Effective Stray Loss Control In Transformers Using Various Sheilding Measures

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Effective Stray Loss Control In Transformers Using Various Sheilding Measures

Major Project - Part II
Review II

Submitted in partial fulfillment of the requirements
of Semester-IV

For the degree of

Master of Technology in Electrical Engineering
(Electrical Power System)

By

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DEPARTMENT OF ELECTRICAL ENGINEERING
AHMEDABAD-382481
MAY 2014

Certificate

This is to certify that Major Project Report entitled **Effiective Stray Loss Control In Transformer Using Various Sheilding Measures** submitted by **Mr. Jimil D Mehta (Roll No: 12MEEE20)**, towards the partial fulfilment of the requirements for semster - IV **Master Of Technology Electrical Engineering** in the feild of **Electrical Power Systems** of Nirma University is the record of work carried out by him under our supervision and guidence. The work submitted has reached a level required for being accepted for the examination . The results embodied in this major project , to the best of my knowledge , have not been submitted to any other university or institution for award of any degree or diploma.

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Undertaking for Originality of the Work

I, **Jimil Mehta (Roll No:12MEEE20)**, give undertaking that the Major Project entitled"**Effiective Stray Loss Control In Transformer Using Various Sheilding Measures "** submitted by me, towards the partial fulfillment of the requirement for the degree of Master of Technology in Electrical Power System, Electrical Engineering,under Institute of Technology, Nirma University, Ahmedabad is the original work carried out by me and I give assurance that no attempt of plagiarism has been made.I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere, it will result in severe disciplinary action.

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Abstract

Transformer is a vital link in the power system network. The transmission and distribution (T & D) loss varies in a range of 10 to 40 % which is considered to be significant high. Contribution of transformers is in the range of 6 % for T & D losses. In a process of reducing total T & D losses, Loss capitalization for the modern age transformers has increased in a great extent. This indicates necessity of reducing losses (i.e. no load loss and load loss).

Stray losses in the transformer contribute around 15 to 40 % in the load losses which is considered to be a significant amount. Hence to match the loss capitalization stray losses shall be reduced. This is achieved by controlling the leakage field.

Large rating transformers are with strong electromagnetic field; If the field is not controlled it links with the various structural parts of the transformer e.g. core clamp, tank and will result in to excessive loss concentration, local heating (i.e. hot spots) and further gasification during service conditions. Gasification in the oil can affect reliability of transformer during service conditions. Reliability is at a prime concern for large rating power transformers; all issues related to stray field are addressed to conserve reliability of transformer.

Various measures e.g. magnetic and nonmagnetic shields are known to control the stray field in the transformers; each of them their having advantages and disadvantages. Effective solution needs to be selected to make shielding measure more optimum. It is possible to effectively control stray field by use of IEM (integral equation method) and FEM (finite element method) precisely.

Acknowledgement

With imense pleasure, I would like to present this report on ”Effiective Stray Loss Control In Transformer Using Various Sheilding Measures”. To practically know anything, project work plays an important role. I am very greatful to evey person who have helped me in my desertation work and providing me their valuable guidance.

I would like to thank my industrial project guide Mr. A. S. Jhala, SM, T & R India Ltd. for their valuable guidance and giving me time from his hectic schedule. I would also like to thank my Internal guide Prof. S. S. Kanojia for her valuable guidance. My special thanks to Mr. Virendra Lakhiani, Technical Director, T & R India Ltd. for his support, important guidance and giving me time from his busy schedule. I would also like to thank Dr. S. C. Vora, PG Co-ordinator, M.Tech(EPS), Electrical Engineering, Institute of Technology, Nirma University & Dr. P. N. Tekwani, HOD, Electrical Engineering, Institute of Technology, Nirma University, Ahmedabad.At last I would like to say thank you to all my friends & family members for their continous support & encouragement.

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Chapter 1

Introduction

1.1 Introduction

Transformer losses comprise a small percentage of the power throughput in a transformer. Yet these losses can produce localized heating which can compromise its operation. It is important to be able to calculate these losses at the design stage so that adequate cooling can be provided. In addition, such calculations and their parameter dependencies can suggest ways of reducing these losses should that be necessary based on cost considerations or design feasibility. There are two main categories of losses, no-load and load losses. No load losses are basically core losses associated with energizing the transformer and driving flux through the core. Load losses are further subdivided into I^2R losses and stray losses. The I^2R losses are resistive losses in the windings and leads caused by the main current flow. The stray losses are the result of the stray flux from the windings or leads impinging on metal parts such as the tank walls, the clamps, and even the windings themselves, resulting in induced eddy currents.

1.2 Literature Survey

Various references have been used for theoretical understandings as well as an aid to the simulation carried out.

1. As an introduction to the fundamental concepts of Stray losses taking place in Transformers, Design ,Maintaince & operation of Core formed Power Transformers by A V Chiplonkar acts as classical guide. it details the basics of stray loss occuring in power transformer in a lucid manner and helps build concepts from a basic level. It provides detailed explanations of the emprical formulas used for stray loss calculation in power transformers .Emphasis is on thorough understanding and where applicable, all pertinent formulae have been derived from fundamental principles.

2. For a quickly covering all the major topics pertaining to the stray losses in transformer ,Transformer Engineering by S V Kulkarni & S A Khaparde is an in-valuable book.The book servers more like an encyclopedia than a textbook and chapter 4 & 5 of the book is a handy reference. It allows us to understand

the concepts within a few days if time is limited. It also provides a basic understanding of places where stray loss occur , factors affecting stray loss, methods to mitigate stray loss.

3. The Transformer Manual by CBIP & Transformer Design Principles by Robert Veccio , Bertrand Pauolin , Dilip Shah , Rajendra Ahuja gives an insight of loss optimization taking place in transformers , used for tendering purpose .

4. FEM method applied to Transformer Design By Xose M Fernandiz helps to model transformer in commercial FEM packages

5. Power Transformer Quality Assurance By Indrajit DasGupta acts as guide for design & selection of the materials .

6. Calculation & Reduction Of Stray & Eddy Losses In Transformers by R S Gargis & D C Paulik presented at IEEE transaction on power delivery , 1993 . this paper shows the accuracy of the FEM software , the structural parts were modelled and stray losses were calculated . the results were experimentally verified .

7. The research paper " 3D Computer Field Model of Power Transformer-Magnetic Field and Power Losses Computation" by S. Wiak, P. Drzymala, H. Welfle XIX International Conference on Electrical Machines - ICEM 2010, Rome helps in modelling of transformer in FEM software.

8. A Reference paper "Analysis of Stray Losses in Power Transformers by 3-D Magnetic Field Simulation" by M.L. Jain ., Chetan Adlija presented at 15 NPSC ,2008 gives details of stray loss taking place at different structural parts of transformer and percentage amount of each of its occurence.

9. Eddy Current & Stray Losses in Power Transformers by M. Rizzo, A. Savini and J. Turowski , this paper gives details of various screens or sheilds used to minimize the transformer tank stray loss . the continous FE & Cu screen was found to be the best .

10. Study on Eddy Current Losses and Shielding Measures in Large Power Transformers by Chen Yongbin, Yang Junyou , Yu Hainian and Tang Renyuan presented at IEEE transaction on Magnetics , 1994 . this paper shows that use of vertical shunts of 10 mm for reducing the tank stray losses is more useful than that of parallel shunts.

11. Minimization Techniques Of Transformer Tanklosses by A. Saleh, A. Omar at CIGRE 2004 .this paper shows tank losses are concentrated in the side walls which have the largest surface area. shielding is extremely effective to dramatically reduce tank losses.

12. Finite Element Analysis of Leakage Inductance of 3-Phase Shell-Type and Core Type Transformers by Mehdi Zare, Seyyed Mohammad Pedram Razi, Hassan Feshki Farahani and Alireza Khodakarami in this paper transformer was modeled in ansys & leakage inductance was calculated & was experimentally verified.

13. Stray losses in power transformer tank walls and construction parts by Lenart Kralj, Damijan Miljavec . this paper calculates the stray loss at lower & upper core clamps of the transformer . The losses are related to the magnetic leakage fields. A time harmonic 3D finite element method is used to compute the magnetic leakage field in the case of nominal load condition of the power transformer.

14. Study on Eddy Current Loss of Core Tie-plate in Power Transformers by Xuejun Ma, Yu Jiang .this paper models tieplate used in transformer in Fem software (Ansys) and shows increase in in the slots of tieplate reduces the eddy current loss produced in the tieplate .

15. Tank Losses and Magnetic Shunts in a Three Phase Power Transformer by Zhanhai Song, Yifang Wang, Shuai Mou, Zhe Wu, Yinhui Zhu, Bingfu Xiang, Ce Zhou . this paper shows the modelling of 3 phase transformer in FEM package and calculates the leakage magnetic feild & stray losses at the tank walls . the sheilding method was used to reduce tank losses which was economic and successful. The results were practically validated.

1.3 Objective of Dissertation

Stray losses in the transformer contribute around 15 to 40% in the load losses which is considered to be a significant amount. Hence to match the loss capitalization stray losses shall be reduced. This is achieved by controlling the leakage field.

Large rating transformers are with strong electromagnetic field; If the field is not controlled it links with the various structural parts of the transformer e.g. core clamp, tank walls ,frames ,flitch plates, Edge stack, and will result in to excessive loss concentration, local heating (i.e. hot spots) and further gasification during service conditions. Gasification in the oil can affect reliability of transformer during service conditions. Reliability is at a prime concern for large rating power transformers.

Various measures e.g. magnetic and nonmagnetic shields for the control of stray loss in structural parts are known to control the stray field in the transformers; each of them their having advantages and disadvantages. Effective solution needs to be selected to make shielding measure more optimum. It is possible to effectively control stray field by use of IEM (integral equation method) and FEM (finite element method) precisely. The FEM software which are to be used are Ansys/ MagNet/ EDMAG-3D.

1.4 Project Planning

LITERATURE SURVEY
↓
FINALIZING PROJECT TITLE
↓
PROJECT DEFINATION AND OBJECTIVE OF PROJECT
↓
ANALYSIS OF TRANSFORMER DESIGN
↓
SIMULATION OF TRANSFORMER
↓
PRACTICAL VALIDATION
↓
CONCLUTION & FUTURE SCOPE
↓
THESIS PREPARATION

Chapter 2

Losses Occuring In Transformer

The losses occuring in the transformer can be broadly classified as follows:

1. No load loss
2. Load loss
   (1) Copper loss
   (2) Stray loss

2.1 No load loss

No load losses occur when the transformer is energized with its rated voltage at one set of terminals but the other sets of terminals are open circuited so that no through or load current flows. In this case, full flux is present in the core and only the necessary exciting current flows in the windings. The losses are predominately core losses due to hysteresis and eddy currents produced by the time varying flux in the core steel. Cores in power transformers are generally made of stacks of electrical steel laminations. These are usually in the range of 0.23 to 0.46 mm (9 to18 mils) in thickness and up to about 1 meter (40 inches). Modern electrical steels have a silicon content of about 3% which gives them a rather high resistivity. Although the thinness of the laminations and their high resistivity are desirable characteristics in reducing (classical) eddy current losses, the high degree of orientation (95%) produces large magnetic domains parallel to the rolling direction . They found that these losses were significantly higher than the losses obtained from a classical eddy current calculation which assumes a homogeneous mixture of many small domains. These non-classical losses depend on the size of the domains in the zero magnetization state where there are equal sized up and down domains. In order to decrease the non-classical eddy current losses, it is therefore necessary to reduce the domain size. This is accomplished in practice by laser or mechanical scribing. A laser or mechanical stylus is rastered across the domains (perpendicular to their magnetization direction) at a certain spacing. This introduces localized stress at the surface since the scribe lines are not very deep. The domain size is dependent on the stress distribution in the laminations. Localized stresses help to refine the domains. Thus, after scribing, the laminations are not annealed since this would relieve the stress. shows the domain pattern in an oriented electrical steel sample before and after laser scribing. The losses were reduced by approx. 12% as a result of laser scribing.

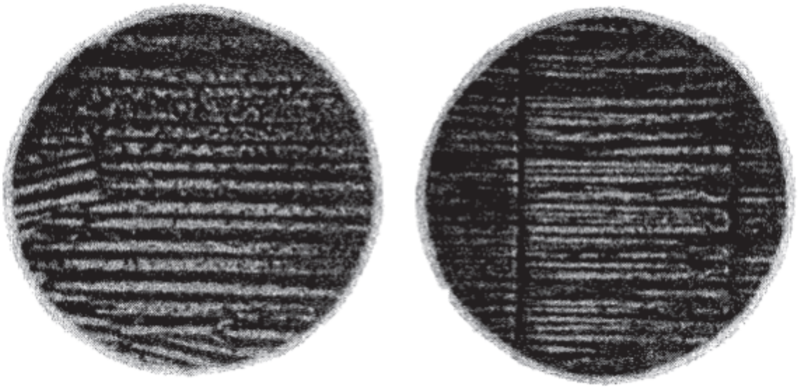

Figure 2.1: Laminated Core

2.2 Load Loss

Load losses occur when the output is connected to a load so that current flows through the transformer from input to output terminals. When measuring load losses, the output terminals are shorted to ground and only a small impedance related voltage is necessary to produce the desired full load current.

Load losses are in turn broadly classified as I^2R losses due to Joule heating produced by current flow in the coils.

And as stray losses due to the stray flux as it encounters metal objects such as tank walls, clamps or bracing structures, and the coils themselves. The stray losses depend on the conductivity, permeability, and shape of the metal object encountered. These losses are primarily due to induced eddy currents in these objects .Even though the object may be made of ferromagnetic material, such as the tank walls and clamps, their dimensions are such that hysteresis losses tend to be small relative to eddy current losses. Although losses are usually a small fraction of the transformed power (0.5% in large power transformers), they can produce localized heating which can compromise the operation of the transformer.

2.3 Loss Capitalization Formula

The capitalizatoin loss formula for power transformer depends on following factors

1. Rate of Intrest (r)
2. Cost of Electrical Energy (EC)
3. Life Of Transformer (n)

4. Cooloing Auxilaries in Transformer
5. Annual loss Factor(LS)
   LS = 0.2 LF + 0.8 (LF^2)
   Here, LF = annual load factor = 0.6

IC= Initial Cost

Wi= Annual Cost of Iron Loss per KW

Wc= Annual Cost of Load Loss per KW

Wp= Annual Cost of Auxilary Loss per KW

Capitalisation Formula is = IC + Wi + Wc + Wp

$$Wi = 8760 \times e \times \frac{(1+r)^n - 1}{r \times (1+r)^n} \tag{2.1}$$

$$Wc = 8760 \times e \times \frac{(1+r)^n - 1 \times LS}{r \times (1+r)^n} \tag{2.2}$$

$$Wp = 0.4 \times 8760 \times e \times \frac{(1+r)^n - 1}{r \times (1+r)^n} \tag{2.3}$$

Chapter 3

Stray Losses Occuring In Structural Parts of Transformer

These are losses caused by stray or leakage flux. Fig. shows the leakage flux pattern produced by the coil currents in the bottom half of a single phase or leg of a transformer, assuming cylindrical symmetry about the center line. This was generated with a 2D finite element program. The main components, core, coils, tank, and clamp are shown .Shunts on the tank wall and clamp were given the material properties of transformer oil so they are not active. shows the same plot but with the tank and clamp shunts or shields activated. These are made of the same laminated electrical steel as the core. The shunts or shields divert the flux from getting into the tank or clamp walls so that the stray losses in Fig. are much less than those in Fig. The stray flux pattern depends on the details of the winding sizes and spacings, the tank size, the clamp position, etc. The losses generated by this flux depend on whether shunts or shields are present as well as geometric and material parameters.

