WEMPEC

Wisconsin Electric Machines & Power Electronics Consortium

35 Years of Collaboration and Innovation 1981–2016

WEMPEC

www.wempec.wisc.edu

WEMPEC Founders

Thomas A. Lipo

Donald W. Novotny

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Founders' Message

Tom Lipo

Don Novotny

The idea of an industrial support organization and the subsequent creation of WEMPEC with the help of people like Norb Schmitz, Ken Phillips, and others has been one of the most satisfying and rewarding experiences of our lives. When we founded WEMPEC in 1981, little did we know that this consortium of companies supporting our research will likely outlive us!

Maybe WEMPEC and the WEMPEC plan was a very good idea at exactly the right time, but the long-term success we celebrate at the 35-year mark owes everything to the dedication and hard work of the faculty, students, staff, and sponsors who have chosen to be part of the WEMPEC family. Over the past 35 years, our students and visiting researchers have contributed to literally every nook and cranny of the power electronics motor drive world. We are extremely proud of them and what they have accomplished both at UW–Madison and at their present places of employment in industry and academia.

The WEMPEC organization has been crucial in providing us the support and incentive to carry out the work we love, and we both are content with the fact that we have left WEMPEC in good hands. We thank all of you for your part in making reality bigger than our dreams. Long live WEMPEC!

Greetings from Bob Lorenz & Tom Jahns, WEMPEC Co-Directors

Bob Lorenz

Tom Jahns

As we celebrate WEMPEC's 35th Anniversary, we invite you to take advantage of this opportunity to learn more about our consortium's past, present, and future. We hope that the material in this booklet will deepen your appreciation of WEMPEC's rich history that has consistently emphasized rigorous and thoughtful preparation of our students, careful attention to the future technology needs of our sponsors, and productive collaborations with research colleagues worldwide.

To begin, we proudly acknowledge and thank WEMPEC's two founders, Professors Emeritus Don Novotny and Tom Lipo, who collaborated to launch WEMPEC back in 1981 when the concept of a university/industry consortium in this field was new and untested. It is a testimony to their vision and dedication that they were so successful in launching WEMPEC and overseeing its rapid growth into a stable and highly productive consortium. We are incredibly fortunate that both of them continue to make valuable contributions to WEMPEC today.

This booklet gives us a welcome opportunity to highlight the impressive accomplishments of our current and graduated students who lie at the very heart of WEMPEC's education and research missions. With over 400 graduates who have earned master's and doctoral degrees, WEMPEC has gained an international reputation for the technical competence of our graduates, distinguished by their broad and deep multidisciplinary skills. WEMPEC's success is reflected in the high levels of professional success that have been achieved by so many of our graduates. We are extremely pleased that many of our alumni maintain active relationships with our program by serving as WEMPEC sponsor representatives.

As WEMPEC co-directors, we are also pleased by the significant progress we are making on preparations for WEMPEC's future. First and foremost, the addition of Professors Bulent Sarlioglu and Dan Ludois as WEMPEC faculty colleagues represents a giant step toward insuring that WEMPEC will continue to be at the forefront of new technical breakthroughs in the fields of electric machines, power electronics, machine drives, and their expanding applications. As a team, we are working to strengthen our laboratory infrastructure to insure that our faculty and students will continue to have access to world-class research facilities.

Our commitment to fulfill our education and technology transfer mission is stronger than ever, reflected in the 20+ graduate and undergraduate courses that we offer to our students, one of the strongest academic programs of its type found anywhere in the world. Building on 31 years of success, our distance learning program continues to serve

our sponsors and engineers working in industry by offering these same courses online to off-campus students, leading to either a capstone certificate or graduate degrees in our master's and doctoral programs.

We conclude by expressing our heartfelt appreciation to all of our WEMPEC sponsors, past and present. We would not be here to celebrate this special anniversary if it were not for the unflagging commitment of our sponsors to support this joint enterprise. Our goal is to ensure that our sponsors will continue to benefit from both our long-term research and our preparation of the next generation of world-class engineers who will help them maintain leadership positions in the markets they serve. We are confident that the next 35 years will bring even greater success to this uniquely productive and synergistic partnership!

WEMPEC's Vision

To be the lifelong hub of a worldwide network of engineers who are active in all facets of power electronics and electromechanical power conversion and their applications.

WEMPEC's Mission

- To maintain a tightly-coupled relationship between WEMPEC-supported university research and educational programs and the engineers in global industry who sponsor and support these programs.
- To continuously improve the WEMPEC program in order to more effectively foster and sustain the growth of advanced electrical energy conversion technologies and their industrial, commercial, residential, consumer, automotive, and aerospace applications.
- To develop effective methodologies for transferring new knowledge gained in WEMPEC-supported research to all engineers in industry who sponsor and support this research, reflecting a long-term commitment to career development of engineers in our field.
- To globally foster the spirit of technological innovation and progress in electrical and electromechanical power conversion.

Message from WEMPEC's Executive Director Jim Sember

JIM SEMBER
WEMPEC Executive Director

An anniversary is a time to pause to consider where we've been and where we're going. Like the ancient Roman god Janus, we look both to the past and the future. WEMPEC's past has been characterized by significant ground-breaking research. During our 35-year history, notable accomplishments include:

- Wind turbine design – 1984
- Reluctance machines – 1987
- Resonant link AC converter – 1988
- Observer-based machine control – 1988
- Adaptive tuning of field oriented drives – 1988
- Soft-switching – 1989
- Active power filters – 1989
- Loss minimizing control of IM drives – 1989
- Optimal PM motor design for field weakening – 1990
- DSP field-oriented control – 1990
- Vector control of synchronous reluctance machines – 1990
- Dual active bridge converters – 1990
- Axial flux PM motor – 1992
- Accurate flux observers – 1992
- Doubly-salient PM motor – 1992
- Self-sensing field-oriented control – 1993
- Inductive vehicle charging – 1993
- Multiphase motor control – 1994
- Coaxial winding transformers – 1994
- Active battery equalization – 1994
- Three level boost rectifier – 1995
- Estimation of flux, position, and velocity in AC machines – 1997
- Self-sensing control of switched reluctance machines – 1998
- Self-sensing control of AC machines – 1993–2016
- Vernier PM motor – 2000
- Deadbeat-Direct Torque and Flux Control – 2001
- Microgrid control – 2002–07
- FI-IPM machines – 2008
- Wireless power transfer – 2010
- Capacitive power transfer – 2012
- Variable leakage flux PM machines – 2012
- Variable magnetization state PM machines – 2013
- Smooth torque flux-switching machines – 2014
- Electrostatic rotating machines – 2014

These accomplishments have been made possible by a uniquely talented group of faculty, many of whom have received world-wide recognition. In 2014 Professor Emeritus Tom Lipo was awarded the IEEE Medal in Power Engineering for contributions to electrical machine and drive topologies. Also in 2014, Professor Bob Lorenz was awarded the IEEE Richard H. Kaufmann award in recognition of his expertise in self-sensing machine methods. In 2015, Professor Tom Jahns was named to the National Academy of Engineering. Professor Emeritus Don Novotny has received numerous awards and concluded 57 years of classroom teaching in 2013, but still teaches sections of short courses today!

WEMPEC is truly a place of rich history: now let's turn toward the future. In the coming years, WEMPEC will be undergoing a leadership transition. Nevertheless, we will build on our historical strength of educating power engineers in theory as well as practical hands-on techniques. We will continue to push the boundaries of technical expertise in electric machines, power electronics, and drive systems; maintaining our focus in these areas while advancing other technical arenas of significance to our sponsors. We will continue to enhance our value to our sponsors so that WEMPEC sponsorship is the most highly leveraged use of scarce research dollars. WEMPEC will remain a place where the multidisciplinary talents of visionary researchers and their students are wedded to the needs of industry in a way unmatched at any other university.

Sponsors (as of April 2016)

ABB Corporate Research Center (U.S.)
ABB Inc., Drives and Power Products Division
Alstom Transport
ANSYS Inc.
Arnold Magnetic Technologies
ASELSAN A.S.
BAE Systems Controls, Inc.
Boeing Company
BorgWarner
Carrier Corporation
Caterpillar, Inc. Tech Center
CRRCR Zhuzhou Institute Co., LTD.
Daikin Industries
Danfoss Power Electronics
Delta Electronics, Inc.
DRS Power & Control Technologies, Inc.
dSPACE, Inc.
Eaton Corporate Research & Technology
Electronic Concepts, Inc.
Electro-Motive Diesel International Corp.
Fiat Chrysler Automobiles
Flanders Electric
Ford Motor Company, Research & Adv. Engr.
Fuji Electric Co., Ltd.
GE Aviation–Electrical Power
GE Global Research Center
Generac Power Systems
GM Powertrain–Electrification
GM R&D–Warren
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John Deere Moline Technology Innovation Ctr.
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Texas Instruments
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Toshiba International Corporation
Toyota Motor Corporation - Japan
Trane Company (Div. of Ingersoll Rand)
Triumph Aerospace Systems-Seattle
TRW Automotive
Unico, Inc. (Div. of Regal)
UTC Aerospace Systems
UTRC (United Technologies Research Center)
Woodward Aircraft Systems
Woodward Industrial Systems
Yaskawa America, Inc.

I would be surprised to find many university led industrial consortiums that have had such a profound impact on their field. The WEMPEC name is recognized globally for its excellence in education, research and its leadership. WEMPEC's contributions to the evolution and development of electric machine and power electronics technology have transformed the field of electromechanical energy conversion and are enablers for the advancements that will be critical to address the many challenges facing the world today related to global warming, energy supply, and economic growth.

— Dr. Michael Degner (PhD '98)
Ford Motor Company

Thomas M. Jahns

Professor
Department of Electrical and Computer Engineering

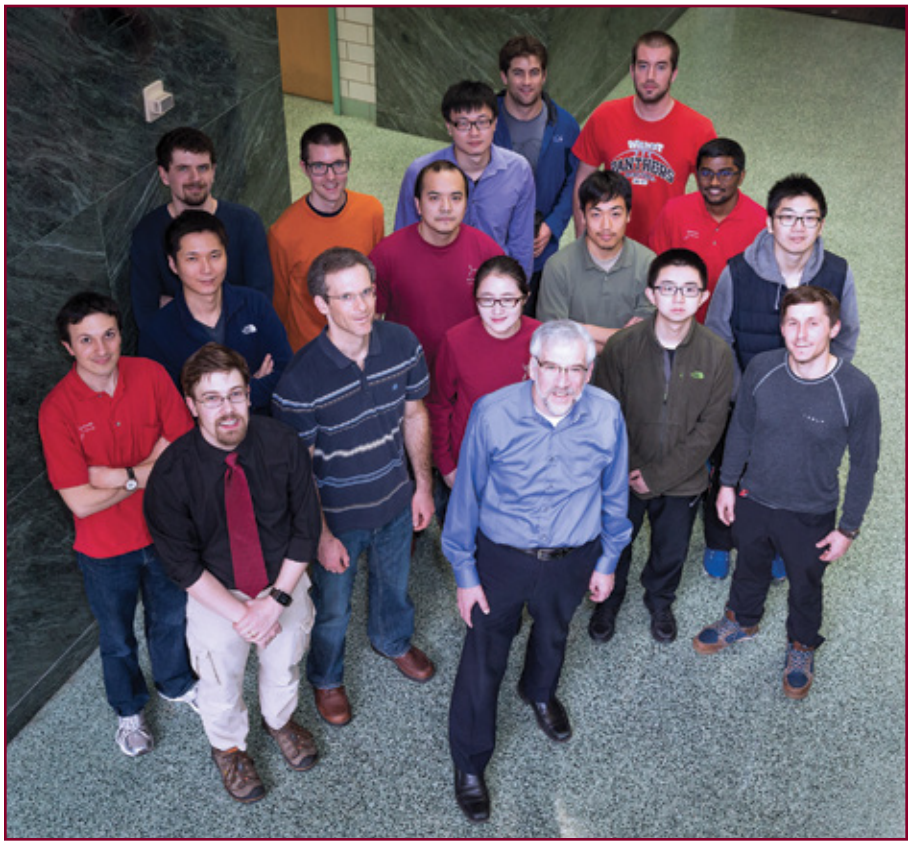
Thomas M. Jahns, IEEE Fellow, received his SB, SM, and PhD ('78) degrees from MIT, all in electrical engineering. Dr. Jahns joined the faculty at UW–Madison in 1998 as Grainger Professor of Power Electronics and Electric Machines in the Department of Electrical and Computer Engineering. He is a co-director of WEMPEC and the Wisconsin Power Electronics Research Center (WisPERC).

Prior to coming to UW–Madison, Dr. Jahns worked for 15 years in GE Corporate Research and Development (now GE Global Research Center) in Niskayuna, New York, where he pioneered the development of high-performance interior PM machines and drives in a variety of research and management positions. During 1996–98, he conducted a research sabbatical at MIT where he directed research activities in the area of advanced automotive electrical systems and accessories as co-director of an industry-sponsored automotive consortium.

Since arriving at UW–Madison, Dr. Jahns has continued to pursue research in AC permanent magnet (PM) synchronous machines, focusing on technical issues associated with high-performance PM traction machines including fault-mode analysis and mitigation, high-frequency loss mechanisms, multiphysics design optimization, and integrated motor drives. His current research interests also include changes to the electric grid to make it much more compatible with massive penetration of distributed energy resources, with research projects focused on renewable energy, microgrids, and battery management.

In 2005, Dr. Jahns received the IEEE Nikola Tesla Technical Field Award. Dr. Jahns is also a past recipient of the IEEE William E. Newell Award and the Distinguished Service Award from the IEEE Power Electronics Society (PELS). He served as PELS president during 1994–95 and as an elected member of the IEEE board of directors during 2001–02.

Dr. Jahns was elected to the U.S. National Academy of Engineering (NAE) in 2015 "for advancement of permanent magnet machines and drives for transportation and industrial applications."

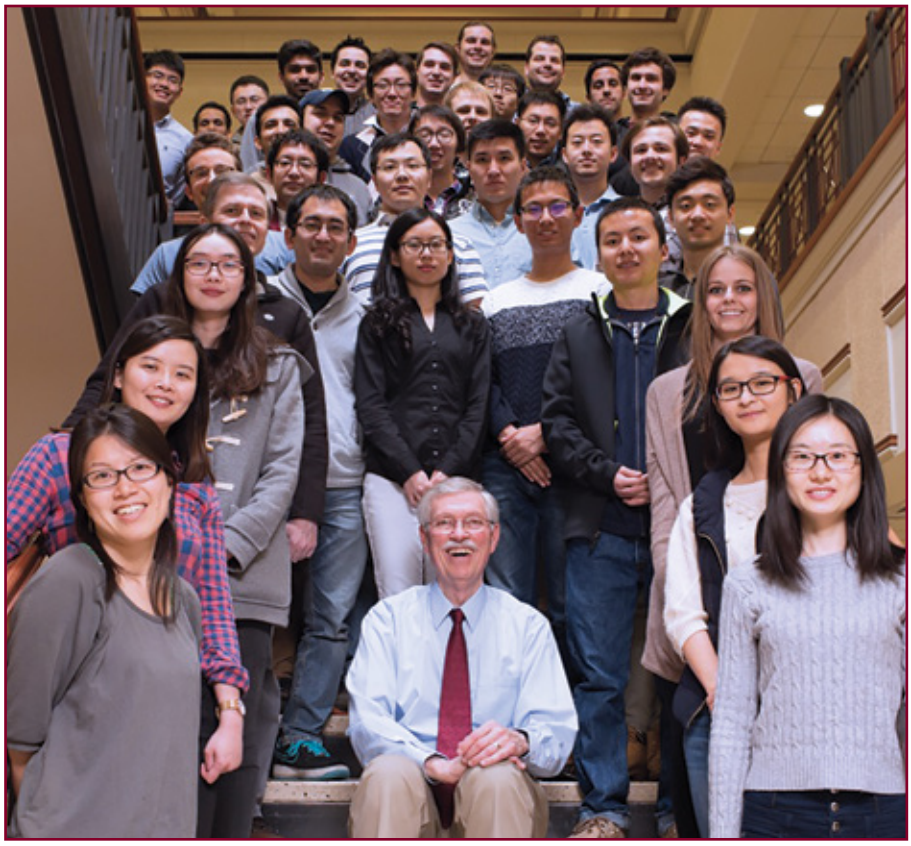


Robert D. Lorenz

Professor
Department of Mechanical Engineering

Robert Lorenz, IEEE Life Fellow, received his BS, MS, and PhD from UW–Madison and an MBA from the University of Rochester. He has been a UW–Madison faculty member since 1984 where he is the Elmer R. and Janet A. Kaiser Chair and the Consolidated Papers Foundation Professor of Controls Engineering in Mechanical Engineering. He is co-director of WEMPEC.

In 1966–67, Dr. Lorenz did his junior years studies in electromechanical engineering at the Monterrey Institute of Technology in Monterrey, Mexico. In 1969–70, Dr. Lorenz did his masters thesis research at the RWTH Aachen University, Germany. From 1970 to 72, he worked for the U.S. Army as a systems test engineer at Aberdeen Proving Ground, Maryland. From 1972 to 1982 he was a member of the research staff at the Gleason Works in Rochester, New York, working on high-performance drives and synchronized motion control. He has been a guest professor at the Catholic University of Leuven, Belgium; the RWTH Aachen University, Germany; and at the Tokyo Institute of Technology, Japan.



His teaching interests focus on physics-based methods for controls design and estimation and their accurate digital implementation in electric machines and power electronics.

His research interests include motor design for self-sensing and loss-minimizing control, power electronic device junction temperature estimation, real-time control of temperature/strain in power electronic modules, deadbeat-direct torque and flux control for loss manipulation without compromising torque dynamics, and wireless power transfer technologies. He has authored more than 300 technical papers, has won 32 IEEE prize paper awards, and holds 26 patents.

Dr. Lorenz was an elected member of the IEEE board of directors 2005–06, the IEEE Industry Applications Society (IAS) president 2001, a distinguished lecturer of the IEEE IAS 2000–01, and awarded the 2003 IEEE IAS Outstanding Achievement Award, the 2006 EPE PEMC Outstanding Achievement Award, the 2011 IEEE IAS Distinguished Service Award, and the 2014 IEEE Richard Harold Kaufman Award.

