Determination of Capitalization Values for No Load Loss and Load Loss in Distribution Transformers

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Abstract: A large number of distribution transformers are being currently used in the electricity distribution network in Sri Lanka. When purchasing them, it is not sufficient to evaluate only the initial price of the transformer. There are no load losses as well as load losses in the transformer during its life span, which is about 35 years. Therefore, a transformer purchaser has to evaluate the total lifetime cost of the transformer, which includes its purchase price, and the cost of losses that can occur during the life of the transformer. Traditionally, this evaluation has been done based on the Total Owning Cost (TOC). This paper discusses setting up of a methodology to calculate capitalization values for losses in distribution transformers used in Sri Lanka, using IEEE loss evaluation guide.

Capitalization values for distribution transformers depend on capacity and energy costs, economic considerations and on their load profiles. In this research, capitalization values are calculated for three different load profiles of the transformers installed in rural, semi-urban and urban areas of Sri Lanka. In future, any utility can purchase distribution transformers by calculating capitalization values using the methodology presented in this study which is based on a set of economic and other parameters suitable for different applications, i.e. rural electrification, loss reduction in urban cities, augmentation of distribution transformers, etc.

Keywords: Transformer, Total owning cost, No-load loss, Load loss

1.   Introduction
1.1   Background

Utilities and licensees for power transmission and distribution are always looking out for the betterment of their transmission and distribution systems' efficiencies by reducing system losses. Increased system voltage, 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, improving of the system power factor by adding shunt capacitors and the reconfiguration of the electricity network are some of the strategies that are used commonly to reduce transmission and distribution losses .

Some of the above mentioned modifications can be implemented more easily than others. For instance, it does not take a great deal of technical expertise to replace a transformer, although technical background at a higher level would be necessary to design a highly efficient and cost optimized transformer. 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%. Table 1 shows some of the calculated efficiency values for a few selected capacities of distribution transformers.

Table 1 - Calculated Efficiency Values for Distribution Transformers used by the CEB

Transformer Rating (kVA)	No Load Loss (W)	Load Loss (W)	Efficiency at 0.5 per unit load of nameplate rating
100	340	1900	98.40 %
160	460	2450	98.68 %
250	610	3150	98.89 %
400	870	4000	99.07 %

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In electricity networks, two types of transformers are used, They are the substation type and the distribution type. Substation type transformers are built to step-up voltage from low voltage at the generator end to high voltage at the transmission system and also for stepping down voltage to distribute energy among various loads in transmission and distribution systems. Distribution transformers are used to step down the voltage to the distribution level voltage for households as well as for commercial and industrial consumers.

Distribution transformers are smaller in capacity but larger in quantity (181 numbers of substation transformers and 25,452 numbers of distribution transformers were in the CEB network at the end of 2013) [1]. Since there are a large number of distribution transformers in use, small losses in each add up to a significant total.

1.2   Losses in Distribution Transformers

Losses in a distribution transformer can be divided into two categories; no load losses and load losses. No load losses occur in the core of the transformer at all times regardless of load. Load losses occur in the transformer only when the transformer is loaded and they vary according to the square of the load current, the most significant cause for load losses being I^2R losses or copper losses.

No load losses occur whenever a voltage is applied to a transformer regardless of the loading on the transformer. No load loss in a distribution transformer has five components, i.e., hysteresis losses in core laminations, eddy current losses in the core laminations, I^2R losses due to no load current, stray eddy current losses in core clamps, bolts and other core components and dielectric losses. Stray eddy current losses, dielectric losses and I^2R losses due to no load current are very small when compared to other losses. Therefore, those losses can often be neglected. Hysteresis losses and eddy current losses on the other hand contribute to over 99% of the no load loss [2].

The second type of loss component is the load loss, which depends on the loading pattern of the distribution transformer. It consists of heat losses in the conductors caused by the load current and eddy currents in the conductors. These losses increase as the operating temperature increases. Therefore, it is often difficult to determine load losses because of the difficulty of anticipating the load pattern. This requires the analysis of the peak load as well as the load factor. The most significant load loss component is the I^2R loss or the copper loss [2].

