

# Microgrid with Electric Vehicles V2G (Vehicle-to-Grid) Support

Gotla Shashisri<sup>1</sup>, Ediga Bhargavi<sup>2</sup>, Byri Madhuvani<sup>3</sup>, Repakula Kavya<sup>4</sup>, Bommana Shruthi<sup>5</sup>

Department of Electrical & Electronics Engineering, G. Pulla Reddy Engineering College, Kurnool, India.

**Abstract:** There has been an increase in the development of microgrids along with advanced energy management systems owing to the demand for reliable and stable power grids. Nevertheless, the frequency stability of the microgrid remains a significant challenge due to load dynamics and low system inertia. To implement frequency control in the microgrid, a model is developed in which Electric Vehicles (EVs) having the ability of Vehicle-to-Grid (V2G) are included. The microgrid consists of a synchronous generator, varying loads, and two groups of EV batteries capable of G2V and V2G depending on their SOC level. In response to frequency variations, a controller is designed to regulate the bidirectional power flow. Simulation studies are performed by developing the microgrid in MATLAB/Simulink under different load disturbances. According to the results obtained through simulation, EV-based V2G helps in achieving grid stability. Through power management between the grid and EV batteries, the model can respond to load dynamics.

**Key Words:** Microgrid, Electric Vehicles, V2G, Frequency Control, State of Charge, Simulink, Smartgrid.

## I. Introduction

Microgrids are becoming popular in today's power systems owing to their ability to incorporate distributed energy sources and operate as islands if required. Frequency stability remains among the key issues of concern associated with microgrid operations since it may become increasingly difficult to maintain system frequencies during load changes and low system inertia.

Due to the growing number of Electric Vehicles (EVs), it becomes possible to take advantage of their energy stored in EV batteries by incorporating them into the existing system. With the help of V2G technology, EVs can consume or generate electricity as necessary for system needs. As such, it becomes possible to use V2Gs as a tool for frequency regulation in microgrids.

The current research aims at modeling a microgrid with EVs incorporated therein using the MATLAB/Simulink software in order to demonstrate the impact of V2Gs on microgrid operation. In particular, the microgrid will include a synchronous generator, dynamic loads, and battery packs of EVs whose SOC determines its response to load disturbances and, consequently, restores the system frequency.

It can be concluded from the simulation results that using EVs helps minimize frequency deviations, which implies an improvement of microgrid operation.

## II. Material And Methods

### Literature Review and Research Gap:

An effective model of a microgrid with EVs operating in G2V and V2G is designed in this study. In order to ensure reliable operation, a control mechanism based on changes in frequency and SOC is developed. The effectiveness of EVs in regulating frequency of the grid in a desirable manner is illustrated through simulations. Some other research work indicates that EV aggregation could improve microgrid load balance and frequency regulation. However, existing models suffer from certain limitations such as inefficiency in EV charge/discharge management, insufficient consideration of SOC-based control, and inability to conduct dynamic load simulations. Furthermore, adaptability in real-time operations and multi-level system modeling is ignored by many researchers.

This article introduces a microgrid system combined with EVs that overcomes above mentioned shortcomings through a control technique based on frequency and SOC. Simulations and modeling are conducted using MATLAB/Simulink software in order to achieve accurate dynamic behavior simulation and efficient utilization of EV batteries for grid stability.

### System Design Considerations:

The design of the system ensures efficient frequency regulation through EVs, ensuring that the system remains stable and the batteries are not damaged. Some of the considerations include:

Maintaining the grid frequency at 0.999 to 1.001 per unit

Efficient management of the EV batteries based on their SOC

Use of Voltage Source Converters (VSC) for reliable bi-directional power flow

Adaptive simulation techniques with various levels of fidelity

Stability during abrupt load variations

### System Configuration Approach:

A synchronous generator, EV batteries grouped together, converters, and dynamic loads are some of the components that form the microgrid system. The EV batteries are categorized into two types depending on their SOC as follows:

G2V Group: EVs in charging mode having an SOC of below 80%

V2G Group: EVs in grid-support mode with an SOC of above 90%

### Procedure Methodology

The grid frequency and battery state of charge (SOC) are constantly monitored by the system. Under normal conditions, the operation of EVs occurs during charging mode. There is a disturbance in the system due to which the grid frequency drops below the threshold of (0.999 pu). In order to help the grid recover from disturbance and restore the grid frequency, discharging of the EVs in V2G takes place.

