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Performance Analysis of High Grade M19 Silicon Steel Core for Distribution Transformer

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Abstract

With increasing competition in the global market continuous research are done to optimize the behavior of materials to be used in transformer. Since silicon (Si) comprises a very good crystallographic arrangement then that of iron (Fe), silicon is fused with iron for considerable reduction of leakage flux in it. A novel M19 high grade silicon steel core has been introduced for 1 KVA 415/230V delta to star connected distribution transformer and stray losses are estimated using Ansys Maxwell. The obtained results are validated by experimental test.
Keyword- M19 Silicon Core, Straylosses, Eddy Current, Distribution Transformer

I. INTRODUCTION

Due to rapid advancement and ultimate growth in the field of transformer design and its manufacturing the researchers preferred that the method of analyzing the materials used in transformer core will sufficiently improve the performance of transformer. The performance of transformer is restricted due to the leakage flux which flows beyond the transformer core to structural components such as tank, frames, flitch plates, bush mounting plates etc [10]. The eddy current loss will give rise to stay loss in the form of heat (hot spots). They affect the reliability of transformer life span like burning of coil over heat change the property of material of transformer[8][9]. The replacement of M19 high grade silicon provides an energy efficient transformer with increased load withstanding capability and reduced voltage drop with increase in load. The M19 high grade silicon steel with its best conducting properties[3], high permeability and high temperature withstand capability as shown in table 1 provides a solution for performance improvement.

Sl No	Parameters	Values
1	Type	CRNO (cold rolled non oriented steel)
2	Silicon content	2.5 – 3.8 %
3	Permeability	8500 µ
4	Operating flux density	14 kilogauss
5	Thickness	0.36 mm
6	Type of insulation	C–3 (organic varnish coating)
7	Core loss	1.98 Watts/Kg

Table 1: Properties of M19 high grade silicon steel

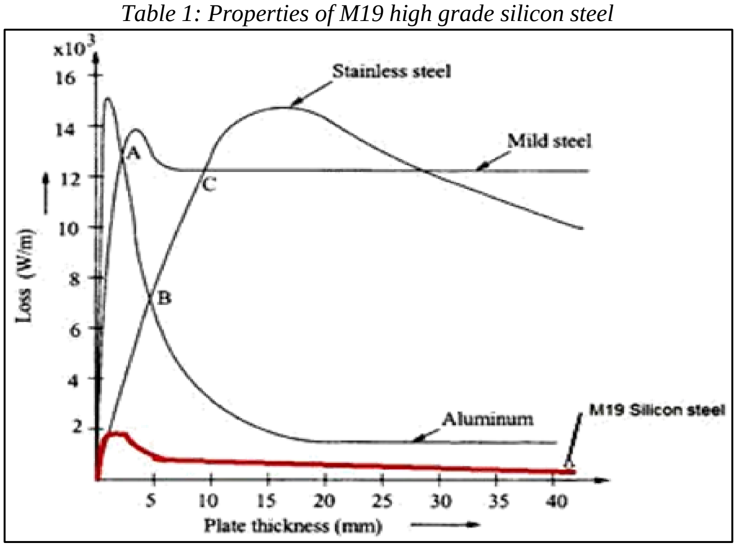

Fig. 1: loss in different materials for radial excitation

Figure 1 shows the loss in different materials for radial excitation in which it can be seen for high grade M19 silicon steel the loss first increases for 2.5mm of thickness and gradually reduces much lesser than 2 W/m compare to stainless steel, mild steel and aluminium.

II. FINITE ELEMENT MODELING OF HIGH GRADE M19 SILICON CORE TRANSFORMER

A three phase 1KVA 415/230V Y/Δ distribution transformer with High grade M19 silicon steel is proposed and modeled using ANSYS Maxwell [6]. The geometry of the core with all dimensions in mm is shown in Figure 2.

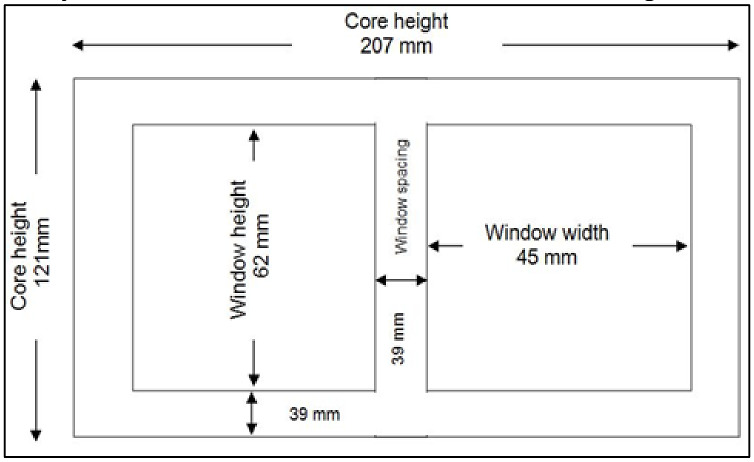

Fig. 2: Geometry of transformer core

The dimensions are fixed as per the design value results obtained from the calculations based on the transformer rating [1][2] as shown in Table 2.

