Lecture Notes in Electrical Engineering

Volume 779

Series Editors

Leopoldo Angrisani, Department of Electrical and Information Technologies Engineering, University of Napoli Federico II, Naples, Italy
Marco Arteaga, Departament de Control y Robótica, Universidad Nacional Autónoma de México, Coyoacán, Mexico
Bijaya Ketan Panigrahi, Electrical Engineering, Indian Institute of Technology Delhi, New Delhi, Delhi, India
Samarjit Chakraborty, Fakultät für Elektrotechnik und Informationstechnik, TU München, Munich, Germany
Jiming Chen, Zhejiang University, Hangzhou, Zhejiang, China
Shanben Chen, Materials Science and Engineering, Shanghai Jiao Tong University, Shanghai, China
Tan Kay Chen, Department of Electrical and Computer Engineering, National University of Singapore, Singapore, Singapore
Rüdiger Dillmann, Humanoids and Intelligent Systems Laboratory, Karlsruhe Institute for Technology, Karlsruhe, Germany
Haibin Duan, Beijing University of Aeronautics and Astronautics, Beijing, China
Gianluigi Ferrari, Università di Parma, Parma, Italy
Manuel Ferre, Centre for Automation and Robotics CAR (UPM-CSIC), Universidad Politécnica de Madrid, Madrid, Spain
Sandra Hirche, Department of Electrical Engineering and Information Science, Technische Universität München, Munich, Germany
Faryar Jabbari, Department of Mechanical and Aerospace Engineering, University of California, Irvine, CA, USA
Limin Jia, State Key Laboratory of Rail Traffic Control and Safety, Beijing Jiaotong University, Beijing, China
Janusz Kacprzyk, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland
Alaa Khamis, German University in Egypt El Tagamoa El Khames, New Cairo City, Egypt
Torsten Kroeger, Stanford University, Stanford, CA, USA
Yong Li, Hunan University, Changsha, Hunan, China
Qilian Liang, Department of Electrical Engineering, University of Texas at Arlington, Arlington, TX, USA
Ferran Martín, Departament d'Enginyeria Electrònica, Universitat Autònoma de Barcelona, Bellaterra, Barcelona, Spain
Tan Cher Ming, College of Engineering, Nanyang Technological University, Singapore, Singapore
Wolfgang Minker, Institute of Information Technology, University of Ulm, Ulm, Germany
Pradeep Misra, Department of Electrical Engineering, Wright State University, Dayton, OH, USA
Sebastian Möller, Quality and Usability Laboratory, TU Berlin, Berlin, Germany
Subhas Mukhopadhyay, School of Engineering & Advanced Technology, Massey University, Palmerston North, Manawatu-Wanganui, New Zealand
Cun-Zheng Ning, Electrical Engineering, Arizona State University, Tempe, AZ, USA
Toyoaki Nishida, Graduate School of Informatics, Kyoto University, Kyoto, Japan
Federica Pascucci, Dipartimento di Ingegneria, Università degli Studi "Roma Tre", Rome, Italy
Yong Qin, State Key Laboratory of Rail Traffic Control and Safety, Beijing Jiaotong University, Beijing, China
Gan Woon Seng, School of Electrical & Electronic Engineering, Nanyang Technological University, Singapore, Singapore
Joachim Speidel, Institute of Telecommunications, Universität Stuttgart, Stuttgart, Germany
Germano Veiga, Campus da FEUP, INESC Porto, Porto, Portugal
Haitao Wu, Academy of Opto-electronics, Chinese Academy of Sciences, Beijing, China
Walter Zamboni, DIEM - Università degli studi di Salerno, Fisciano, Salerno, Italy
Junjie James Zhang, Charlotte, NC, USA

The book series *Lecture Notes in Electrical Engineering* (LNEE) publishes the latest developments in Electrical Engineering - quickly, informally and in high quality. While original research reported in proceedings and monographs has traditionally formed the core of LNEE, we also encourage authors to submit books devoted to supporting student education and professional training in the various fields and applications areas of electrical engineering. The series cover classical and emerging topics concerning:

- Communication Engineering, Information Theory and Networks
- Electronics Engineering and Microelectronics
- Signal, Image and Speech Processing
- Wireless and Mobile Communication
- Circuits and Systems
- Energy Systems, Power Electronics and Electrical Machines
- Electro-optical Engineering
- Instrumentation Engineering
- Avionics Engineering
- Control Systems
- Internet-of-Things and Cybersecurity
- Biomedical Devices, MEMS and NEMS

For general information about this book series, comments or suggestions, please contact leontina.dicecco@springer.com.

