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A study on wireless power transmission system integrated with electromagnetic field

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ABSTRACT

Electric power is impossible to imagine in the world. Wires are typically used to transmit power. Envision a future in which wireless power transfer is probable: Mobile phones, household robots, digital audio players (DAPs), laptop computers, and bearable electronics can charge themselves, freeing us from the need to be joint to a power source by a wire. A wireless mobile charging system using the electromagnetic field is intended to clarify its concept by elucidating it. Users can charge their mobile phones wirelessly in this system without the need to plug in the mobile adapter. A charging pad demonstrates the process of charging a mobile phone, requiring users only to place their adapter circuit on it. The transmitting and receiving parts of this system are designed and built as two distinct entities, each utilizing a coupling electromagnetic field. The oscillation circuit converts DC energy into AC energy, which in turn induces a magnetic field by passing through a frequency. This causes the receiver coil to be induced with an alternating current. The magnetic field coupling between the transmitting coil and the receiving coil can be calculated using Ampere's law, Biot-Savart's law, and Faraday's law. In this paper, The ability of the wireless mobile charger is calculated by varying the space between the coils in a system that utilizes an electromagnetic field for charging wirelessly.

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INTRODUCTION

Up to 20 MV or more might be transmitted by Nikola Tesla in 1897[1]. In 1897, Remote Control Transmission was to begin with outlined by Nikola Tesla. A viable way for transmitting electric control from one point to another is remote control transmission (WPT). The idea of exchanging control without wires, be that as it may, has been around since the late 1890s. Nikola Tesla conceive of extricate the require for wires in charging or controlling gadgets. He was able to light electric bulbs wirelessly at his Colorado Springs Lab utilizing attractive acceptance or resounding inductive coupling. Through a vacuum or air, it is not done with wires or any physical fabric. Through the utilize of WPT, control can be transmitted inductively for brief ranges. Mid-range and Electromagnetic Wave control exchange are utilized through resounding acceptance in it. Difficult to supply control to places is what can be accomplished with the utilize of control lines.

The planning for farther control trade commonly utilized are alluring acknowledgment and microwave control trade. A faltering appealing field transmits inductive essentialness from the transmitter to the collector. This control source-supplied DC is transfigure into high-frequency AC by the transmitter's equipment. The electromagnetic field and a copper wire are boosted with AC in the transmitter. The electromagnetic field incline an AC in the collector coil when it is brought near. The DC is changed over back into AC by the electrons in the getting contraption. The control gets to be utilizable in this DC. Inaccessible control can be transmitted utilizing distinctive procedures. These techniques are utilized most as frequently as conceivable and reasonably for transmitting control: appealing field coupling, alluring acknowledgment, capacitive coupling, radio repeat control transmission, and microwave control transmitting. Inductive coupling is a technique for trading imperativeness wirelessly. A alluring field or B-field is conveyed when an electric current is incited in a wire formed into a coil, based on the ethics of appealing acknowledgment. A changing B-field produces an electromotive oblige in an electrical conductor by implies of the procedure of appealing acknowledgment. Acknowledgment was concocted as 1831 by Michael Faraday, and it was a while later numerically communicated as Faraday's law of acknowledgment by James Secretary Maxwell.

There are two conductors which said to be alluringly coupled when they are outlined in a way such that a modify in current by implies of one wire incline a voltage by infers of the last of the other wire by implies of alluring acknowledgment. Ampere's circuital law states that a changing appealing field or B-field in the district of the to start with wire causes a changing current to stream through it. An electromotive compel (EMF or voltage) is inclined in the other wire by the changing appealing field or B-field, concurring to Faraday's law of acknowledgment. The shared inductance measures the substance of appealing field coupling between two conductors. The coils, when wound with two wires and set found adjoining on a common center, will increase their coupling, allowing the alluring field or B-field of one coil to pass by implies of the another coil. The press center or alluring center of a ferromagnetic texture, such as press or ferrite, can progress alluring flux in coils by updating the alluring field. A single unit may contain two coils, as in a transformer with its basic and assistant windings. On the other hand, the coils may be isolated.
In this civilization, remote charging is quickly advancing from ideas towards benchmarks, and gotten in commercial items, especially cellular phones and transportable devices.[4] Electromagnetic areas like infrared, radiofrequency, obsequious, etc are utilized by this innovation to transmit information or data over the discuss. Our lives are made more commendable and simpler by remote innovation. In this paper, we can concoct an electromagnetic control transmission framework that charges versatile phones and makes a difference us to control our versatile phones ever and charge them wherever we are in the house, the office, the book collection room, or the nearby coffee house. Various applications exist for it, counting pacemakers, computerized sound players (DAPs), toothbrushes, iPods, computerized cameras, tablets, and so on.

