Amorphous Core Distribution Transformers: Challenges, Opportunity and Loss Capitalization for Power Applications in India

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Abstract: - Distribution transformer is an internal link between the distribution network and customers. Keeping in view the frequent failure of distribution transformer, power utilities in the world are now producing distribution transformers on the basis of loss evaluating factors. As the cost of electrical energy has been rapidly rising rural electricity board has introduced amorphous metal core transformer to overcome shortage of electricity. Iron-based amorphous ribbon has been considered as a high efficiency option for distribution transformer core material but only a small penetration into the market has occurred. This paper reviews the present status of amorphous material in distribution transformers and shows that in many situations it is the best option where true energy losses operating conditions are considered fully. Performance of distribution transformer with CRGO and with Amorphous core including losses and improvement in efficiency is discussed in this paper. A case study of Amorphous core transformer of 63 KVA is presented and losses are capitalized and the payback period over the replacement of CRGO transformer of the same capacity is evaluated.

*Key-Words:- Distribution transformers, CRGO,*AMDT, Load losses, Capitalisation of losses, efficiency

1 Introduction

Recent years have brought major changes in the global electric power industry. Shortage of electricity is having cascading effect on industry production and economic development, which can be met by addition to existing generation capacity or by more efficient utilization of existing capacity. During this era highly efficient transformers caught the interest of electric utilities.

It has been estimated that switchover from silicon steel to Amorphous metal core will save about 200 million kWh electrical energy in a year. Currently over 1,250,000 amorphous metal distribution transformers have been installed world wide, helping electric power utilities to improve the efficiency of their transmission and distribution system. In India generating capacity is 130730 MW. Even 1% reduction of losses is equivalent to an addition of 1300 MW generation capacity which saves 5200 crores in capital investment.

2 Sources Of Losses

Out of total power generated 10% are generation losses, 10% are copper losses and 20% are Non technical losses. In addition 20% losses are due to inefficient end use. Hence in all there are 60% losses. One of the major sources of T & D losses in India is transformer. These losses can be minimized by using energy efficient transformer reducing no load losses to practically one third.

Amorphous metal core is basically boron mixed material with non-crystalline atomic structure. Amorphous is having very low specific core loss but gets saturated at 1.57 tesla. Low value of magnetizing current and low core losses makes it much more efficient. However the cost of the Amorphous core material is higher which is compensated over the payback period on account of savings due to reduced losses.

3 Amorphous Core Transformers: Some Facts And Figures

Various facts about the amourphous core transformer are tabulated in Table 1-4, which are self explanatory.

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TABLE 1: No Load Loss Comparison

Ratings (KVA)	Loss Factor		No load losses (Watts)	
	CRGO	AMDT	CRGO	AMDT
63	6.86	27.44	180	45
100	6.77	29.92	260	60
200	7.16	24.51	500	160
315	10.08	31.14	580	200
500	11.00	39.81	900	250

Table 2: Cost Comparison (Rs)

KVA Rating	**CRGO**	**AMDT**
25 KVA	20000	28000
63 KVA	38000	52000
100 KVA	46000	63000

Table 3 : Comparison Of Efficiency

ng (kVA)	**No Load Losses**		**Load Losses**		**Efficiency (%)**	
	CRGO	**AMDT**	**CRGO**	**AMDT**	**CRGO**	**AMDT**
250	570	180	4000	3200	98.2	98.7
500	900	250	6550	4800	98.53	99
630	1000	200	8000	5200	98.54	99.1
730	1250	365	9000	6050	98.65	99.2
1000	1500	450	11800	7650	98.68	99.2

Table 4: Environmental Impact of Amorphous Metal Transformers

t	**USA**	**urope**	**apan**	**China**	**India**
y Savings(billion kWh)	40	25	11	9	2
illion barrels)	70	45	20	15	4
million tons)	35	20	10	12	3
housand tons)	110	70	30	90	22
housand tons)	260	160	75	210	52

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4 Capitalization of Losses

Distribution transformer is the most widely used equipment in the power distribution network. Due to poor performance of thousand of transformers *load* and *no load* losses occur throughout the life of the system causing revenue degeneration year after year. To illustrate the effect of these losses, the capitalized cost for distribution transformer in Indian Power System is worked out in the present paper.

To calculate the capitalized cost of no load losses, the guidelines suggested by an expert committee consisting of representatives from various State Electricity Boards (SEBs), Central Board of Irrigation and Power (CBIP), IEEMA and Rural Electrification Corporation (REC) are used here. The method and formula as decided upon by the working committee follows.

From the recommendation of the committee, the Capitalized cost of transformer ***no load*** losses in R /Kw is given by

$$A = H * E\left[\frac{(1+r)^n - 1}{r*(1+r)^n}\right] \quad . \quad \text{.....(1)}$$

Where,

H = No. of service hours per year of the distribution transformer
r = Rate of interest
n =Life of transformer in a year
E = Energy Cost, i.e. the cost of electrical energy at the bus to which transformer is to be connected (Rs/KWh).

