can be repeatedly charged and discharged, making them perfectly suited for the demands of a bi-directional scheme. This characteristic is essential for the scheme's functionality, as it allows PEVs to act as both consumers and contributors of electricity.

Thirdly, battery degradation is a natural concern for any PEV owner. However, Li-ion technology is constantly undergoing advancements, leading to improvements in battery lifespan. Bi-directional power management systems can further optimize battery health by employing careful management strategies for charging and discharging cycles. These strategies help minimize degradation, ensuring the battery delivers for an extended period. This focus on extending battery life promotes the long-term sustainability of the bi-directional power management scheme.

In addition to this advantage using, it for electrical transport, Li-ion batteries offer several other advantages that make it as an ideal for bi-directional applications. For instance, Li-ion batteries generally faster recharge rates compared to SLA batteries. This faster charging is crucial for efficiently utilizing and capturing excess renewable energy during peak grid production periods. Additionally, Li-ion batteries can discharge a larger portion of their stored energy before needing recharge compared to SLA batteries. This deeper discharge allows PEVs to contribute more significantly to the grid by discharging more power when needed.

Of course, there is no such technology without its drawbacks in existence. Li-ion batteries are generally more expensive than SLA batteries. However, advancements and fast discharge in Li-ion technology and economies of scale have helped bring down the cost in recent years. Additionally, the long-term benefits of bi-directional power management, such as potential cost savings on electricity bills and participation in incentive programs, can offset the initial higher cost of Li-ion batteries. Another consideration is thermal management. Li-ion batteries are sensitive to extreme temperatures. The bi-directional power management system needs to incorporate thermal management strategies to maintain the battery within an optimal temperature range. This ensures efficient operation and maximizes the lifespan of the Li-ion battery.

3. WORKFLOW OF IOT

The Node MCU, a key component in the project since it plays a pivotal role in gathering real-time occupancy data through a systematic workflow. The workflow begins with the deployment of Node MCU microcontrollers strategically placed for a battery. The battery percentage noted. The battery current percentage and relay information is given to Node MCU. Upon sensing occupancy changes, the Node MCU initiates a data collection process, capturing relevant parameters such as the battery percentage. These parameters are then processed within the Node MCU to ensure the battery doesn't get to the lowest extent of zero.

As part of this process, we have used a solar panel for charging the battery of Electrical vehicles (EVs). Using solar panel is a personal solution overcome the continuous draining of battery and can charged at the peak hours or at the time like current is unavailable or power off situation. This raw solar power harvested from the solar power is used to store lithium-ion which is mostly used in Electrical vehicles (EVs). This stored energy is further given to the load.

Now the battery must be given to the load at the peak time or in situation on which the power is not available. This battery can also use as a grid since we are making use of the Electrical vehicles (EVs) battery as a bidirectional plug-in scheme as it directs the power on both way and in a very efficient way. Now the stored power in the battery is converted into ac from dc so we use an inverter to convert it from dc to ac.

When the battery is used as grid (Vehicle-to-grid) instead of the main grid, the battery power is continuously monitored by the Node MCU. The constant monitoring of battery is given to the Node MCU which switch the relay the when the battery switch fifty percentage by the help of the Node MCU.

4. RELATED WORKS

Fazel Mohammadi [2] proposes a way for plug-in hybrid vehicles (PHEVs) to help regulate power grid frequency by adjusting how much power they charge. The strategy considers battery levels, voltage, and frequency fluctuations. Simulations show the approach can effectively reduce peak demand and improve overall grid stability. The research includes a detailed model simulating various scenarios over a 24-hour period.

Md. Ariful Islam [1] tackles managing power flow between electric vehicles (PEVs) and the grid (V2G and G2V). Existing controllers have limitations. This paper proposes a new approach using an adaptive neuro-fuzzy inference system (ANFIS) for better power management. This aims to reduce stress on the grid and utilize unused power effectively. Simulations show the ANFIS controller performs better than traditional controllers, injecting power with less distortion and achieving a smoother battery profile.

