**Suggested Project Topics for BEng and MSc students**
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This by no means is an exhaustive list and I am always open to novel project ideas proposed by prospective project students if the topics are inline with the research field of RPCS lab. Based on our established research track-record and industrial collaboration, I have listed some suggested topics below. The list may be updated in the near future.

## ENERGY STORAGE and POWER ELECTRONICS

### Equivalent circuit modelling (ECM) and state-of-charge (SoC) estimation of Li-ion batteries (LiBs)

Project objectives:
- Develop realistic ECM of LiBs to show the battery dynamics like SoC and temperature variation
- Developing state-of-charge estimation algorithms using Adaptive Filtering Algorithms such Kalman Filter, Extended Kalman Filters, etc

### Physics modelling of the Li-ion batteries (LiBs) for battery electric vehicles

Project objectives:
- Develop Pseudo-2-dimensional (P2D) modelling of batteries to represent all the electrochemical reaction in the batteries during charge/discharge and dynamics like heat transfer and capacity fade

### Multi-physics modelling of the Li-ion batteries (LiBs)

Project objectives:
- Develop Pseudo-2-dimensional (P2D) electro-chemical models of LiB cells to represent all important dynamics including charge/discharge, capacity fade, heat transfer, parasitic reactions between electrode and electrolyte, etc.
- Develop current density and magnetic field models of the LiB electrolyte using COMSOL multi-physics software.
- Validate the current density models using disruptive Graphene-based magnetometer sensors for the online monitoring of the in-situ current flow within individual Li-ion pouch cells
- Develop thermal gradient models of the LiB cells using internal resistance of the individual battery cells
- Develop an effective strategy to calculate the capacity fade of in the individual cells using the multi-physics models

### Condition Monitoring of the Silicon Carbide (SiC)-based power electronic converter in electric vehicles using machine learning

Description: Power electronic converters (PECs) underpins modern electric and hybrid vehicles allowing efficient energy transfer between the vehicle battery system and the drive motors. To simplify construction, reduce costs and increase reliability, manufacturers are seeking ever-tighter system integration. However, this level of integration poses a number of significant challenges including interlinked heat transfer paths, bond wire lift-off and unwanted thermal stresses.

Project objectives:
- Investigate a multi-physics sensor fusion technique to provide accurate prognostics for highly integrated SiC-based PECs.
- Develop machine learning techniques to find correlation between seemingly different type of data , i.e. temperature, electrical quantities (V, I, Z) and mechanical displacement (wire bond movement/device deformity) on the power module.

**Thermal characterisation of the Silicon Carbide (SiC)-based power electronic converter using multi-physics modelling**

Project objectives:
- Develop Magnetic field (current density) modelling of the power modules using COMSOL multi-physics software
- Develop thermal characterisation models using current density models and heat flux analysis to represent all the temperature gradients accurately in the power module

**High Efficiency Power Electronic interface for Vehicle-to-grid (V2G) application**
Description: The use of Electrical Vehicle (EV) battery pack to supply power to the grid (V2G) increases reliability and consistency in the grid as the renewable source, e.g. wind, solar, undergoes its natural fluctuations. Furthermore, power quality can be increased with having battery storage for charging/discharging electricity to the grid. V2G operation is generally using power electronic converters (dc-dc & VSC) and inverters to act as a bidirectional charger capable of charging and discharging the battery on demand while complying with grid standards. Commercial bidirectional chargers typically use conventional 2-level silicon-based PWM converter topologies able to switch at relatively low frequencies. As a result, compared to the size of the battery or EV, they are relatively bulky and suffering from significant power losses.

Project objectives:
- Modelling and designing more efficient power converters based on Silicon-carbide switching devices to reduce the size of bidirectional chargers and reduce the power losses.
- Developing novel converter topologies and control strategies for the rapid response (low latency with high switching frequency) to the grid demand.

