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FERROMAGNETIC POWER TRANSMITTERS

DOMESTIC POWER DISTRIBUTION USING WIRELESS TECHNOLOGY

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Abstract — Wireless power distribution is achieved through the use of inductor-based coils, working on the combined principles of transformer action and resonant inductive coupling. Wireless power distribution eliminates the expenses and difficulties of using wires to power the devices in our homes. A primary coil connected to the main supply and a secondary coil connected to the load is employed. Here, distance is the prime factor that reduces efficiency and effectiveness, which can be resolved by employing ferromagnetic core wound by copper wire, to function as extenders. The biggest contribution was made by NIKOLA TESLA, through his inventions and the infamous TESLA TOWER which was built to wirelessly transfer electricity over a wide area. His idea was to transfer energy by electrostatic induction or induction through plasma [1]. Efficient energy transfer takes place when the resonant frequencies of the primary, extender and the secondary coils are matched. The potential advantage of the proposed method is, to wirelessly distribute power to different appliances with the aid of limited hardware and improve the overall hygiene and outlook of the domestic environment for a greener world.

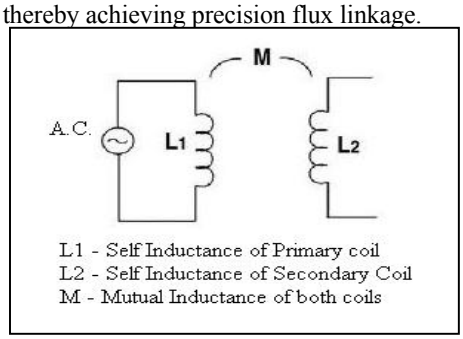
Keywords-Wireless Electricity; Transformer action; Inductive Coupling; Resonant Coupling; Wireless

I. INTRODUCTION

The methodology of transfer of electricity from one place to another without the use of wires is called as Wireless Electricity (Wire-less Electricity). The major principles associated with this idea are transformer action and resonant induction coupling. The design is laid out by using a primary coil supplied with an AC input power supply. The secondary coil, connected to the load receives energy from the primary coil. Both the primary and the secondary coil are copper wires wound over a magnetic core, thus forming an electromagnet. According to Faraday's law, when a conductor carries current, it produces a magnetic field around it. The magnetic lines of force are finite and are dependent on the current through the coil, inductance of the coil and number of turns of the coil. The flux produced by the primary coil links with the secondary coil thereby inducing an e.m.f in the secondary coil. This voltage is applied to the load appliance. The energy transfer is at its maximum, when both the primary and secondary coils are said to be working under the same resonant frequencies, this concept is termed as resonant inductive coupling. This paves the path for efficient power distribution with minimized losses, compared to the conventional wired distribution.

II. RESONANT INDUCTIVE COUPLING AND EXPERIMENTATION

A short range coupling between two inductive coils placed closed to each other is primarily used for achieving distribution of power without wires. Mutual inductance between two coils plays a very vital role in magnetic coupling, thereby achieving precision flux linkage.



However, its short range is a cause of concern as the separation between the two inductive coils is placed very close to each other. Considering its commendable efficiency during power transmission it is used for wireless charging of electrical and electronic devices and one such example is electronic truth brushes.

A. Resonant Induction principle

Resonant induction is conceptually linked with magnetic induction as the two share common principles of transferring electric current through magnetic field lines. Resonance is phenomenon which tends to vibrate an object when a certain frequency is applied. This phenomenon is successfully used in transmission of power between two coils with an added advantage of increased range which is a drawback in short range coupling through magnetic induction that hinders efficient power transmission. Every object resonates and its corresponding resonating frequency is based on the physical

dimensions of that object. An example is creation of coherent light by optical resonance in a laser cavity.

B. RESONANT INDUCTIVE COUPLING – EXPERIMENTATION

Two copper coils with self resonating frequencies can be used for experimentation with each measuring 50.8 centimeters in diameter. The primary copper coil acts as a transmitter with a sourced AC input supply whilst the other copper coil resembles a receiver circuit. Oscillation of the primary coil should be initiated at a particular frequency with the AC input supply in the ON state. The surrounding atmosphere will be filled with magnetic flux lines and nonmagnetic radiations. As one of the circuit objective's is to satisfy frequency matching between two coils, the secondary coil gets energized by receiving the magnetic flux that will be produced in the vicinity of primary coil and starts to vibrate at that reception frequency, showcasing the achievement of one of the objectives. Hence, the oscillation between the two coils can be observed to be similar. This phenomenon is known as "COUPLED RESONANCE", which is the main principle and stands as the backbone behind this proposed idea. After the initial ignition of the process working, an indicating load, for example, a bulb can be connected to the secondary coil and both the coils will start to resonate at a MHz frequency. The bulb will continue to glow even when physical objects like rubbers act as a hindrance between the coils. A reasonable working efficiency can be achieved and the unutilized power will remain in the vicinity of the primary coil restricting it from radiating to the surrounding environment.

