

Design and Simulation of Tesla Coil as a Resonant Transformer

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Abstract - Nikola Tesla is the responsible person that invented Tesla Coil, a type of resonant air cored transformer, used to generate high voltage and low current electricity. Even though the Tesla Coil is an old invention, there are useful for developing many devices today. The Tesla Coil is used to conduct innovative experiments in electrical lighting, fluorescence, x-rays, wireless energy transfer for electrical power transmission and also for educational purposes. Tesla coil designs employed high voltage alternating current power source, high voltage capacitor, and a spark gap to excite the primary side of the Tesla coil system with periodic bursts of high frequency current. The primary and secondary coil is designed in order to resonate at the same frequency. Thus, this paper presents to design and simulate the Tesla Coil as resonant transformer using low direct current (dc) voltage as primary input instead of alternating current (ac) voltage and will produce an ac high voltage at secondary circuit side. This project will prove that even though the input is only a low DC voltage, the Tesla Coil will be able to step up the input voltage and simultaneously generate a high voltage approximately 2kV at the secondary side by the simulation.

Keywords - *Tesla Coil, Low DC voltage, High AC voltage.*

I. INTRODUCTION

People already know about the Tesla Coil is more than a century ago and a significant of amount of articles and books have been written about its theoretical operation and its construction, also the advantages of it and it is a type of resonant transformer by generating high frequency pulses with several kilovolts to megavolts of amplitude, it emit electrical discharges that easily extend for several meters and remind natural lightening [1].

A classical Tesla Coil consists two stages of voltage increase where the first is a conventional iron core transformer that step up the line voltage to a voltage in the range of 12 to 50 kV and the second is a resonant air core transformer (the Tesla coil itself) which steps up the voltage to the range of 200 kV to 1 MV [4].

Following the original Tesla's concept, the emission of electrical discharges from the top of the transformer was an unwanted effect that he considered as the release of a "security valve" [1]. Confining the electrical energy to the conductors and preventing its leakage over their supports or to the ambient air in the form of electrical discharges always occurs when the electric surface density reaches a certain value also have some of the effects involved with its operation are unique to this kind of device [3],[1].

II. BACKGROUND STUDY

Although Tesla Coil is used the concept like a transformer, there are some differences between them. Transformer usually use ferromagnetic as its core meanwhile Tesla coil use only air as its core. Air core coils have lower inductance than ferromagnetic core coils, it always used at high frequencies because they are free from energy losses called core losses that occur in ferromagnetic cores, which increase with frequency. Unlike low frequency power transformers, no ferromagnetic "core" is used, and the windings are "loosely coupled" which means that typically only 10-20% of the primary's total magnetic field links with the secondary winding [5]. Unlike most transformers, output voltage of Tesla Coil is virtually independent of the turns-ratio of the secondary versus the primary. Instead, it is a function of the relative ratio of inductances or

capacitances between the primary and secondary. The result is, extremely high voltages can easily be generated.

As all we know, typical Tesla Coil usually has been made in large scale size and also using medium voltage or high voltage as an input supply. The bulky size of the Tesla Coil is a barrier to the transfer or mobility from one place to another. Besides, the high voltage input that supply to typical Tesla Coil is quite dangerous to the users.

To design a miniature Tesla Coil, the construction of typical Tesla Coil must be well studied. It still use the same concept and theoretical of typical Tesla Coil, but in a different approach. For example, spark gaps used in the Tesla Coil will be replaced to a relay. This is the different approaches but the aim of using it is still the same which spark gap is used as a switch to initiating the discharge of the tank capacitor into the primary winding of the Tesla Coil with the periodic time [2],[6]. The capacitor used to store energy from input source and then energy from the capacitors is transferred into the primary winding when the spark gap fires. For the primary and secondary coil ratio, the ratio of 1:100 will be used in order to step up the input voltage of 24 volt dc to 2 kilovolt ac at the output side.

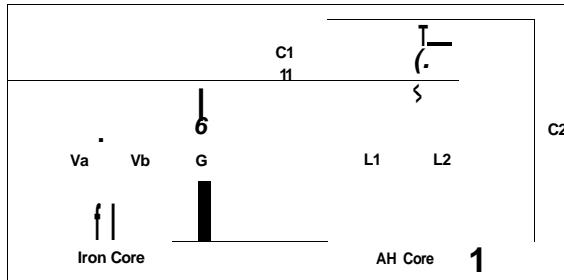


Figure 1 : The classical Tesla Coil

III. METHODOLOGY

This study focuses on how to design the Tesla Coil refers on characteristics and what is the suitable component to be used and relate to the objectives of this project. This following step according flowchart in Figure 1 is implemented to find objectives function of this project.

