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Includes Book!

# Next Course Offering!

## *October 5th, 6th, & 7th 2015 in Albany, New York*

# Design of Reluctance Machines:

## Switched Reluctance (SwR) Motors & Generators and Synchronous Reluctance (SynR) Motors & Generators

**Learn practical Reluctance Machine Design and Drive Requirements by applying key motor principles, academic theory and practical manufacturing experience. Presented by experienced experts in the field.**

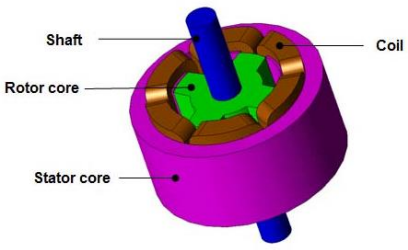
- *Reluctance Motor Operation Principles*
- *SwR & SynR Drive Topologies & Operation*
- *Geometry and Control Details for Low Torque Ripple, Low Noise*
- *Reluctance Motor Design for Traction and High Speed*
- *Reluctance Motor Design Tools, Practical Guidelines, Design Examples*
- *Realistic Possibilities and Limitations for Motor Design*

## Objectives and Benefits:

The principles of the Reluctance Machines, both Switched Reluctance and Synchronous Reluctance topologies are simple, but their design is difficult because of non-linear effects and sensitivity to key dimensions. They are usually designed for specific applications, and produced using unique manufacturing methods, which make the design decisions even more difficult.

This course will use established motor principles and electromagnetic fundamentals to increase your understanding of machine design in the context of Switched Reluctance and Synchronous Reluctance machines. Academic theory will be reduced to practical results with examples and calculation 'how-to', taking realistic manufacturing constraints, especially magnetic saturation, into account. Special emphasis will be on design of application-specific motors, drive requirements, practical design for low-cost manufacturing, and how to achieve specifications such as torque, power density, speed, low noise, etc. The similarities and differences of induction machines, BLDC machines and IPM machines are in almost all topics. Most applications will be motors, with explanation of extending the ideas for generator mode of operation.

The primary goal of this course will be to use a foundation of machine and magnetic concepts to learn Switched Reluctance and Synchronous Reluctance machine design to achieve performance specifications based on the electrical, magnetic, mechanical, and thermal interactions




## Those who will benefit:

- **Motor design engineers**
- **Application engineers**
- **Suppliers to motor manufacturers**
- **Control engineers, Drives engineers**
- **Engineering managers**
- **Others who design, manufacture, test, use or service Reluctance machines, including technical students**

You should have some background in machine design, operation and construction with the equivalent of a B.S. first degree in electrical engineering. Understanding of basic magnetic circuits and inverter principles is needed, but advanced motor theory and control techniques are not essential.

# Course Schedule

*SynR=Synchronous Reluctance SwR=Switched Reluctance;*

## Day 1: Synchronous Reluctance

**08:00-08:30 Registration**

**08:30 Session Begins**

### Overview of Reluctance Motors & Drives

- ○ What is a reluctance machine?
- ○ Feature comparison: SwR & SynR
- ○ SynR is an AC synchronous machine
- ○ SwR is a pulsed DC machine ( = AC?)
- ○ Where they fit in the motor family
- ○ Drive circuits & control basics

### SynR Fundamentals

- ☑ Machine configurations; brief history
- ☑ The phasor diagram in dq axes
- ☑ The saliency ratio: how big should it be and how do we maximize it?
- ☑ Current Waveform
- ☑ Torque vs. speed and position
- ☑ Volt-ampere requirement; power-factor
- ☑ Generating mode

### SynR Motor Design

- ☑ Design process; key trade-offs
- ☑ No. of poles, slots, and phases
- ☑ Rotor geometry: flux-barriers, gap
- ☑ Key dimensions and proportions
- ☑ Mechanical limits and manufacturing
- ☑ Designing for High efficiency

### SynR — Manual sizing

- ☑ Overall sizing; air-gap shear stress
- ☑ Rough proportioning rules
- ☑ Calculating the turns and wire size

### SynR — Detailed design

- ☑ Practical windings, slot fill
- ☑ Practical multi-barrier rotor design
- ☑ Other configurations, geometries
- ☑ Frame, noise, stress, dynamics
- ☑ ***In-Class Design Example:***
  High efficiency integral-kW—better than induction motor?

### SynR — Drive and Control

- ☑ Control strategy, Space vectors
- ☑ Controlling the current waveform
- ☑ Torque vs. speed
- ☑ Sensitivity to measurement errors

**17:30 Session Ends**

**Daily schedule includes**

- **•Mid-morning break (10:30-11:00)**
- **•Lunch (12:30-13:30)**
- **•Afternoon break (15:00-15:30)**

## Day 2: Switched Reluctance

**08:30 Session Begins**

### SwR Fundamentals

- ☑ Machine configurations; brief history
- ☑ The energy conversion diagram
- ☑ Static magnetization curves
- ☑ Current waveform
- ☑ Torque vs. speed and position
- ☑ Energy flow; volt-ampere requirement
- ☑ Generating mode

### SwR Motor Design

- ☑ Design process; key trade-offs
- ☑ Choosing poles & phases
- ☑ Rotor geometry: tooth shape, gap
- ☑ Key dimensions and proportions
- ☑ Mechanical limits and manufacturing design

### SwR — Manual sizing

- ☑ Overall sizing; air gap shear stress
- ☑ Drive voltage and current
- ☑ Rough proportioning rules

### SwR — Detailed design

- ☑ Practical windings, slot fill
- ☑ Practical stator & rotor cores
- ☑ Frame, noise, stress, dynamics
- ☑ ***In-Class Design Example:***
  High speed Fractional kW

### SwR — Drive and Control

- ☑ Torque vs. speed and position
- ☑ Controlling the current waveform
- ☑ Over-running and generating
- ☑ Sensitivity to measurement errors
- ☑ Testing for performance

### SwR — Detailed design

- ☑ ***In-Class Design Example:***
  Traction Motor—better than HEV IPM?

