Lecture Notes in Networks and Systems 608

Sandeep Kumar · Harish Sharma · K. Balachandran · Joong Hoon Kim · Jagdish Chand Bansal *Editors*

Third Congress on Intelligent Systems

Proceedings of CIS 2022, Volume 1

Springer

Lecture Notes in Networks and Systems

Volume 608

The series “Lecture Notes in Networks and Systems” publishes the latest developments in Networks and Systems—quickly, informally and with high quality. Original research reported in proceedings and post-proceedings represents the core of LNNS.

Volumes published in LNNS embrace all aspects and subfields of, as well as new challenges in, Networks and Systems.

The series contains proceedings and edited volumes in systems and networks, spanning the areas of Cyber-Physical Systems, Autonomous Systems, Sensor Networks, Control Systems, Energy Systems, Automotive Systems, Biological Systems, Vehicular Networking and Connected Vehicles, Aerospace Systems, Automation, Manufacturing, Smart Grids, Nonlinear Systems, Power Systems, Robotics, Social Systems, Economic Systems and other. Of particular value to both the contributors and the readership are the short publication timeframe and the world-wide distribution and exposure which enable both a wide and rapid dissemination of research output.

The series covers the theory, applications, and perspectives on the state of the art and future developments relevant to systems and networks, decision making, control, complex processes and related areas, as embedded in the fields of interdisciplinary and applied sciences, engineering, computer science, physics, economics, social, and life sciences, as well as the paradigms and methodologies behind them.

Indexed by SCOPUS, INSPEC, WTI Frankfurt eG, zbMATH, SCImago.

All books published in the series are submitted for consideration in Web of Science.

For proposals from Asia please contact Aninda Bose (aninda.bose@springer.com).

Sandeep Kumar · Harish Sharma ·
K. Balachandran · Joong Hoon Kim ·
Jagdish Chand Bansal
Editors

Third Congress on Intelligent Systems

Proceedings of CIS 2022, Volume 1

Springer

Editors
Sandeep Kumar
Department of Computer Science
and Engineering
CHRIST (Deemed to be University)
Bengaluru, India

Harish Sharma
Department of Computer Science
and Engineering
Rajasthan Technical University
Kota, Rajasthan, India

K. Balachandran
Department of Computer Science
and Engineering
CHRIST (Deemed to be University)
Bengaluru, India

Joong Hoon Kim
School of Civil, Environmental
and Architectural Engineering
Korea University
Seoul, Korea (Republic of)

Jagdish Chand Bansal
South Asian University
New Delhi, India

ISSN 2367-3370 ISSN 2367-3389 (electronic)
Lecture Notes in Networks and Systems
ISBN 978-981-19-9224-7 ISBN 978-981-19-9225-4 (eBook)
https://doi.org/10.1007/978-981-19-9225-4

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

Preface

This book contains outstanding research papers as the proceedings of the 3rd Congress on Intelligent Systems (CIS 2022), held on September 05–06, 2022, at CHRIST (Deemed to be University), Bengaluru, India, under the technical sponsorship of the Soft Computing Research Society, India. The conference is conceived as a platform for disseminating and exchanging ideas, concepts, and results of researchers from academia and industry to develop a comprehensive understanding of the challenges of the advancements of intelligence in computational viewpoints. This book will help in strengthening congenial networking between academia and industry. We have tried our best to enrich the quality of the CIS 2022 through the stringent and careful peer-review process. This book presents novel contributions to Intelligent Systems and serves as reference material for advanced research.

We have tried our best to enrich the quality of the CIS 2022 through a stringent and careful peer-review process. CIS 2022 received many technical contributed articles from distinguished participants from home and abroad. CIS 2022 received 729 research submissions from 45 different countries, viz. Algeria, Australia, Bangladesh, Belgium, Brazil, Bulgaria, Colombia, Cote d'Ivoire, Czechia, Egypt, Ethiopia, Fiji, Finland, Germany, Greece, India, Indonesia, Iran, Iraq, Ireland, Italy, Japan, Kenya, Latvia, Malaysia, Mexico, Morocco, Nigeria, Oman, Peru, Philippines, Poland, Romania, Russia, Saudi Arabia, Serbia, Slovakia, South Africa, Spain, Turkmenistan, Ukraine, UK, USA, Uzbekistan, and Vietnam. After a very stringent peer-reviewing process, only 120 high-quality papers were finally accepted for presentation and the final proceedings.

This book presents first volume of 60 research papers data science and applications and serves as reference material for advanced research.

Bengaluru, India	Sandeep Kumar
Kota, India	Harish Sharma
Bengaluru, India	K. Balachandran
Seoul, South Korea	Joong Hoon Kim
New Delhi, India	Jagdish Chand Bansal

Contents

Editors and Contributors

About the Editors

Dr. Sandeep Kumar is currently a professor at CHRIST (Deemed to be University), Bangalore. Before joining CHRIST, he worked with ACEIT Jaipur, Jagannath University, Jaipur, and Amity University, Rajasthan. He is an associate editor for Springer's *Human-centric Computing and Information Sciences* (HCIS) journal. He has published more than eighty research papers in various international journals/conferences and attended several national and international conferences and workshops. He has authored/edited six books in the area of computer science. Also, he has been serving as the general chair of the International Conference on Communication and Computational Technologies (ICCCT 2021, 22, and 23) and the Congress on Intelligent Systems (CIS 2022). His research interests include nature-inspired algorithms, swarm intelligence, soft computing, and computational intelligence.