To submit a proposal or request further information, please contact the Publishing Editor in your country:

China

Jasmine Dou, Editor (jasmine.dou@springer.com)

India, Japan, Rest of Asia

Swati Meherishi, Editorial Director (Swati.Meherishi@springer.com)

Southeast Asia, Australia, New Zealand

Ramesh Nath Premnath, Editor (ramesh.premnath@springernature.com)

USA, Canada:

Michael Luby, Senior Editor (michael.luby@springer.com)

All other Countries:

Leontina Di Cecco, Senior Editor (leontina.dicecco@springer.com)

**** This series is indexed by EI Compendex and Scopus databases. ****

More information about this series at http://www.springer.com/series/7818

Yang Xu · Yongbin Sun ·
Yanyang Liu · Feng Gao ·
Pengfei Gu · Zheming Liu
Editors

Nuclear Power Plants: Innovative Technologies for Instrumentation and Control Systems

The Fifth International Symposium on Software Reliability, Industrial Safety, Cyber Security and Physical Protection of Nuclear Power Plant (ISNPP)

Springer

Editors
Yang Xu
Department of Engineering Physics
Tsinghua University
Beijing, China

Yanyang Liu
Nuclear Power Institute of China
Chengdu, Sichuan, China

Pengfei Gu
China United Heavy Duty Gas Turbine
Technology Co., Ltd
Shanghai, China

Yongbin Sun
China Techenergy Co., Ltd.
Beijing, China

Feng Gao
China Nuclear Power Design Co., Ltd.
Shenzhen, Guangdong, China

Zheming Liu
Product Information Committee of China
Instrument and Control Society
Beijing, China

ISSN 1876-1100 ISSN 1876-1119 (electronic)
Lecture Notes in Electrical Engineering
ISBN 978-981-16-3455-0 ISBN 978-981-16-3456-7 (eBook)
https://doi.org/10.1007/978-981-16-3456-7

© The Editor(s) (if applicable) and The Author(s), under exclusive license
to Springer Nature Singapore Pte Ltd. 2021
This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Contents

Research on Converged Wireless Communication Network Scheme in Nuclear Power Plants 1
Jia Meng, Ai-Fen Liu, Xiao-Fei Deng, and Wei Wei

Research About Computer Based System Reliability Demonstration Methods in Nuclear Power Plant 8
Dan Xu, Zhao-Lei Hao, Hua Huang, and Xiao-Ming Qian

Multi-ray Intelligent Monitoring System for Mixed Radiation Field Measurements 14
Jin-Xing Cheng, You-Peng Wu, Qing-Bo Wang, Wei-Wei Wen, Ai Yu, Rui Qiu, Yue Zhang, and Wen-Kai Zhu

Basic Model Design of Online Monitoring System for Mixed Radiation Field 24
Jin-Xing Cheng, Wen-Kai Zhu, Qing-Bo Wang, Wei-Wei Wen, You-Peng Wu, and Ai Yu

Duty Ratio Restriction Strategies of Space Vector PWM for Power Amplifiers of AMBs 30
Chun-Yi Wang, Kai Zhang, and Yang Xu

Research and Application of 3D Real-Time Simulation Technology for Thermal and Hydraulic Mechanism in Nuclear Power Plant 45
Zheng-Hui Yang, Hao Wang, and Yi Zhang

Research on Software Quality Evaluation Model of Instrument and Control System in Nuclear Power Plant 55
Huan-Lin Chen, Jian-Qiu Zhou, and Yan Li

The Security Based on Wireless Network in Nuclear Power Plant 64
Dong Zhang and Sheng-Yong Liao

Information Fusion Analysis of Cyberattack Identification Based on D-S Evidence Theory 71
Chao Guo, Jiang-Hai Li, Wen Si, and Xiao-Jin Huang

Power Control System of Small Modular PB-Bi Fast Reactor (SMPBR) 84
Ao-Di Sun and Xin-Yu Wei

Research on Integrated Management Technology for Physical Protection System of Nuclear Facilities 97
Wei-Wei Wen, Jin-Xing Cheng, You-Peng Wu, Qing-Bo Wang, Xian-Bo Chen, Lang Li, Ai Yu, and Wei Yuan

