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Coreless Hall Effect Based Current Sensing Technique with Magnetic Shielding

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Abstract: *In this modern era, most of the equipment is electrostatic type. But still, in measuring current, we use conservative type. So, we developed a Modified coreless Hall Effect based current sensing method with magnetic shielding. The coreless Hall Effect based measurement method uses hall sensors without iron core. Hall sensors are firmly fixed on the insulated current carrying conductor. The magnetic flux produced by the current carrying conductor is measured by Hall sensor. To reduce the external magnetic field interference from the nearby conductors and stray field, magnetic shielding is introduced. The effectiveness of magnetic shielding is analyzed by finite element analysis. Thin sheet of silicon steel used as magnetic shielding effectively reduces the magnetic field interference from the external environment. The measurement system was tested in the distribution system of 11KV/415V-LV side. The full load current is 720Ampere. The current measurement by this method is compared with the current transformer rated 1 class of accuracy. The measurement system measures current with the same accuracy and good linearity due to the absence of magnetic core.*

Keyword: *Hall Effect; MultiSIM; COMSOL; LabVIEW; Coreless Hall Effect; Hall Effect Sensor; Magnetic Shielding*

1. INTRODUCTION

Reliability and safety are the most important considerations in power systems. To obtain the safety and reliability requirements use appropriate current transformers (CTs) for measuring the current to provide a proper metering and fault protection in a power system. A traditional Current Transformer, which is used for measuring the current, consists of a magnetic core. Because of the usage of magnetic core, it faces critical problems such as DC and AC saturation and remnant magnetization. The main cause of these problems is due to the effect of hysteresis. When faults occur in the power systems, the fault currents usually contain large DC offsets, which may cause the iron cores of CTs to be saturated. Distorted waveforms cause the performance of CTs when it's subjected to large instantaneous fault currents. These distorted waves are closely related to the fault current offset, the magnitude of the fault current, remnant magnetic flux density in the CT core, secondary circuit impedance, saturation voltage, and the turns ratio [1]. The fault current will cause the distortion in the current waveforms of the secondary windings. It will lead to false responses in the current detection and protective devices. Therefore, these faults will severely affect the safety and reliability of the power systems.

The main problems associated with the traditional CTs are mainly associated with the iron cores, several solutions for reducing the effects caused by iron cores have been proposed. It will include the use of air-gap CTs [2], magneto optical CTs [3], and linear CTs (i.e., Rogowski coil CTs) [4]. To rectify the iron core saturation problem, researchers proposed many solutions given below. Researchers proved that introducing a small quantity of the magnetic flux in the air gap of an iron core can prevent the magnetic saturation. The rate of decay is, however, slower than that of a traditional CT, and thus, may cause greater error [5], [6]. The use of nonmagnetic materials and a linear coupler to substitute for the iron core of a CT will reduce the magnetic saturation of iron core [7]. The cost of linear CTs is high because these devices are special precision one. It will employ a large, high sensitivity coil for low frequency current measurement; therefore, their applications are limited [8], [9]. Moreover, the need for a closed iron core and the large size of traditional CTs further limit the development of intelligent power protection systems. Therefore, research related to improving and even replacing traditional CTs is ongoing within the power industry.

Also, the use of a magneto-optical CT composed of polished fine optical glass (i.e., A Faraday sensor or rotator) will eliminate the magnetic saturation [10], [11]. A strawboard band is compactly wound around with a wire to measure the magneto magnetic force between the two points. Rogowski coils are mainly used for current measurements (e.g., the mmf of a closed path) [12], [13]. However, the cost of Rogowski coil is high and applications are limited. In traditional CTs, the main structure is made up of iron cores. Its purpose is not only transforming a magnetic field into electricity but also it can block the interference from ambient magnetic fields.

Now a day, Silicon Hall sensors are mainly used by the Hall Effect method. These hall sensors are used in contactless switches, position indicators, meters, and systems for the measurement of speed and rotation in the industry. Hall sensors are also located in systems such as current sensing and control systems in a power systems. In home appliances, domestic electronics, and computers also uses a numerous hall probe. A Hall device has the form of a plate fitted with four contacts, similar to that with which Hall discovered his effect [14]. The Hall device is sensitive to the magnetic field that is perpendicular to the chip plane. For applications where sensitivity to the magnetic field parallel to the device surface is preferred, a vertical Hall device has been devised [15]. In this paper, a new method for performing current measurement is proposed; this method involves the use of Hall sensors without iron cores, called coreless Hall Effect current sensing method. Here the current is measured by four and two hall effect sensors and also a new proposed model of one hall effect sensors with magnetic shielding without iron core and its performance analyzed by the existing current sensing method.

