James R. Hendershot
Electric Motor Design Consultant
Motor Design Tutorial-Workshops

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James Hendershot, IEEE Life Fellow

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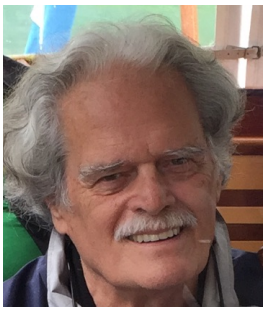
Electric Motor Design & Manufacturing Expert

Generator Design
High Speed Motor Design
Motor Manufacturing Process Design
Motor Design Tutorials
Motor Prototyping Services



PM Synchronous AC Motor Design
Brushless DC Motor Design
Switched Reluctance Motor Design
AC 3-Phase Induction Motor Design
Reluctance Synchronous Motors

Jim Hendershot retired on Sept 9, 2006 from *MOTORSOFT, which* he founded in 1989 and sold to Fisher Electric Technology in 2004. He then founded a company to provide test equipment for universities and motor prototyping services called *MOTORSOLVER LLC*. Due to increased motor design consulting customers he partnered with Clyde Hancock and formed *MOTOR CONSULTANTS LLC* in 2010 and sold out to Clyde on Dec 31, 2014. He now manages full time his electric motor prototyping company called *MOTORSOLVER* LLC with historical beginnings back to Sept 1989. In addition JH continues lecturing & teaching motor design courses & hands-on workshops around the World.

JH has over 40 years experience in practical hands-on PM & SR brushless motor design, manufacturing and development. With past key employments at United Technologies, General Motors, Clifton Precision, Berger Lahr & Pacific Scientific, he has designed hundreds of brushless motors for computer disc drives, servo systems, high speed machine tool spindles, traction drives, hybrid vehicles, micro-turbine and diesel generators. He has written numerous technical papers, publications and given tutorials on many different electric motor topics. Hendershot is the co-author with Professor TJE Miller for two of the leading design books on Permanent Magnet Brushless Motors and Generator Design. (ISBN 1-881855-03-1, 1994 & ISBN 978-0-9840687-0-8, 2010).

The design services are also offered by Jim Hendershot that involve expert electric motor design and simulation for all types motors and generators listed above including axial and radial flux.

He teaches detailed motor design training courses (with optional workshops) at public venues,

conferences and custom design workshops tailored on-site for companies around the World.

The design and simulation tools used by Jim Hendershot for detailed and accurate electric machine design include MotorSolve & Magnet 2D/3D (by Infolytica), PSIM (by PowerSim), AutoCad 3D, PRO-E, Matlab/Simulink, and MathCad.

Jim Hendershot holds a B.S in Physics from Baldwin Wallace University in Berea Ohio along with additional E.E. & M.E. engineering studies at Cleveland State University as well as graduate courses at Case-Western University in Cleveland Ohio. He specializes in the design, analysis, sourcing, manufacturing and teaching of both electro-magnetic and permanent magnetic devices. In addition to continuing studies in magnetics and electric machines Jim Hendershot has over 40 years of extensive experience designing, manufacturing and applying electric motors of most all types.

Jim has enjoyed a long and rich association with Prof. Dr. Tim Miller, founder of the SPEED Consortium at the University of Glasgow, combining Jim's practical hands-on motor design skills with TIM'S theoretical knowledge and research.

For the past 14 years Jim has also been associated with Infolytica Corp, Prof. Dave Lowther (of McGill University), Prof. Ernie Freeman ret. from Imperial College, London and their staff for their FEA based simulation software used around the world for the design and research of electric motors and generators.

James Hendershot developed a Dyno-Kit for teaching electric motor drives used by over 160 US Universities and Colleges for Prof. Ned Mohan of the University of Minnesota. These are used for the lab portion of their Electric Drive Courses. (www.cusp.umn.edu)

Jim Hendershot has created a series of 37 electric machine design lectures for the University of Minnesota, funded by the US Navy Research Labs that are available on www.cusp.umn.edu totaling 10 to12 hrs. of lectures covering all aspects of practical electric machine design.