Step 1 : Make a literature review from the inventor's of Tesla Coil, past experimental and theory, and from the journals.

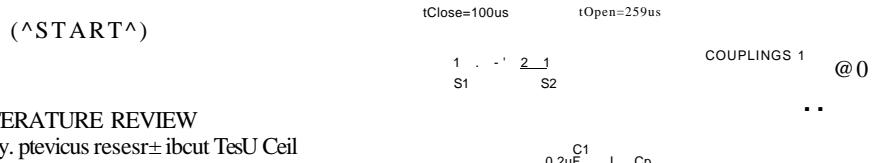
Step 2 : Identify the design of Tesla Coil including the dimension, input and output voltage required, frequency and the value of each component referred to the past researchers.

Step 3 : Design the basic Tesla Coil using the simulation on Pspice through the value of the components that had been calculated.

Step 4 : Testing the simulation using low DC voltage. In this case, the input of Tesla Coil is 24Vdc. The repetition did on simulation to get the desired output.

Step 5 : Get the data from the simulation and compare whether the output follows the characteristics of Tesla Coil or not.

Step 6 : Analyze the result and make some changes of the value of components to get the effect of the changes.



LITERATURE REVIEW
Tesla Coil rheory. previous researches about Tesla Coil

PRELIMINARY EXPERIMENTAL WORK

Identify the component to design Tesla Coil

EXPERIMENTAL WORK

Design the circuit using PSpice or MATLAB

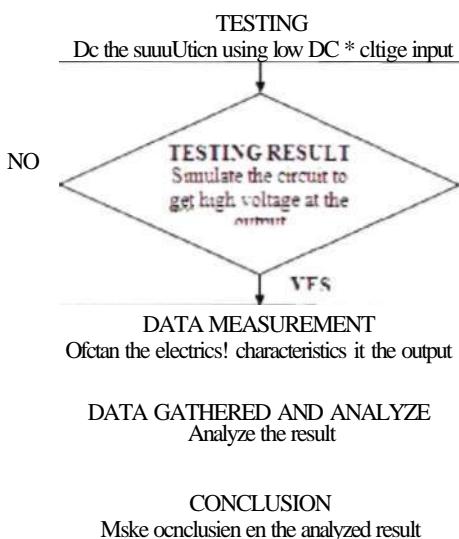


Figure 2 : The flowchart for designation of Tesla Coil.

IV. RESULT AND DISCUSSION

Simulation was conducted on Tesla Coil design using Pspice software. This project observed that the dimension and the values of the components are appropriate with the characteristics of Tesla Coil that have been analyzed from the theoretically, past experimental and some journals. The result was expanded with the changes of the value of each component. The value gives effects of the output of Tesla Coil.

The values of the components as follows;

- Input Voltage = 24V
- C1 = 0.2 uF
- C2 = 2.0nF
- L1 = 12 uH
- L2 = 1000mH

L1 VALUE=12uH L2 VALUE=1000mH

Figure 3 : The schematic diagram for basic Tesla Coil

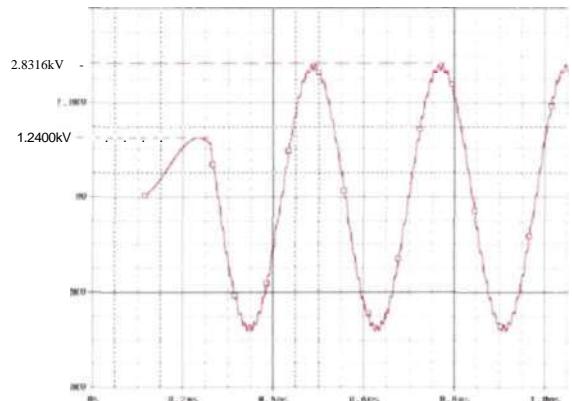


Figure 4 : The waveform of the output

After the simulation, the result of the output voltage and frequency as follows;

- Output Voltage = 2.8316kV
- Frequency
1 cycle = 558.156us - 276.876us
= 281.128us

$$f = \frac{1}{281.128\text{us}} = 3.555\text{kHz}$$

Refers to the amplitude of the voltage and the value of frequency, the simulation result is comply with the characteristics of Tesla Coil where the output voltage and the frequency were going up to kV and khz.

