International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 09 | September - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

Integrating Vehicle-to-Home Unit with Smart Home Energy Management Systems: A Unified Energy Management Framework

Aravinda Raj R [1], Malathy P [2]

[1]Vaigai College of Engineering, Madurai/Tamilnadu, India

aravindvceeee@gmail.com

[2]PSNA College of Engineering and Technology,Dindigul/Tamilnadu, India

Abstract. The increasing acceptance of electric vehicles (EVs) and renewable energy sources (RES) has led to the need for a unified energy management framework that can integrate multiple energy systems, including Vehicle-to-Home (V2H) units, Smart Home Energy Management Systems (SHEMS), Solar PV systems, and the grid. The framework uses a centralized control strategy that makes decisions based on real-time integration of a Vehicle-to-Home (V2H) unit with a Smart Home Energy Management System (SHEMS), which can provide a solution to these challenges by enabling bidirectional power flow between the EV battery and the home. We proposed a unified energy management framework that integrates a Vehicle-to-Home (V2H) unit with a SHEMS using a Perturb and Observe (P-&-O) algorithm. The proposed framework allows for the optimization of energy usage in the home by utilizing the battery of an EV, which can be charged during off-peak hours and discharged during peak hours. The P&O algorithm is a well-known algorithm used in photovoltaic systems to track the Maximum Power Point (MPP) of a solar panel. The algorithm is also applicable to EV charging and discharging systems. The algorithm uses a perturbation signal to change the charging rate of the EV battery and observes the resulting change in the battery voltage. The simulation results can also provide benefits to EV owners, such as reduced electricity costs and increased flexibility in managing their EV charging, helping to achieve efficient and sustainable energy management in residential areas.

Keywords: Solar panel, Electric Vehicle Battery, Vehicle-to-Home (V2H), Smart Home Energy Management Systems (SHEMS), Demand side management.

1 Introduction

Nowadays, the integration of Vehicle-to-Home (V2H) units with Smart Home Energy Management Systems (SHEMS) has gained increasing attention in recent years due to its potential for reducing energy costs and improving energy efficiency. This paper presents a comprehensive overview of integrating electric vehicles (EVs) into smart grids, including the V2H strategy. The authors propose a Demand Response (DR) mechanism based on V2H technology to optimize energy management in residential homes. The P&O algorithm is used for battery charging and discharging management, which is controlled by the SHEMS [1]. This paper provides an overview of the current state of research on integrating EVs into smart grids, including V2H technology. The authors discuss the challenges and opportunities associated with V2H technology and propose a control strategy based on the P&O algorithm to optimize energy management in residential homes. The study shows that the proposed strategy can effectively manage energy consumption and reduce energy costs [2]. The authors consider the impact of renewable energy sources and propose a two-stage control strategy that includes battery charging and discharging management. The proposed strategy is evaluated using simulation results, which demonstrate its effectiveness in improving energy efficiency and reducing energy costs [3]. The integration of electric vehicles (EVs) into the electricity grid is becoming increasingly important as the demand for sustainable energy solutions grows. One approach to this integration is Vehicle-to-Home (V2H) technology, which allows EVs to act as energy storage units that can provide electricity to a home during times of peak demand or grid outages [4]. V2H units allow for the bi-directional flow of energy between electric vehicles (EVs) and homes, enabling homeowners to use their EVs as backup power sources during outages and to optimize energy usage. However, managing the integration of a V2H unit into an intelligent home energy management system can be challenging due to the complex interactions between the EV, the home, and the grid [5]. The P&O algorithm is a population-based stochastic optimization algorithm that is commonly used to solve complex optimization problems. In this case, it can be used to optimize the energy management system of the intelligent home by adjusting the charging and discharging schedules of the EV to ensure that energy is efficiently used, and energy costs are minimized. This paper proposes a model for managing the integration of a V2H unit into an intelligent home energy management system using the P&O algorithm. In addition to controlling the EV battery, the SHEMS can also integrate other energy resources in the household, such as solar panels, wind turbines, and energy storage systems. By optimizing the use of these resources, the SHEMS can reduce the reliance on the grid and increase the use of renewable energy.

2 Related work

Vehicle-to-Home (V2H) Technology focuses on the technical aspects of V2H systems and their potential benefits in terms of energy storage and grid integration [6]. Smart Home Energy Management Systems explore various approaches to managing energy consumption and generation in smart homes, including demand-response strategies, load forecasting, and optimization algorithms. An investigation of energy management techniques applied to smart grids, considering factors such as real-time pricing, demand-side management, and renewable energy integration [7-10]. V2H Integration Challenges addresses the challenges of integrating electric vehicles with home energy systems, including the impact on grid stability, battery degradation, and economic feasibility. EVs are charged the usage of strength from the grid; typically for the duration of off-peak hours when energy calls for is lower and strength prices are cheaper. At some stage in peak demand periods or whilst there may be a want for grid stabilization, excess energy stored in EV batteries may be despatched lower back to the grid to provide additional electricity. V2G can help stability the grid by way of imparting extra energy all through excessive call for, lowering the need for additional fossil-fuel-primarily based power era. Research based on communication protocols and standards necessary for effective communication between the V2H unit, the smart home system, and the power grid. Renewable Energy-Based Charging Scheduling proposes algorithms and approaches to schedule electric vehicle charging based on the availability and forecast of renewable energy generation [11-15]. The economic and environmental benefits of V2H integration include potential cost savings, greenhouse gas emissions reduction, and the overall sustainability of the system. Real-world implementations of V2H integrated with smart home energy management systems, assessing the practical feasibility and lessons learned from actual deployments [16-20].