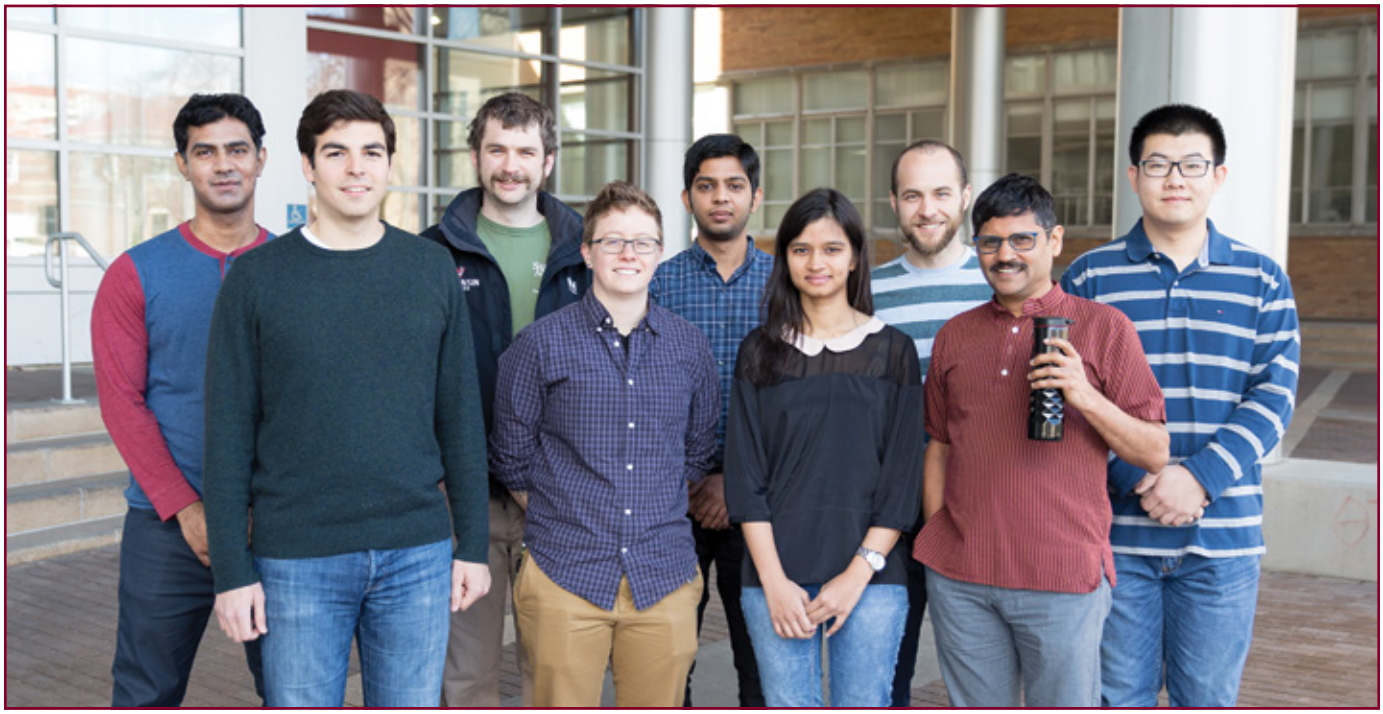
GIRI VENKATARAMANAN

Professor
Department of Electrical and Computer Engineering

Giri Venkataramanan studied electrical engineering at the Government College of Technology, Coimbatore, India, and received his BS from the University of Madras, India. He moved to the United States to continue his studies and obtained his MS and PhD from the California Institute of Technology and the University of Wisconsin–Madison, respectively. Upon graduation, Dr. Venkataramanan moved west to take a teaching appointment at Montana State University–Bozeman. For seven years, he taught electrical engineering, developed several courses, and designed and commissioned power electronics, electric machines and drives lab.

Dr. Venkataramanan returned to UW–Madison as a faculty member in 1999. Since his return, he has played a leading role in expanding and modernizing the laboratory infrastructure, while continuing to direct research in various areas of power conversion. He has been actively conducting research in the areas of power converter topologies, microgrids, wind power systems, grid interface for electric vehicles and utility scale power electronic systems.

Dr. Venkataramanan complements his interests in power electronics with educational activism both inside and outside the classroom, developing hands-on student projects aimed at increasing learning effectiveness and addressing energy development issues. In recognition of his teaching excellence he won the Gerald Holdridge Teaching Award, the 2008 Benjamin Smith Reynolds Award for Excellence in Teaching, and the UW–Madison Chancellor's Award for Distinguished Teaching. In recent years he has been leading various research and education activities related to sustainability of the human enterprise in collaboration with faculty members across campus, including computer sciences, urban and regional planning, agricultural and applied economics, education, and curriculum both nationally and internationally.



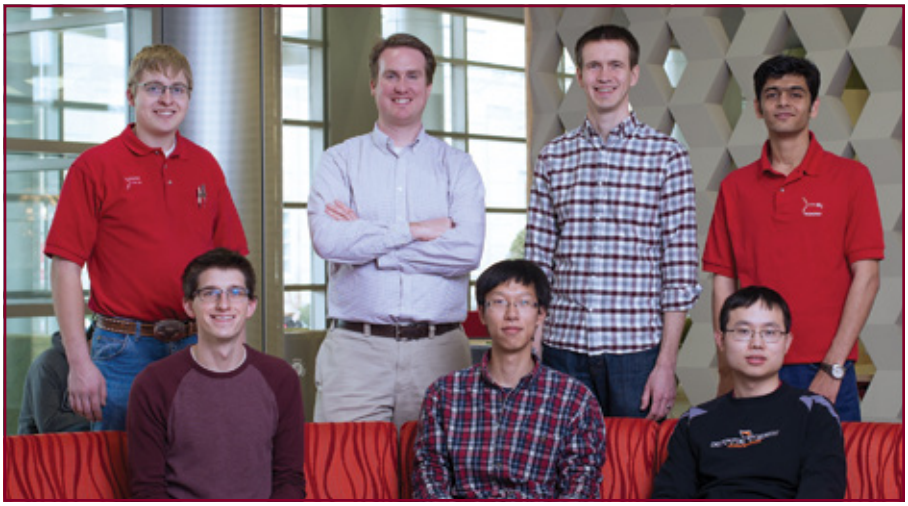
Daniel C. Ludois

Assistant Professor
Department of Electrical and Computer Engineering

As a WEMPEC faculty member, Dr. Ludois's research focus has been on broadening the horizons of capacitive coupling via new dielectric materials and high-frequency power electronics. Applications include compact wireless power transfer for mobile and rotating equipment, brushless electric machine bearing current mitigation, electrostatic (e-field) machinery, and dual energy cores for integrated inductor-capacitors. In 2015, Dr. Ludois's efforts in electrostatic machinery earned him a National Science Foundation CAREER Award, one of the highest honors to be bestowed at the beginning of a career. This high-risk-high-reward work focuses on the removal of steel and copper in electric machines, transitioning entirely to plastic and aluminum for lower cost and ease of manufacturing. Dr. Ludois has published ~30 papers and has two issued and six pending patents. He currently teaches ECE 411 "Introduction to Electric Drives" and ECE 711 "Dynamics and Control of AC Drives" and advises two MS and four PhD students.

Prior to joining WEMPEC as a faculty member, Dan Ludois attended Bradley University in Peoria, Illinois, where he received his BS in physics in 2006. The focus of his undergraduate research was the use of scanning tunneling microscopy (STM) to study semiconductor surface science at the atomic scale. After Bradley, Dan enrolled at the University of Wisconsin –Madison to pursue a PhD in the applied physics area of electrical and computer engineering. During his first year Dan was hired as a TA for Dr. Lorenz's ECE 377, Electrical & Electromechanical Energy Conversion, and realized this could be his career. He joined WEMPEC in 2007 with Dr. Venkataramanan as his PhD advisor. During his time as a WEMPEC graduate student, Dan focused on the modeling and experimental validation of modular multilevel converters (MMCs), receiving his PhD in 2011 for his thesis "Wind Farms with DC Collection Networks Using Bridge of Bridge Multilevel Converters."

During graduate school Dan pursued his own ideas focused on developing national rural electrification strategies and early concepts in capacitively coupled power conversion. From 2008 to 2011, Dan formed teams with his fellow WEMPEC students and faculty to push these concepts forward. Dan's efforts won numerous awards, including the Climate Leadership Challenge Grand Prize, IEEE President's Change the World Competition Outstanding Student Humanitarian Award, UW Engineering Expo, the Burrill Business Plan Competition, among others, garnering more than $135,000 and research incubator space to advance his ideas. After graduation in 2011, Dr. Ludois and his partners used the winnings to cofound Madison start-up C-Motive Technologies Inc., a company that focuses on capacitively coupled power conversion solutions, mainly for machines. In 2012, Dr. Ludois completed the Weinert Applied Ventures in Entrepreneurship (WAVE) certificate within the UW MBA program, received a WARF Innovation Award for his electrostatic machinery patent, and C-Motive placed 2nd in the Wisconsin Governor's Business Plan Contest. In 2013, Dr. Ludois returned to UW–Madison as an assistant professor in the ECE department along with WEMPEC and now serves in an advisory capacity to C-Motive as chief science officer.



Bulent Sarlioglu

Assistant Professor
Department of Engineering Professional Development
Department of Electrical and Computer Engineering

Dr. Bulent Sarlioglu earned a PhD from the University of Wisconsin–Madison, an MS from University of Missouri–Columbia, and BS from Istanbul Technical University, all in electrical engineering. He joined UW–Madison as an assistant professor in 2011. His research advisors were Dr. Thomas Lipo for his PhD and Dr. Richard Hoft for his MS.

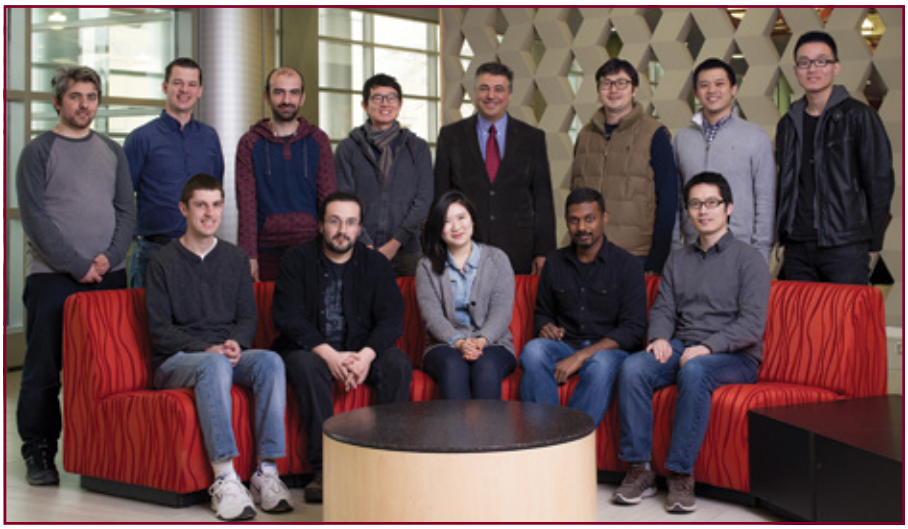
Dr. Sarlioglu's interests include electric machines and power electronics. Current research includes novel flux switching permanent magnet machines and characterization and control of internal permanent magnet machines. His research team also focuses on design and optimization of high-speed machines. In the power electronics area, his research team exploits the wide bandgap devices for use in power electronic converters and addresses many new challenges including EMI/EMC and gate drive design. His research is currently funded by NSF, DOE, and industry. Most recently, he received the Best Paper Award at the 2015 IEEE ITEC and best-presentation recognition at the 2014 IEEE IECON conferences.

Dr. Sarlioglu received the prestigious NSF CAREER award which provides funding to his research team for five years to work on an integrated motor and compressor drive. This approach will achieve self-cooling of the rotor and stator due to inherent gas flow, reduction in the axial length of the compressor, simpler and more robust mechanical design due to reduced axial length, and simpler bearing design due to reduced axial length. Dr. Sarlioglu also received other funding from NSF and DOE. The NSF GOALI project focuses on a novel low pole flux switching permanent magnet machine. The DOE project provides funding for researching grid-connected inverters, including vehicle-to-grid charging. All of these projects provide funding for student assistantships and research.

Dr. Sarlioglu has created many new short courses, including Introduction to EMI/EMC, Introduction to Energy Storage, AC Machine Design Fundamentals, PM Machine Design Boot Camp, Power Electronic Design Boot Camp, and Hybrid and Electric Vehicle Design Boot Camp. Dr. Sarlioglu believes that these courses play a key role for technology transfer from WEMPEC's teaching and research portfolio. He also developed new credit courses in the area of renewable energy and hybrid and electric vehicles in the ECE department.

Dr. Sarlioglu spent more than 10 years at Honeywell's aerospace division, most recently as a staff systems engineer, earning Honeywell's technical achievement award in 2003 and an outstanding engineer award in 2011. He contributed many internally or externally funded R&D programs and realization of many technology development programs for many platforms including Boeing 7E7 (787), Airbus A350, and A380.

Dr. Sarlioglu is the editor of IEEE *Electrification* magazine for electric airplanes. Currently, he is the vice-chair of IEEE Power Electronics Society Technical Committee on Vehicle and Transportation Systems and the secretary of the Industrial Applications Society Transportation Systems Committee. Dr. Sarlioglu is the inventor or co-inventor of 16 U.S. patents—three additional U.S. patents are pending.



Robert H. Lasseter

Professor Emeritus
Department of of Electrical and Computer Engineering

Robert H. Lasseter received his PhD in physics from the University of Pennsylvania, Philadelphia, in 1971. He was a consulting engineer at General Electric until he joined the University of Wisconsin–Madison in 1980. His research interests focus on the application of power electronics to utility systems. This work includes microgrids, interfacing distributed energy resources and renewable to the power distribution system, control of the power transmission systems through FACTS controllers, and the use of power electronics in distribution systems. For the last 10 years he has been the technical lead for the CERTS Microgrid test project at AEP. Professor Lasseter is a Life Fellow of IEEE and an IEEE distinguished lecturer on distributed generation.

CERTS is an organization of four national laboratories (LBNL, SNL, ORNL, PNNL) and PSerc. The Consortium for Electric Reliability Technology Solutions was formed in 1999 to research, develop, and disseminate new methods, tools, and technologies to protect and enhance the reliability of the U.S. electric power system. CERTS research covers three principal areas: real-time grid reliability management, reliability and markets, and distributed energy resources integration. Professor Lasseter is the technical leader of this third area for CERTS. Learn more at certs.lbl.gov/DER.html.

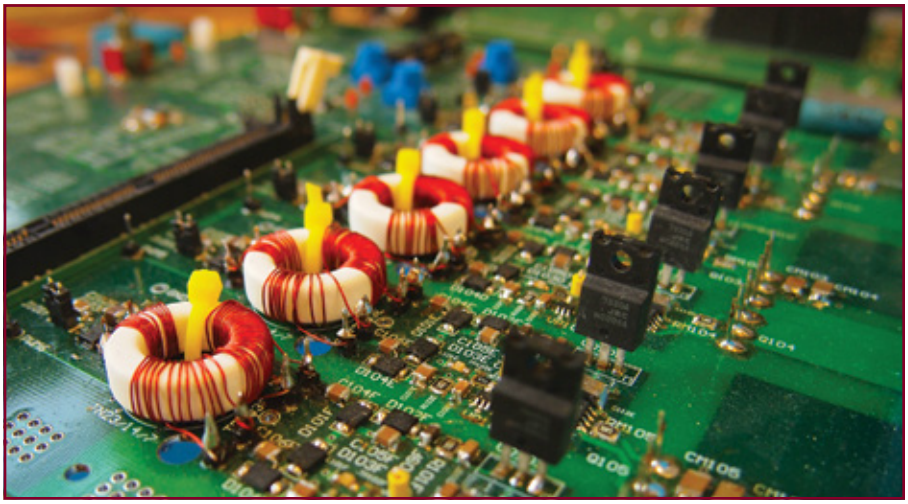
THOMAS A. LIPO

Professor Emeritus
Department of Electrical and Computer Engineering

Thomas A. Lipo is a native of Milwaukee, Wisconsin. He has spent his entire career in the technical field of solid state AC motor drives. He has BEE and MSEE degrees from Marquette University and a PhD from the University of Wisconsin–Madison. From 1969 to 1979, he was an electrical engineer in the Power Electronics Laboratory, Corporate Research and Development, General Electric Company, Schenectady New York, where he participated in some of the earliest work in this field. In 1979 he left GE to take a position as full professor at Purdue University. In 1981, he joined UW–Madison, where he co-founded the industry consortium WEMPEC and served for 28 years as its co-director and as the Grainger Professor for Power Electronics and Electrical Machines. From 2009 to 2013, he simultaneously served as World-Class Professor at Hanyang University in Ansan, South Korea. He has also held briefer positions at Sydney University, Cambridge University, Monash University in Melbourne, Australia, and Harbin Institute of Technology in Harbin, China. He was a Fulbright Fellow at the Norwegian University of Science and Technology, Trondheim, Norway, in 2008. He is presently both emeritus professor at the UW–Madison and research professor at Florida State University.

Dr. Lipo's contributions in the field of electrical machinery and power electronics are extensive, having published over 650 technical papers as well as 42 patents, five books, and eight book chapters. His impact factor on the Microsoft IP Citation Index in 2013 was the highest for the entire field of electrical engineering and second over all fields of engineering. According to Google Scholar he has had over 30,000 citations referring to his work. He has made pioneering contributions to emerging electrical machine topologies including flux switched machines, axial flux machines of many types, self-excited synchronous machines, open winding machines, and novel permanent magnet machines. His efforts in solid-state power converters include work on resonant converters, matrix converters, low switch count and reduced cost rectifiers and inverters to name a few.

Dr. Lipo is a Life Fellow of IEEE and received the Outstanding Achievement Award from the IEEE Industry Applications Society in 1986 for his work in motor drives, the William E. Newell Award of the IEEE Power Electronics Society in 1990 for contributions to power electronics, and the Nicola Tesla IEEE Field Award from the IEEE Power Engineering Society in 1995 for his work on electrical machinery. Dr. Lipo was elected as a fellow of the UK Royal Academy of Engineering (one of only about 25 U.S. members) in 2002 and a member of the U.S. National Academy of Engineering in 2008. In 2012 he was made a charter member of the National Academy of Inventors for his patents on AC machinery. In 2004 he received the Hilldale Award in Physical Sciences from the University of Wisconsin—the university's most prestigious award for scientific research and the only time in its more than 40 year history that an electrical engineering professor was selected for the award. In 2014 Dr. Lipo received the IEEE Medal in Power Engineering, the highest award presented by IEEE for research in the field of power engineering.