5. IMPLEMENTATION APPROACH

The implementation can be divided into several stages:

- Setting up the hardware infrastructure, including Node MCU, inventor and relays.
- Optionally we deploy a solar panel to the Electrical vehicles (EVs).
- Developing a code for the Node MCU that switches the relay when battery reaches fifty percent.
- Integrating the hardware and software components to create a cohesive system.
- Testing the system for functionality, reliability, and scalability.
- Deploying the system in the target environment (domestic application) and providing training to users.

6. FUNCTIONAL REQUIREMENTS OF THE PROPOSED SYSTEM

1. Hardware Components:

- Onboard Charger (OBC): This bi-directional charger is the heart of the system, enabling both charging the PEV battery from the grid and discharging excess power back into the grid. It needs to be compatible with the PEV's battery voltage and communication protocols.
- DC-DC Converter: This converter steps up the DC voltage from the PEV battery to a higher voltage level suitable for the grid connection. Conversely, it steps down the grid voltage for charging the PEV battery.
- Inverter: In some bi-directional systems, an inverter may be used to convert the DC output from the battery or DC-DC converter into AC power compatible with the grid. This might be necessary depending on the grid connection standards.
- Battery Management System (BMS): The BMS plays a crucial role in monitoring and managing the PEV battery's health and safety. It tracks parameters like cell voltage, temperature, current flow, and state of charge (SOC) to ensure safe and efficient operation during both charging and discharging cycles.
- Communication Interface: This interface enables communication between the onboard system (OBC, DC-DC converter, inverter) and external entities. Protocols like CAN (Controller Area Network) or Modbus can be used for communication within the vehicle, while protocols like OpenADR or IEEE 2030.5 can facilitate communication with the grid operator or aggregator.

2. *Software and Control Systems:*

- Energy Management System (EMS): The EMS is the brain of the bi-directional power management scheme. It receives data from the BMS, grid operator, or aggregator (if applicable) and controls the charging and discharging behavior of the PEV battery.

3. *Safety Features:*

- The system needs robust safety features to prevent overcharging, over-discharging, and thermal runaway of the battery. These features can include hardware safeguards and software algorithms that monitor and limit operating parameters.

4. *Additional Considerations:*

- Grid Compatibility: Ensure the bi-directional charging system is compatible with the local grid voltage and connection standards.
- Regulations and Standards: Adhere to relevant regulations and standards for bi-directional charging and grid interconnection.
- Cybersecurity: Implement robust cybersecurity measures to protect the system from unauthorized access and manipulation

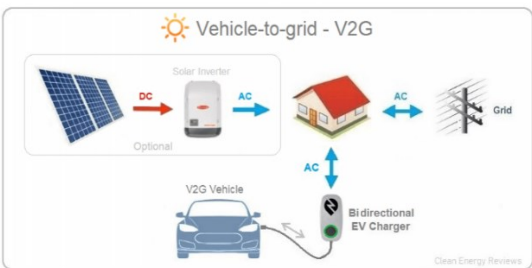
5. *Benefits of a Well-Implemented System:*

- Enhanced Grid Stability: PEVs can contribute to grid stability by discharging excess stored energy during peak demand periods.
- Increased Renewable Energy Integration: Bi-directional schemes can facilitate the integration of renewable energy sources by

storing excess renewable energy in PEV batteries.

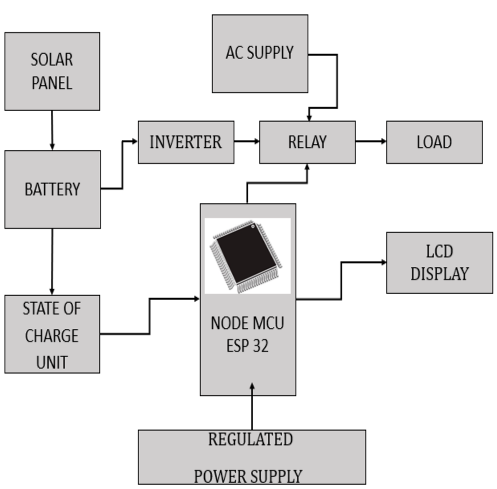
- Potential Cost Savings for PEV Owners: PEV owners participating in bi-directional schemes may benefit from lower electricity bills by strategically charging and discharging their vehicles.