2 Modeling of V2H System

2.1 Smart Home Energy Management Systems

Smart Home Energy Management Systems (SHEMS) are a type of technology designed to help homeowners manage and control their energy usage in Fig. 1. These systems typically include hardware and software that can monitor and control a home's energy consumption, as well as provide real-time feedback on energy usage [21-25]. Smart home energy management systems have been successfully developed through the integration of two new technologies, vehicle-to-grid (V2G) technology and power generation. V2G technology enables electric vehicles (EVs) not only to draw power from the grid, but also to return excess power to the grid when needed. This bidirectional energy flow enables EVs to mimic the power of a mobile phone, optimizing energy distribution and grid stability. During sunny periods, when solar panels produce more energy than the household requires, the excess power can be fed back into the grid, often resulting in net metering or feed-in tariffs that credit homeowners for the surplus energy they contribute. Conversely, during peak demand hours or when solar production is low, the system can automatically shift to grid power to ensure uninterrupted energy supply.

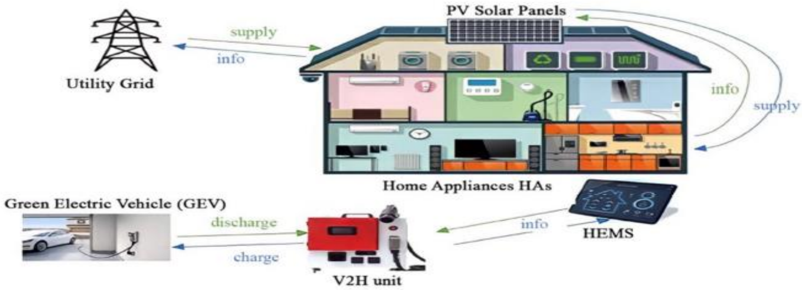

Fig. 1. Smart Home Energy Management System (SHEMS)

The integration of Vehicle-to-Grid (V2G) technology and solar energy generation represents a significant leap forward in this domain. V2G enables electric vehicles (EVs) to not only consume electricity but also feed excess energy back into the grid when needed. When combined with solar panels, homeowners can harness renewable energy to power their homes and charge their EVs [26-28]. The smart system intelligently balances energy production, consumption, and storage, leveraging real-time data and predictive algorithms. This synergy allows homeowners to maximize self-consumption of solar energy, minimize peak demand from the grid, and even contribute to grid stability by participating in demand response programs. Ultimately, the convergence of V2G and solar within smart home energy management transforms residences into dynamic energy hubs, promoting sustainability, resilience, and cost savings while facilitating a cleaner energy future [29-30].

2.2 HCPV Design

HCPV (High Concentration Photovoltaic) design utilizes high-efficiency solar cells and optical components to concentrate sunlight onto small cells. This design can achieve higher conversion efficiencies compared to traditional flat-plate photovoltaic panels. Integrating an HCPV design with V2H and SHEMS can help to maximize the use of renewable energy sources and reduce energy costs. By combining V2H with HCPV, it is possible to create a unified energy management framework that allows the EV battery to be charged using solar power during the day and discharged to power the home at night or during peak demand periods. The smart home EMS can also be programmed to optimize energy usage based on the available solar power, the energy needs of the home, and the current grid conditions [31-34].

The unified energy management framework for V2H and SHEMS integration can be achieved through the use of advanced software algorithms and communication protocols. These algorithms can be used to optimize energy storage and usage, as well as manage the charging and discharging of electric vehicles. Additionally, the communication protocols can enable real-time monitoring and control of energy consumption, allowing homeowners to make informed decisions about their energy usage [35]. Overall, integrating V2H units with SHEMS using HCPV design can provide homeowners with a comprehensive energy management solution that maximizes the use of renewable energy sources and reduces energy costs. Solar energy is a clean, renewable energy that does not produce greenhouse gases. By integrating solar energy into the grid, the overall carbon footprint of electricity generation is reduced, resulting in a more efficient mix. Solar energy can replace the grid, especially in combination with other renewable energy sources [36-38]. V2G technology can help offset this change by using electric vehicle batteries to absorb excess energy during periods of overproduction and to release energy during times of higher or lower demand than new. This will help maintain grid stability and reduce the need for regular backup power. Solar link V2G systems can provide additional services to the grid, such as frequency control and power support. These services help maintain the stability and reliability of the grid and increase overall energy efficiency.

2.3 V2H-HCPV Low Cost Design

V2H (Vehicle-to-Home) technology allows electric vehicles to discharge their batteries to power a home or building during times of peak electricity demand or during a power outage. HVPV (Home Vehicle Power Vector) is a design concept that takes this technology a step further, integrating renewable energy sources, energy storage, and electric vehicle charging infrastructure into a single, holistic system. To design an HVPV system, several factors need to be considered, such as the energy needs of the building, the size of the electric vehicle battery, the capacity of the renewable energy sources, and the available space for energy storage and charging infrastructure. Here are the basic steps for designing an HVPV system:

1. **Determine the energy needs of the building:** This involves assessing the building's electricity consumption patterns, identifying the peak demand times, and estimating the amount of energy required to power the building during those times.
2. **Assess the renewable energy sources:** This involves evaluating the solar or wind potential of the site and assessing the energy production of the renewable energy system. This will support regulate the size and capacity of the renewable energy system required to meet the energy needs of the building.
3. **Evaluate the energy storage options:** This involves selecting the appropriate energy storage system that can store excess energy generated by the renewable energy system and discharge it when needed. The size of the energy storage system will depend on the energy needs of the building and the capacity of the renewable energy system. Supercapacitors, also known as ultracapacitors, offer rapid energy storage and release capabilities. While they have lower energy density compared to batteries, they excel in high-power applications and can be used to manage peak power demands in a V2H-HCPV system.
4. **Integrate all components into a single system:** This involves designing a system that can manage the flow of energy between the renewable energy system, energy storage system, electric vehicle charging infrastructure, and the building. The system should be able to optimize energy use, minimize energy waste, and prioritize energy delivery during peak demand times.