2.PROBLEMS WITH TRADITIONAL HALL EFFECT CURRENT SENSING METHOD

The In a power cable, if an AC flow, then the magnetic field is generated outside the insulator. This magnetic field changes with the waveform of the current due to Ampere's circuital law. Hall sensors have been researched with respect to their ability to sense the variations in a magnetic field and to decrease the overall size of traditional CTs [16]. Based on the principle of the Lorentz force, Hall sensors operate in a quick response time and can measure a wide range of magnetic fields [17]. To exhibit steady performances and high sensitivity related compensation circuits can be integrated into Hall sensors to form Hall ICs to enable these sensors. Mainly, Hall Effect transducers are used in the following types such as open loop Hall Effect transducers and closed loop Hall Effect transducers [18], [19]. Both these transducers contain cores and are mainly used to measure small currents with large bandwidths. Because of these attributes, the problem of core saturation still exists, and the size of the transducers is almost the same as that of traditional CTs. Moreover, even if some specific Hall-effect transducers can be used for performing large current measurements without core saturation, they still cannot be used extensively as of now because of the high price of their special core materials. So the proposed model method is to measure the current with coreless method by the introduction of magnetic shielding.

3. HALL EFFECT BASED CURRENT MEASUREMENT

In this proposed model Linear ratiometric Hall sensor IC A1301 is used which is shown in the Figure 1. It is a continuous-time, ratiometric, linear Hall-effect sensor IC. This Hall Effect Integrated Circuit included in each device includes a Hall circuit, a linear amplifier, and a CMOS Class A output structure.

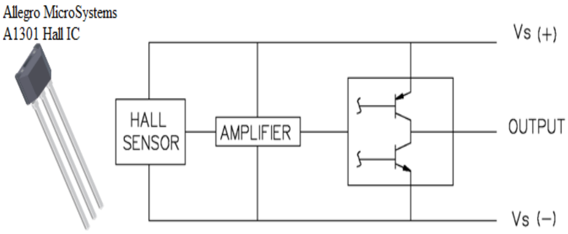


Figure 1 Ratiometric linear Hall-effect sensor IC

Integrating the Hall circuit and the amplifier on a single chip minimizes many of the problems normally associated with low voltage level analog signals.

It is optimized to accurately provide a voltage output that is proportional to an applied magnetic field. These devices have a quiescent output voltage that is 50% of the supply voltage. The Figure 2 shows the functional block diagram of Hall IC A1301.

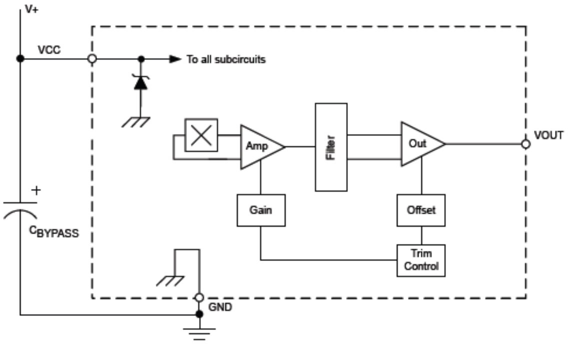


Figure 2 Functional Block Diagram of A1301

The Salient Features of this Hall Effect sensor are Low noise output, Fast power-on time, Ratio metric rail-to-rail output is 4.5 to 6.0V operation, Factory programmed at end-of-line for optimum performance, Robust ESD performance and Solid-state reliability.

3.1 Instrumentation Circuits

The Summing Amplifier is used as weighted adder for averaging circuit. It averages the output Hall voltages for four hall sensors. The inverting adder configuration is used. The input resistance is four times the feedback resistance. As a result added voltage is divided by four and averaging operations of four Hall voltages is achieved. Here the operation is compared among the four, two hall sensors and also one hall sensor with magnetic shielding. The same circuit is used for two hall sensors to increase the input resistance as two times the feedback resistance with the help of jumper in the circuit. The summing amplifier circuit is shown in Figure 3.

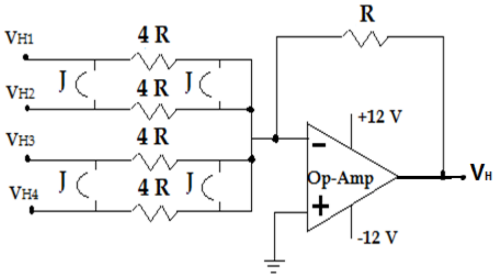


Figure 3 Summing Amplifier circuit

This Hall Effect device has a quiescent output voltage that is 50% of the supply voltage. In the quiescent state (no significant magnetic field: B = 0), the output, V_{OUTQ}, equals one half of the supply voltage, V_{CC}, throughout the entire operating ranges of V_{CC} and ambient temperature, T_A. Due to internal component tolerances and thermal considerations, there is a tolerance on the quiescent output voltage, ΔV_{OUTQ}, which is a function of both ΔV_{CC} and ΔT_A. The Figure 4 shows the plot of quiescent voltage versus supply voltage.

