DETERMINATION OF CAPITALIZATION VALUES FOR NO LOAD LOSSES AND LOAD LOSSES OF DISTRIBUTION TRANSFORMERS

H.M.S.L. Gunarathna Bandara

(109203 X)

Thesis/Dissertation submitted in partial fulfillment of the requirements for the degree

Master of Science

Department of Electrical Engineering

University of Moratuwa

Sri Lanka

April 2015

DECLARATION

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis/dissertation, in whole or part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature of the author Date:
H.M.S.L.G.Bandara

The above candidate has carried out research for the Masters Dissertation under my supervision.

Signature of the supervisor Date:
Eng. W.D.A.S. Wijayapala
Senior Lecturer, Department of Electrical Engineering
University of Moratuwa

Signature of the co-supervisor Date:
Eng. S.R.K. Gamage
Deputy General Manager (DD-01)
Ceylon Electricity Board

ABSTRACT

Transformers are one of the better efficient components in the electricity distribution network. Basically substation transformers and distribution transformers are currently used in the electricity distribution network in Sri Lanka. Evaluation on the purchasing price of the transformer is not enough during the purchasing process. There are losses due to no load losses and load losses in the transformer during life which is about 30-35 years. Therefore, transformer purchaser must be look at total life time cost of the transformer during the purchasing process. Traditionally, this evaluation is done based on Total Owning Cost (TOC). Currently in Sri Lanka, CEB does not use competitive bidding process in purchasing of distribution transformers. And also, CEB has not defined capitalization values for distribution transformers to evaluate them based on TOC.

Main objective of this research is to set up a methodology to calculate capitalization values for distribution transforms in Sri Lanka using IEEE loss evaluation guide. Capitalization values for distribution transformers depend on capacity cost and energy cost, economic considerations and load profile of distribution transformers. In this research, capitalization values are calculated for three different load profiles, i.e. rural, semi urban and urban. A computer based methodology was developed to calculate capitalization values as an outcome of this research. In future, CEB can purchase distribution transformers by using these capitalization values for different applications, i.e. rural electrification, loss reduction in urban cities, augmentation of distribution transformers, etc. And also, any other utility can use computer based model to calculate capitalization values for distribution transformers at any given time corresponding to a set of economic and other parameters.

Key words

Total Owning Cost

Ceylon Electricity Board

Institute of Electrical and Electronic Engineers

ACKNOWLEDGEMENT

First and foremost, I would like to express my sincere gratitude to my supervisors Eng. W.D.A.S. Wijayapala and Eng. S.R.K. Gamage, for their continuous guidance, constructive feedback and support extended throughout this research. Despite their busy schedule, they always remained accessible and their guidance and advice, expertise and insight were by all means truly invaluable.

I would also like to thank all the panel members from the academic staff of Electrical Engineering Department of University of Moratuwa their valuable feedback during the progress reviews.

Thankfulness is extended to my friends in the Ceylon Electricity Board especially to Eng. G. Kishorkumar, Eng. H.D.S. Pathirana, Eng. I.D.J.U. Hemachandra, Eng. (MS) U.S. Gunathunga and Eng. P.M. Piyasena for the encouragement and support given to me for bringing this task to a success.

Finally, I am grateful to my mother, Udari and other family members for all the sacrifices they made along the way and for all the support given to me during various endeavors in my life.

H.M.S.L.G. Bandara

April 2015

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Description
CEB	Ceylon Electricity Board
EC	Energy Cost
ET	Efficiency of Transmission
FC	Fixed Charge Rate
IEEE	Institute of Electrical and Electronic Engineers
IF	Increasing Factor
LF	Load Factor
lf	Loss Factor
LRMC	Long Run Marginal Cost
LTL	Lanka Transformer Limited
PL	Uniform Annual Peak Load
RF	Peak Responsible Factor
SC	System Capacity Cost
TOC	Total Owning Cost

LIST OF APPENDICES

1 INTRODUCTION

The utilities and licensees for power transmission and distribution are always looking for betterment of their transmission and distribution systems efficiency by reducing system losses. Many countries around the world are continuously trying to maintain their annual system losses as low as possible. The annual electricity loss of some Asian countries are shown in Table 1.1 [1].

Table 1.1 : Annual electricity loss in Asian countries

Country	Year		
	2009	**2010**	**2011**
India	21%	20%	21%
Pakistan	20%	16%	17%
Sri Lanka	14%	14%	12%
Thailand	6%	6%	7%
China	6%	6%	6%
Malaysia	6%	6%	6%
Singapore	6%	6%	5%
Japan	5%	4%	5%
South Korea	4%	4%	3%

Source: The World Bank official web site, http://data.worldbank.org/

In Sri Lanka, Ceylon Electricity Board (CEB) is the main electricity generation, transmission and distribution license holder. CEB also had been continuously decreasing its system energy loss since year 2000. In the year 2000 the annual system energy loss value was around 21.35%, but at the end of year 2013 it was reduced up to 10.79%. Figure 1.1 is shown the annual system energy loss values of CEB [2], [4].

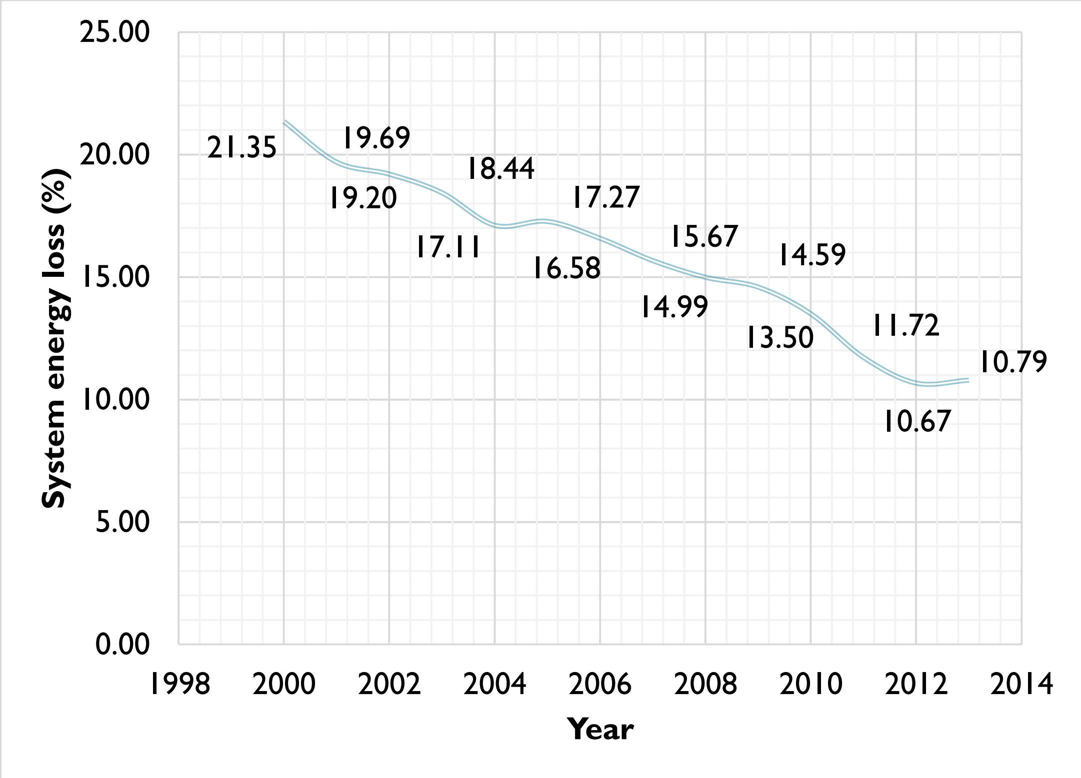

Figure 1.1 : Annual system energy loss values of CEB

Thus, electricity transmission and distribution licensee like CEB is trying to improve their electricity distribution system by reducing losses. Following strategies are being used commonly in order to reduce transmission and distribution losses.

- Increasing the system voltage
- Employing less resistivity conductors with larger current carrying capacity.
- Load balancing or phase balancing
- Adding separate lines or feeders
- Using energy efficient transformers
- Improving system power factor by adding shunt capacitors
- Reconfiguration of the electrical network

Some of the above mentioned modifications can be done more easily than others. For instance, it does not take a great deal of technical expertise to replace a transformer. Although, higher technical background is necessary to design high efficient and cost optimized transformer. Transformers act as passive devices for transforming voltage and current. At the same time, transformers cause an electrical power system to operate more efficiently than most of the electrical devices. So they are operated at 95% - 99% efficiency [3]. Table 1.2 shows some of the calculated efficiency values for distribution transformers which are used by CEB at 0.5 per unit loading.

Table 1.2 : Calculated efficiency values for distribution transformers used in 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 %

In Sri Lanka according to the application, two main categories of transformers are used. Those are substation type and distribution type transformers. Substation type transformers are built to step up the voltage from the low voltage at the generator to high voltage of the transmission system. And also, substation type transformers are located at substations in the transmission and distribution systems for stepping down voltage to distribute energy among various loads. Normally distribution transformers are used to step down the voltage to distribution level voltages for household, commercial and industrial consumers. Distribution transformers are smaller in capacity but higher in quantity. Since there are large number of transformers in use, small losses in each one added up to significant amounts. Total number of transformers in different categories in CEB network at the end of the year 2013 is shown in Table 1.3 [4].

Table 1.3 : Transformers in different categories in CEB network at the end of 2013

Transformer Category	Number of Transformers
Substation Type	181
Distribution Type	25,452

Source: Ceylon Electricity Board, Statistical Unit, "Statistical Digest, 2013"

1.1 Losses in Distribution Transformers

Distribution transformers are designed to step down the voltage to a distribution level for use in industrial, commercial or residential facilities. At the same time, they are very efficient devices in the electricity distribution network. Losses in a distribution transformer can be mainly divided into two categories; no load losses and load losses. Also, distribution transformer's no load losses and load losses can be categorized into other sub categories as mentioned in the Figure 1.2. The no load losses occur in the core of the transformer at all times regardless of load. But load losses occur in the transformer only when the transformer is loaded and its losses vary according to the square of the load current, because the most significant cause for load losses are I^2R losses or copper losses. Thus the load losses are directly proportional to square of the load current (I^2).

No load losses occurs in the distribution transformer core around the clock and throughout whole the year. It happens, when a voltage is applied to the transformer regardless of the loading on the transformer. They remain constant and occur even when the transformer secondary is open. The no load losses in a distribution transformer can be categorized into five components as shown in the Figure 1.2, i.e. hysteresis losses in the core laminations, eddy current losses in the core laminations, I^2R losses due to no load current, stay eddy current losses in core clamps, bolts and other core components and dielectric losses. Stay eddy current losses, dielectric losses and I^2R losses due to no load current are very small over other losses. Therefore those losses can be often neglected. But hysteresis losses and eddy current losses contribute over 99% of the no load losses while hysteresis loss is the biggest contributor [3].

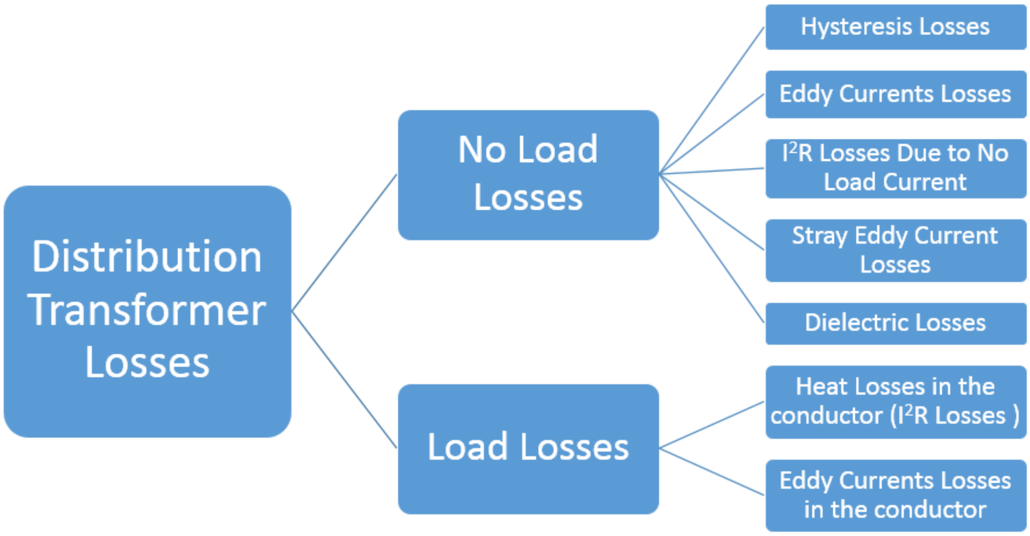

Figure 1.2 : Main contributing causes for distribution transformer losses.

The second type of loss component is load losses. The load losses depend on the loading pattern of the distribution transformer. They mainly consist of the heat losses in the conductor caused by the load current and eddy currents in the conductor. And 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 analysis of peak load as well as the load factor. Then, load factor can be converted to a loss factor. The most significant load loss component is I^2R loss or copper loss.

Transformer efficiency is reduced due to high no load losses and load losses. On the other hand, low efficient transformers affect the environment by requiring increased generation to supply the increased transformer losses. This increased generation to supply the energy losses to distribution transformers causes increased carbon dioxide in the air and contributes to the greenhouse effect [5]. Alternatively, transformers with higher energy efficiency reduce the required generation as well as emission of greenhouse gasses into the air.

1.2 Value of Losses of Distribution Transformers

The determination of amount of losses is important to the transformer purchaser, since it is a value judgment. Determining the value of transformer losses requires consideration of the design fundamentals and assumptions for calculating the cost of losses. Determination of the cost of losses may seem straightforward and simple at first glance. So it is basically the cost to produce, transmit and distribute each kilowatt of transformer loss. The electricity utility must add capacity to its generation, transmission and distribution system to deliver each additional kilowatt required to supply and deliver. It includes transformer losses too. In addition to the cost of generating, transmitting and distributing capacity for transformer losses, there is the cost of generating, transmitting and distributing the electrical energy. These, capacity and energy have to be dealt with individually.

Value of the no load losses and value of the load losses must be calculated throughout the total life span of the distribution transformer. In CEB, life span of a distribution transformer is considered as thirty five (35) years [2]. Total value of no load losses and load losses are spread over thirty five years of the distribution transformer, therefore the purchasing party has to calculate value of losses throughout the transformer life time to take count of the total value of losses in distribution transformers. On the other hand, manufacturing cost of a distribution transformer is increased when lowering the no load losses and load losses of distribution transformers. In other words, manufacturing cost and the value of no load and load losses of a distribution transformer is inversely related to each other. Table 1.4 shows some alternatives [3] which are followed by distribution transformer designers to reduce losses while maintaining the manufacturing cost as lower as possible.

Table 1.4 : Different alternatives to reduce losses during transformer design

		No Load Losses	**Load Losses**	**Manufacturing cost**
To decrease no-load losses				
A	Use low-loss core materials	Lower	No change	Higher
B	Decrease flux density by;			
	Increasing core cross sectional area	Lower	Higher	Higher
	Decreasing voltage per turn	Lower	Higher	Higher
C	Decrease flux path length by decreasing conductor cross sectional area	Lower	Higher	Lower
To decrease load losses				
A	Low-loss conductor material	No change	lower	Higher
B	Decrease current density by increasing conductor cross sectional area	Higher	lower	Higher
C	Decrease current path length by			
	Decreasing core cross sectional area	Higher	Lower	lower
	Increasing voltage per turn	Higher	Lower	lower

Source: Energy Efficient Transformers, by Barry W. Kennedy

1.3 Transformer Economics

The purchaser of distribution transformers wants to make a decision as to what transformer to purchase with optimality. There are various methods for performing an economic analysis of a transformer which helps the consumer to find the optimum solution. But the transformer purchaser has to select most suitable method for economic evaluation. Consistent use of economic method throughout the decision making and purchasing process is recommended for transformer manufacture to design a distribution transformer as to meet needs and values of the customer.

Transformer economics is necessary to weigh the transformer cost against the benefits of transformer efficiency. The time value of money over the life cycle of the alternatives needs to be evaluated. Efficiency improvement to save losses throughout the transformer life time must be compared with the initial cost of transformer purchasing. Basically, there are three types of standard methods for evaluating alternative transformer choices.

- Equivalent investment cost
- Levelized annual cost
- Present worth method

Each one of the above methods is applied to the initial cost of the distribution transformer and the cost of no load losses and load losses. In each method Total Owning Cost (TOC) (Equation 01) is applied. The selection of economic method should have no effect on the decision of what transformer is bought.

$$TOC = Transformer\ Bid\ Value + (No\ Load\ Loss) \times A + (Load\ Loss) \times B \qquad (01)$$

Where, A = Capitalization value of No Load Losses (LKR/W)

B = Capitalization value of Load Losses (LKR/W)

Life cycle costing is the fundamental concept used to derive the Total Owning Cost (TOC). This involves the calculation of total ownership cost over the life span of the transformer. Then the purchaser can compare the cost of losses with the cost of purchasing. Normally, transformer life cycle is considered as the expected life before its failure or expected life before its replacement.

2 PROBLEM STATEMENT

2.1 Identification of the Problem

The transformer cost is the main factor while selecting which transformer to be purchase. In purchase of the transformers, it is needed to evaluate transformer cost along with the cost of losses as well as relationship between the transformer cost and the amount of transformer losses. Thereby transformer purchaser tries to optimize the losses on the power system by purchasing of cost effective and energy efficient transformers. In the same way, transformer designers and manufacturers try to minimize the losses in the transformers at the design phase. The transformer manufacturers incorporate the cost of losses into the cost of the transformer in optimizing the transformer design.

During the transformer design process, designers have to input various data to a computer software or program to determine transformer cost. These data includes the cost of material, labor and overhead cost as well as specified performance characteristics such as impedance, temperature rise and noise levels. And also, transformer designers or manufacturers must weigh the cost of these factors to meet the customer's specification. They use "Total Owning cost (TOC) formula" [3] which is recalled as Equation 01 below to evaluate transformer total cost of its life time. Original transformer manufacturing cost, total no load cost throughout the expected life span of the transformer and the total load loss cost throughout the expected life span of the transformer are included in the transformer total cost.

$$TOC = Transformer\ Bid\ Value + (No\ Load\ Loss) \times A + (Load\ Loss) \times B \qquad (01)$$

Where, A = Capitalization value of No Load Losses (LKR/W)

B = Capitalization value of Load Losses (LKR/W)

So the determination of the transformer total owning cost is not a straightforward task. In some cases, transformer manufactures have to request for capitalization value of no load losses (A) and capitalization value of load losses (B). These capitalization values play a major role in the transformer designing process.

Basically, transformer designers have used these capitalization values as inputs to their transformer design software to create several transformer designs. There are several data sets which belongs to several transformer designs. Finally, those data are used to calculate total owning cost of particular transformer. Then, lowest TOC value is represented by the optimized transformer design as per consumer's request.

CEB uses standard specifications for purchasing transformers. In the specification [6], [7] of the substation transformers of CEB, cost of guaranteed losses is considered. Substation transformers are purchased by CEB through a competitive bidding process. Therefore, by specifying capitalization values for losses in CEB specification, bidders have to follow those values for their transformer designs. Then, CEB can select optimized transformer by considering TOC using data given by the bidders. The lowest TOC value is given by the most optimized transformer design, in general.