1.3   Determination of Losses in the Distribution Transformers

The value of the no load losses and the value of the load losses must be calculated throughout the total life span of a distribution transformer (In the CEB, the life span of a distribution transformer is considered as thirty five (35) years) [3]. Therefore, the purchasing party has to calculate the cost of losses throughout the transformer lifetime to take account of the total value of losses in the distribution transformers. On the other hand, the manufacturing cost of a distribution transformer is increased when it's no load and load losses are lowered.

1.4   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. 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.

$$TOC = Bid\ Value\ + \left(NLL\right) \times A + \left(LL\right) \times B \quad \ldots\ldots (1)$$

where, NLL   = No Load Loss
          LL   = Load Loss

A=Capitalization value of NLL (LKR/W)
B=Capitalization value of LL (LKR/W)

The transformer cost and the efficiency are the main two factors to be considered in purchasing a transformer. The transformer purchaser tries to optimize the losses in the power system by selecting the most cost effective and energy efficient transformers. During the transformer manufacturing process, designers can design a transformer of high cost and high efficiency or one of low cost and low efficiency both meeting specified performance characteristics such as impedance, temperature rise, noise levels etc. A highly efficient transformer while having an initially high cost will have a low cost related to lifetime losses while a less efficient transformer will be cheap to produce but will have a high cost related to lifetime losses. Thus the need arises to produce an optimised transformer suitable for a power system considering the desired technical parameters and economic conditions prevailing in the country.

Transformer designers use the concept of total owning cost (Equation 1) in the design optimisation process which is used by buyers for evaluating offers made by different manufacturers. Thus, the transformer manufacturers request from the users, the capitalization value of no load losses (A) and the capitalization value of load losses (B) for use in the design process. By varying a large number of design parameters, design tools used by the transformer designers select the transformer having the lowest TOC for the optimized design. Therefore, the loss capitalization values play a major role in the transformer designing process.

In the specification [4], [5] of the substation transformers of the CEB, the cost of guaranteed losses are indicated. Substation transformers are purchased by the CEB through a competitive bidding process. Therefore, by including capitalization values for losses in the CEB specifications, bidders will be required to follow those values in their transformer designs. Thus, the CEB can select an optimized transformer by considering TOC using data provided by the bidders. In general, the lowest TOC value is given by the most optimized transformer design.
However, it is not the same in the case of distribution transformers because their capitalization values are not specified during

the purchasing process. Instead. the CEB indicates fixed values for no load losses and load losses in the distribution transformer specifications [6].

The absence of capitalization values for distribution transformers has been identified as a problem by the utility operators.

2.   Methodology

2.1   Capitalization Value of No Load losses and Load Losses

The capitalisation value for no load loss "A" (in LKR/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 [7] 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 LKR/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 behaviour 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 capitalization value of load losses is given by Equation 3 [9].

$$A = \left[\frac{C_{SC} + C_E \times 8760}{ET \times R_{FC} \times IF} \right] \times \frac{1}{1000} \qquad ......(2)$$

$$B = \left[\left\{ \frac{C_{SC} \times RF^2 + [C_E \times 8760 \times (lf)]}{ET \times R_{FC} \times IF \times 1000} \right\} \times PL^2 \right] \qquad ......(3)$$

where,

C_{SC} –   System Capacity Cost
        (LKR/kW/year)
C_E –   Energy cost (LKR / kW-hour)
R_{FC} –   Fixed charge rate
RF   –   Responsibility Factor

lf   –   Loss Factor
PL   –   Uniform annual Peak Load
ET   –   Efficiency of Transmission
IF   –   Increasing Factor
8760 –   Number of hours per year

- **System Capacity Cost**

The System Capacity Cost (C_{SC}) [2] is the levelized annual cost of additional generation, transmission and distribution capacity necessary to supply 1 kW of peak load to the distribution transformer. This value reflects the cost of peak generation, transmission and distribution capacity.

- **Levelized Energy Cost**

The Levelized Energy Cost (C_E) [2] includes a cost proportional to the energy output of the generator. This would include the cost of fuel and the cost of operation, maintenance, and transportation, storage and conversion of fuel to electrical energy.

