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Underwater Wireless Power Transfer Electric Vehicle

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ABSTRACT
Underwater wireless power transfer (WPT) encounters formidable challenges in achieving efficient charging and power transfer, especially when leveraging solar energy. In this study, we present a solution aimed at resolving these challenges by harnessing the principles of transformer induction and adaptive robotic technology. Our primary focus lies in developing a WPT system that not only optimizes charging efficiency but also adapts seamlessly to the demanding underwater conditions, ensuring enhanced overall performance. The core objective of our research revolves around designing a WPT system that attains remarkable efficiency and unity power factor, pivotal for seamless power transmission. Through extensive prototyping and testing, our system demonstrates the ability to transmit an output voltage of approximately 15V over an 8cm air gap, covering a maximum sliding distance of 10cm. This achievement showcases the system's capability to overcome the barriers of underwater power transfer, setting the stage for sustainable operations in challenging aquatic environments. Moreover, our approach integrates diverse energy sources, including solar and grid energy, to bolster the system's adaptability and energy generation capabilities. This integration opens avenues for consistent and optimized power generation, vital for prolonged and reliable underwater applications. By combining cutting-edge technologies and innovative design paradigms, our research aims to propel the advancement of underwater WPT, laying the groundwork for transformative solutions in underwater power transmission. Key components of the system include underwater power transmission modules installed on charging stations or submerged platforms and receiving modules integrated into EVs. These modules communicate wirelessly to establish a power transfer link while ensuring alignment and efficiency during charging sessions. Furthermore, the system is designed to be compatible with existing EV infrastructure, enabling seamless integration into current charging networks. The proposed underwater WPT system presents a promising solution for scenarios where traditional charging methods are impractical or infeasible, such as underwater exploration vehicles, marine research vessels, and submerged infrastructure. By providing a convenient and efficient charging solution, this technology contributes to the advancement of electric transportation in diverse and challenging environments.

Keywords - Resonant magnetic induction, Underwater Communication, Charging infrastructure, Submerged charging, Safety mechanisms, Alignment optimization, Environmental impact, Compatibility Marine exploration, Underwater vehicles

I. INTRODUCTION

An area of engineering that has the potential to transform a number of underwater applications is the study of underwater wireless power transfer, or WPT. But there are major challenges in this field, mostly related to charging time and power transfer efficiency, especially when solar energy is used[16][17].

WPT system optimization is a complex endeavor since the underwater environment poses unique problems such as reduced power transmission capacities and increased attenuation. It is imperative to address these issues, which inspires the creation of creative solutions. In order to lessen the difficulties associated with underwater WPT, this study focuses on combining the transformer induction principle with adaptive robotic technology[1][2]. By utilizing these ideas, The goal is to develop a WPT system that can improve overall performance by boosting charging efficiency and adjusting to the dynamic underwater conditions. Achieving high efficiency and unity power factor, which are essential for efficient power transfer, is emphasized in the design of the suggested system. One of the main objectives is to create a prototype that can effectively transmit an output voltage of about 15V across an 8cm air gap with a 10cm maximum sliding distance. Moreover, the system gains versatility from the use of grid and solar energy sources, which enables optimum power generation—a necessary component for long-term operations in difficult underwater settings [3]. In order to overcome the major issues encountered in underwater WPT, this introduction lays the groundwork for investigating the new strategy of merging transformer induction and adaptive robots. The following sections explore this novel system's technical details and experimental validations in further detail with the goal of proving its viability and revolutionary potential for power transfer under water [4].

II. ENHANCED INDUCTIVE COUPLING METHOD

It involves the transfer of power between wire coils by the use of a magnetic field. The combination of the transmitter and receiving coils constitutes a transformer. An alternating current (AC) over the transmitter coil (L1) generates an equivocating magnetic field (B) by Ampere's equation. The magnetic field flows concluded the receiving coil (L2), where