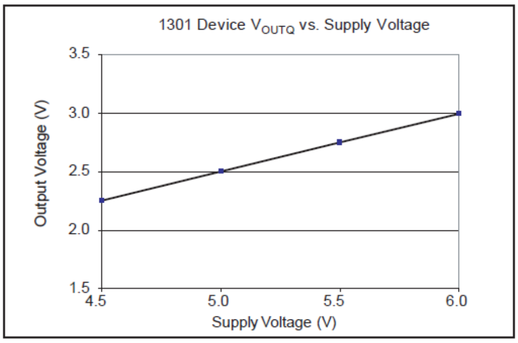


Figure 4 Quiescent voltage Vs supply voltage

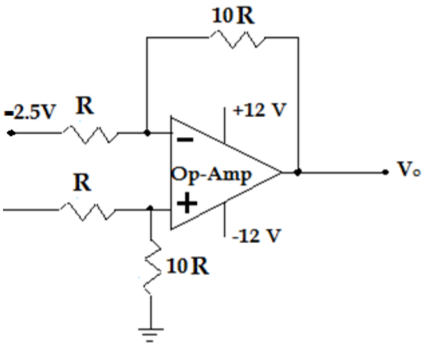


Figure 5 Quiescent Voltage Nullification Circuit

The Figure 5 shows the circuit diagram of the nullification circuit of quiescent voltage.

4.MULTISIM

NI Multisim (formerly MultiSIM) is an electronic schematic capture and simulation program which is part of a suite of circuit design programs, along with NI Ultiboard. Multisim is one of the few circuit design programs to employ the original Berkeley SPICE based software simulation. To check whether the designed summing amplifier and quiescent voltage nullification circuit are given the accurate and desired result.

The Figure 6 shows the SPICE simulation schematics of summing amplifier circuit and quiescent voltage nullification circuit and Figure 7 shows the output of the simulation of weighted adder and differential amplifier.

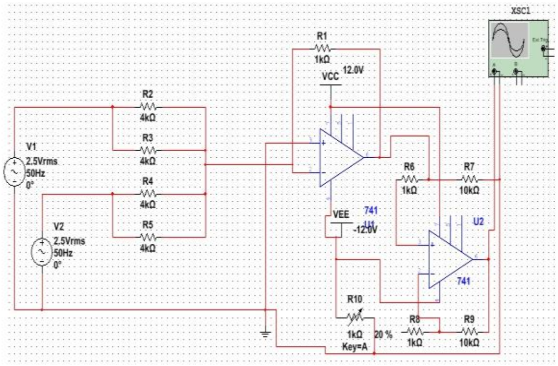


Figure 6 Schematic diagram – MultiSIM

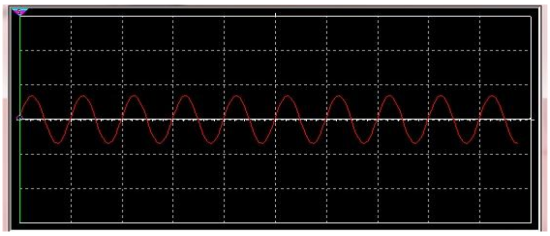


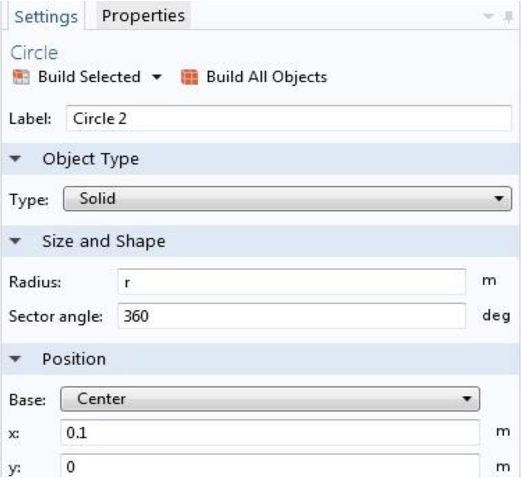
Figure 7 Simulated output of summing amplifier circuit and quiescent voltage nullification circuit

5.DESIGN by COMSOL

COMSOL – COMmunication SOLution. COMSOL Multiphysics is a finite element analysis, solver and Simulation software / FEA Software package for various physics and engineering applications, especially coupled phenomena, or Multiphysics. Here we use COMSOL Multiphysics to see how the magnetic flux distributed in the single conductor and between the two conductors. And also see how the magnetic flux reacts with the high permittivity material. Depending upon the distance between the two conductors their magnetic flux affects each other. To clarify how it influences the current measurement in the Hall Effect sensor by using COMSOL Multiphysics. The entire simulation is done under the AC/DC Module- Magnetic Field Simulation.

5.1 Settings Window

For the sample simulation purpose, consider a conductor with the radius of 0.01 meters and we take the same radius for the two conductors also. The geometry setting is shown in the Figure. For designing a magnetic shielding, consider a rectangle like material with a high permittivity range with a height of 0.1 meter and 0.05 meters away from the conductor shown in the Figure 8, 9, 10.



