Design and Construction of a Portable Tesla Coil

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Introduction

What is a Tesla Coil?

A Tesla coil is an air-core resonant transformer which generates a very high secondary output voltage at a very high frequency. It is able to produce a secondary output voltage of 100kV and above, at a frequency ranging from 50kHz to 500kHz. Unlike normal transformer, voltage rise in a Tesla coil does not depend on the ratio of windings between secondary and primary, instead the voltage rise depends on the resonance effects between primary and secondary.

Basic Circuit Operation

The primary transformer is to step up the mains voltage of 240V to a high output voltage of 8kV or higher. The high output voltage from the primary transformer charges the primary capacitor through the primary coil. This charging lasts until the breakdown voltage of the spark gap is reached. At the breakdown point, the spark gap begins to fire and acts as a very fast switch which now closes the primary tank circuit (refer to Fig. 2). The primary tank circuit acts as a resonant LC circuit resonating at high frequency ranging from 50kHz to 500kHz. The resonance frequency is determined by the L and C values of the primary coil and primary capacitor respectively.

The energy stored in the primary capacitor is now transferred to the primary coil. An electric field is generated by the primary coil and surrounds the secondary coil. The secondary coil absorbs this energy and magnifies the voltage further. The secondary coil together with the toroid on its top is also an LC circuit. The secondary LC circuit must resonate at the same frequency as the primary tank circuit in order to achieve a high secondary output voltage. The high secondary output voltage is found at the toroid. If the toroid is small, sparks will break out from the toroid. If the toroid is big, an electric field will radiate in all directions from the toroid.

The energy in the primary tank circuit will decrease and the voltage will be too low to keep the spark gap arcs running. Hence, the primary tank circuit is open-circuited. The primary capacitor will then be charged until the spark gap will breakdown again.

Testing

Under the normal operation of the quenched gap (i.e. the brass blot is fully tightened and hence there is no extra gap) there is no spark output from the toroid, however there is an electric field generated around the toroid. This generated electric field is able to light up any neon tube or fluorescent tube nearby. Moreover, the quenched gap is very quiet during its normal operation (just a slight hissing sound). The picture (above right) shows the performance of the Tesla coil under the normal operation of our quenched gap. Notice the neon tubes were not connected to any wire.

By loosening the brass blot of the quenched gap by 8mm, giving a total gap length 14.6mm, the Tesla coil could give its best performance (i.e. long sparks output from the toroid). However, the operation of this quenched gap is no longer quiet. The picture below shows the performance of the Tesla coil with the quenched gap having an extra 8mm gap (by loosening its brass blot).

Measured Electric Field Waveform at an Aligned Distance of 2m from the Toroid