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Analysis of Electric Field Distribution on Primary Windings of High-Voltage High-Frequency Transformers with Variables Characteristics

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Abstract* — This research aims to present the study of the effect of Tesla Transformer induce to find the proper dimension. Result will bring to create the design of Tesla Transformer to reduce the High Voltage Electric Field Stress problem which is happen between Primary Winding and Secondary Winding. Because the Tesla Transformer is use induce between this two winding through the air so that it would be the problem insulation. The winding which has the space is Dielectric, while there are create the high voltage in the transformer, it would flash over voltage from the high voltage winding to the low voltage winding that would be damage to the transformer and other device. Research process, the researcher has to study the lay down model of the two winding in the transformer. By consideration from induce that proper for Tesla Transformer reproduce by using FEMLAB program. And compare the Tesla Transformer reproduce which is created the voltage at 120 kV and frequency 120 kHz. The result which is from the compare is the proper lay down position of Primary Winding and the voltage which has design without the flash over. It has to be wind whorl coil at 60 angels from the floor. It would have induced more than other model. Voltage that can measure and have the most proper voltage electric field stress while compare with the lay down of Primary Winding which has the angle from the floor at 0,30,45,60 and 90 angels. The consideration from the reproduce by using FEMLAB program and the result from the test is there are no flash over between the high voltage winding to the low voltage winding while there are lay down the primary winding at the 60 angle

Keywords— Tesla Transformer, High Voltage High Frequency

I. INTRODUCTION

At the present electric distribution system in bus far from ele In the manufacture, to produce Porcelain Insulator, it would use high voltage transformer to distribute the voltage for testing every insulators that produce from the manufacturer to check the primary quality that the insulators are not imperfect in the Porcelain insulator. By using flash over the surface of insulators which is follow the standard ANSI C.29.1976 that using the high frequency in testing the defect inside. It would be effect to the high electricity field stress that occur between the primary coil and secondary coil (Lp, Ls) because this type of transformer is the air axis transformer. It would be a problem in the insulator coil that has the electric air by creating the flash over on the 2 sets of coils. The suitable distance of coil would be reducing that problem. To reduce the problem, it should not make the voltage out of the high voltage high frequency transformer which has set the determine amount. So that, this research would be study the effect of high voltage high frequency transformer induce (tesla transformer). To find the suitable dimension by analyst the result that occurs in this research. It would use the model circuit of tesla transformer by using FEMLAB program. Compare with the testing results that receive from the build up tesla transformer.

II. EQUIPMENT AND RESEARCH METHOD

Equipment that using in the research

1. Matlab Program–using the tesla transformer model to be a design before build up the real one.
2. Femlab Program – using to be a model of distribution the electricity field in tesla transformer
3. PVC tube that has diameter 4 inch – using to be axis for Ls secondary coil binding
4. Enamel Copper Coil size 31 SWG – using to be a LS secondary coil binding
5. Copper tube 0.03 inch that diameter 0.25 inch and 0.5 inch. – using to be a Lp primary coil and Transformer Protection Ring
6. Motor 1 phase – speed at 1450 round per second – using for drive the Rotary Spark cap
7. Low Voltage Capacitor polypropylene size 15 nF 1600 V
8. Neon Sign Transformer 230 V/15000 V – using for transformer power distributor of low voltage tesla transformer

III. METHOD

1. High voltage circuit model, high frequency voltage at 120 kV, high voltage at 120 kHz by using Matlab and Femlab Program
2. Create the model of components and several structure of high voltage high frequency
3. Build up the components and several structure of high voltage high frequency
4. Testing to find the best feature in working of high voltage high frequency and correct the defect part
5. Collect the result from the calculation and the result from the model that using Femlab Program and the result of high voltage high frequency that built up to compare
6. Conclusion of research and testing

