Optimal Design, Re-engineering and Testing of a 50:5A Current Transformer for Medium Voltage Industrial Requirements

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Abstract. The current transformer is one of the types of instrument transformer which is designed in such a manner so as to produce a current in its secondary circuit which in turn proportional to the current flowing through it’s primary circuit. It is one of the components that needs to be installed inside the electrical panel board in order to measure the current flow through each phase of the three phase system inside the panel. Usually these electrical panel boards were designed by electrical based industries. One of such industries which was in need of a 50:5 ratio current transformer had handed over the current transformer design and manufacturing as an industrial work to the authors. In this paper the authors deal with the optimal design and re-engineering and testing of the current transformer that is used in the measurement of current.

Keywords : Current transformer, Electrical panel board, current.

1. Introduction

Since the origin of the cardinal constant-potential transformer in 1885, transformers have become indispensable for the transmission, dispensation and utilization of electric power. A transformer is a passive electrical device which helps in the transformation of electrical energy from one electrical circuit to one or more electrical circuits. A varying or alternating current in any one coil of the transformer produces a varying magnetic flux that in turn stimulates a varying electromotive force or emf across any other coils of the transformer wound around the same core. Electrical energy can be transmitted among the coils, without any physical connection between the two circuits. Among many types of transformer, instrument transformers are high class accuracy electric devices or instruments used for the isolation or transformation of voltage or current. The instrument transformers are most commonly used to operate instruments or metering from high voltage or high current circuits safely by isolating the secondary side of the circuitry from the high voltages or currents. The high voltage or high current circuit is connected with the primary winding of the transformer and the secondary circuit of the transformer is connected to the meter or relay. Instrument transformers are of two types namely current transformer and potential transformers. The current transformer is one of the types of instrument transformer which is designed in such a manner so as to produce a current in its secondary circuit which in turn proportional to the
current flowing through it’s primary circuit. Current transformers help in reducing the high voltage currents flowing through it and the proportionate value is produced so the measurement of current can be done easily using the standard ammeter of small ratings available in the market. The figure 1 describes the parts of the current transformer.

![Figure 1: Current transformer](image)

2. Principle behind current transformer

At the time when the primary winding of the CT gets energized, the primary side ampere turn produces a magnetic field in the core of the current transformer. The magnetic flux which is in link with the secondary circuit of the current transformer induces an electromotive force (EMF) which in turn drives the current in the secondary of the CT. The relation between the primary turns of CT and secondary turns of CT is given as follows

\[ I_1 \times N_1 = I_2 \times N_2 \]  

rearranging the equation (4) be the relationship between current and the turns as shown in equation (2)

\[ \frac{I_1}{I_2} = \frac{N_2}{N_1} \]  

\[ I_2 = n \]  

This is called the transformation ratio of the current transformer.

Where \( I_1 \) and \( I_2 \) are the primary current and secondary current of the current transformer respectively. \( N_1 \) and \( N_2 \) are the primary turns and secondary turns of the current transformer respectively and \( n \) is the turns ratio between secondary to primary winding of the current transformer.

3. Literature survey

Cruden, J. R. McDonald, I. Andonovic, D. Uttamchandani, R. Porrelli and K. Allan paper entitled "Current measurement device based on the Faraday Effect", explains about the performance with respect to the performance of harmonic content and vibration and temperature effects by the sensors in accordance with the sense of operations are noted with the variation in the levels of laboratory test results are revealed with the paper.

Nisha Das and M. K. Kazimierczuk paper entitled "An overview of technical challenges in the design of current transformers", explains the overall technical challenges to be faced clearly by equation representation in the form of lower cutoff frequency and higher cutoff frequency with the bandwidth of the transformer. The entire challenge has been proved by the practical results of PS spice stimulation. And also the practical difficulties which are to be faced like leakage inductance, stray capacitance, ringing parasitic resonance, saturation and mechanical clamping of the current transformer.
A paper entitled “A new standard for instrument transformer applications in industry” by Louie J Powell distinguished that the new standard and consideration for the both the industrial and commercial facilities in which are to be considered for the industrial application which mainly focus on the methodology of standardization of current transformer to its characteristics and application.