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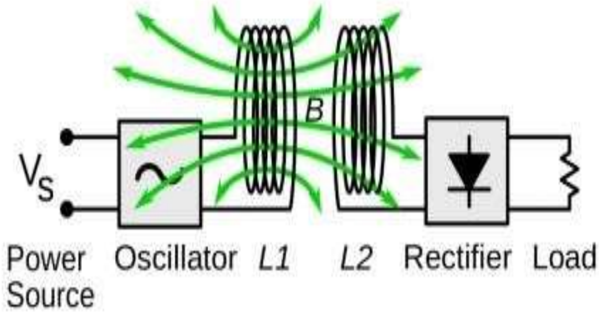
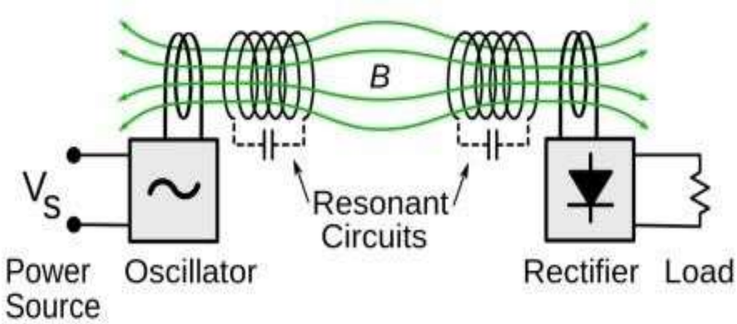
it encourages an alternating EMF (voltage) via Faraday's law of induction, which forms an AC current in the receiver [5][6]. The persuaded alternating current can either directly power the load or be converted into direct current (DC) using a rectifier in the receiver, which then powers the load. Some organizations, charging stands for electric toothbrushes, operate at a frequency of 50/60 Hz, allowing the alternating current (AC) from the power source to be directly functional to the transmitter coil[21][22]. Though, in most organizations, an electronic oscillator is used to generate a sophisticated frequency AC current that powers the coil. This is because transmission efficiency increases with higher frequencies [7][8].



Inductive wireless power system

c. Resonant inductive coupling

Magnetic fields (B, green) are second-hand to transfer power amongst two resonant circuits (tuned circuits), one in the transmitter and one in the receiver. This type of inductive coupling is known as resonant inductive coupling (electro dynamic coupling powerfully coupled magnetic resonance) (see diagram, right). A self-resonant coil, another resonator with an internal capacitance, or a coil of wire coupled to a capacitor make up each resonant circuit. The two are adjusted to take the same resonant frequency of resonance[9][10]. Comparably to how a vibrating tuning fork can reason sympathetic vibration in a distant fork adjusted to the same pitch, the resonance amongst the coils can significantly boost coupling and power transfer [15].



Resounding inductive wireless power system

a) Capacitive Coupling

The counterpart of inductive connection, capacitive coupling (electrostatic induction), involves the transfer of energy amongst electrodes, such as metal plates, via electric fields[11][12]. The space between the electrodes of the transmitter and receiver serves as a dielectric, forming a capacitor. An alternating voltage produced by the transmitter is delivered to the transmitting plate, and an alternating current flows in the consignment circuit as a result of the oscillating electric field's electrostatic induction of an alternating potential on the receiving plate. Power transfer is related to the area of the smaller plate and (for short distances) inside out proportional to the separation; the frequency, square of the voltage, and capacitance amongst the plates all increase the amount of power transferred[13][14].

III.PROPOSED SYSTEM

The proposed underwater wireless power transfer (UWPT) system aims to facilitate energy transmission from a ship to an underwater vehicle. On the ship, a system comprising a solar panel, battery, inverter, and transmitter coil generates and transmits power wirelessly through water. On the vehicle, a receiver coil captures this energy, converting it via a rectifier and voltage regulator to power systems like LED indicators and motor controllers. Voltage sensors monitor battery levels, relaying data to an Arduino connected to an LCD for real-time display. The Arduino also interfaces with a motor control board, enabling vehicle operation based on received power and battery status. This comprehensive system integrates UWPT technology, power management, and control mechanisms to enable sustained underwater vehicle functionality.

a) METHODOLOGY

The methodology outlined entails harnessing solar energy through a panel installed on the ship's surface, converting it into electrical energy, and storing excess power in a battery system. To facilitate continuous power supply, particularly during periods of low sunlight or at night, an inverter translates the generated direct current (DC) electricity into alternating current (AC). This AC electricity is then transmitted wirelessly through water via a transmitter coil on the ship, where it's received by a coil on the underwater vehicle. The received AC energy undergoes conversion into pulsating DC through a rectifier circuit and is subsequently regulated by a voltage regulator to maintain a stable voltage output suitable for the vehicle's components. LED indicators provide visual feedback on the power status, while voltage sensors ensure the battery connected to the receiver system remains within safe operating voltage limits, collectively ensuring efficient power management and utilization for sustained underwater vehicle operations. This methodology integrates solar power generation with wireless power transfer expertise to address the challenges of providing continuous and sustainable power to underwater vehicles. By combining these elements, the system optimizes energy capture, storage, transmission, and utilization, enabling the vehicle to operate effectively in remote or extended missions where traditional power sources may be impractical. The step-by-step process outlined ensures a reliable and efficient power supply chain, from solar energy capture to the delivery of regulated power to the vehicle's systems, enhancing its functionality and operational capabilities in challenging underwater environments.

