

A LOW COST APPROACH TO DESIGN THE TESLA TRANSFORMER FOR TESTING OF INSULATING MATERIALS

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ABSTRACT

A high voltage with high frequency oscillation waveshape, nowadays, is used as a standard test for electrical power equipment. A Tesla transformer is one of the sources that can generate such a waveshape. This paper presents a design and a construction of a Tesla transformer used in insulator tests. The output of the transformer has a rate of 200 kV and 200 kHz. The output waveshape is controlled based on the L-C resonance circuit. The transformer is implemented for insulator tests. It is found that the accuracy of the output obtained from the Tesla transformer is in the satisfactory level.

INTRODUCTION

High frequency and high voltage supplies are required for many applications such as in an input part of high voltage DC generators. In the insulation tests, the high frequency and high voltage waveshapes are used [1,2,3,4]. There are two types of such waveshapes: undamped high frequency oscillation and

damped high frequency oscillation. The first one is used in telecommunication applications, while the latter is used in insulation tests for electrical power devices.

A Tesla transformer is one of the sources that can produce the damped oscillation in high frequency and high voltage waveforms. Operations of the Tesla transformer are based on a resonance circuit. This paper shows a design procedure of the Tesla transformer. The construction of the transformer is based on local components available in Thailand. The application of the Neon sign transformer as a source for the input part of the Tesla transformer is presented. The output obtained from the Tesla transformer during a test of insulators is illustrated.

DESIGN PROCEDURES

The basic circuit diagram of a Tesla transformer is shown as Figure 1. The primary winding and the secondary winding of the transformer are linked using the air core. The quenching gap (QG) is used as a switching device. On closing the gap, the current can flow in the

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primary winding, and this can induce the high frequency oscillation in the secondary winding. The frequency of the output waveshape can be controlled using Equation 1 [1,2]:

$$f = \frac{1}{2\pi\sqrt{L_1 C_1}} \quad (1)$$

where,

f = the oscillation frequency of an output wave shape

L_1 = the inductance of the primary winding

C_1 = the capacitance at the primary side.

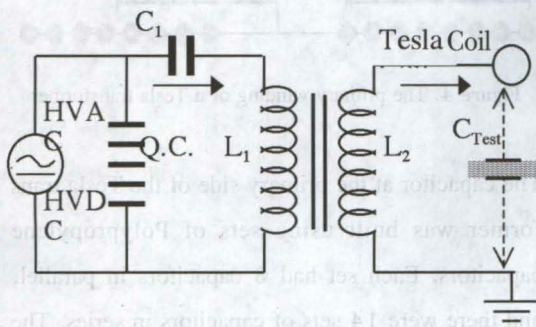


Figure 1. A circuit diagram for a Tesla transformer

In order to design a Tesla transformer, the capacitance at the secondary side of the transformer has to be known. The capacitance consists of the load capacitance, the stray capacitance of the winding, the capacitance of a sphere gap and the capacitance of the electric stress control device. When the output frequency is designated, the inductance of the winding can be determined using Equation 2 [1,2]:

$$f = \frac{1}{2\pi\sqrt{L_2 C_2}} \quad (2)$$

where,

f = the oscillation frequency of an output waveshape

L_2 = the inductance of the secondary winding

C_2 = the total capacitance at the secondary side.

Due to that the current flowing at the secondary side of the Tesla transformer is in the shape of pulses comprising high frequency components, the size of the conductor used in the secondary winding has to be designed by taking into account the skin effect. The copper wire was used in the secondary winding. The winding was wound in the form of a cylindrical shape on a PVC tube. Equation 3 was used to adjust the value of the inductance of the winding in order to be related to that of Equation 2[4, 5, 6].

$$L = \frac{(NR)^2}{9R+10H} \quad (3)$$

where,

L = the inductance (in micro-Henries)

R = the radius of the coil (in inches)

N = the number of turns

H = the height of the coil (in inches).