Francisco das Chagas Fernandes Guerra, Wellington Santos Mota paper entitled "Current transformer Model" explains the model for lower frequency application transformers; it may include the comparative study between the calculated values with the proposed output with their workout comparisons. On the aspects of frequency, current, time constants and deviation with the graphical representation.

The paper entitled the “Current transformer Testing” by A. H. M. ARNOLD explained clearly about the current transformer standards and its distinction on the basis of methods used for the testing of current transformers along their standard consideration while testing the process in the current transformers in comparison with the standard current transformers.

“Electronic System for Increasing the Accuracy of In-Service Instrument-Current Transformers” by Daniel Slomovitz explains about the compensating methods which have been proposed in their current transformer to increase the accuracy standards of the transformers to fulfil the accuracy standards which are to be learned. It also explains the burden calculation to increase the level of accuracy in the current transformer to overcome on the practical challenges.

“Determination of current transformer Errors at Primary Currents up to 100 000 A”, explained by describing a method for testing precision current transformers to overcome errors at the primary currents with the negligible resistance and a high sensitivity of the current transformers.

“Current Transformer Burden and Saturation” explains that Saturation in CT is an area where qualitative understanding abounds, but quantitative methods are limited in accuracy. The Performance of specific protective relays on saturating CT's is fairly well understood and is a subject of considerable concern on the part of engineers in industry. This paper has identified some of the major ways in which saturation can affect the performance of relays and has suggested several steps that can reduce the significance of CT saturation in planning an industrial power system.

“Design of the Instrument Current Transformer for High Frequency High Power Applications” by A-R A. M. Makky, H. Abo-Zied, F.N. Abdelbar, P.Mutschler briefed the Design of an instrument current transformer having a high rating of primary current and high rating of frequency is a challenging process. Normally one can get an instrument current transformer having high current or high frequency. This problem occurs due to the physical configuration of the core. Traditionally, at high frequency shunt resistance can be used to get a signal from the primary current. This method faces many problems. For this work, our approach is to design and implement a high frequency instrument current transformer, the primary current up to 200 A and 400 KHz.

4. Spade works
Medium-voltage AC drives produce greater power output than the smaller drives, enabling the optimal control of electric motors which power industrial loads found in mines, power stations, or metal processing plants. They operate at higher supply voltages to obtain lower losses and use smaller cables that add up overall drive efficiency.
Alfa Switchgear (I) Pvt.Ltd. is one of India’s immense manufacturers of high voltage (HT) and low voltage (LT) panels with extensive experience of 25 years and now an instigate in the Indian Market and flourishing in international markets. They carry out the electrical panel design installation work all over India and Asia. They are also consultants, contractors and manufacturers of electrical panels up to 36kV. They usually get projects from major industries in designing and manufacture of electrical panel boards. One of the industries in Erode which is the manufacturer and supplier of commercial kitchen equipment & furniture has placed an order in Alfa Switchgear (I) Pvt.Ltd for the electrical panel board design. Inside the panel board various electrical components are present. There also exists a busbar. It is nothing but a metallic bar conductor which is present inside switchgear and panel boards. The current needs to be distributed throughout the panel board by the bus bar. The current at input has to be stepped down by the current transformer and then fed to measuring meters. This is commonly done. It is a three phase system as per the company requirement. So an individual phase has to be fixed with an individual current transformer.