Label: Circle 2
Type: Solid
Radius: r m
Sector angle: 360 deg
Base: Center
x: 0.1 m
y: 0 m

Figure 8 Geometry settings for conductor

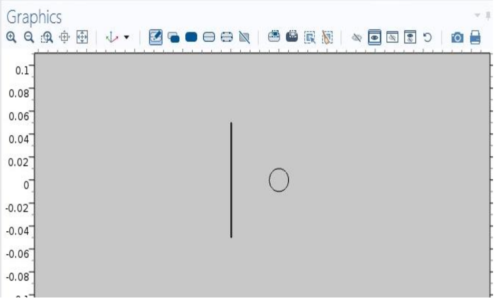
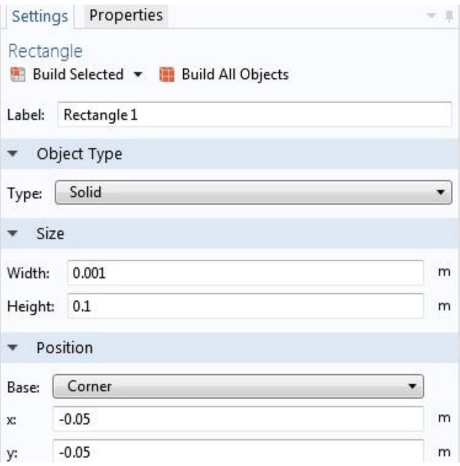


Figure 9 Geometry settings for conductor with shielding



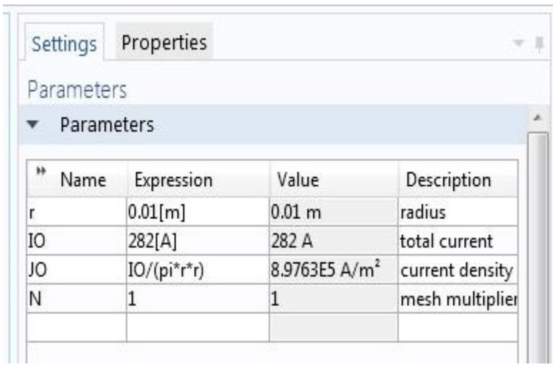
Label: Rectangle 1
Type: Solid
Width: 0.001 m
Height: 0.1 m
Base: Corner
x: -0.05 m
y: -0.05 m

Figure 10 Geometry setting for Magnetic shielding

5.1.1 Parameters and Scope

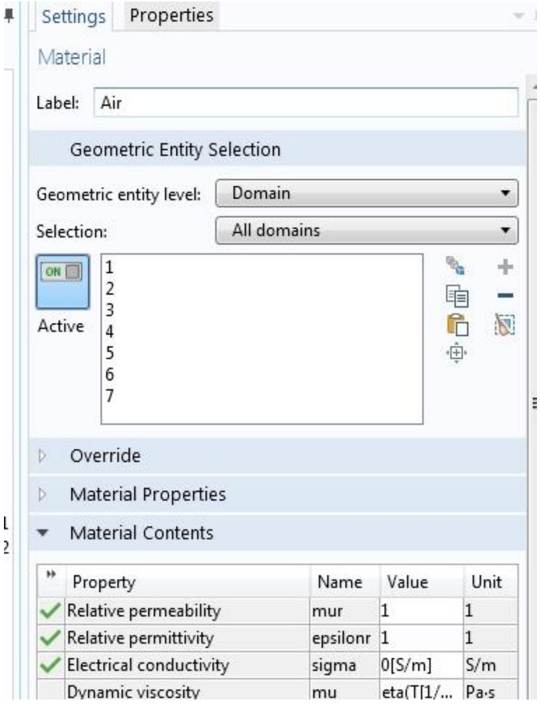
Parameters are user-defined constant scalars that are usable throughout the model. That is to say, they are "global" in nature.

In parameter setting, consider a sample value for the parameters current, current density. For the conductor testing, give the R.M.S value of the current as 200A. Therefore the peak value of the current is 282A. By using a calculation, find the value of current density as 8.9763E5 A/m^2 which is shown in the Figure 11.



Name	Expression	Value	Description
r	0.01[m]	0.01 m	radius
I0	282[A]	282 A	total current
J0	I0/(pi*r*r)	8.9763E5 A/m²	current density
N	1	1	mesh multiplier

Figure 11 Parameter initialization



Label: Air
Geometric entity level: Domain
Selection: All domains

1
2
3
4
5
6
7

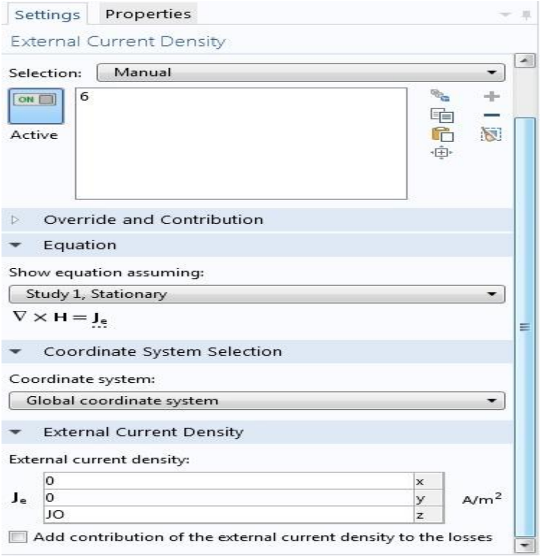
	Property	Name	Value	Unit
✓	Relative permeability	mur	1	1
✓	Relative permittivity	epsilonr	1	1
✓	Electrical conductivity	sigma	0[S/m]	S/m
	Dynamic viscosity	mu	eta(T[1/...	Pa·s

Figure 12 Material-Air with shielding

The "scope" of a Parameter or Variable is a statement about where it may be used in an expression. All Parameters are defined in the Global Definitions node of the model tree. This means that they are global in scope and can be used throughout the model tree.