Calculation and Selection of Cross-Sectional Area of Instrumentation and Control Cable Core 106
Xiao-Yu Liu and Xin-Nian Huang

The Formulation of BOP Auxiliary System Centralized Control Network in Nuclear Power Plant 114
Xiao-Feng Li, Zhi-Yin Liu, Lei Jiang, Heng Li, and Zhou Xiao

An AHP-Fuzzy Complex Evaluation Method for MCR Human Factors Engineering Verification and Validation 123
Yuan Gao and Yi-Wei Ma

Research on Control Strategy of Nuclear Island Ventilation Systems in Nuclear Power Plant 134
Zhou Xiao, Heng Li, Li-Ming Zhang, Xin Du, and Hua-Qing Peng

The Safety Function Design Improvement of Circulation Water Filter System in CPR1000 Unit 148
Lei Jiang and Hui Wang

A Study About Unit Testing for Embedded Software of Control System in Nuclear Power Plant 157
Wang Xi, Wei Liu, Tao Bai, and Ji Shi

Design of Defence in Depth for I&C System in Pressurized Water Reactor Nuclear Power Plant 164
Tao Fu, Gong-Jie Li, and Li-Ming Zhang

Test Analysis About Hydrogen Detection Equipment Under Severe Accident in Nuclear Power Plant 177
Dan Xu, Zhou Xiao, Ya-Jie Tian, and Xiao-Ming Qian

Research of Advanced Control Algorithm in Primary Loop Control System 186
Zhi-Guang Deng, Bi-Wei Zhu, Qian Wu, Peng He, Mei-Qiong Xiang, Tao Xu, and Yue Qing

Research of SSAE-GPC in Coordinated Control System of Nuclear Power Plant 199
Zhi-Guang Deng, Qian Wu, Bi-Wei Zhu, Xin Lv, Jia-Liang Zhu, Si-Jie Xu, and Xue-Mei Wang

Reliability Verification Scheme for Safety Class DCS and Its Implementation in Nuclear Power Plant 216
Ming-ming Liu, Yang Chen, Xian-jian He, and Biao Xu

An Ergonomic Analysis of Main Control Room Console in Nuclear Power Plant Based on Jack 226
Yu-Tong Li, Ming-Ming Liu, Qing-Huai Huang, Nan Gao, Guan-Ron Liu, and Mao Zhou

Verification Method and Basic Guarantee of RPS Availability in Nuclear Power Plant 239
Xian-Jian He, Ming-Ming Liu, Qing Zhang, Xiao-Jun Luo, and Jing Wen

Design Method of Human-Computer Interactive Interface of MTS Based on DCS of Nuclear Power Plant 247
Li-Jun Dang, Jun Huang, and Qi Ye

Formally Verified a Front-End of the Trusted Code Generator for Safety I&C Software of NPPs 260
Lin Lan, Quan Ma, Rong-Bin Hou, Wei Jiang, Ming-Xing Liu, Fei Yang, and Yong Li

Design of Emulation System for Safety DCS 273
Hao Peng, Xu Zhang, Zhi-Guang Deng, Qi Chen, Yu Zhang, and Wei Jiang

Trusted Algorithm Compiler for Safety I&C Software of NPPs Based on Formal Methods 282
Fei Yang, Lin Lan, Quan Ma, Wen-Xing Han, Ming-Xing Liu, and Wei Jiang

Design and Implementation of Translation-Based Virtual DCS Based on Simulink 292
Xu Zhang, Zhi-Guang Deng, Quan Ma, and Ming-Ming Liu

Testing Verification of Pressurizer Control in Nuclear Power Plant Based on Comparative Simulation 301
Xu Zhang, Zhi-Guang Deng, Hao Peng, and Qi Chen

Optical Fiber Communication and Wireless Communication Technology Oriented to Internet of Things 316
Xiao-Chen Yang, Zhen-Yu Yan, Zeng-Jun Chun, and Lai-Long Zou

Research on Reliability Design of PROFIBUS Fieldbus System in Conventional Island of Nuclear Power Plant 332
Xin- Nian Huang, Heng Li, Xiu-Sen Chen, and Xiao-Yu Liu