Table 2.1: No load loss and full load loss values for distribution transformers

Transformer (kVA)	No load loss (W)	Full load loss (W)
100 kVA, 11 kV / 415V	270	2150
160 kVA, 11 kV/ 415V	360	2650
250 kVA, 11 kV/ 415V	550	3700
400 kVA, 11 kV/ 415V	770	4700
100 kVA, 33 kV/ 415V	340	1900
160 kVA, 33 kV/ 415V	460	2450
250 kVA, 33 kV/ 415V	610	3150
400 kVA, 33 kV/ 415V	870	4000

Source: CEB STANDARD, 098:2000, Medium Voltage Distribution Transformers

But, it is not similar in the case of distribution transformers, because, capitalization values are not specified for the purchase of distribution transformers. Instead of that, CEB specifying fixed values for no load losses and load losses in the distribution transformer specification [8]. Table 2.1 shows the fixed loss values for different transformer categories. Also, the purchasing of the distribution transformer is not done through competitive bidding process. It is done by directly ordering form Lanka Transformer Limited (LTL) which is a subsidiary of CEB.

Therefore, absence of the usage of capitalization values for distribution transformers was identified as a problem by distribution division in CEB. Because, lowest manufacturing cost of the distribution transformer is not the only requirement to the CEB. In some cases, original cost will be a very low value but the value of life cycle cost of that particular transformer will become much higher. CEB can optimize distribution transformers in their network by using capitalization value of no load losses (A) and capitalization value of load losses (B).

2.2 Research Objective

The objective of this research is to develop a methodology to determine loss capitalization values suitable for distribution transformers in Sri Lanka.

2.3 Importance of the Study

Capitalization value of no load losses and load losses are not defined for distribution transformers in Sri Lanka. CEB is the dominant distribution license holder which has over 25,000 number of distribution transformers [4] in their distribution network. However, CEB is not concerned about TOC of their distribution transformer. Because, LTL produces distribution transformers based on fixed values of no load losses and load losses. No load losses and load losses are maintained within the defined loss values, but the value of Total Owning Cost (TOC) is not calculated for the particular distribution transformer design.

Some of the distribution transformers have placed in rural areas under rural electrification projects while some of the distribution transformers are situated in urban areas. Load demand pattern, demand growth, peak demand value, peak occurring time and responsibility to the national system peak are different between rural areas and urban areas. Therefore, the behavior of the transformer is different according to the place where the transformer is used. There are some places which have different load characteristics than rural and urban areas. And also, capitalization values are dependent on economic situation of the country as well as the cost of the energy and capacity of the organization. Therefore, using this research, it is possible to analyze about the sensitivity of the economic considerations on to the capitalization values too.

Using the fundamental equations and theories, capitalization values for distribution transformers can be calculated. CEB can use these for their tenders to purchase distribution transformers. And also, CEB can use these values for competitive bidding process. In addition to the calculation of the capitalization values for different load profiles, a methodology is developed in this research to find out capitalization values for any utility. Hence, by using this methodology anyone in the power sector can determine loss capitalization values easily.

3 METHODOLOGY

3.1 Calculation of Capitalization Values for Distribution Transformers

Distribution transformer evaluation is done by using total owning cost (TOC). In the TOC formula, the total owning cost is given by the purchasing cost of the transformer plus the cost of transformer no load losses and load losses discounted to present value and levelized over the life of the distribution transformer.

The transformers committee of the Institute of Electrical and Electronics Engineers (IEEE) has identified the requirement for a standard to evaluate the losses of substation transformers. They published a method for evaluating substation transformer no load and load losses entitled IEEE Loss Evaluation Guide for Power Transformers and Reactor (C57.120-1991) [9]. Evaluation of auxiliary power losses was included in this guide as well. This method is very similar to the method for distribution transformers except the dealing with auxiliary power losses. Because, in distribution transformers they do not have auxiliary unit. Calculation of the capitalization value of no load losses (A) and capitalization value of load losses (B) in a distribution transformer is done by using annualized total owning cost (Equation 01).

$$TOC = Transformer\ Bid\ Value + (No\ Load\ Loss) \times A + (Load\ Loss) \times B \qquad (01)$$

Where, A = Capitalization value of No Load Losses (LKR/W)

B = Capitalization value of Load Losses (LKR/W)

3.1.1 Capitalization value of no load losses

Basically, this is the value of unit no load loss of a distribution transformer throughout its life span. So this value can be presented as a value of LKR / W or USD / W. The ‘A’ value depends on cost of capacity and energy required to generate, transmit and distribute no load transformer losses, fixed charge rate. Figure 3.1 shows the factors attributed to the capitalization value of no load losses. This value does not depend on the loading pattern of the transformer. Capitalization value of no load losses is same in the entire life span of the distribution transformer. And also, no load losses are constant from a utilities perspective. The power to serve no load losses come from the base load demand of the system.

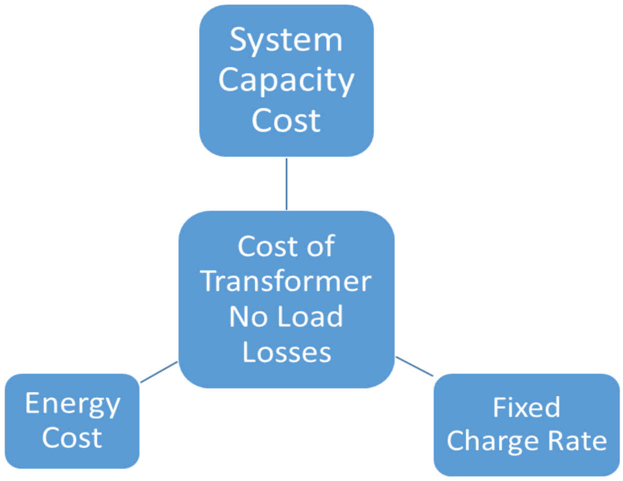

Figure 3.1 : Factors attributed to the capitalization value of no load losses

Steps involved in determining capitalization value of no load losses is shown as in the Figure 3.2.

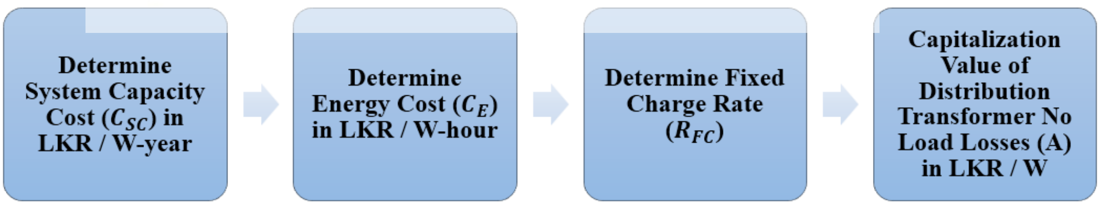

Figure 3.2 : Steps to find out capitalization value of no load losses

Equation 02 [9] can be used to calculate the no load loss capitalization value "A".

$$A = \left[\frac{C_{SC}+C_E \times 8760}{ET \times R_{FC} \times IF}\right] \times \frac{1}{1000} \qquad (02)$$

Where, C_{SC} – System capacity cost (LKR / kW / year)

C_E – Energy cost (LKR / kW-hour)

R_{FC} – Fixed charge rate

ET – Efficiency of transmission

IF – Increasing factor

8760 – Number of hours per year

3.1.2 System capacity cost

System Capacity Cost (C_{SC}) [3] 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. This component includes the cost of generation in the cost of generation in reserves. The system capacity cost is given by the Equation 03.

$$C_{SC} = C_{GC} + C_{TC} + C_{DC} \quad (03)$$

Where,

$C_{SC} - System\ capacity\ cost$ (LKR / kW / year or USD / kW / year)

$C_{GC} - Generation\ capacity\ cost$ (LKR / kW / year or USD / kW / year)

$C_{TC} - Transmission\ capacity\ cost$ (LKR / kW / year or USD / kW / year)

$C_{DC} - Distribution\ capacity\ cost$ (LKR / kW / year or USD / kW / year)

The value of the generation capacity cost is determined by using the cost of installing generation and the fixed charge rate for generation. And also, the transmission capacity cost is determined by using the cost of installing transmission systems. In a similar way, the distribution capacity cost is determined by using the cost of installing distribution systems.

3.1.3 Levelized energy cost

The term, levelized energy cost (C_E) [3] includes any cost proportional to the energy output of the generator. This would include the cost of fuel and the cost of operation, maintenance, the transportation, storage and conversion of fuel to electrical energy. For an example, for a coal power plant it would include the cost of the coal, the cost to operate and maintain the equipment to transport coal and operate and maintain the equipment necessary to convert coal to electrical energy and the cost of transmission and distribution of that converted energy up to the distribution end.

3.1.4 Annual fixed charge rate

The levelized annual fixed charge rate (R_{FC}) [3] 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 the following components,

- Minimum acceptable return
- Book depreciation
- Income taxes
- Local property taxes and insurance

3.1.5 Efficiency of transmission

The term, efficiency of transmission (ET) [9] is defined as the energy received at the input terminals of the transformer divided by the energy transmitted from the source. Normally, the efficiency varies with loading, location, voltage level or seasonally, etc. Sometimes, the efficiency of transmission becomes significantly large in some instances. But a general, overall system efficiency is adequate for this term according to the IEEE loss evaluation guide.

3.1.6 Increasing factor

The Increasing factor (IF) [9] represents the additional cost (other than direct purchase cost) that the user must pay to acquire the transformer. This term includes components like purchase price of the transformer, overhead fees and taxes. According to the IEEE loss evaluation guide, some of the examples of applicable cost increase factors are mentioned below.

- Sales tax
- Architect-engineers fee
- Consultant’s supervision fee
- Contractor’s fee
- Job order fee (imposed by outside organizations)
- Interest during construction
- Extended warranty and transportation insurance

3.2 Capitalization Value of Load Losses

Basically, the capitalization value of load losses (B) is the value of unit load loss of a distribution transformer throughout its life span. So this value can be presented as a value of LKR / W or USD / W. The capitalization value of the load losses is not constant for the distribution transformer and varies according to the load pattern, load growth and behavior of the load profile. The ‘B’ value is dependent on annual loss factor, peak responsible factor, equivalent annual peak load, fixed charge rate of the transformer as well as the cost of capacity and energy required to generate, transmit and distribute transformer losses [3]. Figure 3.3 shows the factors attributed to the capitalization value of load losses.

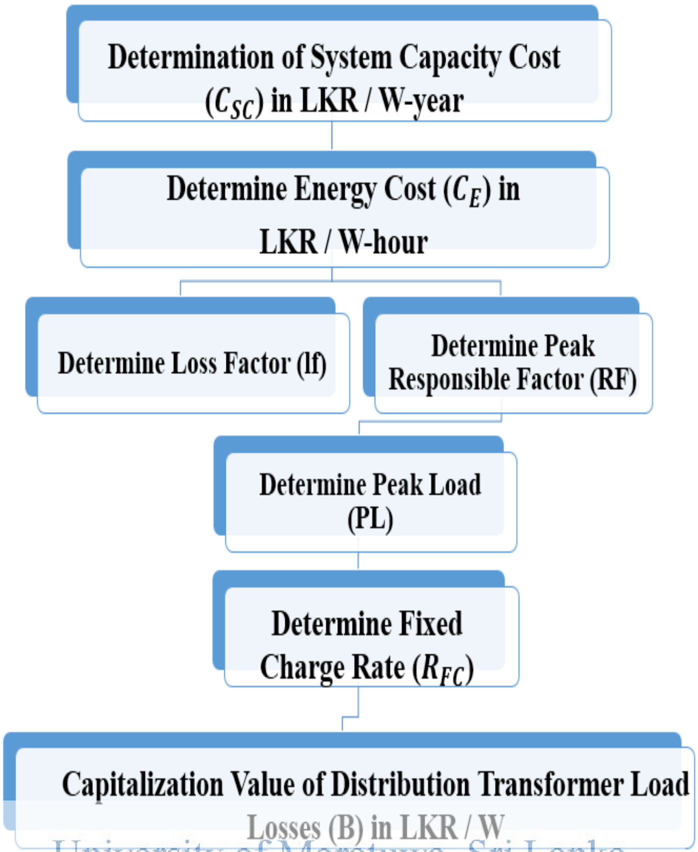

Figure 3.4 : Flow chart for the determining the capitalization value of Load Losses

3.3 Bottom up Approach

Distribution transformers are installed in different geographical locations in the country. Such as, rural areas and urban areas. In between, there are some load profile patterns which are a mixer of rural and urban load patterns. Hence, the behaviors of these load profiles are different from each other. Therefore, analysis of load profiles has to be done for each kind of application. As an example, demand growth, responsibility of the peak loading and load factor are different in rural areas from urban areas. Basically, these kinds of factors are calculated using field measurement data in different areas. This kind of approach is known as “Bottom up” approach in utility planning which is shown in the Figure 3.5.

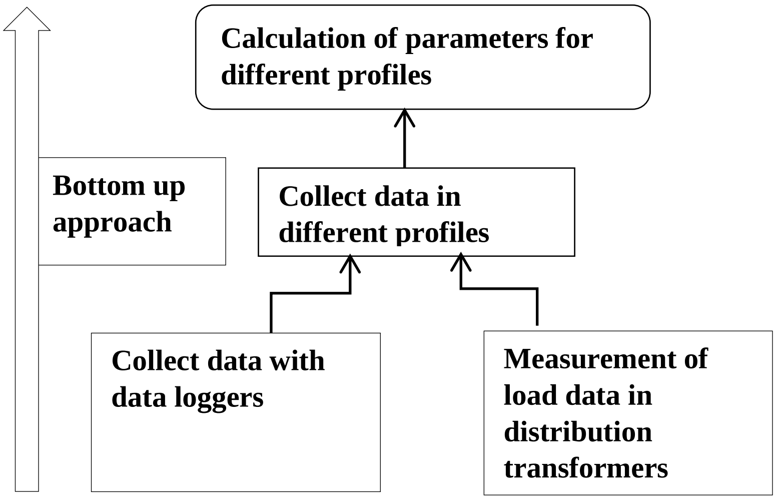

Figure 3.5 : Bottom up approach

3.4 Categorization of Distribution Transformers

Distribution transformers behave in different ways according to their load profiles. Measurement were made on distribution transformers located in the Sabaragamuwa province (CEB Sabaragamuwa Province). Distribution transformers are picked from several areas like Embilipitiya, Kolonna, Godakawela, Balangoda, Kahawaththa, Openayake, Rathnapura, Wewalwaththa, Kuruwita, and Eheliyagoda in a random scattered nature. Therefore, in this study distribution transformers are categorized into three groups as discussed below.

3.4.1 Distribution transformers in rural areas

- In this category distribution transformers in rural areas are considered. These kind of transformers are found in rural villages.
- Consumption of energy is largely on household activities with relatively very low commercial or industrial consumers.
- Only morning and night peaks appears.
- Distribution transformers selected for the study are shown in Table 3.1.

Table 3.1 : Selected distribution transformers in rural areas

Distribution transformer name	Substation Identification Number (SIN)	Name plate rating (kVA)
Mapalana	C056	160
Deiyannegama	C051	100
Udahagoda	U016	100
Dombagaswinna	T042	100
Wijeriya	U044	100

3.4.2 Distribution transformers in semi urban areas

- Distribution transformers in small towns, especially at places like junctions and small towns, are considered in this category.
- Consumption of energy in household activities as well as considerable amount of commercial and industrial activities, are seen.
- Morning, day time and night peaks appears in the load curve.
- Distribution transformers selected for the study are shown in Table 3.2.

Table 3.2 : Selected distribution transformers in semi urban areas

Distribution transformer name	Substation Identification Number (SIN)	Name plate rating (kVA)
Gonakumbura	C074	100
Bisokotuwa	S081	160
Weligepola	S030	100
Kalthota	P137	100
Rakwana	Q071	160

3.4.3 Distribution transformers in urban areas

- Distribution transformers in heavily commercialized towns are considered.
- Consumption of energy due to commercial & industrial activities are prominent but there are very small number of household consumers as well.

- Day time peak is dominant compared to morning or night peaks.
- Distribution transformers selected are shown in Table 3.3.

Table 3.3 : Selected distribution transformers in urban areas

Distribution transformer name	Substation Identification Number (SIN)	Name plate rating (kVA)
Rathnapura Clock Tower	F066	250
Sevana Camp	R051	100
Yodagama	R039	400
Moragahayata	F045	250
Kudugalwaththa	F058	250

3.5 Data Collection

Data collection was done in above distribution transformers using data loggers. Data logger and energy meters were placed at the secondary side of the distribution transformer. Data were collected as average current, average voltage, average power factor, export demand and average frequency at fifteen (15) minutes intervals. Data logger and energy meters were placed at each locations for more than seven days. Data was collected in week days as well as weekends. Digital energy meters were placed permanently in some of the places. Some of the load data of distribution transformers were taken from provincial planning engineer's unit which were taken at system peak. Figure 3.6 shows some of the load data at distribution transformers. Figure 3.7 shows a sample of the data recorded using a data logger at Yodagama-R039 (400 kVA) distribution transformer.

	B	C	D	E	F	G	H	I	J	K	L
1		CSC:	Ratnapura - East								
2											
3		SIN No(A-001)	Substation Name	Date(DD/M	Capacity(kVA)	No .of feeders	Feeder Name	R	Y	B	N
4		C-001	Meehitiya	20/1/2014	100	2	Ratnapura	100	109	82	36
5		C-002	Ollugala	29/1/2014	100	2	Dandeniya	22	23	16	13
6		C-003	Malwala	20/1/2014	160	3	Ilukwatta	49	9	60	40
7		C-004	Gilimale	24/1/2014	100	3	Ilukwatta	80	10	12	60
8		C-005	Pallawakanda	23/1/2014	100	2	Pallawakanda	16	12	47	30
9		C-007	Guruluwana Tea	19/2/2014	160	1	Labuwawa	0.5	0.4	0	0.6
10		C-008	Samanaliya Tea	13/2/2014	160	1	Mahayaya	65	0	0	65
11		C-009	Siripagama	13/2/2014	100	2	Palabaddala	30	6	1	26
12		C-010	Gonakumbura 1	21/2/2014	100	3	Demalagamma	46.2	63.4	65.7	23.7
13		C-011	Ketandola	24/2/2014	100	2	Patulpana	53	46	16	39
14		C-012	Upper Hakamuwa	17/2/2014	150	2	Pahala Hakamu	37.4	68.9	51.2	22.7
15		C-013	Lower Hakamuwa	17/2/2014	160	3	Siman Mw	99.1	77.9	0	52.9
16		C-015	Patulpana	24/2/2014	160	2	Katandola	8	108	53	40
17		C-016	Galabada Tea	29/1/2014	160	1	Galabada State	55	37	88	37
18		C-017	Fernidel Tea	29/1/2014	250	2	Meegastenna	103	67	48	39
19		C-018	Silver Land Tea	12/2/2014	250	1	Silver Land	5	0	0	5
20		C-019	Gallella	28/1/2014	160	3	Gallella Hospit	1	1	3	3
21		C-020	Babarabotuwa Te	28/5/2014	100	1	Babarabotuwa	3	3	3	1
22		C-021	Ratganga	4/2/2014	100	3	kudawa	38	31	50	24
23		C-022	Hapugastenna Ru	25/1/2014	250	2	Hale Ela	19	24	6	20

Bulathkohupitiya | Kuruwita | Kiriella | Eheliyagoda | Metro | Kalawana | Nivitigala | East