The current in each phase of a three phase system is given by

\[ I = \frac{P}{(V \times \sqrt{2} \times p.f)} \]  

(4)

Where

- \( I \) stands for per phase current in three phase system
- \( P \) stands for Power
- \( V \) is Three phase voltage
- \( p.f \) stands for power factor

\( P = 28.218 \text{KW}(\text{Value obtained from the Industry}) \)
\( V = 420 \text{V} (\text{Value obtained from the Industry}) \)
\( p.f = 0.8 (\text{Value obtained from the Industry}) \)

Therefore by substituting the value of \( P, V \) and \( p.f \) in equation (4), the value of \( I \) is obtained as follows

\[ I = \frac{28218}{(420 \times 1.732 \times 0.8)} \]

\[ I = 48.49 \text{A} \]

(5)

From the above calculation it found that the current through a single phase system ranges between 48A to 50A. Thus the current transformer recommended is of ratio 50 : 5. In this case the authors have been provided with a project from the Alfa Switchgear (I) Pvt.Ltd to design the required current transformer.

Initially while designing the CT in order to meet the company’s requirement, authors have taken some of the CTs from the company that have been removed from the panel due to reasons like mishandling during testing, malfunctioning due to the reasons like short circuit and other miscellaneous reasons. Authors have undergone a study using these CT towards the core materials, its design structure and also the improvements that can be added to it’s design to overcome it’s defects. Authors have also experienced a profound exploration on the windings of the current transformer. Initially authors unwinded the winding of the current transformer and looked into the winding and deeply investigated it’s diameter, it’s physical property and it’s electrical properties like it’s resistivity towards electricity and losses\(^{15}\)(25) that occurs during electrical and magnetic conductivity. They have undergone a study\(^{6}\)(11) over a period of a month in exploring about the defects in the CT’s and a study regarding the material selection of core and winding. Finally after considering the requirements in designing the CT they have started the design. Initially the winding of the transformer was done manually by them after the successful selection of the core. The ratio as per the requirement is 50 : 5. Authors were successful to
some extent but due to the mistakes like uneven distribution of turns and the man made procedures in winding of the current transformer they have reached the efficiency only upto 94% approximately. But in the environment of the industrial needs even a small mismatch leads to the great impact in the side of productivity, accuracy and in sensitive zones it may also lead to severe accidents. On the other hand the company is satisfied with the efficiency in the range between 97 % and 100%. The company suggests to use machine driven for proper winding and insulation. Authors spent a week to gain knowledge about the winding machine and to learn machine winding. Finally after attaining knowledge in the winding, authors as a team achieved the CT with evenly distributed less air gap winding to meet the efficiency of Industry. Finally completed the CT by re-engineering it once again using machinery. This time authors have obtained an efficiency level of 98% which is better than the previous result and has met the industry’s requirement. Below mentioned the design calculation of the current transformer. Figure 2 shows the spade works carried out at the initial stages.

5. Design of current transformer

After analyzing the technical challenges and standards in designing the CT the following further steps were carried out

5.1. Derivation of transformer ratio

Transformation Ratio (k) is known as the ratio of the EMF in the secondary coil to that of EMF in the primary coil.

\[ k = \frac{E_2}{E_1} \]  

\[ E_1 \text{ is given by } (4.44\Phi_m f N_1) \]  

\[ E_2 \text{ is given by } (4.44\Phi_m f N_2) \]  

Substituting the value of \( E_1 \) and \( E_2 \) in (7),

\[ k = \frac{E_2}{E_1} = \frac{4.44\Phi_m f N_2}{4.44\Phi_m f N_1} \]  

Simplifying the above equation,

\[ k = \frac{E_2}{E_1} = \frac{N_2}{N_1} \]  

Now,
\[ V_1 = E_1 + VD \text{ (Voltage drop)} \quad (10) \]
\[ E_2 = V_2 + VD \text{ (Voltage drop)} \quad (11) \]

Due to the resistance in the windings and also due to some leakage flux, there exists some loss in voltage. This loss in voltage is called Voltage Drop.

Voltage drop can be neglected due to ideal cases.