### Magnetic Analysis

- ☑ Magnetic circuits & analysis
- ☑ Magnetization & loss curves: mfr data
- ☑ Magnetization & loss curves: testing
- ☑ Analysis needs for SwR & SynR
- ☑ Analytic design vs. Finite-Elements
- ☑ Finite-elements: Overview, 2D vs. 3D
- ☑ Co-simulation with Simulink

**17:30 Session Ends**

**Day 2, 17:30**
**Special Extra:**
**FEA Demonstration,**
**Including Refreshments**

## Day 3: General

**08:30 Session Begins**

### Design improvement

- ☑ How to get more torque
- ☑ How to get low torque ripple,
- ☑ How to get low noise
- ☑ How to get higher efficiency

### Sizing & Scaling Principles

- ☑ Figures of merit, usual values
- ☑ Principles of scaling laws
- ☑ General scale factors, sensitivity
- ☑ Practical limits to scaling

### Materials & Mfg.

- ☑ Magnetic material data
- ☑ Effect of magnet pricing & availability
- ☑ Losses, heat, efficiency, loss minimization
- ☑ High speed issues, limits
- ☑ Reference Data
- ☑ Modular & Automated Mfg.

### Thermal & Structural

- ☑ Thermal & structural modeling
- ☑ Material data
- ☑ Losses, heat, temperature
- ☑ Forces & noise
- ☑ Typical parameter values
- ☑ Practical expectation, limits

### Related topics (as time allows)

- ○ PM-assisted SynR--Might we want to add magnets?
- ○ SwR machines with magnets
- ○ Flux-switching machines
- ○ Axial-flux reluctance machines
- ○ Linear reluctance machines
- ○ Sensor requirements (current, position)
- ○ More on Torque vs. speed
- ○ More on Control strategy
- ○ Cross-saturation between phases

**15:30 Adjourn**

***Note: Course content is subject to change. Entire agenda may not be covered, depending on time used for questions and extended discussion.**

**Dr. Keith W. Klontz** is President and Founder of Advanced MotorTech LLC, a computer-aided engineering (CAE) services company with emphasis on advanced electric machine and magnetic component design and analysis. He holds BS & MS degrees in Electrical Engineering from the University of Illinois, and a PhD in Electrical Engineering from the University of Wisconsin. Dr. Klontz is a world-recognized expert in electric machine design and has over 40 years hands-on experience with electric machine design engineering, from concept to performance to failure analysis. He has been involved in the research, development, prototype manufacture and testing of very high performance machines from 10 Watts to 8 MW. He has also developed and presented motor training classes to well over 1000 motor engineers and technicians. Recent work includes implementing CAE tools and developing design techniques for the design of alternators and motors for high efficiency, high power density and cost effectiveness.

**Dr. Tim Miller** (now retired) is the founder of the *Scottish Power Electronics and Drives* Consortium at the University of Glasgow, with power engineering research in electric power systems, power electronics, and electric machines. He is the author or co-author of 10 books in electric power engineering and many papers, patents and training courses. He has led and contributed to R&D in permanent-magnet brushless machines, synchronous reluctance machines, switched reluctance machines and drives, line-start motors, AC commutator (universal) motors, DC machines, and wound-field AC generators including superconducting machines. Formerly with General Electric in Schenectady, N.Y., Tim began his career in a steel tube company (TI/Tube Products) with periods at British Gas and GEC Power Transmission and Distribution. He holds a PhD from Leeds University and was awarded the IEEE Tesla award in 2008. He is a Life Fellow of IEEE.

# General Information

## Tuition Fees Include:

- ☑ Extensive Training Manual (Full Color)
- ☑ Exclusive Offering: Book "Reluctance Machines"
- ☑ Mid-Morning & Afternoon Break w/ Refreshments Each Day
- ☑ Lunch Each Day in Session
- ☑ Signed Certificate of Course Completion

## Host Hotel Location:

**Albany Marriott**
**189 Wolf Road**
**Albany, New York 12205**
**Phone: 518-458-8444**

## Accommodations:

A block of rooms has been reserved at the beautiful ***Albany Marriott*** in Albany, New York. Reservations should be made **before September 14, 2015**. Identify yourself as a participant of the **Advanced MotorTech group.** *Additional directions and information will be sent with your enrollment confirmation.

## Enrollment:

☐ Yes! Please enroll me in **Course No. SRM-1015 'Design of Reluctance Machines', Oct 5-7, 2015**
**Fee: $1725 USD**
*(We reserve the right to not enroll anyone considered to be a competitor, at our sole discretion.)*

## Payment: (Deadline: *must be received before start of course)

☐MasterCard ☐Visa ☐Amex

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

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* Cancellations received later than 14 days before the course are subject to a 15% late cancellation fee. Cancellations made 13 – 7 days before the course starts are subject to a 50% cancellation fee. Cancellations made less than 7 days before the course starts are subject to the full fee, but all course materials will be shipped to you.