2009 IEEE Electric Ship Technologies Symposium
(ESTS 2009)

Baltimore, MD, USA
20 – 22 April 2009
# TABLE OF CONTENTS

## PLENARY 1: Electric Ships Realities and Challenges

**Chair:** David Clayton, NavSea

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS Rules for Integrated Power Systems (IPS)</td>
<td>1</td>
</tr>
<tr>
<td>Feasibility Study of Noise Pattern Analysis Based Ground Fault Locating Method for Ungrounded DC Shipboard Power Distribution Systems</td>
<td>18</td>
</tr>
<tr>
<td>All Electric Ship</td>
<td></td>
</tr>
<tr>
<td><strong>Chair:</strong> Tim McCoy, ConverTeam US</td>
<td></td>
</tr>
<tr>
<td>Statistically Robust Design for the All-Electric Ship from a Network Theoretic Perspective</td>
<td>23</td>
</tr>
<tr>
<td>A Modern and Open Real-Time Digital Simulator of All-Electric Ships with a Multi-Platform Co-Simulation Approach</td>
<td>28</td>
</tr>
<tr>
<td>Geographically Distributed Thermo-Electric Co-Simulation of All-Electric Ship</td>
<td>36</td>
</tr>
<tr>
<td>Small-Signal Methods for Electric Ship Power Systems</td>
<td>44</td>
</tr>
<tr>
<td>Fault Current Limiter Allocation in Electric Ship Power Systems</td>
<td>53</td>
</tr>
</tbody>
</table>

## Analysis

**Chair:** Mohamed Bellkhayat, Northrop Grumman

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigation of Accelerating Numerical-Field Analysis Methods for Electric Machines with the Incorporation of Graphic-Processor Based Parallel Processing Techniques</td>
<td>59</td>
</tr>
<tr>
<td>Analytical Model-Based Analysis of High-Speed Flywheel Energy Storage Systems for Pulsed Power Applications</td>
<td>65</td>
</tr>
<tr>
<td>Estimating Transient Response of Simple AC and DC Shipboard Power Systems to Pulse Load Operations</td>
<td>73</td>
</tr>
<tr>
<td>Cognitive Engineering Studies of DSS and Dealing with Uncertainty in Load for Real-Time Adaptive Power System Reconfiguration</td>
<td>79</td>
</tr>
</tbody>
</table>
Maritime Automation, and Emergency Handling – Software: Design, System Integration and Quality .................. 86
Stefan Elgåfoss, Torbjørn Skramstad, Vibeke Dalberg

Electrical Machines
Chair: Chris Hodge, BMT UK

Effects of Magnet Shape on Torque Characteristics of Interior Permanent Magnet Machines .................... 93
Lusu Guo, Leila Parsa

A Survey of Real-Time Power-Loss Minimizers for Induction Motors .............................................................. 98
Ali M. Bazzi, Philip T. Krein

Design and Comparison of an Optimized Permanent Magnet-Assisted Synchronous Reluctance Motor (PMa-SynRM) with an Induction Motor with Identical NEMA Frame Stators ........................................... 107
Robert Vartanian, Hamid A. Toliyat

Ship Brushless-Generator Shaft Misalignment Simulation by Using a Complete Mesh-Model for Machine Voltage Signature Analysis (MVSA) .............................................................................................................. 113
Claudio Bruzzese, Angelo Rossi, Ezio Santini, Varo Benucci, Andrea Millerani

Neural Network Based Modeling of Audible Noise for High Frequency Injection Based Position Estimation for PM Synchronous Motors at Low and Zero Speed ....................................................... 119
Ahmad Arshan Khan, Osama Mohammed

Medium Voltage DC
Chair: Mischa Steurer, Florida State University

Using Functional Failure Mode and Effects Analysis to Design the Monitoring and Diagnostics Architecture for the Zonal MVDC Shipboard Power System ............................................................... 123
R.R. Soman, E.M. Davidson, S.D.J. McArthur

Modeling, Simulation and Experimental Validation of a Generation System for Medium-Voltage DC Integrated Power Systems ............................................................................................................... 129
G. Sulligoi, A. Tessarolo, V. Benucci, M. Baret, A. Rebora, A. Taffone

