# 200 KVA Distribution Transformer Life Time Cost Evaluation Including Environmental Cost

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*Abstract*— A large number of distribution transformers are being currently used in the electricity distribution network in India. During purchasing them, it is not sufficient to evaluate and analyze only the bid price of the transformer. There are no-load losses as well as load-losses in the transformer during its lifetime. The cost evaluation of transformers is depends on total owning cost (TOC) method that consist of transformer bid price and cost of transformer losses. Similar to energy cost, greenhouse gas (GHG) emissions are also assigned a price by energy markets. Therefore this study recommended an innovative transformer cost evaluation methodology by introducing the environmental cost (EC) into the conventional TOC method. This environmental cost is coming from the cost to buy GHG emission credits because of the GHG emissions associated with supplying transformer losses throughout the transformer lifetime. It is important to include the environmental cost of transformer losses into the cost minimizing evaluation of distribution transformers. So the transformer with minimum TOC would be the most energy efficient transformer, such transformer are commercially and technically viable. Reduction in power losses in transformer further improves the economy of power industry and impact the global environment. The paper also discusses the case of MPPKVVCL Jabalpur where adoption of such energy efficiency transformer can reduce the electrical power generation requirement due to lower losses and reduction in $co_2$ emissions.

***Key words:*** MPPKVVCL, Transformer Life Time Cost Evaluation

## I. INTRODUCTION

In present scenario electricity demand always ahead that of electricity generation, the demand of electricity in India is enormous and is growing steadily to equalize the electrical supply and demand it is necessary for electrical utilities and power licensees to go for energy efficient electrical equipment for huge saving as this would be utilized for future needs. Utilities for power transmission and distribution are always looking out for the betterment of their transmission and distribution systems' efficiencies by reducing system losses, use of conductors of lower resistance and having a larger current carrying capacity, load balancing or phase balancing, addition of separate lines or feeders, use of energy efficient transformers, Increased system voltage, improving of the system power factor by adding shunt capacitors and the reconfiguration of the electricity network are some of the methods that are used to reduce transmission and distribution losses. Some of the mentioned modifications can be implemented more easily than others. In entire system transformer plays vital role in step up and step down in voltage so power passes through the transformer incurred losses [10].Transformers act as passive devices for transforming voltage and current. At the same time, transformers assist the electrical power system to operate more efficiently by maintaining their efficiencies usually above 98%. The transformer in our system continuous loaded from generation system to transmission system and extended to distribution system. In transferring power from one end to another power losses occurred along with heat loss in which loss percentage belonging to transformers also, these losses not only impose heavy financial cost but also affect global environment. Energy efficient transformers have reduced total losses (no load losses and load losses). Energy efficient transformer reduces energy consumption and consequently reduces the generation of electrical energy and greenhouse gas emission. Energy efficient transformer cost more but use less energy than low efficiency transformer Therefore by evaluating the transformers with different design by using cost evolution methodology such that there capitalization cost is minimize which include cost of losses and other environmental factor. Table 1 shows some of the calculated efficiency values for a few selected capacities of distribution transformers. In MPPKVVCL, a distribution company state of Madhya Pradesh, the distribution transformer with different rating and efficiencies is listed below table.

| Transformer rating (KVA) | No-load loss (W) | Load loss (W) | Efficiency at 0.5 per unit of name plate rating (%) |
|---|---|---|---|
| 25 | 175 | 595 | 98.65 |
| 63 | 300 | 1050 | 99.05 |
| 100 | 435 | 1500 | 98.40 |
| 200 | 500 | 2300 | 99.25 |

Table 1: Distribution transformer different rating and efficiencies

Distribution transformers are smaller in capacity but larger in quantity. In Madhya Pradesh the power distribution companies is divided into three zonal independent companies MPPKVVCL Jabalpur, MPMKVVCL Bhopal, MPKPVVCL Indore according to their annual report total number of power transformer are 5,368 and total number of distribution transformer are 4,75,246 [1]. Since there are a large number of distribution transformers in use, small losses in each add up to a significant total.

