

2025 IEEE 70th Holm Conference on Electrical Contacts (HLM 2025)

**San Antonio, Texas, USA
15-22 October 2025**



**IEEE Catalog Number: CFP25HLM-POD
ISBN: 979-8-3315-5997-7**

**Copyright © 2025 by the Institute of Electrical and Electronics Engineers, Inc.
All Rights Reserved**

Copyright and Reprint Permissions: Abstracting is permitted with credit to the source. Libraries are permitted to photocopy beyond the limit of U.S. copyright law for private use of patrons those articles in this volume that carry a code at the bottom of the first page, provided the per-copy fee indicated in the code is paid through Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923.

For other copying, reprint or republication permission, write to IEEE Copyrights Manager, IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08854. All rights reserved.

****** This is a print representation of what appears in the IEEE Digital Library. Some format issues inherent in the e-media version may also appear in this print version.***

IEEE Catalog Number:	CFP25HLM-POD
ISBN (Print-On-Demand):	979-8-3315-5997-7
ISBN (Online):	979-8-3315-5996-0
ISSN:	1062-6808

Additional Copies of This Publication Are Available From:

Curran Associates, Inc
57 Morehouse Lane
Red Hook, NY 12571 USA
Phone: (845) 758-0400
Fax: (845) 758-2633
E-mail: curran@proceedings.com
Web: www.proceedings.com

CURRAN ASSOCIATES INC.
proceedings
.com

Holm Conference 2025 – TABLE OF CONTENTS

Foreword	iii
Conference Officers and Committees	iv
Conference Sponsors and Supporters	vi
Morton Antler Lecture	viii
Erle Shobert Prize Paper Award	x
Ragner Holm Scientific Achievement Award.....	xiii
Armington Recognition Award	xv
Young Investigator Award	xvi
Call for Papers: Holm 2026	xviii

YOUNG INVESTIGATOR PRESENTATIONS

Chair: Pat Lees; Co-Chair: Marcel Mainka

1.1 Whispers of Wear: How Audio Analysis Reveals the Approaching Contact Failure	1
Julian Angel Czajor, Toni Israel and Tom Kufner, Staubli Electrical Connectors AG	
1.2 Application Research on New Composite Materials in High-Power Sealed Relay Contacts	9
Xiufang Zhang, Xiaofang Yan, Xiaoping Bai, Jiayang Fei, Dai Wan and Zhong Huang, Fuda Alloy Materials Co., Ltd.	
1.3 Investigating Electrical Connector Failures in Photovoltaic Power Systems	15
Steven DiGregorio, Laurie Burnham and Bruce H. King, Sandia National Laboratories	
1.4 Clinching - Creating an Electrical Model	20
Max Mathias Huter, Christian Hildmann, Stephan Schlegel and Maria Kosse, TU Dresden	
1.5 Evaluation of Press-Fit-Zone Performance Across PCB Surface Finishes Such As ENIG, Immersion Tin, Immersion Silver, and OSP	28
Akshata Ankush Sangle ¹ , Stefan Goetz ¹ and Florian Bruhn ² , ¹ RPTU Kaiserslautern-Landau, ² iwis smart connect GmbH	

CIRCUIT BREAKERS

Chair: Karumbu Meyyappan; Co-Chair: Roland Timsit

2.1 X-ray Radiation in High-Voltage Vacuum Interrupter and Its Impact on Ceramic Surface Charge Distribution	34
Wei Sun, Huantong Shi, Jian Wu, Xingwen Li, Xi'an Jiaotong University	
2.2 Statistical Analysis to Predict the Maximum Number of Operations in Electrical Endurance Tests of Low Voltage Circuit Breakers	41
Pierantonio Arrighetti, Andrea Balestero and Fabio Dell'Agnola, ABB S.p.A.	

2.3 Development of a Hydropneumatic Actuator for Supercritical Fluid Circuit Breakers	47
Zhiyang Jin, Alfonso Cruz, Samuel M. Neall, Yang Liu, Mohd. Sadeed Al Hossain, Mahitha Pothuri, Chanyeop Park, Lukas Graber, Georgia Institute of Technology	
2.4 A Contactor Design for the Commutation Path in Fuse-Current-Limiting Hybrid DC Circuit Breakers	51
Yuki Okegawa ¹ , Shungo Zen ² , Nozomi Takeuchi ¹ , Wataru Ohnishi ³ , Yusuke Nakano ⁴ , Naoto Kodama ⁵ and Yuki Inada ⁶ , ¹ Institute of Science Tokyo, ² Aoyama Gakuin University, ³ The University of Tokyo, ⁴ Kanazawa University, ⁵ Nagoya University, ⁶ Saitama University	