III. 19TH CENTURTY ELECTRICITY

A. WIRELESS POWER TRANSFER

In the early 19th century, Nikola Tesla used electrostatic induction or induction through plasma, to transfer wireless power, instead of the proposed method of using resonance magnetic fields. Furthermore, Tesla conducted various tests to establish an environment where electricity can be transferred from one place to another without using wires, most prominent experiment being the Wardenclyffe tower. This tower is also popularly known as the Tesla tower. According to sources, Tesla wanted to bring electricity from the huge resources at Niagara Falls power plant and disperse it all around the globe using the Tesla tower [2]. The tower was dynamited in the year 1917.

With advent in technology, radio waves were considered for wireless transfer of power and lasers were also used on a small scale. However, radio waves were not feasible due to their dispersive nature and thereby leading to enormous wastage. Lasers on the other hand, required line of sight for uninterrupted energy transfer and were also considered very dangerous.

B. TESLA COIL

Nikola Tesla invented the Tesla coil and used it to conduct numerous innovative experiments. In 1899, he achieved a major breakthrough in his work at Colorado by transmitting 100 million volts of electric power wirelessly over a distance of 26 miles to light up a bank of 200 light bulbs and run one electric motor. He claimed to have achieved 95% efficiency [3]. The circuit diagram of the Tesla coil is shown below.

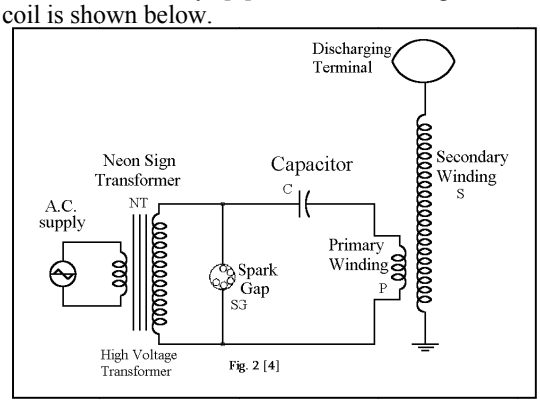
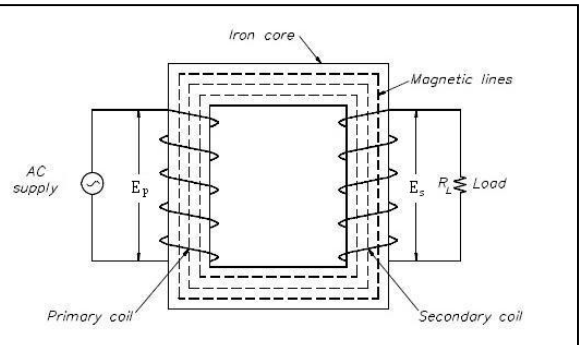


Fig. 2 [4]

Referring to Fig. 2, the capacitor C forms two resonant circuits: one with the primary coil P, and another with the secondary coil S. The voltage is supplied by the neon sign transformer NT. The spark gap SG consists of two electrodes separated by a gap, filled with an inert gas. When the required amount of high voltage is applied across it, spark forms, ionizing the gas, and allowing conduction. As the voltage across the gap SG increases, the charge across the capacitor C also increases. When the gap sparks, the capacitor discharges into the primary and the secondary windings. Thus, the voltage “bounces” back and forth at an extremely fast rate. The method Tesla used to wirelessly transmit electricity was the employment of the earth's own resonance, which he discovered to be approximately 8 Hz, with its specific vibrational frequency to conduct AC electricity via a large electric oscillator at about 7.8Hz. When the rate of discharge between the capacitor C and primary P, matches that of the same capacitor C and secondary S, the two circuits are said to be "in resonance". The voltage rises to such high levels that it is discharged through the discharge terminal in the form of an electric arc. However, there were several safety hazards that were needed to be considered. A Tesla coil produces high voltage electric arcs. These arcs cause permanent damage to electrical devices on contact. Many devices can also be damaged without being directly struck by the arc, due to the sheer amount of voltage being transferred. Tesla coils also destroy hearing aids and cardiac pacemakers in their vicinity. For all the above reasons, this technology has been languishing in obscurity and not much research has been carried out in the field of wireless energy transfer.