**Stability analysis of the battery pack and bi-directional charger for Vehicle-to-grid (V2G) application**

Battery energy storage system (BESS) increases reliability and consistency of the supplied power in the grid as the renewable source, e.g. wind power, solar panel, undergoes its natural fluctuations. Furthermore, power quality can be increased with having battery storage for charging and discharging electricity to the grid. However, the capital cost of battery packs is a major obstacle and one solution is to use aged battery packs from electrical vehicle (EV). Aging can change characteristics such as the internal resistance, capacity and efficiency of the battery pack. Bi-directional dc-dc converters and voltage source converters (VSCs) used to connect the battery pack to the rest of the system may become unstable as well.

Project objectives:
- Stability analysis of the power electronic converter subject to variation in internal voltage and resistance of the battery pack.
- Simulation of the integrated system (battery pack, converter) using Matlab/Simulink

**Silicon-Carbide-Based Power Electronics for Wave Energy Converters**
Unlike fossil fuels, wave energy is clean, sustainable and causes no air pollution and noise. Compared with wind, solar and other RES, wave energy is also more steadily available and has denser energy concentration, which can be captured by wave energy converters (WECs). This project is industrially sponsored by EcoWavePower Ltd (https://www.ecowavepower.com/) developed ground-breaking on-shore economical WEC systems.

Project objectives:

- Develop novel control approaches and state-of-the-art WEC power electronics to significantly improve the WEC overall performance so that LCOE of wave can be close to or even lower than that of solar.
- An integrated WEC design using silicon carbide devices to increase switching speed (20KHz), blocking voltage capabilities and tolerance to junction temperature and the efficiency of the power output (> %98.5). The design must simplify the construction, reduce costs and increase temperature reliability (+40$^{o}$C) using a novel package.

## ELECTRIC DRIVE PROPULSION SYSTEM

**Hypeloop - the next generation of public transport**

Description: The Hyperloop is an open-source idea proposed by the futurist and founder of Tesla, SpaceX, Elon Musk as an alternative mode of transportation to the California High Speed rail project to significantly reduce the travel time and cost of inter-city journeys. The first Hyperloop will be between Los Angeles and San Francisco reducing the travel time to only 30 minutes with a total estimation of 840 passengers per hour. Currently many organizations, private companies, government agencies, universities and student group have formed R&D projects and competitions based on this concept which resulted in multiple variation of the Hyperloop system ranging from the use of the original concept of "Air Bearings" to the use "Electromagnetic suspension".
Virgin Hyperloop One is the company which builds the first real prototype of Hyperloop (https://hyperloop-one.com/). This project is for building a miniature system demonstrating the Hyperloop concept and find an innovative solution for challenging air resistance and pressure through the Hyperloop pod to achieve an aircushion lift and proportion to minimize friction and resistance in motion within a low pressure or near vacuum tubing. This project is a well-rounded engineering project that students need to demonstrate different skills and knowledge including planning and cost estimation.

Project objectives:

- Develop MATLAB simulation models for an electro-mechanical propulsion system, i.e.  a motor system, to achieve levitation and propulsion through either Air Bearings or Electromagnetic Levitation.
- Develop a motor controller to regulate the motor system through a control panel/program communicating with the capsule via wireless communications (TCP).
- Develop motor drive control system design using a micro-controller
- Design and Develop software GUI for controlling the motor and communication system
- Mechanical design/3D printing of the hyper-loop capsule and tube

**Fully Battery-powered Electric Propulsion System for Small Marine Boats**

Description: In UK small marine vessels vastly outnumber large marine vessels and collectively create far more pollution on a par with that from the respective Heavy Goods Vehicle population. Large marine vessels have already started benefitting from electric drivetrains reducing emissions and costs. However, the sector of smaller vessels has not adopted the technology due to the hurdle of 'no Regenerative Braking', well-known in Automotive Electric Vehicles. Moreover, the transient dynamics caused by large load variations in small ships seriously reduce the efficiency of the electric drivetrain and need specialised torque measurement techniques. This project is industrially sponsored with the DuodriveTrain, http://www.duodrivetrain.uk/, and have the following objectives:

Project objectives:
- Develop a mathematical modelling framework in MATLAB/Simulink for the mechanical marine propulsion system with the associated electric drive system (including electric motors) to create a complete electric drive system energised by batteries.