Sl No	*Parameters*	*Values*
1	*EMF per turn*	*0.00540 Wb*
2	*Net core area*	*0.004504 m²*
3	*Gross core area*	*0.005005 m²*
4	*Secondary turns*	*382 turns*
5	*Primary turns*	*747 turns*
6	*Primary side current*	*1.4 A*
7	*Area of cross section in primary side*	*0.36 mm²*
8	*Secondary current*	*4.5 A*
9	*Area of cross section in Secondary side*	*2.14 mm²*
10	*Area of the conductor*	*2172.8 mm²*

Table 2: Design Specification for proposed 1KVA 415/230V Y/Δ distribution transformer

Figure 3 shows the scheme of the modeled transformer in which the transformer core is a silicon sheet of high grade M19 silicon steel.

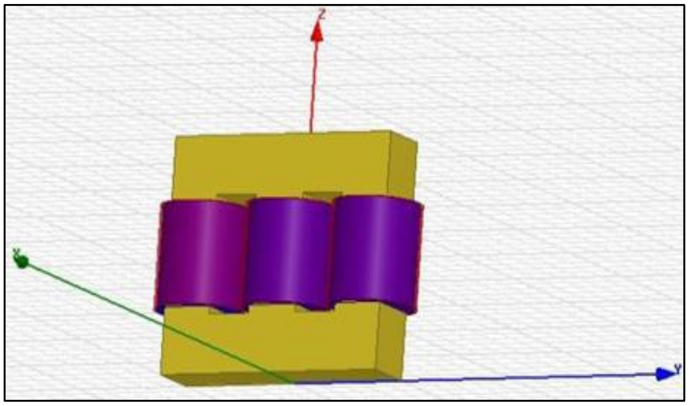

Fig. 3: 3D Model of proposed transformer with M19 silicon steel core

To compute magnetic flux linkage, the magneto static field solver uses the following relation,

$$Ø=\int B.dA \qquad (1)$$

Where,
B- Magnetic flux density.

A- Area over which flux density is computed.
The magnetic flux value computed is the total flux that passes through the surface where the graphical representation is shown in Figure 4.

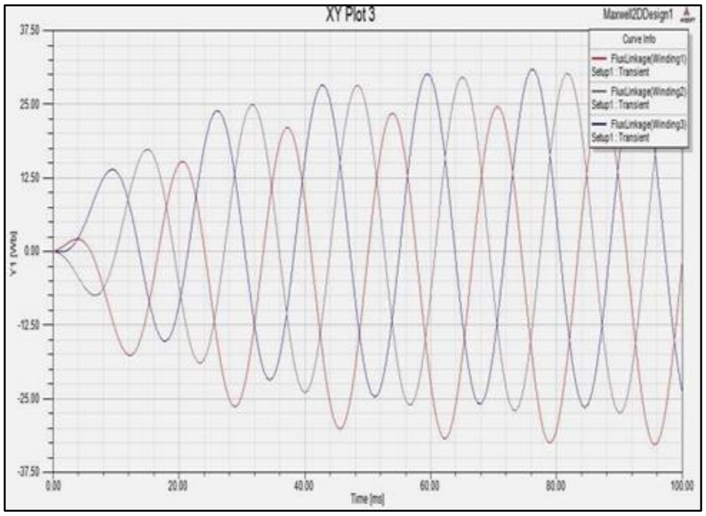

Fig. 4: Flux linkage through the core (with respect to 100 ms)

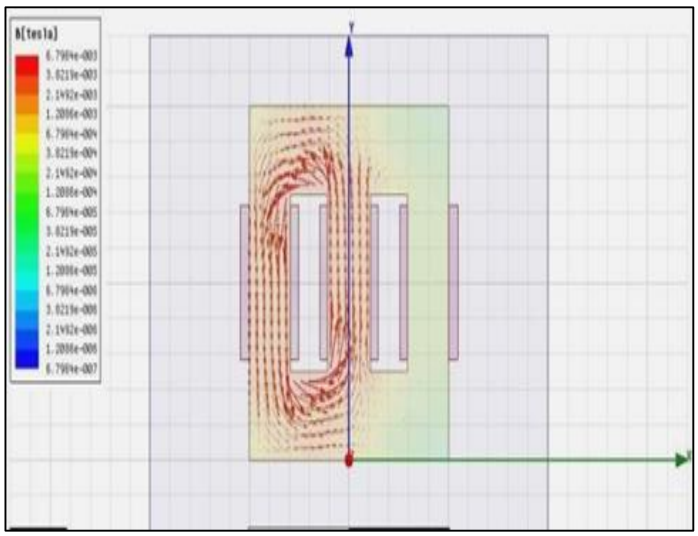

Fig. 5: Vector direction of the flow of flux (primary side)

