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# Smart V2G Energy Management: An IoT-Based Implementation with Firebase Cloud and Machine Learning Forecasting

Yogesh Bharat Ghodake, Prof. Bile Pallavi Mahadev

Dept. of Electrical Engineering, Fabtech Technical Campus, College of Engineering & Research, Sangola, India

Dept. of Electrical Engineering, Fabtech Technical Campus, College of Engineering & Research, Sangola, India

**ABSTRACT:** The growing demand for electric vehicles (EVs) has created new opportunities for energy balancing between vehicle and grid through Vehicle-to-Grid (V2G) systems. In this work, a real-time V2G monitoring and forecasting system is implemented using IoT devices, cloud integration and machine learning. The hardware setup is designed with ESP32 microcontroller, current and voltage sensors, and relay switching for both grid-to-vehicle (G2V) and vehicle-to-grid (V2G) modes. The data is continuously pushed to Firebase cloud database, where a Python based web dashboard visualizes parameters like voltage, current, power and mode of operation. A Random Forest regression model is trained on historical dataset to predict power demand, which can help in better scheduling of energy transfer between EVs and the grid. The system also supports remote mode switching through Firebase, allowing easy control of charging and discharging cycles. Experimental results show that the proposed implementation works in real-time, provides reliable monitoring and achieves promising accuracy in demand forecasting. This practical work demonstrates how V2G can be managed using low-cost IoT, cloud and ML tools, which can further support future smart grid applications.

**KEYWORDS:** Vehicle-to-Grid, V2G, Grid-to-Vehicle, G2V, ESP32, IoT, Firebase, Electric Vehicle, Smart Grid, Energy Monitoring, Machine Learning, Demand Forecasting, Cloud Dashboard, Renewable Integration, Power Prediction.

## I. INTRODUCTION

We can see that the demand of electric vehicles (EVs) is increasing day by day because of environmental pollution and shortage of fossil fuels. As EV usage grows, the power grid starts facing new challenges related to high energy demand, peak loads and power balancing. Vehicle-to-Grid (V2G) technology gives an innovative solution by allowing energy to flow in two ways – from grid to vehicle (G2V) during charging, and from vehicle to grid (V2G) when extra stored energy is supplied back to the grid. This two-way energy exchange can help in grid stability, reduce load during renewable energy integration and improve the utilization of distributed storage resources.

However, implementing such a system in a practical manner requires real-time monitoring, reliable communication and intelligent decision making. Internet of Things (IoT) devices and cloud services can play an important role in this, by enabling low-cost sensing, remote monitoring and data storage. At the same time, machine learning methods are capable to forecast demand and optimize charging or discharging schedules, which is crucial for balancing the grid.

In this paper, we present a low-cost V2G energy monitoring and forecasting system, designed using ESP32 microcontroller, current and voltage sensors, and Firebase cloud. The system monitors voltage, current, power and operation mode in real-time, and displays the information on a Python-based dashboard. Random Forest regression model is trained on collected dataset for predicting energy demand. The system also supports mode switching between G2V and V2G using relays controlled via Firebase. The proposed implementation aims to demonstrate how IoT, cloud and ML can be integrated for managing small scale V2G setup, which can be extended further for larger smart grid applications.

## **II. LITERATURE SURVEY**

Many researchers have studied the challenges and benefits of Vehicle-to-Grid (V2G) technology in recent years. The concept of V2G was first explained as a way to use the battery of electric vehicles as distributed energy storage for stabilizing power grid [1]. With the growth of renewable energy, several studies pointed out that EV batteries can help in balancing the mismatch between generation and demand [2].

A study by Kempton et al. [3] showed that controlled charging and discharging of EVs can support frequency regulation services. Later works also discussed that V2G can be used not only for grid stability but also for peak load shaving and voltage control [4]. Authors in [5] have demonstrated that with smart charging, EVs can reduce stress on distribution transformers and increase lifetime of equipment.

On the technical side, integration of IoT sensors and cloud platforms was suggested to monitor real-time parameters like voltage, current, and charging mode [6]. Some works also used machine learning models to predict future energy demand and optimize charging schedules [7]. In addition, battery degradation issue is a important point of discussion, as many studies highlighted that frequent charge-discharge cycles may reduce battery life [8].