Dr. Harish Sharma is an associate professor at Rajasthan Technical University, Kota, in the Computer Science and Engineering Department. He has worked at Vardhaman Mahaveer Open University, Kota, and Government Engineering College, Jhalawar. He received his B.Tech. and M.Tech. degrees in Computer Engineering from Government Engineering College, Kota, and Rajasthan Technical University, Kota, in 2003 and 2009, respectively. He obtained his Ph.D. from ABV—Indian Institute of Information Technology and Management Gwalior, India. He is a secretary and one of the founder members of the Soft Computing Research Society of India. He is a lifetime member of the Cryptology Research Society of India, ISI, Kolkata. He is an associate editor of *The International Journal of Swarm Intelligence* (IJSI) published by Inderscience. He has also edited special issues of the many reputed journals like *Memetic Computing*, *Journal of Experimental and Theoretical Artificial Intelligence*, *Evolutionary Intelligence*, etc. His primary area of interest is nature-inspired optimization techniques. He has contributed to more than 105 papers published in various international journals and conferences.

Dr. K. Balachandran is currently a professor and the head of CSE at CHRIST (Deemed to be University), Bengaluru, India. He has 38 years of experience in research, academia, and industry. He served as a senior scientific officer in the Research and Development Unit of the Department of Atomic Energy for 20 years. His research interest includes data mining, artificial neural networks, soft computing, and artificial intelligence. He has published more than fifty articles in well-known SCI-/SCOPUS-indexed international journals and conferences and attended several national and international conferences and workshops. He has authored/edited four books in the area of computer science.

Professor Joong Hoon Kim is a faculty of Korea University in the School of Civil, Environmental and Architectural Engineering, obtained his Ph.D. from the University of Texas at Austin in 1992 with the thesis "Optimal replacement/rehabilitation model for water distribution systems." His major areas of interest include optimal design and management of water distribution systems, application of optimization techniques to various engineering problems, and development and application of evolutionary algorithms. His publication includes "A New Heuristic Optimization Algorithm: Harmony Search," Simulation, February 2001, Vol. 76, pp 60–68, which has been cited over 6700 times by other journals of diverse research areas. His keynote speeches include "Optimization Algorithms as Tools for Hydrological Science" in the Annual Meeting of Asia Oceania Geosciences Society held in Brisbane, Australia, in June of 2013, "Recent Advances in Harmony Search Algorithm" in the 4th Global Congress on Intelligent Systems (GCIS 2013) held in Hong Kong, China, in December of 2013, and "Improving the convergence of Harmony Search Algorithm and its variants" in the 4th International Conference on Soft Computing For Problem Solving (SOCPROS 2014) held in Silchar, India, in December of 2014. He hosted the first, second, and sixth Conference of International Conference on Harmony Search Algorithm (ICHSA) in 2013, 2014, and 2022. He also hosted the 12th International Conference on Hydroinformatics (HIC 2016). Also, he has been serving as an honorary chair of Congress on Intelligent Systems (CIS 2020, 2021, and 2022).

Dr. Jagdish Chand Bansal is an associate professor at South Asian University, New Delhi, and a visiting faculty at Maths and Computer Science, Liverpool Hope University, UK. He obtained his Ph.D. in Mathematics from IIT Roorkee. Before joining SAU, New Delhi, he worked as an assistant professor at ABV—Indian Institute of Information Technology and Management Gwalior and BITS Pilani. His primary area of interest is swarm intelligence and nature-inspired optimization techniques. Recently, he proposed a fission-fusion social structure-based optimization algorithm, spider monkey optimization (SMO), which is being applied to various problems from the engineering domain. He has published more than 70 research papers in various international journals/conferences. He is the editor-in-chief of the journal MethodsX published by Elsevier. He is the series editor of the book series Algorithms for Intelligent Systems (AIS) and Studies in Autonomic, Data-driven, and Industrial Computing (SADIC), published by Springer. He is the editor-in-chief of the *International Journal of Swarm Intelligence* (IJSI) published by Inderscience. He is also the associate editor of *Engineering Applications of Artificial Intelligence* (EAAI) and *ARRAY*, published by Elsevier. He is the general secretary of the Soft Computing Research Society (SCRS). He has also received gold medals at UG and PG levels.

Contributors

Shaik Janubhai Mahammad Abubakar School of Electronics Engineering, Vellore Institute of Technology, Vellore, India

Kadum Ali Ahmed University of Kerbala, Karbala, Iraq

B. Aishwarya SRM Institute of Science and Technology, Kattankulathur, Chennai, Tamil Nadu, India

Naseer Al-Imareen Széchenyi István University, Győr, Hungary;
Al-Qadisiyah University, AL Diwaniyah, Iraq

Ibrahim Alameri Faculty of Economics and Administration, University of Pardubice, Pardubice, Czech Republic;
Nottingham Trent University, Nottingham, UK;
Jabir Ibn Hayyan Medical University, Najaf, Iraq

Wael A. E. Ali Electronics and Communications Engineering Department, Arab Academy for Science, Technology and Maritime Transport, Alex, Egypt

Bradly Alicea Orthogonal Research and Education Laboratory, Champaign-Urbana, IL, USA;
OpenWorm Foundation, Boston, MA, USA

