Design and Fabrication of Tesla Coil

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ABSTRACT

Tesla Coil is a device which is used for obtaining high voltage at high frequency. The purpose of construction of Tesla coil is to be able to deliver power other than conducting wires or transmission lines i.e. wireless power transmission. Tesla invented his coil with the intention of transmitting electricity through the air medium. He conducted much research in this area. The Tesla coil uses high frequency transformer action and resonant voltage amplification together for the generation of very high potential in the range of tens to 100 kV. It is easiest way to produce very high voltage at the maximum value in order of MV using high resonant frequency and maximum voltage is obtained. Tesla coil circuits were used commercially in spark gap radio transmitters for wireless telegraphy until the 1920s,and in electrotherapy and pseudo medical devices such as violet ray. Today, their main use is entertainment and educational institutes for research work. In many commercial applications and educational institute there is need to develop equipment for testing against switching & lightning surges. Also there is need to design equipment's to study visual corona and ionization of gases under the electrical stress. Typical Tesla coil which normally has mobility issue due to their bulky size. The proposed design has similar functionality as that of typical Tesla coil with comparatively small size. This paper explores the simple construction theory and design of 5 to 10 KV tesla coil for laboratory application.

Keyword - *Transformer, Toroid, capacitor bank, spark gap.*

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1. INTRODUCTION

Tesla coil was developed in 1891 by Nikola Tesla; the tesla coil was created to perform experiment in creating high voltage electrical discharges [2]. It consists of a power supply, capacitor and coil transformer set so that voltage peaks alternate between the two and electrodes set so that sparks jump between through the air.

The tesla coil an air core resonant transformer which generate the high output voltage. A capacitive electrode in the form of a smooth metal sphere or torus attached to the secondary terminal of the coil [2].

Generally the tesla coil use to conduct a experiments in electrical lightning, X-ray generation, high voltage high frequency ac current phenomena, electro therapy in medical field and wireless transmission of electricity [5].

2. WORKING PRINCIPLE

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 ionizes 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 ionized 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 [4].

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.

3. CONSTRUCTION

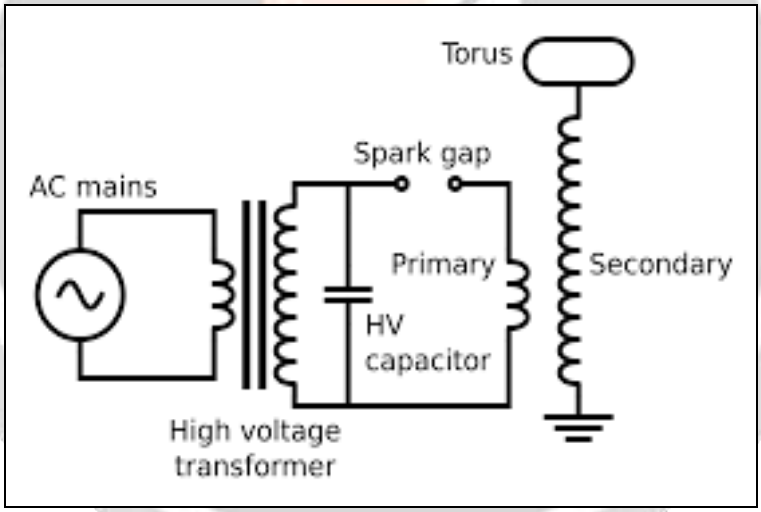

Fig 1. Typical Tesla coil circuit [6]

The Tesla Coil is a machine for generating extreme high voltages; it is a high voltage air core resonant transformer. Tesla coil has 6 basic components. The first one is the primary transformer. Second is the capacitor, which is a high voltage capacitor that is usually homemade, but can be purchased for high price from commercial suppliers. Another one important part is the spark gap; two conductors are separated by small air gap to produce spark gap.

Forth is the primary coil consisting about 8 to 12 turns of thick heavy gauge wire wound around the base of the secondary coil. Fifth is the secondary coil and it consisting of many hundreds of turns of relatively thin, small gauge enamel wire. The primary and secondary coil makes up an air core transformer. That means that there is no iron core inside the coil. Sixth basic component is the toroid. The toroid is generally made up of aluminium sheet and it is placed on the top of the secondary coil. The high voltage spark radiate in all direction from surface of the toroid.

