Advanced MotorTech, LLC
9117 Park Blvd.
Largo, FL 33777

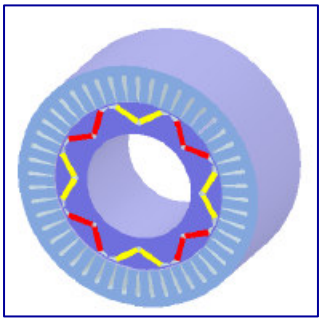
L.A. Area

Design of Interior Permanent Magnet and Brushless DC Machines – Taking Theory to Practice

Learn practical IPM and BLDC Machine Design by applying motor characteristics, academic theory and manufacturing practices

May 10-12, 2010, Torrance, CA

- ***IPM & BLDC Machine Theory & Design Methods***
- ***Practical Magnetic Analysis, New Understanding***
- ***Putting Magnets & Winding Designs to Work***
- ***Performance & Loss Calculations***
- ***Realistic Practice & Expectation***
- ***Understanding & Choosing Controls***

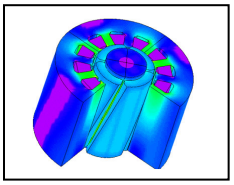


Objectives and Benefits

This course addresses the key state-of-the-art application-oriented design issues for IPM & BLDC machines. We will use basic motor principles to increase your understanding of integrating permanent magnets into any IPM or BLDC machine design. Academic theory will be reduced to practical results with calculation 'how-to', taking manufacturing constraints into account. Special emphasis will be on design differences and new trends in IPM/BLDC motors, including new analysis techniques and design options to achieve specifications such as efficiency, power density, and torque per amp. The similarities and differences of IPM/BLDC machines, compared to induction machines and wound-field synchronous machines, are in nearly all topics.

The course material is presented using a combination of modern machine design concepts and computer techniques. The specification requirements, design steps, and analysis approaches are discussed for motors and drive systems for a variety of applications such as hybrid vehicles, all-electric traction, wind turbine generators, home appliances, aerospace, and industrial. Included is the application of advanced control algorithms and newer manufacturing methods.

The primary goal of this course will be to provide an up-to-date foundation of IPM and Brushless DC machine design practice to produce accurate and realistic design results based on the electrical, magnetic, mechanical, and thermal interactions.



Those who will benefit:

- **Motor design engineers**
- **Application engineers, especially for EV, HEV and, UAV Wind Energy**
- **Suppliers to motor manufacturers**
- **Control engineers**
- **Engineering and R&D managers**
- **Others who specify, design, analyze, manufacture or service IPM or BLDC machines**

You should have some background in electric machine operation and construction such as the equivalent of a B.S. degree in engineering. Understanding of basic magnetic circuits is needed, but advanced motor theory and control techniques are not essential.

Course Schedule

Day 1: May 10

7:30-8:00 Registration

8:15 Session Begins

Fundamentals of PM Machine Design – Quick Review

- ☑ Applications, Types, Trends
- ☑ BLDC vs. BLAC vs. IPM
- ☑ PM Rotor Configurations, & Why
- ☑ Torque Production in PM Machines

PM Material

- ☑ Understanding PM Material
- ☑ PM Material Options
- ☑ Physics of Demagnetization
- ☑ Temperature, Aging, Conditioning
- ☑ Losses

Steel Core

- ☑ Electrical Steels for IPM/BLDC
- ☑ Coatings & Heat Treatment
- ☑ Core Loss Calculations & Modeling
- ☑ Segmented & Hinged Laminations
- ☑ Soft Magnetic Composites
- ☑ Sources of Good Data

Magnetic Analysis Techniques & Calculations

- ☑ Non-linear Magnetic Circuits
- ☑ Slot Shape, Pole Shape
- ☑ Air gap effect, Saturation
- ☑ Motor Design Software & FEA
- ☑ Calculating Required Flux

BLDC Machine Design

- ☑ Winding MMF & Winding Factor
- ☑ Magnetic Circuit Design, Torque
- ☑ Performance, Operating Limits
- ☑ Example Design
- ☑ Air Gap Flux Density, Reactances

IPM Machine Design

- ☑ Unique Characteristics
- ☑ Magnetic Circuit Design
- ☑ Reluctance Torque, Options
- ☑ Performance, Operating Limits
- ☑ Example Design

How to Design an IPM Motor, Part I

- ☑ Sizing, 1st Approximation
- ☑ Specification, Materials, Cooling
- ☑ Choosing Poles, Slots, Frequency
- ☑ Designing Rotor PM Configuration
- ☑ Designing Stator Slots
- ☑ Designing the Winding

4:45 Session Ends

Day 2: May 11

8:15 Session Begins

How to Design an IPM Motor, Part II

- ☑ Getting Torque, Speed, Current
- ☑ Design for Max Torque per Amp
- ☑ Lowering Cost by Magnet & Lamination Design
- ☑ Reducing Cogging & Pulsation Torque
- ☑ Optimization Methods & Expectations

Performance Calculations

- ☑ Design Specifications
- ☑ d-q Equivalent Circuit
- ☑ Key Figures of Merit
- ☑ Torque vs. Speed
- ☑ FEA Models, Simulation

Practical Design Windings

- ☑ Coils, Phases, Circuits
- ☑ Winding Pattern Choices
- ☑ Manufacturing Considerations
- ☑ MMF Harmonics
- ☑ Some Practical Tricks of the Trade

Concentrated Winding Designs

- ☑ Applications, Pros & Cons
- ☑ Fractional Slot-Winding Design
- ☑ End-Winding Loss
- ☑ Winding Factor
- ☑ Slot/Pole Combinations to Choose/Avoid