Harishchander Anandaram Amrita Vishwa Vidyapeetham, Coimbatore, Tamil Nadu, India

Sujatha Arun Kokatnoor Department of Computer Science and Engineering, School of Engineering and Technology, CHRIST (Deemed to be University), Bangalore, Karnataka, India

Armand Kodjo Atiampo Unité de Recherche et d'Expertise du Numérique (UREN), Université Virtuelle de Côte d'Ivoire (UVCI), Abidjan, Côte d'Ivoire

Sumit Babu Harcourt Butler Technical University, Kanpur, India

Sakshi Bajpai Computer Science and Engineering Department, Chandigarh University, Mohali, Punjab, India

Krishnan Balachandran Department of Computer Science and Engineering, Christ (Deemed to be University), Bengaluru, India

Richa Bansal Electronics and Communication Engineering Department, Chandigarh University, Mohali, Punjab, India

Prachi Bhagat Prof. Department of Electronics Engineering, Government College of Engineering, Yavatmal, India

Praveen Bhagavatula G. H. Raisoni College of Engineering, Nagpur, India

Anjali. S. Bhalchandra Department of Electronics Engineering, Government College of Engineering, Aurangabad, India

Dhaval Bhoi U & P U. Patel Department of Computer Engineering, Faculty of Technology and Engineering (FTE), Chandubhai S. Patel Institute of Technology (CSPIT), Charotar University of Science and Technology (CHARUSAT), Anand, Gujarat, India

R. Bhuvaneshwari Department of Computer Science and Engineering, College of Engineering, Guindy, Anna University, Chennai, India

Abiot Sinamo Boltena Ministry of Innovation and Technology, Addis Ababa, Ethiopia

Kristína Boratková Slovak University of Technology in Bratislava, Bratislava, Slovakia

Maamar Bougherara LIMPAF Laboratory, Bouira University, Bouira, Algeria;
Department of Computer Science, High Normale School of Kouba, Algiers, Algeria

Seyed M. Buhari School of Computer Science and Engineering, Vellore Institute of Technology, Chennai, TamilNadu, India

Bandi Kanti Chaitanya B.V Raju Institute of Technology, Tuljaraopet, Telangana, India

Prasun Chakrabarti Lincoln University College, Petaling Jaya, Malaysia;
ITM SLS Baroda University, Vadodara, India

Tulika Chakrabarti Sir Padampat Singhania University, Udaipur, Rajasthan, India

Bharathi Raja Chakravarthi Insight SFI Research Centre for Data Analytics, Data Science Institute, National University of Irelan, Galway, Ireland

Nenavath Chander Department of Computer Science and Engineering, Osmania University, Hyderabad, Telangana, India

V. S. Ajay Chandrasekar Department of Surgical Oncology, Saveetha Medical College, Thandalam, Tamil Nadu, India

Chandravesh Chaudhari Department of Commerce, CHRIST (Deemed to be University), Bangalore, Karnataka, India

Paresh Chaudhari G. H. Raisoni College of Engineering, Nagpur, India

Chitransh Chaudhary Computer Science and Engineering Department, Chandigarh University, Mohali, Punjab, India

Thomas Chen School of Science and Technology, Department of Engineering, University of London, Northampton Square London, UK

Ravindranath C. Cherukuri CHRIST (Deemed to be University), Bangalore, Karnataka, India

K. Chinmayee School of Electronics Engineering, Vellore Institute of Technology, Vellore, India

Himanshu Choudhary Indian Institute of Technology, Mandi, India

Franco Cicirelli CNR—National Research Council of Italy—Institute for High Performance Computing and Networking (ICAR), Rende, Italy

Juan C. Correa Colegio de Estudios Superiores de Administracion, Bogota, Colombia

Hanna Danylchuk Cherkasy Bohdan Khmelnytsky National University, Cherkasy, Ukraine

Suman Deswal Department of Computer Science and Engineering, DCRUST, Murthal, Sonipat, India

G. Devadasu CMR College of Engineering and Technology (Autonomous), Hyderabad, India

Sapna Dewari Department of Computer Science and Engineering, Chandigarh University, Mohali, Punjab, India

Vipul Dhamde G. H. Raisoni College of Engineering, Nagpur, India

Messaoudi Djihad Department of Computer Science, High Normale School of Kouba, Algiers, Algeria

Denny Dominic Department of Computer Science and Engineering, Christ (Deemed to be University), Bengaluru, India

Eugene Fedorov Cherkasy State Technological University, Cherkasy, Ukraine

R. Gandhiraj Department of Electronics and Communication Engineering, Amrita School of Engineering, Amrita Vishwa Vidyapeetham, Coimbatore, India

N. K. Geetha Department of Mathematics, Dayananda Sagar College of Engineering, Bangalore, Karnataka, India

Michael Brian George University of South Africa (Unisa), Roodepoort, South Africa

Debasish Ghose Indian Institute of Science, Bengaluru, India

Mesay Samuel Gondere Faculty of Computing and Software Engineering, Arba Minch University, Arba Minch, Ethiopia

Ankit Grover Orthogonal Research and Education Laboratory, Champaign-Urbana, IL, USA;
Manipal University Jaipur, Jaipur, Rajasthan, India

Meenu Gupta Department of Computer Science and Engineering, Chandigarh University, Mohali, Punjab, India

