Physics-Informed Digital Twin for Degradation-Aware Control of Hybrid Electric Powertrains

EPSRC funded PhD studentship with full fee waiver and £21,805 pa stipend (2026/27 rate)

Project Code: DLA_DTP_2026_08

Main Supervisor: Dr Khoa Dang Hoang

Co-Supervisor: Dr Qiang Hua, Dr Fuhu Che

Project Introduction

Hybrid electric powertrains are critical for decarbonizing transport, but their control systems currently ignore component degradation: motors, batteries, fuel cells, and power electronics deteriorate over time, reducing efficiency and reliability. This project will develop a physics-informed digital twin that learns component degradation patterns in real-time and adapts control strategies accordingly. By combining first-principles physics models with machine learning, the system will predict remaining component life while optimizing performance, enabling predictive maintenance and extending powertrain lifespan. This represents a mechanism shift from reactive to proactive powertrain management.

Project Details

Background and Motivation: Electric and hybrid powertrains are fundamental to achieving Net Zero transport, yet current control strategies treat components as static entities. In reality, electric motors experience demagnetization and winding degradation, batteries lose capacity and increase resistance, and power electronics suffer from bond-wire fatigue and thermal cycling damage while fuel cells degrade through catalyst and membrane ageing, altering voltage characteristics and dynamics. Conventional model predictive control (MPC) uses fixed parameters that become increasingly inaccurate over the vehicle's 10–15-year lifespan, leading to suboptimal efficiency and unexpected failures.

Research Gap: While physics-based models capture degradation mechanisms and machine learning excels at pattern recognition, no existing framework integrates both for real-time adaptive powertrain control. Physics-Informed Neural Networks (PINNs) have shown promise in fluid dynamics and structural health monitoring but remain unexplored for electrified powertrains. The key challenge is creating a hybrid digital twin that respects physical laws (energy conservation, thermal limits) while learning from operational data without requiring extensive offline training.

Research Objectives

1) Develop a physics-informed neural network architecture that embeds powertrain conservation laws (electromagnetic, thermal, electrochemical) into the learning process.
2) Create degradation prediction models for selected critical components (e.g. permanent magnet motors and lithium-ion batteries), with extensibility to fuel cells and SiC power modules.
3) Design a real-time adaptive control algorithm that optimizes torque distribution between electric motor and hydrogen fuel cell system while maximizing component lifetime
4) Validate the digital twin framework using hardware-in-the-loop testing with industry-standard platforms (Texas Instruments DSP, OPAL-RT real-time simulator)

Methodology and 3-Year Plan

Year 1-Foundation: Develop physics-informed neural network (PINN) architectures for degradation modelling of selected hybrid powertrain components (electric motor, battery, and inverter), with extensibility to fuel cells. Collect baseline experimental data from laboratory test rigs and embed physical constraints (electromagnetic, thermal, and electrochemical laws) into neural network loss functions.

Year 2-Integration and Control: Integrate component-level models into a complete hybrid powertrain digital twin. Design a degradation-aware model predictive control (MPC) strategy and conduct hardware-in-the-loop (HIL) validation using a real motor drive and battery emulator. Disseminate early results through conference publications.

Year 3-Validation, Thesis, and Dissemination: Perform extensive powertrain-level validation and comparative analysis against conventional control approaches. Quantify efficiency improvements and component lifetime extension under representative operating conditions. Complete thesis writing and submit journal and conference publications.

Expected Impact: This research will enable electric vehicle manufacturers to extend powertrain warranties (currently limited to 8 years/100k miles), reduce total cost of ownership, and support vehicle-to-grid applications where battery degradation is a critical barrier. The framework is generalizable to other applications including grid energy storage and renewable microgrids.

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Project-specific entry requirements

Essential Qualifications:

- First class or upper second-class honours degree (or equivalent) in Electrical/Electronic Engineering, Control Engineering, Mechatronics, or closely related discipline
- Strong mathematical foundation (linear algebra, differential equations, optimization)
- Programming experience in at least one language (Python, MATLAB, C/C++)
- Understanding of control systems fundamentals

Desirable Skills and Experience:

- Knowledge of electric machines, power electronics, or battery systems
- Experience with embedded systems programming (DSP, microcontrollers)
- Familiarity with machine learning frameworks (TensorFlow, PyTorch)
- Prior exposure to hardware-in-the-loop or real-time simulation
- Understanding of electric vehicle powertrains or hybrid systems

Personal Attributes:

- Strong problem-solving abilities & analytical thinking
- Ability to work independently and as part of a multidisciplinary team
- Excellent written and oral communication skills
- Enthusiasm for experimental research and hands-on engineering
- Commitment to completing the PhD within the standard 3-year EPSRC timeframe.

Further Information

This call is open to **UK Applicants only**.

Applicants should be of outstanding quality and exceptionally motivated. The studentships are funded for 3 years (subject to satisfactory annual performance and progression review) and will provide for tuition fees and a tax-free stipend paid monthly.

Please note that there are more projects than funded studentships available and therefore this is a competitive application process which will include an interview. Shortlisted candidates will be contacted for an interview in person or via Teams. After interview the most outstanding applicants will be offered a studentship.

Queries about the application process are welcome and should be emailed to pgrscholarships@hud.ac.uk.

Informal enquiries about this project should be directed to Dr Khoa Dang Hoang.

Type of Award: Doctor of Philosophy (PhD).

Eligibility: UK applicants only. First Class or Upper Second-Class Honours degree or equivalent in a relevant subject area, please refer to the entry requirements on the specific projects being advertised.

Location: Huddersfield.

Funding: 3 years full time research covering tuition fees and tax-free bursary (stipend) starting at £21,805 for 2026/27 & increasing in line with the EPSRC guidelines for subsequent years. Funded via the Engineering & Physical Sciences Research Council Doctoral Training Programme.

Duration: 3 years full-time plus 12 months writing up (please note no funding available for writing up period).

Closing date: 28th April 2026

Start date: 1st October 2026

Application details

- Go to the EPSRC webpage and download the Expression of Interest Form 2026.
- Provide copies of transcripts & certificates of all relevant academic and professional qualifications.
- Provide references from 2 individuals – contact your referees to request that they send them directly to pgrscholarships@hud.ac.uk from their email address.
- Proof of eligibility – e.g. scan of passport photo page.
- Completed forms, including all relevant documents should be submitted via-email to pgrscholarships@hud.ac.uk.

Please note: if you do not attach all the relevant documentation prior to the closing date your application will not be considered.

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