Architecture of the Future Low-Carbon, Resilient, Electrical Power System

Future Architecture of the Network (FAN) – Te Whatunga Hiko

Workstream 1 – Proposed Summer Project

Project title: Replacing the computationally intensive components of EMT (Electromagnetic Transients) simulation with PINN (Physics Informed Neural Network).

Relevant Workstream(s): WS1

This project is offered to help in the ongoing research in the Future Architecture of Network (FAN) programs, where the benefit, design and analysis of DC electricity grids are explored. The FAN project is a 7-year, New Zealand wide research program led by the University of Canterbury. The project is broken into five workstream, where this summer student project is a part of Workstream 1, which is the development of fast and accurate numerical analysis tools to simulate large-scale hybrid AC/DC grids, such as Power-Flow Analysis, Fault Analysis, Harmonic Analysis, Transient Stability, and Electromagnetic Transients. Also, WS1 proposes a future architecture of the hybrid AC/DC, which will be the focus of this project.

Project Description

Neural networks-based models are ubiquitous in approximating various physical phenomena and engineering models. Purely data driven neural networks can deviate significantly from the actual physics of the model and generally require significant amount of training data. Therefore, for systems whose governing physical laws are known, physics informed neural networks[1] are proposed to represent underlying complex systems.

Electromagnetic transient (EMT) simulation tools-based programs are used extensively to study AC/DC power systems due to their high-fidelity component models but have some limitations. The underlying differential equations corresponding to time evolving state variables of model components and network are discretized and usually solved as a system of linear equations for each successive time step. However, the nonlinear controls[2] associated with AC/DC models require a computationally expensive iterative solver or incorporate delay in the feedback signal, which reduces the accuracy and can introduce stability issues. Therefore, nonlinear control becomes a candidate for replacing with PINN. Converter controls used in AC-to-DC and DC-to-AC conversion exhibit significant nonlinearity due to presence of Phase-Locked Loop (PLL) and hence, becomes ideal candidate for replacement with PINNs.

The potential candidate will have to:

1) Understand the mathematical concepts of PINNs.
2) Replace the underlying equations of PLL with PINNs.
3) Test the resultant surrogate model with the actual model with statistical rigor.

The potential candidate will:

1) Build theoretical foundation of Physics Informed Neural Networks.
2) Implement the cutting-edge machine learning solution techniques to an actual engineering problem.

Specific requirements

- Masters of Applied Data Science student.
- Good knowledge of statistical hypotheses testing and neural networks.
- Experience in MATLAB or Python will be helpful.
- Domain knowledge is not mandatory but should be willing to work in collaboration with domain experts.
- Good academic track record.
- High proficiency in written and spoken English.
- Enthusiastic applicants (any nationality) that want to make a positive impact in the world and can work in a collaborative environment.

Potential Supervisor(s) -- could be confirmed later: Aprajay Verma, Josh Schipper, Neville Watson.

Based in: University of Canterbury, EPECentre.

Reference

1. Physics Informed Neural Networks (PINNs): An Intuitive Guide | Towards Data Science
2. Scalable Physics-Informed Neural Networks for Accelerating Electromagnetic Transient Stability Assessment