Efficiency Improvements in Transformers by Adoption of New Magnetic Material

Ravi Kumar Vaishya[1], Shalini Vaishya[2], S.K. Bajpai[3]
[1,2,3] Dept. of Elect. Engg. GGITS, Jabalpur (M.P.) India.

ABSTRACT
Since independence in India there has always been shortage of electricity and at no point of time we have been able to meet the peak demand. The gap between the demand and generation can be bridged/minimized by either improving the installed capacity or reducing the consumer demand. The gap between availability & demand is of order 6% as on date. If we take into account the issues like environment pollution and global warming, the preferred option is to increase the energy efficiency or minimize the consumer demand, as in the other alternative particularly in India, where thermal generation dominates, increased environmental pollution is inevitable [1].The paper covers design of transformer using a new technology superior magnetic material with thin sheets of lazer grade or amorphous core. Iron Boron Silicon amorphous alloy is a unique alloy whose structure of metal atoms occurs in random patters as opposed to conventional CRGO steel which has an organized crystalline structure. The paper covers design of distribution transformer using conventional material and the new technology improved core materials. The reflection on the no-load and load losses due to change in the material have been worked out. Commercial and technical feasibility for adoption of new technology core material has been detailed out and the payback period is quite attractive. By reducing the regular power loss in the transformer, economy of the power sector and global environmental impact can be improved.[8] The paper also covers the working of quantum of electrical power that can be saved if adopted in the state of M.P. The reduced Electrical Power generation requirements due to lower losses have also been translated to reduction in the CO2 emissions polluting the environment.

Keywords- Core, Copper, Tank, Steel Radiator, Transformer Oil, Power Factor, Losses, Load Factor, Insulation Material, CRGO, Lazer Grade, Amorphous core

I DEFINITION OF THE PROBLEM

The demand for electricity in India is enormous and is growing steadily. This growth has been slower than country's economic growth. To balance this demand and supply of electricity, it is the time to go for improvement in energy efficiency electrical equipment in use by the utilities and also by the consumers. Ways to improve energy efficiency of one of the electrical equipment used by utilities has been discussed in coming pages.

The power plant generates electricity at low voltage rating and the generated power has to be transmitted through long transmission line at extra high voltage i.e. 440, 220 & 132 KV to reduce the line losses and conductor size. This extra high voltage power is then stepped down to the desired voltage which is then used in the industrial, commercial, transportation & domestic sectors.

The voltage in the entire system can only be steped up & down by using transformers of different capacity. The power passes through the transformers involving transformer losses i.e. no-load and load losses.

These transformer losses impose heavy financial losses and impact the environment globally. By reducing these losses in the transformer, economy of the power sector and global environmental impact can be improved. [2]

Thus our objective is to design an energy efficient transformer which reduces the total transformer loss by 60%.

II ENERGY EFFIC IENT TRANSFORMERS

No – load loss resulted from the magnetization of core laminations, depends upon the following parameters of core: -

(i) Thickness varies from 0.23 to 3.0 mm
(ii) Quality - CRGO, HI-B Grade, Lazer Grade, Amorphous
(iii) Flux density
(iv) Specific gravity of core

Reduction in No-load losses can be achieved by
(i) Using better quality core
(ii) Sharpening the edges of the core at appropriate angle
(iii) Building Single strip core building for reduced the air gap.
(iv) Annealing the core so as to

- Reduce mechanical stress in the lamination to a minimum to yield optimum magnetic proprieties
- Prevent contamination of the steel with oxygen and or carbon
- Retain or enhance the insulation quality of the lamination coating.

Iron Boron Silicon amorphous alloy is a unique alloy whose structure of metal atoms occurs in random patters as opposed to conventional CRGO steel which has an organized crystalline structure. The higher resistance to magnetization and demagnetization through the crystalline structure leads to higher core losses in CRGO.

Load loss of transformer depends on the load on the transformer. [6]

(i) Load Current (I)
(ii) Resistance of the Wire and strips used to construct the coils.
(iii) Gap between Cores - Coil with tank.

Reduction in load losses can be achieved by

(i) Using higher size of the conductor.
(ii) Reducing size of core
(iii) Reducing Winding Temperature.
(iv) Improving conductor resistivity.