### A. Losses in Distribution Transformers

The transformer losses are divided into two parts no-load losses and load losses. The no-load losses are constant, while the load losses are proportional to transformer load. Core loss is the power dissipated in the magnetic core subjected to a time-varying magnetizing force. . Core loss includes hysteresis and eddy current losses of the core. No-load losses or excitation losses are incident to the excitation of the transformer. No-load losses include core loss, dielectric loss, conductor loss in the winding due to excitation current, and conductor loss due to circulating current in parallel windings [1].

| Transformer rating | MPVVCL Jabalpur | MPVVCL Bhopal | MPVVCL Indore |
|---|---|---|---|
| 16KVA | 3927 | 1984 | 6325 |
| 25KVA | 5756 | 62332 | 3927 |
| 63KVA | 2490 | 34063 | 32556 |
| 100KVA | 26883 | 26883 | 38226 |
| 200KVA | 6329 | 9971 | 16969 |

Table 2: Number of distribution transformer in three zonal distribution companies

### B. *Transformer Economics*

Transformer economics is necessary to weigh the transformer cost against the benefits of its efficiency. The time value of money over the life cycle of the alternatives needs to be evaluated. Efficiency improvements to save losses throughout the transformer lifetime must be compared with the initial cost of the transformer. Basically, there are three types of standard methods for evaluating alternative transformer choices, i.e., equivalent investment cost, levelized annual cost and present worth method. Each one of these methods is applied to the initial cost of the distribution transformer and to the cost of no load losses and load losses. The selection of the most economical method should have no effect on the decision on the type of transformer to be bought. Life cycle costing is the fundamental concept used to derive the Total Owning Cost (TOC). This involves the calculation of the total ownership cost over the life span of the transformer [8]. Then the purchaser can compare the cost of losses with the initial cost at the time of purchasing of the transformer. Normally, the transformer life cycle is considered as its expected life before it fails or replaced.

## II. Methodology

The basic concept of this guide is that the evaluation for each type of loss (no-load, load, and auxiliary) is the sum of (1) the demand portion, and (2) the energy portion.

- The demand portion is the cost of installing system capacity in dollars per kilowatt, and
- The energy portion is the present value of the energy that will be used by one kilowatt of loss during the book life of the transformer, converted to dollars per kilowatt.

For sake of convenience adding like terms, the values are levelized, that is, converted to yearly values, and then the sum is divided by the fixed charge rate for transformers and any other appropriate factors, to give equivalent values that can be used directly by the manufacturer in designing and pricing the transformer, and later by the user in comparing bids. Fixed charge rates are the "cost of ownership," and have the dimensions of dollars-per-dollar-per-year, or simply per-year. The units are satisfied in the following basic equation [8].

### A. *Determination of TOC*

The capitalizations value for no load loss "A" (in Rs/W or USD/W) is the value of a unit no load loss of a distribution transformer throughout its life span. This value depends on the cost of capacity and energy required to generate, transmit and distribute no load transformer losses. Equation 2 [8] shows the factors used to calculate the no load loss capitalization value "A". This value does not depend on the loading pattern of the transformer. The capitalization value of no load losses is same throughout the life span of the distribution transformer. No load losses are constant from a utilities perspective and the power to serve no load losses come from the base load demand of the system. The capitalization value of load losses "B" (in Rs/W or USD/W) is the value of a unit load loss of a distribution transformer throughout its life span. This value varies according to the load pattern, load growth and the behavior of the load profile. The "B" value is dependent on the annual loss factor, peak responsible factor, equivalent annual peak load, and the fixed charge rate of the transformer as well as on the cost of capacity and energy required to generate, transmit and distribute transformer losses [2].The most widely used method for the economic evaluation of distribution transformers is the TOC method, which is based on the following formula [2, 9].

$$TOC = BP + CL$$

Where TOC indicates the total owning cost (in Rs or \$), BP refers to transformer purchasing price (in Rs or \$) and CL is the cost (in Rs or \$) of transformer losses throughout the transformer lifetime. The cost of transformer losses CL is computed as follow.

$$CL = CNLL + CLL$$

Where

$$CNLL = A \times NLL$$
$$CLL = B \times LL$$

Where CNLL is the cost of transformer no-load loss throughout the transformer lifetime (\$), CLL is the cost of transformer load loss throughout the transformer lifetime (\$), A indicates the no-load loss factor (in \$/kW), NLL refers to transformer no-load loss (in kW), B indicates the load loss factor (in \$/kW) and LL refers to transformer rated load loss (in kW). By combining equation (1)–(4), the conventional TOC formula is obtained.

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

The factors A and B are computed according to (11) and (12), respectively.

