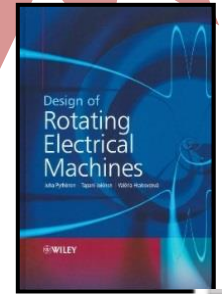


**Permanent Magnet AC Machine Design**  
*Includes BLDC, IPM and SMPM motors and generators*  
**-Taking Theory to Practice**

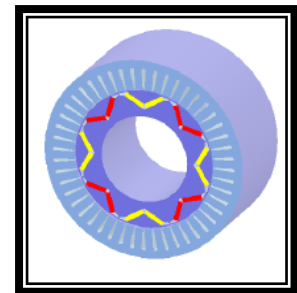


**Join Us in Hartford, Connecticut!**  
**August 23<sup>rd</sup>, 24<sup>th</sup>, and 25<sup>th</sup>, 2016**  
**At the Marriott Hartford/Windsor Airport**

**Learn to Design PMAC Motors and Generators: SMPM, BLDC, IPM, and PM Generators by applying practical experience, academic theory, material characteristics & manufacturing practices:**

**Permanent Magnet AC Machine Design Methods**

- Practical Magnetic Analysis Techniques for Motors**
- Selecting Materials, Poles, Slots, Turns, Shapes**
- Putting Magnets & Coils to Work, Concentrated Coils**
- Performance & Loss Calculations That Work**
- Realistic Practice & Expectation**
- How to Test for Parameters & Performance**



**Objectives & Benefits:**

Get the “How-to” for state-of-the-art, application-oriented design of sinusoidal Surface Mounted PM (SMPM), trapezoidal Brushless DC (BLDC) machines, Interior Permanent Magnet (IPM) motors & PM generators. Learn solid foundations of PMAC machine design techniques based on academic theory and years of practical experience, taking manufacturing limits and costs into account.

You will learn about the latest PMAC motor design trends, including:

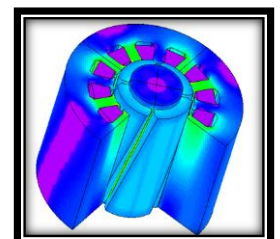
- ◆ Rare Earth Magnets Versus Low Cost Ferrite magnets
- ◆ New Analysis Techniques, Computer-Aided Engineering, Quick Approximations
- ◆ Trade-offs for Achieving Efficiency, Power Density, Torque-Per-Ampere, Constant Power Speed Range
- ◆ Design for Flexible Manufacturing, Low Cost, and New Manufacturing Methods

Material in this course is engineering you can't find in a book, & you can't get from software training! Presentations include specification requirements, design steps, balancing cost and performance, good rules of thumb, analysis approaches & test methods. Applications include hybrid electric drives, traction, wind turbine generators, home appliances, aerospace, and industrial applications.

The updated material in this course is a combination of the latest machine design concepts & computer techniques, with a heavy dose of experience. You will also understand the major similarities & differences of PMAC machines, compared to induction machines & wound-field synchronous machines.

**Those who will benefit:**

- ◆ **Motor & Generator Design Engineers**
- ◆ **Drive & Control Engineers**
- ◆ **Application Engineers, Especially for EV, HEV, UAV, Wind Energy, High Efficiency**
- ◆ **Suppliers to Motor Manufacturers**
- ◆ **Engineering & R&D Managers**
- ◆ **Others Who Specify, Design, Manufacture or Service SMPM, BLDC or IPM Machines**
- ◆ **Electric Machine Professors & Graduate Students**



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

## \*Course Schedule\*

### Day 1: Tuesday, August 23<sup>rd</sup>

7:45-8:15 Registration

8:15 Session Begins

#### Fundamentals of PMAC Machines

- ☑ PMAC: BLDC vs. IPM vs. SMPM
- ☑ PM Rotor Configurations, & Why
- ☑ Torque Production in PMAC Machines
- ☑ Equivalent Circuit of PMAC, & Options
- ☑ Predict Performance, Sine vs BLDC Model
- ☑ PM Machine Design Steps, Using CAE

