

MEASURES TO REDUCE TRANSFORMER FAILURES IN THE DISTRIBUTION NETWORK OF CEB

A dissertation submitted to the
Department of Electrical Engineering, University of Moratuwa
in partial fulfillment of the requirements for the
Degree of Master of Science



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

by

VAJIRA BANDARA WIJEKOON

Supervised by
Professor H.Y.R. Perera
Dr. H.M. Wijekoon

Department of Electrical Engineering
University of Moratuwa, Sri Lanka

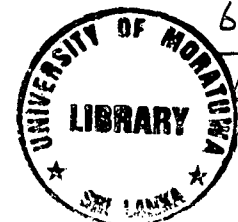
University of Moratuwa



96809

February 2011

96809



96809

621.3 "11"

621.3(043)

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.

UOM Verified Signature

V.B. Wijekbon
3rd February 2011

We endorse the declaration by the candidate.

UOM Verified Signature

Professor H.Y.R. Perera

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations

www.lib.mrt.ac.lk

UOM Verified Signature

Dr. H.M. Wijekoon

CONTENTS

Declaration	i
Abstract	iv
Acknowledgment	v
List of figures	vi
List of tables	vii
Chapter 1 – Introduction	1
1.0 Background	1
1.1 Motivation	4
1.2 Objective of the study	5
1.3 Scope of work	5
Chapter 2 - Causes for transformer failures	7
2.0 Voltage stresses	7
2.1 High switching and short circuit currents	10
2.2 Overloading	11
2.3 Transformer ageing	12
2.4 Incorrect installation practices	13
Chapter 3 - Transformer installations	17
3.0 MV and LV network configuration of CEB	17
3.1 Transformer installation practices in CEB	18
3.2 Earthing methods	21
Chapter 4 - Lightning surges	27
4.0 Typical lightning surge	27
4.1 Lightning effect on conductors	29
4.2 Lightning in Sri Lanka	33
4.3 Lightning effects on transformers	36
Chapter 5 – Transient wave simulation	39
5.0 PSCAD Software tool for transient analysis	39
5.1 Basic installation arrangements	39
5.2 Parameter selection for modeling	41
5.3 PSCAD Simulation	44
5.4 Simulation results	49
5.5 Observation of results	53
Chapter 6 - Conclusion	55
References	60

Appendix I	Photographs of the new earth layouts and their laying	62
Appendix II	Drawing of the shuttering for conventional earth block in-situ casting	64
Appendix III	Layout drawing of the improved earthing system – Horizontal conductor part	65
Appendix IV	Layout drawing of the improved earthing system – Vertical cylinder and horizontal conductor part	66
Appendix V	Layout drawing of the improved earthing system – Different mixes for horizontal conductor part & cylinder	67



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Abstract

Ceylon Electricity Board (CEB) has many transformer installations in its distribution network, with their capacities ranging from 100 kVA to 1000 kVA. The latest transformer designs are very much simplified and optimized. Due to the vast spread in the distribution network and practical constraints in employing high end protective devices, these transformers more frequently undergo adverse impacts imposed by the condition of the network and by the nature. These transformers are nowadays manufactured to operate almost without supervision. A high failure rate of nearly 3% per year (out of approximately 20,000 installed transformers) could be observed. When added up the cost due to loss of transformers, the overall loss becomes nearly one billion rupees per year. Although most of the causes contributing for these failures are thought beyond our control, it is investigated and found that this failure rate can be drastically reduced by merely following better erection practices.

This report discusses many causes for distribution transformer failures and elaborates on measures that can be adopted for reducing transformer failures, mainly through proper erection practices.



University of Moratuwa, Sri Lanka
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Existing transformer installations are studied and analyzed to see whether the present auxiliary gear used, lead connecting methods followed and earthing done are acceptable for proper functioning of transformers. It is analyzed and shown that the earthing method practiced presently on MV transformer installations is not effective. A research which has been initiated to determine an improved earthing system is introduced and discussed in this report. Conclusions of this research would be arrived after a careful study.

