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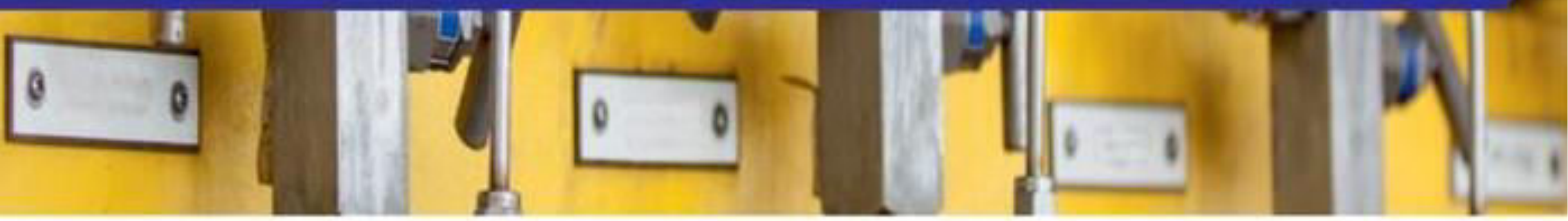

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Smart Grid Connected EV Charging SND Load Management System

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ABSTRACT: The increasing penetration of electric vehicles (EVs) imposes significant stress on conventional power grids due to uncontrolled charging and rising peak demand. To address these challenges, this paper presents a smart grid connected EV charging and load management system that enables intelligent, efficient, and reliable operation of EV charging infrastructure. The proposed system integrates EV charging stations with a smart grid through an energy management system (EMS) and smart meters to monitor realtime grid conditions, load demand, and electricity pricing. Load management strategies such as peak shaving, load shifting, demand response, and vehicle-to-grid (V2G) operation are implemented to minimize peak load, improve grid stability, and enhance renewable energy utilization. The system dynamically schedules and controls EV charging based on grid status and battery requirements, thereby reducing operational costs and improving power quality. The proposed approach supports sustainable transportation and provides a scalable solution for future smart city applications.

KEYWORDS— Electric Vehicles (EV), Smart Grid, Load Management , IOT, Vehicle - to -Grid (V2G), Renewable Energy, Smart Charging. (IoT), Battery Management System (BMS), Smart Grid, Renewable Energy Integration, Bidirectional Power Flow, Energy Management System

I. INTRODUCTION

The rapid growth of electric vehicles (EVs) is transforming the transportation sector toward a more sustainable and eco-friendly future. However, the increasing penetration of EVs poses significant challenges to conventional power grids, primarily due to uncoordinated charging behavior and the resulting rise in peak electricity demand. Uncontrolled EV charging can lead to grid instability, voltage fluctuations, and increased operational costs for utilities [2], [6].To address these challenges, the integration of EV charging infrastructure with smart grid technology has emerged as a promising solution. A smart grid enables two-way communication between the utility and consumers, facilitating real-time monitoring, control, and optimization of energy usage. Advanced energy management systems (EMS) combined with smart meters allow efficient scheduling of EV charging based on grid conditions, electricity pricing, and user requirements [1], [3].Various load management strategies have been proposed to mitigate the impact of EV charging on the grid. Techniques such as peak shaving, load shifting, and demand response help in reducing peak load demand and improving overall grid efficiency [4], [10]. Additionally, vehicle-to-grid (V2G) technology enables EVs to act as distributed energy storage units, supplying power back to the grid during peak demand periods, thereby enhancing grid reliability and stability [9].Several research works have focused on optimal scheduling and coordination of EV charging to ensure efficient energy utilization. Decentralized and real-time control approaches have been developed to manage large-scale EV integration without overloading the distribution network [7], [8]. Furthermore, the integration of renewable energy sources with EV charging systems supports sustainable energy usage and reduces carbon emissions [11], [14].In this context, this paper proposes a smart grid connected EV charging and load management system that ensures intelligent and efficient operation of EV charging infrastructure. The proposed system dynamically monitors grid conditions and optimizes charging schedules to minimize peak demand, reduce operational costs, and improve power quality. This approach provides a scalable and reliable solution for future smart cities with high EV penetration.