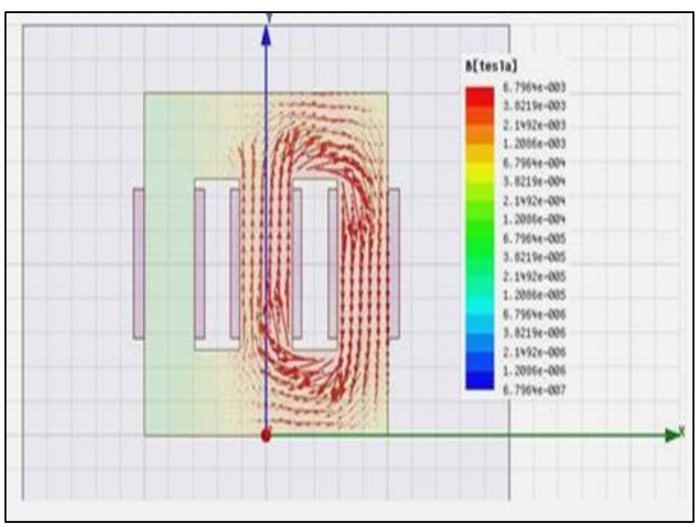

Fig. 6: Vector direction of the flow of flux (secondary side)

Vector diagram of the flow of flux through the core in the direction in which the initial starting flux from the primary side to the secondary return flux in the opposite direction [7] is shown in Figure 5. It can be seen from Figure 6 that the flux after flowing through the secondary side it gets return over the opposite direction to the primary side of the transformer [5].

III. HARDWARE IMPLEMENTATION & EXPERIMENTAL RESULTS

This section elaborates the experimental setup & presents a scheme for experimental purpose with butt joint core overlapped in an orderly manner with reduced air gap which avoids the high reluctance path problem [8]. Figure 7 shows the High grade M19 silicon steel set up for Butt core stacks. Figure 8 shows the prototype model of three phase 1KVA 415/230V Y/Δ distribution transformer with High grade M19 silicon steel.

Fig. 7: High grade M19 silicon steel being fabricated for Butt core stacks

Load test and OC&SC test are conducted on the proposed prototype model and obtained results are compared and validated with conventional 1KVA 415/230V transformer.

Fig. 8: Prototype model of three phase 1KVA 415/230V Y/Δ distribution transformer with High grade M19 silicon steel

