Simscape Fundamentals for Physical System Modeling

1. Title

Simscape Fundamentals for Physical System Modeling

2. Target Audience

This course is designed for mechanical, electrical, and mechatronics engineering students, researchers, and practicing engineers who want to learn how to model and simulate multi-domain physical systems without deriving governing equations by hand. It suits learners with a working knowledge of MATLAB and Simulink who need to represent mechanical, electrical, and magnetic components as physical networks and combine them into unified mechatronic system models. No prior Simscape experience is required, though familiarity with basic engineering physics (mechanics, circuits, electromagnetics) is helpful for interpreting the modeling examples.

3. Course Outcomes

- Understand the physical-network modeling approach used by Simscape versus traditional signal-flow Simulink modeling.
- Apply Simscape blocks to represent mechanical translation and rotation systems.
- Create electrical circuit models using Simscape Electrical components.
- Analyze magnetic system behavior using Simscape magnetic domain blocks.
- Design multidomain mechatronic models that couple mechanical, electrical, and magnetic subsystems.
- Implement control strategies for mechatronic systems within the Simulink/Simscape environment.
- Evaluate simulation results to validate physical system behavior.
- Troubleshoot common Simscape modeling errors (unconnected ports, domain mismatches, solver issues).
- Prepare complete mechatronic case-study models from specification through simulation.
- Optimize physical models for simulation accuracy and computational efficiency.

4. Course Objectives

- Provide a structured, progressive learning path from mechatronic systems theory through Simscape fundamentals to complete multidomain case studies.
- Build proficiency with the physical-network modeling paradigm through hands-on block-diagram exercises.

- Prepare learners to model real engineering systems that span mechanical, electrical, and magnetic domains.
- Reinforce every concept through practical examples and lab exercises drawn from real mechatronic applications.
- Equip learners with the domain-specific toolbox knowledge (Simscape, Simscape Electrical) needed to build production-ready physical models.

5. Course Outline

The course comprises 32 hours of theory and labs and is divided into 7 different chapters. Each chapter will be followed by hands-on lab exercises to reinforce learning and gauge understanding of the topics covered.

6. Table of Contents (TOC)

Module 1: Introduction to Mechatronic Systems

- What defines a mechatronic system: multi-domain integration in engineering design
- Examples of mechatronic systems across industries (automotive, robotics, consumer devices)
- The shift from purely mechanical to electric, hybrid, and autonomous systems
- Why physical modeling matters for analysis, synthesis, and optimal design
- The role of domain expertise and software tools in mechatronic system development

Module 2: Introduction to Simscape

- The Simscape physical-network modeling approach vs. traditional signal-flow blocks
- Simscape libraries, domains, and block connections
- Physical signals vs. Simulink signals
- Building and configuring a basic Simscape model
- Running simulations and interpreting Simscape results

Module 3: Modeling Mechanical Translation and Rotation

- Translational mechanical elements: mass, spring, damper blocks
- Rotational mechanical elements: inertia, rotational spring, rotational damper blocks
- Building translational system models (e.g., mass-spring-damper systems)
- Building rotational system models (e.g., shafts, gears, flywheels)
- Lab: simulating and validating a mechanical translation/rotation system

Module 4: Modeling Electrical Systems

- Electrical domain blocks: resistors, capacitors, inductors, sources
- Building basic circuit models in Simscape Electrical
- Simulating electrical circuit behavior and transient response
- Combining electrical components into more complex circuit models

- Lab: modeling and simulating an electrical circuit system

Module 5: Modeling Magnetic Systems

- Magnetic domain blocks and magnetic circuit fundamentals
- Representing magnetic components (coils, cores, actuators) in Simscape
- Coupling magnetic and electrical domains (e.g., solenoids, electromagnets)
- Simulating magnetic system response
- Lab: modeling a magnetic actuator or electromagnetic device

Module 6: Modeling Mechatronic Systems (Multi-Domains) and Their Control

- Coupling mechanical, electrical, and magnetic domains into a single model
- Techniques for interfacing physical domains within Simscape
- Adding control loops to multidomain physical models
- Simulating and analyzing closed-loop mechatronic system behavior
- Lab: building a multidomain system with an integrated controller

Module 7: Case Studies of Modeling Mechatronic Systems

- Case study walkthroughs of complex, real-world mechatronic systems
- End-to-end model development: specification through simulation
- Using simulation results to inform design decisions
- Applying simulation data toward a rudimentary machine learning model of an engineering system
- Capstone lab: building and validating a complete mechatronic case-study model