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Calculation of Real Time Load Losses of Distribution Transformers Connected to a Feeder

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Abstract-It is essential to know the losses in a Distribution Transformer (DT), while the transformer is included in a circuit, as the values of load losses and no-load losses are required for calculation of total losses in the feeder and hence for the purpose of energy audit. The load losses and no-load losses are also necessary for calculation of Total Owning Cost (TOC) of DT. Since No-load losses are constant and are known before hand in a DT, only load losses need to be calculated. In this paper, an approach is developed to calculate the real time load losses of all DTs connected in a feeder.

Keywords- *Distribution Transformer, Losses, Feeder, Energy Audit, Total Owning Cost*

I. INTRODUCTION

Distribution Transformers (DTs) are large in number in any power distribution company. Hence, the cumulative losses of all these transformers in a feeder become considerable. These transformers are installed in the field, getting exposed to the sun, wind and the rain. In a typical power distribution utility situated on the coastal Karnataka (India), both the heat and the rain are extreme; the tree branches fall regularly on the Low Tension (LT) lines emanating from the DTs. Due to LT short circuit as well as the moisture entering the DTs, there is accelerated ageing, and hence frequent failure of DTs. Due to heat generated in the core and accelerated ageing, the properties of the core changes, leading to increase in core losses[5]. Since there is no adequate staff to monitor these DTs on a regular basis, DT failure percentage is as high as 15% in the year 2017-18 and is a matter of serious concern. These DTs are replaced by a repaired one, not a new one.

In Division ‘A’, DTs fail mainly due to:

- Un- balanced loading: 6%
- Moisture entering into DTs due to excessive rain: 5%
- Short circuit in the Low voltage (LT) circuit due to falling of tree branches on the LT lines: 4%

The failed DTs are replaced by repaired ones, within a day. On an average, every DT fails in 7years and hence gets repaired every seventh year. The typical life span of DT is 35 years. The DTs, which are manufactured as per IS-2026 and IS-1180 standards, are only procured, with rigorous and transparent procedure. But, this discipline is not maintained in monitoring the repair and testing the repaired DTs. Hence the Load losses, of the DTs increase drastically, after the repair.

A. *Distribution Losses*

Distribution Transformer (DT) mainly consists of the core and the windings. The DT losses occur in these two parts. Hence, DT losses are broadly classified as:

1) *No load losses or core losses*

No load losses occur in the core part of the DT and depend upon the materials used for construction of the core. This loss can be further divided into eddy current loss and hysteresis loss. No load losses are constant for a given capacity of DT.

2) *Load losses or copper losses*

It results from the resistive components, used for building the primary and secondary windings. This loss depends upon the DT load at any point of time and hence forms variable loss.

In this paper, an attempt is made to calculate load losses by using average load current in each DT. Since core loss for a given DT is known before hand and remain constant, only load losses are calculated for all the DTs connected to a feeder to know the total losses of all the DTs in that circuit.

II. TOTAL OWNING COST OF DTS

A. *Significance of calculating losses in evaluating Total Owning Cost of DTs*

Distribution Transformers (DT) are purchased not only on initial cost but also the cost to operate and maintain the DT over its life. In this regard, Total Ownership Cost (TOC) is calculated over the life span of the DT. The basic formula for TOC is [2]:

TOC= Initial Purchase Cost of DT+ Cost of No-load loss+ Cost of load loss.

Since the cost of future losses needs to be taken into consideration, it is necessary to discount these future costs to equate them to present-day cost. Then the cost of no-load and load losses are calculated using the following formulas:

Cost of No-load Losses = A × (No-load Losses)

Cost of Load Losses = B × (Load Losses)

The calculation of A and B values are not easy; especially where the DT failure rate is high and the failed DTs are being replaced by repaired DTs.

In such cases, real time calculation of load losses, as described in this paper is an easier way of arriving at the Total Owning Cost of DTs. No-load loss is constant for a particular capacity of DT, and hence only load loss need to be calculated.

B. Single line diagram of the feeder under study

The feeder under study emanates from 110/33/11 kV Sub-station and is connected with 5 number of 25 kVA DTs, 8 of 63 kVA DTs, 4 of 100 kVA DTs, 1 of 200 kVA DT and 1 of 250 kVA DT as shown in Fig.1. This feeder caters to both urban and semi-urban domestic and commercial consumers. All the DTs are metered with communication facilities and the real time values are available in the Sub-division and Division computer systems for monitoring and analysis.

