INTELLIGENT RAILWAY SIGNALING FAILURE ALERT SYSTEM

M.A Nadeera Sugandi

159289J

Degree of Master of Science in Industrial Automation

Department of Electrical Engineering

University of Moratuwa

Sri Lanka

April 2021

INTELLIGENT RAILWAY SIGNALING FAILURE ALERT SYSTEM

M.A Nadeera Sugandi
159289J

Dissertation submitted in partial fulfilment of the requirements
for the degree Master of Science in Industrial Automation

Department of Electrical Engineering

University of Moratuwa
Sri Lanka

April 2021

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:

M.A Nadeera Sugandi

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

Signature of the supervisor: Date:

Prof. Buddhika Jayasekara

ABSTRACT

One of the key factor for the development of the country is the efficiency of the transport system. In Sri Lanka, 20 percent of the passengers travel by the train. The demand for the rail transportation systems have been increased by the increment of rail transportation facilities and the population. Recently rail transport was introduced to Sri Lanka in 1864 to transport goods, but currently popular for the passenger transportation.

The railway signaling system is used to cater the traffic issues by utilizing the limited resources such as trains and tracks. The loss due to the failure of the signal system is substantial, as this result in the loss of human lives and human hours in addition to the loss of damages to properties. For the reliable signaling system main input is train detection.

Currently Sri Lanka Railway hasn't got a proper Failure diagnosis and maintenance reporting system. Therefore, it is essential to have a system to ensure that railway signals are reliable and safe.

The research is based on an intelligent fault detection method on railway signal color light signals. Before commencing the research, several literature surveys had been done on railway signalling and railway fault diagnosis methods, railway signal maintenance and signal fault detecting mechanism. Moreover attention was placed on other industrial intelligent fault diagnosis methods. A brief go through on signal aspect circuits, circuit relays and relay theories, would help find out the most suitable method for fault detection.

To carry on the research many color light signals inputs, outputs were obtained and surveys were done on different signal lamps, signal poles, signal aspect faults and faulty ranges in each red, amber, green circuits were identified. Mainly research was done by a case study, from the three signal aspect pole 263 where located in Colombo- Fort yard. All the data of case study 263, three signal aspect pole's data was recorded manually and the current and voltage reading fault ranges in each red , amber, green circuit's electric

components were observed. Considering observed data and survey data model is implemented for the case study.

The Model is implemented with three input subsystems and six outputs. The proposed model uses a fuzzy system and the model is design by MATLAB Simulink system. Fuzzy system is developed using the “mamdani” technique.

The system is tested with actual readings for different faulty modes and justified that model output result and actual readings are accurate. The final develop model shows that the proposed method has the capacity to find faults in each Red, Amber and Green color light circuits.

Key words: Fault detection, fault diagnosis, fuzzy logic, Signal aspect, Signal aspect pole, MATLAB, Railway

DEDICATION

I dedicate my M.Sc. research dissertation to my beloved parents for their guidance given throughout my life.

ACKNOWLEDGEMENT

I would like to give my sincere gratitude to my project supervisor Prof. Buddhika Jayasekara for his continuous guidance and support and the motivation throughout the research to develop the result in to a fruitful outcome.

Support I received from my office environment is great and never forgotten.

I would like to thank the Chief Engineer Signal and Telecommunication sub department, Mr J.I.D Jayasundara. Special thanks to Deputy Chief Engineer Signal and Telecommunication Mr V.C.D Jayasekara who given me continuous guidance to success this research.

I would like to sincerely thank for the kind cooperation of Signal Supervisor Mr T.L Padmarajan and all my friends who helped me and encouraged me this programme by extending their support.

Finally, my special thanks to my beloved parents and family members for supporting me during the research period.

