



# **SEGREGATION AND ANALYSIS OF DISTRIBUTION LOSSES AND MITIGATING TECHNIQUES**

Master of Electrical Engineering Thesis

J.P.R. JAYASINGHE

Department of Electrical Engineering  
University of Moratuwa,  
Sri Lanka

2005

84120



## Abstract

The operational efficiencies of a utility depend on the losses in the electrical distribution network. High losses contribute to inefficient electrical network resulting large tariff to utility consumers. Hence more attention should be paid to minimize and maintain system losses to an economical level.

The situation reveals that the distribution losses of the CEB are higher than that of developed countries. Detailed energy audit should be carried out to identify the areas where the loss level is high. The study will help to localize the area suffering from high energy losses. Thus the measurement should be carried by installing energy meters for the said areas.

This thesis presents a study about the electrical losses in low voltage distribution system of CEB. The nature of the distribution losses in low voltage power distribution system, their sources, measurement of technical and non-technical losses and their impact on the system are presented. The steps that can be taken to have an assessment of the distribution losses and steps to be taken to reduce technical losses and corrective actions to plug non-technical losses by proper administrative actions are detailed. A methodology to segregate distribution losses is also presented.

Variation of low voltage distribution losses and voltage drop with consumer density per km were calculated. According to that results low voltage distribution line length in semi urban areas have to be limited in order to maintain the required voltage regulation and also to bring down LV losses.

Unbalance voltages can results in adverse effects on equipment and the electric distribution system. Under unbalanced condition the distribution system will incur more losses as heating effects ( $I^2R$  losses). More over, inaccuracy of metering power in three phase circuits due to unbalance current or voltage is discussed . Method for the selection of a distribution transformer of optimum capacity for given loading



conditions is presented. In this regard economic evaluation is done based on initial transformer cost and operation and maintenance cost of transformer over its life.

## Contents

	Page
Declaration	I
Abstract	II
Acknowledgement	III
List of figures	IV
List of tables	V

### Chapters

<b>1. Introduction.</b>	<b>1</b>
1.1 Background	1
1.2 Motivation	3
1.3 Objectives	4
1.4 Scope	5
1.5 Methodology	5
<b>2. Distribution loss management</b>	<b>7</b>
2.0 Distribution losses	7
2.1 Technical losses	7
2.2 Reasons for high technical losses	8
2.3 Reasons for non-technical losses	8
2.4 Measures for reducing technical losses	9
2.4.1 Short term measures	9
2.4.2 Long term measures	9
2.5 Measures for reducing non technical losses	10
2.6 Initiative required	10
<b>3. Calculation of the losses</b>	<b>12</b>
3.0 Theoretical analysis	12


3.1 Uniformly distributed loads	14
3.1.1 Calculation of voltage drop	14
3.2 Power losses in distribution network	17
3.2.1 Calculation of power losses	17
3.2.2 Improved lumped load model	19
3.3 Theoretical analysis of voltage drop and power/energy loss	21
3.3.1 Calculation of voltage drop	21
3.3.2 Power losses	23
3.3.2.1 Energy losses (kWh)	23
<b>4. Sample study (segregation of losses)</b>	<b>25</b>
4.0 Substation selection	25
4.1 Calculation of distribution system losses	26
4.1.1 Calculation period	26
4.2 Total distribution losses	26
4.3 Methodology	28
4.3.1 Model data base	28
4.3.2 Equipment data base	28
4.3.4 Protection data base	28
4.4 Network analysis for technical loss reductions	29
4.5 Segregation of losses	29
4.5.1 Measuring of total losses	29
4.5.2 Evaluation of losses	31
4.6 Identifying of high loss areas	32
4.7 Advantage of energy audit	32
<b>5. Impact of voltage imbalance</b>	<b>33</b>
5.0 Introduction	33
5.1 Definitions of voltage unbalance	34
5.2 Losses in imbalance distribution network	37
5.2.1 $I^2R$ loss in distribution lines due to unbalance	37
5.2.2 Effects of unbalance for the distribution losses	38
5.3 Effect of unbalance voltage at metering power in 3-phase circuit	39

