

IEEE POWER & ENERGY SOCIETY

The IEEE Power & Energy Society is an organization of IEEE members whose principal interest is in the advancement of the science and practice of electric power generation, transmission, distribution, and utilization. All members of the IEEE are eligible for membership in the Society and will receive this TRANSACTIONS upon payment of the annual Society membership fee (\$35.00) plus an annual subscription fee (print: \$65.00; electronic: \$25.00; print and electronic: \$80.00). For information about joining, contact the IEEE using the information below. *Member copies of Transactions/Journals are for personal use only.*

PES PUBLICATIONS BOARD

MARIESA CROW, *Chair*

DAMIR NOVOSEL MIRIAM SANDERS CHRISTOPHER E. ROOT PATRICK P. RYAN SAIFUR RAHMAN

IEEE TRANSACTIONS ON POWER DELIVERY EDITOR-IN-CHIEF

WILSON XU
Univ. of Alberta

POWER ENGINEERING LETTERS EDITOR-IN-CHIEF

MAHMUD FOTUHI-FIRUZABAD
Sharif Univ. of Technology

KIT PO WONG, *Past Editor-in-Chief*

IEEE TRANSACTIONS ON POWER DELIVERY EDITORS

JOSE MANUEL AVENDANO-MORA, Southern Calif. Edison, USA
YOSHIHIRO BABA, Doshisha Univ.
TIANSHU BI, North China Electric Power Univ.
SUKUMAR M. BRAHMA, New Mexico State Univ.
ANTONIO CATALIOTTI, Università di Palermo, Italy
GARY CHANG, NATIONAL Chung Cheng Univ.
NILANJAN RAY CHAUDHURI, GE Global Research Center
VALENTINA COSENTINO, Univ. of Palermo, Italy
FRANCISCO DE LEON, Polytechnic Inst. of Nyu
SÉBASTIEN DENNETIERE, Réseau de Transport d'Electricité, France
MOHAMED ELMOURSI, Masdar Inst. of Science and Technol., UAE
CHRISTIAN M. FRANCK, Swiss Fed. Inst. of Technol. Zurich
WALMIR FREITAS, Univ. of Campinas

ORIOLO GOMIS-BELLMUNT, Technical Univ. of Catalonia
THOMAS E. GREBE, Enernex Corporation
JINLIANG HE, Tsinghua Univ.
ALI HOOSHYAR, Univ. of Toronto, Canada
BRIAN K. JOHNSON, Univ. of Idaho, USA
DRAGAN JOVICIC, University of Aberdeen, UK
ADRIA JUNYENT-FERRE, Imperial College of UK
S. V. KULKARNI, Indian Inst. of Technology, Bombay
UDAYA KUMAR, Indian Inst. of Sci. High Voltage Lab, Bangalore
JEAN MAHSEREDJIAN, Ecole Polytech., Montreal
ALI MEHRIZI-SANI, Washington State Univ.
JACOB MERRIMAN, Burns & McDonnell
IGOR PAPIĆ, Univ. of Ljubljana, Slovenia

SARATH PERERA, Univ. of Wollongong, Australia
LISA QI, ABB
JIANGCHAO QIN, Arizona State Univ.
AFSHIN REZAEI-ZARE, Hydro One Networks, Inc., Canada
MARYAM SAEEDIFARD, Georgia Inst. of Technology
SUBHRANU SAMANTARAY, Indian Inst. of Technology, Bhubaneswar
MAJID SANAYE-PASAND, Univ. of Tehran
KLEBER MELO SILVA, Univ. of Brazil
JOSE CARLOS VIEIRA, Univ. of São Paulo, Brazil
PENG WANG, Nanyang Technological Univ., Singapore
XIAORONG XIE, Tsinghua Univ. of China
LIE XU, Univ. of Strathclyde
GUANGYA YANG, Technical Univ. of Denmark
YI ZHANG, RTDS Technologies, Canada
DONGBO ZHAO, Argonne National Lab.

PES EXECUTIVE COMMITTEE

SAIFUR RAHMAN, *President*

FRANK C. LAMBERT, *President-Elect*
JESSICA BIAN, *Secretary*
NOUREDINE HADISAID, *Treasurer*
BRUNO MEYER, *Director, Division VII*
OPEN, *Director Elect, Division VII*

DAMIR NOVOSEL, *Immediate Past President*
MAZANA ARMSTRONG, *Vice President, Chapters*
EDVINA UZUNOVIC, *Vice President, Education*
TOMMY MAYNE, *Vice President, Meetings*
JUAN CARLOS MONTERO, *Vice President, Membership and Image*

SHAY BAHRAMIRAD, *Vice President, New Initiatives/Outreach*
MARIESA CROW, *Vice President, Publications*
FARNOOSH RAHMATIAN, *Vice President, Technical Activities*
PATRICK P. RYAN, *Executive Director*

PES EXECUTIVE OFFICE

PATRICK P. RYAN, *Executive Director*

KRISTIN CAPALDO, *Editorial Assistant*
YUEN CHAN, *PES Administrator*
MAUREEN DALTON, *Senior Manager, Marketing, Communications & Membership*
DEAN FIORINO, *eCommerce Administrator*
LATOYA GOURDINE, *Administrator, PES Education & Meeting Services*
KATHY HEILMAN, *Administrator, PES Education & Meeting Services*
ROSEANNE JONES, *Administrator, PES Education & Meeting Services*
CHERYL KOSTER, *Administrator, Society Publications*
SUSAN KOVAL, *Senior Manager, PES Education & Meeting Services*