In addition to the coils stray flux, there is also flux produced by the leads. This flux can generate losses, particularly if the leads are close to the tank wall or clamps. We should also mention losses in the tank wall depending on how the leads are taken out of the tank. As Figs. indicate, there is also stray flux within the coils themselves. This flux is less sensitive to the details of the tank and clamp position or whether shunts or shields are present. The coil flux generates eddy currents in the wires or individual strands of cable conductors.

3.1 Tie Plate Losses(Flitch Plate Losses)

The tieplate (also called flitch plate) is located just outside the core inthe space between the core and innermost winding. It is a structural plate which connects the upper and lower clamps. Tension in this plate provides the clamping force necessary to hold the transformer together should a short circuit occur. It is usually made of magnetic steel or stainless steel and could be subdivided into several side by side vertical plates to help reduce the eddy current losses. Fig. shows a schematic diagram of one of the tieplates associated with one leg.

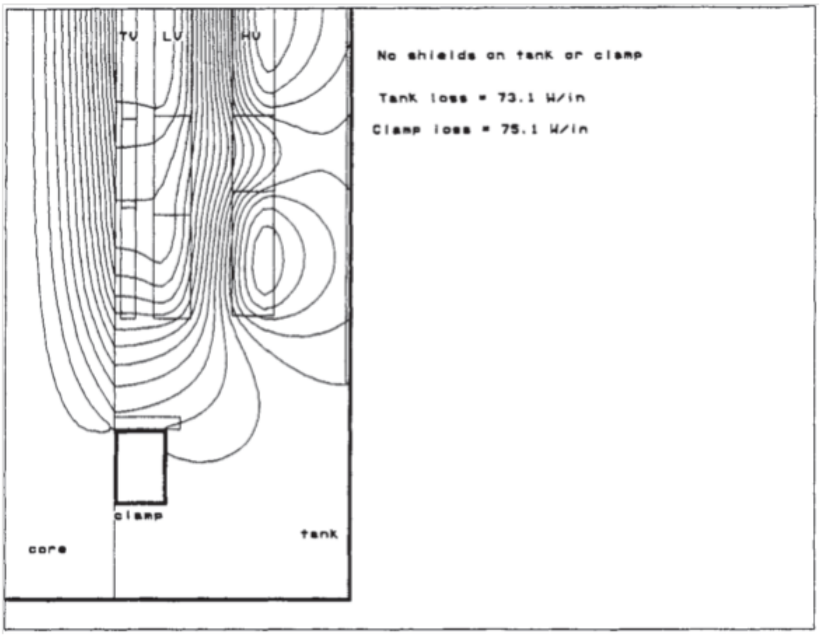

Figure 3.1: Leakage Flux Distribution In Transformer without Sheild

3.2 Core Edge Losses

Core edge loss is the stray loss occurring due to flux impinging normally (radially) on core laminations. The amount and path of leakage field in the core depends on the relative reluctances of the alternative magnetic circuits. Load conditions of the transformer also have significant influence; In large transformers, the radially incident flux may cause considerable eddy currents to flow in the core laminations resulting in local hot spots. The effect of type of flitch plate (magnetic or non-magnetic) on the core edge loss is also explained. A non-magnetic (stainless steel) flitch plate increases the core edge loss since it allows (due to its higher skin depth) the flux to penetrate through it to impinge on the laminations. Hence, although the use of non-magnetic flitch plate may reduce the loss in it (assuming that its thickness is sufficiently small), the core edge loss is generally increased. The first step of the core is usually slit into two or three parts to reduce the core edge loss in large transformers. If the stack height of the first step of the core is less than about 12 mm, slitting may have to be done for the next step also. The use of a laminated flitch plate for large generator transformers and autotransformers is preferable since it also acts as a magnetic shunt .

3.3 Frame Losses

Frames (also called as yoke beams), serving to clamp yokes and support windings, are in vicinity of stray magnetic field of windings. Due to their large surface area and efficient cooling, hot spots seldom develop in them. Non-magnetic steel is not recommended as a material for frames. It is expensive, difficult to machine and

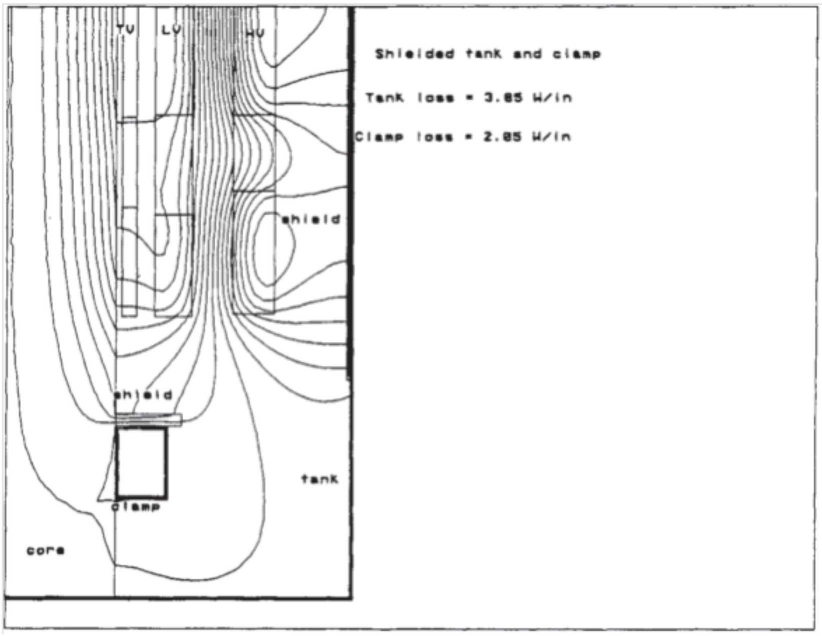

Figure 3.2: Leakage Flux Distribution In Transformer with Sheild

stray losses will be lower only if its thickness is sufficiently small. The loss in frames due to leakage field can be reduced by either aluminum shielding or by use of non-metallic platforms for supporting the windings. In distribution transformers, the stray loss in the tank may not be much since the value of leakage field is low. In power transformers, sometimes a frame of non-magnetic material (stainless steel) is used. As explained its thickness should be as small as mechanically possible; otherwise its loss may exceed the corresponding value for frame made of (magnetic) mild steel material.

3.4 Tank Losses

The tank stray loss forms a major part of the total stray loss in large power transformers. Stray flux departing radially from the outer surface of winding gives rise to eddy current losses in transformer tank walls. Though the stray flux density in the tank wall is low, the tank loss may be high due to its large area. Hot spots seldom develop in the tank, since the heat is carried away by the oil. A good thermal conductivity of the tank material also helps to mitigate hot spots. The stray loss in tank is controlled by magnetic/eddy current shields.

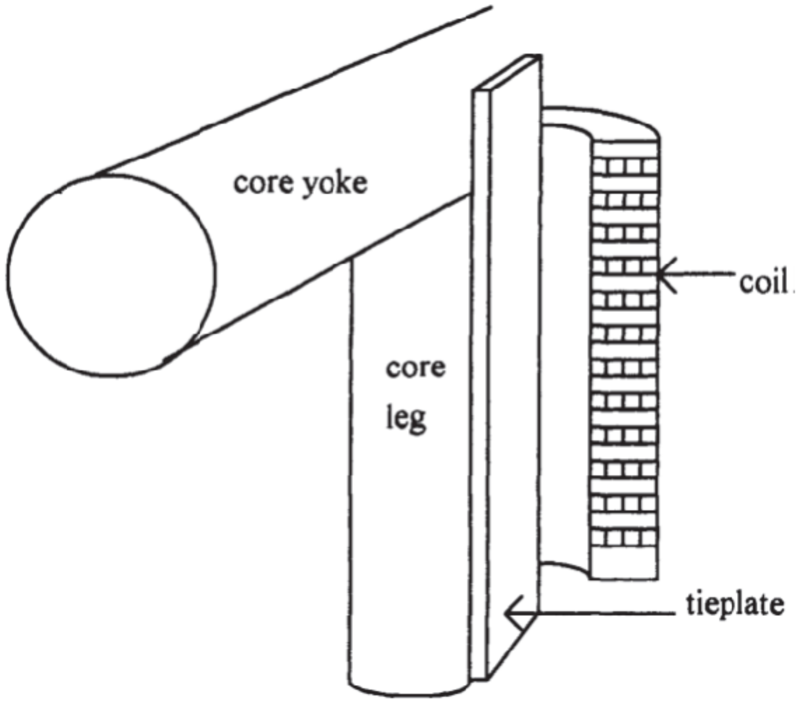

Figure 3.3: Tie Plate

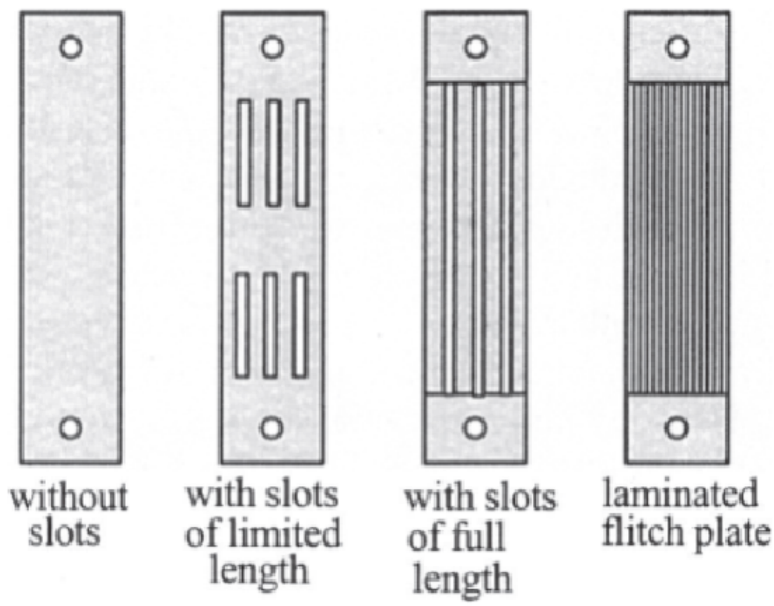

Figure 3.4: Laminated Flitch Plate With Slots

Figure 3.5: Tank Wall Sheilding

Chapter 4

Measure to Control Stray Loss In Transformer

Measures of stray loss control

The stray loss in a structural component is reduced by a number of ways

1. By use of laminated material
2. By use of high resistivity material
3. Reduction of flux density in the component by use of material with lower permeability
4. Reduction of flux density in the component by provision of a parallel magnetic path having low reluctance and loss
5. Reduction of flux density in the component by diverting/repelling the incident flux by use of a shielding plate having high conductivity

Three methods are commonly used for reducing stray losses in tanks. The first method uses yoke shunts which collect the leakage field coming out of the windings so that there is very little flux external to the core and windings. Secondly, magnetic shunts can be provided on the tank so that they carry most of the leakage flux. Thirdly, the tank may be lined with aluminum or copper plates (shields) the eddy currents in these plates tend to shield the tank from most of the radial incident flux.

Some geometrical factors have a significant influence on the tested stray losses. A small difference in heights of LV and HV windings can affect various stray loss components in different ways. For example, if LV winding is taller by 1% and is placed symmetrically with respect to HV winding height, the losses in the core clamping structures reduce, whereas the losses in the tank increase. On the contrary, if HV winding is taller, the stray losses in the core, frames and flitch plates increase, and those in the tank reduce.

4.1 Use Of Magnetic Sheilding

The magnetic shunts are more effective in controlling stray losses as compared to the non-magnetic (eddy current) shields. They offer a low reluctance path to the leakage flux constraining its path in a predetermined fashion. In the case of eddy current shields, the flux repelled by them may find a path through nearby structural components negating the advantages of shielding. An ideal magnetic shunt (infinite permeability) has no magnetic voltage drop across its length. The magnetic shunts are basically useful to shield structural components from the leakage field. They are not used for shielding against the field of high currents. If magnetic shunts are of adequate thickness and are made of CRGO laminations with lower watts/kg characteristics, the losses in them are almost negligible. Usually, left over pieces of core laminations (from original rolls) are used to make a magnetic shunt. The height of magnetic shunts should be higher than the height of windings.

There are two types of Magnetic Sheilding :

1. Widthwise Shunt

2. Edgewise Shunt

The width-wise shunts (more commonly used) are placed on the tank as shown in figure The width of shunts should be as small as possible to reduce entry losses at their top and bottom portions where the leakage field impinges on them radially.

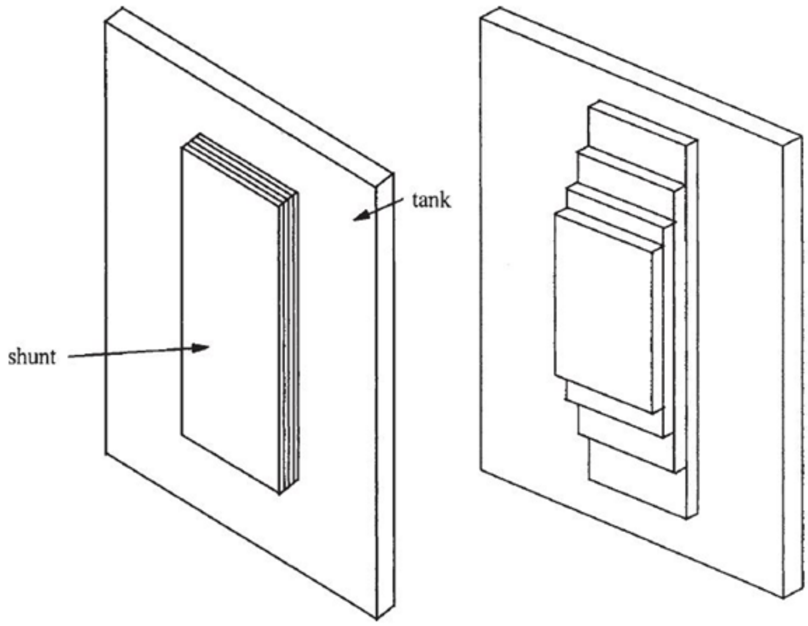

Figure 4.1: Width Wise Shunt

The other type of magnetic shunt, edge-wise shunt, is better than width-wise shunt because the flux is incident on the thickness (edge) of laminations resulting in negligible eddy loss in them. A typical edge-wise shunt is shown in figure . The effective permeability of laminations as seen by the incident flux is much higher for this shunt as compared to the width-wise shunt since the flux does not encounter any non-magnetic gaps once it enters the shunt. In the width-wise shunt, due to non-magnetic gaps (however small they be), the effective permeability at the entry point reduces making it less effective as compared to the edge-wise shunt. A substantial reduction in tank stray losses is reported in by the use of edge-wise shunts. It is preferable to experimentally check the quantum of stray loss reduction before standardizing the use of edge-wise shunts.

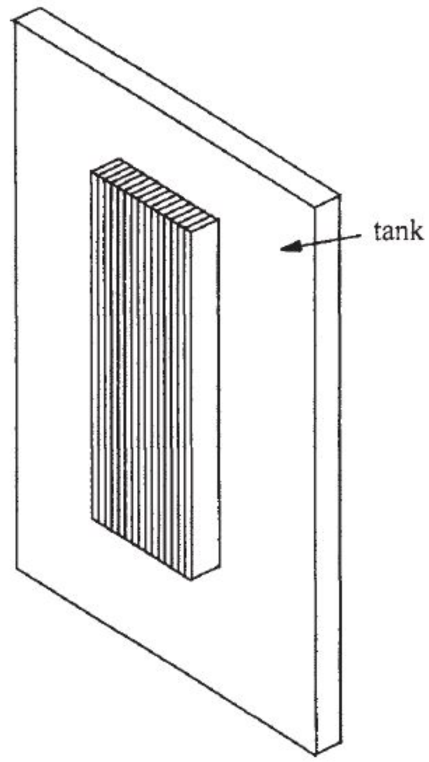

Figure 4.2: Edge Wise Shunt

4.2 Use Of Yoke Shunts

Yoke shunts are another form of magnetic shunts (flux collectors), which are placed parallel to the yoke at the top and bottom ends of the windings. These shunts can be quite effective since the fluxes coming out from the three phases can add up to zero in them. The yoke shunts provide an excellent means of guiding the leakage field safely back to the core minimizing stray losses in the tank and other structural components. Hence, the gap between the shunt and yoke must be kept sufficiently small for the effective control of the leakage field.