### B. *Calculation of loss evaluation factors A and B*

In this paper, the A and B factors that are used in TOC formula (5) are computed as follows [8]

$$A = \frac{LIC+LECN}{ET\times FCR\times IF}$$

$$B = \frac{LIC\times PRF^2\times PUL^2+LECL\times TLF^2}{ET\times FCR\times IF}$$

Where LIC is the levelised annual generation and transmission system investment cost (in \$/kW-yr), LECN is the levelised annual energy and operating cost of transformer no-load loss (in \$/kW-yr), ET is the efficiency of transmission, FCR is the fixed charge rate that reveals the 'cost of ownership', IF is the increase factor, PRF is the peak responsibility factor that obtain from the transformer load at the time of the system peak load divided by the transformer peak load, PUL is the peak per unit transformer load that derives from the average of the yearly peaks throughout the transformer base life divided by the rated transformer load loss, LECL is the levelised annual energy and operating cost of load loss (in \$/kW-yr) and TLF is the transformer loading factor.

The levelised costs LECN and LECL are computed as follows

$$LECN = CRF \times HPY \times AF\times \sum_{j=1}^{BL} CYEC \times \frac{(1+EIR)^j}{(1+D)^j}$$

$$LECL = CRF \times HPY \times \sum_{j=1}^{BL} CYEC \times \frac{(1+EIR)^j}{(1+d)^j}$$

 

Where CRF is the capital recovery factor (18), HPY reveals the transformer operation in hour per year (typically 8760 h), AF represents the transformer availability, BL is the number of years of transformer lifetime, EIR (%) is the annual inflation rate of the energy cost (cost of electricity), d (%) refers to the discount rate (interest rate) and CYEC indicates to the current year energy cost (in $/kWh). It should be noted that throughout this paper, the current year (or year 0) is defined as the year before the first year of transformer operation.

The capital recovery factor, CRF, is computed as follows

$$\text{CRF} = \frac{d\times(1+d)^{BL}}{(1+d)^{BL}-1}$$

The peak per unit load, PUL derives from the following equation

$$\text{PUL} = \frac{\sum_{j=1}^{BL} \text{ITL}\times(1+\text{TPLIF})^{j}}{BL}$$

Where ITLTPL indicates the initial (year 0) transformer load with respect of transformer peak load and TPLIF indicates the transformer peak load annual incremental factor (%). ITLTPL and TPLIF are evaluate from transformer load curve. The transformer loading factor, TLF, is calculated by

$$\text{TLF} = \sqrt{L_f \times \text{PUL}^2}$$

Where $L_f$ refers to the loss factor that derives from the load factor LF, that is, the mean transformer loading throughout its lifetime, represented as an equivalent percentage of its nominal power, according to the following equation.

$$L_f = 0.15LF + 0.85LF^2$$

$$LF = (\text{Average Load}/\text{Peak Load})$$

Where LF is the Load Factor

### C. *Determination of $TOC_e$*

The objective of this paper is to modify the TOC method properly by considering all aspects of the transformer cost evolution by evaluating the environmental cost with transformer losses. Therefore we introduce EC into TOC.

$$TOC_e = TOC + EC$$

Where EC is the environmental cost

$$EC = A_e \times ((NLL - NLL_r) + B_e \times (LL - LL_r)$$

$A_e$ indicates the no-load loss factor (in $/kW), NLL refers to transformer no-load loss (in kW), $B_e$ indicates the load loss factor (in $/kW) and LL refers to transformer rated load loss (in kW).

## III. CALCULATION OF CURRENT YEAR GHG EMISSION COST FACTOR C

The current year GHG emission cost factor C (in $/MWh) is computed as follows

$$C = C_{cy} \sum_{i=1}^{n} f_i\, e_i$$

Where $C_{cy}$ is the current year GHG emission cost value in $/tCO_2$, where $tCO_2$ denotes the tonnes of equivalent CO2 emissions, $e_i$ is the emission factor (in $tCO_2$ /MWh) for fuel type i, $f_i$ is fraction (in %) of end-use electricity coming from fuel i and n is the number of fuels in the electricity mix. In particular, three greenhouse gases: (i) carbon dioxide ($CO_2$), (ii) methane ($CH_4$) and (iii) nitrous oxide ($N_2O$) are considered [11]. According to the type of fuel (i.e., propane, solar, biomass, geothermal, coal, diesel, natural gas, wind, nuclear etc.), GHG emissions are converted into equivalent $CO_2$ emissions (expressed in $tCO_2$ ) in terms of their global warming potential. In order to estimate the emission factor of each fuel type, the following equation is used.