Here give property for the air domain, such as relative permittivity and relative conductivity as 1. And also the property of the electrical conductivity as 0 for the simulation of two conductors and a single conductor with magnetic shielding showed in the Figure 12.

For conductor property, give the current density value to the circle dimension mentioned above. It is shown in the Figure 13 & 14.


Settings | Properties

External Current Density

Selection: Manual

6

Active

Override and Contribution

Equation

Show equation assuming:

Study 1, Stationary

$\nabla \times \mathbf{H} = \mathbf{J}_e$

Coordinate System Selection

Coordinate system:

Global coordinate system

External Current Density

External current density:

$\mathbf{J}_e$	0	x	A/m^2
	0	y	
	JO	z	

☐ Add contribution of the external current density to the losses

Figure 13 Current density in the conductor

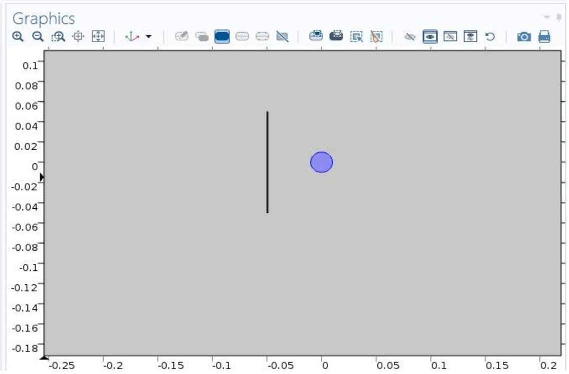
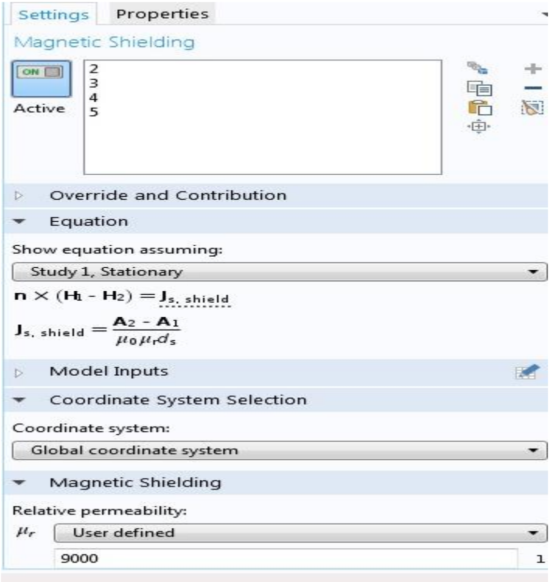


Figure 14 Current density in the conductor with shielding

For magnetic shielding setting, give the relative permeability value as 9000 which was the value of the silicon steel material. It is shown in the Figure 15.

In this graphics window, see the magnetic field flux density how it varies from the different distance. The variation in the magnetic field flux density denoted in the scale of the graphics window. The red colour denotes the high magnetic field flux density. Slowly the magnetic field flux density decreases to the low value. The blue colour denotes the high magnetic field flux density. The Figure 16 shows the Magnetic flux density of the two conductors and a single conductor with magnetic shielding.


Settings | Properties

Magnetic Shielding

Active

2
3
4
5

Override and Contribution

Equation

Show equation assuming:

Study 1, Stationary

$\mathbf{n} \times (\mathbf{H}_1 - \mathbf{H}_2) = \mathbf{J}_{s,\,\text{shield}}$

$\mathbf{J}_{s,\,\text{shield}} = \frac{\mathbf{A}_2 - \mathbf{A}_1}{\mu_0 \mu_r d_s}$

Model Inputs

Coordinate System Selection

Coordinate system:

Global coordinate system

Magnetic Shielding

Relative permeability:

μ_r User defined

9000 1

Figure 15 Magnetic shielding permeability settings

5.1.1.1 Results

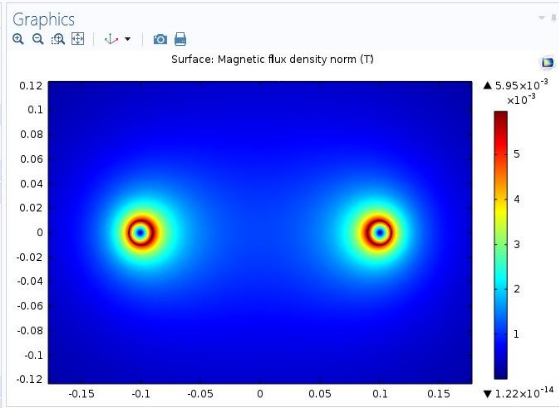


Figure 16 Result for mf without shielding

From the Figure 17, infer that the magnetic shielding does not allow the magnetic flux inside and outside the conductor. The magnetic flux will surround through the magnetic shielding. Therefore the external interference cannot alter the magnetic field flux density value. So we can easily measure the current value with the help of only one Hall Effect sensor. Result diagram also helps where to place the Hall Effect sensor to find the accurate value of the current flowing through the conductor.

