DTA3/COFUND Programme Research Project Proforma

University Alliance
Doctoral Training Alliance

Page 1 – General Information

Project code	CUEN08
Partner University	Coventry University
Faculty/School/Department/Research Centres	EEC, CEM, FCS
First supervisor Please provide name and weblink	Prof James Brusey https://pureportal.coventry.ac.uk/en/persons/james-brusey
Second supervisor Please provide name and weblink	Dr Jonathan Nixon https://pureportal.coventry.ac.uk/en/persons/jonathan-nixon
Third supervisor Please provide name and weblink	Dr Kojo Sarfo Gyamfi https://pureportal.coventry.ac.uk/en/persons/sarfo-gyamfi
Fourth (external) supervisor	
External/industrial supervisor	
Which of the supervisors listed above is an early-career-researcher (within 5 years of completing their doctoral degree)	Dr Kojo Sarfo Gyami
Contact details for project for informal applicant queries Email address	Prof James Brusey j.brusey@coventry.ac.uk
DTA Programme:	DTA Energy
Project title	Neural-network simulation of complex mini-grids

Co-funded by the Horizon 2020 programme of the European Union

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 801604.

Page 2 – Project Description

Scientific Excellence (500 words)	Electrical grids are characterised as systems having many sources, massive numbers of loads, and a complex, non-uniform network connecting the two. Thus, simulation of such a system is computationally intensive. Fast simulation of such systems is a key enabler for optimising them, reducing their cost, and for avoiding catastrophic system failure. While neural networks have primarily been developed for machine learning, it is also possible to use them to emulate dynamic non-linear systems [1]. Such an approach has been shown to be computationally efficient and can be made even more so by making use of specialised hardware, such as GPUs or TPUs [2]. Furthermore, autoencoder NNs [3] can reduce dimensionality, which is particularly important when dealing with systems with large numbers of degrees of freedom. The use of NNs also makes it straightforward to learn a model from past data. This is particularly important when the detailed characteristics of the components of the system are unknown. For many mini-grids, infrastructure and available expertise is minimal. Thus, expert simulation and optimisation may not be feasible. This PhD program is intended to bring together ideas from machine learning, dimensionality reduction, physical system simulation, and mini-grid design to develop a method to allow a mini-grid to self-learn, to adjust to a changing physical environment, and possibly to self-repair and thus enable and reduce the cost of this technology for a wide audience of isolated and semi-isolated communities. [1] R. van der Merwe, T. K. Leen, Z. Lu, S. Frolov, and A. M. Baptista, "Fast neural network surrogates for very high dimensional physics-based models in computational oceanography," *Neural Networks*, vol. 20, no. 4, pp. 462–478, 2007.

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	[2] K. Sato, C. Young, and D. Patterson, "An in-depth look at Google's first Tensor Processing Unit (TPU) | Google Cloud Blog." [Online]. Available: https://cloud.google.com/blog/products/gcp/an-in-depth-look-at-googles-first-tensor-processing-unit-tpu. [Accessed: 31-Jan-2019]. [3] G. E. Hinton and R. R. Salakhutdinov, "Reducing the Dimensionality of Data with Neural Networks," *science.sciencemag.org*, vol. 313, no. 2006, pp. 504–507, 2009.
Aim (400 words)	Aim The overall aim is to simplify simulation of a mini-grid so that it is feasible for a non-expert to design, install and maintain it successfully. Objectives leading to this aim include: • investigate methods to simplify and speed-up simulation of a mini-grid • enable automatic derivation of a simulation model of a mini-grid based on obtainable data. Research Questions: 1. Can a NN-based model be learnt from an existing simulation of a complex mini-grid and how accurate is the result? 2. What NN architecture suits this best? Specifically, should dimensionality reduction approaches be used? 3. Can a NN-based model be learnt from observable (simulated) data from different parts of the mini-grid network and how does accuracy vary depending on amount of data? 4. Can a NN-based model be learnt from observable (real-world) data from different parts of the mini-grid network and how does accuracy vary depending on amount of data?

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	Methodology 1. Initial work will be based on existing simulation approaches to mini-grids. During this first phase, a variety of comparative simulation approaches will be tested, including NNs and other methods. 2. The second phase will involve planning the development of a mini-grid and validation of a simulation against this. 3. During the third phase real-world data will be tested to obtain an approach to self-learning of a simulation for a particular mini-grid. 4. The final stage will develop tools and approaches for aiding design and maintenance of a mini-grid.
Strategic Relevance (300 words)	Current approaches to mini-grids involve parachuting in expertise to perform initial set-up and installation of the system. This tends to lead to partially installed systems (where funding is cut-off part way through) or systems that fall into disrepair (due to lack of on-the-ground expertise in the community). While educational approaches may help (such as Barefoot College), there is still a need to reduce the complexity of designing and maintaining such systems. Our vision is an approach to mini-grids that leads to systems that self-learn, self-optimise, and self-repair and are thus easier, cheaper, and longer lasting than existing approaches.
Interdisciplinarity and fit with DTA3	This work spans two key disciplines: the electrical engineering of mini-grids and computer science / machine learning. It thus requires input from an interdisciplinary team allowing cross-pollination of ideas between the two groups. Furthermore, it meets the DTA3 focus on practical, industry-linked programs and has potential to lead to new products or even new markets.
Industrial Relevance (300 words)	The aim of this program is to perform research that leads to new products in the area of mini-grids and renewable systems. Thus there is significant potential for collaboration and interaction with these industries. Furthermore, our group have established ties with mini-grid installers and OEMs through past project in Rwanda, Nepal, and The Philippines.

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Economic and Societal Impact (300 words)	Mini-grids provide a key benefit to otherwise vulnerable and isolated communities around the world, ranging from having light to study at night to being able to refrigerate food. Furthermore, they enable use of renewable technology, such as solar panels and wind power. However, simply parachuting in technology is not a sustainable solution due to the complexity of current systems. Developing mini-grid systems that can self-learn, self-optimise and self-repair is likely to enable a much wider adoption and ensure that systems are long-lived.

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Page 3 – Admission Requirements

Specific Admission Requirements Detail any subject specific degree qualifications or disciplines, relevant skills, experience	Successful applicants will have: • Entry criteria for applicants to PHD A minimum of a 2:1 first degree in a relevant discipline/subject area with a minimum 60% mark in the Project element or equivalent with a minimum 60% overall module average. In the event of a first degree classification of less than 2:1, a Masters Degree in a relevant engineering, business or computer science subject area will be considered as an equivalent. The Masters must have been attained with overall marks at minimum merit level (60%). In addition, the dissertation or equivalent element in the Masters must also have been attained with a mark at minimum merit level (60%). *or* • a taught Masters degree in a relevant discipline, involving a dissertation of standard length written in English in the relevant subject area with a minimum of a merit profile: 60% overall module average and a minimum of a 60% dissertation mark *PLUS* • the potential to engage in innovative research and to complete the PhD within a three-year period of study • a minimum of English language proficiency (IELTS overall minimum score of 7.0 with a minimum of 6.5 in each component)

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	Additionally: • Knowledge and/or experience of mini-grid simulation models is desirable, but not essential • Proficiency in at least one general purpose programming language is essential and will be tested for during the application process. • A good knowledge of renewable energy and sustainability is expected • Experience in one or more of the following areas is highly desirable: machine, learning, neural-networks, energy systems modelling, mathematical optimisation, Python, multi-criteria/objective decision making
Minimum IELTS score	a minimum of English language proficiency (IELTS overall minimum score of 7.0 with a minimum of 6.5 in each component)

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