TESLA TRANSFORMER CIRCUITS

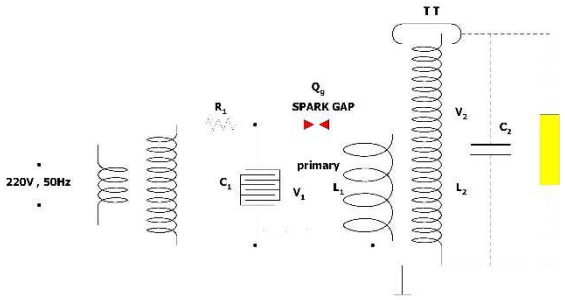


Fig. 1. Showing the circuit of Tesla Transformer

- High voltage 120 kVrms
- Frequency 120 kHz
- Voltage impulse 0 - 15 kVrms
- Capacity C_2 value around 40 pF

TABLE I. PARAMETER VALUE THAT CALCULATE FROM THE BASE EQUATION

L_1	Primary		Secondary	
	L_1 (μH)	C_1 (μF)	L_2 (mH)	C_2 (PF)
90°	28.45			
60°				
45°	72.09	6.366	43.97	40
30°				
0°	64.70			

Equation that use for calculate parameter

- In case that oscillation has occur between L_1 and C_1 the frequency that would occur

$$f = \frac{1}{2\pi\sqrt{L_1C_1}}$$

- Condition that occur from oscillation low voltage induce and high voltage tune

$$f_1 = f_2 = \frac{1}{2\pi\sqrt{L_1C_1}} = \frac{1}{2\pi\sqrt{L_2C_2}}$$

High Voltage coil model

It is necessary to consider

D = Diameter size of axis that binding coil L2
H = High of coil for binding
G = Coil size for binding

TABLE II. SHOWING THE TUBE SIZE AND THE HIGH THAT SUITABLE FOR BINDING HIGH VOLTAGE COIL

Diameter (inch)	High/diameter	Length of coil binding (inch)
3	6.0:1	18.0
4	5.0:1	20.0
5	4.5:1	22.5
6	4.0:1	24.0
7	3.5:1	24.5
8	3.0:1	24.0
More 8	3.0:1	24.0

HIGH VOLTAGE COIL, IT WOULD BIND ACCORDING TO TABLE II

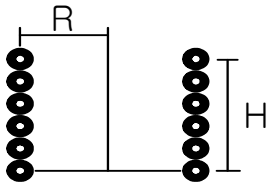
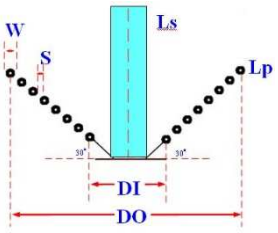


Fig. 2. Show the dimension in binding high voltage coil

when L = induce , μH
R = diameter radius to the center of coil,inch
N = binding amount
H = high of binding, inch

Low voltage coil model

1. Angle with the floor at 30°, 45°, 60°, using copper tube size 5/16 inch, thick 0.03 inch for low voltage coil



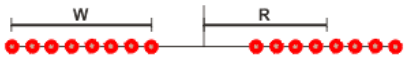
$$L = \frac{(NA)^2}{30A - 11DI}$$

$$A = \frac{DI + N(W+S)}{2}$$

Fig. 3. Show the primary coil at the angle 30°, 45°, 60°

W = diameter of copper tube = 5/16 inch
S = binding distance = 1/2 inch
DI = inside diameter of Lp = 14 inch
DO = outside diameter of Lp = 34 inch
N = Lp binding = 10 round

2. Angle to the floor at 0º using copper tube size 5/16 inch, thick 0.03 in to be low voltage



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

Fig. 4. Show the Primary coil at the angle 0º

IV. RESULT

The model of electricity field distribution of high voltage high frequency transformer that follow to finite element process by using FEMLAB program. It is determine that voltage in the low coil should have electricity voltage at 15 kV. high voltage coil has electricity voltage at 120 kV and permittivity (ε_r) of PVC tube equal to 3.5.

The model of electricity field compare at the angle with the low voltage at 90, 60, 45, 30 and 0 degree. The result of the model of electricity show as follow.