IV. TRANSFORMER ACTION

The Transformer sketch consists of 2 windings namely, Primary Winding and Secondary Winding. The windings are coils wound around a ferromagnetic core. The number of turns in the primary winding is denoted as n_p and that of secondary winding as n_s. The alternating current produces a varying magnetic flux in the primary winding which links with the secondary winding. This magnetic linking induces an e.m.f in the secondary winding which is dependent on the number of turns n_s and n_p. The effect is termed as Mutual Induction. When the secondary winding is connected to a load, an electric current I_s starts to flow through the circuit.



Core Type Transformer [5]

Assuming ideal transformer action, the voltage in the secondary winding E_s and the voltage in the primary winding E_p are related as in (1). [6]

$$E_s/E_p = n_s/n_p \quad (1)$$

The currents I_s and I_p in the secondary and primary windings respectively, are related as in (2).

$$I_s/I_p = n_p/n_s \quad (2)$$

In a Transformer, the Windings are placed close to each other and the setup is used to raise or lower the output voltage of the secondary by changing n_s and n_p suitably. The major losses in a transformer are copper loss, Hysteresis loss and Eddy current loss. In reality, transformer efficiency is greater than 90 percent.

V. PROPOSED IDEA

Tesla's invention embarked a milestone in the development of wireless power. In the early 1890s, Nikola Tesla invented the **TESLA COIL**, which was a type of resonant transformer used to generate very high voltage, low current and high frequency alternating electricity, which was used to transmit electric power over large distances. In this proposed idea, the usage of Ferro power transmitters for successful energy transfer between two resonating coils can be achieved even in the presence of physical objects. Coupling resonant system works remarkably well as the transfer takes place with minimum losses as the electric energy that is not used up by the receiver during transmission does not get radiated into the surrounding environment, but remains in the vicinity of the transmitter thus increasing the working efficiency. Also, the devices in the vicinity do not utilize the energy from the primary coil because of the inability to match its frequency with that of the source coil. Questions have been raised on safety concerns during its working from time to time. The public safety threshold for the magnetic field produced by the primary coil is 100mT (milli-Tesla) [7]. Therefore, the primary coil must be designed such that the standards for safety are met, to avoid any health hazards. Hence, a primary coil producing magnetic field with intensity much less than 100mT should be considered.

A. FERROMAGNETIC EXTENDERS

Ferromagnetic materials are materials which exhibit the property of ferromagnetism. Ferromagnetism is the phenomenon by which certain materials form permanent magnets, or are attracted to magnets. Ferromagnetic materials exhibit the strongest type of magnetism, above all the other naturally occurring materials. Even a small external magnetic field can magnetize it, thereby making it a magnet. It is a manifested fact that, a small external magnetic field can line-up the magnetic domains with each other within the material, thereby magnetizing it [8]. All permanent magnets are either ferromagnetic or ferrimagnetic in nature. Common examples of ferromagnetic materials are iron, nickel and cobalt. The ferromagnetic materials have the ability to stay magnetized even after the removal of the applied field. It also has the capacity to increase the intensity of the driving magnetic field by a large factor. This is the principle working of the EXTENDER core. As extenders, ferromagnetic materials are used to extend the area of the magnetic field produced by the primary coil, so as to magnetically link with the secondary coil winding. Iron being the common ferromagnetic material, is used as an extender here. The iron core is designed in such a way that it also has a resonant frequency equal to that of both the primary and secondary coils. A copper wire of certain length and diameter, is wound around the iron core with a specific number of turns and connected in parallel to a variable capacitor to maintain resonance condition. The extender core is settled within the maximum area coverage of the magnetic flux from the primary coil.

The linking of flux lines induces an e.m.f in the extender coil, by the principle of electromagnetic induction. The extender core is a closed circuit and therefore, current flows in the circuit, which leads to the generation of its own magnetic field. The magnetic flux coverage of the extender coil is such that, the magnetic lines link with the secondary windings and induces a voltage at its end. The load is

connected to the secondary coil, therefore leading to a current flow in the destination circuit. Extenders are used under situations where the secondary coil is considerably away from the source coil.

B. THE PRACTICAL OUTLOOK

The distribution of power in a domestic environment is achieved in a wireless fashion by placing the primary coil at a location where it has the highest probability of eliminating the need of a ferromagnetic extender. Under circumstances where the primary coil cannot effectively transfer its energy to the secondary coil, an extender can be used. Extenders act as repeaters by producing a magnetic field similar to that produced by the primary coil.