#### Control of PMAC Motors

- ☑ Constant Torque Control, Base Speed
- ☑ Speed & Torque Limits
- ☑ Drives, 6-step, PWM, Vector Control
- ☑ Traction: Field-Weakening & Peak Torque
- ☑ Control Issues Impacting Machine Design
- ☑ Machine Issues Impacting Control Design
- ☑ Current & Position Sensing, Sensorless

#### PM Material

- ☑ Permanent Magnet BH Loops
- ☑ PM Parameters, Understanding the Data
- ☑ PM Material Options, Trade-offs
- ☑ Demagnetization Effects
- ☑ Temperature, Aging
- ☑ Change Rare Earth to Ferrite, Costs

#### Steel Core Material

- ☑ Core Steel for PMAC, Key Cost Issues
- ☑ Understanding Mfr. Data for PM Fields
- ☑ Coatings, Punching & Heat Treatment
- ☑ Segmented & Hinged Laminations, CCW
- ☑ Soft Magnetic Composites for PMAC?
- ☑ Sources of Good Data

#### Magnetic Circuit Analysis

- ☑ Magnetic Circuits & Analysis with PMAC
- ☑ Airgap Flux, EMF; Sine or Square?
- ☑ Slot Leakage, Saturation, Inductances
- ☑ Reluctance Torque & dq Model
- ☑ Intro to Motor Design Software & FEA
- ☑ PMAC Machine Performance Calculation

#### SMPM, BLDC and IPM Rotor Design

- ☑ Construction, Principles
- ☑ Physics of Rotor Magnetization
- ☑ Effect of Changing Number of Poles
- ☑ Magnet Shape, Choices, Trade-offs
- ☑ Barriers: Number, Shape, Options
- ☑ Base design to use for Benchmark
- ☑ Some New Variations, Practical Tips

16:45 Session Ends

### Day 2: Wednesday, August 24<sup>th</sup>

8:15 Session Begins

#### Practical Windings for PMAC

- ☑ Coils, Phases, Slots, Pole Shape
- ☑ Series, Parallel Circuits, Wye vs. Delta
- ☑ Winding Pattern Choices, Effect on Cost
- ☑ Winding MMF & Harmonics
- ☑ Distributed vs. Concentrated Windings
- ☑ Single/Double Layer, Fractional Slot

#### Sizing & Scaling Laws

- ☑ Key Sizing Factors, Figures of Merit
- ☑ Current Density & Electric Loading
- ☑ Flux Density, MMF Drop
- ☑ Ke, Kt, Maxwell Shear Stress for PMAC
- ☑ Scaling: Varying Diameter, Axial Length

#### Loss Calculations & Segregation

- ☑ PMAC Losses, Thermal Balance
- ☑ Problem of Core Loss Prediction
- ☑ How to Determine Core Loss Coefficients
- ☑ Eddy Current Loss, Segmenting Magnets
- ☑ Loss Segregation, Efficiency Calculation
- ☑ Practical Ways to Reduce Losses

#### How to Design a BLDC Motor

- ☑ Specification, Materials, Cooling
- ☑ Choosing Poles, Slots, Frequency
- ☑ Designing Rotor BLDC Configuration
- ☑ Designing Stator Slots & Winding
- ☑ Efficiency vs. Power Density
- ☑ Design Example: In-Class Choice

#### How to Design an IPM Motor

- ☑ IPM Machine Topologies
- ☑ Practical Motor Sizing & Key Ratios
- ☑ Equivalent Circuit Parameter Analysis
- ☑ Designing Barriers, Saturated Bridges
- ☑ Reducing Cogging Torque
- ☑ Design Example: Rare Earth vs. Ferrite

#### Modeling & Simulation

- ☑ Analytic vs. Finite-Element Methods
- ☑ Motor Design Software & Books
- ☑ FEA Software, Proper Role
- ☑ Linked CAE Simulation
- ☑ Design Optimization Methods

16:45 Session Ends

### Day 3: Thursday, August 25<sup>th</sup>

8:15 Session Begins

#### Thermal & Mechanical Design

- ☑ Mechanical Design, Fits, Tolerances for PM
- ☑ Losses, Heat, Cooling, Temperature
- ☑ Cooling Tradeoffs – Self-Cool, Fan, Liquid
- ☑ Forces & Noise; Tips to Lower Noise
- ☑ Transients During Peak Torque
- ☑ Thermal, Mechanical Structural Data
- ☑ Magnet Retention--Banding, Core Bridges
- ☑ Practical Expectation, Limits