2.4 Bidirectional DC-DC converter Ultracapacitor

Design of V2H (Vehicle-to-Home) ultracapacitor arrangement is a device that allows electric vehicles (EVs) to store energy from the grid or from renewable sources, such as solar panels, and use it to power homes during blackouts or peak energy demand time. Here are some concerns for designing a V2H ultracapacitor system:

1. **Energy Storage Capacity:** The first consideration when designing a V2H ultracapacitor system is the energy storage capacity. The system should be able to store enough energy to power the home for a reasonable amount of time during an outage or peak demand period. The amount of energy stored will depend on the size of the home, the number of appliances, and the desired backup time. The energy storage capacity of an ultracapacitor module can be calculated using the following equation:

$$E = 0.5 \times C \times V^2 \quad (1)$$

Where E is the energy storage capacity in joules, C is the capacitance in farads, and V is the voltage in volts. This equation assumes that the voltage is constant during the discharge process.

2. **Power Conversion:** The V2H ultracapacitor system should be able to convert the DC voltage of the ultracapacitor module to the AC voltage needed to power the home. This can be achieved using an inverter or a power electronics converter.

3. **Control and Monitoring:** The V2H system should have a control and monitoring system that allows for safe and efficient operation. This includes monitoring the state of charge of the ultracapacitor module, managing the power flow between the EV battery and the home, and protecting the system from overvoltage, overcurrent, and over temperature conditions.

4. **Voltage and Current Ratings:** The bidirectional DC-DC converter should be designed to handle the voltage and current requirements of the ultracapacitor module and the home's electrical system. The converter should also be able to handle the voltage and current of the EV battery during charging and discharging.

5. **Topology:** There are several topologies that can be used for bidirectional DC-DC converters, such as the buck-boost, SEPIC, and Cuk topologies. The choice of topology will depend on factors such as efficiency, size, and cost.

6. **Control and Monitoring:** The bidirectional DC-DC converter should have a control and monitoring system that allows for safe and efficient operation. This includes controlling the power flow between the ultracapacitor module and the home's electrical system, and between the EV battery and the ultracapacitor module. The control system should also be able to detect and respond to overvoltage, overcurrent, and over temperature conditions in Fig. 2.

7. **Efficiency:** The bidirectional DC-DC converter should be designed to operate with high efficiency to minimize power losses and maximize the amount of power that can be transferred between the ultracapacitor module and the home's electrical system. This can be achieved through careful component selection, such as choosing high-efficiency MOSFETs and inductors, and optimizing the control algorithm.

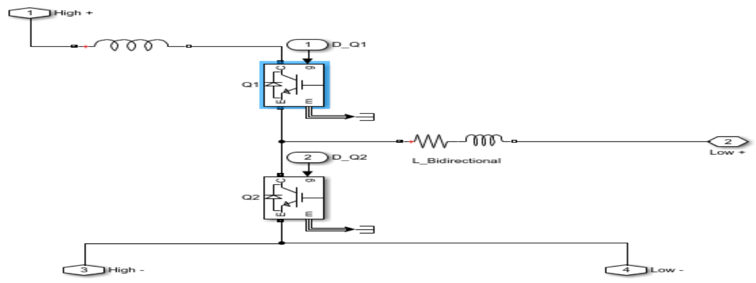

Fig. 2. Bidirectional DC-DC Converter

2.5 DC-DC Boost converter

Determine the Input and Output Voltage: In Fig. 3. The first stage in planning a DC-DC Boost converter is to determine the input and output voltage stages. The given input voltage is the voltage level that is available from the power source, while the output voltage is the desired voltage level that the load requires.

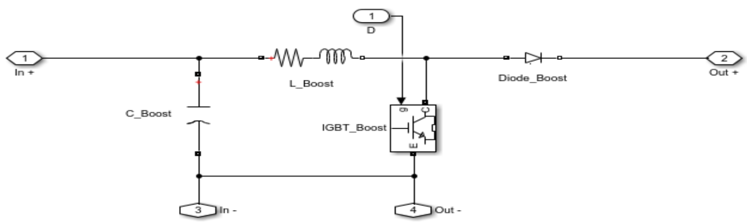

Fig. 3. DC-DC Boost Converter

1. **Determine the Output Power:** The second stage is to control the output power essential by the load. This can be estimated by multiplying the output voltage with the load current.
2. **Choose the Switching Frequency:** The next stage is to choose the switching frequency of the converter. The switching frequency is the frequency can be used at which the converter switches on and off. Higher frequencies generally result in smaller components, but also lead to higher switching losses.
3. **Select the Inductor:** The inductor is a crucial component in a DC-DC Boost converter. It is used to store energy during the on-time of the switch and release it during the off-time. The inductance value is calculated using the following formula:

$$L = \left(\frac{(V_{out}*(V_{in}-V_{out}))}{(I_{out}*f_s)}\right) \quad (2)$$

where V_{out} is the output voltage, V_{in} is the input voltage, I_{out} is the output current, and f_s is the switching frequency.

4. **Choose the Capacitor:** The capacitor is used to filter the output voltage of the converter. The value of the capacitor depends on the load current and the preferred output voltage swell. The capacitance value can be calculated using the following formula:

$$C = \left(\frac{(I_{out}*(1-D))}{(\Delta V * f_s)}\right) \quad (3)$$

where I_{out} is the output current, D is the duty cycle of the switch, ΔV is the desired output voltage ripple, and f_s is the switching frequency.

5. **Select the Switch:** The switch is used to control the flow of current in the converter. The most common type of Switch used in DC-DC Boost converters is the IGBT. The IGBT should have a low on-resistance and a high voltage rating to handle the input voltage.

6. **Choose the Diode**: The diode is used to provide a path for the inductor current when the switch is off. The diode should have a low forward voltage drop and a fast recovery time to minimize losses.