Some manufacturers use wound steel pressure ring on the top of the windings, which not only acts as a clamping ring (for mechanical stability during short circuits) but it also reduces the stray losses in structural components. The steel ring provides a low reluctance path for the leakage field coming out of the windings and diverts it into the yoke away from the structural components.

Figure 4.3: Yoke Shunt

4.3 Use Of Eddy Current Sheilding

Aluminum or copper shields are used for shielding structural components from the high current and leakage fields. Eddy currents induced in them repel the incident field reducing the losses in structural components. As discussed , the thickness of these shields should be adequate for their effectiveness and for reducing the loss in shields themselves. In most of the cases, the loss in the structural component and eddy current shield is more than that of the structural component and magnetic shunt. However, the eddy current shields have the advantage that they can be fitted on odd shapes of the tank unlike magnetic shunts. The weight of the eddy current shield is also usually lower than the magnetic shunt. For shielding a tank from the high current field, the eddy current shields are better than the magnetic shunts.

The components required to make the eddy current shielding arrangement are of simpler construction and the shields can be suitably formed to protect the areas having complex shapes. The disadvantage of this method is that there are losses produced in the shield itself and these must be accurately evaluated. The shield dimensions have to be properly designed and adequate cooling needs to be provided to limit its temperature rise. Secondly, the diverted flux from the shield may cause overheating in the nearby unprotected structural parts. Hence, the design and positioning of the eddy current shields have to be done more carefully as compared to the magnetic shunts.

Figure 4.4: Eddy Current Sheilding

Chapter 5

Design Of Transformer

5.1 Rating

3 phase , 100 MVA , 220/66 KV , star/star connected , 15 % impedence , 50 Hz , core type power transformer .

5.2 Material Specifications

1. Winding - Copper,relative permiability μ = 0.9999 ,conductivity σ = 58000000 siemens/mtr
2. Core - CRGO,relative permiability μ= 15000 , ,conductivity σ = 10000 siemens/mtr
3. Tank - Electrical Steel ,relative permiability μ = 500 , ,conductivity σ = 1560000 siemens/mtr
4. Flitch Plate, Yoke Beam - iron relative permiability μ = 4000 , ,conductivity σ = 10300000 siemens/mtr

5.3 Dimensions of Transformer

1. Core Diameter = 775 mm
2. Leg Centre = 1615 mm
3. Window Height = 2225 mm
4. Radial Diameter LV winding = 775/2 + 66 = 453.5 mm
5. Radial Diameter HV winding = 453.5 + 77 +100 = 630.5 mm
6. Thickness of LV winding = 100 mm
7. Thickness of HV winding = 123 mm
8. Height of LV winding = 1925 mm

9. Height of HV winding = 1925 mm
10. Bottom Clearance = 110 mm
11. Top Clearance = 110 + 60 + 20 = 190 mm
12. Tank = 5336 * 2926 * 3965 mm
13. Tank Thickness = 15 mm
14. Flitch plate = 3295 * 210 * 16 mm
15. Yoke Beam = 3230 * 210 * 16 mm
16. LV turns = 252
17. HV turns = 800
18. LV current = 874.77 A
19. HV current = 262.43 A
20. HV to HV clearance = 110 mm

5.4 Calculations

1. E_t (Volt/turn): = 0.5 $\sqrt{M}VA$ = 0.5 $\sqrt{1}00000$ = 158.77
2. Flux Density = 1.6 T = Bm
3. E_t = 4.44 * f * Bm * Ai
4. Ai = Net Area = 4316.114 mm
5. Space Factor = 0.97
6. Gross Area = 4316.114/ 0.97 = 4449.60 mm
7. Diameter of core (d)
   Ai = $\frac{\pi}{4}$ *d^2
   d = 775 mm
8. HV current = 100 * $\frac{1000}{\sqrt{3}}$ * 220 = 262.44 A
9. LV current = 100 * $\frac{1000}{\sqrt{3}}$ * 66 = 874.77 A
10. HV turns = 220 * 1000 / 158.77 = 800.00
11. LV turns = 66 * 1000/ 158.77 = 262.44
12. Current Density = 3 A/ m^2

13. Conductor Used = PICC (Paper Insulated Copper Conductor)
    PICC = 1.3 mm to 4 mm (length)
    PICC (width) = 5 to 7 * (length)
14. Winding Used = Continuous Disc Type
15. No. of Disc = 38
16. Disc clearance = 5 mm
17. Radial Height of Conductor = 1925 mm
18. Thickness of LV winding = 100 mm
19. Thichness of HV winding = 123 mm
20. Clearances used are according to Indian Standards & Company Practice

Chapter 6

Stray Loss Calculation

6.1 Total Stray Loss

Stray Loss (without shields) = MVA * Z * (5.67- 1.77 log(MVA)) / 0.65
= 100 * 0.14 * (5.67 - 1.77 * 2)/ 0.65
= 45.86 KW

6.1.1 Tank Losses

Average ohmic loss = 2.54 * 10^4 W/m^3
Tank volume = 4 * 4.5 * .01 m^3
Total Loss = 2.54 * 10^4* 4 * 4.5 * .01 * 6 KW
= 30.618 KW

6.1.2 FlitchPlate & Yokebeam Loss

Flitchplate & Yokebeam loss = 2.65 * 10^4 *$W^{2.4}$ *B^2
W = width of Flitch plate in mtr
B = flux Density in Tesla
Flitch plate & Yoke beam loss = 2.65 * 10^4*$0.210^{2.4}$ *1.23^2 * 5
= 5.124 KW

6.2 Total Stray Loss with Sheilds

Different kinds of Sheilds use for the control of Stray losses are

1. EdgeWise Shunt
2. WidthWise Shunt
3. Partial Shunt
4. FullHieght Shunt

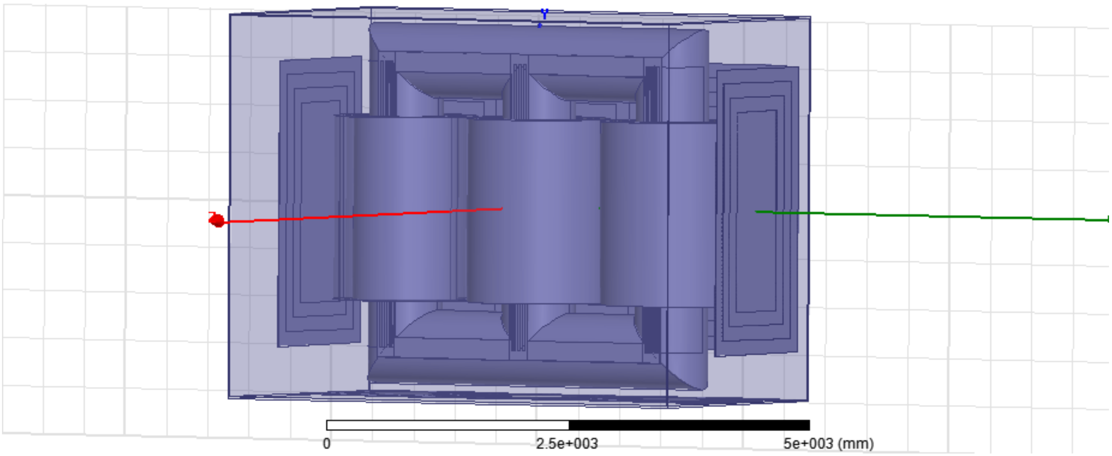

Figure 6.1: Edge Wise Geometry

6.3 Total Stray Loss with EdgeWise Shunt

Stray Loss calculation using EdgeWise Sheeild can be done using either CRGO or Copper material.

6.3.1 EdgeWise Sheild having CRGO material

The Fluxdensity at flitchplate , tank is calculated
The Ohmicloss at flitchplate , tank , sheilds is calculated.

The loss density at tank is 7.931 * 10^3 W/ m^3

Total tank loss is = 7.93*10^3 * 4* 4.5 * 0.01* 6
= 8. 64 KW

Area of bottom shields = (830*830) + (730*730) + (630*630) + (530*530)mm^2
= 0.68 + 0.53 +0 .39 + 0.28 m^2

Volume Of bottom Sheild = 1.88 * .01 m^3
= .0188 m^3

Loss density at Sheilds = 1.57 * 10^4 W/ m^3

Loss at bottom sheilds is = .0188* 1.57*10^4*3
= 0.879 KW

Area at Side & Back Sheilds = (730*3000) + (630*2800) + (530*2600) + (430*2400)mm^2
= 2.19 + 1.76 + 1.37 + 1.032 m^2
= 6.364 m^2

Volume of Side & Back Sheilds = 6.364 * 0.01m^3
= 0.06364 m^3

loss at Side & Bottom Sheild = 0.06364* 1.57* 10^4 * 5
= 5 KW

Flux Density At Flitchplate = 0.8 T

Loss at Flitchplate = 2.65 * 10^4*$0.210^{2.4}$ * 0.80^2 * 6
= 2.40 KW

Total Stray Loss = 2.4 + 5 + 0.879 + 8.64 KW
= 16.92 KW

6.3.2 EdgeWise Sheild having Copper material

The Fluxdensity at flitchplate , tank is calculated

The Ohmicloss at flitchplate , tank , sheilds is calculated.

The loss density at tank is 1.04 *10^4 W/ m^3

Total tank loss is = 1.04*10^4* 4*4.5*0.01*6
= 11.23 KW

Area of bottom shields = (830*830) + (730*730) + (630*630) + (530*530) mm^2
= 0.68 + 0.53 +0 .39 + 0.28m^2

Volume Of bottom Sheild = 1.88 * .01m^3

= .0188 m^3

Loss density at Sheilds = 2.087 * 10^4 W/m^3

Loss at bottom sheilds is = .0188* 2.087*10^4 *3
= 1.173 KW

Area at Side & Back Sheilds = (730*3000) + (630*2800) + (530*2600) + (430*2400) mm^2
= 2.19 + 1.76 + 1.37 + 1.032m^2
= 6.364 m^2

Volume of Side & Back Sheilds = 6.364 * 0.01 m^3
= 0.06364 m^3

loss at Side & Bottom Sheild = 0.06364* 2.087* 10^4 * 5
= 6.618 KW

Flux Density At Flitchplate = 0.82 T

Loss at Flitchplate = 2.65 * 10^4*$0.210^{2.4}$* 0.82^2 * 6
= 2.52 KW

Total Stray Loss = 2.52+ 6.618 + 1.173 + 11.23 KW
= 21.541 KW

6.4 Total Stray Loss with Partial Shunt

Stray Loss calculation using EdgeWise Sheeild can be done using either CRGO or Copper material.

6.4.1 Partial Height Sheild having CRGO material

The Fluxdensity at flitchplate , tank is calculated

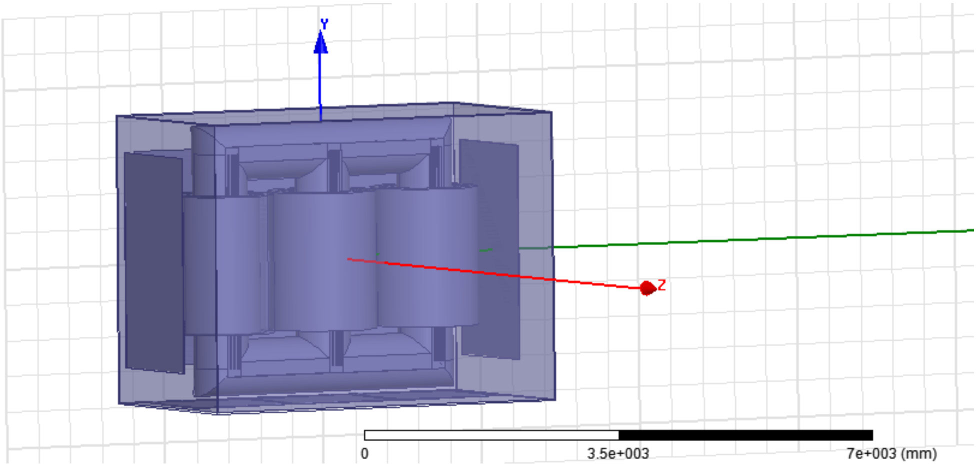

Figure 6.2: Partial Height Shunt Geometry

The Ohmicloss at flitchplate , tank , sheilds is calculated.

The loss density at tank is 5.155 * 10^3 W/m^3

Total tank loss is = 5.155*10^3* 4*4.5*0.01*6
= 5.568 KW

Area of bottom shields = (830*830) + (830*830) + (830*830) + (830*830)mm^2
= 0.68*4m^2
=2.72 m^2

Volume Of bottom Sheild = 2.72 * .01m^3
= .0272m^3

Loss density at Sheilds = 1.40* 10^4 W/m^3

Loss at bottom sheilds is = .0272* 1.40*10^4 *3
= 1.142 KW

Area at Side & Back Sheilds = (730*3000) + (730*3000) + (730*3000) + (730*3000)mm^2
= 2.19 *4m^2
= 8.76m^2

Volume of Side & Back Sheilds = 8.76 * 0.01m^3
= 0.0876m^3

loss at Side & Bottom Sheild = 0.0876* 1.40*10^4 * 5
= 6.132 KW

Flux Density At Flitchplate = 0.75 T

Loss at Flitchplate = 2.65 * 10^4 *$0.210^{2.4}$ *0.75^2 * 6
= 2.11 KW

Total Stray Loss = 2.11 + 5.568 + 1.142 + 6.132 KW
= 14.95 KW

6.4.2 Partial Height Sheild having Copper material

The Fluxdensity at flitchplate , tank is calculated

The Ohmicloss at flitchplate , tank , sheilds is calculated.

The loss density at tank is 1.04 * 10^4 W/m^3

Total tank loss is = 1.04 *10^4 * 4*4.5*0.01*6
= 11.232 KW

Area of bottom shields = (830*830) + (830*830) + (830*830) + (830*830) mm^2
= 0.68*4 m^2
=2.72 m^2

Volume Of bottom Sheild = 2.72 * .01m^3
= .0272 m^3

Loss density at Sheilds = 1.5 * 10^4 W/m^3

Loss at bottom sheilds is = .0272* 1.5*10^4 *3
= 1.224 KW

Area at Side & Back Sheilds = (730*3000) + (730*3000) + (730*3000) + (730*3000) mm^2
= 2.19 *4 m^2
= 8.76 m^2

Volume of Side & Back Sheilds = 8.76 * 0.01m^3
= 0.0876 m^3

loss at Side & Bottom Sheild = 0.0876* 1.3* 10^4 * 5
= 5.694 KW

Flux Density At Flitchplate = 0.77 T

Loss at Flitchplate = 2.65 * 10^4 * $0.210^{2.4}$* 0.77^2 * 6
= 2.22 KW

Total Stray Loss = 2.22 + 5.694 + 1.224 + 11.232 KW
= 20.37 KW

6.5 Total Stray Loss with Width Wise Shunt

Stray Loss calculation using Width Wise Sheild can be done using either CRGO or Copper material.

The stacks used are of 20 mm.

6.5.1 Width Wise Sheild having CRGO material

The Fluxdensity at flitchplate , tank is calculated

The Ohmicloss at flitchplate , tank , sheilds is calculated.