SISSIE LIN, *PES Operations & Resource Center*
SHANON NASON, *Administrator, Member Services*
MARIA PROETTO, *Senior Administrator, Publications*
ANGELIQUE RAJSKI PARASHIS, *Project Manager*
RANDI E. SCHOLNICK, *Administrator, Society Publications*
DANIEL TOLAND, *Scholarship Plus Program Director*
MICHAEL WILSON, *Senior Project Manager,*
IEEE Smart Grid Village

445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331 USA
e-mail: pes@ieee.org
fax: +1 732 562 3881
vox: +1 732 562 3883
WWW: <http://www.ieee-pes.org>

IEEE OFFICERS

JAMES A. JEFFERIES, *President*
JOSÉ M. F. MOURA, *President-Elect*
WILLIAM P. WALSH, *Secretary*
JOSEPH V. LILLIE, *Treasurer*
KAREN BARTLESON, *Past President*

WITOLD M. KINSNER, *Vice President, Educational Activities*
SAMIR M. EL-GHAZALI, *Vice President, Publication Services and Products*
MARTIN J. BASTIAANS, *Vice President, Member and Geographic Activities*
FORREST D. "DON" WRIGHT, *President, Standards Association*
SUSAN "KATHY" LAND, *Vice President, Technical Activities*
SANDRA "CANDY" ROBINSON, *President, IEEE-USA*

BRUNO C. MEYER, *Director, Division VII—Energy and Power Engineering*

DIVISION DIRECTORS

RENUKA P. JINDAL, *Director, Division I*
F. D. "DON" TAN, *Director, Division II*
VIJAY K. BHARGAVA, *Director, Division III*
JENNIFER T. BERNHARD, *Director, Division IV*
JOHN W. WALZ, *Director, Division V*

JOHN Y. HUNG, *Director, Division VI*
BRUNO C. MEYER, *Director, Division VII*
DEJAN MILOJICIC, *Director, Division VIII*
ALEJANDRO "ALEX" ACERO, *Director, Division IX*
TOSHIO FUKUDA, *Director, Division X*

IEEE EXECUTIVE STAFF

STEPHEN P. WELBY, *Executive Director & Chief Operating Officer*

THOMAS SIEGERT, *Business Administration*
JULIE EVE COZIN, *Corporate Governance*
DONNA HOURICAN, *Corporate Strategy*
JAMIE MOESCH, *Educational Activities*
EILEEN M. LACH, *General Counsel & Chief Compliance Officer*
VACANT, *Human Resources*
CHRIS BRANTLEY, *IEEE-USA*

CHERIF AMIRAT, *Information Technology*
KAREN HAWKINS, *Marketing*
CECELIA JANKOWSKI, *Member and Geographic Activities*
MICHAEL FORSTER, *Publications*
KONSTANTINOS KARACHALIOS, *Standards Association*
MARY WARD-CALLAN, *Technical Activities*

IEEE Periodicals

Transactions/Journals Department

Senior Director, Publishing Operations: DAWN MELLEY

Director, Editorial Services: KEVIN LISANKIE *Director, Production Services:* PETER M. TUOHY

Associate Director, Editorial Services: JEFFREY E. CICHOCKI *Associate Director, Information Conversion and Editorial Support:* NEELAM KHINVASARA

Managing Editor: MARTIN J. MORAHAN *Senior Journals Coordinator:* GEORGE CRISCIONE

IEEE TRANSACTIONS ON POWER DELIVERY (ISSN 0885-8977) is published bimonthly by The Institute of Electrical and Electronics Engineers, Inc. Responsibility for the contents rests upon the authors and not upon the IEEE, the Society, or its members. **IEEE Corporate Office:** 3 Park Avenue, 17th Floor, New York, NY 10016-5997. **IEEE Operations Center:** 445 Hoes Lane, Piscataway, NJ 08854-4141. **NJ Telephone:** +1 732 981 0060. **Price/Publication Information:** Individual copies: IEEE Members \$20.00 (first copy only), nonmembers \$199.00 per copy. (Note: Postage and handling charge not included.) Member and nonmember subscription prices available upon request. **Copyright and Reprint Permissions:** Abstracting is permitted with credit to the source. Libraries are permitted to photocopy for private use of patrons, provided the per-copy fee of \$31.00 is paid through the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923. For all other copying, reprint, or republication permission, write to: Copyrights and Permissions Department, IEEE Publications Administration, 445 Hoes Lane, Piscataway, NJ 08854-4141. Copyright © 2018 by The Institute of Electrical and Electronics Engineers, Inc. All rights reserved. Periodicals Postage Paid at New York, NY and at additional mailing offices. **Postmaster:** Send address changes to IEEE TRANSACTIONS ON POWER DELIVERY, IEEE, 445 Hoes Lane, Piscataway, NJ 08854-4141. GST Registration No. 125634188. CPC Sales Agreement #40013087. Return undeliverable Canada addresses to: Pitney Bowes IMEX, P.O. Box 4332, Stanton Rd., Toronto, ON M5W 3J4, Canada. IEEE prohibits discrimination, harassment and bullying. For more information visit <http://www.ieee.org/nondiscrimination>. Printed in USA.