Small Signal Stability Analysis of a Shipboard MVDC Power System ................................................................. 135
Seetharama R. Rudraraju, Anurag K. Srivastava, Suresh C. Srivastava, Noel N. Schulz

Real-Time Simulation-Based Design of a Power-Hardware-in-the-Loop Setup to Support Studies of Shipboard MVDC Issues ............................................................................................................. 142
M. Andrus, M. Steurer, C. Edrington, F. Bogdan, H. Ginn, R. Dougal, E. Santi, A. Monti

An Innovative Generation Control System for Improving Design and Stability of Shipboard Medium-Voltage DC Integrated Power System ....................................................................................... 152
Vittorio Arcidiacono, Antonello Monti, Giorgio Sulligoi

Simulation
Chair: Chris Daffis, NavSea

A Comparison of Co-Energy and Lorenz Force Based Simulations of Rail Guns ................................................. 157
C.G. Hodge, J.O. Flower, A. Macalindin

Advances in High-Speed Real-Time Multi-Rate Simulation Techniques for Ship Power Systems .................. 165
Roy Crosbie, John Zenor, Dale Word, Richard Bednar, Narain Hingorani
Advanced Simulation Concept for Onboard Ship Grids Featuring Complex Multiterminal Power-Electronic Systems
Carsten Heising, Martin Oettmeier, Roman Bartelt, Volker Staudt, Andreas Steimel

Simulation Environment for Onboard Subsystems of an Electric Ship
Tomasz Haupt, Gregory Henley, Bhargavi Parihar, Noel Shultz

Distributed Dynamic Energy Resource Control
Wayne W. Weaver, Philip T. Krein

Power Converters
Chair: Zareh Soghomonian, BMT Syntek

Zero-Sequence Current Dynamics in Parallel-Connected Voltage Source Converters
Yu Zhang, Zhenhua Jiang

Floating Capacitor Voltage Regulation in Diode Clamped Hybrid Multilevel Converters
James A. Ulrich, Ashish R. Bendre

Output Voltage Regulation in Matrix Converter Fed Power Electronic Transformer for Power Systems Application in Electric Ship
Shabari Nath, K.K. Mohapatra, Ned Mohan

Double Sided Spray Cooled Bi-Directional Power Conversion Module
Brian L. Rowden, Derik W. Trowler, Juan C. Balda

Design and Implementation of a 6kW Three-Phase Active Buck Rectifier
Jeffrey W. Czapor, Edward W. Hankey, Ashish R. Bendre, John W. Bess, Sven R. Englund

Reconfiguration & Survivability
Chair: Terry Ericsen, ONR

Real-Time Implementation of an Intelligent Algorithm for Electric Ship Power System Reconfiguration
Pinaki Mitra, Ganesh K. Venayagamoorthy

DC Zonal Electrical System Fault Isolation and Re-Configuration
Rob Cuzner, Aaron Jeutter

A Reconfiguration Algorithm for a DC Zonal Electric Distribution System Based on Graph Theory Methods
Julia P. Certuche-Alzate, Miguel Vélez-Reyes

Genetic Algorithm Based Damage Control for Shipboard Power Systems
Tushar Amba, Karen L. Butler-Purry, Milad Falahi

Algorithm Development for Evaluating the IPS Survivability Due to its Topology
Svetlana V. Poroseva, Nathan Lay, M. Yousuff Hussaini

Modeling
Chair: Patrick Chapman, University of Illinois

A Linear Programming Approach to Shipboard Electrical System Modeling
Ricky R. Chan, Scott D. Sudhoff, Yonggon Lee, Edwin L. Zivi

Design and Optimization of an Hybrid Sailboat by a Power Modeling Approach
Florian Dupriez-Robin, Luc Loron, Fabien Claveau, Philippe Chevrel
Modelling Method for Complex Induction Machines Used in Naval Applications Using an Advanced Simulation Concept ................................................................. 278
Carsten Heising, Martin Oettmeier, Roman Bartelt, Jie Fang, Volker Staudt, Andreas Steimel

Modeling and Simulation of Shipboard Power System Protection Schemes Using Coordination of Overcurrent Relay .............................................. 282
Ankush Saran, Anurag K. Srivastava, Noel N. Schulz