Prashant Gupta Prin. L. N. Welingkar Institute of Management Development and Research (WeSchool), Mumbai, India

Radha Gupta Department of Mathematics, Dayananda Sagar College of Engineering, Bangalore, Karnataka, India

Suneet Gupta CSE Department, Mody University Laxmangarh, Sikar, India

H. S. Gururaja Department of ISE, B.M.S. College of Engineering, Bengaluru, India

Deivanai Gurusamy Lincoln University College, Petaling Jaya, Malaysia

Asha Hegde Department of Computer Science, Mangalore University, Mangalore, Karnataka, India

J. Hemadharshini School of Computer Science and Engineering, Vellore Institute of Technology, Chennai, TamilNadu, India

Diksha Hooda CSED, Thapar Institute of Engineering and Technology, Patiala, India

Grant Royd Howard University of South Africa (Unisa), Roodepoort, South Africa

CH Hussaian Basha Nitte Meenakshi Institute of Technology, Karnataka, India

M. Indrasena Reddy BVRIT HYDERABAD College of Engineering for Women, Bachupally, Hyderabad, India

Nour Ismail Electrical Engineering Department, Alexandria University, Alex, Egypt

Bhat Geetalaxmi Jairam Department of Information Science and Engineering, The National Institute of Engineering, Mysore, India

Varaprasad Janamala Department of Electrical and Electronics Engineering, School of Engineering and Technology, Christ (Deemed to be University), Bengaluru, Karnataka, India

Xue-bo Jin School of Artificial Intelligence, Beijing Technology and Business University, Beijing, China

Garima Joshi Panjab University, Chandigarh, India

Kapil Joshi Uttaranchal Institute of Technology, Uttaranchal University, Dehradun, India

A. Kambire Department of EE, Nanasaheb Mahadik College of Engineering, Peth, India

Divneet Singh Kapoor Electronics and Communication Engineering Department, Chandigarh University, Mohali, Punjab, India

Hrutuja Kargirwar G. H. Raisoni College of Engineering, Nagpur, India

M. S. Karthika Devi Department of Computer Science and Engineering, College of Engineering, Guindy, Anna University, Chennai, India

Jaspreet Kaur Chandigarh University, Mohali, Punjab, India

Satwinder Kaur Panjab University, Chandigarh, India

Sukhpreet Kaur MIT Art, Design and Technology University, Pune, India

Sandeep Kelkar Prin. L. N. Welingkar Institute of Management Development and Research (WeSchool), Mumbai, India

Liubov Kibalnyk Cherkasy Bohdan Khmelnytsky National University, Cherkasy, Ukraine

H. B. Kolekar Department of EE, Nanasaheb Mahadik College of Engineering, Peth, India

Karuppanan Komathy Academy of Maritime Education and Training, Chennai, India

Shrutika Konde G. H. Raisoni College of Engineering, Nagpur, India

Konda Hari Krishna Koneru Lakshmaiah Education Foundation, Vaddeswaram, AP, India

Balachandran Krishnan Department of Computer Science and Engineering, School of Engineering and Technology, CHRIST (Deemed to be University), Bangalore, Karnataka, India

Keerthana Krishnan Department of Electronics and Communication Engineering, Amrita School of Engineering, Amrita Vishwa Vidyapeetham, Coimbatore, India

Jayant Kulkarni Department of Instrumentation Engineering, Vishwakarma Institute of Technology, Pune, India

Nilima Kulkarni MIT Art, Design and Technology University, Pune, India

Golla Naresh Kumar B.V Raju Institute of Technology, Tuljaraopet, Telangana, India;
Lovely Professional University, Phagwara, Punjab, India

Raj Kumar Computer Science and Engineering Department, Chandigarh University, Mohali, Punjab, India

Rajesh Kumar Meerut Institute of Technology, Meerut, India

Rakesh Kumar Department of Computer Science and Engineering, Chandigarh University, Mohali, Punjab, India

S. N. Kumar Department of EEE, Amal Jyothi College of Engineering, Kottayam, Kerala, India

Niranjali Kumari Panjab University, Chandigarh, India

Pappu Soundarya Lahari Department of Electrical and Electronics Engineering, School of Engineering and Technology, Christ (Deemed to be University), Bangalore, Karnataka, India

M. Lakshmi Vaishnavi School of Electronics Engineering, Vellore Institute of Technology, Vellore, India

Naveen Kumar Laskari BVRIT HYDERABAD College of Engineering for Women, Bachupally, Hyderabad, India

Maryna Leshchenko Cherkasy State Technological University, Cherkasy, Ukraine

Anand Kumar Madasamy National Institute of Technology Karnataka, Suratkal, Karnataka, India

M. Madhusudhan Reddy K.S.R.M College of Engineering, Kadapa, Andhra Pradesh, India

Rania Mahmoud Electronics and Communications Engineering Department, Alexandria Higher Institute of Engineering and Technology, Alex, Egypt

Abhijit Maji B.V Raju Institute of Technology, Tuljaraopet, Telangana, India

Janvi Malhotra Computer Science and Engineering Department, Chandigarh University, Mohali, Punjab, India

Sweta Manna Department of Computer Science and Engineering, Maulana Abul Kalam Azad University of Technology, Haringhata, WB, India

