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Design of a Solar-Assisted Wireless Charging Station for Electric Vehicles using TX–RX Coils

S.Snehapriya[1], N.Naveen Bharathi[2], R.Nithish[3], A.Ramakrishnan[4]

Assistant Professor, Department of EEE, M.A.M. School of Engineering Tiruchirappalli, Tamil Nadu, India[1]

Student, Department of EEE, M.A.M. School of Engineering Tiruchirappalli, Tamil Nadu, India[2-4]

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ABSTRACT: The rapid growth of electric vehicles (EVs) has significantly increasedthe demand for efficient, safe, and sustainable charging solutions. However, conventional plug-in charging systems present several challenges, including cable degradation, risk of electric shocks, frequent maintenance requirements, and heavy dependence on the electrical grid. These limitations not only affect user convenience but also raise safety and reliability concerns, especially in outdoor and public charging environments. To overcome these issues, the proposed system introduces a solar-powered wireless charging solution that promotes clean energy utilization and reduces grid dependency. The system incorporates a solar panel combined with a battery storage unit, ensuring a continuous and reliable power supply even during periods of low sunlight or high demand. Wireless Power Transfer (WPT) technology is employed using transmitter and receiver coils, enabling efficient contactless energy transfer to the EV battery and eliminating the need for physical connectors. This enhances safety, minimizes wear and tear, and improves overall user experience. Furthermore, an Arduino Nano microcontroller integrated with an LCD display is used to monitor system parameters such as charging status and battery levels in real time. The proposed system offers an eco-friendly, reliable, and user- friendly solution, making it highly suitable for next-generation EV charging infrastructure.

KEYWORDS: Electric Vehicles, Solar Energy, Arduino Nano, EV Charging Infrastructure, Energy Efficiency

I. INTRODUCTION

The rapid adoption of Electric Vehicles (EVs) has created a growing demand for efficient, safe, and sustainable charging solutions. Conventional plug-in charging systems, though widely used, face several challenges such as cable wear and tear, risk of electric shocks, high maintenance, and dependence on grid power. These limitations reduce reliability and user convenience, particularly in outdoor and public environments.

To address these issues, this project proposes a solar-powered wireless EV charging system. The system integrates renewable solar energy with Wireless Power Transfer (WPT) technology to enable contactless charging. A solar panel along with a battery storage unit ensures continuous power availability, while transmitter and receiver coils facilitate efficient energy transfer without physical connections. Additionally, an Arduino Nano-based monitoring system provides real-time updates on charging status and battery levels. This approach enhances safety, reduces maintenance, and supports eco-friendly energy utilization.

OBJECTIVES

The specific objectives of the system are as follows:

- To design and develop a solar-powered wireless charging system for EVs
- To reduce dependence on conventional grid-based charging
- To implement Wireless Power Transfer (WPT) for contactless energy transmission
- To improve safety by eliminating physical cables and connectors
- To integrate battery storage for continuous power supply
- To monitor system performance using Arduino Nano and LCD display
- To enhance user convenience and system reliability
- To promote renewable energy usage in EV infrastructure

II. LITERATURE SURVEY

2.1 Farghly,A.,etal. (2025)
Farghly et al. presented a comprehensive review of Wireless Power Transfer (WPT) techniques for electric vehicle (EV) charging, emphasizing the importance of contactless energy transfer in modern transportation systems. The study provides a detailed classification of WPT technologies, including inductive coupling, resonant inductive coupling, and capacitive power transfer, and evaluates their suitability for EV applications based on efficiency, transfer distance, and operational complexity. Among these, resonant inductive coupling is identified as the most efficient and widelyadopted technique due to its ability to transfer power over moderate distances with reduced energy losses. The authors also discuss the key components of WPT systems, such as transmitter and receiver coils, compensation networks, and power electronic converters, highlighting their role in improving system performance. One of the major challenges identified in the study is coil misalignment, which significantly reduces power transfer efficiency and affects system reliability. Additionally, the paper addresses issues related to electromagnetic interference, safety regulations, and thermal management in high-power charging systems. The authors further explore recent advancements in coil design optimization, frequency tuning, and control strategies that aim to enhance system efficiency and reduce losses. The integration of WPT with renewable energy sources is also discussed as a potential solution for sustainable EV charging infrastructure. Overall, this review provides valuable insights into the current state of WPT technology and identifies future research directions to improve efficiency, scalability, and practical implementation in real-world EV charging systems.