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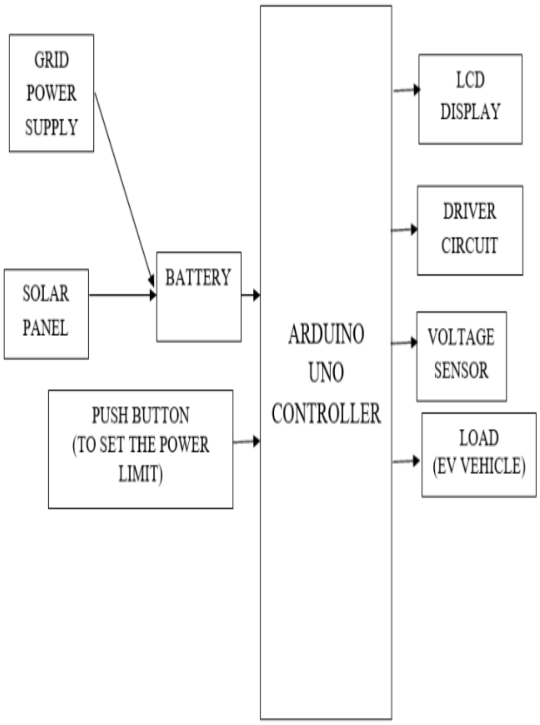
II. BLOCK DIAGRAM



III. WORKING PRINCIPLE

To attain our proposed system need to use Arduino, Voltage sensor, solar and grid and interfaced with battery. LCD and buzzer is used in this proto type. Normally load takes power supply from solar as primary and then grid as order. The micro controller reads the data from voltage sensor.

Whenever peak time persists automatically share the renewable energy or grid to battery power. DC to DC and AC to DC converter is used to convert renewable energy to ac energy. Controller is used to send the calculated amount of grid and renewable energy use to the EB section. Voltage sensor is used to measure the line voltage.
Here voltage sensor is used for protect the devices from faults like 1.over voltages 2.under voltage. If any one of the above problem happens the device is automatically share or switch off the device. Controller status and everything is displayed in LCD. The whole process is controlled by microcontroller.

And also Push button is used to set power limit as per user convenience or needs

IV. HARDWARE REQUIREMENTS

- Power Supply
- Solar Panel
- Battery
- Arduino microcontroller.
- Voltage sensor
- LCD Display
- DC/DC & AC/DC converter
- Push Button

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V. SOFTWARE REQUIREMENTS

- Arduino IDE Complier
- Proteus testing tool
- Embedded c

VI. HARDWARE DESCRIPTION

POWER SUPPLY
The potential transformer will step down the power supply voltage (0-230V) to (0-6V) level. Then the secondary of the potential transformer will be connected to the precision rectifier, which is constructed with the help of op–amp. The advantages of using precision rectifier are it will give

SOLAR PANEL
A solar cell panel, solar electric panel, photo-voltaic (PV) module or solar panel is an assembly of photo-voltaic cells mounted in a framework for installation. Solar panels use sunlight as a source of energy to generate direct current electricity. A collection of PV modules is called a PV panel, and a system of PV panels is called an array. Arrays of a photovoltaic system supply solar electricity to electrical equipment

BATTERY
A battery is a device that stores chemical energy and converts it to electrical energy. The chemical reactions in a battery involve the flow of electrons from one material (electrode) to another, through an external circuit. The flow of electrons provides an electric current that can be used to do work.

WHAT IS CELL IN BATTERY
Cell. Battery. A cell is a single unit device which converts chemical energy into electric energy. A battery usually consists of group of cells. Depending on the types of electrolytes used, a cell is either reserve, wet or dry types

A chemical reaction between the metals and the electrolyte frees more electrons in one metal than it does in the other. The metal that frees more electrons develops a positive charge, and the other metal develops a negative charge

HOW ENERGY STORED IN BATTERY
Batteries use chemistry, in the form of chemical potential, to store energy, just like many other everyday energy sources. For example, logs store energy in their chemical bonds until burning converts the energy to heat.

POWER GRID
The power grid is a network for delivering electricity to consumers. The power grid includes generator stations, transmission lines and towers, and individual consumer distribution lines. Step 1: Energy is Generated. The generator produces energy

ARDUINO UNO CONTROLLER
The Arduino Uno is a popular microcontroller board, part of the Arduino family, renowned for its simplicity, versatility, and ease of use in electronics projects.

VII. COMPONENTS AND FEATURES

Microcontroller: The Uno is powered by the ATmega328P microcontroller, providing ample functionality for various projects.

Digital and Analog I/O Pins: It includes 14 digital input/output pins, among which 6 support pulse width modulation (PWM) output, and 6 analog input pins, offering flexibility for connecting sensors, actuators, and other components.