- **Annual Fixed Charge Rate**

The levelized Annual Fixed Charge Rate (R_{FC}) [2] converts the levelized annual cost of losses into a capitalized value. This term is also referred to as the annual cost ratio. The levelized annual fixed charge rate can be multiplied by the bid price to convert the cost of the transformer into an annual cost. This term consists of components like, minimum acceptable return, book depreciation, income taxes and insurance.

- **Efficiency of Transmission**

The Efficiency of Transmission (ET) [7] is defined as the energy received at the input terminals of the distribution transformer divided by the energy transmitted from the source. Normally, this efficiency varies with loading, location, voltage level or season, etc. The efficiency of transmission becomes significantly large in some instances.

- **Increasing Factor**

The Increasing factor (IF) [7] represents the total cost that the user must pay to acquire the transformer. This term includes components like purchase price of the transformer, overhead fees and taxes.

2.2 Categorization of Distribution Transformers

Distribution transformers behave in different ways according to their load profiles. Therefore, in this study distribution transformers are categorized into three groups i.e. transformers installed in rural areas, semi-urban areas and urban areas. The loads attached to transformers installed in the three areas give rise to three different load profiles. In rural areas, the transformer has a predominant peak in the evening (18 00 hours to 22 00 hours) and during the rest of the time a very small load. In urban areas, the peak occurs during the day as they serve mostly commercial loads. In semi-urban areas, the load curve is in between rural and urban load profiles (Table 2).

2.3 Data Collection

Measurements were done on a selected number of distribution transformers installed in rural, semi-urban and urban areas using data loggers and energy meters, which were placed at the secondary side of the respective distribution transformers. The average current, average voltage, average power factor, export demand and average frequency at fifteen (15) minute intervals were recorded over a period of 7 days at each of the transformers. Using recorded data from five distribution transformers, load curves shown in Figure 1, Figure 2 and Figure 3 were plotted for rural, semi-urban and urban areas respectively.

Table 2 - Distribution Transformer Categorization Criteria

Category	Load Profiles		
	Rural	**Semi Urban**	**Urban**
Locations	Rural villages	Small towns	Commercia lised towns
Type of loads	Mainly households	Household, commercial & industrial	Mainly commercial & industrial
Transformer peak occurring time	Night	Day time (morning) & night	Day time

2.4 Calculation of Load Factor and Loss Factor

With the collected load demand data, a graph was plotted with demand (kW) against duration of the demand values (Hours). Another graph was plotted with square values of load currents (A^2) against the duration of the load currents (Hours). These graphs were used to calculate the load factor and the loss factor of distribution transformers. The load factor is considered as a measure of utilization of the electricity network. The average load can be calculated by using the value of the area under the curve and the duration of the curve (Equation 5 and Equation 6). The peak value of

the demand curve was found and the load factor was calculated using the average load and the peak value from the graph, as shown in Equation 7.
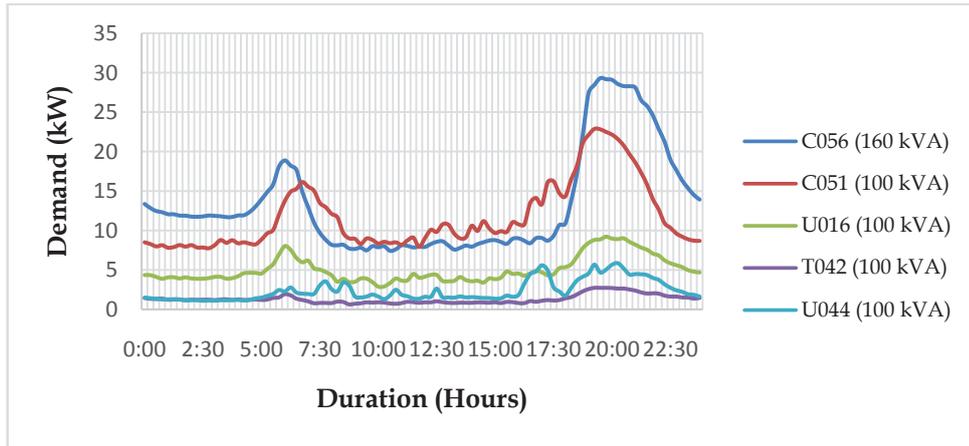