Hence,
\[ V_1 = E_1 \quad (12) \]
\[ E_2 = V_2 \quad (13) \]

Hence,
\[ \frac{E_2}{E_1} = \frac{V_2}{V_1} \quad (14) \]

Also, in a transformer, the power across the primary as well as the secondary winding is equal. Hence,
\[ V_1 \times I_1 = V_2 \times I_2 \quad (15) \]
\[ \frac{V_1}{V_2} = \frac{I_2}{I_1} \quad (16) \]

Now, combining above equations,
\[ k = \frac{E_2}{E_1} = \frac{N_2}{N_1} = \frac{V_2}{V_1} = \frac{I_2}{I_1} \quad (17) \]

Where,
- \( I_1 \) represents the current in the primary coil
- \( I_2 \) represents the current in the secondary coil
- \( E_1 \) is emf in the primary coil
- \( E_2 \) is emf in the primary coil
- \( V \) is the voltage in the respective coil
- \( N_1 \) is number of turns of the primary coil
- \( N_2 \) is number of turns of the secondary coil
- \( \Phi_m \) is the mutual flux in the core

5.2. Core calculation

The core of a transformer or transformer’s core is considered as the magnetic circuit. For a given current transformer, the magnetic circuit is defined as the iron toroid core that consists of a long narrow circular bar of silicon steel that has been rolled up. The secondary turns of wire are wound around the toroid core of the current transformer.

5.2.1. Cross sectional area of the core\((S)\)

The cross-sectional area is considered as the area of a two-dimensional shape that has been obtained when a three-dimensional object is sliced in perpendicularly with some specified axis at a certain specified point. In other words if a plane intersects a specified solid (a 3-dimensional object), then the region which is common to the plane and the solid is known as cross-section of the solid.

Calculation

Figure 3 indicates the shape of the core.
Let $D_1$ be the external diameter of the core or the diameter of the outer circle core. $D_2$ be the inner diameter of the core or the diameter of the inner circle core height of the core and $R_1$ and $R_2$ are the external and internal radius of the current transformer core. Let $H$ indicate the height of the core. Consider $S$ indicates the cross sectional area of the core. For the current transformer of rating 50:5 the standard values for the inner diameter and the outer diameter and the height are specified at Reference: IEC 60044-1. Instrument transformers – Part 1: Current transformers.

The standard values of the diameters and the height are as below:
External Diameter, $D_1 = 6\text{cm}$
Internal Diameter, $D_2 = 4\text{cm}$
Height of the core, $H = 3\text{cm}$

The cross sectional area of the core is given by,

$$S = (D_1 - D_2) \times \left(\frac{H}{2}\right)$$

Step 1: Substituting the value of $D_1$ and $D_2$

$$D_1 - D_2 = 6 - 4 = 2\text{ cm}$$

Step 2: Substituting the value of $H$

$$\frac{H}{2} = \frac{3}{2} = 1.5\text{cm}$$

Step 3:

$$S = (D_1 - D_2) \times \left(\frac{H}{2}\right)$$

$$S = 3\text{cm}$$

The cross sectional area of the core $S = 3\text{cm}$.

Figure 4 indicates the finally designed core for the project.
5.3. Primary turn calculation

In this type of transformer the busbar or the cable whose current needs to be measured is taken as the primary side of the current transformer. Therefore the number of turns in the primary of the current transformer is one.

The current flowing through the primary winding of the current transformer is 50 A.

5.4. Secondary turn calculation

It indicates the number of turns present in the secondary of the current transformer. The secondary winding is wound over the core of the current transformer. Number of turns to be wound depends upon the factors like current which needs to flow through the secondary of the current transformer, the material which is used to manufacture the secondary of the current transformer, etc.

5.4.1. Calculation

Let us consider the number of secondary turns as \( N_s \) and the current flowing through the secondary turns of the current transformer is \( I_s \). The current flowing through the secondary winding of the transformer as per the requirement is 5A. Let us consider \( N_p \) to be the number of turns in the primary winding of the current transformer. Hence the current flowing through the primary winding of the current transformer is given by \( I_p \). Since the busbar is considered as the primary winding of the current transformer the \( N_p \) is taken as 1. The current flowing through the current transformer \( I_p \) is taken as 50A as per the requirement.

