

INTELLIGENT LOAD SHEDDING MECHANISM FOR CEB NETWORK

Rajapaksha Vithanage Dona Hansi Nilanka Rajapaksha

(109246F)

 University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
Dissertation submitted in partial fulfillment of the requirements for the degree of
www.lib.mrt.ac.lk Master of Science

Department of Electrical Engineering

University of Moratuwa

Sri Lanka

May 2015

DECLARATION OF THE CANDIDATE AND SUPERVISORS

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:

(R. V. D. H. N. Rajapaksha)



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 my supervision.

.....

Signature of the supervisor

Date:

(Prof. H. Y. R. Perera)

ACKNOWLEDGEMENTS

Foremost, I would like to express my sincere gratitude to my supervisor Prof. H.Y.R. Perera for the continuous support given for the research, for the motivation, enthusiasm and immense knowledge.

My sincere thanks go to Mr. Eranga Kudahewa, Electrical Engineer in System Control branch in transmission division for enlightening me the first glance of the research and extending all the assistance required and giving technical instructions.

Furthermore I must thank Mr. H. D. S. Thimothis, Deputy General Manager(System Control) and all Engineers in System Control branch in transmission division and all Engineers in Protection Development branch in transmission division for the guidance and assistance they have given during my research period.

Further, I would like to pay my gratitude to all the lecturers engaged in the MSc course sessions for making our vision broader and providing us with the opportunity to improve our knowledge in various fields.

Moreover technical staff working in Grid sub stations who have helped me in providing exact data on my request during failure analysis done by myself.



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

My sincere thanks also should go to Mrs. Dhammika Tilakasena, Deputy General Manager (Asset Management(transmission)), Mr. G.W.V. Priyantha, Chief Engineer(Maintenance Planning) and my colleague Engineers who work with me in Asset Management(transmission) branch and all the office staff there who always gave their co-operation to conduct my research work.

It is a great pleasure to remember the kind cooperation of all my colleagues who have helped me in this Post Graduate programme by extending their support during the research period.

My special thanks go to my parents Mr. and Mrs. Piyatilake Rajapaksha, my husband Asanka, my sisters and brother for supporting me spiritually throughout my life and tolerating my engagement on this work.

R. V. D. H. N. Rajapaksha

ABSTRACT

Load Shedding plays a major role as the guard which protects the power system from a disturbance-induced collapse. In Sri Lanka, Ceylon Electricity Board being the major power network authorizer practice ‘under-frequency load shedding’ with the support of under-frequency load shedding relays.

There are some drawbacks of this under frequency load shedding scheme which promotes power system authorizers to shift into a computerized power management system to form an ‘automated load shedding scheme’.

An intelligent load shedding system can provide faster and optimal load relief by utilizing actual operating conditions and knowledge of past system disturbances [1]

As the first step in this study a research survey was done about present load shedding system practiced in Ceylon Electricity Board. Past failure analysis was done to identify major drawbacks of the system.

During literature survey characteristics of an intelligent load shedding system were observed and the way of forming an intelligent load shedding system in a power network was studied.

Through selection of southern part of CEB network including seven grid substations, two major hydro power plants, two thermal power plants and three mini hydro power plants, model was designed using MATLAB software.

Initially a data bank was formed including load data, generation data for the selected network. Load data at each grid substation for a week day, Saturday and for Sunday were formed based on the load equations derived depending on the time of the day (off-peak, day-peak, night-peak). Generation data was adjusted according to the total load requirement. Feeders that can be shed were selected considering the category of load

connected at each feeder and categorization by System Control center as high priority feeders and low priority feeders.

Coding was built up in MATLAB software after importing excel sheets consisting all the data collected and modeled to create a 'Graphical User Interface'(GUI). Further code was extended for the load shedding process which activates once a power imbalance occurs between generation and demand. Simulation was done for tripping of major hydro power plants which contribute to load shedding process.

Further comparisons were done between existing load shedding mechanism which is under frequency load shedding(UFLS)and Intelligent Load Shedding (ILS) mechanism in Power System Simulator for Engineering(PSS/E) software which is the software used by System Control Center branch in transmission division for analyzing and simulating power system performance.

It is concluded that reasonable improvements can be achieved through application of intelligent load shedding mechanism to CEB network which contributes to quality of uninterrupted supply to consumers.



