TECHNO ECONOMIC ANALYSIS ON THE USE OF FULLY INSULATED CABLE FOR 33KV OVERHEAD POWER DISTRIBUTION SYSTEM IN SRI LANKA

D. M. A. K Dissanayake

(139556 H)

Dissertation submitted in partial fulfillment of the requirements for the
Degree Master of Science in Electrical Installations

Department of Electrical Engineering

University of Moratuwa
Sri Lanka

October 2017

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 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 Date:

(D. M. A. K Dissanayake)

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

…….

Signature of the supervisor Date:

(Dr. K.T.M. Udayanga Hemapala)

…….

Signature of the supervisor Date:

(Eng. K. Weerasooriya)

ABSTRACT

Electricity Supply has become a fundamental commodity of present society. Hence, the availability and the reliability of the electricity distribution system have gained an utmost concern. Currently, Sri Lankan electricity distribution system of all over the island other than Colombo and Kandy Cities are networked through the 33kV Bare Overhead (BOH) lines. Ceylon Electricity Board (CEB) is being rapidly expanded 33 kV distribution network to cater rural electrification demands and the urban development demands. 33kV network has been constructed with poles and towers, many 33 kV lines pass through jungles and thick vegetation and further expose to the sea and lightning prone areas.

Therefore, nowadays the utility has to face some critical issues along with existing distribution system, especially higher number of feeder tripping during the rainy seasons due to thick vegetation. Even with the new regulations and demands, lines are unable to maintain right-of-way with required safety clearance especially in urban areas. Thus, in my dissertation discussed the 33kV Aerial Bundled Cable (MVABC) system as a more economical alternative to Medium Voltage Bare Overhead (MVBOH) lines. Further, address how to mitigate certain operational, climatic and environmental issues with MVABC. It is presented a comparative economic analysis of MVABC with MVBOH and MVUG systems. The analysis takes into consideration the initial investment costs, net present value (NPV) of operational and maintenance costs and NPV of unserved energy of lines along with their specific lifetime period.

Further, an algorithm has been developed that can be used all over the country to make decision for MVABC adaptation on feeders. Finally, a Software Tool is developed to make easy to generate decision for the same and review each case by doing the Sensitivity Analysis.

The dissertation concludes with few recommendations, technical issues associated with MVABC can be mitigated by purchasing cables according to the finalized specification. Use of MVABC shall improve availability and the reliability of consumers' power supply wherever the decision generated by mathematical model is yes.

Keywords: Electricity Distribution System, Medium Voltage, Bare Overhead System, Aerial Bundled Cable

ACKNOWLEDGEMENT

Foremost, I pay my sincere gratitude to Dr. K.T.M. Udayanga Hemapala, Eng. Kapila Weerasooriya and Eng. Kamal Illeperuma who encouraged and guided me to conduct this research and on preparation of final dissertation.

I extend my sincere gratitude to Dr. Nalin Wickramarachchi, Head of the Department of Electrical Engineering and all the lecturers and visiting lecturers of the Department of Electrical Engineering for the support extended during the study period.

Further, I extend my sincere gratitude to Eng. Anura Wijepala past Chairman CEB, Eng. Ratnayake CE (Planning & Development) Colombo City, Eng. (Mrs.) Narmali CE (Planning & Development) WPN, Eng. Jaliya EE (Development) WPN, Eng. Nilantha EE (Maintenance) WPN, Eng. Chamath EE (SCADA) Colombo City and Mrs. Kayathiri for supporting me during the study period.

Finally but not least a big thank goes to my wife, Ganguli Chathurika for finding me free time and free mind to do the research by taking away my other responsibilities and my parents and other family members for their continuous encouragement.

TABLE OF CONTENTS

DECLARATION i
ABSTRACT ii
ACKNOWLEDGEMENT iii
TABLE OF CONTENTS iv
LIST OF FIGURES vi
LIST OF TABLES viii
LIST OF ABBREVIATIONS ix
1 INTRODUCTION 1
1.1 Background 1
1.2 Motivation 1
1.3 Objectives of the study 4
1.4 Methodology 4
1.5 Contributions 5
1.6 Organization 5
2 LITERATURE REVIEW 6
2.1 General Information 6
2.2 Identified Alternative Solutions for MV BOH with their attributes 6
3 VERIFY THE INITIAL PRACTICES AND ISSUES WITH MV ABC 12
3.1 Factors to be considered during the preparation of Specification of MV ABC 12
3.2 Factors to be considered in MV ABC Installation 14
4 GENERAL CAPITAL COST ANALYSIS OF MV ABC AGAINST MV BOH AND MV UG 18
4.1 Capital Cost Calculation for 33kV BOH line per km 18
4.2 Capital Cost Calculation for 33kV ABC per km 21

4.3 Capital Cost Calculation for 33kV UG per km 28
5 MV ABC ECONOMIC FEASIBILITY STUDY FOR DIFFERENT FEEDERS 30
6 CASE STUDIES FOR MODEL VALIDATION 38
6.1 Case Study 01: Kotugoda GSS Feeder No.11 38
6.2 Case Study 02: Katunayake GSS Feeder No.06 41
7 SOFTWARE DEVELOPMENT FOR MV ABC ANALYSIS 46
7.1 Overview of MV ABC Selection Tool 46
7.2 Functions of MV ABC Selection Tool 46
8 DISCUSSION AND CONCLUSIONS 56
REFERENCES 57