$$e_i = ( e_{CH_2,i} + e_{CH_4,i} \times 21 + e_{N_2O,i} \times 310) \times \frac{0.0036}{n_i\times(1-\lambda_i)}$$

Where $e_i$ is the emission factor (in tCO2 /MWh) for fuel type i, $eCO_2$,i is the $CO_2$ emission factor (in kg/GJ) for fuel i, $eCH_4$,i is the $CH_4$ emission factor (in kg/GJ) for fuel i, $eN_2O$,i is the $N_2O$ emission factor (in kg/GJ) for fuel i, $\lambda_i$ is the conversion efficiency (in %) for fuel i and li represents the fraction (in %) of electricity lost in transmission and distribution for fuel i. The factor 0.0036 in (12) is used so as to convert kg/GJ into tCO2 /MWh.

For calculation of environmental cost factor $A_e$ and $B_e$, there are following steps as given below (i) calculation of the current year GHG emission cost factor C,

– Computation of loss difference between a reference transformer and a evaluated transformer.
– Calculation of the environmental factors $A_e$ and $B_e$.

The no-load loss environmental factor $A_e$ and the load loss environmental factor $B_e$ are computed as follows

$$A_e = \frac{LECN_e}{ET\times FCR\times IF} \qquad B_e = \frac{LECL_e\times TLF^2}{ET\times FCR\times IF}$$

Where $LECN_e$ is the levelised annual environmental cost of no-load loss (in $/kW-yr) and $LECL_e$ is the levelised annual environmental cost of load loss (in $/kW-yr) that are computed as follows

$$LECN_e = CRF \times HPY \times AF\times \sum_{j=1}^{BL} C \times \frac{(1+EIR_e)^j}{(1+D)^j}$$

$$LECL_e = CRF \times HPY \times \sum_{j=1}^{BL} C \times \frac{(1+EIR_e)^j}{(1+D)^j}$$

Where $EIR_e$ is the annual escalation rate (in %) of the current year GHG emission cost $C_{cy}$.

By using above equations and methodology we can find out the different costs related to distribution transformer

## IV. CALCULATION AND RESULTS

### A. *Overview*

The proposed method is used for the economic evaluation of three different transformers shown in table 1 (model 1 to model 3 denoted as DT1 to DT3).these model correspond to three–phase oil filled naturally cooled distribution transformer 50Hz, 200 KVA. The typical distribution transformer load profile of MPPKVVCL Jabalpur of figure 1 is used, that is, domestic profile.

| Transformer type (core type) | Capacity KVA | No load loss, watt | Load loss, watt | Purchase price $ |
|---|---|---|---|---|
| D1(CRGO steel) | 200 | 500 | 2800 | 3076.92 |
| D2( Hi-B grade) | 200 | 300 | 2300 | 3538.72 |
| D3(laser grade) | 200 | 180 | 2300 | 4000 |

Table 3: Evaluation of three different transformers

### B. *Evaluation without environmental cost*

It is supposed that the transformer loading profile is that of the domestic load of MPPKVVCL Jabalpur of Fig.1 with the characteristics shown in Table 3.In order to compute the A and B loss evaluation factors, the 13 input parameters of Table 5 are required. Based on the input data of Table 5 and using the TOCAPP application shown in the calculations part of Table 5, it is found that A = $9104.26/kW and

B=2717.19.The TOC (without the environmental cost) results for the three different transformer models of Table 3. These results outcomes based on the factors A and B of Table 5, the purchase price and the losses of each transformer model of Table (3), implementing TOC formula. A Table 7 shows that despite the fact that transformer design D1 is the cheapest one concerning the bid price, the transformer model D1 is the worst investment in long term, since it has the highest TOC. In contrast, it is clear that transformer model D3 is the best investment in long term, since it has the lowest TOC. Although the bid price of D1 is 23.08% cheaper than the bid price of D3, the TOC of D1 is 31.07% more expensive than the TOC of D3 throughout the 30 years of transformer lifetime. The above-mentioned difference in the TOC of D1 and D3 is attributed to the difference in the cost of losses of D1 and D3, as Table 7 shows.