Figure 3.6 : Load data at distribution transformers

Time/Date	2013.03.11	2013.03.12	2013.03.13	2013.03.14	2013.03.15	2013.03.16	2013.03.17	Average	2013.03.11	2013.03.12	2013.03.13	2013.03.14	2013.03.15	2013.03.16	2013.03.17	Average
0:00	46150	49030	39210	42750	38620	36150	36620	41218.57	4059.39	4545.46	2949.58	3483.36	2902.70	2506.67	2540.50	3283.95
0:15	46290	49420	39040	42280	38740	33190	38060	41002.86	4125.92	4679.93	2973.88	3443.73	2898.03	2135.98	2738.08	3285.08
0:30	42570	49250	37730	43580	37810	32930	37520	40198.57	3492.42	4668.08	2772.37	3661.06	2749.60	2101.61	2656.37	3157.36
0:45	42900	48690	37160	40010	37390	31740	37850	39391.43	3546.20	4572.46	2663.25	3067.68	2688.08	1939.23	2694.30	3024.46
1:00	43690	50120	37790	39580	38620	32330	35660	39684.29	3687.73	4807.11	2767.81	2994.28	2851.92	2011.22	2385.35	3072.20
1:15	46060	48620	36100	39650	38570	32950	35830	39682.86	4079.38	4491.68	2535.46	3004.50	2830.95	2085.14	2448.27	3067.91
1:30	45820	49410	37430	39310	37940	32040	35210	39594.29	4015.76	4635.79	2717.19	2937.64	2725.19	1966.63	2377.86	3053.72
1:45	47940	47220	36870	40060	38160	31260	35090	39514.29	4334.91	4226.30	2615.98	3043.73	2761.50	1864.80	2354.84	3028.87
2:00	47350	45970	36040	38450	39110	31270	35400	39084.29	4244.96	3980.35	2480.70	2790.66	2885.48	1862.21	2399.37	2949.10
2:15	46160	47620	36520	37880	38240	32040	36190	39235.71	4035.64	4243.65	2533.78	2699.84	2753.45	1950.69	2506.00	2960.44
2:30	46580	48430	36320	38920	38240	31530	37120	39591.43	4125.49	4367.89	2499.33	2841.60	2759.05	1899.51	2646.42	3019.90
2:45	44710	46790	35330	39110	38350	30330	36100	38674.29	3841.11	4188.68	2381.11	2879.40	2770.62	1753.66	2515.36	2904.28
3:00	41980	46260	36780	38090	38290	29930	36500	38261.43	3385.69	4103.26	2597.94	2737.38	2757.30	1708.17	2571.17	2837.27
3:15	43840	41690	35700	37690	37270	30580	35640	37487.14	3688.94	3320.83	2442.01	2680.48	2612.91	1783.09	2445.96	2710.60
3:30	43310	41090	35240	38490	38730	30130	36060	37578.57	3588.81	3217.54	2383.72	2789.95	2818.55	1733.06	2496.00	2718.23
3:45	42570	46510	35960	37260	38240	30410	37110	38294.29	3469.60	4142.64	2477.38	2602.36	2752.75	1766.80	2638.19	2835.68
4:00	43500	48860	33480	39460	39400	30840	37680	39031.43	3621.23	4590.06	2135.67	2906.29	2938.36	1819.02	2711.28	2960.27
4:15	45110	48390	34310	38650	44710	31920	35980	39867.14	3898.34	4518.53	2269.57	2788.19	3811.83	1936.00	2475.06	3099.65
4:30	46810	44220	35240	39030	45140	35400	38210	40578.57	4211.14	3790.04	2416.71	2871.89	3908.33	2392.19	2811.47	3200.25
4:45	46530	44750	35670	38720	49090	38320	38590	41667.14	4177.90	3904.58	2447.94	2856.19	4686.32	2812.18	2877.25	3394.62
5:00	46460	54600	40500	41680	48950	41070	38750	44572.86	4197.74	5756.76	3125.18	3382.20	4559.40	3263.84	2920.68	3886.54
5:15	49770	57580	43440	46020	51670	42410	39610	47214.29	4819.14	6460.94	3636.89	4159.82	5128.47	3462.93	3023.17	4384.48

Figure 3.7 : Recorded load data using data logger

3.5.1 Calculation of load factor and loss factor

With the collected load demand data, a graph is plotted between demands (kW) vs duration of the demand values (Hours). Another graph is plotted between square values of load currents (A^2) vs duration of the load currents (Hours). These graphs are used to calculate load factor and loss factor of distribution transformers.

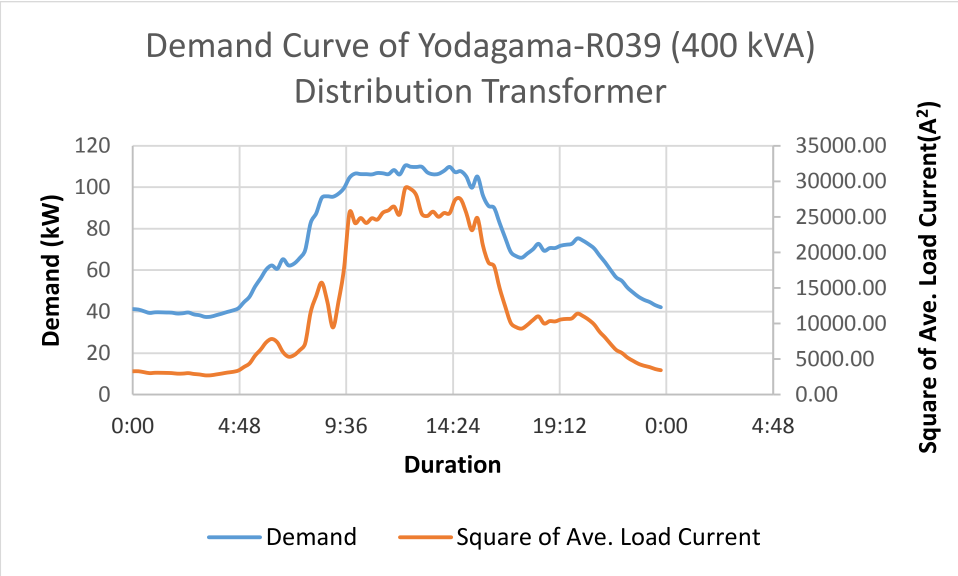

Figure 3.8 : Demand curve and loss of load curve, Yodagama – R039 (400 kVA)

The load factor is considered as a measure of utilization of the electricity network. Because, in electrical networks peak power is observed for a short duration. The capacity of the electricity network is not fully utilized during the off peak time. Thus, in the graph plotted between demand values (kW) vs duration (Hours), the area under the plotted graph represented how best transformer is utilized. The average load can be calculated by using value of the area under the curve and duration of the curve (Equation 06 and Equation 07). And also, the peak value of the demand curve was found and the load factor was calculated using average load and the peak value from the graph, as shown as in the Equation 08 and Equation 09.

$$E = \int_0^T P dh = \text{Area under demand curve} \qquad (05)$$

$$P_{av} = \frac{1}{T}\int_0^T P(t)\,dt \qquad (06)$$

Average Load = [Area under the load curve / Duration] (07)

Peak Load = Peak load value from the graph (08)

Load Factor = (Average Load / Peak Load) (09)

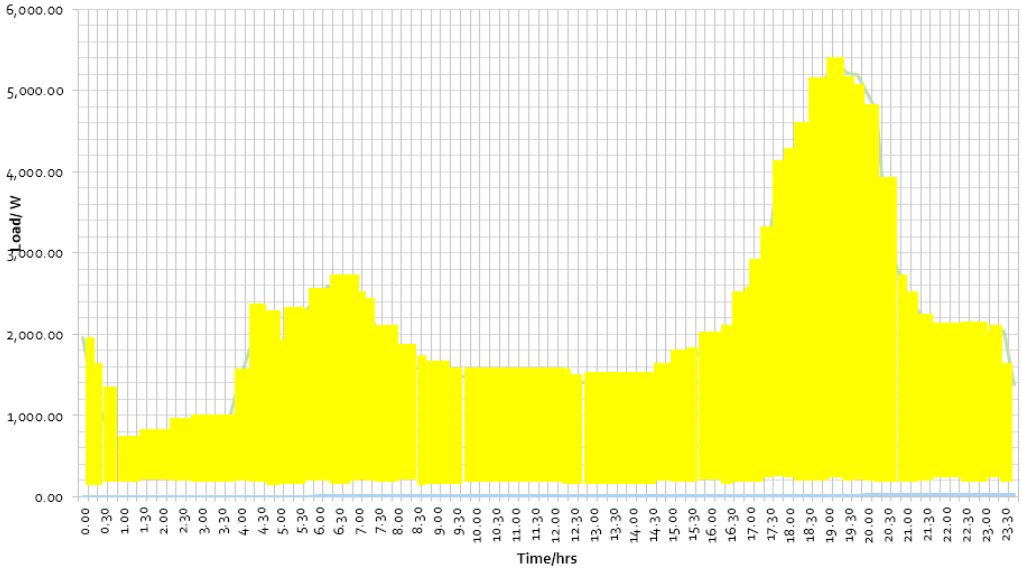

Figure 3.9 : Graph between load demand vs. duration

In the same way, the calculation of load factor and loss factor in load profiles of distribution transformers in rural, semi urban and urban areas were done. As per the Equation 10 if the resistance (R) is constant, then the power loss is directly proportional to the square values of load current (A^2). A graph was plotted between Square values of load currents (A^2) vs Duration (Hours) as shown in the Figure 3.8. Then, the Loss factor was calculated using Equation 07, 08 and 09 as shown above.

Power Loss = $(I^2) \times R$ (10)

Where,

I – Load Current (A)

R – Impedance (Ω)

Distribution planning engineers are used Equation 11 which is an empirical equation.

$$lf = (a \times LF) + (b \times LF^2) \quad (11)$$

Where,

LF - Load Factor

lf - Loss Factor

a = (1-b)

a, b – constant values dependent on loading profile

In CEB, planning engineers use 0.2 and 0.8 respectively for ‘a’ and ‘b’. Then the Equation 11 was recalled in the following manner.

$$lf = (0.2 \times LF) + (0.8 \times LF^2) \quad (11)$$

3.5.2 Uniform annual peak load

The term uniform annual peak load (PL) [3] was given the levelized peak load per year over the life of the transformer. Also it expresses by the transformer’s initial peak load with an estimated load growth rate and a maximum allowable load before the transformer change out is required.

This uniform annual peak load was calculated using following Equation 14 [3],

$$PL = \left[\left\{\sum_{j=1}^{n_1}\left[b(1+g)^{(j-1)}\right]^2 * \left[\frac{1}{(1+i)^{n_1}}\right]\right\} * \left\{\frac{i(1+i)^{n_1}}{(1+i)^{n_1}-1}\right\}\right]^{1/2} \quad (14)$$

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

Relationship between Load Factor (LF), Loss Factor (lf) and the Annual Peak Loading (PL) was given by the Equation 15 according to the IEEE loss evaluation guide [9].

$$(LF^2) = (lf) \times (PL^2) \qquad (15)$$

Where, LF - Load Factor

lf - Loss Factor

PL - Uniform Annual Peak Loading

3.5.3 Peak responsibility factor

The term peak responsibility factor (RF) [3] describes the diversity of the load on the transformer. The peak responsibility factor (RF) indicates as the relationship between the transformer peak load and the transformer load at the time of the utility system peak load. This means, 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. The peak responsibility factor (RF) is calculated using Equation 16, below.

$$RF = \frac{\text{Transformer load at the system peak}}{\text{Transformer peak load}} \qquad (16)$$

4 DETERMINATION OF CAPITALIZATION VALUES

4.1 Calculation of the Capitalization Value of No Load Loss

The capitalization value of no load loss (A) is calculated according to the methodology describes in the chapter 03, under the section 3.1.1. By recalling the Equation 02.

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

Where, C_{SC} – System capacity cost (LKR / kW / year)

C_E – Levelized energy cost (LKR / kW-hour)

R_{FC} – Fixed charge rate

ET – Efficiency of transmission

IF – Increasing factor

8760 – Number of hours per year

4.1.1 Calculation of fixed charge rate

Fixed Charge Rate (R_{FC}) is given by the combination of following components according to the methodology describes in the chapter 03, under the section 3.1.4.

- Minimum Acceptable Return = 12.75 %

  This term represents opportunity cost.

- Book Depreciation = 2.86%

  Distribution transformers are taken as fixed assets in the accounting perspective of CEB. Hence, the value of 1/35 is given as a percentage for book depreciation by using straight line method.

- Income taxes = 0%

  This term is not relevant to semi government organizations like CEB. Hence income taxes are taken as zero.

- Local Property taxes and insurance = 0.1%

  There was no any local property tax value for CEB properties. But CEB takes 0.1% as their self-insurance reserves [2], [13].

Therefore, fixed charge rate is given by as follows.

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

4.1.2 Efficiency of the transmission

The CEB's overall system loss in year 2013 was 10.79 % [4]. As per the IEEE loss evaluation guide [9], the efficiency of the transmission (ET) was calculated as follows.

Efficiency of the Transmission (ET) = (1 – overall losses) = (1 – 0.1079) = 0.8921

4.1.3 Increasing factor

As mentioned in the chapter 03, in section 3.1.6 several factors affect this term. CEB considers overhead cost together with labor charges. And also, sales taxes are not applicable to CEB. Therefore, components like overhead cost, sales taxes and consultancy fees are not taken for the calculation of increasing factor (IF). The purchase price is the only component considered. Hence, increasing factor is taken as 1.00 for the calculation.

Increasing Factor (IF) = (purchase price + overhead + taxes) / (purchase price)

= (purchase price + 0 + 0) / (purchase price) = 1.00

4.1.4 System capacity cost

System capacity cost (C_{SC}) for each month in the year of 2013 is shown in the Table 4.1 [11]. Therefore average annual value of system capacity cost is taken as 24,000.00 LKR / kW /year

Table 4.1 : System capacity cost values for the year 2013 [11]

Month	Generation system capacity cost (LKR/kW/year)	Transmission & distribution system capacity cost (LKR/kW/year)	Total system capacity cost (LKR/kW/year)
January	1654.29	349.46	2003.75
February	1548.86	335.43	1884.29
March	1551.65	327.98	1879.63
April	1685.88	358.99	2044.87
May	1593.31	337.73	1931.04
June	1609.52	343.92	1953.44
July	1704.03	329.00	2033.03
August	1736.42	328.75	2065.17
September	1704.85	325.48	2030.33
October	1740.27	329.48	2069.75
November	1760.89	336.58	2097.47
December	1754.62	337.43	2092.05
Average annual value			**24,000.00**

4.1.5 Energy cost

Average energy cost (C_E) for the present year (2013) is taken as 12.69 LKR / kWh [11]. The average energy cost was escalated over the life time of the distribution transformer, then the present worth of the energy cost was taken and levelized it over the life span of distribution transformer shown in Table 4.2. Also, inflation (a) was calculated as 6.425 % (Appendix 01) [12] and the rate of return (i) was calculated as 10.42 % (Appendix 02) [12] respectively. Number of years of the life time of a distribution transformer (n) was taken as 35 years.

Table 4.2 : Calculation of the levelized energy cost

Year	Cost of energy [$C_{e,1} \times (1+a)^n$]	Present worth factor (PWF) - [(1+i)^(-n)]	Present worth value [(C_e)×(PWF)]
1	13.51	0.91	12.23
2	14.37	0.82	11.79
3	15.30	0.74	11.36
4	16.28	0.67	10.95
5	17.33	0.61	10.59
6	18.44	0.56	10.25
7	19.62	0.51	9.92
8	20.88	0.46	9.60
9	22.23	0.42	9.28
10	23.65	0.38	8.98
11	25.17	0.35	8.69
12	26.79	0.31	8.41
13	28.51	0.29	8.13
14	30.34	0.26	7.87
15	32.29	0.24	7.61
16	34.37	0.21	7.37
17	36.58	0.19	7.13
18	38.93	0.18	6.90
19	41.43	0.16	6.67
20	44.09	0.15	6.45
21	46.92	0.13	6.24
22	49.94	0.12	6.04
23	53.15	0.11	5.85
24	56.56	0.10	5.66
25	60.19	0.09	5.47
26	64.06	0.08	5.29
27	68.18	0.08	5.12
28	72.56	0.07	4.96
29	77.22	0.06	4.79
30	82.18	0.06	4.64
31	87.46	0.05	4.49

32	93.08	0.05	4.34
33	99.06	0.04	4.20
34	105.43	0.04	4.06
35	112.20	0.04	3.93
Sum of present worth (LKR / kWh)			255.27

The capital recovery factor (CRF) [9] was used to compute the levelized cost throughout the life span of the distribution transformer (35 years).

CRF = $[i \times ((1+i)^n)] / [((1+i)^n) - 1]$

= $[0.1042 \times ((1+0.1042)^{35})] / [((1+0.1042)^{35}) - 1]$

=0.1075

Sum of present worth (LKR / kWh) = 255.27

Levelized annual cost of energy (C_E) = 255.27×0.1075

= 27.45 LKR / kWh

Therefore, the capitalization value of no load losses is calculated using above mentioned data in the section 4.1.1 to section 4.1.5.

System capacity cost (C_{SC}) = 24,000 LKR / kW / year

Levelized energy cost (C_E) = 27.45 LKR / kWh

Fixed charge rate (R_{FC}) = 0.1571

Efficiency of transmission (ET) = 0.8921

Increasing factor (IF) = 1.00

Hours per year (HPY) = 8760

$$A = \left[\frac{24000 + 27.45 \times 8760}{0.8921 \times 0.1571 \times 1}\right] \times \frac{1}{1000}$$

= 1887 LKR / W

4.2.1 Calculation of loss factor, uniform annual peak loading and responsibility factor

Loss factor (lf) is calculated in terms of load factor (LF). Normally, the load factor is considered as a measure of utilization of the electricity network. So, the load factor and loss factor are calculated according to the methodology as mentioned in the chapter 03 in section 3.5.1. Uniform annual peak loading and peak responsibility factor are calculated according to the methodology as mentioned in the Chapter 03 in section 3.5.2 and section 3.5.3 respectively.

4.2.2 Sample calculation for distribution transformers in rural areas

The calculation of the load factor (LF) and the peak responsible factor (RF) are calculated using measurement, made on several distribution transformers in rural areas. Transformers in rural areas were selected according to norms mentioned in the Chapter 03 under the Section 3.4.1. Using recorded data from five distribution transformers, load curves were plotted as in the Figure 4.1. A Sample calculation was done using data recorded from Mapalana distribution transformer – C056 (160 kVA). Recorded data were attached as Appendix 03.

Average Load = [Area under the Load curve / (24x7)]

= [2254.37 / (24x7)]

= 13.42 kW

Peak Load = 29.32 kW

Load Factor = (Average Load / Peak Load)

= (13.42 / 29.32)

= 0.4577

$\simeq$ 46 %

In the similar manner, load factors were calculated for the rest of the distribution transformers. The calculated values of load factor for each distribution transformer are shown in the Table 4.3.

