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HELLO TOMORROW

Faculty of Science and Engineering

POSTGRADUATE RESEARCH

Department of Electrical & Electronic Engineering Postgraduate Research Conference
26 November 2025
Programme of Events & Abstracts

Contents

Date: Wednesday 26 November
Conference Location: Nancy Rothwell Building

Introduction

The Department is proud of our postgraduate research community and strongly values the contribution of over 250 PhD students to the research of the Department. Our annual poster conference is an exciting event which showcases the high level and breadth of research projects undertaken by our PhD students. We are also very pleased that our 2nd year MSc students have an opportunity to also exhibit at this event.

I would like to thank all the students who are exhibiting their important contributions, the judging panel including members of our Industrial Advisory Group, Dr Steven Li and the Faculty DA PGR Experience Team for making the event happen.

Prof Alexander Lanzon
Head of Department for Electrical and Electronic Engineering

Conference Outline

Wednesday, 26th November
Nancy Rothwell Building

9:00 - Nancy Rothwell_Event Space B

    Registration and Refreshments

9:30 - Nancy Rothwell_Blended Th1 (GA.056)

    Opening Address from Dr. Siniša Djurović

10:00 - Nancy Rothwell_Event Space B

    Poster Voting (Voting Form Closes at 14:00)
    Lunch – Pizza Buffet (From 12:00)

14:00 - Nancy Rothwell_Event Space B

    Cheese & Wine Reception

14:30 - Nancy Rothwell_Blended Th1 (GA.056)

    Prize Presentation - Prof. Alexander Lanzon + IAG Members
    Closing Statement by Prof. Alexander Lanzon

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POSTGRADUATE RESEARCH

MSc Abstracts

Time–Current–Voltage Characteristic enhanced Directional Overcurrent Protection for Low Inertia System

Name: Yining Bai
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Supervisor: Dr.Haiyu Li
Research Group: Msc year2
Year of Study: 2

The global transition toward a Net Zero power system has significantly increased the penetration of renewable energy sources (RES), leading to reduced system inertia and lower fault current levels. These changes severely affect the performance of conventional overcurrent relays (OCRs), which rely on current magnitude for operation and coordination. This project proposes an enhanced directional overcurrent relay (DOCR) protection scheme incorporating a Time–Current–Voltage (T–I–V) characteristic to improve sensitivity and coordination under low-inertia conditions. The voltage-dependent factor K is introduced into the relay tripping equation to account for fault severity and voltage depression, enabling faster operation without altering traditional relay parameters such as TDS or pickup current. The optimal relay settings are determined through Sequential Quadratic Programming (SQP) optimization to minimize total tripping time while satisfying coordination constraints. The scheme is tested and validated on a distribution network integrated with both wind and photovoltaic (PV) distributed generation units using DIgSILENT PowerFactory. Expected results demonstrate reduced total relay operating time, improved selectivity, and enhanced protection reliability for inverter-based low-inertia systems, contributing to the resilience of future Net Zero distribution networks.

Intelligent Wireless Power Transfer via a 2-Bit Reconfigurable Transmissive Metasurface and Fabry–Perot Cavity Feeder

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Research Group: MSc Year 2
Year of Study: MSc Year 2

The growing demand for efficient and flexible power delivery in intelligent electronic systems has accelerated research into wireless power transfer (WPT) technologies. This work presents an intelligent WPT framework employing a 2-bit reconfigurable transmissive metasurface (RTM) in conjunction with a Fabry Perot cavity (FPC) feeder. The FPC, composed of an artificial magnetic conductor (AMC) and a partially reflective surface (PRS), is engineered to generate a uniform quasi-planar excitation field, enabling efficient illumination of the RTM with a subwavelength system profile. Each metasurface unit cell provides four discrete transmission phase states ($0°$, $90°$, $180°$, and $270°$), enabling precise control of the transmitted wavefront for adaptive beam focusing and spatial energy routing. The presented configuration achieves low-profile integration and flexible spatial control of power flow. A MATLAB-based computational model was developed to synthesize quantized phase distributions and evaluate the far-field focusing performance. Simulation results verify accurate electromagnetic energy localization at specified target coordinates, confirming the effectiveness of the proposed design.

Power system disturbance detection and analysis based on machine learning

Name: Shuyu Jia
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Supervisor: Haiyu Li
Research Group: MSc 2year
Year of Study: 2year

Abstract：

This study proposes a machine learning–based framework for intelligent detection and analysis of power system disturbances. With the growing penetration of renewable energy sources, modern power systems have become increasingly complex and prone to diverse disturbances, resulting in significant operational and economic challenges. Traditional detection methods often struggle to provide accurate and timely responses under such dynamic conditions. To address this, the proposed model integrates power quality (PQ) disturbance classification and voltage stability assessment using data generated from the IEEE 14-bus transmission system. The framework extracts multi-domain features—time, frequency, and time-frequency—to train machine learning classifiers capable of recognizing voltage sag, swell, harmonics, and other PQ events with high precision. Furthermore, the system incorporates a real-time voltage stability predictor to evaluate post-disturbance recovery performance. Simulation results demonstrate that the integrated ML-based approach outperforms conventional methods in both detection accuracy and computational efficiency, contributing to more resilient and intelligent grid operation.

Optimal planning for Barking Town district energy centre: A case study

Name: Yuan Shou
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Supervisor: Alessandra Parisio
Theme: Muti-objective Planning; Heat Pumps; Cogeneration; Multi-energy System; District heating,
Year of Study: 2

Energy storage and heat pump (HP) technologies are poised to play a pivotal role in the decarbonisation of heating and the broader transition towards cleaner energy systems over the forthcoming decades. The London Borough of Barking, situated in proximity to the capital, is committed to achieving net-zero carbon status. Central to this initiative is the development of a Strategic Energy Centre (SEC), which investigates the synergies between Combined Heat and Power (CHP) and HP technologies. The objective is to supply low-carbon heat to the Barking Town Centre (BTC) District Heating Network (DHN).

As specified in the Barking tender documentation, the energy centre's development is structured in three phases. Phase 1, encompassing the primary heat network installation, is substantially complete. Phase 2 entails the installation of large-scale heat-only boilers (HoB) within the SEC North building. Phase 3 proposes the integration of CHP and a water-source heat pump (WSHP) system, utilising the adjacent River Roding as its source, within the SEC South building.

This project subsequently outlines a multi-objective optimisation framework to determine the optimal configuration of this hybrid energy hub. The system model integrates an internal combustion engine (ICE) unit, thermal energy storage (TES), HoB, and either air-source (ASHP) or water-source (WSHP) heat pump systems. The inclusion of heat pumps is anticipated to mitigate both fuel expenditure and environmental costs.

A Mixed-Integer Linear Programming (MILP) model is formulated to identify the ideal installed capacities of each component. The model is structured to maximise the project's Net Present Value (NPV) whilst simultaneously minimising whole-life-cycle carbon dioxide emissions. This model incorporates electricity pricing from the UK energy market and the prevailing carbon pricing mechanisms under the UK Emissions Trading Scheme (UK ETS). The analysis is predicated upon predicted hourly heating and electricity demand profiles representative of the local context, employing regional climate data to simulate the variable operational performance of the heat pump systems.

Name: Ge Tian

Abstract

This work presents a novel framework for quantum communication using holographically engineered aperiodic lattice (AL) terahertz quantum cascade lasers (QCLs) as multi-frequency optical sources for continuous-variable quantum key distribution (CV-QKD).

Building upon the concept of degenerate phase-matching in AL-QCLs—where multiple THz defect modes share identical phase-matched pump frequencies—the system enables multi-wavelength, electrically switchable nonlinear mixing within a single integrated cavity. Numerical analysis using the nonlinear transfer matrix method shows that the nonlinear conversion efficiency is resonantly enhanced by the group index modulation (slow-light effect), while the phase-matching condition is governed by the engineered effective refractive index dispersion of the AL structure.

The generated multi-frequency optical field can be spectrally filtered to isolate each frequency channel, which then serves as an independent quantum carrier.

Each carrier is subjected to Gaussian modulation of its quadratures and transmitted through the communication channel, where the receiver (Bob) performs homodyne or heterodyne coherent detection to measure the corresponding quadrature components.

Through classical post-processing—including parameter estimation, error correction, and privacy amplification—secure keys are extracted from the continuous measurement outcomes.

This hybrid approach integrates multi-channel THz photonics with quantum information processing, offering a scalable and tunable platform for parallel CV-QKD and wavelength-division-multiplexed quantum communication.

The proposed system provides a compact, on-chip, and electrically controllable source for next-generation high-capacity quantum-secure networks.