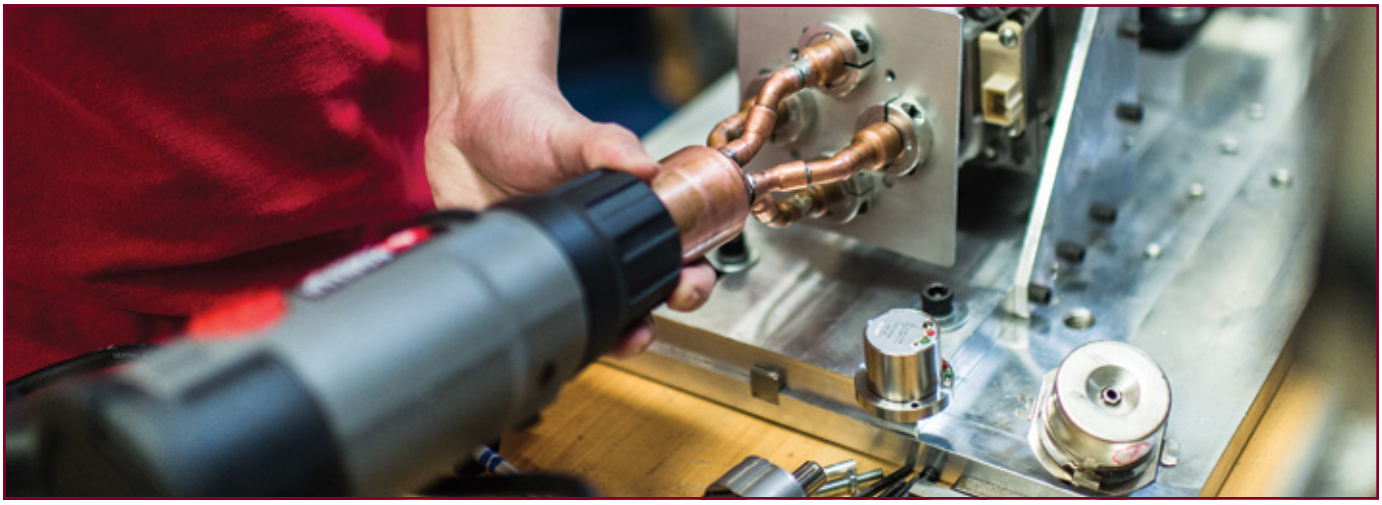
Donald W. Novotny

Professor Emeritus
Department of Electrical and Computer Engineering

Donald W. Novotny, IEEE Fellow, received his BS and MS degrees in electrical engineering from the Illinois Institute of Technology, Chicago, in 1956 and 1957, and his PhD from the University of Wisconsin–Madison in 1961. Since 1961, Dr. Novotny has been a member of the faculty at the University of Wisconsin–Madison, where he is currently Grainger Professor Emeritus of Power Electronics and co-founder and former co-director of WEMPEC. He retired from full-time activity in 1996 but continues teaching part-time.

From 1976 to 1980, he served as chairman of the Department of Electrical and Computer Engineering. He also served as an associate director of the University-Industry Research Program from 1972 to 1974 and from 1980 to 1993. He has been active as a consultant to many organizations and a visiting professor at Montana State University; the Technical University of Eindhoven, Eindhoven, Netherlands; the Catholic University of Leuven, Leuven, Belgium; and a Fulbright Lecturer at the University of Ghent, Ghent, Belgium.

Dr. Novotny's teaching and research interests include electric machines, variable frequency drive systems, and power electronic control of industrial systems. He is the coauthor of three textbooks on electromechanical systems; has contributed chapters on variable speed drive systems in two handbooks on electric machines and drives; and has published more than 100 technical articles on electric machines, variable frequency drives, and power electronic control of industrial systems. He has received 11 prize paper awards from the IEEE Industry Applications Society and other groups, and three awards for outstanding teaching from the University of Wisconsin–Madison, the College of Engineering, and the Department of Electrical and Computer Engineering. Other awards include the IEEE-IAS Outstanding Achievement Award in 1998, the 2009 IEEE-PES Nikola Tesla Award, and a Third Millennium Award from IEEE-IAS in 2000. In addition to his regular university teaching, he has been very active in continuing education through short courses and seminars for industry, IEEE tutorials, and video-tape courses for off-campus graduate study. He also served for twelve years as chairman of the Electrical Engineering Program for the National Technological University (NTU).



WEMPEC Staff

James W. Sember
Executive Director

James Sember has worked in the power electronics and power systems arena for more than 35 years. After obtaining his BSEE from Cornell University, he spent 15 years working on AC drive development engineering and engineering management. He gained extensive experience with controls and power electronics development and held an engineering leadership position in a multinational and cross-cultural product development environment.

Subsequently, he led product development for generators, automatic transfer switches, and generator paralleling switchgear. He obtained an executive MBA in 2002, after which he led a business division supplying medium-voltage UPS, multi-megawatt-scale grid-connected energy storage, and power electronics for reactive power compensation. He grew the business at a compound annual growth rate of 27 percent over five years and achieved profitability. He developed many state-of-the-art applications for grid-connected energy storage with a variety of battery energy storage technologies.

Mr. Sember has been associated with WEMPEC for the majority of his career as a sponsor. In 2013, he joined WEMPEC as its first executive director, while continuing to remain active with battery energy storage with a focus on lithium-ion batteries and systems. Power electronics is an intriguing and challenging combination of technologies. In addition to power electronics circuit design, the discipline includes power systems, machine design, machine control, analog and digital electronics, digital signal processing, and real-time embedded system control. Mr. Sember has done engineering work in all of these areas. He holds nine U.S. patents

Helene Demont
Administrative Director

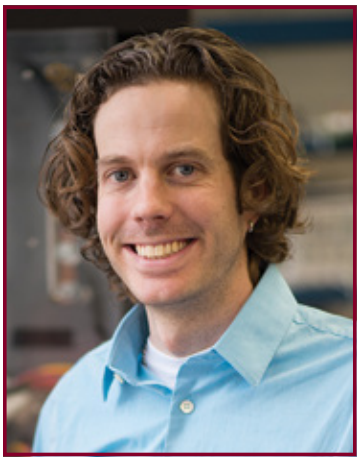
Helene Demont became the official WEMPEC administrative director on February 1, 2013, but she is not a new face to the WEMPEC family.

From 1986 until 2013 she was involved with our distance learning program, providing student support services for the 200+ off-campus students enrolled annually. Helene served as the liaison between off-campus students and the UW–Madison faculty and administration. Students kindly refer to her as *Mother Outreach*, as she provided assistance with every detail, making the process as seamless as possible.

These skills have transferred nicely to her new role with WEMPEC as she keeps track of 70 graduate students, 30 visiting scholars, eight faculty and an executive director.

Helene Demont had been involved with continuing engineering education since 1986. She has been active in the American Society of Engineering Education (ASEE), serving as general conference chair (2008), program chair (2005, 2000), division chair (2003–05), and board secretary (2000–03, 2007–2010). Helene was awarded the Joseph Biedenbach Distinguished Service Award in 2008 for her work and commitment to the Continuing Professional Development Division of ASEE. Helene was also given the University of Wisconsin–Madison campus Classified Employee Recognition Award in 1995.

She earned a certificate in distance learning administration from UW–Madison in 2008, her bachelor of science in public administration from Upper Iowa University in May 2011, and has begun a masters in adult education from Edgewood College. Helene has three grown daughters of whom she is very proud. In her free time, Helene teaches ballet classes to children and adults and has become an avid road cyclist who has completed several two-day, 150-mile rides to raise funds for Leukemia and Muscular Dystrophy research



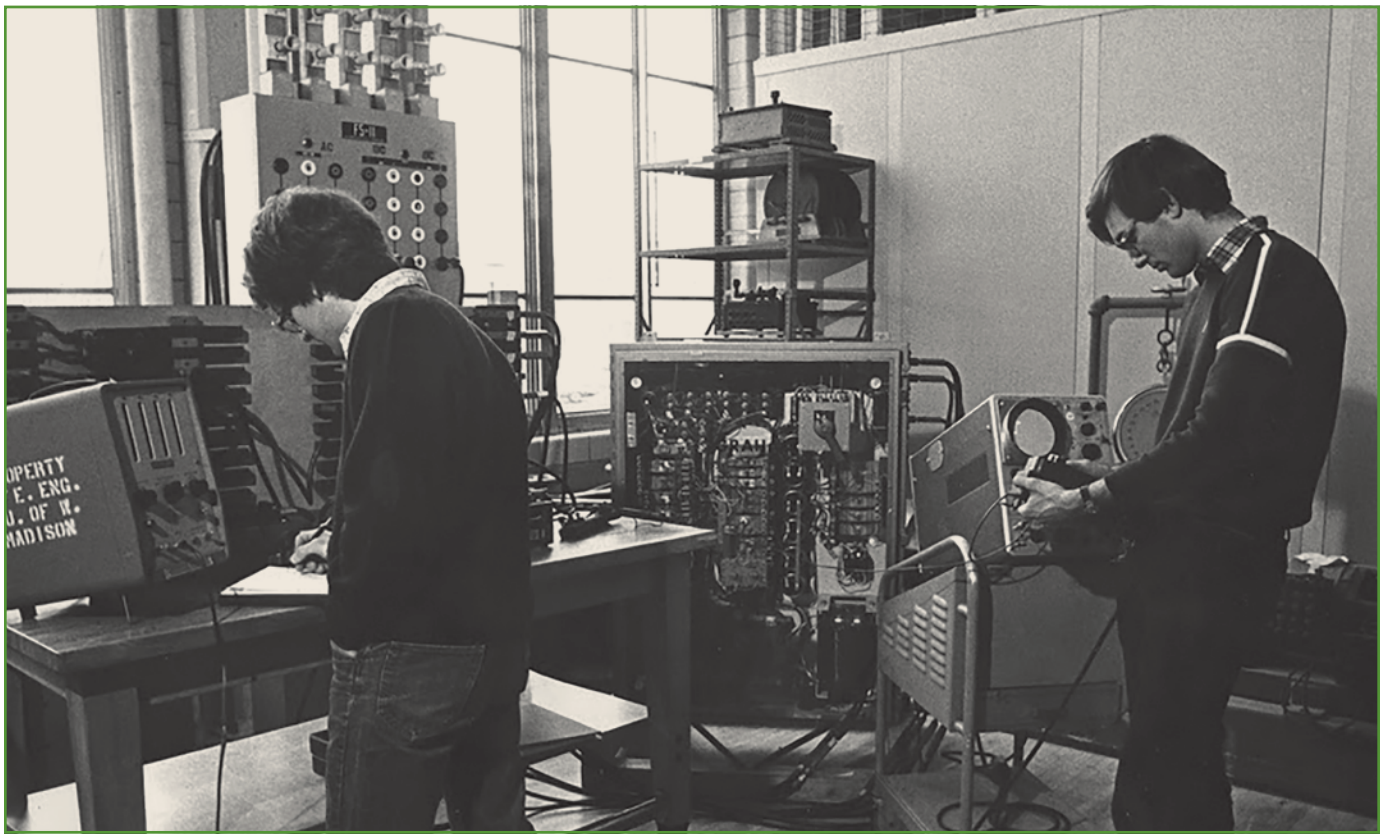
KYLE M. HANSON
WEMPEC Lab Manager

Kyle is a WEMPEC alum, having obtained his MS in mechanical engineering with Professor Lorenz in 2011. Since his graduation, Kyle spent four years with Ford Motor Company, where he gained extensive experience troubleshooting AC electric motors, embedded code, VB.net applications, feedback controllers, and electrical circuits as well as working with dynamometers for their electric vehicles. Kyle became a lead calibration engineer, responsible for production C-Max and Fusion electric machine characterization.

Most recently, Kyle worked for Bruker (formerly Prairie Technologies) where he was responsible for CE-marking, manufacturing, continuous improvement and new feature development for medical instrumentation.

WEMPEC student support staff.

35 Years of Collaboration and Innovation



WEMPEC lab, 1980s.

In the 1970s rising energy prices coupled with developments in the emerging field of power electronics were creating a major worldwide expansion in power engineering activity. The UW–Madison faculty in electric machines recognized the need to expand the UW program to become a dominant player in this growth area. To reinforce the need for this expansion, it was decided to enlist the support of Wisconsin industry, and in the spring of 1980 a preliminary proposal for an industrial support group was developed by Professors Donald W. Novotny and Norbert L. Schmitz. Initial contact was established with Professor Thomas A. Lipo (then at Purdue University) with the goal of attracting him to Wisconsin. With Professor Lipo's assistance, the proposal was modified and expanded, and he was named as the faculty member to be hired.

The preliminary proposal was discussed with a small group of industrial contacts consisting of Steve Bomba of Allen-Bradley Company and Roy Hyink and Ken Phillips of Eaton Corporation (then Cutler Hammer Inc). Discussion and modification of the proposal occupied several months and resulted in the final program plan used to create the Wisconsin Electric Machines and Power Electronics Consortium (WEMPEC). The program plan outlined the goals, administrative structure, and operation of the consortium and has served with remarkably few changes to the present time. Incorporating educational, research, and service components, the overall program was designed to create a close working relationship between program faculty, students, and industrial sponsors. Emphasis was on *generic* research projects "of a basic and widely applicable nature" and means for rapidly communicating the results to the sponsors. Expanded programs of resident instruction and continuing education courses were also emphasized. The Wisconsin Alumni Research Foundation (WARF) was designated to handle any patents developed in the program. The sponsor contribution was set at $5,000 per year

with a maximum of three sponsorship units available to a single company.

The program was formally initiated in January 1981 with three sponsors: Allen Bradley Co.mpany, the Graham Company, and Eaton/ Cutler Hammer. Professor Lipo joined the faculty in January 1981, and by the end of the year, six additional companies became part of the list of charter sponsors. The first WEMPEC Review Meeting was held at Union South on April 21, 1982, at which time there were 12 sponsors. The program summary for the first 15 months of operation listed nine graduate students, two visiting professors, and three visiting scholars. A total of 11 WEMPEC reports were completed, three short courses were offered, and a total of 24 projects were started, completed or continued during the period. There were 34 industrial representatives in attendance at this first review meeting.

From 1982 to 1985, the program grew in terms of industrial sponsors, students, and visiting professors and scholars. The first MS degree (Tim Rowan) was awarded in 1982 and the first PhD (Daniel Kirschen) in 1985. The focus of the research within WEMPEC during this early period was primarily on electric drive systems with much of the work related to energy conservation and efficiency improvement. High performance, field oriented drives were also a major developing technology and a number of research projects and tutorial reports were devoted to this area.

In December 1984, Professor Robert D. Lorenz joined the UW Department of Mechanical Engineering faculty. Through an affiliate appointment in the Department of Electrical and Computer Engineering (ECE), he became a WEMPEC faculty member, allowing expansion of WEMPEC into motion control applications and control design. In the spring of 1985, Professor Deepak M. Divan joined the ECE faculty and also became a member of the WEMPEC faculty, adding expertise in power electronics. As a result of these additions, WEMPEC attracted participation from electronic equipment manufacturers, control specialists, and machine tool companies. The scope of WEMPEC activity was again expanded to include power system applications in 1988 by the addition of Professor Robert H. Lasseter.

The 10-year anniversary meeting, held on April 17, 1991, was attended by more than 140 representatives from 41 companies. During the tenth year of operation there were 47 graduate students in the program, nine of whom received degrees and a total of 52 separate research projects were

> Danfoss continues to benefit from our relationship with WEMPEC; we have been a sponsor for 20+ years. WEMPEC research is internationally renowned and relevant to our research and development. Danfoss values our WEMPEC alumni and our continued engagement with WEMPEC students, faculty, and staff.
>
> *—Tom Flygare*
> *Danfoss Power Electronics*

WEMPEC lab, 1990s.

listed for the year. The new Grainger Electric Machines and Power Electronics Laboratory, funded at a level of nearly $1 million (with more than $600,000 from The Grainger Foundation), was dedicated at the meeting. The laboratory served very well with no major modifications until the laboratory improvement efforts initiated in 1998.

Over the first 10 years of operation, a total of over $1.6 million in sponsor contributions provided the base funding for a program that had grown to be one of the largest of its kind in the U.S., involving more than 80 different graduate students and awarding more than 40 advanced degrees.

By 1993, the program had reached a size where full-time administrative support was essential and Ms. Kathy Torok was hired as an administrative assistant. She began the newsletter *WEMPEC Review*. She continued in this position until October 2000, when Ms. Bonnie Johnson filled her position beginning in January 2001. The WEMPEC library and conference room were completed in 1994, providing both a research library and space for meeting with the many company representatives coming to campus to discuss projects and meet with students.

In June 1996, Professor Novotny announced his retirement. He has continued to participate in WEMPEC activities by teaching on campus and outreach courses and participating in WEMPEC staff meetings.

The five years between 1996 and 2001 were a time of rapid change of personnel, organization, laboratory facilities, and technology. Professor Deepak Divan left the university, first on leave and then permanently in August 1998, to start and run his own company. Randy Gascoigne, who managed the WEMPEC laboratory from 1988 to 1995 and served as a consultant until 2000, also left to be part of Professor Divan's start-up company. In the fall of 1998, Professor Thomas M. Jahns joined the Department of Electrical and Computer Engineering and the WEMPEC program. In the fall of 1999, Professor Giri Venkataramanan accepted a position, bringing the number of WEMPEC faculty back up to the pre-1996 level of five professors. Ray Marion, who had participated in the laboratory on a part-time basis, became the lab manager upon the departure of Randy Gascoigne.

From August 1998 to July 2008, WEMPEC participated with Virginia Polytechnic Institute and three other schools in an NSF Center called the Center for Power Electronic Systems (CPES). Professor Lipo served as the CPES Campus Director for UW–Madison and Professor Lorenz and Professor Jahns were technical thrust area leaders. Many WEMPEC students participated in CPES projects and in other CPES educational and research activities. WEMPEC sponsors were automatically an associate member of CPES. At this time, the WEMPEC sponsor contribution was increased to $10,000 to better reflect

> The WEMPEC program offers an incredible opportunity in terms of classroom education, hands on experience, and networking with industry leaders. A critical mass of first-class students, faculty, and staff provides a powerful and truly unique academic experience. From an industry perspective, this combination produces graduates who are experts in theory and applications as well as positive members of an organization.
>
> *— Dr. James McFarland (PhD 2015)*
> *Generac Power Systems*

First WEMPEC inverter drive, 1982.

First Grainger instructional lab, 1990–2000.

increased graduate student stipends and other rising costs.