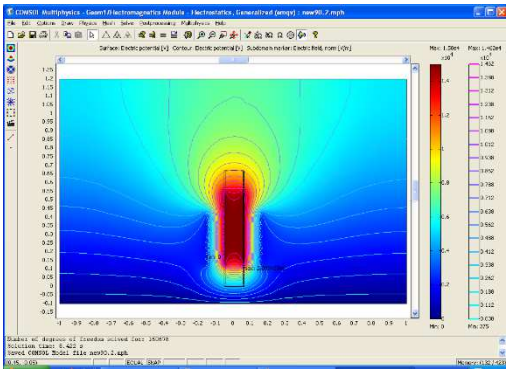


Fig. 5. The model of electricity filed at the low voltage coil in the angle 90 degree from the floor which would have the amount of electricity field maximum equal to 20.99 kV/cm at the beginning of high voltage coil (1st dimension)

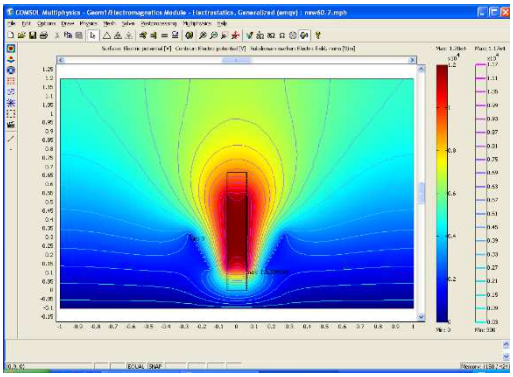


Fig. 6. The result of model of electricity field distribution at the low voltage at the angle 60 degree from the floor. It would have electricity field maximum equal to 15.20 kV/cm at the beginning of high voltage coil (2nd dimension)

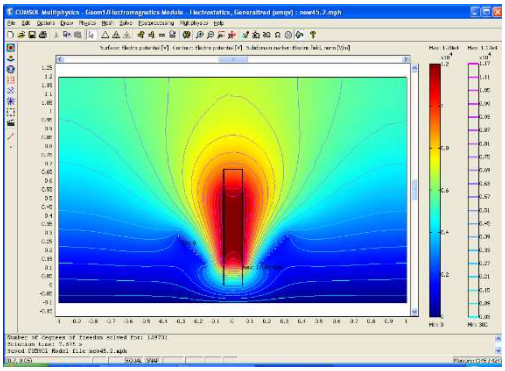


Fig. 7. The result of model of electricity field distribution at the low voltage at the angle 45 degree from the floor. It would have electricity field maximum equal to 13.95 kv/cm at the beginning of high voltage coil (3rd dimension)

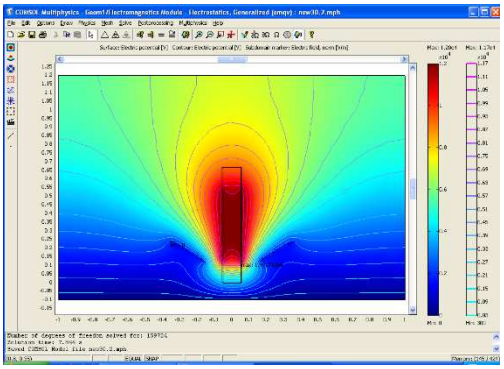


Fig. 8. The result of model of electricity field distribution at the low voltage at the angle 30 degree from the floor. It would have electricity field maximum equal to 14.91 kV/cm at the beginning of high voltage (4th dimension)

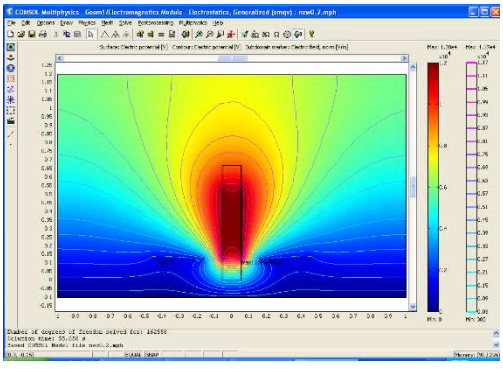


Fig. 9. The result of model of electricity field distribution at the low voltage at the angle 0 degree from the floor. It would have electricity field maximum equal to 14.99 kV/cm at the beginning of high voltage (5th dimension)