7. **Design the Control Circuit:** The control circuit is used to regulate the output voltage of the converter. The most common control method used in DC-DC Boost converters is pulse-width modulation (PWM). The control circuit should be designed to provide stable and accurate regulation.

2.6 HVPV Controller Algorithm

The HCPV and P&O (Perturb and Observe) algorithm is a control strategy used in HCPV systems to extract the maximum power from the solar panel. The algorithm is based on a feedback loop that continuously adjusts the duty cycle of the DC-DC converter to maintain the solar panel operating at its maximum power point (MPP). The P&O algorithm works by perturbing the operating voltage of the solar panel and observing the change in the output power. The algorithm then adjusts the voltage in the direction of the perturbation that resulted in increased power output and continues this process until the maximum power point is reached. The algorithm constantly monitors the output power and adjusts the duty cycle of the DC-DC converter to maintain the solar panel at the MPP in Fig. 4.

In HCPV systems, the P&O algorithm needs to be adapted to account for the high concentration ratio of the system, which can result in non-linear behavior and temperature effects. Additionally, the algorithm needs to be optimized to achieve fast tracking of the MPP, while minimizing overshoot and oscillations around the MPP. One advantage of the P&O algorithm is its simplicity and ease of implementation. However, it may suffer from slow tracking speed, especially under rapidly changing irradiation conditions.

Therefore, other MPPT algorithms such as Incremental Conductance (INC) or Fractional Open Circuit Voltage (FOCV) are also used in HCPV systems to provide faster and more accurate tracking of the MPP.

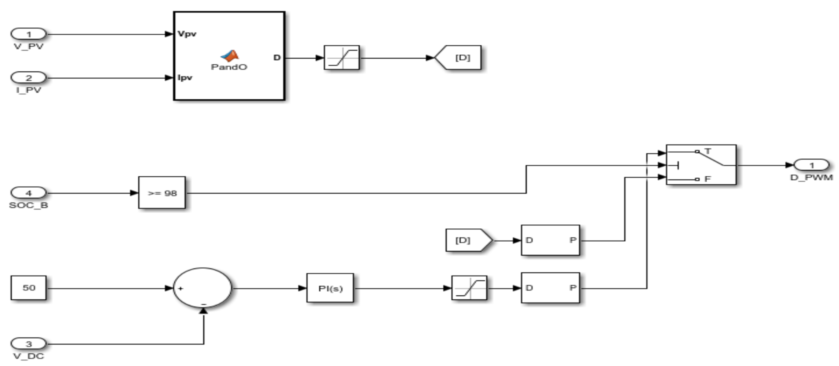

Fig. 4. MPPT Using P & O Algorithm

2.7 Energy Transfer in Different cases at a Smart House

Case I - Grid-to-EV charging

There are different types of grid-to-EV charging systems, but in general, they use smart charging algorithms to manage the charging process. These algorithms can adjust the charging rate of EVs based on real-time energy demand and availability, and they can also prioritize the use of renewable energy sources. In Fig. 5. Standard grid-to-EV charging typically involves connecting an EV to a charging station, which is then connected to the electricity grid. The EV owner can then initiate the charging process, and the charging station communicates with the smart charging system to determine the optimal charging rate.

Fig. 5. Grid-to-EV charging

Case II - Grid-to-EV charging enhanced by Solar PV

Solar-enhanced charging can be implemented in several ways. One approach is to use a simple grid-tied solar PV system to provide electricity to the charging station, either partially or completely offsetting the energy consumed from the grid. Another approach is to use battery storage systems to store the solar-generated electricity and use it to charge the EVs at a later time, even when solar power is not available.

Advanced solar-enhanced charging systems can incorporate smart charging algorithms to optimize the use of solar power for charging EVs. For example, the charging system can monitor the output of the solar PV system and adjust the charging rate of the EVs to match the available solar power, while also taking into account other factors such as the state of charge of the battery and the energy demand on the grid in Fig. 6.

Fig. 6. Grid-to-EV charging enhanced by Solar PV

Case III – V2H charging and discharging enhanced by Solar PV

In Fig. 7 shows Vehicle-to-Home (V2H) technology allows electric vehicles (EVs) to discharge their batteries to power homes during peak demand periods, which can reduce stress on the power grid and lower energy costs. This technology can be enhanced by Solar Photovoltaic (PV) systems, which can provide additional energy to charge the EVs and power homes during the day.

Fig. 7. V2H charging and discharging enhanced by Solar PV

Designing a V2H power electronic system involves several key components and considerations. Now are certain of the important features to consider:

Bidirectional Power Conversion: V2H systems require power converters capable of converting DC power from the EV battery to AC power for household use and vice versa. Typically, a bidirectional charger/inverter is used for this purpose. It should have high efficiency and be able to handle the power levels required for both charging the EV and supplying power to the home.

Power Electronics Topology: Various power electronics topologies can be used for V2H systems, such as a two-level voltage source inverter (VSI) or a three-level neutral point clamped (NPC) inverter. The choice of topology depends on factors like system requirements, power rating, efficiency, and cost.

Energy Management System: An intelligent energy management system is essential for controlling the power flow between the EV and the home. It monitors the power demand in the home, EV battery state-of-charge, and grid conditions to determine when to charge the EV or supply power to the home. The energy management system should have communication capabilities to interface with the EV and the grid.

Battery Charging and Discharging Control: V2H systems should incorporate battery charging and discharging control mechanisms to protect the EV battery. It contains monitoring the EV battery - voltage, current, temperature, and State-of-Charge to ensure safe operation. Additionally, the control system should manage the charging and discharging rates based on user preferences and grid conditions.

Grid Connection and Protection: V2H systems need to be connected to the electrical grid to allow bidirectional power flow. This requires proper grid connection equipment, such as a grid-tied inverter, along with appropriate protection mechanisms like overvoltage and overcurrent protection.