M.A.Nadeera Sugandi

TABLE OF CONTENTS

DECLARATION i
ABSTRACT ii
DEDICATION iv
ACKNOWLEDGEMENT v
LIST OF TABLES xi
LIST OF ABBREVIATION xii
CHAPTER 1 1
INTRODUCTION 1
1.1 General and Back Ground 1
1.2 Railway Signaling System 1
1.2.1 Sri Lanka Railways Signaling Maintenance & Rectification Mechanism 3
1.2.2 Typical Signal Circuit used in Sri Lanka Railway 5
1.2.3 Signal Process 5
1.2.4 Signal Aspect Circuit 8
1.2.5 Relay Theory 9
1.3 Research Initiating Statements 12
1.4 Objective 12
1.5 Methodology 13
1.6 Justification of Methodology 14
1.6.1 Alternative Approaches for Failure Monitoring 14
CHAPTER 2 16
LITERATURE SURVEY 16
2.1 Researches Based on Rail Way Fault Diagnosis And Intelligent Control System 16
2.2 Summary of Literature Review 23
2.2.1 Advantages of the Proposed System 23
CHAPTER 3 25
SYSTEM MATHEMATICAL MODEL 25

3.1 Case Study 263 Experimental Data 25
3.1.1 Red Bulb 30
3.1.2 Amber Bulb 32
3.1.3 Green Light 34
3.1.4 Amber Bulb Rule Base 36
3.1.5 Green Bulb Rule base 36
3.2 Justification of Fuzzy Values with Observed Data of Case Study – Signal Pole 263 37
CHAPTER 4 41
SYSTEM DESIGN AND DEVELOPMENT 41
4.1 Experimental Data 41
4.2 Fault Detection and Diagnosis Methodology 44
4.3 Fuzzy Model for fault detection 45
4.3.1 Software Design Consideration: Fuzzy Logic Controller Design 46
4.4 Red Bulb Rule Base 54
4.5 Amber Bulb Rule Base 60
4.6 Green Bulb Rule Base 66
CHAPTER 5 71
MODEL DESCRIPTION WITH ASSUMPTIONS 71
5.1 Lamp Circuit Failure Identification 71
5.2 Validation of the Results of Intelligent Base Signaling Failure Alert System 76
5.2.1 Case Study 263 signal Red Bulb Results 77
5.2.2 Case Study 263 signal Amber Lamp Results 82
5.2.3 Case Study 263 Signal Green Bulb Results 87
CHAPTER 6 92
CONCLUSION 92
6.1 Research Summary and Conclusion 92
6.2 Scope for Future Research 93
REFERENCES 94

LIST OF FIGURES

Figure 1 : Railway Signals 2
Figure 2: Basic Structure of Railway Signaling Process 3
Figure 3 : Sri Lanka Railway Interlocking Relay House 4
Figure 4: Colombo Fort Yard Track Plan. 5
Figure 5: Symbols of Yard Track Plan Signal Process 5
Figure 6: Signal Aspect Circuit 8
Figure 7: Coil Energized 9
Figure 8: Coil De-Energized 9
Figure 9: The Increase in Flux Increased the Back EMF 10
Figure 10: The Drop Away Time on Disconnection. 11
Figure 11: The Graph of Release Time of Relay. 11
Figure 12: The Basic Track Circuit 16
Figure 13: Track Circuit Termination Model with Tuning Unit Capacitors 17
Figure 14: Designed Structure and Training and Validation of "Fault detection and diagnosis for railway track circuit using Neuro-Fuzzy" Research 17
Figure 15: Results of Railway Track Circuit Fault Diagnosis Using Recurrent Neural Networks 18
Figure 16: Fuzzy Logic Controller for the Gate Control Intelligent System 19
Figure 17: Modelling diagram of gate control of the intelligent Railway System 19
Figure 18: Linguistic Rules and Fuzzy Rule Matrix 20
Figure 19: Gate Control Membership Function 20
Figure 20: Overall Intelligent Railway Cross Level Gates and Signaling System 21
Figure 21: Intelligent Railway Cross Level Gates and Signaling System Response With and Without Fuzzy Logic Controller 21
Figure 22: Block Diagram of Automated Railway Track Fault Detection System Using Robot 22
Figure 23: Case Study of Signal Pole 263 25