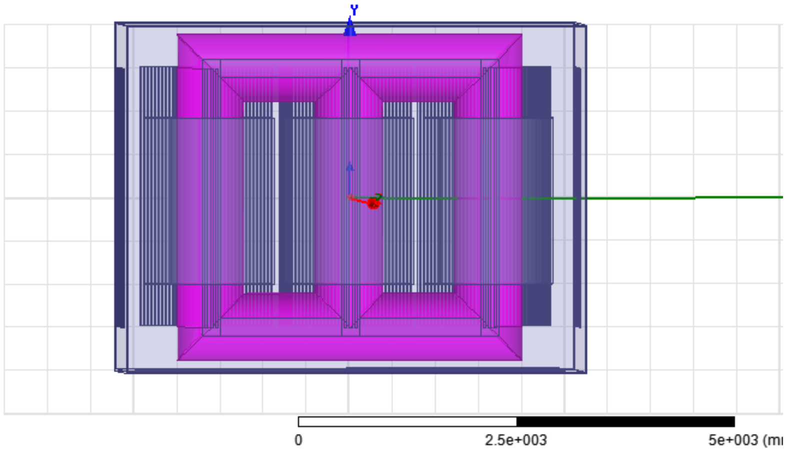

Figure 6.3: Width Wise Shunt Geometry

The loss density at tank is 6.094 * 10^3 W/m^3

Total tank loss is = 6.094 *10^3 * 4*4.5*0.01*6
= 6.580 KW

Area of bottom shields = (830*830) + (830*830) + (830*830) + (830*830)mm^2
= 0.68*4 m^2
=2.72 m^2

Volume Of bottom Sheild = 2.72 * .01m^3
= .0272 m^3

Loss density at Sheilds = 9.18 * 10^3 W/m^3

Loss at bottom sheilds is = .0272* 9.18 *10^3*3
= 0.749 KW

Area at Side & Back Sheilds = (730*3000) + (730*3000) + (730*3000) + (730*3000)mm^2
= 2.19 *4 m^2
= 8.76 m^2

Volume of Side & Back Sheilds = 8.76 * 0.01m^3
= 0.0876 m^3

loss at Side & Bottom Sheild = 0.0876* 9.18 * 10^3 * 5
= 4.020 KW

Flux Density At Flitchplate = 0.65 T
Loss at Flitchplate = 2.65 * 10^4 *$0.210^{2.4}$ *0.65^2 * 6
= 1.586 KW

Total Stray Loss = 1.586 +4.020 + 0.749 + 6.580 KW
= 12.935 KW

6.5.2 Width Wise Sheild having Copper material

The Fluxdensity at flitchplate , tank is calculated

The Ohmicloss at flitchplate , tank , sheilds is calculated.

The loss density at tank is 1.121 * 10^4 W/ m^3

Total tank loss is = 1.121 *10^4 * 4*4.5*0.01*6
= 12.106 KW

Area of bottom shields = (830*830) + (830*830) + (830*830) + (830*830) mm^2
= 0.68*4 m^2
=2.72 m^2

Volume Of bottom Sheild = 2.72 * .01m^3
= .0272 m^3

Loss density at Sheilds = 1.02 * 10^4 W/m^3
Loss at bottom sheilds is = .0272* 1.02 *10^4 *3
= 0.844 KW

Area at Side & Back Sheilds = (730*3000) + (730*3000) + (730*3000) + (730*3000)mm^2
= 2.19 *4 m^2

$= 8.76\ m^2$

Volume of Side & Back Sheilds = $8.76 * 0.01 m^3$
$= 0.0876\ m^3$

loss at Side & Bottom Sheild = $0.0876 * 1.02 * 10^4 * 5$
= 4.467 KW

Flux Density At Flitchplate = 0.67 T
Loss at Flitchplate = $2.65 * 10^4 * 0.210^{2.4} * 0.67^2 * 6$
= 1.674 KW

Total Stray Loss = 1.674 +4.467 + 0.844 + 12.106 KW
= 19.091 KW

6.6 Total Stray Loss with Full Height Shunt

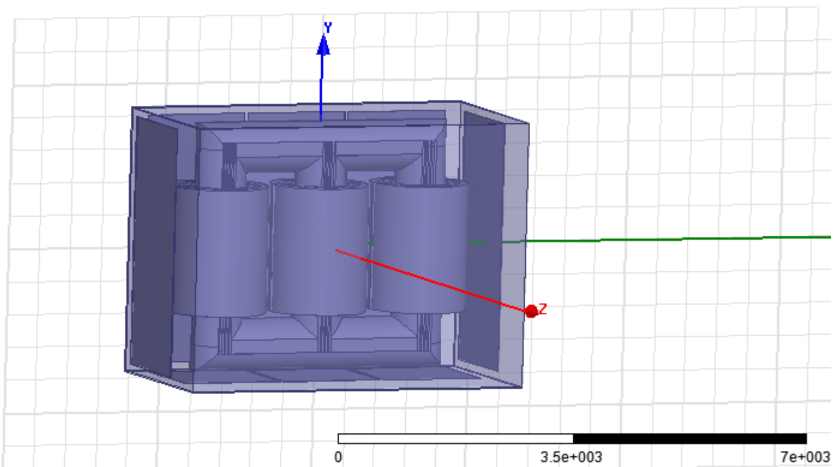

Figure 6.4: Full Height Shunt Geometry

Stray Loss calculation using Width Wise Sheild can be done using either CRGO or Copper material.

6.6.1 Full Height Sheild having CRGO material

The Fluxdensity at flitchplate , tank is calculated

The Ohmicloss at flitchplate , tank , sheilds is calculated.
The loss density at tank is 5.33 * 10^3 W/m^3

Total tank loss is = 5.33 *10^3 * 4*4.5*0.01*6
= 5.756 KW

Area of bottom shields = (830*830) + (830*830) + (830*830) + (830*830)mm^2
= 0.68*4 m^2
=2.72 m^2

Volume Of bottom Sheild = 2.72 * .01m^3
= .0272 m^3

Loss density at Sheilds = 10.29 * 10^3 W/m^3
Loss at bottom sheilds is = .0272* 10.29 *10^3*3
= 0.840 KW

Area at Side & Back Sheilds = (730*3775) + (730*3775) + (730*3775) + (730*3775)mm^2
= 2.75 *4 m^2
= 11.04 m^2

Volume of Side & Back Sheilds = 11.04 * 0.01m^3
= 0.11 m^3

loss at Side & Bottom Sheild = 0.11* 6.83 * 10^3 * 5
= 3.756 KW

Flux Density At Flitchplate = 0.6 T
Loss at Flitchplate = 2.65 * 10^4* $0.210^{2.4}$ * 0.6^2 * 6
= 1.352 KW

Total Stray Loss = 1.352 + 5.75 + 0.840 + 3.756 KW
= 11.704 KW

6.6.2 Full Height Sheild having Copper material

The Fluxdensity at flitchplate , tank is calculated

The Ohmicloss at flitchplate , tank , sheilds is calculated.

The loss density at tank is 8.16 * 10^3 W/ m^3

Total tank loss is = 8.16 *10^3 * 4*4.5*0.01*6
= 8.812 KW

Area of bottom shields = (830*830) + (830*830) + (830*830) + (830*830)mm^2
= 0.68*4 m^2
=2.72 m^2

Volume Of bottom Sheild = 2.72 * .01m^3
= .0272 m^3

Loss density at Sheilds = 9.3 * 10^3 W/m^3
Loss at bottom sheilds is = .0272* 8.3 *10^3 *3
= 0.677 KW

Area at Side & Back Sheilds = (730*3775) + (730*3775) + (730*3775) + (730*3775)mm^2
= 2.75 *4 m^2
= 11.04 m^2

Volume of Side & Back Sheilds = 11.04 * 0.01m^3
= 0.11 m^3

loss at Side & Bottom Sheild = 0.11* 1.24 * 10^4 * 5
= 6.82 KW

Flux Density At Flitchplate = 0.62 T
Loss at Flitchplate = 2.65 * 10^4* $0.210^{2.4}$* 0.62^2 * 6
= 1.443 KW

Total Stray Loss = 1.443 + 6.82 + 0.677 + 8.812 KW
= 17.752 KW

6.7 Cost Benifit Analysis

The cost benifit analysis of the various sheilds used in the geometry is as shown below

6.7.1 EdgeWise Shunt

The total Volume of the CRGO used in Sheilds is 0.08244 m^3

The Density of CRGO material is 7.65 gms/ cm^3

The total Weigth of CRGO material is 630.66 Kg .

Cost of CRGO material is 120 RS/kg

So, total cost of CRGO material used in Sheilds is Rs 75,679

Now , taking production cost , transportation cost , labour charge as 12.5 % of material cost

So total Cost is Rs 85,138

Cost Of Load Loss/Kw is Given by

$$Wc = 8760 \times e \times \frac{(1+r)^n - 1 \times LS}{r \times (1+r)^n} \tag{6.1}$$

Taking r = 0.1 n = 25

We get , Wc = Rs 82,20,000 for 35.742 Kw

In Sheilds the losses are 16.92 Kw

So the cost is Rs 38,91,000

Net Savings is Rs 82,20,000-38,91,000-85,138

= Rs 42,43,000

6.7.2 Partial Height Shunt

The total Volume of CRGO used in the Sheilds is 0.1148 m^3

The Density of CRGO material is 7.65 gms/ cm^3

The total Weigth of CRGO material is 878.22 Kg .

Cost of CRGO material is 120 RS/kg

So, total cost of CRGO material used in Sheilds is Rs 1,05,386

Now , taking production cost , transportation cost , labour charge as 12.5 % of material cost

So total Cost is Rs 118559.25

Cost Of Load Loss/Kw is Given by

$$Wc = 8760 \times e \times \frac{(1+r)^n - 1 \times LS}{r \times (1+r)^n} \tag{6.2}$$

Taking r = .1 n = 25

We get , Wc = Rs 8220000 for 35.742 Kw

In Sheilds the losses are 14.95 Kw

So the cost is Rs 34,38,000

Net Savings is Rs 82,20,000-34,38,000-1,18,559

= Rs 46,63,440

6.7.3 Width Wise Shunt

The total Volume of CRGO used in the Sheilds is 0.1148 m^3

The Density of CRGO material is 7.65 gms/ cm^3

The total Weigth of CRGO material is 878.22 Kg .

Cost of CRGO material is 120 RS/kg

So, total cost of CRGO material used in Sheilds is Rs 105386

Now , taking production cost , transportation cost , labour charge as 15 % of material cost

So total Cost is Rs 1,21,193

Cost Of Load Loss/Kw is Given by

$$Wc = 8760 \times e \times \frac{(1+r)^n - 1 \times LS}{r \times (1+r)^n} \tag{6.3}$$

Taking r = 0.1 n = 25

We get , Wc = Rs 82,20,000 for 35.742 Kw

In Sheilds the losses are 12.93 Kw

So the cost is Rs 29,75,000

Net Savings is Rs 82,20,000-29,75,000-1,21,193

= Rs 51,45,000

6.7.4 Full Height Shunt

The total Volume of CRGO used in the Sheilds is 0.1372 m^3

The Density of CRGO material is 7.65 gms/ cm^3

The total Weigth of CRGO material is 1050 Kg .

Cost of CRGO material is 120 RS/kg

So, total cost of CRGO material used in Sheilds is Rs 125950

Now , taking production cost , transportation cost , labour charge as 12.5 % of material cost

So total Cost is Rs 1,41,693

Cost Of Load Loss/Kw is Given by

$$Wc = 8760 \times e \times \frac{(1+r)^n - 1 \times LS}{r \times (1+r)^n} \tag{6.4}$$

Taking r = 0.1 n = 25

We get , Wc = Rs 82,20,000 for 35.742 Kw

In Sheilds the losses are 11.704 Kw

So the cost is Rs 26,91,000

Net Savings is Rs 82,20,000-26,91,000-1,41,693

= Rs 53,87,306

Chapter 7

FEM Model & Simulation Results

7.1 Transformer Analysis without Sheild

The simplified FEM model of 100 MVA , 220/66 KV , Y-Y connected transformer is shown. It contains LV windings , HV windings , Core , Yoke beams , Tank & Flitchplate.

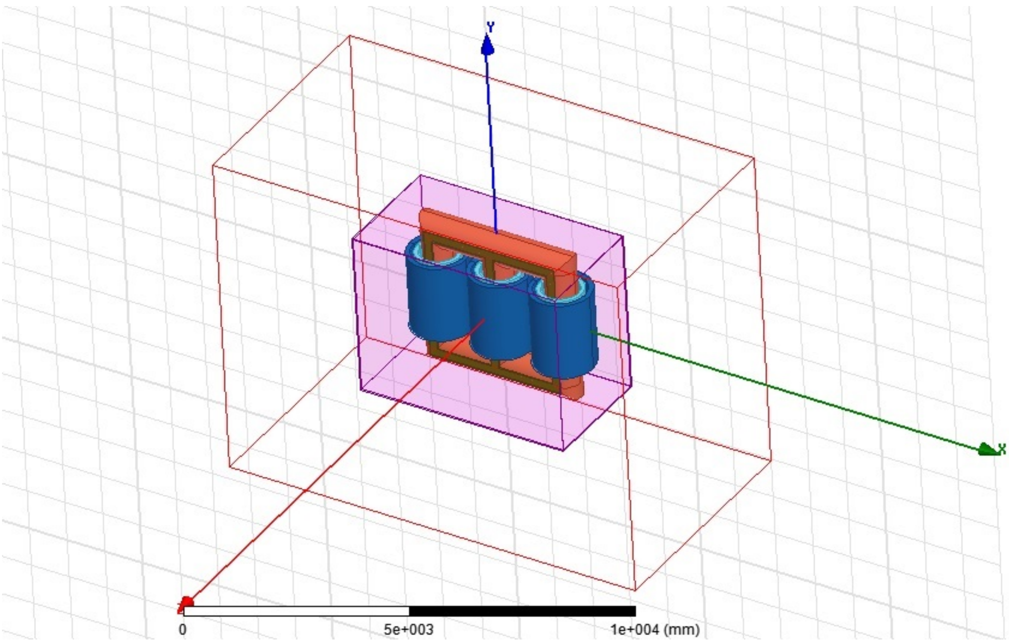

Figure 7.1: FEM Model of Transformer

The average flux density in core is 1.6 T .

The Flux Density at the Tank wall is 0.25 T.

The average ohmic loss at Tank wall is 2.54 * 10^4 W/ m^3

The average Flux Density at yoke & Flitchplate is 1.01 T.

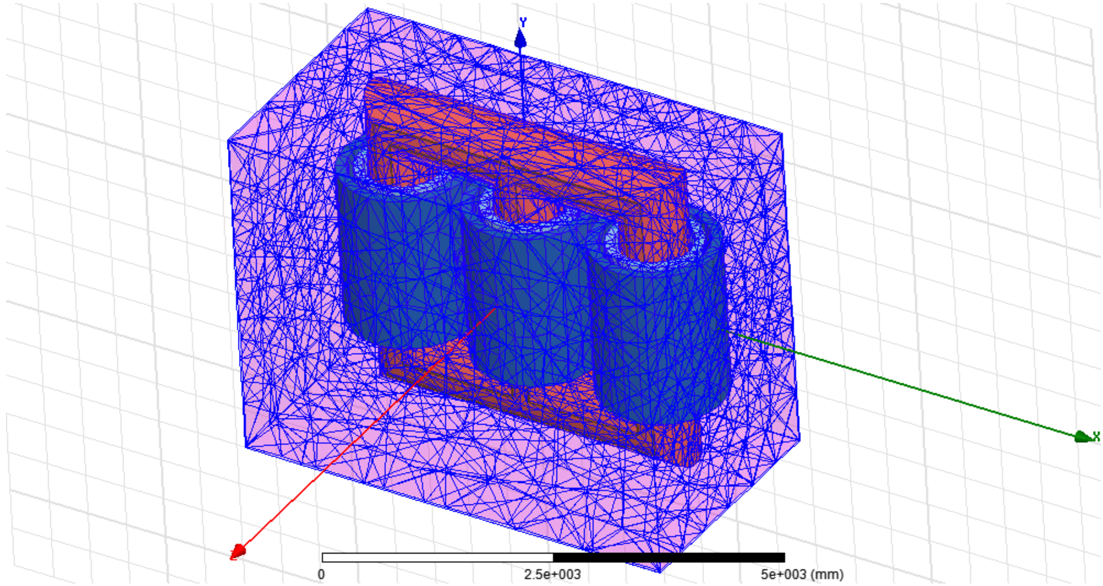

Figure 7.2: Meshed FEM Model of Transformer

7.2 Transformer Analysis with EdgeWise Sheild

The Flux Density at the Tank wall is 0.18 T.