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

TABLE OF CONTENTS

DECLARATION OF THE CANDIDATE AND SUPERVISORS.....	ii
ACKNOWLEDGEMENTS	iii
ABSTRACT	iv
LIST OF FIGURES.....	viii
LIST OF TABLES.....	xi
LIST OF ABBREVIATIONS.....	xii
LIST OF APPENDICES.....	xiii
Chapter 1- INTRODUCTION.....	1
1.1 Background	1
1.2 Requirement of the load shedding scheme	1
1.3 Motivation	1
1.4 Objectives	2
1.5 Methodology	3
Chapter 2- ANALYSIS OF EXISTING LOAD SHEDDING SCHEME.....	4
2.1 Existing Load Shedding Scheme.....	5
2.2 Historical Failure Analysis.....	6
2.2.1 Analysis of partial failure occurred on 06 th May 2013 at 20:41 hours	6
2.2.2 Analysis of partial failure occurred on 29 th October 2013 at 15:27 hours.....	11
2.2.3 Analysis of major failure occurred on 07 th December 2007 at 04:48 hours.....	14
2.3 Weaknesses of the existing load shedding mechanism.....	16
Chapter 3- INTELLIGENT LOAD SHEDDING MECHANISM	17
3.1 Forming mathematical model in MATLAB software	18
3.1.1 Selection of reduced network.....	19
3.1.2 Data collection and modeling.....	20
3.1.3 Extracting load data of the feeders that can be shed	22
3.1.4 Importing modeled data into MATLAB software.....	23
3.1.5 Designing Graphical User Interface (GUI) in MATLAB software.....	24

3.1.6	Developing the program algorithm and coding to update optimal load shedding tables and to activate load shedding.....	25
3.1.7	Application of case studies in MATLAB software.....	27
Chapter 4- RESULT ANALYSIS IN PSS/E.....		33
4.1	Introduction to PSS/E software	33
4.2	Planning Criteria.....	33
4.2.1	Voltage criterion	33
4.2.2	Thermal criterion	34
4.2.3	Security criterion.....	34
4.2.4	Stability criterion	34
4.3	Static versus Dynamic Analysis	34
4.3.1	Static Analysis.....	34
4.3.2	Dynamic Analysis.....	34
4.4	Result Analysis.....	35
4.4.1	Implementation of ILS in PSS/E software	35
4.4.2	Implementation of UFLS in PSS/E software	43
4.4.3	Comparison of UFLS and ILS through waveforms obtained in PSS/E software	43
4.4.4	Result Analysis on loads shed through ILS and UFLS	50
Chapter 5- CONCLUSION AND RECOMMENDATIONS.....		60
5.1	CONCLUSION	60
5.2	RECOMMENDATIONS	61
Reference List.....		63
Appendices.....		64



LIST OF FIGURES

	Page	
Figure 2.1	Frequency plot of 132 kV Sub C feeder at Kolonnawa GIS On 06 th May 2013 at 20:41:39 hrs	07
Figure 2.2	DFR record at Kotugoda GSS at 20:41 hrs	08
Figure 2.3	DFR record at Lakvijaya power station at 20:41 hrs	08
Figure 2.4	Frequency plot at 15:27 hours on 29 th October 2013	11
Figure 2.5	Load of the feeders shed under load shedding stage-I	12
Figure 2.6	Load of the feeders shed under load shedding stage-II	13
Figure 2.7	Load of the feeders shed under load shedding stage-III	13
Figure 2.8	Load of the feeders shed under load shedding stage-IV	14
Figure 3.1	Basic representation of Intelligent Load Shedding System	17
Figure 3.2	Selected network for MATLAB modeling	19
Figure 3.3	Graphical User Interface (GUI) designed in MATLAB software	24
Figure 3.4	View of selected plots for a Sunday	25
Figure 3.5	Flow Chart for the load shedding mechanism	26
Figure 3.6	MATLAB coding for checking frequency and frequency deviation Rate	27
Figure 3.7	Plots of 'load and generation Vs. time' and 'operation of power plants Vs. time' for example-01	28
Figure 3.8	Plots of 'load and generation Vs. time', 'frequency Vs. time' and 'feeder Shutdowns' for example-01	29
Figure 3.9	Plots of 'load and generation Vs. time' and 'operation of power plants Vs. time' for example-02	30
Figure 3.10	Plots of 'load and generation Vs. time', 'frequency Vs. time' and 'feeder Shutdowns' for example-02	30
Figure 3.11	Plots of 'load and generation Vs. time' and 'operation of power plants Vs. time' for example-03	31

