Solar Based Dynamic WPT EV Charging System: Renewable Energy Prediction Model

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Abstract: The deployment of a powered by sunlight wireless charging system is examined in this research in order to meet the increasing demand for effective battery charging for electric cars (EVs). Since EVs are becoming a viable way to cut pollution, upgrading the infrastructure for charging them is essential to increasing customer convenience and dependability. Over the past 30 years, wireless power transfer (WPT) and solar energy harvesting have advanced significantly, especially in terms of power levels that can be used for charging. The capacity to forecast when solar energy will be most available determines how effective such a system will be reducing dependency on the grid and optimizing the usage of clean, renewable energy. By surpassing the constraints of battery technology, this study seeks to stimulate additional advancements in solar-based

Keywords: - *Wireless Power Transfer (WPT), Solar energy, Electric vehicles (EVs), Wireless charging, Renewable energy, Solar-powered WPT, Battery charging, Sustainable transportation, Dynamic charging, Stationary charging, Green energy solutions..*

I. INTRODUCTION

A revolutionary change in transportation, the rise of electric cars (EVs) aims to lessen the harm internal combustion engines cause to the environment. The need for environmentally friendly and sustainable transportation options is growing along with the number of vehicles on the road worldwide. Effective EV use and creative recharge methods are essential given the rising levels of greenhouse gas emissions and the depletion of fuel supplies. Conversely, EVs provide a low-pollution substitute for traditional automobiles.

Wireless power transfer (WPT) technology, especially dynamic charging systems that allow cars to charge while driving, is one viable answer. Energy can be transferred from stationary sources to automobiles via transformer windings by employing inductive power transfer. In order to increase range and improve operational efficiency, this article investigates solar-driven wireless charging as a sustainable EV charging technique that uses receiver coils mounted on cars and emitter coils buried in roads.

Furthermore, by doing away with the necessity for physical connectors, Wireless Power Transfer (WPT) systems present a viable alternative for electric vehicle (EV) charging, improving the efficiency and convenience of the charging process. The carbon footprint of EVs may be further decreased by combining WPT systems with renewable energy sources like solar power. However, maintaining reliable and effective power supply is made more difficult by the unpredictability of solar energy. In order to maximize solar-based dynamic WPT for EVs, this section examines the use of Renewable Energy Prediction Models (REPM). AI-driven forecasting is used to match charging operations with the highest solar energy availability.

LITERATURE SURVEY

Significant research into electric vehicles (EVs) and wireless power transfer (WPT) systems, especially solar-driven wireless charging technologies, has been fuelled by the growing demand for environmentally friendly transportation options. The potential of WPT and solar energy to overcome the drawbacks of traditional charging techniques has been the subject of numerous studies. This review of the literature focuses on important studies that set the stage for the creation of solar-powered EV wireless charging devices.

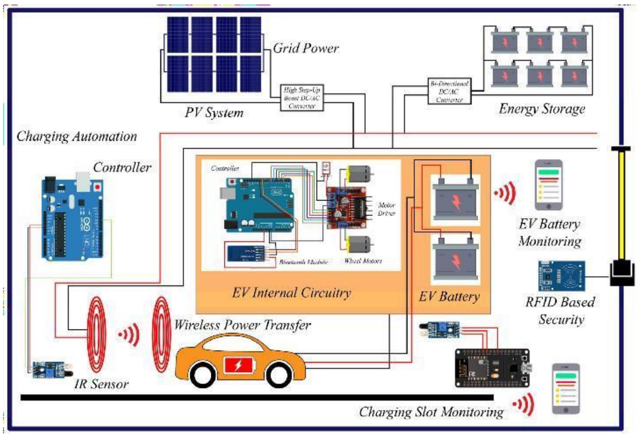

Fig-Architecture of model

For EVs, Wireless Power Transfer (WPT) has become a viable substitute for traditional plug-in charging techniques. The potential of dynamic wireless charging systems, which use inductive power transfer to charge cars while they are moving, was highlighted by researchers like Covic and Boys (2013). These systems increase convenience and range without requiring frequent stationary recharge stops by using magnetic resonance and inductive coupling between transmitter coils placed in roads and receiver coils mounted in automobiles.