Transmission system stability analysis of inverter-based energy resources

Name: Naser Veliu
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Supervisor: Robin Preece
Research Group: Advanced MSc
Year of Study: 2

The rapid decarbonisation of the UK power system and increasing penetration of inverter-based resources (IBRs) are fundamentally reshaping grid dynamics. Unlike synchronous generators, IBRs reduce system inertia and introduce complex control interactions, making stability assessment more challenging. This project investigates transmission system stability under high IBR penetration using frequency-domain methods, with a focus on the Generalised Nyquist and Bode frameworks. Detailed time-based Electromagnetic Transient models and simplified mathematical analytical models will be developed to capture the dynamic behaviour of IBRs under varying grid conditions. The study compares small- and large-signal responses, evaluates the applicability and limitations of frequency-domain stability analysis, and defines disturbance thresholds and stability boundaries. The results provide practical insights to support secure grid operation and guide Transmission Operators on the integration of renewable energy resources at transmission level.

Abstract Template:

Control of 2-DOF helicopter under healthy and faulty condition based on reinforcement learning

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Supervisor: Long Zhang
Research Group: Msc year 2
Year of Study: MSC year2

Unmanned Aerial Vehicles （UAVs） has been commonly applied in both industry and commercial area. However, realising stable, robust control of UAVs is not an easy quest as they are generally multi-input, multi-output (MIMO) with physical coupling and multiple types of disturbance. Accordingly, it is essential to establish accurate dynamic model of UAVs and develop high performance and fault tolerance controller for UAVs system. Accordingly, a stablising controller based on reinforcement learning framework will be tested on the physical Quanser Aero 2 system under both healthy and faulty condition. The different types of damages with different levels of severity will be implemented on the fans of Aero 2, which include single cut, symmetrical cut, middle cut and etc. The subsequent experimental results will illustrate the impacts on system dynamics, tracking performance and vibration level due to the damage. Ultimately, this research will provide a control algorithm which is effective for fault tolerance control systems.

Modelling, Control and Stability Analysis of Inverters in Low-Inertia Microgrids

Name: Zhenyuan Yang
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Supervisor: Mahdieh Sadabadi
Theme: Net Zero
Year of Study: Postgraduate Year 2

As renewable energy sources such as solar and wind power are increasingly integrated into the grid, traditional large rotating electrical machine systems are gradually being replaced by inverter-based resources (IBRs). This change reduces grid inertia, bringing new challenges to maintaining stable frequency and voltage during the operation. This study explores how grid-forming (GFM) inverters can help solve these problems by making the power grid more stable and flexible. In this project, a grid-forming (GFM) inverter model with droop control and a traditional grid-following (GFL) inverter model were constructed using MATLAB/Simulink. The simulation results were used to analyze and compare the performance of these two models. In the next stage of the project, additional grid-forming inverter control strategies, including virtual synchronous machine (VSM) and matching control, will be studied to further evaluate their dynamic performance and stability. This research helps to understand how advanced inverter controls can make future renewable-based power systems more reliable and resilient.

QoS-Guaranteed Matching-Based Activation in Pinching-Antenna Systems

Yishi Zhang

Supervisor's Name: Daniel Ka Chun So

Abstract: Pinching-antenna systems (PASS) use a dielectric waveguide with low attenuation, and multiple small pinching antennas can be distributed along it, enabling many unique advantages compared with conventional antennas. In this poster, we consider a discrete matching-based PASS downlink with L candidate positions, N activated antennas, and K users, where non-orthogonal multiple access (NOMA) and quality-of-service (QoS) constraints are imposed. We address two gaps in existing discrete matching-based PASS models—neglect of optimal power allocation (OPA) and QoS—by introducing the QoS-guaranteed OPA into the system. Specifically, users are ordered by effective channel gains; closed-form minimum power coefficients $\alpha_k^{\min}$ are derived to meet each user's QoS targets $R_{\min}$, subsequently a bisection step maximizes the strongest user's coefficient α_K under feasibility, leading the remaining power is allocated within the matching-based scheme to maximize sum rate. Additionally, an OFDMA (OMA) baseline with water-filling and fixed power allocation are provided. The results show that OPA yields clear gains at higher QoS (e.g., $R_{\min=}$ 1.5 , 2 bps/Hz), whereas improvements are marginal when QoS is low ($R_{\min} = 1$ bps/Hz); outage remains largely unchanged when weak users can always meet $R_{\min}$, while fixed splits may sacrifice maximum sum rate to enforce QoS. These results indicate that QoS-guaranteed OPA is an effective enhancement for matching-based PASS deployment. We will evaluate both sum rate and energy efficiency, and derive scheme-dependent PASS power models, where P_{other} will be considered.

Machine Learning Based State Classification in the Digital Substations

Name: Linghan Zheng
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Supervisor: Haiyu Li
Research Group: 2yr Msc
Year of Study: 2

Based on the IEC 61850 standard, this study proposes a machine learning framework for digital substation state classification. A 66/11 kV virtual substation model is built in MATLAB/Simulink to simulate normal, faulty, and cyberattack states. Voltage and current data are extracted and pre-processed through the IED and then trained using a supervised learning model. This approach aims to effectively distinguish between operational, faulty, and attack states, improving the safety, reliability, and real-time monitoring capabilities of smart substations.

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PGR Abstracts

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Robust Inertia-Constrained Unit Commitment for Low-Inertia Power Systems

Name: Mohammad Habieb Al-Khayat
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Supervisor: Eduardo Alejandro Martinez Cesena
Research Group: EEE Power systems
Year of Study: 2nd year

The increasing displacement of synchronous generation by inverter-based Variable Renewable Energy (VRE) significantly reduces system inertia, limiting the grid's capability to withstand frequency deviations following disturbances. Conventional Unit Commitment (UC) formulations neglect this aspect, leading to schedules that may not secure dynamic stability. This work develops an Inertia-Constrained UC (UC-IC) formulation that explicitly integrates simplified inertia constraints into the UC framework, ensuring adequate frequency support under the largest possible disturbance. The formulation is derived from the swing equation and establishes a linear relationship between the total committed inertia, the allowable Rate of Change of Frequency (RoCoF), the frequency nadir, and the specified primary response time. The UC-IC ensures that sufficient synchronous inertia is committed to maintain frequency within permissible limits, while accounting for Frequency Response Reserves (FRR) from both synchronous and inverter-based units. Offering a practical framework for secure and reliable operation of low-inertia power systems. Sensitivity analyses conducted on a 4-bus and the RTS-GMLC systems demonstrate that longer response times and lower inertia availability require additional commitment of flexible synchronous capacity, reducing VRE utilisation and increasing operational costs. The results highlight the inherent trade-off between frequency stability requirements and energy costs.

Name: Yao Li

Abstract

Extreme climate events are occurring frequently worldwide, while the penetration of renewable energy in power systems is rapidly increasing. However, the volatile output as well as the weak inertial support available from renewable energy sources will degrade the capability of power systems to reject disturbances, leading to a higher frequency and risk of large-scale blackouts in power systems.

The recent increasing frequency of extreme climate events and the severe societal and financial losses they caused have heightened the need to improve resilience of the power system. Served as a critical assessment metric, the modelling of post-failure system restoration plays an important role in general resilience assessment. Traditional generalized restoration models in resilience assessment commonly only consider components repair, which is too simplified to adapt to the increasingly complex operation environment of power systems. To improve the current models of restoration typically used in resilience assessment, this research proposes a generalized multi-stage restoration model for resilience assessment. To achieve this, the generalized models for black start stage, network reconfiguration stage, and load restoration stage are constructed by time-based simulation. Then the temporal overlapping between these stages is modelled to accelerate the restoration progression. The case study shows that the proposed model can help accelerate the restoration and enhance the assessment of resilience in power systems.

Improvement of Computational Efficiency on Energy Management Systems

Name: Jiayi Liu
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Supervisor: Victor Levi
Research Group: Electrical Energy and Power Systems
Year of Study: Second year

The integration of electricity, gas, and heating into a multi-energy system (MES) has attracted growing interest, driven by the deployment of energy-conversion facilities such as CHP units, heat pumps, gas turbines, and power-to-gas. Operating and planning each sector in isolation— while ignoring inter-sector couplings—leads to suboptimal energy efficiency and constrains the evolution of the energy mix. This study targets the computational efficiency of state estimation (SE) for MES. A per-unit (p.u.) MES model is established, comprising electricity, gas, and heating subsystems operating under quasi-steady-state conditions. Static SE via weighted least squares (WLS) and dynamic SE via an iterated extended Kalman filter (IEKF) are first applied independently to the three subsystems. A centralised SE is then formulated by integrating subsystem objectives and coupling constraints via a Lagrangian approach. To alleviate the computational burden of the centralised problem, a decentralised SE based on primal–dual decomposition is proposed, which partitions the primal problem into three subsystem subproblems and solves the dual via either a Newton-type second-order method, a gradient-based scheme, or Armijo backtracking line search. For bad-data processing, the largest normalised residual (LNR) test with WLS and a variational Bayesian IEKF (VBIEKF) are employed.

