

CIREN Chicago Workshop 2024

Resilience of Electric Distribution Systems

IET Conference Publications 882

Chicago, Illinois, USA
7-8 November 2024

ISBN: 979-8-3313-1730-0

Printed from e-media with permission by:

Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571



Some format issues inherent in the e-media version may also appear in this print version.

Copyright© (2024) by the Institution of Engineering and Technology
All rights reserved.

Printed with permission by Curran Associates, Inc. (2025)

For permission requests, please contact the Institution of Engineering and Technology
at the address below.

Institution of Engineering and Technology
Futures Place, Kings Way
Stevenage, Hertfordshire
U.K. SG1 2UA
United Kingdom

Phone: +44 (0)1438 313311

www.theiet.org

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
Email: curran@proceedings.com
Web: www.proceedings.com

TABLE OF CONTENTS

Using Machine Learning for Long-Term Forecasting of Extreme Weather-induced Distribution Grid Failures.....	1
<i>Rahul Dubey, Brian Reed, Mishal Thadani</i>	
Resilience of Electric Distribution Systems in Brazil: Analysis of the Regulatory Framework and the Ongoing Project in the Sector.....	6
<i>Lucas Malheiros Nunes, Ricardo Brandão Silva, Lindemberg Nunes Reis</i>	
Results from Lab Testing of Vanadium Redox Flow Battery	11
<i>Anthony Colonnese, Peter Curtiss, Hung Ngo, Ben Lavoie</i>	
Enhancing Asset Management for Improved Resilience Through Representative Generation Profiles	17
<i>Luis Henrique T. Bandoria, Bruno Cortes, Madson C. Almeida, Renato M. Monaro</i>	
Developing Metrics to Assess Electric Utility Climate Resilience.....	22
<i>Neil Weisenfeld, Tara Pelton, Horacio Martinez Michel</i>	
Enhancing LV System Resilience Through Probabilistic Forecasting of Interdependent Variables: Voltage, Reactive and Active Power.....	27
<i>Anthony Faustine, Lucas Pereira</i>	
Hybrid Load Restoration for Hierarchically Controlled Microgrids	32
<i>Fei Feng, Lizhi Wang, Ella Zhou, Sina Zarrabian</i>	
Enhancing Grid Reliability: Optimal Allocation of DER for Load Support During Contingencies.....	37
<i>Felipe Silva, Rafael Barros</i>	
Increasing Resilience by Means of a Two-Dimensional Transformer Fleet Management Approach in a German Utility	42
<i>Alexei Babizki, Rolf Funk</i>	
Evaluating Overhead Distribution Structure Resilience Through Full-Scale Testing.....	47
<i>Steven Dulin, Joe Potvin</i>	
URI Winter Storm Impact on the Texas Electricity Grid & Lessons Learned - a Review.....	52
<i>Sarat Chandra Vegunta, Nelson Bacalao, Giovani Sasso Scarpati, Azadeh Shadman</i>	
T&D Circuit Segmentation for Improved Resilience - a Case Study	57
<i>Sarat Chandra Vegunta, Nelson Bacalao, Giovani Sasso Scarpati, Azadeh Shadman, Ram Nath</i>	
Advanced Power Quality Analytics for Improved Power System Resilience	62
<i>Sarat Chandra Vegunta, Christian Blug, Alkeshkumar Patel</i>	
Enhancing Distribution Grid Resilience in Era of Increasingly Electrified World	67
<i>Vijay Shah, Sushil Joshi, Cristian Val, Dick Jackman</i>	
Certified Insulation Systems for Improving Resilience of Transformers and Distribution Grids.....	72
<i>Evanne Wang, Jean-Claude Duart, Radoslaw Szewczyk, Fabio Scatiggio, Giorgio Campi</i>	