Clock Speed: Operates at 16 MHz, providing decent processing power for most DIY and educational projects.

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Memory: It offers 32 KB of Flash memory (program storage), 2 KB of SRAM (temporary data storage), and 1 KB of EEPROM (non-volatile memory) for data retention.

USB Connectivity: Equipped with a USB interface for programming and power, simplifying the connection to computers.

Power Options: Can be powered via USB connection or an external power supply through a barrel jack (7-12V DC).

Compatibility: Works seamlessly with a wide range of shields (additional boards) that extend its capabilities for various applications.

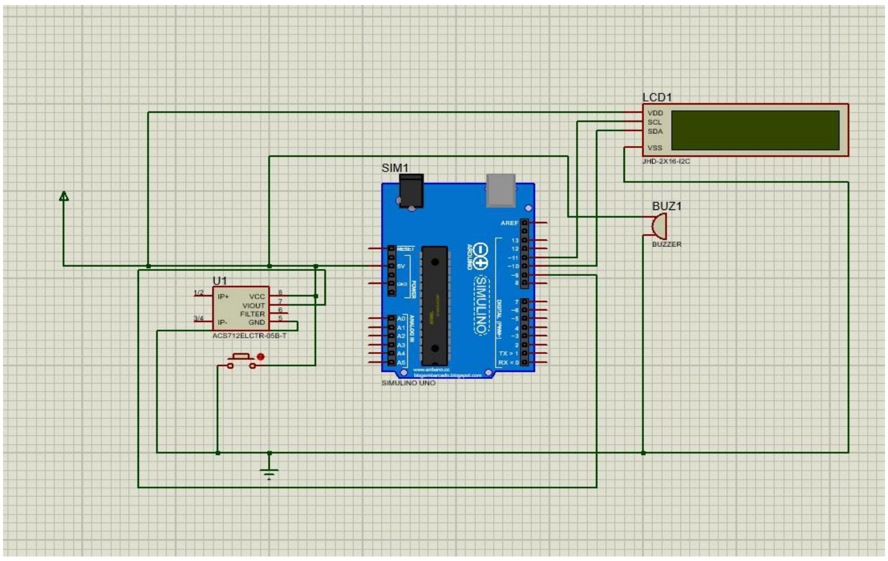
VOLTAGE SENSOR
A voltage sensor can in fact determine, monitor and can measure the supply of voltage. It can measure AC level or/and DC voltage level. The input to the voltage sensor is the voltage itself and the output can be analog voltage signals, switches, audible signals, analog current level, frequency or even frequency modulated outputs. That is some voltage sensors can provide sine or pulse trains as output and others can produce Amplitude Modulation, Pulse Width Modulation or Frequency Modulation outputs. In voltage sensor. That measurement is based on the voltage divider.

MAINLY TWO TYPES ARE OF VOLTAGE SENSORS ARE AVAILABLE
- Capacitive type voltage sensor &
- Resistive type voltage sensor.

LCD DISPLAY
LCD 16x2 is a 16-pin device that has 2 rows that can accommodate 16 characters each. LCD 16x2 can be used in 4-bit mode or 8-bit mode. It is also possible to create custom characters. It has 8 data lines and 3 control lines that can be used for control purposes.

SPECIFICATIONS OF 16X2 LCD:
1.Display Size: 16 characters × 2 rows
2.Operating Voltage: 4.7V to 5.3V
3.Current Consumption: 1mA (without backlight)
4.Interface: Parallel (4-bit or 8-bit mode)
5.Driver IC: HD44780 (or compatible)
6.Character Size: 5×8 pixel matrix
7.Backlight: LED (optional)

VIII. CIRCUIT DIAGRAM



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IOT MODULE

The ESP8266 WiFi Module is a self contained SOC with integrated TCP/IP protocol stack that can give any microcontroller access to your WiFi network. The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor.

