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# Optimal Energy Management in V2G EV System for Hybrid Power Integration and Sustainable Development

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**ABSTRACT**

Energy management between electric vehicles and the grid system for hybrid integration is the primary goal of this Endeavour. Amidst ecological degradation and the depletion of fossil fuels, the global renewable energy generation scale, particularly for wind power, has grown significantly in recent years. However, when connected to the power grid, the randomness, intermittent nature, and uncertainty significantly impair the power system's dependability and lead to several issues. Therefore, in order to guarantee the safety and stability of the power system, grid-connected electricity must fall within specific bounds. Additionally, increasing the rate at which hybrid power generation is incorporated into the power system has become extremely. A method for mitigating the oscillations of large-scale wind power is examined through the utilization of vehicle-to-grid (V2G) systems. Battery cells are gradually being replaced by electric vehicles (EVs) as energy storage components in an effort to lower the investment costs of energy storage. Furthermore, as the number of EVs rises, its operability gets increasingly better. Therefore, an energy management and optimization system is created and modeled in order to overcome the voltage variations and manage the energy quickly in this approach. In this method,we are going to discuss about how the energy management takes place when the power is supplied from wind to grid system. Energy management plays a key role in the power system.So, we are going to consider mainly 3-cases based on the equal distribution of power to the connected loads. They are 1) connecting to wind, 2) connecting to solar and connecting to 3) Hybrid System. In the first case the energy management is obtained by considering the power from wind to grid system and the supply of power to loads, Electric Vehicles and to the consumer loads. In the second case the energy management is obtained by considering the power from solar to grid system and the supply of power to loads, Electric Vehicles and to the consumer loads. In the third case we will connect both solar and wind as a hybrid resources to grid system and the supply of power to loads, Electric Vehicles and to the consumer loads.

**Keywords:** Electric Vehicle(EV),Solar Photo Voltaic(SPV), Wind Turbine(WT), Hybrid Energy Resource(HER),Grid connected system, Matlab/Simulink.

## I. INTRODUCTION

With increasing overall emphasis on sustainable energy practices, renewable energy sources like wind energy has gain major traction as key components of the energy mix. However, the inherent intermittency and variability of wind power pose challenges for grid stability and energy management [1]. Addressing these challenges requires innovative solutions that not only enable efficient integration of renewable energy but also enhance overall reliability and flexibility of the electricity grid. In this context, Vehicle-to-Grid (V2G) systems have emerged as a promising technology at the intersection of transportation and energy sectors [2]. By leveraging the growing fleet of electric vehicles (EVs) equipped with bidirectional charging capabilities, V2G systems enable the exchange of energy between EV batteries and the grid. This bidirectional energy flow not only facilitates EV charging but also allows EVs to provide as mobile energy storage unit, providing flexibility and grid support services [3].Incorporation of V2G systems with wind power offers a unique opportunity to address the challenges associated with renewable energy integration while simultaneously optimizing the utilization of EVs and promoting sustainable transportation. By intelligently managing the charging and discharging of EV batteries in coordination with wind power generation patterns and grid demand, V2G systems can help mitigate the variability of wind power, reduce peak load demand, and improve grid stability.

This methodology focuses on exploring the potential synergies between V2G systems and wind power integration through comprehensive energy management and optimization strategies [4]. The primary objective is to develop and evaluate techniques for maximizing the benefits of V2G systems in enhancing grid stability, minimizing energy costs, and reducing greenhouse gas emissions [5].In the detection of explanatory typical weather change and dropping dependence on fossil fuels, the integration of renewable energy sources into the electricity grid has become imperative. Among these sources, wind power holds significant promise due to its abundant availability and relatively low environmental impact.

Electricity grid has become imperative. Among these sources, wind power holds significant promise due to its abundant availability and relatively low environmental impact. However, the variable nature of wind power generation presents challenges for grid operators in maintaining stability and reliability.