Annealing of Wires & Strips for better performance and life of the transformer as it

- Improve the machine-ability
- Obtain grain size and produce uniformity.
- Increase activity of metal
- Modify and improve electric & magnetic properties.
- Release internal stresses
- Help to produce a definite micro structure

III DESIGN OF ENERGY EFFICIENT TRANSFORMERS

(a) Cost Benefit- For techno commercial study a practical size of 200 KVA,11/0.433KV distribution transformer has been considered. For comparison purpose 200KVA distribution has been designed using three different core materials CRGO M-4,HiB and lazer grade stampings. The thickness of stampings in case of M-4 and HiB grades has been taken as 0.27mm & that of lazer grade as 0.23mm based on availability of these core materials in the market. The working flux density before approaching the Knee point in case of all the materials and also watt loss/Kg are different .This amounts to that the weight of the core and also losses particularly iron losses are going to be different when designed considering these three cores. Transformers with three cores under consideration have been designed and weight of core, iron losses 7 also load losses have been detailed out in table –I. Due to variation in total weight of transformers and due to variation in the rate of different cores, the initial cost of the transformers for the three designs works out to be different as indicated in table-I. Here it is pertinate that the initial cost alone cannot be taken for ensuring commercial viability but we need to take into account the variation in the iron and load losses as well.

In case we consider/assume

(i) Rate of interest (@ 10 %)
(ii) rate of electrical energy as Rs 3/kwh
(iii) life of transformer (as 25 years)
(iv) Load factor of distribution transformer as 60%

The iron and copper losses can be capitalized for working out the commercial feasibility. The capitalized cost of iron losses (Wi),Copper losses (Wc) and total cost (Ct) including initial cost as worked out as indicated in table-I A 200 KVA 11/0.433 KV Transformer with different three core materials:

Table -1

Parameters	Conven.	EET I	EET II
Core material	CRGO M-4	HiB	Lazer Grade
Thickness	0.27	0.27	0.23
Watt/Kg	1	0.56	0.3
Weight of core	396Kg	457Kg	465Kg
Iron Losses	500 Watts	300 Watts	180 Watts
Load Losses	2800 Watts	2300 Watts	2300 Watts
Initial Cost	200000	230000	260000
Wi	119272	71563	42938
Wc	291979	243316	243316
Ct	611251	544879	546254
<u>Saving per transformer</u>		66372	64997

Saving in respect of KW Total Saving in Losses = 0.82 KW Number of Transformer required to save one number 25

KVA transformer will be 25/0.82 = 30 nos. Thus for every 30 installation of 200 KVA EET, one number 25 KVA transformer will be saved.[10]

Case OF MP State Utility

The total installed distribution transformers in M.P. state as on feb 2012 are [15]:

Table 2

	MP Distribution				
Capacity in KVA(a)	East zone	Central zone	West zone	Total(b)	KVA(axb)
16KVA	3927	375	5756	10058	160928
25KVA	17797	26603	6981	51381	1284525
63KVA	23177	30893	31222	85292	5373396
100KVA	18467	21740	36490	76697	7669700
200KVA	5426	9457	12101	26984	5396800
					19885345

CALCULATION OF ENERGY SAVING IN MWH: -

Energy saving by Energy Efficient 200 KVA Transformer = 0.82 KW per hour

Thus saving for 1 KVA = (0.82 / 200) KWh

Net saving by replacing entire transformers of the system will be

19885345 * 0.82 / 200 KWh = 81530 KWh

<u>**≈ 81.5 MW per hour**</u>

(b) Environmental benefit

- The heat dissipation by the Tank Surface & Radiators can be reduced by designing better energy efficient transformer thus will be beneficial to the global environment.
- This reduction in the heat dissipation will improves the life of insulations of the core, oil & winding and thus save the wastage in the form of burning or heating.
- For every 25 installation of 200 KVA Energy Efficient transformer, one number 25 KVA transformer will be saved thus this will save natural resources, metal & alloy, conversion & processing energy.
- Since Generation of power lost in terms of transformer losses will be reduce, the emission of CO2 will be reduced.[12]

Calculation of co2 emission reduction: -

60 W of electricity emits Co2 @ 60 grams/hr[14]

i.e. 1 W will emit Co2 @ 1 gram /hr

thus, 81530000 W will emit Co2 81530000 grams /hour i.e. 81530 Kg / hour Co2 emission will be reduced in the environment.