Abstract Template:

Investigation of combined electro-thermo-mechanical effects on XLPE insulation for HVDC Dynamic Offshore Cables

Name: James Oxford
Email: james.oxford@manchester.ac.uk
Supervisor: Dr Tony Lujia Chen, Prof Ian Kinloch
Research Group: Power and Energy, Advanced Nanomaterials
Year of Study: 2

Abstract body text; Times New Roman, Size 12; Left Justified; Max. 200 words; No figures or tables to be included.

The North Sea offers both the windiest and shallowest waters for offshore wind generation in Europe. For subsea transmission over 70 km, DC offers a more favourable method to AC. Wind power, generated in AC, will need to be converted to DC before transmission by an AC/DC converter substation. These substations have a large footprint and can only feasibly be installed on fixed structures up to water depths of 100 m, beyond which floating platforms are economically favourable. These floating platforms will require a dynamic section of DC export cable to connect to the static subsea section on the seabed. This dynamic section will be subject to the mechanical forces of the North Sea, which can generate sea waves over 30 m in rough conditions, on top of its operating thermal strain while transmitting GW of power. It is vital that the insulation material of these DC dynamic cables can handle the operating conditions for a suitable product life cycle.

This project investigates the effect of thermal and mechanical ageing on DC electrical treeing in XLPE samples using well-established needle electrode methodologies and considers the additional effects of overlain AC harmonics from a VSC on the DC steady state transmission.

Prevention of Cyber Attacks on Energy Management Systems

Name: Ye Shen
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Supervisor: Victor Levi
Research Group: Electrical Energy and Power Systems
Year of Study: Second year

As global energy demand rises and the European Union Commission targets climate neutrality by 2050, multi-energy systems (MES) have emerged as a key paradigm for coupling electricity, gas, and heat to enhance resilience and efficiency while containing economic impacts. This study aims to improve the computational efficiency and bad data detection accuracy of state estimation (SE) for MES. A per-unit (p.u.) MES model is developed for the electricity, gas, and heating subsystems under quasi-steady-state operation. Static SE via weighted least squares (WLS) and dynamic SE via an iterated extended Kalman filter (IEKF) are first deployed independently within each subsystem. A centralised MES SE is then formulated by integrating subsystem objectives and coupling constraints through a Lagrangian approach. For bad-data processing—two schemes are evaluated: largest normalised residual with WLS (LNR–WLS) and a variational-Bayesian IEKF (VB–IEKF). Across three bad-data scenarios, VB–IEKF consistently achieves superior state-estimation accuracy and higher bad-data detection performance compared with LNR–WLS.

Enhancement of Observability of Low-Voltage Distribution Network

Name: Aleksandra Spasić
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Supervisor: Jovica V Milanović
Research Group: Power Systems
Year of Study: Second

Observability in low-voltage networks (LVNs) is vital for reliable operation and integration of low-carbon technologies. However, limited smart meter (SM) coverage—often below 50%—significantly constrains monitoring and state estimation accuracy. This study develops a data-driven framework that enhances LVN observability under sparse measurement conditions by explicitly addressing uncertainty in both load allocation and line parameters. The method combines a Long Short-Term Memory (LSTM) neural network for estimating unobserved loads with probabilistic sampling. Additionally, a Gaussian Process (GP) model is used to infer unknown line parameters based on the electrical neighbourhood of each segment. To identify the factors that most strongly influence voltage profiles, a Morris screening sensitivity analysis is performed across all loads and lines. The results highlight a small subset of highly influential parameters—typically corresponding to large consumers or main-feeder lines—whose refinement yields the largest improvement in network visibility. The proposed framework provides a systematic and scalable approach to enhance LVN observability, enabling distribution system operators to prioritize parameter modelling or targeted sensor deployment while minimizing additional instrumentation costs.

Techno-Economic and Environmental Analysis of Vehicles-to-Ship (V2S) Applications on Hybrid Propulsion Ships

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Supervisor: Eduardo A. Martínez Ceseña
Research Group: Power System
Year of Study: 2

Building on the growing efforts to decarbonise maritime transports, this study proposes an approach to integrate vehicle-to-ship (V2S) and ship speed optimisation as a form of virtual energy storage to minimise emissions from hybrid propulsion ships. The approach aligns propulsion demand with the temporal availability of clean energy, enhancing system performance without the need for additional storage infrastructure. A Mixed-Integer Linear Programming model is developed using piecewise linear approximations to co-optimise ship speed (nonlinear model) and the energy dispatch of diesel generators, PV systems, and EV batteries, subject to constraints on voyage timing, battery state of charge, EV availability, and power balance. Scenario-based analysis demonstrates that speed optimisation alone achieves a modest emissions reduction of 3.9%, while V2S integration yields up to a 94.5% reduction when sufficient EV capacity is available. The combined application of both strategies enables zero-emission operation when at least 66% of the transported vehicles are electric, identifying this as a practical threshold for full decarbonisation. These findings highlight the effectiveness of jointly optimising speed and energy dispatch in hybrid ship operations. Future work will focus on enhancing model realism, incorporating techno-economic analysis, and embedding uncertainty to support decision-making for low-emission maritime transport.

A Hybrid Sequential Convex Programming
Framework for Unbalanced Three-Phase AC OPF

Name: Sary Yehia
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Supervisor: Prof. Alessandra Parisio
Research Group: Power and Energy Division – Power Systems Research Group
Year of Study: 2

Unbalanced three-phase distribution networks are increasingly prevalent due to asymmetric line parameters, single-phase loads, and distributed energy resources (DERs). Solving the associated AC Optimal Power Flow (OPF) problem is crucial for efficient and reliable operation but remains nonlinear and nonconvex. This work presents a hybrid Sequential Convex Programming (h-SCP) framework that combines a fixed McCormick outer approximation of bilinear voltage-current terms, first-order Taylor linearizations, and an adaptive conic trust-region constraint to preserve feasibility and promote convergence. The resulting formulation remains convex at each iteration and ensures convergence to a stationary point satisfying the first-order Karush-Kuhn-Tucker (KKT) conditions of the nonlinear OPF. Case studies on IEEE test feeders and a real low-voltage (LV) network in Cyprus demonstrate high numerical accuracy with optimality gaps below 10^{-4} p.u. and runtimes up to twice as fast as IPOPT. Future work aims to extend this framework into a real-time co-simulation platform for multi-energy systems, integrating electrical and thermal dynamics through MATLAB-RTDS coupling. This will enable closed-loop validation of advanced MPC-based control strategies under realistic operating conditions.

Resilience-oriented Distribution Network Investment Planning Under Windstorm Uncertainties with Explicit Economic Valuation

Name: Maoyuan Yin
Email: maoyuan.yin@postgrad.manchester.ac.uk
Supervisor: Eduardo A. Martínez Ceseña, Jaise Kuriakose
Research Group: Power Systems
Year of Study: 2nd Year

Power system resilience against high-impact low-probability (HILP) events such as windstorms has become increasingly critical due to the threat of climate change. However, traditional investment planning frameworks typically fail to economically justify resilience enhancements due to the very low probability of HILP events (i.e., their expected value tends to be zero). This study proposes a framework that assigns economic value to specific resilience levels using constraints. A two-stage stochastic mixed-integer linear programming (MILP) model is formulated with a resilience metric threshold constraint that incentivises resilience enhancement investments regardless of HILP event probabilities, explicitly linking investment costs to resilience levels. Uncertainties from HILP events, particularly windstorms, are captured using scenarios generated from Monte Carlo simulation (MCS), while overhead line (OHL) hardening is considered as the resilience enhancement investment option. The framework is validated on a real network, using a cost-resilience Pareto front to provide decision-makers with explicit economic trade-off information for resilience-oriented investment planning.

Electrical Performance of Transformer Insulation Materials under DC Stress

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Research Group: High Voltage Engineering Research Group
Year of Study: Second year

Over recent decades, high voltage direct current (HVDC) transmission projects have become increasingly integrated into power grids due to the growing demand for bulk energy transfer over long distances and the need to interconnect asynchronous systems. Better understanding the effects of DC stress on the insulation systems of converter transformers, key components of HVDC systems, has therefore become urgent. In 2010, a CIGRE Technical Brochure (406) reported statistics on failures in transformers used for HVDC applications and evaluated the applicability of standardized AC transformer tests to transformers designed for HVDC. It concluded that there is a need to update current standards and define new tests and methodologies for assessing insulation performance under DC stress. In 2016, CIGRE Technical Brochure (646) continued this work and provided guidelines for liquid and solid insulation conductivity tests under DC stress. Using a three-electrode plane-to-plane arrangement and following the methodology proposed in this later publication, the aim of this research is to study the electrical performance of transformer insulation materials under DC stress, particularly more environmentally friendly alternatives to mineral oil, which has been the main focus of study in recent decades.