High Power Clean DC BUS Generation Using AC-Link AC to DC Power Voltage Conversion, DC Regulation, and Galvanic Isolation .................................... 290
Ian C. Evans, Rudy Limpaecher

**Modular Power**

**Chair:** Herb Ginn, Michigan State University

A Compact Bi-Directional Power-Conversion System Scheme with Extended Soft-Switching Range ........................................ 302
Liang Jia, Sudip K. Mazumder

Possible Applications of Plug-in Hybrid Electric Ships ......................................................................................................................... 310
Sven De Breucker, Eefje Peeters, Johan Driesen

Integration of a Bi-Directional DC-DC Converter Model Into a Large-Scale System Simulation of a Shipboard MVDC Power System ........................................ 318
Il-Yop Chung, Wenxin Liu, Mike Andrus, Karl Schoder, Siyu Leng, David A. Cartes, Mischa Steurer

Optically-Modulated Active-Gate Control (OMAG) for Switching Electrical Power-Conversion Systems ........ 326
Sudip K. Mazumder, Tirthajyoti Sarkar

Soft-Switching Capability Analysis of a Dual Active Bridge Dc-Dc Converter ........................................... 334
Zhiyu Shen, Rolando Burgos, Dushan Boroyevich, Fred Wang

**PLENARY 2: Integrated Power Systems**

**Chair:** Lynn Petersen, US Navy

The State-of-the-Art of Integrated Electric Power and Propulsion Systems and Technologies on Ships ........ 340
Timothy J. McCoy, John V. Amy Jr.

Integrated Electric Power System Supervision for Reconfiguration and Damage Mitigation ......................... 345
Murat Yasar, Adam Beytin, Gaurav Bajpai, Harry G. Kwatny

Integrated Simulation of Communication, Protection, and Power in MVDC Systems ........................................ 353
Antonello Monti, M. Colciago, P. Conti, M. Maglio, R.A. Dougal

**Protection**

**Chair:** John Amy, BMT Syntek

Circuit Breaker Protection Considerations in Power Converter-Fed DC Systems ................................................. 360
Rob Cuzner, Doug MacFarlin, Don Clinger, Michael Rumney, Gene Castles

Designing Microprocessor-Based Protection Hardware for Ultra-Critical Applications ........................................ 368
David McGinn, Vijay Muthukrishnan, Wei Wang

System Study of Fault Current Limiter for Shipboard Power System ................................................................. 376
Bart Diaz, Thomas H. Ortmeier, Bruce Pilvelait, Mike Izenson, Weibo Chen, Nathan Spivey
Analysis of Fault Events in MVDC Architecture ................................................................. 380
A. Ouroua, J. Beno, R. Hebner

Power Semiconductors

Chair: Sharon Berman-Curtin, DARPA

Investigation of the Turn-Off Characteristics of a GTO Thyristor in an Inductive-Based Pulse Forming Network ................................................................. 388
John G. Ciezki, Thomas E. Salem

Modeling and Simulation of 2 kV 50 A SiC MOSFET/JBS Power Modules ................................................................. 393
Zheng Chen, Rolando Burgos, Dushan Boroyevich, Fred Wang, Scott Leslie

IGCTs vs. IGBTs for Circuit Breakers in Advanced Ship Electrical Systems ................................................................. 400
Richard F. Schmerda, Slobodan Krstic, Edward L. Wellner, Ashish R. Bendre

Comparison of Current Sharing Among Paralleled Devices in Wire-Bonded and Planar Power Modules .......... 406
Tong Liu, Khai D.T. Ngo, G.Q. Lu, Rolando Burgos, Fred Wang, Dushan Boroyevich

Shipboard Power Systems

Chair: Giorgio Sulligoi, University of Trieste

Dynamic Load Shedding for Shipboard Power Systems Using the Non-Intrusive Load Monitor ................................................................. 412
Arun Shrestha, Edward L. Foulks, Robert W. Cox

Mitigation against Overvoltages on a DC Marine Electrical System ................................................................. 420
S.D.A. Fletcher, P.J. Norman, S.J. Galloway, G.M. Burt

