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SmartCharge: A Resonant Inductive Approach to Simultaneous Wireless Power Delivery for Low Power Devices

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Abstract: As the automobile industry enters a new era, it is transitioning quickly from IC engine vehicles to electric vehicles. The demand for electric vehicles is rising, which also causes a rise in the number of charging stations. In this concept, the automobile is wirelessly charged by inductive coupling using a wireless charging system. The automobile only needs to be parked on the charging location. One of the technologies that may be one step ahead of us is wireless power transmission. This technology may lead to new wireless charging applications that we can utilize on a regular basis. The transmission of electrical energy from source to load for a distance without any conducting wire or cables is called Wireless Power Transmission. The concept of wireless power transfer was realized by Nikola Tesla. Wireless power transfer can make a remarkable change in the field of the electrical engineering which eliminates the use conventional copper cables and current carrying wires. Day by day new technologies are making our life simpler. Wireless charging through resonance could be one of the next technologies that bring the future nearer. In this project it has been shown that it is possible to charge low power devices wirelessly via inductive coupling. It minimizes the complexity that arises for the use of conventional wire system. In addition, this work also opens up new possibilities of wireless systems in our other daily life uses.

Keywords: *Wireless Systems, Low power devices, Inductive Charging, Inductive Coupling,*

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I.INTRODUCTION:

We live in a world of technological advancement. New technologies emerge each and every day to make our life simpler. Despite all these, we still rely on the classical and conventional wire system to charge our everyday use low power devices such as mobile phones, digital camera etc. and even mid power devices such as laptops. The conventional wire system creates a mess when it comes to charging several devices simultaneously. It also takes up a lot of electric sockets and not to mention the fact that each device has its own design for the charging port. At this point a question might arise. What if a single device can be used to charge these devices simultaneously without the use of wires and not creating a mess in the process? We gave it a thought and came up with an idea. The solution to all these dilemma lies with inductive coupling, a simple and effective way of transferring power wirelessly. Wireless Power Transmission (WPT) is the efficient transmission of electric power from one point to another trough vacuum or an atmosphere without the use of wire or any other substance. This can be used for applications where either an instantaneous amount or a continuous delivery of energy is needed, but where conventional wires are unaffordable, inconvenient, expensive, hazardous, unwanted or impossible. The power can be transmitted using Inductive coupling for short range, Resonant Induction for mid-rangeand Electromagnetic wave power transfer for high range. WPT is a technology that can transport power to locations, which are otherwise not possible or impractical to reach. Charging low power devices and eventually mid power devices by means of inductive coupling could be the next big thing. The objective of this project is to design and construct a method to transmit wireless electrical power through space and charge a designated low power device. The system will work by using resonant coils to transmit power from an AC line to a resistive load. Investigation of various geometrical and physical form factors evaluated in order to increase coupling between transmitter and receiver. A success in doing so would eliminate the use of cables in the charging process thus making it simpler and easier to charge a low power device. It would also ensure the safety of the device since it would eliminate the risk of short circuit. The objective also includes the prospect of charging multiple low power devices simultaneously using a single source which would use a single power outlet.

II INDUCTANCE OF COIL AND COIL DESIGN

An ideal inductor has inductance, but no resistance or capacitance, and does not dissipate or radiate energy. However, real inductors have resistance (due to the resistance of the wire and losses in core material), and parasitic capacitance (due to the electric field between the turns of wire which are at slightly different potentials). At high frequencies the capacitance begins to affect the inductor's behavior; at some frequency, real inductors behave as resonant circuits, becoming self-resonant. At frequencies above this the capacitive reactance becomes the dominant part of the impedance. Energy is dissipated by the resistance of the wire, and by any losses in the magnetic core due to hysteresis. At high currents, iron core inductors also show gradual departure from ideal behavior due to nonlinearity caused by magnetic saturation. At higher frequencies, resistance and resistive losses in inductors grow due to skin effect in the inductor's winding wires. Core losses also contribute to inductor losses at higher frequencies

