Finite Element Analysis of Gapped Toroids Core

[1]Bhavik B. Patel, [2]Vinod Gupta, and[3]J.G. Jamnani

[1,3] Dept. of Electrical Engineering, Institute of Technology, Nirma University, Ahmedabad
[2] Electrical Research And Development Association, Vadodara

Abstract-**This paper presents the modeling and analysis of gapped toroids core used in the zero flux type current transformer. The method uses finite-element method to determine effect of the primary conductor current and air gap length on the air gap flux. Gapped toroids core with two air gap lengths (2 mm, 4mm) and for different current is to be analyzed. The result is compared with each other. The paper shows the FEA results for the same.**

***Index Terms*— Air gaps, Zero-flux type current transformer, Gapped toroids core, Finite-element methods.**

I. INTRODUCTION

THE area of electronics requires high-performance current transformers for the following reasons:-

• Static converter's switching frequency extends from 100 Hz to 1 MHz so the high cutoff frequency of current transformers has to be extended to over 10 MHz.

• Current shape can be sinusoidal or pulsed containing a dc component or high-frequency ringing.

• Metal–oxide–semiconductor field-effect transistors (MOSFETs) or insulated-gate bipolar transistors (IGBTs) are generating high values which may reach up to several kilo amperes per microsecond. So, static converters generate strong radiated and conducted electromagnetic interference (EMI) [1], [2].

This paper aims to explain the effects of variation in the air gap length on the gapped toroids core characteristics of air gap flux Vs primary conductor current and predict the performance of the Zero Flux type current transformer.

The basic working principle of the zero flux type current transformer is as shown in Fig.1. Here the primary conductor is placed in the center of the gapped toroids core. The Hall Effect element is placed in the air gap for sensing the air gap flux which is produced by the primary current. The Hall element gives the output voltage which is proportional to the primary current and the wave form of the output voltage is same has current wave form. For improving the dynamic response, close loop operation of the Hall Effect current sensor is employed. In this method the output of Hall element is to be amplified and it feedback in the feedback coil to compensate the core flux and make it zero. The output current of the feedback coil is passing through the low resistance shunt and the voltage drop across it is measured and it gives the current measurement.

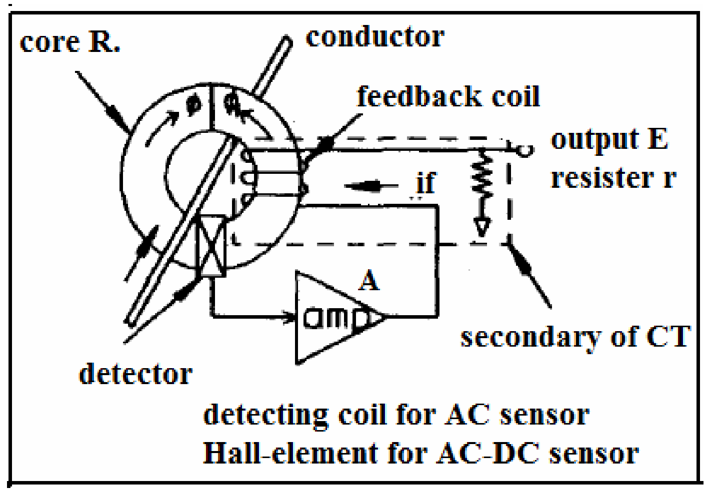

FIG.1 The Schematic Of Basic Working Principle Of ZFCT

II. GEOMETRY MODEL OF THE GAPPED TOROIDS CORE

The construction of gapped toroids core simply consists of gapped toroids core made of high permeability material with air gap. For analysis the effect of the air gap length on characteristics of the air gap flux Vs primary current, two model of gapped toroid core are prepared with two different air gap length of 2mm and 4 mm. Selections of 2mm and 4mm air gap length is for comparative analysis. The air gap should be equal to or greater than the width of hall IC.

The geometry model is as shown in Fig.2 for the 4mm air gap. The complete model data for both models are given in table.1.