Design of High Voltage Interconnects for Discharge Free Operation in Aerospace Applications

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Research Group: High Voltage Group
Year of Study: 2

The electrification of transportation, including aircraft, being driven by sustainable emission targets, is seeing an increased demand in their electrical power systems (EPS). The More Electric Aircraft (MEA) for example, replaces systems powered by pneumatic, hydraulic and mechanical power with electrical power, increasing efficiency and reducing overall emissions. This means that the EPS in aircraft need to be developed to handle increased power demands. At the heart of an aircraft's EPS are power converters that play a crucial role in supplying power to aircraft components. These power converters need to be able to handle the increasing power demands in MEA and one way is to support higher voltages, as an increase in current increases the weight and size of electrical components which are not ideal for aircraft efficiency. Therefore, electrical insulation systems in these power converters need to be designed to withstand these higher voltages risk free. This PhD focuses on investigations on design methods and limitations of high voltage interconnects. Current work has included partial discharge inception voltage modelling and high frequency breakdown testing of such systems.

Lifetime Analysis of Insulation Systems in Transportation Electrification

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Research Group: High Voltage Group – Power and Energy Division
Year of Study: 2

Partial discharge (PD) is a critical factor in the degradation of high-voltage (HV) polymeric dielectric materials, particularly for those that will be used in transportation electrification applications where insulation reliability is paramount. This paper investigates the surface degradation patterns and mechanisms induced by PD in polyether ether ketone (PEEK) 100μm thick films. A series of electrical endurance tests were conducted at various voltages (1.0 – 1.6kVRMS) and frequencies (500Hz – 1.5kHz) with time-to-failure data analysed by Weibull distributions. Surface degradation was characterised by laser confocal microscopy, revealing a progressive erosion pattern with maximum depth reaching 75.68μm at 1.0kVRMS-1kHz sinewave and decreasing at higher voltages. An equivalent breakdown strength is derived from the remaining thickness after erosion, which matches that obtained in high-frequency-low-ramp-rate breakdown voltage tests of the film samples. This research confirms that the rate of erosion increases as applied voltage and frequency increases, contributing to the reduced lifetime and emphasising the necessity of controlling electrical stress in polymer-based insulation systems. The simulation and experimental results provide insights that may be used to deliver predictive lifetime analysis for HV insulations and contribute to the development of PD-resistant dielectrics.

Keywords: *Erosion rate, Partial discharge, PD-resistant, Polymeric dielectric, Surface degradation.*

Development of Digital Twin for Power Transformer

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Research Group: High Voltage Group
Year of Study:2nd

Transformer digital twin, as a virtual replica of real-world transformer, capable of simulating its behaviour, analysing operational data and optimizing performance. Transformer digital twin provides a comprehensive analysis of transformer conditions, supports real-time decision making, and helps with predictive maintenance scheduling.

This poster first introduces the functionality of digital twin and explains how each layer (Data acquisition layer, Modelling, Simulation and Data Analytics layer, Application and Action layer) interacts and cooperates to analyse the data and feedback information. To illustrate how digital twin operates, an example of Frequency Response Analysis (FRA) - based digital twin is presented. This digital twin consists of two complementary models: physics-based model and data-driven model. Physics-based model, based on physical law, generates training FRA data for machine learning algorithm used in data-driven model. With the aid of trained machine learning model, the data-driven model is able to give detailed diagnoses of the winding deformation.

Ageing Assessment of Transformer Liquid and Solid Insulation Systems through Molecular Dynamics Simulation

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Research Group: High Voltage Group
Year of Study: 2nd Year

Oil-paper insulation scheme has been used in power transformer for over century which shows good reliability during operation. Beyond its role as electrical insulation, cellulose-based paper insulation also provides mechanical support the winding, while liquid insulation functions as cooling medium and ageing information carrier. Therefore, ageing assessment of insulation, especially for cellulose-based paper insulation, is critical to guarantee the reliable operation and asset management of power transformer.

Despite decades of experimental research, the microscopic mechanisms underlying insulation degradation and ageing products formation are still not fully understood. Recent achievements in computational chemistry offers powerful molecular simulation approaches to explore these processes at atomic level. Among them, Molecular Dynamics (MD) simulation is a representative theory that commonly used to predict physical properties of a material, such as modulus and heat capacity, and with Reactive Force Field (ReaxFF), it can also capture chemical reactions. Density Functional Theory (DFT) is another widely used computational method that provides high-accuracy insights into reaction kinetics and charge behaviour.

This poster presents a general introduction of the application of MD and DFT methods on transformer insulation degradation study. Case studies, including pyrolysis of cellobiose, highlight the potential of molecular simulation to reveal fundamental ageing mechanisms and support future transformer research.

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Year of Study: 2

This research develops a transformer mechanical digital twin to enhance winding mechanical fault diagnosis through Frequency Response Analysis (FRA). A comprehensive lumped parameter modelling approach has been established, combining analytical electrical parameter calculations with systematic fault simulation studies. The novel P-L-D-T notation framework (Position-Length-Degree-Type) enables consistent fault characterization across ten detailed case studies covering both continuous and interleaved winding configurations. Key findings demonstrate that axial deformations produce frequency shifts up to 4.5 kHz with emergence of new resonance points, while radial deformations generate measurable shifts up to 0.9 kHz. Comparative analysis reveals that interleaved windings exhibit reduced radial sensitivity but maintain strong axial sensitivity, with middle-position deformations consistently producing the most pronounced FRA changes. The systematic investigation incorporates both electrical parameter modifications and geometric parameter variations, generating a structured FRA signature database under controlled fault conditions. This foundation provides essential training data for supervised machine learning development, validated sensitivity patterns for automated interpretation systems, and demonstrates the feasibility of transformer mechanical digital twin technology for advancing power system asset management capabilities.

Ageing Assessment of Transformer Insulation Systems using Dual-temperature Method

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Research Group: High Voltage Group
Year of Study: 2nd Year PhD

Ageing assessment of transformer insulation systems has continuously been a technical challenge faced by the transformer industry. Various laboratory ageing schemes have been used over the years to assess the performance of oil-paper insulation systems and hence to support thermal design and operation of power transformers. Such laboratory ageing studies can be divided into three main types: single-temperature ageing cell, dual-temperature test system and functional life test model. Among these, dual-temperature test system is less complicated and less costly than the functional life test model, but is able to simulate non-uniform temperature profile, which cannot be achieved by the single-temperature ageing cell. This work aims to investigate the ageing performance of thermally upgraded paper insulation in combination with various transformer liquids using the dual-temperature ageing system. Temperature measurements were conducted for a better understanding of the temperature profile within the test cell. Preliminary Computational Fluid Dynamics (CFD) simulations were also conducted to model the thermal profile and liquid flow within the ageing cell. Long term ageing experiments will be conducted to further assess the mechanical and dielectric properties of both solid and liquid insulation materials.

Name: Zhanan Ao

This work investigates the long-term performance of a Fibre Bragg Grating (FBG) sensor used for in situ thermal monitoring of random wound electric machine coils. An experiment was performed using a motorette instrumented with an FBG thermal sensing system. The motorette was energised under a standard S6 duty cycle with overloaded thermal levels to facilitate accelerated lifetime testing and to replicate the thermal conditions of electric machines. The performance of the FBG sensor was evaluated through calibrations conducted both before and after the experiments to assess changes in the transfer function and sensitivity. Additionally, FBG measurements were compared with those of a Type K thermocouple to analyse relative performance, including differences in measurements and response times. The results enhance the understanding of FBG sensor performance in electric machine environments and further highlight its potential as a promising solution for in situ thermal monitoring.

On-state Resistance - Informed Online Condition Monitoring Algorithms for Power MOSFETs in Power Electronic Converters

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Year of Study: 2

Condition monitoring (CM) can provide the health status of the vulnerable components of power electronic converters such as power MOSFETs to enable predictive maintenance, so that safety issues and economic loss caused by unexpected failure of power converters can be mitigated. Two online CM algorithms for power MOSFETs in buck, boost and three-phase two-level voltage source inverters based on the increase in on-state resistance during the power MOSFETs degradation process are proposed. The proposed methods have a lower sensor requirement compared with the existing methods based on directly measuring drain-source voltage and current, thereby enhancing reliability and robustness of the condition monitoring. In addition, both methods have low computational burden and have theoretical proof for the performance of the CM results, which is an advantage over digital twins-based online CM methods. Both methods are verified by simulation in MATLAB/Simulink and LTspice. Future work includes verification of both methods on real converter prototypes.

DiRAViG: Differentiable Region Assignment Vision Graph Networks

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Year of Study: 2

Vision Graph Neural Networks (GNNs) offer a powerful alternative to Convolutional Neural Networks (CNNs) and Transformers for modeling complex visual relationships in images. However, they still face two challenges: the high computational cost of repeated global k-NN graph constructions and the misalignment of rigid patch tokenization with object boundaries. We propose **DiRAViG**, which replaces fixed patches with boundary-aligned region tokens produced by a differentiable end-to-end assignment, and propagates on a fixed, sparse one-hop spatial contact graph with few-step diffusion. A bidirectional pixel–region pathway aggregates the features into regions and projects them back to the image grid, preserving fine details and stabilizing training. On ImageNet-1K, DiRAViG-S achieves 77.8% Top-1 at 1.5 GMACs and DiRAViG-M reaches 81.5% at 4.2 GMACs. Compared to Pyramid ViG-S (~4.6 GMACs) and ViHGNN-S (~6.3 GMACs), DiRAViG-S cuts MACs by 35% and 52% at comparable accuracy. These results demonstrate that DiRAVIG offers a more scalable and boundary-aware solution for efficient vision analysis.

