DESIGNED AND IMPLEMENTATION OF HIGH VOLTAGE HIGH FREQUENCY WIRELESS TRANSMISSION SYSTEM

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DESIGNED AND IMPLEMENTATION OF HIGH VOLTAGE HIGH FREQUENCY WIRELESS TRANSMISSION SYSTEM

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Abstract: *Wireless power transmission system is used to transmit the power without using of conductor. The wireless power transmission area is about high voltage with small current hence there is no risk of heat generation. We are able to generate high voltage with high frequency and it can be used for testing the apparatus for switching surges. It can also transmit the electrical power wirelessly up to certain distance depends upon its rating which holds the great future of wireless energy transmission. Tesla Coil is used for wireless power transmission. A Tesla Coil is a high voltage, high frequency, resonant transformer capable of producing many thousands of volts in the form of lightening like discharges. It was primarily built for experiments investigating x-rays, high frequency alternating current phenomena, electrotherapy, and Wireless Electric Power Transmission. In this paper the simulation model and its results are shown with using Java circuit simulator. This paper also includes designed data and the experimental results of working model.*

Keywords: HF transformer, Java circuit simulator, Spark gap tesla coil, Wireless power transmission, etc.

I. INTRODUCTION

Wireless communication is the transmission of the energy over a distance without the usage wires or cables where in distances involved may be short or long. Wireless operations permits services such as long-range communications that are merely unfeasible using wires. Wireless energy transfer or wireless power transmission is the transmittance of electrical energy from a power source to an electrical load without interconnecting wires. Wireless transmission is useful in cases where interconnecting wires are inconvenient, hazardous, or impossible. The problem of wireless power transmission differs from that of wireless telecommunications, such as radio. In the past, product designers and engineers have faced challenges involving power: the continuity of supplied power, recharging batteries, optimizing the location of sensors, and dealing with rotating or moving joints. Although those challenges remain, new demands that arise from increased use of mobile devices and operation in dirty or wet environments mean that designers require new approaches to supplying power to equipment. Wireless Power Transmission from the time of Tesla has been an underdeveloped technology. Tesla had always tried to introduce worldwide wireless power distribution system. But due to lack of funding and technology of that time, he was not able to complete the task. Then onwards this technology has not been developed up to the level

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which would be completely applicable for practical purpose. Research has always been going on and recent developments have been observed in this field.

Wireless energy transfer, by definition it does not require direct electrical conductive contacts. Various systems work by transmitting electromagnetic energy from an external power source through a medium by running a large AC current through an external coil to generate a magnetic flux. The changing magnetic flux induces a current in an internal coil.

The term high voltage usually means electrical energy at voltages high enough to harm or death upon living things. High voltage is used in electrical power distribution, in cathode raytubes, to generate X-rays and particle beams, to demonstrate arcing, for ignition, in photomultiplier tube, in high power amplifier vacuum tubes and other industrial and scientific applications. Frequencies at which the response amplitude is a relative maximum are known as the system's resonant frequencies. Resonant inductive coupling or electro dynamic induction is the near field wireless transmission of electrical energy between two coils that are tuned to resonate at the same frequency. The equipment to do this is sometimes called a resonant or resonance transformer.

II. TESLA COIL INTRODUCTION

Wireless energy transfer, by definition, does not require direct electrical conductive contacts. Various systems work by transmitting electromagnetic energy from an external power source through a medium by running a large AC current through an external coil to generate a magnetic flux. The changing magnetic flux induces a current in an internal coil.

After his inventions about the poly-phase powering systems Nikola TESLA has focused himself more to experiments with high voltages, high currents and high frequencies. One of his goals was to transmit electrical energy without a power network directly from a central plant to the different consumers. In New York TESLA has done his first trial for this new technology. Then at the change of the century 1899-1900 TESLA moved to the high lands of Colorado Springs. There he has executed so many experiments, which has not been repeated in all its details and specialties until these days. Now, exactly one hundred years after a review about this impressive and important experiments may be of a particularly interest.