The transformation ratio is given by

\[
\frac{N_s}{N_p} = \frac{I_p}{I_s}
\]

(20)

By reframing the above equation the \( N_s \) is given as follows

\[
N_s = \left( \frac{I_p}{I_s} \right) \times N_p
\]

(21)

Substitute

\[
I_p = 50A \\
I_s = 5A \\
N_p = 1
\]

in the above equation

Step 1:

\[
\frac{I_p}{I_s} = \frac{50}{5} \\
= 10
\]

Step 2:

\[
N_p = 1 \\
\]

Substituting the value of \( N_p \) and \( \frac{I_p}{I_s} = 10 \) in equation (21)

\[
N_s = \left( \frac{I_p}{I_s} \right) \times N_p
\]

(22)

Number of turns in the secondary of the current transformer \( (N_s) = 10 \) turns
5.5. Wire calculation

The secondary of the current transformer is a coil wound over the core of the current transformer with even distribution into which the primary winding i.e., bus bar or cable is passing through it. The material chosen for the secondary winding is copper. The type of core chosen is ring type core. The length of one turn around the core is measured and it is found to be 10 cm. The number of turns required as calculated is found to be 10 turns.

Total length of the wire is given by

$$\text{Total length (l)} = \text{length of one turn} \times \text{total number of turns}$$  \hspace{1cm} (23)

Step 1:
- Length of one turn = 10 cm

Step 2:
- Total number of turns = 10

Step 3:
- Total length (l) = 10 cm
- Total length(l) = 1 m

5.6. Calculation of CT burden

Current transformer burden also known as CT burden\[^{23}\] is said to be the load connected across its secondary circuit. It is expressed in VA (volt-ampere).

5.6.1. Reason for CT burden

Burden\[^{23}\] on the secondary side is due to relay meters, connected loads and resistance of secondary winding in CT.

As per the requirement the current in the secondary winding of the transformer is 5 A. Generally the power factor lag\[^{21}\] in the secondary side of the transformer by 0.75 due to the load connected across it.

The burden of the transformer is given by

$$\text{Equivalent VA} = \text{current through the coil} \times \text{the voltage drop across it}$$ \hspace{1cm} (24)

Step 1:
- Current through the secondary winding = 5 A

Step 2:
- Voltage drop = current flowing through the winding \times internal resistance of the winding \hspace{1cm} (25)
  -  = 5 \times 0.2
  -  = 1 V

Step 3:
- Equivalent VA = 5 \times 1
- The CT Burden(VA) = 5 VA

6. Wire selection
6.1. IEC standard
As per the reference taken from the IEC IEC 60044-1. Instrument transformers – Part 1: Current transformers, the following process has been carried out.

6.2. Selection of SWG

SWG - Standard Wire Gauge
British Standard Wire Gauge is a collection of wire sizes given by BS 3737:1964 and it is generally abbreviated to SWG. It is also called the British Standard Gauge or Imperial Wire Gauge.

Based on the International Electrotechnical Commission Standard, to withstand the total burden, the wire has to meet out the certain requirement and it can be satisfied by making use of the wire with SWG (Standard wire gauge) = 16 – 18. The diameter of the 16SWG wire is 1.83mm. The main consideration during the selection of material is that it has to withstand the temperature at Burden\(^3\) and Overload times.