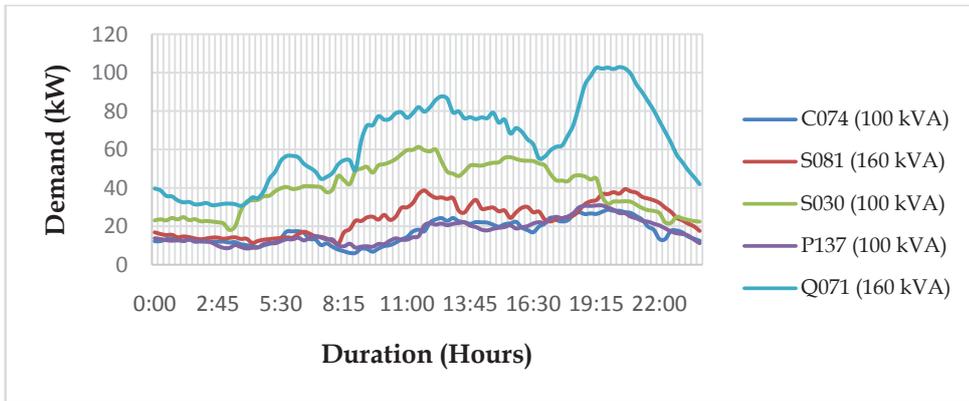**Figure 1 - Demand Curves for Distribution Transformers in Rural Areas**

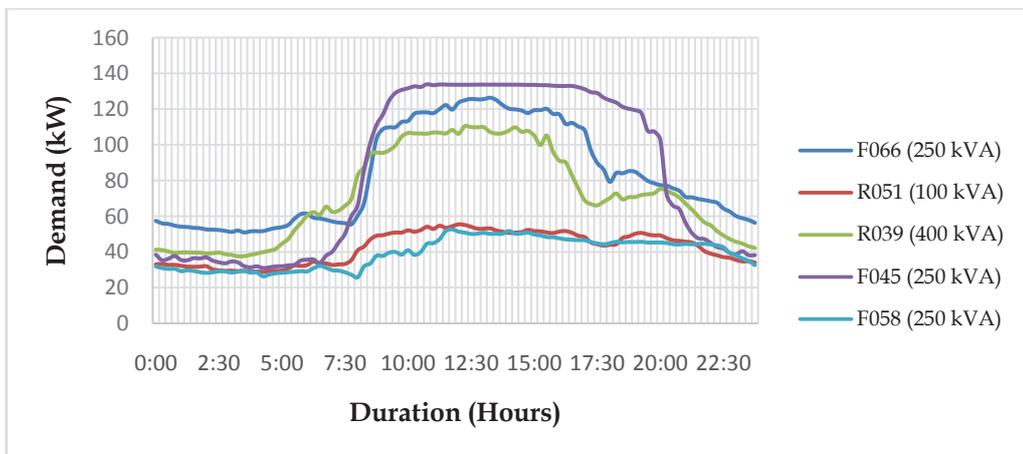**Figure 2 - Demand Curves for Distribution Transformers in Semi-urban Areas**

Figure 3 - Demand Curves for Distribution Transformers in Urban Areas

$$E = \int_0^T P\,dh = \text{Area under demand curve} \quad \quad \dots(4)$$

$$P_{av} = \frac{1}{T}\int_0^T P(t)\,dt \quad \quad \dots(5)$$

Average Load

= [Area under the load curve / Duration] …(6)

LF = (Average Load/Peak Load)   …..(7)

where LF is the Load Factor

In the same way, the calculation of the load factor and the loss factor in load profiles of distribution transformers in rural, semi-urban and urban areas were done. As per Equation 8, if the resistance (R) is constant then the power loss would be directly proportional to the square value of the load current (A^2). A graph was plotted with square values of load currents (A^2) against. the duration (Hours). Thereafter, the Loss factor was calculated using Equation 6 and 7 as shown above.

Power Loss = (I^2) × R   …..(8)

where
I   = Load current (A)
R   = Resistance (Ω)

Distribution planning engineers use Equation 9 to calculate the Loss factor (lf)

lf = (a × LF) + (b × LF^2)   …..(9)
a, b – constant values dependent on loading profile while a = 1-b.