TABLE.1
Geometry Model Data

SR. NO	Description	2mm model	4mm model
1	Inner Diameter of core	50	50
2	Air gap Length	2	4
3	Outer Diameter of Core	70	70
4	Conductor Diameter	10	10
5	Outer Boundary Diameter	120	120

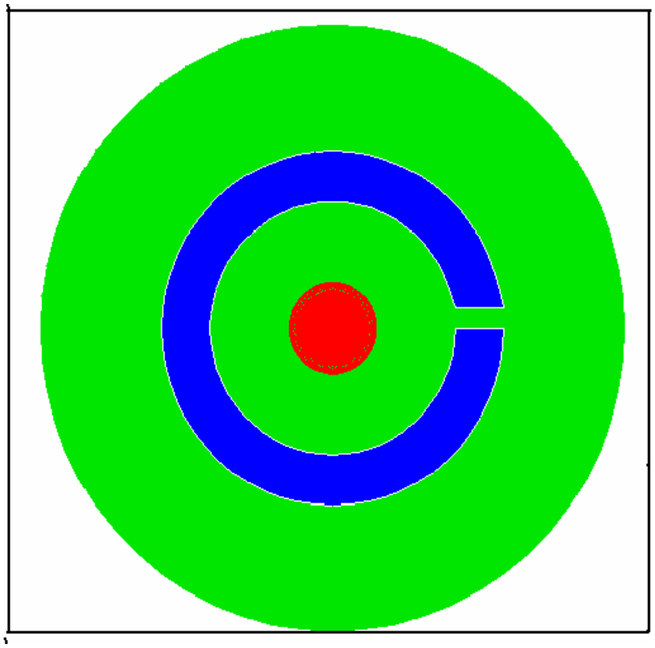

FIG.2 The Geometry Model For The 4mm air Gap

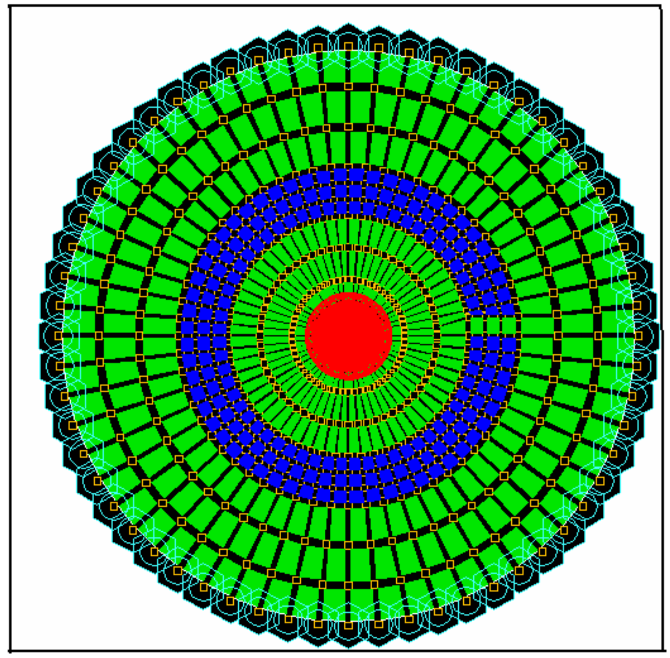

FIG.3 The Complete View of Finite Element Model with 4mm Air Gap

III. FINITE ELEMENT MODEL

The finite element model is described as the representation of the geometric model in terms of finite number of elements and nodes, which are the building blocks of the numerical representation of the model for solution. In addition to information about element and nodes, this model also contains information about material and other properties, electromagnetic sources and boundary conditions [3].

In proposed model of the gapped toroids core, the material specification assign to the model is as given in the tabel.2.

TABLE.2
Material Specification Assign to the model

SR. NO	Material name	Permeability (m/H)
1	Primary conductor	795780
2	Magnetic core	400
3	Air(Outer boundary)	795780

The Dirichlet boundary condition is defined on the outer periphery of the model. The current density in the primary conductor is assigned such a way that the total current magnitude passing through the conductor is equal to required current. In each case the current density has been changed and the results are taken for the same. In first case Jz = 12738 A/m^2 is used in the elements. Here only 2D analysis is done because of the Z axis symmetry of the model. The complete finite element model of gapped toroids core is shown in the Fig.3.