The cables with SWG 16 can withstand temperatures up to 400 F / 204 \(^\circ\)C

7. Resistivity of the wire

7.1. Resistivity

The electrical resistivity (ρ) of the material is the electrical resistance per unit length of the material and per unit of cross-sectional area of the material at a specified temperature. Generally, Resistivity of copper is given as 1.724 x 10\(^{-8}\)ohm-m. The SI unit of electrical resistivity is given as ohm-metre (Ωm). It is commonly represented in terms of Greek letter ρ (rho).

\[
ρ = \frac{R \times (\frac{4}{\pi})}{l} \tag{26}
\]

In order to obtain the resistance of the material the above equation is reframed as

\[
R = \frac{ρ \times (\frac{4}{\pi})}{l} \tag{27}
\]

Where:

- R is the electrical resistance of the material which is measured in ohms
- l is the length of the material which is measured in metres (m)
- A is the cross-sectional area of the material which is measured in \(m^2\)

A is given by the below equation

\[
A = \pi \times (r^2) \tag{28}
\]

Where

- \(\pi\) is the mathematical concept whose value is 3.14. r is the radius.

Step 1:

Diameter of the wire is 1.83mm, the radius is given by

\[
\text{Radius}(r) = \frac{\text{Diameter}}{2}
\]
Step 2: Substituting the value of radius in equation (28)

\[ A = 3.14 \times (0.915 \times 10^{-3})^2 \]

\[ A = 2.628 \times (10^{-6}) \]

Cross sectional area of copper (A) = 2.628 x (10^{-6}) m

Step 3:

\[ R = \frac{(1.724 \times 10^{-8}) \times \frac{1}{2.628 \times 10^{-8}}}{2} \]

Resistance of wire (R) = 6.5mohm

8. Insulating material

Sufficient insulation\(^{[3]}\) between different active parts of the CT is necessary for its safe operation. Insulation is responsible for improving the performance of the transformer when it is operated. The durability and stability of a transformer depends highly upon the proper utilization of the insulation materials present within the transformer. Here Insulating tape is used to provide insulation. Figure 5 indicates the insulation process carried out for the project. The insulating tape is available in various colors namely black, red, blue, brown, orange, yellow, green, white grey. Based upon the withstanding capacity needed, black insulating tape has been chosen.

![Figure 5.Insulation Setup](image)

9. Testing of current transformer

The test is carried out to check the performance of the CT that was designed. Two ammeters were chosen and one of them is connected with the primary and the other one with the secondary of the current transformer as shown in figure 6.
The switch is turned on and the current flowing through the primary of the current transformer is varied by adjusting the variable load connected across it and the current flowing through the primary and the secondary were noted down. Table 1 indicates the reading obtained via the test conducted and analysed to check the performance of the CT.

### Table 1. Testing Results

| Primary current (Ip) | Secondary current (Is) |
|----------------------|------------------------|
| 5                    | 5                      |
| 10                   | 10                     |
| 20                   | 20                     |
| 30                   | 20.5                   |
| 40                   | 41                     |

To ensure accuracy and optimal service reliability of the CT the following 6 electrical tests should be performed.

#### 9.1. Ratio test

The ratio test is done in order to prove that the ratio of the CT is as specified, and to verify the ratio is correct at different taps of a multi tap CT. The voltage ratio of potential transformers and the turn’s ratio are equivalent and they can be given as $N_2/N_1 = V_2/V_1$. Usually the ratio test is carried out by applying a voltage that matches the current transformer’s secondary side which is under test while the voltage at the primary side is measured in order to calculate the turns ratio from the above mentioned expression.
9.2. Polarity test

The current transformer's polarity is determined by the coil's directions in which they are made to wound around the transformer core either in anticlockwise direction or in clockwise direction and the way in which the leads are brought out of the current transformer. All current transformers have the polarity named subtractive polarity. A current transformer which is under the test is considered to have correct polarity if the direction of instantaneous current in primary and secondary in it is opposite to each other. The polarity marks indicated on a current transformer represent the relative directions of the primary and secondary currents in it. The polarity test is done to prove the statement that the predicted direction of current in secondary of the current transformer is correct for a given direction of primary current in the current transformer. It is important to check the proper polarity while installing the current transformer and connecting it to the protective relays and power metering. At the instant of time when the primary current is entering the primary terminal of the current transformer, the corresponding secondary current should be leaving the similarly indicated or marked secondary terminal. The current transformer which is under test is assumed to have proper and correct polarity if instantaneous current direction for primary and secondary current is opposite to each other. The polarity current transformer is critical when it is being used together in single-phase applications or three-phase applications. In recent days current transformer's test equipment is capable of doing the automated ratio test by using the simplified test lead setup which will display polarity as correct or incorrect. Verification of CT polarity can be done manually by making use of a 9V battery and analog voltmeter.