III. DATA COLLECTION

Since the daily or monthly average current of Low Voltage (LV) side and High Voltage (HV) side of all DTs are available, these are noted and tabulated. As an example, the average daily LV side current for the month of January 2018 pertaining to the 200 kVA DT connected to above circuit is as shown in Fig.2.

The average load current on the LV side of all the DTs connected to the feeder for the month of January 2018 are given in table 1.

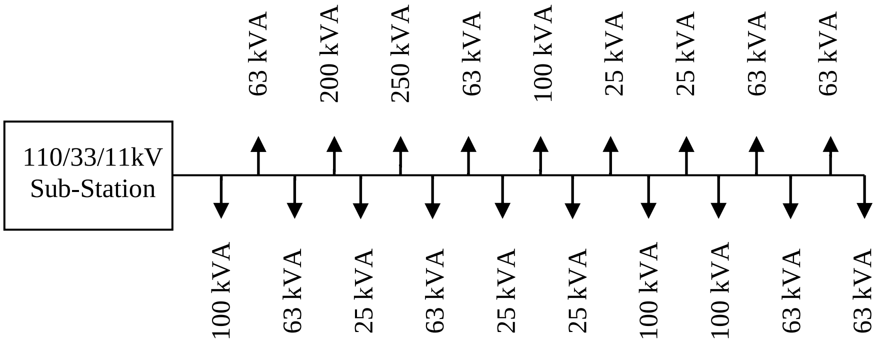

Figure 1. Single Line Diagram

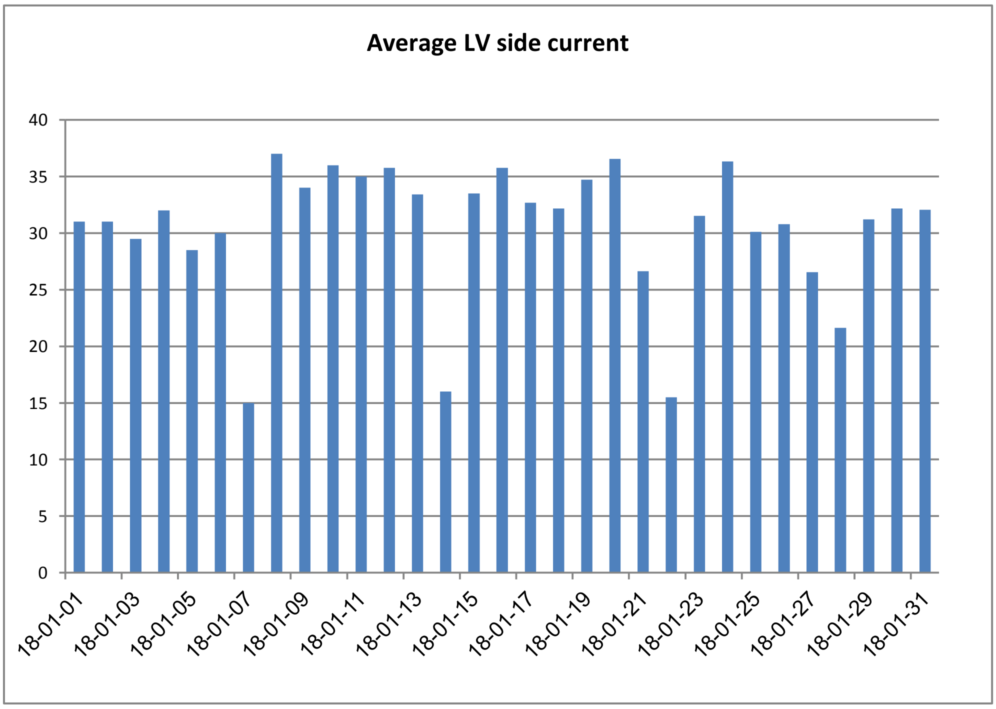

Figure 2. Average daily LV side load current of 200kVA DT for the month of January 2018

TABLE I. AVERAGE LOAD CURRENT ON THE LV SIDE OF ALL DTS

Sl. No	Capacity of DT, in kVA	Average LV side current, in Amps, for the month of January 2018
1	100	22.86
2	63	15.24
3	63	19.05
4	200	30.48
5	25	10.16
6	250	35.56
7	63	13.97
8	63	12.45
9	25	5.84
10	100	21.59

Sl. No	Capacity of DT, in kVA HV side	Average LV side current, in Amps, for the month of January 2018
11	25	11.43
12	25	9.40
13	100	28.45
14	25	13.21
15	100	24.89
16	63	13.72
17	63	10.92
18	63	14.98
19	63	10.67

IV. LOAD LOSS CALCULATION

From the TABLE 1, average HV side current of all DTs connected to the circuit can be calculated, as the corresponding values of LV side currents are available, using the formula:

$$\frac{LV\ current}{HV\ current} = \frac{HV\ voltage}{LV\ voltage} \tag{1}$$

The load loss in HV or LV winding is given by [4]: 3×(current) ² ×(winding resistance)

Here, values of winding resistance of both LV side and HV side are known for all capacities, assuming the resistance does not vary with temperature.