### *C. Evaluation incorporating environmental cost*

In this section, the model of Table 3 is consider using the proposed method, that is, the TOCe formula that include the environmental cost. The required input data values taken from Table 6. So as to compute the current year GHG emission cost factor C of the Madhya Pradesh state electricity board in which the domestic load of Fig. 1 is connected. It is considered that the current year GHG emission cost value is Ccy = $5.54/tCO_2$. As can be seen from Table 4, C =$4.05/ MWh we selected reference transformer[16], which means that NLLr = 0.193 kW and LLr = 1.909 kW. Table 8 shows that the environmental cost due to transformer load loss is positive for D1, D2 and D3, and the ratio of the environmental cost over the TOCe is +1.4% and 0.0033% for D1 and D3, respectively. It can be concluded from Table 8 that the best investment is model D3 since it has the lowest TOCe.

| Fuel type | Coal | Dies el | Hydr o | Natur al gas | RES | nucle ar |
|---|---|---|---|---|---|---|
| Fuel indicato r, i | 1 | 2 | 3 | 4 | 5 | 6 |
| $f_i$ % | 63.1 5 | 0 | 17.0 2 | 0.013 5 | 17.0 2 | 1.44 |
| $e_{CO_2,i}$ kg/Gj | 94.6 | 74.1 | 0 | 56.1 | 0 | 0 |
| $e_{CH_4,i}$ kg/Gj | 0.00 2 | 0.00 2 | 0 | 0.003 | 0 | 0 |
| $e_{N_2O,i}$ kg/Gj | 0.00 3 | 0.00 2 | 0 | 0.001 | 0 | 0 |
| $n_i$ ,% | 35 | 30 | 100 | 45 | 100 | 35 |
| $\lambda_i$ ,% | 15 | 15 | 15 | 15 | 15 | 15 |
| $e_i$ $(t_{CO_2}/MWh)$ | 1.15 1 | 1.05 8 | 0 | 0.536 | 0 | 0 |
| C, $/MWh | 4.05 | | | | | |

Table 4: Calculation of the Current Year CHG Emission Cost Factor C

| Input Parameters | | |
|---|---|---|
| Symbol | Values | Unit |
| AF | 0.97 | _ |
| HYP | 8760 | h/yr |
| BL | 30 | Yr |
| CYEC | 0.089 | $/kW |
| EIR | 0.035 | Per year |
| FCR | 0.148 | $/$/yr |
| D | 0.10 | Per year |
| LF | 0.629 | _ |
| $I_f$ | 0.44 | _ |
| ET | 0.889 | _ |
| LIC | 148.32 | $/KW-yr |
| EIR | 0.845 | _ |
| PRF | 0.809 | _ |

Table 5: Calculation of A and B Loss Evaluation Factor

| Calculated Parameters (Output) | | |
|---|---|---|
| Symbol | Value | Unit |
| RF | 0.106 | _ |
| PUL | 0.79 | _ |
| LECN | 1049.81 | $/kw-yr |
| LECL | 1105.06 | $/kw-yr |
| A | 9104.26 | $/kw |
| B | 2717.19 | $/kw |

Table 6: Calculated Parameters (Output)

From the table it is clearly shown that the purchase price of D3 is more compare to D1 and D2 but the costs calculated with the help of TOCAPP(MATlab) shown that the total owing cost of transformer D1 is more compare toD1and D3. As per purchase criteria D3 is expensive than that of D2 and D1 but as per TOC the D1 is expensive that of D3.so if we replace the old transformer with the D3 model i.e. energy efficient transformer which saves not even money or energy but it also saves environment.

| Input Parameters | | |
|---|---|---|
| Symbol | Values | Unit |
| AF | 0.97 | _ |
| HYP | 8760 | h/yr |
| BL | 30 | Yr |
| C | 0.007 | $/kW |
| $EIR_e$ | 0.045 | Per year |
| FCR | 0.148 | $/$/yr |
| D | 0.10 | Per year |
| LF | 0.629 | _ |
| $I_f$ | 0.44 | _ |
| ET | 0.889 | _ |
| LIC | 148.32 | $/kw-yr |
| EIR | 0.845 | _ |
| PRF | 0.809 | _ |

Table 7: Calculations of $A_e$ and $B_e$ environmental factors

| Calculated Parameters (output) | | |
|---|---|---|
| Symbol | Value | Unit |
| RF | 0.106 | _ |
| PUL | 0.79 | |
| $LECN_e$ | 52.69 | $/kw-yr |
| $LECL_e$ | 55.46 | $/kw-yr |
| $A_e$ | 400.38 | $/kw |

| | | |
|---|---|---|
| $B_e$ | 113.27 | $/kw |

Table 8: Calculated Parameters (Output)

Considering an exchange rate of 1 US$ to 65.01 Indian rupees and 1 euro to 72.33 Indian rupee, the cost of distribution transformers of model D1 the capitalization value of load losses in distribution transformer is calculated as 2717.19 US$ / W. the capitalization value of no load losses in distribution transformer is calculated as 9104.26 US$ / W. the environmental cost due to no load loss is calculated as 400.38US$/W and environmental cost due to load loss is calculated as 113.27US$.