2.2 Monteagudo,R.,etal.(2024)
Monteagudo et al. proposed an advanced optimization approach for the allocation of electric vehicle charging stations using a combination of Genetic Algorithm approaches that are used. The study focuses on addressing the increasing demand for EV infrastructure and the challenges associated with uneven distribution of charging stations in urban and suburban areas. By analyzing population density, residential distribution, and transportation patterns, the authors developed a hybrid algorithm that identifies optimal locations for charging stations to maximize accessibility and minimize installation and operational costs. The Genetic Algorithm is used to explore various placement possibilities and find the best solution based on predefined criteria, while the Weighted K-Means method helps in clustering demand points to improve efficiency. The study also considers practical constraints such as land availability, power grid capacity, and user demand variability. The results demonstrate that the proposed method significantly improves network efficiency, reduces congestion at charging stations, and ensures better utilization of resources compared to traditional planning methods. Furthermore, the research highlights the importance of data-driven decision-making in designing EV infrastructure and emphasizes the role of optimization techniques in achieving sustainable urban development. This work provides a strong foundation for future research in intelligent EV charging station planning and management.

2.3 Carvalhosa,S.,etal.(2024)
Carvalhosa et al. presented an innovative approach for implementing electric vehicle charging systems in existing residential condominiums, where infrastructure limitations often restrict the installation of conventional charging setups. The study addresses the challenges faced by residents in multi-dwelling units, such as limited electrical capacity, high installation costs, and lack of dedicated parking spaces for EV charging. To overcome these issues, the authors proposed a shared charging system that utilizes smart energy management techniques to distribute available power among multiple user efficiently. The system incorporates scheduling algorithms and load balancing strategies to ensure fair energy distribution while preventing overload conditions. Additionally, the study highlights the importance of communication technologies for monitoring and controlling charging operations in real time. The proposed solution reduces the need for extensive infrastructure modifications and makes EV charging more accessible in urban residential areas. The authors also discuss the economic and environmental benefits of adopting such systems, including reduced energy consumption and lower carbon emissions. The results indicate that the proposed method improves system efficiency and enhances user satisfaction by providing a reliable and cost-effective charging solution. This research contributes significantly to addressing real-world challenges in EV adoption, particularly
in densely populated region.

2.4 EXISTING SYSTEM
The existing electric vehicle (EV) charging systems are predominantly based on conventional wired charging technology, where electrical energy is transferred from the power grid to the vehicle through physical connectors and charging cables. These systems are widely adopted due to their simplicity and established infrastructure; however, they come with several inherent limitations. The dependence on direct plug-in mechanisms requires user intervention, which

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can be inconvenient and time-consuming, especially in public charging environments. Moreover, repeated use of cables leads to mechanical wear and tear, increasing maintenance costs and reducing system reliability over time. Safety is another major concern, as exposed conductive parts can pose risks of electric shock, particularly in wet or harsh environmental conditions. Additionally, most existing charging stations rely heavily on non-renewable energy sources, contributing to increased carbon emissions and environmental degradation. Although some advanced systems incorporate fast-charging technologies, they often result in high power demand, placing stress on the electrical grid and potentially leading to instability during peak usage periods. In recent years, wireless power transfer (WPT) technology using inductive coupling between transmitter (TX) and receiver (RX) coils has been introduced as an alternative solution; however, current implementations still face challenges such as lower energy transfer efficiency, precise alignment requirements between coils, limited transmission distance, and higher initial setup costs. Furthermore, the integration of renewable energy sources like solar power into existing systems remains minimal, limiting their sustainability and long-term viability. Therefore, despite technological advancements, the existing EV charging infrastructure still lacks a fully efficient, user-friendly, and environmentally sustainable solution, highlighting the need for an improved system that combines wireless charging.