In the CEB, planning engineers use 0.2 and 0.8 for 'a' and 'b' respectively. Then the Equation 9 becomes:

lf = (0.2 × LF) + (0.8 × LF^2)   …..(9)

- **Uniform Annual Peak Load**
The term uniform annual Peak Load (PL) [2] is given to the levelized peak load per year over the life of the transformer. It is dependent on the initial peak load, the estimated load growth rate and the maximum allowable load of the transformer.

$$PL = \left[\left\{\sum_{j=1}^{n_1}\left[b(1+g)^{(j-1)}\right]^2 * \left[\frac{1}{(1+i)^{n_1}}\right]\right\} * \left\{\frac{i(1+i)^{n_1}}{(1+i)^{n_1}-1}\right\}\right]^{1/2} \quad \dots(10)$$

where,
b - Initial transformer load in per unit of the transformer nameplate rating.
g - The annual peak load growth of the distribution transformer in per unit
n - Number of years of the transformer life
i - Minimum acceptable return
The relationship between the Load Factor (LF), Loss Factor (lf) and the Annual Peak Loading (PL) is given in Equation 11, which is as per the IEEE loss evaluation guide [7].

(LF^2) = (lf) × (PL^2)   ….. (11)

where,
LF - Load Factor
lf - Loss Factor
PL - Uniform Annual Peak Loading

- **Peak Responsibility Factor (RF)**
The peak Responsibility Factor (RF) [2] describes the diversity of the load on the transformer. It indicates the relationship between the transformer peak load and the transformer load at the peak time of the utility system load. This means that the peak loading on a distribution transformer does not occur at the same time as the peak loading on the various components of the generation, transmission and distribution system.

RF = $\dfrac{\text{Transformer load at system peak}}{\text{Transformer peak load}}$ ….. (12)

3.   Determination of Capitalization Values

3.1   Calculation of the Capitalization Value of No Load Loss
Calculation of Fixed Charge Rate
The Fixed Charge Rate (R_{FC}) is given by the combination of following components.
- Minimum Acceptable Return =12.75%
  This term represents opportunity cost.
- Book Depreciation = 2.86%

Distribution transformers are taken as fixed assets in the accounting practices of the CEB. Hence, for book depreciation a value of 1/35 is given as a percentage by using the straight-line method.
- Income taxes = 0%
  This term is not relevant to semi-government organizations like the CEB. Hence income taxes are taken as zero.
- Local Property taxes and insurance = 0.1%

There was no local property tax value for CEB properties. However, the CEB takes 0.1% as their self-insurance reserves [3], [8]. Therefore, the fixed charge rate is as given below:

Fixed Charge Rate = (12.75 + 2.86 + 0 + 0.1) %
= 15.71 %

Efficiency of Transmission (ET)
The CEB's overall system loss in the year 2013 was 10.79 % [1]. Based on the IEEE loss evaluation guide [7], the Efficiency of the Transmission (ET) was calculated as follows.

$$ET = (100\% - \text{overall losses}\%)$$
$$= (100 - 10.79)\%$$
$$= 89.21\%$$

Increasing Factor (IF)
The CEB considers overhead cost together with labour charges. Sales taxes are also not applicable to the CEB. Therefore, components like overhead cost, sales taxes and consultancy fees are not taken for the calculation of the Increasing Factor (IF). The purchase price is the only component considered. Hence, the increasing factor is taken as 1.00 for the calculation.

$$IF = \frac{(\text{purchase price} + \text{overhead} + \text{taxes})}{\text{purchase price}} \quad ....(13)$$

$$= \frac{(\text{purchase price} + 0 + 0)}{(\text{purchase price})}$$

$$= 1.00$$

System Capacity Cost (C_{SC})
The system capacity cost (C_{SC}) for each month in the year 2013 was taken as 24,000.00 LKR / kW /year [9].

