RELIABILITY IMPROVEMENS IN 33 kV DISTRIBUTION LINES IN THE COASTAL BELT: A CASE STUDY

M.M.F.P. Seneviratne

09/8672

Degree of Master of Science

Department of Electrical Engineering

University of Moratuwa,
Sri Lanka

February 2014

RELIABILITY IMPROVEMENTS IN 33 kV DISTRIBUTION LINES IN THE COASTAL BELT: A CASE STUDY

Mawathage Mohan Francis Perera Seneviratne

09/8672

Dissertation submitted in partial fulfillment of the requirement for the degree of Master of Science

Department of Electrical Engineering

University of Moratuwa,
Sri Lanka

February 2014

DECLARATION

"I declare that this is my own work and this dissertation dose 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 in 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 Candidate

M.M.F.P. Senevirathne

Date:

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

Prof. Ranjit Perera

Senior Professor

Department of Electrical Engineering,

University of Moratuwa

Date:

ABSTRACT

In Sri Lanka, majority of MV network runs through vegetation, hilly and polluted areas etc. Hence, it has been vulnerable to many faults caused by wayleaves, insulator flash over due to lightning, switching operations and the effect produced by pollution in the insulators etc.

The insulator failure due to saline pollution in particular is a problem that increases failure significantly. The priority 33 kV feeder, Ratmalana Feeder -9 which feeds power from Ratmalana GSS to Angulana PSS and Moratuwa PSS causes flashover of insulators frequently.

While analyzing the outage details in the Ratmalana Feeder - 9, it has been noted that the most of the tripping are due to insulator flashover and wayleaves. During the monsoon period, the tripping rate is very high. The routing maintenance including washing of insulators in this line is being done once a year during the monsoon period.

In this case study four possible solutions were discussed to overcome this problem. The solutions are composed of introducing UG cable, LYNX line, CC line and increased frequency of maintenance.

Analyzing the economic parameters, implementation of UG cable is not a viable solution. The other three solutions are viable and increasing of maintenance frequency is the most viable. The implementation of LYNX line as an alternative route is practically a difficult task to maintain safety clearance to buildings and other lines as per CEB safety standards. Replacing existing conductor by CC is a better approach in this specific case. RUBY SAX CC is newly introduced CC which is equivalent to LYNX conductor manufactured by locally.

In this case study, most viable solution is increasing of maintenance frequency. To minimize the trippings, it is recommended that maintenance to be done periodically and efficiently with skilled field staff and proper maintenance schedule especially during monsoon period. Secondly, vegetation management system should be efficiently adopted.

Finally, the public awareness programme is to be implemented on vegetation management along the RF – 9. Therefore, introduction of efficient and effective maintenance programme periodically with increased frequency is the most viable solution which could be recommended by the findings of this study.

ACKNOWLEDGEMENT

This work has been carried out at the Department of Electrical Engineering, University of Moratuwa.

Completing the project work and writing this dissertation was certainly a challenge.

First and foremost let me thank my project supervisor, Prof. Ranjit Perera Senior Professor, University of Moratuwa, for his guidance and support rendered to me in the correct path by giving thoughtful comments and encouragement beyond his role of Project supervisor for completion of this final dissertation successfully.

I also take this opportunity to extend my sincere thanks to Dr. Wijekoon, Chief Engineer (Transmission Planning), Eng. W. Jayaratne Chief Engineer (Distribution Maintenance) and Mrs Lokubalasuriya Chief Engineer (Planning & Development) in WPS-1 who always directed me in numerous way specially giving thoughtful comments and encouragement whenever I discussed technical issues to carry out this project successfully.

I deeply appreciate my office staff specially Mr. Costa, Mr. Gomes and Mrs Ishara Gunatilaka and sincerely thank them for helping me in every way in preparing this dissertation.

I also thank Eng G.D.S.N. Weerapperuma, Branch Engineer, Eng. A.K. Pussawalage, Electrical Engineer and Mr. Aluthge, Cosumer service Coordinator of Moratuwa LECO Branch for extending their support by providing data to make it a success.

I would also like to express my appreciation to all my colleagues and particularly to Eng. Bathiya, Buddhika, Lahiru, Roshen, and Chamil, for their encouragement.

Also, I wish to remember my brothers Manilal, Niranjan, Ravindra, Jagath, and my sister Theja. In particular, I am grateful to my wife Dhammie for her love and continuous encouragement. In conclusion, I owe my gratitude to my dear mother for her love, moral support and understanding from the start to the end of this course.

Above the all, I thank Almighty God for granting me wisdom and courage to make it a success.

TABLE OF CONTENTS

Declaration of the Candidate & Supervisor		i
Abstract		ii
Acknowledgement		iii
Table of Content		iv
List of Figures		vi
List of Tables		vii
List of Abbreviations		viii
List of Appendices	.	ix
1 Introduction		**1**
1.1 Background		1
1.2 Flashover Mechanism – General Theory		4
1.3 Motivation		6
1.4 Objectives	.	6
1.5 Scope of work		6
2 Problem Statement		**8**
3 Reliability Analysis of 33kV Network		**12**
3.1 Reliability status of 33kV network of C.E.B		12
3.2 Calculation of SAIFI/SAIDI in RF - 9		15
4 Possible Solution for Improvements		**17**
4.1 Bare Conductors use for MV Line		17
4.1.1 All Aluminum Conductors (AAC)		17
4.1.2 All Aluminum Alloy Conductors (AAAC)		17
4.1.3 Aluminum Conductor with Steel Reinforced (ACSR)		18
4.1.4 Aluminum Alloy Conductors Steel Reinforced (AACSR)		19
4.2 Insulated Cables		20
4.2.1 Underground Cables		20
4.2.2 Aerial Bundled Conductors (HV)		21

