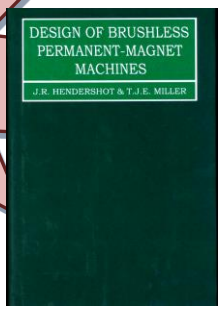
ADVANCED MOTORTECH LLC
5237 PARK STREET NORTH
SAINT PETERSBURG FL 33709-1011 USA
727-412-8200
TRAINING@ADVANCEDMOTORTECH.COM

Includes 882 pg Book!
*Design of Brushless Permanent Magnet Machines*
*by Hendershot & Miller*




# Permanent Magnet AC Motor Design

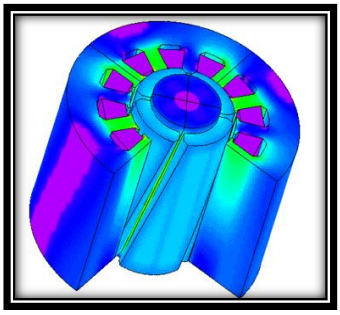
## *-Taking Theory to Practice*

***Includes BLDC, IPM, SurfPM and PMaSynRel machines***

## *Join Us LIVE, On-Line:* March 9-10-11, 2021

**Learn Design Methods of PMAC Motors and Generators: SMPM, BLDC, IPM, PM-Assisted Synchronous Reluctance, and PM Generators by applying practical experience, academic theory, material characteristics & manufacturing practices and costs:**

- ☑ **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; In-Class Design**
- ☑ **How to Calculate & Test for Parameters & Performance**



## Objectives & Benefits:

Get the "How-to" for state-of-the-art, application-oriented design of sinusoidal Surface Mounted PM (SMPM) machines, trapezoidal Brushless DC (BLDC) motors, 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 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 & Scaling Size
- 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 industrial, hybrid electric drives, traction, wind turbine generators, home appliances, and aerospace.

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

## Those who will benefit:

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

**Practical design concepts you can't get from books or software training**

*You should know electric motor and generator principles, operation & construction such as an undergraduate engineering course in electric machines & drives. Understanding of basic magnetic circuits is needed, but advanced motor theory & control is not essential.*

# *Course Schedule (*All times are Eastern Time Zone, USA*)*

## Day 1:

**9:45-10:10 On-Line Entry; AV check**
**10:15 Sessions Begin**

### 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

**17:45 Session Ends**

## Day 2:

**9:45-10:10 On-Line Entry; AV check**
**10:15 Sessions Begin**

### 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 & PM-Asst SynRel 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

**17:45 Session Ends**

## Day 3:

**9:45-10:10 On-Line Entry; AV check**
**10:15 Sessions Begin**

### 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 Energy Efficiency
- ☑ Energy Efficiency System Considerations
- ☑ Small, Medium, Large Overview
- ☑ Efficiency Standards, and lack thereof
- ☑ 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

***The real stuff for real engineering!***

**16:00 Closing & Adjourn**

***Please Note:***

*Daily schedule includes:*

- *Three AM & Three PM sessions, approximately 1 hour, each*
- *10 minute breaks between sessions*
- *45 minute Lunch Break*

**Day 2 – PM**
**Special Extra**
**FEA Motor Design Demo**

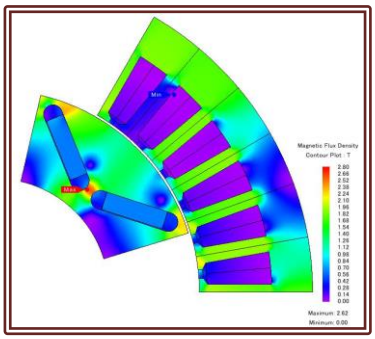
- *Session breaks will not be coincident with topic breaks*
- *Course content and schedule is subject to change. All listed material may not be covered in the course.*

## 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 and instructor in electric machine design and has over 50 years of hands-on experience with electric machine applications and design engineering, from concept to performance to repair and failure analysis. He has been involved in the research, development, prototyping, testing and/or training of very high performance machines from 5 Watts to 1150 MW, with speeds ranging from angle positioning torque-motors to 120,000 rpm machines. Recent work includes design of extremely high efficiency PM and induction motors, very high power density machines, permanent magnet alternators, brushless d.c. traction motors, brush d.c. motors, universal ac/dc motors, and low cost manufacturing.

