

Use of Energy Efficient Transformers in Asia

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Abstract - Standby power of electric appliances, which would cause significant power wastage, has raised concerns among governments and regulatory bodies around the world. No-load loss of distribution transformers, however, is yet another source of huge power wastage that has not caught the appropriate attentions from relevant organizations in many countries. According to the experience in Japan, the total no-load loss power wastage could be 1.5 times of the total wastage caused by standby power. Dramatic reduction of no-load loss is made possible by amorphous metal distribution transformers (AMDTs). Experiences of using AMDTs in Asia are presented in this paper. Progresses in Japan and a number of Asian countries are also reviewed.

I. INTRODUCTION

Transformer loss is one of the significant components accounting for energy loss in distribution system. There are two categories of loss [1] : No-load loss, also known as core loss or iron loss, exists as long as the transformer is operating and is regardless of the loading. Major component of no-load loss is hysteresis loss in the transformer core. In addition, Eddy current in the core is also another important source of loss. Load loss, on the other hand, varies according to the loading condition. This is mainly the I^2R loss due to the resistance of transformer winding. Load loss exists when every there is a load current. Since the transformer windings are commonly made with copper (although aluminum windings are used in some cases), load loss is often referred as copper loss.

To a certain degree, no-load loss is similar to the standby power of electric appliances - when an appliance is in standby mode, energy is still being consumed. In the past decade, huge efforts have been spent by authorities, institutions, engineers, manufacturers, etc. to reduce standby power. International standards have been brought in place and are commonly accepted. No-load loss of distribution transformer, despite of the general awareness of its existence, has however caught considerably less attentions than the appliance standby power. Analyses are made upon this phenomenon. Experiences in adapting energy efficient transformers in Asia are also discussed.

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II. QUANTIFYING NO-LOAD LOSS

Before any meaningful analysis is done, it is important to quantify the impact of no-load loss.

It has been estimated that the transformer no-load loss in Japan is 27 billion kWh per year, which is 1.5 times the standby power of all electric appliances in the country [2]. The amount of such loss in Japan alone is already equivalent to the generation capacity of a number of large nuclear plants.

Besides Japan, other countries are also facing the same challenge. Table 1 summarizes the no-load loss projection of major countries in 2010 [3].

	Projected Distribution Transformer Core Loss @ 2010 (billion kWh)
USA	81
European countries	43
China	49
India	11

Table 1. Global no-load loss projection at 2010

Given the huge amount of energy involved, attempts at various levels should be made to improve the situation.

III. ENERGY EFFICIENT TRANSFORMER

Reduction of no-load loss relies on the availability of transformer core with better magnetic performance. There are two areas that have to be improved: hysteresis and Eddy current in the transformer core.

With significant improvement in manufacturing process, very thin sheet of silicon steel is now available. Transformer made with these sheets can achieve good improvement in Eddy current loss. Hysteresis loss, however, is primarily material dependent and silicon steel has demonstrated little progress in addressing this type of loss.

To attain significant improvement, amorphous metals are used to make transformer cores. Because of the special properties of this material, both hysteresis and eddy current losses are significantly reduced. Comparing with typical silicon steel transformer cores, the no-load loss reduction will usually be as dramatic as 70-80%. Table 2 is a generic

performance comparison among typical silicon steel distribution transformer, high efficiency silicon steel distribution transformer, and amorphous metal distribution transformer (AMDT) [4].

Rating (kVA)	No-load losses (W)		
	Typical Silicon Steel	Hi Efficiency Silicon Steel	Amorphous Metal
Single Phase			
25	100	50	20
50	210	105	32
100	320	160	54
Three Phase			
300	950	475	185
1000	2400	1200	420
2500	4800	2400	850

Table 2. Transformer no-load loss comparison

The advantage of energy efficient transformer is not limited to reduction of losses. Since these losses are converted into heat energy, cooling oil inside the transformer tank will be heated up and this will lead to emission of green house gases. Distribution transformers in USA today are generating 35-40 million tons of carbon dioxide per year [3]. If all these transformers are replaced by AMDTs, a very substantial reduction of CO₂ emission will be achieved. Another AMDT-specific advantage is the superior electrical performance under presence of significant line harmonic [5].

While the improvements brought by energy efficient transformers can be easily understood, the decision to adopt new technologies can be intricate. Valuation of the product, regulatory considerations, authorities' awareness about the no-load loss issues and the corresponding policies are all affecting the decision.