The similar pattern occurs in case of decreased load, where the grid frequency rises above 1.001 pu, following which EVs move back into the charging mode.

In order to test the performance of the system, dynamic variations are applied to the load at regular time frames (10 s and 30 s).

### MATLAB Simulation

Simulation of the recommended model is done using Simscape Electrical in MATLAB/Simulink. Analysis of system performance is done at different levels of fidelity as follows:

Low Fidelity – Average Value Converter and sample time extended

Medium Fidelity – Shorter time step and high accuracy

High Fidelity – Detailed Switching model

Grid frequency, power flow between the EV and grid, and changes in Battery State of Charge are among others results obtained from simulations. It is evident from the results obtained that vehicle-to-grid support based on EV stabilizes the frequency.

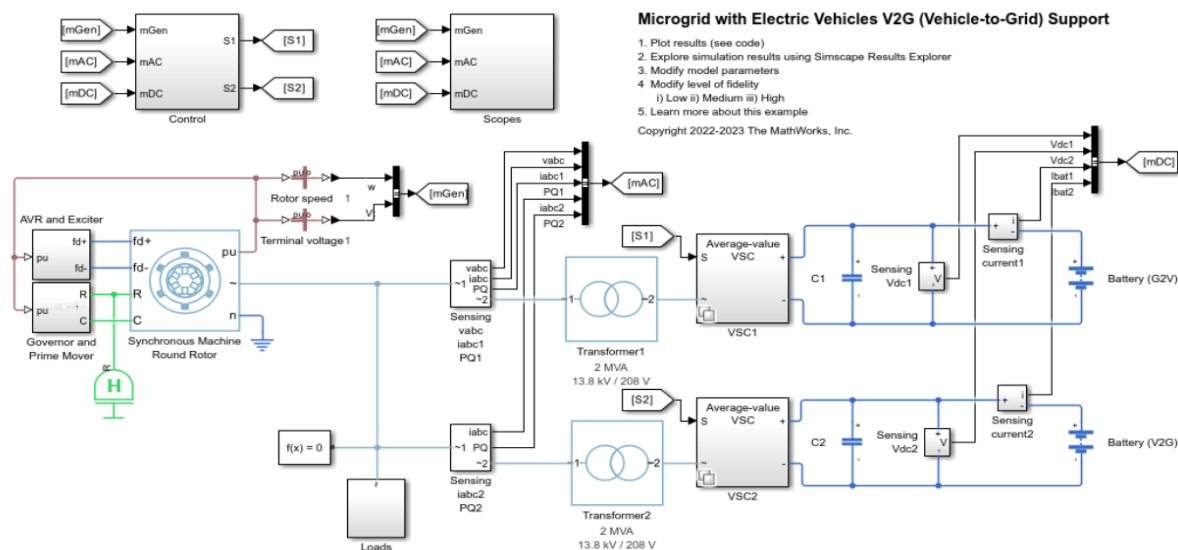


Fig 1. MATLAB Modelling

### Features

- **Microgrid Simulation Environment:** The process involves the development of an extensive simulation environment in MATLAB/Simulink, which helps in simulating the power generation and loading dynamics in the microgrid system.
- **Electric Vehicle Integration (V2G/G2V):** Electric vehicle battery packs having two-directional current flow have been integrated into the grid; the grid will be able to charge/discharge the batteries based on the state of the grid.
- **Constant Frequency Monitoring and Control:** Frequency monitoring takes place throughout the simulation process, and if there is any deviation from the required frequency range of (0.999–1.001 pu), appropriate actions will be taken.
- **Dynamic Load Variation Testing:** Dynamic variations of load have been introduced at fixed intervals to study the stability of the microgrid system.
- **State-of-Charge-Based Energy Management:** The State-of-Charge (SOC) determines how the energy from the batteries would be managed without under-charging and overcharging.

### Outputs

- **Frequency Response of Grid:** Frequency response of the grid varies depending on the load and other factors during real-time operation.
- **Active Power Exchange Information:** Active power exchange occurs while charging and discharging the EV batteries.

- **SOC Curves:**

This curve indicates the SOC changes at different periods, indicating the charging and discharging cycles of the battery.

- **Microgrid Stability Performance:**

The stability performance of the microgrid system can be evaluated by analyzing the frequency range of the microgrid.