EVs can be powered by solar energy, which is acknowledged as a renewable and sustainable resource that has the potential to lessen reliance on the grid.[1] [15]

II. PROPOSED WORK

A network of carefully placed solar panels will be included into the system to optimize energy capture all day long. The WPT infrastructure will receive power straight from these panels. Predicting solar energy availability will be made easier with the use of real-time weather data, such as cloud cover, temperature, humidity, and solar radiation. The data will be used to train sophisticated machine learning models (such as neural networks and time-series forecasting) that forecast both short- and long-term solar energy production. When the weather changes, the models will be able to adapt in real time. [2]. Soleimani, A., Khosravi, A., Mirsalim, M., & Kashani, S. A. (2022). cutting-edge studies on solar-powered wireless charging for electric cars. 16(1) Energies, 282.

Since solar input is the main energy source, a monitoring system is necessary to ensure its efficient usage. With an emphasis on accuracy and real-time data provision, the methodology combines current and voltage sensors with the PV module system.

The system runs at a high frequency, specifically using ACS712 current sensors and 0–25 V DC voltage sensors. The ongoing observation of the electrical characteristics of PV modules. The ESP32 microcontroller, Blynk IoT platform, and ACS712 and 0–25 V DC voltage sensors are used in the study to track and analyse the PV system's power metrics. Accurate voltage readings from the 0–25 V DC sensors are matched by precise current measurements from the ACS712 sensors. The Blynk IoT platform functions as the interface for remote monitoring and visualization, while the ESP32 microcontroller acts as the central processing unit, guaranteeing real-time data collecting. The effectiveness and accessibility of tracking the performance of the solar energy system are improved by this hardware and IoT combination.[3]

III. MODULES

1. *Magnetic Field Formation*

The system is made up of a secondary side with a filter and rectifier, and a main side with a power source and stepdown transformer. The task of transforming low frequency 60 Hz AC voltage into high frequency current falls to the power inverter. Through the high-frequency coil built into the power line, this high-frequency current creates a magnetic field. This high-frequency magnetic field is captured by the pickup module on the secondary side, and it is converted into direct current (DC) voltage by the rectifier to enable effective power transmission to the electric vehicle's battery.[4]

2. *Controller Logic*

The Arduino Uno is an open-source board that is based on the Microchip ATmega328P and uses the ATmega328 microcontroller. Digital pins (D4 to D7) are used to interface the LCD with the Arduino; pin 2 is used for the Enable pin, and pin 1 is used for the RS pin. To alter the contrast, the Vo pin is connected to the potentiometer, while the R/W pin is grounded. The charging state is tracked by an inbuilt infrared sensor, and the microcontroller triggers a relay to start charging when a vehicle is spotted. To improve energy management and system sustainability, the system stops charging if there isn't a car present .Connectivity and Integration.

3. *Transmitter (TX) Part*

A step-down transformer, which lowers the 230V AC mains voltage to a safer 0-12V AC output, is used to start the transmitter part of fig 3 of the setup. Depending on its configuration, it can provide either 0V (ground) or 12V AC. After that, a bridge rectified rectifier is used to correct this AC output.

Made up of four diodes, which allows AC to be converted to DC via full-wave rectification. To guarantee a steady DC signal for additional processing, the rectified DC voltage is subsequently filtered to eliminate any remaining AC ripple. To provide high frequency alternating current across a centre-tapped coil, a transistor is used in the transmitter circuit. A magnetic field is produced around this coil by the alternating current. One side of the coil is connected to a resistor in this setup, and the other side is connected to an NPN transistor's collector terminal. The transistor is activated during operation by current flowing through the base resistor, which causes the inductor (coil) to charge with energy. High-frequency oscillations are produced when the inductor discharges when the transistor turns off.

4. *Receiver Part (RX)*

According to Faraday's law of electromagnetic induction, the magnetic field produced by the transmitter coil in the wireless charging system's receiver portion causes an electromotive force (EMF) to be induced in the receiving coil. A linked battery is directly charged using this produced EMF. To transform the induced alternating current (AC) voltage into a steady direct current (DC) voltage appropriate for battery storage, the receiver unit integrates a bridge rectifier. A filtering stage is subsequently applied to the rectified voltage in order to remove any remaining ripples and guarantee a steady DC output.

