

THE UNBALANCED LOAD COST ON TRANSFORMER LOSSES AT A DISTRIBUTION SYSTEM

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ABSTRACT

Small differences in transformer losses are not important when a transformer is analyzed alone but they are significant when the population of transformers present in an electricity distribution system are considered. Based on those facts, it was analyzed the effects of the unbalanced loads connected to the secondary of transformer in the transformer load losses. The load losses are calculated based on distribution transformers load measurement in the field, and on the values of standards ABNT-NBR5440 1999.

The measured power of transformers were 30, 45 and 75 kVA, the most common rated power for transformers in a Brazilian distribution system. Such measurements statistically represent the population of three-phase transformers from a power utility with 15% of deviation from the most probable value. Analysis is also carried out comparing the ideal case of perfect balanced loads with the real case. Finally, it is obtained the total annual cost caused by unbalanced loads in their transformers for a power utility.

INTRODUCTION

In general, distribution transformers are analyzed considering perfectly balanced loads. It is correct to consider a balanced system in a comprehensive analysis, i.e., macroscopic. If there are unbalanced loads, the adding effect in a particular feeder results in an increasingly balanced load toward the substation [3]. This approach does not present an accurate load loss outcome when there is a strong imbalance in the system. This is due to the nonlinear behaviour of losses in relation to the load. Therefore, it is required a more individualized analysis of each equipment considering its imbalance.

STATISTICAL LOAD MODEL

Three phase loads usually are balanced and they have a well-defined effect on transformer's load losses. The probability to have imbalance is higher in a system with a great number of single-phase loads that have different connected time and power. Therefore, transformers in residential and commercial areas, where the equipments are predominantly monophasic, present great chances to suffer from unbalanced load during their operation.

The control of power and connected time of this type of load is impractical and it inevitable results in imbalance. It is necessary to know the behaviour of the load to calculate load losses both for specific equipment as for a whole system.

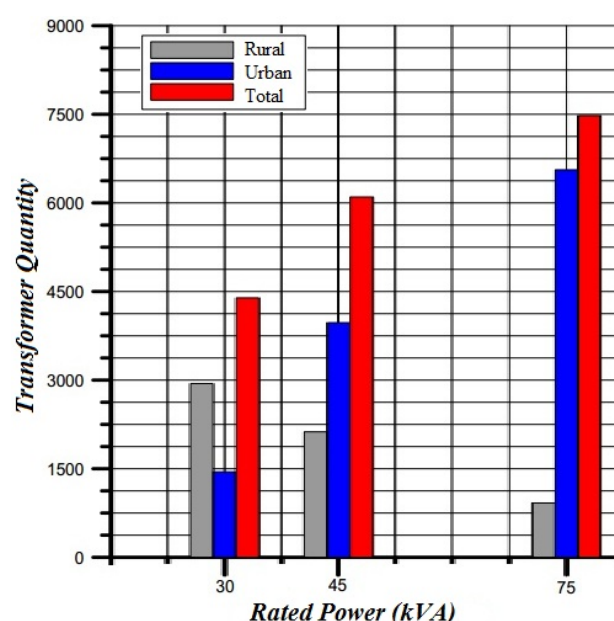


Figure 1 - Population of transformers analyzed

One way to obtain a reliable load model is by a statistical method. To this, it is necessary to carried out field measurements. The rated power of 30, 45 and 75 kVA was chosen in this paper because they are the most considered three-phase transformers on a standard Brazilian distribution system. The analyzed population is showed in Figure 1 and the number of samples for measurements presented at Table 1. A large percentage of consumers connected to these transformers are classified as residential consumers, as can be seen in Figure 2, which can produce unbalanced load for transformers that feeds them.

Table 1 - Measurement Sampling[5].

Power (kVA)	Population	Samples
30	4300	40
45	5900	42
75	7400	44

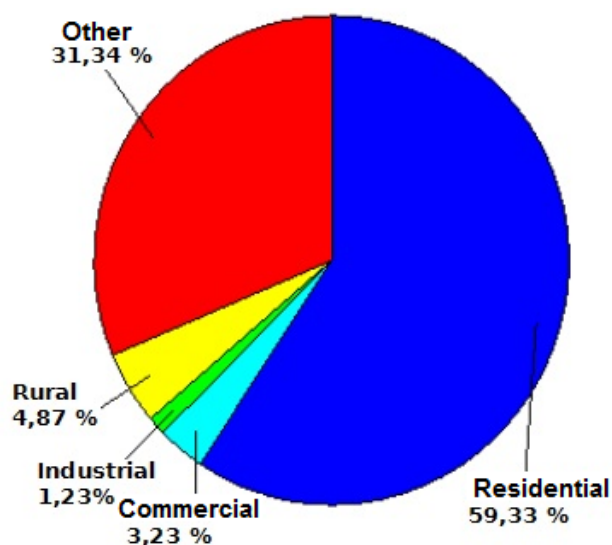


Figure 2 - Percentage distribution of 45 kVA transformer

LOAD LOSSES

With the sample measurement data were calculated phase load losses per phase for each transformer. The total energy consumed (losses) at the measurement period, seven days, was considered representative of the behaviour of each sample. This defines a general day that can be extrapolated to an annual value of losses. This process was applied to all measurements and for the hypothetical situation that the imbalance was not present.

