Engineering Applications of Computational Methods

Volume 9

The book series Engineering Applications of Computational Methods addresses the numerous applications of mathematical theory and latest computational or numerical methods in various fields of engineering. It emphasizes the practical application of these methods, with possible aspects in programming. New and developing computational methods using big data, machine learning and AI are discussed in this book series, and could be applied to engineering fields, such as manufacturing, industrial engineering, control engineering, civil engineering, energy engineering and material engineering.

The book series Engineering Applications of Computational Methods aims to introduce important computational methods adopted in different engineering projects to researchers and engineers. The individual book volumes in the series are thematic. The goal of each volume is to give readers a comprehensive overview of how the computational methods in a certain engineering area can be used. As a collection, the series provides valuable resources to a wide audience in academia, the engineering research community, industry and anyone else who are looking to expand their knowledge of computational methods.

This book series is indexed in both the **Scopus** and **Compendex** databases.

Dinghui Wu · Juan Zhang · Junyan Fan ·
Dandan Tang

Performance Optimization of Fault Diagnosis Methods for Power Systems

Springer

Dinghui Wu
School of Internet of Things Engineering
Jiangnan University
Wuxi, Jiangsu, China

Juan Zhang
School of Internet of Things Engineering
Jiangnan University
Wuxi, Jiangsu, China

Junyan Fan
School of Internet of Things Engineering
Jiangnan University
Wuxi, Jiangsu, China

Dandan Tang
School of Internet of Things Engineering
Jiangnan University
Wuxi, Jiangsu, China

National Key Research and Development Program of China
National Natural Science Foundation of China

ISSN 2662-3366 ISSN 2662-3374 (electronic)
Engineering Applications of Computational Methods
ISBN 978-981-19-4577-9 ISBN 978-981-19-4578-6 (eBook)
https://doi.org/10.1007/978-981-19-4578-6

This book is dedicated to our families, who have always encouraged and supported us to explore knowledge and chase our dreams.

Preface

Fault diagnosis of power systems is a process to detect, locate and identify a variety of faults by analyzing power data such as electrical quantity and switching quantity based on professional knowledge of electrical engineering. Timely and accurate fault diagnosis is conducive to rapid fault removal and reduces the impact of fault as possible. With the development of power systems, the scale is expanded and the structure is getting more and more complex, making the stability analysis of power systems more and more difficult. Traditional model-based fault diagnosis methods for power systems are facing challenges, and therefore, inapplicable for timely analysis, and the accuracy of fault diagnosis needs to be improved at the same time.

Aming to optimize the performance of existing methods and improve the speed and accuracy of fault diagnosis, a methodology of fault diagnosis for power systems is proposed. This book is mainly focused on the performance optimization of fault diagnosis methods for power systems including both model-driven ones, such as the convolutional neural network, and data-driven ones, such as random matrix theory. Studies on fault diagnosis of power systems have long been the focus of electrical engineers and scientists. Pursuing a holistic approach to improve the accuracy and efficiency of existing methods, the underlying concepts of several algorithms are introduced and then further applied in various situations for fault diagnosis of power systems in this book. The primary audience for the book would be the scholars and graduate students whose research topics include the control theory, applied mathematics, fault detection and so on.

Wuxi, China
May 2022

Dinghui Wu
Juan Zhang
Junyan Fan
Dandan Tang

Acknowledgements This book is supported by the National Natural Science Foundation of China with Grant No. 61572237, the National Key Research and Development Program of China with Grant No. 2020YFB1711102 and 2020YFB1711100.