III. SYSTEM ARCHITECHTURE DIAGRAM

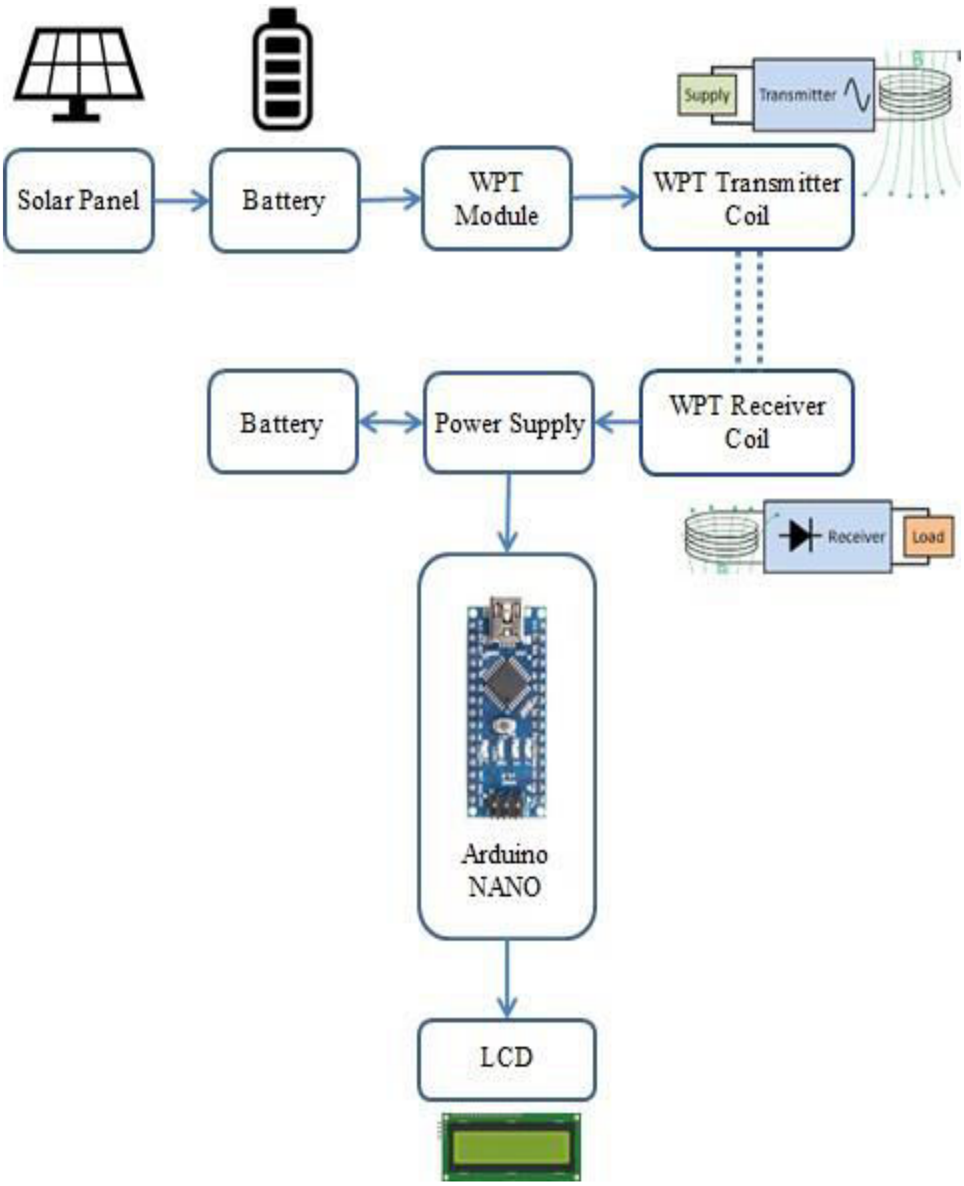

Fig.3.1 Architecture Diagram

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IV. HARDWAREDESCRIPTION

4.1 ARDUINO NANO

The Arduino Nano is defined by its sustainability, consistency, and adaptability. Its small form factor makes it suitable for portable and embedded projects, allowing for seamless integration into various devices. To begin utilizing the Arduino Nano, users typically require the Arduino IDE and a mini USB connection for programming and power supply. This simplicity ensures that even those new to microcontroller programming can easily set up and develop projects without the need for additional peripherals or complex setups. Whether used for prototyping or embedded applications, the Arduino Nano offers a reliable solution for digital and analog input/output tasks, making it a popular choice among hobbyists and professionals alike.