5.3.1 Two and half-element meters	39
5.3.1.1 Derivation of formulas	40
5.3.2 Three element meters	42
5.3.2.1 Derivation of basic formulas for 3-element meters	43
5.4 Mitigation of voltage unbalance and its effects.	43
<b>6. Sample study (distribution transformer losses)</b>	<b>45</b>
6.1 Distribution transformers	45
6.1.1 Analysis of transformer loading	45
6.1.2 Building of load curve	46
6.1.3 Load duration curve	47
6.2 Preliminary calculation for selection of transformer	48
6.2.1 Calculation of loss component of 400kVA transformer	48
6.3 Selection of optimum capacity transformer	52
6.3.1 Loss of transformer life	52
6.3.2 Comparison of distribution transformers based on economic evaluation	53
6.3.2.1 Calculation criteria	53
<b>7. Conclusions, remarks and discussion</b>	<b>56</b>
<b>References</b>	<b>58</b>
<b>Appendices</b>	
Appendix A	60

## DECLARATION

The work submitted in this dissertation is the result of my own investigation, except where otherwise stated.

It has not already been accepted for any degree, and is also not being concurrently submitted for any other degree.

  
J.P.R. Jayasinghe

Date. 09/09/2025

We endorse the declaration by the candidate.

### ***UOM Verified Signature***

Professor H.Y.R. Perera

Date.

### ***UOM Verified Signature***

Dr. H.M. Wijckoon

Date.

## Acknowledgement

I wish to express my profound gratitude and sincere appreciation to my project supervisors, Professor H.Y.R. Perera and Dr. H.M. Wijekoon for their constant guidance and constructive suggestions.

I sincerely thank and highly value the support in the system planning branch of western province 1 and Kaldemulla consumer service centre for data collection, load reading, and practical issues in the all phase of this work. Your supports made this work a success.

Last but not least I would like to express my deepest gratitude and love to my wife Shiromi and my three sons Binith , Lathika, and Nidula. Your love, invaluable response and patience helped me to reach this target under tiring circumstances.



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)





## List of Figures

Figure	Page
3.1 Line to neutral equivalent circuit	12
3.2 Phasor diagram	13
3.3 Generalized line with uniformly distributed loads.	14
3.4 Load lumped at the mid point	16
3.5 One half load lumped at the end	16
3.6 Power loss model	18
3.7 Exact lumped load model	19
3.8 Exact lumped load model	21
3.9 Voltage drop in a three phase semi urban scheme.	22
3.10 Variation of energy loss with consumer density.	24
4.1 Measuring of total losses	29
4.2 Steps of Evaluation of losses	31
5.1 Symmetrical components of an unbalance system voltages.	35
5.2 Simple three phase network.	37
5.3 Simple three phase network with impedance in the neutral line.	38
5.4 Three phase 3 wire delta connected 2-1/2 element connections.	40
5.5 Phasor diagram of three phase 4-wire 2-element meter with delta connected CT41	
5.6 Three phase four wire three element connection	42
5.7 Phasor diagram of 3-phase, 4-wire, 3-element meter.	43
6.1 Load curve of Kalapura substation 400kVA.	46
6.2 Load duration curve for Kalapura substation 400kVA.	47
6.3 Transformer loss profile Kalapura 400kVA sub B - 028	50
6.4 Transformer loss profile 200kVA Sub.	51
6.5 Comparison of losses between lower end and higher end transformers.	51

## List of tables

Table	Page
1.1 Past system losses – CEB distribution planning branch report – 2004.	4
3.2 Voltage drop in a three phase semi urban scheme with consumer density.	22
3.3 Percentage power and energy loss with consumer density.	23
6.1 Recommended copper and iron losses for transformers conforming I.S. 2026 – 1962.	46
6.2 400kVA Transformer loss profile.	49
6.3 200kVA Transformer loss profile	50
6.4 No load and load loss component at 128 kVA average demand.	54



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)