

**TECHNO ECONOMIC ANALYSIS ON THE USE OF
HTLS CONDUTORS FOR SRI LANKA'S
TRANSMISSION SYSTEM**

Hewa Buhege Dayan Yasaranga

(118696J)



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

Degree of Master of Science

Department of Electrical Engineering

University of Moratuwa
Sri Lanka

May 2015

**TECHNO ECONOMIC ANALYSIS ON THE USE OF
HTLS CONDUTORS FOR SRI LANKA'S
TRANSMISSION SYSTEM**

Hewa Buhege Dayan Yasaranga

(118696J)



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

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

Department of Electrical Engineering

University of Moratuwa
Sri Lanka

May 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 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: _____

Date: _____

H.B.D. Yasaranga



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

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

Signatures of the supervisors:

Date: _____

Eng. W.D.A.S. Wijayapala

Date: _____

Dr. K.T.M.U. Hemapala

ACKNOWLEDGEMENT

This dissertation is prepared as a result of the support and guidance provided by various personnel and parties.

First of all, I should be thankful to the supervisors of the research study, Eng. WDAS Wijayapala and Dr. KTMU Hemapala, for their guidance, rendered throughout the study period as well as to the point of finishing of this thesis. Their continuous supervision and advices on the research, pave me the way for successful completion of the scope of work.

Secondly, I should be thankful to Mr. Kusum Shanthi, Deputy General Manager, Transmission Design and Environment Branch of Ceylon Electricity Board for giving me the first glimpse on my research topic. What I have acquired, working under his supervision in Transmission Design branch of CEB, became very useful for the completion of this thesis.

At the same time, I should be thankful to the Head of the Department, Electrical Engineering, Dr. Preenath Dias for arranging the postgraduate course and providing all the facilities required.

My special gratitude shall be given to Dr. Asanka Rodrigo, who is the course coordinator of the MSc Electrical Engineer programme for organizing all the academic activities as well as progress reviews of the research studies. His commentaries during the progress presentations were very vital to the improvement of this research study.

At the same time, I should appreciate the corporation given by all other lecturers of the department of Electrical Engineering, university of Moratuwa for their guidance and constructive criticism during progress presentations.

All my batch mates in the MSc programme shall be given a great appreciation for their support throughout the study period as well as during the research period.

ABSTRACT

High Temperature Low Sag (HTLS) conductors are introduced into the electricity transmission systems by the conductor manufacturers, with the idea of mitigating some of the disadvantages shown by conventional overhead conductors such as ACSR (All Aluminium Conductor Steel Reinforced).

Compared to conventional conductors, HTLS conductors have some of the improved electrical and mechanical characteristics, where by employing these conductors in overhead transmission lines, some of the complex issues related to power transmission could be resolved.

However due to their novel appearance and lack of service experiences in the field, most of the utilities in the world are in a dilemma whether to use these conductors instead of ACSR or other conventional types of conductors that have provided a great service to the utilities throughout hundreds of years.

Situation in Sri Lanka is also not that different. Almost the entire Sri Lanka's transmission system is comprising with overhead lines constructed using conventional conductors, especially ACSR. Therefore the knowledge and the experience regarding the use of HTLS or any other types of conductors remain minimal among utility engineers.

Therefore under this study, the use of these so called HTLS conductors for Sri Lanka's electricity system is discussed in terms of technical and economic aspects under three different categories of overhead line construction. Conclusions are drawn based on simulations results and comparisons are also elaborated.

TABLE OF CONTENTS

DECLARATION	ii
ACKNOWLEDGEMENT	iii
ABSTRACT	iv
LIST OF FIGURES	viii
LIST OF TABLES	x
LIST OF ABBRIVIATIONS	xii
LIST OF APPENDICES	xiii
1.0 INTRODUCTION	1
1.1 BACKGROUND	1
1.2 SCOPE OF WORK	2
2.0 LITERATURE REVIEW	3
2.1 OVERHEAD BARE CONDUCTORS FOR TRANSMISSION LINES	3
2.2 CONDUCTOR PROPERTIES	4
2.2.1 Ultimate Tensile Strength (UTS)	4
2.2.2 Cross Section Area	4
2.2.3 Modulus of Elasticity	5
2.2.4 Linear Thermal Expansion Coefficient	6
2.2.5 Unit Resistance	6
2.3 CONDUCTOR FORMATION	7
2.3.1 Conventional Conductors	7
2.3.2 High Temperature Conductors (Low Loss Conductors)	8
2.3.3 Low Loss Conductors	9
2.4 CONDUCTOR MATERIAL	11
2.5 CONDUCTOR BEHAVIORS	13
2.5.1 Current Carrying Capacity (CCC)	13
2.5.2 Sag Tension Calculation	15
2.6 CONDUCTOR COMPARISON	17
2.7 ADVANTAGES OF HTLS CONDUCTORS	19
2.8 DISADVANTAGES OF HTLS	21