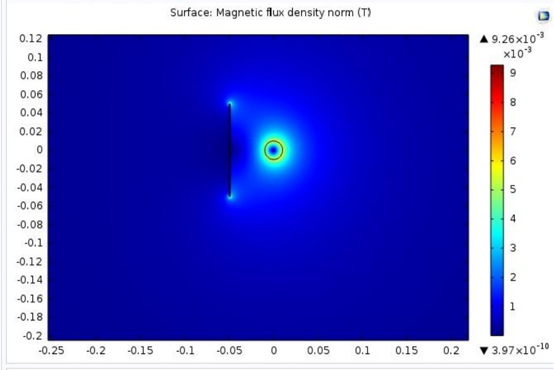


Figure 17 Result for mf with shielding

6. LabVIEW VI for DATA ACQUISITION

LabVIEW (short for Laboratory Virtual Instrument Engineering Workbench) is a system-design platform and development environment for a visual programming language from National Instruments.

LabVIEW includes built-in support for NI hardware platforms such as Compact DAQ and Compact RIO, MAX and VISA toolsets.

The VI for data acquisition is shown in the Figure 18. The given VI is used for the acquisition of data from a current measurement setup with and without magnetic shielding.

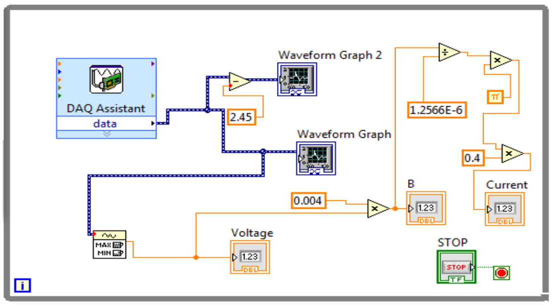


Figure 18 LabVIEW VI for Data Acquisition

The output voltage Data Acquisition of the hall sensor is done through NI USB 6009(DAQ). The output from the sensor is interfaced with NI USB 6009 DAQ to the LabVIEW. When the supply is given sensor measures the current flowing through the conducting cable and the output value of current is displayed in the LabVIEW. This output is compared with the reference current transformer and the accuracy is checked. In this the magnetic field from nearby cables affects the function of sensor.

In order to avoid the ambient interference we have employed the magnetic shielding. We have used thin sheet of Silicon steel. Now the sensor is shielded from the magnetic interference by the silicon steel, the measurement is now taken and it is interfaced with LabVIEW to check the output and it is found to be accurate compared with that to the reference current transformer.

7. RESULTS AND DISCUSSION

7.1 Problem of External Field Interference due to Nearby Power Line

The results observed in the simulation of magnetic field produced by two adjacent conductors are shown in Figure 19.

The spacing between two conductors is 0.2m and each conductor is carrying 200A current. A finite Element Analysis (FEA) simulation result clearly shows that the adjacent conductor produces magnetic interference and it affects the accuracy of current measurement. And hence magnetic shielding has been introduced in order to minimize the external magnetic field interference into the sensing unit. The effectiveness of magnetic shielding is simulated by the FEA software and it is shown in the Figure 20.

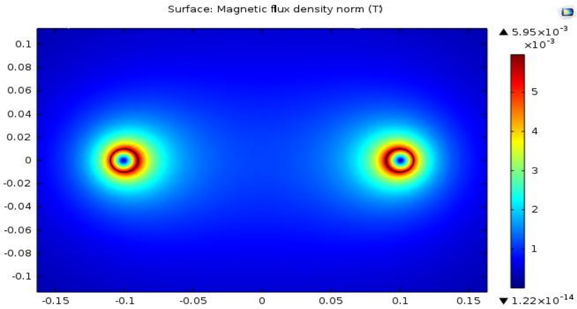


Figure 19 Magnetic flux density around two adjacent conductors

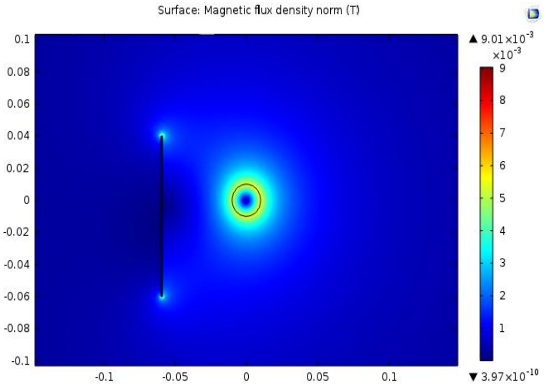


Figure 20 Magnetic flux distribution with magnetic shielding

In the simulation process, the magnetic shielding (thin sheet of Silicon Steel) is placed 0.05m away from the conductor. The shielding effectively reduces the magnetic field into the external environment. Due to this advantage, the proposed model consist only one Hall Effect sensor.