OBJECTIVES OF THE STUDY

A wireless mobile charging system using the electromagnetic field is exhibited in this paper as its primary objective. Users can wirelessly charge their cellular phones without the need for a power adapter, according to this system. A charging pad demonstrates the process of charging a mobile phone, requiring users only to place their adapter circuit on it. The transmitter and receiver parts are designed and constructed to form a system based on a coupling magnetic field. The oscillation circuit incline an AC magnetic field by converting DC energy into AC energy via frequency passes, which in turn incline a response in the receiving coil. Magnetic field coupling between the transmitting coil and the receiving coil can be calculated using Ampere's law, Biot-Savart's law, and Faraday's law. The wireless mobile charger using electromagnetic induction is constructed with varying distances between its coils determining its efficiency. We tried to make this system effective at a low cost.

BACKGROUND

There aren't many electromagnetic power transmitters available on the market these days. Resonant near-field magnetic field coupling for wireless power was first demonstrated at MIT in the summer of 2007. Scientists at MIT presented this tightly coupled electromagnetic resonance system for mid-range electromagnetic power transfer in 2007.Wireless power transfer may provide illumination from over two meters away for a 60W bulb with an efficiency of about 40%.[2] In 2008, Intel developed wireless power through inductive coupling. The application of Witricity technology in portable devices is a significant hurdle. By adjusting their connected resonators, several receiving coils can be charged simultaneously via resonant magnetic coupling [3]. This leads to increased efficiency all around. There are several possible causes of interference.

Two coils inside the oscillator receive electricity at the same resonant frequency when a sinusoidal signal is sent to them. The designs are still in the laboratory stage of development and are not yet ready for general release. High-frequency transmissions are always made up of exposed coils and are broadcast at undesired frequencies.

The main part of any WPT system is the antenna. The effective power sent and received will depend on the antenna configuration. When choosing an antenna for a certain application, such as WPT or communications, the main considerations are usually its impedance matching, gain, bandwidth, and polarization. This study outlines two goals: the first is to explore the current state of WPT antennas and past research. The second objective is to observe it and determine which antenna technology is optimal for near-field WPT.

Resonant coupling, microwaves, and the Tesla effect are the most well-known techniques for wireless power transfer. Power can be transmitted wirelessly thanks to these methods. Resonant coupling is a technique that MIT researchers successfully tested for use in wireless power transmission. This method could be used to supply moderate power to handheld mobile gadgets. For this application, MIT researchers created a design that satisfies the IEEE standard for radio frequency exposure to humans, guaranteeing user safety.

PRINCIPLE OF WORKING

Electromagnetic Induction

Faraday explained electromagnetic induction using lines of force. The base station's charging plate's wire coils produce a magnetic field as current passes through them. Without making physical touch, a nearby coil of wire can create an electrical current in this area. In an inductive charging configuration, energy is transferred between the two objects by the electromagnetic field. Usually, charging is done at a charging station. An electrical gadget uses an inductive coupling to receive energy in order to power itself or charge its batteries.

According to Faraday's Law, the magnetic flux varies at a rate that is directly proportional to the voltage induced in a coil, $d\upsilon/dt$, and the number of wire turns in the coil (N). The cue that serves as an example of Faraday's Law results from:

$V=N\frac{d\phi}{dt}$……………………………………(i)

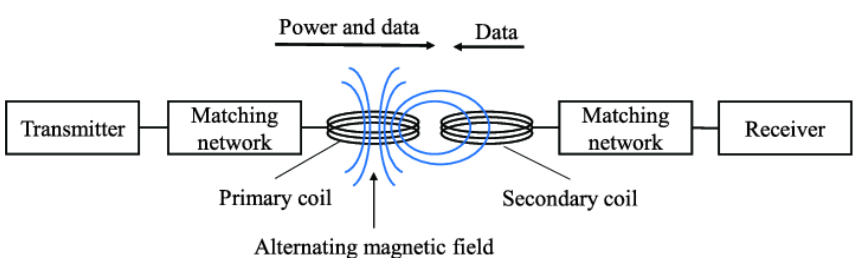
where V is the electromotive force (EMF) or induced voltage.
N is the total number of wire turns in the coil.
$d\phi/dt$ = The rate at which the magnetic flux varies