Professor Annette Muetze accepted an appointment as assistant professor in May 2004 and became a WEMPEC faculty member. Professor Muetze's area of interest was electric machine design and analysis as related to electric drives. In July 2004, Professor Bob Lasseter retired, but has continued his research in the area of microgrids with only limited participation in WEMPEC. Randy Gascoigne rejoined the WEMPEC program in 2004 with responsibility for the second generation laboratory upgrade funded by the Grainger Foundation.

During the evolution and growth of WEMPEC, the teaching program incorporating regular credit courses, credit and noncredit outreach (now distance learning) courses, short courses, and tutorials has grown and developed to keep pace with technology and the needs of students and sponsors.

The number of regular credit courses increased from seven in 1981 to 19 in 2010 and is presently 21. The first videotaped outreach course was produced in 1984; by 2010 there were 16 WEMPEC courses available through the outreach program. In September 2010, the WEMPEC outreach (distance learning) program became formally managed by the College of Engineering's Engineering Professional Development (EPD) as an online degree program. In 2015, a new Capstone Certificate Program was introduced and has seen enrollment of 30 students in the first year. In the past five years, the number of students taking online degree courses has become roughly equal to the number of on-campus students. WEMPEC faculty have published six textbooks over the 35 year duration of WEMPEC and, in addition, more than 50 sets of the recorded lectures of the distance-learning credit courses have been sold or rented for use as in-house courses by WEMPEC sponsors and other organizations.

Significant events in the 5 years preceding the 30th Anniversary Annual Review Meeting May 18–19, 2011, include the retirement of Professor Lipo in 2008 after a distinguished 46-year career in industry and academia. He remains active in WEMPEC research and continues his worldwide travels. Other events include completion of the second generation test stands in the Grainger Laboratory, the termination of WEMPEC faculty participation in CPES as that program reached the end of its 10-year life, and the departure of Professor Annette Muetze to accept a position in England. There was also a change in administrative support as Bonnie Johnson retired after eight years with WEMPEC, and was replaced by Sandra Finn in 2009.

The last five years have seen continued growing diversity of sponsors, coupled with a continuation of the number and quality of graduate students, visiting scholars and faculty from around the world. As costs rose, especially the cost of tuition for out of state students, sponsorship was increased to $15,000.

Many important personnel changes have occurred during this time. Three faculty members have been added: Professor Yehui Han in 2010, Professor Bulent Sarlioglu in 2011, and Professor Dan Ludois in 2013. Professor Yehui Han departed at the end of 2015 to pursue other interests. Helene Demont, having had a long involvement with WEMPEC through coordinating the distance learning program for 30 years, moved in early 2013 to succeed Sandra Finn as WEMPEC administrative director. An outside ad-hoc review committee identified the need for additional

administrative support to ease the administrative burden on the faculty directors. In 2013, Jim Sember was hired to fill a position as executive director with oversight of finances, operations, and other staff members. Ray Marion retired in January of 2016 after working in and managing the WEMPEC labs for more than 22 years. He was succeeded by Kyle Hanson, who is a 2011 graduate of the WEMPEC program.

Many important infrastructure improvements have also been made. In 2012, construction of the Wisconsin Energy Institute (WEI) building was completed. WEMPEC is able to make use of this state-of-the art building for research involving microgrids, advanced energy storage for grid and electric vehicle applications, power device reliability, as well as providing additional dynamometers. In 2014, Johnson Controls donated state-of-the-art battery cell testing systems, which reside in the WEI building. WEMPEC lab safety was improved by the addition of emergency stop push-buttons. Additional space in Engineering Hall was obtained for lab benches, graduate student and visiting scholar desks and a library/meeting room. In late 2014, GM offered to donate three high-speed state-of-the-art dynamometers that had been used to develop machines for electric vehicles. Two of the dynamometers are rated at 170 kW with speeds up to 15,000 RPM. The first of these larger high-speed systems was commissioned in late 2015 and has already been used by three projects. These systems provide WEMPEC with test capability for machines that is unprecedented in most other university research programs.

Through the addition of faculty and staff, WEMPEC has been able to expand contact with our sponsors. The monthly newsletter was revived with wider coverage of WEMPEC activities. More sponsors have taken advantage of the opportunity for a technology teview meeting with the WEMPEC faculty. These half day meetings provide the opportunity for a sponsor to discuss any technical concern they may have—ranging from immediate problems to multiyear technical road maps. These meetings are held in Madison with relevant faculty participation. Additionally, more students and sponsors are taking advantage of the opportunity for summer internships. These internships provide students with opportunities for significant real-world experience which build relationships for future hiring, as well as providing opportunities for technology transfer.

Over the 35 years of WEMPEC operation, approximately 120 PhDs and 280 MS degrees have been awarded. WEMPEC research activity has resulted in more than 1,500 individual project descriptions listed in the annual WEMPEC Program Summaries. The results of this research have been reported in more than 1300 WEMPEC Research Reports. In addition to the regular schedule of credit courses and distance learning courses, nearly 75 short courses have been offered over the 35-year period.

The international reputation of the WEMPEC program has attracted more than 120 visiting faculty members from all over the world to spend sabbatical time of three months or more in Madison. There have been an even larger number of visiting scholars including many postdocs and doctoral candidates who have spent time in the WEMPEC community over this same period. Many significant aspects of

We at GM are pleased to be an active WEMPEC member. There is no better institution than WEMPEC to lead and guide our thinking in electric drives. We continue to invest in our time and attention to WEMPEC, including the recent donation of three dynamometers to the UW labs. WEMPEC students consistently show great new possibilities as well as pragmatic advances in machines and controls. We rely on WEMPEC to staff our engineering groups, and through the outreach program, we continue the education of the GM team. WEMPEC has a culture of excellence and service that has served industry for 35 years, and we are looking forward with WEMPEC to create what will come next."

— Peter Savagian, General Director
General Motors Powertrain

Grainger Lab today.

WEMPEC research activity resulted from the interactions fostered by these visits.

All of this has been made possible by a cumulative total of over $17 million in sponsor contributions and by the enthusiastic support and countless hours of participation in seminars, individual meetings and attendance at annual meetings by the engineers and managers in our sponsors' organizations. The 35th year, with 90 sponsors and 70 on-campus graduate students—plus another 40 off-campus with their coursework delivered via the web—and over 75 active research projects, is far larger and stronger than any early vision and plan (or even the wildest dreams) for WEMPEC. The WEMPEC faculty, staff, and students are dedicated to continuing this tradition of excellence and program growth.

WEMPEC lab, early 2000s.

WEMPEC IN THE CLASSROOM

Campus Classroom

The WEMPEC faculty have developed and continue to evolve a full range of semester-long courses in the fields of electrical machines, power electronics, AC drives, power systems, renewable energy, and real-time control of electromechanical systems. During the 35 years since WEMPEC began, the growth of the faculty and financial resources and the increased number of students has resulted in an increase from seven courses in 1981–82 to the present 21 courses taught in cooperation with other faculty colleagues in the Electrical and Computer Engineering and Mechanical Engineering departments. Most of these courses are offered for credit as digitally recorded lectures through the University of Wisconsin–Madison College of Engineering Online Degree program, noted in the list below with asterisks. The following undergraduate courses are taught at least once each academic year:

* Denotes a course that is also offered as a credit course in the Online Degree Program

ECE 304—Electric Machines Lab
ECE 355—Electromechanical Energy Conversion*
ECE 356—Electrical Power Processing for Renewable Energy Systems
ECE 377—Fundamentals of Electrical and Electromechanical Power Conversion*

In addition, Professor Giri Venkataramanan has been engaged in teaching courses that offer undergraduates the opportunity to gain hands-on experience building power converters and renewable energy sources. These courses help attract new students into the power engineering field.

Starting with three courses in 1981–82, there are now a total of ten 400- and 500-level courses offered to both senior undergraduate and graduate students, three of which are laboratory courses. These are typically taught once per year or once every two years.

ECE 411—Introduction to Electric Drive Systems*
ECE 412—Power Electronic Circuits*
ECE 427—Electric Power Systems*
ME 446—Automatic Controls*
ME 447—Computer Control of Machines and Processes*
ECE 504—Electric Machines and Drive Systems Laboratory*
ECE 511—Theory and Control of Synchronous Machines*
ECE 512—Power Electronics Laboratory*
ME 547—Physics-based Modeling for Computer Control*
ECE/ME 577—Automatic Controls Laboratory*

There are currently seven courses regularly offered at the advanced graduate level, compared with two offered in 1981–82.

ECE 711—Dynamics and Control of AC Drives *
ECE 712—Solid State Power Conversion*
ECE 713—Electromagnetic Design of AC Machines*
ECE 714—Utility Applications of Power Electronics*
ECE/ME 739—Advanced Automation and Robotics*
ME 746—Dynamics of Controlled Systems*
ME 747—Advanced Computer Control of Machines and Processes*

Laboratory teaching is greatly enhanced by the Grainger Teaching Laboratory for Electric Machines and Power Electronics. This teaching environment is regarded as one of the best in the nation for electric machines, power electronics, and their integrated control. The laboratory is also used regularly to provide off-campus online degree students with an advanced laboratory experience by scheduling ECE 504, ECE 512, and ME/ ECE 577 at least once every two years during the summer.

WEMPEC has been a foundational institution in machines and drives for 35 years. I am fortunate to have been involved in the program for the past 20 years, both as a graduate student and as part of a sponsoring company. WEMPEC has been one of the best sources for the next generation of engineers making a difference in industry.

—Nick Nagel (PhD 1999)
Triumph Aerospace Systems

Summer Lab for distance learning students.

Distance Learning Classroom

Distance education continues to be a major priority of the WEMPEC faculty, providing a valuable benefit to the employees of WEMPEC sponsor organizations and engineers everywhere. The UW–Madison online degree program offers 19 of the 21 undergraduate and graduate courses listed in the preceding section via recorded lectures.

The ability to offer this broad range of online courses to off-campus students in the areas of power electronics, electric machines, control, and power systems makes it possible for working engineers to earn master's degrees at their home locations with a minimum of on-campus residency requirements. A few dedicated engineers continue on, using the online degree program as the basis for earning their doctoral degrees with their employer's support.

Some of the engineers who choose to use the online degree program to pursue advanced degrees are engaged in research projects under the supervision of one of the WEMPEC faculty members. These research projects are typically conducted using employer laboratory facilities and often involve research topics related to the engineer's primary area of job responsibility. As demonstrated by a long track record of successful online degree students, these research projects often lead to innovative technical contributions that mutually benefit the student employee as well as the employer.

In addition to the online degree program, another popular online program is now available that offers practicing engineers an opportunity to earn a Capstone Certificate in Power Conversion and Control. This certificate is offered to online students who successfully complete a fixed sequence of three graduate courses in power electronics, drives, and controls. In addition to the value of this certificate as a respected credential for practicing engineers in their workplace, this capstone program also serves as a critical stepping stone for students wishing to apply for admission into our online master of science degree programs in either electrical engineering (power engineering) or mechanical engineering (controls).

WEMPEC courses offered via the online degree program are updated regularly to ensure that students are exposed to the most recent developments in each of the key areas of power technology. Students view recorded lectures at times and locations that fit their schedules, while completing course assignments and tests on schedules comparable to those of their on-campus counterparts. Arrangements are made to ensure convenient access to the responsible WEMPEC faculty member via telephone and email for all course-related questions. Live sessions are also offered by TAs and faculty depending on the course.

For complete program and course information, visit the Department of Engineering Professional Development (EPD) Online Degrees and Capstone Certificates website: epd.wisc.edu/online-degrees. You can also directly contact Daryl Haessig, program manager of the power area online degree and capstone certificate programs, to discuss any questions regarding program and course options, at daryl.haessig@wisc.edu or by telephone at 608-262-8819.

Lab tour for Short Course participants.

Short Courses

One of the longest and deepest traditions surrounding the University of Wisconsin is the Wisconsin Idea, which encompasses a general principle: that education should influence people's lives beyond the boundaries of the classroom.

In the spirit of the Wisconsin idea, WEMPEC faculty actively engage and teach in short courses that are provided by the University of Wisconsin–Madison Department of Engineering Professional Development. The materials are specially created to benefit the participants with the most up-to-date and relevant information and they include the most recent teaching material and research outcomes from WEMPEC faculty. Other speakers are invited from industry and national labs with high credentials to teach in these short courses as well.

Under the leadership of Professor Sarlioglu, WEMPEC's short course portfolio increased from roughly four short courses to more than 10 over the last five years. The new courses in the area of power conversion have increased in both breadth and depth and include Power Electronics Design Boot Camp, AC Machine Design Fundamentals, Introduction to Electrical Energy Storage, Introduction to EMI/EMC, Hybrid and Electric Vehicle Boot Camp, High Speed Electric Machine Design (on-site), and Introduction to Electric Machines and Drives.

The short courses are typically taught over three or four days and are held on the Madison campus. On-site and shorter versions of these courses are also held at company locations if requested. In addition to presentations in these short courses, participants are provided in-class hardware and software demonstrations and a tour of the WEMPEC labs.

WEMPEC sponsors receive a discount to attend short courses. You can find more information about the short courses scheduled for the coming months via links on the WEMPEC website (www.wempec.wisc.edu) or EPD website (epd.wisc.edu). You are invited to direct your questions to Bulent Sarlioglu at sarlioglu@wisc.edu or 608-262-2703.

RESEARCH AREAS

WEMPEC research focuses on three major areas: Advanced Machines, Power Converters, and Controls & Sensor Technology, with significant investigations in other areas as well.

WEMPEC's objective is to perform the highest quality long-term research that results in technology advancements that lead to future industrial growth. WEMPEC research seeds long-term technological developments and discoveries that are years ahead of commercially available products. WEMPEC leads the world in pushing the envelope in machines, converters, and controls in unique synergistic relationships to achieve new and innovative technology.

Every time I have the opportunity to visit WEMPEC I learn a lot. I enjoy my time and I love WEMPEC!

—Dr. Xiaochuan Jia
GE-Aviation

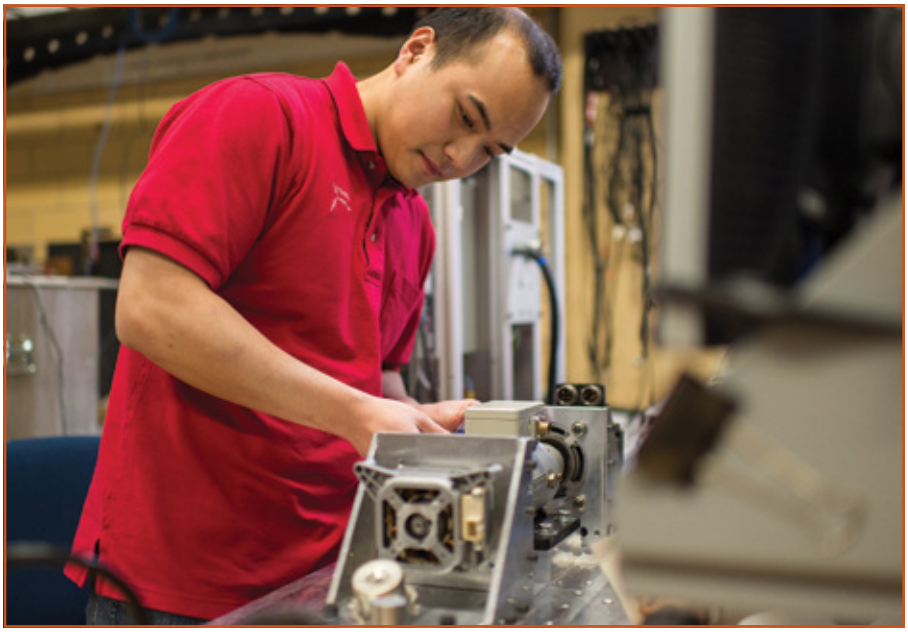
ADVANCED MACHINES

Electric machines are finding ever-expanding applications and continue to be a central focus of attention for WEMPEC because of the critical role they play in producing and using electric energy. Electric machine research at WEMPEC has earned an international reputation for its long history of groundbreaking innovations that span a wide spectrum of new topologies ranging from axial-airgap machines to double-airgap machines and, more recently, electrostatic machines.

Permanent Magnet (PM) Machines

WEMPEC faculty members have pioneered the development of interior PM (IPM) machines that are used in nearly all hybrid- and battery-electric passenger vehicles now in commercial production. Major technical progress has also been achieved in other important areas including the development of modular, fault-tolerant PM machines that are far less vulnerable to potentially crippling fault conditions, and new PM machine topologies that minimize torque ripple or minimize rare-earth magnet material while delivering world-class torque density characteristics.

Other work is under way pursuing innovative approaches to designing PM machine stators and rotors that reduce losses and improve thermal management. For example, prototype axial-field machines have been realized using aluminum foil windings that are competitive with copper wire windings, and coordinated electrical, magnetic, and thermal modeling activities are under way to establish practical design guidelines. Rotating heat pipes are also being developed for insertion into PM machine rotors to significantly improve the cooling of thermally limited magnets that are often buried deep inside.



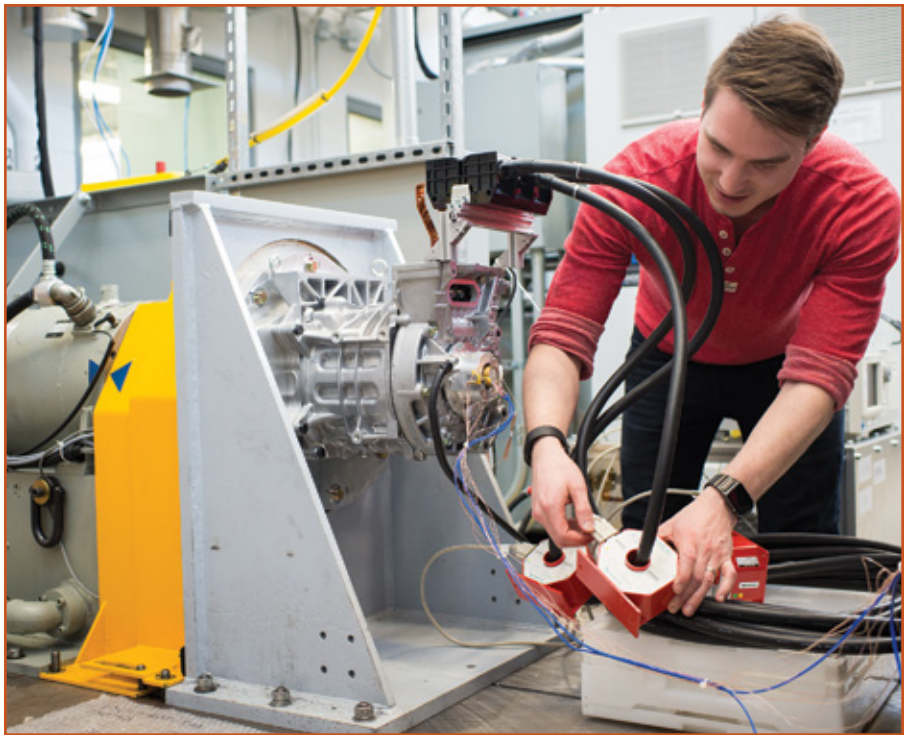
PM machine short-circuit fault testing.