Control of IPM/BLDC Motors

- ☑ Digital vs. Analog Control
- ☑ DSP vs. Micro Controller
- ☑ Current and Position Sensing
- ☑ PWM, 6-step, Modulation
- ☑ Current Control, Torque Control, Field Weakening
- ☑ Vector Control
- ☑ Sensorless Control

Loss Calculations & Segregation

- ☑ Loss Components
- ☑ Problem of Core Loss Prediction
- ☑ Eddy Current Losses
- ☑ Efficiency Calculation
- ☑ Practical Ways to Reduce Losses

Thermal Analysis

- ☑ Thermal Modeling
- ☑ Losses, Heat, Efficiency
- ☑ Typical Parameter Values
- ☑ Reference Data

4:45 Session Ends

Day 3: May 12

8:15 Session Begins

Wind Energy Application

- ☑ Wind Energy Conversion System Configurations
- ☑ Gearless Application
- ☑ Geared Application
- ☑ Design Example

Traction and Propulsion Applications

- ☑ PM Machines in Automotive
- ☑ EV and HEV Applications
- ☑ Toyota Prius PM Motor
- ☑ Honda Insight PM Motor
- ☑ Honda FCX PM Motor
- ☑ HEV Example Design
- ☑ Fault Tolerant EV Design Example

Power Tools Applications

- ☑ Design Requirement
- ☑ Control Options
- ☑ Design Example

Realistic Manufacturing Tolerances

- ☑ Important Key Parameters
- ☑ Issues with Core Steels
- ☑ Issues with Magnets
- ☑ High speed Design Example

New Trends & Technologies – What, Why, When

- ☑ Linked CAE Simulation
- ☑ Hardware-in-Loop Simulation
- ☑ Transverse Flux & Torodial Winding Machines
- ☑ Control of Chinese Magnet Market

11:45 Adjourn

Future Courses:

To receive brochures on upcoming courses, please tell us your interests:

- □ Induction Machine Design
- □ Design of Magnetic Components for Power Electronic Circuits
- □ Switched Reluctance Machine Design
- □ Traction Motor Design and Drives
- □ Focused motor type or issue:

_____

_____

- □ Other_____

_____

Instructors:

Dr. Mehdi Abolhassani is an experienced machine design trainer and Principal R&D Engineer with TECO-Westinghouse Motor Co., Round Rock, TX. Dr. Abolhassani received his PhD degree in Electrical Engineering from Texas A&M University and has experience in teaching graduate and undergraduate courses. He has over 15 years experience in designing, manufacturing, and testing permanent magnet motor drives and power electronic converters from fractional hp to 2 MW, in various automotive, traction, industrial and home appliances applications. Dr. Abolhassani has been a leader in various product development projects from concept to production. He is a contributor to chapters of *DSP-Based Electro-mechanical Motion Control*, and *Handbook of Power Electronics, 2nd Edition: Devices, Circuits and Applications*. He holds 12 issued or pending US and international patents. His expertise areas include electrical machine design, variable speed drives for traction and propulsion applications, power electronics for automotive, and wind energy conversion systems.

Dr. Keith W. Klontz is President and CEO of Advanced MotorTech LLC, a computer-aided engineering services company with emphasis on electric machine and magnetic component design. He holds BS & MS degrees in Electrical Engineering from the University of Illinois, Champaign-Urbana, and a PhD in Electrical Engineering from the University of Wisconsin-Madison. Dr. Klontz is a world-recognized expert in electric machine design and has over 35 years hands-on experience with electric machine design engineering, from concept to performance to failure analysis. He has been involved in the research, development and testing of very high performance machines from 10 Watts to 8 MW, with speeds ranging from angle positioning torque-motors to 60,000 rpm machines. Recent work includes developing design techniques and implementing new manufacturing methods for permanent magnet alternators, brushless d.c. motors, brush d.c. motors, high efficiency induction motors, and very high power density machines.

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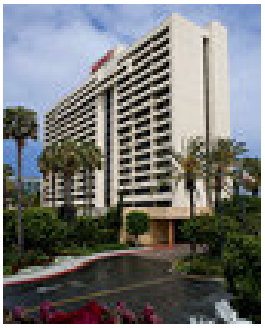
General Information



Fee Includes: Workbook, program materials, break refreshments, and certificate.

Cancellation: Notify us at least seven days before the course starts for 100% refund. Cancellations received later than seven days before the course are subject to a 15% late cancellation fee. Cancellations made after the course starts are subject to the full course fee.

Location: Torrance Marriott South Bay
3635 Fashion Way
Torrance, CA 90503
Phone: 310-316-3636

Accommodations: A **reduced-rate block** of rooms has been reserved at the Torrance Marriott South Bay Hotel for reservations made **before April 25th**. Identify yourself as a participant in this course to reserve a room at the reduced rate. Additional directions and information will be sent with your enrollment confirmation. Please make your own reservations.

☐ **Yes! Please enroll me in Course No. IPM-BLDC-1005**
IPM/BLDC Machine Design, May 10-12, 2010
Fee: $1295.00 (USD only)

PAYMENT: (Deadline: must be received before start of course)

☐ MasterCard ☐ VISA ☐ Amex

- Cardholder Name _____
- Card No. _____
- Exp ___/___/___ Billing Zip_____ Security Code: _____

□ Check enclosed (payable to Advanced MotorTech, LLC) *
□ Bill my company* □ Purchase Order*
* Please note payment deadline above; no exceptions; subject to approved credit.

Name _____

Title _____

Company _____

Address _____

City _____ State _____Zip _____

Phone ( ) _____ email_____

To Enroll: Phone: (727) 412-8200 Fax: (727) 412-8203
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Email: Training@advancedmotortech.com