In parallel, the transportation sector is undergoing a transformation with the increasing adoption of electric vehicles (EVs) driven by the goals of reducing greenhouse gas emissions and dependence on oil [6]. EVs not only offer a cleaner mode of transportation but also serve as mobile energy storage units with their onboard batteries. The convergence of these two trends has given rise to the concept of V2G systems, which leverage the bidirectional capabilities of EV batteries to support grid operations. V2G systems enable EVs not only depict energy from the grid but also to feed surplus energy back into the grid when required [7]. This bidirectional surge of electricity opens up new avenues for grid management and renewable energy integration. The integration of V2G systems with wind power offers a synergistic key to the challenge pose by the variability of renewable energy generation. By utilizing EV batteries as flexible energy storage units, V2G systems can help smooth out the fluctuations in wind power output, enhance grid stability, and optimize the utilization of renewable energy resources [8].This methodology focuses on exploring the potential of V2G systems for wind power integration, with a specific emphasis on energy management and optimization strategies. The overarching goal is to develop methodologies that enable efficient coordination between wind power generation, EV charging, and grid demand to maximize the benefits for both the electricity grid and EV owners. The imperative for sustainable energy practices has driven a global shift towards renewable energy sources, with wind power rising as a prominent supplier to this transition. Though, the inherent intermittency and variability of wind power generation pose significant challenges for grid stability and energy management. Simultaneously, the rapid proliferation of electric vehicles (EVs) presents an opportunity to revolutionize both the transportation and energy sectors. V2G technology stands at the nexus of these transformations, offering a promising solution to the challenges of renewable energy integration and grid optimization. V2G systems enable bidirectional power flow between EV batteries and the grid, allow EVs to serve as mobile energy storage unit. This bidirectional capability unlocks a range of grid-supportive functionalities, including peak shaving, load balancing, and ancillary services provision.

In the context of wind power integration, V2G systems hold particular promise. By leveraging the flexibility of EV batteries, V2G systems can help mitigate the variability of wind power generation, thereby enhancing grid stability and reliability. Through intelligent energy management strategies, V2G systems can absorb surplus energy during periods of high wind power output and release it during peak order periods or while wind production is low. This technique aims to explore the potential synergies between V2G systems and wind power integration, focusing on energy management and optimization strategies. The overarching objective is to develop methodologies that maximize the benefits of V2G systems in enhancing grid stability, minimizing energy costs, and promoting the efficient use of renewable energy resources.In order to integrate wind power, the proposed method suggests a cooperative optimal dispatch technique for vehicle-to-grid (V2G) systems. The ideal scheduling of EV clusters is determined by applying a suitable DP algorithm, which makes the energy exchange between EVs and the grid operate with great flexibility and efficiency.

## II. PROPOSED SYSTEM

The proposed system aims to integrate Vehicle-to-Grid (V2G) technology with wind power generation to enhance grid stability, promote renewable energy utilization, and optimize energy management. It involves the bidirectional flow of electricity between EV batteries and the grid, enabling EVs to store excess energy during period of maximum wind power production with discharge it back to the grid when needed. Advanced optimization algorithms will be developed to schedule the charging and discharging of EV batteries based on real-time wind power forecasts, grid demand, and market prices, potentially incorporating machine learning techniques for improved prediction accuracy. The system will also implement grid stability enhancement measures such as frequency regulation, voltage support, and reactive power control using V2G- enabled EVs, while maximizing economic benefits through various market participation strategies like energy arbitrage and participation in ancillary services markets. A techno-economic assessment will be conducted to evaluate the feasibility and viability of deploying V2G systems for wind power integration, considering investment costs, operational expenses, revenue streams, and potential environmental benefits. Validation will be performed through a pilot project or demonstration site, collaborating with stakeholders to gather feedback and address practical challenges. Additionally, advocacy for supportive policy and regulatory frameworks will be pursued to facilitate the widespread adoption and deployment of V2G systems for wind power integration, addressing barriers and incentivizing investments in sustainable energy technologies. Through these efforts, the proposed system aims to exploit the benefits of renewable energy integration while addressing the challenges of grid stability and energy management in the transition towards a low-carbon future.

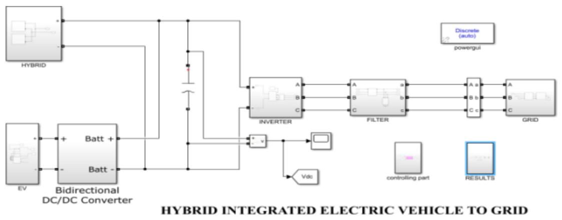


**Fig.**1 Schematic Diagram of Hybrid Integrated Electric Vehicle to Grid System

The proposed vehicle-to-grid (V2G) operation is tested within a Hybrid integrated system. The overall system results include battery voltage, current, battery power, and state of charge (%SOC), as well as wind side voltage, wind power, and current.