A. *Sample calculation for 100 kVA DT*

HV side current=0.9 A; HV side resistance = 20 ohms

LV side current=22.86 A; LV side resistance = 10 milliohms

Therefore, the load loss =

3×[(0.9×0.9×20) + (22.86×22.86×10/1000)] = 64.28 watts

hence the load loss for all DTs can be calculated as in table 2.

B. *Sample TOC calculation for 15 years for 100 kVA DT*

Based on the load loss details obtained from Sl.No.1 of table 2:

Load loss per day = 64.28 watts =0.06428 KW

Load loss for 15 years = 0.06428×15×5×8760 = Rs 42,232

(Here, 5 is the average power purchase cost in Rupees, and 8760 is the number of hours per year. Both the power purchase cost and the load loss are assumed to be constant for 15 years, for calculation purpose. In reality, the actual figures of load loss per month and yearly power purchase cost will be available in the field, which can be included in the calculation.)

No Load loss for 15 years = 0.19×15×5×8760 = Rs 1,24,830

Purchase cost of 2 star 100 kVA DT = Rs 1,01,570

Therefore, TOC for 15 years for this DT = Purchase cost + No load loss cost + Load loss cost

= Rs 101570+124830+42232 = Rs 2,68,632

Here the TOC for a particular DT comes around 2.6 times the initial purchase cost of the DT. But in reality, TOC comes around 16 times the purchase cost. The reasons for low TOC in this case are:

(1) We have assumed the DT to be a 2 star rated one, which has low no load loss and low load loss. In the field, most of the DTs are repaired good conventional DTs, which will have 3 times these loss figures.

(2) The load on the particular DT for January 2018 is very small. We have assumed the same load for 15 years on this DT. The actual load will be around 100 amps for most of the 100 kVA DTs, and hence load losses will be more. The actual load will be available in the field, which can be included in the calculation for realistic TOC.

TABLE II. LOAD LOSSES

Sl. No.	Capacity of DT in kVA	Average current , in Amps, for the month of January 2018		Load Loss in kVA
		HV Side	LV Side	
1	100	0.9	22.86	64.28
2	63	0.6	15.24	50.35
3	63	0.75	19.05	78.67
4	200	1.2	30.48	128.43
5	25	0.4	10.16	76.73
6	250	1.4	35.56	116.70
7	63	0.55	13.97	42.30
8	63	0.49	12.45	33.58
9	25	0.23	5.84	25.37
10	100	0.85	21.59	57.34
11	25	0.45	11.43	97.11
12	25	0.37	9.40	65.65
13	100	1.12	28.45	99.55
14	25	0.52	13.21	129.68
15	100	0.98	24.89	76.22
16	63	0.54	13.72	40.78
17	63	0.43	10.92	25.86
18	63	0.59	14.98	48.68
19	63	0.42	10.67	24.67

V. DISCUSSION

In Division ‘A’, trained staff and adequate facility are not available to carry out the process of Total Owning Cost (TOC). Since, all the DTs are metered and hourly readings are remotely sent to the computer systems installed in Division ‘A’, these readings are being used for calculation of DT Energy Audit and Feeder Energy Audit, effectively. But, the Total Owning Cost (TOC) of DTs are not at all calculated so far. The novel method explained in this paper is a simple and effective way to calculate the TOC, in Division ‘A’.

VI. CONCLUSION

The proposed method of calculating the real time load losses of all the DTs connected to a feeder is an easy step in analyzing Energy Audit of the feeder as well as finding the Total Owning Cost (TOC) of DTs. As all the DTs in the feeder are repaired ones, their No-load losses and Load losses need to be recorded afresh. No-load losses are recorded after repairing the DT, but before putting it back to service. The real time load losses calculated by above method, when added to No-load losses gives the total losses of a DT in the feeder. When the Total losses are available, the calculation of TOC becomes easier. The Total Owning Cost of DTs is not at all calculated in any Indian Power distribution utilities. A simpler method of calculating TOC with available resources will encourage the utilities to make an attempt in calculating TOC of Distribution Transformers. In this way, the method explained in this paper will be a boon to Indian power distribution utilities.

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