M. Manohar Department of Computer Science and Engineering, School of Engineering and Technology, Christ (Deemed to be University), Bangalore, Karnataka, India

Denis Manolescu Robotics Lab, School of Mathematics, Computer Science and Engineering, Liverpool Hope University, Liverpool, UK

Muneer S. G. Mansoor College of Engineering, University of Information Technology and Communications (UOITC), Baghdad, Iraq

Bijith Marakarkandy Prin. L. N. Welingkar Institute of Management Development and Research (WeSchool), Mumbai, India

Riya Mehta Computer Science and Engineering Department, Chandigarh University, Mohali, Punjab, India

Midhunchakkaravarthy Lincoln University College, Petaling Jaya, Malaysia

Sujoy Mistry Department of Computer Science and Engineering, Maulana Abul Kalam Azad University of Technology, Haringhata, WB, India

Teena Mittal Chitkara University Institute of Engineering and Technology, Chitkara University, Rajpura, Punjab, India

Aniruddha Mohanty CHRIST (Deemed to be University), Bangalore, Karnataka, India

Kapil Mundada Department of Instrumentation Engineering, Vishwakarma Institute of Technology, Pune, India

Kiran Mungekar ThinkGestalt.Tech, Mumbai, India

Prithvi K. Murjani School of Electronics Engineering, Vellore Institute of Technology, Vellore, Tamil Nadu, India

S. Naikawadi Department of EE, Nanasaheb Mahadik College of Engineering, Peth, India

P. Nandini Department of Computer Science and Engineering, The National Institute of Engineering, Mysore, India

M. Narule Department of EE, Nanasaheb Mahadik College of Engineering, Peth, India

Olga Nechyporenko Cherkasy State Technological University, Cherkasy, Ukraine

Libero Nigro University of Calabria, DIMES, Rende, Italy

Kouassi Adelphe Christian N'Goran Laboratoire de Recherche en Informatique et Télécommunication (LARIT), INPHB, Abidjan, Côte d'Ivoire

Arishi Orra Indian Institute of Technology, Mandi, India

Ashok Pal Chandigarh University, Mohali, Punjab, India

Manoj Kumar Panda Department of Electronics and Communication Engineering, Amrita School of Engineering, Amrita Vishwa Vidyapeetham, Bengaluru, India

Thandava Krishna Sai Pandraju Department of Electrical and Electronics Engineering, Dhanekula Institute of Engineering and Technology, Vijayawada, Andhra Pradesh, India

Ritesh Patel U & P U. Patel Department of Computer Engineering, Faculty of Technology and Engineering (FTE), Chandubhai S. Patel Institute of Technology (CSPIT), Charotar University of Science and Technology (CHARUSAT), Anand, Gujarat, India

Kaustubh Pathak ABV—Indian Institute of Information Technology and Management, Gwalior, India

Manoj A. Patil Department of Computer Science and Engineering, School of Engineering and Technology, Christ (Deemed to be University), Bangalore, Karnataka, India;
Department of Information Technology, Vasavi College of Engineering, Hyderabad, Telangana, India

Manav Prabhakar Indian Institute of Science, Bengaluru, India

R. Pranav Department of EEE, B.M.S. College of Engineering, Bengaluru, India

K. P. Sabari Priya School of Computer Science and Engineering, Vellore Institute of Technology, Chennai, TamilNadu, India

Alok Ranjan Prusty DGT, RDSDE, NSTI(W), Kolkata, West Bengal, India

Geetanjali Purswani Department of Commerce, CHRIST (Deemed to be University), Bangalore, Karnataka, India

Shaik. Rafikiran Sri Venkateswara College of Engineering (Autonomous), Tirupati, India

Toufiq Rahatwilkar Department of Instrumentation Engineering, Vishwakarma Institute of Technology, Pune, India

Ranjitha Rajan Lincoln University College, Kota Bharu, Malaysia

Sujatha Rajkumar School of Electronics Engineering, Vellore Institute of Technology, Vellore, Tamil Nadu, India

R. Ramasamy Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Avadi, Tamil Nadu, India

Kokila Ramesh Department of Mathematics, FET, Jain (Deemed-to-be-University), Bangalore, Karnataka, India

Rinkle Rani CSED, Thapar Institute of Engineering and Technology, Patiala, India

Neha Rastogi Uttaranchal Institute of Management, Uttaranchal University, Dehradun, India

Chowtakuri Jagath Vardhan Reddy B.V Raju Institute of Technology, Tuljaraopet, Telangana, India

K. Adi Narayana Reddy BVRIT HYDERABAD College of Engineering for Women, Bachupally, Hyderabad, India

Mure Vamsi Kalyan Reddy School of Electronics Engineering, Vellore Institute of Technology, Vellore, Tamil Nadu, India

Vandana Reddy Department of Computer Science and Engineering, School of Engineering and Technology, CHRIST (Deemed to be University), Bangalore, Karnataka, India

Kartik Sahoo Indian Institute of Technology, Mandi, India

Gopal Sakarkar D. Y. Patil Institute of Master of Computer Applications and Management, Pune, India

T. M. Sanjeevaditya Department of Computer Science and Engineering, College of Engineering, Guindy, Anna University, Chennai, India

Meenakshi Sarkar Indian Institute of Science, Bengaluru, India

Tarun Saroch Computer Science and Engineering Department, Chandigarh University, Mohali, Punjab, India