- Develop novel predictive control/optimisation approaches using (DuodriveTrain's patented direct torque & thrust measurement technique to remove the transient dynamics in the electric drive trains including the electric machines,
- Increase the electric drive propulsion efficiency in conventional as well as autonomous surface vessels, and improve battery life using optimisation techniques

## ENERGY EFFICIENCY IN BUILDING ENVIRONMENT

**Residential Load Forecasting for Individual Appliances: Machine Learning Approach**
Energy companies and government face challenges in successful smart meters roll-out where only ~50% of the planned smart meters are installed in homes in UK. Companies can hardly give any estimation to their customers or users that how much energy they will save in the future, and how they can translate the saving to money. This is project is industrially sponsored by *Voltaware* Ltd (https://voltaware.com/)

Project objectives:
- Develop machine learning techniques for the prediction of power consumption by the individual home appliances.
- Developing state-of-the-art real-time monitoring tools using their disaggregated power consumption data collected from three countries UK, Italy and France and several households.

**Wireless Intelligent agent for Energy Management in Home Environment using Situational Awareness algorithms**
Description: Low-cost monitoring of energy usage and providing energy efficiency by a home energy management system (HEMS) is still a challenging problem considering the rise of household energy cost. Algorithms like situational awareness (SA) can be employed for the real-time scheduling, power distribution, and automation of wireless sensor network (WSNs) of home appliances/renewables. Such algorithms can provide a vision of the network events before the event occurs in a distributed fashion.

Project objectives:
- Develop machine learning (ML) techniques to learn the behaviour of home users using energy usage pattern data
- Implement an intelligent agent for the SA-based HEMS system. The agent will make automated decisions to control the home renewable sources (wind/solar + batteries).
- Design suitable communication system for the SA-based system architecture including appropriate Communication protocol, security algorithms,
- Selection of an appropriate Ad-hoc network (MAC layer, Physical layer)
- Develop optimal Control/Adaptive Dynamic Programming (ADP) for optimising the wireless sensor networks (WSNs).

## WIRELESS ENGINE MONITORING

**Onboard calibration of diesel engines using wireless sensor networks for emission reduction and performance boost in small marine boats**
Description: One of the significant challenges in small and mid-size Marine Vessels is cutting the Fossil fuel use & air pollution generated by the current marine diesel engines. This project is industrially sponsored with the DuodriveTrain, http://www.duodrivetrain.uk/, and have the following objectives:

Project objectives:

- Develop an integrated energy monitoring system using an engine wireless sensor network (eWSN) and a propeller cartridge to enable torque & thrust data (with position/speed) readings and remote monitoring.
- Investigate a specialised and modern sensors (ultrasonic, optical, …) to acquire the measurements in the harsh environment like ship's engine.
- Design the sensor network (different locations of sensors and the proximities to the marine engine) for the patented award-wining propeller cartridge, TorqueFlange® to send an accurate monitoring data to the engine.
- Develop an advanced sensor fusion technique to significantly reduce the probability of measurement error using signal processing, ML and AI techniques.

**Wireless sensor networks for the monitoring of the diesel engines in small marine boats using beam-forming techniques**

Description: Beamforming can provide narrow beams with significant gains, and directional and secure transmissions with high spectral efficiency. This project is industrially sponsored with the DuodriveTrain, http://www.duodrivetrain.uk/, and have the following objectives:

Project objectives:

- Design an antenna array with directional radio links (beam-forming) for the sensors to communicate in real-time with the engine control unit.
- Carry out Link-budget study and ray-trace testing to calculate the power loss in transmission and determine the best sensor location.