The average ohmic loss at Tank wall is 7.33 * 10^3 W/ m^3 (CRGO material)
The average ohmic loss at Sheild is 1.57 * 10^4 W/ m^3 (CRGO material)
The average Flux Density at yoke & Flitchplate is 0.75 T.
The average ohmic loss at Tank wall is 1.04* 10^4 W/ m^3 (Copper material)
The average ohmic loss at Sheild is 2.08 * 10^4 W/ m^3 (Copper material)

7.3 Transformer Analysis with Partial Height Sheild

The Flux Density at the Tank wall is 0.15 T.
The average ohmic loss at Tank wall is 5.155 * 10^3 W/ m^3 (CRGO material)
The average ohmic loss at Sheild is 1.40 * 10^3 W/ m^3 (CRGO material)
The average Flux Density at yoke & Flitchplate is 0.70 T.
The average ohmic loss at Tank wall is 1.04* 10^4 W/ m^3 (Copper material)
The average ohmic loss at Sheild is 1.4 * 10^4 W/ m^3 (Copper material)

7.4 Transformer Analysis with Width Wise Sheild

The Flux Density at the Tank wall is 0.11 T.

The average ohmic loss at Tank wall is 6.094 * 10^3 W/ m^3 (CRGO material)
The average ohmic loss at Sheild is 9.18 * 10^3 W/ m^3 (CRGO material)
The average Flux Density at yoke & Flitchplate is 0.65 T.

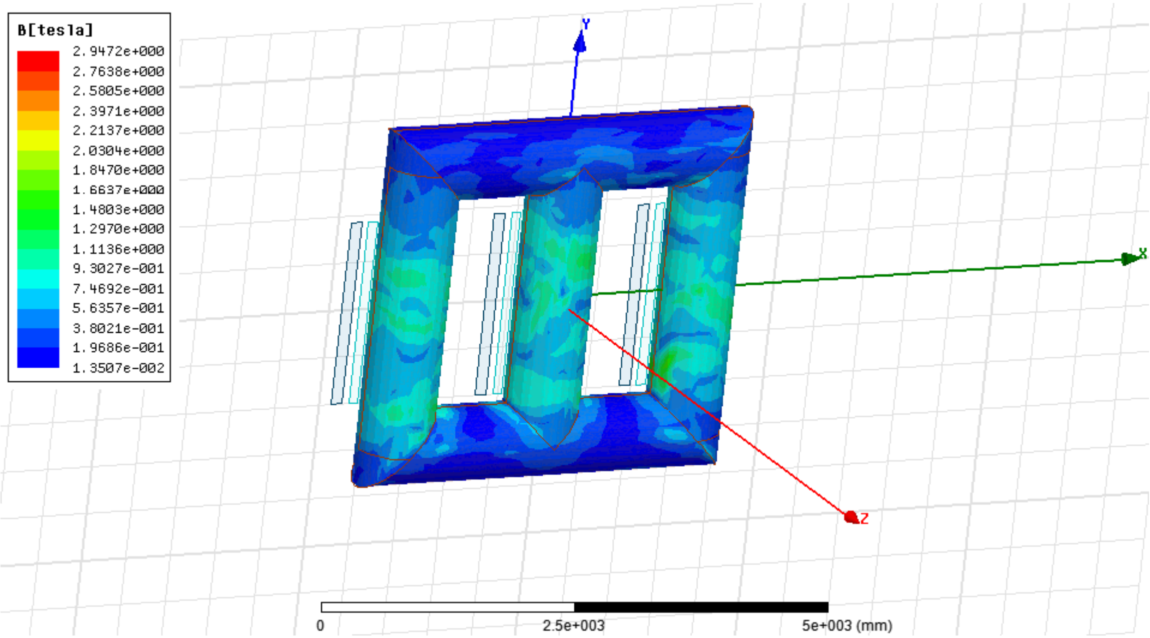

Figure 7.3: Flux Density in Core

The average ohmic loss at Tank wall is 1.121* 10^4 W/ m^3 (Copper material)
The average ohmic loss at Sheild is 1.024 * 10^4 W/ m^3 (Copper material)

7.5 Transformer Analysis with Full Height Sheild

The Flux Density at the Tank wall is 0.08 T.
The average ohmic loss at Tank wall is 5.33 * 10^3 W/ m^3 (CRGO material)
The average ohmic loss at Sheild is 8.83 * 10^3 W/ m^3 (CRGO material)
The average Flux Density at yoke & Flitchplate is 0.6 T.
The average ohmic loss at Tank wall is 8.16* 10^3 W/ m^3 (Copper material)
The average ohmic loss at Sheild is 1.24 * 10^4 W/ m^3 (Copper material)

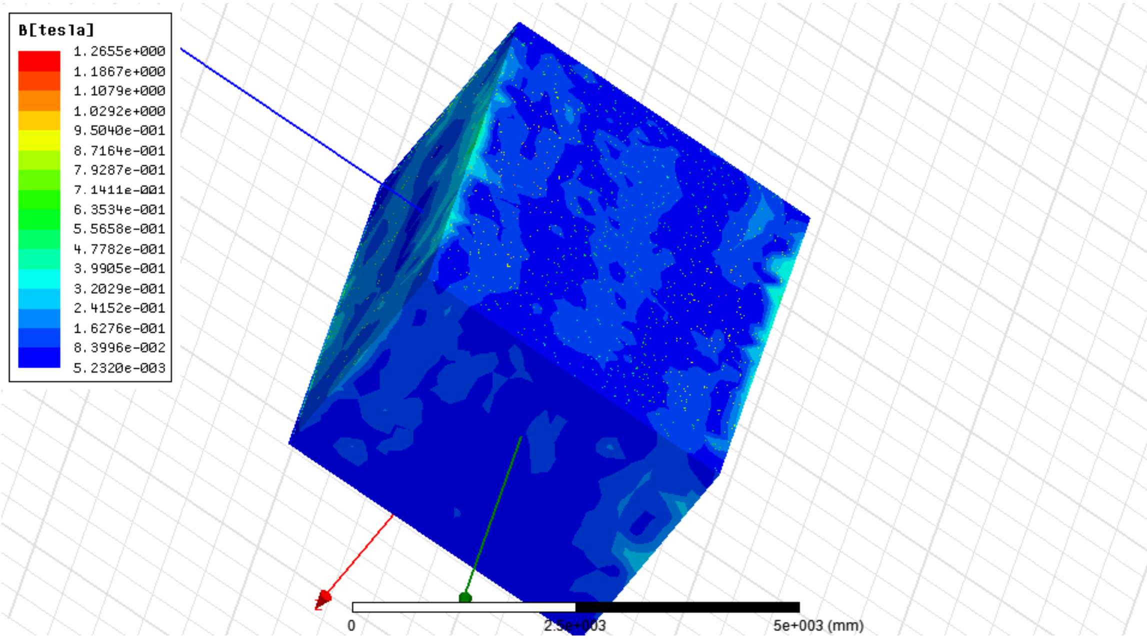

Figure 7.4: Flux Density in Tank Wall

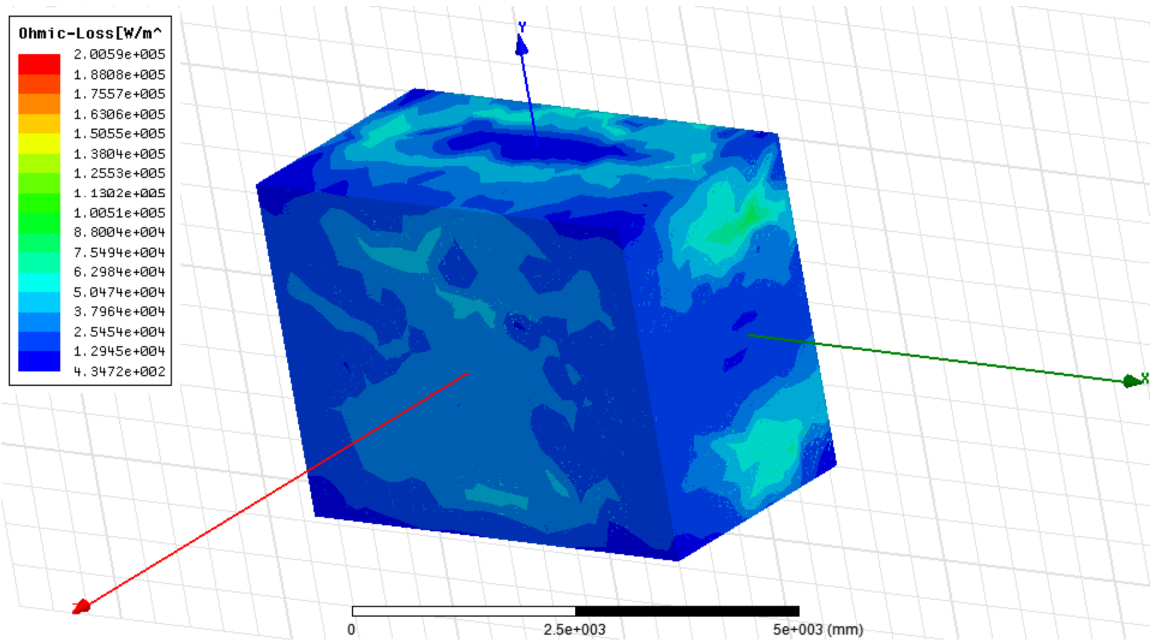

Figure 7.5: Ohmic Loss in Tank Wall

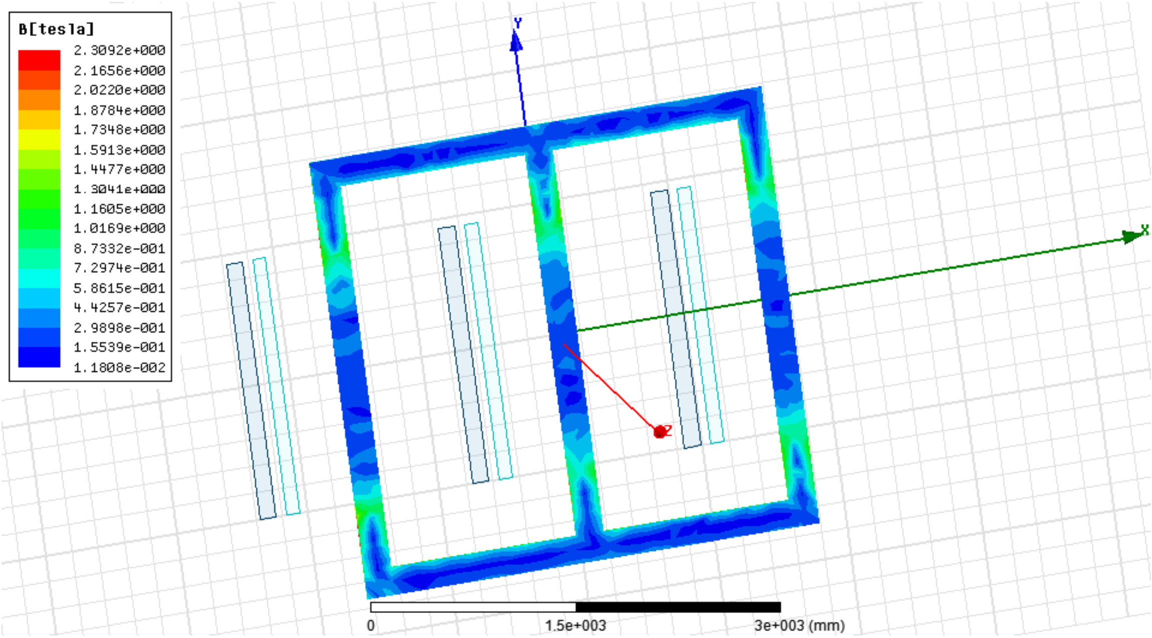

Figure 7.6: Flux Density in Flitch Plate & Yoke Beam

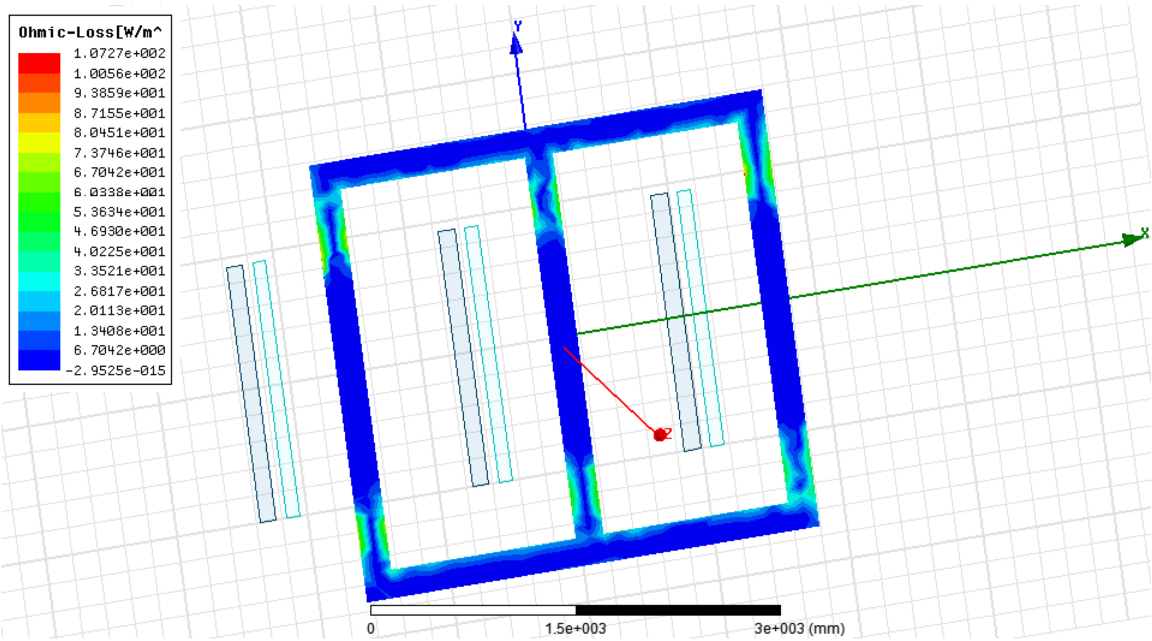

Figure 7.7: Ohmic Loss in Flitch Plate & Yoke Beam

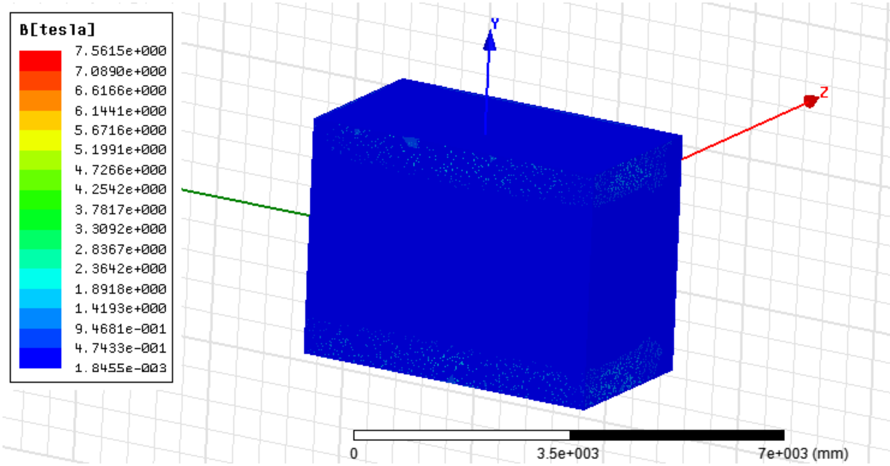

Figure 7.8: Flux Density at Tank EdgeWiseShunt(CRGO)

