Training Course on Motor Control and Drives for Electric Propulsion

Professional Development Training Course Outline

Category	Engineering	**Duration**	10 Days
Base Fee	$3,000 USD	**Delivery Mode**	Online / On-site Hybrid

Course Introduction

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This comprehensive training course on Motor Control and Drives for Electric Propulsion offers a deep dive into the fundamental principles and advanced techniques for efficiently and precisely controlling electric motors in various propulsion applications, particularly in Electric Vehicles (EVs), Hybrid Electric Vehicles (HEVs), and industrial electric drives. Participants will gain expert-level understanding of diverse motor types, including Permanent Magnet Synchronous Motors (PMSM), Induction Motors (IM), and Switched Reluctance Motors (SRM), along with the sophisticated power electronic converters (inverters) and control algorithms that enable their performance. Training Course on Motor Control and Drives for Electric Propulsion emphasizes a holistic design approach, integrating aspects of energy efficiency, torque control, speed regulation, thermal management, and robust operation. Attendees will acquire hands-on experience with industry-standard simulation tools (e.g., MATLAB/Simulink, PSIM) and practical control implementations, crucial for shaping the future of electric propulsion and automation.

The program highlights cutting-edge advancements and industry best practices, exploring trending topics such as Field-Oriented Control (FOC), Direct Torque Control (DTC), Model Predictive Control (MPC) for motor drives, sensorless control techniques, and the integration of AI/ML for predictive diagnostics and optimal efficiency mapping. Participants will delve into the intricacies of NVH (Noise, Vibration, and Harshness) reduction, electromagnetic compatibility (EMC) from motor drives, and advanced fault detection and fault-tolerant control strategies. By the end of this course, attendees will possess the expertise to design, analyze, and optimize high-performance, efficient, and reliable motor control systems for electric propulsion, enabling them to lead innovation and overcome complex engineering challenges in the burgeoning electromobility, robotics, and industrial automation sectors. This training empowers professionals to drive the transition towards intelligent and highly efficient electric drive systems.

Programme Curriculum

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Course Objectives

1. Understand the operating principles and characteristics of key electric motor types for propulsion (PMSM, IM, SRM).
2. Analyze and select appropriate motor drive topologies and power electronic converters (inverters).
3. Master Pulse Width Modulation (PWM) techniques for efficient and precise motor control.
4. Implement Vector Control (Field-Oriented Control - FOC) for high-performance AC motor drives.
5. Apply Direct Torque Control (DTC) principles for fast and robust torque response.
6. Understand and utilize sensorless control techniques for cost and reliability optimization.
7. Design control loops for current, speed, and position regulation in electric drives.
8. Perform efficiency optimization across various operating regions of electric motors.
9. Address thermal management challenges in high-power density motor drives.
10. Utilize simulation tools (e.g., MATLAB/Simulink, PSIM) for motor drive design and validation.
11. Explore advanced control strategies such as Model Predictive Control (MPC) and AI/ML integration.

12. Implement fault detection, isolation, and fault-tolerant control for improved reliability.
13. Understand NVH (Noise, Vibration, and Harshness) mitigation and EMC considerations in electric drives.

Organizational Benefits

1. Accelerated R&D cycles for electric propulsion systems and electrified products.
2. Improved performance, efficiency, and range of their EV/HEV products.
3. Reduced energy consumption in electric drives across various applications.
4. Enhanced product reliability and robustness through advanced control and fault tolerance.
5. Faster troubleshooting and diagnosis of motor drive-related issues.
6. Competitive advantage in the rapidly expanding electromobility and industrial automation markets.
7. Development of in-house expertise in critical electric propulsion technologies.
8. Optimization of manufacturing processes by understanding drive requirements.
9. Compliance with evolving industry standards related to drive performance and safety.
10. Contribution to sustainability goals by designing more energy-efficient and intelligent electric drive systems.

Target Participants

- Motor Control Engineers
- Power Electronics Engineers
- Electrical Engineers
- Automotive Engineers (EV/HEV Powertrain)
- Robotics Engineers
- Industrial Automation Engineers
- Control System Designers
- Researchers and Developers in Electric Drives

Course Outline

Module 1: Introduction to Electric Motors for Propulsion

- **Electric Motor Fundamentals:** Torque, speed, power, efficiency.
- **Types of Motors:** DC Motors, Induction Motors (IM), Permanent Magnet Synchronous Motors (PMSM), Switched Reluctance Motors (SRM).
- **Motor Selection Criteria:** Matching motor type to application requirements (traction, robotics, industrial).
- **Motor Construction and Principles:** Stator, rotor, windings, magnetic fields.
- **Case Study:** Comparing the advantages and disadvantages of PMSM vs. Induction Motors for an EV traction application.

Module 2: Power Electronics for Motor Drives (Inverters)

- **Role of Inverters:** DC-AC conversion for motor operation.
- **Three-Phase Inverter Topologies:** Voltage Source Inverters (VSIs), Current Source Inverters (CSIs).

- **Power Semiconductor Devices:** MOSFETs, IGBTs, **SiC, GaN** applications in motor drives.
- **Switching Losses and Efficiency:** Impact of switching frequency.
- **Case Study:** Analyzing the power circuit of a 3-phase inverter for a 400V EV traction motor.

Module 3: Pulse Width Modulation (PWM) Techniques

- **Introduction to PWM:** Generating AC from DC, controlling voltage and frequency.
- **Sinusoidal PWM (SPWM):** Basic principles, modulation index.
- **Space Vector PWM (SVPWM):** Superior harmonic performance, better DC bus utilization.
- **Discontinuous PWM (DPWM):** Reducing switching losses.
- **Case Study:** Implementing SVPWM for a 3-phase inverter in a simulation environment (e.g., MATLAB/Simulink).