4.2.3 Areal or Universal Cable 23
4.3 Partially Covered Conductors 24
4.3.1 Single Sheath Covered Conductor 24
4.3.2 SAX Conductor . 26
4.3.3 PAS/BLX Conductors . 27
4.3.4 Covered Conductors Increased Thickness (CCT) 27
4.3.5 Multiple sheaths CC (Medium Voltage) . 27
4.3.6 Spacer Cables . 28
4.4 Comparison of Possible Solutions 30
4.5 Increasing Routing Maintenance Frequency of the Line 31
4.5.1 Live Washing of Insulators . 31
4.6 Proposed possible solutions 33
4.7 Existing RF - 9 Data . 33
4.8 Cost Estimation 33
4.9 Calculate Unserved Energy Cost for Total Outages in RF9 43
4.10 Calculation of Economic Parameters 47
4.10.1 Definition of PV Cost, PV Benefits, CBR & NPV 47
4.10.2 Economic Evaluation 48

5 Comparison of Different Options 53
5.1 NPV for Different Solutions 53
5.2 Solution - 1 . 54
5.3 Solution - 2 . 54
5.4 Solution - 3 . 55
5.4.1 Advantages of using CC in RF-9 and MV lines . 56
5.4.2 Selection of Size of the CC 56
5.4.3 Are Protection of CC . 57
5.5 Solution - 4 . 58
5.5.1 Preventive Maintenance 58

6 Conclusion 61
7 Recommendations 63

List of Figures

Page

Chapter 2

Figure 2.1 The single line diagram for feeding arrangement of the RF-9 9

Figure 2.2 Photograph of RF - 9. 10

Figure 2.3 Phograph of RF – 9. 10

Figure 2.4 The Flashover 33kV Pin Insulator 11

Figure 2.5 The Flashover 33kV Shackle Insulators 11

Chapter 4

Figure 4.1 Typical ACSR conductor 18

Figure 4.2 A typical Areal Bundled Conductor line 21

Figure 4.3 'Universal' overhead cable 23

Figure 4.4 Single sheath CC 25

Figure 4.5 SAX Conductor Line in Ratmalana Area 26

Figure 4.6 Basic triple extruded design 28

Figure 4.7 Cross-section triple extrude BLX 28

Figure 4.8 Spacer Cables 29

Figure 4.9 Schematic Cost VS reliability of various distribution systems 30

Figure 4.10 Live washing of insulators 31

Figure 4.11 Average Load Current of the Uyana Feeder 11kV 38

Figure 4.12 Average Load Current of the Angulana Guru Palliya 11kV Feeder 40

Figure 4.13 Average Load Current of the Angulana Guru Palliya 11kVFeeder 41

Figure 4.14[a] Weekday Load Curve of RF – 9 44

Figure 4.14[b] Average Load Curve Weekdays of R - 9 44

Figure 4.15 Load Curve of Saturday of RF – 9 45

Figure 4.16 Load Curve of Sunday of RF – 9 45

LIST OF TABLES

		Page
Chapter 1		
Table 1.1	Types of pollutions effect for flashover of insulators and Their sources	2
Chapter 2		
Table 2.1	Outage Details of RF - 9	9
Chapter 3		
Table 3.1	The statistics of 33kV distribution network in WPS-1	12
Table 3.2	The statistics of 33kV network in NWP .	13
Table 3.3	Comparison of statistics on reliability indices of CEB/LECO Regions and other countries	14
Chapter 4		
Table 4.1	Physical data of the ACSR	19
Table 4.2	Comparison of Cables and Conductors	30
Table 4.3	Min. distance for energized washing & resistivity of water used	32
Table 4.4	Average energy delivered in Uyana 11kV feeder per month	37
Table 4.5	Calculated average current of the Angulana Guru Palliya Feeder	39
Table 4.6	Average energy reading of distribution substations CEB Area	41
Table 4.7	Capital cost incurred in each possible solution	48
Table 4.8	Reliability assumptions each possible solution	48
Chapter 5		
Table 5.1	Economic Parameters of possible solutions	53
Table 5.2	The min. safety clearance of the MV lines to any structure, . buildings	54
Table 5.3	The vertical clearance of conductors in different cct. on Same support	55
Table 5.4	The important parameters of LYNX and SAX conductors .	56

LIST OF ABBREVIATIONS

Abbreviations	Description
AAC	All Aluminium Conductor
AAAC.	All Aluminium Alloy Conductor
AACSR	All Aluminium Alloy Conductor Steel Reinforced
ABC	Areal Bundled Conductor
ACSR	Aluminium Conductor Steel Reinforced
Avg.	Average
CC	Covered Conductor
CCT	Covered Conductor- Thickness
CBR	Cost to Benefit Ratio
CEB	Ceylon Electricity Board
GSS	Grid Substation
HDPE	High Density Polyethylene
IEC	International Electrotechnical Commission
kWh	Kilo Watt Hour
LECO	Lanka Electricity Company
Max.	Maximum
Min.	Minimum
LKR M	Sri Lankan Rupees
MV	Medium Voltage
MVA	Mega Volt Ampere
NPV	Net Present Value
Max.	Maximum
OHL	Over Head Line
PSS	Primer Substation
RF - 9	Ratmalana Feeder - 9
UG	Under Ground
XLPE	Cross Link Polyethylene

LIST OF APPENDICES

Appendix	Description	Page
Appendix A: The outage data and the consumer statistics of the RF - 9	.	65
Appendix B: Trapezoidal Method		67
Appendix C: The recorded outage details of RF - 9 in the year 2012		68
Appendix D: Load Current in the RF – 9 at each time intervals		70
Appendix E: Load Current & Calculated unserved energy in RF- 9	..	72
Appendix F: Definitions for Economic Evaluation		74