**Methodology (V2G-Based Microgrid Algorithm)**

In addition, by integrating EVs in microgrids, the proposed V2G based microgrid control strategy employs systematic techniques that help ensure efficient and stable operation of the grid.

In this case, the microgrid network is modeled with different loads, battery banks of EVs, and synchronous generators. The grid frequency and battery SOC levels are always monitored in the system. The mode of operation of the EV batteries depends on the control algorithm of these two parameters.

EVs with less battery SOC remain in G2V mode while the system operates normally. At the same time, during the system disturbance such as increased load, the grid frequency is reduced below the lower limit. To allow high SOC level EV batteries to discharge power to the grid, the control system identifies the deviation and switches to V2G mode.

Conversely, while the load reduces and grid frequency rises above the upper limit, the control system switches back EVs to G2V mode to consume excess electricity. Consequently, the grid frequency becomes stable within the specified limits.



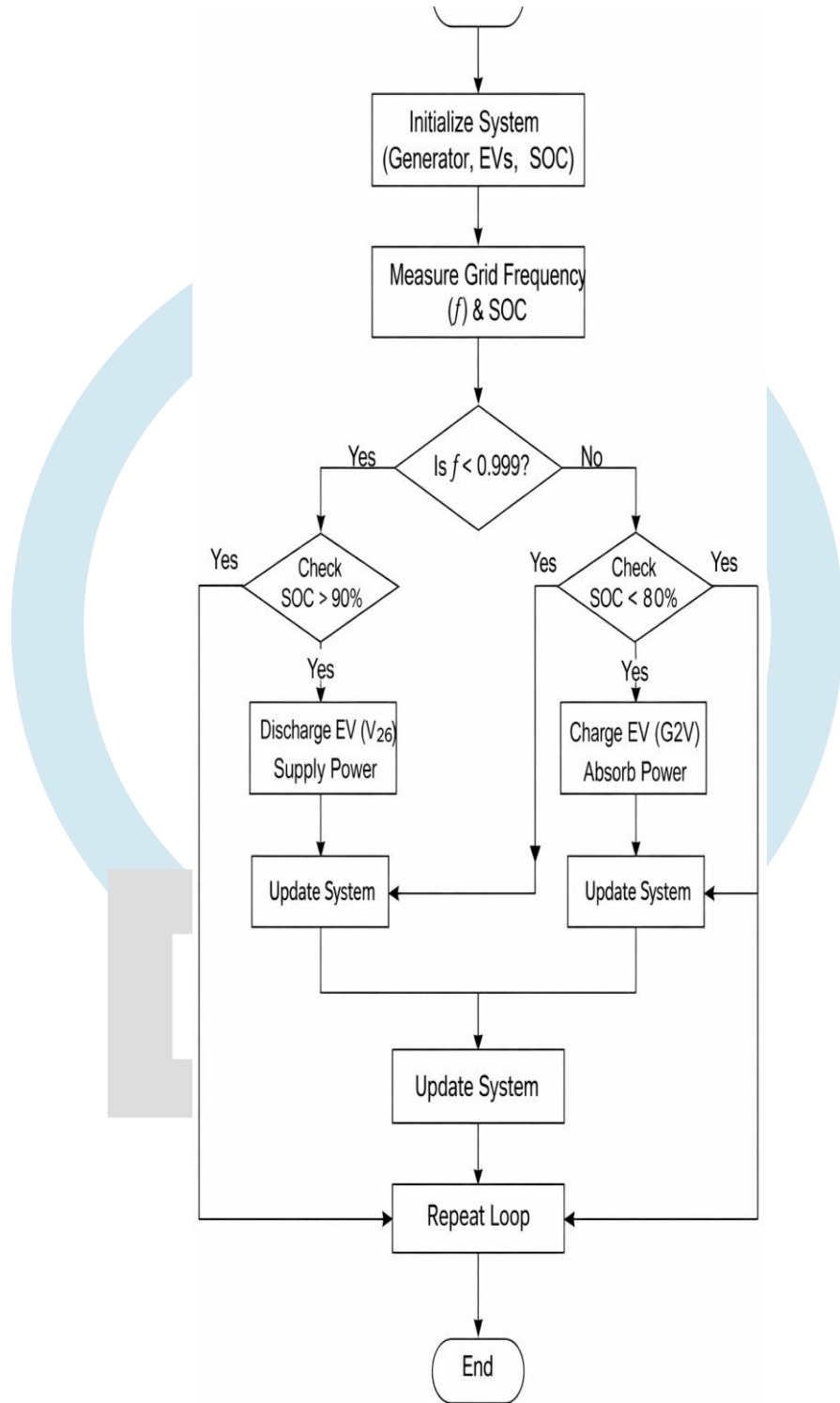


Fig 2. V2G Microgrid Control Algorithm Flow Chart

## 1 Frequency Deviation Detection

The grid frequency is constantly tracked against the standard frequency:

$$\Delta f = f_{ref} - f_t$$

where:

$f_{ref}$  → nominal frequency (1 pu)

$f_t$  → actual grid frequency speed (from motor/ odometry)

## 2 Power Balance Equation

$$P_{gen} + P_{V2G} = P_{load}$$

where:

$P_{gen}$  → power from generator

$P_{V2G}$  → power from EV battery (discharging +ve & charging -ve)

$P_{load}$  → power demand the microgrid power balance is defined as:  $P_{gen} + P_{V2G} = P_{load}$

where:

- $P_{gen}$  → generator power
- $P_{V2G}$  → EV battery power (+ve discharge, -ve charge)
- $P_{load}$  → load demand

## 3 Frequency Dynamics

Frequency dynamics for the system can be expressed as:

$$df/dt = 1/2H(P_{gen} + P_{V2G} - P_{load})$$

where:

$H$  → system inertia constant

## 4 SOC (State of Charge) Model

Calculation of battery state of charge is given by:

$$SOC_t = SOC_{(t-1)} + (P_{bat} \cdot \Delta t) / E_{bat}$$

where:

$P_{bat}$  → power from battery

$E_{bat}$  → total battery capacity

## 5 Control Strategy (Decision Logic)

### Case 1: Under Frequency Condition

$$f_t < f_{min}$$

Then,

if  $SOC > 90\%$ ,

$$P_{V2G} = +P_{discharge}$$

(The EVs act as power supplier to the grid)

### Case 2: Over Frequency Condition

$$f_t > f_{max}$$

If:

$$SOC < 80\%$$

Then:

$$P_{V2G} = -P_{charge}$$

(EVs consume power)

### Case 3: Normal Condition

$$0.999 \leq f_t \leq 1.001$$

$$P_{V2G} = 0$$

(Nothing happens)

## 6 Converter Control (VSC Model)

The energy exchange between the converters is defined as:

$$P=V*I$$

Current control:

$$I_{ref} = P_{ref}/V$$

## 7 Optimization Objective

The system optimizes for minimizing the frequency difference:

$$\min \sum (\Delta f)^2$$

under constraints:

$$SOC_{min} \leq SOC \leq SOC_{max}$$

## Simulation Framework

The described microgrid is simulated using MATLAB/Simulink along with Simscape Electrical. This framework can be used for analyzing the dynamics of a microgrid powered by Electric Vehicles (EVs), that are able to provide Vehicle to Grid (V2G) for frequency regulation.

### Components

- **Model of Synchronous Generator:**  
It represents the main source of energy and its control systems for frequency and voltage control.
- **Model of EV Batteries:**  
It simulates EV batteries with their State of Charge (SOC) that is able to charge (G2V) and discharge (V2G).
- **Model of Voltage Source Converter (VSC):**  
It provides a two-way power flow from/to EV batteries with average-value and switching models.
- **Control Algorithm:**  
This algorithm controls charging/discharging operations through frequency and SOC parameters.
- **Measurement Blocks:**  
They provide grid frequency measurement, power flow measurement, and SOC measurement.
- **Dynamic Load Model:**  
Simulates varying load conditions to analyze system performance under disturbances.

### Need for Simulation Platform

This system entails several dynamics and interactions between the generators, the batteries of EVs, and their control strategies, making it necessary to have a robust and versatile environment that can accommodate analysis. The MATLAB/Simulink framework is an excellent model and simulation tool since it does not rely on any physical hardware.

Through simulation, it becomes possible to evaluate different scenarios within safe and economic boundaries, while different levels of fidelity can be tested to determine the best balance between the two aspects.

Moreover, the simulation tool helps in carrying out extensive analysis of the various parameters associated with the system, such as frequency dynamics, power flow, and SOC dynamics.

