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VEHICLE TO GRID (V2G) TECHNOLOGY FOR FUTURE SMART GRID

[1]Aditi Raju Kadam, [2]Akash Dadahari Bagul, [3]Dhanjaj Hiralal Kanade, [4]Atharv Mahesh Nagare, [5]Prof. S.T.Kamble

[1]UG Scholar, Electrical Dept. SND Collage of Engineering and Research center,Yeola,Nashik
[2]UG Scholar, Electrical Dept. SND Collage of Engineering and Research center,Yeola,Nashik
[3]UG Scholar, Electrical Dept. SND Collage of Engineering and Research center,Yeola,Nashik
[4]UG Scholar, Electrical Dept. SND Collage of Engineering and Research center,Yeola,Nashik
[5]Asst. Prof. Electrical Dept. SND Collage of Engineering and Research center,Yeola,Nashik

ABSTRACT- The increasing penetration of electric vehicles (EVs) has brought significant opportunities and challenges for energy systems. Vehicle-to-Grid (V2G) technology, which enables bidirectional energy flow between EVs and the power grid, plays a pivotal role in ensuring grid stability, integrating renewable energy sources, and reducing carbon emissions. This project aims to develop a prototype V2G-integrated EV system that demonstrates energy exchange between EV batteries and the grid. The prototype will showcase load balancing, peak shaving, and renewable energy optimization. The study further explores literature, identifies challenges, and proposes a block diagram for practical implementation.

Keywords: Vehicle-to-Grid (V2G), Electric Vehicles (EVs)

I. INTRODUCTION

The Electrification of transportation has become a vital strategy for reducing greenhouse gas (GHG) emissions and supporting the decarbonization of power systems. In the global movement toward sustainable energy, the integration of electric vehicles (EVs) with smart grids stands out as a transformative approach, reshaping both transportation and energy sectors. This integration is driven by the dual goals of lowering environmental impacts and leveraging renewable sources such as wind and solar photovoltaics (PVs). Beyond serving as modes of transport, EVs can act as mobile energy storage systems, enhancing the reliability, flexibility, and resilience of power networks. Their ability to exchange energy with the grid enables them to stabilize supply-demand fluctuations and support renewable energy utilization.

At the same time, concerns about fossil fuel depletion and environmental degradation have accelerated the adoption of EVs as a cleaner alternative to internal combustion engine vehicles. With rising adoption rates, attention has shifted to advanced applications like Vehicle-to-Grid (V2G) and Vehicle-to-Everything (V2X) technologies. These allow EV batteries to provide stored energy when idle, thereby contributing to grid balancing and powering auxiliary loads. Current research focuses on strengthening connectivity, refining charging/discharging technologies, and developing efficient energy management strategies to make EV-grid integration more effective.Transportation electrification is crucial in achieving decarbonization goals. EVs are no longer just consumers of energy but also potential providers through V2G integration. This integration allows EVs to act as mobile energy storage units that can support demand response, renewable integration, and emergency grid services. As fossil fuel reserves decline and environmental concerns rise, EV-based smart grid solutions are essential for sustainable infrastructure.Key features include:

II. BLOCK DIAGRAM

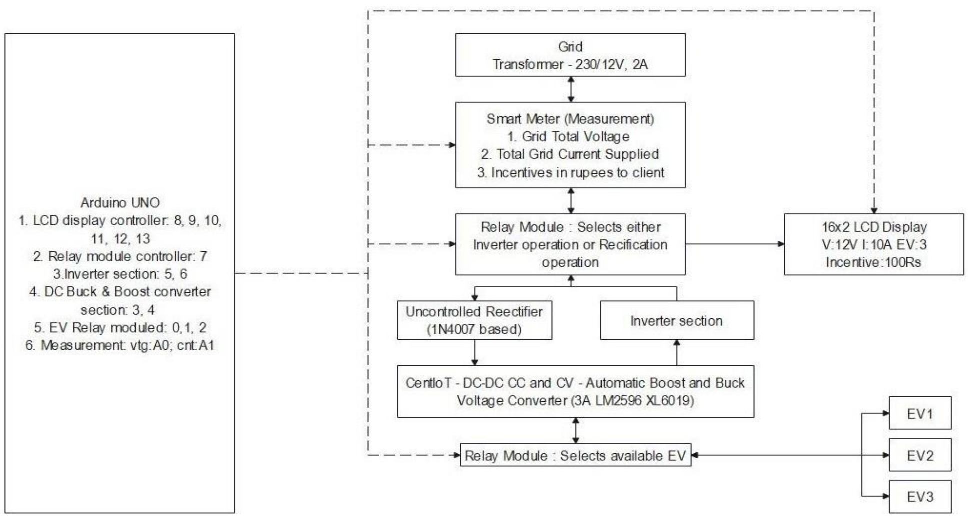

Fig1- Block Diagram

1. Arduino UNO (Control Unit)

It acts as the central controller of the entire system.It performs tasks such as:

- Controlling the display, relay modules, inverter, and converter.
- Measuring voltage and current.
- Managing EV charging/discharging operations.

Pin Configuration:

a. LCD display controller: Pins 8–13 → Displays parameters like voltage, current, EV number,

   incentives.

b. Relay module controller: Pin 7→ Switches between rectifier or inverter operation.

c. Inverter section: Pins 5, 6→ Controls inverter for DC to AC conversion.

d. DC Buck & Boost converter: Pins 3, 4→ Adjusts voltage for charging or discharging as

   required.

e. EV Relay module: Pins 0, 1, 2→ Selects the active EV (EV1, EV2, EV3).

f. Measurement: Analog inputs A0 (voltage), A1 (current).

2. Grid Transformer (230V/12V, 2A)

Steps down AC mains voltage from 230V to 12V AC suitable for measurement and conversion. It provides input to both the smart meter and rectifier/inverter section.

3. Smart Meter (Measurement Unit)
Measures key grid parameters:

1. Total grid voltage
2. Total grid current supplied
3. Calculates incentives (monetary rewards) for the client based on energy supplied or consumed.

This data is sent to the LCD display and the Arduino for control logic.

1. Relay Module (Operation Selector)

This relay determines the mode of operation:

- Rectification mode (AC → DC): Used for charging the EVs.
- Inversion mode (DC → AC): Used for sending energy from EVs to the grid.

2. Power Conversion Section

- Uncontrolled Rectifier (1N4007-based): Converts AC (from the grid) to DC for charging EVs.
- Inverter Section: Converts stored DC from EVs back to AC for feeding to the grid.

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3. DC–DC Converter (Buck and Boost Converter)

Model: *CentIoT CC/CV Automatic Boost and Buck Converter (LM2596, XL6019)*

Functions:

- Maintains constant voltage and current.
- Steps voltage up (boost) or down (buck) as needed for optimal EV charging or discharging.

EV Selection Relay Module This relay selects which EV (EV1, EV2, EV3) will be charged or discharged. The Arduino controls this based on priority or availability.

4. LCD Display (16x2)

Displays:

- Voltage (V)
- Current (I)
- Active EV number
- Earned incentive in rupees

III. SYSTEM REQUIREMENTS

3.1 Functional Requirements

1. Bidirectional Power Flow:

   The system should allow both AC-to-DC (rectification) for charging EVs and DC-to-AC (inversion) for returning stored power from EVs to the grid.
2. Energy Measurement:

   Smart meter should continuously measure voltage, current, and energy supplied or consumed, along with incentive calculation in rupees.
3. Microcontroller Control:

   The Arduino UNO should control all modules, including:

   - Relay operation (rectifier/inverter mode selection)

- LCD display updates
- EV relay selection
- Voltage and current measurement

4. Relay Switching:

   Relays must accurately switch between:

   - Rectification mode (charging EVs)
   - Inversion mode (feeding energy to grid)
   - EV selection (among EV1, EV2, and EV3)

5. Voltage & Current Regulation:

   A DC–DC Buck and Boost Converter should maintain stable output for different EV charging conditions.

6. Display Output:

   The system should display:

   - Voltage (V)
   - Current (I)
   - Active EV number
   - Incentive earned

7. Safety and Protection:

   The system should handle overload, reverse current, and short-circuit protection through controlled switching and measurement feedback.