7.1.1 Measurement Setup

The current measurement was done in the distribution system of 500KVA, 11KV/415V (LV Side). Full load current is 700Ampere. The Figure 21 shows that measurement setup with reference CT of class 1 of accuracy and coreless Hall Effect Current sensor. And Figure 22 & 23 shows the measurement DAQ setup without magnetic shielding and with magnetic shielding respectively.

Let us consider current through the conductor,

I = 100Ampere

The magnetic field produced at a point 2cm away from the centre of the conductor is calculated using Biot-Savart law.

$$B = \frac{\mu_o I}{2\pi r}$$

Where,

B is the magnetic flux density at a distance *r* from the center of the conductor.

I is the electric current flowing in the conductor.
$\mu_\circ$ is the permeability of free space.

$$B = \frac{\mu_\circ * 100}{2\pi * 0.02}$$

We get,
$B=9.999*10^{-4}$ Tesla

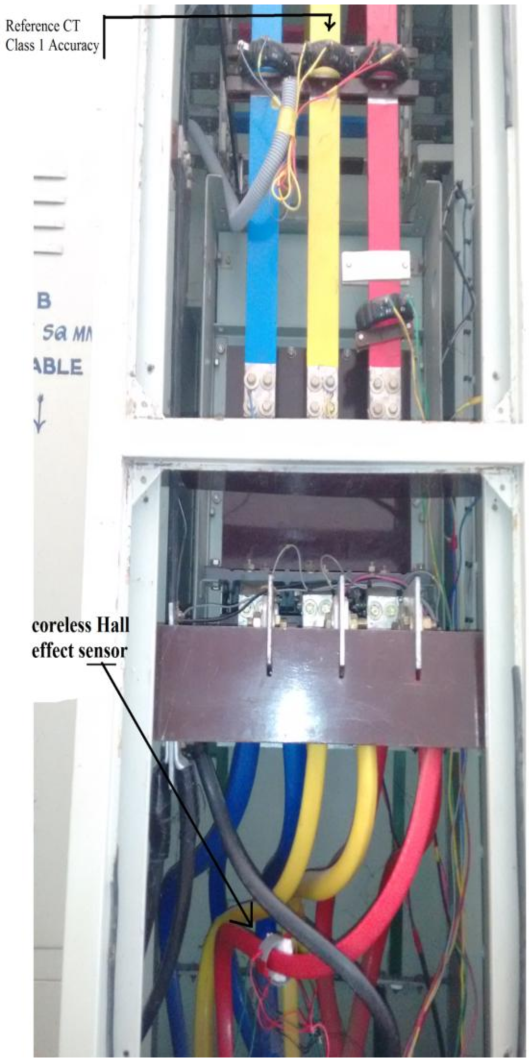


Figure 21 Measurement setup

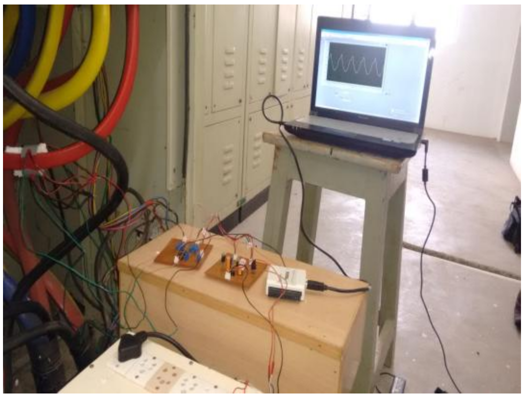


Figure 22 Measurement setup without shielding

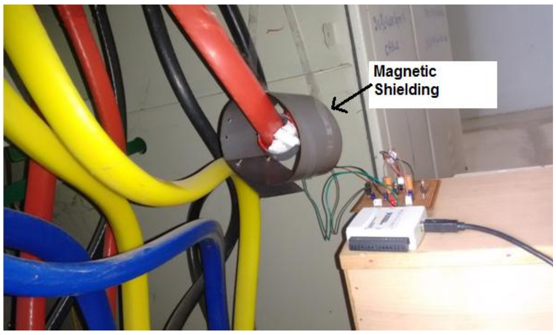


Figure 23 Measurement setup with magnetic shielding

7.1.1.1 Sample Calculation

Let us consider current through the conductor,
$I = 100$Ampere

The magnetic field produced at a point 2cm away from the centre of the conductor is calculated using Biot-Savart law.

$$B = \frac{\mu_\circ I}{2\pi r}$$

Where,
B is the magnetic flux density at a distance *r* from the center of the conductor.
I is the electric current flowing in the conductor.
$\mu_\circ$ is the permeability of free space.

$$B = \frac{\mu_\circ * 100}{2\pi * 0.02}$$

We get,
$B=9.999*10^{-4}$ Tesla
Hall sensor IC produces 2.5mV for 0.1mTesla.
And hence, for $9.999*10^{-4}$ Tesla, the sensor produces output of 0.02499Volts.

