Eskom	Engineering Instruction	Technology

Title: **LOSS FACTORS FOR PROCUREMENT OF TRANSFORMERS (2019 CALCULATION)**

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Instruction

This document gives the No Load Loss factor and the Load Loss Factor to be used in Eskom Distribution Business transformer and mini substation procurement. The maximum losses of distribution transformers smaller than 2 MVA are laid down in SANS 780 (2019).

These factors should be implemented in

Revision requirement

Because of the continuous changes in tariffs and economic conditions the document needs to be updated regularly. Updating at least every 3 years is recommended.

Revision history

This revision cancels and replaces any versions of transformer loss factors which were compiled before.

Date	Rev.	Compiled by	Clause	Remarks
Nov 2019	1	HJ Geldenhuys	3	2019 Tariffs used for tariff in the calculations
Nov 2019	1	HJ Geldenhuys	3,4	2019 Eskom Economic Evaluation Parameters used.

(Note: This calculation has been in existence before 2005. The method was first introduced by B Meyer and ever since been maintained by Dr Hendri Geldenhuys.)

1. Normative references

The references listed here were used in this document's compilation. For future updates of the document the most recent editions of the relevant documents should be used.

[1] SANS 780: 2019 Edition 5. Distribution transformers

[2] Eskom Tariffs and Charges 2018/2019

[3] Eskom Directive, Financial Planning and Economic Regulation: Economic Evaluation Parameters. Rev.1 Dated 24-4-2019

[4] Eskom Technology Standard 240-45395762. Specific requirements for distribution pole and ground-mounted transformers up to 33 kV and 1 MVA Dated 26/06/2017.

[5] Eskom Technology Standard 240-56062752. Specification for medium voltage miniature substations for systems with nominal voltages of 3.3kV, 6.6kV, 11 kV and 22 kV. Dated 16/10/2019.

[6] Eskom Technology Standard 240-57648800. New oil filled auxiliary transformers rated 1 MVA and below and 33 kV and below. Dated 18/11/2014.

2. Background

This document calculates the loss factors to be used in Distribution Business transformer procurement. The cost of ownership of a transformer comprise of the capital cost plus the cost of energy losses. The cost of iron and copper losses depend on the following variable factors:

- Cost of electricity
- Cost of capital
- Load factor of the transformer

The capital cost of transformers depends on the following factors:

- Cost of copper conductor

- Cost of core steel
- Cost of labour and manufacturing

All of these parameters vary (often radically and unpredictably) over the economic life-time of the transformer. The eventual outcome of this calculation, in nature, is very uncertain. For this reason Eskom has been using the same IEEE formula for this calculation since 2001. The approach has been that since all of these factors are uncertain, using the same consistent approach over time is an appropriate way to deal with the uncertainty. This approach is continued here.

2.1 Cost of ownership of a transformer

Because of the associated losses over the life of a transformer, the cost of ownership is the sum of the initial capital cost plus the cost of the losses of the life of the transformer:

The following capitalisation formula must be used in tender evaluation of transformers:

$$Total\,cost = A + \text{NLLF} \times P_{NL} + \text{LLF} \times P_{LL}$$

where:

A = Cost of purchasing the transformer,

P_{NL} = No-load losses, kW

P_{LL} = Load loss, kW

NLLF = No-load Loss Factor, R/kW

LLF = Load Loss Factor, R/kW

The economic life of a transformer is assumed to be 25 years.

3. Calculation method for No Load Loss factor and the Load Loss factor

The two formulas used to calculate the loss factors are:

NLLF = 12 * MD * PVA-MD + 8760 * EC * PVA-E

LLF = 12 * MD * K^2 * G^2 * PVA-MD + 8760 * EC * TLF * G^2 * PVA-E

here

NLLF = No Load Loss Factor

LLF = Load Loss Factor

MD = Maximum Demand charge (purchase price of electricity by distribution)

EC = Energy Charge (purchase price of electricity by distribution)

K = Transformer peak responsibility factor (how the transformers' loads contributes to the system peak)

K is taken as 0.9

G = Transformer peak ratio (Ratio of the transformers peak load vs its rated capacity)

G is taken as 0.7

PVA = Present Value of Annuity (used to discount future cash flows over 25yrs to present values)

PVA-E = PVA for Energy

PVA-MD= PVA for Maximum Demand

LF = System load factor

LF is taken as 0.6

TLF = Transformer Loss Factor = 0.8 * LF^2 + 0.2 *LF

The calculation and the econometric parameters used in calculating the PVA are as follows:

- Assumption: PVA = PVA-E = PVA-MD.

PVA = 1+ [[1- (1 (1/(1+r))$^{(25-1)}$)] / r]

r - Eskom's weighted average cost of capital (real discount rate) before tax as per the Eskom ECONOMIC EVALUATION PARAMETERS (2019) of 9.5%

This is the same as the Excel PV Function where the interest rate is taken as Eskom's weighted average cost of capital (per year), the period is taken as 25 years, the payment is 1 unit per year, the future value is zero and the first payment is at the beginning of the period.