Figure 3.12	Plots of 'load and generation Vs. time', 'frequency Vs. time' and 'feeder Shutdowns' for example-03	32
Figure 4.1	Load modeled feeder wise in PSS/E	36
Figure 4.2	Machine file updated with generation data in PSS/E	36
Figure 4.3	Diary file written for case study-01	37
Figure 4.4	Diary file written for case study-02	37
Figure 4.5	Diary file written for case study-03	38
Figure 4.6	Diary file written for case study-04	39
Figure 4.7	Frequency waveform obtained for case study-01	39
Figure 4.8	Voltage waveform obtained for case study-01	40
Figure 4.9	Frequency waveform obtained for case study-02	40
Figure 4.10	Voltage waveform obtained for case study-02	41
Figure 4.11	Frequency waveform obtained for case study-03	41
Figure 4.12	Voltage waveform obtained for case study-03	42
Figure 4.13	Frequency waveform obtained for case study-04	42
Figure 4.14	Voltage waveform obtained for case study-04	43
Figure 4.15	Frequency waveforms obtained through application of UFLS and ILS for case study-01	44
Figure 4.16	Voltage waveforms obtained under UFLS for case study-01	44
Figure 4.17	Voltage waveforms obtained under ILS for case study-01	44
Figure 4.18	Frequency waveforms obtained through application of UFLS and ILS for case study-02	45
Figure 4.19	Voltage waveforms obtained under UFLS for case study-02	46
Figure 4.20	Voltage waveforms obtained under ILS for case study-02	46
Figure 4.21	Frequency waveforms obtained through application of UFLS and ILS for case study-03	47
Figure 4.22	Voltage waveforms obtained under UFLS for case study-03	48

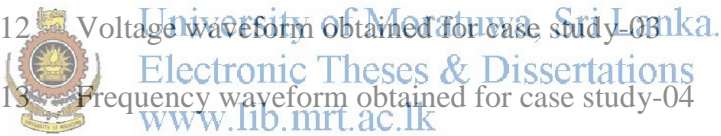


Figure 4.23	Voltage waveforms obtained under ILS for case study-03	48
Figure 4.24	Frequency waveforms obtained through application of UFLS and ILS for case study-04	49
Figure 4.25	Voltage waveforms obtained under UFLS for case study-04	49
Figure 4.26	Voltage waveforms obtained under ILS for case study-04	49
Figure 4.27	Total MW disconnected under UFLS for case study-01	52
Figure 4.28	Total MW disconnected under ILS for case study-01	53
Figure 4.29	Total MW disconnected under UFLS for case study-02	54
Figure 4.30	Total MW disconnected under ILS for case study-02	54
Figure 4.31	Total MW disconnected under UFLS for case study-03	56
Figure 4.32	Reactive power components of interrupted feeders with less MW values under UFLS for case study-03	57
Figure 4.33	Total MW disconnected under ILS for case study-03	58
Figure 4.34	Reactive power components of interrupted feeders under ILS for case study-03	59



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

LIST OF TABLES

		Page
Table 2.1	Existing Load shedding scheme in CEB	05
Table 2.2	Power stations tripped	09
Table 2.3	Grid substations tripped	09
Table 2.4	Load shed under existing load shedding mechanism on 07 th December 2007 at 04:48 hrs	15
Table 3.1	Derived Demand curve equations for each GSS based on time of the day	20
Table 3.2	Descending order of real power and reactive power of the feeders which can be shed	22
Table 4.1	Permissible voltage variation in 220 kV, 132 kV and 33 kV systems	33
Table 4.2	Total load shed under UFLS and ILS	48
Table 4.3	Difference between disconnected load and generation loss under UFLS and ILS	48
Table 4.4	Number of interrupted feeders under UFLS and ILS	49
Table 4.5	Uninterrupted load under UFLS and ILS as a percentage (%) of total load connected	49



LIST OF ABBREVIATIONS

Abbreviation	Description
CEB	Ceylon Electricity Board
UFLS	Under Frequency Load Shedding
ILS	Intelligent Load Shedding
PSS/E	Power System Simulator for Engineering
GUI	Graphical User Interface
GSS	Grid Sub Station
PS	Power Station
GIS	Gas Insulated Substation
DFR	Digital Fault Recorder
KCCP	Kelaniya Combined Cycle Power plant
SCADA	Supervisory Control and Data Acquisition
PLC	Programmable Logic Controller
MH	Mini Hydro
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
STM-1	Synchronous Transport Module level-1
SDH	Synchronous Digital Hierarchy management
ITU-T	International Telecommunication Union- Telecommunication Standardization Sector



University of Moratuwa, Sri Lanka.
 Kelaniya Combined Cycle Power plant
www.lib.mrt.ac.lk

LIST OF APPENDICES

Appendix	Description	Page
Appendix-A:	Selected reduced network from CEB system	61
Appendix-B:	'loadData.m' file created in MATLAB software to read demand in each GSS from excel file	62
Appendix-C:	'generationData.m' file created in MATLAB software to read generation at each power station from excel file	63
Appendix-D:	'gui.m' file created in MATLAB software to view 'GRAPHICAL USER INTERFACE'	64
Appendix-E:	'loadSheddable.m' file created in MATLAB software to read demand of each GSS feeder which can be shed from excel file	66
Appendix-F:	'cutoff.m' file created in MATLAB software to define 'cutoff' function for load shedding	67
Appendix-G:	'simulateSystem.m' file created in MATLAB software for the simulation	68
Appendix-H:	'run.m' file created in MATLAB software to run the Simulation	71
Appendix-I:	Load Shedding Sequence used in ILS mechanism for PSS/E simulation	72