E. Sarvesh Department of Computer Science and Engineering, College of Engineering, Guindy, Anna University, Chennai, India

Lars Schmidt-Thieme Information Systems and Machine Learning Lab, Hildesheim, Germany

Emanuele Lindo Secco Robotics Lab, School of Mathematics, Computer Science and Engineering, Liverpool Hope University, Liverpool, UK

Anshul Sharma Electronics and Communication Engineering Department, Chandigarh University, Mohali, Punjab, India

Durga Prasad Sharma AMUIT MOEFDRE under UNDP and MAISM under RTU, Kota, India

Hosahalli Lakshmaiah Shashirekha Department of Computer Science, Mangalore University, Mangalore, Karnataka, India

Sarita Silaich Department of Computer Science and Engineering, Government Polytechnic College Jhunjhunu, Jhunjhunu, India

Ajay Singh UCALS, Uttaranchal University, Dehradun, India

Anuraj Singh ABV—Indian Institute of Information Technology and Management, Gwalior, India

Divya Singh Department of Computer Science and Engineering, Chandigarh University, Mohali, Punjab, India

Kiran Jot Singh Electronics and Communication Engineering Department, Chandigarh University, Mohali, Punjab, India

Raghuraj Singh Harcourt Butler Technical University, Kanpur, India

Utkarsh Singh Computer Science and Engineering Department, Chandigarh University, Mohali, Punjab, India

Neeraj Sirawag Computer Science and Engineering Department, Chandigarh University, Mohali, Punjab, India

S. Sona School of Computer Science and Engineering, Vellore Institute of Technology, Chennai, TamilNadu, India

Sonal Department of Computer Science and Engineering, DCRUST, Murthal, Sonipat, India

B. Srinivasa Varma Department of EE, Nanasaheb Mahadik College of Engineering, Peth, India

Suresh Kumar Sudabattula Lovely Professional University, Phagwara, Punjab, India

R. Suganya School of Computer Science and Engineering, Vellore Institute of Technology, Chennai, TamilNadu, India

Suman Department of Computer Science and Engineering, UIET, MDU, Rohtak, Haryana, India

Amit Thakkar Department of Computer Science and Engineering, Faculty of Technology and Engineering (FTE), Chandubhai S. Patel Institute of Technology (CSPIT), Charotar University of Science and Technology (CHARUSAT), Anand, Gujarat, India

Khushal Thakur Electronics and Communication Engineering Department, Chandigarh University, Mohali, Punjab, India

Zacrada Françoise Odile Trey Laboratoire de Recherche en Informatique et Télécommunication (LARIT), INPHB, Abidjan, Côte d'Ivoire

M. Upendra Kumar Department of Computer Science and Engineering, Muffakham Jah College of Engineering and Technology, Affiliated to OU, Hyderabad, Telangana, India

M. Vasim Babu KPR Institute of Engineering and Technology, Arasur, Coimbatore, Tamil Nadu, India

Renu Vig Panjab University, Chandigarh, India

C. N. S. Vinoth Kumar SRM Institute of Science and Technology, Kattankulathur, Chennai, Tamil Nadu, India

R. Vishal Department of Computer Science and Engineering, College of Engineering, Guindy, Anna University, Chennai, India

Venkata Nitin Voona School of Electronics Engineering, Vellore Institute of Technology, Vellore, India

C. Xavier Department of Computer Science and Engineering, Christ (Deemed to be University), Bengaluru, India

Vaishali Yadav Manipal University Jaipur, Jaipur, Rajasthan, India

B. Yamuna Department of Mathematics, Dayananda Sagar College of Engineering, Bangalore, Karnataka, India

Mária Ždímalová Slovak University of Technology in Bratislava, Bratislava, Slovakia

Design and Analysis of Genetic Algorithm Optimization-Based ANFIS Controller for Interleaved DC-DC Converter-Fed PEMFC System

CH Hussaian Basha, Shaik. Rafikiran, M. Narule, G. Devadasu, B. Srinivasa Varma, S. Naikawadi, A. Kambire, and H. B. Kolekar

Abstract The Maximum Power Point Tracking (MPPT) controllers are used for enhancing the working performance of proton exchange membrane fuel cell (PEMFC)-related power generation systems. In this article, a genetic optimization-based Artificial Neuro-Fuzzy Inference System (ANFIS) concept is applied to the interleaved non-isolated boost converter-interfaced fuel cell stack system in order to improve the operating efficiency of a transformerless DC-DC converter. The proposed MPPT controller is compared with the other conventional adaptive Perturb & Observe controller in terms of settling time of peak power point, oscillations related to fuel cell output voltage, and tracing time period of MPPT controller. The second objective of this work is design of an interleaved DC-DC converter for improving the output voltage profile of the fuel block. The characteristics of this converter are wide output operation, less potential stress, and more voltage gain.