Resilience-Aware Allocation and Dispatch of Distributed BESS in Microgrid Structured RES-based Grids	78
<i>Ali Elrayyah, Mohammad Alnaeem, Rimmesh Shah</i>	
Fault and Protection Management for a Micro Grid with Low Short Circuit Ratio	83
<i>Etienne Toutain, Nikola Stankovic, Boris Deneuville, Rémy Everaere</i>	
Quantifying the Resilience of Sector-Coupled Energy Systems Based on Potential Impacts of Climate Change on the Distribution Grid	88
<i>Paul-Hendrik Homberg, Florian Hankammer, Nadine Lienenklaus, Markus Zdrallek</i>	
Harmonics Mitigation in an Islandable Medium Voltage Microgrid	93
<i>Sébastien Gouraud, Maria Veizaga, Rémy Everaere</i>	
PoleWrap for Increasing the Resilience of Utility Poles Against Extreme Weathers	98
<i>Davoud Zamani, Talieh Zargar</i>	
Self-Assembling Microgrids for Resilient Distribution Systems of the Future	103
<i>Vaibhav Donde, Ryan (Chih-Che) Sun, Christabella Annalicia, Hannah Burroughs, Brady McBride, Rahul Jha, Kevin Morrissey, Manuel Garcia, David Fobes</i>	
Contribution of Electric Vehicle Supply Infrastructures Based on DC Microgrid to Internal and Grid-Side Resilience.....	108
<i>Francesca Marasciuolo, Giuseppe Forte, Gioacchino Tricarico, Maria Dicorato</i>	
Extensive Meshed Network Resilience Analysis.....	113
<i>Vit Krcal, Jan Koudelka, Matej Vrtal, David Topolane</i>	
Quantifying Distribution System Resilience from Utility Data: Large Event Risk and Benefits of Investments.....	118
<i>Arslan Ahmad, Ian Dobson</i>	
Directional Zero Sequence Active Power Algorithm for Resonant Earthed Networks	123
<i>Stephen Williams, James Osborne, Vikram Hadya, Ashish Gupta, Zunash Ijaz</i>	
Topographical Assessment of Electrical Distribution System Vulnerability to Heavy Rainfall Events	128
<i>Florian Hankammer, Nadine Lienenklaus, Markus Zdrallek, Frank Aschenbroich</i>	
Multiport Power Converters to Enhance Resilience in Distribution Networks	133
<i>Martí Domínguez-Hernandez, Marc Cheah-Mañé, Robert Griñó, Oriol Gomis-Bellmunt</i>	
GIS-Based Approach to Improve the Resilience of the Distribution Network	138
<i>Montserrat Montalà-Palau, Marc Cheah Mañé, Oriol Gomis-Bellmunt</i>	
Experimental Tests on an Islanded Microgrid with a Diesel Generator and Inverter-Based Battery Energy Storage System in Synchronous Operation.....	143
<i>Nikola Stankovic, Philippe Bertazzon, Cristian Jecu</i>	
Laboratory Test to Validate Concepts to Build Up and Operate a Microgrid at Distribution Grid Level After a Blackout.....	147
<i>Maximilian Mütherig, Giuseppe Puleo, Wolfgang Krause, Markus Zdrallek</i>	
“Through a Glass, Darkly” – Making Sense of Condition / Health Indices	152
<i>John Webb, Kai Hencken</i>	

Quantifying Resilience Enhancing System Parameters for Electrical Low and Medium-Voltage Grids	157
<i>Paul Runte, Ann Kathrin Seyfried, Johanna Myrzik</i>	
Remote Attestation by Means of Trusted Computing in Regional Power Grids	162
<i>Andreas Wark, Carl-Heinz Genzel, Michael Kreisköther, Torsten Sowa</i>	
Problems and Solutions for Circulating Current Generation in Distributed Power Connection.....	167
<i>Jeong In Kim, Dong Yeol Shin, Seung Won Yoon</i>	
Electrical Resilience: Adaptation to the Volcanic Eruption in La Palma.....	172
<i>Iñaki Bidarte, José María Galache, Iker Mellado</i>	
Using Advanced Analytics and Artificial Intelligence to Improve Resilience: Distribution Network Topology and Loss Identification	177
<i>Xabier Aldecoa</i>	
Design and Technology Innovation to Meet the Resilient Requirements of the Evolving Sub- Transmission and Distribution Network.....	181
<i>Sylvain Ibanez, Shine Damodaran, Kirushnaraj Perumal, Damien Jeanneau, Rajesh Khanna, Sivakumar Narayanaswamy</i>	
Extension of a Low-Voltage Laboratory Grid by a Grid-forming Unit to Perform Microgrid Studies	186
<i>Giuseppe Puleo, Maximilian Mütherig, Markus Zdrallek, Dirk Aschenbrenner</i>	
Energy Modi: Transactive Grid Management Scheme for Resilient Micro-Grids	191
<i>Aditya Pappu, Gerwin Hoogsteen, Juan Camilo López, Johann L. Hurink</i>	
Generation Mix Scenarios Benchmarking for Renewable Power Systems: Analysis and Proposals	196
<i>Angel Molina-Garcia, Ana Fernandez-Guillamon, Guillermo Martinez-Lucas</i>	
Automated Tightly-Stacked Protection Coordination.....	201
<i>Farnaz Harirchi, Yoav Sharon</i>	
Utility Seeks to Improve Reliability and Resilience for Rural Customers with Dynamic Boundary Microgrid – a Feasibility Study	206
<i>Michael Geocariss</i>	
Improving Smart Grid Resilience Using Unavailability Analysis and Maintenance Optimization.....	212
<i>Matej Vrtal, Daniel Krpelik, Pavel Praks, Radim Bris, Radek Fujdiak, Petr Toman</i>	
Resilience Analysis in Medium Voltage Distribution System: Case Study	217
<i>Matej Vrtal, Vit Krcal, Jan Koudelka, Daniel Krpelik, Radek Fujdiak, Petr Toman</i>	
Geospatial Analysis of Grid Resilience: Assessing Failure Impacts, Suggesting Solutions, and Estimating Economic Implications.....	222
<i>Guillaume L'Her, Celine Ramstein, Mark Deinert</i>	
Resilient Features of a Grid-Forming Multiport Power Converter.....	227
<i>Sam Harrison, Mebtu Beza, Agustí Egea Alvarez</i>	
LVAC Microgrid Control for Resilient Operation: Pilot Results	232
<i>Jacob Miscio, Aniket Joshi, Harish Suryanarayana</i>	