3.0	METHODOLOGY	24
3.1	PROCEDURE	24
3.2	GENERAL GUIDELINES	24
3.3	EXTENT OF STUDY	25
3.4	DESIGN PROCESS OF OVERHEAD LINES	26
3.4.1	Survey Data Collection	26
3.4.2	Design Data for Supports	27
3.4.3	Weather Data Inputs.....	29
3.4.4	Safety Factors.....	30
4.0	THERMAL UPGRADING OF EXISTING TRANSMISSION LINES	32
4.1	INTRODUCTION	32
4.2	ALTERNATIVES TO UPGRADE EXISTING TRANSMISSION LINE... 32	
4.3	ALGORITHM FOR RESTRINGING	33
4.3.1	Study of Reconstruction of Existing Line Using Manual Method.....	34
4.3.2	Reconstruction with the use of Design Software – PLS CADD.....	48
4.3.3	Selection of HTLS Conductors for Restring.....	57
5.0	IMPROVING CLEARANCE OF EXISTING LINES	60
5.1	INTRODUCTION	60
5.2	ALGORITHM FOR CLEARANCE IMPROVEMENT	62
5.2.1	Study of Clearance Improvement of Existing Line.....	63
5.2.2	Use of HTLS conductors to improve clearance of existing lines.....	75
5.3	STRINGING REQUIREMENTS	76
5.4	SUMMARY	78
6.0	CONSTRUCTION OF NEW TRANSMISSION LINE	80
6.1	INTRODUCTION	80
6.2	ALGORITHM FOR NEW LINE CONSTRUCTIONS.....	81
6.2.1	Checking the Terrain.....	82
6.2.2	Power Requirement.....	84
6.2.3	EMF Evaluation	87
6.3	SELECTION OF HTLS CONDUCTOR FOR NEW LINES.....	90
6.3.1	Conductor Selection.....	90
6.4	CAPACITY IMPROVEMENT USING HTLS CONDUCTORS	97

6.5	STRINGING OF HTLS CONDUCTORS	98
6.6	REDUCTION OF TOWERS USING HTLS CONDUCTORS.....	99
7.0	RESULTS	102
7.1	UPRATING EXISTING TRANSMISSION LINES	102
7.2	CLEARANCE IMPROVEMENT IN EXISTING LINES	104
7.3	CONSTRUCTION OF NEW TRANSMISSION LINES.....	104
	CONCLUSION	107
	REFERENCES.....	109
	APPENDIX A	112
	APPENDIX B	115
	APPENDIX C	118
	APPENDIX D	119
	APPENDIX E	139



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

LIST OF FIGURES

Figure 2.1 - ACSR conductor formation.....	7
Figure 2.2 - AAAC formation.....	8
Figure 2.3 - Gap Conductor formation.....	9
Figure 2.4 - ACCC formation	10
Figure 2.5 - ZTACIR formation.....	10
Figure 2.6 - ACSS formation	11
Figure 2.7 - Conductor Sag and Tension	15
Figure 2.8 - KPT of different conductors.....	18
Figure 3.1 - Requirement of new Overhead lines	25
Figure 4.1- Algorithm for Transmission Line Upgrading.....	33
Figure 4.2 - Aerial view of Pannipitiya – Ratmalana line.....	35
Figure 4.3 - Current Carrying Capacity of Zebra Conductor.....	36
Figure 4.4 - Forces Acting on Towers	37
Figure 4.5 - Wind & Weight Span of Towers.....	38
Figure 4.6 - Unused Weight Span of Towers.....	39
Figure 4.7 - Unused Wind Span of Towers (a)	40
Figure 4.8 - Unused Wind Span of Towers(b).....	41
Figure 4.9 - Angle Compensation of angle towers	41
Figure 4.10 - Feature Code View	49
Figure 4.11 - Weather Criteria File	49
Figure 4.12 - Automatic Sagging Criteria.....	50
Figure 4.13 - Section Modify window	51
Figure 4.14 - Profile view of Pannipitiya –Kolonnawa ACSR Lynx line.....	52
Figure 4.15 - Section Modify window for Zebra conductor	52
Figure 4.16 - Profile View of Pannipitiya-Ratmalana 132kV Zebra line	53
Figure 4.17 - (a) Electric Field of Pannipitiya – Ratmalana Existing Lynx Line	54
Figure 4.18 - (b) Electric Field of Pannipitiya – Ratmalana Upgraded Zebra line....	54
Figure 4.19 - (a) Magnetic Field of Pannipitiya – Ratmalana Existing Lynx Line.....	54
Figure 4.20 - (b) Magnetic Field of Pannipitiya – Ratmalana Upgraded Zebra Line .	54