## III. RESULTS and DISCUSSIONS

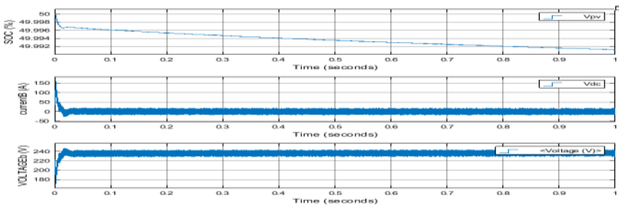


**Fig.2:** Battery outputs

Fig.2 shows the outputs of Soc, Voltage and current ratings of battery related with the values of 50%, 245V and 150A respectively. Overall battery related analysis crucial for maximizing the benefits of vehicle to grid integration while ensuring the reliability and longevity of vehicle batteries.

Fig3 shows the output values of PV voltage and DC link voltage. The above figure shows that the simulation

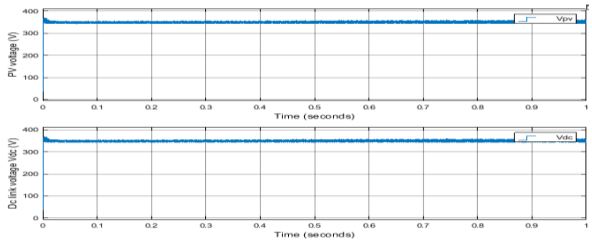


**Fig.3** Outputs of $V_{PV}$ and DC link Voltage

output values of PV voltage, DClink voltage with values of 360V, 360V. In the analysis of hybrid -based grid.

Integration for vehicle-to-grid energy management, examining both the voltage output of photovoltaic (PV) systems and the direct current (DC) voltage requirements is crucial. This includes assessing the compatibility between PV voltage outputs and DC voltage requirements for vehicle charging, as well as implementing appropriate voltage conversion and management systems to optimize energy flow and efficiency within the grid integration framework.

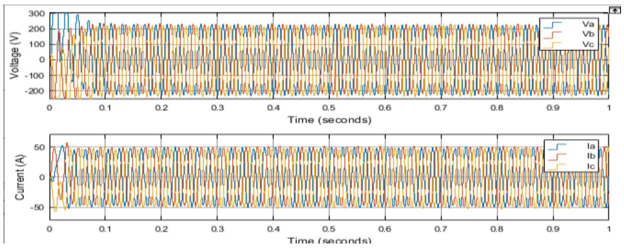


**Fig.4** Wind side Voltage and Current

Fig.4 shows that the simulation output values of voltage and current at wind side voltage and current with the values of 300V, 65A in positive peak and -200V, -65A in the negative peak. By analyzing wind side voltage and current, stakeholders can optimize the integration of wind energy into vehicle-to-grid systems, enhancing overall energy management efficiency and sustainability.

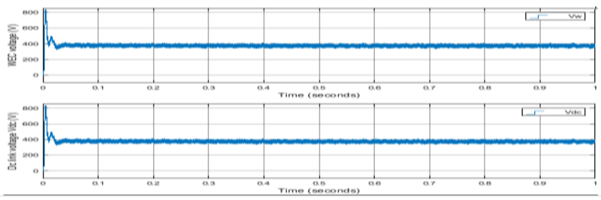


**Fig.5** Outputs of WEC Voltage and DC Link Voltage

Fig.5 shows the simulation output values of WEC voltage and DClink voltage with the values of 810V, 810V. By analyzing $V_w$ and $V_{dc}$, stakeholders can optimize the performance and efficiency of vehicle-to-grid systems, ensuring reliable and sustainable integration with the grid.

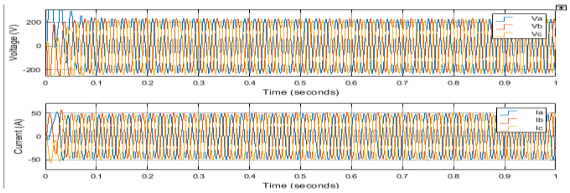


**Fig.**6 Inverter side Voltage and Current

Fig.6 shows that the simulation output values of voltage and current at inverter side voltage and current with the values of 300V, 55A in positive peak and -250V, -55A in the negative peak. The electrical characteristics of inverters used to convert DC power from sources such as solar panels or batteries into AC power for grid integration.