U.S. Patents (18)

Five patents on Switched Reluctance DC Brushless Motors, 4883999, 4995159, 5015903, 5111095 & 5652493

Two patents on slotless DC Servo Motors, 3953750 & 4110645

Four patents on magnetic particle clutches and brakes, 3620335, 3664473, 3672476, & 3680671

Six Patents on PM-AC Synchronous Machines, 6880229, 7042130 , 2003/0168926A1, 8227948, 8575800 & 9343987

One patent on Eddy Curretn brake on personal escape Device fromk burning building, 20170333735

Professional Affiliations

IEEE Life Fellow (2000)

Member of SAE

Past member of ASME

Charter Member of IMCS (Incremental Motion Control Society)

Member of SMMA (Small Motor Manufactures Association)

Books and Publications authored or co-authored:

1. **Hendershot, J.R. (**92 pages) "**Dynamometer and Servomometer Testing of Electric Machines**" **(**Vibrac div of Dana Corp. 1975)
2. **Hendershot, J.R**. Stevenson, $_{th}$J.M. & MacMinn, S.R. (90 pages) "**Switched Reluctance Drive Tutorial Course**" presented 25 IEEE-IAS Annual meeting, Seattle WA (IEEE 1990)
3. **Hendershot, J.R.** (217 pages) "**Design of Brushless Permanent Magnet DC Motors**" ISBN 1-881855-00-7, (Magna Physics Publishing 1991)
4. **Hendershot, J.R**. & Miller T.J.E. **Design of Brushless Permanent Magnet DC Motors** (550 pages) ISBN 0-19-859389-9 (Oxford Press 1994)
5. **Hendershot, J.R.** et al. (over 1600 pages) "**Pump Handbook**", (2001) Third edition ISBN 0-070340323 & (2007) Fourth edition ISBN 9780071460446 Co-authored chapters 6.1.1 & 6.2.2, ISBM, (McGraw-Hill)
6. **Hendershot, J.R.** & Miller T.J.E. (822 pages in color) "**Design of Brushless Permanent-Magnet Machines**", ISBN 976-0-9840687-0-8 (Hendershot & Miller 2010)
7. **Hendershot, J.R,** & J.T. Larkins, **Electric Drives For Heavy Urban Transit Buses, (**2001) Incremental Motion Control System Society, University of IL
8. **Hendershot, J.R**. "**Brushless Motors Without Permanent Magnets",** (1994)**,** Incremental Motion Control System Society, University of IL
9. **Hendershot, J.R. "Brushless DC Motor Phase, Pole & Slot Configurations",** (1996) Incremental Motion Control System Society, University of IL**,**
10. **Hendershot, J.R. "AC, Brushless, Switched Reluctance Motor Comparisons**" 1999) Incremental Motion Control System Society, University of IL
11. **Hendershot, J.R. " Causes & Sources of Audible Noise in Electric Motors"** (2005) Incremental Motion Control System Society, University of IL
12. **Hendershot, J.R. " A Five Phase Switched Reluctance Brushless DC Motor With A Low Loss Magnetic Circuit"** (1992), Incremental Motion Control System Society, University of IL
13. **Hendershot, J.R. "High Speed Brushless Permanent Magnet Motors for Spindles & Compressors"** (1997), Incremental Motion Control System Society, University of IL
14. **Hendershot, J.R. "Switched Reluctance Brushless DC Motors for Adjustable Speed Drives and High Efficiency"** (2000), Incremental Motion Control System Society, University of IL
15. **Hendershot, J.R. "Switched Reluctance Brushless DC Motors With Low Loss Magnetic Circuits"** (1991), Incremental Motion Control System Society, University of IL
16. **Hendershot, J.R. "Pole & Slot Number Selection Procedure for PM Synchronous Machines" CWIEME Berlin,** (2016)

Jim Hendershot is a prolific world traveler, having visited 34 countries while teaching electric machine design and consulting in many of those countries since 1966. His latest textbook on electric machine design, co-authored with Prof. TJE Miller has been transuated into the Japanese language.

He has served as a consultant for Infolytica Corp. in Montreal since 2005 for their electric machine Design software products. In the fall of 2017, Infolytica was aquired bythe Mentor Graphics div. of SIEMENS and Jim Henderhot continues this annual consulting relationship with Mentor-Siemens.

Electric machine design lectures and workshops

Prepared & recorded (37) 15 to 20 minute lectures on the **Design of Electric Machines** for the University of Minnesota "**Consortium of Universities for Sustainable Power** "and posted on their consortium web site (**www.*cusp.umn.edu***) used a supplemental teaching material for lecture preparation by University professors all over the world to better prepare electrical engineers how to design practical electric motor and generators. These lectures are also available to any student, professor or practicing engineer via the **CUSP.UMN.EDU** web site.

Conducted electric machine design workshops around the world for Infolytica Corp. of Montreal.

Taught private (customized for companies) and public electric motor design workshops all around the world in USA, Turkey, Germany, Switzerland, Japan, Australia, Singapore and France.