Figure 5.1 - Alteration of ground profile in Kolonnawa – Pannipitiya 132kV line...	60
Figure 5.2 - Algorithm for Line Clearance improvement	62
Figure 5.3 - Sky View of the area near tower Number 11 and 12	64
Figure 5.4 - Profile drawing of the present section view	65
Figure 5.5 - Profile view of the section with new tensioned Lynx Conductor	66
Figure 5.6 - Profile view of the section after reducing insulator discs	72
Figure 5.7 - Use of the middle tower as a section tower.....	74
Figure 5.8 - PLS Criteria file for the use of ACCC conductor	77
Figure 6.1 - Algorithm for Construction of New Transmission Line	81
Figure 6.2 - PLS profile design of proposed Nawalapitiya line route	82
Figure 6.3 - Cost Benefit Analysis of Habarana – Veyangoda overhead line	86
Figure 6.4 - EMF Field vs Distance from conductor	89
Figure 6.5 - Excel Programme interface of conductor comparison	96
Figure 6.6 - Stringing requirements of ACSR Vs Gap	98
Figure 6.7 - Profile view of Kirindiwela – Kosgama line with Zebra	100
Figure 6.8 - Profile view of Kirindiwela – Kosgama line ACCC- Drake conductor	100



LIST OF TABLES

Table 2.1 - Aluminium Conductor Material	12
Table 2.2 - Core Material	12
Table 2.3 - Conductor Properties Comparison.....	17
Table 2.4 - Comparison of conductors	19
Table 3.1 - Sample Profile Data Input for PLSCADD Software	27
Table 3.2 - Basic Spans of Transmission Lines	28
Table 3.3 - Wind Span Transmission Lines	28
Table 3.4 - Weight Span of Transmission Lines.....	28
Table 3.5 - Wind pressure on components.....	29
Table 3.6 - Temperature Limits	30
Table 3.7 - Safety Factors for towers	31
Table 4.1 - Tower Types and Span length of Pannipitiya-Ratmalana Line	34
Table 4.2 - Loads addable to existing towers.....	42
Table 4.3 - Additional Vertical Loads on Towers.....	43
Table 4.4 - Additional Transverse Forces.....	44
Table 4.5 - Tension vs Ground Clearance.....	46
Table 4.6 - EMF exposure limits	47
Table 4.7 - EMF comparison	55
Table 4.8 - Summary flow chart of Pannipitiya- Ratmalana line uprating.....	56
Table 4.9 - Factors to be considered for Economic Feasibility.....	57
Table 4.10 - Conductor Stringing Tensions	58
Table 4.11 - Properties of HTLS conductors	59
Table 5.1 - Clearance from conductors	61
Table 5.2 - Section details where ground clearance is violated	64
Table 5.3 - Span details of the Sections where ground clearance is violated	65
Table 5.4 – Number of discs in an insulator string set.....	68
Table 5.5 - Requirement of Insulators based on CEB technical specifications	69
Table 5.6 - Suspension String details.....	69
Table 5.7 - Alteration of the length of the insulator string	71

Table 5.8 - Selection of suitable HTLS conductor for clearance improvement.....	76
Table 6.1 - Power Capacity of Different Zebra Configurations.....	84
Table 6.2 - Properties of Zebra and TACSR/AS conductors.....	87
Table 6.3 - Summary of Cost Benefit Analysis	87
Table 6.4 - EMF details of Proposed New Habarana- Sampoor 400kV line.....	88
Table 6.5 -Transmission line Capital Project Costs.....	91
Table 6.6 - Loss Evaluation of HTLS conductors.....	93
Table 6.7 - Mechanical Properties of different conductors.....	94
Table 6.8 - Comparison of various sub conductor configurations.....	97
Table 6.9 - Number of towers used with different conductors	101
Table 7.1 - Addition in forces on towers when Zebra conductor is used;	102
Table 7.2 - EMF level under the power line with the use of Zebra conductor	103
Table 7.3 - Selection of HTLS conductors to replace ACSR Lynx Conductor.....	103
Table 7.4 - Comparison of performances of HTLS conductors compared to Zebra	103
Table 7.5 - Comparison of Sag characteristics of HTLS Vs ACSR	104
Table 7.6 - Loss Evaluation of HTLS conductors Vs Conventional conductors.....	105
Table 7.7 - Loss Evaluation at similar low load cases.....	105
Table 7.8 - Economic gain over 30 year period.....	106



LIST OF ABBRIVIATIONS

ROW	-	Right of Way
HTLS	-	High Temperature Low Sag
ACSR	-	Aluminium Conductor Steel Reinforced
AAAC	-	All Aluminium Alloy Conductor
EMF	-	Electromagnetic Field
KPT	-	Knee Point Temperature
TACSR	-	Thermal Resistant Aluminium Alloy Conductor Steel Reinforced
CEB	-	Ceylon Electricity Board
G(Z)TACIR	-	Gap Type (Super) Thermal Resistance Aluminium Conductor Steel Reinforced
ACCC	-	Aluminium Conductor Composite Core
ACSS	-	Aluminium Conductor Steel Supported
CCC	-	Current Carrying Capacity
NPV	-	Net Present Value
IEE	-	Initial Environment Examination



University of Moratuwa, Sri Lanka.
Net Present Value
Electronic Theses & Dissertations
www.lib.mru.ac.lk

LIST OF APPENDICES

Appendix A- Sample Current Carrying Capacity Calculation

Appendix B- Sag Tension Calculation

Appendix C- Single Line Diagram of Sri Lanka's Transmission system

Appendix D- PLS CADD Design of Pannipitiya-Rathmalana Line

Appendix E- 50% lightning flashover voltages



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