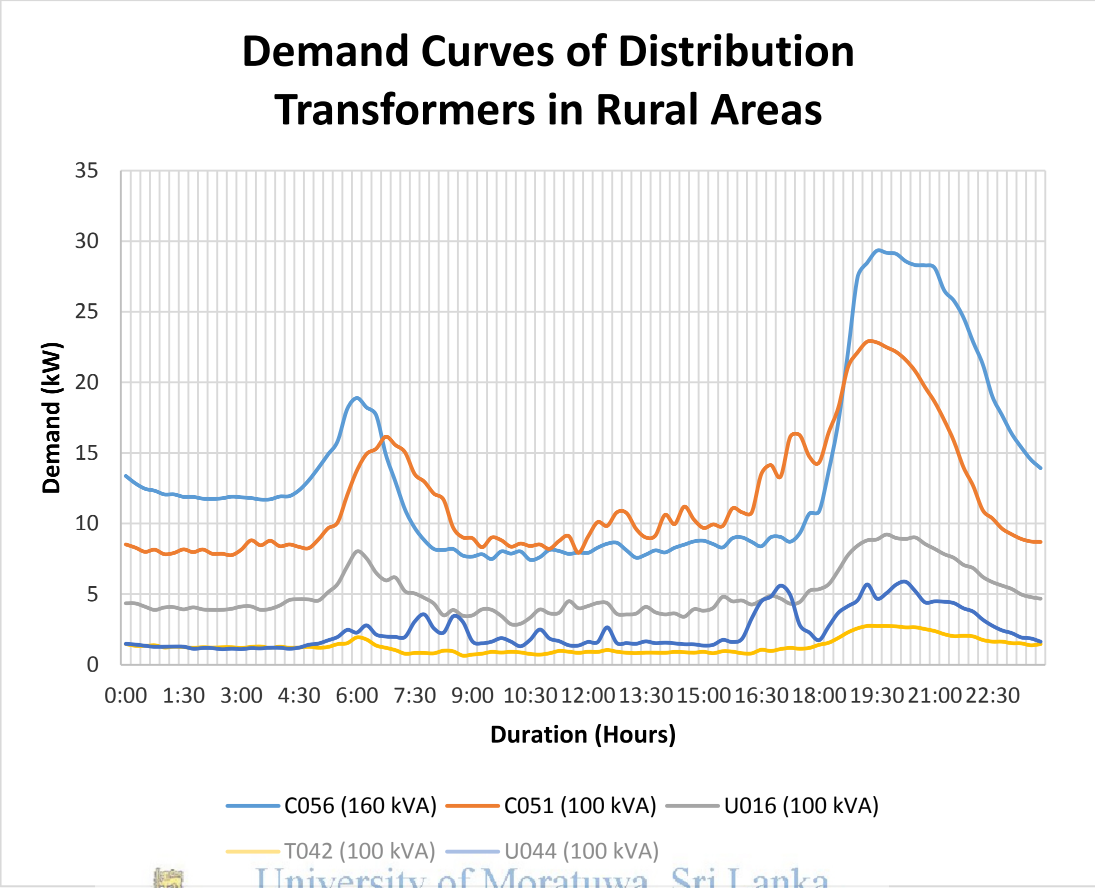

Figure 4.1 : Demand curves for distribution transformers in rural areas

Table 4.3 : Calculated Load Factors for distribution transformers in rural areas

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

Then by taken the average of the Load Factors in above mentioned distribution transformers, Load Factor for distribution transformers in rural areas was considered as **48%.**

Loss Factor of distribution transformers in rural areas was calculated by recalling the Equation 11.

$$lf = (0.2 \times LF) + (0.8 \times LF^2) \quad (11)$$
$$= (0.2 \times 0.48) + (0.8 \times 0.48^2)$$
$$= 0.28$$

And also, the peak responsibility factor (RF) is another important term in the capitalization value equation (Equation 04). 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. By using data measured from Mapalana distribution transformer – C056 (160 kVA) and recalling the Equation 16,

$$RF = \frac{\text{Transformer load at the system peak}}{\text{Transformer peak load}} \quad (16)$$

$$= (26.80\ kW) / (29.32\ kW) = 0.91$$

The Peak Responsibility Factors (RF) were calculated for other distribution transformers in rural areas and are shown in the Table 4.4.

So, an average value was obtained as 0.90 for the peak responsibility factor of distribution transformers in rural areas by considering sample calculated values in Table 4.4. Therefore, peak responsibility factor (RF) of distribution transformers in rural areas was considered as 0.90.

Calculation of uniform annual peak loading (PL) was done by recalling the Equation 15 from chapter 03 in section 3.5.3.

$$(LF^2) = (lf) \times (PL^2) \quad (15)$$

Where, LF - Load Factor

lf - Loss Factor

PL - Uniform annual Peak Loading

Load factor (LF) = 0.48

Loss factor (lf) = 0.28

Uniform annual peak loading (PL) $= [(LF^2) / (lf)]^{0.5}$

= 0.9071

Table 4.4 : Calculated values for the peak responsibility factor of distribution transformers in rural areas.

Name of Sub Station	Average at System Peak (kW)	Peak Load (kW)	Peak Responsible Factor
Mapalana (C056)	26.80	29.32	0.9141
Deiyannegama (C051)	20.43	22.88	0.8927
Udahagoda (U016)	8.37	9.22	0.9078
Dombagaswinna (T042)	24.68	27.41	0.9003
	Average		0.9000

Then the capitalization value of load losses for distribution transformers in rural areas is calculated as shown below.

System capacity cost (C_{SC}) = 24,000 LKR / kW / year

Levelized energy cost (C_E) = 27.45 LKR / kWh

Fixed charge rate (R_{FC}) = 0.1571

Efficiency of Transmission (ET) = 0.8921

Increasing Factor (IF) = 1.00

Loss Factor (lf) = 0.28

Peak responsibility factor (RP) = 0.9

Uniform annual peak load (PL) = 0.9071

Hours per year (HPY) = 8760

$$B = \left[\left\{\frac{C_{SC} \times RF^2 + [C_E \times 8760 \times (lf)]}{ET \times R_{FC} \times IF \times 1000}\right\} \times PL^2\right] \quad (4)$$

$$B = \left[\frac{24000 \times 0.9 \times 0.9 + 27.45 \times 8760 \times 0.28}{0.8921 \times 0.1571 \times 1 \times 1000}\right] \times 0.9071 \times 0.9071$$

= 509.43 LKR / W

Exchange rate of 1 USD to Sri Lankan rupees is considered as 130. Thus, the capitalization value of load losses in distribution transformers (B) in rural areas is taken as **500 LKR / W** or **3.92 USD / W.**

4.2.3 Sample calculation for distribution transformers in semi urban areas

The demand curves for five distribution transformers installed in semi urban areas are shown in Figure 4.2 below.

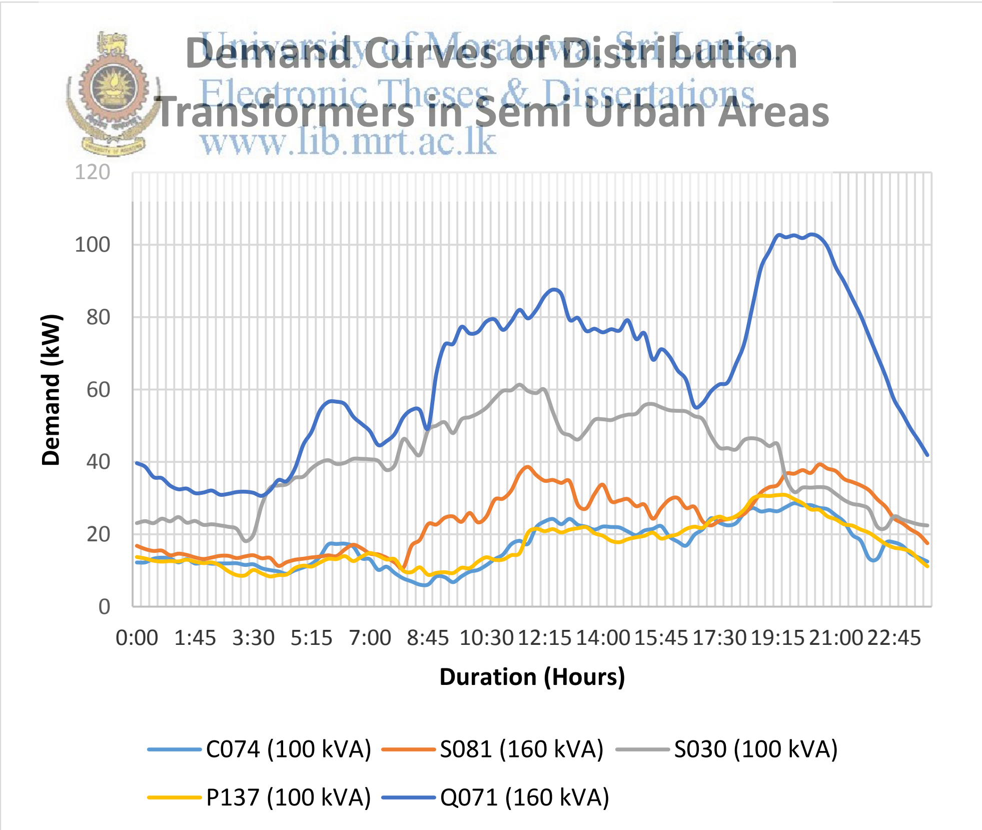

Figure 4.2 : Demand curves for distribution transformers in semi urban areas

Following a similar procedure as described in 4.2.2 the capitalization value of load losses in distribution transformers (B) for semi urban areas is calculated to be **750 LKR / W** or **5.69 USD / W**.

4.2.4 Sample calculation for distribution transformers in urban areas

The demand curves for five distribution transformers installed in urban areas are shown in Figure 4.3 below.

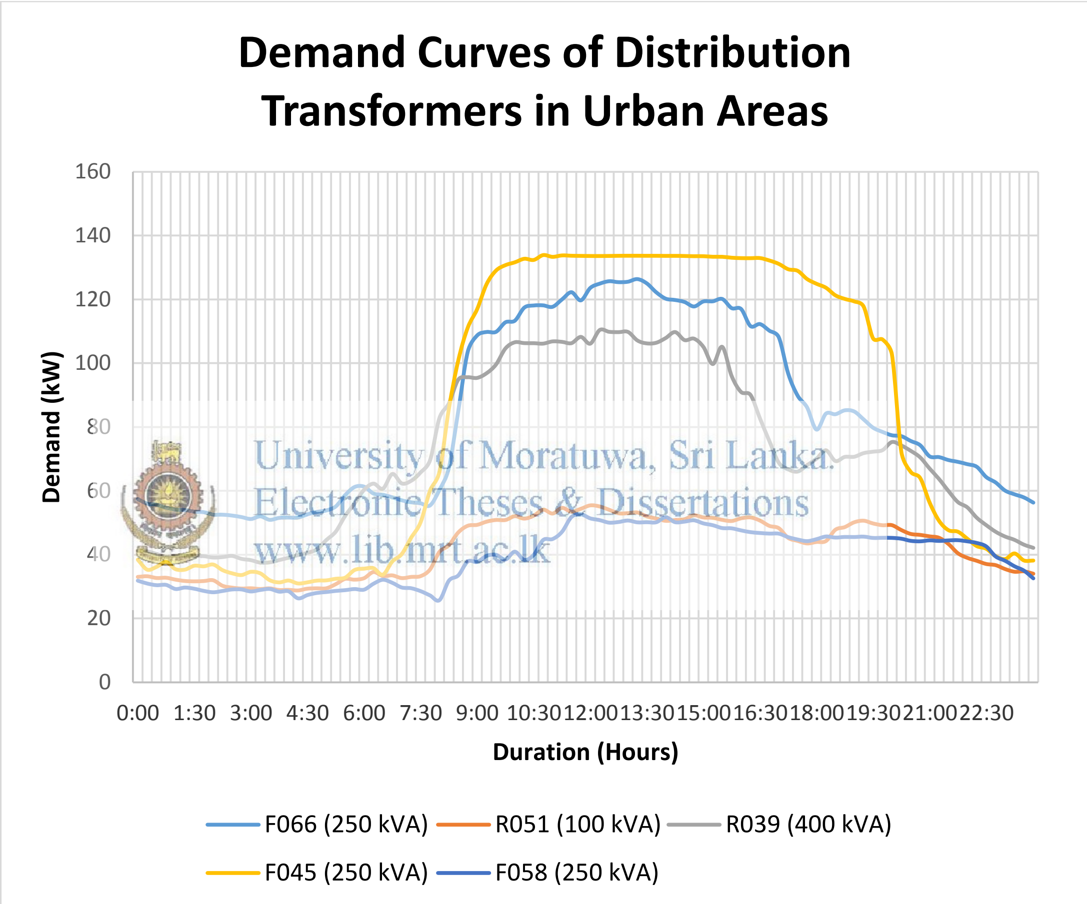

Figure 4.3 : Demand curves for distribution transformers in urban areas

Following a similar procedure as describe in 4.2.2 the capitalization value of load losses in distribution transformers (B) for urban areas is calculated to be **900 LKR / W** or **6.79 USD / W**.

The summery of calculated no load loss and full load loss capitalization values are shown in Table 4.5 below.

Table 4.5 : Summery of calculated capitalization values

Distribution transformer's load profiles	**Capitalization value of no load losses (A)**	**Capitalization value of load losses (B)**
Rural	1900 LKR/W (14.52 USD/W)	500 LKR/W (3.92 USD/W)
Semi Urban	1900 LKR/W (14.52 USD/W)	750 LKR/W (5.69 USD/W)
Urban	1900 LKR/W (14.52 USD/W)	900 LKR/W (6.79 USD/W)

5 DISCUSSION BASED ON CALCULATED RESULTS

5.1 Variation of Total Owning Costs with Different Distribution Transformer Capacities

After the calculation of capitalization value of no load losses and load losses, it is necessary to calculate Total Owning Cost (TOC) for distribution transformers with different capacities. Though LTL produce distribution transformers below 100 kVA capacity [18]. Currently, CEB uses distribution transformers 100 kVA and up wards. Calculated capitalization values for distribution transformers in rural areas under the section of 4.2.2 were used to calculate TOC. Table 5.1 shows the calculated TOC for different capacities and the same is graphically shown the Figure 5.1.

Table 5.1 : Calculated TOC for different distribution capacities

Transformer capacity (kVA)	Purchase price (LKR)	No load loss (W)	Load loss (W)	TOC (LKR)
25	190,720.00	75	460	**563,220.00**
50	250,915.00	140	780	**906,915.00**
100	765,495.00	340	1900	**2,361,495.00**

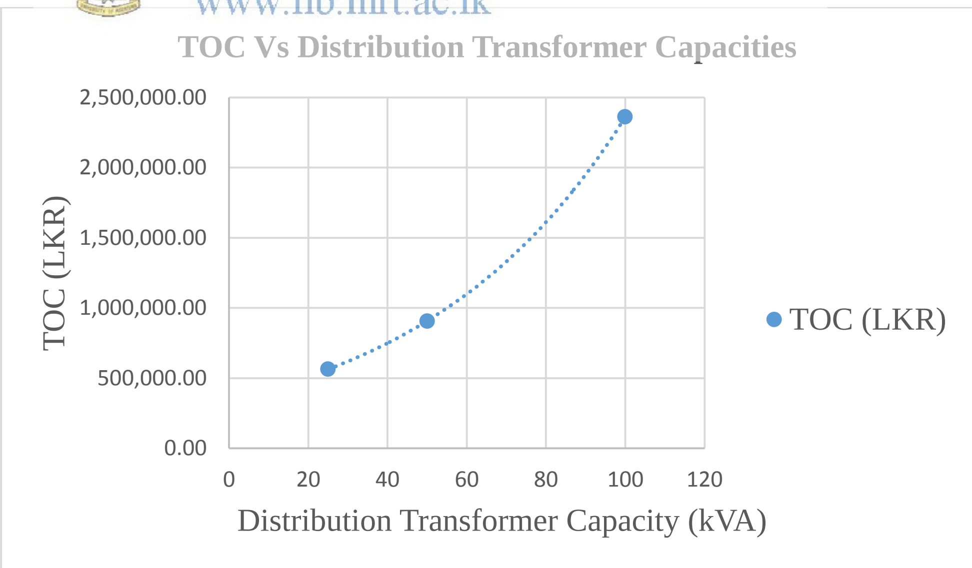

Figure 5.1 : Calculated TOC for different distribution transformer capacities

5.2 Comparison with a Neighboring Country

In this research, determination of the capitalization values for distribution transformers relevant to three categories of load profiles were done by using IEEE loss evaluation guide. Table 5.2 shows a comparison of loss capitalization values calculated for Sri Lanka with the currently used loss capitalization value of Bangladesh [18].

Table 5.2 : Comparison of loss capitalization values calculated for Sri Lanka with values of Bangladesh

	NLL capitalization value (A) in USD/W	**LL capitalization value (B) in USD/W**
Rural areas in Sri Lanka	14.50	4.00
Semi Urban areas in Sri Lanka	14.50	5.50
Urban areas in Sri Lanka	14.50	7.00
In Bangladesh	5.75	2.54

The average generation cost in Bangladesh is about 9.22 LKR (exchange rate of 1 Bangladesh currency 'taka' equal to 1.72 LKR) in year 2013 [20]. In the same year, the average generation cost in Sri Lanka was about 17.70 LKR [4]. In Bangladesh, the generation of electricity is mainly based on their own natural gas and therefore lower rates of electricity price [20]. But in Sri Lanka, electricity generation was mainly based on oil in the same year causing high cost of generation [4].

Levelized energy cost or the Long Run Marginal Cost (LRMC) is shown much difference in two countries. The difference between these two energy cost values was responsible for the large difference in the calculated capitalization values. The Total Owning Cost (TOC) for three capacities distribution transformers installed in rural areas of Sri Lanka and Bangladesh are compared in Table 5.3 below and graphically illustrated in Figure 5.2 [20], [21], [22].

Table 5.3 : Comparison of TOC for different capacities of distribution transformers

	TOC (USD)	
Transformer Capacity	**Sri Lanka (rural areas)**	**Bangladesh**
100 kVA, 11 kV / 415 V	17,743.46	9,923.18
250 kVA, 11 kV / 415 V	31,533.19	18,139.63
400 kVA, 11 kV / 415 V	41,803.88	25,578.71

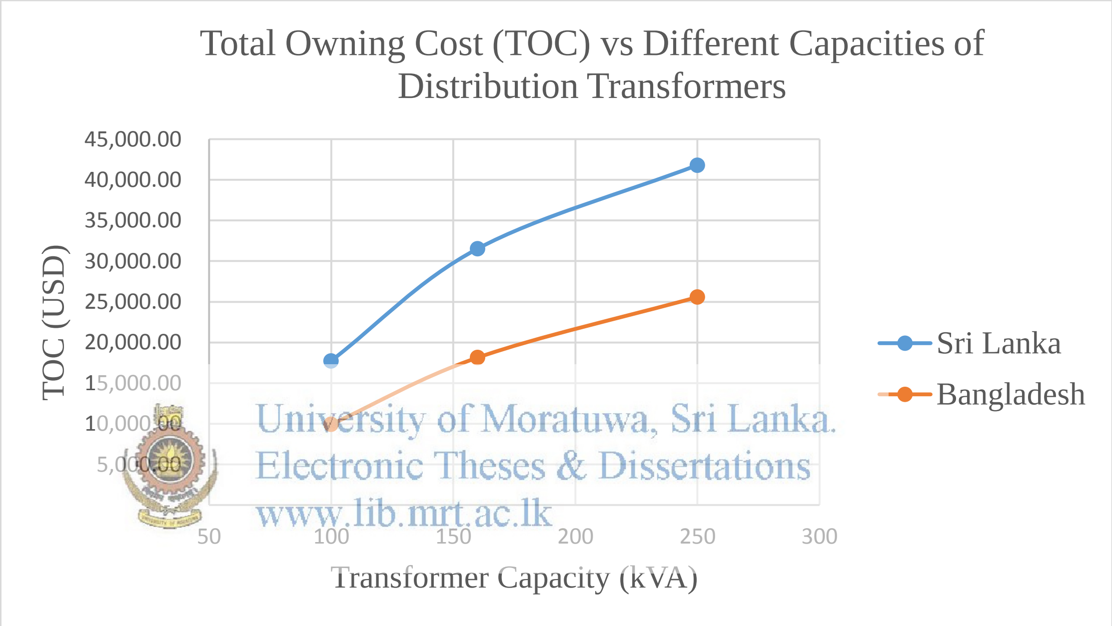

Figure 5.2 : Comparison of TOC for different capacities of distribution transformers

6 COMPUTER BASED METHODOLOGY FOR THE CALCULATION OF THE CAPITALIZATION VALUES

A computer based capitalization value calculation Model was developed using Microsoft Excel Macro Program. Figure 6.1 is a snapshots of the model for data entering. Source code of the program is attached as Appendix 06.