Research and Practice of Design Process (Knowledge) Reuse in the Data State Environment of Nuclear Power Design Company 341
Jing Ma, Wei-Qi Dai, and Wei-Jian Lei

Study on the Feedwater Control of the Once-Through Steam Generator in the Sodium-Cooled Fast Reactor (SFR) 354
Wen Jiao, Xin-Yu Wei, Pei-Wei Sun, and Xian-Shan Zhang

Design and Improvement for γ Dose-Rate Monitor System of Nuclear Power Plant 370
Liang Li, Jin Fan, Yue Zhang, and Wei-jie Huang

Discussion on the Software V&V Technology in Nuclear Power Plants 380
Hui-Hui Liang, Wang-Ping Ye, Wei Liu, and Jian-Zhong Tang

Research and Application of RPN Key Technologies in Nuclear Power Plants 386
Ya-Jie Tian, Tian-You Li, Zhen-Yu Shen, Hua-Qing Peng, Rui Zhang, Li Zeng, Jing Shang, and Jing Li

Design of Intelligent Test System for RPI in Nuclear Power Plant 400
Qian Wu, Na Sun, and Rui-Ping Zhang

Documentation Verification Based on Natural Language Processing for Safety-Critical Digital I&C System in NPP 411
Tao Bai, Xin-Sheng Yang, Ji Shi, and Hua-Qing Peng

Software Quality Evaluation of Non-safety Digital I&C System in NPPs 420
Wang-Ping Ye

Preliminary Study on Improving the Automation Level of Large Commercial Pressurized Water Reactor 429
Dong-Bao Lv, Ri-Gang Chen, and Xi-Yun Li

Research and Application of FPGA V&V Technology in NPP Safety I&C System 436
Sheng-Chao Wang, Wang-Ping Ye, and Tao Bai

Research of Software V&V Technology in the Non-safety DCS of NPPs 444
Sheng-Chao Wang, Wang-Ping Ye, Jian-Zhong Tang, and Tao Bai

Structural Design and Dynamic Analysis of Nuclear Safety DCS Cabinet with Light-Weight and Impact Resistance 452
Jun-An Dai, Ming-Xing Liu, Xiao Wu, Zhi Chen, Dong-Wei Wang, Fa-Qiang Li, and Chang-Wen Yao

Research and Application of the Verification and Validation Method Based on Embedded Technology in Nuclear Power Plants 463
Chao Zhang, Wang-Ping Ye, Sheng-Chao Wang, and Ji Shi

Research and Application of Time-PSF Calculation Method for HRA in Nuclear Power Plant 470
Qian Wu, Yi-Ming Liu, and Rui-Ping Zhang

Reliability Assessment Research and Application for PCBA Solderless Press-In Connection Technique in DCS Safety Class Devices in Nuclear Power Plants 483
Zhong-Qi Liang, Jian-Gang Li, Rui-Feng Zhang, and Lian-Chun Wang

Research on the Application of Human Factors Engineering in the Physical Protection System of Nuclear Facilities 490
Bi-Yao Wang, Hua-Ping Chen, Jian Liu, Ji-Wei Zhang, Shuang Li, Qian Zhang, and Zhen-Hua Luan

The Design and Implementation of an LSTM-Based Steam Generator Level Prediction Model 505
Jing-Ke She, Jia-Ni Wang, Su-Yuan Yang, and Shi-Yu Xue

Research on Defense-In-Depth Standards for Information Security in NPP I&C System 518
Zhi-Wu Guo, Lu Zhu, and Liang Zhou

The Analysis for Method of I&C Equipment Period Demonstrating in NPP Refueling Cycle Extension Project 527
Zhi-Wu Guo and Long-Qiang Zhang

Spurious Actuation of I&C Systems Analysis Methodology in Nuclear Power Plant 536
Zhen Yang, Hui Jiang, Ya-Jie Tian, Jia-Lin Ping, and Huan Huang

Analysis for Periodic Test Interval of Digital I&C System for NPP Based on PSA Technology 551
Sun Wei and Li-Ming Zhang

Research and Application of Nuclear Instrumentation System EMI Design in Nuclear Power Plant 563
Jing Li, Li-Ming Zhang, Tian-You Li, and Jing Shang

Research on the Design Improvement of Important Function Interface for Tripping and Load Rejection in Nuclear Power Plant 573
Shan-Shan Gu, Bin Zeng, Heng Li, Li-Ming Zhang, and Hua-Qing Peng