For the load loss calculated were used the values of rated losses of standard ABNT NBR 5440, 1999 instead of ABNT NBR 5440, 2011. Because the result obtained by using of ABNT NBR 5440, 1999 is more representative due to the fact that most of the existing transformers have losses standardized by ABNT NBR 5440 of 1999 or older than it.

STATISTICAL ANALYSIS

The values of annual losses of each sample were used to obtain a most probable value of the annual loss for imbalance and balance. The initial statistical analysis represented the statistical dependence by a normal distribution. This analysis presented always poor fitting. Therefore, you can not take the mean value of a normalized distribution as the most probable value for the load. Then, eight distributions were tested: Lognormal, Gamma, Exponential, Extreme Value Smallest, Largest Extreme Value, Weibull and Logistic Loglogistic.

For samples of 30 and 45 kVA, the Weibull distribution was the best fitting by Anderson-Darling criterion. This occurred both for balanced and to imbalance cases. For 75 kVA, Gamma distribution was the best fit. Figure 3 presents the result for 30 kVA transformers. In this figure it can be seen for the balanced case that the most probable values for the

annual energy loss, in kWh, is 439.44 kWh, and for the unbalanced case this value is 558.81 kWh. Therefore, the error by considering balanced load for 30 kVA distribution transformers is 11,9.37 kWh annually for each transformer.

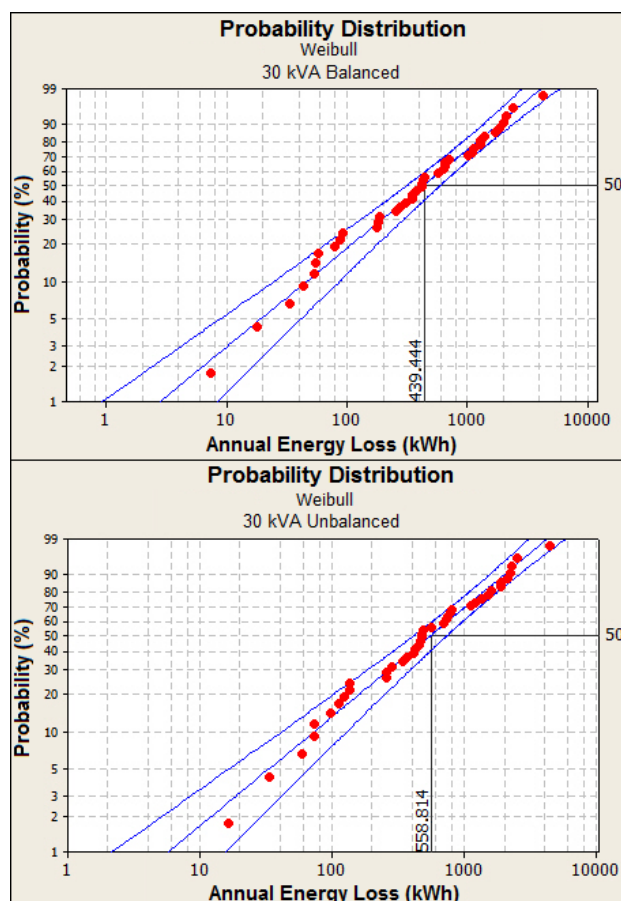


Figure 3 - Distributions for 30 KVA transformers.

FINANCIAL IMPACT

The system evaluated in this paper has 17,600 transformers, all of which were assumed operating in two situations: feeding unbalanced loads and balanced loads. These transformers are divided according 30, 45 and 75 kVA as shown in Table 2.

Table 2 - Annual Loss

Power (kVA)	Annual Losses Per Unit (kWh)	
	Balanced	Unbalanced
30	439,4	558,8
45	794,0	952,1
75	1201,6	1325,2

There are other levels of rated power for transformers in this system, however, these were not analyzed because they are not so common.

Table 3 - Annual Loss System

Power (kVA)	System Annual Losses (MWh)		Difference (%)
	Balanced	Unbalanced	
30	1890	2403	27,2%
45	4685	5617	19,9%
75	8892	9807	10,3%

There are an increase of 27.2%, 19.9% and 10.3% in system losses for transformers of 30, 45 and 75 kVA respectively. Therefore, considering the load balanced to calculate the transformation losses in a distribution system can provide a significant error in the result.

Finally, for the population of transformers 30, 45 and 75 kVA, there are the average increases in the annual cost of losses presented in Table 4. In this way the system loses US\$ 133,743.65 annually due to unbalanced loads. Finally, the cost of imbalance may become increasingly important for a company with a larger number of transformers.

Table 4 - Financial imbalance impact.

Power (kVA)	Loss System Difference (MWh)	Cost Annual Difference
30	513,3	US\$ 29.078,06
45	932,7	US\$ 52.840,11
75	914,8	US\$ 51.825,48
	Total	US\$133.743,65

In this study this costs of the losses could be used to buy about 95 30kVA transformers with copper windings or 60 75kVA transformers.

CONCLUSION

Three phase transformers in a distribution system feeding single-phase loads will have great probability of suffering imbalance. This affects the load losses compared to the ideal balanced case. More studies of financial effects are needed to a better control and knowledge of imbalance. To the increase of losses caused by imbalance should be avoided by the utilities and corrected if possible. The quest for a more efficient distribution system certainly passes for the imbalance reduction.

It is required a more detailed study, microscopic analysis, to get a better idea of the losses in a system. The equipment could be analyzed statistically to extend the result obtained for the system as a whole and thereby reduce possible errors existing in a macroscopic analysis.

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