- Reduced Environmental Impact: Increased reliance on renewable energy and optimized grid management can contribute to a cleaner and more sustainable energy future.



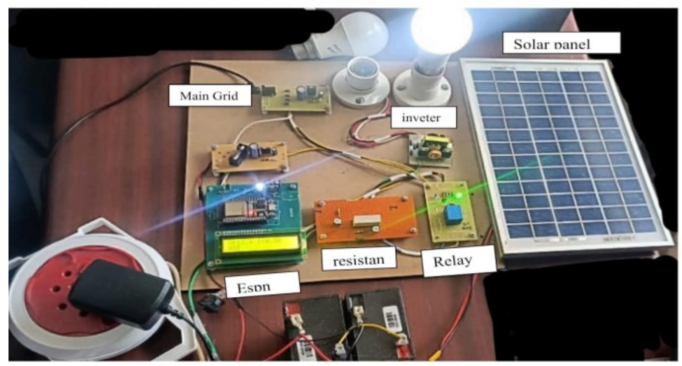
7. FLOW CHART

Below is a simplified diagram illustrating the workflow of the Bidirectional power management scheme in plug-in electric vehicle integrated with electric grid System and this diagram illustrates how the Node MCU interacts with the power supply and the relay and say about how a Node MCU work as a central unit for the Bidirectional power management scheme.



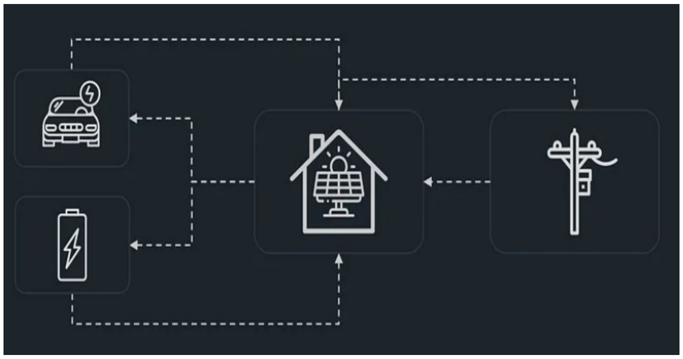
7. EXPERIMENTAL RESULT

This experiment investigates the feasibility of using a Node MCU and relay to implement a bi-directional power management scheme for a PEV integrated with the grid. The primary objective is to preserve battery health by automatically cutting off electricity to the grid from the PEV battery when it reaches a predefined discharge threshold, which in this experiment is set at 50%. In this experiment, real-time battery data, such as voltage and state of charge (SOC), are accessed by connecting the Node MCU to the PEV's Battery-Management-System(BMS).



Additionally, it is connected to a relay that manages the bi-directional power flow by controlling the connection between the grid inverter and the PEV battery. The Node MCU code continuously monitors the battery's SOC data received from the BMS. When the SOC falls below the set threshold (50% in this experiment), the Node MCU activates the relay, disconnecting the battery from the grid and halting power discharge. Safety features and error handling routines are incorporated into the code for reliable operation. This experiment demonstrates a basic bi-directional power management setup with a safety cut-off mechanism. Setting the discharge limit at 50% balances grid contribution with battery preservation, as deeper discharges can accelerate battery degradation. The effectiveness of this approach relies on the accuracy of the BMS data and the reliability of the Node MCU and relay components. However, this is a simplified setup that doesn't encompass the complexities of a real-world bi-directional charging system. Factors like grid communication protocols, advanced charging algorithms, and safety certifications are not included. Further testing with different battery types and discharge rates is necessary to assess the impact on battery health.
Future work can involve integrating the system with a smart charging algorithm that considers grid conditions, electricity prices, and user preferences to optimize charging and

discharging cycles. Additionally, exploring communication protocols for interaction with the grid operator or aggregator would enable participation in demand response programs. Long-term testing with real-world PEV fleets would be crucial to analyse the impact of bi-directional charging on battery degradation and overall system efficiency.