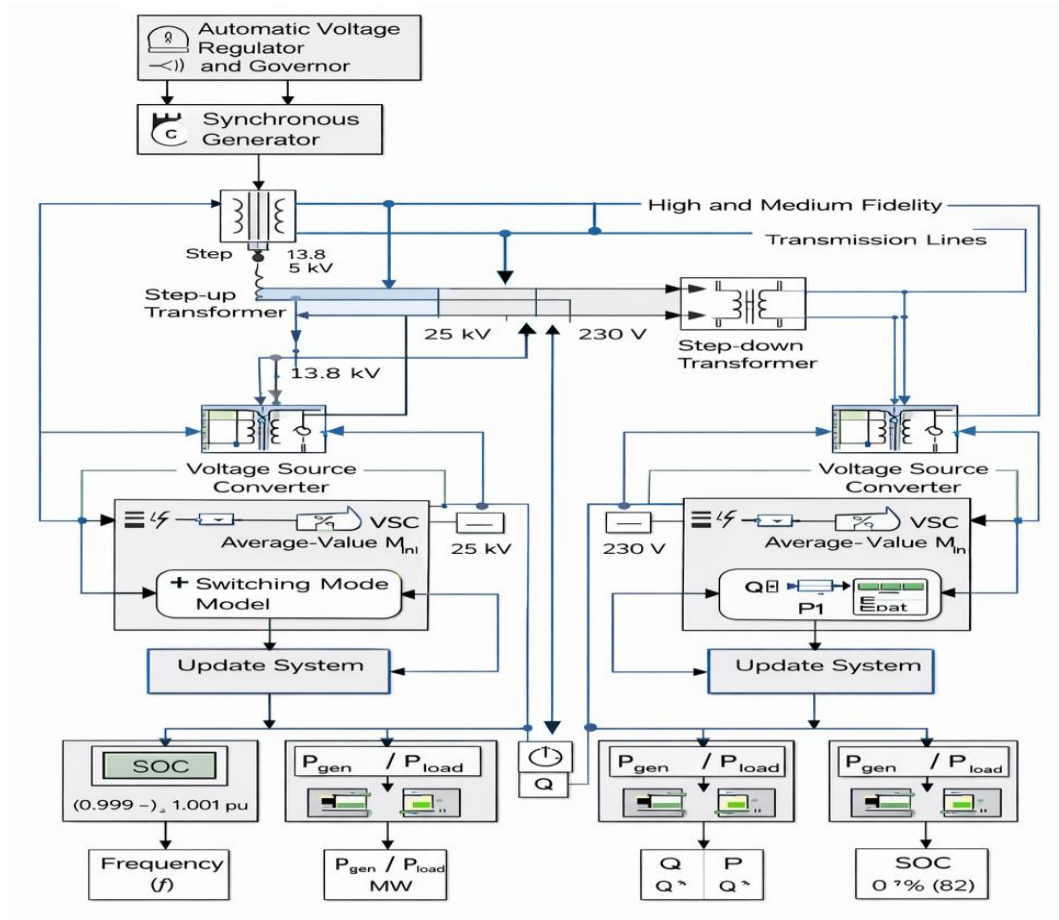


Fig 3. Circuit Diagram of Microgrid Integrated with EVs (V2G) for Frequency Regulation