b) BLOCK DIAGRAM

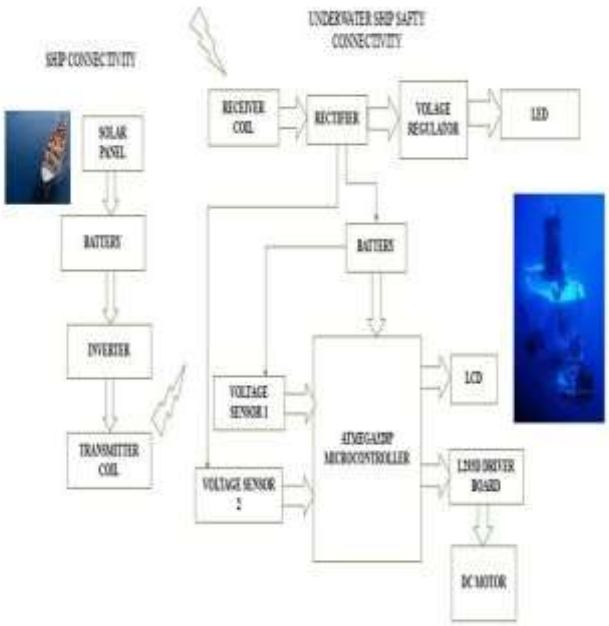


Figure1.Block diagram representation of system

i) TRANSMITTER SECTION

A solar panel installed on the ship's surface captures sunlight and converts it into electrical energy. This energy can be used to power various systems on the ship or stored in a battery for later use. The solar panel can be connected to a battery system. The battery serves as an energy storage device, storing excess energy generated by the solar panel. It ensures a continuous power supply, especially when there's insufficient sunlight or during night-time.

An inverter is necessary to convert the direct current (DC) electricity engendered by the solar panel and stored in the battery into alternating current (AC) electricity. AC is commonly used for power transmission. The transmitter coil is a crucial part of the UWPT system. It's connected to the inverter and generates an alternating magnetic field. This field carries the electrical energy, which is then transmitted wirelessly through the water to a receiver coil.

ii) RECEIVER SECTION

Positioned on the underwater vehicle, the receiver coil's purpose is to absorb the energy that is wirelessly sent from the transmitter coil on the ship. The alternating magnetic field is received, and it is then transformed back into electrical energy [23][24]. For the vehicle's systems to use the alternating current that the receiver coil received, it must be changed to direct current (DC). This is accomplished by transforming the AC signal into a pulsing DC signal using a rectifier circuit. To guarantee a steady voltage output, the rectifier's pulsing DC signal must be controlled. To keep the voltage

