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Design and Study of a Small Tesla Coil for Wireless Power Transmission in Domestic Sector

[1] Anandita Goswami [2] Diptanu Dey [3] Bharat Kumar Boyanapalli [4] Prasenjit Debnath
[5] Rajnish Kumar Chaudary
[1] Department of Electronics & Communication Engineering,
[2][3][4][5] Department of Electrical Engineering
National Institute of Technology
Agartala

***Abstract*:-- This paper has focused on the step-by-step design of a high frequency medium size (1-3 kW) air-cored resonance transformer commonly called tesla coil, that can be easily used for measurements and general research. Therefore, the task is to minimize the number of stochastic and unknown parameters influencing the device functionality and pointing out pros and cons of each solution. The physical dimension of the tesla transformer has been chosen due to cost effectiveness and availability of the regarding components. This design has mainly two units' viz., a power supply and tesla coil. The power supply which fed the Tesla coil having voltage rating 12kV and current rating 120mA has been designed by using three microwave oven components. These components are assembled as dual MOTs voltage doubler circuit and necessary simulation has been carried out by using MicroSimSchematics for the verification of performance.**

Index Terms:--Microwave Oven , Transformer, Multi mini Capacitors, MicroSim Schematics, Toroid, Tesla Coil CAD

I. INTRODUCTION

A Tesla coil is a special type of transformer which takes up the primary voltage to a significantly higher secondary voltage. This secondary voltage is fed to a metallic dome or toroid circuit for dissipation of electric equipotential line. When an apparatus is within a limit such that it receives significant amount of electric flux, the apparatus starts working. Another method states that these electric lines can be converged and collected by another metallic dome and can be stepped down so that it can be fed to any regular apparatus. In the first case, only those apparatus that operate on very high voltages like fluorescent lamp, CFL, CRT, etc can be operated directly using a Tesla coil. When the Tesla coil emits electric flux, it comes in terms of kilovolts and miliamperes. As the Copper losses are dependent on current , Tesla coil significantly reduces such losses.

II. DESIGN OF TESLA COIL

Cylindrical Primary Coil Design

The primary coil was designed the a cylindrical one, made of PVC coated conducting wire. For the secondary coil to move freely inside the primary coil, the inner diameter of the primary turn must be a bit more than the outer diameter of the secondary coil. For optimal performance, secondary and primary circuits must have the same resonance frequency. The value of the primary capacitor is taken as 0.033µF. Now, the primary inductance may be calculated by the equation (1)

$$L_p = \frac{1}{C_p}\left[\frac{1}{2\Pi f s}\right]^2 \quad \text{.......... (1)}$$

The cylindrical coil is also better for compact design. It distributes the flux evenly to the secondary, and doesn't cause much variation in flux density. It is also easier to place in domestic households as it requires less space.

Pole Type Secondary Coil Design

The secondary diameter and height (D/H) ratio has been chosen as 1:5. As per the position of a typical household, it was decided that secondary coil height should be 50cm and to maintain the D/H ratio, suitable coil diameter is 10cm. The 26 SWG (diameter of 0.457mm) magnet wire is used for secondary coiling through out 55cm. Since, no spacing between the turns, thus total number of turns are above 1100. The secondary inductance is given by Wheeler's [4] emperical equation (2).

$$L_s = \frac{R_s^2 N^2}{2540\,(9\,R_s + 10\,H)} \qquad (2)$$

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Where; Ls is secondary inductance (mH), Rs is secondary radius (cm), H is secondary height (cm), N is number of turns.

The secondary self capacitance is estimated by a formula due to Medhurst [5] is given in equation (3).

$C_s = KD$……………………(3)

Where; Cs is secondary self capacitance (pF), D is secondary diameter (cm), K is a constant depending on the D/H ratio.