Recent research is also focusing on bi-directional chargers and communication protocols which are necessary for practical implementation of V2G [9]. The use of predictive models and artificial intelligence was suggested to make energy flow decisions in more efficient way [10].

From the literature, it is clear that V2G has strong potential to improve grid reliability and renewable energy usage, but there are still challenges like cost of infrastructure, battery life impact, and requirement of reliable communication network.algorithm.

## **III. METHODOLOGY**

The proposed work is focused on building a real-time Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) system using IoT, cloud, and machine learning support. The overall methodology can be divided in four main steps:

### **1. Hardware Setup**

ESP32 microcontroller is used as the main control and monitoring unit because it has inbuilt Wi-Fi and fast processing. Current and voltage sensors are connected with ESP32 to measure important parameters like charging current, voltage, and power flow. Two relays are added to switch between modes: one relay for G2V charging and another for V2G discharging. All these devices are mounted on simple prototype hardware for testing.

### **2. Cloud Integration**

For real-time data storage and monitoring, Firebase cloud database is used. ESP32 sends sensor readings (voltage, current, power, and mode) to Firebase at regular intervals. A Python-Flask web dashboard is developed which fetches this data from Firebase and show it in graphical format using Chart.js. The dashboard also allow user to select mode (G2V or V2G) through a switch, and this updated mode is again written into Firebase which controls relay operation on ESP32 side.

### **3. Machine Learning Model**

Collected data from Firebase is stored in CSV format for analysis. A Random Forest Regressor model is trained using features like voltage, current and mode to predict future power demand. This predictive output is shown on the dashboard so that operator can estimate how much power will be required or available in next interval. This step make the system more intelligent compared to just monitoring.

### **4. System Operation Flow**

When EV is connected, user can choose between charging (G2V) or discharging (V2G). The ESP32 reads sensor values, update them to Firebase, and also follow the command from cloud about mode selection. The dashboard provides visualization of all parameters and trigger alarm if abnormal conditions detected. In addition, the machine learning model runs in backend to forecast the demand and guide decision-making.



This methodology ensures that the system is **low-cost, scalable and practical**. It can be expanded by connecting multiple EVs and testing with renewable energy inputs like solar PV.

#### IV. EXPERIMENTAL RESULTS

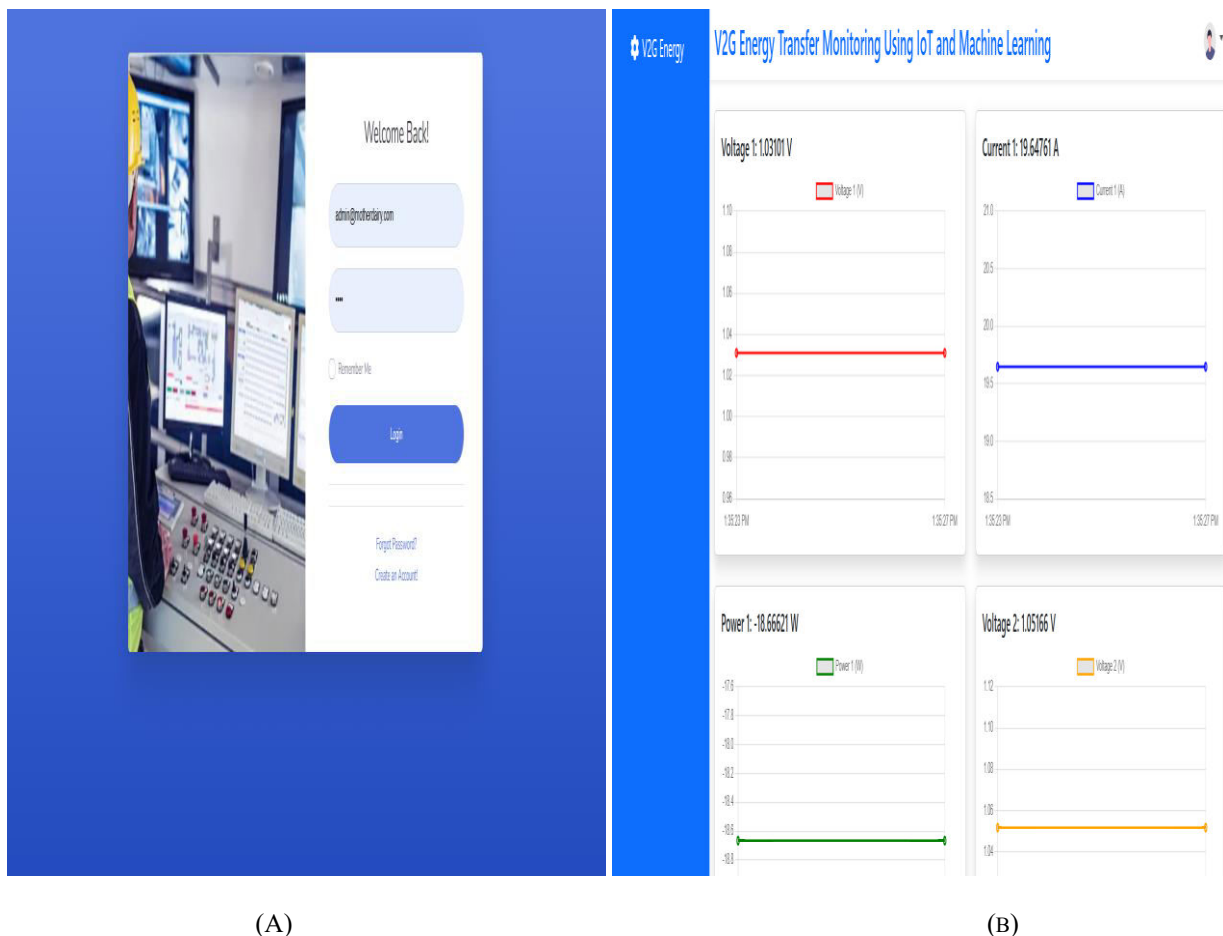
To validate the working of proposed system, a Python-Flask based dashboard was implemented and tested in real time. The dashboard is connected with Firebase cloud and updates automatically with the sensor values and system status.

