# **TABLE OF CONTENTS**

CONTENTS	Page No.
Title Page	i
Certificates	iii
Acknowledgement	xi
Table of Content	xiii
List of Figures	xxi
List of Tables	xxvii
List of Abbreviations	xxxiii
List of Symbols	XXXV
Preface	xxxvii
CHAPTER 1 – PROLOGUE	1-28
1.1 Introduction	
1.2 Impact of Series Compensation on Distance Relaying	
1.2.1 Under and Over Reaching of Relays	
1.2.2 Current and Voltage Inversion	
1.2.3 Precarious Operation of MOV	
1.2.4 Addition of Transients and Harmonics	
1.3 Literature Survey	
1.3.1 Protection Methodologies for Fixed Series Capacitor Compensated Power Network	
1.3.1.1 Mathematical Network Modelling based Protection Methodologies	

- 1.3.1.2 Signal Processing and Intelligent Computing based Protection Methodologies
- 1.3.2 Protection Methodologies for FACTS Compensated Power Network
  - 1.3.2.1 Mathematical Network Modelling based Protection Methodologies
  - *1.3.2.2* Signal Processing and Intelligent Computing based Protection Methodologies
- 1.3.3 Summary of Literature Survey
- 1.4 Objective of the Research Work
- 1.5 Thesis Outline
- 1.6 Conclusion

# CHAPTER 2 – CONCEPTS OF SIGNAL PROCESSING AND29-46FEATURE VECTORS EXTRACTION

- 2.1 Introduction
- 2.2 Fourier Transform
- 2.3 Short Time Fourier Transform
- 2.4 Wavelet Transform
  - 2.4.1 Continuous Wavelet Transform
  - 2.4.2 Discrete Wavelet Transform
- 2.5 Empirical Mode Decomposition
- 2.6 Feature Vector Selection Mechanism

2.6.1 Feature Vector Selection with DWT

2.6.2 Feature Vector Selection with EMD

### CHAPTER 3 – FAULT EVENTS CLASSIFICATION USING DWT & 47-92 MACHINE LEARNING TECHNIQUES

- 3.1 Introduction
- 3.2 Machine Learning Techniques
  - 3.2.1 Parametric Machine Learning Algorithms

#### 3.2.2 Non-Parametric Machine Learning Algorithms

- 3.3 K-Nearest Neighbor (K-NN) Technique
- 3.4 Support Vector Machine (SVM) Technique
- 3.5 Probabilistic Neural Network (PNN)
- 3.6 Proposed DWT and Non-Parametric ML based Fault Events Classification Scheme
  - 3.6.1 Training and Testing Mechanism
- 3.7 Case Study and Results

*3.7.1* Test Case I: Two-Bus Series Compensated Transmission Test Network

3.7.2 Test Case II: Modified IEEE 9-Bus Series Compensated Test Network

- 3.8 Evolving Fault Events Identification
- 3.9 Performance During CTs Saturation
- 3.10 Conclusion

## CHAPTER 4 – FAULT EVENTS CLASSIFICATION USING EMD & 93-130 MACHINE LEARNING TECHNIQUES

4.1 Introduction

- 4.2 Proposed EMD and Non-parametric ML based Fault Events Classification Scheme
  - 4.2.1 Training and Testing Mechanism
- 4.3 Case Study and Results
  - 4.3.1 Test Case I: Two-Bus Series Compensated Transmission Test Network
  - 4.3.2 Test Case II: Modified IEEE 9-Bus Series Compensated Test Network
- 4.4 Evolving Fault Events Identification
- 4.5 Conclusion

## CHAPTER 5 – FAULT EVENTS CLASSIFICATION USING 131-186 ENSEMBLE AND DEEP LEARNING TECHNIQUES

- 5.1 Introduction
- 5.2 Ensemble Learning
  - 5.2.1 Bagging
  - 5.2.2 Boosting
  - 5.2.3 AdaBoost
- 5.3 Proposed DWT and Ensemble Learning based Fault Events Classification Scheme
  - 5.3.1 Training and Testing Mechanism
- 5.4 Case Study and Results
  - 5.4.1 Test Case I: Two-Bus Series Compensated Transmission Test Network

- 5.4.2 Test Case II: Modified IEEE 9-Bus Series Compensated Test Network
- 5.4.3 Test Case III: Series Compensated Parallel Transmission Network (Third test system)
- 5.5 Performance of Ensemble learning Based Scheme During CTs Saturation
- 5.6 Cross-Country Fault Events Identification using Ensemble Learning based Scheme
- 5.7 Evolving Fault Events Identification using Ensemble Learning based Scheme
- 5.8 Deep Learning Mechanism
  - 5.8.1 Convolution Neural Network
  - 5.8.2 Recurrent Neural Network
  - 5.8.3 Deep Belief Networks
  - 5.8.4 Autoencoder
- 5.9 Proposed DWT and Deep Learning based Fault Events Classification Scheme
  - 5.9.1 Training and Testing Mechanism
- 5.10 Case Study and Results
  - 5.10.1 Test Case I: Two-Bus Series Compensated Transmission Test Network
  - 5.10.2 Test Case II: Modified IEEE 9-Bus Series Compensated Test Network
  - 5.10.3 Test Case III: Series Compensated Parallel Transmission

Network (Third test system)

5.11 Cross-Country Fault Events Identification using Ensemble Learning

based Scheme

5.12 Evolving Fault Events Identification using Ensemble Learning

based Scheme

5.13 Conclusion

## CHAPTER 6 – FAULT EVENTS DISTANCE ESTIMATION USING 187-228 INTELLIGENT COMPUTING

- 6.1 Introduction
- 6.2 Fundamentals of Neural Network Models
  - 6.2.1 Feed-Forward Neural Network
  - 6.2.2 Linear Neural Network
  - 6.2.3 Cascaded-Forward Neural Network
  - 6.2.4 Generalized Regression Neural Network
- 6.3 Proposed Intelligent Computing Based Fault Distance Estimation Methodology
  - 6.3.1 Training and Testing Mechanism
- 6.4 Case Study and Results
  - 6.4.1 Test Case I: Two-Bus Series Compensated Transmission Test Network
  - 6.4.2 Test Case II: Modified IEEE 9-Bus Series Compensated Test Network
  - 6.4.3 Test Case III: Series Compensated Parallel Transmission

Network (Third test system)

6.5 Location of Evolving Fault Events	
6.6 Conclusion	
CHAPTER 7 – CONCLUSION AND FUTURE SCOPE	229-232
7.1 Conclusion	
7.2 Future Scope	
References	233-248
Appendices	249-252
List of Publications	253-255