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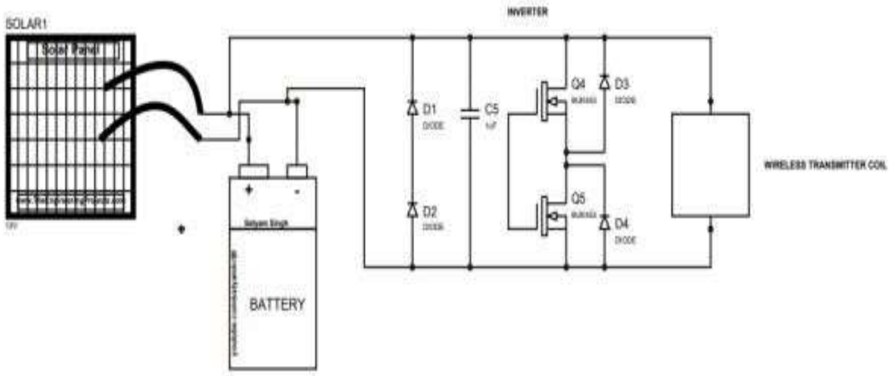
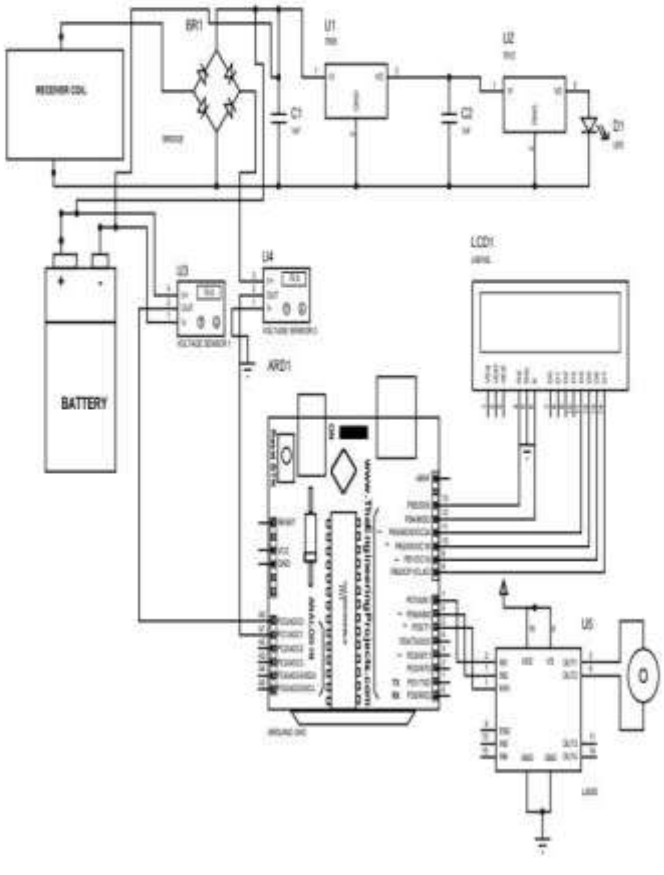
level necessary for the vehicle's components constant, a voltage regulator circuit is used. LED indicators can be used to display the current state of the
received power, giving a clear indication of how well the system is receiving and converting electricity. The voltage of the battery that is attached to the receiver system can be observed by voltage sensors. By providing information about the battery's charge state, these sensors help to ensure that it remains within safe operating parameters [18][19][20].

iii) CIRCUIT DIAGRAM TRANSMITTER SECTION



iv) RECEIVER SECTION



v) PIN EXPLANATION

An Arduino microcontroller can be used to process data from the voltage sensors. The monitor on the receiver battery and rectifier voltage levels. The receiver voltage sensor data pins connected on the Arduino Uno A0 pin, and the battery voltage sensor data pin connected on the A1 pin. The data's display the on an LCD screen. The LCD RS pin connected on the Arduino Uno digital 13th pin. The enable pin connected on the digital 12th pin and datas pins D4-D7 pins connected

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on the Arduino Uno D8-D11 pins. It acts as an interface between the sensors and the display unit, providing realtime information about the voltage status. This board can be used to control and drive motors or other devices in the underwater vehicle. It receives signals from the Arduino and provides the necessary power and control to run the vehicle's systems. Tthe dc motor control is help of the L293D driver board. The L293D driver board the L293D driver board INT1,INT2 and EN pins connected on the Arduino Uno D7-D5 pins and the dc motor connected on the L293D driver board OUT1 and OUT2 pins

IV. ARDUINO UNO

The Arudino Uno microcontroller is powered by an ATmega328p. The programme is deposited in its 32KB flash memory, and data is deposited in its 2KB SRAM and 1KB EEPROM. The Arduino Uno has fourteen digital input/output pins. It is possible to get pulsewidth modulation (PWM) output from six of them. It has six pins for analog input that are also pins for digital input. Since the ATmega328P has a 16MHz operating frequency and can read analog signals, these pins are suitable for sensors and other analog devices. The ATmega328P has considerable processing power for a range of applications. The VIN pin of the Ardunio Uno can be used to link it to a regulated power source, an external power supply, or a USB connection.
When linked to a computer, its USB connector allows for programming and serial communication. This interface also provides power to the board. The microprocessor and other related components are guaranteed a constant 5V supply by a voltage regulator on the board. Many sensors and modules can be utilized with the Ardunio Uno because it runs on 5 volts, and you may restart the program execution by pushing the reset button. The wide range of sensors, shields, and modules it is compatible with make it versatile and suitable for a number of applications. The Ardunio Uno can be programmed using the Ardunio integrated development environment (IDE), which supports a truncated version of C/C++. The Arduino Uno's software and hardware are both available as open source. This means that the design files and source code may be modified and distributed. The Arduino Uno has a large and active user and developer community. There are a ton of online resources, forums, and tutorials available for assistance.