The Tesla Coil is an air-core transformer with primary and secondary coils tuned to resonate. The primary and secondary circuits function as step-up transformer which converts relatively low-voltage high current to high-voltage low current at high frequencies. The Tesla Coil demonstrates the fundamental principles of high frequency electrical phenomena. It shows the principles of ionization of gases and behavior of insulators and conductors when in contact with high frequency electrical fields.

III. BASIC TESLA COIL CONCEPT

It is a high voltage, high frequency, resonant transformer capable of producing many thousands of volts in the form of lightening like discharges. It was primarily built for experiments investigating x-rays, high frequency alternating current phenomena,

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electrotherapy and wireless power for electric power transmission. With this coil, Tesla was able to generate voltages of such magnitude; they would shoot out of the apparatus as bolts of lightning. Today, Tesla Coils are mainly built by amateur enthusiasts all over the world for the sole reason of the exhilarating thrill of producing their very own lightning.

A Tesla coil is a special transformer that can take the ~220 volt electricity from your house and convert it rapidly to a great deal of high-voltage, high-frequency, low amperage power. The high-frequency output of even a small Tesla coil can light up fluorescent tubes held several feet away without any wire connections. Even a large number of spent or discarded fluorescent tubes (their burned out cathodes are irrelevant) will light up if hung near a long wire running from a Tesla coil while using less than 100 watts drawn by the coil itself when plugged into an electrical outlet! Since the Tesla coil steps up the voltage to such a high degree, the alternating oscillations

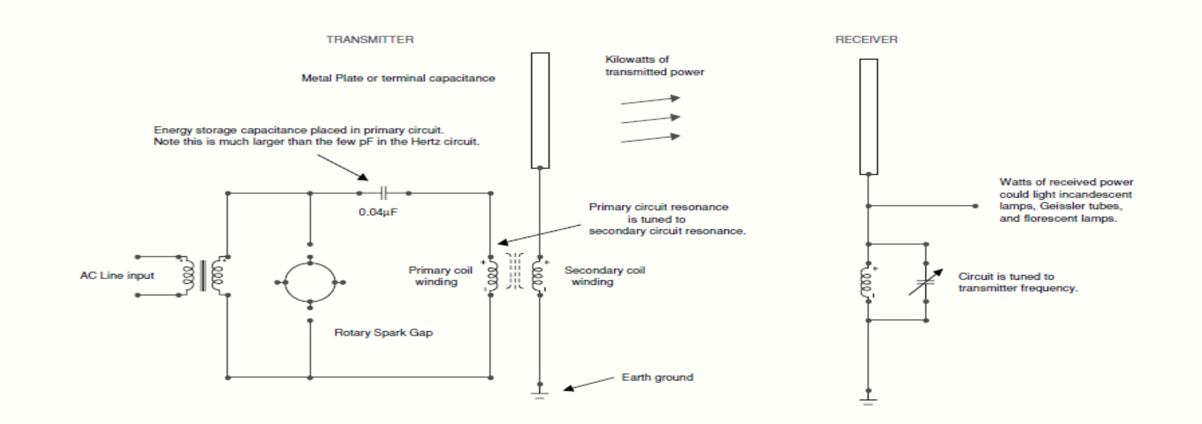

Fig.1 Tesla Coil Equivalent Circuit

Fig.1 shows the equivalent circuit of tesla coil and its working is described below. As the capacitor charges from the high voltage power supply, the potential across the static spark gap electrodes increases until the air between the spark gap ionises allowing a low resistance path for the current to flow through; the "switch" is closed. Once the capacitor has discharged, the potential across the spark gap is no longer sufficient to maintain ionised air between the electrodes and the "switch" is open. This happens hundreds of times a second producing high frequency (radio frequency) AC current through the primary coil. The capacitor and primary coil produces an LCR (inductor-capacitor-resistor) circuit that resonates at a high resonant frequency.

The secondary coil and top load also create an LCR circuit that must have a resonant frequency equal to the resonant frequency of the primary circuit. The high resonant frequency coupling of the primary coil with the secondary coil induces very high voltage spikes in the secondary coil. The top load allows a uniform electric charge distribution to build up and lightning like strikes are produced from this to a point of lower potential, in most cases ground. The coupling between the primary and secondary coils do not act in the same way as a normal transformer coil would but works by high frequency resonant climbing or charging to induce extremely high voltages. The true physics is still not completely understood but can be modelled experimentally.