One of three lecturers at IAS in Seattle, Oct 12,1990 presented a Tutorial course on **Switched Reluctance Drives** with Dr. J.M. Stephenson and Dr. S.R. MacMinn

Author of over 50 technical papers and magazine articles on the design of **PM brushless & PM-AC** synchronous machines as well as switched reluctance machines.

Jim Hendershot is a popular lecturer on designs & trends in electric motors and generators for local chapter IEEE meetings (Florida International University, University of Dayton and University of Wisconsin).

Presented three hour lecture at IEEE-IEMDC 2017 in Miami
Co-authored by Tim Burress of Oak Ridge National Laboratory
Edited by: Emeritus Professor Ernie Freemen, FREng & Fellow Royal Academy of Engineering (1987)

World Energy Shortage Exacerbated by Critical Shortage of Experienced Electric Machine Design Engineers Lecture, NSF – Sponsored Workshop in Abu Dhabi Nov 2012

Professional Awards:

1. **Life Fellow** (2000) of the Institute of Electrical and Electronics Engineers **(IEEE**).
2. **EMERF annual award for "Outstanding Contributions to the Electric Machines Industry"** awarded at 2011 **SMMA** annual meeting
3. **Member SAE** (2000)
4. **PAST Member ASME** (2013)
5. **Charter member Motion Control Association** (MCS in 2006))
6. **Member of Small Motors Manufacturing Association** (SMMA)
7. **Outstanding Contribution - IEMDC BERLIN** (2017), **"A Lifelong Commitment to Industry"**

Expert Wirtness and Technical Services Rendured

Provided expert witness activities including deposition and report preparation plus a trip to Nottingham UK to witness hardware testing for a patent infringement case between VIDEOJET Technologies from Nottingham England and MARKEM Machines in Keene NH (GB patent # 2369602 and US # 2010/0172681)

Provided prior art search in behalf of AMETEK Corp of Kent OH defended against alleged patent infringements owned by Papst Licensing GmbH & Co. KG in Germany. Discovered prior art against the 1988 & the1989 PAPST patents in a 1924 textbook by KROFT so the case was dropped.

Provided expert witness services for Finmeccanica S.p.A. (and the University of Rome) inItaly against General Motors Corp.(the defendant.) The case was Finmeccanica S.p.A et al. vs. General Motors Corporation, number 07-794 in the U.S. District Court for the Eastern District ofVirginia. Eventually transferred to California (LA District Court) The case lasted from about 2005 untillate May 2009 when GM offered a settlement and then on June 1 2009 GM filed bankruptcy.

Currently under contract providing technical advice and witness services to the US department of Justice regarding an alleged white-collar crime against two former employees of Sprung Brett RDI Inc. of Buffalo NY.

Currently under contract providing expert witness support for the plaintif on aplastic injection molding case.

Appendix A List of recorded 37 lectures by James Hendershot posted on *CUSP.umn.edu* entitled:

"Electric Motor Design Course Lectures"

1 - History & Introduction of Electric Machine Types
2 - Basic Electric Motor & Generator Operational Theory
3 - Three Phase Power Converter Control Strategies for Three Machine Types
4 - Practical Design Process for Electrical Machines
5 - Electric Machine Sizing
6 - Losses in Electrical Machines
7 - Analytical design method vs. FEA analysis method Design Methods
8 - Electric Machine Performance Discussion
9 - Magnetic Materials for Electric Machines
10 - Selection of Phases, Poles, Stator & Rotor Slots
11 - Stator Configuration Design Criteria
12 - Stator Laminations & Core Studies
13 - Stator Insulation System vs. Voltage & Temperature
14 - Stator Phase Circuits & Coil Design, Part 1
15 - Stator Phase Circuits & Coil Design, Part 2
16 - Introduction to Poly-Phase Induction Machines
17 - Poly-Phase Induction Machine Theory
18 - Poly-Phase Induction Machine Design Strategy
19 - Equivalent Circuit Parameters., Measurements and Torque vs. Speed Plots
20 - Rotor Design for A-Synchronous Induction Machines
21 - Rotor Design for A-Synchronous Induction Machines,
22 - Rotor Design for A-Synchronous Induction Machines,
23 - Reluctance Synchronous Motors (Salient Pole Rotor)
24 - Reluctance Synchronous Machine Theory
25 - Rotor Design of Reluctance Synchronous Machines
26 - Performance Analysis of Reluctance Synchronous Machines
27 - PM-DC Brushless and PM-AC Synchronous Machines
28 - PM Synchronous Design Theory, SPM & IPM Rotor Types
29 - Permanent Magnet Rotor Design (SPM & IPM)
30 - Performance Calculations for SPM & IPM Brushless Machines
31 - Torque vs. Speed & K_t vs. K_e for SPM, IPM & PMSM brushless motors
32 - PM Synchronous Generator Design Principles
33 - Thermal Design Considerations for Electric Machines
34 - Electric Machine Cooling Strategies
35 - Mechanical Design Issues for Electrical Machines
37 - Summary & Electric Machine Design Challenges