- OperatingVoltage:3.8V–4.2V
- Communication:SMS/Callalerts
- Network:Quad-bandGSM(850/900/1800/1900MHz)

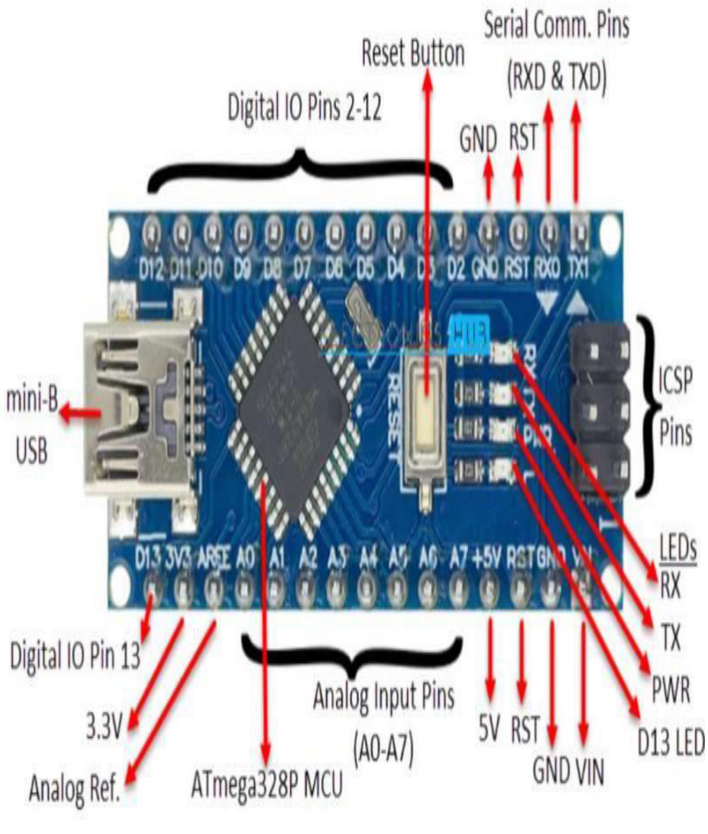

Fig 4.1 Pin Details of Aurdino Nano

4.2 POWER SUPPLY

A power supply (sometimes known as a power supply unit or PSU) is a device or system that supplies electrical or other types of energy to an output load or group of loads. The term is most commonly applied to electrical energy supplies, less often to mechanical ones, and rarely to others.This circuit is a small +5V power supply, which is useful when experimenting with digital electronics. Small inexpensive wall transformerswith variable output voltage are available from any electronics shop and supermarket. Those transformers are easily available, but usually their voltage regulation is very poor, which makes then not very usable for digital circuit experimenter unless a better regulation can be achieved in some way. The following circuit is the answer to the problem.

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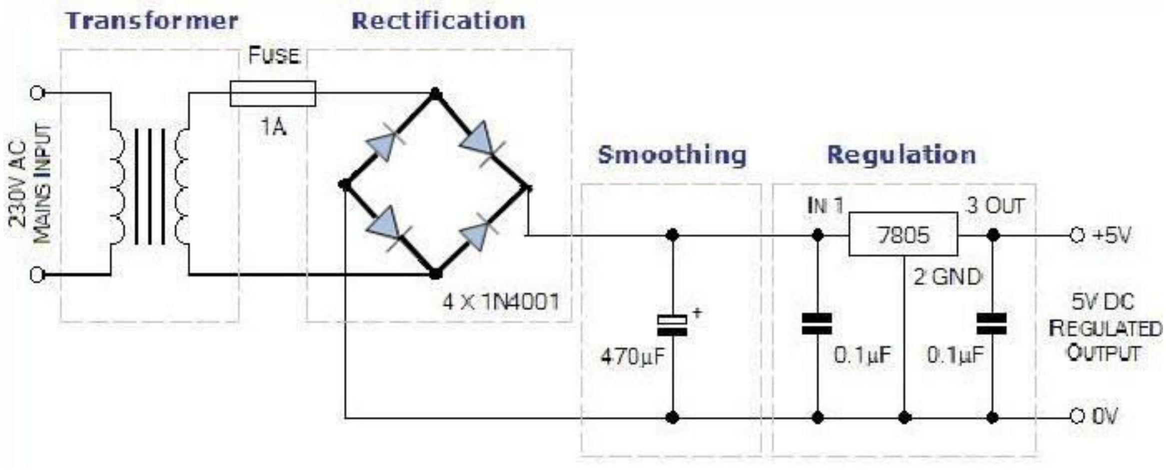