ISBN: 978-81-929339-1-7

IV. DESIGN OF TESLA COIL

High Voltage Power Supply which is the most essential part of the tesla coil design. There are a number of alternative power supplies that can be used for Tesla coils. The neon sign transformer (NST) is the most common power supply used. These are used to power neon gas tubes for commercial sign purposes. Their voltage output can vary from about 2,000V to 15,000V and can have a current output from about 10mA to 120mA. There are two different types of NST the older iron cored and the newer switch mode NST. Spark gap is another important part of the tesla coil. Spark gaps are the "brain" of the Tesla Coil and they are high the voltage switches that allow the tank circuit capacitance to charge and discharge. As performance of the spark gap switch is improved, peak powers in the tank circuit grow without requiring additional input power. When a good coiler sets up and fires a system, the first thing he looks at is his ground. The second thing he looks at is his spark gap system. There are mainly three way of spark gap arrangements static spark gap, rotary spark and gap combined. The static spark gap is a simple high voltage switch that is very easy to make and operate. As the tank capacitor charges from the high voltage power supply, the potential across the static spark gap electrodes increases until the air between the spark gap ionizes allowing a low resistance path for the current to flow through; the "switch" is closed.

A high voltage spark gap becomes very hot during operation and the ionized air surrounding the spark gap will keep the switch closed for longer than desired. It is therefore common for a static spark gap to make up of many smaller spark gaps aligned in series this will reduce the heat produced and dissipate the heat created more effectively. It is also common practice to integrate a fan to quench the spark gap which will blow away the ionised air quickly and help to keep the electrodes cool. Quenching the spark gaps allow the "switch" to be open and closed quicker which will allow the primary circuit to produce higher firing frequency pulses. A more advanced spark gap is the rotary spark gap where multiple electrodes on a rotating disc pass two fixed electrodes. The rotating disc is powered by a synchronous motor to allow an easy method of varying the spark gap firings. This also helps to keep each electrode cool as there are many electrodes where only two on the rotating disc are firing at one time. An ideal material to use for the spark gap electrodes is tungsten rods as they resist ware and tarnishing due to prolonged use in spark gaps.

High voltage capacitor bank consists of a high voltage capacitor rated at about two or three times the RMS voltage rating of the high voltage transformer, so if you have a NST rated at 10,000 VAC its RMS voltage would be ~14,000VAC, so the tank capacitor must be able to withstand ~40,000 volts. This is because the primary circuit can have many very high voltage peaks present when in operation which can damage a too lower rated capacitor. The tank capacitance usually varies between about 1nF to about 50nF depending on the resonant properties of the primary circuit design.

There are a number of alternative methods for obtaining high voltage capacitors. A very common method of producing such a capacitor is to create an array of smaller rated

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capacitors, known as an MMC (Multi Miniature Capacitor). The individual capacitors are set in parallel and series combinations to get the desired voltage and capacitance rating.

The following two equations are used for calculating the combined total capacitance parallel and series arrays:

$$C_{parallel} = C_1+C_2+C_3+........+C_n \qquad C_{series}=\frac{1}{\frac{1}{C\,1}+\frac{1}{C2}+\frac{1}{C3}+\cdots\frac{1}{Cn}}$$

$$C = \frac{10^6}{6.283 \times Z \times f}$$

$$where\ z = \frac{E}{I}$$

For our design E=2KV Output of HV T/R and I=2mAout current of HV T/R & C=3.1nF

Adding capacitors in series effectively doubles their voltage rating, whilst adding capacitors in parallel has no effect on the voltage rating. High voltage (~1,000V) polypropylene capacitors are usually used for MMC types of tank capacitor. This method can be quite expensive due to the number of capacitors needed, depending on the design some can have over 100 individual capacitors.

There are three main types of primary coil (inductor): spiral, helical and inverse conical. Helical coils are wound into a helix of equal diameter. Spiral coils (or pancake coils) are wound into a flat spiral. Helical coils are wound into a vertical helical spiral. Inverse conical coils are wound into a conical spiral with an inclined angle of 30° to 45°.

