International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 04 | April - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Ultra Capacitor Based EV Charging Prototype

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Abstract— The increasing adoption of electric vehicles (EVs) has created a demand for efficient and rapid charging technologies. This project presents an ultra capacitor-based EC wireless charging system, where an EV or robotic system can be charged wirelessly while in motion. The system utilizes transmitter (TX) and receiver (RX) coils for energy transfer, enhanced by an ultra-capacitor for fast charging. The TX unit consists of a solar-powered TX coil, which transmits power wirelessly. The RX unit, integrated with an Arduino-controlled receiver circuit, captures the transmitted energy to charge the ultra-capacitor. An LCD display is used for real-time monitoring of charging status, while motors drive the robot autonomously. The ultra-capacitor enables rapid energy storage and discharge, ensuring quick charging and efficient power delivery to the EV. This project demonstrates a significant step toward contactless and high-speed energy transfer in electric mobility applications, enhancing convenience, efficiency, and sustainability. With the accelerating adoption of Electric Vehicles (EVs) and autonomous robotic systems, the demand for efficient, sustainable, and rapid charging technologies has never been greater. Conventional plug-in charging methods are often slow, inconvenient, and unsuitable for moving systems. This project introduces a novel ultra-capacitor-based EC (Energy Capture) wireless charging system that enables dynamic, contactless energy transfer to EVs or mobile robots while in motion. The system is composed of a solar-powered transmitter (TX) coil that wirelessly transmits energy to a receiver (RX) coil mounted on the moving platform. The RX coil is connected to an ultra-capacitor-based energy storage unit, which offers high-speed charging and discharging, superior to conventional battery systems. The Arduino microcontroller governs the energy transfer process, monitors key system parameters, and displays the charging status on an LCD module. The robotic unit, driven by DC motors, simulates the motion of an EV, demonstrating the feasibility of in-motion wireless charging. The incorporation of ultra-capacitors significantly improves the system's response time, energy efficiency, and lifecycle durability. This project is a step toward smart, eco-friendly energy systems, offering a practical solution for future mobility applications such as highways with embedded charging lanes, automated logistics robots, and urban EV fleets. The outcome promotes reduced charging downtime, improved energy utilization, and greater operational flexibility.

1.INTRODUCTION

Environmental agencies are opposing the using of fossil fuels as a means of energy for transportation. The environmental contamination resulting from internal combustion engines and the finite availability of fossil fuels are pushing numerous initiatives to investigate alternate fuel technologies. Furthermore, aside from the pollution resulting from the present fuels utilized, there is a reliance of the United States government on foreign oil supplies. The EPA, as well as Federal and State governments, have imposed specific targets for the phasing out of vehicles powered by fossil fuels. Furthermore, these concerns have prompted numerous government agencies to enforce the usage of alternate fuel sources. Currently, there is a diverse array of alternative fuel sources being utilized and investigated for transportation purposes. One of the initial alternative fuel sources investigated for transportation purposes was the electric or battery-powered device. This form of energy for transportation possesses numerous environmental benefits compared to conventional fossil fuel sources. These factors encompass the absence of any emissions of air or noise pollution into the surrounding environment. The primary issue regarding electric vehicles is their range of travel, which is limited without the need for maintenance. The battery system is the primary factor leading to a decrease in the vehicle's range. The battery system is limited to a specific number of charge and discharge cycles. The battery system's relative size often occupies a significant portion of the available space aboard the vehicle. Battery systems possess a limited range of permissible power that can be utilized for vehicle propulsion. This is a significant problem that arises during the early stages of electric vehicle development. Several factors or variables determine this ability, including the vehicle's drive pattern, such as the battery's properties, as well as the vehicle's speed, acceleration, and braking patterns. The electric vehicle has limitations in terms of its operational range and the space it requires for its propulsion components. Modern electric vehicles utilize technologies that transfer the available electric current directly into the battery units in order to charge them. This results in significant strain on the functioning of the electric and energy storage systems. The battery systems are incapable of withstanding high currents applied to the terminals for brief durations. This diminishes the overall lifespan of the battery system and has the potential to inflict severe harm on the battery system.all walks of life to join us in shaping a brighter, cleaner, and more sustainable future for all. Together, let us harness the power of the sun and the wind to propel us towards a world where energy is abundant, clean, and equitable for all.