Influence of Extreme Temperatures on the Lifespan of Power Transformers and Cables in Benin's Electricity Distribution Network by 2035-2050: Innovative Approach for Sustainable Improvement of Resilience	237
<i>Gbètonджи O. Acclassato, Mathias Houekpoheha, Guy H. Houngue, Hagninou E. V. Donnou, Sylvain Hekponhoue</i>	
Technological Roadmap for Enhancing Electric Distribution Resilience in Brazil: A Framework for Classifying Extreme Weather Events	241
<i>Victor Ribeiro, João Mello, Alexandre Nascimento, Bianca Lobo, Guilherme Martins, Lindemberg Reis</i>	
Federated Learning Forecasting for Strengthening Grid Reliability and Enabling Markets for Resilience	246
<i>Lucas Pereira, Vineet Nair, Bruno Dias, Hugo Morais, Anuradha Annaswamy</i>	
Resilient Control Center to Substation Device Communication	251
<i>Ina Berenice Fink, Markus Dahlmanns, Gerrit Erichsen, Klaus Wehrle</i>	
LVDC Distribution System for Long Distance in Mountainous Areas for Resilience Enhancement	256
<i>Kento Yonezawa, Masayuki Wakutani, Takuya Sakamoto, Takaya Anegawa, Takumi Yoshioka, Hiroyuki Ono, Kazuo Hisatomi, Yuya Kawachi, Kazuma Okamoto, Yasutaka Nishigaki, Kazuki Ogawa</i>	
A Study of Indirect Damage Prediction for Electrical Poles During Typhoons Using Deep Learning	261
<i>Kazuhiro Yokoyama, Masayuki Wakutani, Takaya Anegawa, Takumi Yoshioka, Takuya Sakamoto, Hiroki Mori, Sebastian Wikander</i>	
Power System Resilience and Enhancement Assessment for Volcanic Risk in Taranaki, New Zealand	266
<i>Hugh Mace, Andrew Lapthorn, Neville Watson, Thomas Wilson, James Williams</i>	
Advanced Resilience Planning for Distribution Systems	271
<i>Ahmad Bin Afzal, Nabil Mohammed, Shehab Ahmed, Charalambos Konstantinou</i>	
A Study on a Multi-Purpose ESS Utilization Business Model for Enhancing Grid Resilience.....	276
<i>Ji-Gwan Kim, Sang-Won Lee, Kyeong-Hwan Kim, Seung-Bum Bae, Seung-Min Jang</i>	
Research on Fault Prediction and Self-Healing Strategy of Power Distribution System Based on Big Data Analysis	280
<i>Jie Shen</i>	
Intentional Islanding Method with Temporary Overvoltage Analysis	286
<i>Myungseok Yoon, Jinwoo Jeong, Sungyun Choi</i>	
Development of a Web-Based Module for Automatic Electrical Energy Management on an Animal Farm for a Resilient Electrical System	290
<i>Evina N. W. Mathias, Djoulako C. Léonce, Ossomo O. J. Rostand, Youmsi M. Astride, Julius K. Tanka</i>	
Co-Simulation and Small-Signal Analysis Tool for Multiple DER Integration Studies	295
<i>Carlos Gómez-Aleixandre, Óscar Pasarín, Peter Mola Makolo, Marc Cheah-Mane, Martín González-Antuña, Ángel Navarro-Rodríguez, Cristian Blanco, Pablo García, Oriol Gomis-Bellmunt</i>	
A New Method for Assessing Grid Resilience and Power Outages Based on Dynamic Systems Theory	300
<i>Arndt Telschow, Oliver Mai, Lars Molske, René Böringer, Oliver Kamps</i>	