Fig 4.2 Power Supply

4.3 LCD (LIQUID CRYSTAL DISPLAY)

LCD (Liquid Crystal Display) screen is an electronic display module and findawiderangeofapplications. A16x2 LCDdisplayis verybasic moduleand is very commonly used in various devices and circuits.A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD, The data register stores the data to be displayed on the LCD The data is the ASCII value of the character to be displayed on the LCD.Liquid crystal displays are used for display of numeric and alphanumeric character in dot matrix and segmental displays. The two liquid crystal materials which are commonly used in display technology are nematic and cholesteric whose schematic arrangement of molecules is shown in fig. The most popular liquid crystal structure is the Nematic Liquid Crystal (NLC). In this all the molecules align themselves approximately parallel to a unique axis (director), while retaining the complete translational freedom. The liquid is normally transparent, but if subjected to a strong electric field, disruption of the well ordered crystal structure takes place causing the liquid to polarize and turn opaque.

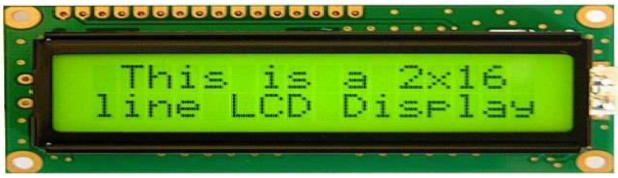

Fig 4.3 LCD Display

4.4 PV PANEL

A photovoltaic (PV) panel, commonly known as a solar panel, is a device that converts sunlight directly into electricity using the principle of the photovoltaic effect PV panels are widely used in renewable energy systems to generate clean and sustainable electrical power. As the demand for alternative energy sources increases due to environmental concerns and the depletion of fossil fuels, photovoltaic technology has gained significant importance across the world. PV panels play a crucial role in solar power generation systems used in residential buildings, industries, agricultural fields, and remote areas where conventional electricity supply is limited or unavailable.

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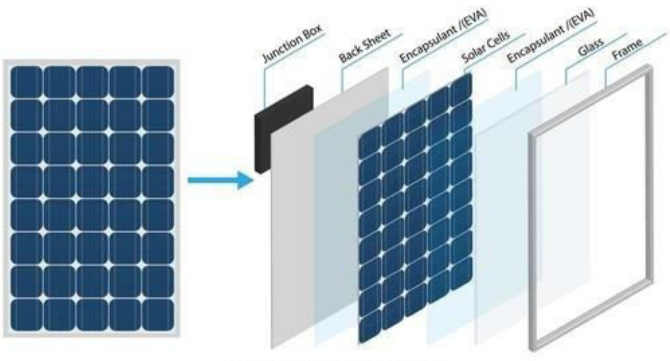

Fig 4.4 PV Panel

4.5 WIRELESS POWER TRANSFER (WPT)COILS–TRANSMITTER AND RECEIVER

The operation of WPT coils is based on the principle of electromagnetic induction, which was discovered by Michael Faraday. According to this principle,when an alternating current flows generates changing magnetic field around the coil. If another coil is placed within the range of this magnetic field, the changing magnetic field will induce an electrical changing magnetic field around the coil. If another coil is placed within the range of this magnetic field, the changing magnetic field will induce an electrical current in the second coil. In wireless power transfer systems, the transmitter coil acts as the primary coil and the receiver coil acts as the secondary coil. When alternating current is supplied to the transmitter coil, a time-varying magnetic field is produced. This magnetic field spreads through the surrounding air and interacts with the receiver coil. As a result, an alternating voltage is induced in the receiver coil. This induced voltage is then converted into usable electrical power using rectifier circuits and voltage regulators, which can be used to charge a battery or power electronic devices.