2.ULTRACAPACITOR WORKING PRINCIPLE

The fundamental working principle of an ultracapacitor is as follows:
Charging: When a voltage is applied across the electrodes (positive voltage to one electrode and negative voltage to the other), electrons are driven out of one electrode and onto the other. This accumulation of electrons on the surface of the electrodes creates a double layer of charges – one layer of positive ions at the negative electrode and a corresponding layer of negative ions at the positive electrode. This is known as the electric double layer.
Energy Storage: The energy is stored primarily in the electric

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double layer and is proportional to the surface area of the electrodes and the square of the voltage applied. Due to the high surface area of the porous electrode materials and the very small separation between them, ultracapacitors can store a significant amount of energy in this electric double layer.

Quick Charge and Discharge: The energy stored in an ultracapacitor can be quickly released when needed. Unlike batteries that involve chemical reactions, ultracapacitors release energy through the movement of ions within the electrolyte and the redistribution of charges across the double layer. This enables ultracapacitors to deliver high power outputs and rapid charge and discharge cycles.

Cycling: Ultracapacitors are designed to withstand a large number of charge and discharge cycles without significant degradation. This is because there are no chemical reactions taking place that degrade the electrode materials over time, as is the case in batteries.

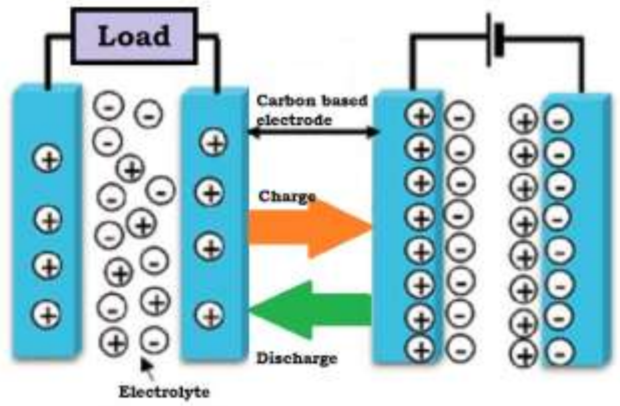

Fig.1 ultracapacitor working

3.METHODOLOGY FOR ULTACAPACITOR BASED EV CHARGING PROTOTYPE

The current methods for charging electric vehicles (EVs) and robotic systems largely rely on traditional wired charging systems and static wireless charging technologies. Conventional wired charging involves physically plugging the EV or robot into a charging station, which can be either AC or DC based. While this method is widely adopted, it is often inconvenient due to the need for manual intervention, and the connectors are prone to wear and environmental damage. Additionally, it poses safety risks in outdoor conditions and is not suitable for fully autonomous systems. Another common approach is static wireless charging, which operates using Inductive Power Transfer (IPT). In this system, energy is transferred wirelessly between a transmitter coil installed on the ground and a receiver coil in the vehicle. Although this eliminates the need for physical connectors, it still requires the vehicle to be stationary and precisely aligned with the transmitter for efficient charging. Any misalignment or air gap significantly reduces the efficiency of power transfer. Thus, static wireless charging is more suited to parked vehicles and does not support continuous mobility. In terms of energy storage, most EVs and robotic platforms rely on lithium-ion batteries. While these batteries offer high energy density, they have several drawbacks, including slow charging times, degradation over repeated cycles, and complex thermal management requirements. The limited charging/discharging lifespan also affects the long-term performance and sustainability of such systems. Solar-powered EV charging stations are another alternative, where solar panels generate energy to charge EV batteries. This is a more sustainable and environmentally friendly option but is typically used in stationary setups and is dependent on weather conditions. The energy captured is stored in batteries for later use, which again involves the challenges associated with battery technology.

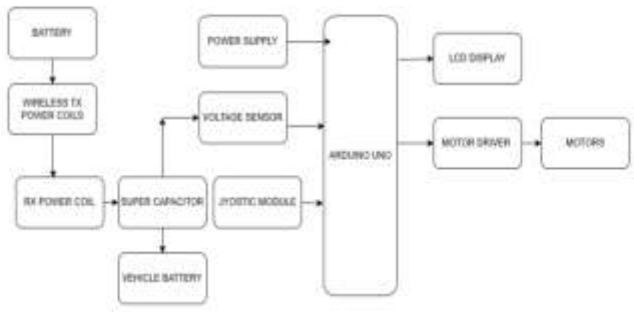

Fig.2 Block diagram of Monitoring & Controlling

3.1 Arduino Uno board

The Arduino Uno is an open-source microcontroller board based on the ATmega328P microchip, widely used in embedded systems and IoT applications due to its simplicity, affordability, and flexibility. It features 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, USB connection, power jack, and reset button. The board operates at 5V and can be powered through a USB cable or an external adapter. The ease of programming through the Arduino IDE and its extensive library support make it a popular choice for students, hobbyists, and researchers alike.