a) VOLTAGE SENOR
A voltage sensor is an electronic device that measures the voltage level of an electrical circuit. It provides information about the potential difference between two points in the circuit, helping to monitor and control electrical systems. Voltage sensors are essential components in various applications, from power distribution and renewable energy systems to electronic devices and automotive systems.

b) PIN CONFIGURATIONS
Vcc (Power Supply): This pin is responsible for providing the required power to the voltage sensor. It is usually connected to the positive terminal of the power source. The voltage level supplied to this pin depends on the specifications of the sensor, and it is essential to safeguard that the voltage falls inside the specified operating range to avoid damaging the sensor.

GND (Ground): The ground pin serves as the reference point for the electrical circuit. It is associated to the negative terminal of the power source. The ground pin completes the electrical path, allowing current to flow through the sensor.
Output: The output pin provides a signal that represents the measured voltage level. This can be in the form of an analog voltage, a digital signal, or a communication protocol. The voltage level or signal provided at this pin is proportional to the voltage being measured by the sensor.

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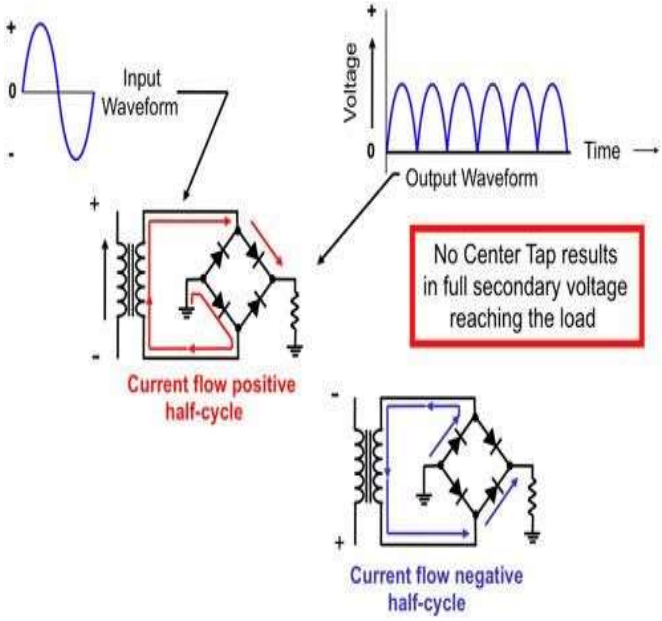
c) FEATURES

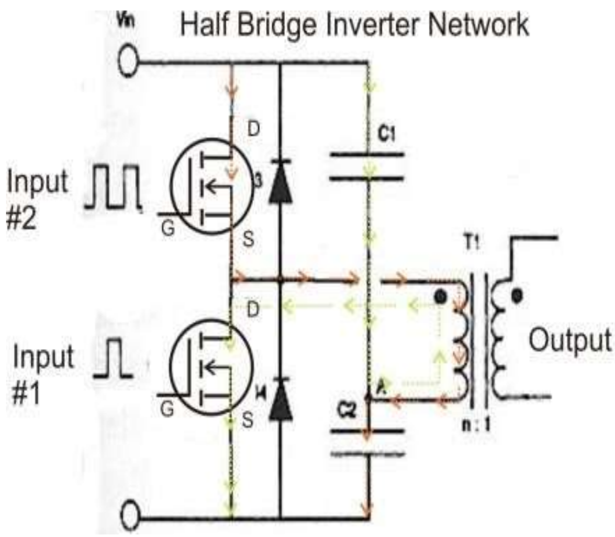
Voltage sensors are considered to provide precise measurements of voltage levels, ensuring reliable and accurate data. They are capable of measuring a wide range of voltage values, from low millivolt levels to high kilovolt levels, depending on the specific sensor's capabilities.

Many voltage sensors incorporate isolation techniques to protect sensitive electronics from potential electrical hazards. This isolation helps prevent damage to the measurement circuitry.

Voltage sensors typically have fast response times, allowing them to quickly detect changes in voltage levels.



They are designed to consume minimal power, making them suitable for battery-powered or energy-efficient applications.