Calculation of reduction in coal consumption: -

Coal require to generate 1 unit i.e. 1KWh = 0.75 Kg

Coal require to generate 81530KWh = 81530 * 0.75

= 61148 Kg / h

i.e. coal require in a year will be 61148 * 24 * 365 =

535656480 Kg / yr

Net Saving in Coal Consumption will be 535657 Tons per year

IV ELECTRICAL UTILITY BENEFITS

(a) Demand side management-Installation of our design energy efficient transformer will help in improving the demand side management since the power lost in the form of transformer losses will be reduced and more power can be delivered from the same capacity of transformer in the distribution system.

(b) Reduction in the rate of failure- The agricultural consumers imposes load more than 100% of the capacity of the transformer which is uncontrolled during the Rabi Season. The maximum failure of the transformer occurred during this season in the rural areas.

Energy efficient transformer will help in reducing rate of failure in normal course and in Rabi season since

(i) The core of our designed transformer will saturate on 125% loading and conductor is designed with relatively lower current density to bear additional current and thus 25 % additional loading can be sustain by this transformer.
(ii) Since the heat dissipation of the transformer is reduced, the life of insulation in the core, oil & windings will be improved which reduces the failure of the transformers.
(iii) The reduction in the winding temperature will reduce the resistance of the coil which in turn reduces the load losses.
(iv) The losses of Energy Efficient Transformer will be reduced as compare to the conventional transformer and thus the generation of saved power will be reduced and this will save generation as well as the consumption of fossil fuel and emission of harmful gases in the environment.

V CONCLUSION

There is enormous potential for saving energy and increasing efficiency by employing these transformers, and paper intends to promote higher standards to govern their use. There is also potential for improvements through capacity building with manufacturers and the end-users.

A transformer was designed to find the better quality core to reduce the losses and improve the efficiency of the transformer as well as entire transmission & distribution system for a greener future. Since independence there is power shortage of Electrical energy. Despite all out efforts by state/Central government we have not been able to meet the electrical energy demand .The gap between availability & demand is of order 6% as on date. The proposed low loss transformer will bridge the gap between supply & demand. Since the reduction will be at the load end, it is a more beneficial than adding at generation side.

REFERENCES

[1] T. J. Hammons, B. Kennedy, R. Lorand, S. Thigpen, B. W. Mc Connel, S. Rouse, T. A. Prevost, C. Pruess, S. J. Dale, V. R. Ramanan, T. L. Baldwin, "Future trends in energy-efficient transformers", IEEE Power Engineering Review, vol. 18, no. 7, pp. 5-16, 1998.

[2] M J McDermott and Associates, Impact of Purchasing Energy- Efficient Transformers, European Copper Institute, July 2001.

[3] B. Kennedy, Energy Efficient Transformers, Mc Graw - Hill, 1998.

[4] W. T. J. Hulshorst and J. F. Groeman, Energy Saving in Industrial Distribution Transformers, KEMA report, May 2002.

[5] P. R. Barnes, J. W. Van Dyke, B. W. McConnell, S. Das, "Determination Analysisi of Energy Conservation Standards for Distribution Transformers," Oak Ridge National Laboratory, ORNL-6847, July 1996.

[6] S. Merritt, S. Chaitkin, "No Load versus Load Loss," IEEE Industry Applications Magazine, vol. 9, no 6, pp. 21-28, Nov.2003.

[7] P. S. Georgilakis, "Decision support system for evaluating transformer investments in the industrial sector," Journal of Materials Processing Technology, vol. 181, no. 1-3, pp. 307-312, 2007.

[8] B. W. McConnell, "Increasing Distribution Transformer Efficiency:Potential for Energy Savings," IEEE Power Engineering Review, vol.18, no 7, pp. 8-10, July 1998.

[9] R. Targosz (ed) et al., The Potential for Global Energy Savings from High Energy Efficiency Distribution Transformers, Leonardo Energy, European Copper Institute, February 2005.

[10] European Copper Institute, The Scope for Energy Saving in the EU Through the Use of Energy-Efficient Electricity Distribution Transformers, December 1999.

[11] Loss Evaluation Guide for Power Transformers and Reactors, ANSI/IEEE Standard C57.120, August 1992.

[12] European Commission, External Costs: Research results on socio- environmental damages due to electricity and transport, Directorate-General for Research, Brussels, Study 20198, 2003.

[13] NEMA, Guide for Determining Energy Efficiency for Distribution Transformers, NEMA Standards Publication TP 1-2002.

[14] Ministry of Environment and Forest, Govt. of India

[15] www.mppmcl.com