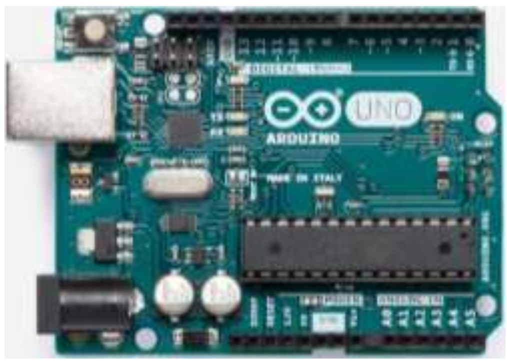

Fig.3. Arduino Uno

In the context of motor control and monitoring, the Arduino Uno acts as the central controller that reads data from various sensors, processes the inputs, and executes control actions such as regulating speed or triggering safety mechanisms. Its reliable performance and compatibility with a wide range of modules and sensors make it ideal for developing real-time embedded control systems. The Arduino Uno circuit board has 14 digital input and output pins out of which 6 can be used as PWM outputs and another 6 as analog inputs. It also consists a 16 MHz ceramic resonator, a power jack and USB connection on the circuit board.

3.2 LCD(LIQUID CRYSTAL DISPLAY):

The term LCD stands for liquid crystal display. It is one kind of electronic display module used in an extensive range of applications like various circuits & devices like mobile phones, calculators, computers, TV sets, etc. These displays are mainly preferred for multi-segment light-emitting diodes and seven segments. The main benefits of using this module are inexpensive; simply programmable, animations, and there are no limitations for displaying custom characters, special and even animations, etc.

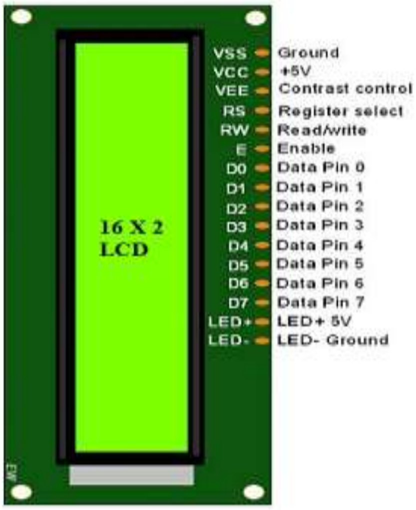

Fig.4. LCD 16x2

Nowadays, we always use the devices which are made up of LCDs such as CD players, DVD players, digital watches, computers, etc. These are commonly used in the screen industries to replace the utilization of CRTs. Cathode Ray Tubes use huge power when compared with LCDs, and CRTs heavier as well as bigger. These devices are thinner as well power consumption is extremely less. The LCD 16×2 working principle is, it blocks the light rather than dissipate. This article discusses an overview of LCD 16X2, pin configuration and its working.

3.3 Voltage sensor:

A voltage sensor is a device that measures the voltage of an electrical circuit. Voltage sensors are used in many applications, including monitoring and controlling equipment and machinery. Different types of voltage sensors work in various ways.This type uses an electromagnetic field to detect changes in voltage. The sensor's exposure to an electric current generates a magnetic field. It induces currents in nearby conductors, such as wires or circuit boards, sensitive enough to detect these changes. This type of sensor is often used with microcontrollers since they can easily measure changes in electromagnetic fields around them with the help of built-in analog-to-digital converters (ADCs). A voltage sensor, also known as a voltmeter or voltage detector, is a device that measures and monitors the electrical potential difference between two points in an electric circuit. It detects, measures, and monitors voltage signals, which can be either AC or DC. The output of a voltage sensor is a measurable signal, often an analog voltage or current, that reflects the detected voltage level.