### III. Result

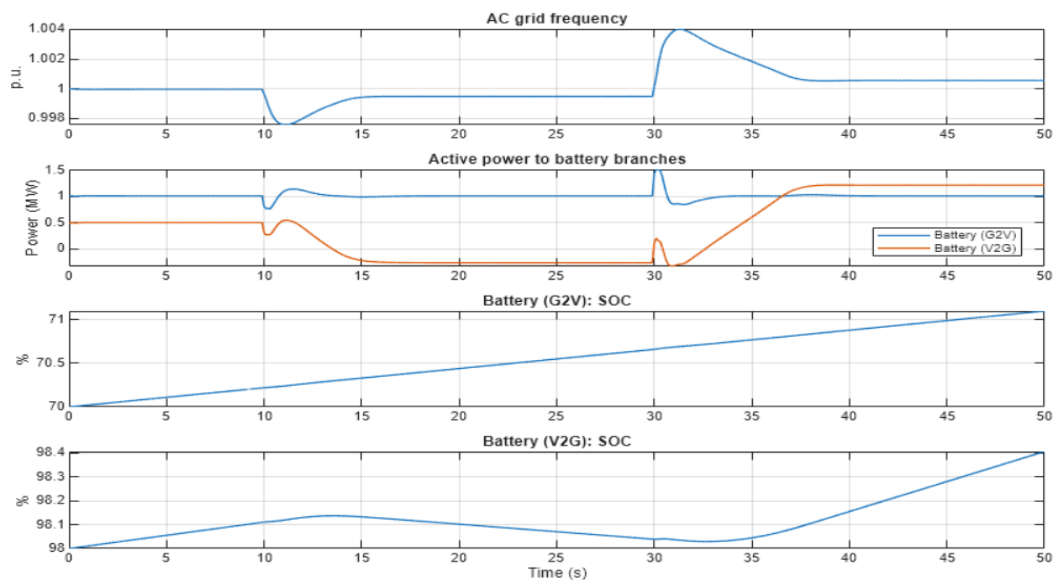


Fig 4. MATLAB Simulation Results

### IV. Conclusion

MATLAB/Simulink simulation gave a solid platform to perform an analysis on frequency, power flow, and EV battery state of charge prior to its practical application, thus proving that this technology was feasible. By combining V2G with state-of-charge (SOC) control, dynamic energy balancing could be achieved as EVs could supply and withdraw energy when there were frequency variations.

With the help of Simscape Electrical, the proposed simulation performed well in terms of handling dynamic loads while keeping the frequency at 0.999–1.001 p.u. In addition, the battery performance was maximized, minimizing the fluctuations.

In this paper, we explore the possibility of utilizing EVs equipped with V2G capabilities for improving the performance of microgrids. The technique described above is applicable to future smart grids.

### V. Future Scope

The following extensions can be considered for future work in order to increase the performance and usefulness of the suggested system:

- Using renewable energy sources like photovoltaics and wind generators to make a hybrid microgrid architecture
- Use of real-time control techniques with the help of HIL or embedded systems
- Drawing up of intelligent systems for energy management by implementing AI techniques
- Further development of efficient battery management techniques that increase the life span of EV batteries
- Use of communication protocols for coordinating the system in smart grids
- Large scale participation of EVs with aggregation and demand response techniques
- Considering the economic issues involved including cost optimization and energy pricing issues
- Handling of uncertainties involved.

### References

1. Y. Bian, H. Wang, J. Zhang, J. Yan, and X. He, "Optimal Allocation of Hybrid Energy Storage Capacity for Microgrids Considering Electric Vehicles," *IEEE Access*, vol. 13, 2025.
2. W. Kempton and J. Tomic, "Vehicle-to-Grid Power Fundamentals: Calculating Capacity and Net Revenue," *Journal of Power Sources*, vol. 144, no. 1, pp. 268–279, 2005.
3. H. Liu, K. Huang, Y. Yang, and H. Wei, "Real-Time Vehicle-to-Grid Control for Frequency Regulation," *Protection and Control of Modern Power Systems*, vol. 3, 2018.
4. S. Iqbal et al., "V2G Strategy for Primary Frequency Control of an Industrial Microgrid," *Electronics*, vol. 9, no. 4, 2020.
5. Y. Yoo, Y. Al-Shawesh, and A. Tchagang, "Coordinated Control Strategy of V2G for Frequency Control," *Energies*, vol. 14, no. 9, 2021.
6. H. Liu, Z. Hu, Y. Song, and J. Wang, "Vehicle-to-Grid Control for Supplementary Frequency Regulation," *IEEE Transactions on Power Systems*, vol. 30, no. 6, pp. 3110–3119, 2015.
7. S. Dinkhah, C. A. Negri, M. He, and S. B. Bayne, "V2G for Reliable Microgrid Operations: Voltage/Frequency Regulation," *IEEE ITEC Conference*, 2019.
8. Vidya M. S. and V. Chandran, "Reduction of Frequency Deviation in Microgrid Using EVs," *IJITEE*, vol. 14, no. 4, 2025.
9. Kulat H.S. et al., "Integrating V2G Technology for Grid Stability," *Journal of Energy Systems*, 2024.
10. Yao S., Wu F., and Bian Z., "Bibliometric Analysis of V2G System Studies," *Discover Sustainability*, vol. 7, 2026.