Flux Switching PM Machines

WEMPEC is actively working on novel configurations of flux switching PM machines that offer special performance capabilities by moving the magnets to the stator. As a result, the rotors of these machines consist only of stacks of steel laminations, yielding rugged rotor structures suitable for high-speed operation that are similar to those found in switched reluctance machines. Both radial and axial flux switching machines are being investigated. Candidate applications include integrated machine-compressors that combine electromagnetic and fluid dynamic design elements into a single physical structure.

Variable Flux PM Machines

WEMPEC faculty members have also pioneered variable-flux IPM machines that can achieve very significant loss reduction in cyclical applications by varying the magnet airgap flux during operation. This airgap flux variation has been achieved by designing machines that intentionally cross-couple the leakage flux or actively manipulate the PM magnetization state during operation. These machines are designed to enable variable flux and variable magnetization as key manipulated states for control. As part of this new class of PM machine technology, flux-intensifying IPM machines have been developed that reduce PM materials and losses in duty cycle applications when compared to classical flux-weakening IPM machines



Dynamometer-based machine testing.

Wound-Field Synchronous Machines for Traction Applications

Interest in applying wound-field synchronous machines (WFSMs) as electric vehicle traction motors has revived. WFSMs have several potentially significant advantages over state-of-the-art IPM synchronous machines and induction machines. These include reduced cost from the removal of rare earth permanent magnets, higher efficiencies though power factor improvements and loss-optimized field control, and improved safety through field control during inverter fault conditions. Promising wireless power transfer techniques for rotor field excitation have been developed for these machines.

Electrostatic Rotating Machinery

WEMPEC is a pioneer in the development of innovative electrostatic rotating machines. These machines may be injection molded or 3D printed using plastic and aluminum, drastically reducing materials and manufacturing costs. Applications of particular interest are low-speed direct drive machines with dielectric fluid-filled airgaps, as well as machines that can losslessly hold their positions under load for long periods of time, overcoming limitations that have long plagued electromagnetic machines. WEMPEC research has advanced the torque density of rotating electrostatic machines to the point that they are now comparable to air-cooled NEMA frame induction machines. Advances expected during coming years in dielectric materials and geometric optimization will enable designs that meet or exceed the capabilities of air-cooled PM machines.

POWER CONVERTERS

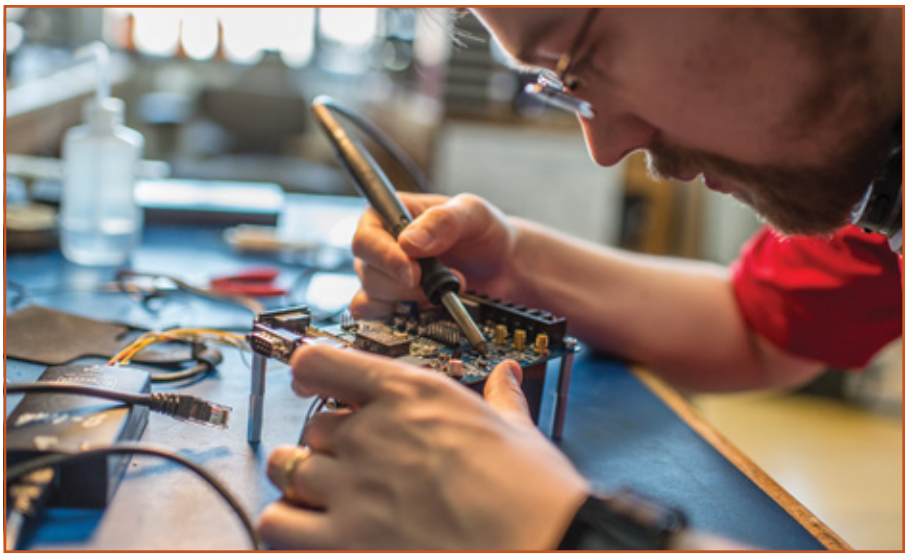
Converter Topologies

Modeling and development of power converter topologies for a variety of applications continues to be a major focus for WEMPEC research. The development of higher-speed power semiconductor switching devices that can reach higher power levels increases the switching stresses on components and reinforces the need for soft-switching techniques, originally pioneered by WEMPEC, to manage the undesirable dynamics. Ongoing work in this area includes the introduction of an entirely new approach for high-frequency dc-to-dc power conversion using capacitor coupling to replace transformer coupling and the introduction of Stored Energy Modulation or SEM. Application of SEM to drive applications reduces the DC link capacitance to fractions of a microfarad from thousands of microfarads.

Early work on the development of matrix and multilevel converters laid the foundation for more recent work in the area of vector switching AC-AC converters and modular multilevel converters. These have led to optimized topologies and various design-oriented models for applying reactive components in order to achieve robust performance.

Power Electronics Integration

WEMPEC is taking advantage of the availability of wide-bandgap silicon-carbide and gallium-nitride power semiconductor switches to achieve breakthroughs in power electronics that will enable future power converters that are smaller, lighter, and more environmentally rugged than anything that is available today. Projects are under way to demonstrate higher levels of modularization and physical integration of power electronics into loads or sources. These features are becoming increasingly important for a wide variety of important applications ranging from motor drives to batteries and solar PV arrays. WEMPEC research in this area is enabling new approaches for gate drive designs, efficiency characterization, and understanding and mitigating EMI/EMC aspects of these devices. In addition, new approaches are being developed for implementing fault-tolerant capabilities in machine drives that are valuable for use in everything from renewable energy systems such as wind-turbine generators to electrified propulsion for land, sea, and air transportation. Fault tolerance is particularly critical for demanding applications such as flight-critical aerospace pumps and actuators where disabling failures cannot be tolerated.



Construction of control card for integrated modular motor drive (IMMD).

Component Integration

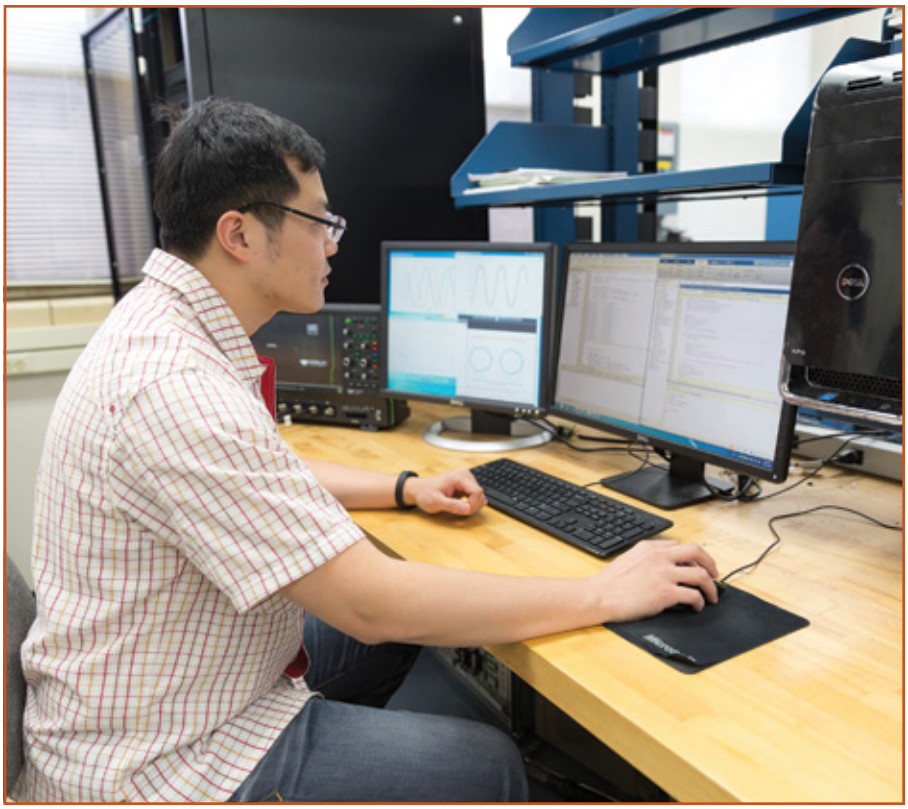
The key to reducing the size and cost of power conversion equipment is achieving higher levels of integration of components and structures. Passive components such as inductors and capacitors are fundamental components of nearly all power electronic conversion systems. WEMPEC is working on an innovative approach to a highly integrated inductor (L) and capacitor (C) design by storing magnetic and electric field energy in a common volume, constituting a dual energy core (DEC). The DEC enables a four-terminal integrated LC device that may be applied in nearly any AC or DC circuit configuration since its characteristics appear as decoupled lumped elements.

CONTROLS & SENSOR TECHNOLOGY

Research in advanced controls constitutes the third major thrust of the WEMPEC program that ties together advanced machines and power converters. In the early days, WEMPEC faculty led the way in education and application of flux vector control and in development of flux observer and current regulator technologies. The concept of *form follows function* has inspired the adoption and integration of goals for self-sensing-based control, dynamic loss minimization control, dynamic loss partitioning control, and integration of these controls with next-generation electric machine design.

Deadbeat Control with Design for Dynamic Loss Manipulation

WEMPEC development of deadbeat-direct torque and flux control (DB-DTFC) enabled the fastest and smoothest possible torque dynamics with virtually independent control of flux linkage. This research set the stage for development of flux linkage control for purposes of self-sensing, loss partitioning, loss minimization, loss utilization for braking, and other beneficial results, all without affecting the torque dynamics. WEMPEC research has also demonstrated that machines can and should be designed with these goals in mind, and that machines designed for loss-minimizing control are crucial to achieving their full energy savings potential in a wide range of load cycles. WEMPEC research has also developed real-time dynamic loss models for machines that are needed to exploit the loss reduction capability of DB-DTFC.



Designing self-sensing machine.

Self-Sensing Control & Design for Self-Sensing

WEMPEC has been a leader in design of electric machines to be sensors and power converters, such as design for self-sensing. Self-sensing design methodologies for induction machines, flux-weakening and flux-intensifying IPM machines, and surface PM machines have been developed and demonstrated. WEMPEC research has demonstrated that machines can be designed for self-sensing without compromising power conversion capability.

Injection-based self-sensing control for high dynamic stiffness control at zero and very low speeds using both rotating and pulsating voltage vectors was pioneered by WEMPEC research more than two decades ago. Classical voltage injection or its dual, current injection-based methods for self-sensing have generally all introduced some form of torque ripple. WEMPEC has more recently developed flux linkage injection-based self-sensing methods (based on DB-DTFC) that should systematically produce no torque ripple.

WEMPEC research has also developed self-sensing methods in which complex spatial harmonic content is used as part of the saliency tracking. This has been shown to systematically improve the accuracy of self-sensing.

The current research is exploring how digital image tracking methods can be used to advantage to significantly improve accuracy.

Power Device Dynamic Thermal Sensing & Control

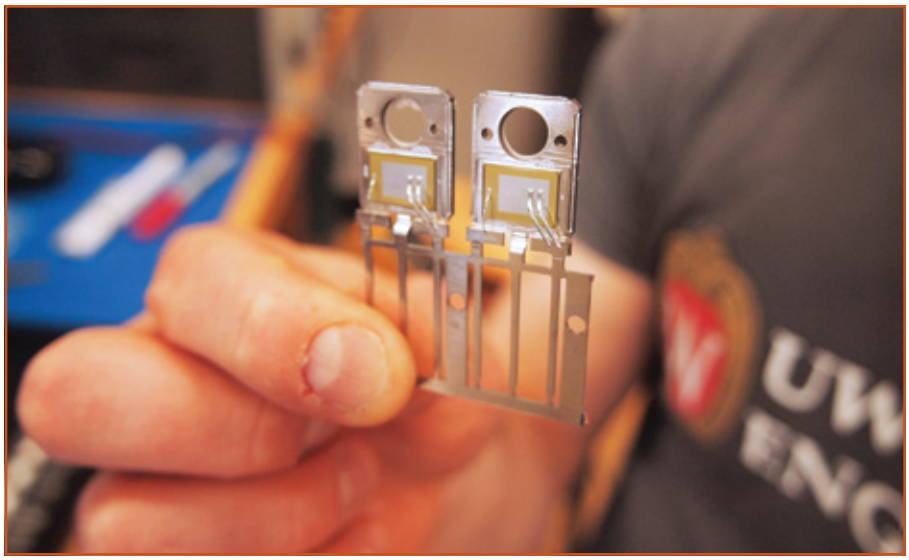
WEMPEC has had a strong focus on reliability in power electronics based on power cycling. Observer-based methods using only low bandwidth baseplate temperature sensors can be substantially improved by using high bandwidth Tj sensing. Control methods for the change in junction temperature (ΔTj) using integrated sensors have been demonstrated but have been limited by the lack of accurate, widely applicable methods for integrated Tj sensing. WEMPEC research has developed several generations of non-invasive Tj sensing that are now being integrated into active ΔTj control to mitigate the limitations of the current technology.

For non-invasive Tj sensing on devices and for general control of the converter, current is a key variable to sense. WEMPEC has been a pioneer in integrating sub-millimeter-sized point-field detectors such as GMRs into strategic locations of highly integrated power modules to enable control of gate and phase currents, junction temperature and speed.

Since device and interconnect strain is a key cause of failure in power modules, WEMPEC research has led in the development of technology to make accurate strain measurements in operating power electronic devices. This research is aimed at enabling accurate strain control to be integrated into the design focus for multiphysics integration of power devices.

Using Drives as Sensors

WEMPEC research has developed methods to enable drives to be used as a primary sensor for the system in which they are installed. The methods extract the systematic data contained in the drive signals sampled at PWM switching frequencies, without needing to employ higher precision sensors. The methods developed separate spatial content from temporal content and enable spatial or temporal synchronous averaging. This takes full advantage of the high sample rates to allow significant spatial or synchronous averaging, which in turn enables the use of adaptive methods to learn the system properties and decouple the normal system properties. The result is precision measurement of very small, but highly significant signals that would not be measurable by classical methods based on current signature analysis



Unencapsulated devices used for sensor integration.

Ford F-150 truck converted to battery-electric powertrain for EV research.

UTILITY APPLICATIONS

WEMPEC research is delivering innovative approaches for building smaller-scale distributed generation systems that can be integrated with more conventional centralized power generation systems or function separately. WEMPEC faculty members have long been leaders in the development of new microgrid concepts. This work has contributed substantially to the fact that the microgrid is now the dominant paradigm for distributed energy systems incorporating a wide range of power generation sources encompassing renewable wind and solar, natural gas generators, and microturbines. WEMPEC researchers are working with faculty colleagues in other parts of the university to develop promising new electric grid architectures that embody bottom-up concepts giving utility customers many more options for generating their own power and avoiding outages. This ongoing research is directly tackling technical challenges posed by the intermittency of renewable energy sources, creating exciting opportunities for breakthroughs that are needed in every aspect of the future electrical grid. WEMPEC is conducting fundamental research for V2G inverter design and control for performing utility grid services. In addition to efforts focused on the developed world, WEMPEC research is aggressively applying these same distributed energy system concepts in innovative ways to provide practical and reliable electricity to unserved and under-served communities and larger population centers around the world.

480V 3-phase microgrid testbed including cabinets for solar PV microsource (left) and smart switch (right).

ENERGY STORAGE AND POWER TRANSFER

Batteries and Ultracapacitors

Reflecting the growing needs for advanced electrical energy storage for a variety of important applications, WEMPEC research efforts have continued to expand in scope and magnitude. WEMPEC researchers are delivering innovations that are critical for the future use of batteries and other electrochemical energy storage components in both electric propulsion systems for land-based vehicles, as well as grid-based energy storage systems needed to overcome the intermittency limitations of renewable energy sources. Optimized hybrid battery systems have been developed that combine high-energy-density batteries with high-power-density ultracapacitors to meet the demanding requirements of electrified vehicles. WEMPEC has made major progress toward addressing important battery management issues, including the development of more accurate models to monitor battery state-of-charge (SOC) and aging mechanisms, as well as improved techniques for equalizing the charge among long series strings of batteries. The unique combination of state-of-the-art battery test equipment in our laboratories combined with on-road electric research vehicles is providing WEMPEC researchers with valuable advantages for pursuing new advances in this field

Wireless Power Transfer

Wireless power transfer utilizes dynamic electric or magnetic fields to transfer power between systems without a galvanic connection. Coupling inductors/capacitors, compensation networks, and power converters must be designed in close coordination to achieve a high-performance system.

WEMPEC has developed and demonstrated advanced wireless power transfer techniques for efficiently transmitting electric power across 30 centimeters of airgap while maintaining an intrinsically safe level of flux linkage in the air gap, offering promising approaches for eliminating the physical plugs from plug-in vehicles. WEMPEC developed surface spiral winding technology, coupled via megahertz resonant technology has the potential to improve safety with intrinsically low flux density in the airgap and 95 percent efficiency of power transfer in the low kW power range. Other innovative winding designs that minimize proximity effect and eddy current losses are under development, along with power converter circuits to enable this technology.

A closely related area of WEMPEC research focuses on using wide bandgap power devices to increase switching frequencies to the MHz range at kW power levels which allow capacitive coupling to be used for power transfer, turning coupling structures into simple surfaces.

Surface spiral winding for wireless power transfer.

Battery testing using thermal chambers in the Johnson Controls Energy Systems Laboratory.

WEMPEC Electric Machines and Power Electronics Research Labs

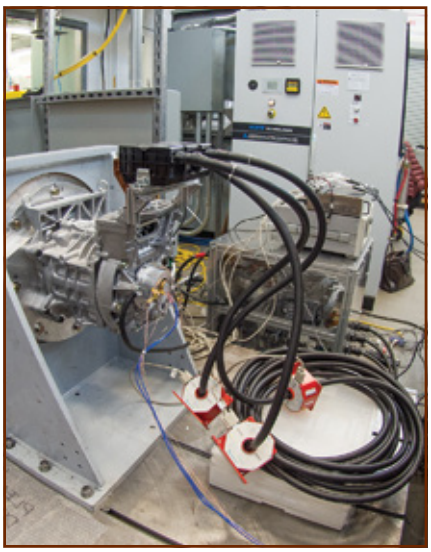
The WEMPEC research labs are equipped for 50 to 60 graduate students to work on machines, motor drives, power electronics circuits, microgrids, battery systems, electric traction systems, wireless power transfer, and machine and power electronics packaging research. We recently expanded our test capability by the generous donation of three high-speed dynamometers from GM, to include more than 15 dynamometer test benches for controls and electric machine research.