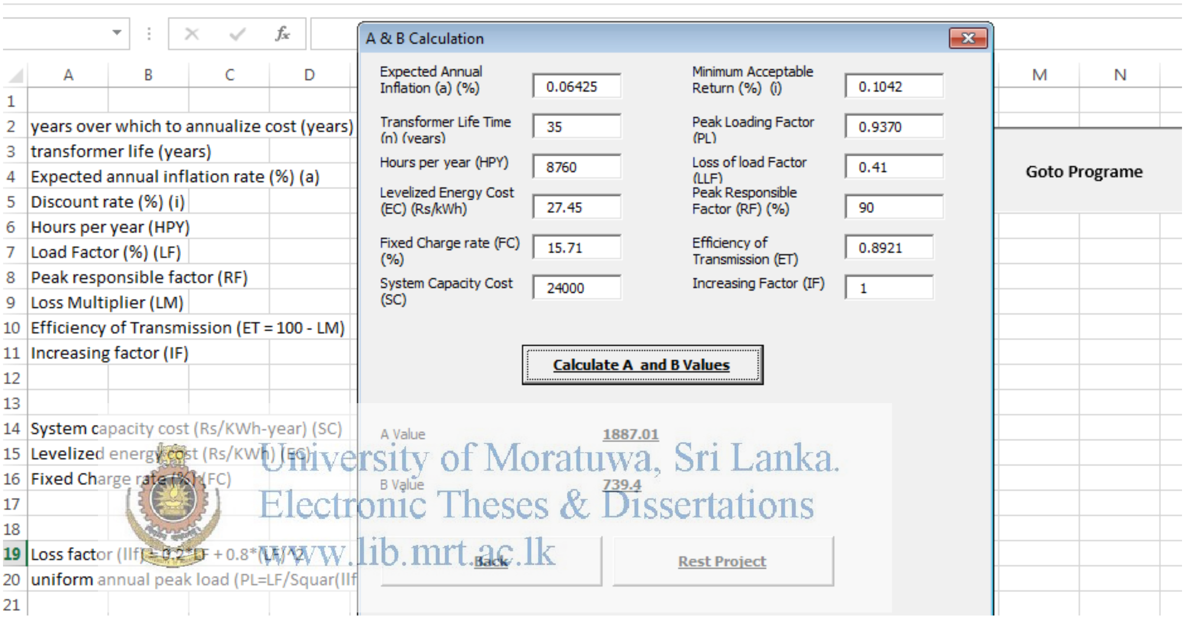

Figure 6.1 : Snapshot of the computer based model

7 CONCLUSION AND RECOMENDATION

7.1 Conclusion

Utilities in many countries currently use the concept of the Total Owning Cost (TOC) to evaluate transformers in the procurement process. In Sri Lanka, CEB still do not use this method for the evaluation process when procuring distribution transformers. Instead, CEB uses fixed values for no load losses and load losses. Based on those fixed values for no load losses and load losses LTL produce distribution transformers.

Capitalization value of no load losses (A) and capitalization value of load losses (B) are required to calculate TOC. Amount of the capitalization values depend on various factors such as, the cost of generating, transmitting and distributing capacity for transformer losses, the cost of generating, transmitting and distributing the electrical energy, economic consideration and factors which are sensitive to the loading profile of a distribution transformer.

The transformers committee of the Institute of Electrical and Electronics Engineers (IEEE) has identified the requirement for a standard to evaluation the losses of substation transformers. They have published a method for evaluating capitalization values for transformer no load and load losses in "IEEE Loss Evaluation Guide for Power Transformers and Reactor" (C57.120-1991) [9].

In this research determination of the capitalization values for distribution transformers in three categories of load profiles (i.e. rural, semi urban and urban) was done by using the IEEE loss evaluation guide. The calculated capitalization values for distribution transformers are summarized in the Table 7.1.

Table 7.1 : Calculated capitalization values for distribution transformers

Profile	**Capitalization value of no load losses (A)**	**Capitalization value of load losses (B)**
Rural	1900 LKR/W (14.52 USD/W)	500 LKR/W (3.92 USD/W)
Semi Urban	1900 LKR/W (14.52 USD/W)	750 LKR/W (5.69 USD/W)
Urban	1900 LKR/W (14.52 USD/W)	900 LKR/W (6.79 USD/W)

7.2 Recommendation

This research was carried out for the determination of the capitalization values for no load losses and load losses of distribution transformers for different load profiles, and the main recommendations of this research are summarized as below.

- Future purchasing of distribution transformers in Sri Lanka should be based on optimum Total Owning Cost (TOC).
- Optimum Total Owning Cost can be calculated using the capitalization value of no-load losses (A) and the capitalization value of load losses (B).

Total owning cost	=	Purchase price of the transformer	+	Net present value of life time no load losses	+	Net present value of life time load losses

- Capitalization value of no-load losses (A) and the capitalization value of load losses (B) for any set of economic parameters can be determined by the model developed in this research.

REFERENCES

[1] The World Bank Official Web Site, http://data.worldbank.org/

[2] Ceylon Electricity Board, "Annual Report, 2012"

[3] B.W. Kennedy, *Energy Efficient Transformers*,1998, McGraw Hill Companies, Inc, United States of America

[4] Ceylon Electricity Board, Statistical Unit, "Statistical Digest, 2013"

[5] Pavlos. S. Georgilakis," Environmental cost of distribution transformer losses" Applied Energy 88 (2011) 3146–3155.

[6] CEB Specification, 108-1:2014_5 MVA 33 kV\11 kV Power Transformer with on load Tap Changer.

[7] CEB standard, 108-1:2014_5 MVA 33 kV\11 kV Power Transformer with on load Tap Changer.

[8] CEB Specification, 098_2000_MEDIUM VOLTAGE DISTRIBUTION TRANSFORMERS.

[9] Loss evaluation guide, IEEE C57.120-1991

[10] CEB, MEDIUM VOLTAGE DISTRIBUTION SYSTEM DEVELOPMENT PLAN 2014/2023, DISTRIBUTION DIVISION 03.

[11] Bulk Supply Tariff Forecast based on Tariff Methodology, 2011, Deputy General Manager (Energy Marketing Branch)

[12] Central Bank of Sri Lanka web site, www.cbsl.gov.lk

[13] Ceylon Electricity Board, "Annual Report, 2011"

[14] D.J. Downing, B.W. Mcconnell, P.R. Barns, S.W Hadley, J.W. Van Dyke; Economic analysis of efficient distribution transformer trends,1998, Oak Ridge National Laboratory, ORNL-6927.

[15] NEMA Standards publication TP 1-2002, Guide for Determining Energy Efficiency of Distribution Transformers. National Electrical Manufacturers Association. Rosslyn, Virginia

[16] Ceylon Electricity Board, Statistical Unit, "Statistical Digest, 2002-2012

[17] B.W. Mcconnell, P.R. Barns, S. Das J.W. Van Dyke; Supplement to the "Determination Analysis" (ORNL-6847) and Analysis of the NEMA Efficiency Standard for Distribution Transformers, 1998, Oak Ridge National Laboratory, ORNL-6927.

[18] Tender specifications. (2013), Lanka Transformers Limited

[19] Super Star Engineering Ltd. (2014) Distribution-Transformers [online] Available from;http://superstarengineering.com/11-415kv-distribution-transformer [Accessed: 10th April 2015]

[20] Mustafa, K. M., Tahreen T. C., & Siban S. (2013) Energy Subsidies in Bangladesh: A profile of groups vulnerable to reform. Bangladesh Institute of Development Studies. *Research Report*. International Institute for Sustainable Development.

[21] General Electric Manufacturing Company Limited. (2013) Distribution-Transformers price list [online] Available from;http://www.gemco.gov.bd/index.php?option=staticpagemanager&task=price_list [Accessed: 26 th April 2015]

[22] Ceylon Electricity Board, "Price List, 2013"

APPENDIX 01

Monthly Inflation Percentage Rates Year 2010-2013 [12]

	Year			
Month	**2010**	**2011**	**2012**	**2013**
January	3.2	6.1	6.5	8.1
February	3.3	6.1	6.1	8.6
March	3.4	6.2	5.9	8.8
April	3.8	6.4	5.7	8.8
May	3.9	6.6	5.6	8.8
June	4.3	6.7	5.8	8.6
July	4.6	7.0	6.0	8.3
August	4.9	7.1	6.3	8.0
September	5.3	7.2	6.5	7.8
October	5.7	7.1	6.8	7.6
November	6.1	6.9	7.2	7.3
December	6.2	6.7	7.6	6.9

APPENDIX 02

Monthly Average Weighted Fixed Deposit Percentage Rates, Year 2010-2013 [12]

	Year			
Month	**2010**	**2011**	**2012**	**2013**
January	10.46	8.16	9.11	13.53
February	9.99	8.14	9.37	13.82
March	9.71	8.17	9.84	13.94
April	9.61	8.16	10.56	13.83
May	9.50	8.24	10.38	13.90
June	9.40	8.22	10.78	13.61
July	9.28	8.16	11.27	13.36
August	9.17	8.11	11.54	12.82
September	8.68	8.11	11.92	12.57
October	8.48	8.12	12.32	12.38
November	8.17	8.21	12.78	11.96
December	8.20	8.95	13.21	11.78

APPENDIX 03

Data (Demand in 'W') of Mapalana Distribution Transformer- C056 (160 kVA)

Time/ Date	2013.05.11	2013.05.12	2013.05.13	2013.05.14	2013.05.15	2013.05.16	2013.05.17
0:00	13116.58	12816.39	12374.91	12968.63	14461.01	13068.36	14773.03
0:15	12774.88	12394.48	11393.47	12051.27	13357.21	13398.5	14536.71
0:30	11977.3	12025.2	11259.93	12084.17	12944.55	12737.68	14218.66
0:45	11374.97	11979.02	11266.38	11934.72	12742.84	12534.41	14435.85
1:00	11289.6	11954.08	11145.95	11617.97	12702.41	12325.45	13418.5
1:15	11144.23	11972.73	11094.35	11897.73	12317.71	12658.98	13373.77
1:30	10838.61	11606.57	11062.25	11634.69	12175.35	12744.99	13171.85
1:45	10824.68	11445.51	11221.86	11610.87	11943.97	12892.72	13250.34
2:00	10578.89	11561.63	11127.03	11468.73	11909.78	12607.15	13084.33
2:15	10548.14	11590.44	11156.71	11328.95	11951.92	12416.41	13213.13
2:30	10654.37	11566.57	11133.48	11404	12135.78	12435.98	13184.32
2:45	10935.86	11916.44	11142.73	11299.06	12440.28	12502.37	13097.01
3:00	10763.77	11461.63	10854.36	11286.16	12984.33	12514.04	13127.55
3:15	10527.93	11648.93	10816.51	11297.99	12821.76	12502.37	13026.26
3:30	10405.3	11483.35	10652.44	11105.31	12694.03	12535.97	13035.73
3:45	10452.67	11639.04	10948.12	11154.13	12508.88	12516.62	12799.77
4:00	10521.26	11894.51	11015.43	11638.18	12627.15	12778.75	12939.17
4:15	10451.81	11901.82	10986.4	11900.75	12927.35	12451.25	12991.86
4:30	10684.48	12351.25	11206.38	12139.65	14149.2	12872.94	13132.49
4:45	11116.49	12686.5	12184.81	13984.27	14490.69	13745.79	13196.36
5:00	11566.57	13143.46	12926	16963.22	14719.49	14854.75	13405.33
5:15	13221.31	14366.82	13786.65	17709.41	14908.08	16180.69	14071.36
5:30	16166.49	15073.88	14376.5	15342.03	16846.88	17952.19	15085.92
5:45	18726.12	16975.26	19264.36	17102.56	17085.79	20846.84	16814.84
6:00	18468.07	21660.77	18345.92	16466.05	16899.08	22268.26	18116.48
6:15	20092.27	18871.27	18553.65	15001.41	16392.72	21461.16	17217.82
6:30	21239.93	18691.06	17558.18	15348.91	15687.17	19697.02	15495.14
6:45	18976.85	15981.34	17303.2	11603.77	13511.18	14422.09	12517.26
7:00	15219.67	12757.68	13541.07	13638.48	13115.94	10325.58	12130.41
7:15	10757.81	9025.01	11714.9	12943.69	11471.53	9978.45	11059.72
7:30	8842.66	8795.08	10376.97	10589.65	9225.86	9671.21	10396.11
7:45	7749.83	8744.39	8803.31	10273.32	8286.14	7921.21	9968.77
8:00	7837.13	7758	7496.94	9444.99	8207.86	7627.47	9003.3
8:15	9960.87	6903.81	6844.94	10958.65	7222.98	7792.62	7193.09
8:30	8445.21	6623.02	7481.89	10998.44	7344.48	7039.98	9449.29
8:45	8516.02	6630.54	7195.02	9632.88	8024.22	6538.94	7587.69
9:00	8297.96	7459.95	7765.74	9120.28	6794.4	6745.38	7437.16
9:15	7753.48	7718.86	8393.23	9532.94	6391.42	7404.47	7584.52

9:30	7641.23	7847.03	7989.17	9885.18	7239.75	7063.63	4719.97
9:45	8116.9	9327.95	7499.31	9651.64	7998.2	6778.49	6813.33
10:00	8123.57	9977.37	7906.38	7827.03	7997.12	7111.16	6151.44
10:15	8006.16	8539.02	8437.96	8604.83	7392.43	7715.85	7457.16
10:30	7368.56	9144.15	6854.4	8743.31	6317.23	7027.29	6527.54
10:45	7895.19	8385.7	7757.14	8993.19	6689.73	7924.66	5694.04
11:00	7896.7	8831.69	8349.79	9752.5	8274.53	7876.7	5936.4
11:15	7598.01	11129.18	8469.35	9175.76	7345.98	6600.44	6051.01
11:30	7740.58	8103.78	9177.69	8247.22	8397.53	7579.3	5727.16
11:45	10226.23	7601.23	8149.59	7865.95	7814.77	7204.27	6802.79
12:00	8844.6	7231.58	8101.63	9350.8	8763.74	7104.06	6055.74
12:15	8025.29	7922.72	7814.34	8521.39	11380.99	8103.35	6264.12
12:30	8254.31	7854.34	9801.74	9645.19	9507.99	7672.84	7252.87
12:45	9464.34	6667.75	8552.36	8908.89	11276.91	7958.2	7630.27
13:00	7154.6	6923.43	8754.92	7836.06	9761.26	9494.82	6778.06
13:15	6827.31	6755.48	8863.3	7240.18	10286.22	6902.57	6194.23
13:30	8624.18	7316.52	8470.64	8357.75	9371.66	6442.6	5988.17
13:45	8218.4	7689.83	8760.73	9004.59	8957.49	6888.16	7179.76
14:00	8492.58	7529.63	8062.93	9232.1	8756.43	7296.95	6305.19
14:15	9671.86	7171.37	8171.31	8825.46	9874.21	7790.69	6490.12
14:30	8812.99	8406.13	9198.5	9444.77	9272.74	7759.29	6643.23
14:45	8600.96	8679.23	8623.54	9460.04	9584.33	8272.97	7912.18
15:00	9310.16	8195.39	9389.94	9624.98	8032.82	9033.83	7896.05
15:15	9376.82	7881.22	7994.33	8794.49	8555.58	8618.16	8600.53
15:30	7981.64	8040.13	7793.7	9659.81	8404.19	8030.02	8271.3
15:45	8355.81	9972.7	7501.89	10745.98	8066.8	7071.38	10980.16
16:00	7688.33	9275.75	7544.68	11222.08	9121.57	8051.1	10205.37
16:15	6510.23	9136.62	8326.51	8396.02	11778.39	8473.65	8290.01
16:30	8641.81	8427.85	8210.87	8191.52	10584.92	7285.77	7388.78
16:45	9160.92	11453.84	10057.58	9360.91	8255.82	7268.57	7683.17
17:00	9003.73	8685.25	10316.12	10141.93	7729.61	8600.31	8861.58
17:15	7407.91	8308.5	8688.48	10835.44	7938.42	9810.34	8011.96
17:30	8114.32	7945.08	9801.74	12333.41	10216.34	8350.22	8474.94
17:45	10228.38	9013.83	11048.33	11543.73	12726.07	10168.81	10227.3
18:00	8877.07	10498.25	14717.12	11524.86	12470.82	10391.38	7551.99
18:15	11131.98	13057.02	13360.65	20533.1	16163.7	11130.47	10723.19
18:30	15171.07	16527.98	17446.2	21060.59	18902.45	15214.94	16102.2
18:45	19757.66	22283.52	24066.2	23652.68	24291.78	19711.21	21072.85
19:00	27107.95	27206	25671.26	29955.29	29408.87	25067.86	27740.81
19:15	27373.31	28917.51	29183.3	28478.18	28298.19	26988.33	30073.13
19:30	25891.89	28288.95	29523.71	29304.36	28768.05	28919.01	34556.07
19:45	27119.34	28386.79	29876.59	29749.71	29585.85	28885.47	30657.4
20:00	27047.95	29044.17	29111.69	30143.45	29090.18	28602.04	30686.21

20:15	26943.23	26599.81	28699.24	30814.38	28370.23	29001.37	29612.09
20:30	25966.73	27212.24	28276.26	29318.77	28198.84	28816.44	30377.41
20:45	26078.76	27884.67	27850.05	28818.16	27590.71	29892.28	29881.96
21:00	27135.9	26132.74	29482.2	29539.83	26956.29	28984.82	28538.82
21:15	27255.03	24958.41	26072.31	28095.62	26447.99	25643.52	27094.18
21:30	27262.99	24114.8	24767.67	28436.03	23367.75	25562.67	26967.04
21:45	26437.24	22398.78	23729.4	26824.74	22141.38	23832.46	26731.2
22:00	25324.62	19890.13	21090.27	24838.84	20561.48	23519.14	24779.92
22:15	22303.31	21265.31	18815.14	23772.46	18332.16	21775.6	22657.91
22:30	20052.7	17209.65	17230.08	20417.84	16828.17	19704.55	21525.94
22:45	18468.93	16152.95	16038.98	18493.23	16239.39	18288.08	20046.84
23:00	16628.62	14097.59	14768.09	18171.74	15895.33	17386.63	17629.84
23:15	15591.26	12937.83	14441.44	17000.63	14741.42	16613.35	16429.49
23:30	14337.79	12581.99	13887.88	15754.91	14018.03	15516.86	15565.46
23:45	13871.37	12251.91	13416.99	14553.69	13512.9	14890.45	14981.84

APPENDIX 04

Data (Demand in ‘W’) of Rakwana Distribution Transformer- Q071 (160 kVA)