An Energy-Efficient Sleep-Mode Strategy for RIS-Empowered Cell-Free Massive MIMO

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Year of Study: 2

With the explosive growth of data traffic and the ubiquitous connectivity of wireless devices, the energy demands of wireless networks have inevitably escalated. Reconfigurable intelligent surface (RIS) has emerged as a promising solution for 6G networks due to its energy efficiency (EE) and low cost, while cell-free massive multiple-input multiple-output (CF mMIMO) was proposed as an innovative network architecture without fixed cell boundaries to enhance these measures even further. However, existing studies often assume consistently high traffic loads, neglecting the dynamic nature of user demand. This can result in underutilized access points (APs) and unnecessary energy expenditure during low-demand periods. To tackle the challenge of EE in CF mMIMO systems during low load periods, this paper propose a novel energy-efficient transmission scheme that jointly coordinates active APs and multiple passive RISS. Specifically, a dynamic AP sleep-mode strategy is designed, where certain APs are selectively deactivated while nearby RISs assist in maintaining coverage. To maximize EE, we formulate the EE maximization as a fractional programming problem and adopt the Dinkelbach method in conjunction with alternating optimization (AO) to iteratively solve the coupled subproblems: (i) AP selection via a hybrid branch-and-bound (BnB) and greedy algorithm, (ii) RIS phase shift optimization using gradient projection. Additionally, transmit power is allocated to users through a heuristic zero-forcing strategy. Simulation results show that the proposed scheme achieves significantly higher EE than existing methods in both low and moderate user scenarios.

CSPDet3D: Cross-Level Semantic-Guided Dynamic Pruning for Efficient 3D Small Object Detection

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Year of Study: 2

Deep learning-based object detection has become prevalent in increasing number of applications, from robotic vision or medical image analysis. Small objects in indoor point clouds present a challenge as there are few points and weak geometric cues, making the model pruning prone to over-pruning and missed detections. We present CSPDet3D, which integrates semantic guidance into dynamic spatial pruning and cross-level fusion. First, a semantic-guided pruning module combines geometric scores with uncertainty measures (entropy and confidence) to preserve voxels in ambiguous regions. Second, a cross-level semantic-guided channel attention transfers global semantic statistics from coarse to fine levels to recalibrate channels before fusion, strengthening small-object features while keeping computation low. On ScanNet-md40, CSPDet3D improves mAP@0.25/0.5 by 0.8/1.3 points over DSPDet3D with similar speed and a small memory change (12.3 FPS; 700→715 MB). On TO-SCENE-down, it gains +2.63 mAP@0.25 (66.12→68.75) and +1.72 mAPS@0.25, with comparable efficiency (13.7 FPS; 800→822 MB). The results show that semantic uncertainty and cross-level context mitigate over-pruning and enhance small-object perception, delivering a better accuracy–efficiency trade-off for real-time 3D detection.

Energy Efficiency Optimization of STAR-RIS Assisted MIMO-NOMA Networks

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Research Group: Communications and Signal Processing
Year of Study: 2

Simultaneous transmission and reflection reconfigurable intelligent surface (STAR-RIS) extends coverage beyond conventional RIS by enabling full-space signal manipulation. This paper investigates a STAR-RIS assisted multiple-input multiple-output (MIMO) non-orthogonal multiple access (NOMA) system. We aim to maximize the energy efficiency (EE) of this system, which is modeled to include the direct link between the base station (BS) and the reflection-user (R-user), which mostly exists in practice. We jointly optimize the active and passive beamforming, respectively at the BS and STAR-RIS, by decomposing the original non-convex problem into two tractable subproblems, which are then efficiently solved via an alternating optimization (AO) algorithm. The non-convexity is addressed by integrating the Dinkelbach method, quadratic fractional programming (QFP), semidefinite relaxation (SDR), and successive convex approximation (SCA) to convert each subproblem into a convex form. Numerical results demonstrate that the proposed scheme can substantially improve overall EE over existing STAR-RIS assisted MIMO-NOMA networks.

Direct thermal simulations of Super-blackbody Metasurface for Radiation-induced activation in CO₂ Reduction

Name: Rithichan Chhorn
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Supervisor: Joel Loh
Research Group: *Photonics, Electronics & Quantum Technologies*
Year of Study: 1

Recent advances in nanophotonics have allowed for greater control of incandescent radiation, harvesting its properties to great effect. However, the characterization of emission using FDTD methods have generally been limited to calculating emission and invoking Kirchoff's law. Thermal transfer simulations are restricted between simple structures. Utilizing direct thermal simulations, we present near field energy spectra for two metasurfaces designed to emit thermal radiation at the CO_2 stretching mode of 4250nm allowing for molecule activation to drive the catalysis process. A narrow emitter with peak absorptivity of 94.4% at 4.3μm and a wide emitter with peak 78.7% absorptivity at 4.42μm. Both emitters display enhanced near field radiative effects 500 nm from the surface with EM energy density at 750K exceeding that of a blackbody with the same temperature with a 2.7 and 2.51 times enhancement, respectively, over the far field energy density at peak wavelengths.

Fabrication and Experimental Analysis of Indium-free Organic Photovoltaic cells.

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Supervisors: Prof. Matthew Halsall, Dr. Iain Crowe
Research Group: OPV
Year of Study: 2nd

Organic Photovoltaics have gained tremendous attention ever since the first report in 1986. OPVs do not require high temperature processing, can be optically tuneable and are lightweight, posing advantageous over conventional silicon cells. OPVs require a Transparent Conductive Electrode (TCE) and use Indium Tin Oxide (ITO). Unfortunately, Indium is scarce and expensive, increasing the cost of OPV devices. ITO also transmits UV- light that is detrimental to Organic compounds used in OPVs. Several alternatives to ITO have been reported in literature for OPV application. This work reports the use of Aluminium-doped Zinc Oxide (AZO) as an alternative to ITO. AZO is abundantly available and has the advantage of reflecting UV light while possessing high optical transparency. The sputtering process for AZO was optimised to deposit a transparent and conductive film. Finally, OPV devices using AZO film were fabricated and was almost at par with ITO counterpart. Further work is required for AZO to be a stand-out option in OPV applications with great prospects as a cheap, flexible and UV reflective option.

Proposed Mechanism for combined perception and power supply for a micro scale robot

Name: Revathy Ravuri
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Supervisor: Tim J Echtermeyer
Research Group: 2D Materials
Year of Study: 2

Complex interactions in nature emerge from local interactions between individual agents. This project aims to apply this principle of local interactions in swarms of micro-robots to exhibit global behaviour. Designing such systems is challenging due to the dominance of surface forces over inertial forces, alongside the inherent micro-scale design and fabrication constraints. This PhD project investigates the design a micro-robot capable of inherently sensing the presence of a neighbour and reacting to it based on a simple control law that can be embedded in the fabrication of the robot itself.

Silicon Carbide Single–Photon Emitters Integrated into Photonic Circuits (PICs) for Quantum Optics

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Research Group: Photonic Science
Year of Study: Second year

Abstract

Considering the need to tackle the current computing challenges, including the speed of processing and the vast energy resource consumed, and find a way to achieve high sensitivity at the nanoscale, single-photon emitters (SPEs) are a cornerstone and among the most crucial components required for further improvement of quantum technologies such as computing, quantum communication, and sensing.

The wide-bandgap SiC semiconductor, with features such as bright emission, compatibility with photonic integration, and longer spin coherence times, is a promising and significant candidate for scalable SPEs. This material hosts color centres like silicon vacancies (Vsi) and divacancy (VsiVc) that emit single photons at ambient temperature and can be utilized for telecom applications. By creating and integrating these color centres with SiC-on-insulator photonic integrated circuits (PICs), we can develop a scalable single photon emitter to address these challenges.

Enhancing light-matter interactions within hybrid integrated photonic structures

Name: Jinpeng Wu
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Supervisor: Dr Iain Crowe & Dr Huanqing Ye
Theme: Photonics, Electronic & Quantum Technologies
Year of Study: 2

Efficient and reliable single-photon sources are essential for advancing quantum information and photonic technologies. This work aims to enhance light–matter interactions through multiple approaches to improve the performance of such sources in fibre-integrated platforms. Guided by the Purcell effect, our strategy focuses on increasing the quality factor (Q), reducing the mode volume (V), and improving the coupling efficiency between emitters and optical modes.

Experimentally, a time-resolved photoluminescence (TRPL) setup was developed and validated using emissive films deposited on fibre endfaces, confirming the system's capability to characterise long-lived emission dynamics. Numerically, COMSOL simulations of an AFM-tip-based structure reveal strong local field enhancement near the apex, indicating the potential for plasmon-assisted emission enhancement. These complementary approaches pave the way for compact, versatile, and fibre-compatible enhanced single-photon sources for future photonic and quantum applications.