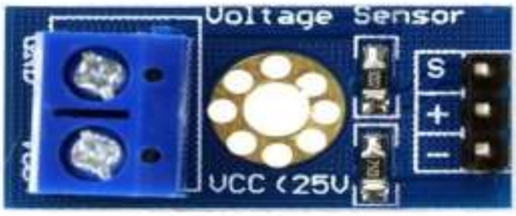

Fig.5. Voltage Sensor

The sensor communicates via a serial interface, making it easy to integrate with microcontrollers like Arduino and ESP8266. Its built-in voltage and current sensing circuits eliminate the need for external sensors, simplifying circuit design. The PZEM-004T is particularly useful in IoT-based applications, where real-time electrical monitoring is required for safety, efficiency, and automation. In this project, the PZEM-004T plays a crucial role in monitoring the electrical performance of the single-phase induction motor, providing continuous feedback that is used for analysis, control, and protection purposes. Its precise readings contribute significantly to the overall reliability and effectiveness of the motor management system.

3.4 RX and TX coils:

In the context of wireless power transfer and other electronic systems, "Tx" stands for transmitter and "Rx" stands for receiver. These terms refer to the components that send and receive signals or power, respectively. Transmitter coils (Tx) generate a magnetic field to transmit power, while receiver coils (Rx) detect this field and convert it back into electrical power

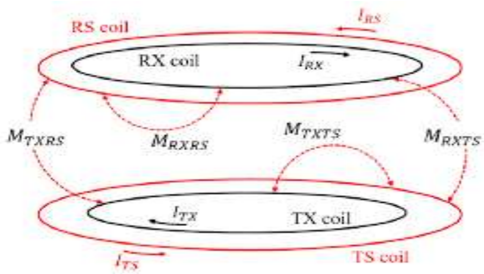

Fig.6.RX and TX coils

Tx (Transmitter) Coil:

Purpose: Initiates the transfer of power by generating a magnetic field.

Function: Usually connected to a power source and is energized to create a magnetic field that induces current in the receiver coil.

Example: In wireless charging, the Tx coil in the charging pad generates the magnetic field to transfer power to the phone.

Rx (Receiver) Coil:

Purpose: Detects the magnetic field and converts it back into electrical power.
Function: When placed within the magnetic field created by the Tx coil, it experiences a changing magnetic flux, which induces an electric current.
Example: In wireless charging, the Rx coil in the phone detects the magnetic field and converts it into electrical power to charge the battery.

4 RESULTS:

The proposed ultra-capacitor-based EC wireless charging system provides an innovative solution for charging electric vehicles and autonomous robots efficiently. By utilizing TX and RX coils along with solar power, the system offers a sustainable and high-speed energy transfer mechanism. The integration of Arduino ensures real-time monitoring, while ultra-capacitors facilitate rapid charging. This project contributes significantly to advancing wireless charging technology and enabling efficient EV adoption.

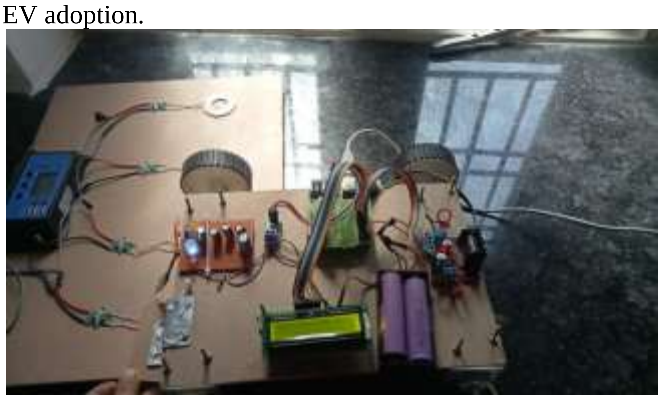

Fig.8 Hardware model

5 CONCLUSION:

The proposed ultra-capacitor-based EC wireless charging system provides an innovative solution for charging electric vehicles and autonomous robots efficiently. By utilizing TX and RX coils along with solar power, the system offers a sustainable and high-speed energy transfer mechanism. The integration of Arduino ensures real-time monitoring, while ultra-capacitors facilitate rapid charging. This project contributes significantly to advancing wireless charging technology and enabling efficient EV adoption.

FUTURE SCOPE

.Enhancing efficiency with advanced coil designs and resonant circuits.
.Implementing Al-based charging optimization algorithms.
.Scaling the system for highway-based dynamic EV charging.
.Integrating smart grid connectivity for optimized energy management.

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