Time/ Date	2013.09.06	2013.09.07	2013.09.08	2013.09.09	2013.09.10	2013.09.11	2013.09.12
0:00	67797.03	59356.43	57314.36	57450.49	56905.94	58811.88	60037.13
0:15	68750	59492.57	53910.89	56905.94	57178.22	55408.41	58948.02
0:30	63849.01	55408.41	52685.64	52549.5	55680.69	54319.31	56361.38
0:45	62079.21	55272.28	53230.2	51868.81	55544.55	54047.03	56633.66
1:00	62351.48	48601.48	51868.81	51596.53	56633.66	49826.73	53366.34
1:15	61670.79	54727.72	48193.07	49962.87	51324.26	49146.04	52141.09
1:30	63712.87	52141.09	51188.12	47240.1	51188.12	51596.53	51460.39
1:45	60173.27	52549.5	49146.04	48601.48	49418.32	48056.93	51732.67
2:00	57858.91	51732.67	48465.35	49962.87	52685.64	49690.59	50507.42
2:15	60173.27	52141.09	50915.84	47648.51	52277.23	48873.76	52685.64
2:30	59764.85	53230.2	47376.24	48193.07	51188.12	45878.71	51051.98
2:45	58267.33	52413.37	49009.9	48873.76	50779.7	46831.68	52277.23
3:00	59084.16	50779.7	50643.56	49282.18	51188.12	49009.9	51868.81
3:15	58539.6	53230.2	49146.04	49282.18	51051.98	48329.21	52957.92
3:30	56769.8	49690.59	50779.7	48465.35	52413.37	49962.87	52277.23
3:45	58403.46	51732.67	47512.38	47648.51	52549.5	47920.79	48737.62
4:00	61534.65	52413.37	50643.56	46559.4	53230.2	47784.65	53094.06
4:15	58811.88	56089.11	52549.5	50779.7	57586.63	53910.89	55272.28
4:30	61398.51	55816.83	54591.58	47784.65	58267.33	51324.26	53774.75
4:45	67252.47	60581.68	59492.57	50779.7	59356.43	54183.17	56089.11
5:00	74876.24	70519.8	68886.14	56769.8	64801.98	57858.91	59628.71
5:15	82908.41	76101.48	71064.35	59492.57	72970.3	57722.77	58539.6
5:30	86311.88	79096.53	82772.28	61670.79	82091.58	66163.36	60990.1
5:45	87400.99	84950.49	85631.19	62079.21	84269.8	68205.44	63440.59
6:00	92710.39	86584.16	82908.41	60037.13	80049.5	68341.58	65891.09
6:15	89987.62	82500	86992.57	58675.74	81002.47	66163.36	66299.5
6:30	80049.5	79913.36	78279.7	57722.77	85086.63	63985.15	62759.9
6:45	74467.82	75420.79	81955.44	57586.63	80730.2	64393.56	59220.3
7:00	78415.84	69566.83	76509.9	57450.49	63849.01	69158.41	64665.84
7:15	76101.48	61398.51	62215.35	61534.65	65346.53	62351.48	63849.01
7:30	74603.96	62079.21	62351.48	64938.12	64257.42	63032.18	69022.28
7:45	62896.04	63576.73	69294.55	78007.42	69294.55	68750	62759.9
8:00	63985.15	69430.69	67116.34	78415.84	79641.09	80457.92	66844.06
8:15	68477.72	78824.26	70383.66	70928.22	81683.17	82500	67660.89
8:30	73242.57	71608.91	63168.32	74059.4	76782.18	88353.96	73106.43
8:45	84133.66	71200.49	60915	72970.3	73242.57	103329.21	80730.2
9:00	97883.66	94888.61	50915.84	70383.66	97202.97	101150.99	78960.39
9:15	118304.45	88081.68	85495.05	71881.19	105235.15	105371.28	72289.6

9:30	116126.24	87264.85	83589.11	75693.07	101559.4	112314.35	71745.05
9:45	107277.23	94071.78	95977.72	73514.85	115037.13	115173.26	80185.64
10:00	92710.39	89170.79	87537.13	78551.98	96930.69	104554.45	83997.52
10:15	79368.81	76373.76	75284.65	78960.39	104282.18	77871.29	74603.96
10:30	98564.35	89170.79	85358.91	79913.36	108774.75	87809.4	71881.19
10:45	115853.96	101423.27	84950.49	75284.65	117079.21	120482.67	80321.78
11:00	112722.77	92029.7	85495.05	75012.37	109727.72	118032.18	82363.86
11:15	113131.19	96658.41	90123.76	82227.72	113539.6	109455.44	86856.43
11:30	122116.33	92846.53	91893.56	85222.77	117759.9	111905.94	92438.12
11:45	123477.72	90668.31	100061.88	89579.21	108094.06	114628.71	71064.35
12:00	118440.59	105779.7	95160.89	88898.51	113675.74	108502.47	83725.25
12:15	116806.93	106732.67	95024.75	89851.48	127698.02	119801.98	84678.22
12:30	113131.19	102240.1	103056.93	89170.79	124702.97	132462.87	88490.1
12:45	110136.14	107685.64	102103.96	91485.15	116943.07	128106.43	88353.96
13:00	113811.88	98428.22	90668.31	84950.49	103873.76	117759.9	85631.19
13:15	117215.34	86992.57	78143.56	81955.44	91076.73	90940.59	82227.72
13:30	100061.88	81274.75	86992.57	81683.17	94888.61	77054.45	81410.89
13:45	99653.46	74603.96	90123.76	75829.21	101014.85	93254.95	73106.43
14:00	99108.91	76373.76	91485.15	76509.9	97202.97	90123.76	69839.11
14:15	92165.84	85222.77	75965.34	78824.26	113131.19	87400.99	73923.27
14:30	112722.77	94344.06	74603.96	75965.34	138044.55	98836.63	79641.09
14:45	115445.54	103737.62	76373.76	78824.26	139542.08	105507.42	74603.96
15:00	101831.68	100334.16	77735.15	74331.68	133688.12	91757.42	78007.42
15:15	96522.28	101150.99	78143.56	73242.57	136955.44	94752.47	87945.54
15:30	103193.07	88762.37	70519.8	67797.03	121299.5	88898.51	77599.01
15:45	107277.23	98700.49	82363.86	68341.58	115173.26	88898.51	77190.59
16:00	87673.27	95024.75	79913.36	66435.64	121980.2	93935.64	79232.67
16:15	97611.38	71472.77	78688.12	72425.74	105371.28	94071.78	77190.59
16:30	90259.9	76373.76	80321.78	70655.94	108502.47	76509.9	76101.48
16:45	81955.44	74603.96	76918.32	67797.03	84269.8	73242.57	68750
17:00	84133.66	75420.79	78824.26	66163.36	83861.38	77054.45	68477.72
17:15	90940.59	81138.61	82772.28	63985.15	83452.97	83997.52	70383.66
17:30	86311.88	83180.69	85903.46	68886.14	84133.66	87945.54	73514.85
17:45	84133.66	75556.93	84542.08	75693.07	85086.63	91076.73	77871.29
18:00	91076.73	87809.4	86039.6	78279.7	89579.21	94752.47	82091.58
18:15	91485.15	96658.41	89306.93	89443.07	92029.7	97066.83	93663.36
18:30	105779.7	98564.35	98836.63	103329.21	100742.57	105235.15	109863.86
18:45	115717.82	109863.86	115309.4	113675.74	112178.22	106051.98	122388.61
19:00	118304.45	109863.86	120346.53	114220.29	121435.64	113811.88	129467.82
19:15	119529.7	114628.71	120618.81	124022.27	124975.24	123477.72	130420.79
19:30	120891.09	118440.59	117079.21	125928.22	119121.28	122252.47	130693.07
19:45	118440.59	118304.45	119393.56	126608.91	122933.17	121844.06	130693.07
20:00	122388.61	121163.36	115173.26	126472.77	124566.83	117351.48	125792.08

20:15	129467.82	122797.03	114356.43	127289.6	121844.06	119393.56	124839.11
20:30	127970.29	121299.5	118576.73	122797.03	117623.76	121435.64	125111.38
20:45	125519.8	119121.28	115717.82	121435.64	115990.1	114356.43	123341.58
21:00	112858.91	108366.33	116126.24	114084.16	117215.34	109863.86	117759.9
21:15	108910.89	105235.15	113948.02	110136.14	110272.27	107413.36	112178.22
21:30	109727.72	101014.85	105371.28	106732.67	104690.59	101695.54	106051.98
21:45	103193.07	99653.46	97883.66	104554.45	97066.83	96522.28	103737.62
22:00	98292.08	95705.44	95160.89	95433.17	90532.18	93118.81	94888.61
22:15	89306.93	86856.43	87673.27	87264.85	89715.34	90532.18	92982.67
22:30	83861.38	81955.44	81955.44	80049.5	82363.86	87809.4	87264.85
22:45	75420.79	74876.24	75284.65	76509.9	78279.7	79641.09	80594.06
23:00	74740.1	72698.02	73650.99	70519.8	72561.88	72425.74	76646.04
23:15	69702.97	66707.92	67388.61	64257.42	70655.94	73650.99	71745.05
23:30	66163.36	63440.59	64393.56	62896.04	67252.47	69430.69	66299.5
23:45	62896.04	59628.71	59356.43	60037.13	62623.76	64257.42	64529.7

APPENDIX 05

Data (Demand in 'W') of Yodagama Distribution Transformer-R039 (400 kVA)

Time/ Date	2013.03.11	2013.03.12	2013.03.13	2013.03.14	2013.03.15	2013.03.16	2013.03.17
0:00	46150	49030	39210	42750	38620	36150	36620
0:15	46290	49420	39040	42280	38740	33190	38060
0:30	42570	49250	37730	43580	37810	32930	37520
0:45	42900	48690	37160	40010	37390	31740	37850
1:00	43690	50120	37790	39580	38620	32330	35660
1:15	46060	48620	36100	39650	38570	32950	35830
1:30	45820	49410	37430	39310	37940	32040	35210
1:45	47940	47220	36870	40060	38160	31260	35090
2:00	47350	45970	36040	38450	39110	31270	35400
2:15	46160	47620	36520	37880	38240	32040	36190
2:30	46580	48430	36320	38920	38240	31530	37120
2:45	44710	46790	35330	39110	38350	30330	36100
3:00	41980	46260	36780	38090	38290	29930	36500
3:15	43840	41690	35700	37690	37270	30580	35640
3:30	43310	41090	35240	38490	38730	30130	36060
3:45	42570	46510	35960	37260	38240	30410	37110
4:00	43500	48860	33480	39460	39400	30840	37680
4:15	45110	48390	34310	38650	44710	31920	35980
4:30	46810	44220	35240	39030	45140	35400	38210
4:45	46530	44750	35670	38720	49090	38320	38590
5:00	46460	54600	40500	41680	48950	41070	38750
5:15	49770	57580	43440	46020	51670	42410	39610
5:30	51690	72160	46720	48500	55550	47830	42580
5:45	50350	70950	50690	56340	58810	60360	44950
6:00	51220	75730	57630	54570	65220	65710	52040
6:15	55430	81620	57790	60360	59670	65300	55650
6:30	56940	78680	54530	55580	55280	67810	55820
6:45	54580	68900	49020	54500	51710	61110	47060
7:00	55900	59100	43140	58620	52030	53240	44180
7:15	59280	62050	45190	41860	55340	52240	55980
7:30	70390	53960	48660	39660	55520	55040	67080
7:45	71040	65260	48100	45700	70810	54980	61070
8:00	68040	62810	79360	60890	122700	61760	54190
8:15	78340	60930	111900	59500	127300	48910	54850
8:30	96560	62300	106100	82730	116900	49570	79890
8:45	100400	55990	102800	47260	56820	57510	108400
9:00	72350	51720	85630	36970	59090	65820	86200
9:15	74170	64920	58530	86820	97690	54100	101800

9:30	84900	74690	93990	117000	95580	53770	107200
9:45	91290	64280	125900	121200	110700	63300	155700
10:00	74020	63260	126600	97360	92310	67980	154400
10:15	71490	65690	125600	97840	74600	67440	143400
10:30	71930	74660	126700	92350	78690	73720	148900
10:45	87200	70980	104700	104600	78230	85820	127500
11:00	77530	62740	88940	108300	72360	113300	112700
11:15	89000	63860	123700	116200	72830	115200	152100
11:30	112100	70890	121800	113800	75350	107500	142500
11:45	111200	69770	118900	103000	109200	113500	132200
12:00	116000	68230	117100	105100	125500	107600	103400
12:15	117700	75070	111100	141400	134500	106300	114800
12:30	119300	81210	116400	136500	119700	115800	108000
12:45	101600	90260	112100	109400	74130	104500	64180
13:00	91940	83680	91620	80670	66390	72010	72330
13:15	89400	61240	90750	60360	67750	57490	77940
13:30	81170	62170	83760	57540	70010	64510	79320
13:45	63750	67690	70050	66620	108600	68630	124600
14:00	65520	66770	67080	77900	94860	74890	133200
14:15	67180	69440	83320	113600	117800	116800	130200
14:30	64370	68290	82760	118000	134700	158900	123700
14:45	61460	76560	84460	115600	138900	151400	125500
15:00	66050	90000	95530	114400	132000	145300	92500
15:15	61670	108200	103500	115600	127800	123000	58410
15:30	58350	115200	110900	113200	127500	115400	95370
15:45	60330	118000	92630	108500	116300	60540	115500
16:00	58880	114400	97870	93560	67410	80890	123800
16:15	61740	118400	95460	91580	55030	99750	108400
16:30	54920	76050	96880	93490	57870	100800	98840
16:45	51880	76140	68620	83880	58310	83290	106900
17:00	49050	69940	60850	86090	53310	89850	72450
17:15	53350	65330	58380	97000	54290	77370	61350
17:30	52910	64040	57120	96110	57750	78880	55430
17:45	52880	58610	62310	97490	56130	82930	65950
18:00	53330	60960	64360	99970	58970	89680	63160
18:15	64200	66640	66860	79460	65530	93810	72400
18:30	61610	68460	67480	67180	72370	73090	75310
18:45	66150	72960	66090	65900	75820	71690	75820
19:00	63200	79280	66950	66900	69770	71630	77030
19:15	69640	77770	70140	73640	63570	72880	75070
19:30	70200	78610	75820	71360	63880	71190	74860
19:45	75460	80100	75730	72220	62620	67640	75480
20:00	78220	85180	72510	74630	67150	73050	76340

20:15	77100	77670	75230	80200	67420	72870	69030
20:30	82200	74940	74390	78080	59480	70730	67880
20:45	76880	72970	73730	74920	59830	66440	68560
21:00	68140	66700	67580	73970	62570	64440	65360
21:15	61760	63990	63570	71590	54030	64050	66860
21:30	57480	60030	61700	65330	51370	58970	64620
21:45	56310	57580	61230	59640	48870	55550	56060
22:00	54450	60810	57550	57820	46190	50430	56390
22:15	51650	55820	54710	55210	43430	46130	53940
22:30	48350	50950	54050	51690	42570	44780	52370
22:45	47300	49190	48900	51460	40100	41830	51400
23:00	47580	47550	47280	48290	38670	40540	49780
23:15	51330	47150	42020	44440	39490	39300	48650
23:30	48880	43040	40620	42700	38810	39610	48200
23:45	49970	39090	42240	41340	37330	37670	47230

APPENDIX 06

Microsoft Excel Macro Code for Computer Based Calculation of Capitalization Values

%==%

```
Private Sub CommandButtonto2LLF_Click()

Me.Hide

FormLLF.Show

End Sub

Private Sub CommandButtonBack2TD_Click()

'Unload Me

MsgBox ("Please input values and proceed with 'next' button")

End Sub

Private Sub CommandButtonPWFCRF_Click()

Dim TFlifetime, RateOfReturn, Inflation As Double

Dim nValue As Double

Dim aValue As Double

Dim iValue As Double

TFlifetime = Val(TextBox1.Value)

RateOfReturn = Val(TextBox2.Value) / 100

Inflation = Val(TextBox3.Value) / 100

PresentEnerCost = Val(TextBox4.Value)

nValue = TFlifetime

aValue = Inflation

iValue = RateOfReturn

Call RefreshNresult(nValue)

Call RefreshAResult(aValue)

Call RefreshIResult(iValue)

Dim CRFvalue As Double

Dim PWFValue As Double

Dim ECValue As Double
```

```
CRFvalue = (RateOfReturn * ((1 + RateOfReturn) ^ TFlifetime)) / (((1 + RateOfReturn) ^ TFlifetime) - 1)

LabelCRF.Caption = CRFvalue

PWFValue = (1 - ((1 + Inflation) / (1 + RateOfReturn)) ^ TFlifetime) / (RateOfReturn - Inflation)

LabelPWF.Caption = PWFValue

ECValue = PresentEnerCost * PWFValue * CRFvalue

LabelEC.Caption = ECValue

Call RefreshECresult(ECValue)

End Sub

%=============================================================%

Private Sub CommandButtonBack2PL_Click()

Me.Hide

FormPL.Show

End Sub

Private Sub CommandCalLLF_Click()

Dim LossFac, LossofLoadFac, PeakLoad As Double

Dim llfValue As Double

Dim plValue As Double

LossFac = Val(TextBox1.Value) / 100

LossofLoadFac = (0.2 * LossFac) + (0.8 * LossFac ^ 2)

PeakLoad = LossFac / (Sqr(LossofLoadFac))

LabelLLF.Caption = LossofLoadFac

LabelPL.Caption = PeakLoad

llfValue = LossofLoadFac

plValue = PeakLoad

Call RefreshLLFresult(llfValue)

Call RefreshUAPLresult(plValue)

End Sub

Private Sub GotoformFC_Click()

'MsgBox (LLFValuePass)
```

```
Me.Hide
FormFC.Show
End Sub
%================================================================%
Dim RateOfReturn, BookDepre, Taxes, LocalPropTaxInsuara, Sum As Double
Private Sub CommandButtonBack2LLF_Click()
Me.Hide
FormLLF.Show
End Sub
Private Sub CommandButtonFC_Click()
RateOfReturn = Val(TextBox1.Value)
BookDepre = Val(TextBox2.Value)
Taxes = Val(TextBox3.Value)
LocalPropTaxInsuara = Val(TextBox4.Value)
Sum = RateOfReturn + BookDepre + Taxes + LocalPropTaxInsuara
LabelFC.Caption = Sum
Call RefreshFCresult(Sum)
'sgBox (FCValuePass)
End Sub
Private Sub CommandButton2FormABD_Click()
Unload Me
FormSC.Show
End Sub
%================================================================%
Dim SysCap As Double
Private Sub CommandButton_GoTOFormABD_Click()
Call RefreshSCresult(Val(TextBoxSCValue.Value))
'MsgBox (SCValuePass)
Me.Hide
FormABD.Show
```

```
End Sub

Private Sub CommandButtonBack2TD_Click()

Unload Me

FormFC.Show

End Sub

Private Sub CommandButtonSC_Click()

Me.TextBoxSCValue.Value = Val(TextBoxGCValue.Value) +
Val(TextBoxTCValue.Value) + Val(TextBoxDCValue.Value)

End Sub

Private Sub OptionButton1_Click()

Me.CommandButtonSC.Enabled = True

Me.TextBoxGCValue.Visible = True

Me.TextBox13.Visible = True

Me.TextBoxDCValue.Visible = True

Me.TextBoxSCValue.Enabled = False

SysCap = Val(TextBoxGCValue.Value) + Val(TextBoxTCValue.Value) +
Val(TextBoxDCValue.Value)

End Sub

Private Sub OptionButton2_Click()

Me.TextBoxGCValue.Visible = False

Me.TextBoxTCValue.Visible = False

Me.TextBoxDCValue.Visible = False

Me.CommandButtonSC.Enabled = False

Me.TextBoxSCValue.Enabled = True

' RefreshSCresult (Val(TextBoxSCValue.Value))

End Sub

%==============================================================%

Dim Inflat, RateOfReturn, EnergyCost, HoursPerYear, PeakLoadFac, LossofLoadFac,
PeakResponsibleFac, FixedChargeRate, SysCapCost, EfficiencyOfTransmisson,
IncreasingFac, aValue, Bvalue As Double

Dim TFlifetime As Integer

Private Sub CommandButtonEF_Click()
```

```
' Variables for Calculate transformer loss data

Inflat = Val(TextBox8.Value) / 100

RateOfReturn = Val(TextBox9.Value) / 100

TFlifetime = Val(TextBox7.Value)

EnergyCost = Val(TextBox10.Value)

HoursPerYear = Val(TextBox1.Value)

PeakLoadFac = Val(TextBox17.Value)

PeakResponsibleFac = Val(TextBox3.Value) / 100

LossofLoadFac = Val(TextBox18.Value)

FixedChargeRate = Val(TextBox16.Value) / 100

SysCapCost = Val(TextBox19.Value)

EfficiencyOfTransmisson = Val(TextBox20.Value)

IncreasingFac = Val(TextBox21.Value)

aValue = (SysCapCost + HoursPerYear * EnergyCost) / (FixedChargeRate *
EfficiencyOfTransmisson * IncreasingFac * 1000)

Bvalue = (((SysCapCost * PeakResponsibleFac ^ 2) + (HoursPerYear * EnergyCost *
LossofLoadFac)) * (PeakLoadFac ^ 2)) / (FixedChargeRate * EfficiencyOfTransmisson *
IncreasingFac * 1000)

LabelAval.Caption = Round(aValue, 2)

LabelBval.Caption = Round(Bvalue, 2)

End Sub

Private Sub RestWork_Click()

' Unload.Me

Me.Hide

FormPL.Show

End Sub

Private Sub CommandButtonBack2SC_Click()

Me.Hide

FormSC.Show

End Sub

Private Sub UserForm_Initialize()
```

```
TextBox7.Value = nValuePass

TextBox9.Value = iValuePass

TextBox8.Value = aValuePass

TextBox10.Value = ECValuePass

'TextBox9.Value = MARValuePass

TextBox17.Value = UAPLValuePass

TextBox16.Value = FCValuePass

TextBox19.Value = SCValuePass

TextBox18.Value = LLFValuePass

End Sub
```

%==%

```
Public nValuePass, iValuePass, aValuePass As Double

Public PLValuePass, CRFValuePass, ECValuePass, MARValuePass, FCValuePass,
SCValuePass As Double

Public LLFValuePass, UAPLValuePass As Double

Function RefreshNresult(n As Double)

nValuePass = n

End Function

Function RefreshPLresult(testres2 As Double)

PLValuePass = testres2

End Function

Function RefreshCRFresult(testres3 As Double)

CRFValuePass = testres3

End Function

Function RefreshECresult(testres4 As Double)

ECValuePass = testres4

End Function

Function RefreshMARresult(testres5 As Double)

MARValuePass = testres5

End Function

Function RefreshFCresult(testres6 As Double)
```

```
FCValuePass = testres6
End Function
Function RefreshSCresult(testres7 As Double)
SCValuePass = testres7
End Function
Function RefreshLLFresult(LLF As Double)
LLFValuePass = LLF
End Function
Function RefreshUAPLresult(uapl As Double)
UAPLValuePass = uapl
End Function
Function RefreshAResult(a As Double)
aValuePass = a
End Function
Function RefreshIResult(i As Double)
iValuePass = i
End Function
Sub Button1_Click()
FormPL.Show
End Sub
%==========================================================%
```

REFERENCES

[1] The World Bank Official Web Site, http://data.worldbank.org/

[2] Ceylon Electricity Board, “Annual Report, 2012”

[3] B.W. Kennedy, *Energy Efficient Transformers*,1998, McGraw Hill Companies, Inc, United States of America

[4] Ceylon Electricity Board, Statistical Unit, “Statistical Digest, 2013”

[5] Pavlos. S. Georgilakis,” Environmental cost of distribution transformer losses” Applied Energy 88 (2011) 3146–3155.