The frequency of an AC circuit directly controls the induced voltage. The frequency causes an increase in the current's rate of change. The following is the inductance cue:

L = NμA/l .. (ii)
$\mu = \mu_r \mu_o$
where L is the coil's inductance in Henrys.
N = The coil's wire number of twists
μ = Core material permeability
μ_r = Air's relative permeability (1
μ_o= Free space permeability (4π ×〖10〗^(-7) μ/m)
A= The coil's area in square meters
l = The coil's average length in meters

Inductive Coupling

When two conductors are set up so that an electromagnetic induction causes a voltage to cross the ends of the other wire when there is a change in current across one of the wires, they are said to be inductively or magnetically connected. According to Ampere's circuital law, the first wire's current changes in response to changes in the magnetic field surrounding it. According to Faraday's law of induction, the changing magnetic field induces an electromotive force (EMF or voltage) in the second wire. The amount of inductive coupling between two conductors is measured by the mutual inductance. To improve their coupling, two wire coils can be positioned along a common axis such that the second coil crosses the first coil's magnetic field. A ferromagnetic substance, such as iron or ferrite, has a magnetic core that improves coupling in coils, raising the magnetic flux. Two coils can be found in a single device, such as the primary and secondary windings of a transformer. Alternatively, you might separate the coils.



A coil is subjected to a current. In its vicinity, a fluctuating magnetic field is generated. The two coils are magnetically connected when the first coil's fluctuating magnetic field induces a second coil, which in turn causes the second coil to sense an induced voltage. The second coil experiences an induced voltage due to mutual inductance, which can be computed using the cue that follows:

$$L_M = K\sqrt{L_1 L_2}$$

where the coefficient coupling between the two coils is given by L_M= Mutual inductance K = φ_1/φ_2 L = coil one's inductance, L = coil two's inductance.

The aforementioned calculations explain how voltage is started in a second coil and the ethics of induction. A resistor (Rp) and an inductor (L1) in the circuit are linked to an AC source, which causes the resistor to heat up and cause power loss. The AC source induces a fluctuating current in (L1), the inductor. It then generates voltage in

L2 by creating this magnetic field. The receiver circuit, which consists of L2, Rs, and RL, is powered by a change in the transmitter's magnetic field. Once more, Rs represents the inductor's power loss and RL represents the load.

MATERIALS AND METHODS

The following hardware elements are needed to build the suggested wireless mobile charger system:
1) Copper (30 gauge) wire
2) The transistor TTC 5200
3) A 9-volt battery
4) Diodes 1N4007
5) Capacitor with 1000 µF
6) Warming basin
7) Resistor with 3.3k
8) Breadboard
9) 5V regulated supply, car mobile charger, or charging pin
10) Use any round-shaped material to create the coil.

System Requirements

Utilizing several equipment kinds in a wireless power transmission system.

1. The transistor TTC 5200: A semiconductor is a transistor. Transistors are devices that switch or amplify electrical power and signals. It's the semiconductor material. It has an external circuit connected to three terminals. A transistor is made up of three terminals: the base, emitter, and collector.

Figure. 2.TTC5200 transistor

2. 1N4007 Diodes: Designed for circuits that are used to converting alternating current to direct current, the 1N4007 diode is a rectifier.

Figure. 3.1N4007 Diode

3. Heat sink: A heat-sink dissipates the heat from the transistor. It releases heat efficiently into the surrounding air. There are numerous varieties of heat-sinks available, including as copper sheets, copper blocks, and finned aluminum.

Figure. 4. Heat Sink

4. Use any round-shaped material to create the coil:

Primary coil: A primary coil is a coil that is a component of an electrical circuit that causes changes in its current to influence changes in an adjacent circuit. This phenomenon is known as "current over the primary coil incline the secondary coil."

Secondary coil: A secondary coil is one in which current flows through the first coil to start the secondary coil.

5. 3.3k resistor: A resistor is a two-terminal circuit device that provides electrical resistance. In electrical circuits, resistors are used to split voltages, generate signal levels, bias active devices, stop transmission lines, and reduce current flow. The resistors are in charge of these tasks.

Figure.5. 3.3K Resistor

6. Copper (30 gauge) wire:

Figure. 6. 30 gauge Copper wire

7. 5V regulated supply, car mobile charger, or charging pin:

Figure. 7. Car mobile Charger

8. 12V power supply (such as battery, regulated power supply): To input 12 volt power, we can use a trainer board, battery, or regulated power supply.