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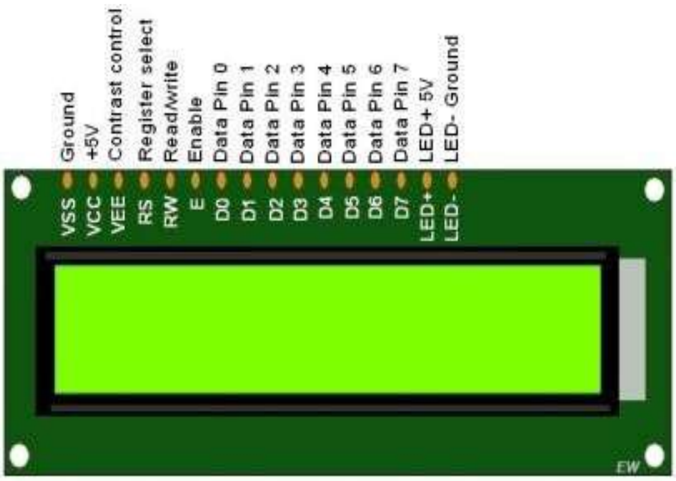
d) LCD

An alphanumeric display module that is frequently used is called a 16x2 LCD (Liquid Crystal Display). It has two rows that can display 16 characters each, for a total of 32 characters. To show text or rudimentary graphics, it uses a mix of liquid crystal characteristics and electrical voltage. These modules are frequently used to show data such as text messages, sensor readings, and menu options in electronic projects and equipment. They are programmable to display particular data or messages and are compatible with microcontrollers. The 16x2 LCD is a popular option for a variety of applications, from hobbyist projects to industrial equipment displays, thanks to its small size, ease of use, and versatility.



Pin names	Function
Ground	Ground (0V)
Vcc	Supply voltage; 5V (4.7V – 5.3V)
VEE	Contrast adjustment; through a variable resistor
Register Select	Selects command register when low; and data register when high
Read/write	Low to write to the register; High to read from the register
Enable	Sends data to data pins when a high to low pulse is given
DB0-DB7	8-bit data pins
Led+	Backlight V_{CC} (5V)
Led-	Backlight Ground (0V)

e) L293D DRIVER BOARD

A well-liked motor driving IC is L293D. A 16-pin integrated circuit is used. There are eight pins on either side of the IC. There are four ground pins, four input pins, four output pins, two enable pins, one VSS pin, and one VS pin. If you would like to acquire how to interface the L293D with a microcontroller, it is not necessary to do so in this instance.

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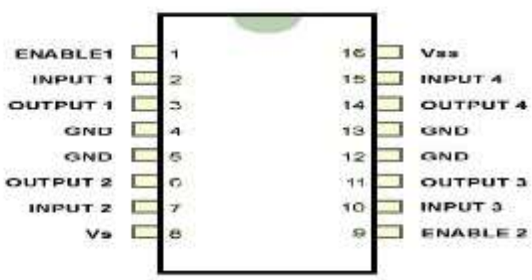


L293D Pin Configuration PIN DESCRIPTIONS

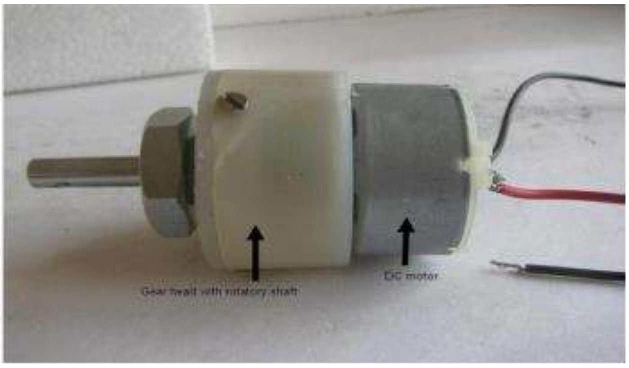
Enable: The corresponding portion of the IC is enabled when the enable pins are set to true, or 1. Both the Enable 1 and Enable 2 chips enable the inputs and outputs on the left and right halves of the integrated circuit, respectively.

1. **V_{SS}** – A 5 volt input is required for this pin. This is how the semiconductor gets electricity for operation.
2. **V_S** – The voltage that we must deliver to the motors is connected to this pin. The output pins are where this voltage is released.

The output is typically 1.8 to 2 volts less than the Vs because of the gates employed in the IC.