Module 4: DC Motor Control (Review and Foundation)

- **Separately Excited DC Motor Model:** Electrical and mechanical equations.
- **Armature Voltage Control:** Speed control.
- **Field Control:** Flux weakening for high-speed operation.
- **Four-Quadrant Operation:** Motoring and braking.
- **Case Study:** Designing a closed-loop speed control system for a DC motor using a PI controller.

Module 5: Induction Motor Control

- **IM Equivalent Circuit:** Steady-state and transient models.
- **Scalar Control (V/f Control):** Simple, open-loop speed control.
- **Limitations of Scalar Control:** Poor dynamic performance, low speed torque.
- **Rotor Flux Orientation:** Concept for decoupling torque and flux control.
- **Case Study:** Simulating the response of an Induction Motor under V/f control.

Module 6: Vector Control (Field-Oriented Control - FOC) for AC Motors

- **Principle of Field Orientation:** Decoupling of torque and flux components.
- **Park and Clarke Transformations:** dq0 reference frame.
- **Current Control Loops:** Inner current regulation loops (id, iq).
- **Speed and Position Control:** Outer loops, cascade control.
- **Case Study:** Implementing an FOC algorithm for a PMSM in a simulated EV traction application, demonstrating precise torque control.

Module 7: Direct Torque Control (DTC)

- **Principle of DTC:** Direct control of torque and stator flux.
- **Switching Table Design:** Selecting inverter states based on flux and torque errors.
- **Advantages of DTC:** Fast torque response, sensorless capability.
- **Limitations of DTC:** Higher torque ripple, variable switching frequency.
- **Case Study:** Comparing the dynamic torque response of FOC and DTC for an Induction Motor drive.

Module 8: Sensorless Control Techniques

- **Motivation for Sensorless Control:** Cost reduction, reliability improvement.
- **Back-EMF Based Methods:** For PMSM and IM at medium-high speeds.
- **High-Frequency Injection Methods:** For low-speed and zero-speed operation.
- **Observer-Based Methods:** Kalman Filters, Luenberger Observers for state estimation.

- **Case Study:** Designing a basic back-EMF observer for sensorless speed estimation of a PMSM.

Module 9: Advanced Control Strategies

- **Model Predictive Control (MPC) for Drives:** Optimizing control actions over a prediction horizon.
- **Sliding Mode Control (SMC):** Robust control for non-linear systems.
- **Adaptive Control:** Handling parameter variations and uncertainties.
- **Observer Design for Fault Diagnosis:** Estimating unmeasurable states.
- **Case Study:** Exploring the benefits of MPC for trajectory tracking in an electric vehicle.

Module 10: Thermal Management in Motor Drives

- **Heat Generation in Motors and Inverters:** Losses in windings, core, semiconductors.
- **Cooling Systems:** Air cooling, liquid cooling (direct, indirect), oil cooling.
- **Thermal Modeling and Simulation:** Predicting temperature distribution and hotspots.
- **Impact on Performance and Lifetime:** Derating curves, thermal limits.
- **Case Study:** Analyzing the thermal performance of an EV traction motor under continuous high-power operation.

Module 11: Efficiency Optimization and Energy Management

- **Loss Minimization Techniques:** Optimizing switching patterns, flux weakening.
- **Efficiency Maps:** Plotting efficiency across torque-speed range.
- **Regenerative Braking Control:** Maximizing energy recovery.
- **Energy Management Strategies:** Coordinating motor and battery in HEVs.
- **Case Study:** Developing a control strategy to maximize regenerative braking energy capture for an EV during deceleration.

Module 12: NVH and EMC Considerations in Electric Drives

- **Noise, Vibration, and Harshness (NVH):** Sources (magnetic, mechanical), mitigation.
- **Electromagnetic Compatibility (EMC):** Reducing EMI from inverter switching.
- **Filtering Techniques:** Common-mode and differential-mode filters.
- **Shielding and Grounding:** Best practices for EMI reduction.
- **Case Study:** Identifying the sources of audible noise in an electric motor and suggesting design modifications for NVH reduction.

Module 13: Fault Detection, Isolation, and Fault-Tolerant Control

- **Common Faults in Drives:** Open-phase, short-circuit, sensor faults.
- **Fault Detection Methods:** Current signature analysis, voltage monitoring.
- **Fault-Tolerant Control:** Reconfiguration, redundancy for continued operation.
- **Predictive Maintenance:** Using drive data for early fault warning.
- **Case Study:** Designing a simple fault detection algorithm for an open-phase fault in a 3-phase motor drive.

Module 14: Simulation and Hardware Implementation

- **Software Simulation Tools:** MATLAB/Simulink (Simscape Electrical), PSIM, Ansys Motor-CAD.
- **Hardware Platforms:** DSPs, Microcontrollers, FPGAs for real-time control.
- **Code Generation:** From simulation models to embedded code.
- **Upcoming Scheduled Sessions**

Start Date	End Date	Location	Price
23 Nov 2026	04 Dec 2026	Online	$2,000
23 Nov 2026	04 Dec 2026	Physical	$3,000
23 Nov 2026	04 Dec 2026	Physical	$6,000
23 Nov 2026	04 Dec 2026	Physical	$6,000
23 Nov 2026	04 Dec 2026	Physical	$12,000
23 Nov 2026	04 Dec 2026	Physical	$9,000
23 Nov 2026	04 Dec 2026	Physical	$12,000
23 Nov 2026	04 Dec 2026	Physical	$12,000

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