The inverse conical coil and spiral coil are far more common and both can be used in small and medium power Tesla coils. For larger high power (1000W and over) Tesla coils the spiral primary coil design is best. In this paper the spiral coil design for all power ranges of Tesla coil due to its simplicity and no obvious difference in efficiency from that of the inverse conical coil design. The coil is made from hollow copper tubing (micro bore) with a diameter of about 6-8mm. A frame is constructed to support and fix the copper coil in place. The frame is usually made from sheets of a good insulator like polypropylene (plastic chopping boards are a good source for this).There is a reason for using hollow tubing known as the skin effect. So for higher frequencies, the centre of the conductor is not used or available for the current to pass through. Using a solid conductor is just wasteful not required, so for high frequency applications tubing is ideal for use as a conductor. Coil diameter (D) =2.5inches (63.5mm) No. of turns (N) =12, Wire diameter (W) =5mm, Turn spacing (S) =10 mm So, Inductances of coil (L) = 46.45µH, Self capacitance (C) = 3.353 pF, Height of the coil (H) = 20 cms

The skin depth can be calculated using the following equation: $\delta=\frac{1}{\sqrt{\pi\mu f\sigma}}$

Where f is the frequency of the current in the conductor, µ is the relative permeability of the conductor material and σ is the electrical conductivity of the conductor material.

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The approximate dimensions for the secondary coil are the height of the coil should be about 5 to 7 times the diameter of the pipe used and the number of turns on this pipe should be about 1000. A good starting diameter for a Tesla coil is around 60mm to 80mm. I believe it is easier to design and make the secondary coil and top load first and build the other components of the Tesla coil around these components as the other components can be adjusted more easily whereas the secondary coil and top load are fixed once built.

The top secondary winding is directly connected to a top load discharge terminal usually in the form of a toroid or sometimes a sphere. The bottom secondary winding is directly connected to an excellent RF ground connection.

The inductance of the secondary coil is calculated using the same equation above for the helical primary coil. The self capacitance of the secondary coil is given using the Medhurst equation. This equation is only an approximation but is sufficiently accurate to allow an inaccuracy of only a few Pico-farads. Medhurst equation:

$$C = 0.29\ L + 0.41\ R + 1.94\sqrt{\frac{R^3}{L}}$$

Where C is the self capacitance in Pico-farads, L is the length of the coil in inches and R is the radius of the coil in inches.

The capacitance of the toroid is approximated by the following equation:

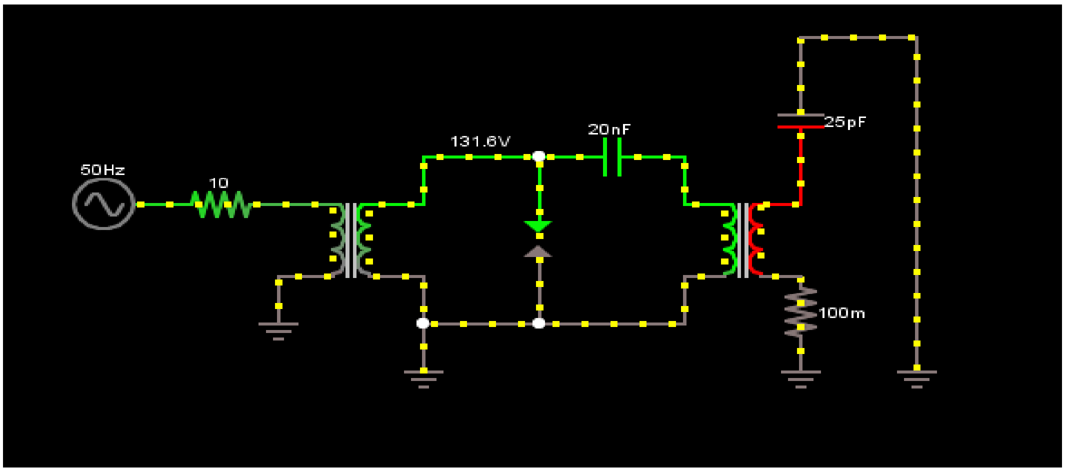
$$C = 1.4\left(1.2781 - \frac{D_2}{D_1}\right)\sqrt{\pi D_2(D_1 - D_2)}$$

Where C is the capacitance of the toroid in Pico-farads, D1 is the total outer diameter of the toroid in inches and D2 is the diameter of the cross section of the toroid in inches, i.e. the diameter of the tubing used for the toroid.