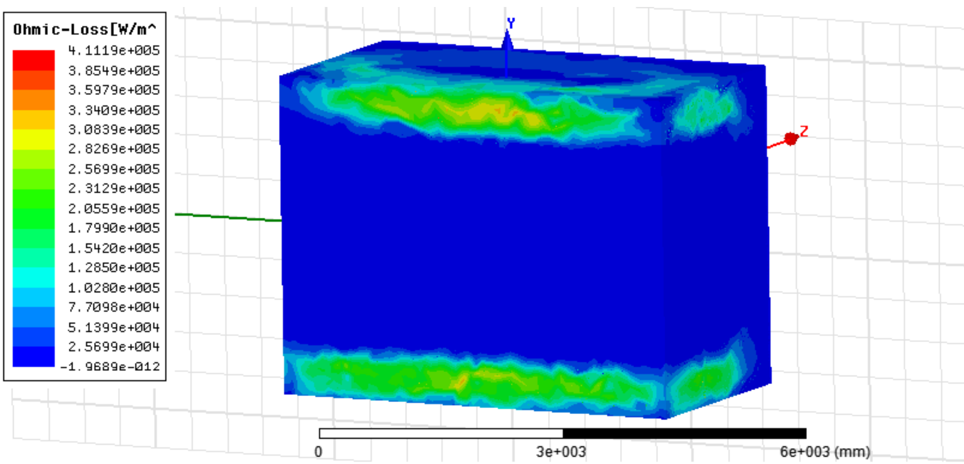

Figure 7.9: Ohmic Loss at Tank EdgeWiseShunt(CRGO)

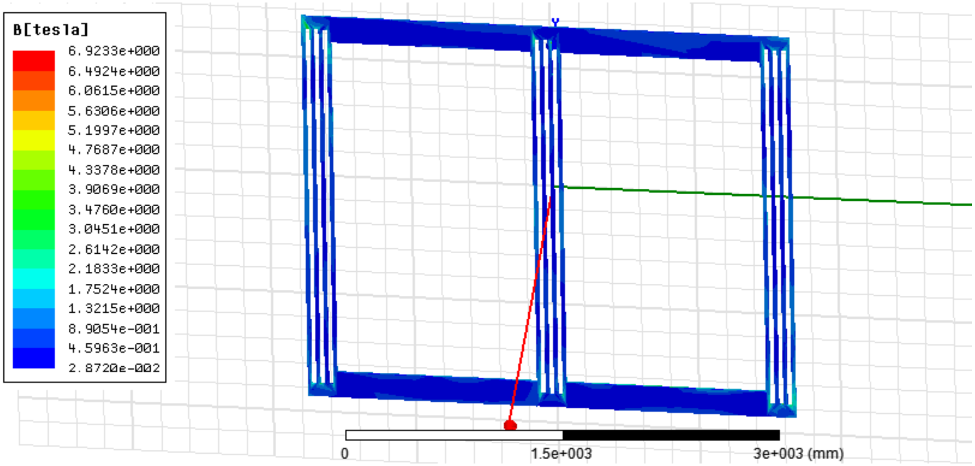

Figure 7.10: Flux Density at Flitchplate EdgeWise(CRGO)

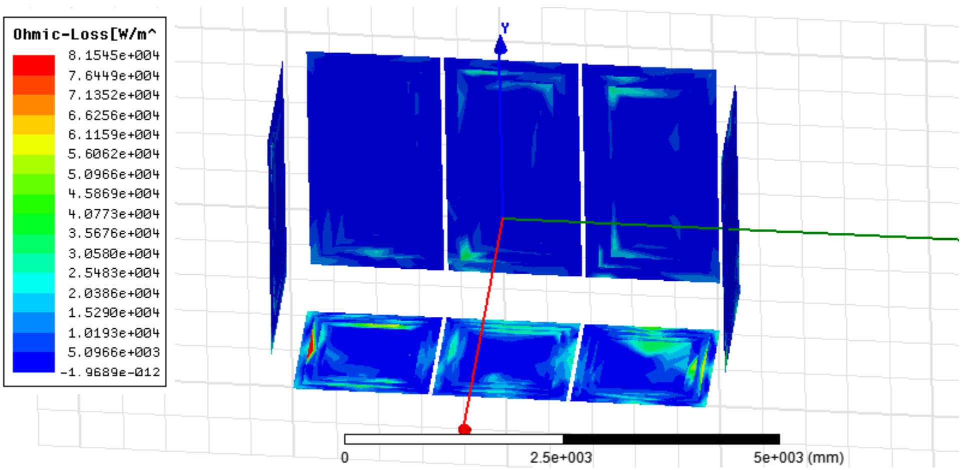

Figure 7.11: Ohmic Loss in Sheild(CRGO)

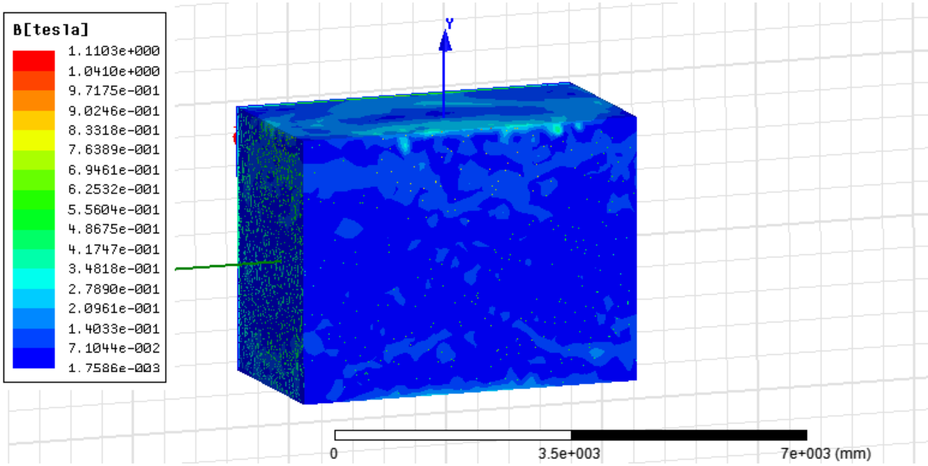

Figure 7.12: Flux Density at Tank EdgeWiseShunt(Copper)

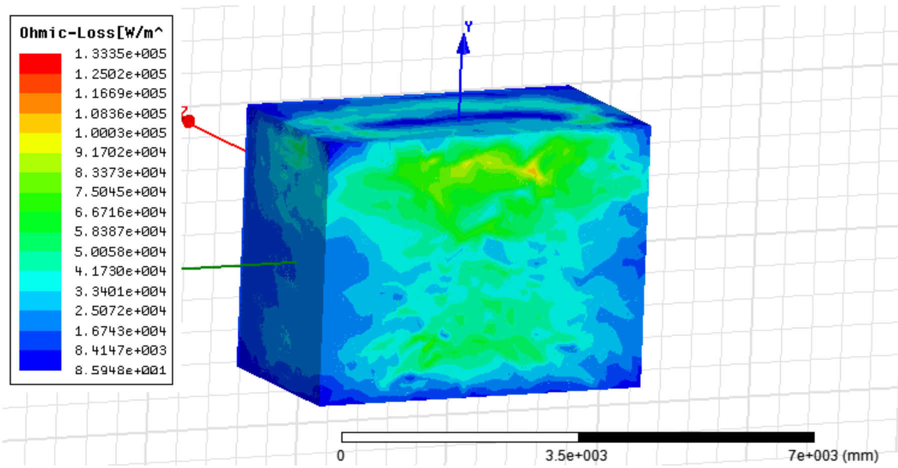

Figure 7.13: Ohmic Loss at Tank EdgeWiseShunt(Copper)

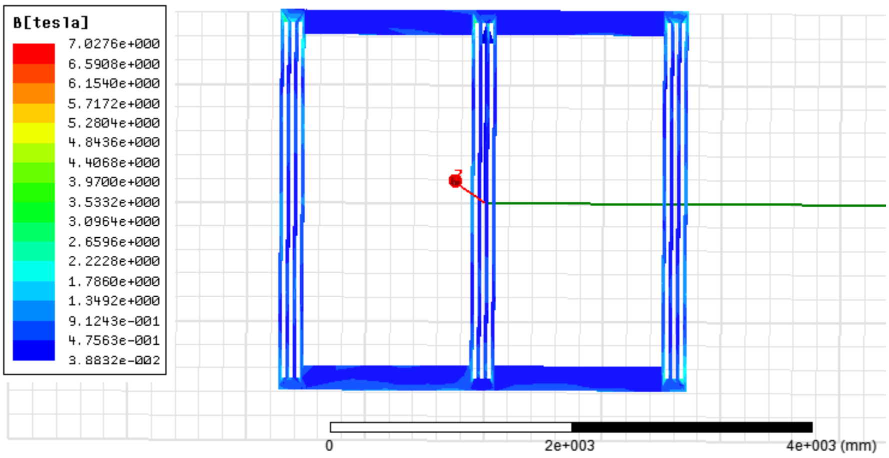

Figure 7.14: Flux Density at Flitchplate EdgeWise(Copper)

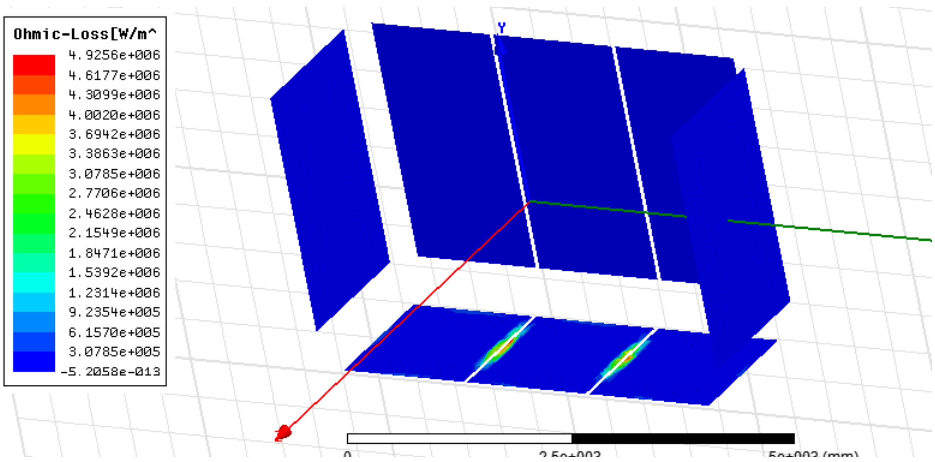

Figure 7.15: Ohmic Loss in Sheild(Copper)

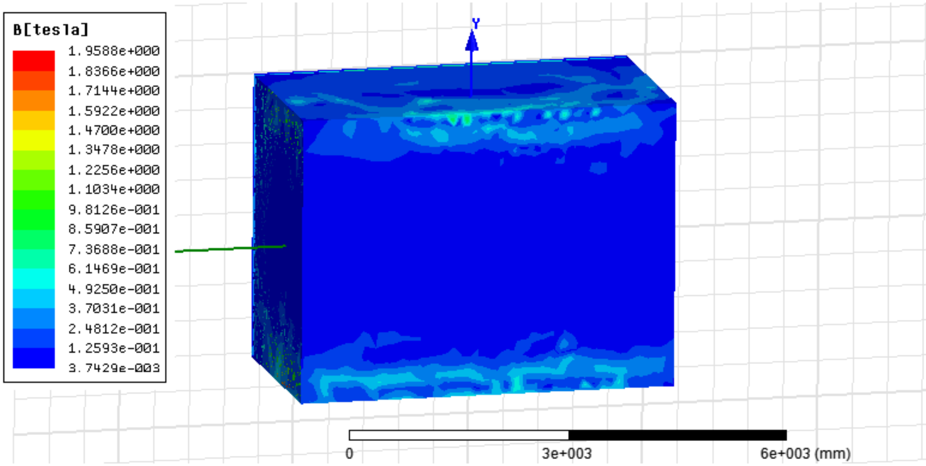

Figure 7.16: Flux Density at Tank Partial lHeight Shunt(CRGO)

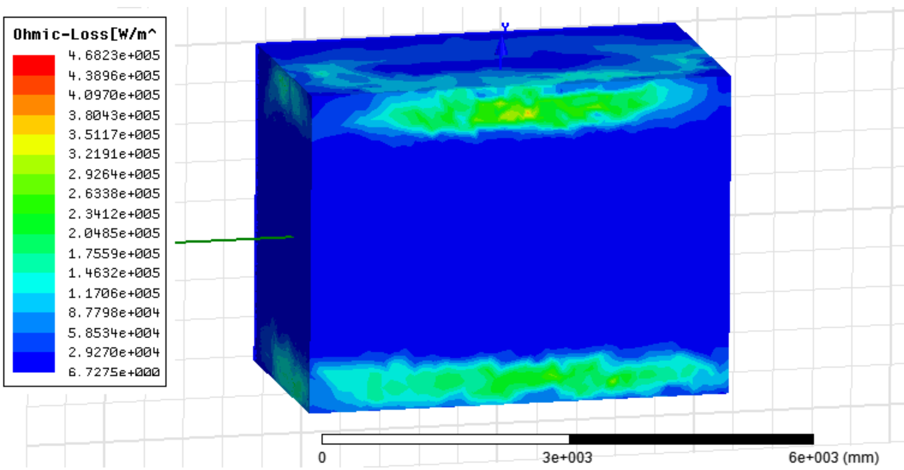

Figure 7.17: Ohmic Loss at Tank Partial Height Shunt(CRGO)

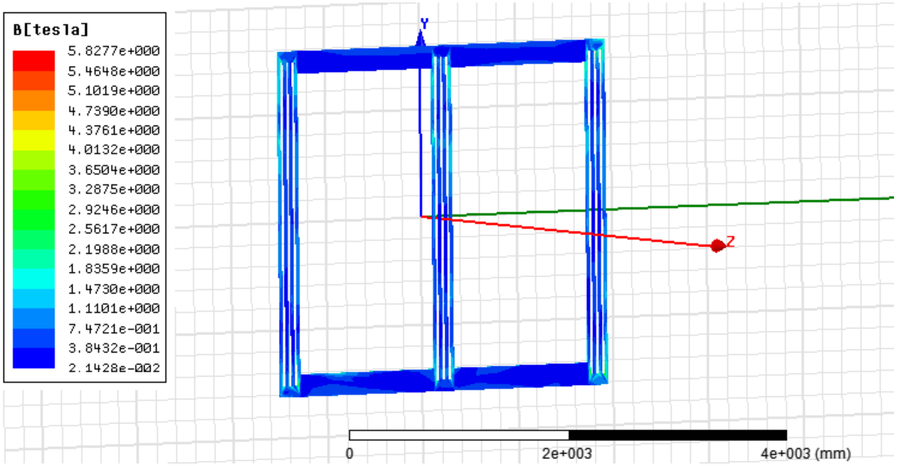

Figure 7.18: Flux Density at Flitchplate Partial Height (CRGO)