Keywords Duty ratio · Genetic algorithm · High MPP tracking speed · Interleaved DC-DC converter · Low oscillations of MPP

1 Introduction

Nowadays, most of the global industries as well as human beings are focusing on automotive systems because of its fast growth, low maintenance cost, less dependence on fossil fuels, and high profits [1]. In addition, the availability of fossil fuels is

CH Hussaian Basha (✉)
Nitte Meenakshi Institute of Technology, Karnataka 560064, India
e-mail: sbasha238@gmail.com

Shaik. Rafikiran
Sri Venkateswara College of Engineering (Autonomous), Tirupati, India

M. Narule · B. Srinivasa Varma · S. Naikawadi · A. Kambire · H. B. Kolekar
Department of EE, Nanasaheb Mahadik College of Engineering, Peth, India
e-mail: principal@nmcoe.org.in

G. Devadasu
CMR College of Engineering and Technology (Autonomous), Hyderabad, India

S. Kumar et al. (eds.), *Third Congress on Intelligent Systems*, Lecture Notes in Networks and Systems 608, https://doi.org/10.1007/978-981-19-9225-4_1

reducing slowly. Hence, the power generation cost of fossil fuel-dependent systems is very high. From the literature review, the conventional or nonrenewable power production systems are illustrated as thermal, nuclear, oil, and natural gasses [2]. The disadvantage of conventional energy systems is global warming [3]. All over the world, coal is the very inexpensive and efficient way to produce electricity. The features of thermal power plants are cheap in coal use and require less space for installing [4]. The demerits of coal power production systems are that it requires high cost for starting the boilers and is difficult in an ash handling plant [5]. However, the demerits of coal systems are limited by using the oil power stations. The merits of oil power generation systems are high energy density, encourage the economy of the world, and are moderately reliable [6]. But, the drawbacks of oil power systems are high air pollution and ozone depletion.

In article [7], nuclear power systems are utilized for converting explosion radius energy into useful active power. The merits of nuclear power plants are low carbon energy source, less carbon footprints, less cost in operation, and high energy density [8]. The disadvantages of nuclear power production systems are high initial cost and high impact on human life [9]. There are many disadvantages due to the conventional energy systems which are limited by using the nonconventional energy systems. The nonconventional energy systems are illustrated as solar, wind, tidal, and fuel stack. The features of wind power generation systems are cost-effective, clean energy, less working cost, and efficient utilization of land space and create more economy for human lives [10]. The drawbacks of wind energy systems are unpredictable, continuous interruptible power supply, less flexible, and high impact on wildlife [11]. Solar is a natural source which is available freely in nature. The working nature of solar is similar to the normal *P–N* junction diode [12]. The features of solar PV are less maintenance cost and environmental free source of energy. The only disadvantage is less continuity in supply. So, in this article, a PEMFC is used for automotive systems in order to run the vehicle without any distortions [13]. The fuel stack demands every year are mentioned in Fig. 1.

The major consideration of fuel cells is nonlinear behavior which is solved by using the maximum power point finding controller. At various temperature conditions, the fuel cell gives various peak power points on the I-V curve. In article [14],

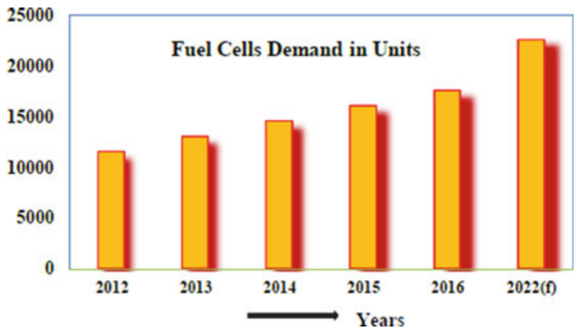

Fig. 1 Yearly fuel stack production strategy in terms of units

a P&O controller is utilized for continuous tracing of MPP. Here, the perturbation of power has been done and it is equated with the previously stored data. The equated results give the positive signal, and then the perturbation moves in identical direction or else the variation moves in inverse direction. The disadvantages of the P&O method are more oscillations in fuel cell output voltage, requiring more sensors to sense the fuel stack output variables [15]. Due to this situation, an incremental conductance methodology is used in article [16] for fast improving the entire hybrid system performance. This incremental conductance concept gives less power oscillations and high MPP tracing speed when equated with the other conventional controller. The only drawback is more implementation cost. However, the disadvantages of above-explained MPPT techniques are compensated by using an adaptive variable step size P&O controller [17]. In this adaptive controller, at first, an extreme step value is utilized for making the fast convergence speed of fuel cell MPP. After that, the power point finding controller step length is optimized to determine the accurate position of MPP. But, this MPPT method is most suitable for the uniform working temperature of the fuel stack. At the dynamic working temperature of a fuel cell, an ANFIS is used for optimizing the overall system size.

2 Operation of Fuel Cell Power System

At present, there are different types of fuel stack modules offered in the market. The major types of fuel cell modules are alkaline fuel module, direct methanol fuel module, PEMFC, and solid oxide-based fuel module [18, 19]. In article [20], the authors used the phosphoric acid-based fuel cell module for running the battery-related electric vehicle system. The most attractive features of this fuel cell are available in commercial, high lifetime, and low market cost when compared to the other fuel cell topologies. The molten carbonate fuel cell is used in article [21] for enhancing the efficiency of internal fuel processing. This type of fuel cell works at high temperature conditions. The molten carbonate fuel cell stack has the instability in electrolyte and produces high carbon dioxide content. So, in this work, PEMFC is considered for electric vehicle application. The features of PEMFC are high lifetime period, low power losses, and most adoptable by automotive systems. The operation of the selected fuel cell is explained by using Fig. 2. From Fig. 2, the hydrogen chemical and water membrane are converted to electricity by utilizing the redox chemical reaction. Here, each fuel module provides uninterrupted energy until supplying the hydrogen input. Whereas in batteries, the fuel is available by inbuilt and the working of batteries is completely dependent on the oxidant material's chemical reaction. The applications of fuel cell technology are residential, commercial, and industry-related systems. The fuel cell design constants and its power curves are shown in Table 1 and Fig. 3. Based on Fig. 2, the chemical oxidation of fuel cell is obtained as,