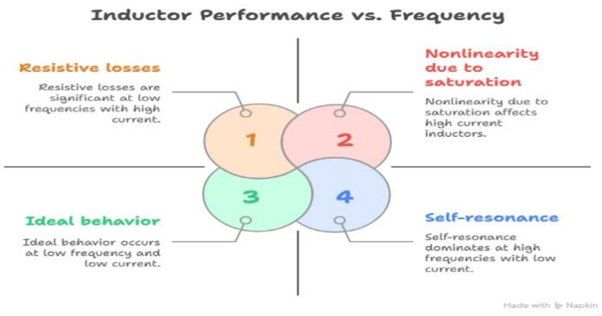


Figure-1: Inductive Performance Vs. frequency

2.1 INDUCTIVE COUPLING

Inductive or Magnetic coupling works on the principle of electromagnetism. When a wire is proximity to a magnetic field, it generates a magnetic field in that wire. Transferring energy between wires through magnetic fields is inductive coupling. If a portion of the magnetic flux established by one circuit interlinks with the second circuit, then two circuits are coupled magnetically and the energy may be transferred from one circuit to the another circuit. This energy transfer is performed by the transfer of the magnetic field which is common to the both circuits. In electrical engineering, two conductors are referred to as mutual-inductively coupled or magnetically coupled when they are configured such that change in current flow through one wire induces a voltage across the end of the other wire through electromagnetic induction. The amount of inductive coupling between two conductors is measured by their mutual inductance.

2.2 INDUCTIVE CHARGING

Inductive charging uses the electromagnetic field to transfer energy between two objects. A charging station sends energy through inductive coupling to an electrical device, which stores the energy in the batteries. Because there is a small gap between the two coils, inductive charging is one kind of short distance wireless energy transfer. Induction chargers typically use an induction coil to create an alternating electromagnetic field from within a charging base station, and a second induction coil in the portable device takes power from the electromagnetic field and converts it back into electrical current to charge the battery. The two induction coils in proximity combine to form an electrical transformer. Greater distances can be achieved when the inductive charging system uses resonant inductive coupling.

2.3 SINGLE LAYER COIL

A single layer coil, as shown in figure, has two advantages. Firstly, like all air core coils, it is free from iron losses and the non-linearity mentioned above. Secondly, single layer coils have the additional advantage of low self-capacitance and thus high self-resonant frequency. In the simple case of a single layer solenoid coil the inductance may be calculated as follows:

$$L = (d^2 n^2) / (l + 0.45d) \ [\mu H] \quad (1)$$

Where L is the inductance, d is the coil diameter in meters, l is the coil length in meters and n is the number of turns.

2.4 LOSSES IN COIL

At high frequencies, particularly radio frequencies (RF), inductors have higher resistance and other losses. In addition to causing power loss, in resonant circuits this can reduce the Q factor of the circuit, broadening the bandwidth. In RF inductors, which are mostly air core types, specialized construction techniques are used to minimize these losses. The losses are due to these effects: I. Skin effect: The resistance of a wire to high frequency current is higher than its resistance to direct current because of skin effect. Radio frequency alternating current does not penetrate far into the body of a conductor but travels along its surface. Therefore, in a solid wire, most of the cross sectional area of the wire is not used to conduct the current, which is in a narrow annulus on the surface. This effect increases the resistance of the wire in the coil, which may already have a relatively high resistance due to its length and small diameter. II. Parasitic capacitance: The capacitance between individual wire turns of the coil, called parasitic capacitance, does not cause energy losses but can change the behaviour of the coil. Each turn of the coil is at a slightly different potential, so the electric field between neighbouring turns stores charge on the wire. So the coil acts as if it has a capacitor in parallel with it. At a high enough frequency this capacitance can resonate with the inductance of the coil forming a tuned circuit, causing the coil to become self-resonant.

III. LITERATURE SURVEY

The literature survey for an IoT based wireless charging station project would involve researching existing studies, articles, and patents related to wireless charging technology, IoT integration, and sustainable energy solutions. Specifically, the literature review should focus on the following areas:

- Wireless Charging Technology: Understanding the current state-of-the-art in wireless charging technology, including inductive coupling, resonant charging, and radio frequency (RF) wireless charging. Identifying key advancements, challenges, and limitations in wireless charging systems for various devices such as smartphones, wearables, and electric vehicles.

- IoT Integration: Investigating how IoT technology can improve the functionality and efficiency of wireless charging stations. Exploring how IoT sensors, data analytics, and cloud computing can be used to monitor charging status, optimize energy transfer, and enable remote control and management of charging stations.

- Sustainable Energy Solutions: Analyzing the potential environmental benefits of using wireless charging stations powered by renewable energy sources such as solar, wind, or kinetic energy. Reviewing studies on the energy efficiency and sustainability of wireless charging systems in comparison to traditional wired charging methods.

- Market Trends and Commercial Applications: Researching market trends, industry reports, and case studies on the adoption of wireless charging technology in various sectors, including consumer electronics, transportation, and smart cities. Identifying potential opportunities and challenges for integrating IoT technology into wireless charging infrastructure.
- Regulatory and Safety Considerations: Understanding the regulatory requirements and safety standards for deploying wireless charging stations in public spaces, homes, and commercial buildings. Reviewing guidelines from regulatory authorities and industry associations on electromagnetic compatibility (EMC), efficiency, and interoperability of wireless charging systems is essential.