Design and Implementation

System Design:

1. **Transmitting circuit:** In this circuit the resistance of 3.3k is connected between one side of primary coil and base of TTC 5200 transistor. The other side of the primary coil is connected with the collector transistor. The emitter transistor is connected with -12 volt. +12 volt is supplied to the primary coil.

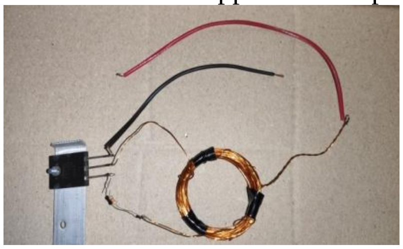


Figure. 8. Transmitting Circuit

2. **Receiving circuit:** In receiving coil, we used four IN4007 Diodes and make a bridge connection. This diode bridge is connected with secondary or receiving coil and load (Mobile car charger).

Figure. 9. Receiving Circuit

Block Diagram:

1. **Block Diagram of transmitting circuit:** Control is connected to the transmitter. A copper coil is coiled in a few turns. An attractive field is made when the coil gets control. As a result, control is shared.
2.

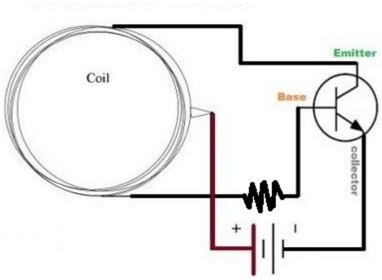


Figure.10. Block diagram of transmitting circuit

3. **Block Diagram of receiving circuit:** The secondary coil, or receiving coil, is made in the same way as the primary coil. Ensuring that the secondary has low resistance at the transmitter's frequency and that the energy is optimally attentive is achieved by running it at the same resonant frequency as the main. There are a few different ways to extract energy from the secondary coil: you can directly rectify the AC, or you can utilize a regulator circuit to create DC voltage.

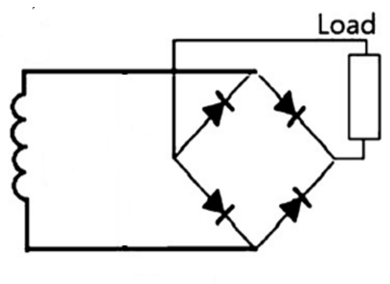


Figure.11. Block diagram of receiving circuit

Project Description:

To make this remote cellular phone charger venture, two circuits were utilized. The accepting circuit is the other and the transmitting circuit is the to begin with. An electromagnetic field is made over the coil by the high-frequency rotating current (AC) delivered by the transmitting circuit. The electromagnetic field causes the auxiliary coil to deliver a substituting current when it gets close the essential coil. Bridge rectifier diodes are utilized to change over the auxiliary coil's AC back to DC. The cellular phone is at that point charged utilizing the DC.

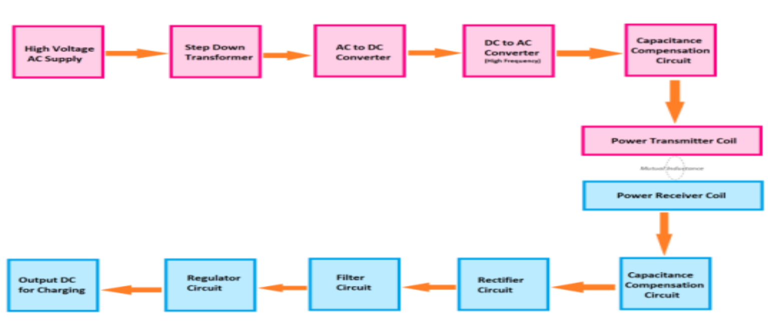


Figure.12. Block Diagram of Wireless Charging using Induction Coupling

RESULTS AND DISCUSSION

A Flow Chart of the working

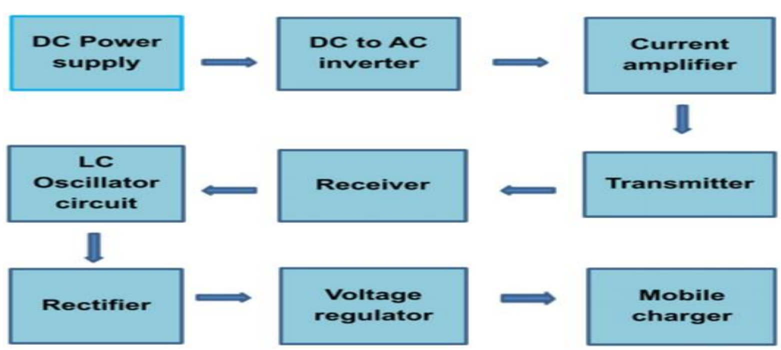


Figure.13. Flow Chart of the system of wireless charging

Experimental Result

12V power is supplied in the input and the secondary coil is kept two cm away from the primary coil, which generates magnetic field between these coils. As a result the power get reduced. So we get 5V power as output.