Design, Modelling and Stability Analysis of an Integrated Shipboard DC Power System ................................................................. 428
Alexander L. Julian, Robert M. Cuzner

DC Power System Stability ................................................................. 433
C.G. Hodge, J.O. Flower, A. Macalindin

On Studying the Power Supply Quality Problems Due to Thruster Start-Ups ................................................................. 440
J.M. Prousalidis, P. Mouzakis, E. Sofras, D. Muthumuni, O. Nayak

Faults detection

Chair: Boris Jacobson, Raytheon

Detection and Location of Intermittent Faults by Monitoring Carrier Signal Channel Behavior of Electrical Interconnection System ................................................................. 449
Charles Kim

Fault Location for DC Marine Power Systems ................................................................. 456
David Thomas, Mark Sumner, David Coggins, Xiaohui Wang, Jing Wang, Rinze Geertsma

A Sequence-Based Control Scheme for Voltage-Source Converters in Naval and Commercial Microgrids ......... 461
S.K. Mazumder, K. Acharya

Machine Learning Techniques for Diagnosing and Locating Faults Through the Automated Monitoring of Power Electronic Components in Shipboard Power Systems ................................................................. 469
**Electrical Components**

**Chair:** Antonello Monti, University of South Carolina

Gearing Ratios of a Magnetic Gear for Marine Applications .......................................................... 477

Nicolas W. Frank, Hamid A. Toliyat

Novel Undervoltage Release Concept ................................................................................................. 482

Edward Wellner, Richard Schmerda, Alvin Zemlicka

Improved Input Power Conditioning for Fractional Horsepower Shipboard Valve Actuators .............. 484

Edward J. Hankey, Jeffrey W. Czapor, Ashish R. Bendre, John W. Bess, Sven R. Englund

Initial Development of a Solid-State Fault Current Limiter for Naval Power Systems Protection .......... 491

Jack Bourne, Marcelo Schupbach, Joe Carr, H. Alan Mantooth, Juan Balda

**Propulsion**

**Chair:** Scott Sudhoff, Purdue University

State of the Art in Electric Propulsion – Viewpoint on Redundancy ....................................................... 499

Sami Kanerva, Jan-Fredrik Hansen

Power Split e-CVT Ship Propulsion System ......................................................................................... 505

Claudio Rossi, Piero Corbelli, Luca Zarri, Domenico Casadei

Economic Benefits of Hybrid Drive Propulsion for Naval Ships .............................................................. 515

Gene Castles, Greg Reed, Ashish Bendre, Robert Pitsch

Compact DC Power and Propulsion Systems - the Definitive Solution? ............................................... 521

M. Butcher, R. Maltby, P.S. Parvin

**Insulation and Thermo Analysis**

**Chair:** Albert Tucker, Consultant

Measurement of Partial Discharge in Machine Winding Insulation During Short-Rise Time Pulse Voltage .... 529

C.D. Taylor, S. Grzybowski

Accelerated Electrical Degradation of Machine Winding Insulation ..................................................... 533

S.R. Chalise, S. Grzybowski, C.D. Taylor

Notional All-Electric Ship Thermal Simulation and Visualization ............................................................ 539


System-Level Thermal Modeling and Co-Simulation with Hybrid Power System for Future All Electric Ship ........................................................................................................................................... 547

Ruixian Fang, Wei Jiang, Jamil Khan, Roger Dougal

**Tests, Evaluation and Certification**

**Chair:** Joseph Maurio, NGC

A Platform for the Testing and Validation of Dynamic Battery Models ............................................... 554

Michael Knauff, Dagmar Niebur, Chika Nwankpa

A Medium Voltage DC Testbed for Ship Power System Research ......................................................... 560


**Generation and Storage**

**Chair:** Fei Wang, CPES

---


Saurabh Kulkarni, Surya Santoso

---

**Fuel Cell Propulsion System for Marine Applications** .................................................. 574

L. Luckose, H.L. Hess, B.K. Johnson

---

**Power Sharing Control of Fuel Cell/Gas-Turbine Hybrid Power Systems** ............................... 581

Atideh Abbasi, Zhenhua Jiang

---