.HOW IT WORK

The RX and TX pins of the ESP8266 Module are connected to RX and TX Pins on the Arduino board. Since the ESP8266 SoC cannot tolerate 5V, the RX Pin of Arduino is connected through a level converter consisting of a 1KΩ and a 2.2KΩ Resistor. Finally the GPIO2 pin is connected to an LED to test the working of the program

IX. OUTPUT

X. HARDWARE

The hardware solution of the Smart Grid Connected EV Charging and Load Management System consists of an integrated setup of renewable energy sources, storage systems, and control units to ensure efficient power distribution. The system uses a solar panel as the primary energy source, supported by the power grid and a battery for backup and energy storage. An Arduino Uno microcontroller acts as the central controller, continuously monitoring voltage levels through a voltage sensor and making intelligent decisions to switch between solar, grid, and battery sources based on availability and load demand. Power conversion is handled using AC-DC and DC-DC converters to maintain suitable voltage levels for EV charging. A 16x2 LCD display provides real-time system status, while a buzzer alerts users during fault conditions such as over-voltage or under-voltage. Additionally, a push button allows manual control of load limits, and an optional ESP8266 WiFi module enables IoT-based remote monitoring. This hardware setup ensures reliable, efficient, and smart energy management for EV charging applications.

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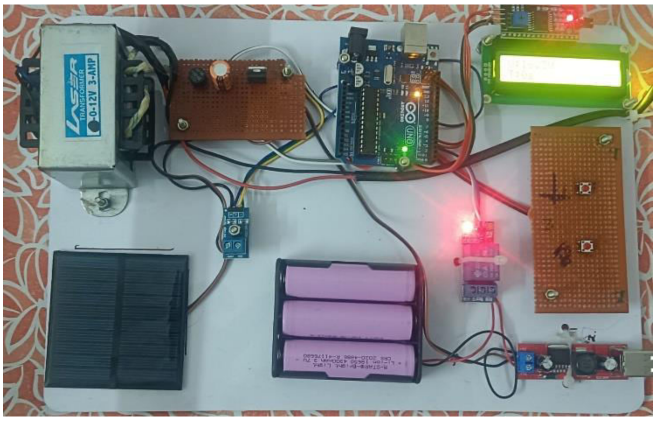


