Computation of Technical Power Loss of Feeders and Transformers in Distribution System using Load Factor and Load Loss Factor

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Abstract– **Power system losses can be divided into two categories: technical losses and non-technical losses. Technical losses are naturally occurring losses (caused by actions internal to the power system) and consist mainly of power dissipation in electrical system components such as transmission lines, power transformers, measurement systems, etc. Technical losses result from the impedance of the network components such as electric lines/ cables, transformers, metering and protecting equipment etc. Non-technical losses, on the other hand, are caused by theft, metering inaccuracies. In this paper a method for energy loss calculation is presented.**

Keywords– Line Loss, Transformer Loss, Load Factor, Load Loss Factor and Load Duration Curve

I. INTRODUCTION

System loss is basically arithmetic difference between the units purchased from bulk suppliers and the units billed to consumers in the respective period. The total system loss for any given period is expressed as percentage of total energy input in the system and is computed as follows:

Total distribution loss = (Energy input- Energy sold)/ Energy input/ 100

The total losses comprises of technical loss and commercial loss. The commercial loss mainly consists of losses due to theft of energy and unrecovered billed amount. While, technical losses are the losses occurred in the electrical elements during transportation of energy from the source to consumer end and mainly comprises of ohmic and iron losses. Technical loss is an inevitable consequence of transfer of energy across transmission and distribution networks.

Losses in an electrical system can be classified into two categories:

1) Current depending losses
   - Copper Losses = $(\text{Current})^2$ * Resistance
2) Voltage depending losses
   - Iron Losses of transformers
   - Dielectric Losses (insulation materials)
   - Losses due to Corona.

Causes of Line Loss

Line Losses are a result of passing current through an imperfect conductor such as copper. The conducting material has characteristic impedance that produces a voltage drop along the line proportional to the current flow.

The resistive component (*R*) of the impedance (*Z*) contributes to active power losses (Ploss).

The line losses can be calculated based on the measured current load as:

$P_{loss} = I^* (I * r/l * L) = I^2R$

Where,

I is current

r/l is resistance / Kilometre

L is length of cable in Kilometres

For a 3phase system, the losses for each phase are calculated separately according to the measured current as:

$P_{loss\ total} = P_{loss\text{-}a} + P_{loss\text{-}b} + P_{loss\text{-}c}$
$= I_a^2R_a + I_b^2R_b + I_c^2R_c$

Causes of Transformer losses

Power transformer losses are a combination of the power dissipated by the cores magnetizing inductance (Iron loss) and the windings impedance (Copper loss). Iron losses are a function of the applied voltage and are often referred to as no load losses – they are induced even when there is no load current. Copper losses are a function of the winding current and are often referred to as load losses.

These losses are calculated for any operating condition if a few parameters of the power transformer are known. The transformer manufacturer commonly provides this information on the transformer test sheet:

- Rated total kVA of the power transformer (VATXtest).
- Rated voltage of the power transformer (VTXtest).
- No‐load test watts (LWFeTXtest) – the active power consumed by the transformers core at the rated voltage with no load current (open circuit test).
- Full‐load test watts (LWCuTXtest) – the active power consumed by the transformers windings at full load current for rated kVA (short circuit test).
- %Excitation current – ratio of No‐load test current (at rated voltage) to full load current.
- %Impedance – ratio of Full‐load test voltage (at rated current) to rated voltage.

The No - Load and Full - Load VAR losses (LVFeTXtest and LVCuTXtest) may not be provided, but are calculated from the above data.

To determine the actual transformer losses, the test losses must be scaled for use at the actual operating voltage and current.

$$\text{LVFeTXtest} = \sqrt{\left(\text{VATXtest} * \frac{\%\ \text{Excitation}}{100}\right)^2 - (LWFeTtest)^2}$$

$$\text{LVCuTXtest} = \sqrt{\left(\text{VATXtest} * \frac{\%\ Impedance}{100}\right)^2 - (LWCuTtest)^2}$$

$$\text{LWFe} = \text{LWFeTXtest} * \left(\frac{V_{\text{actual}}}{V_{\text{TXtest}}}\right)^2$$

$$\text{LVFe} = \text{LVFeTXtest} * \left(\frac{V_{\text{actual}}}{V_{\text{TXtest}}}\right)^2$$

$$\text{LWCu} = \text{LWCuTXtest} * \left(\frac{I_{\text{actual}}}{I_{\text{TXtest}}}\right)^2$$

$$\text{LVCu} = \text{LVCuTXtest} * \left(\frac{I_{\text{actual}}}{I_{\text{TXtest}}}\right)^2$$

Approach for calculation of loss

Load Factor

The ratio of the average load during a designated period to the peak or maximum load occurring in that period [1].