Communication and Control: Effective communication and control interfaces are crucial for V2H systems. They enable the system to interact with the EV, home appliances, and the grid. Communication protocols such as CAN (Controller Area Network) or Ethernet can be used to establish communication links between the different components.

2.8 Perturb and Observe Optimization Technique

The "Perturb and Observe" algorithm is a commonly used technique in the field of photovoltaic systems for maximum power point tracking. However, in the context you mentioned, which involves integrating a Vehicle-to-Home (V2H) unit with smart home energy management systems, the use of the Perturb and Observe algorithm might not be immediately clear. Based on the information provided, it seems that the authors of the paper or study you mentioned have proposed a unified energy management framework that incorporates both V2H technology and smart home energy management systems. This framework likely aims to optimize energy usage, storage, and distribution within a smart home environment, considering the availability of energy from both the electric grid and an electric vehicle (EV) connected to the home.

The specific role of the Perturb and Observe algorithm within this framework would depend on how it is being utilized. However, typically, the Perturb and Observe algorithm is employed for tracking the maximum power point (MPP) of a photovoltaic system by perturbing the operating voltage or current and observing the resulting power change. This technique ensures that the photovoltaic system operates at its maximum efficiency point, thus maximizing the power output. In the context of integrating a V2H unit with a smart home energy management system, the Perturb and Observe algorithm might be used to optimize the charging and discharging of the EV battery based on factors such as the available solar energy, energy demand within the home, and the current state of the EV battery. By perturbing the charging or discharging rate and observing the resulting changes in the overall energy system, the algorithm can determine the optimal operating point to minimize energy costs or maximize self-consumption.

2.8.1 Flow chart for the framework:

Creating a flowchart for Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) systems using a Perturb and Observe (P&O) algorithm involves several steps in Fig. 8.

Start: Initiate the energy management framework.

Measure Energy Inputs: Monitor and measure the energy inputs to the system, including solar energy production, grid energy availability, and EV battery state of charge (SoC).

Determine Energy Demand: Assess the energy demand within the smart home, considering factors such as appliances, lighting, heating/cooling, and user preferences.

Check V2H Suitability: Determine if there is a need or opportunity to use the EV battery for supplying energy to the home based on the energy demand and the EV battery SoC.

Perturb and Observe Algorithm: If V2H is suitable, apply the Perturb and Observe algorithm to optimize the charging and discharging of the EV battery. This algorithm continuously adjusts the charging and discharging rate and observes the resulting changes in the overall energy system.

Optimal Operating Point: The Perturb and Observe algorithm finds the optimal operating point for the EV battery based on factors such as available solar energy, energy demand, and battery SoC. This point maximizes self-consumption, minimizes energy costs, or fulfills any other defined objective.

Charge/Discharge Control: Control the V2H unit to charge or discharge the EV battery based on the determined optimal operating point.

Monitor and Update: Continuously monitor the energy inputs, energy demand, and battery SoC to adapt to any changes or fluctuations.

Energy Distribution: Based on the overall energy system status, distribute the energy to the various components within the smart home, such as appliances, storage systems, and the electric grid.

End: Conclude the energy management framework.

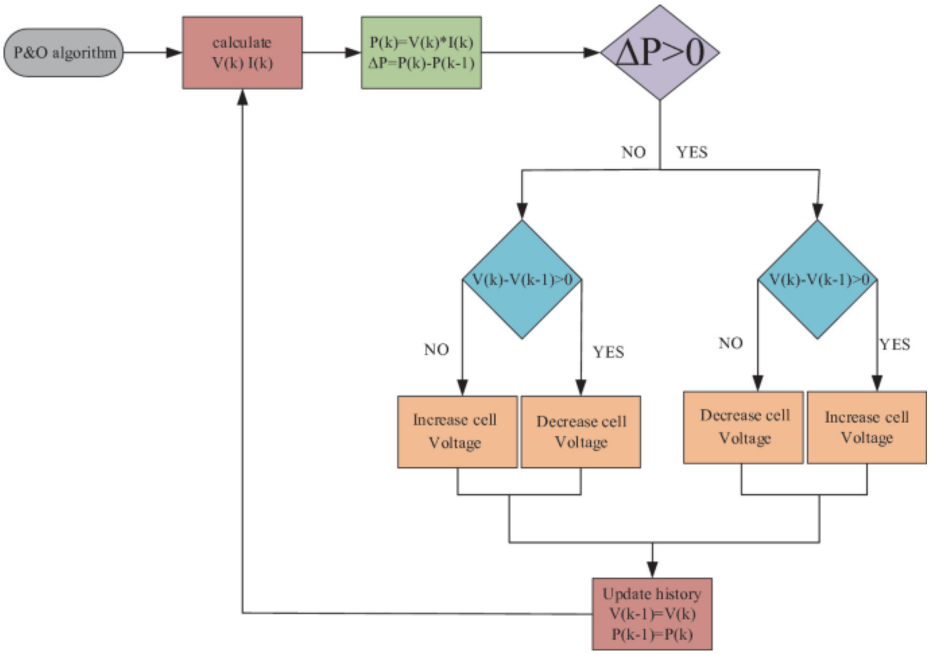

Fig. 8. Flow chart Frame work

The HCPV system would incorporate sensors to measure the intensity of incoming sunlight and the performance of the solar cells. These sensors would provide data on the current operating point of the solar cells. The P&O algorithm would continuously analyze the sensor data to determine whether the system is operating at or near its maximum power point. If not, the algorithm would initiate perturbations to the operating voltage of the solar cells. The P&O algorithm's adjustments to the operating voltage would affect the output power of the solar cells. This, in turn, could impact the optimal concentration of sunlight onto the solar cells. The HCPV system's tracking mechanism would adjust the concentration of sunlight to align with the new operating conditions. The combination of HCPV and the P&O algorithm would lead to improved overall efficiency by maximizing power output from the solar cells while maintaining accurate concentration. This would result in higher energy generation and improved utilization of available sunlight.