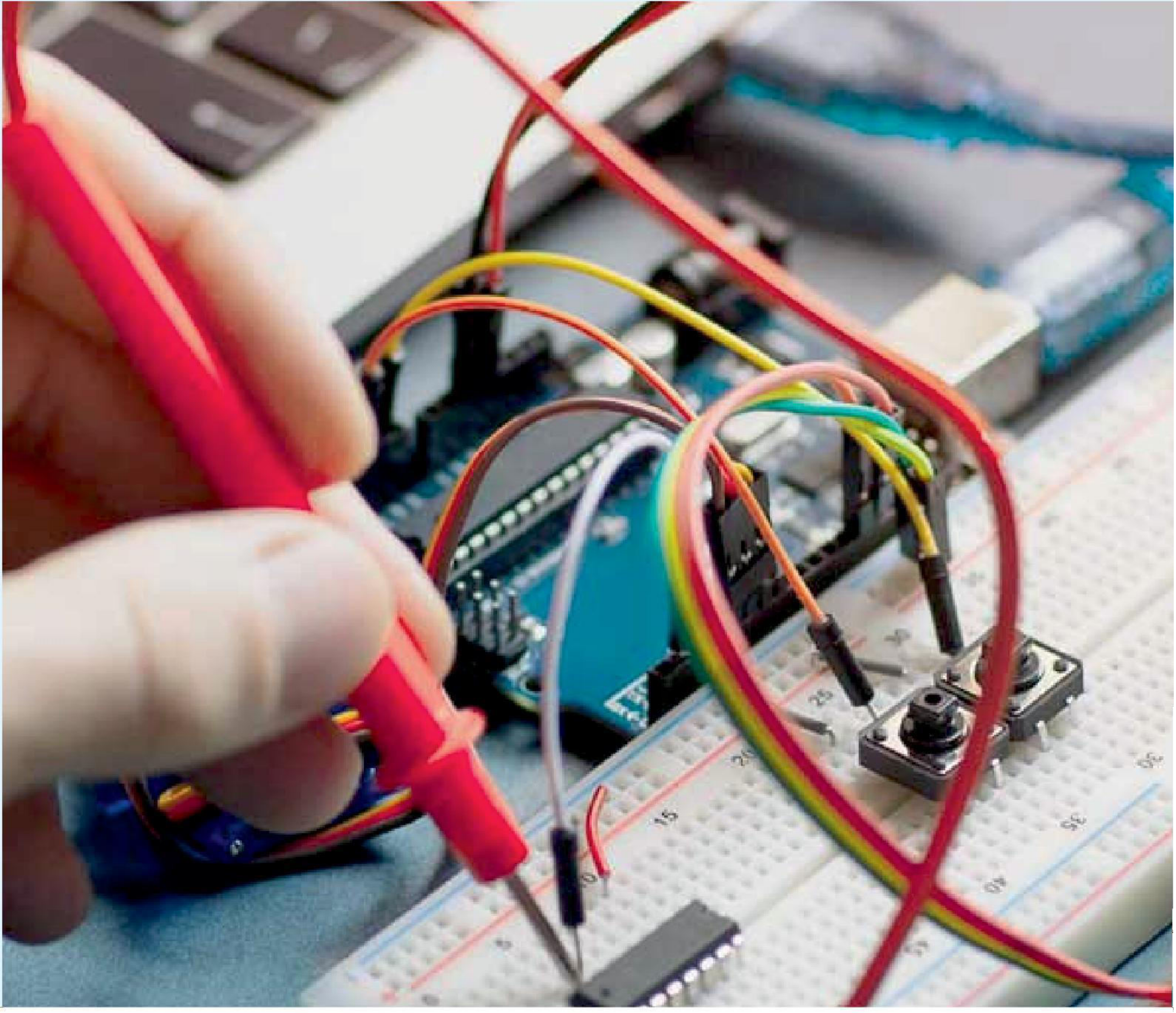
XI. CONCLUSION

In conclusion, the comprehensive analysis of load management strategies (user preferred, grid preferred, and solar) in combination with arduino controller shows the significant advantages of integrating grid and renewable in EV charging infrastructure.

The study considers individual users and explores a hypothetical case in india, connected to the National Electricity Market, which operates with varying pricing structures. It shows significant benefits across economic, environmental, and operational dimensions with the integration of grid and solar.

REFERENCES

[1] Rehman AU, Shafiq A, Ullah Z, Iqbal S, Hasanien HM. Implications of smart grid and customer involvement in energy management and economics. Energy 2023; 276:127626. https://doi.org/10.1016/j.energy.2023.127626.
[2] Rochd A, Laamim M, Benazzouz A, Kissaoui M, Raihani A, Sun H. Public charging infrastructure for EVs: a comprehensive analysis of charging patterns & real-world insights—case study of Rabat City, Morocco. Energy Rep 2023;9:216–34. https:// doi.org/10.1016/j.egyr.2023.05.259.
[3] Visaria AA, Jensen AF, Thorhauge M, Mabit SE. User preferences for EV charging, pricing schemes, and charging infrastructure. Transp Res Part Policy Pract 2022; 165:120–43. https://doi.org/10.1016/j.tra.2022.08.013.
[4] Sanjari MJ, Karami H. Analytical approach to online optimal control strategy of energy storage devices in energy system. J Energy Storage 2020;29:101328. https://doi.org/10.1016/j.est.2020.101328.
[5] Iqbal S, Jan MU, Rehman A-U, Rehman AU, Shafiq A, Rehman HU. Feasibility study and deployment of solar photovoltaic system to enhance energy economics of king Abdullah campus, University of Azad Jammu and Kashmir Muzaffarabad, AJK Pakistan. IEEE Access 2022;10:5440–55. https://doi.org/10.1109/ ACCESS.2022.3140723.
[6] Wang B, Yu X, Wu Q, Li Z, Jiang R, Qian G, et al. Case studies of a distributed building energy system incorporating with EVs considering effects of random charging behaviors and time-of-use pricing in electricity. Case Stud Therm Eng 2022;38:102297. https://doi.org/10.1016/j.csite.2022.102297.
[7] Emrani A, Achour Y, Sanjari MJ, Berrada A. Adaptive energy management strategy for optimal integration of wind/PV system with hybrid gravity/battery energy storage using forecast models. J Energy Storage 2024;96:112613. https://doi.org/ 10.1016/j.est.2024.112613.
[8] Yan J, Zhang J, Liu Y, Lv G, Han S, Alfonzo IEG. EV charging load simulation and forecasting considering traffic jam and weather to support the integration of renewables and EVs. Renew Energy 2020;159:623–41. https://doi.org/10.1016/j. renene.2020.03.175.
[9] Spaven F, Liu Y, Baghdadi M. Going further with smaller EVs: system-level battery range, emissions and charging infrastructure analysis. J Clean Prod 2022;369: 133349. https://doi.org/10.1016/j.jclepro.2022.133349.
[10] Iqbal S, Habib S, Ali M, Shafiq A, Rehman AU, Ahmed EM, et al. The impact of V2G charging/discharging strategy on the microgrid environment considering stochastic methods. Sustainability 2022;14, no. 20, Art. no. 20. https://doi.org/ 10.3390/su142013211.



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