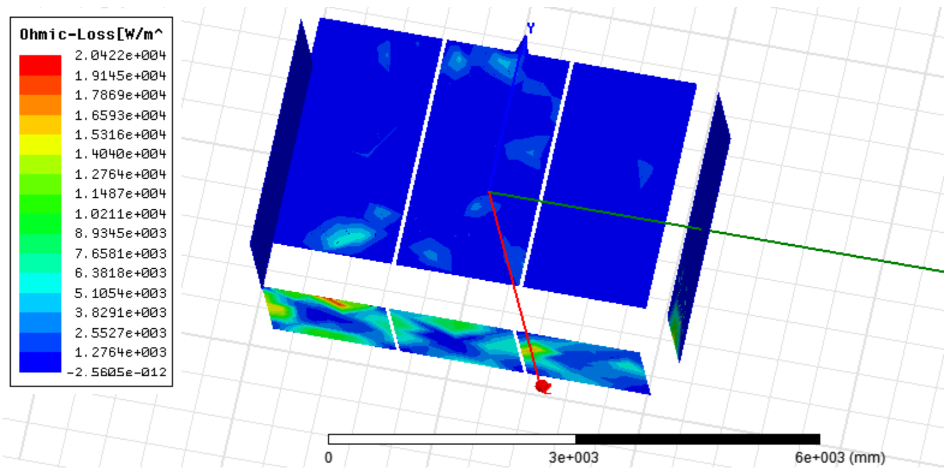

Figure 7.19: Ohmic Loss in Partial Height Sheild(CRGO)

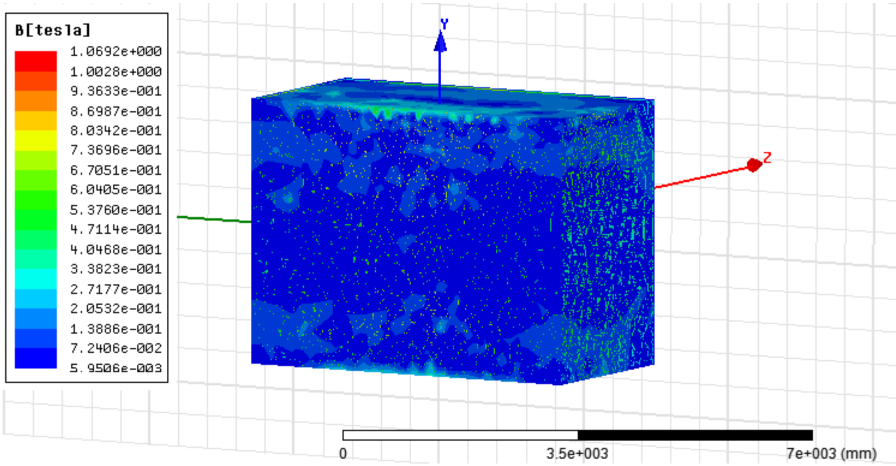

Figure 7.20: Flux Density at Tank Partial lHeight Shunt(Copper)

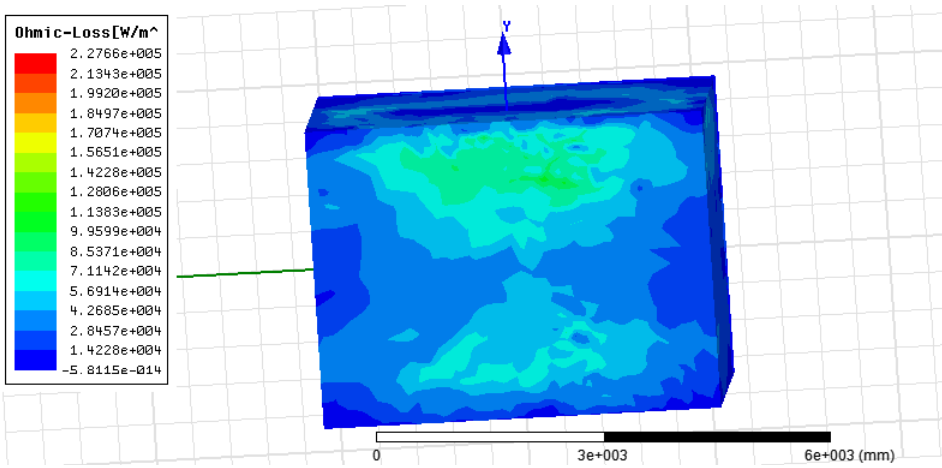

Figure 7.21: Ohmic Loss at Tank Partial Height Shunt(Copper)

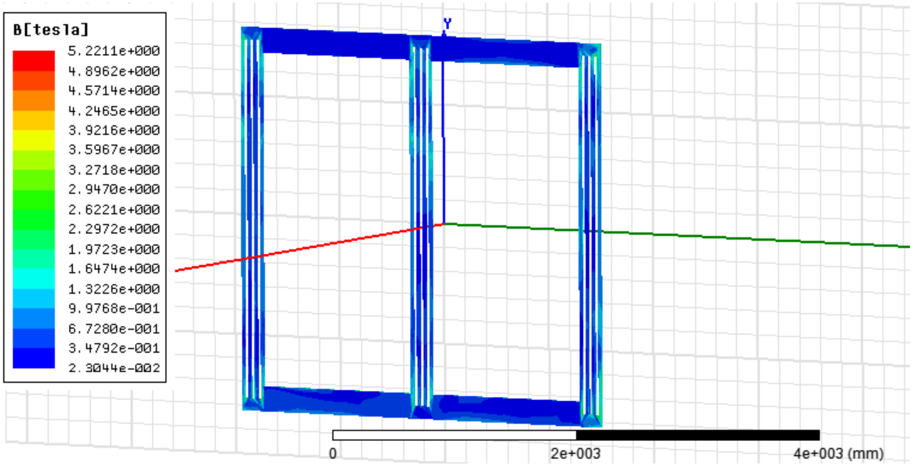

Figure 7.22: Flux Density at Flitchplate Partial Height (Copper)

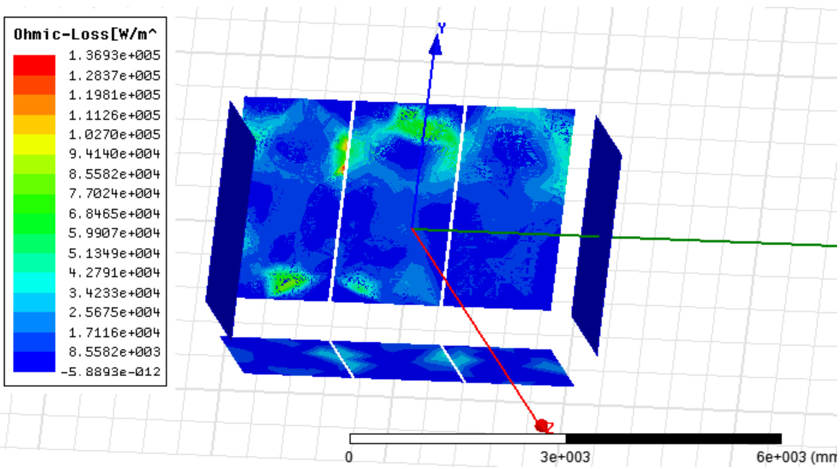

Figure 7.23: Ohmic Loss in Partial Height Sheild(Copper)

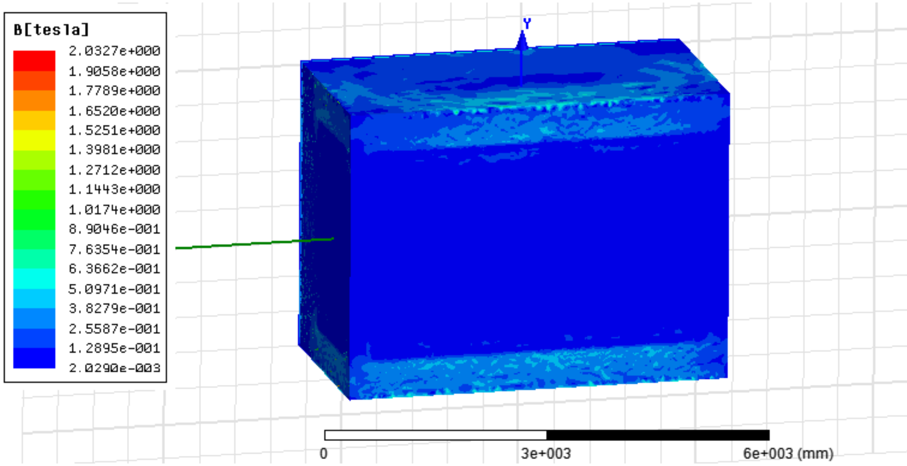

Figure 7.24: Flux Density at Tank Width Wise Shunt(CRGO)

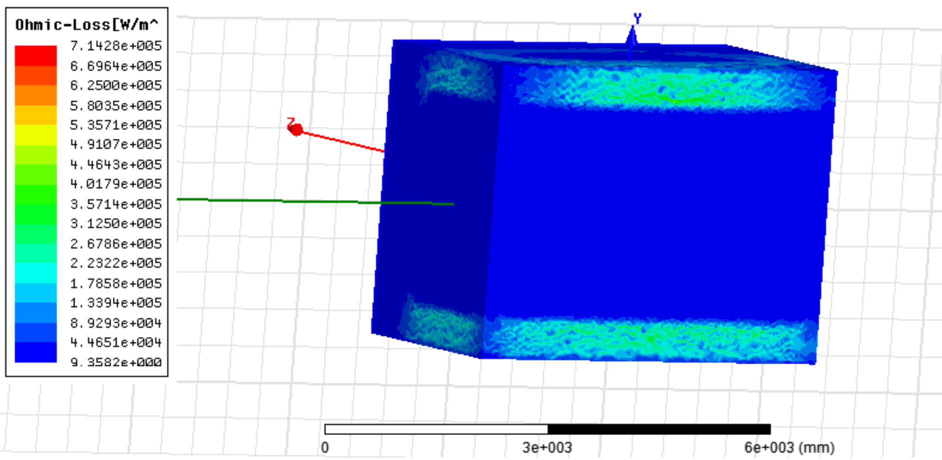

Figure 7.25: Ohmic Loss at Tank Width Wise Shunt(CRGO))

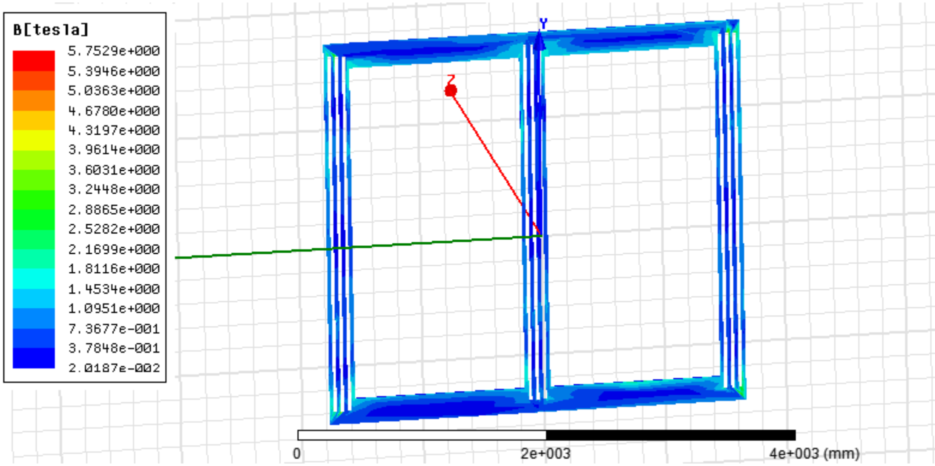

Figure 7.26: Flux Density at Flitchplate Width Wise (CRGO)

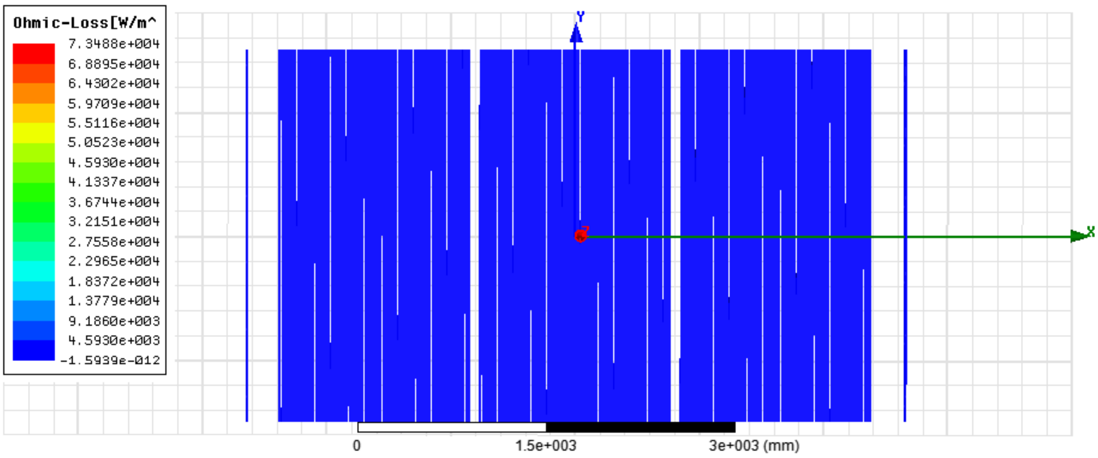

Figure 7.27: Ohmic Loss in Width Wise Sheild(CRGO)

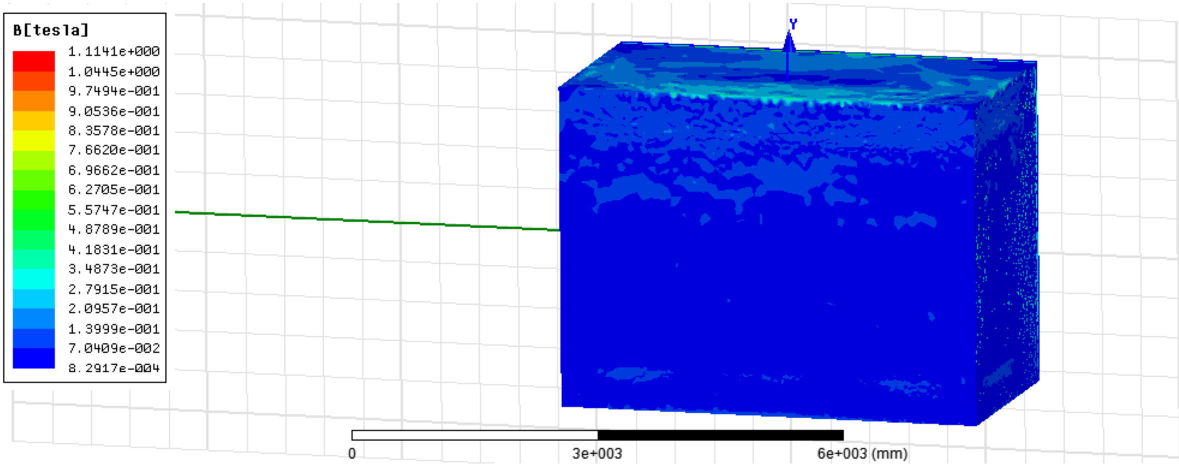

Figure 7.28: Flux Density at Tank Width Wise Shunt(Copper)

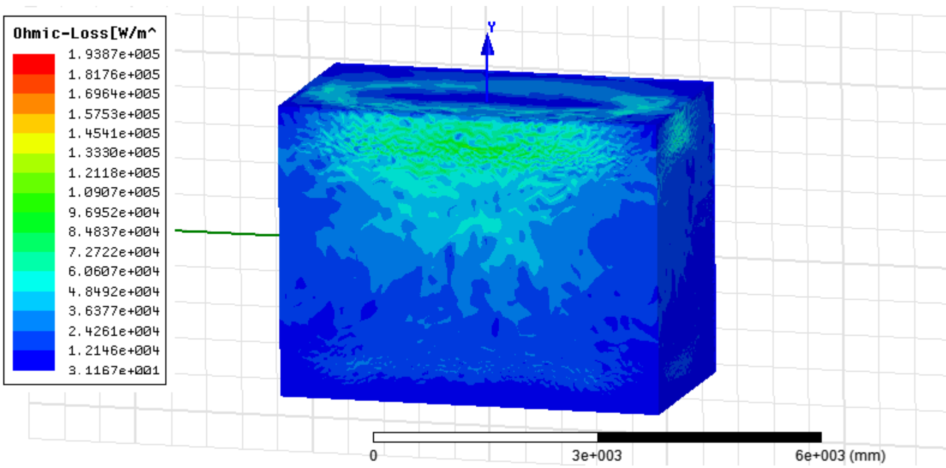

Figure 7.29: Ohmic Loss at Tank Width Wise Shunt(Copper)