Outage Prediction for Extreme Weather Events Based on Machine Learning	305
<i>Lena Peter, Katarina Knezovic, Muhammad Jawad, Neeraj Katiyar, Milos Subasic, Ashwin Shirsat</i>	
Spectral Analysis for Tracking Transient Effects in Distribution Grids	310
<i>Patrick Lehnen, Patrick Mack, Markus De Koster, Ingo Stadler, Eberhard Waffenschmidt</i>	
Energy Supply Time in an Islanded Grid Portion Re-Energized by Local Renewable Sources	315
<i>Jane Marchand, Jérôme Buire, Vincent Debusschere, Jean Pompee, Iulia Ivan, Arturo Bretas, Nouredine Hadjsaid</i>	
A Novel Resilience Tool and Its Application to Senegal's Power System	320
<i>Florian Sparavier, Sébastien Leyder, Céline Ramstein, Luca Pizzimbone</i>	
Integrative Modelling and Resilience Enhancement in Critical Infrastructure Systems: A Comprehensive Approach	325
<i>Radek Fujdiak, Matej Vrtal, Pavel Praks, Jan Benedikt, Petr Toman, Michal Beloch</i>	
Monitoring and System Estimation Tool for a Hydro Power Plant in Automated Islanded Grid Operation for Emergency Power Supply	330
<i>Johanna Timmermann, Claudia Bernecker-Castro, Rolf Witzmann, Tobias Lechner, Sebastian Seifried, Michael Finkel, Dirk Menker, Christian Dellmann</i>	
Analysing Level of Harmonics in MV-Networks to Enhance Newly Designed Function for Real-time Monitoring of Residual Current Level in Dispatch System.....	335
<i>Karolina Cechova, Jaroslava Orsagova</i>	
On-Site Testing of Critical Components in Distribution Grids.....	340
<i>Uwe Kaltenborn, Peter Coors, Michael Sowerby, Thomas Melle</i>	
Compensate Renewable Energy Producers for Periods When Local Constraints Do Not Allow Them to Inject Using the Linear Regression	345
<i>Luc Rodriguez, Jean-Baptiste Noel, Vincent Van Robaey</i>	
Improving Grid Resilience Through Transition Indicators for Island Operation.....	350
<i>David Riebesel, Ramy R. Fathalla, Gert Mehlmann, Matthias Luther</i>	
Active Multipath Pseudowire Ensures Uninterrupted Communications for Line Differential Protection	355
<i>Hansen Chan, Rob Wright, Kin-Yee Wong</i>	
A Framework for Improving Grid Resilience by Improving the Reliability of Load Following Services of Microgrids	360
<i>Bernhard Primas, Marco Lauricella, Matthias Schloeder, Matthias Biskoping</i>	
Study About the Improvement Asset Reliability and Utilization by Re-Establishing the Replacement Criteria for Transformers Using AMS	365
<i>Yu Jung An, Jung Su Yoo, Dong Jin Geum, Hui Sik Oh, Tae Ho Kim, Hyo Yeon Lee</i>	
Electric Power Infrastructure Exposure Index for Resilience Studies	369
<i>Davis Montenegro, Jared Green</i>	
Multi-Assessment Tool for Electric Distribution Systems	374
<i>Albert Gili Selga, Pol Paradell Solà, Antonio Pepiciello, Tolga Yalçin, Jorge Alejandro Torres García, Jose Luis Domínguez-García, Jacob Rodríguez-Rivero, Inmaculada Prieto, Ana Romero, Alejandro Berro, Rocío Domínguez</i>	