LIST OF FIGURES

Figure 1-1: Inadequate Safety Clearance……..……...2
Figure 1-2: Non Standard Construction……..……..2
Figure 1-3: O & M difficulties……..…..…….....3
Figure 1-4: Vegetation Problems…… 3
Figure 2-1: MV BOH Top Failure Causes..... 6
Figure 2-2: MV Covered Cable Cross Section Structure 7
Figure 2-3: MV Covered Cable Damages at Supportive Points..... 7
Figure 2-4: MV Underground Cable Structure..... 8
Figure 2-5: Direct Buried Cable Trench Layout..... 9
Figure 2-6: MV ABC Cross Section Structure 10
Figure 2-7: MV ABC Construction flexibility..... 11
Figure 3-1: Stress Crack on HDPE Outer Sheath of MVABC..... 12
Figure 3-2: Damaged Copper Screen..... 13
Figure 3-3: Burnt Outer Sheath..... 13
Figure 3-4: Improved Cable Structure 14
Figure 3-5: Installation of SA where ACB placed in betweeen ABC line..... 14
Figure 3-6: Induced voltage of single core cable earth at the end..... 15
Figure 3-7: Induced voltage of single core cable earth at both end..... 16
Figure 3-8: Induced Current mitigated by having Earth Bonding at all Joint..... 16
Figure 4-1: Capital Cost Calculation Flow Chart of MV ABC..... 21
Figure 4-2: Designed Pegging line diagram of 1km length MV ABC... 24
Figure 5-1: Inputs for the economic feasibility 30
Figure 6-1: 33kV Kotugoda GSS Feeder No.11 in Geographical map .. 38
Figure 6-2: 33kV Katunayake GSS Feeder No.06 in Geographical map..... 41
Figure 6-3: The algorithm to select correct installation methodology for the electrical distribution system..... 44
Figure 7-1: User Interface of MV ABC Selection Tool 46
Figure 7-2: Starting User Interface of MV ABC Selection Tool..... 47
Figure 7-3: User Interface of the Feeder Cost Calculation..... 48
Figure 7-4: User Interface of Material Cost Calculation 49

Figure 7-5: User Interface of Labour Cost Calculation 50
Figure 7-6: User Interface of O & M Cost Calculation 51
Figure 7-7: User Interface of Unserved Energy Cost Calculation..... 52
Figure 7-8: User Interface of Social Benefits 52
Figure 7-9: User Interface of Report Summery 53
Figure 7-10: User Interface of Sensitive Analysis_ Part 1 54
Figure 7-11: User Interface of Sensitive Analysis_ Part 2 55

LIST OF TABLES

Table 1-1: 33kV Breakdown Analysis of Distribution Division 02 in the Year 2014 2
Table 1-2: Annual Network Maintenance Cost of NWP, CEB 3
Table 2-1: Summery of available solution 11
Table 4-1: Cable Size Selection for the comparison 18
Table 4-2: Standard Material List for 1 km Racoon Conductor 33kV on 11m Pole 18
Table 4-3: Standard Labour Rate for 1km Racoon Conductor 33kV on 11m Pole 20
Table 4-4: ABC Support requirements according to pegging line diagram 25
Table 4-5: Estimated Material List for 1 km ABC 33kV on 11m Pole .. 26
Table 4-6: Drafted Standard Labour Rate for 1km ABC 33kV on 11m Pole 27
Table 4-7: Standard Rate for 1km UG 33kV Cable laying in direct buried method 28
Table 4-8: Summery of Capital Cost Values 29
Table 5-1: Average Operational Cost of Brazilian Distribution System in US$/ pole 32
Table 5-2: The cost of unserved energy for the Sri Lanka system 33
Table 5-3: Sample format of Daily HT Feeder Failure Report 2016 of WPN, Ceylon Electricity Board. 34
Table 6-1: Feeder 11, HT Interruption details for MV BOH in the year 2016 [18] 39
Table 6-2: Based on the assumptions calculated values for MV ABC Feeder 11 39
Table 6-3: Feeder 06, HT Interruption details in the year 2016 [18] 42
Table 6-4: Based on the assumptions calculated values for MV ABC Feeder 06 42

LIST OF ABBREVIATIONS

Abbreviation	Description
MV	Medium Voltage
ABC	Aerial Bundle Cable
BOH	Bare Over Head
CC	Covered Conductor
UG	Underground
CEB	Ceylon Electricity Board
LECO	Lanka Electricity Company
CMC	Colombo Municipal Council
GSS	Grid Substation
LKR	Sri Lankan Rupee
US$	United State Dollar
WPN	Western Province North
NWP	North Western Province
TNB	Tenaga Nasional Berhad
O&M	Operation & Maintenance
NPV	Net Present Value
kWh	kilo watt hour
XLPE	Cross Link Polyethylene
PVC	Polyvinyl Chloride
ROW	Right of Way
kV	kilo Volts