IV. ANALYSIS RESULTS

The results are taken for the various current densities. The effect of current variation on air gap flux is observed.
The results are taken for the two model of air gap 2mm and 4mm with various current densities.
Here the analysis results taken are:

- Residual magnetic flux density.
- The vector potential plot (flux plot).

The results of the flux plot and residual magnetic flux density for the 2mm air gap model with 100 Amp. primary current is sown in the Fig.4 and Fig.5 respectively.

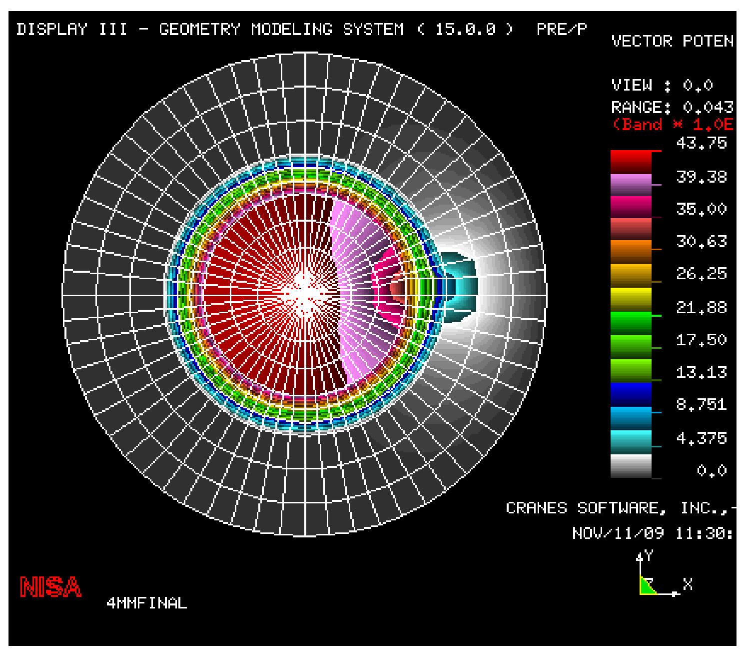

FIG.4 The Flux Plot of 2mm Air Gap Model with 100amp. Current

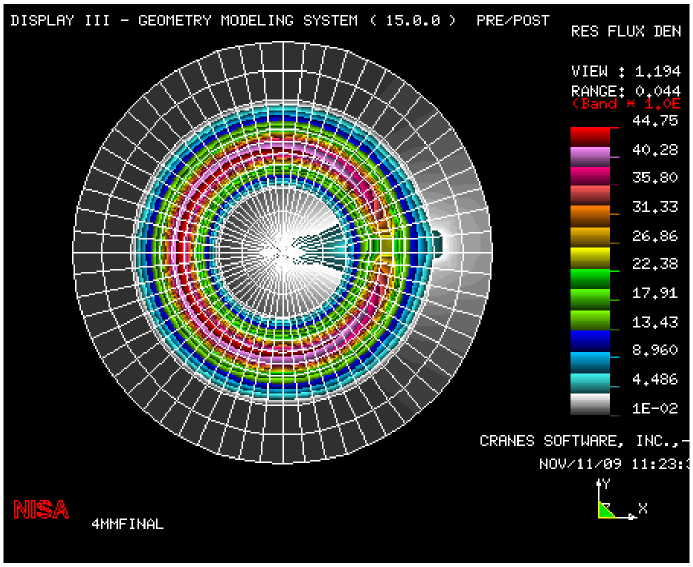

FIG.5 The Residual Flux Density Plot of 2mm Model with 100amp. Current

V. COMPARITION OF THE RESULTS

The results of both the model for various current values are shown in the Table.3