7. CONCLUSION

Bi-directional power management schemes an innovative approach to the energy landscape is provided by bi-directional power management methods for plug-in electric vehicles (PEVs) coupled with the electric grid. With the help of this technology, PEVs become active players in the grid rather than passive consumers of power, promoting sustainability and efficiency. PEVs can mitigate peak demand on the grid by acting as distributed energy storage units, which can improve stability and perhaps lessen dependency on conventional power plants. Furthermore, extra renewable energy (wind, solar) may be stored in PEV batteries during periods of high production and used later, promoting a cleaner grid with less reliance on fossil fuels. PEV owners that take part in bi-directional programs may also experience reduced power costs and enticing rewards for bolstering system stability, resulting in a scenario where both PEVs and the grid are winners. This experiment provides a basic proof-of-concept for a bi-directional power management scheme with a Node MCU and relay for battery protection. Further research and development.

REFERENCES

1. MD. ARIFUL ISLAM 1, JAI GOVIND SINGH2, (Senior Member, IEEE), ISRAT JAHAN1, M. S. HOSSAIN LIPU 3,4, TASKIN JAMAL1,5, (Senior Member, IEEE),RAJVIKRAM MADURAI ELAVARASAN6,7,AND LUCIAN MIHET-POPA8, (Senior Member, IEEE)1Department of Electrical and Electronic Engineering, Ahsanullah University of Science and Technology, Dhaka 1208, BangladeshDepartment of Energy, Environment, and Climate Change, School of Environment, Resources and Development, Asian Institute of Technology (AIT), Khlong Nueng, Pathum Thani 12120, Thailand.
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3. Mohammadi, F.; Nazri, G.-A.; Saif, M. A Bidirectional Power Charging Control Strategy for Plug-in Hybrid Electric Vehicles. Sustainability 2019, 11, 4317. https://doi.org/10.3390/su11164317.
4. Nina Sorokina[1], Julian Estaller[1], Anton Kersten[2], *Graduate Student Member, IEEE*, Johannes Buberger[1], Manuel Kuder[1], Torbjorn Thiringer[·2], *Senior Member,IEEE*,Richard Eckerle[1] and Thomas Weyh[1][1]*Bundeswehr University Munich, Department of Electrical Engineering,* Neubiberg, Germany.
5. Liserre, T. Sauter, and J. Y. Hung, ''Future energy systems: Integrating renewable energy sources into the smart power grid through industrial electronics,'' *IEEE Ind. Electron. Mag.*, vol. 4, no. 1, pp. 18–37, Mar. 2010, doi: 10.1109/MIE.2010.935861.
6. C. F. Calvillo, A. Sánchez-Miralles, and J. Villar, ''Synergies of electric urban transport systems and distributed energy resources in smart cities,'' *IEEE Trans. Intell. Transp. Syst.*, vol. 19, no. 8, pp. 2445–2453, Aug. 2018.
7. M. H. Rehmani, M. Reisslein, A. Rachedi, M. Erol-Kantarci, and M. Radenkovic, ''Integrating renewable energy resources into the smart grid: Recent developments in information and communication technologies,'' IEEE Trans. Ind. Informat., vol. 14, no. 7, pp. 2814–2825, Jul. 2018, doi: 10.1109/TII.2018.2819169.
8. M. H. Rehmani, M. Reisslein, A. Rachedi, M. Erol-Kantarci, and M. Radenkovic, ''Integrating

renewable energy resources into the smart grid: Recent developments in information and communication technologies,'' *IEEE Trans. Ind. Informat.*, vol. 14, no. 7, pp. 2814–2825, Jul. 2018, doi: 10.1109/TII.2018.2819169.