The total capacitance of the secondary coil and toroid is not quite the sum of the two but about 80% to 90% of their sum, so an efficiency factor is introduced to their sum. This is due to their close proximity which causes the toroid to shield some of the secondary coil surface area from ground reducing their self capacitance. This is not too important as this discrepancy can be overcome by tuning the primary coil with the secondary later.

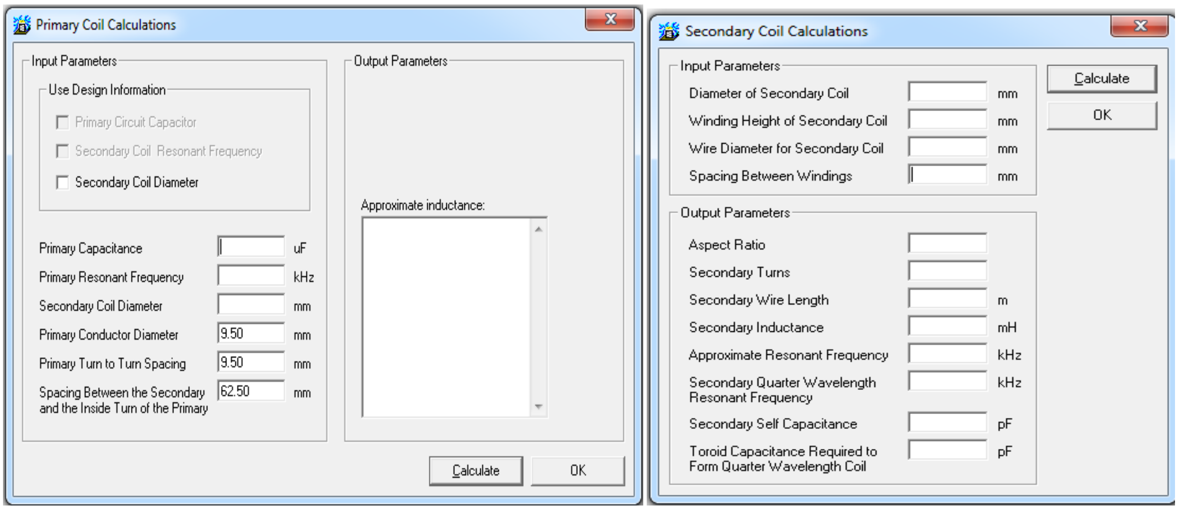
V. SIMULATION AND RESULTS

JAVA CIRCUIT SIMULATOR for making the simulation of TESLA COIL.



A transformer steps the input voltage up 100x to create a high voltage. After a few seconds, the voltage is high enough to fire the spark gap. The capacitor and the primary coil of the second transformer then form a resonant circuit. The secondary transformer coil is attached to a toroid, represented here by a capacitor connected to ground. It also forms a resonant circuit with the same resonant frequency, about 200 kHz The energy is gradually transferred from the first circuit to the second, and then the spark gap stops conducting, leaving all the energy in the toroid circuit.

Once the spark gap stops conducting, it takes a while for the voltage to build up enough for it to fire again. The simulation speed is slowed down quite a bit so that the 200 kHz oscillations can be seen. You might want to reload the circuit instead of waiting. TESLA COIL CAD VERSION 2.0 is used for calculation of the winding parameters.



We can easily find the length, Diameter, capacitance, winding turns and other parameters.

VI. CONCLUSION

Java circuit simulator is very useful software for tesla coil design. Simulation model of TESLA COIL is very helpful for component selection for experimental set up. We are able to generate high voltage with high frequency and it can be used for testing the apparatus for switching surges. It can also be used for study about visual corona and ionization of gases under the high electrical stress. It can also transmit the electrical power wirelessly up to certain distance depends upon its rating which holds the great future of wireless energy transmission.

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