TABLE.3
The Results of Both Model For various Current

SR. NO	Current (Amp.)	Avg. Flux Density In The Air Gap (gauss/cm^2)		Avg. Flux In Air Gap (gauss)	
		2mm	4mm	2mm	4mm
1	0.01	0.0775	0.02274	0.03836	0.02223
2	0.1	0.7748	0.2281	0.3836	0.2229
3	1.0	7.753	2.281	3.836	2.229
4	10	77.53	22.80	38.36	22.28
5	25	193.8	57.02	95.92	55.72
6	50	389.5	114.6	192.80	112.0
7	100	800	228.1	383.6	222.9
8	200	1552	500	800	400
9	300	2325	900	1151	700
10	400	3098	1130	1533	900
11	500	3871	1239	1916	1113

The results of both the models are plotted in the separate graph as shown in Fig.6 and Fig.7 respectively. The results show that as the air gap length increases, the characteristics of flux Vs current become non linear. This is an important point while designing a core of zero flux type current sensor. The air gap should be as small as possible to obtain the linear characteristics of flux vs. current.

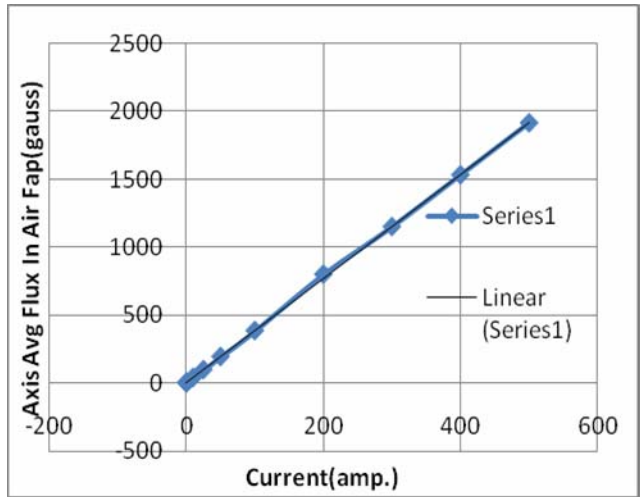

FIG.6 The Characteristics Of Current Vs Avg. Air Gap Flux For 2mm Air Gap Model

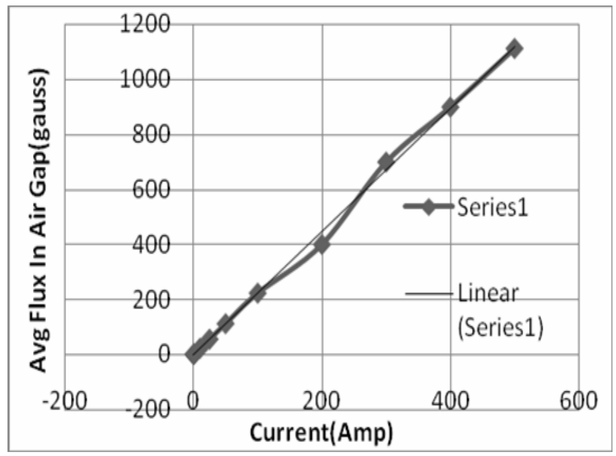

FIG.7 The Characteristics Of Current Vs Avg. Air Gap Flux For 4mm Air Gap model

VI. CONCLUSION

Analysis results shows that as the air gap length increases, the characteristics of flux Vs current become non linear. The flux for the same current is higher in case of smaller air gap model. For design core of ZFCT with higher accuracy, the close loop operation is necessary. In close loop operation of Hall Effect current sensor, it is possible to make air gap length smaller and to achieve zero flux in the core simultaneously.

VII. REFERENCES

[1] F. Costa E. Labour and F. Forest. "current measurement in static converters and realization of a high frequency passive current probe (50a300mhz)," in Proc. EPE93, vol. 4, no. 377, Brighton, U.K., pages 478{783, Aug 1993.
[2] F. Forest F. Costa, E. Labour and C. Gautier. "wide bandwidth, large ac currentprobe for power electronics and emi measurements,". IEEE Trans. Ind. Electron.,vol. 44, pages 502{511, Aug 1997.
[3] Cranes Software.Inc Michigan. "The NISA User Manual (formerly NISA Notes and Documentation)".