3 Simulation and Results

The simulation would likely depict the various components of the energy management framework, including the Vehicle-to-Home Unit (VHU), Smart Home Energy Management System (SHEMS), and the P&O algorithm. It may also include external factors, such as weather conditions or energy tariffs. The VHU component would include the charging and discharging of the electric vehicle (EV) battery, while the SHEMS component would manage the energy usage within the home, such as controlling the heating and cooling systems, lighting, and appliances. The P&O algorithm would optimize the energy usage of the VHU and SHEMS by adjusting the charging and discharging schedules of the EV battery and controlling the energy consumption of the home.

The simulation would also show the communication between the components, such as data exchange between the VHU and SHEMS, and the P&O algorithm's input and output parameters. Smart home energy management system would be the central control system for the home's energy usage. It would be responsible for monitoring energy usage patterns and making decisions about when and how to use energy based on various inputs, such as weather forecasts, time of day, and user preferences. Vehicle-to-home unit would be a device that connects the home's electrical system to an electric vehicle (EV) in Fig. 9. It would allow the EV to charge when there is excess energy available in the home's system, and it could also discharge energy back into the home when needed. The P&O algorithm works by perturbing the energy flow and observing the impact on the system. The algorithm adjusts the energy flow direction based on the observed results until an optimal point is reached. In the context of this framework, it would be used to optimize energy usage in the home by finding the most efficient and cost-effective way to use available energy. Energy storage system would be a system for storing excess energy generated by the home's renewable energy sources, such as solar panels. It could include batteries, capacitors, or other types of storage devices. The energy storage system would ensure that excess energy is not wasted and can be used when needed.

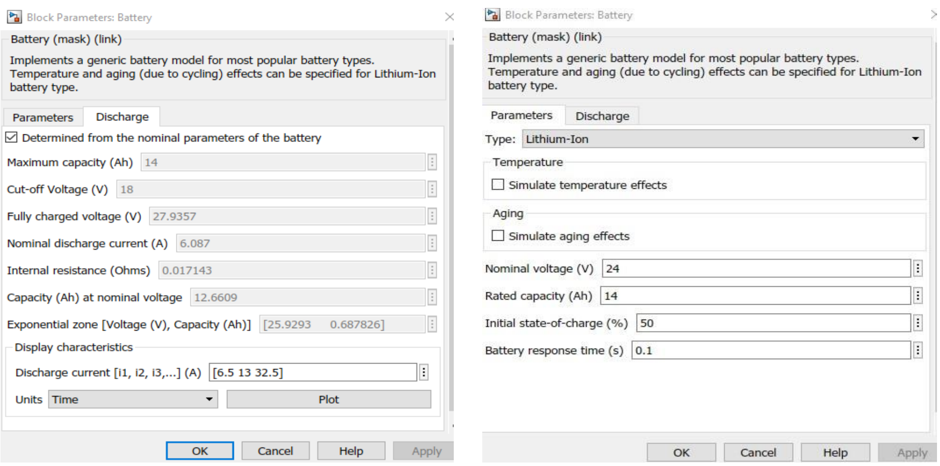

Fig. 9. Battery parameters

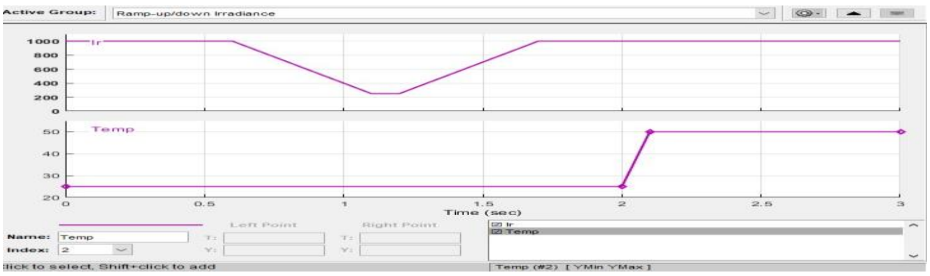

Fig. 10. Solar Level

Solar radiance level, also known as solar irradiance or solar insolation, refers to the amount of solar energy received per unit area on the Earth's surface from the sun. It is a measure of the intensity of sunlight at a specific location and time, and it is typically expressed in watts per square meter (W/m^2) or kilowatts per square meter (kW/m^2) in Fig. 10.

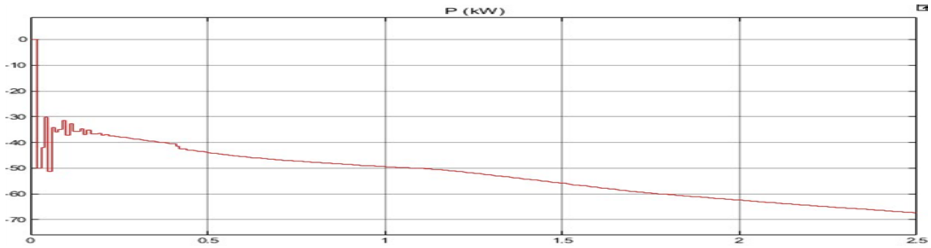

Fig. 11. Power Output

State of Charge (SoC): The current level of charge in the EV battery affects the amount of power that can be discharged to the home. A higher SoC allows for more power output. It is important to note that V2H technology is still evolving, and the power output capabilities can vary between different EV models and V2H systems in Fig. 11.