Fig.7 shows that the simulation output values of voltage and current at grid side voltage and current with the values of230V, 30A in positive peak and -230V, -40A in the negative peak. This analysis includes voltage stability, current flow management, grid-

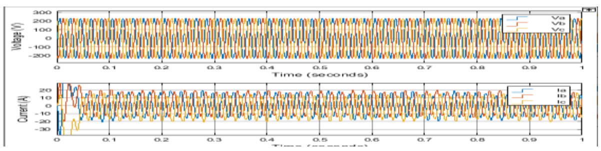


**Fig.7** Grid side Voltage and Current

synchronization, grid support functions. It's maximizing their benefits for both grid operators and electric vehicles owners.

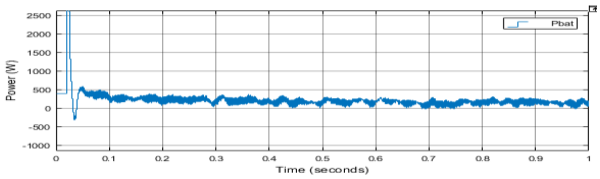


**Fig.8** Battery Power

Fig.8 shows that the output values of battery power with the values of 2600W. It involves several key aspects such as power capacity, power transfer efficiency, peak shaving and maximize the benefits of electric vehicle technology.

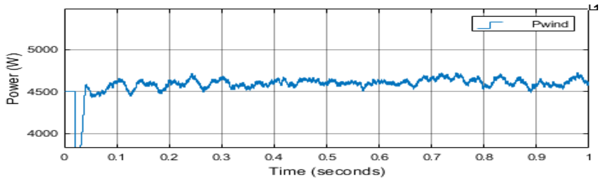


**Fig.9** Wind Active Power

Fig.9 shows that the output values of Wind active power with the values of 4100W. It's involves several considerations such as wind power generation power forecasting, vehicle charging and discharging, grid services and it reduce greenhouse gas emissions associated with electricity generation.

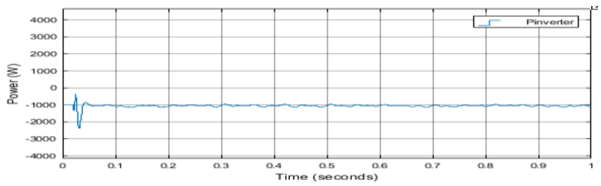


**Fig.10** Inverter Active Power

Fig.10 shows that the output values of inverter active power with the values of -2300W. It improves the power conversion efficiency, grid stability, voltage regulation, grid support functions and maximize the utilization of renewable energy resources.

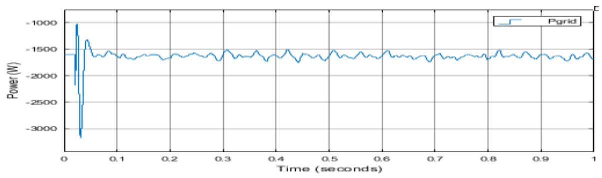


**Fig.11** Grid Active Power

Fig.11shows the output values of grid active power with the values of -3200W. It helps in understanding how electric vehicles interact with the grid, managing the flow of power, and ensuring stability and efficiency in the grid system.

**Table.1 Comparison Table of Existing System and Proposed System**

| configuration/parameter | Solar integrated | Wind integrated | Hybrid integrated |
|---|---|---|---|
| Inverter side voltage | 1.57 | 1.85 | 1.73 |
| Inverter side current | 1.45 | 0.67 | 1.40 |
| Grid side voltage | 0.04 | 0.09 | 0.04 |
| Grid side current | 3.25 | 3.51 | 3.22 |

**Table. 2 Power Comparison Table**

| configuration/parameter | Solar integrated | Wind integrated | Hybrid integrated |
|---|---|---|---|
| Dc link power | 5700 | 4500 | 5750 |
| Inverter power | 1120 | 1050 | 1165 |
| Grid power | 1720 | 1625 | 1750 |

## IV. CONCLUSION

Energy supervision among electric vehicles and the grid system for hybrid combination is the major aim of this work. Using vehicle-to-grid (V2G) systems, a method of reducing the instability of large-scale wind generation is examined. Electric vehicles (EVs) are continuously being evaluated to replace battery cells as energy storage components in request to lower the speculation expenses of energy storage. Using the MATLAB/SIMULINK 2018a software, the concert results of electric vehicles, the grid, and loads with dissimilar voltage, current, and power waveform characteristics may be evaluated. The integration of V2G systems presents a capable way for optimizing the utilization of renewable energy sources, mainly wind power, while enhancing grid steadiness and flexibility. By leveraging the energy storage ability of electric vehicle (EV) batteries, V2G systems can effectively store excess energy during periods of high wind power generation and discharge it when needed to balance grid demand**.**

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