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Grid to Vehicle and Vehicle to Grid Technology

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Abstract: *Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) technologies represent a modern bidirectional energy management system that integrates electric vehicles (EVs) with the power grid. In the G2V mode, electric vehicles draw energy from the grid for charging in an efficient, controlled, and cost-effective manner. In contrast, the V2G mode enables EVs to return stored energy back to the grid during peak demand, helping to balance load, enhance grid stability, and support renewable energy integration. This two-way interaction transforms EVs into mobile energy storage units, reducing stress on the grid and improving overall energy reliability. By enabling flexible power flow and intelligent communication systems, V2G and G2V technologies contribute significantly to sustainable energy management, reduced carbon emissions, and the development of smart grid infrastructure. Their combined capabilities make them essential components in the future of clean transportation and advanced power systems.*

Keywords*:* Vehicle-to-Grid (V2G), Grid-to-Vehicle (G2V), Bidirectional power flow, Electric vehicles (EVs), Smart grid:

I. INTRODUCTION

Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) technologies play a crucial role in modern power and transportation systems by enabling intelligent energy exchange between electric vehicles (EVs) and the electrical grid. G2V allows EVs to receive controlled and optimized charging from the grid, ensuring energy is delivered efficiently, safely, and often during off-peak hours to reduce load stress and electricity costs. In contrast, V2G adds a bidirectional capability where EVs can discharge stored energy back to the grid during peak demand, acting as mobile energy storage units that support grid stability, frequency regulation, and renewable energy balancing. With advanced communication protocols, smart meters, and power electronics, these technologies enable seamless coordination between EVs and grid operators. As the adoption of electric mobility continues to rise, G2V and V2G systems contribute to a more flexible, sustainable, and resilient energy ecosystem by reducing carbon emissions, improving grid reliability, and integrating distributed renewable resources. Their combined impact positions them as essential innovations for the future of smart grids and clean energy transitions.

II. PROBLEM STATEMENT

Despite the growing importance of electric vehicles, the integration of Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) technologies faces several technical, operational, and infrastructural challenges that limit their widespread deployment. The power grid often struggles to handle the sudden increase in EV charging demand, which can lead to voltage fluctuations, overloading of distribution networks, and inefficient energy management. At the same time, V2G technology requires highly reliable bidirectional chargers, advanced communication systems, and standardized control protocols, which are still under development and not uniformly adopted. Concerns such as battery degradation, lack of proper charging infrastructure, cybersecurity threats, and limited coordination between EV owners and grid operators further complicate real-time power flow management. These issues create a barrier to achieving the full potential of G2V and V2G systems in improving grid stability, supporting renewable energy integration, and enabling efficient energy utilization. Therefore, there is a need for optimized control strategies, robust infrastructure, and standardized communication frameworks to ensure the effective implementation of G2V and V2G technologies.

III. LITERATURE REVIEW

Research on Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) technologies has expanded significantly over the past decade, focusing on their potential to improve energy management, grid stability, and renewable energy integration. Early studies primarily examined controlled EV charging strategies to reduce grid stress and optimize load distribution, highlighting the benefits of smart charging and scheduling algorithms. Later literature introduced V2G as a bidirectional solution, presenting EVs as distributed energy storage units capable of providing ancillary services such as peak shaving, frequency regulation, and voltage support. Several authors have investigated the impacts of V2G on battery life, communication protocols, and power electronic interfaces, emphasizing the need for reliable bidirectional chargers and standardized control mechanisms. Recent research also explores advanced forecasting models, optimal energy trading systems, and the role of V2G in supporting solar and wind power variability. Overall, literature consistently shows that G2V and V2G technologies offer significant technical and economic advantages, but challenges remain in infrastructure development, cybersecurity, interoperability, and large-scale implementation, motivating further research in this evolving field.