9.3. Excitation (Saturation) test

When a current transformer is saturated the magnetic path which is inside the current transformer will act as a short circuit on the transmission line. All of the energy which is provided by the primary winding is shunted away from the secondary winding and it is used in the creation of a magnetic field inside the current transformer. Saturation testing for a CT describes the rated knee point as the point at which the current transformer is no longer able to be in proportion with the output current in its specified ratio. The test for the correctness of excitation is done by applying an AC voltage to the secondary winding of the current transformer and it is done by increasing the voltage in steps until the saturation point of the current transformer is achieved. The "Knee" point of the current transformer is obtained by monitoring a small voltage increase which leads to a large increase in the value of current. The test voltage is gradually made to decrease to zero in order to de-magnetize the current transformer. The results obtained from the test are plotted on a logarithmic graph and it is also evaluated based on the transition period between normal operation and operation at the saturation point. Tests for excitation have been performed by giving an AC voltage to the secondary winding of the current transformer and by increasing the voltage in steps until the saturation point of the current transformer is reached. Published manufacturer's data should be compared with the results of the excitation test or previous recordings in order to determine any deviations from the curves obtained previously. As per the standard of IEEE, the saturation can be defined as the point at which the tangent is at 45 degrees to the secondary exciting current. It is also known as knee point. This test helps in the verification of correct accuracy rating of the current transformer and in order to confirm that there are no short circuits present in the primary winding or secondary winding of the current transformer which is under test.

9.4. Insulation resistance test
The insulation which exists between the CT windings and windings to ground should be checked to ensure the dielectric strength during the performance of a comprehensive current transformer test. Three tests which should be done in order to determine the condition of the insulation of the current transformer are listed below:

1. **Primary to secondary**: This test is performed in order to check the condition of the insulation between high to low.

2. **Primary to ground**: This test is done in order to check the condition of the insulation between high to ground.

3. **Secondary to ground**: This test is done in order to check the condition of the insulation between low to ground.

9.5. **Winding resistance test**

The DC resistance measurement of the windings of the current transformer is an important measurement for accessing state and accuracy of the current transformer. Resistance of the windings in a current transformer will change after a period of time depending on the usage, external conditions i.e., atmospheric condition of the surrounding and loading effect of the current transformer. It is advised to measure DC winding resistance in a rotational manner on a single tap or multi tap current transformer. A high range of accuracy is needed. Current transformer’s winding resistance is found by dividing the voltage drop across the winding with the applied dc current through the winding. The CT should be demagnetized after the completion of the winding resistance test. Measurement of the resistance of the windings of the current transformer is done by passing a DC current through the winding and by measuring the voltage drop in it. Divide the measured voltage by the measured current.

10. **Conclusion**

Thus the mathematical design and the overall outcome of the current transformer was done and with the help of the readings value obtained from the mathematical calculation followed by the fabrication of core and the winding of the current transformer was carried out successfully along with the various analysis on them by varying type of values as test cases. Thus the current transformer of ratio 50:5 was obtained as a finalized one. The entire testing procedure of the current transformer such as to check its operation, its accuracy and verification of the standards whether it matches with the international standards of instrument transformer on the basis of the global framework has been carried out successfully. Then the installation process of the designed current transformer at Alfa Switchgear(I) Pvt.Ltd has been done successfully and it is in a very good working condition. Further improvement in the accuracy of the readings obtained from the current transformer can be achieved only by eliminating the negligence and manual errors that occur during the manufacturing of core and by eliminating the losses[27] that occur in the winding part and the core part of the designed current transformer.

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