[6] CEB Specification, 108-1:2014_5 MVA 33 kV\11 kV Power Transformer with on load Tap Changer.

[7] CEB standard, 108-1:2014_5 MVA 33 kV\11 kV Power Transformer with on load Tap Changer.

[8] CEB Specification, 098_2000_MEDIUM VOLTAGE DISTRIBUTION TRANSFORMERS.

[9] Loss evaluation guide, IEEE C57.120-1991

[10] CEB, MEDIUM VOLTAGE DISTRIBUTION SYSTEM DEVELOPMENT PLAN 2014/2023, DISTRIBUTION DIVISION 03.

[11] Bulk Supply Tariff Forecast based on Tariff Methodology, 2011, Deputy General Manager (Energy Marketing Branch)

[12] Central Bank of Sri Lanka web site, www.cbsl.gov.lk

[13] Ceylon Electricity Board, “Annual Report, 2011”

[14] D.J. Downing, B.W. Mcconnell, P.R. Barns, S.W Hadley, J.W. Van Dyke; Economic analysis of efficient distribution transformer trends,1998, Oak Ridge National Laboratory, ORNL-6927.

[15] NEMA Standards publication TP 1-2002, Guide for Determining Energy Efficiency of Distribution Transformers. National Electrical Manufacturers Association. Rosslyn, Virginia

[16] Ceylon Electricity Board, Statistical Unit, “Statistical Digest, 2002-2012

[17] B.W. Mcconnell, P.R. Barns, S. Das J.W. Van Dyke; Supplement to the "Determination Analysis" (ORNL-6847) and Analysis of the NEMA Efficiency Standard for Distribution Transformers, 1998, Oak Ridge National Laboratory, ORNL-6927.

[18] Tender specifications. (2013), Lanka Transformers Limited

[19] Super Star Engineering Ltd. (2014) Distribution-Transformers [online] Available from;http://superstarengineering.com/11-415kv-distribution-transformer [Accessed: 10th April 2015]

[20] Mustafa, K. M., Tahreen T. C., & Siban S. (2013) Energy Subsidies in Bangladesh: A profile of groups vulnerable to reform. Bangladesh Institute of Development Studies. *Research Report*. International Institute for Sustainable Development.

[21] General Electric Manufacturing Company Limited. (2013) Distribution-Transformers price list [online] Available from;http://www.gemco.gov.bd/index.php?option=staticpagemanager&task=price_list [Accessed: 26 th April 2015]

[22] Ceylon Electricity Board, "Price List, 2013"

APPENDIX 01

Monthly Inflation Percentage Rates Year 2010-2013 [12]

	Year			
Month	**2010**	**2011**	**2012**	**2013**
January	3.2	6.1	6.5	8.1
February	3.3	6.1	6.1	8.6
March	3.4	6.2	5.9	8.8
April	3.8	6.4	5.7	8.8
May	3.9	6.6	5.6	8.8
June	4.3	6.7	5.8	8.6
July	4.6	7.0	6.0	8.3
August	4.9	7.1	6.3	8.0
September	5.3	7.2	6.5	7.8
October	5.7	7.1	6.8	7.6
November	6.1	6.9	7.2	7.3
December	6.2	6.7	7.6	6.9

APPENDIX 02

Monthly Average Weighted Fixed Deposit Percentage Rates, Year 2010-2013 [12]

	Year			
Month	**2010**	**2011**	**2012**	**2013**
January	10.46	8.16	9.11	13.53
February	9.99	8.14	9.37	13.82
March	9.71	8.17	9.84	13.94
April	9.61	8.16	10.56	13.83
May	9.50	8.24	10.38	13.90
June	9.40	8.22	10.78	13.61
July	9.28	8.16	11.27	13.36
August	9.17	8.11	11.54	12.82
September	8.68	8.11	11.92	12.57
October	8.48	8.12	12.32	12.38
November	8.17	8.21	12.78	11.96
December	8.20	8.95	13.21	11.78

APPENDIX 03

Data (Demand in 'W') of Mapalana Distribution Transformer- C056 (160 kVA)

Time/ Date	2013.05.11	2013.05.12	2013.05.13	2013.05.14	2013.05.15	2013.05.16	2013.05.17
0:00	13116.58	12816.39	12374.91	12968.63	14461.01	13068.36	14773.03
0:15	12774.88	12394.48	11393.47	12051.27	13357.21	13398.5	14536.71
0:30	11977.3	12025.2	11259.93	12084.17	12944.55	12737.68	14218.66
0:45	11374.97	11979.02	11266.38	11934.72	12742.84	12534.41	14435.85
1:00	11289.6	11954.08	11145.95	11617.97	12702.41	12325.45	13418.5
1:15	11144.23	11972.73	11094.35	11897.73	12317.71	12658.98	13373.77
1:30	10838.61	11606.57	11062.25	11634.69	12175.35	12744.99	13171.85
1:45	10824.68	11445.51	11221.86	11610.87	11943.97	12892.72	13250.34
2:00	10578.89	11561.63	11127.03	11468.73	11909.78	12607.15	13084.33
2:15	10548.14	11590.44	11156.71	11328.95	11951.92	12416.41	13213.13
2:30	10654.37	11566.57	11133.48	11404	12135.78	12435.98	13184.32
2:45	10935.86	11916.44	11142.73	11299.06	12440.28	12502.37	13097.01
3:00	10763.77	11461.63	10854.36	11286.16	12984.33	12514.04	13127.55
3:15	10527.93	11648.93	10816.51	11297.99	12821.76	12502.37	13026.26
3:30	10405.3	11483.35	10652.44	11105.31	12694.03	12535.97	13035.73
3:45	10452.67	11639.04	10948.12	11154.13	12508.88	12516.62	12799.77
4:00	10521.26	11894.51	11015.43	12638.18	12627.15	12778.75	12939.17
4:15	10451.81	11901.82	10986.4	11900.75	12927.35	12451.25	12991.86
4:30	10684.48	12351.25	11206.38	12139.65	14149.2	12872.94	13132.49
4:45	11116.49	12686.5	12184.81	13984.27	14490.69	13745.79	13196.36
5:00	11566.57	13143.46	12926	16963.22	14719.49	14854.75	13405.33
5:15	13221.31	14366.82	13786.65	17709.41	14908.08	16180.69	14071.36
5:30	16166.49	15073.88	14376.5	15342.03	16846.88	17952.19	15085.92
5:45	18726.12	16975.26	19264.36	17102.56	17085.79	20846.84	16814.84
6:00	18468.07	21660.77	18345.92	16466.05	16899.08	22268.26	18116.48
6:15	20092.27	18871.27	18553.65	15001.41	16392.72	21461.16	17217.82
6:30	21239.93	18691.06	17558.18	15348.91	15687.17	19697.02	15495.14
6:45	18976.85	15981.34	17303.2	11603.77	13511.18	14422.09	12517.26
7:00	15219.67	12757.68	13541.07	13638.48	13115.94	10325.58	12130.41
7:15	10757.81	9025.01	11714.9	12943.69	11471.53	9978.45	11059.72
7:30	8842.66	8795.08	10376.97	10589.65	9225.86	9671.21	10396.11
7:45	7749.83	8744.39	8803.31	10273.32	8286.14	7921.21	9968.77
8:00	7837.13	7758	7496.94	9444.99	8207.86	7627.47	9003.3
8:15	9960.87	6903.81	6844.94	10958.65	7222.98	7792.62	7193.09
8:30	8445.21	6623.02	7481.89	10998.44	7344.48	7039.98	9449.29
8:45	8516.02	6630.54	7195.02	9632.88	8024.22	6538.94	7587.69
9:00	8297.96	7459.95	7765.74	9120.28	6794.4	6745.38	7437.16
9:15	7753.48	7718.86	8393.23	9532.94	6391.42	7404.47	7584.52

9:30	7641.23	7847.03	7989.17	9885.18	7239.75	7063.63	4719.97
9:45	8116.9	9327.95	7499.31	9651.64	7998.2	6778.49	6813.33
10:00	8123.57	9977.37	7906.38	7827.03	7997.12	7111.16	6151.44
10:15	8006.16	8539.02	8437.96	8604.83	7392.43	7715.85	7457.16
10:30	7368.56	9144.15	6854.4	8743.31	6317.23	7027.29	6527.54
10:45	7895.19	8385.7	7757.14	8993.19	6689.73	7924.66	5694.04
11:00	7896.7	8831.69	8349.79	9752.5	8274.53	7876.7	5936.4
11:15	7598.01	11129.18	8469.35	9175.76	7345.98	6600.44	6051.01
11:30	7740.58	8103.78	9177.69	8247.22	8397.53	7579.3	5727.16
11:45	10226.23	7601.23	8149.59	7865.95	7814.77	7204.27	6802.79
12:00	8844.6	7231.58	8101.63	9350.8	8763.74	7104.06	6055.74
12:15	8025.29	7922.72	7814.34	8521.39	11380.99	8103.35	6264.12
12:30	8254.31	7854.34	9801.74	9645.19	9507.99	7672.84	7252.87
12:45	9464.34	6667.75	8552.36	8908.89	11276.91	7958.2	7630.27
13:00	7154.6	6923.43	8754.92	7836.06	9761.26	9494.82	6778.06
13:15	6827.31	6755.48	8863.3	7240.18	10286.22	6902.57	6194.23
13:30	8624.18	7316.52	8470.64	8357.75	9371.66	6442.6	5988.17
13:45	8218.4	7689.83	8760.73	9004.59	8957.49	6888.16	7179.76
14:00	8492.58	7529.63	8062.93	9232.1	8756.43	7296.95	6305.19
14:15	9671.86	7171.37	8171.31	8825.46	9874.21	7790.69	6490.12
14:30	8812.99	8406.13	9198.5	9444.77	9272.74	7759.29	6643.23
14:45	8600.96	8679.23	8623.54	9460.04	9584.33	8272.97	7912.18
15:00	9310.16	8195.39	9389.94	9624.98	8032.82	9033.83	7896.05
15:15	9376.82	7881.22	7994.33	8794.49	8555.58	8618.16	8600.53
15:30	7981.64	8040.13	7793.7	9659.81	8404.19	8030.02	8271.3
15:45	8355.81	9972.7	7501.89	10745.98	8066.8	7071.38	10980.16
16:00	7688.33	9275.75	7544.68	11222.08	9121.57	8051.1	10205.37
16:15	6510.23	9136.62	8326.51	8396.02	11778.39	8473.65	8290.01
16:30	8641.81	8427.85	8210.87	8191.52	10584.92	7285.77	7388.78
16:45	9160.92	11453.84	10057.58	9360.91	8255.82	7268.57	7683.17
17:00	9003.73	8685.25	10316.12	10141.93	7729.61	8600.31	8861.58
17:15	7407.91	8308.5	8688.48	10835.44	7938.42	9810.34	8011.96
17:30	8114.32	7945.08	9801.74	12333.41	10216.34	8350.22	8474.94
17:45	10228.38	9013.83	11048.33	11543.73	12726.07	10168.81	10227.3
18:00	8877.07	10498.25	14717.12	11524.86	12470.82	10391.38	7551.99
18:15	11131.98	13057.02	13360.65	20533.1	16163.7	11130.47	10723.19
18:30	15171.07	16527.98	17446.2	21060.59	18902.45	15214.94	16102.2
18:45	19757.66	22283.52	24066.2	23652.68	24291.78	19711.21	21072.85
19:00	27107.95	27206	25671.26	29955.29	29408.87	25067.86	27740.81
19:15	27373.31	28917.51	29183.3	28478.18	28298.19	26988.33	30073.13
19:30	25891.89	28288.95	29523.71	29304.36	28768.05	28919.01	34556.07
19:45	27119.34	28386.79	29876.59	29749.71	29585.85	28885.47	30657.4
20:00	27047.95	29044.17	29111.69	30143.45	29090.18	28602.04	30686.21

20:15	26943.23	26599.81	28699.24	30814.38	28370.23	29001.37	29612.09
20:30	25966.73	27212.24	28276.26	29318.77	28198.84	28816.44	30377.41
20:45	26078.76	27884.67	27850.05	28818.16	27590.71	29892.28	29881.96
21:00	27135.9	26132.74	29482.2	29539.83	26956.29	28984.82	28538.82
21:15	27255.03	24958.41	26072.31	28095.62	26447.99	25643.52	27094.18
21:30	27262.99	24114.8	24767.67	28436.03	23367.75	25562.67	26967.04
21:45	26437.24	22398.78	23729.4	26824.74	22141.38	23832.46	26731.2
22:00	25324.62	19890.13	21090.27	24838.84	20561.48	23519.14	24779.92
22:15	22303.31	21265.31	18815.14	23772.46	18332.16	21775.6	22657.91
22:30	20052.7	17209.65	17230.08	20417.84	16828.17	19704.55	21525.94
22:45	18468.93	16152.95	16038.98	18493.23	16239.39	18288.08	20046.84
23:00	16628.62	14097.59	14768.09	18171.74	15895.33	17386.63	17629.84
23:15	15591.26	12937.83	14441.44	17000.63	14741.42	16613.35	16429.49
23:30	14337.79	12581.99	13887.88	15754.91	14018.03	15516.86	15565.46
23:45	13871.37	12251.91	13416.99	14553.69	13512.9	14890.45	14981.84

APPENDIX 04

Data (Demand in 'W') of Rakwana Distribution Transformer- Q071 (160 kVA)

Time/ Date	2013.09.06	2013.09.07	2013.09.08	2013.09.09	2013.09.10	2013.09.11	2013.09.12
0:00	67797.03	59356.43	57314.36	57450.49	56905.94	58811.88	60037.13
0:15	68750	59492.57	53910.89	56905.94	57178.22	55408.41	58948.02
0:30	63849.01	55408.41	52685.64	52549.5	55680.69	54319.31	56361.38
0:45	62079.21	55272.28	53230.2	51868.81	55544.55	54047.03	56633.66
1:00	62351.48	48601.48	51868.81	51596.53	56633.66	49826.73	53366.34
1:15	61670.79	54727.72	48193.07	49962.87	51324.26	49146.04	52141.09
1:30	63712.87	52141.09	51188.12	47240.1	51188.12	51596.53	51460.39
1:45	60173.27	52549.5	49146.04	48601.48	49418.32	48056.93	51732.67
2:00	57858.91	51732.67	48465.35	49962.87	52685.64	49690.59	50507.42
2:15	60173.27	52141.09	50915.84	47648.51	52277.23	48873.76	52685.64
2:30	59764.85	53230.2	47376.24	48193.07	51188.12	45878.71	51051.98
2:45	58267.33	52413.37	49009.9	48873.76	50779.7	46831.68	52277.23
3:00	59084.16	50779.7	50643.56	49282.18	51188.12	49009.9	51868.81
3:15	58539.6	53230.2	49146.04	49282.18	51051.98	48329.21	52957.92
3:30	56769.8	49690.59	50779.7	48465.35	52413.37	49962.87	52277.23
3:45	58403.46	51732.67	47512.38	47648.51	52549.5	47920.79	48737.62
4:00	61534.65	52413.37	50643.56	46559.4	53230.2	47784.65	53094.06
4:15	58811.88	56089.11	52549.5	50779.7	57586.63	53910.89	55272.28
4:30	61398.51	55816.83	54591.58	47784.65	58267.33	51324.26	53774.75
4:45	67252.47	60581.68	59492.57	50779.7	59356.43	54183.17	56089.11
5:00	74876.24	70519.8	68886.14	56769.8	64801.98	57858.91	59628.71
5:15	82908.41	76101.48	71064.35	59492.57	72970.3	57722.77	58539.6
5:30	86311.88	79096.53	82772.28	61670.79	82091.58	66163.36	60990.1
5:45	87400.99	84950.49	85631.19	62079.21	84269.8	68205.44	63440.59
6:00	92710.39	86584.16	82908.41	60037.13	80049.5	68341.58	65891.09
6:15	89987.62	82500	86992.57	58675.74	81002.47	66163.36	66299.5
6:30	80049.5	79913.36	78279.7	57722.77	85086.63	63985.15	62759.9
6:45	74467.82	75420.79	81955.44	57586.63	80730.2	64393.56	59220.3
7:00	78415.84	69566.83	76509.9	57450.49	63849.01	69158.41	64665.84
7:15	76101.48	61398.51	62215.35	61534.65	65346.53	62351.48	63849.01
7:30	74603.96	62079.21	62351.48	64938.12	64257.42	63032.18	69022.28
7:45	62896.04	63576.73	69294.55	78007.42	69294.55	68750	62759.9
8:00	63985.15	69430.69	67116.34	78415.84	79641.09	80457.92	66844.06
8:15	68477.72	78824.26	70383.66	70928.22	81683.17	82500	67660.89
8:30	73242.57	71608.91	63168.32	74059.4	76782.18	88353.96	73106.43
8:45	84133.66	71200.49	60915	72970.3	73242.57	103329.21	80730.2
9:00	97883.66	94888.61	50915.84	70383.66	97202.97	101150.99	78960.39
9:15	118304.45	88081.68	85495.05	71881.19	105235.15	105371.28	72289.6