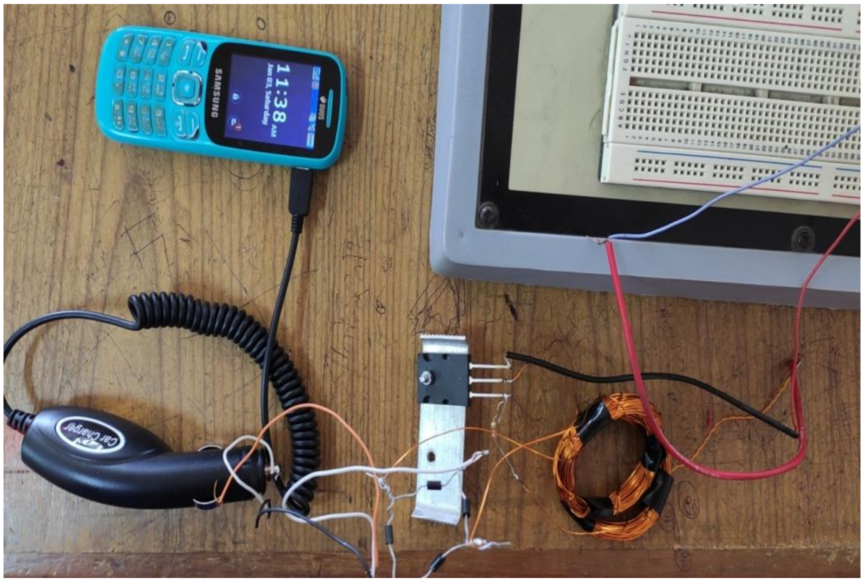


Figure.14. Wireless mobile charger Circuit using electromagnetic field

Cost Analysis

The cost analysis have been done with Bangladeshi currency.

Table 1. Cost analysis for this work

Equipment	Quantity	Cost
TTC 5200 transistor	01	45 ৳
1N4007 Diode	04	10 ৳
Resistor	01	02 ৳
Copper wire	30 gauge	300 ৳
Heat sink	01	30 ৳
Mobile car charger or Capacitor	01	160 ৳
Wire	2 gauge	30 ৳
Total		577 ৳

Design Calculation

Transmitting Coil,
The transmitting coil's radius, r = 3.92 cm
The cross-sectional radius, a = 0.03483 cm
Size of coil wire: 30 gauge
D, or diameter, is 7.92 cm.
The winding's width, h = 0.454 cm
35 turns is the number of transmitting coil turns (N).

Receiving Coil,
The transmitting coil's radius, r = 3.92 cm
The cross-sectional radius, a = 0.03483 cm
Size of coil wire: 30 gauge
D, or diameter, is 7.92 cm.
The winding's width, h = 0.454 cm
35 is the number of turns in the receiving coil (N)

Calculating the Winding's Inductance Theoretically:
Inductance of transmitter coil, L = $N^2\mu_0 r$(ln(8r/a)-1.75)

$$= 35^2 \times 4\pi \times 10^{-7} \times 3.92(\ln\left(\frac{8\times3.92}{0.03483}\right) - 1.75)$$

= 0.03049 H

= 30.49 mH

Inductance of receiver coil, L = $N^2\mu_0 r$(ln(8r/a)-1.75)

$$= 35^2 \times 4\pi \times 10^{-7} \times 3.92(\ln\left(\frac{8\times3.92}{0.03483}\right) - 1.75)$$

= 0.03049 H

= 30.49 mH

Calculating the Winding's Resistance Theoretically:

Resistance of the Winding (R) = $\rho\frac{l}{A}$

Length of the Transmitter Coil, l = The coil's circumference×N

= 2π×D×N

= 2× 3.1416 ×7.92× 35

= 1741.6989 cm

Length of the Receiving Coil, l = The coil's circumference×N

= 2π×D×N

= 2× 3.1416 ×7.92× 35

= 1741.6989 cm

A = 2πr(r+h)