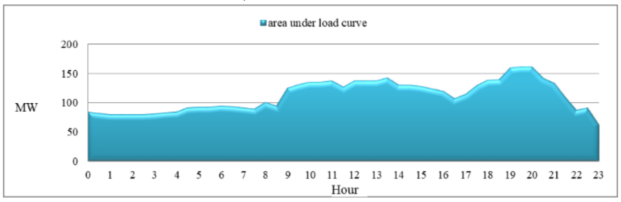


Fig. 1: Daily load curve of distribution transformer 200 KVA

## V. Conclusion and Recommendations

Based on the results summarized in Table 5 and table 6 above, TOC can be calculated for any transformer if the no-load loss and full load loss and the initial purchase price are known. Table 7 shows the Total Owning Cost (TOC) for typical 33kV/400V 3- phase distribution transformers used in Madhya Pradesh electricity board of Madhya Pradesh together with their initial purchase prices for comparison. The no-load loss and load loss values of transformers presently used by the MPSEB as summarized in Table 2 and table 3 were used for this calculation. Table 8 shows the purchase price and complete cost of D1,D2 and D3 with and without environmental cost. The results clearly show that customers should not get misled by the attractive low initial prices of transformers but that they need to be guided by the Total Owning Cost (TOC) taking life time costs due to transformer losses into consideration. They should also be concerned of the type of the load profile applicable to the transformer they purchase, as indicated in this study from the load profiles of transformers Installed in rural, semi-urban and urban areas of Madhya Pradesh.

| Parameter | Model | | |
|---|---|---|---|
| | DT1 | DT2 | DT3 |
| Bid price (B.P),$ | 3076.92 | 3538.46 | 4000 |
| NLL, kW | 2.8 | 2.3 | 2.3 |
| LL, kW | 0.5 | 0.3 | 0.18 |
| $\Delta P_{NLL}$ ,kW | 0.3067 | 0.1067 | -0.0133 |
| $\Delta P_{LL}$ ,kW | 0.894 | 0.394 | 0.394 |
| $C_{NLL}$ ,$ | 4552.1 | 2731.2 | 1638.74 |
| $C_{LL}$ ,$ | 7608.15 | 6249.58 | 6249.28 |
| $C_L$ ,$ | 12160.28 | 8980.68 | 7888.72 |
| TOC ,$ | 15237.2 | 12519.29 | 11888.72 |
| $EC_{NLL}$ ,$ | 122.91 | 42.84 | -5.23 |
| $EC_{LL}$ ,$ | 101.94 | 45.3 | 45.30 |
| EC ,$ | 224.85 | 88.14 | 40.07 |
| $TOC_e$ ,$ | 15461.81 | 12607.25 | 11966.33 |
| $BP/TOC_e$ ,% | 19.9 | 28.06 | 33.42 |
| $CL/TOC_e$ ,% | 78.64 | 71.23 | 65.92 |
| $EC/TOC_e$ ,% | 2.85 | 1.3 | 0.06 |
| $TOC/TOC_e$ ,% | 98.54 | 99.30 | 99.35 |

Table 9: Calculation of $TOC_e$ incorporating environmental cost

| Transformer type (core type) | Capacity KVA | No load loss watt | Load loss watt | Purchase price In dollar $ | Toc when installed in Madhya Pradesh (in dollar,$) | |
|---|---|---|---|---|---|---|
| | | | | | A=9104.26 B=2717.19 | $A_e$=400.38 $B_e$=113.27 |
| D1(CRGO steel) | 200 | 500 | 2800 | 3076.92 | 15237.2 | 15461.81 |
| D2( Hi-B grade) | 200 | 300 | 2300 | 3538.72 | 12519.29 | 12607.25 |
| D3(lazer grade) | 200 | 180 | 2300 | 4000 | 11888.72 | 11966.33 |

Table 10: Total owning cost in dollar of three model of transformers of same rating but different in design

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