IV. VALUATION OF TRANSFORMER

As of today, energy efficient transformers are generally more expensive than the traditional silicon steel transformers. Price of AMDT, for example, is approximately 30% higher than its traditional counterpart. This price premium, however, is paid back by the energy saved in the service life of the transformer. Therefore, the obvious and simplest method to determine whether an energy efficient transformer worth its price is to evaluate if the total time value of the energy saved by the transformer in its service life is greater than its price premium today.

Another well-known method is the Total Owning Cost (TOC) approach. Instead of comparing the prices, this approach focuses on the cost, both present and future. While the initial purchasing price of the transformer represents the present cost, both the no-load loss and load loss represent

future costs since these losses will cause some energy (and hence fuel) wastage in the future when the transformer is operating. In this sense, an energy efficient transformer will have a lower future cost than the traditional type.

Quantitatively, TOC is evaluated by

$$TOC = P_0 + A \times NLL + B \times LL$$

where P_0 = initial purchasing price of the transformer
 NLL = no-load loss of the transformer
 LL = load loss of the transformer
 A = A-factor (capitalized cost per watt of NLL)
 B = B-factor (capitalized cost per watt of LL)

Both the payback approach and the TOC approach should be applicable for purchasers in any country. However, there is an observed trend that countries in North Asia are more used to the payback approach while the opposite is true for countries in South Asia. This is probably due to the fact that South Asian countries have more exposure to project financing from World Bank and Asian Development Bank, who require valuations to be done by TOC method in many cases.

In a very general sense, purchasers in North Asia can accept a payback period of 5 to 7 years. However, there is a trend to request for faster payback. Although there are still more factors to consider before adopting the new technology, the first criteria for decision making – ability to fulfill the payback period requirement – can be determined base on some objective parameters such as electricity fee, interest rate and the prices of transformers.

In South Asia, however, the situation is quite different. While calculating and comparing of TOC are straightforward, the determination of A and B factors are not. Eventhough there are guidelines for establishing these factors, the actual processes can be complicated. Authorities determine these factors according to particular views on economic and other parameters, resulting the observation of a wide range of A and B factors in South Asia. For some countries in the region, A and B factors have not been established at all.

	Utility	A-factor (USD/Watt)	B-factor (USD/Watt)
Philippines	NEA	10.00	3.50
Philippines	MERALCO	6.00	1.40
Nepal	NEA	7.80	1.10
Bangladesh	REB	8.14	2.44
India	Various	4.10	0.54
Laos	EDL	5.25	3.67

Table 3. A and B factors of selected countries in South Asia

Because of the variations in practices among South Asian countries, valuing transformers with a unified manner is difficult.

V. OTHER FACTORS

Besides valuation, regulatory considerations and industrial design will certainly affect the adoption of energy efficient transformers. Kennedy [6] has pointed out that deregulation in the US has encouraged the use of minimal efficiency standard rather than a balanced valuation. Reform of the utility industries in Asia is going to bring along changes. Transformer energy efficiency is one of the topics that should be discussed by utilities, regulators, transformer manufacturers and users.

VI. AMDT PROGRESSES IN ASIA

This section uses AMDT adoption as an example to illustrate the awareness of no-load loss and the corresponding policies in Asian countries.

	Approximate number of AMDT supplied to utilities	Major kVA range	No. of local mfr. equipped with AMDT mfg. ability
Japan	300,000	10-50	6
India	110,000	10-100	20
Korea	30,000	30-100	4
Philippines	30,000	30-100	0
China	20,000	80-500	9
Bangladesh	15,000	10-100	0
Taiwan	10,000	25-100	4

Table 4. AMDT in Asia

Japan is by far the largest user of AMDT in Asia. The Government has demonstrated concerns on energy efficiency by introducing policies and schemes to encourage and reinforce no-load loss reduction [2].

India is the second largest player in the region. Government authorities in India are taking a very supportive position towards energy efficient transformers [7].

China is growing very fast in terms of AMDT application. Like India, Chinese Government is actively encouraging the use of energy efficient transformers [8].

VII. CONCLUSION

Huge amount of energy has been lost due to no-load loss of transformer core. Energy efficient transformer such as AMDT can effectively lower such energy wastage and at the

same time reduces green house gases emission. In Asia, while the use of energy efficient transformer has grown rapidly in the last few years, the growths are concentrated in a number of countries where their governments are taking an active role to promote energy efficiency. It is suggested that all governments and relevant authorities in the region should investigate the no-load loss issue and determine the appropriate policies towards the application of energy efficient transformers.

VIII. REFERENCES

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XI. BIOGRAPHY

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