LAB DYNAMOMETER CAPABILITY			
#	Power	Torque	Speed
2	170 kW	391 Nm	15,000 rpm
1	97 kW	129 Nm	12,000 rpm
12+	< 20 kW	<100Nm	<7000 rpm

LAB POWER CAPABILITY	
480V~ 3P	50 to 200A
240V~ 3P	50A
208V~ 3P 4W	50A

A variety of commercial and specially constructed power converters and DSP-based controllers are available for general drives and power converter research activities. Printed circuit board assembly/disassembly equipment includes a pick-and-place machine, inspection microscope, and a variety of current technology soldering and de-soldering equipment. A large range of test and measurement instruments needed for power electronics and machines research are available in the lab including Yokogawa power meters, 12-bit oscilloscopes, dynamic signal analyzers, high-power DC and AC supplies, 60 differential voltage probes, and a correspondingly high number of current probes.

We continue to expand and upgrade our facilities with recent acquisitions of new lab space and the conversion of a graduate student office into a fourth research lab with seven benches. Our labs now include more than 34 maple-surface movable work-stations for researchers to build and test equipment. In addition, we installed a new E-stop safety system in all of our labs to shut down power from all three phase receptacles in the event of an emergency.



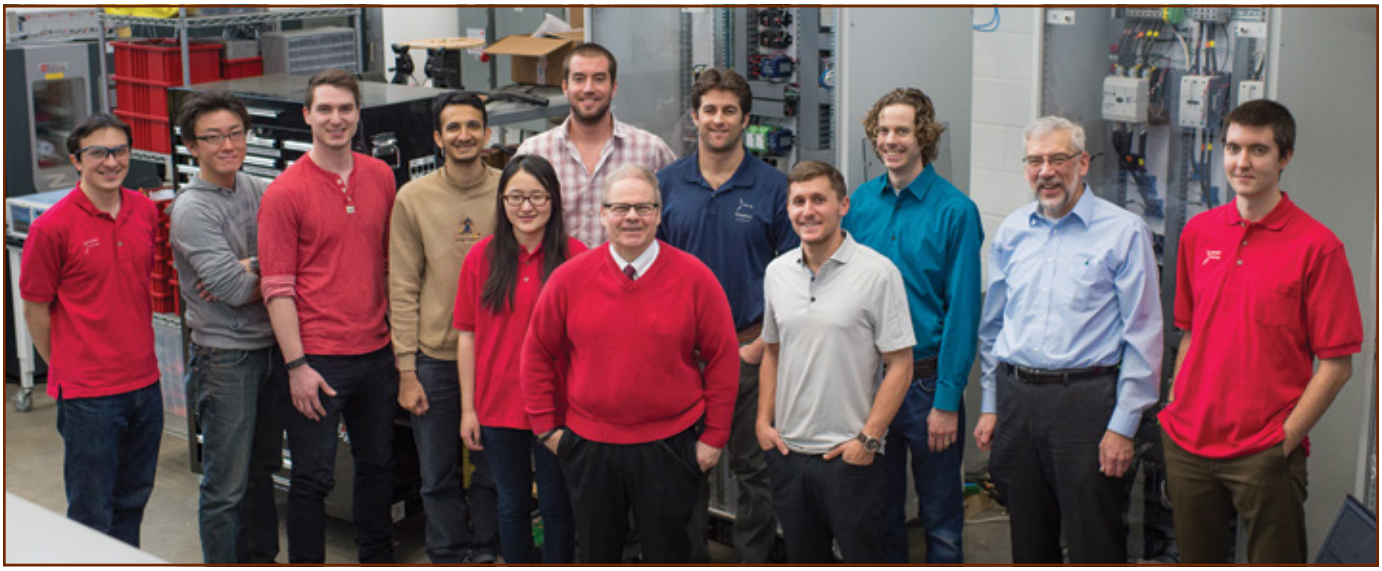
170 KW, 15,000 RPM Dynamometer in use.

Battery test equipment including thermal chambers and cyclers.

Wisconsin Energy Institute (WEI)

The newest laboratory space available to WEMPEC researchers is the Integrated Energy Systems Laboratory (IESL) that was commissioned in 2013 when the WEI building was opened. The labspace, consisting of a high-bay lab and an adjacent staging laboratory, was custom-designed for research focused on grid integration topics including microgrids, renewable energy, energy storage, and advanced electric energy systems. The lab features five research bays, each equipped with water, compressed air, natural gas, exhaust, and access to 750kVA of isolated 480V, 3-phase electric power that is readily expandable to 2MVA. The lab also includes a five-ton overhead lift and separate overhead wiring trays for power and communications connections. The high-power microgrid testbed is currently configured for 208/480V 3-phase power, including a 250A static switch for utility synchronization and connection. Several 45kW inverters are configured with custom controls to serve as flexible interface units to several different types of dc sources including both real and emulated solar PV and battery micro-sources. Other available sources and loads include a 60kW natural gas generator, resistive load banks up to 155kW, and a high-performance 170kW dynamometer donated by GM that can be programmed to emulate a wide variety of prime movers or loads including wind turbines and internal combustion engines. Additional special test facilities available in IESL include state-of-the-art battery cycling and test equipment donated by JCI, and an Opal RT OP5600 hardware-in-the-loop (HiL) real-time computer.

MICROGRID CAPABILITY	
Isolated Utility Connection	750 kVA
Static Switch Sync & Connection Point	250 A
Grid Connected Inverter	45 kW
Natural Gas Generator	60 kW
Photovoltaic Array	8 kW
Simulated Wind Turbine (dyno + motor)	135 kW
Resistive Load Bank	155 kW
Battery Bank	4 kW



First-generation developers and users of the WEI Integrated Energy Systems Laboratory.

2016 Current Graduate & Undergraduate Students

PhD students

Apoorva Athavale
Dheeraj Bobba
Adria Brooks
Pablo E. Castro-Palavicino
Le Chang
Parikshith Channegowda
Zhe Chen
Gilsu Choi
Wooyoung Choi
Jiejian Dai
Zhentao Du
Huthaifa M. Flieh
Kevin Frankforter
Brent Gagas
Baoyun Ge
Aditya Ghule
Mahima Gupta
Skyler Hagen
Di Han
Philip Hart
Ryoko Imamura
Hao Jiang
Ju Hyung Kim
Ryan Knippel
Shang-Chuan Lee
Woongkul Lee
Silong Li
Yingjie Li
Jianyang Liu
Wenbo Liu
Ashray Manur
Seth McElhinney
He Niu
Hung-Yen Ou Yang
Dinesh Pattabiraman
Marc Petit
Michael Rios
Andy Schroedermeier
Lee Shaver
Adam Shea
Minhao Sheng
Yuying Shi
Timothy Slininger
Kang Wang
Yukai Wang
Yichao Zhang
Junjian Zhao
Ruxiu Zhao
Bo Zhu
Guangqi Zhu

MS students

Steve Chang
Calvin Cherry
Cong Deng
Jacob Dubie
Joseph Goldman
Ramesh K. Govindarajan
Mitchell Marks
Narciso Marmolejo
Peter Meyer
Casey Morris
Will Plaxico
Timothy Polom
Ricardo Ramirez
Erik Schubert
Boru Wang
Teng Wu
Yujiang Wu
Yang Xu
Yinghan Xu
Ruonan Zhou
Yutong Zhu

Undergraduate students

Muhammad Alvi
Charles Duff
Zheng Gao
Terrance Thurk
Jacob Free
Chad Davis

Grainger Power Engineering Award and Undergraduate Fellowships

In 1997, The Grainger Foundation established a major award program for students who earn an undergraduate or graduate degree with a specialization in the field of electric power engineering in the University of Wisconsin–Madison College of Engineering. These awards are intended to reward highly qualified and motivated students who pursue programs of study in electric machines and drive systems, industrial motion control, power electronics, or electric power systems. More than 250 awards have been granted since 1997, and the majority of the graduate-degree recipients have been students in the WEMPEC program. Visit wempec.wisc.edu/803.htm for more details.

2016 Grainger Power Engineering Award Winners.

ALUMNI

1981 MS
Hamdy M. Bahnassy* — N. Schmitz

1981 PhD
Mehrdad Ehsani* — N. Schmitz
Nathaniel Gunaratnam* — D.W. Novotny

***** *Indicates already in ECE program; became WEMPEC students in '81*

1982 MS
Timothy J. Kolb — D.W. Novotny
Timothy M. Rowan — T.A. Lipo

1982 PhD
K. Ahmed — T.A. Lipo

1983 MS
David M. Brod — D.W. Novotny
Roy Steve Colby — D.W. Novotny
Isidoro Couvertier — D.W. Novotny
Takayoshi Matsuo — T.A. Lipo
Donald S. Zinger — T.A. Lipo

1984 MS
Wallace H. Creer — T.A. Lipo
William J. Hunt — D.W. Novotny
Benson Lee — R.H. Lasseter
Eduard Muljadi — T.A. Lipo
Kamarudin Nordin — D.W. Novotny

1985 MS
Leonard J. Bohmann — R.H. Lasseter
Kwon C. Chang — T.A. Lipo
Jin Heung Chung — R.H. Lasseter
John P. Hoffman — D.W. Novotny
Joseph D. Law — T.A. Lipo
John M. Loehrke — R.D. Lorenz

1985 PhD
Daniel S. Kirschen — D.W. Novotny
Timothy M. Rowan — T.A. Lipo
Chu-Gen Wang — T.A. Lipo

1986 MS
Grant K. Garnett — R.D. Lorenz
David A. Kaiser — T.A. Lipo
Jim D. Kershner — R.D. Lorenz
Terrance M. Lettenmaier — D.W. Novotny
Dennis K. Schade — R.D. Lorenz
Longya Xu — T.A. Lipo

1986 PhD
H. Soebagio — T.A. Lipo
Kwa-Sur Tam — R.H. Lasseter

1987 MS
Mark R. Bachhuber — R.D. Lorenz
Ivan R. Brouwer — R.D. Lorenz
Robert A. Cook — R.D. Lorenz
Mike B. Eberlein — R.D. Lorenz
Patrick L. Jansen — D.W. Novotny
A. Reza Kashani — R.D. Lorenz
Mustansir Kheraluwala — D.M Divan.
Mark S. Kramer — T.A. Lipo
K. Mathias Meyer — R.D. Lorenz
Oliver D. Patterson — D.M. Divan
Doug Van De Riet — R.D. Lorenz

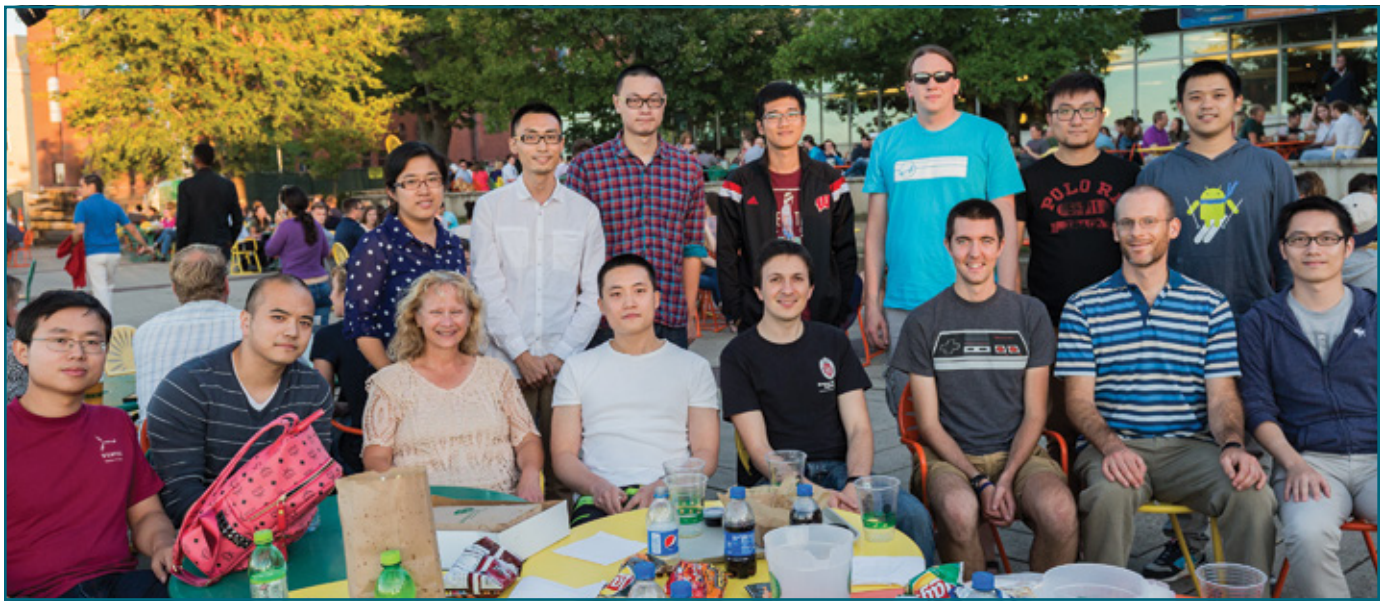
1987 PhD
Roy Steve Colby — D.W. Novotny
Eduard Muljadi — T.A. Lipo
Joseph O. Ojo — T.A. Lipo
Richard F. Schiferl — T.A. Lipo
Pradeep K. Sood — T.A. Lipo
Li-Cheng Zai — T.A. Lipo

1988 MS
Kai Chi Lam — T.A. Lipo
Eric G. Mundt — R.D. Lorenz
S. Y. Tam — R.H. Lasseter
Oliver Wilke — R.D. Lorenz

1988 PhD
Yen-Ren Liu — R.H. Lasseter
Donald S. Zinger — T.A. Lipo

1989 MS
Beena S. Acharya — D.M. Divan
William B. Dittman — T.A. Lipo
Greg T. Jackson — R.D. Lorenz
Brian K. Johnson — R.H. Lasseter
Vikram Kaura — D.W. Novotny
Patrick Michael Kelecy — R.D. Lorenz
Lowell M. Rausch — D.M. Divan
Shien-Yang Wu — D.M. Divan

1989 PhD
Leonard J. Bohmann — R.H. Lasseter
Sheng-Ming Yang — R.D. Lorenz



A relaxing summer evening on the Memorial Union Terrace.

1990 MS

Robert M. Cuzner — R.D. Lorenz
Kam Tim Hung — R.D. Lorenz
Christopher C. Jensen — T.A. Lipo
Karl W. Marschke — T.A. Lipo
Jim Nesbitt — D.W. Novotny
Patrick H. Nugent — R.D. Lorenz
Deborah R. Wolfson — R.D. Lorenz
Jiarong Zhou — R.H. Lasseter

1990 PhD

Paulo R. Caldeira — T.A. Lipo
Thomas G. Habetler — D.M. Divan
Julio C. Moreira — T.A. Lipo
Longya Xu — T.A. Lipo
Xingyi Xu — D.W. Novotny

1991 MS

Craig Bonneville — R.D. Lorenz
Michael R. Buhl — R.D. Lorenz
Craig M. Goshaw — R.D. Lorenz
Ahmet Hava — T.A. Lipo
Sasan Jalali — R.H. Lasseter
Ka Shu Ko — R.H. Lasseter
Douglas K. Maly — D.W. Novotny
Moncef Moatemri — R.D. Lorenz
Norbert Niedhorn — R.D. Lorenz
Shawn L. Peterson — R.D. Lorenz
Mina M. Rahimian — T.A. Lipo
Bhaskar Singh — T.A. Lipo
James L. Skinner — T.A. Lipo
Bernhard Werner — R.D. Lorenz
Herman L. N. Wiegman — D.M. Divan

1991 PhD

Mustansir Kheraluwala — D.M. Divan
Joseph D. Law — T.A. Lipo
Peter B. Schmidt — R.D. Lorenz
Hamid A. Toliyat — T.A. Lipo

1992 MS

Mark Cooper — R.D. Lorenz
Craig Johnson — R.D. Lorenz
Mark S. Rauls — D.W. Novotny
Scott W. Repplinger — T.A. Lipo

1992 PhD

Ping Ping Dai — R.D. Lorenz
Brian K. Johnson — R.H. Lasseter
Yuefeng Liao — T.A. Lipo
Gary L. Skibinski — D.M. Divan
Giri Venkataramanan — D.M. Divan

1993 MS

Jeffrey Brozek — T.A. Lipo
Jonathan Carpenter — R.H. Lasseter
Shaotang Chen — T.A. Lipo
Hassan Cherradi — D.M. Divan
Matthew J. Corley — R.D. Lorenz
Michael W. Degner — R.D. Lorenz
Alexander Kurnia — D.M. Divan
J. Daniel Ruvalcaba — D.W. Novotny
Joel B. Wacknov — T.A. Lipo
Ian Wallace — D.M. Divan

1993 PhD

Jonathan C. Boomgaarden — R.D. Lorenz
Jen-Ren Fu — T.A. Lipo
Herbert Hess — D.M. Divan
Sasan Jalali — R.H. Lasseter
Patrick L. Jansen — R.D. Lorenz
Feng Liang — T.A. Lipo

1994 MS

Robb G. Anderson — R.D. Lorenz
Diane E. Borgard — R.D. Lorenz
Po-Tai Cheng — D.M. Divan
William D. Grube — R.D. Lorenz
Bradley J. Heeres — D.W. Novotny
Stephen Hsien-Yuan Li — T.A. Lipo
Carl E. Martensson — R.H. Lasseter
Andrew J. Meyer — R.D. Lorenz
Mohamed O.E. Mohamed — T.A. Lipo
Steven A. Orth — R.D. Lorenz
Kevin T. Ousdigian — R.D. Lorenz
Tracy L. Reineking — R.D. Lorenz
Andrew J. Shakal — T.A. Lipo
David T. Willett — R.D. Lorenz

1994 PhD
Irfan Alan — T.A. Lipo
Chingchi Chen — D.M. Divan
Patrick Michael Kelecy — R.D. Lorenz
Takayoshi Matsuo — T.A. Lipo