The stray capacitance of such a winding can be calculated using Equation 4 [4,5,6].

$$C_s = 0.29H + 0.41R + 1.94 \sqrt{\frac{R^3}{H}} \quad (4)$$

where,

C_s = the stray capacitance (in pico-Farads)

R = the radius of the coil (in inches)

H = the height of the coil (in inches)

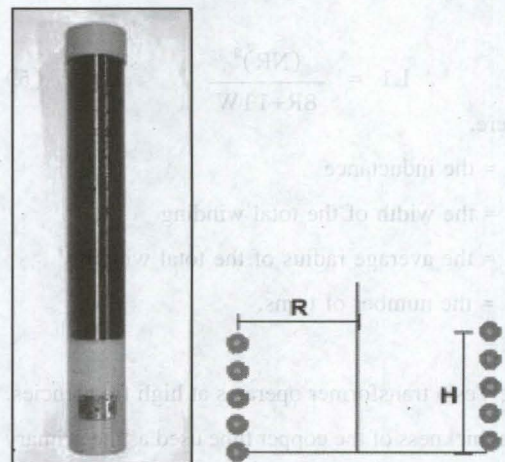


Figure 2. Secondary winding of the Tesla transformer

The Neon transformer which can produce a high voltage for Neon lamps is selected as a source for the primary side of the Tesla transformer. The Neon transformer has a rate of 220/1500 V and 30 mA. Two Neon transformers are connected in parallel so that the output current can be increased.



Figure 3. Neon transformers used as a source

For the transformer used for transferring the high frequency and high voltage waveshapes to the output, conductors of the primary winding has to be designed so that such conductors are able to with stand the high current pulse due to the short circuit operation of quenching gaps. The primary winding was built using the copper tube. The primary winding was wound in the shape of the flat spiral. The inductance of such a winding was calculated using Equation 5[4,5,6].

$$L1 = \frac{(NR)^2}{8R+11W} \quad (5)$$

where,

L = the inductance

W = the width of the total winding

R = the average radius of the total winding

N = the number of turns.

The Tesla transformer operates at high frequencies. The thickness of the copper tube used as the primary winding has to take into account the skin depth effect.

The skin depth was calculated at the output frequency (200 Hz), and the thickness of the tube was selected to be higher than that.

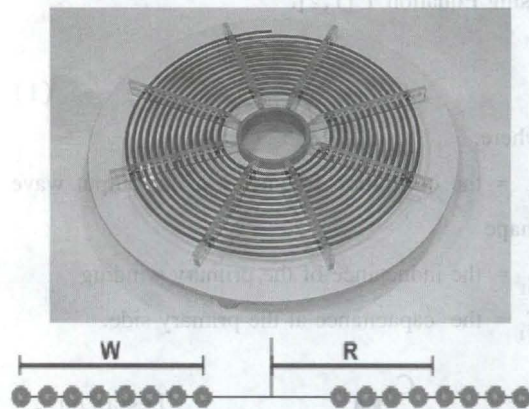


Figure 4. The primary winding of a Tesla transformer

The capacitor at the primary side of the Tesla transformer was built using sets of Polypropylene capacitors. Each set had 3 capacitors in parallel, and there were 14 sets of capacitors in series. The total capacitance from the measurement was around 12.9 nF. The capacitance is shown as Figure 5.

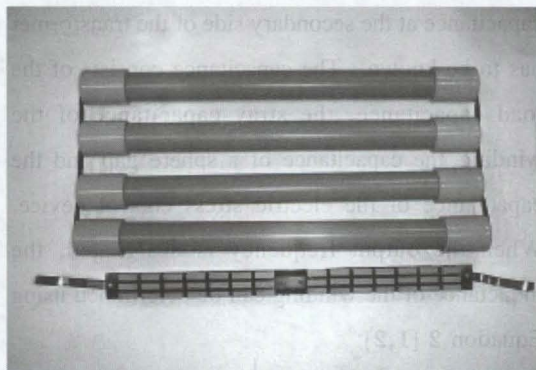


Figure 5. The capacitance at the primary winding

The quenching gap was constructed using copper tubes. There were 10 gaps in series, and the distance of the gap was 0.75 cm. This is as shown in Figure 6



Figure 6. The quenching gaps

APPLICATIONS OF A TESLA TRANSFORMER IN INSULATOR TESTS

A Tesla transformer was assembled as shown in Figure 7. The transformer was designed at a rate of 200kV and 200 kHz. The object used for implementing the transformer was a porcelain insulator employed in a 24-kV distribution system. Figure 8 shows the output waveshape of the transformer.

