WM9RF-15 Electric Propulsion Systems

27/28

Department
WMG
Level
Taught Postgraduate Level
Module leader
Kamyar Nikzadfar
Credit value
15
Module duration
4 weeks
Assessment
100% coursework
Study location
University of Warwick main campus, Coventry

Description

Introductory description

Electric propulsion lies at the core of modern electric vehicles, involving the integration of key subsystems such as tyres, transmission, electric machines, and drive technologies, all of which collectively contribute to the overall vehicle attributes.

The layered architecture of both the vehicle and its propulsion system necessitates the use of appropriate analytical and design tools and methodologies.

From a systems-level perspective, high-level vehicle attributes are significantly influenced by subsystem characteristics, including the sizing and integration of electric propulsion components. At an intermediate level, the performance of the electric propulsion system is closely linked to the functional architecture of lower-level subsystems such as the electric machine, power electronics drive, and control logic.

Therefore, it is essential for engineers and professionals in this field to develop a robust understanding of both vehicle-level performance requirements and the operational architecture of subsystems. They must also be capable of conducting system- and subsystem-level analysis using suitable tools and methods.

Module aims

This module is designed to equip students with the skills to apply a model-based systems engineering approach to the design of electric propulsion systems. Students will learn how to select appropriately sized components based on vehicle-level performance attributes and how to design electric machines in conjunction with their associated control systems at the mid level.

Throughout the module, students will develop the ability to translate high-level vehicle performance requirements into corresponding propulsion system characteristics. They will gain insight into a range of electric machine technologies and drive system architectures.

The module also explores mid-level and subsystem-level aspects by examining different types of electric machines, along with their modelling and analysis using equivalent circuit representations in appropriate reference frames. In addition, students will study control strategies and commutation techniques, as well as the architecture of inverter systems used in electric propulsion.

Finally, students will learn how to integrate mid-level models into higher-level vehicle models in order to perform comprehensive, system-level analysis.

Outline syllabus

This is an indicative module outline only to give an indication of the sort of topics that may be covered. Actual sessions held may differ.

1. Introduction to Electric Vehicle Propulsion

- Overview of electric propulsion system architectures
- Regenerative braking in electric vehicles
- Comparison with conventional powertrains

1. Vehicle-Level Modelling and Performance Requirements

- Powertrain theory including road load equations and tractive force estimation
- Drive cycles (e.g. WLTP) and vehicle simulation
- Vehicle energy consumption and range prediction

1. Component Sizing Using Model-Based Methods

- Power and energy requirements
  Sizing of:
- Electric drive unit (electric machine and reducer)
- Power electronics
- Battery systems

1. Electric Machines for Propulsion

- Types of machines (e.g. PMSM, IM, SRM)
- Operating principles and performance characteristics

- Machine selection criteria for automotive use

1. Power Electronics and Drive Systems

- Fundamentals of power electronic converters and inverters
- Switching devices (e.g., IGBT, MOSFET)
- Commutation and control of electric drives

1. Torque Control and Reference Frames

- Vector Control
- Clarke and Park transformations
- Implementation in simulation environments (e.g. MATLAB/Simulink)

1. Model-Based System Integration

- Integrating subsystems into a complete propulsion model
- Functional interfaces and co-simulation
- System-level validation against vehicle targets

Learning outcomes

By the end of the module, students should be able to:

- Evaluate the road load and performance demands of electric vehicles through vehicle-level analysis. [AHEP:4; 7, M1, M2, M3]
- Size and specify key components of electric powertrain systems using a model-based approach to meet defined vehicle performance and efficiency targets. [AHEP:4; 7, M1, M2, M3, M5]
- Analyse and compare a range of electric machine technologies used in propulsion systems, including their principles of operation, performance characteristics, and suitability for automotive applications. [AHEP:4; 7, M4, M5, M6]
- Design and implement control strategies and drive system for propulsion electric machines ensuring accurate and stable operation. [AHEP:4; 7, M2, M4, M3, M5]
- Integrate and simulate electric propulsion systems using model-based development techniques, and validate system-level performance against design requirements. [AHEP:4; 7, M2, M3]
- Work collaboratively within a team to resolve problems in the context of electric propulsion systems [AHEP:4; 7, M16]

Indicative reading list

Reading lists can be found in Talis

Specific reading list for the module

Subject specific skills

Calculation and analysis of road load and vehicle propulsion requirements
Sizing and specification of electrified propulsion system components
Mapping electric vehicle attributes to propulsion system component characteristics
Understanding types and operational characteristics of electric machines
Knowledge of power electronics used in electric motor applications
Principles and implementation of electric machine control
Practical skills in sizing key electric vehicle components through hands-on activities
Practical experience in modelling and controlling electric machines

Transferable skills

Critical thinking; Problem solving; Self-awareness; Communication; Teamwork and working effectively with others; Information literacy (research skills); Digital literacy; Sustainability; Professionalism; Organisational awareness.

Study

Study time

Type	Required
Lectures	12 sessions of 1 hour (8%)
Seminars	10 sessions of 1 hour (7%)
Tutorials	8 sessions of 1 hour (5%)
Online learning (independent)	10 sessions of 1 hour (7%)
Private study	50 hours (33%)
Assessment	60 hours (40%)
Total	150 hours

Private study description

Private study learning includes:

- Revision of lectures after delivery
- Completion of independent study task and self-directed learning task

Costs

No further costs have been identified for this module.

Assessment

You must pass all assessment components to pass the module.

Assessment group A

	Weighting	Study time	Eligible for self-certification
Assessment component			
Sizing of Electric Propulsion Systems Components - Group Task	40%	24 hours	Yes (extension)

In this assessment, a group of students is provided with a set of vehicle-level performance attributes and parameters, such as vehicle mass. Using a model-based approach, students are required to size the main components of the electric propulsion system to ensure all specified performance criteria are met. The final design will then be validated using high-fidelity modelling.

Reassessment component

Sizing of Electric Propulsion Systems Components - Individual Task			No

In this assessment, the student is provided with a set of vehicle-level performance attributes and parameters. Using a model-based approach, students are required to size the main components of the electric propulsion system to ensure all specified performance criteria are met. The final design will then be validated using high-fidelity modelling.

Assessment component

Modelling, Control and Validation of Electric Propulsion Systems	60%	36 hours	No

In this assessment, students are required to adopt a model-based approach to develop and control an electric machine. They will apply their knowledge to construct a representative model of the machine and drive system. Finally, the proposed design will be integrated into a complete vehicle model to verify that the overall system meets the specified performance requirements.

Reassessment component is the same

Feedback on assessment

Written report: Written feedback will be provided using the WMG feedback template and will address each of the assessed learning outcomes. The strengths and weaknesses of the report will

be outlined, and suggestions for improving the current report will also be discussed.

Availability

Pre-requisites

To take this module, you must have passed:

- All of
  - WM993-15 Modelling and Simulation of Systems

There is currently no information about the courses for which this module is core or optional.