1995 MS
Saviz Artang — R.H. Lasseter
Marc Artmeyer — R.D. Lorenz
Carl H. Benker — D.M. Divan
William E. Brumsickle — D.M. Divan
Gus Collins — R.D. Lorenz
Douglas A. Dallmann — K. Shenai
Lance P. Haines — R.D. Lorenz
Hagen Jahn — R.D. Lorenz
Michael C. Klabunde — T.A. Lipo
David P. Leary — R.H. Lasseter
Hsin-Hua Li — T.A. Lipo
Alfredo Munoz-Garcia — D.W. Novotny
Nicholas J. Nagel — R.D. Lorenz
Gregory J. Rajala — R.D. Lorenz
Yihchih Shern — R.H. Lasseter
Chiping Sun — D.W. Novotny
Steven H. Walker — R.D. Lorenz
Yanhong Xue — T.A. Lipo

1995 PhD
Mehmet Aydemir — T.A. Lipo
Mukul Chandorkar — D.M. Divan
Shaotang Chen — T.A. Lipo
Keith Klontz — D.W. Novotny
Nasser H. Kutkut — D.M. Divan
Yifan Zhao — T.A. Lipo

1996 MS
Mitchell Bradt — R.H. Lasseter
Steven Fredette — D.M. Divan
Vivek Karandikar — R.D. Lorenz
Weihua Ma — D.W. Novotny
Scott M. Manson — R.H. Lasseter
Sameer P. Pendharkar — K. Shenai
Dinyu (Dan) Qin — T.A. Lipo
Tod R. Tesch — R.D. Lorenz
Malay Trivedi — K. Shenai

1996 PhD
Long–Jang Li — R.D. Lorenz
Yue Li — T.A. Lipo
David R. Seidl — R.D. Lorenz

1997 MS
Metin Aydin — T.A. Lipo
Alex M. De Broe — T.A. Lipo
Carl Dister — R.D. Lorenz
Darin A. Engelhart — R.D. Lorenz
Chih Ling Han — R.D. Lorenz
David Hyypio — T.A. Lipo
Ekrem Kayikci — R.D. Lorenz
Ahmed Mahmoud — R.D. Lorenz
Kevin L. Payette — R.D. Lorenz
Jerry A. Putman — R.D. Lorenz
James E. Walters — R.D. Lorenz
Craig R. Winterhalter — R.D. Lorenz

1997 PhD
Mustafa A. Al-Saffar — T.A. Lipo
Clark Hochgraf — R.H. Lasseter
Alexander Julian — T.A. Lipo
Hsin-Hua Li — T.A. Lipo (co-advisor)
Xiaogang Luo — T.A. Lipo
Mohamed O.E. Mohamed — T.A. Lipo
Michael J. Ryan — R.D. Lorenz

1998 MS
Robert B. Bettendorf — R.D. Lorenz
Dennis Borowy — T.A. Lipo
Marcela Gonzalez — R.D. Lorenz
Laureen Hellouin — R.D. Lorenz
Kurt I. Jaeger — R.D. Lorenz
Frederick Kieferndorf — D.W. Novotny
Chad M. Licht — R.D. Lorenz
Wei Liu — R.D. Lorenz
Frank Phlippen — R.D. Lorenz
Aakash Rao — T.A. Lipo
Jeffrey J. Shutter — R.D. Lorenz
Pinet Sriyotha — R.D. Lorenz
John W. Taylor — R.D. Lorenz
Neil H. Tice — R.D. Lorenz

1998 PhD
William E. Brumsickle — D.M. Divan
Braz de Jesus Cardoso Filho — T.A. Lipo
Michael W. Degner — R.D. Lorenz
Ahmet Hava — T.A. Lipo
Gautam Sinha — T.A. Lipo
Ana V. Stankovic — T.A. Lipo

1999 MS
Eric L. Benedict — T.A. Lipo
Mark G. Dollevoet — R.D. Lorenz
Michael C. Harke — R.D. Lorenz
Jun Kikuchi — T.A. Lipo
Hyunbae Kim — R.D. Lorenz
Sigurd Ovrebo — R.D. Lorenz
Oliver Peterson — T.A. Lipo
Mark C. Sevey — R.D. Lorenz
Michael Shannon — T.A. Lipo
Weizhong Tang — R.H. Lasseter

1999 PhD
Po-Tai Cheng — D.M. Divan
Roy I. Davis — R.D. Lorenz
Vinod John — T.A. Lipo
Jian Luo — T.A. Lipo
Madhav D. Manjrekar — T.A. Lipo
Alfredo Munoz-Garcia — T.A. Lipo
Nicholas J. Nagel — R.D. Lorenz
Bulent Sarlioglu — T.A. Lipo
Herman L. N. Wiegman — R.D. Lorenz

Planting a memorial tree at the Nanjing University of Aeronautics and Astronautics (NUAA).

Professor Lorenz with Visiting Scholars.

2000 MS

Eric A. Carter — R.D. Lorenz
Jennifer Chung — R.D. Lorenz
Mark A. Ferderer — R.D. Lorenz
Stephen Fusi — T.A. Lipo
Enrique Ledezma — T.A. Lipo
Jongsoo Lim — R.D. Lorenz
Jaehyung Park — T.A. Lipo
John H. Sorebo — R.D. Lorenz
Clarissa M. Thomas — R.D. Lorenz

2000 PhD

Melik Dolen — R.D. Lorenz
Dinyu (Dan) Qin — T.A. Lipo

2001 MS

Nathan Harris — T.M. Jahns
Ji Li — G. Venkataramanan
David Oteman — T.A. Lipo
Allen Windhorn — R.H. Lasseter

2001 PhD

Barbara H. Kenny — R.D. Lorenz
Taiyou Yong — R.H. Lasseter

2002 MS

Gary Buckingham — R.H. Lasseter
Ho Chan — T.M. Jahns
Ayman El-Refaie — T.M. Jahns
Christoph Giebeler — R.D. Lorenz
Christopher Houle — R.H. Lasseter
Nathan Lebens — G. Venkataramanan
Dustin A. Murdock — R.D. Lorenz
Jody J. Nelson — G. Venkataramanan
Shihong Park — T.M. Jahns
Daniel M. Saban — G. Venkataramanan
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2002 PhD

Jun Kikuchi — T.A. Lipo
Renato Lyra — T.A. Lipo
Alessandro Moreira — T.A. Lipo
Velimir Nedic — T.A. Lipo
Ronghai Qu — T.A. Lipo
Juan Tapia — T.A. Lipo

2003 MS

Theodore P. Bohn — R.D. Lorenz
Ian P. Brown — R.D. Lorenz
Michael F. Cash — R.D. Lorenz
Patrick Flannery — G. Venkataramanan
Yusuke Fukuta — G. Venkataramanan
Christian Hareide — R.D. Lorenz
Jason J. Hartwig — R.D. Lorenz
Jesse Krase — T.A. Lipo
Won-Kyoung Lee — T.M. Jahns
Erik R. Olson — R.D. Lorenz
Wen Ouyang — T.A. Lipo
Trine Pande-Rolfsen — R.D. Lorenz
Charles Romenesko — R.D. Lorenz
Daniel M. Saban — R.D. Lorenz
Vijay Srinivasan — G. Venkataramanan
Jackson Wai — T.M. Jahns
Yue Xu — R.D. Lorenz
Hao Howard Zhang — T.A. Lipo

2003 PhD

Ashish Bendre — G. Venkataramanan
Subhashish Bhattacharya — G.Venkataramanan
Rick Kieferndorf — T.A. Lipo
Lixiang Wei — T.A. Lipo
Brian Welchko — T.A. Lipo

2004 MS

Travis Bashaw — T.A. Lipo
James A. Buerosse — R.D. Lorenz
Jeffrey J. Connors — R.D. Lorenz
Chirdpong Deelertpaiboon — R.H. Lasseter
David K. Farnia — R.D. Lorenz
Raahul Hassan — R.H. Lasseter
Dong Gee Hong — R.D. Lorenz
Jae-Hyuck Kim — T.M. Jahns
Paul Mezs — T.M. Jahns
Jonathan Nord — G. Venkataramanan
Erick L. Oberstar — R.D. Lorenz
Nitin R. Patel — R.D. Lorenz
Devang Sachdev — G. Venkataramanan
Mark A. Spickard — R.D. Lorenz
Hong-Yue (Ray) Tang — R.D. Lorenz

2004 PhD

Metin Aydin — T.A. Lipo
Eric L. Benedict — T.A. Lipo
Sib Chakrabarti — T.M. Jahns
Hyunbae Kim — R.D. Lorenz
Shihong Park — T.M. Jahns
Yong-Sug Suh — T.A. Lipo
Damir Zarko — T.A. Lipo

2005 MS

Shreesha Adiga Manoor — R.D. Lorenz
Sandeep Bala — G. Venkataramanan
Felix B. Bierbaum — R.D. Lorenz
James W. Claerbout — R.D. Lorenz
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Mark Putnam — G. Venkataramanan
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2005 PhD
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2006 MS
Jei-Hoon Baek — T.M. Jahns
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Jonathan Bird — T.A. Lipo
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2007 MS
Korwin J. Anderson — R.D. Lorenz
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Bee-See Heng — A. Muetze
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Scott E. McPherren — R.D. Lorenz
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2007 PhD
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2008 MS
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2008 PhD
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2009 MS
Seth M. Avery — R.D. Lorenz
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2013 MS

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2014 PhD

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Justin Reed — G. Venkataramanan
Chen-Yen Yu — R.D. Lorenz

2015 MS

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Minhao Sheng — R.D. Lorenz
Diego Valencia — G. Venkataramanan
Brian Veik — R.D. Lorenz
Todd Velde — R.D. Lorenz
Kang Wang — R.D. Lorenz
Jiyao Wang — Y. Han
Ruxiu Zhao — R.D. Lorenz

2015 PhD

Seth Avery — R.D. Lorenz
Phil Kollmeyer — T.M. Jahns
Ye Li — Y. Han
James McFarland — T.M. Jahns
Caleb Secrest — R.D. Lorenz
KeeHo Shin — T.A. Lipo
Wanjun Zhang — T.M. Jahns

VISITING PROFESSORS

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Khaled E. Addoweesh — University of King Saud, Riyadh, Saudi Arabia (1993–94)

Jin-Woo Ahn — Kyungsung University, Pusan, Korea (1998–99)

Hirofumi Akagi — Okayama University, Okayama, Japan (1995–96)

Kan Akatsu — Tokyo University of Agriculture and Technology, Japan (2005–08)

Mats Alakula — Lund Institute of Technology, Lund, Sweden (2000)

Nihan Altintas — Yildiz Technical University, Istanbul, Turkey (2015–16)

Mehmet Aydemir — Gazi University, Ankara, Turkey (2001–02)

Michael Barnes — University of Manchester, Manchester, United Kingdom (2006–07)

Alberto Bellini — Universita' di Parma, Parma, Italy (2000)

Francesco Benzi — University of Pavia, Pavia, Italy (1985–86)

Fabio Capponi — "La Sapienza," Rome, Italy (2003–04)

Lei Chen — Harbin Institute of Technology (2015–16)

Yaow Ming Chen — National Taiwan University, Taipai, Taiwan (2011–12)

Ming Cheng — Southeast University, Nanjing, China (2011)

B.H. Cho — Korean Advanced Institute of Science and Technology (KAIST), Seoul, Korea (1989–90)

Nam-Sup Choi — Yosu National University, Cheonnam, Korea (1999–2000)

Alfio Consoli — University of Catania, Catania, Italy (1985–86)

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Seshagiri Roa Doradla — India Institute of Technology, Kanpur, India (1994–95)

Levent Eren — Izmir University of Economics, Balcova, Turkey (2014–15)

A pleasant afternoon outing on Lake Mendota with Visiting Professor Gianmario Pellegrino.

Fatih Evran — Gazi University, Ankara, Turkey (2013–14)

Shuhua Fang — Southeast University, Nanjing, China (2013–15)

Ying Fan — Southeast University, Nanjing, China (2014–15)

Eisenhawer de Moura Fernandes — Federal University of Campina Grande, Brazil (2012–14)

Xinghe Fu — Southeast University, Nanjing, China (2014–15)

Dawei Gao — Tshingua University, Beijing, China (2011–13)

Guillermo Garcia — National University of Rio Cuarto, Argentina (1996–98)

Dieter Gerling — University of Federal Defense, Munich, Germany (2004)

Zhenyan Hao — Nanjing University of Aeronautics and Astronautics, Nanjing, China (2014–15)

D. Grahame Holmes — Monash University, Melbourne, Australia (1988–89, 1994–95, 2005–07)

Sun-Ki Hong — Hoseo University, Chung-Nam, Korea (1999–2000, 2008–09)

Surong Huang — Shanghai University of Technology, Shanghai, China (1994–96, 1998–2000, 2001)

Kenichi Iimori — Kagoshima University, Kagoshima, Japan (1997–98)

Borislav Jeftenic — University of Belgrade, Belgrade, Yugoslavia (1990)

Min-Seok Joo — Yonsei University, Seoul, Korea (2000–02)

Man-Woun Kang — Taejon National University of Technology, Taejon, Korea (1997–98)

Ahmet Karaarslan — Afyon Kocatepe University, Afyon, Turkey (2013–14)

Faeka Khater — Cairo University, Cairo, Egypt (1993)

Byung Taek Kim — Kunsan National University, Jeonbuk, Korea (2012–14)

Dong-Hee Lee — Kyungsung University, Busan, Korea (2012–13)

Dae--kyong Kim — Sunchon National University, Suncheon, Korea (2014–15)

Gi-Taek Kim — Kangwon National University, Chunchon, Korea (1994–96)

Gyu-Sik Kim — University of Seoul, Korea (2003–05)

Heung-Guen Kim — Kyung-pook National University, Taegu, Korea (1990–91)

Jong-Gyeum Kim — Gangneung Wonju National University, Gangwon, Korea (2012–14)

Tae Heoung Kim — Gyeongsang National University, Gyeoungnam, Korea (2011–14)

Youn Hyun Kim — Hanbat National University, Daejeon,Korea (2011–13)

Liviu Kreindler — University of Bucharest, Bucharest, Romania (1991–92)

Akira Kumamoto — University in Osaka, Japan (March 1987–88)Viacheslav Kuznetsov — Moscow Power Engineering Institute, Moscow, Russia (1993–94)

Byung-il Kwon — Hanyang University, Korea (2001–02, 2008–09)

Joseph Law — University of Idaho, Moscow, Idaho (1983–84)

Gerard Ledwich — University of Queensland, Brisbane, Australia (1991–92)

Cheol-Gyun Lee — Dong-Eui University, Pusan, Korea (2002–03)

Dong Choon Lee — Yeungnam University, Korea (2004–05)

Dong-Hee Lee — Kyungsung University, Busan, Korea (2011–12)

Ju Lee — Hanyang University, Seoul, Korea (2005–07)

Hao Li — China University of Mining and Technology, XuZhou, China (2014–15)

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Fan Liao — Dalian Railway School of Technology, Dalian, China (1987–88)

Shir-Kuan Lin — National Chiao Tung University, Hsinchu, Taiwan (1995–96)

Robin Lisner — Monash University, Australia (2004)

Jiaxi Liu — Harbin Institute of Technology, China (2014–15)

Tian-Hua Liu — National Institute of Technology, Taiwan, China (1990–92)

Chao Lu — Tsinghua University, Beijing, China (2011–12)

Yumin Lu — Guangzi University, Nanning, China (2014–15)

Seyed Madani — University of Puerto Rico, Pureto Rico (2004, 2005)

Udaya Madawala — University of Auckland, Auckland, New Zealand (2008)

Sergio Martinez — University of Madrid, Spain (2010–12)

Jan A. Melkebeek — Free University of Gent, Belgium (1982)

Wellington Santos Mota — Federal University of Paraiba, Brazil (1995–98)

Alfredo Munoz-Garcia — Politecnical Naval Academy, Chilean Navy, Chile (2005)

Yoshihiro Murai — Gifu University, Gifu, Japan (1987–88, 1991, 1994–95)

Takashi Nagano — Miyakonojo National College of Technology, Miyakonojo, Japan (2005–06)

Istvan Nagy — Technical University of Budapest, Budapest, Hungary (1991–92)

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Robert Nilssen — Norwegian University of Science and Technology, Norway (2004–05)

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Jun Oyama — Nagasaki University, Nagasaki, Japan (1987–88)

Antonio Feltrin Padilha — FEIS-UNESP, Ilha Soteira, Brazil (1995–97)

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Edison da Silva — Federal University of Paraiba, Brazil (1990–91, 1994–96)

Kwang M. Son — Dong-Eui University, Korea (2001–02)

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Seung-Ki Sul — Seoul National University, Seoul, Korea (1995–96)

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Professor Jahns at the grill during the fall picnic with Visiting Professor Shuhua Fang.