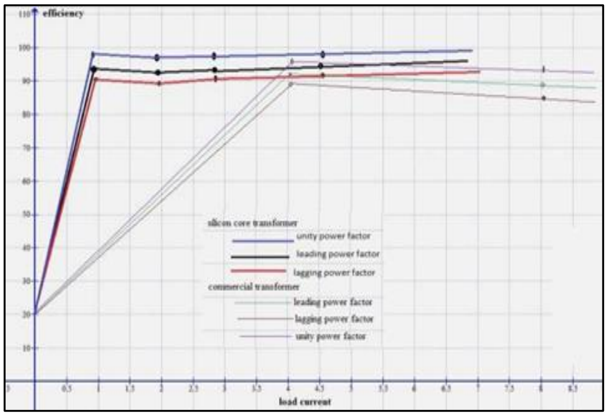

Fig. 9 (a): Characteristic curve for load current Vs Efficiency

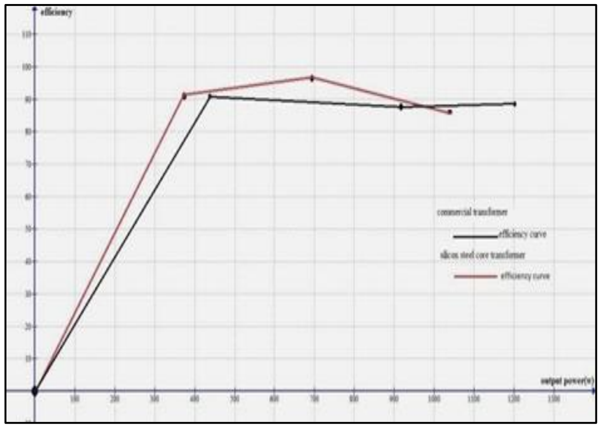

Fig. 9 (b): Characteristic curve for output power Vs Efficiency

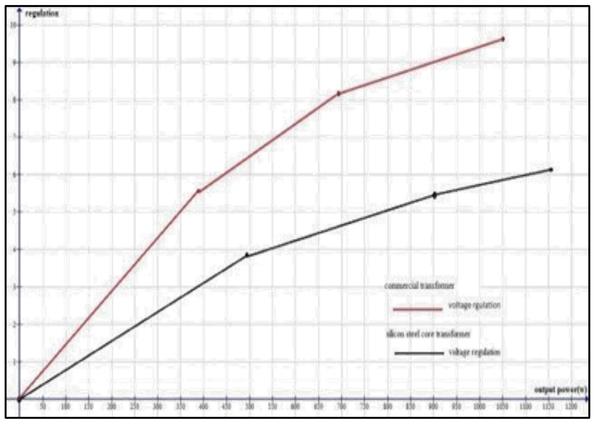

Fig. 9 (c): Characteristic curve for

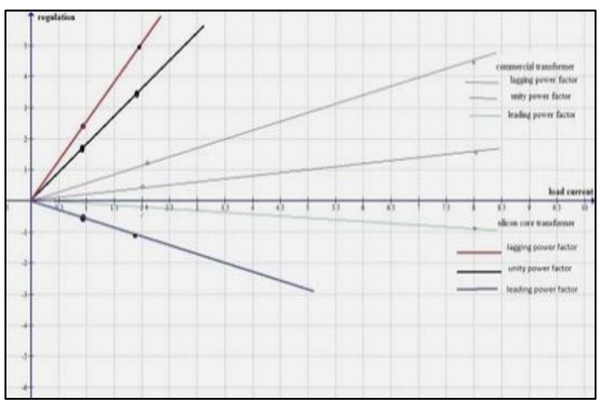

Fig. 9 (d): Characteristic curve for load current Vs Regulation

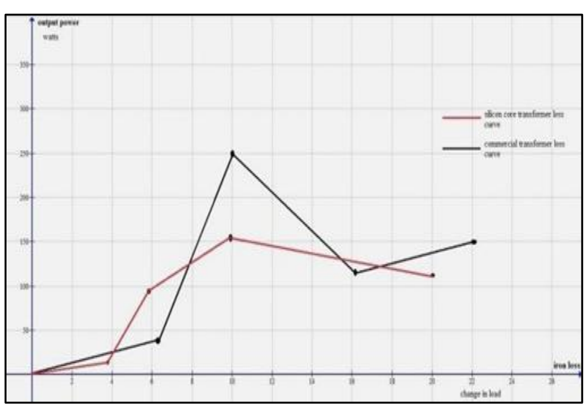

Fig. 9 (e): Characteristic curve for iron loss Vs output power

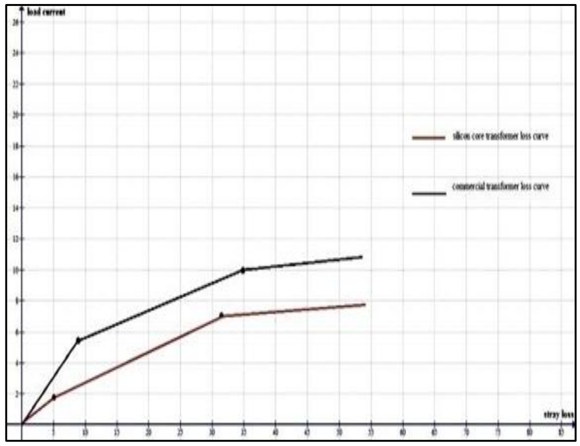

Fig. 9 (f): Characteristic curve for stray loss Vs load current

Figure 9(a) to 9(f) shows the Performance characteristic curve for High grade M19 silicon core graphically in comparison with conventional transformer.

S.N	*Parameters*	*M19 Si core*	*Conventional transformer*
1	*Iron loss*	*10 w*	*30 w*
2	*Copper loss*	*6.374 w*	*11.94 w*
3	*Stray loss*	*2.019 w*	*3.582 w*
4	*Total loss*	*16.3740w*	*41.94 w*
5	*Voltage regulation*	*5.217%*	*4.89%*
6	*Efficiency*	*96.22%*	*94.09%*

From the table 3 it is clearly seen that the iron loss of about 20 watts, copper loss of about 5.566 watts and stray loss of about 1.563 watts were reduced. This reduction in losses provides a way for the improvement in the transformer efficiency by 2.13%.

IV. CONCLUSION

This paper proposed a new high grade M19 silicon core for distribution transformer. A prototype model has been built and the experimental results shows that by introducing high grade M19 silicon steel, total losses are considerably reduced by avoiding stray losses flowing in structural components. Comparison of prototype model with conventional model illustrates that there is an improvement in the transformer efficiency by 2.13%.

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