Appendix B List of design workshops and lectures by JR Hendershot (41)

PM Synchronous Alternator Design Tutorial, Oriental Motor, 2005
BLDC MOTOR DESIGN WORKSHOP, SMMA, ST LOUIS, 2010
DESIGN & OPTIMIZATION OF BLDC-AC SYNCHRONOUS MACHINES, E-DRIVES Orlando, 2010
BRUSHLESS PM-AC & DC SYNCHRONOUS WORKSHOP, CIRCOR Aerospace, Dayton, 2010
PM Synchronous Alternator Design Tutorial, July 2010, Venice FL
AC INDUCTION MOTOR WORKSHOP FOR INVERTER OPERATION, CWIEME Chicago, 2010
PM-AC & DC SYNCHRONOUS MACHINES WORKSHOP, AKRIBIS SINGAPORE, 2011
DESIGNING YOUR BLDC MOTOR (or GENERATOR), SAN ANTONIO TX, 2011
Dual-Fed A-Synchronous Generator for 2 MW Wind Turbine, IEEE-ECCE, 2011
BRUSHLESS PM-AC & DC SYNCHRONOUS MACHINES , AFRL/RZPG, Dayton WPAFB, 2011
BRUSHLESS PM-AC & DC SYNCHRONOUS MACHINES , Infolytica, Los Angeles 2011
History of Electric Machines (Motors & Generators), SMMA St Louis, 2012
PM Synchronous & AC Induction Machines for Flight Apps, NASA GLENN, Cleveland, 2012
Reducing Cost in Brushless PM-AC Machines, E-DRIVES, Orlando, 2012
(3) Electric Machine design Workshop for Aerospace, Infolytica, Los Angeles CA, 2012
Tramway Traction Motor Design Workshop, ALSTOM, France, 2013
Electric Machines, Present & Future, MMT Tech Days, France, 2013
Motor/Generator Design Workshop for Vehicle Traction, VALEO, France, 2013
Poly-Phase AC Induction Motor & Generator Design Process, Infolytica, Milwaukee, 2013
PM-AC Synchronous Brushless Machine Workshop (IPM & SPM), Infolytica, Milwaukee, 2013
New Automotive Applications for Electric Motors, MACCON GmbH, Munich, 2013
Electric Traction Machine Choices For Hybrid & Electric Vehicles, FIU, MIAMI, 2014
Electric Machine Design Choices for Hybrid & E Vehicles, McGill University, Montreal, 2014
PM-AC Synchronous Motor/Generator Design Workshop, Infolytica, Dallas, 2014
EV Traction Motor Design Workshop, (3) Machine Types, Infolytica, Dearborn MI, 2014
PM-AC Brushless Synchronous Motor Design for Surgical Tools, STRYKER, Michigan, 2014
Generator Designs Including Choices for Hybrid Vehicles, CWIEME-BERLIN 2015
Motor Efficiency and Standardization Lecture, CWIEME-BERLIN 2015
Electric Powered Flight (MEA), IEEE Peal Chapter, Dayton OH, 2015
Electric Traction Motor Design Tapping the Potential of E-Mobility 2015 CWIEME Chicago
Generator Designs Including Choices for Hybrid Vehicles, CWIEME Shanghai 2015
Electric Motor & Driver Workshop NASA Cleveland, June 2016
Electric Motor & Driver Workshop NASA Cleveland, September 2016
MOTORSOLVE Analysis of 2010 Toyota Prius Traction Motor, Infolytica Engage 2015
Generator Designs Including Choices for Hybrid Vehicles, CWIEME Berlin 2016
Designing a PM Generator for a Hybrid Vehicle With MOTORSOLVE, Infolytica Engage 2016
Motor, Generating, Simulation For BMW i3 Traction Machine, IEEE-IEMDC 2017
E-Car Project Insight Tutorial, BMW i3 Electric Traction Drive. CWIEME Chicago 2017
BMW-I3 Electric Traction Drive lecture at IESF Automotive in Munich 2017
Analysis of the BMW i3, E-Cars electic motor-generator, Siemens PLM Connection Phoenix 2018
High density PM electric motor & generator design, EV Momentum Berlin 2018