9. S. A. El-Batawy and W. G. Morsi, ''Optimal design of community battery energy storage systems with prosumers owning electric vehicles,'' *IEEE Trans. Ind. Informat.*, vol. 14, no. 5, pp. 1920–1931, May 2018, doi: 10.1109/TII.2017.2752464.
10. S. Morsalin, K. Mahmud, and G. E. Town, ''Scalability of vehicular M2M communications in a 4G cellular network,'' *IEEE Trans. Intell. Transp. Syst.*, vol. 19, no. 10, pp. 3113–3120, Oct.2018,doi:10.1109/TITS.2017.2761854.
11. A. Kersten, M. Kuder, and T. Thiringer, "Hybrid output voltage modulation (pwm-fshe) for a modular battery system based on a cascaded hbridge inverter for electric vehicles reducing drivetrain losses and current ripple," *Energies*, vol. 14, no. 5, p. 1424, 2021.
12. A. Kersten, M. Kuder, A. Singer, W. Han, T. Thiringer, T. Weyh, and R. Eckerle, "Elimination/mitigation of output voltage harmonics for multilevel converters operated at fundamental switching frequency using matlab's genetic algorithm optimization," in *2020 22nd European Conference on Power Electronics and Applications (EPE'20 ECCE Europe)*, 2020, pp. 1–12.
13. E. Grunditz, *Design and Assessment of Battery Electric Vehicle Powertrain, with Respect to Performance, Energy Consumption and Electric Motor Thermal Capability*. Doctoral Thesis at Chalmers University of Technology, Gothenburg, Sweden, 2016.
14. O. Josefsson, *Investigation of a Multilevel Inverter for Electric Vehicle Applications*. Doctoral Thesis at Chalmers University of Technology, Gothenburg, Sweden, 2016.
15. A. Kersten, M. Kuder, E. Grunditz, Z. Geng, E. Wikner, T. Thiringer, T. Weyh, and R. Eckerle, "Inverter and battery drive cycle efficiency comparisons of chb and mmsp traction inverters for electric vehicles," in *2019 21st European Conference on Power Electronics and Applications (EPE '19 ECCE Europe)*, 2019, pp. P.1–P.12.
16. Y. Cao, R. C. Kroeze, and P. T. Krein, "Multi-timescale parametric electrical battery model for use in dynamic electric vehicle simulations," *IEEE Transactions on Transportation Electrification*, vol. 2, no. 4, pp. 432–442, Dec 2016.
17. A. Kersten, E. Grunditz, and T. Thiringer, "Efficiency of active threelevel and five-level npc inverters compared to a two-level inverter in a vehicle," in *2018 20th European Conference on Power Electronics and Applications (EPE'18 ECCE Europe)*, Sep. 2018, pp. P.1–P.9.
18. M. A. Hannan, M. S. H. Lipu, P. J. Ker, R. A. Begum, V. G. Agelidis, and F. Blaabjerg, ''Power electronics contribution to renewable energy conversion addressing emission reduction: Applications, issues, and recommendations,'' *Appl. Energy*, vol. 251, Oct. 2019, Art. no. 113404.
19. S. Pazouki, A. Mohsenzadeh, and S. Member, ''Simultaneous planning of PEV charging stations and DGs considering financial, technical, and environmental effects,'' *Can. J. Electr. Comput. Eng.*, vol. 38, no. 3, pp. 238–245, 2015.
20. A. Zakaria, F. B. Ismail, M. S. H. Lipu, and M. A. Hannan, ''Uncertainty models for stochastic optimization in renewable energy applications,'' *Renew. Energy*, vol. 145, pp. 1543–1571, Jan. 2020.