Software-Hardware Co-design for Pixel-Parallel Processor Arrays: Dynamic Quantisation for Low-bit Neural Networks

Name: Yizhen Bi
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Supervisor: Prof. Piotr Dudek
Theme: Computer Vision, Edge Artificial Intelligence, Embedded Systems
Year of Study: 2

To meet the stringent power and latency constraints of edge vision systems, this work proposes a low-bit quantisation training framework tailored for Pixel Processor Arrays (PPAs). Building upon traditional Straight-Through Estimator (STE) and Periodic Regulariser Quantisation (PRQ), an improved strategy—Dynamic STE (DSTE)—is introduced, addressing long-standing challenges in training binary and ternary neural networks, particularly accuracy degradation and threshold sensitivity. On the XNOR-Net architecture for PPAs using the MNIST dataset, DSTE improves the binary model's test accuracy from 79.57% (STE) to 93.86%. On benchmarks with a ResNet-20 architecture under a 1-bit weights / 32-bit activations quantisation setting, our method achieves 90.95% accuracy, and with a ResNet-18 architecture under a 1-bit weights / 1-bit activations setting, achieves 91.96% accuracy. Beyond algorithm design, this work implements an XNOR-Net architecture for PPAs on the SCAMP5d system using the MNIST dataset. Compared with previous convolutional neural network (CNN) implementations on SCAMP5d, the proposed design reduces total inference time from 244 microseconds to about 23 microseconds, while maintaining a comparable accuracy of 93.69%, consistent with both PC-tested and prior works.

Measurement of finite plate size in pulsed eddy current testing

Name: Rui Guo
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Research Group: Sensors & Electronics
Year of Study: 2

Pulsed eddy current methods have been used to measure thickness and physical properties of metallic materials. These methods are applicable to plates of infinite size or plates much larger than the sensor size (3-5 times). However, existing methods (single-frequency or multi-frequency eddy current method) for solving circular plates of finite size are limited to the frequency domain and cannot satisfy relative thick samples or samples with high magnetic permeability. In this research, a pulsed eddy current (PEC) analytical method for finite radius plates is proposed by extending the finite size DoddDeeds model and the truncated region eigenfunction expansion (TREE) to the time domain. Based on the modified analytical solution, a radius measurement method for finite size circular carbon steel plates is introduced. The radius measurement method is experimentally verified and the results show that the average error is less than 1%.

Abstract Template:

Deployable and Reconfigurable Electrical Capacitance Tomography for Robotic Grippers

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Supervisor: Prof. Wuqiang Yang
Research Group: Sensors and Electronics
Year of Study: 2

Electrical capacitance tomography (ECT) was advanced from fixed-geometry sensing toward deployable, in-gripper permittivity imaging. The earlier study established feasibility with a three-finger gripper carrying a 12-electrode ring arranged as three groups of four. The effect of the inter-group to intra-group gap ratio (GGR) was quantified by simulation and bench tests, using back projection and Landweber with weighted electrode pairs and multi-angle fusion. For stratified and annular targets, correlation coefficients remained high across GGRs (simulation/experiment $\geq 0.90/0.77$ and $\geq 0.85/0.91$, respectively). For two-object targets, coefficients stayed ≥ 0.80 for GGR 2:1–14:1, with experimental results at GGR = 5 closely matching simulation, thereby validating structure-level characterization under variable spacing.

Building on this foundation, a reconfigurable sensing head and a physics-guided learning pipeline were developed for per-view acquisition and rotation fusion across 36 views (10° steps). The encoder integrates normalised capacitances with angle-matched sensitivity tensors, a compact U-Net produces per-view images. A few Landweber iterations at inference enforce measurement consistency, optional Otsu masks limit boundary artifacts, and rotation derotation with averaging yields the fused image. Ablation studies isolate contributions: removing the physics channel lowers SSIM by up to ~0.34; disabling projection-consistency reduces SSIM by ~0.12–0.26; omitting per-angle refinement (t = 0) causes the largest drops (to ~−0.40); replacing the correlation-driven objective with pure MSE degrades structure in 5/6 settings despite occasional CC increases. End-to-end latency on an NVIDIA L4 achieves ~0.33 s per 36-view revolution at t = 1 (~3 Hz), with ~15 ms per additional Landweber iteration.

Together, the structural analysis of electrode geometry and the physics-guided reconstruction pipeline deliver angle-robust, near-real-time reconstructions suitable for in-situ monitoring in adaptive robotic grasping and provide a reproducible route to deployable ECT sensing in compact end-effectors.

High-Performance, Low-Voltage Organic Thin-Film Transistors (OTFTs) Based on Polymer Blends and Skin-Compatible Hydrogels

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Supervisor: Dr Leszek Majewski
Research Group: Sensors and Electronics
Year of Study: 2

The rising demand for sustainable and health-monitoring electronics has driven interest in biocompatible, solution-processed organic thin-film transistors (OTFTs). Benefiting from flexibility, light weight, and simple structure, OTFTs are promising for wearable bioelectronics. Here, high-performance polymer blend OTFTs were achieved using the 8D-P system, exhibiting a low threshold voltage of –0.7280 V, ensuring safe low-voltage operation and ranking among the best polymer-blend OTFTs reported to date. Surface modification of Al_xO_y further improved carrier mobility. Additionally, the feasibility of A-based hydrogel substrates and the integration of natural polymers (C/S) demonstrated potential for biodegradability. This study provides a pathway toward high-performance, low-voltage, and environmentally sustainable OTFTs for next-generation wearable devices.

Abstract Template:
mmWave Radar-Enabled Predictive Tool Health Monitoring for Smart Manufacturing

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Supervisor: Anthony Peyton, Michael O'Toole
Research Group: EM sensing Lab
Year of Study: 2nd

Abstract body:

This research presents a real-time, non-contact mmWave FMCW radar solution for monitoring the health of micro-milling tools within digital manufacturing. Using micro-Doppler vibrometry, our method enables the early detection of runout, wobbling, and presymptomatic tool defects, even in harsh factory environments with dust, noise, and poor lighting. The system utilizes 77–81 GHz radar to capture micro-Doppler phase changes from the tool spindle, which are then converted into displacement and compared against a digital baseline to identify deviations indicative of tool faults. Results demonstrate robust separation of tool motion from machine vibrations, enabling micrometre-scale condition monitoring and high repeatability for baseline building and fault detection. This approach enhances tool reliability and product quality while supporting predictive maintenance in Industry 4.0 environments with minimal process disruption. Future work aims to integrate multi-tool tracking, extend to multi-radar setups, and apply machine learning classifiers for automatic fault taxonomy and early warning.

Electromagnetic sensing of snow and sea ice thickness

Name: Rauan Khangerey
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Research Group: Sensors and Electronics
Year of Study: 2

The continuous decrease in sea ice volume is a significant consequence of climate change due to its importance to local populations, ecosystems, the Earth's absorption of solar radiation and oceanic circulation. This necessitates the monitoring of both area extent and vertical sea ice thickness (SIT). Determining SIT is of particular concern as satellite instruments can only produce an indirect measurement and rely on the assumption of hydrostatic equilibrium and either external data or outdated models. In situ validation of these measurements is difficult due to the rough and electromagnetically dispersive internal structure of sea ice as well as the presence of snow on its surface. To compensate, a dual modality towed system has been proposed, integrating electromagnetic induction (EMI) together with ground penetrating radar (GPR). Initial work on the GPR side is based on complementing the EMI by measuring the thickness of the snow on the ice. Simulations have been carried out on the suitability of different radar antennas, including bowtie, V-dipole, Vivaldi and spiral, with ongoing work focused on hollow bowties and spiral antennas. The design and initial attempts at simulating a prototype PCB have subsequently taken place with additional focus on signal processing and antenna deconvolution techniques.

Abstract Template:

Factorized Computation Machine

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Research Group: Sensors and Electronics
Year of Study: 2nd

Deep learning is increasingly constrained by power consumption, much of which is spent on data movement to and from off-chip (global) memory. In contrast, biological systems minimise energy use by avoiding global storage: memory and computation are local and tightly coupled.

This PhD explores hardware-software co-design for the Factorised Computation paradigm, where computation is highly localised and no global memory is required. The research focuses on highly parallelisable and localised algorithms, such as Belief Propagation, Factor Graph Neural Network and Neural Cellular Automata. The hardware work includes designing a computer architecture tailored for these algorithms. The primary goal is to reduce data movement and enable massive parallelism for accelerating computer vision and graph-based algorithms.