Similarly the Capitalized cost of ***load losses*** in Rs/ kW (**B**) may be given in terms of the 'cost of ***no load*** losses (**A)**' by defining a loss load factor (**L.S**.),

B =A* L.S. . .....(2)

With this interpretation of A and B the capitalized cost of the transformer (TOC) may be given by

TOC = Initial Cost of Transformer + Cost of the No-load Losses + Cost of the Load Losses
= IC + (A*Wi) + (B*Wc) . .....(3)

Where,

IC = Initial cost of transformer as quoted by the manufacturer (Rs)
W_i = No load losses of the transformer
W_c = Load losses of the transformer

According to REC the values described for various parameters of equations [1-3] are: (Assuming that transformer is not in service for 15 days in a year due to repair and maintenance)

1. No. of service hours: **H** = 350 * 24 = 8400 hrs
2. *Life of transformer*: **n** = 25 years
3. *Rate of interest*: After taking into account various factors the rate of discount for the investment in the capitalization formula is decided as 12 % i.e.**r** = 12%
4. *Loss load factor (**LS**)*: This is given in terms of the load factor (**LF**) as per the recommendation of the working committee

LS = $0.2\ LF + 0.8\ LF^2 = 0.132$ ..... (4)

Assuming energy charges as Rs 2.70 per unit at 11 KV terminal distribution transformer values of **A** and **B** factor can be worked out.

From eq.(1); Capitalized cost of no load losses A= 177,882 Rs/kW

From eq. (2) & (4); Capitalized cost of load losses B= 23,480 Rs/kW

From eq. (3)

Capitalised cost of the transformer
= IC+177882*Wi+23480*Wc . .....(5)

5 Comparison of Capitalised Cost

The Table 1 Compares the two types of the transformer w.r.t. to no load and load losses. For a 63 KVA transformer load losses as per the Table is 1235 watts.

Initial cost of CRGO transformer = Rs 38000/
Capitalized cost of CRGO transformer (from eq. 3)
= Rs 99016/

Initial cost of Amorphous core transformer = Rs 48000/

Capitalized cost of Amorphous core transformer
= Rs 85002/-

Though the initial cost of Amorphous core transformer is high but over a period of one year the Amorphous core transformer is definitely cheaper as its capitalized cost is approx. 85,000/- against the capitalized cost of Rs. 99,016/- for CRGO and also saves the considerable amount of energy.

The losses of the 63 KVA Distribution Transformer in Indian Power System are capitalized over a period of 1 year. Generated capacity committed to feed these losses shall include the losses in the system and shall take into account the plant load factor. Plant load factor is assumed as 60 % and minimum losses up to the distribution transformer is 10 %. Assuming 50 % of the distribution transformer operates under full load during peak hours the capitalized system losses with CRGO and Amorphous transformers are calculated, capitalized and are tabulated in Table 5. A comparative study of design parameters for different rating is carried out and it is found that though the

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initial cost of 63 KVA transformers is on higher side but when the losses are capitalized it is found to be on lower side.

6 Challenges and Opportunities

- When switching from a standard to a high efficiency transformer, one should investigate if there is enough space and whether the foundation can support the additional weight. Amorphous transformers have about 50% bigger cores.
- Other field data indicates that for Total Harmonic Distortion level of 75% the increase in no load loss in amorphous cores is around 60 % whereas it is 300% in transformers with silicon-iron cores.
- Replacing all distribution transformers by energy efficient types could save 200 TWh a year, equivalent to 130 million tonnes of CO_2 emissions (table 1.4). An advantage large enough to justify the effort.
- Introduction to Amorphous core can brought about a dramatic change in the performance of distribution transformer, which reduces the No-load loss to 70% and 60% lower exciting current and a smaller temperature rise as compared to CRGO steel core transformer[11].

7 CONCLUSION

High-efficiency transformers are a mature technology with their economic and environmental benefits clearly demonstrated. Although Amorphous metal transformers are often more expensive than silicon steel units they can be more cost effective in many electric power systems. Where energy costs are sufficiently high, amorphous metal transformers make economic as well as environmental senses.

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Table 5

S.no	Parameters	CRGO	AMDT
1.	No. of distribution transformers	15,00,000	15,00,000
2.	No load loss=No. of transformer*No load losses/transformer/10^6	270MW	67.5MW
3.	Cost of no load losses per year in Rs	408.24 Crores	102.06 Crores
4.	Load losses	1852.5MW	1852.5MW
5.	Cost of load losses per year in Rs	2800.9 Crores	2800.9 Crores
6.	Generated capacity required to feed no load losses	495 MW	123.75 MW
7.	Generated capacity required to feed load losses	1698 MW	1698 MW
8.	Total generation capacity required to feed losses	495+1698= 2193 MW	1821.75 MW
9.	Investment cost for generation and T & D to feed losses (Rs 5crores/MW)	10965 Crores	9108.75 Crores
10.	Investment cost of distribution transformer in Rs	5700 Crores	7200 Crores
11.	Total capital Investment in Rs	16665 Crores	16308.75 Crores

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