5. *Data Collection and Integration*

REPMs collect weather data, such as temperature, humidity, cloud cover, and solar irradiance, both in current time and in the past. Forecasting solar energy production and determining when the WPT system can anticipate peak power availability depend heavily on this data.

Prediction accuracy can be increased by tracking solar panel efficiency, such as output in different weather scenarios. The models can more accurately take into consideration elements like panel orientation, shading, and deterioration by examining historical performance data.

6. *AI-Driven Solar Energy Forecasting*

To forecast solar energy output, machine learning methods such as neural networks, regression models, and time-series analysis are used. To generate precise forecasts, these models use real-time sensor data, historical trends, and current weather forecasts.

The AI models constantly update their forecasts in response to changing weather conditions, ensuring that the WPT system is operating with the most recent data and enabling real-time power transfer modifications.

7. *Solar Panel Array*

The information acquired is essential for making real-time modifications to guarantee effective power transmission and avoid energy waste. Proximity sensors are used for alignment, temperature sensors are used for heat management, and energy sensors track power flows and availability.

Generates electricity from sunshine to run the EV charging station. Based on the required voltage and current output, high-efficiency photovoltaic (PV) panels can be linked in parallel or series. Depending on the amount of sunshine, these panels are connected to Maximum Power Point Tracking (MPPT) controllers, which modify the operating voltage and optimize power production. MPPT improves energy yield by mitigating variations in solar radiation . ought to be rated to produce sufficient power to charge EVs in the allotted period. Usually, a mix of polycrystalline and monocrystalline panels is employed.[7]

8. *Battery Energy Storage System (BESS)*

Stores extra energy produced by solar panels to guarantee constant power supply on overcast days or for charging at night. Use of lithium-ion or lithium-iron-phosphate (LiFePO4) high-capacity batteries, which are renowned for their extended cycle life and high energy density. For longevity and safety, a Battery Management System (BMS) is integrated to monitor temperature, current, voltage, and charge cycles. Enough backup storage is ensured by sizing the capacity according to the anticipated EV charging load and typical daily energy generation.

9. *Microcontroller/Embedded System (e.g., Arduino, Raspberry Pi)*

Acts as the central control unit managing all system operations. Collects data from sensors and controls the WPT, battery, and solar systems. A Raspberry Pi may be preferred due to higher processing power for real-time operations, while Arduino could handle simpler tasks like sensor data acquisition and control.

The **Microcontroller/Embedded System** module, such as an Arduino or Raspberry Pi, is a core component in the Solar-Based Dynamic WPT EV Charging System, functioning as the primary control unit to manage and coordinate various system operations. Key functionalities and features of this module include:

Centralized System Control

- The microcontroller acts as the central control hub, overseeing the management and synchronization of the Wireless Power Transfer (WPT), battery, and solar subsystems.
- It ensures that each system component operates efficiently and interacts smoothly with other modules, maintaining optimal performance for the entire setup.

Data Collection from Sensors

- This module collects data from an array of sensors within the system. These sensors may include

WPT and Power Management

- The microcontroller controls power distribution between the WPT system, the EV battery, and the solar array or Battery Energy Storage System (BESS).

WPT and Power Management

- The microcontroller controls power distribution between the WPT system, the EV battery, and the solar array or Battery Energy Storage System (BESS).
- By managing this distribution, it ensures that the system maximizes the use of available renewable energy from the solar array while balancing the power requirements of the EV charging process.

Real-Time Processing and Control

- A Raspberry Pi may be preferred for its higher processing power, which supports real-time operations, complex data processing, and predictive calculations, essential for dynamic charging adjustments.
- Meanwhile, an Arduino can handle simpler tasks such as data acquisition and control signals, managing basic sensor readings and transmitting information to other system components.

Remote Data Transmission and Control Integration

- This module interfaces with Wi-Fi or Zigbee modules to enable remote data transmission, allowing the system to send data to a central server or cloud platform for analysis and control.

Interfaces with Wi-Fi or Zigbee modules for remote data transmission and control integration.

10. Communication Module (e.g., Wi-Fi, Zigbee)

Enables data transmission between the hardware system and the cloud or local servers. Wi-Fi is suitable for short-range communication, while Zigbee may be more energy-efficient in low-power, remote monitoring applications. Modules are programmed for secure, real-time data exchange.