Contents

1 Introduction 1
1.1 Background and Significance 1
1.1.1 Background 1
1.1.2 Significance 2
1.2 Book Organization 3
1.3 Preliminaries 4
1.3.1 Gaussian Fitting 4
1.3.2 Random Matrix Theory 5
1.3.3 Federated Learning 8
References 11

2 Short-Term Wind Power Prediction Based on DP-RVESN Model 13
2.1 Introduction 13
2.2 Methodology 15
2.2.1 Kernel Principal Component Analysis (KPCA) 15
2.2.2 Network Structure 16
2.2.3 Robust Variational Reasoning 18
2.3 Proposed Hybrid Forecasting Model 21
2.4 Experimental Results and Analysis 22
2.4.1 Data Process (DP) 24
2.4.2 Prediction Results 27
2.5 Conclusion 29
References 32

3 A Fault Detection Method for Power Systems Based on Random Matrix Theory 35
3.1 Introduction 35
3.2 Fault Detection Method Based on Random Matrix Theory 36
3.2.1 Construction of Random Matrix and Data Processing 36
3.2.2 Fault Detection Method Based on the Maximum Eigenvalue Variation Rate 37

3.2.3 Discussions with the Other Methods 39
3.3 Case Studies 40
3.3.1 Case 1: Effectiveness Verification of the MEVR Method Under Three-Phase Short-Circuit on Bus 9 41
3.3.2 Case 2: Effectiveness Verification of the MEVR Method Under Load Jump of Bus 29 45
3.4 Conclusion 48
References 48

4 A Fault Location Method for Power Systems Based on Random Matrix Theory 51
4.1 Introduction 51
4.2 Fault Location Method Based on Random Matrix Theory 52
4.2.1 Fault Location Based on the Largest Eigenvector 53
4.2.2 Discussions with the Other Methods 54
4.3 Case Study 57
4.3.1 Case 1: Effectiveness Verification of the Proposed Method for Simple Fault 58
4.3.2 Case 2: Effectiveness Verification of the Proposed Method for Simultaneous Multiple Faults 61
4.3.3 Case 3: Effectiveness Verification of the Proposed Method for Successive Multiple Faults 62
4.4 Conclusion 65
References 66

5 Joint Weighted Domain Adaptation Network for Bearing Fault Diagnosis 67
5.1 Introduction 67
5.2 Preliminaries 69
5.2.1 Transfer Learning Problem 69
5.2.2 MMD 70
5.2.3 JWDD 71
5.3 JWDAN for Transfer Fault Diagnosis 73
5.3.1 JWDAN 73
5.3.2 Training JWDAN 76
5.4 Experiments 78
5.4.1 Data Description 78
5.4.2 Experimental Setup 80
5.4.3 Results 81
5.4.4 Hyper-Parameters Analysis 83
5.4.5 Ablation Study 84
5.5 Conclusion 86
References 86

6 Bearing Fault Diagnosis of Wind Motor Based on Shared-FedAvg with Non-IID Data 89
6.1 Introduction 89
6.2 Related Knowledge 90
6.2.1 Federated Learning 90
6.2.2 IID and Non-IID 92
6.2.3 Fault Diagnosis on Client Side Based on WPD-CNN 93
6.3 Fault Diagnosis Algorithm Based on Shared-FedAvg 95
6.4 Experimental Analysis 97
6.4.1 Experimental Data 98
6.4.2 Different Diagnostic Strategies 99
6.4.3 Experimental Analysis 100
6.5 Conclusion 106
References 106

7 Federated Learning for Rotating Machinery Fault Diagnosis with Knowledge Distillation 109
7.1 Introduction 109
7.2 Related Knowledge 110
7.2.1 Federated Learning 110
7.2.2 Knowledge Distillation 111
7.3 Proposed Method 112
7.3.1 Dirichlet Data Splitting Strategy 114
7.3.2 CNN for Fault Diagnosis 114
7.3.3 Preposed Efficient Fault Diagnosis Methods 114
7.4 Experiments 117
7.4.1 Setup 117
7.4.2 Performance Overview of FedAvg 120
7.4.3 Evaluate Performance of KD-FedAvg 121
7.4.4 Generalization Analysis 122
7.5 Conclusion 126
References 126

Acronyms

CNN	Convolutional neural network
ESN	Echo state network
RMT	Random matrix theory