Our Contribution:

- Smart Bidirectional Energy Management.
- Grid Stability Enhancement.
- Efficient Charging Infrastructure Design:

IV. METHODOLOGY

The methodology for implementing G2V and V2G technology involves a systematic approach that begins with understanding the power system requirements, EV charging behavior, grid limitations, and energy demand patterns. First, a detailed analysis is carried out to study existing charging infrastructure, battery characteristics, and grid load variations to define the technical requirements for both unidirectional and bidirectional power flow. In the design phase, smart chargers, bidirectional inverters, communication modules, and control algorithms are selected and integrated to enable seamless energy exchange between EVs and the grid. Power flow models are developed to simulate charging (G2V) and discharging (V2G) scenarios, ensuring safe voltage levels, efficient energy transfer, and battery health optimization. The system is then equipped with real-time monitoring using IoT sensors and communication protocols such as PLC, Wi-Fi, or CAN to coordinate EV-grid interaction. Next, the hardware setup—including chargers, protection devices, and measurement units—is assembled and configured to test grid connectivity, energy flow, and load-balancing functions. Finally, various test cases such as peak-hour grid support, off-peak charging, frequency regulation, and renewable energy integration are conducted to evaluate system performance, efficiency, stability, and user convenience. This structured methodology ensures reliable, safe, and efficient implementation of G2V and V2G technologies for smart energy management.

V. WORKING

The G2V and V2G system works by enabling two-way communication and power transfer between the electric vehicle (EV) and the grid, controlled through a Bluetooth-based monitoring setup. In G2V mode, AC power from the grid is supplied to a bidirectional converter, where it is rectified and regulated to safely charge the EV battery while monitoring voltage, current, and state of charge. The same converter enables V2G operation by reversing the power flow and converting stored DC battery energy back into synchronized AC power that can be fed into the grid during peak demand. A Bluetooth module is integrated with the microcontroller to provide wireless communication, allowing the user to monitor parameters such as battery status, charging current, energy flow direction, and system alerts through a mobile application. The system also features clear control and indication mechanisms: LEDs or display modules show charging, discharging, fault conditions, and grid connection status. A mode selection switch or Bluetooth-controlled option enables the user to toggle between G2V (charging mode) and V2G (discharging mode) based on grid conditions or user preference. Overall, the system ensures efficient battery charging, safe bidirectional power conversion, and user-friendly real-time monitoring through Bluetooth connectivity.

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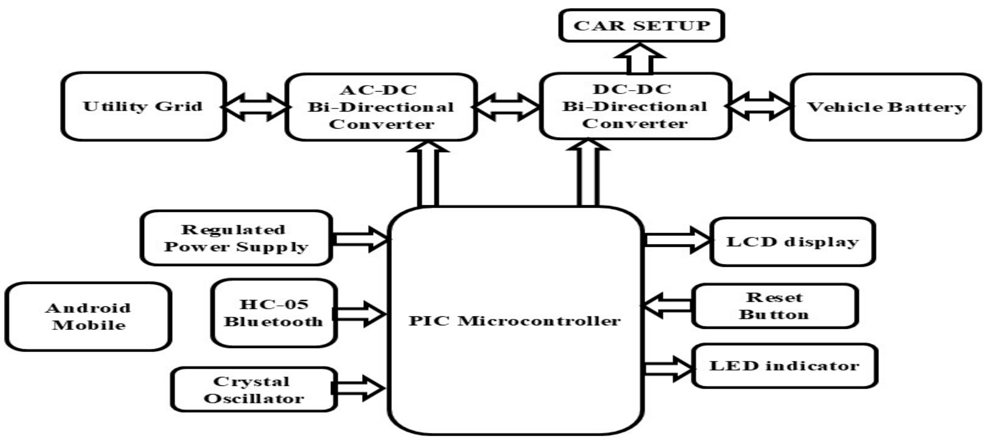
WORKING PRINCIPLE

Vehicle Connection – The electric vehicle (EV) is connected to the charging station via a bidirectional charger.
Authentication & Communication – EV and grid communicate using smart protocols (e.g., Bluetooth, Wi-Fi) to verify identity and compatibility.
Mode Selection – User selects either G2V mode (charging EV from grid) or V2G mode (discharging EV to grid).
Power Conversion – AC power from grid is converted to DC for battery charging (G2V) or DC from battery is converted to AC for grid supply (V2G) using bidirectional inverter.
Charging/Discharging Control – Control unit regulates current, voltage, and state of charge to ensure safe energy flow.
Monitoring & Indication – Battery status, power flow, and mode are monitored and displayed via LCD or mobile app.
Disconnection & Data Logging – After charging/discharging, EV disconnects safely, and energy transactions are logged for analysis or billing..