Studies are carried out to determine the most probable lightning pattern in Sri Lanka and their effects on the distribution network, especially on transformers. A transient waveform simulation is done to observe the voltage stresses exerted on transformers for few selected installation arrangements. This is further expanded to carry out a sensitivity analysis to observe the behavior of voltage stresses under different types of lightning surges. A better installation practice is thereby proposed.

Acknowledgement

I would like to thank my supervisors Professor H.Y.R. Perera and Doctor H.M. Wijekoon for being supportive and giving guidance and inspiration during my work.

I mention with gratitude Mr. Gemunu Abeysekera who was the Additional General Manager of Distribution Region 3 of CEB, who encouraged me to study on this wonderful field at the very beginning of my undertaking work as the Chief Engineer Distribution Maintenance in the Western South II Province of CEB. Also I thank Mr. F.K. Mohideen, the present Additional General Manager of Distribution Region 3, for the encouragement given to make this work a success.

It is not fair if I do not acknowledge the support extended by my subordinates in the Distribution Maintenance Branch of CEB who willingly undertook certain assignments related to the study. Further special thanks go to my colleagues Thilak, Charitha, Gayan and Kokila for their corporation extended, that gave me immense encouragement.



University of Moratuwa, Sri Lanka.

Electronic Theses & Dissertations

www.lib.mrt.ac.lk

I would like to express my gratitude to my beloved wife Kumari for the moral support given and for tolerating my absence amidst the piled up family work. Many thanks go to my loving daughters Udani and Methuli who relieved my stress after continuously engaging in the project work.

Finally I thank Ceylon Electricity Board for providing me with opportunity and resources to carry out this study.

List of figures

<i>Figure</i>		<i>Page</i>
1.1	(A) More than 35 years old CEB Transformer still serving in Bulathsinhala, (B) Modern single pole mounted transformer	3
2.1	Effect of phase earth faults in LV systems with and without neutral point earth	10
2.2	Ageing curves of insulation paper with moisture	12
2.3	Concrete Mesh Earth (A) Mesh before concreting, (B) Mesh inserted into the ground pit before concreting	15
3.1	Distribution network configuration of CEB	17
3.2	A Typical single pole transformer installation	18
3.3	CEB's transformer installation practices	19
3.4	Illustration of critical soil volume	21
3.5	Soil resistivity graphs (20% moist soil)	23
4.1	Lightning surge current waveform	27
4.2	Illustration of surge travelling along MV conductor and flashover	30
4.3	Illustration of protective distance	33
4.4	Isokeraunic map of Sri Lanka	34
4.5	Voltage distribution on the HW earth lead, when arrester functions	37
5.1	Transformer installation arrangements used for transient analysis	40
5.2	Arrester data used for simulation	42
5.3	Stray impedance in a 115/23 kV, 50 MVA transformer	43
5.4	Installation arrangement 1 modeled in PSCAD	45
5.5	Installation arrangement 2 modeled in PSCAD	45
5.6	Installation arrangement 3 modeled in PSCAD	46
5.7	Installation arrangement 4 modeled in PSCAD	47
5.8	Installation arrangement 5 modeled in PSCAD	48
5.9	Description of output measurement nodes	48
5.10	Output plots for arrangement 1 with 10 kA, 8/20 μ s waveform	49
5.11	Output plots for arrangement 2 with 10 kA, 8/20 μ s waveform	50
5.12	Output plots for arrangement 3 with 10 kA, 8/20 μ s waveform	50
5.13	Output plots for arrangement 4 with 10 kA, 8/20 μ s waveform	51
5.14	Output plots for arrangement 5 with 10 kA, 8/20 μ s waveform	51

List of tables

<i>Table</i>		<i>Page</i>
3.1	Soil resistivities and earth resistances with the concrete block and single rod	22
3.2	Earth models used for research study	25
3.3	Earth resistance measurements of the model earth installations	26
4.1	Initial and final slopes of lightning voltage surge waveforms and their protective distances in MV circuits	35
5.1	Constants of the surge waveforms found through curve fitting	41
5.2	Summarized results of sensitivity analysis	52



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