3. **Input** – Whether or whether an output must be sent to the appropriate output pin is determined by the input pin. The output in the corresponding output pin is likewise 1 when the input is true. When the input is zero on the input pin, the output is also zero on the corresponding output pin.
4. **Output** – The motor's terminals are linked to the output pin. As mentioned above, its output is controlled by the input pins.
5. **GND –** These pins represent Zero, or the ground pins. Up to 4 motors can be controlled simultaneously by the L293D IC. The -ve terminal of each motor is linked to the GND when four motors are connected to the IC, and the +ve terminal is connected to the outputs.

V. DC MOTOR



Although the gear head's outside body is self-possessed of high-density plastic, opening it is not difficult because the outer and inner structures are fastened together with screws. The primary cause of this could be periodic lubrication of the gear head.There is threading in the plastic frame that makes it simple to mount nuts and vice versa from the gear head.

a) WORKING OF GEARED DC MOTOR

The DC motor operates within a reasonable voltage range. The motor's RPM, or revolutions per minute, increases with increased input voltage. For instance, if the motor activates between 6 and 12 volts, its RPM will be lowest at 6 volts and highest at 12 volts.

In terms of voltage, we can placed the equation as:

RPM= K1 * V, where,

K1= induced voltage constant

V=voltage applied

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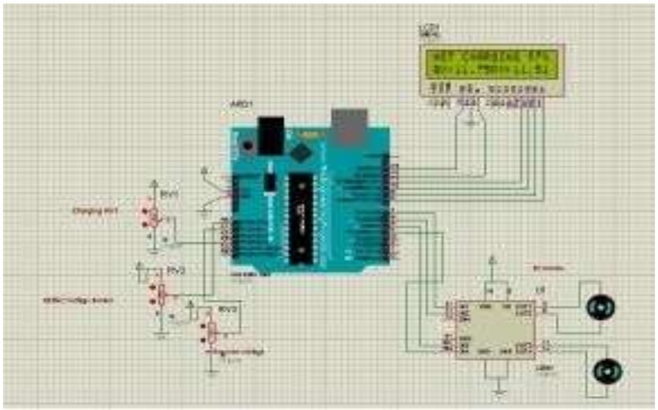
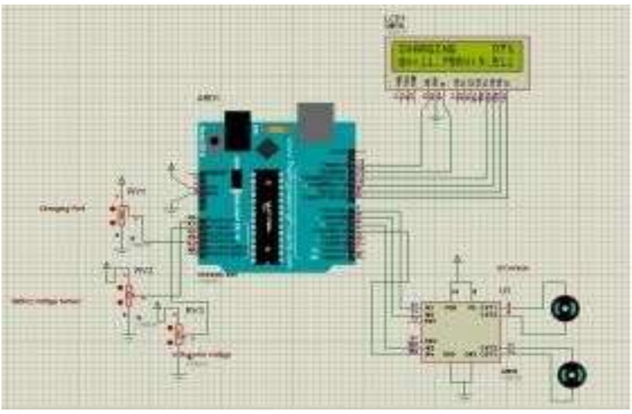
It's fascinating to learn how the gears operate. The conservation of angular momentum principle provides an explanation for it. More RPM will be covered by the smaller-radius gear than by the larger-radius gear. But rather than the other way around, the larger gear will provide the smaller gear with higher torque. The gear ratio is found by comparing the angular velocities of the energy-transferring input and output gears. The principle of energy conservation is also observed when several gears are coupled together. The gear next to it continuously alternates in the opposite direction from the other gear.

RPM and torque in every DC motor have an inverse relationship. Therefore, a gear with higher torque will harvest a lower RPM, and vice versa. The idea of pulse width modulation is used in a geared DC motor. Because the gear of a geared DC motor is relatively tiny, more speed is transferred to the gear head's bigger teeth, which causes the gear head to revolve. The smaller duplex component of the gear is further rotated by the larger gear. The torque, but not the speed, from the previous gear is transferred to the smaller duplex component, which in turn transfers to the superior part of the other gear and so forth. Because the duplex half of the third gear has more teeth than the others, it transfers more torque.

VI.RESULT SIMULATION RESULT





To ensure effective charging and power transmission in underwater wireless power transfer (WPT) systems, real-time monitoring and feedback are crucial. An LCD monitor that shows current voltage levels and charging status makes this

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possible. Users have instant access to vital information about the system's operation, including battery and receiver voltage levels, thanks to the LCD panel. While receiver voltage levels show the voltage that the underwater gadget is receiving, battery voltage represents the power source's current charge level. With the help of these updates, users may monitor how the system is operating and decide how best to maximize efficiency and guarantee dependable power transfer in difficult underwater situations.