Figure 24: Fuzzy Logic Control of Intelligent Based Railway Signaling Failure Alert System 26
Figure 25: Observing Data 26
Figure 26: The Equivalent Circuit of Signal Aspect Circuit 27
Figure 27: Three Aspect Signal 27
Figure 28: Three Aspect Control Signal 28
Figure 29: Common Circuit Diagram 28
Figure 30: Mat Lab Plot 30
Figure 31: The Equivalent Circuit for Amber Light 32
Figure 32: The Equivalent Circuit for Green Light 34
Figure 33: Spectral Power Distribution of Incandescent Bulb 38
Figure 34: Schematic Diagram of Three Aspect Signal 39
Figure 35: Measuring Currents and Voltages in Relay circuits 41
Figure 36: Flow Chart of Proposed Modeled 43
Figure 37: The Concept of Fault Detection 44
Figure 38: Fuzzy System 45
Figure 39: Triangular Function 46
Figure 40: Structure of Fuzzy System 48
Figure 41: Fuzzy Subsystem Using Mat lab Simulink Window 53
Figure 42: Fuzzy Rule Matrix of the Intelligent Sub 53
Figure 43: Triangular Functions for Red Lamp Voltage Failure Rate 58
Figure 44: Triangular Function for Red Lamp Current Failure Rate 58
Figure 45: Fuzzification Design 59
Figure 46: Fuzzification Design of Red Lamp Circuit 59
Figure 47: Fuzzy Rule Base 60
Figure 48: Negative Big Voltage Rule Base 60
Figure 49: Triangular Functions for Amber Lamp Voltage Failure Rate 65
Figure 50: Triangular Functions for Amber Lamp Current Failure Rate 65
Figure 51: Triangular Functions for Green Lamp Voltage Failure Rate 70

Figure 52: Triangular Functions for Green Lamp Current Failure Rate 70
Figure 53: MATLAB 2014a Model for the Red Bulb Circuit and Current Faulty Diagram 72
Figure 54: MATLAB 2014a Model for the Red Bulb Circuit and Voltage Faulty Diagram 72
Figure 55: MATLAB 2014a Model for the Amber Bulb Circuit and Current Faulty Diagram 73
Figure 56: MATLAB 2014a Model for the Amber Bulb Circuit and Voltage Faulty Diagram 73
Figure 57: MATLAB 2014a Model for the Green Bulb Circuit and Current Faulty Diagram 74
Figure 58: MATLAB 2014a Model for the Green Bulb Circuit and Voltage Faulty Diagram 74
Figure 59: When No Failures in the Circuit 76
Figure 60: When failure in the circuit 76
Figure 61: Structure of Intelligent Based Future Implementation 93

LIST OF TABLES

Table 1: Fort 263 Signal Extract 6
Table 2: Comparison of Researches Based On Rail Way Fault Diagnosis and Intelligent Control System 24
Table 3: Case Study 263 Signal Minimum Voltages and Currents for Threes Aspect Work 37
Table 4: Observation Voltage Data of Color Signal 263, 550 & 478,556) 40
Table 5: Readings of Relays When Each Lamp Working 45
Table 6: Failure Mode 47
Table 7: Rule Base for Signal Circuit Failures Identification 52
Table 8: Rule base for Red Bulb 57
Table 9: Amber Bulb Rule Base 64
Table 10: Green Bulb Rule Base 69
Table 11: Red Lamp Working Conditions Results 80
Table 12: Red Lamp Circuit Faulty Condition 81
Table 13: Amber Lamp Working Condition 85
Table 14 : Amber Lamp Circuit Faulty Condition 86
Table 15: Green Lamp Working Condition 90
Table 16: Green Lamp Circuit Faulty Condition 91

LIST OF ABBREVIATION

LSTM	Long Short-Term Memory
GSM	Global System For Mobile Communication
GPS	Global Positioning System
RE	Red Lamp
DE	Amber Lamp
HE	Green Lamp
RECR	Red Bulb Checking Relay
HDECR	Amber Green Checking Relay
EMF	Electromotive Force
CLS	Color Light Signal
CO	Call On