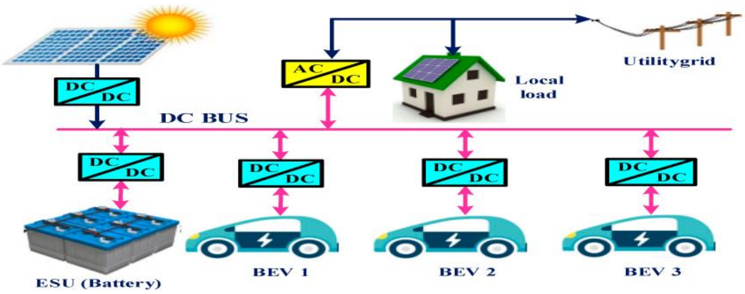

Fig. 12. Overall System

In Fig. 12 Utilities can use EVs as a flexible demand response tool, reducing strain on the grid during peak times. EV owners can earn money by selling excess energy back to the grid or participating in grid support programs. V2G can help store excess renewable energy during periods of high generation and feed it back into the grid when needed.

4 Conclusion

This study highlights the importance of V2H technology as a potential solution to address increasing energy demand and environmental concerns. The V2H technology allows electric vehicles (EVs) to not only consume energy from the grid and renewable energy sources but also feed the excess energy back to the grid or use it to power home appliances. This feature can significantly reduce the energy bill and carbon footprint of households, while also ensuring a reliable and resilient energy supply. The P&O algorithm used in the strategic framework enables the system to optimize the energy flow based on the energy demand and availability, without compromising the user's comfort and convenience. The potential benefits of integrating V2H with a smart home energy management system and the effectiveness of the P&O algorithm in achieving optimal energy utilization. This research can be helpful for policymakers, utility companies, and households to design and implement sustainable energy systems that can contribute to a greener future.

Acknowledgment

"I would like to express my heartfelt gratitude to everyone who has contributed to the completion of this research project on Integrating Vehicle-to-Home Unit with Smart Home Energy Management Systems: A Unified Energy Management Framework by using the P&O Algorithm. I would like to thank my supervisor, my friends and family for their unwavering support and motivation during the ups and downs of this research endeavor. Thank you all for your dedication and commitment to this project".

References

1. Javadi, M.S.; Gough, M.; Lotfi, M.; Nezhad, A.E.; Santos, S.F.; Catalão, J.P. Optimal self-scheduling of home energy management system in the presence of photovoltaic power generation and batteries. Energy, 210, 118568 (2020).
2. Ramalingam, S.P.; Shanmugam, P.K. A Home Energy Management System with Peak Demand Reduction Using Ant Colony Optimization and Time of Use Pricing Scheme. In Soft Computing for Problem Solving; Springer: Berlin, Germany; pp. 531–546 (2021).
3. Tutkun, N.; Burgio, A.; Jasinski, M.; Leonowicz, Z.; Jasinska, E. Intelligent Scheduling of Smart Home Appliances Based on Demand Response Considering the Cost and Peak-to-Average Ratio in Residential Homes. Energies, 14, 8510 (2021).
4. Jiang, Y.; Song, L.; Allen, J.K.; Mistree, F. Home Energy Management System (HEMS): Coupled Flexible Load Management in Homes. In Proceedings of the International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Online, Volume 85413, p. V005T05A016, (17–19 August 2021).
5. Abdelwahed, A.S.; Zekry, A.; Amer, G.M.; Tawfeek, R.M. Implementation of a Priority-Based Home Energy Management System. In Proceedings of the International Mobile, Intelligent, and Ubiquitous Computing Conference (MIUCC), Cairo, Egypt; pp. 84–89, (26–27 May 2021).
6. Shakir, M.; Biletskiy, Y. Smart Microgrid Architecture For Home Energy Management System. In Proceedings of the IEEE Energy Conversion Congress and Exposition (ECCE), Vancouver, BC, Canada; pp. 808–813, (10–14 October 2021).
7. M. Javidi, "Integration of Electric Vehicles into Smart Grids with Emphasis on Demand Response and Vehicle to Home strategies", et al (2017).

8. Blonsky, M.; Munankarmi, P.; Balamurugan, S.P. Incorporating Residential Smart Electric Vehicle Charging in Home Energy Management Systems. In Proceedings of the 2021 IEEE Green Technologies Conference (GreenTech); pp. 187–194, Online, 7–9 April 2021.

9. Dagdougui, Y.; Ouammi, A.; Benchrifa, R. High Level Controller-Based Energy Management for a Smart Building Integrated Microgrid With Electric Vehicle. Front. Energy Res., 8, 248 (2020).

10. J. Zhan, "Integration of Electric Vehicles into Smart Grids: State-of-the-Art and Future Challenges", et al (2019).

11. Dawoud, S.M., "Developing different hybrid renewable sources of residential loads as a reliable method to realize energy sustainability". Alex. Eng. J., 60, 2435–2445 (2021).

12. Luo, F.; Kong, W.; Ranzi, G.; Dong, Z.Y, "Optimal Home Energy Management System With Demand Charge Tariff and Appliance Operational Dependencies. IEEE Trans. Smart Grid", 11, 4–14 (2019).

13. Mehrjerdi, H.; Hemmati, R., "Coordination of vehicle-to-home and renewable capacity resources for energy management in resilience and self-healing building". Renew. Energy, 146, 568–579 (2019).

14. Yang, Y.; Wang, S., "Resilient residential energy management with vehicle-to-home and photovoltaic uncertainty". Int. J. Electr. Power Energy Syst., 132, 107206 (2021).

15. Datta, U.; Saiprasad, N.; Kalam, A.; Shi, J.; Zayegh, A., "A price-regulated electric vehicle charge-discharge strategy for G2V, V2H and V2G". Int. J. Energy Res., 43, 1032–1042 (2019).

16. Slama, S.A.B., "Design and implementation of home energy management system using vehicle to home (H2V) approach". J. Clean. Prod., 312, 127792 (2021).