Energy Cost (C_E)
The average energy cost (C_E) for the year 2013 is taken as 12.69 LKR / kWh [11]. Since the average energy cost has escalated over the lifetime of the distribution transformer, the present worth of the energy cost was taken and levelized over the life span of the distribution transformer. The inflation (a) and the discount rate (i) were taken as 6.425 % [10] and 10.42% [12] respectively. The life time of a distribution transformer (n) was taken as 35 years. The Capital Recovery Factor (CRF) [7] was used to compute the levelized cost throughout the life span of the distribution transformer (35 years).

$$C_E = \{\Sigma [C_k / (1+i)^k]\} * CRF \quad ..... (14)$$

where C_k is the electricity price in the kth year and;

$$CRF = \frac{[i * ((1+i)^n)]}{[((1+i)^n) - 1]} \quad .....(15)$$

$$= \frac{[0.1042 * ((1+0.1042)^{35})]}{[((1+0.1042)^{35}) - 1]}$$

$$= 0.1075$$

$$\Sigma [C_k / (1+i)^k] = 255.27 \text{ LKR/kWh}$$

Thus, the levelized annual cost of energy (C_E) is given by Equation (14) as;

$$C_E = 255.27 \times 0.1075 \text{ LKR/kWh}$$

$$= 27.45 \text{ LKR / kWh}$$

Therefore, the capitalization value of no load losses can be determined using Equation (2) and the above calculated data can be summarized as given below.

$$C_{SC} = 24{,}000 \text{ LKR / kW / year}$$
$$C_E = 27.45 \text{ LKR / kWh}$$
$$R_{FC} = 0.1571$$
$$ET = 0.8921$$
$$IF = 1.00$$
$$A = \left[\frac{24000 + 27.45 \times 8760}{0.8921 \times 0.1571 \times 1}\right] \times \frac{1}{1000}$$
$$= 1887 \text{ LKR / W}$$

The exchange rate considered was 1 US$ to 130 Sri Lankan Rupees. Then, the capitalization value of no load loss (A) in a distribution transformer can be taken as **1900 LKR / W** or **14.52 US$ / W.**

3.2 Calculation of the Capitalization Value of Load Loss
The capitalization value of load loss (B) can be calculated using Equation (3) once all parameters in this equation have been determined. Values for system capacity cost (C_{SC}), levelized energy cost (C_E), fixed charge rate (R_{FC}), Efficiency of Transmission (ET) and Increasing Factor (IF) have been already calculated in Section 3.1 in calculating the capitalization value of no load losses. However, terms like Responsibility Factor (RF), loss factor (lf) and uniform annual peak load (PL) have to be calculated. These parameters are sensitive to the load profiles of

distribution transformers. Therefore, these parameters are calculated for different load profiles of distribution transformers installed in rural, semi-urban and urban areas.

Calculation of the Loss Factor, Uniform Annual Peak Loading and Responsibility Factor

The Loss Factor (lf) is calculated in terms of Load Factor (LF). Normally, the load factor is considered as a measure of the utilization of the electricity network. So, the load factor and the loss factor are calculated according to the methodology mentioned above. The uniform annual peak loading and peak responsibility factor are also calculated according to this methodology.

Sample Calculation for Distribution Transformers in Rural Areas

The calculation of the load factor (LF) and the peak Responsible Factor (RF) are made using measurements made on several distribution transformers in rural areas. Transformers in rural areas were selected according to norms mentioned above. A sample calculation was done using data recorded from Mapalana distribution transformer – C056 (160 kVA).

Average Load $=$ Area under the Load curve

$$\frac{}{24 \times 7}$$

$$= [2254.37 / (24 \times 7)]$$

$$= 13.42 \text{ kW}$$

Peak Load $= 29.32$ kW

Load Factor $=$ (Average Load / Peak Load)
$= (13.42 / 29.32)\%$
$= 46 \%$

Similarly, load factors were calculated for the rest of the distribution transformers installed in rural areas. The calculated values of the load factor for each distribution transformer are shown in Table 3.

Thereafter, by taking the average of the Load Factors in the above mentioned distribution transformers, the Load Factor for distribution transformers in rural areas were taken as **48%.** The peak responsibility factor (RF) is another important term in the capitalization value equation (Equation 3).