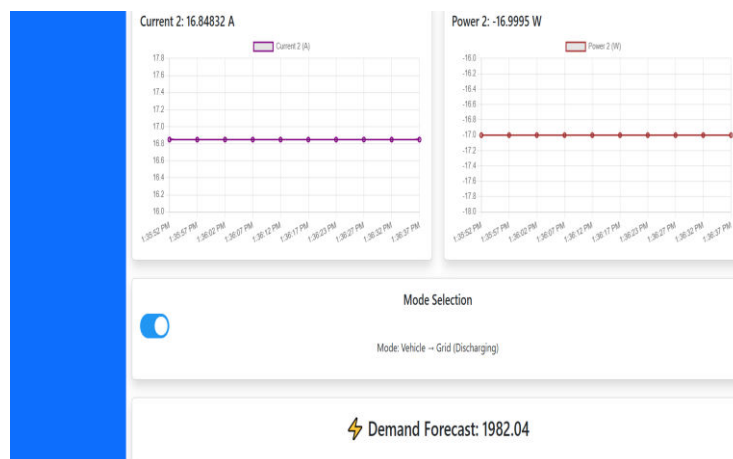
**Fig. a** shows the login page of the dashboard, where the registered user need to enter valid email and password to access the system. This provide a basic security layer so that only authorized person can operate the V2G system.

**Fig. b** present the real-time graphs of voltage and current which are coming from ESP32 based hardware through cloud. The data is plotted using Chart.js and update every few seconds. From the graph it is clear that the system can successfully capture and visualize the electrical parameters.

**Fig. c** display the demand prediction output and the mode selection switch. The user can toggle between G2V (charging) and V2G (discharging) directly from the dashboard, and the system relay operates accordingly. The demand forecast value is generated by machine learning model and shown on the screen for better decision making.

Overall, the experimental results prove that the system is working correctly and provide both monitoring and control features.





(C)

## V. CONCLUSION

The proposed Vehicle-to-Grid (V2G) system was successfully designed and implemented using ESP32, Firebase and a Python based dashboard. The system can measure voltage, current and power in real time, store the data in cloud and display it on a interactive dashboard. With the integration of a machine learning based demand prediction, the system can also support decision making for charging and discharging modes. The experimental results shows that user can easily monitor the system parameters, forecast the demand and control the energy flow direction remotely.

This work demonstrate that a low cost and IoT based approach can make V2G technology more practical and scalable. In future, the system can be extended with more advanced ML models, renewable energy sources integration and large scale deployment for smart grid applications.

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