$$H_2 \rightarrow 2H^+ + 2e^- \tag{1}$$

$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O + \text{Energy} \tag{2}$$

$$2H^+ + 2e^- + \frac{1}{2}O_2 \rightarrow H_2O \tag{3}$$

$$V_0 = N * V_{FC} \tag{4}$$

$$V_{Oh} = E_{Ot} - V_{FC} - V_{Ac} - V_{Co} \tag{5}$$

$$V_{FC} = E_{Ot} - V_{Oh} - V_{Ac} - V_{Co} \tag{6}$$

As related to Eq. (1), it is clearly determined that the input supply of a fuel cell is hydrogen and this hydrogen is converted into hydrogen ions along with the electrons. The separated electrons flow to the external circuit in order to generate the light energy. After that, the hydrogen ions are transferred from the gas diffusion layer to the cathode. In the cathode layer, the oxygen is combined with the input fuel for delivering the water. Here, each and every fuel cell gives very less power

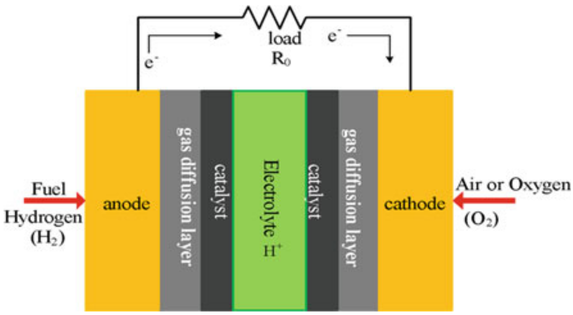

Fig. 2 Working strategy of proton exchange membrane fuel cell system

Table 1 Complete design parameters of fuel module at various working temperatures

Variables	Specifications
Peak working current of stack (I_{MPP})	52A
Peak working voltage of PEM fuel cell (V_{MPP})	24.0 V
Utilized open circuit potential of PEMFC (V_{OC})	42.00 V
Maximum generated power of PEMFC	1260 W
Pressure of oxygen on PEMFC	1.00 bar
Flow rate of air in fuel stack (I_{npm})	$2.4*10^3$
Hydrogen-related partial pressure on fuel stack	1.5 bar
Basic air utilizing quantity in PEMFC (I_{pm})	$4.615*10^3$
Total cells utilized (n)	42.00

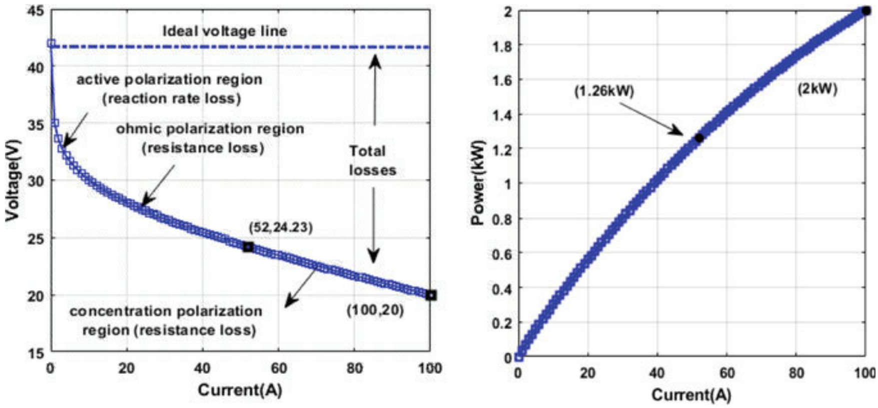

Fig. 3 PEM fuel cell output, **a** voltage versus current characteristics, plus, **b** power versus current characteristics

which is not useful for industry application. So, there are multiple types of fuel cells that are interconnected for improving the power supply capability of fuel-dependent electric vehicle systems. The total selected fuel cells for forming a module are given in Eq. (4). In Eq. (4), the variable '*N*' gives the entire amount of cells in the fuel stack, and V_0 is total cell output voltage. Similarly, the variable V_{FC} is defined as one fuel cell potential which is obtained by using Eq. (5). The detailed working considerations of the fuel system are shown in Table 1. The ohmic polarization loss, active, and concentrated ohmic polarization losses are defined as V_{Oh}, V_{Ac}, and V_{Co}, respectively.

3 Analysis of Transformerless Interleaved DC-DC Converter

From the previous published articles, the power converters are illustrated as isolated with transformer, and non-isolated power converters. The isolated converters require an extra rectifier circuit for protecting the semiconductor switches from high input power supply. In article [22], the authors used the isolated based zero voltage switching-related power converter for hybrid fuel cell grid-connected systems in order to make the constant grid voltage. The features of this topology are high voltage gain, more flexible, less manufacturing cost, and wide output operation. But, it gives more power conduction losses. So, to compensate for the disadvantages of conventional power converters, in this article, an interleaved methodology is used for designing the transformerless boost converter.