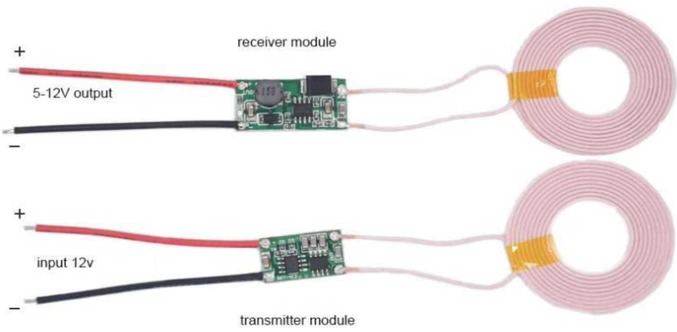

Fig 4.5 Wireless Power Transmission Coil

V. SOFTWARE DESCRIPTION

Proteus software is a comprehensive electronic design automation(EDA) tool widely used for schematic capture, circuit simulation, and Printed Circuit Board (PCB) design. It is developed by Lab center Electronics and has become one of the most popular platforms among students, researchers, hobbyists, and professional engineers for designing and testing electronic circuits virtually before implementing them in hardware. The software provides an integrated environment where users can create circuit schematics, simulate analog and digitals ystems, test microcontroller-based applications, and design PCB layouts within a single workspace. Because of its user-friendly interface and powerful simulation capabilities, Proteus plays a vital role in academic institutions and industrial environments for teaching, prototyping, and product development purposes. It is developed by Labcenter Electronics and has become one of the most popular platforms among students, researchers, hobbyists, and professional engineers for designing and testing electronic circuits virtually before implementing them in hardware. The software provides an integrated environment where users can create circuit schematics, simulate analog and digitalsystems, test microcontroller-based applications, and designPCBlayouts within a single workspace. Because of its user-friendly interface and powerful simulation capabilities, Proteus plays a vital role in academic institutions and industrial environments for teaching, prototyping,

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and product development purposes Proteus is primarily known for its ability to simulate both analog and digital circuits accurately. It allows users to place various electronic components such as resistors, capacitors, inductors, diodes, transistors, operational amplifiers, logic gates, and many other devices directly onto a schematic design area. The software includes a large library of components, which makes it convenient for users to select and integrate required elements into their circuit design. Each component can be configured with specific parameters such as resistance value, After designing the schematic, the user can run simulations to observe the behavior of the circuit in real time. The simulation results can be viewed using virtual instruments such as oscilloscopes, voltmeters, ammeters, logic analyzers, and signal generators available withinthe software environment. One of the most powerful features of Proteus is its microcontroller simulation capability. Unlike many basic circuit simulators, Proteus supports embedded system development by allowing users to simulate microcontrollers along with their firmware code. It supports a wide range of microcontrollers from popular manufacturers such as Microchip Technology and Atmel, as well as boards based onplatforms like Arduino. Users canwrite embedded programs in languages such as C or Assembly using external compilers, generate the corresponding HEX file, and then load that file into the microcontroller modelin Proteus. During simulation, the software executes the program as it wouldrun on real hardware, enabling users to verify functionality without physically assembling the circuit. This feature significantly reduces development time, cost, and risk of hardware damage during early testing stages.