## Enrollment Fee Includes:

- ☑ Your choice: PDF files or hardcopy paper in binder, of our Extensive 400+ page Training Manual (Full Color), materials delivered about 1-2 weeks before the course starts
- ☑ Access to the Live HD Broadcast, with two-way interaction capability
- ☑ Book "**Design of Brushless Permanent Magnet Machines"** by Hendershot & Miller
- ☑ Signed Certificate of Course Completion



## Broadcast Information:

**Hours: Live 10:15am to 17:45pm, Eastern Time Zone USA**
**Type: Classroom Setting; Live Instructor at Large-View Screen** *(Not voice-over-slides)*
*(Just like a live classroom, session recordings will not be available for later viewing)*
**Platform: Custom 1080p WEBEX; Entry Credentials with Password Required**

## To Attend This Course:

- **We will send a WEBEX Link and Entry credentials; please confirm receipt**
- **Recommended connection & bandwidth: Ethernet, 50MBs download** (5 MBs minimum)
- **Recommended viewing: 15 inch or larger monitor;** (1280 × 800 minimum**;** viewing ability, streaming quality, and compatibility with mobile devices, smaller screens and lower resolution, cannot be assured**)**
- **For now, we can accept attendees in: North America, UK/Europe, Japan, Korea, Australia, New Zealand, Brazil**

*(Exceptions are not likely, but possible, on a case by-case only, at our sole discretion)*

***Enrollment:** ☐ **Yes! Please enroll me in the 3-day course: Course ID: PMAC–2103**

### Permanent Magnet AC Motor Design, March 9-10-11, 2021

**Fee: $2125.00 for USA shipping address**
**$2425.00 for all International shipping addresses**

**Early Enrollment Fee†: $1975.00 for USA shipping address**
**$2275.00 for International shipping addresses**

*(We reserve the right to not enroll anyone, for any reason, at our sole discretion.)*

**Early Enrollment Discount!**
**Payment by Feb 1, 2021**

**Payment (USD$ only):** *(Payment Deadline: Payment must be received 2 weeks before the course; Early Enrollment payment must be received by February 1, 2021, no exceptions; †Invoiced and †PO payments not eligible for early discount)*

☐ MasterCard ☐ VISA ☐ AMEX

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

☐ Check (payable **to Advanced MotorTech, LLC**); ☐ †Invoice me; ☐ †Purchase Order; *Subject to approved credit.*

Name _____Title _____

Company _____

Shipping Address _____

City _____ State _____Zip _____

Phone ( ) _____ Email_____

***Our Most Popular Course!***

***By Enrolling for our course:**

(1) YOU AGREE to provide us a verifiable address with this enrollment for trackable shipment of training materials Sorry, a PO Box is not acceptable for this. Delivery without signature required will be used
(2) YOU AGREE to not allow any unpaid individuals to view any of the training content with intent to learn from our broadcast
(3) YOU AGREE to screen-capture only handwritten white-board/flipchart writing, and visual samples shown.
(4) YOU AGREE, with exception of (3) screen-captures, to not allow any recording of the broadcast without permission in writing and prior payment of a recording fee. All training material and broadcast content is copyright protected.
(5) YOU AGREE to not hold us responsible for poor connection, poor audio, or poor visual quality due to issues with your hardware, software, ISP, or facility. (*If in doubt, please contact us in advance for an Audio/Visual check*.)
(6) YOU AGREE cancellations made more than 14 days before the course starts AND BEFORE shipment of the training materials, are subject to a 15% cancellation fee. Cancellations made 14 days or less before the course starts, OR AFTER shipment of training materials are subject to a 50% cancellation fee.

**Email:** Training@AdvancedMotorTech.com • **Phone: (727) 412 – 8200** • Postal Mail: 5237 Park Street N, Saint Petersburg FL 33709