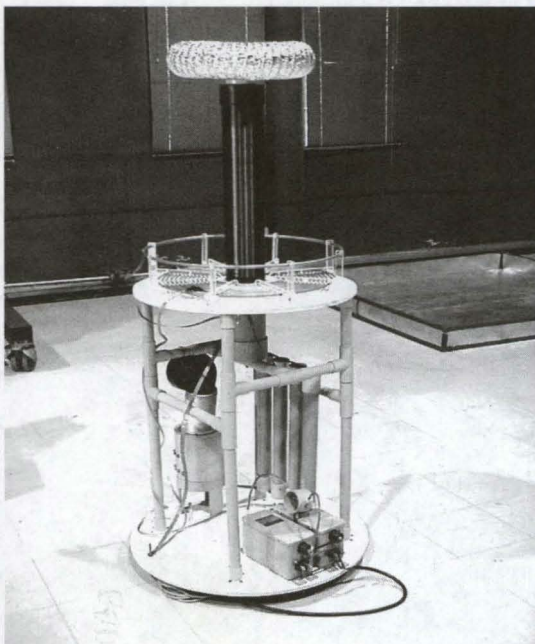


Figure 7. A Tesla transformer

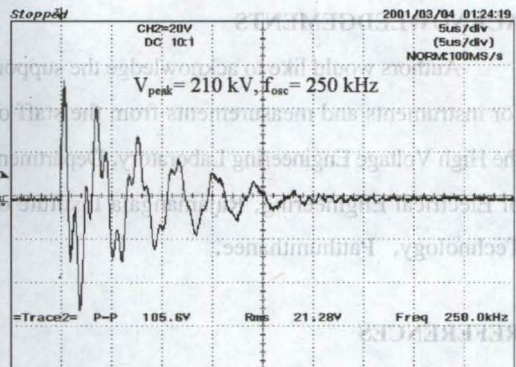


Figure 8. Output waveshape from the Tesla transformer

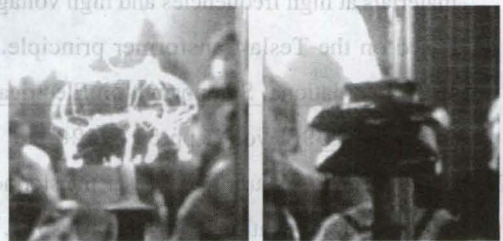


Figure 9. Tesla transformer testing insulator

CONCLUSIONS

A Tesla transformer has been designed and assembled. All components used in the transformer are available from local suppliers in Thailand. A Neon transformer has been used as a source for the transformer in order that the size of the transformer can be reduced. The transformer has been implemented in tests of porcelain insulators. It has been found that the amplitude and the oscillation frequency of the output waveshape are slightly different from those obtained in calculations. This is due to that formulas used in calculations of inductances and capacitances are approximation ones and may not be accurate enough. Further work will be the improvement of the design, the analysis of equivalent circuits and the determination of exact values for inductances as well as capacitances.

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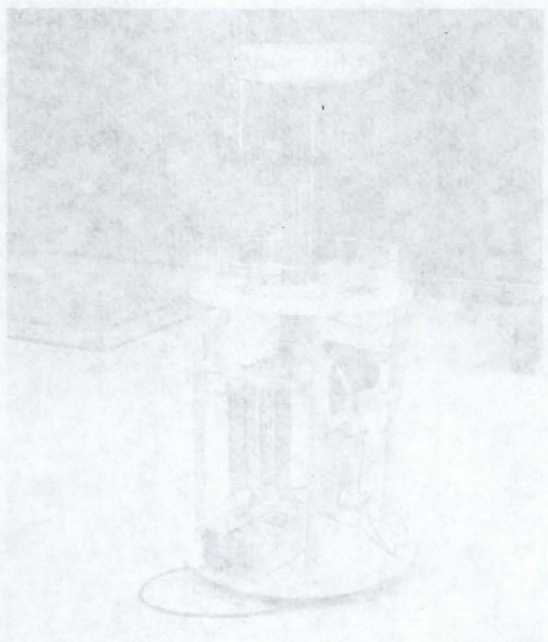


Figure 7 A Tesla transformer