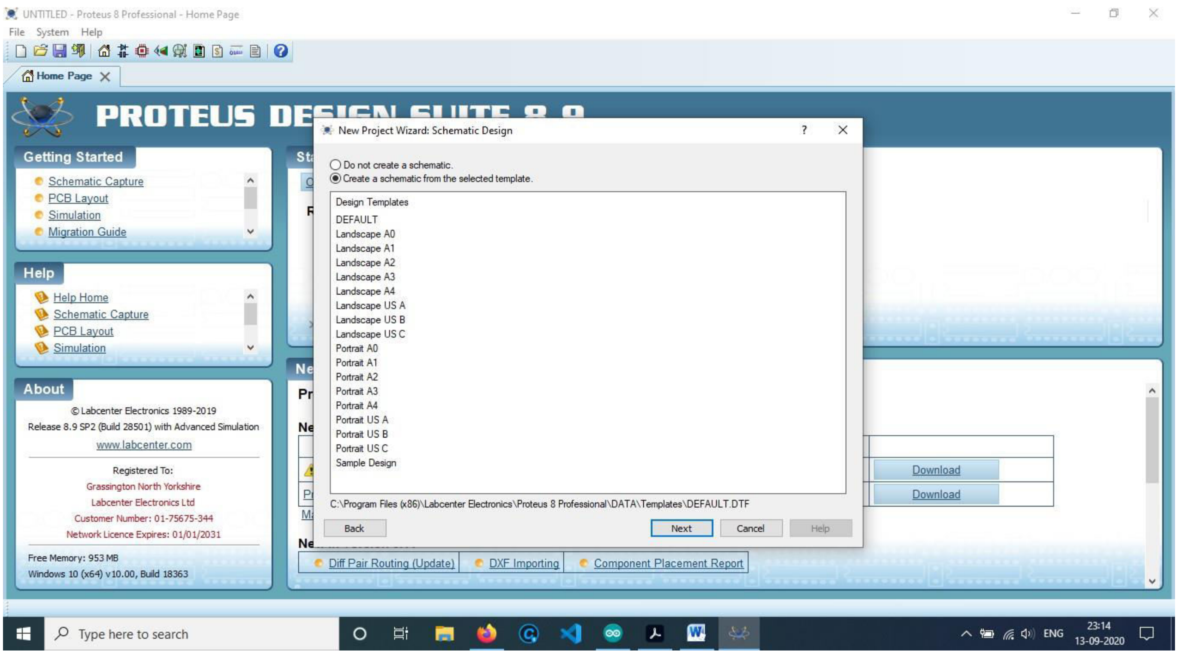

Fig 5.1 Proteus Suite

VI. METHODOLOGY

The methodology adopted for advanced system evaluation involves a systematic approach to analyze the performance of the integrated solar-powered wireless EV charging system under different conditions. Initially, the system is tested under standard operating conditions to establish a baseline for comparison. Following this, various parameters such as solar panel output, battery charge level, wireless power transfer distance, and coil alignment are varied one at a time to observe their individual effects on system performance. The wireless power transfer module is analyzed by adjusting the position and orientation of the transmitter and receiver coils to study the impact of alignment on energy transfer efficiency.

VII. CONCLUSION

The design and development of a solar-assisted wireless charging station for electric vehicles using TX–RX coils present a significant advancement in modern EV charging technology by combining convenience, efficiency, and sustainability. This system effectively addresses the limitations of conventional wired charging methods by eliminating

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the need for physical connections, thereby reducing mechanical wear, improving safety, and enhancing user comfort. The integration of wireless power transfer through inductive coupling ensures seamless energy transmission between the transmitter and receiver coils, while the incorporation of solar energy as a primary or supplementary power source reduces dependence on the conventional power grid and promotes the use of clean, renewable energy. Throughout the system, careful consideration is given to optimizing power transfer efficiency, maintaining proper coil alignment, and ensuring stable operation under varying environmental and load conditions. The inclusion of intelligent control mechanisms and monitoring software further enhances system reliability by regulating voltage, current, and temperature, and by preventing issues such as overcharging and energy loss. Although challenges such as alignment sensitivity, initial setup cost, and efficiency limitations exist, continuous improvements in wireless power transfer technology and solar energy utilization are expected to overcome these constraints. Overall, the proposed system demonstrates a practical and eco-friendly solution for future electric vehicle infrastructure, supporting the global transition toward sustainable transportation. It not only improves the accessibility and ease of EV charging but also contributes to reducing carbon emissions and energy consumption, making it a promising approach for smart cities and next-generation mobility systems.

VIII. FUTURE SCOPE

1) Integration of advanced Maximum Power Point Tracking (MPPT) techniques to further improve solar energy harvesting efficiency under varying weather conditions.
2) Development of dynamic wireless charging systems, enabling electric vehicles to charge while in motion on specially designed roads.
3) Improvement in coil design and alignment mechanisms to enhance power transfer efficiency and reduce energy losses.
4) Incorporation of Artificial Intelligence (AI) and machine learning algorithms for smart energy management, load prediction, and adaptive charging control.
5) Expansion of the system with IoT-based monitoring and control, allowing real-time tracking, remote access, and data analytics.
6) Use of high-efficiency power electronics components to minimize losses and increase overall system performance.
7) Integration with smart grid technology to enable bidirectional power flow and better energy distribution.
8) Development of compact and cost-effective designs to make the system more affordable and suitable for widespread adoption.
9) Implementation of multi-vehicle wireless charging stations to support simultaneous charging of multiple EVs.
10) Enhancement of energy storage systems, such as advanced batteries or supercapacitors, to ensure continuous operation during low solar availability.
11) Adoption of standardization protocols for wireless charging to ensure compatibility across different EV models and manufacturers.

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