Closed-Loop Management Optimization of Technical Change in PWR Nuclear Power Plant 582
Min Long, Fang Li, and Li-Chuang Tian

Research on the Application of STPA Method in Reliability Analysis of Safety Spray Control in NPP 589
You-Ran Li

Study for Reliability Analysis of Operator Response Process Under IBLOCA Accident in Nuclear Power Plant 599
Zhi-Hui Xu, Jie-Mei Zhang, Xue-Gang Zhang, Ming Jia, De-Song Su, and Hua-Qing Peng

Failure Analysis and Optimization of Turbine Speed-Up Control for Nuclear Power Plant 610
Le-Yuan Bai, Xu-Feng Wang, Heng Li, and Bin Zeng

Research on Application of Humidity Instrument in Nuclear Power Plant Ventilation System 616
Lu Liu, Heng Li, Zhi-Yin Liu, and Zhou Xiao

Current Situation Analysis and Research of Computer-Based Procedure System for Nuclear Power Plant 623
Can Zhou, Yong-Quan Xie, and Zhi-Yao Liu

Study on the Design of HSI Color System in Nuclear Power Plant 633
Xiao-Mei Xu, Xing-Can Yang, De-Song Su, and Xue-Gang Zhang

Study for Human Reliability Analysis on Reactor Pit Injection for SA Mitigation in NPP 641
Jie-Mei Zhang, Zhi-Hui Xu, Xue-Gang Zhang, Ming Jia, and De-Song Su

Research and Application of Life Monitoring Scheme of Plant Computer Information and Control System 649
Jian-Wang Qiao, Bo Cheng, Jie Zou, Hua-Qing Peng, Li-Ming Zhang, Yi-Qian Wu, and Zhen-Hua Luan

Application Research on Intelligent Fault-Diagnosis of Nuclear Power Plant Equipment Based on Support Vector Machine 657
Kai Gu, Zhi-Hong Lv, Jian-Quan Xu, Zhang-yu, and Hua-Qing Peng

Safety and Reliability Analysis Based on the FMECA of the Fire Protection System of NPPs 665
Xu-Tao Bai, Dan-Dan Sun, Hua-Song Fang, and Xiao-Chen Zhang

Improvement in Test Methods and Structural Design for In-core Coolant Level Detector of HPR1000 674
Wei-Jie Huang, Peng Deng, Bao-Cheng Li, Zhi-Jun Li, and Liang Li

Discussion of Intelligent IP Camera Application in Nuclear Power Plant Video Monitoring System 681
Lei Li, Fei-Yang Sun, Zheng-Tao Chen, and Ya-Jie Tian

Research About Smart Power Plant for Chinese Heavy-Duty Gas Turbine Development and Application 688
Guo-Gang Shu, Peng-Fei Gu, Xue-Fei Zhai, Bao Heming, and Cao Ying

Intelligent Safety Monitoring System for Nuclear Power Plant Based on the Convolution Neural Network 696
Xu-Tao Bai, Dan-Dan Sun, Xiao-Chen Zhang, and Bao-Cheng Sun

Improvement and Research on the Level Measurement of High Low Pressure Heater and Deaerator in Nuclear Power Plant 706
Hai-Ying Fan, Hua-Qing Peng, Xin-Nian Huang, Heng Li, and Xiao-Feng Li

Qualification Test Research on Level Transmitter Equipment for Diesel Engine Lubricating Oil System 716
Jing-Yuan Yang, Gang Jin, Qi Wu, and Li-Qin Zhang

Study on the Load Following Control of SMR with Flexible Load 724
Ming-Ming Liu, Ao-Di Sun, Lei-Lei Qiu, Ru Zhang, and Xin-Yu Wei

The Verification for RRC System of Nuclear Power Plant Based on Digital Twins Technologies 738
Jia-Lin Ping, Li-Ming Zhang, Can Zhou, Chun-Bing Wang, and Chao Lu

Research on a Low-Latency Communication Module for the Reactor Protection System 746
Le Li, Zhi-Hui Zhang, Jian-Xin Ma, and Chao Gao

Research About Software Verification and Validation of Control and Protection System for Chinese Heavy-Duty Gas Turbine 757
Peng-Fei Gu, Zhe-Ming Liu, He-Ming Bao, Tao Bai, and Xue-Fei Zhai

Author Index 765