11. WPT System Control Software

The WPT System Control Software serves as the central controller for managing the dynamic wireless charging process. It performs several essential functions to ensure the efficient and safe transfer of power between the transmitter and receiver coils in the WPT system:

- **Activation and Power Level Management**: The control software dynamically adjusts the activation status and power levels of both the transmitter and receiver coils. This ensures that the WPT system operates optimally according to the vehicle's position, distance, and alignment between the EV's receiver coil and the stationary transmitter coil. By monitoring these parameters, the software maintains precise coil alignment and improves charging efficiency, minimizing energy loss.
- **Adaptive Power Output**: The control software adjusts the power output based on the EV's battery status and the availability of power from the solar array or Battery Energy Storage System (BESS). When the solar array provides sufficient energy, the system prioritizes solar power for charging. If solar power availability fluctuates due to environmental factors, the BESS can compensate, providing a consistent and reliable power source for uninterrupted charging.
- **Optimization Based on Renewable Energy Prediction Models**: Integrated with renewable energy prediction models, the control software can anticipate solar energy availability and adjust the WPT system's charging behaviour accordingly. By predicting fluctuations in solar power, it can maximize the use of renewable energy and adapt charging schedules, reducing dependency on the grid and enhancing sustainability.

IV. HARDWARE MODULES

a. Atmega 328p

The Atmel ATmega328P is a 32K 8-bit microcontroller based on the AVR architecture. Many instructions are executed in a single clock cycle providing a throughput of almost 20 MIPS at 20MHz [9]. The ATMEGA328-PU comes in an PDIP 28 pin package and is suitable for use on our28 pin AVR Development Board. The computer on one hand is designed to perform all the general purpose tasks on a single machine like you can use a computer to run a software to perform calculations or you can use a computer to store some multimedia file or to access internet through the browser, whereas the microcontrollers are meant to perform only the specific tasks, for e.g., switching the AC off automatically when room temperature drops to a certain defined limit and again turning it ON when temperature rises above the defined limit[10].

b. 4047IC

The CD 4047 IC is one kind of multivibrator including a high voltage. The operation of this IC can be done in two modes like Monostable & Astable. This IC requires an exterior resistor & capacitor to decide the output pulse width within the monostable mode & the o/p frequency within the astable mode [11].

This IC operates at 5 Volts, 10 Volts, 15Volts & 20Volts. The 4047 IC is a CMOS multivibrator that works in two modes like monostable & astable [12]. The 4047 IC applications include a wide range like generation of the pulse wave, sine wave, and DC signal to AC signal conversion, etc.

c. 16*2 LCD

This is the example for the Parallel Port. This example doesn't use the Bi-directional feature found on newer ports, thus it should work with most, if not all Parallel Ports. It however doesn't show the use of the Status Port as an input for a 16 Character x 2 Line LCD Module to the Parallel Port [14]. These LCD Modules are very common these days, and are quite simple to work with, as all the logic required running them is on board.