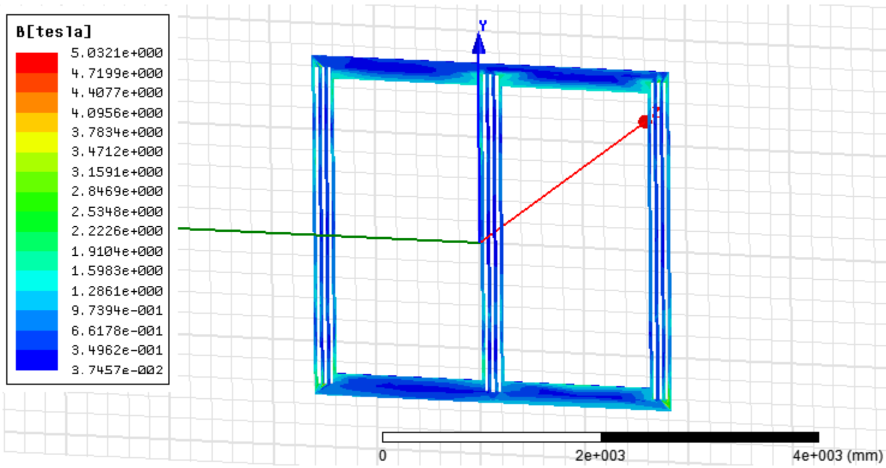

Figure 7.30: Flux Density at Flitchplate Width Wise (Copper)

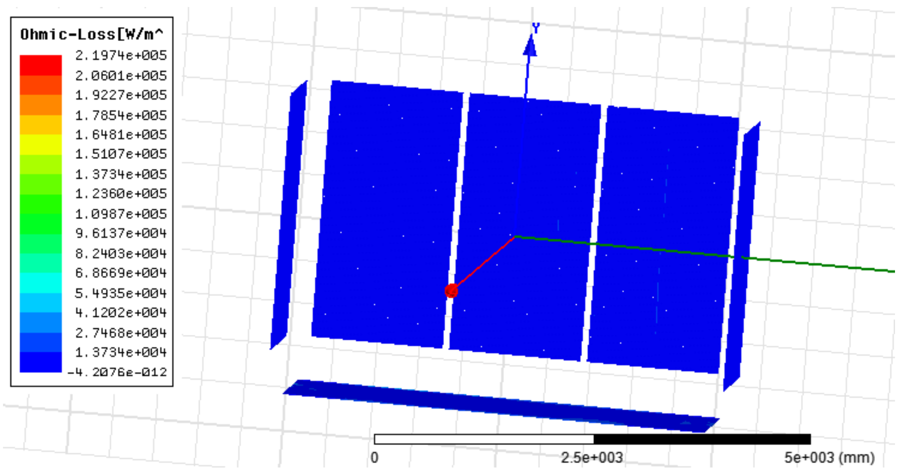

Figure 7.31: Ohmic Loss in Width Wise Sheild(Copper)

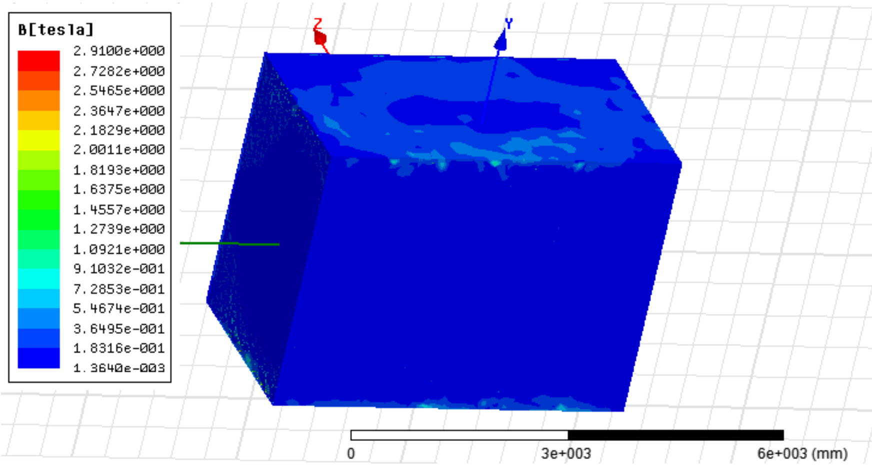

Figure 7.32: Flux Density at Tank Full Height Shunt(CRGO)

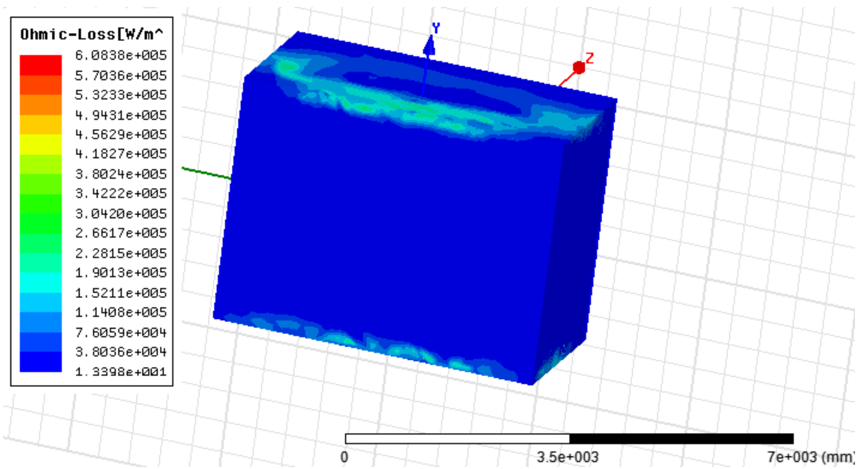

Figure 7.33: Ohmic Loss at Tank Full Height Shunt(CRGO)

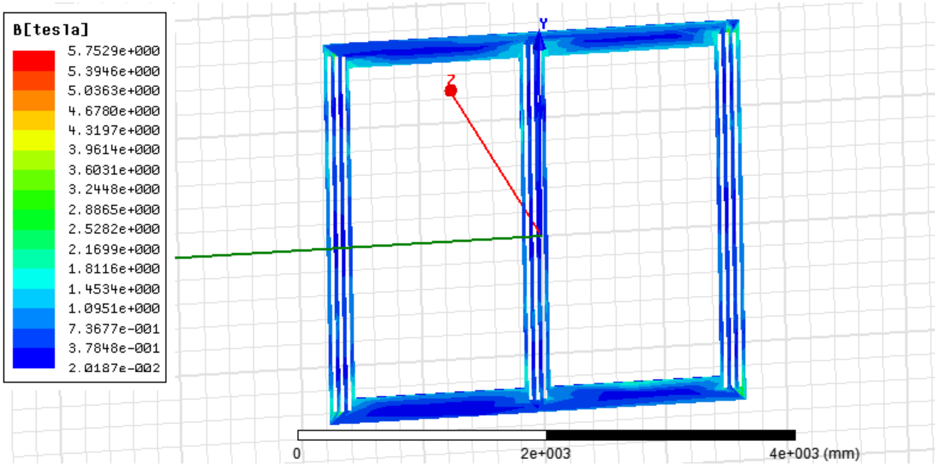

Figure 7.34: Flux Density at Flitchplate Full Height (CRGO)

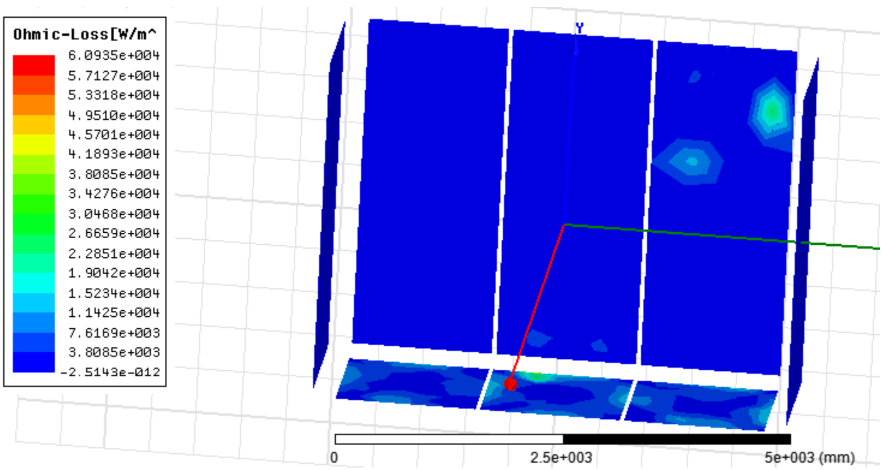

Figure 7.35: Ohmic Loss in Full Height Sheild(CRGO)

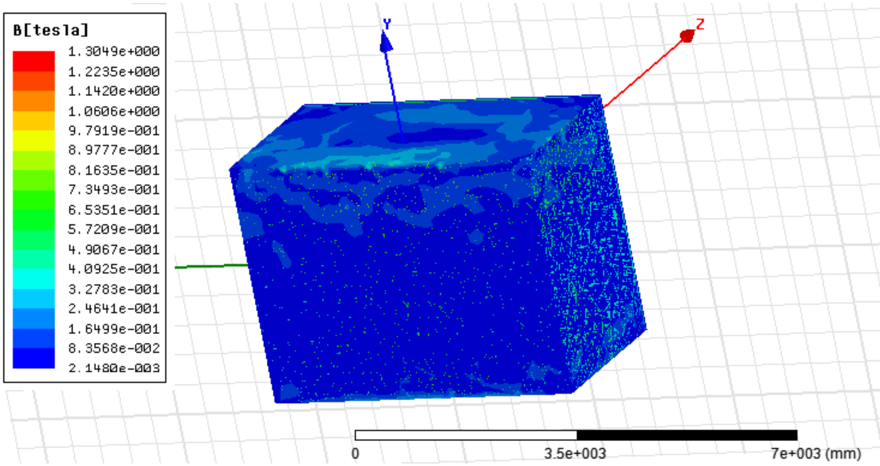

Figure 7.36: Flux Density at Tank Full lHeight Shunt(Copper)

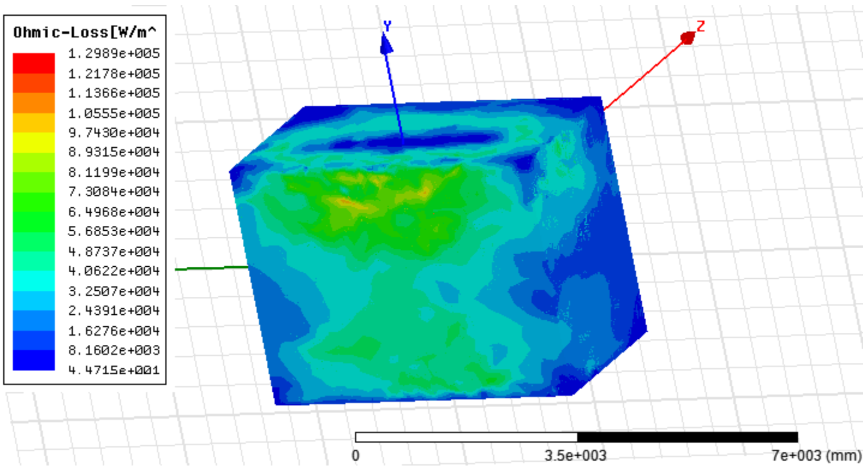

Figure 7.37: Ohmic Loss at Tank Full Height Shunt(Copper)

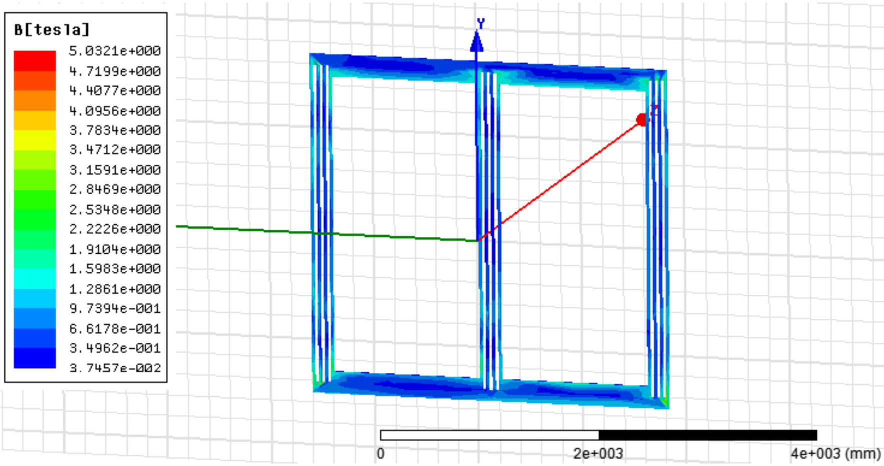

Figure 7.38: Flux Density at Flitchplate Full Height (Copper)

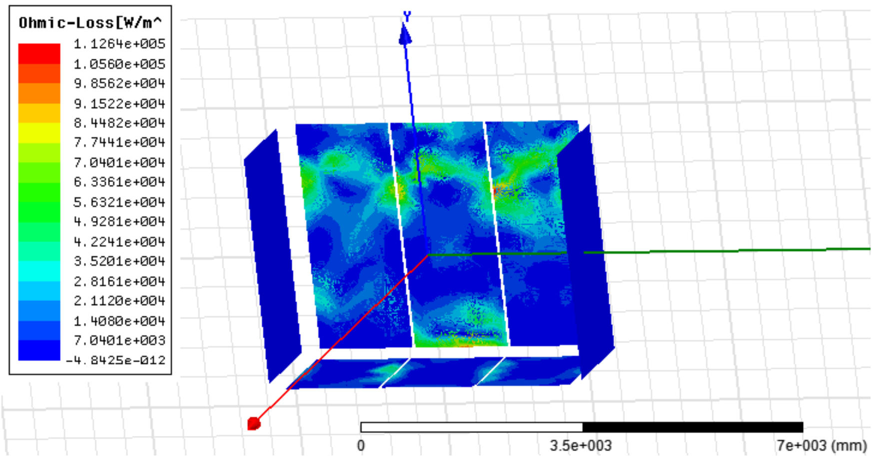

Figure 7.39: Ohmic Loss in Full Height Sheild(Copper)

Chapter 8

Conclusion

Here the 3D model of 100 MVA , 220/66 KV , Y-Y connected Transformer is shown in the fig.7.1 . The model is simplified & stray losses are calculated . They occur at Tank,Yoke Beams , Flitchplates & Other Structural parts of the Transformer . These losses are almost 45 KW . These losses are to minimized, they can be minimized by various shielding measures .

Here various Sheilding Measures are used & Stray losses are evaluated . the full height shunt gives the minimum losses & edgewise shunt gives maximum losses. CRGO & Copper any material can be used for sheilds , but CRGO material gives less losses.

Thus CRGO material with full height shunt gives the minimum losses.

Here the cost benifit analysis of the sheilds used is shown, maximum savings in Rupees occurs when Full Ht. Shunt of CRGO material is used.

The FEM softwares which are used are ANSYS / MagNet/ EDMag - 3D .

Reduction of Stray Losses also reduces the Capitalization Cost of the Transformer.

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