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Professor Lipo reunited with former Chinese graduate students in Wuhan, China

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Apoorva Athvale — Indian Institute of Technology, Hyderabad, India (2010)

Emrullah Aydin — Gazi University, Ankara, Turkey (2012–13)

Noor Baloch — Yaskawa Electric Corp., Kitakyushu, Japan (2014–15) (2015)

Sobhi Barg — University of Oviedo, Gijón, Spain (2014–15)

Jamaica Barnette — North Carolina A & T, USA (2004, 2005)

Lennart Baruschka — University of Hannover, Hannover, Germany (2007)

Flemming Bendixen — Grundfos, Denmark (2002)

Stefen Bernet — Technical University of Ilmenau, Ilmenau, Germany (1995–96)

Claudio Bianchini — Universita di Modena e Reggio Emilia, Reggio Emilia, Italy (2008)

Matthias Biskoping — AIX Control GmbH/ISEA, Eslohe, Germany (2008–09)

Ayalew Biyadgie — University of Oviedo, Spain (2016)

Barbara Boazzo — Politechnic University of Torino, Italy (2012–14)

Giovanni Bottiglieri — University of Catina, Italy (2003)

Andreas Broesse — Technical University of Aachen, Aachen, Germany (1996)

Bernd Cebulski — Technical University of Chemnitz, Chemnitz, Germany (1996–97)

Emrah Cetin — Erciyes Universitesi Muhendslik Fakutest, Kayseri, Turkey (2015–16)

Seo-Geon Chang — LG Electronics Systems Co. Ltd., Kyungki-Do, Korea (1997–98)

Xiaomeng Cheng —Tsinghua University, Beijing, China (2009–10)

Edward Chikuni — University of Zimbabwe, Harare, Zimbabwe (1996–97)

Sung-Joon Cho — Hyundai Heavy Industries Co. Ltd, Gyeonggido, Korea (2006–07)

Miroslav Chomat — Academy of Sciences of the Czech Republic, Czech Republic (1999–2000)

Yong-Ho Chung — Goldstar Industrial Systems Company, Ltd., Kyngki-Do, Korea (1994–96)

Mauricio Beltrao de Rossiter Correa — Universidade Federal de Campina Grande, Brazil (2001–02)

Fabio Crescimbini — University of Rome "La Sapienza," Rome, Italy (1986)

Carlos Martínez Diez — University of Oviedo, Gijón, Spain (2013–14)

Shichuan Ding — Anhui University, Hefei, China (2014–15), (2015-16)

Shri Dixit — Microprocessor Application Engineering Center, University of Pune, India (1988–90)

Marc Dokus — Leibniz University, Hannover, Germany (2016)

Vaibhav Donde — University of Illinois, Urbana-Champagne, Illinois (2004)

Bo Dong — Tsinghua University, Beijing, China (2010–12)

Dushan Drevensek — University of Maribor, Maribor, Slovenia (2000–01)

Wei Du — Tsinghua University, Beijing, China (2012–14)

Deng Duo — Anson Iron and Steel Co., China (1983–86)

Bashir Ebrahimi — University of Tehran, Iran (2013–14)

Mohamed El-Morsi — Transworld Development & Trading Co., Cairo, Egypt (2003–04)

Henrik Engdahl — Royal Institute of Technology, Stockholm, Sweden (1997–98)

Daniel Efren Gaona Erazo — University of Oviedo, Gijón, Spain (2016)

Azza Fahim — University of Cairo, Egypt (1983) National Research Center of Cairo, Egypt (1989–90)

Yakov Familiant — University of Wisconsin, Milwaukee, USA (2006)

Huthaifa Flieh — University of Oviedo, Gijón, Spain (2013–15)

Juio Merino Fernandez — Polytechnic University of Madrid, Spain (2011–12)

Pablo Garcia Fernandez — University of Oviedo, Gijon, Spain (2004)

Luca Del Ferraro — University of Rome 'La Sapienza,' Italy (2005)

Martin Fleischhauer — Bundeswehr University of Munich, Germany (2011–12)

Matthias Foerster — Ilmenau Technical University, Ilmenau, Germany (2001–02)

Matteo Gamba — Politechnic University of Torino, Italy (2014–15)

Francesco Gennaro — University of Catania, Catania, Italy (1998)

Xiaozi Goa — Tianjin University, Tianjin, China (2010–12)

Teck Chiang Goh — Nagaoka University of Technology, Nagaoka, Japan (2011–12)

Juan Manuel Guerrero — University of Oviedo, Gijon, Spain (2002)

Lutz Gutenberg — RWTH Aachen University, Aachen, Germany (2008–09)

Hilmi Gurleyen — Yildiz University, Istanbul, Turkey (2015–16)

Seo Gyu-Seok — Kyungpook National University, Daegu, Korea (2008)

Christoph Hackl — Technical University of Munich, Germany (2003)

Makoto Hagiwara — Tokyo Institute of Technology, Tokyo, Japan (2004)

Christian Hareide — Norwegian University of Science and Technology, Trondheim, Norway (2002–03)

Jan Hasenauer — University of Stuttgart, Stuttgart, Germany (2007)

Florian Hauser — Karlsruhe University of Applied Sciences, Karlsruhe , Germany (2007–08)

Yi Kang He — China (1982–83)

Laureen Hellouin — University of Nantes, France (1997–98)

Siroos Hemmattti — K.N. Toosi University of Technology, Tehran, Iran (2011–12)

Felix Hess — University of Stuttgart, Stuttgart, Germany (2007)

Kieth Hoffman — Queensland University of Technology, Brisbane, Australia (1989–90)

Masafumi Horio — Fuji Electric Device Technology Co., Ltd., Matsumoto, Japan (2007–09)

Takumi Ito — Toshiba Mitsubishi--Electric Industrial Systems Corporation, Fuchu, Japan (2013–14)

Hagen Jahn — Technical University of Dresden, Dresden, Germany (1994–95)

Jin-Hong Jeon — Korea Electrotechnology Research Institute, Korea (2004–05)

Yu-Seok Jeong — Seoul National University, Seoul, Korea (2001–02)

Sheng Ji — Shenyang University, China (1987–88)

Shiqi Ji — Tsinghua University, Beijing, China (2013–14)

Tan Wei Jian — China (1982)

Qin Jiang — Victoria University of Technology-Footscray, Melbourne, Australia (1997–98)

Takushi Jimichi — Tokyo Institute of Technology, Tokyo, Japan (2007–08)

Malte John — Leibniz University Hannover, Germany (2013–14)

Neils Jorgenssen — Denmark (1993–94)

Taeyoung Jyung — Kyungpook National University, Kyungpook, South Korea (2007–08)

Shingo Kato — Honda R&D Company, Saitama, Japan (2005–07)

Takashi Kato — Nissan Research Center, Kangawa, Japan (2010–12)

Christian Kaufmann — Technical University of Ilmenau, Germany (2014–15)

Faeka Khater — National Research Center, Cairo, Egypt (1985–87)

Kyu-Chan Kim — LG Electronics Systems Co. Ltd., Kyungki-Do, Korea (1995–97)

SeHwan Kim — Yeungnam University, Kyungbuk, Korea (2014–15)

Young-Kyoun Kim — Samsung Electronics Co., Ltd (2005)

Ayuki Koishi — Toyota Motor Corporation, Aichi, Japan (2014–16)

Takeshi Komatsu — Kagoshima University, Kagoshima, Japan (2005–06)

Pauli Johannes Komi — Finland (2002–03)

Ulf Kreutzer — Universitat der Bundeswehr, Munich, Germany (2009)

Oystein Krovel — Norwegian University of Science and Technology, Norway (2004–05)

Rüdiger Kusch — Technical University of Berlin, Berlin, Germany (2001–02)

Hyuk-Il Kwon — Pohang Iron & Steel Co. Ltd., Pohang, Korea (1995–96)

Jaime Arroyo Ledesma — Cinvestav, Guadalajara, Mexico (2005–06)

Jin-Won Lee — Samsung Electronics Co. Ltd., Suwon City, Korea (1994–95)

Wook-Jin Lee — Seoul National University, Seoul, South Korea (2007–08)

Alessandra Del Cengio Leonardi — University of Padova, Padova, Italy (1992–96)

Franco Leonardi — University of Padova, Padova, Italy (1993–95)

Ricardo Leuzzi — Politecnico di Bari, Gioia del Colle, Italy (2015)

Xianglin Li — Southeast University, Nanjing, China (2012–14)

Fang Liu — Hefei University of Technology, Hefei, China (2012–13)

Poh Chiang Loh — Monash University, Clayton, Victoria, Australia (2001)

Richard Lund — Norwegian University of Science and Technology, Trondheim, Norway (2001)

Ståle Lygren — NTNU, Trondheim, Norway (2005)

Matheus S. Macedo — Tiradendes University, Aracaju, Brazil (2016)

Pukar Mahat — Institute of Energy Technology Aalborg University, Aalborg, Denmark (2008)

Manuel Pinilla Martin — Technical University of Madrid, Madrid, Spain (2008–09)

Carlos Martínez — University of Oviedo, Gijón, Spain (2014–15)

Francesco Martinez —University of Madrid, Madrid, Spain (2011–12)

Yoichi Matsushita — Kagoshima University, Kagoshima, Japan (2001)

Hugo Mendonca — Universidad Politécnica de Madrid, Spain (2013–14)

Kenji Mitsumoto—Toshiba Corporation, Tokyo, Japan (2006)

Roberto Moncada Gatica — University of Concepcion, Chile (2005, 2009)

Yong-Ky Moon — Samsung Electronics Co. Ltd., Suwon City, Korea (1995–96)

Takashi Nagano — Miyakonojo National College of Technology, Japan (2005–06)

Tsuyoshi Nagano — Nagaoka University of Technology, Nagaoka, Japan (2014–15)

Melissa Naghibian—University of Wisconsin–Madison, Madison, WI, USA (2006)

Hayato Nakano — Fuji Electric Systems, Matsumoto, Japan (2010–13)

Noriya Nakao — Shibaura Institute of Technology, Nagaoka, Japan (2014–15)

Helmut Niedrist — Technical University of Graz, Graz, Austria (1996–97)

Naoto Niimura — Toshiba Mitsubishi--Electric Industrial Systems Corporation, Fuchu, Japan (2014–15)

Carlos E. Nino — University of Puerto Rico, Puerto Rico (2005)

Akihiro Nonaka — Kagoshima University, Kagoshima, Japan (2003–04)

Professor Lorenz in Nissan, Japan, for a research collaboration

David O'Brien — Monash University, Clayton, Victoria, Australia (2000)

Yoshiya Ohnuma — Nagaoka University of Technology, Nagaoka, Japan (2011–13)

Giovanna Oriti — University of Catania, Catania, Italy (1995–98)

Sigurd Ovrebo — Norwegian University of Science and Technology, Trondheim, Norway (2001)

Debiprasad Panda — India Institute of Science, Bangalore, India (2000–02)

Niklas Panten — Christian-Albrechts-University of Kiel, Germany (2013–14)

Chandana Pathirage — Aalborg University, Aalborg, Denmark (2000)

Trinde Pande-Rolfsen — Norwegian University of Science and Technology, Trondheim, Norway (2002–03)

Niklas Panten — Christian--Albrechts–University of Kiel, Germany (2012–13)

Jung Wook Park — Seoul, Korea (2003–04)

Sun S. Park — Kolon Engineering, Seoul, Korea (1990–91)

Mark Pedersen — Aalborg University, Denmark (2005–06)

Chandana Perera — Aalborg University, Aalborg East, Denmark (2000)

Shekar Perlekar — Central Electronics Engineering Research Institute (CEERI), Pilani, India (1986)

Marc Petit — RWTH Technical University of Aachen, Germany (2013–15)

Frank Phlippen — Technical University of Aachen, Aachen, Germany (1997–98)

Paolo Piagi — Universita di Torino, Torino, Italy (1994–95, 2005)

Daniel Pohlenz — Ilmenau Technical University, Ilmenau, Germany

Sagar Pokhrel — University of Oviedo, Gijón, Spain (2014–15)

Mario Pulvirenti — University of Catania, Italy (2014–15)

Stefan Quadrat — University of Bundeswehr, Munich, Germany (2010)

Francesco Quattrone — Leibniz University, Hannover, Germany (2010–12)

Christian Rabus — University of Erlangen-Nuremberg, Nuremberg, Germany (2010)

U.M. Rao — Central Electronics Engineering Research Institute (CEERI), Pilani, India (1987–87)

David Diaz Regiosa — University of Oviedo, Gijon, Spain (2007–08)

Habib Rehaolia — University of Tunis, Tunisia (1985)

Leopoldo Resta — SIEI Peterlongo, Gerenzano, Italy (1994–95)

Luiz Antonio d.Souza Ribeiro — University Federal da Paraiba, Paraiba, Brazil (1996–98)

Jan Richnow — University of Bundeswehr, Munich, Germany (2010)

Javier Rivas — Carlos 3tr University of Madrid, Madrid, Spain (2005–07)

Ben Rudolph — TMEIC, Roanoke, VA (2015–16)

Thomas Rump — University of Rostock, Germany (2010)

Hong Je Ryoo — Industrial Application Laboratory/ KERI, Korea (2004–06)

Khaled Mohammed Sakkoury — Peace Fellowship Trainee, Egypt (1992–93)

Ahmet Saleque — University of Oviedo, Gijón, Spain (2014–15)

Carlos Bo Santiago — University of Puerto Rico, Mayaguez (2002)

Hiroyuki Sano — JSOL, Tokyo, Japan (2008–10)

Kensuke Sasaki — Nissan Research Center, Atsugi, Japan (2013–16)

Michael Saur — University of Erlangen, Germany (2012–14)

Michael Schüett — University of Rostock, Germany (2013–14), (2015–16)

Guiseppe Scarcella — University of Catania, Catania, Italy (1998)

Salman Khalid Sheikh — University of Oviedo, Gijón, Spain (2016)

Yuichi Shibukawa — Nissan Research Center, Kanagawa, Japan (2007–10)

Shen Shicen — Beijing Institute of Control Engineering (1986–87)

Professor Jahns with WEMPEC alumni and past visitors at Huazhong University of Science and Technology (HUST).

Olaf Simon — University of Karlsruhe, Karlsruhe, Germany (1994–95)

Stev Skaar — Norwegian University of Science and Technology, Norway (2005)

Brigitte Sneyers — University of Brussels (1983)

Eng Kian Kenneth Sng — Ngee Ann Polytechnic, Singapore (1995–96)

Rainer Sommer — Technical University of Berlin, Berlin, Germany (1990)

Joong-Ho Song — Korea Institute of Science and Technology, Seoul, Korea (1995–96)

Ana Stankovic — Nikola Tesla EE Institute, Belgrade, Yugoslavia (1990)

Ewgenij Starschich — RWTH Aachen University, Toenisvorst, Germany (2006–07)

Oscar Stielau — Rand Africaans University, Johannesburg, South Africa (1991–91)

Gorazd Stumberger — University of Maribor, Maribor, Slovenia (1997–98)

Bum-Seok Suh — Hanyang University, Seoul, Korea (1997–98)

Yongsug Suh — Chonbuk National University, South Korea (2016–17)

Chiping Sun — Harbin Institute of Technology, Harbin, China (1990)

Zhenxing Sun — Southeast University, China (2016–17)

Takahiro Suzuki — Hitachi, Ltd., Hitachi, Japan (2008–09)

Yusaku Suzuki — JSOL Corporation, Tokyo, Japan (2010–12)

Jun Tamura — Nissan Research Center, Kangawa, Japan (2010–12)

Chun Tang — University of Adelaide, Australia (2012–14)

Roberto Terrigi — Ansaldo Ricerche, Italy (2004)

Valentin Tijeras — Universidad de Granada, Granada, Spain (2000)

Akio Toba — Fuji Electric Company, Ltd., Tokyo, Japan (1997–98)

Shunsuke Tobayashi — Toshiba Mitsubishi--Electric Industrial Systems Corporation, Fuchu, Japan (2012–13)

Chengde Tong — Harbin Institute of Technology, Harbin, China (2015–16)

Jose Torrico — Unicamp, Brazil (2000)

Eigo Totoki — Mitsubishi Electric Corporation, Amagaski, Japan (2014–16)

Pietro Tricoli — University of Naples 'Federico II,' Naples, Italy (2005)

Andrew Tuckey — Eindhoven University of Technology (2000–01)

Mark Ubbink — HAN University Arnhem/Nijrnegen, Arnehm, The Netherlands (2009)

René Cristián Valenzuela — University of Concepción, Concepción, Chile (2001–02)

Christoph van der Broeck — Technical University of Aachen, Germany (2011–13)

Mostafa Valavi — Norwegian University of Science and Technology, Trondheim, Norway (2012–14)

Rahul Varma — Central Electronics Engineering Research Institute (CEERI), Pilani, India (1986–87)

Carlos Veganzones — Polytechnical University of Madrid, Spain (2012–13)

Jens-Uwe Vilsser — University of Karlsruhe, Germany (1994–95)

Oskar Wallmark — Chalmers University of Technology (2005)

Marsha Walters — North Carolina AT&T, Greensboro, NC, USA (2006, 2007)

Feng Xiang Wang — China (1982–83)

Kang Wang — Northwestern Polytechnical University, Xi'an, China (2012–14)

Liang Wang — Tsinghua University, Beijing, China (2012–13)

Li Mei Wang — Shenyang University of Technology, Shenyang, China (1998–99)

Xiaocan Wang — Technical University of Munich, Germany (2013–14)

Kai Warns — Technical University of Aachen, Aachen, Germany (1997–98)

Masaki Wasekura — Toyota Motor Corporation, Toyota, Japan (2011–13)

Bernhard Werner — Technical University of Aachen, Aachen, Germany (1990–91)

Karsten Wiedmann — University of Hannover, Hannover, Germany (2009)

Rudolf Wieser — Technical University of Vienna, Vienna, Austria (1997–98)

Hon Win Woon — University of Warwick, Warwick, United Kingdom (2006–07)

Assistant Professor Sarlioglu with graduate students.

Hanguang Wu — University of Fuzhou, Peoples Republic of China (1984–86)

Fan Wu — Harbin Institute of Technology, China (2014–15)

Shanshan Wu —Tsinghua University, Beijing, China (2007–08)

Wei Xie — Universität der Bundeswehr--Munich, Germany (2013–14)

Yan-Hong Xue — Tsing Hua University, Beijing, China (1989–90)

Sheng-Yang Yeh — University of Taiwan, Taiwan (1986)

Sung-Jung Yoon — Samsung Aerospace, Yongin-Kun, Kyungki-Do, Korea (1995–96)

Xinmei Yuan—Tsinghua University, Beijing, China (2008–09)

Li Zhang — Southeast University (2016–17)

Shujun Zhang — Norwegian University of Science and Technology, Trondheim,Norway (2010–11)

Xiaoguang Zhang — Harbin Institute of Technology, Harbin, China (2012–13)

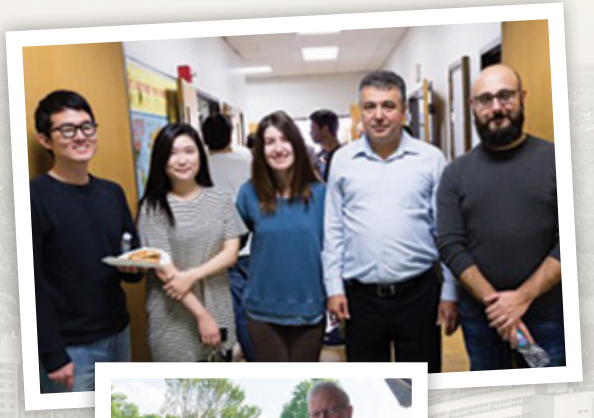
Fei Zhao — Hanyang University, ERICA Campus, Korea (2013–14)

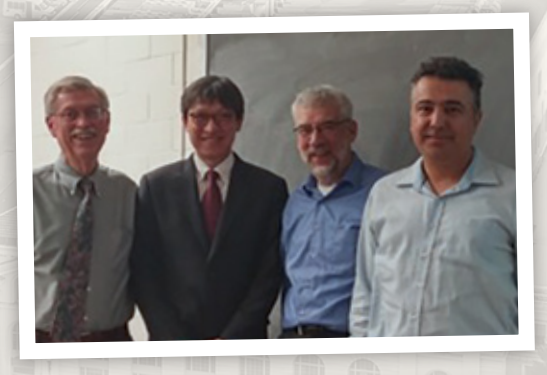
Yifan Zhao — China University of Mining and Technology, Xuzhou, China (1990–91)

Visiting Professor Jiang and his daughter.

Prof. Lorenz tries on his German doctoral hat.

Relaxing at the international potluck dinner.





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