V. HARDWARE OUTPUTS

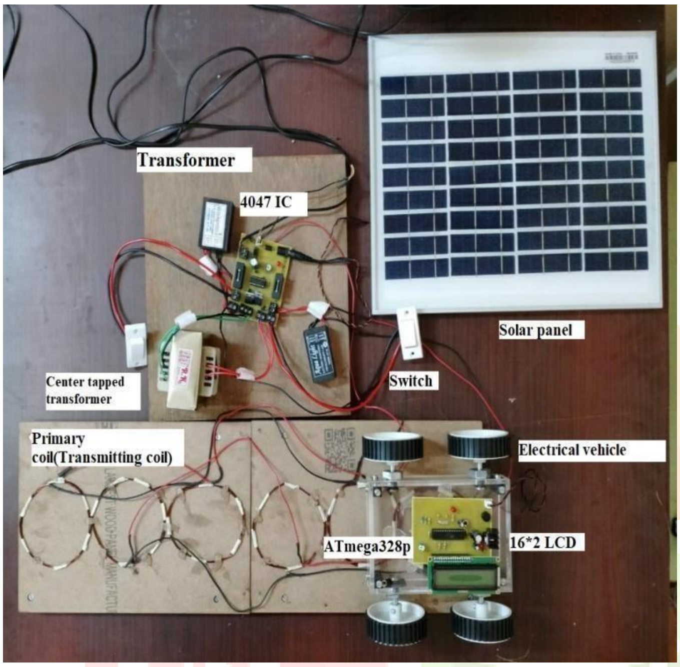

Fig-Reference model

The system makes use of a solar panel, battery, transformer, regulator circuitry, copper coils, AC to DC converter, atmega controller and LCD display to develop the system. The system demonstrates how electric vehicles can be charged while moving on the road, eliminating the need to stop for charging [15]. The solar panel is used to power the battery through a charge controller. The battery is charged and stores dc power. The DC power now needs to be converted to AC for transmission. For this purpose, we here use a transformer.

The power is converted to AC using a transformer and regulated using regulator circuitry. This power is now used to power the copper coils that are used for wireless energy transmission. A copper coil is also mounted underneath the electric vehicle.

When the vehicle is driven over the coil's energy is transmitted from the transmitter coil to ev coil. Please note the energy is still DC current that is induced into this coil [16]. Now we convert this to DC again so that it can be used to charge the EV battery.

VI. USES AND APPLICATION

The solar-based dynamic Wireless Power Transfer (WPT) system for Electric Vehicles (EVs) offers several valuable uses and applications that address key limitations in traditional EV charging methods, specifically enhancing range, convenience, and sustainability. Below, we outline the principal uses and advantages of this innovative technology.

Dynamic solar-based wireless charging is particularly useful in alleviating "range anxiety"—the fear of depleting battery power during travel—which remains one of the main barriers to widespread EV adoption. This technology allows vehicles to charge while in motion, extending their operational range and providing drivers with the confidence to travel longer distances without frequent stops for recharging. This capability is especially advantageous in regions with limited EV charging infrastructure, making EVs more practical for both urban and rural travel.

Solar-based WPT systems harness renewable solar energy, reducing the reliance on fossil fuels and traditional grid electricity. By generating power from solar panels integrated along the travel routes, this system promotes clean energy use and minimizes carbon emissions. The use of a sustainable energy source aligns with global efforts to reduce environmental impact, positioning solar-powered WPT as a green alternative to grid-dependent EV charging solutions.

By integrating renewable energy prediction models, solar-based WPT systems can forecast the availability of solar energy and optimize the energy supply for real-time charging needs. This predictive capability enables efficient resource management, ensuring energy is available when needed and reducing wastage. Additionally, as this infrastructure can be deployed along highways and frequently traveled routes, it facilitates continuous energy flow, easing pressure on traditional charging stations and reducing peak load demand on the grid.

VII. SCOPE

The field of sustainable energy and emerging technologies is continuously advancing, offering promising opportunities for future research and development. This section explores potential areas for researchers and innovators to further enhance our knowledge and fully leverage the capabilities of Solar Power Generation Systems, Wireless EV Charging Systems, EV Grid Integration Models, and Wireless Power

Transmission (WPT). These future directions aim to play a crucial role in accelerating the transition to cleaner and more efficient energy solutions.

CONCLUSION

In conclusion, this project on a solar-based dynamic Wireless Power Transfer (WPT) system for Electric Vehicle (EV) charging highlights the potential of integrating renewable energy prediction models to create a sustainable and efficient charging infrastructure. The research underscores that by harnessing solar energy predictions through AI, WPT systems can optimize energy usage, reduce reliance on traditional power sources, and lower carbon emissions, making EV charging more environmentally friendly. These renewable energy prediction models, which leverage advanced algorithms to forecast solar power availability, play a crucial role in ensuring that EV charging is both convenient and responsive to fluctuations in energy supply.

Moreover, the project emphasizes the importance of further enhancing these prediction models to increase their accuracy, reliability, and scalability. By incorporating additional renewable energy sources such as wind, the system's resilience and adaptability to changing environmental conditions can be improved, offering a more robust solution for future charging demands. As we continue to refine and expand this technology, the vision of a revolutionized EV charging landscape, where clean energy powers vehicles seamlessly and sustainably, becomes increasingly achievable. This integration of AI-driven prediction models into WPT systems not only advances EV infrastructure but also aligns with broader goals of renewable energy adoption and environmental stewardship.

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