$= 2\times 3.1416 \times 3.92(3.92 + 0.454)$

$= 107.732\ cm^2$

ρ = Copper's Resistivity= $1.72\times 10^{-8}\ \Omega m$

The Transmitter Coil's Resistance = $\rho\frac{l}{A}$

$$= 1.72\times 10^{-8}\,\frac{1741.6989}{107.732}\ \Omega$$

$$= 2.78\times 10^{-7}\ \Omega$$

The Receiver Coil's Resistance = $\rho\frac{l}{A}$

$$= 1.72\times 10^{-8}\,\frac{1741.6989}{107.732}\ \Omega$$

$$= 2.78\times 10^{-7}\ \Omega$$

Resonant frequency of the coil used for receiving:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

$$= \frac{1}{2\times 3.1416\times\sqrt{30.49\times 10^{-3}\times 1000\times 10^{-6}}}$$

= 28.82 Hz

L = 30.49 mH

C = 1000 μF

f = 28.82 Hz

Resonance Receiving coil satisfies condition:

For there to be resonance,

$X_L = X_C$

XL is the inductive reactance (coil reactance) = $2\pi\times f\times L$

$$=2\times 3.1416\times 28.82\times 30.49\times 10^{-3}$$

= 5.52 K Ω

X_C = Capacitive Reactance = $\frac{1}{2\pi f C}$

$$= \frac{1}{2 \text{ X } 3.1416 \text{ X } 28.82 \text{ X } 1000\times 10^{-6}}$$

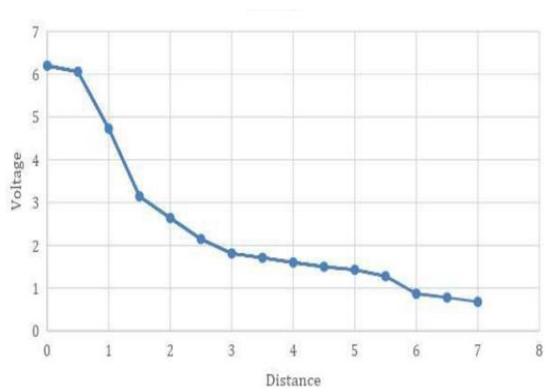
= 5.52 K Ω

In this manner, XL = XC, which leads to resonance and wireless power transfer.

Case 1

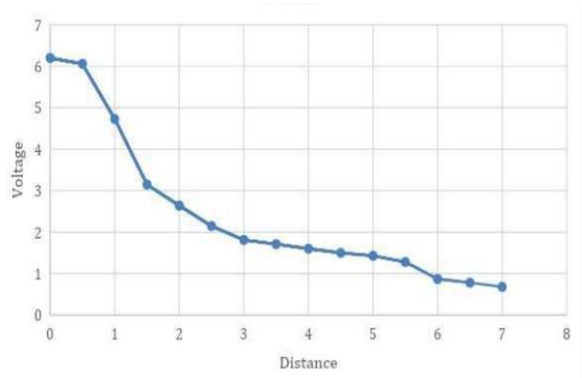
25 turns in the main coil.

25 turns are present in the secondary coil.



Graph. 1. Voltage Versus Distance graph (for 25 turns)

Case 2
35 turns are present in the primary coil.
35 turns are present in the secondary coil.



Graph. 2. Voltage Versus Distance graph (for 35 turns)

CONCLUSION AND RECOMMENDATION

There will be wide use of wireless charging technologies, especially for movable electronics, mobile phones, and consumer electronics. Through reverberative inductive coupling, this system makes charging a variety of widgets vastly simpler and further worthwhile. Mobile bias are charged wirelessly by a system that uses receiver and secondary coils in addition to transmitter and primary coils. To probe changes in the affair voltage and, accordingly, effectiveness, the distance between the coils was acclimated. It was noted that the effectiveness was great.

(i) The magnetic field decreases as the distance between the coils grows.
(ii) There is an increase due to the number of turns.

As a result, the experimental findings agree with the theoretically predicted situation. Even though wireless charging is still in its infancy, it is anticipated that the technology will undergo a significant evolution in the next years.

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APPENDIX

MIT	Massachusetts Institute of Technology
WPT	Wireless Power Transfer
GEO	Geosynchronous Earth Orbit
AC	Alternating Current
DC	Direct Current