9:30	116126.24	87264.85	83589.11	75693.07	101559.4	112314.35	71745.05
9:45	107277.23	94071.78	95977.72	73514.85	115037.13	115173.26	80185.64
10:00	92710.39	89170.79	87537.13	78551.98	96930.69	104554.45	83997.52
10:15	79368.81	76373.76	75284.65	78960.39	104282.18	77871.29	74603.96
10:30	98564.35	89170.79	85358.91	79913.36	108774.75	87809.4	71881.19
10:45	115853.96	101423.27	84950.49	75284.65	117079.21	120482.67	80321.78
11:00	112722.77	92029.7	85495.05	75012.37	109727.72	118032.18	82363.86
11:15	113131.19	96658.41	90123.76	82227.72	113539.6	109455.44	86856.43
11:30	122116.33	92846.53	91893.56	85222.77	117759.9	111905.94	92438.12
11:45	123477.72	90668.31	100061.88	89579.21	108094.06	114628.71	71064.35
12:00	118440.59	105779.7	95160.89	88898.51	113675.74	108502.47	83725.25
12:15	116806.93	106732.67	95024.75	89851.48	127698.02	119801.98	84678.22
12:30	113131.19	102240.1	103056.93	89170.79	124702.97	132462.87	88490.1
12:45	110136.14	107685.64	102103.96	91485.15	116943.07	128106.43	88353.96
13:00	113811.88	98428.22	90668.31	84950.49	103873.76	117759.9	85631.19
13:15	117215.34	86992.57	78143.56	81955.44	91076.73	90940.59	82227.72
13:30	100061.88	81274.75	86992.57	81683.17	94888.61	77054.45	81410.89
13:45	99653.46	74603.96	90123.76	75829.21	101014.85	93254.95	73106.43
14:00	99108.91	76373.76	91485.15	76509.9	97202.97	90123.76	69839.11
14:15	92165.84	85222.77	75965.34	78824.26	113131.19	87400.99	73923.27
14:30	112722.77	94344.06	74603.96	75965.34	138044.55	98836.63	79641.09
14:45	115445.54	103737.62	76373.76	78824.26	139542.08	105507.42	74603.96
15:00	101831.68	100334.16	77735.15	74331.68	133688.12	91757.42	78007.42
15:15	96522.28	101150.99	78143.56	73242.57	136955.44	94752.47	87945.54
15:30	103193.07	88762.37	70519.8	67797.03	121299.5	88898.51	77599.01
15:45	107277.23	98700.49	82363.86	68341.58	115173.26	88898.51	77190.59
16:00	87673.27	95024.75	79913.36	66435.64	121980.2	93935.64	79232.67
16:15	97611.38	71472.77	78688.12	72425.74	105371.28	94071.78	77190.59
16:30	90259.9	76373.76	80321.78	70655.94	108502.47	76509.9	76101.48
16:45	81955.44	74603.96	76918.32	67797.03	84269.8	73242.57	68750
17:00	84133.66	75420.79	78824.26	66163.36	83861.38	77054.45	68477.72
17:15	90940.59	81138.61	82772.28	63985.15	83452.97	83997.52	70383.66
17:30	86311.88	83180.69	85903.46	68886.14	84133.66	87945.54	73514.85
17:45	84133.66	75556.93	84542.08	75693.07	85086.63	91076.73	77871.29
18:00	91076.73	87809.4	86039.6	78279.7	89579.21	94752.47	82091.58
18:15	91485.15	96658.41	89306.93	89443.07	92029.7	97066.83	93663.36
18:30	105779.7	98564.35	98836.63	103329.21	100742.57	105235.15	109863.86
18:45	115717.82	109863.86	115309.4	113675.74	112178.22	106051.98	122388.61
19:00	118304.45	109863.86	120346.53	114220.29	121435.64	113811.88	129467.82
19:15	119529.7	114628.71	120618.81	124022.27	124975.24	123477.72	130420.79
19:30	120891.09	118440.59	117079.21	125928.22	119121.28	122252.47	130693.07
19:45	118440.59	118304.45	119393.56	126608.91	122933.17	121844.06	130693.07
20:00	122388.61	121163.36	115173.26	126472.77	124566.83	117351.48	125792.08

20:15	129467.82	122797.03	114356.43	127289.6	121844.06	119393.56	124839.11
20:30	127970.29	121299.5	118576.73	122797.03	117623.76	121435.64	125111.38
20:45	125519.8	119121.28	115717.82	121435.64	115990.1	114356.43	123341.58
21:00	112858.91	108366.33	116126.24	114084.16	117215.34	109863.86	117759.9
21:15	108910.89	105235.15	113948.02	110136.14	110272.27	107413.36	112178.22
21:30	109727.72	101014.85	105371.28	106732.67	104690.59	101695.54	106051.98
21:45	103193.07	99653.46	97883.66	104554.45	97066.83	96522.28	103737.62
22:00	98292.08	95705.44	95160.89	95433.17	90532.18	93118.81	94888.61
22:15	89306.93	86856.43	87673.27	87264.85	89715.34	90532.18	92982.67
22:30	83861.38	81955.44	81955.44	80049.5	82363.86	87809.4	87264.85
22:45	75420.79	74876.24	75284.65	76509.9	78279.7	79641.09	80594.06
23:00	74740.1	72698.02	73650.99	70519.8	72561.88	72425.74	76646.04
23:15	69702.97	66707.92	67388.61	64257.42	70655.94	73650.99	71745.05
23:30	66163.36	63440.59	64393.56	62896.04	67252.47	69430.69	66299.5
23:45	62896.04	59628.71	59356.43	60037.13	62623.76	64257.42	64529.7

APPENDIX 05

Data (Demand in ‘W’) of Yodagama Distribution Transformer-R039 (400 kVA)

Time/ Date	2013.03.11	2013.03.12	2013.03.13	2013.03.14	2013.03.15	2013.03.16	2013.03.17
0:00	46150	49030	39210	42750	38620	36150	36620
0:15	46290	49420	39040	42280	38740	33190	38060
0:30	42570	49250	37730	43580	37810	32930	37520
0:45	42900	48690	37160	40010	37390	31740	37850
1:00	43690	50120	37790	39580	38620	32330	35660
1:15	46060	48620	36100	39650	38570	32950	35830
1:30	45820	49410	37430	39310	37940	32040	35210
1:45	47940	47220	36870	40060	38160	31260	35090
2:00	47350	45970	36040	38450	39110	31270	35400
2:15	46160	47620	36520	37880	38240	32040	36190
2:30	46580	48430	36320	38920	38240	31530	37120
2:45	44710	46790	35330	39110	38350	30330	36100
3:00	41980	46260	36780	38090	38290	29930	36500
3:15	43840	41690	35700	37690	37270	30580	35640
3:30	43310	41090	35240	38490	38730	30130	36060
3:45	42570	46510	35960	37260	38240	30410	37110
4:00	43500	48860	33480	39460	39400	30840	37680
4:15	45110	48390	34310	38650	44710	31920	35980
4:30	46810	44220	35240	39030	45140	35400	38210
4:45	46530	44750	35670	38720	49090	38320	38590
5:00	46460	54600	40500	41680	48950	41070	38750
5:15	49770	57580	43440	46020	51670	42410	39610
5:30	51690	72160	46720	48500	55550	47830	42580
5:45	50350	70950	50690	56340	58810	60360	44950
6:00	51220	75730	57630	54570	65220	65710	52040
6:15	55430	81620	57790	60360	59670	65300	55650
6:30	56940	78680	54530	55580	55280	67810	55820
6:45	54580	68900	49020	54500	51710	61110	47060
7:00	55900	59100	43140	58620	52030	53240	44180
7:15	59280	62050	45190	41860	55340	52240	55980
7:30	70390	53960	48660	39660	55520	55040	67080
7:45	71040	65260	48100	45700	70810	54980	61070
8:00	68040	62810	79360	60890	122700	61760	54190
8:15	78340	60930	111900	59500	127300	48910	54850
8:30	96560	62300	106100	82730	116900	49570	79890
8:45	100400	55990	102800	47260	56820	57510	108400
9:00	72350	51720	85630	36970	59090	65820	86200
9:15	74170	64920	58530	86820	97690	54100	101800

9:30	84900	74690	93990	117000	95580	53770	107200
9:45	91290	64280	125900	121200	110700	63300	155700
10:00	74020	63260	126600	97360	92310	67980	154400
10:15	71490	65690	125600	97840	74600	67440	143400
10:30	71930	74660	126700	92350	78690	73720	148900
10:45	87200	70980	104700	104600	78230	85820	127500
11:00	77530	62740	88940	108300	72360	113300	112700
11:15	89000	63860	123700	116200	72830	115200	152100
11:30	112100	70890	121800	113800	75350	107500	142500
11:45	111200	69770	118900	103000	109200	113500	132200
12:00	116000	68230	117100	105100	125500	107600	103400
12:15	117700	75070	111100	141400	134500	106300	114800
12:30	119300	81210	116400	136500	119700	115800	108000
12:45	101600	90260	112100	109400	74130	104500	64180
13:00	91940	83680	91620	80670	66390	72010	72330
13:15	89400	61240	90750	60360	67750	57490	77940
13:30	81170	62170	83760	57540	70010	64510	79320
13:45	63750	67690	70050	66620	108600	68630	124600
14:00	65520	66770	67080	77900	94860	74890	133200
14:15	67180	69440	83320	113600	117800	116800	130200
14:30	64370	68290	82760	118000	134700	158900	123700
14:45	61460	76560	84460	115600	138900	151400	125500
15:00	66050	90000	95530	114400	132000	145300	92500
15:15	61670	108200	103500	115600	127800	123000	58410
15:30	58350	115200	110900	113200	127500	115400	95370
15:45	60330	118000	92630	108500	116300	60540	115500
16:00	58880	114400	97870	93560	67410	80890	123800
16:15	61740	118400	95460	91580	55030	99750	108400
16:30	54920	76050	96880	93490	57870	100800	98840
16:45	51880	76140	68620	83880	58310	83290	106900
17:00	49050	69940	60850	86090	53310	89850	72450
17:15	53350	65330	58380	97000	54290	77370	61350
17:30	52910	64040	57120	96110	57750	78880	55430
17:45	52880	58610	62310	97490	56130	82930	65950
18:00	53330	60960	64360	99970	58970	89680	63160
18:15	64200	66640	66860	79460	65530	93810	72400
18:30	61610	68460	67480	67180	72370	73090	75310
18:45	66150	72960	66090	65900	75820	71690	75820
19:00	63200	79280	66950	66900	69770	71630	77030
19:15	69640	77770	70140	73640	63570	72880	75070
19:30	70200	78610	75820	71360	63880	71190	74860
19:45	75460	80100	75730	72220	62620	67640	75480
20:00	78220	85180	72510	74630	67150	73050	76340

20:15	77100	77670	75230	80200	67420	72870	69030
20:30	82200	74940	74390	78080	59480	70730	67880
20:45	76880	72970	73730	74920	59830	66440	68560
21:00	68140	66700	67580	73970	62570	64440	65360
21:15	61760	63990	63570	71590	54030	64050	66860
21:30	57480	60030	61700	65330	51370	58970	64620
21:45	56310	57580	61230	59640	48870	55550	56060
22:00	54450	60810	57550	57820	46190	50430	56390
22:15	51650	55820	54710	55210	43430	46130	53940
22:30	48350	50950	54050	51690	42570	44780	52370
22:45	47300	49190	48900	51460	40100	41830	51400
23:00	47580	47550	47280	48290	38670	40540	49780
23:15	51330	47150	42020	44440	39490	39300	48650
23:30	48880	43040	40620	42700	38810	39610	48200
23:45	49970	39090	42240	41340	37330	37670	47230

APPENDIX 06

Microsoft Excel Macro Code for Computer Based Calculation of Capitalization Values

%===%

```
Private Sub CommandButtonto2LLF_Click()
Me.Hide
FormLLF.Show
End Sub
Private Sub CommandButtonBack2TD_Click()
'Unload Me
MsgBox ("Please input values and proceed with 'next' button")
End Sub
Private Sub CommandButtonPWFCRF_Click()
Dim TFlifetime, RateOfReturn, Inflation As Double
Dim nValue As Double
Dim aValue As Double
Dim iValue As Double
TFlifetime = Val(TextBox1.Value)
RateOfReturn = Val(TextBox2.Value) / 100
Inflation = Val(TextBox3.Value) / 100
PresentEnerCost = Val(TextBox4.Value)
nValue = TFlifetime
aValue = Inflation
iValue = RateOfReturn
Call RefreshNresult(nValue)
Call RefreshAResult(aValue)
Call RefreshIResult(iValue)
Dim CRFvalue As Double
Dim PWFValue As Double
Dim ECValue As Double
```

```
CRFvalue = (RateOfReturn * ((1 + RateOfReturn) ^ TFlifetime)) / (((1 + RateOfReturn) ^ TFlifetime) - 1)

LabelCRF.Caption = CRFvalue

PWFValue = (1 - ((1 + Inflation) / (1 + RateOfReturn)) ^ TFlifetime) / (RateOfReturn - Inflation)

LabelPWF.Caption = PWFValue

ECValue = PresentEnerCost * PWFValue * CRFvalue

LabelEC.Caption = ECValue

Call RefreshECresult(ECValue)

End Sub

%==============================================================%

Private Sub CommandButtonBack2PL_Click()

Me.Hide

FormPL.Show

End Sub

Private Sub CommandCalLLF_Click()

Dim LossFac, LossofLoadFac, PeakLoad As Double

Dim llfValue As Double

Dim plValue As Double

LossFac = Val(TextBox1.Value) / 100

LossofLoadFac = (0.2 * LossFac) + (0.8 * LossFac ^ 2)

PeakLoad = LossFac / (Sqr(LossofLoadFac))

LabelLLF.Caption = LossofLoadFac

LabelPL.Caption = PeakLoad

llfValue = LossofLoadFac

plValue = PeakLoad

Call RefreshLLFresult(llfValue)

Call RefreshUAPLresult(plValue)

End Sub

Private Sub GotoformFC_Click()

'MsgBox (LLFValuePass)
```

```
Me.Hide
FormFC.Show
End Sub
%===============================================================%
Dim RateOfReturn, BookDepre, Taxes, LocalPropTaxInsuara, Sum As Double
Private Sub CommandButtonBack2LLF_Click()
Me.Hide
FormLLF.Show
End Sub
Private Sub CommandButtonFC_Click()
RateOfReturn = Val(TextBox1.Value)
BookDepre = Val(TextBox2.Value)
Taxes = Val(TextBox3.Value)
LocalPropTaxInsuara = Val(TextBox4.Value)
Sum = RateOfReturn + BookDepre + Taxes + LocalPropTaxInsuara
LabelFC.Caption = Sum
Call RefreshFCresult(Sum)
'sgBox (FCValuePass)
End Sub
Private Sub CommandButton2FormABD_Click()
Unload Me
FormSC.Show
End Sub
%===============================================================%
Dim SysCap As Double
Private Sub CommandButton_GoTOFormABD_Click()
Call RefreshSCresult(Val(TextBoxSCValue.Value))
'MsgBox (SCValuePass)
Me.Hide
FormABD.Show
```

```
End Sub
Private Sub CommandButtonBack2TD_Click()
Unload Me
FormFC.Show
End Sub
Private Sub CommandButtonSC_Click()
Me.TextBoxSCValue.Value = Val(TextBoxGCValue.Value) +
Val(TextBoxTCValue.Value) + Val(TextBoxDCValue.Value)
End Sub
Private Sub OptionButton1_Click()
Me.CommandButtonSC.Enabled = True
Me.TextBoxGCValue.Visible = True
Me.TextBox13.Visible = True
Me.TextBoxDCValue.Visible = True
Me.TextBoxSCValue.Enabled = False
SysCap = Val(TextBoxGCValue.Value) + Val(TextBoxTCValue.Value) +
Val(TextBoxDCValue.Value)
End Sub
Private Sub OptionButton2_Click()
Me.TextBoxGCValue.Visible = False
Me.TextBoxTCValue.Visible = False
Me.TextBoxDCValue.Visible = False
Me.CommandButtonSC.Enabled = False
Me.TextBoxSCValue.Enabled = True
' RefreshSCresult (Val(TextBoxSCValue.Value))
End Sub
%=================================================================%
Dim Inflat, RateOfReturn, EnergyCost, HoursPerYear, PeakLoadFac, LossofLoadFac,
PeakResponsibleFac, FixedChargeRate, SysCapCost, EfficiencyOfTransmisson,
IncreasingFac, aValue, Bvalue As Double
Dim TFlifetime As Integer
Private Sub CommandButtonEF_Click()
```

```
' Variables for Calculate transformer loss data
Inflat = Val(TextBox8.Value) / 100
RateOfReturn = Val(TextBox9.Value) / 100
TFlifetime = Val(TextBox7.Value)
EnergyCost = Val(TextBox10.Value)
HoursPerYear = Val(TextBox1.Value)
PeakLoadFac = Val(TextBox17.Value)
PeakResponsibleFac = Val(TextBox3.Value) / 100
LossofLoadFac = Val(TextBox18.Value)
FixedChargeRate = Val(TextBox16.Value) / 100
SysCapCost = Val(TextBox19.Value)
EfficiencyOfTransmisson = Val(TextBox20.Value)
IncreasingFac = Val(TextBox21.Value)
aValue = (SysCapCost + HoursPerYear * EnergyCost) / (FixedChargeRate *
EfficiencyOfTransmisson * IncreasingFac * 1000)
Bvalue = (((SysCapCost * PeakResponsibleFac ^ 2) + (HoursPerYear * EnergyCost *
LossofLoadFac)) * (PeakLoadFac ^ 2)) / (FixedChargeRate * EfficiencyOfTransmisson *
IncreasingFac * 1000)
LabelAval.Caption = Round(aValue, 2)
LabelBval.Caption = Round(Bvalue, 2)
End Sub
Private Sub RestWork_Click()
' Unload.Me
Me.Hide
FormPL.Show
End Sub
Private Sub CommandButtonBack2SC_Click()
Me.Hide
FormSC.Show
End Sub
Private Sub UserForm_Initialize()
```

```
TextBox7.Value = nValuePass

TextBox9.Value = iValuePass

TextBox8.Value = aValuePass

TextBox10.Value = ECValuePass

'TextBox9.Value = MARValuePass

TextBox17.Value = UAPLValuePass

TextBox16.Value = FCValuePass

TextBox19.Value = SCValuePass

TextBox18.Value = LLFValuePass

End Sub

%=================================================================%

Public nValuePass, iValuePass, aValuePass As Double

Public PLValuePass, CRFValuePass, ECValuePass, MARValuePass, FCValuePass,
SCValuePass As Double

Public LLFValuePass, UAPLValuePass As Double

Function RefreshNresult(n As Double)

nValuePass = n

End Function

Function RefreshPLresult(testres2 As Double)

PLValuePass = testres2

End Function

Function RefreshCRFresult(testres3 As Double)

CRFValuePass = testres3

End Function

Function RefreshECresult(testres4 As Double)

ECValuePass = testres4

End Function

Function RefreshMARresult(testres5 As Double)

MARValuePass = testres5

End Function

Function RefreshFCresult(testres6 As Double)
```

```
FCValuePass = testres6
End Function
Function RefreshSCresult(testres7 As Double)
SCValuePass = testres7
End Function
Function RefreshLLFresult(LLF As Double)
LLFValuePass = LLF
End Function
Function RefreshUAPLresult(uapl As Double)
UAPLValuePass = uapl
End Function
Function RefreshAResult(a As Double)
aValuePass = a
End Function
Function RefreshIResult(i As Double)
iValuePass = i
End Function
Sub Button1_Click()
FormPL.Show
End Sub
%=============================================================%
```

years over which to annualize cost (years)	35
transformer life (years)	35
Expected annual inflation rate (%) (a)	6.425
Discount rate (%) (i)	10.42
Hours per year (HPY)	8760
Load Factor (%) (LF)	
Peak responsible factor (RF)	
Loss Multiplier (LM)	10.79
Efficiency of Transmission (ET = 100 - LM)	
Increasing factor (IF)	

System capacity cost (Rs/KWh-year) (SC)	24084.82
Levelized energy cost (Rs/KWh) (EC)	36.75
Fixed Charge rate (%) (FC)	15.71

Loss factor (llf) = 0.2*LF + 0.8*(LF)^2
uniform annual peak load (PL=LF/Squar(llf)