VI. BLOCK DIAGRAM



COMPONENTS USED

- Utility Grid
- AC-DC Bidirectional Converter.
- DC-DC Bidirectional Converter.
- Vehicle Battery.
- PIC Microcontroller.
- Bluetooth module.
- LCD display.
- Regulated Power Supply.
- Crystal oscillator.
- Reset Button.
- LED indicator.
- CAR Setup

1. Utility Grid

This is the main electrical power supply system.
Power flows from the grid to the electric vehicle (charging) or from the vehicle to the grid (discharging) depending on the requirement.

2. AC-DC Bi-Directional Converter
Converts AC power from the grid to DC power for storing energy in the vehicle battery (G2V).
Converts DC power from the battery to AC power for returning power back to the grid (V2G).
Since it works in both directions, it is called bi-directional.

3. DC-DC Bi-Directional Converter
Manages proper voltage levels between the converter and the vehicle battery.
Ensures safe battery charging and discharging.
Allows controlled energy exchange between the system and the battery.

4. Vehicle Battery
Stores electrical energy.
Used for powering the vehicle or transferring stored energy back to the utility grid when needed.

5. PIC Microcontroller
This is the brain of the system.
Controls all operations such as:
Power flow direction (charging or discharging)
Communicating with a mobile device
Displaying system status
Monitoring battery and converter activity

6. HC-05 Bluetooth Module
Enables wireless communication between the Android phone and the microcontroller.
Receives user commands and sends system status.

7. LCD Display
Shows real-time system status such as:
Charging status
Battery voltage
Power flow (grid ↔ vehicle)

8. Regulated Power Supply
Provides stable operating voltage to the microcontroller and other electronic components.
Protects the circuit from voltage fluctuations.

9. Crystal Oscillator
Provides the clock signal to the microcontroller.
Ensures the microcontroller runs at an accurate and stable speed.

10. Reset Button
Used to restart the microcontroller program.
Helpful during system faults or reconfiguration.

11. LED Indicator
Provides visual status, such as:
Power ON
Charging active

Discharging (V2G) active
Fault indication

12. CAR Setup

Represents the EV vehicle interface.
Includes wiring and safety systems required to connect the battery and converters.

VII. ADVANTAGES

- Enables two-way power flow, supporting both EV charging and energy return to the grid.
- Promotes efficient utilization of renewable energy by allowing EVs to act as distributed storage units.
- Improves grid stability during peak demand by supplying stored battery energy back to the grid.
- Provides flexibility with remote operation via Bluetooth.
- Cost-effective solution using a PIC microcontroller for control and monitoring.
- Enhances sustainability by integrating EVs with smart grid infrastructure.
- Scalable design suitable for future smart grid and microgrid

VIII. LIMITATIONS

- High initial cost of bidirectional chargers and infrastructure.
- Battery degradation due to frequent charging and discharging cycles.
- Dependence on stable grid communication and smart control systems.

IX. CONCLUSION

This project successfully designed and implemented a bidirectional power transfer system for electric vehicles using PIC microcontroller control. The system operates efficiently in both G2V and V2G modes, achieving smooth power flow and synchronization with the grid. It enables EVs to function not only as consumers but also as distributed energy sources, promoting smart grid development and renewable energy utilization.

X. FUTURE SCOPE

The future scope of G2V and V2G technology encompasses efficient energy management, bidirectional power flow, and smart grid integration. G2V focuses on reliable and fast charging of electric vehicles from the grid, while V2G enables EVs to supply stored energy back to the grid during peak demand, supporting grid stability and renewable energy utilization. These technologies also include advanced monitoring, control systems, and communication protocols to optimize charging/discharging cycles, minimize battery degradation, and facilitate real-time energy transactions, making them a key component of sustainable and intelligent energy ecosystems.

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