Name: Yu Li

Inductive Tomography for Magnetic Powder Tablet Tracking in Pharmaceutical Fluidized Beds

Abstract

Electromagnetic tomography (EMT) is a non-contact measurement technique. In pharmaceutical and chemical fluidized beds, real-time monitoring of tablet motion is hindered by the system's opacity and the intrusiveness of conventional measurement methods.This study proposes a novel non-invasive tracing method based on an EMT system for tracking tracer tablets filled with magnetic powder in a pharmaceutical fluidized bed. A Sparse Bayesian Learning (SBL) reconstruction algorithm is proposed, and this method outperforms conventional algorithms such as LBP, Landweber, Tikhonov, and OMP in identifying and localizing sparse targets. Experimental evaluations involving varying magnetic powder contents, tablet orientations, and results demonstrate a typical localization accuracy of 0.22cm for a single target and a minimum resolvable distance of approximately 1.54 cm between multiple targets. The innovative combination of magnetic powder tracers with EMT offers a promising solution for dynamic tablet monitoring in industrial fluidized bed research applications.

Abstract Template:
Artificial Neural Network Modelling of Oxide Thin Film Transistors

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Research Group: Sensors & Electronics
Year of Study: 2

This work presents an artificial neural network (ANN)-based modeling approach for oxide thin-film transistors (TFTs) using experimental indium gallium zinc oxide (IGZO) and tin monoxide (SnO) TFTs data. The ANN-TFT models accurately reproduce the nonlinear output characteristics with MAE = 1.21×10^{-9} A (IGZO) and 1.44×10^{-8} A (SnO). A single-hidden-layer network with 20 neurons was identified as the optimal structure, balancing accuracy and computational efficiency. Reducing the gate-voltage step from 2 V to 0.5 V decreased the MAE from 10^{-5} to 10^{-8}, highlighting the importance of data resolution. The multilayer perceptron (MLP) model outperformed the radial basis function (RBF) model across 10 independent runs, showing superior stability and generalization. Circuit-level validation further demonstrated that introducing overlapping capacitance and 0.1 nF electrode-substrate capacitance enabled the ANN-TFT inverter simulation to match experimental waveforms at 4–8 kHz, with mean absolute error (MAE) values of 0.188–0.300 V. The results confirm that accurate capacitance representation is essential for bridging device-level modeling and high-frequency circuit simulation.

Abstract Template:

Motion-Aware Query-Based Framework for Action Unit Recognition in Micro-Expressions

Name: Runze Wang
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Supervisor: Jayawan Wijekoon
Research Group: Electronics and Sensor
Year of Study: Year 3

Facial micro-expressions are rapid, involuntary facial movements that reveal concealed emotional states and are critical for understanding genuine human emotion. However, recognizing Action Units (AUs) in micro-expressions remains challenging due to subtle motion, short duration, and severe class imbalance. To address these issues, we propose a motion-aware attention framework for multi-label AU recognition. The method extracts optical flow and optical strain between onset and apex frames to capture both displacement and deformation of facial muscles. These motion representations are processed by a CNN backbone for spatial encoding, followed by a Query2Labels-based decoder that models AU dependencies through cross-attention. To handle imbalanced AU occurrences, we employ symmetric focal loss, which enhances learning from rare activations. Experiments on CASME II and SAMM demonstrate that the proposed approach achieves superior performance compared with existing AU detection models, with higher mAP scores. The framework provides a lightweight yet interpretable solution for analyzing subtle and spontaneous facial behaviors.

Online Self-Calibration for Reconfigurable Robot-Assisted Transcranial Magnetic Stimulation (Robo-TMS)

Name: Wenzhi Bai
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Supervisor: Dr. Zhenhong Li, Prof. Andrew Weightman, Prof. Zhengtao Ding
Research Group: Control Systems and Robotics Group
Year of Study: 2nd year PhD

Robot-assisted transcranial magnetic stimulation (Robo-TMS) integrates advanced robotics with conventional TMS, a non-invasive brain stimulation procedure increasingly applied in both clinical treatment and neuroscience research. Accurate calibration between the robot and tracking system is essential, yet conventional hand–eye calibration requires the camera to remain fixed, a constraint often violated in practice due to unintentional movement or the need for better visibility. Existing alternatives reformulate the problem as marker tracking, but these approaches demand continuous line-of-sight to both the head and end-effector markers, which is difficult to ensure in clinical settings. To address this limitation, we propose an online self-calibration method that performs hand–eye calibration online, enabling the use of a movable camera without maintaining simultaneous visibility of both markers. The proposed method is validated through a series of experiments, demonstrating improved accuracy, robustness, and suitability for Robo-TMS applications hence significantly improve the clinical efficiency.

Backward-looking Persistent Excited Dual Control-based Model Predictive Control

Name: Chunyi Cao
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Supervisor: Zhongguo Li
Research Group: Control Systems and Robotics Group
Year of Study: 2nd year

This project introduces a new control framework designed to help autonomous systems follow desired paths accurately while learning about uncertainties in the operation environment. Our approach combines learning and control in one process so that the system can not only stay on course but also improve its understanding of unknown factors as it moves. To achieve this, we developed a new learning method that uses past data more effectively to estimate uncertainties in real time. Unlike traditional methods that rely on random disturbances or manual tuning, our system actively seeks excitation trajectories that provide useful information for learning. By balancing accurate path tracking with active exploration, the framework ensures reliable performance in uncertain conditions. Both numerical simulation and experimental applications show that the method can improve adaptability and stability for autonomous systems.

Development of a visuo-haptic recognition system to enhance robotic perception in cluttered environments

Name: Matthew Hardcastle
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Supervisor: Xiaoxiao Cheng
Research Group: Control Systems and Robotics
Year of Study: 2nd

Multi-modal sensory fusion is an approach to robotic sensing that combines different sensory modalities together to enable them to benefit from their individual strengths and compensate for their limitations. Vision is the primary sensory modality used in robotics as it provides global, rapid, detailed information about objects of interest. However, environmental constraints such as poor lighting or obstruction of the visual field can impair the ability of visual senses to perceive effectively, and reduce the effectiveness of object perception. Additionally, some physical properties of objects useful in identification and interaction, such as mass and centre of inertia, cannot be identified purely visually and require alternative sensory modalities to perceive effectively. Tactile sensors provide information about objects surfaces, physical properties and interaction forces during contact, but are limited by their local sensory focus and requirement for physical interaction to generate sense data. This project investigates methods of fusing visual and tactile sensory input together into a visuo-haptic object recognition system for use in nuclear decommissioning gloveboxes using RGB camera information and Gelsight Mini visual tactile sensors, with a midst mapping approach to sensory fusion where object features are extracted separately and processed together.

Name: Wending Heng

Abstract:

Accurately decoding human motion intentions from surface electromyography (sEMG) is essential for myoelectric control and has wide applications in rehabilitation robotics and assistive technologies. However, existing sEMGbased motion estimation methods often rely on subject-specific musculoskeletal (MSK) models that are difficult to calibrate, or purely data-driven models that lack physiological consistency. This paper introduces a novel Physics-Embedded Neural Network (PENN) that combines interpretable MSK forward-dynamics with data-driven residual learning, thereby preserving physiological consistency while achieving accurate motion estimation. The PENN employs a recursive temporal structure to propagate historical estimates and a lightweight convolutional neural network for residual correction, leading to robust and temporally coherent estimations. A two-phase training strategy is designed for PENN. Experimental evaluations on six healthy subjects show that PENN outperforms state-of-theart baseline methods in both root mean square error (RMSE) and R^2 metrics.

Reinforcement Learning for Frequency Regulation with New dynamic frequency response services

Name: Yongjia Huang
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Research Group: Control Systems & Robotics
Year of Study: 2nd year

Abstract:
Renewable energy integration introduces significant frequency variability to the grid, necessitating fast-response services beyond traditional methods. This research addresses the control of new dynamic frequency services (Dynamic Containment, Moderation, and Regulation) introduced by the UK's NESO, which rely on battery energy storage systems (BESSs). A critical gap exists in applying reinforcement learning to these novel services, especially concerning the simultaneous management of BESS State of Charge (SoC) to prevent depletion or overcharging. We propose a sophisticated control scheme combining safe reinforcement learning (Safe RL) and multi-agent reinforcement learning (MARL) within a centralized training with centralized execution (CTCE) framework. This is the first study to apply this methodology to these specific services with explicit SoC consideration. Our approach utilizes a high-fidelity frequency dynamics model (swing equation) augmented with BESS SoC dynamics. The RL reward function is engineered to incentivize precise frequency regulation while strictly penalizing actions that compromise SOC limits. The proposed algorithm's effectiveness and robustness are validated on the standard IEEE 14-bus test system, demonstrating efficient frequency stabilization while ensuring BESS availability. Future work will investigate detailed BESS response dynamics and communication latencies.