4. DESIGN

Tesla coil transformer design employs a medium to high voltage power source, one or more high voltage capacitors and spark gap to excite a multiple layer primary inductor coil with periodic burst of high frequency current. The primary and secondary circuit both being tuned so they resonate at the same frequency

Coil is implemented as an air core transformer. The primary and secondary coil is placed co-axially and the magnetic circuit is represented only by the ambient air. Energy from primary to the secondary coil is travelled through air gap only at operating frequency. The operating frequency is also the resonant frequency of the secondary coil, which forms a resonant circuit. The inductance of the secondary winding is formed by the number of coil turns and conductor cross- section.

Requirement for the operating frequency of our Tesla coil is in the range above 10 kHz.

The output voltage in resonant and always a sine wave. The effective value of the output voltage is proportional to the primary voltage and transformation ratio.

4.1 Secondary Coil*:*

The coil is made up of purely inductive material. It is wound on PVC pipe. The toroid is placed on the top of the secondary coil. This design makes the secondary LC circuit. Generally the secondary coil wound with 700- 1200 turns. Some secondary coils can have almost 2000 turns. Magnet wire is used to wind the coil.

- There's always a little space between turns, so the error factor are introduced in the equation which assumes the coil turns are 97% perfect [7].

$$\text{Secondary Coil Turns} = (1/\text{Magnet wire diameter} + 0.000001) \times \text{Secondary Wire winding Height} \times 0.97 \quad \text{……..(1)}$$

- The capacitance of the secondary coil will be used to calculate the secondary LC circuit resonate frequency. Coil dimensions are given in inches [7].

$$\text{Secondary Capacitance (PF)} = (0.29 \times \text{Secondary wire winding Height} + (0.41 \times (\text{Secondary Form Diameter} / 2)) + (1.94 \times \sqrt{\text{Secondary Form Diameter} / 2})^3) / \text{Secondary Wire winding Height})) \quad \text{……..(2)}$$

- The height to width ratio should be about 5:1 for small Tesla coil, 4:1 for average sized Tesla coils about 3:1 for large Tesla coils .

Secondary Coil Capacitance is given by

$$C = 1.4\left(1.2789 - \frac{D1}{D2}\right) * \left(\sqrt{\pi D2(D2 - D1)}\right) \quad \text{……..(3)}$$

Where

C = Capacitance in Pico farad

D1 = Outside Diameter of toroid in inches

D2 = Diameter of cross section of toroid

- Secondary Coil Inductance is given by

$$L = \frac{(NR)^2}{9R + 10H} \quad \text{……..(4)}$$

Where

L = Inductance of coil in micro henrys (µH)

R = Radius of coil in inches

N = number of turns

W = width of coil in inches

4.2 Primary Coil:

The primary coil is used with the primary capacitor to create the primary LC circuit. The primary coils also responsible for transferring power to the secondary coil.

The Primary Coil is usually flat, called a pancake coil. Some smaller tesla coil use vertical helix shaped primary. For the primary coil copper tube is used. There should be ¼ inch spacing between each turn.

Coil Inductance is given by the

$$L = \frac{(NR)^2}{8R + 11W} \quad \text{……..(5)}$$

Where

L = Inductance of coil in micro henrys (µH)

R = Radius of coil in inches

N = number of turns

W = width of coil in inches

4.3 Toroid:

The top load is used with the secondary coil to create the secondary LC circuit. Generally a toroid or sphere shape is used. The ring diameter refers to the widest length from edge to edge of a toroid shape. We have to find several equations for different sized top loads. Without knowing which is the most accurate in any case, we use the average of all the equations [7].

$$\text{Toroid Capacitance 1} = ((1 + (0.2781 - \text{Ring Diameter} / (\text{Overall Diameter} - \text{Ring Diameter}))) \times 2.8 \times \sqrt{((\pi \times (\text{Overall Diameter} \times \text{Ring Diameter})) / 4)} \quad \text{.....(6)}$$

5. RESONATING FREQUENCY

Resonating Frequency is given by

$$F = \frac{1}{2\pi\sqrt{LC}} \quad \text{.....(7)}$$

Where

L = Secondary Coil Inductance

C = Toroid Capacitance

Same calculations should be done for primary side as well secondary side

6. CONCLUSION

The goal of this project is to extend knowledge of electrical engineering And High Voltage Engineering. The coil is design is capable of producing spark at input voltage of 5-10kV

After studying and developing the model of TESLA COIL we came to following conclusion:

- 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 of visual corona and ionization of gases under the electrical stress.
- It can also transmit the electrical power wirelessly up to certain distance depends upon its ratings.

7. REFERENCE

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