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

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

Workstream 1 –Summer Project

Project title: Numerical Accuracy and Stability Analysis of Integration Methods used in EMT-type Simulation

Relevant Workstream(s): WS 1

This project is offered to help in the ongoing research in the Future Architecture of Network (FAN) programme, 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 for Power-Flow Analysis, Fault Analysis, Harmonic Analysis, Transient Stability, and Electromagnetic Transients. Also, WS1 proposes a future architecture of the hybrid AC/DC.

Project Description:

In this project, the student will investigate the numerical accuracy and stability of several integration methods, including the Trapezoidal Rule, Backward Euler, Trapezoidal Rule with 2-point Interpolation (as used in PSCAD/EMTDC), Critical Damping Adjustment technique (employed in EMTP), and 2-Stage Diagonally Implicit Runge-Kutta (2s-DIRK) (applied in XTAP). These methods will be evaluated using simple circuits with linear and nonlinear RLC components, subject to step changes in voltage and current sources as well as switch operations. The student can write the solution programs in MATLAB or Python or any other familiar software. The main objectives are to evaluate the accuracy and stability of these methods, compare their performance against analytical solutions, and determine the most effective methods for different circuit scenarios.

As the sole participant in this project, you will gain a deep understanding of numerical integration techniques and their application to electrical circuit analysis. You will develop skills in modelling and simulation, and learn to analyse the stability and accuracy of different methods. Additionally, you will enhance your ability to select appropriate numerical methods for specific types of circuits, thereby improving the reliability and efficiency of your simulations. This project will provide a comprehensive evaluation of integration methods, offering valuable insights and practical guidelines for future applications.

Helpful Resources:

- H. W. Dommel, "Digital Computer Solution of Electromagnetic Transients in Single-and Multiphase Networks," in *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-88, no. 4, pp. 388-399, April 1969, doi: 10.1109/TPAS.1969.292459.
- F. L. Alvarado, R. H. Lasseter and J. J. Sanchez, "Testing Of Trapezoidal Integration With Damping For The Solution Of Power Transient Problems," in *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-102, no. 12, pp. 3783-3790, Dec. 1983, doi: 10.1109/TPAS.1983.317872.
- J. R. Marti and J. Lin, "Suppression of numerical oscillations in the EMTP power systems," in *IEEE Transactions on Power Systems*, vol. 4, no. 2, pp. 739-747, May 1989, doi: 10.1109/59.193849.
- PSCAD/EMTDC software documentation on “interpolation and switching”

- T. Noda, K. Takenaka and T. Inoue, "Numerical Integration by the 2-Stage Diagonally Implicit Runge-Kutta Method for Electromagnetic Transient Simulations," in *IEEE Transactions on Power Delivery*, vol. 24, no. 1, pp. 390-399, Jan. 2009, doi: 10.1109/TPWRD.2008.923397.
- J. Tant and J. Driesen, "On the Numerical Accuracy of Electromagnetic Transient Simulation With Power Electronics," in *IEEE Transactions on Power Delivery*, vol. 33, no. 5, pp. 2492-2501, Oct. 2018, doi: 10.1109/TPWRD.2018.2797259.

Further resources will be provided as the project advances.

Specific requirements:

- BE(Hons) - Electrical and Electronic Engineering (EEE) student or Mechatronics student- Second (first Pro), Third (second Pro) or Fourth (Third Pro) year.
- Basic knowledge of electrical networks and power electronics switches
- Good knowledge of Numerical integration methods or solution of differential equations.
- Some familiarity with power system simulation tools like PSCAD/EMTDC and MATLAB/SIMULINK will very helpful but not necessary.
- Excellent 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): Veerabrahmam Bathini, Josh Schipper, Neville Watson

Based in: University of Canterbury, EPECentre