FRETTING, SLIDING, AND LUBRICATION 1

Chair: John McBride; Co-Chair: Stanislav Kharin

3.1 Lubricants for Tinned Connector Systems - Facing Sustainability Issues in the Industrial Connectivity	57
Marcel Mainka and Thomas Wielsch, Weidmüller Group	
3.2 Alternatives to Slip Rings — A Review	65
Glenn F. Dorsey ¹ , Jerry Lichter ² , ¹ Consultant, ² Deublin, Hoerbiger Rotary Solutions	
3.3 Construction and Validation of a Slip Ring Test Bench using 50 Years of Data	73
Grant Justice and Patrick K. Bowen, Deringer-Ney Inc.	

CONTACTS

Chair: Xin Zhou; Co-Chair: Timo Muetzel

4.1 Electrical Contact Resistance and Roughness Over Many Scales	81
Robert L. Jackson, Auburn University	
4.2 Long and Short-Term Performance of Electrical Contact Systems in Natural Origin Gas Mixtures of Nitrogen, Carbon Dioxide and Oxygen	88
Daniel Schiffbauer ¹ , Takaya Susuki ² , Toru Koike ² , Shuhei Takao ² , Yuko Imazawa ² and Toshiyuki Uchii ² , ¹ Toshiba International Corporation, ² Toshiba Energy Systems and Solutions Corporation	
4.3 The Impact of Contact Spot Proximity on the Validity of Greenwood's Model	97
Robert D. Malucci, RD Malucci Consulting	

RELIABILITY 1

Chair: Guang Yang; Co-Chair: Rod Martens

5.1 Residual Lifetime Prediction of AC Contactors based on Feature-Reconstructed BiGRU	104
Chen Hu ¹ , Silei Chen ¹ , Xingwen Li ¹ , Xiang Yang ² , Weilong Tang ² and Bo Fu ² , ¹ Xi'an Jiaotong University, ² Siemens Electrical Apparatus Ltd.	
5.2 Model for Determining the Lifetime of a Connector Subjected to Fretting Corrosion	111
Erwann Carvou, University of Rennes	
5.3 Outdoor Test Capability to Replicate Industry-Relevant Photovoltaic Connector Failures	117
Bruce H. King, Steven DiGregorio and Laurie Burnham, Sandia National Laboratories	
5.4 Potentials of Inductively Heated Tools for Contacting Primary-insulated Copper Litz Wires without Contact Element	122
Miriam Eichinger, Alexander Kuehl, Marcel Baader, Joerg Franke and Florian Risch, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)	

ARCING 1

Chair: Deepak Patil; Co-Chair: Thomas Schoepf

- 6.1 DC Series-Parallel Arc Fault Detection Method using Time-Frequency Features and SVM/BPNN ... 130**
Chaojie Luo, Runkun Yu, Zhengyu Fei and Xingwen Li, Xi'an Jiaotong University
- 6.2 An Experimental Study of the Influences of Arc Runner Angle and External Magnetic Field on Low Voltage DC Switching 135**
Mingli Yan, Suleiman M. Sharkh and John W. McBride, University of Southampton
- 6.3 Experimental Study on the Influence of Design Parameters on 1500V DC Circuit Breaker Interruption Performance 142**
Dongkyu Shin, Dongyoel Lee, HD Hyundai Electric

CONNECTORS 1

Chair: Xinwen Li; Co-Chair: Guenther Horn

- 7.1 Uncapped Photovoltaic Connectors – A Combined Field and Chamber Study to Verify and Elucidate Degradation 149**
David C. Miller, Rachael L. Arnold, Delos Ashcraft, Peter L. Hacke, Steven C. Hayden, Oscar Hathaway, Aubrey Jackson, Chun-Sheng Jiang, Jimmy M. Newkirk, Greg Perrin, Kent Terwilliger, National Renewable Energy Laboratory (NREL)
- 7.2 Generation of Bioinspired Asymmetric Topographic Structures on Silver Connectors via Direct Laser Interference Patterning 157**
Silas Daniel Schuetz, Philipp Leonhard-Trautmann, Lena Hinsberger, Sebastian Suarez and Frank Muecklich, Saarland University
- 7.3 Influence of Accelerated Aging of Lead-Free Sn Plating on Connector Extraction Force 162**
Elizabeth Gainey, George Flowers, Sudip Saha and Robert Jackson, Auburn University
- 7.4 Influence of Ni and Zn Coatings on the Microstructure of Steel Electrodes 170**
Christoph Kenel, Pierre Corfdir, Luca Sulmoni and Patrick Suetterlin, ABB Switzerland AG