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IV. PROPOSED SYSTEM

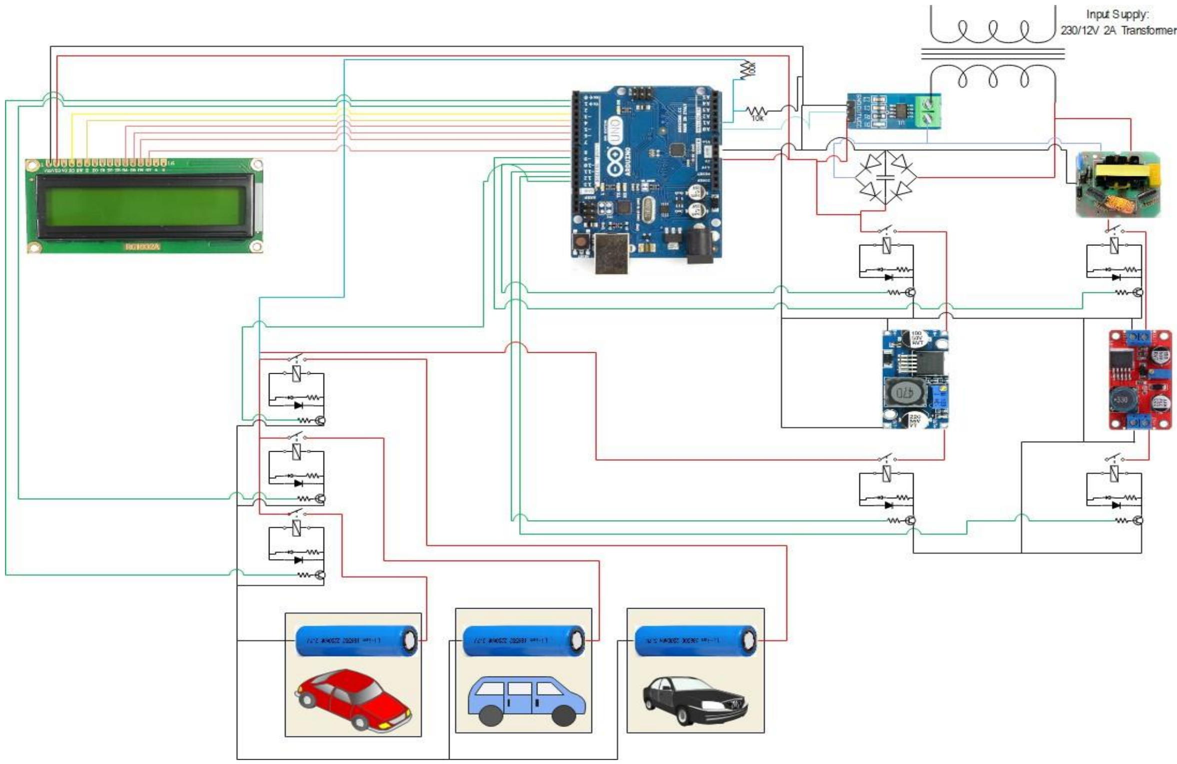

Figure 2- System Architecture circuit diagram

a. Input Source: The grid (230V AC) powers the system through a step-down transformer.

b. Measurement Unit: The smart meter continuously measures grid voltage, current, and computes energy parameters.

c. Control Unit (Arduino UNO): It processes the measurements, decides mode of operation, and controls relays, inverter, and converter.

d. Relay Network: Controls both mode selection (Rectification/Inversion) and EV selection.Rectifier & Inverter Modules: Perform AC↔DC conversion depending on power flow

e. DC–DC Converter: Maintains constant current/voltage suitable for EV battery charging.

f. Display Interface: LCD displays system status, parameters, and incentives.

V. CONCLUSION

By permitting twoway power flow between EVs and the electrical grid, the suggested Smart Bi directional GridConnected EV Charging System guarantees effective use of energy resources. The system detects grid characteristics, automates energy management, and offers realtime rew ards using smart metering, PWMbased control, and Arduino UNO.It shows how to apply Vehic leGrid (V2G) concepts for future smart cities and sustainable mobility in a costeffective and sca lable manner.

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