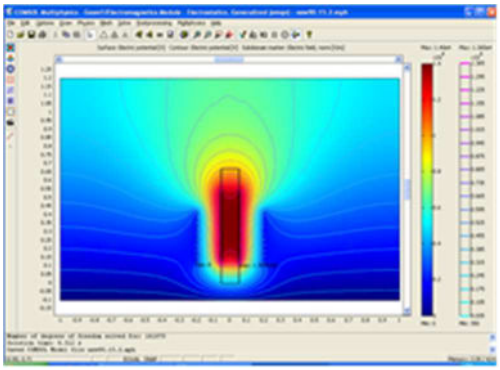


Fig. 10. The result of model of electricity field distribution at the low voltage at the angle 90 degree from the floor. It would expand the distance between the Lp and Ls coil from the previous 4 inch to be 5.5 inch., which would have the electricity field amount maximum equal to 18.23 kV/cm. at the beginning of high voltage (6^{th} dimension).

The tesla transformer testing result which have put the Lp coil at the angle 90, 60, 45, 30, 0 degree. Oscillation that retains it should be calculated in each type The tesla transformer testing result which have put the Lp coil at the angle 90, 60, 45, 30, 0 degree. Oscillation that retains it should be calculated in each type

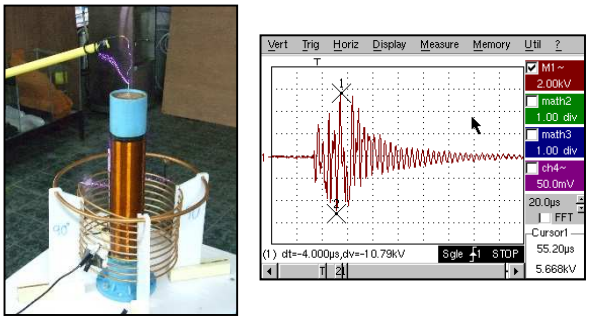


Fig. 11. Testing in putting Lp coil at the angle 90 degree and Wave that could calculate of Lp at the angle 90 degree

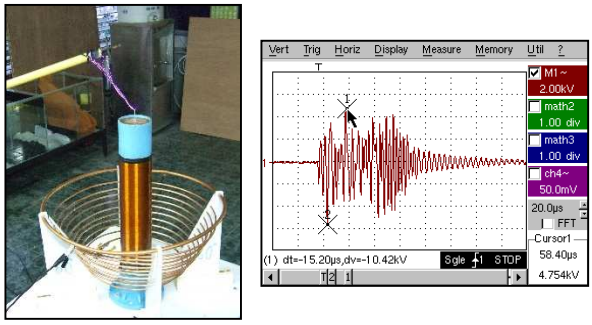


Fig. 12. Testing in putting Lp coil at the angle 60 degree and Wave that could calculate of Lp at the angle 60 degree

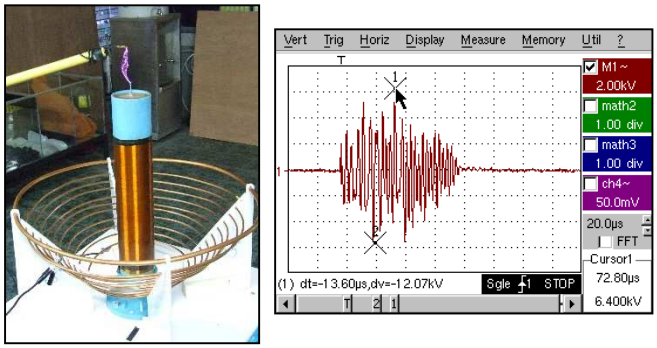


Fig. 13. Testing in putting Lp coil at the angle 45 degree and Wave that could calculate of Lp at the angle 45 degree

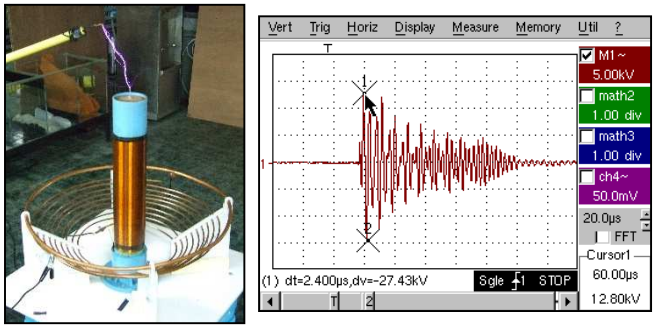


Fig. 14. Testing in putting Lp coil at the angle 30 degree and Wave that could calculate of Lp at the angle 30 degree