#### Testing: Losses & Model Parameters

- ☑ Electrical: R, L, Volts, Amps, PF
- ☑ Mechanical: Torque, RPM, Heat
- ☑ Back-EMF, Open-Circuit Losses
- ☑ d,q Inductances, Design for Inductance
- ☑ Core Loss, Bearings, Fan
- ☑ Cogging Torque & Short-Circuit Losses
- ☑ Inverter Operation Testing

#### Design for Wind Energy

- ☑ Wind Energy Conversion System Configurations
- ☑ Small, Medium, Large Overview
- ☑ Design Example

#### Design for Traction

- ☑ EV & HEV Applications
- ☑ Toyota Prius IPM Motor
- ☑ Honda Insight SMPM Motor
- ☑ Other HEV Examples
- ☑ HEV Example Design

#### New Trends & Technologies –

##### What, Why, When

- ☑ Status of Chinese Magnet Market
- ☑ Axial Flux PM Machines
- ☑ Transverse Flux Machines
- ☑ Toroidal Winding Machines
- ☑ New Materials
- ☑ Modular & Automated Manufacturing

15:00 Closing & Adjourn

**We will keep you nourished!**

Daily schedule includes:

Mid-morning break (10:00)

Lunch (12:00-13:15)

Afternoon break (15:00)

Day 2 – PM  
Special Extra FEA  
Demo + Reception!

\*Course content is subject to change. All issued material may not be covered contingent on time used for Questions & Answers.

#### Instructor:



**Dr. Keith W. Klontz** is President and CEO of Advanced MotorTech LLC, an engineering services company with emphasis on electric machine 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 40 years hands-on experience with electric machine applications and design engineering, from concept to performance to failure analysis. He has been involved in the research, development, testing and training of very high performance machines from 10 Watts to 50 MW, with speeds ranging from angle positioning torque-motors to 60,000 rpm machines. Recent work includes design of permanent magnet alternators, brushless d.c. motors, brush d.c. motors, high efficiency induction motors, very high power density machines, and low cost manufacturing.

**Tuition Fees Include:**

- Extensive Training Manual (Full Color)
- Hard Cover Book "Design of Rotating Electrical Machines" by Juha Pyrhonen
- Mid-Morning & Afternoon Break w/ Refreshments Each Day
- Lunch Each Day
- Signed Certificate of Course Completion



**Host Hotel Location:**

**Marriott Hartford/Windsor Airport**  
**28 Day Hill Road**  
**Windsor, Connecticut 06095**  
**(860) 847-5011**  
**(Free Airport Shuttle)**  
**Also convenient to New York, Boston, Providence Airports**

**Accommodations:**

A block of rooms has been reserved at the beautiful Marriott Hartford/Windsor Airport hotel in Windsor Connecticut, just north of Hartford. Reservations should be made **before August 1, 2016**. Identify yourself as a participant of the Advanced MotorTech group to reserve a room at the reduced rate. \*Additional directions & information will be sent with your enrollment confirmation.

**Enrollment:**

- Yes! Please enroll me in **Course No. PMAC- 0816**  
**PMAC Machine Design, August 23-25, 2016**  
**Fee: \$1725.00 (USD only)**

**Payment:** (\*Deadline, must be received prior to 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 \_\_\_\_\_



**How did you hear about us?**

- Email/Constant Contact       Electrical Apparatus Magazine
- Social Media (Facebook/Twitter/LinkedIn)       Other (Please Specify) \_\_\_\_\_

\* Cancellations received earlier than 14 days before the course are subject to a 15% late cancellation fee. Cancellations made within 7- 13 days before the course starts are subject to a 50% cancellation fee. Cancellations made after the course starts are subject to the full fee.

**Phone:** (727) 412 - 8200  
**Fax:** (727) 412 - 8299  
**Email:** [Training@AdvancedMotorTech.com](mailto:Training@AdvancedMotorTech.com)  
**Mail:** 4951 71<sup>st</sup> Ave. North, Pinellas Park, FL 33781 USA