SYSTEM MODEL

Wireless charging systems for electric vehicles can be categorized into four types based on their operating techniques. These include the Capacitive Wireless Charging `System, Permanent Magnetic Gear Wireless Charging System, Inductive Wireless Charging System, and Resonant Inductive Wireless Charging System. The Inductive Wireless Charging System operates based on Faraday's law of induction. It uses the mutual induction of magnetic field or flux between the transmission and reception coil to transmit power wirelessly. When an AC supply is applied to the transmitter coil, it creates an AC magnetic field that passes through the receiver coil. This magnetic field moves electrons in the receiver coil, causing AC power output that is then rectified and filtered to charge the battery of an electric vehicle. The amount of power transferred depends on the frequency, mutual inductance, and distance between the transmission and reception coil. The operating frequency of the Inductive Wireless Charging System ranges from 19 to 50 kHz. However, there are some limitations to the Inductive Wireless Charging System. The harmonic current can cause heating in a conductor, leading to an increase in current value higher than expected. This mechanism leads to losses in the distribution of current in the conductor, including the skin effect and proximity effect. The skin effect is caused by the surface current that does not penetrate far into the conductor's body but travels along its surface. Therefore, in a large diameter conducting wire, most of the cross-sectional area of the wire is not used to conduct the current. This effect increases the wire's resistance in the coil, which may already have a high resistance due to its length and small diameter. The proximity effect is caused by the conductor's magnetic field, which disrupts the current distribution in adjacent carriers.

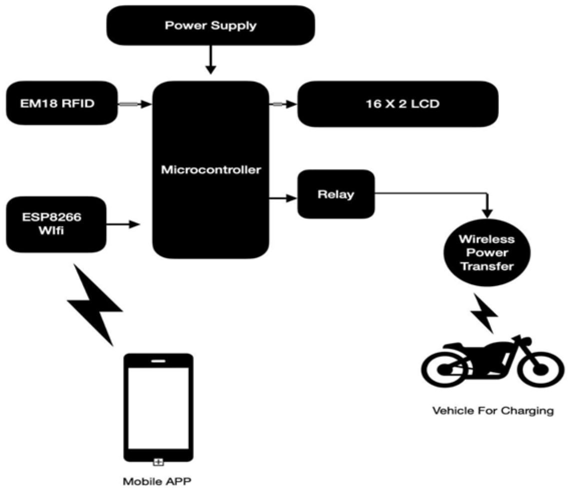
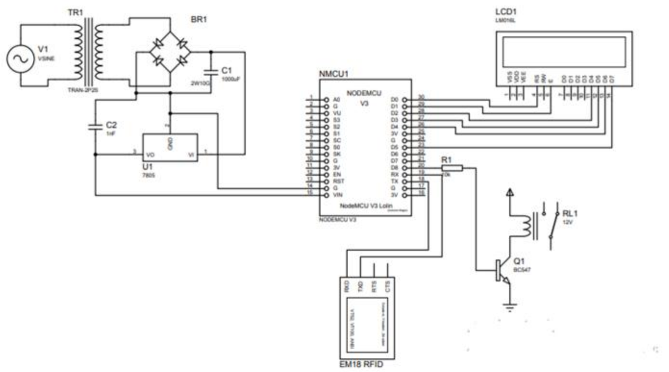


Figure -2: Block diagram



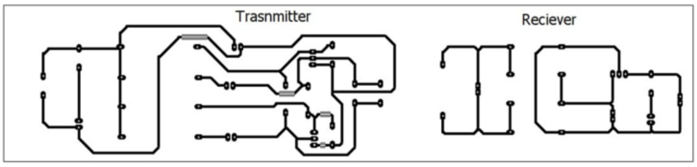


Figure 3: Circuit diagram Figure 3: Circuit diagram

IV RESULTS

The simulation produced the anticipated outcomes, which are as follows: first, the car would arrive and then stand in a particular location with a primary coil at the bottom. Next, a person would scan an RFID card to complete the transaction, after which the vehicle would begin to charge. This information about the transaction, the charging location, the charging spot, the charging time, the charging cost, and all other related information would be recorded.

Figure -4: Hardware Board

V.CONCLUSION

The purpose of the project was to develop and put into service an electronic charger through resonance inductive coupling. A circuit has been developed and implemented after an analysis of a complete system step by step in order to optimize it. The results from the experiment have shown that significant improvement has been made in power transfer efficiency. The resonant inductive coupling method, which allows a wireless transfer of power from the source coil to the load coil and is able to be charged with an inexpensive charging device, has been defined and demonstrated.

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