VII. HARDWARE RESULT

Solar energy is gathered via panels mounted on the outside of the ship and stored in battery systems, offering a dependable power source even in remote or hazardous underwater locations. Through the cooperative efforts of the transmitter and receiver coils, wireless power transfer is made possible by the alternating magnetic field generated by the ship's power source. The receiving coil of the underwater vehicle uses rectification and voltage regulation to convert this energy back into electrical power, guaranteeing system compatibility. The system additionally integrates safety measures such as LED alerts and voltage sensors to allow operators to adequately monitor battery condition and power conversion.
When it comes to maritime operations and exploration, this integrated UWPT system ensures reliable performance, efficient power transmission, and increased safety. The talk makes it obvious that integrating solar panels, battery storage, and wireless power transfer technologies solves the basic problems associated with underwater vehicle powering. The system is helpful for many underwater applications, including as operations and exploration, because to its dependability in remote and dangerous locations. Furthermore, the incorporation of safety measures like voltage sensors and LED alarms shows a dedication to guaranteeing both system longevity and human safety. This underwater power delivery system is a feasible solution to the power supply requirements of underwater vehicles and has the potential to completely transform maritime research and operations since it offers a reliable and effective power source. Expanding the scope could involve further research and development aimed at enhancing efficiency and scalability.

CHARGING PERCENTAGE LEVEL	BATTERY'S TRANSMITTING VOLTAGE LEVEL in (Volts)	RECEIVING VOLTAGE LEVEL in (Volts)
108%	13.00V	9.38V
98%	12.95 V	8.94V
89%	11.58V	7.38V

Charging Percentage Level:
This shows the battery's percentage of charge. It indicates that the battery is fully charged when it reaches 100%.

Battery Voltage Level:
The voltage across the battery terminals is measured using this. A completely charged battery is indicated by a value of 13.10 volts.

Receiving Voltage Level:
This gauges the voltage that a system or device is receiving. The voltage being received is shown by a value of 7.99 volts.

Charging Percentage Level:
This shows the battery's percentage of charge. It indicates that the battery is being depleted as it falls.

Battery Voltage Level:
The percentage of charge decreases to 98%, but the battery voltage stays pretty constant at 13.07 volts. This suggests that there is still a good amount of charge left in the battery.

Receiving Voltage Level: The receiving voltage level has increased to 8.94 volts, nevertheless. This could mean that there is more demand on the gadget or that it is using more power.

Charging Percentage Level:
Further decrease in charging percentage to 89%, suggesting continued discharge of the battery.

Battery Voltage Level:
The battery voltage level remains at 13.07 volts, indicating that it still has a substantial charge.

Receiving Voltage Level:
The receiving voltage level increases further to 9.14 volts. This could imply even higher demand or a change in the charging conditions.

- Impact on Receiving Voltage:
- The receiving voltage level demonstrates sensitivity to changes in the charging percentage.
- As the charging percentage decreases, there's an observable increase in the receiving voltage level.
- This pattern indicates a potential adjustment in power transfer efficiency or energy consumption dynamics.

VIII. CONCLUSION

In conclusion, the development of an efficient underwater wireless power transfer (WPT) system, integrating transformer induction and adaptive robotic technology, represents a significant stride in overcoming critical challenges associated with power transmission in aquatic environments. The culmination of this research underscores the potential for transformative advancements in various fields reliant on sustained power sources beneath the water's surface. This achievement not only addresses the hurdles of charging time and power transfer efficiency but also establishes a foundation for enhanced operations in underwater settings. Furthermore, the unity power factor attainment and integration of diverse energy sources, encompassing solar and grid energy, showcase the adaptability and reliability of the system. This adaptability is paramount for ensuring consistent power availability and optimized energy generation, crucial for sustained applications across various underwater fields. The amalgamation of cutting-edge technologies in this research marks a pivotal step forward in underwater power transmission, offering unprecedented opportunities for oceanography, marine research, infrastructure maintenance, aquaculture, communication, search and rescue operations, environmental monitoring, and more. The adaptability and efficiency of this WPT system pave the way for advancements in exploration, research, and industry, promising greater efficiency, autonomy, and sustainability in underwater operations. As this technology continues to evolve, its potential impact on underwater applications is substantial. Through ongoing innovation and refinement, the prospects for reliable, efficient, and autonomous power transmission beneath the waves hold immense promise, unlocking new frontiers for exploration, research, and sustainable utilization of our underwater resources.

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