Brushless DC Motor Design
Course Outline

I. Basic Concepts

A. Torque
B. Motor Action
C. Mechanical and Electrical Measures
D. Motor Size

II. Basic Configurations of BLDC Motors

A. Outer Rotor
B. Inner Rotor
C. Inner Rotor Slotless
D. Switched or Variable Reluctance

III. Magnetic Modeling

A. Magnetic Circuit Concepts
B. Magnetic/Electrical Analogy
C. Carter's Coefficient
D. Material Properties
E. Steel
F. Permanent Magnets
G. Magnet Operating Point

IV. Steel Selection

A. Motor Construction
B. Stator Assembly
C. Steel Characteristics
D. Core Losses
E. Annealing and Processing
F. Appropriate Gages for Various Applications
G. Assembly Methods
H. Housings

V. Magnet Characteristics and Selection

A. Magnet Types and Properties
B. Operating Temperature Ranges
C. Magnetizing Fixtures and Techniques
D. Magnet Testing

VI. Electrical and Mechanical Relationships

A. Inductances - Self and Mutual
B. Energy and Co-Energy
C. Slot Leakages
D. Force, Mutual and Reluctance Torques

VII. Brushless Motor Operation

A. Magnetic Circuit Model
B. Flux Linkage
C. Back EMF
D. Forces on Conductors

VIII. Magnetic Elements and Their Performance

A. Methodologies
B. Magnetic Circuit Configurations
C. Reluctance
D. Member Reluctance Commutations
E. Magnetic Reluctance Factor
F. Magnetic Leakage Factor
G. Load Line
H. Magnet Flux Density
I. MMF Drops
J. Cogging Effect of Skew

IX. Sizing and Shaping the Motor

A. Shafts
B. Bearings
C. Shaft and Bearing System
D. Magnet Wire
E. Insulation
F. Motor Envelope
G. Motor Cross Section
H. Phases
I. Poles
J. Teeth
K. Flux Densities
L. Tooth Tips
M. Structural Magnetic Materials
N. Rotor Inertia

X. Stator Winding Design Considerations

A. Winding Patterns - Series and Parallel
B. Number of Conductors - Wire Size and Slot Fill

XI. Motor Drive Schemes

A. Two Phase Motors
B. One Phase On - Two Phase On Operation

C. H-Bridge Drives - Serve Drives
D. Three Phase Motors
E. Delta and Wye Connections
F. PWM Methods

XII. Performance Characteristics

A. Relation of Torque Constant and Back EMF Constant to Current Profiles
B. Phase Resistance
C. Establish Speed-Torque Curve
D. Optimize Motor Constant
E. Power, Losses, Efficiency

XIII. Motor Commutation Patterns

A. Trapezoidal vs. Sinusoidal Drives
B. Torque vs. Position
C. Commutation Sequence

XIV. Thermal Considerations

A. Thermal Models
B. Thermal Time Constant
C. Thermal Resistance
D. Thermal Capacity

XV. Clean Sheet Design

A. Methodology and Approach
B. Procedure Summary

Work Sessions

1. Boundary Element Analysis of Example Motor
2. Finite Element Analysis of Example Motor
3. Clean Sheet Design Example

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William H. Yeadon, P.E., Yeadon Energy Systems., Iron River, Mich., has over 40 years experience in the electric motor industry including work in design and development, production, quality assurance and engineering management. Prior to starting his consulting firm in 1993, he worked at A.O. Smith, Redmond Motors, Warner Electric and Barber Colman Company.