Physics-informed Data-driven Control of Soft manipulator Systems through Koopman-operator Theory

Name: Zexi Ji
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Research Group: Control Systems and Robotics Group
Year of Study: 2

Soft robots have attracted widespread attention for their compliance, flexibility, and inherent safety, positioning them as a leading direction in future robotic research for safe human-robot collaboration. However, modelling the dynamics of such systems often lead to highly nonlinear and computationally intensive models, posing significant challenges for real-time control with conventional methods. With the advancement of deep learning and increasing availability of rich input-output data, data-driven control has emerged as a promising alternative for learning complex system dynamics directly from data. Among them, Koopman operator theory offers a rigorous treatment for capturing the underlying dynamics with its ability to represent nonlinear dynamics as a globally linear, yet higher-dimensional operator. This provides a fresh lens to bridge the nonlinear modelling with established linear control theory.

In this project, we integrate data-driven modeling with physics-informed neural architectures to advance Koopman operator–based control for soft manipulator systems. By enforcing energy conservation, work–energy consistency, and physically constrained latent dynamics, the proposed framework achieves stable, data-efficient, and interpretable control models, demonstrating the potential of physics-informed Koopman learning for soft robotic systems.

Robust Multi-Agent Autonomous Search
via Consensus-Based Dual Control

Name: Donglin Li
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Supervisor: Zhengtao Ding
Theme: Autonomous Search
Year of Study: 2

Autonomous multi-agent systems are increasingly employed for exploration, monitoring, and source-seeking tasks in uncertain environments. Achieving cooperative estimation and control among agents remains challenging due to noisy sensing, communication constraints, and dynamic environmental changes. This research presents a Consensus-Based Dual Control (CDC) framework that unifies distributed estimation, active learning, and optimal control. The proposed Cooperative Active Learning-based Dual Control (COAL-DCEE) enables each agent to perform local estimation using particle filters while exchanging information through consensus-based fusion. The dual control mechanism optimally balances exploration and exploitation to minimize uncertainty and guide agents toward the source efficiently. Simulation results demonstrate that the proposed method achieves faster convergence, lower root mean square error (RMSE), and improved robustness compared with traditional non-cooperative strategies. This framework provides a scalable and adaptive solution for multi-robot cooperative source seeking.

Abstract Template:

Model Transfer and Selection Control Under Varying and Faulty Conditions

Name: Yunbo Li
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Supervisor: Long Zhang
Research Group: Control Systems and Robotics Group
Year of Study: 2

Robust and safe control under varying and faulty conditions is paramount for reliable and safe operation of autonomous systems. This paper presents a framework for model transfer and selection control applicable across various autonomous systems of the same type, with one specific case study focusing on unmanned aerial vehicles (UAVs) under varying and faulty conditions. The proposed approach integrates multiple sharing and selection models based control algorithms, enabling the transfer of controllers between different systems of the same type. The effectiveness is validated through real-world experiments and extensive results highlight the potential of model transfer and sharing control methodologies to enhance performance of autonomous system under different operating and faulty conditions.

Sequential U-Net++: Two-Stage Deep Learning Pipeline for Motion Artifact Denoising in Functional Near-Infrared Spectroscopy (fNIRS)

Name: Chaoyuan Liang
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Supervisor: Dr. Zhenhong Li, Prof. Alex Casson
Research Group: Control Systems and Robotics Group
Year of Study: 2

Functional near-infrared spectroscopy (fNIRS) monitors cortical activation through oxy- and deoxy-hemoglobin changes but is vulnerable to motion artifacts that degrade signal quality and bias analyses. We propose a two-stage, segment-aware denoising pipeline that first detects motion artifacts and then corrects only contaminated segments to preserve hemodynamic fidelity. The detection stage uses a U-Net++ network to produce a binary, time-resolved mask; the correction stage also uses a U-Net++ network to reconstructs masked segments while keeping sampling and duration unchanged. Training uses a physiologically informed simulation framework together with public experimental references. We evaluate on a simulated dataset (with ground-truth clean signals and artifact masks) and multiple experimental datasets. Compared with conventional methods and a strong deep-learning method, the pipeline yields higher artifact-detection accuracy, lower reconstruction error, lower residual artifacts, stronger 0.01–0.1 Hz hemodynamic power, and lower runtime. These results indicate that segment-aware denoising offers robust, plug-and-play preprocessing for real-world fNIRS studies.

Name: Liyang Ma

Abstract.

As wind energy becomes increasingly important in global energy systems, accurately evaluating the performance of wind farms is essential for understanding wind generation efficiency and fostering sustainable development. The aim of this paper is to assess wind power generation efficiency under different climatic wind conditions. A data-driven approach is used to simulate the power generation of ten leading wind farms in the UK, using real wind data and geographic information while considering wake effects. Furthermore, to evaluate whether these wind farms perform optimally when climate-related wind patterns change, we modify the layouts of the wind farms and compare their performance with the original designs. Extensive results from 15 years (2008 to 2023) of wind data show that the originally designed layouts of these ten leading wind farms will no longer be optimal when the wind resource changes.

Abstract Template:
Unified Hazard-Aware Multi-Domain Robotic Fleet Mapping

Name: Alexander Morley
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Supervisor: Pawel Ladosz, Kieran Wood, Simon Watson
Research Group: Cradle
Year of Study: 2

When deploying a multi-locomotion heterogeneous robotic fleet, a shared probabilistic measure of risk is required to enable both local and fleet-level decisions grounded in the true traversability hazards of the environment, while respecting energy and communication constraints.

This work introduces a unified risk-aware and game-theoretic planning framework for fully heterogeneous fleets; Merging Lambda-Field risk representations with OctoMap volumetric mapping to provide a common currency of risk for cooperative decision making and equilibrium-based task allocation.

(Semi-) Autonomous Control of Manipulator Robots in Challenging Environments

Name: Naseel Sinan
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Supervisor: Murilo Marinho and Tingting Mu
Research Group: RAICo, Robotics for Extreme Environment Lab
Year of Study: 2024 - 2028

Nuclear gloveboxes are confined environments commonly used in the nuclear industry, and the primary interest in the industry has been decommissioning of older gloveboxes, which contain irradiated and brittle items stored for more than half a century. Using robotics in such a radiated zone is the best method possible. Achieving fully autonomous decommissioning requires the use of Task and Motion Planning (TAMP) Algorithms. However, TAMP algorithms are limited in their use inside confined spaces, their ability to perform non-monotonous rearrangements, and their further understanding of the aspect of physical dependency in cluttered settings, which can deter the safety factor vital in operating inside a nuclear glovebox.

State-of-the-art methods based on optimization, sampling, and learning each offer distinct advantages and drawbacks. Many of these algorithms struggle to scale effectively, often spending excessive time searching for an optimal motion plan instead of allowing the task planner to take precedence. Addressing this imbalance requires improved logic and the usage of learned heuristics to enhance planning efficiency and overall system robustness.

Abstract Template:

A Novel P2P Trading Framework Benefiting Both Microgrids and the Main Grid

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Supervisor: Zhengtao Ding
Research Group: Control Systems & Robotics
Year of Study: Year 2

This paper proposes a multi-microgrid peer-to-peer (P2P) energy trading framework that benefits both microgrids and the main grid. The framework considers the demand satisfaction, trading revenues, and energy generation and storage costs of microgrids with mixed renewable energy sources. Meanwhile, to ensure the main grid's utility, mechanisms for trading quantities bargaining and trading fees are designed. The problem is formulated as a bi-level game. A Nash bargaining framework is introduced to model the competitive interactions among multiple microgrids and the main grid. A fully distributed alternating direction method of multipliers (ADMM), sharing only limited trading information, is applied to the bargaining problem to protect the privacy of individual microgrids. A proportional allocation method is formulated to ensure a rapid and fair allocation of utility among households within each constituent microgrid. Finally, numerical simulations based on a scenario involving Manchester and three surrounding towns validate the feasibility and effectiveness of the proposed framework.

Abstract:

Data-driven condition monitoring of mooring systems: A demonstration with the M4 multi-float wave energy converter

Name: Heng Yang
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Supervisor: Dr. Long Zhang
Research Group: Control Systems and Robotics Group
Year of Study: 2

Monitoring the condition of mooring systems is essential for the safe operation and timely maintenance of floating platforms including wave energy converters (WECs). However, mooring dynamics are highly nonlinear due to nonlinearities in wave forcing, marine growth effects on floater and mooring cables or chains, WEC dynamics, synthetic cable or chain nonlinearity, and floater-mooring coupling. These effects reduce the effectiveness of linear system identification methods and make accurate condition assessment challenging. In this study, we introduce a data-driven approach for condition monitoring that uses dynamic modeling to address these challenges. The method enables continuous monitoring, allowing gradual or sudden changes to be detected and faults addressed promptly. A time-delay neural network (TDNN) with Bayesian regularization backpropagation and a hyperbolic tangent sigmoid (tansig) activation function is employed to model the system's behavior. The approach is validated using two surrogate fault scenarios: (i) two different mooring configurations tested in the same basin, and (ii) nominally identical configurations tested in two different basins. Using six-degree-of-freedom (6-DoF) motion data, the approach is demonstrated to identify the fault condition for all sea states under both scenarios, demonstrating the robustness and sensitivity for even subtle changes, for unseen and complex conditions.