The self- resonance frequency of the secondary without top load is given in equation (4).

$$F_s = \frac{1}{2\Pi\sqrt{L_s C_s}} \quad \text{………………..(4)}$$

Where; Fs is self-resonance frequency of the secondary (kHz), Ls is secondary inductance (mH), Cs is secondary capacitance (pF).

c. Toroid design

The selected top terminal [6] is a toroid with an outer diameter d1 and a cross-section diameter d2.The toroid capacitance is calculated from the following emperical equation (6).

$$C_{top} = 2.3(1.2781 - \frac{\quad}{d_1})\sqrt{0.1217 d_2 (d_1 - d_2)}$$

Where, Ctop is toroid capacitance (pF), d1 is toroid outer diameter (cm), d2 is toroid diameter .

III. CURRENT LIMITING AND SAFETY

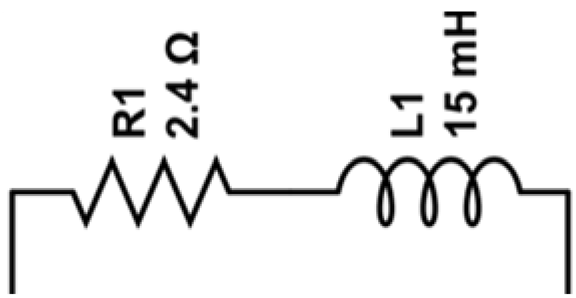

Figure 1: Resistance-inductor assembly

In order to limit the current flowing through the coil, an assembly of resistor of 2.4Ω and inductor of 15 mH is added in series. This restricts the current to 2A.

IV. RESULTS:

After the Tesla Coil was ready, the Voltage and current was measured at various points by placing the receiving arrangements at various intervals. The received values of Voltage and Current was multiplied to get the value of received power. The ratio of received power anddissipated power indicates the efficiency of the transmission. This efficiency was measured at various distances from the dissipating coil, and the graph was plotted as shown in figure 2.

As shown in the graph, the efficiency of the system is more or approximately equal to 40% till 5 metres. A typical domestic household can be well covered within 5 metre radius.

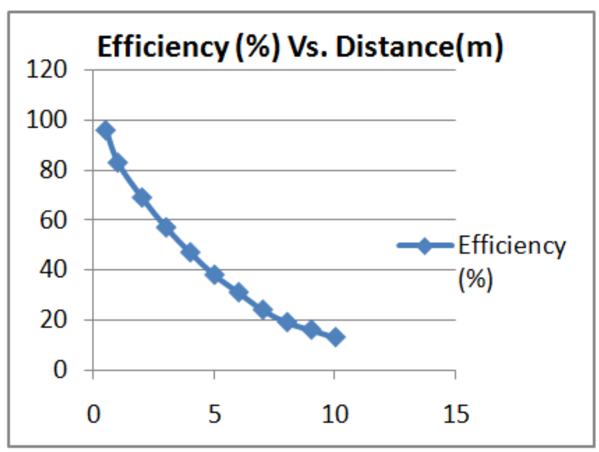

Figure 2: Efficiency Vs. Distance graph for the Tesla Coil

Direct Applications of wireless power transmission using Tesla Coil include Fluorescent lamps where high voltage and low current is required. Furthermore there is no requirement of choke or ballast as Tesla coil is already suppyilng high voltage.CFL also can run directly by the use of Tesla coil. Relatively smaller Neon Signs can be powered by the use of similar Tesla coils. Besides CRT appliances like Televisions, Biomedical monitors can be powered directly by similar Tesla coils.

Indirect applications of Tesla coils involve the convergence of electric lines which can be collected by another metallic dome and can be stepped down so that it can be fed to any regular apparatus which include fan, pumps, inductive loads, Incandescent Lamps.

Therefore ultimately the usage of Tesla Coils provide excellent transportation in short range (1-2m radius) with almost no loss transmission along with negligible current hazards (max 2 mA) and is amazingly cost effective and almost maintenance free.

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