LF = Average load / Maximum load

Load Loss Factor

The actual losses of the circuit / plant item is calculated by applying a factor to the total losses assuming maximum current to flow through that circuit / plant item during the whole period. This factor is called as Load Loss Factor (LLF) which is defined as:

$$\text{Load Loss Factor} = \frac{\text{Actual loss (kWh) during period}}{\text{Loss at maximum current (kWh)}}$$

There are methods giving the relationship between the Load Loss Factor (LLF) and the Load Factor (LF). The formulae used for the calculations are shown below. The methods outlined in this document are to be used to calculate the Loss Components for the various categories in the distribution network. These Loss Components will then be used to calculate the overall LLF's for the various customer connections [2].

Relationship between load factor and load loss factor

As loss is an approximate square function of the demand as given in the equation above, it is required to calculate exact relation between load factor and load loss factor for calculation of the losses.

The empirical equation given below gives relationship between load factor and load loss factor.

$LLF = k * LF + (1\text{-}k) * LF^2$

Where k = coefficient.

It can be proved that coefficient k varies from consumer to consumer depending upon type and class of the consumer which can be derived from the following equation.

$$k = \frac{LLF - LF^2}{LF - LF^2}$$

Losses in feeder

Loss in a feeder for a given period (which is one month in this case) is given by the equation below.

$\text{Technical loss in MU} = I^2 \times R \times L \times LLF \times 24 \times 30 \times 10^{-9}$

Where,

I = Load in amp.

R = Resistance of the conductor in ohms/ kilometre

L = Length of the feeder in kilometres

LLF = Load loss factor

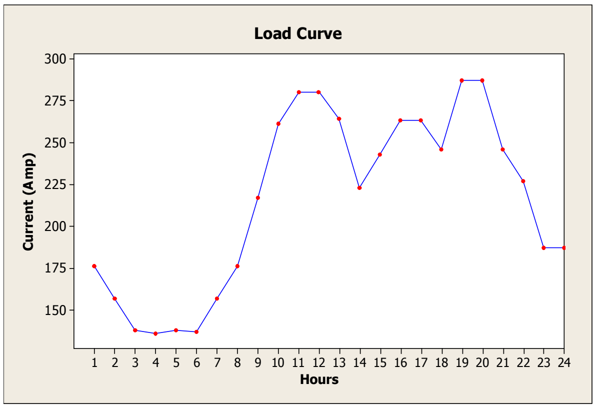
Table 1: Feeder data: 24 hours log

Feeder No.	1	2	3
Size of cable	**240 Sqmm**	**120 Sqmm**	**300 Sqmm**
Time	**Amp**	**Amp**	**Amp**
1	176	103	135
2	157	91	115
3	138	85	117
4	136	85	117
5	138	85	117
6	137	85	97
7	157	85	118
8	176	90	116
9	217	105	157
10	261	157	216
11	280	169	247
12	280	167	247
13	264	168	254
14	223	167	252
15	243	205	252
16	263	199	252
17	263	207	233
18	246	202	215
19	287	209	183
20	287	216	167
21	246	196	149
22	227	160	147
23	187	141	147
24 / 0	187	120	147
LF	0.75	0.67	0.69
LLF	0.60	0.50	0.52
K	0.19	0.20	0.21

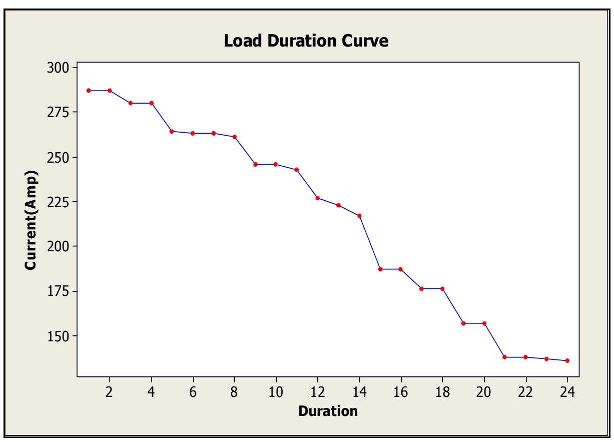
From Table I K is taken as 0.20

Load Curve and Load Duration Curve

A load curve corresponds to a graphic representation of the demand as a function of the time, along any period T (year, month, week, day or a fraction of them). A load-duration curve is obtained by putting in decreasing order the registered demand values in the load curve [3].