VI. MODERN APPLICATION

The proposed idea can be implemented for a safe and secure design of bank vault system. To be more precise, it can be used to control the vault-lock rods that are attached to the pneumatic pressure piping mechanism. This control can be achieved using primary and secondary coils along with extenders, to maximize the control range, thereby combining security with efficiency.

A. CONSTRUCTION

A central processing unit is connected to 3 primary transmitter coils via primary pneumatic pressure valves. Each primary coil has its own resonating frequency, different from the other 2 coils. Wireless energy is transferred to their corresponding secondary coils connected to the vault system. Each secondary coil is connected to a secondary pneumatic pressure valve which is in turn connected to a vault rod. Other devices being used are a capacitance sensitive touch pad input-display panel and a de-multiplexer unit. The vault is as shown in fig. 3.

B. WORKING

Let us assume that the security code for opening the vault is 312. During start up, number 312 is entered in the touch panel and microprocessor runs an inbuilt program to verify the input with its reference value 312, which is stored in the processor memory. In case of a match, then an output signal is given to a de-multiplexer. The de-multiplexer has a single input line which transfers its signal to one among the various output lines. The output line is selected with the aid of 'select' signals from the microprocessor. This is almost equal to the working of a television remote. The output pulse corresponding to no.3 is obtained. Likewise, the pulse related to numbers 1 and 2 are transmitted separately.

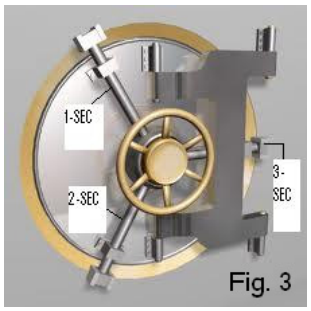
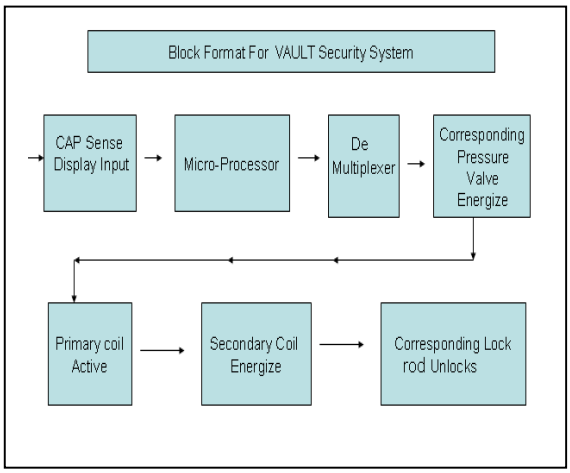


Fig. 3

Once the de-multiplexer outputs no.3 pulse, signal is given to the corresponding primary pneumatic pressure valve. This valve moves up and shorts the primary coil wire with a suitable AC supply wire. Now the primary coil energizes, it gets magnetized and starts to resonate at its preset frequency. The magnetic field produced by the primary coil links with the secondary coil via extenders, which to resonate at the same frequency, thereby inducing an e.m.f. This induced e.m.f produces a current that drives the corresponding secondary pneumatic pressure valve connected to the rod. Now one of the rods is open. Similarly, the process is repeated to unlock the other two rods. A delay is programmed in the processor to provide time gap between each rod opening and closing sequences. The delay is programmed in such a way that the primary coil de-energizes once the rod is unlocked.



C. ADVANTAGES

This concept of vault design is highly advantageous as it minimizes the need of congested wiring. A wider control can be achieved with the use of extenders. The system functions effectively in its domain as the frequency linking the primary and secondary coils cannot be easily tapped and in case of frequency being tapped by an intruder, the vault rods do not unlock itself as the codes have be entered precisely. In case of incorrect inputs or security breaches, the alarm circuit will

sound instantly, thereby alerting the security personnel and preventing any chances of system hacking.

VII. LEVERAGE OF WIRELESS POWER OVER WIRED POWER DISTRIBUTION

As long as the magnetic field produced by both the primary and extender coils has their intensities restricted much within the value of 100mT, there can be no harm done to humans or other living organisms. The magnetic fields weakly interact with the biological tissues of the body and so, are not prone to cause any damage to any living beings. The idea of wireless power distribution eliminates the expenses and use of messy wires. A single source coil is enough to power multiple devices within its coverage or a room.

VIII. FUTURE SCOPE

According to researches, wireless energy transfer is only efficient for smaller distances. The efficiency is said to be around 45% for 2 meters and they have to be twice as efficient to compete with the conventional chemical batteries. We are still working on the concept which might change the face of electricity distribution in future.

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