The Amplifier produces the voltage gain of 10. And thus the output voltage of the hall sensor after crossing the weighted adder and differential amplifier and is 0.2499Volts. The output voltage data acquisition is done with the help of NI-DAQ and results are manipulated and displayed.

The measured current through the modified coreless Hall Effect current sensor method is compared with reference to CT rated 1 class of accuracy. And the Accuracy level of class1 is achieved through our measurement method. The accuracy of traditional CTs is compared with four Hall Effect sensor and two hall effect sensor and finally with the proposed model (i.e.) one Hall Effect sensor with magnetic shielding.

8. CONCLUSION

A modified coreless Hall Effect current sensor for current measurement has been developed. Simulation and measurement results prove that the modified coreless Hall sensor with magnetic shielding can accurately measure the current. And it does not experience the non linearity and saturation related problems usually encountered in Current Transformer. The addition of magnetic shielding around the sensor unit effectively reduces the external magnetic field interference from nearby power lines. The modified Coreless Hall Effect current measurement exhibits the following features like Current measurement range up to 700Ampere with class 1 accuracy. Also It is small in size and low cost compared to Current Transformer. There is also an absence of saturation and remnant magnetization problem.

9. ACKNOWLEDGMENT

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REFERENCES

[1] “IEEE Guide for the Applications of Current Transformers Used for Protective Relaying Purposes”, IEEE Standard C37.110-1996, 1996.

[2] “An IEEE power system relay committee report: Gapped core current transformer characteristics and performance,” IEEE Trans. Power Del., vol. 5, no. 4, pp. 1732–1740, Nov. 1990.

[3] T. W. Cease and P. Johnston, “A magneto-optic current transducer,” IEEE Trans. Power Del., vol. 5, no. 2, pp. 548–555, Apr. 1990.

[4] W. F. Ray, “Rogowski transducers for high bandwidth high current measurement,” in Proc. IEEE Colloq. Low Frequency Power Meas. Anal., London, U.K., Nov. 2, 1994, pp. 10/1–10/6.

[5] An IEEE Power System Relay Relaying Committee Report, “Gapped core current transformer characteristics and performance,” IEEE Trans. Power Delivery, vol. 5, no. 4, pp. 1732–1740, Nov. 1990.

[6] V. Molcrette, J. L. Kotony, J. P. Swan, and J. F. Brudny, “Reduction of inrush current in single phase transformer using virtual air gap technique,” IEEE Trans. Magn., vol. 34, no. 4, pp. 1192–1194, Jul. 1998.

[7] M. Vakilian and R. C. Degeneff, “A method for modeling nonlinear core characteristics of transformers during transient,” IEEE Trans. Power Delivery, vol. 9, no. 4, pp. 1916–1925, Oct. 1994.

[8] S.A.Dyer,Survey of Instrumentation and Measurement. Hoboken, NJ: Wiley, 2001, p. 344.

[9] W. F. Ray and C. R. Hewson, “High performance Rogowski current transducers,” in Conf. Rec. IEEE IAS Annu. Meeting, Rome, Italy, Oct. 2000, vol. 5, pp. 3083–3090.

[10] J. Song, P. G. McLaren, D. J. Thomson, and R. L. Middleton,“ A clamp-on magneto-optical current transducer for power systems,” in Proc. Can. Conf. Electr. Comput. Eng., vol. 2. May 1996, pp. 884–887.

[11] A. Cruden, Z. J. Richardson, J. R.McDonald, I. Andonovic, W. Laycock, and A. Bennett, “Compact 132 kV combined optical voltage and current measurement system,” IEEE Trans. Instrum. Meas., vol. 47, no. 1, pp. 219–223, Feb. 1998.

[12] A. P. Chattock, “On a magnetic potentiometer,” Phil. Mag. J. Sci., vol. 24, no. 5, p. 9696, Jul./Dec. 1887.

[13] M. Chiampi, G. Crotti and A. Morando, “Evaluation of flexible Rogowski coil performances in power frequency applications,” IEEE Trans. Instrum. Meas., vol. 60, no. 3, pp. 854–862, Mar. 2011.

[14] E. H. Hall, “On a new action of the magnet on electric currents,” Amer. J. Math., vol. 2, no. 3, pp. 287–292, 1879.

[15] R. S. Popovic, “The vertical Hall-effect-device,” IEEE, Electr. Devices. Lett., vol. 5, no. 9, pp. 357–358, Sep. 1984.

[16] N. Chen and Y. P. Tsai, “Power current micro sensor,” Taiwan, Patent I 263 050, Oct. 1, 2006.

[17] S. M. Sze, Semiconductor Sensors. Hoboken, NJ: Wiley, 1994, pp. 205–246.

[18] L. Cristaldi, A. Ferrero, M. Lazzaroni, and R. Ottoboni, “A linearization method for commercial Hall-effect current transducers,” IEEE Trans. In-strum. Meas., vol. 50, no. 5, pp. 1149–1153, Oct. 2001.

[19] P. Poulichet, F. Costa, and É. Labouré, “A new high-current large-bandwidth DC active current probe for power electronics measurements,” IEEE Trans. Ind. Electron., vol. 52, no. 1, pp. 243–254, Feb. 2005.

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