(a)



(b)

Fig. 1: Graphs are drawn with the help of Minitab 14

Technical loss in feeder in MU is:

$$\text{Technical loss} = I^2 \times R \times L \times LLF \times 24 \times 30 \times 10^{-9}$$

Technical loss of feeder in MU for year
$= 3 \times I^2 \times R \times L \times LLF \times 8760 / 10^9$

Where
$LLF = k * LF + (1 - k) * LF^2$

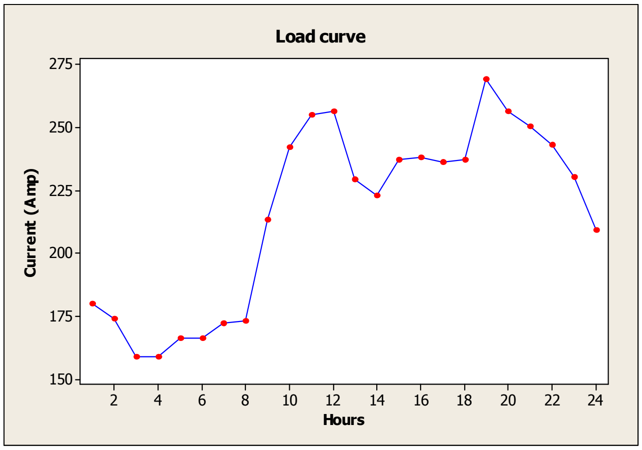
With the help of above formula we can calculate the losses in all the feeders in the system.

Table II: Losses in transformer

Substation Transformer	Transformer 1 (10 MVA)	Transformer2 (10 MVA)	Transformer3 (20MVA)
Time	**Amp**	**Amp**	**Amp**
1	180	192	222
2	174	169	197
3	159	156	173
4	159	156	172
5	166	156	172
6	166	156	183
7	172	156	186
8	173	162	197
9	213	196	228
10	242	217	279
11	255	227	294
12	256	227	307
13	229	222	326
14	223	215	295
15	237	222	341
16	238	222	341
17	236	222	339
18	237	235	328
19	269	246	367
20	256	246	348
21	250	240	310
22	243	240	290
23	230	234	283
24/0	209	220	257
Max	**269**	**246**	**367**
Average	**216**	**206**	**268**
LF	**0.8**	**0.83**	**0.73**
LLF	**0.66**	**0.71**	**0.56**
K	**0.11**	**0.13**	**0.15**

Load Curve and Load Duration Curve

Load curve and Load duration curve of above data is graphically shown in Fig. 2:



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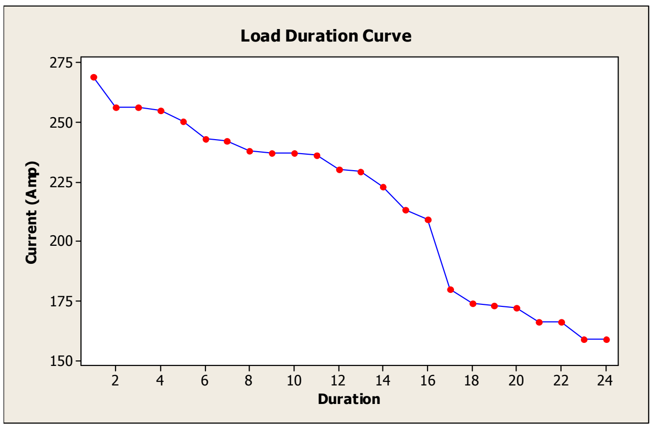

(b)

Fig. 2: Load curve and Load duration curve

Loss in a typical power transformer can be calculated as given in the formula below:

Technical loss of Transformer in MU for year = {No load loss + [(% loading) ^{2} * rated Cu. loss * LLF]} * 24 * 365 / 10^6

II. CONCLUSION

A paper demonstrates the capability of Load factor and load loss factor to calculate the power losses of the network. A method for power loss calculation is presented, the methodology is simple to implement. The data used is readily available with the engineers of power Distribution Company. The results obtained can be used for financial loss calculations and can be presented to regulator for tariff determination process.

Table III: Sample Calculations

Loss Calculation of feeder	
Cable size	300 Sqmm
Length of the cable	6 KM
Peak load	243 A
LF	0.75
LLF (K=.20)	0.59
Loss in MU = 3*(242)^2*0.1173*6*0.59*24*365 / 10^9	0.64 MU
Loss Calculation of transformer: 20 MVA	
11 kV peak Load	690 A
Full load	1050 A
% load	65.71
LF	0.75
LLF (k = 0.13)	0.59
Rated loss:	
No load loss	16.8 KW
Full load (Cu) loss	68 KW
MU loss in transformer = {16.8 + [(0.6571) ^{2} * 68 * 0.59]} * 24 * 365 / 10^6	0.30 MU

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