17. Shemami, M.S.; Alam, M.S.; Asghar, M.S.J., "Reliable Residential Backup Power Control System Through Home to Plug-In Electric Vehicle (H2V)". Technol. Econ. Smart Grids Sustain. Energy, 3, 8 (2018).

18. Shakir, H.H.; Zdiri, M.A.; Salem, F.B., "Optimal Energy Management of Smart Grid Connected Residential PV Power System". In Proceedings of the 2021 12th International Renewable Energy Congress (IREC), Hammamet, Tunisia, 26–28 October 2021; pp. 1–4 (2021).

19. Sharda, S.; Sharma, K.; Singh, M. A, Real-Time Automated Scheduling Algorithm with PV Integration for Smart Home Prosumers. J. Build. Eng., 44, 102828 (2021).

20. Diyan, M.; Khan, M.; Zhenbo, C.; Silva, B.N.; Han, J.; Han, K.J. Intelligent Home Energy Management System Based on Bi-directional Long-Short Term Memory and Reinforcement Learning. In Proceedings of the International Conference on Information Networking (ICOIN), Jeju Island, Korea, 13–16 January 2021; pp. 782–787 (2021).

21. Chioran, D.; Valean, H. Design and Performance Evaluation of a Home Energy Management System for Power Saving. Energies, 14, 1668 (2021).

22. Hussain, M.M.; Akram, R.; Memon, Z.A.; Nazir, M.H.; Javed, W.; Siddique, M. Demand Side Management Techniques for Home Energy Management Systems for Smart Cities. Sustainability, 13, 11740 (2021).

23. Rocha, H.R.; Honorato, I.H.; Fiorotti, R.; Celeste, W.C.; Silvestre, L.J.; Silva, J.A. An Artificial Intelligence based scheduling algorithm for demand-side energy management in Smart Homes. Appl. Energy, 282, 116145 (2020).

24. Liu, Y.; Xiao, B.; Yao, G.; Bu, S. Pricing-based demand response for a smart home with various types of household appliances considering customer satisfaction. IEEE Access, 7, 86463–86472 (2019).

25. S. Shao, M. Pipattanasomporn, and S. Rahman, "Grid Integration of Electric Vehicles and Demand Response With Customer Choice," IEEE Transactions on Smart Grid, vol. 3, no. 1, pp. 543 –550, (Mar. 2012).

26. K. Yoshimi, M. Osawa, D. Yamashita, T. Niimura, R. Yokoyama, T. Masuda, H. Kondou, and T. Hirota, "Practical Storage and Utilization of Household Photovoltaic Energy by Electric Vehicle Battery," presented at the Innovative Smart Grid Technologies (ISGT), IEEE PES, pp. 1 –8 (2012).

27. I. Cvetkovic, T. Thacker, D. Dong, G. Francis, V. Podosinov, D. Boroyevich, F. Wang, R. Burgos, G. Skutt, and J. Lesko, "Future Home Uninterruptible Renewable Energy System With Vehicle-To-Grid Technology," in IEEE Energy Conversion Congress and Exposition, ECCE 2009, pp. 2675 –2681 (2009).

28. T. Hansen, R. Roche, S. Suryanarayanan, H. J. Siegel, D. Zimmerle, P. Young, and A. Maciejewski, "A Proposed Framework for Heuristic Approaches to Resource Allocation in the Emerging Smart Grid," presented at the IEEE PES International Conference on Power Systems and Technology (POWERCON 2012), Auckland, New Zealand, pp. 1–6 (2012).

29. T. Lajnef, S. Abid, and A. Ammous, ''Modeling, Control, and Simulation of a Solar Hydrogen/Fuel Cell Hybrid Energy System for Grid-Connected Applications'', Hindawi Publishing Corporation Advances in Power Electronics, 9 pages, (2013).

30. X. Wu, X. Hu, Y. Teng, S. Qian and R. Cheng, "Optimal integration of a hybrid solar-battery power source into smart home nanogrid with plug-in electric vehicle", Journal of Power Sources, vol. 363, pp. 277-283, (2017).

31. M. Alirezaei, M. Noori and O. Tatari, "Getting to net zero energy building: Investigating the role of vehicle to home technology", Energy and Buildings, vol. 130, pp. 465-476, (2016).

32. W. Zhao, L. Ding, P. Cooper and P. Perez, "Smart Home Electricity Management in the Context of Local Power Resources and Smart Grid", Journal of Clean Energy Technologies, pp. 73-79, (2014).

33. H. Shin and R. Baldick, "Plug-In Electric Vehicle to Home (V2H) Operation Under a Grid Outage", IEEE Transactions on Smart Grid, vol. 8, no. 4, pp. 2032-2041, (2017).

34. M.S.Sivagamasundari, P. Melba Mary and V.K. Velvizhi "Maximum Power Point Tracking For Photovoltaic System by Perturb and Observe Method Using Buck Boost Converter" International Journal

of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 2, Issue 6, (June 2013).

35. E.I.O. Rivera, "Maximum Power Point Tracking using the Optimal Duty Ratio for DC-DC Converters and Load Matching in Photovoltaic Applications," Twenty Third Annual IEEE Applied Power Electronics Conference and Exposition, APEC 2008, pp. 987-991, (2008).

36. Kavita Rathore1, Sunil Kumar, “Net Zero Emissions for Our Future Generations through Renewables: A Brief Review”, International Journal of Energy Resources Applications (IJERA), Vol. 2, Issue 1, page 39-56, (June 2023).

37. Sunil Kumar, Kavita Rathore, “Renewable Energy for Sustainable Development Goal of Clean and Affordable Energy”, International Journal of Materials, Manufacturing and Sustainable Technologies (IJMMST), Vol. 2, Issue 1, page 01-15, (April 2023).

38. Kumar S, Rathore K., “Renewable Energy for Sustainable Development Goal of Clean and Affordable Energy”, Int J Mater Manuf Sustain Technol, ;2:01–15, (2023).