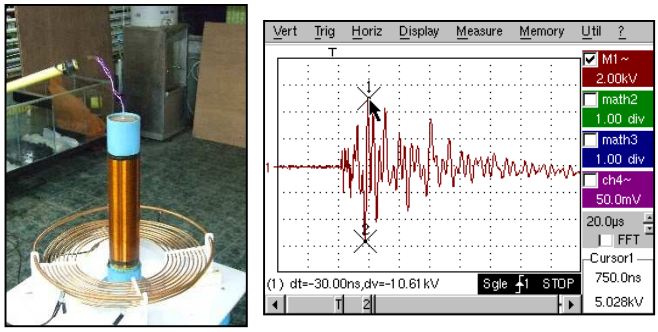


Fig. 15. Testing in putting Lp coil at the angle 0 degree and Wave that could calculate of Lp at the angle 0 degree

TABLE III. COMPARING VOLTAGE THAT FLOW OUT OF THE PUTTING PRIMARY COIL AT THE ADJUSTING POSITION FROM THE ROUND 8 IN EACH TYPE.

Primary Coil Position (Lp)	External Voltag (kV)			
	1 th Without Toroid	2nd Without Toroid	3rd With Toroid	Remarks
0^o	106.1	96	102.4	
30^o	274.3	139.9	105.1	
45^o	120.7	131.7	102.4	
60^o	104.2	129.8	157.7	
90^o	107.9	129.8	212.6	1st and 3rd Breakdown

TABLE IV. COMPARING THE EXTERNAL FREQUENCY OF PRIMARY COIL PUTTING AT THE ADJUST POSITION AT 8 ROUND BINDING IN EACH TYPE

Primary Coil Position (Lp)	External Frequency (kHz)		
	1th Without Toroid	2nd Without Toroid	3rd With Toroid
0^o	102	128	125
30^o	108	122	120
45^o	110	138	130
60^o	135	127	120
90^o	125	145	135

TABLE V. COMPARE THE RESULT OF DISTRIBUTION ELECTRICITY FIELD MODEL BETWEEN PRIMARY COIL (LP) AND SECONDARY COIL (LS) IN THE SEVERAL ANGLE BY USING FEMLAB AND CALCULATION.

Primary Coil Position (Lp)	Maximum of Electricity Field (kV/cm)	
	Model Testing by using FEMLAB Program	Calculating Result by using the formula
0^o	14.99	12.48
30^o	14.91	13.16
45^o	13.95	14.00
60^o	15.20	15.15
90^o	18.23	17.32

V. CRITICISM EXPERIMENT RESULT

According to the result of tesla transformer testing and the electricity field model that design in the putting of low and high voltage coil of tesla transformer 3 times. It would consider to chose by using the distribution impulse by indicate it in the adjustment atmosphere. Primary coil at the same point which is binding 8 round of primary coil at the difference angle $0^o, 30^o, 45^o, 60^o$ and 90^o from the table 3 and table 4. It would see that at this point the distribution voltage, would almost the same amount with the model at 120 kV 120 kHz and it is the amount of rounding of primary coil Lp that close to the high amount from the model. According to the comparing, it can conclude that to put the primary coiol (Lp) from the floor at the angle 60^o. It is the internal voltage and high electricity field stress that has the most suitable than other model.

VI. RESEARCH CONCLUSION

To study the effect of the high voltage transformer induce and high frequency for finding the suitable dimension. It would start in determining the transformer is external impulse and frequency. The characters of coil induce (the suitable dimension in putting the low voltage coil Lp in the several positions and the model amount that using FEMLAB. The amounts that receive from Simulation, would use for compare analyst with the result of test that get from high voltage transformer and high frequency which was created.) The analysis in the several parameters, it could be link that to put the Lp coil in the suitable angle, it should be at 60 angle according this research.

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