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24	6 ;	3.0	I:	1000	u : i i	:::6
24	0. 2	10 0	I:	1000	C " « «	i;S»
24	P :	...	*4	1000	: U M	; in
24	0.2	u	36	1000	1. "S"0	J.4S
24	0.2	I.0	4S	1000	1. "WS	iiii
24	0 :	2I)	i:	1000	3JI9S	::16
24	0:	:c	I:	3000	1.10::	1.0:S
24	0.:	:o	i:	3000	1. "093	L590
24	005	3 G	i:	1000	:sd-:	3 55S
*	0 10	:o	i:	1000	: KM	1 " i
24	015	:o	i:	1000	:s;:«	5 550

mw changes' atue

Table 1 : The result of the changes values of L1, L2, C1 and C2

From the observation, the changes values of inductor L1 and L2 gives the similar effects to the output voltage. The larger value of inductor L2 performs that high voltages produces than inductor L1. This because formed as an electromagnet or transformer. An electrical inductor stored energy in the magnetic field formed when current flow through the coil. This energy is released when the current decreases and the magnetic field is going down. The higher inductor L2 value gives more charge and the takes more times cause the frequency become low. For the changes of capacitor C1, there is no significant effect to the output. The voltage and frequency is stable at this condition.

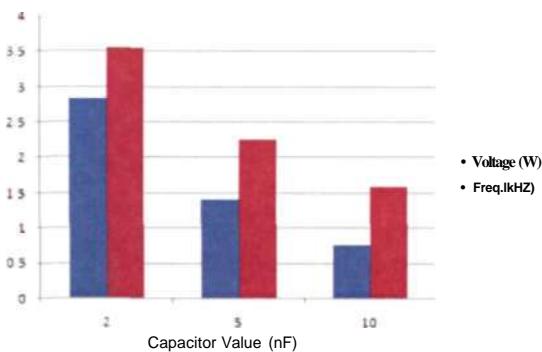


Figure 5 : Relationship between Frequency and Voltage due to Capacitor C2

From the graph, the increases value of capacitor reduces to the voltage and the frequency. The capacitor reacts to a changing voltage, it is known as a reactive component

$$Xc = \frac{1}{2\pi f C}$$

Where,

Xc - capacitive reactance in ohm

(Q)

f -frequency

C - capacitance in Farad (F)

The capacitive reactance varies inversely with the frequency when $f = 0$, X_c is infinite and decreases as frequency increases[7]. Therefore, the greater capacitive reactance cause the lower frequency and the higher the frequency cause of less the reactance for a given capacitor.

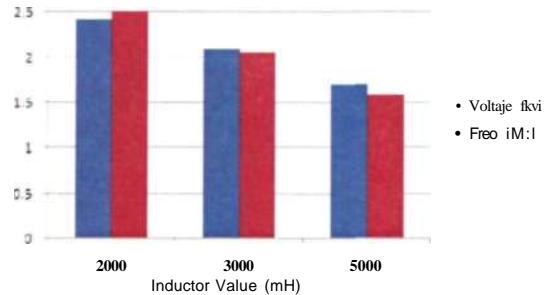


Figure 6 : The relationship between frequency and voltage due to Inductor L2

Voltage and frequency becomes lower when increasing the inductor. As a passive electrical component, an inductor will induced a voltage due to time varying magnetic field in the coil.

V. CONCLUSION

In this project, Tesla Coil is proven can be built in miniature scale, by using a low voltage as the input with desired output. The value of component can give effects to the output voltage and frequency. The simulation works provides an understanding on how to generate the AC high voltage. Besides that, it also verifies that the circuit that has been designed is capable of converting and transferring the input electricity supplied to the secondary circuit using the air as a medium. In addition, the simulation circuit has considered as a reference circuit arrangement for the hardware development.

VI. FUTURE DEVELOPMENT

The race to develop the modern of the typical Tesla Coil among the scientists and engineers is ongoing. Since the scientific literature about the Tesla coil using the dc voltage is not easily found, therefore this project is carried out to be a sensible part of the research studies. In addition, the simulation result gives a meaningful indicator regarding the effort to create a small scale Tesla Coil for innovation purposes. It should be note that the final systems of this project would provide an understanding of systems principle and give significant contribution for further research of Tesla Coil construction.

So, it was recommended for future researcher to develop small sized of Tesla Coil using parameters from this project or else provided that the characteristics of Tesla Coil are not change. It can be determine in many ways approach to the theoretical of Tesla.

VII. REFERENCE

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