Reliable 5G Network Slicing for Distributed Energy Systems: Validation of Live Performance During High-Load Event.....	379
<i>Dennis Overbeck, Hendrik Schippers, Fabian Kurtz, Christian Wietfeld</i>	
Rooting for Resilience: Lidar and AI for Utility Vegetation Management.....	384
<i>S. H. Lucia Woo, Chris Boreland, Robin Tatcher</i>	
Expansion of Modular Template Framework for Resilience Valuation.....	389
<i>Russel Like</i>	
Driving Programmatic Reliability Targets Using Historical Outage Data.....	395
<i>Bryan Knowles, Dwayne Tector, Yll Zeka, Ken Fuller</i>	
Dynamic Power Quality Monitoring Via Power Decomposition	399
<i>Mattewos Tefferi, Nick Nakamura, Aleksandar Stankovic, Hanoch Lev-Ari, Nenad Uzelac</i>	
Forecasting Needs for Improving Grid Resilience in Shore Power Infrastructures.....	404
<i>Herbert Amezquita, Pedro Costa, Guilherme Paraíso, Carlos Cardoso, Carlos Castro, Lucas Pereira, Hugo Moraes</i>	
Grid-Wide Distribution Resilience Planning Framework.....	408
<i>Matthew Rylander, Prajwal Gautam, Nick Heine</i>	
Distribution Resiliency Through FLISR Implementation	413
<i>Jason Estel</i>	
CoMap Project: Integration of Grid Analyzers in Digital Twins for Improved Grid Monitoring and Resilience	418
<i>Juan Alvaro Montoya Perez, Christian Bendfeld, Jonas Steffen, Derk Gonschor, Detlef Naundorf, Marvin Albrecht</i>	
Enhancing Resilience - Asset Monitoring and Digitalization Help to Add DER and NOG Switchgear.....	423
<i>Thomas Duerr, Oliver Hartmann, Puneet Singh, Erhard Aumann</i>	
Strategic Load Shedding for Reduced Impact of Extreme Weather Events on Distribution Systems	428
<i>Celso Rocha, Jared Green, Van Holsomback, Brian Deaver</i>	
A Data-Driven Approach to Assessing Brazilian Power Grid's Resilience to Extreme Weather Events.....	433
<i>Lucas Amaro, Rafael Gomes, Roger Alves</i>	
Risk-Informed Decision-making (RIDM) for Enhancing Energy Control System Reliability.....	438
<i>David Dolezilek</i>	
Enhancing Electric Power System Resilience Through Modern Digital Protection Systems	443
<i>David Dolezilek</i>	
Physical-Informed Machine Learning Framework for Outage Prediction Against High Impact Events to Enhance Grid Resilience	448
<i>Mengmeng Zhuang, Andrija Sadikovic</i>	
Resilience-Oriented Planning of Distribution Networks with a Two-stage Approach	453
<i>Giuditta Pisano, Adriano Casu, Fabrizio Pilo</i>	

Optimization of Hydrogen-Based Management System for Enhancing Distribution Network Resilience	458
<i>Ali Hassan Kamlo, Fabrizio Pilo, Simona Ruggeri</i>	
Prosumer-Enabled Grid Resilience – Emerging Systems View from Pilots and Vision for Standards Based Interoperability	463
<i>Mayank Sharma, Jean Wild</i>	
Benefits and Use-Cases of Four-wire Inverters for Inverter-based DERs	468
<i>Nishant Bilakanti, Wenzong Wang, Aminul Huque, Ramkrishna Mishan</i>	
Evaluation of Open-Phase Detection Technologies: Relay Protection Logics and UL 1741SB Certified Inverter	473
<i>Yiwei Ma, Aminul Huque, Charles Brewster</i>	
Eco-Friendly IoT Switchgear – Reducing Uncertainty While Accelerating SF6-Free Transition	478
<i>Andres Laso, Kennedy Darko, Mattewos Tefferi, François Gegot, Nick Nakamura, Nenad Uzelac</i>	
A Vulnerability-Based Approach to Quantify Short-term Failure Probabilities of MV Cables and Joints in Presence of Heat Waves	483
<i>Emanuele Ciapessoni, Andrea Pitto, Diego Cirio, Giovanni Pirovano</i>	
Modeling Damage Cascades in Critical Infrastructure for Power Outages	488
<i>Benjamin Lickert, Kushal Srivastava, Kris Schroyen, Mirjam Fehling-Kaschek, Alexander Stolz</i>	
Holistic Resilience Monitoring in State-Of-the-art Power Supply Systems	493
<i>Kris Schroyen, Benjamin Lickert, Kushal Srivastava, Sebastian Ganter, Mirjam Fehling-Kaschek, Jörg Finger, Alexander Stolz</i>	
Renewable Energy Output Control Method to Resolve Electricity Supply and Demand Imbalance	498
<i>Jiho An, Hae-Young Jeong, Yong-Sam Kim, Hwan-Ki Park</i>	
Re-Energization of a Power System with a Distribution Network	502
<i>Yorgo Laba, Frédéric Colas, Antoine Bruyère, Xavier Guillaud, Xavier Legrand, Thibault Prevost, Gilles Torresan</i>	

Author Index