RELIABILITY 2

Chair: Zk Chen; Co-Chair: Koichiro Sawa

- 8.1 Electric-thermal Long-term Behavior of Compression Connections with Transmission Line Conductors at Realistic Outdoor Conditions 178**
Christian Hildmann¹, Markus Gödicke¹, Stephan Schlegel¹, Maria Kosse¹ and Jérémy Unterfinger²,
¹TU Dresden, ²Amprion GmbH
- 8.2 Parameter Correlation Analysis of Multi-parameter Degradation of Electromagnetic Relays based on Vine Copula and LSTM 186**
Zhaobin Wang^{1,2}, Dongkun Ma¹, Shang Shang^{1,2}, Tianyang He¹, Li Tan¹ and Kang Wu¹,
¹Jiangsu University of Science and Technology, ²University of Leeds
- 8.3 Accelerated Testing of Gold Based Materials during Hot Switching Cycles in a MEMS Test Platform 193**
John McBride¹, Thomas Bull¹ and Yan Yang², ¹University of Southampton, ²TaiCaan Technologies Ltd.
- 8.4 Tin Whisker Mitigation: A Practical Approach for Product/Process Qualification to JEDEC JESD201A 199**
Philip Lees, Littelfuse, Inc.

FRETTING, SLIDING, AND LUBRICATION 2

Chair: David Williams; Co-Chair: Helene Gauthier

- 9.1 Analysis of Relative Motion and Contact Resistance of an Automotive Electrical Connector by Coupling Vibrations and Temperature** 206
Daniel Mburasek Mawidi¹, Mack Mavuni Nzamba², Hans Essone Obame³, Erwann Carvou¹,
¹University of Rennes, ²Université Nouveaux Horizons, ³Ecole Normale Supérieure
- 9.2 Effect of Operating Temperature and Application Quantity of Lubricants on the Fretting Behavior of Silver Plated Electrical Contacts** 214
Michael Blauth, Sören Tülling, Jian Song, Ostwestfalen-Lippe University of Applied Sciences and Arts
- 9.3 Motions Induced by Vibration of Wire-Connector Systems and their Influence on Fretting Behavior of Electrical Connectors** 222
Jian Song, Roman Probst, Jonas Hengstler, Dirk Hilmert,
Ostwestfalen-Lippe University of Applied Sciences and Arts

ARCING 2

Chair: Daniel Gagnon; Co-Chair: Peter Meckler

- 10.1 In-situ Monitoring of Electrode Wear during Arcing** 229
Pierre Corfdir, Luca Sulmoni, Christoph Kenel and Patrick Sütterlin, ABB Switzerland Ltd.
- 10.2 Validations of Electric Arc Simulation** 236
Wenkai Shang, Meng Li, Shihu Ma, Oleg Chernukhin, Runan Mo, Somasekhar Machani, ANSYS, Inc.
- 10.3 Multiphysics Arc Simulations of the Short-Circuit Interruption of a Miniature Circuit Breaker** 241
Ilario Triscari, Gabriel Lantz, Markus Abplanalp, Nagesh Tumu, Ondine Chanon, ABB Ltd.
- 10.4 Observations of Break Arc Behaviors of AgSnO₂ Contacts in an Inductive Load Circuit up to DC20V under External Magnetic Field Application of Difference Levels** 245
Reo Oikawa and Makoto Hasegawa, Chitose Institute of Science and Technology

CONNECTORS 2

Chair: Robert Malucci; Co-Chair: Peter Berger

- 11.1 Investigation on Signal Integrity of High-Frequency Interconnect Structure with Board Edge Copper Removal Technique** 251
Chaoyi Wang, Jinchun Gao, Jiayu Liu, Zhijiao Chen, Beijing University of Posts and Telecommunications
- 11.2 Observations from the Field: *In Situ* Evidence of Photovoltaic Connector Failures** 258
Laurie Burnham¹, Bruce King¹, Steven Digregorio¹, Tapasvi Lolla², Wayne Li² and David Miller³,
¹Sandia National Laboratories, ²Electric Power Research Institute, ³National Renewable Energy Lab
- 11.3 Analysis of Metallization in Coatings of Commercial Solar PV Connectors** 265
Tapasvi Lolla¹, Wayne Li¹, Laurie Burnham², David Miller³, Bruce King² and Steven Digregorio²,
¹Electric Power Research Institute, ²Sandia National Laboratories, ³National Renewable Energy Lab
- 11.4 Experimental Investigation of the Failure Mechanism for Power Connectors under Hot-Swapping Conditions** 273
Chang Sun, Chao Zhang, Wanbin Ren, Harbin Institute of Technology

- Author Index** 280