Table 3 - Calculated Load Factors for Distribution Transformers in Rural Areas

Name of Sub Station	Load
Mapalana (C056)	46 %
Deiyannegama (C051)	51 %
Udahagoda (U016)	55 %
Dombagaswinna (T042)	48 %
Wijeriya (U044)	41 %
Average	**48 %**

Normally, the peak responsible factor indicates the relationship between the transformer peak load and the transformer load at the time of the utility system peak load. When using data measured from Mapalana distribution transformer – C056 (160 kVA), Equation 9 and Equation 12 become,

lf $= (0.2 \times LF) + (0.8 \times LF^2)$
$= (0.2 \times 0.48) + (0.8 \times 0.48^2)$
$= 0.28$

RF $= \dfrac{\text{Transformer load at system peak load}}{\text{Transformer peak load}}$
$= \dfrac{26.8 \text{ MW}}{29.32 \text{ MW}}$
$= 0.91$

Peak Responsibility Factors (RFs) calculated for other distribution transformers in rural areas are shown in Table 4.

Table 4 - Calculated Values of the Peak Responsibility Factor of Distribution Transformers in Rural Areas.

Name of Sub Station	RF
Mapalana (C056)	0.91
Deiyannegama (C051)	0.89
Udahagoda (U016)	0.91
Dombagaswinna (T042)	0.90
Average	0.90

Therefore, peak responsibility factor (RF) of distribution transformers in rural areas has been considered as 0.90 in this study.

The calculation of the uniform annual peak loading (PL) is done by using Equation 11.

$$(LF^2) = (lf) \times (PL^2)$$

where,
LF - Load Factor
lf - Loss Factor
PL - Uniform Annual Peak Loading

According to the results calculated above, for distribution transformers in rural areas,

Load factor (LF) = 0.48
Loss factor (lf) = 0.28

Thus from Equation 11
$$(PL) = [(LF^2) / (lf)]^{0.5}$$
$$= 0.91$$

Now using all the calculated parameters in Equation 3.

$$B = \left[\left\{ \frac{C_{SC} \times RF^2 + [C_E \times 8760 \times (lf)]}{ET \times R_{FC} \times IF \times 1000} \right\} \times PL^2 \right]$$

$$B = \left[\frac{24000 \times 0.9 \times 0.9 + 27.45 \times 8760 \times 0.28}{0.89 \times 0.1571 \times 1 \times 1000} \right] \times 0.91 * 0.91$$

$$B = 509.4 \text{ LKR/W}$$

Considering an exchange rate of 1 US$ to 130 Sri Lankan rupees, the capitalization value of load losses in distribution transformers (B) in rural areas is calculated as **3.92 US$ / W.**

Following a procedure similar to what was described above, the capitalization value of load losses (B) in distribution transformers for semi-urban areas is calculated to be **750 LKR/W** or **5.69 US$/W** and the capitalization value of load losses in distribution transformers (B) for urban areas is calculated to be **900 LKR/W** or **6.79 US$/W**. The calculated values for loss capitalisation values for rural, semi-urban and urban areas of Sri Lanka are summarized in Table 5 below.

4. Conclusion and Recommendations

Based on the results summarized in Table 5 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 6 shows the Total Owning Cost (TOC) for four capacities of typical 33kV/400V 3-phase distribution transformers used in Sri

Lanka based on whether they are installed in rural, semi-urban or urban areas of Sri Lanka together with their initial purchase prices for comparison. The no-load loss and load loss values of transformers presently used by the CEB as summarized in Table 1 were used for this calculation.

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 Sri Lanka.

Table 5 - Calculated Capitalization Values for Distribution Transformers

Profile	A (US$/W)	B(US$/W)
Rural Areas	14.5	3.92
Semi-urban Areas	14.52	5.69
Urban Areas	14.52	6.79

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Table 6 - Comparison of Total Owning Cost (TOC) with the initial Purchase Prices of Distribution Transformers

Capacity kVA	No-load Loss (W)	Load Loss (W)	Purchase Price (LKR)	TOC when Installed in Sri Lanka (LKR)		
				Rural Area	Semi Urban Area	Urban Area
				A= 1887.6 LKR/W		
				B = 509.6 LKR/W	B = 739.7 LKR/W	B = 882.7 LKR/W
100	340	1900	545,700.00	2,155,724.00	2,592,914.00	2,864,614.00
160	460	2450	668,600.00	2,785,416.00	3,349,161.00	3,699,511.00
250	610	3150	823,200.00	3,579,876.00	4,304,691.00	4,755,141.00
400	870	4000	1,189,100.00	4,869,712.00	5,790,112.00	6,362,112.00