PVA = 10.33

Energy Charge (EC)

The 2019 Eskom tariff book gives the WEPS tariff as:

WEPS - Non-local authority rates

Active energy charge (c/kWh)											
High demand season (Jun-Aug)						Low demand season (Sep-May)					
Peak		Standard		Off Peak		Peak		Standard		Off Peak	
VAT incl		VAT incl		VAT incl		VAT incl		VAT incl		VAT incl	
260.32	**299.37**	78.86	**90.69**	42.83	**49.25**	84.94	**97.68**	58.44	**67.21**	37.08	**42.64**

The effective average over a year of this is 60.10191c/ kWh

The WEPS ancillary service charge is R0.0038 per kWh.

Ancillary service charge for loads and generators		
Voltage	Ancillary service charge (c/kWh)	
	VAT incl	
< 500V	0.39	**0.45**
≥ 500V & < 66kV	0.38	**0.44**
≥ 66kV & ≤ 132kV	0.36	**0.41**
> 132kV / Transmission connected	0.34	**0.39**

The total EC = 60.54c per kWh

Maximum Demand charge (MD)

Distribution network charges for loads						
Voltage	Network capacity charge (R/kVA/m)		Network demand charge (R/kVA/m)		Urban low voltage subsidy charge (R/kVA/m)	
	VAT incl		VAT incl		VAT incl	
< 500V	16.65	**19.15**	31.57	**36.31**	0.00	0.00
≥ 500V & < 66kV	15.27	**17.56**	28.96	**33.30**	0.00	0.00
≥ 66kV & ≤ 132kV	5.45	**6.27**	10.10	**11.62**	13.45	**15.47**
> 132kV / Transmission connected	0.00	0.00	0.00	0.00	13.45	**15.47**

The Network Capacity Charge and Network Demand Charge (without VAT) is taken from the 2019 tariff book (extract above); for the WEPS tariff, on the 500V to 66kV bus is respectively R 15.27 per kVA per month and R 28.96 per kVA per month.

MD = R15.27/ kVA/m + R28.96/ kVA/m = R 44.23 kVA/m

4. Loss factors for 2019 to 2025

The variables were used to calculate the NLLF and the LLF in accordance with the method described above to derive the 2019 values.

Future values were derived by assuming the electricity pricing components would escalate at the PPI, per the Eskom Economic Evaluation document:

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6 LOCAL INDICATORS

Table 1: Local Indicators

South Africa	2011/12 Actuals	2012/13 Actuals	2013/14 Actuals	2014/15 Actuals	2015/16 Actuals	2016/17 Actuals	2017/18 Actuals	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27
GDP	3.20%	2.20%	2.20%	1.50%	1.50%	0.30%	1.00%	0.80%	1.60%	2.00%	2.10%	3.30%	3.30%	3.30%	3.30%	3.30%
CPI	5.00%	5.70%	5.80%	6.10%	4.60%	6.40%	5.30%	4.70%	5.20%	5.40%	5.40%	6.00%	6.00%	6.00%	6.00%	6.00%
PPI	6.80%	6.20%	6.00%	7.50%	3.60%	7.00%	4.80%	5.60%	5.80%	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%
Repo Rate	5.50%	5.00%	5.00%	5.75%	6.25%	7.00%	6.50%	6.75%	6.75%	6.50%	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%

Source: Eskom Treasury Market Analysis, Mandla Maleka (011) 800 2557.

Other values were assumed to remain as for 2019.

Table 1: No load and load loss factors for 2019 to 2025

	The Loss Factors for Power Transformers (2019 calculation.)	
	No Load Loss Factor	**Load Loss Factor**
2019	R 62 700 /kW	R 13 700 /kW
2020	R 63 800 /kW	R 13 900 /kW
2021	R 67 600 /kW	R 14 700 /kW
2022	R 71 700 /kW	R 15 600 /kW
2023	R 76 000 /kW	R 16 600 /kW
2024	R 80 500 /kW	R 17 500 /kW
2025	R 85 400 /kW	R 18 600 /kW

Annex A – Extract from SANS 780:2019 the new-reduced maximum losses, table 1 for single phase and table 2 for three phase transformers.

SANS 780:2019
Edition 5

Table 1 — Standard power ratings and standard component losses for transformers with a single-phase primary winding[a]

1	2	3	4
Rated power	**Component losses**		**Amorphous losses**
	No-load loss (P_O)	**Load loss (P_{LL})**	
kVA	W	W	W
Um ≤ 24 kV			
5	23	130	10
16	49	320	23
32	76	540	36
64	119	910	57
Loss constant A	8,0	40,0	3,50
Loss constant B	0,650	0,750	0,673
[a] No extrapolation is allowed beyond the values listed in this table.			

Table 2 — Standard power ratings and standard component losses for transformers with three-phase primary windings[a]

1	2	3	4
Rated power	No-load loss (P_O)	Load loss (P_{LL})	Amorphous core loss (P_O)
kVA	W	W	W
25	70	520	30
50	110	880	40
100	190	1 500	70
160	270	2 200	100
200	320	2 600	120
250	380	3 100	140
315	450	3 600	170
400	540	4 400	200
500	630	5 200	230
630	750	6 200	280
800	900	7 500	330
1 000	1 070	8 900	390
1 250	1 260	10 500	460
1 600	1 520	12 800	550
2 000	1 790	15 100	640
2 500	2 120	18 000	760
3 150	2 520	21 500	890
Loss constant A	6,00	43,50	2,50
Loss constant B	0,750	0,770	0,730

[a] No extrapolation is allowed beyond the values listed in this table.