

# Workstream 1 Update

**Drs. Josh Schipper, Veerabrahmam Bathini, Aprajay Verma, Radnya Mukhedkar, Neville Watson and Nirmal Nair**

*3<sup>rd</sup> February 2026*  
*Wellington, NZ*



Future Architecture  
of the Network  
**TE WHATUNGAHIKO**

# Outline

- Summary of research objectives and direction
- Contributions of the research team
- Contributions of the postgraduate students
- Contributions of the undergraduate students

# Workstream Objectives

We will develop a large-scale digital model encompassing DC grids and their interface to AC grids. They will enable operational steady-state, dynamic and transient studies associated with distributed power electronic converter interfaced technologies.

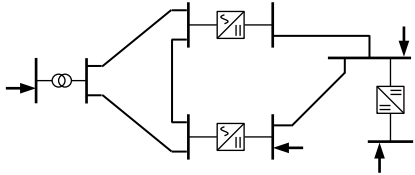
**Development** of power system analysis tools.

**Create outcomes** for grid Architecture!

# Workstream Progress

## Achieved Objectives

### POWERFLOW ANALYSIS TOOL



NZ transmission line  
model conversion

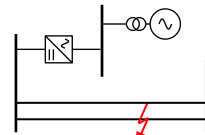


Cigre benchmark  
hybrid AC-DC network  
model conversion



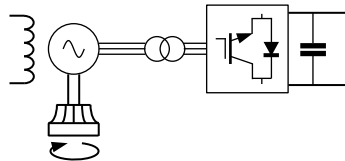
## Continuing Objectives

### SHORT-CIRCUIT ANALYSIS TOOL



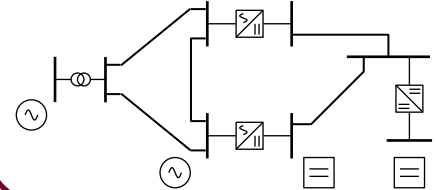
Dynamic Assessment

### TRANSIENT ANALYSIS TOOL



## Objectives Beginning

### ARCHITECTURE



NZ and large scale  
models with DC



# Workstream Research Team

## Leadership



Radnya  
Mukhedkar



Neville  
Watson



Nirmal  
Nair

## Researchers



Veerabrahmam  
Bathini



Josh  
Schipper



Aprajay  
Verma



Ajeesh  
Azeez

# Workstream Students

## PhD Students



Choidorj  
Adiyabazar



Christian  
Yap



Dilshani  
Maheepala



Reza  
Sepehrzad

## Summer Students

Edward Birchler-Stockdill  
Corey Hamill  
Russell Flint  
Sarah Ruelens

## Final Year Project Students

Alec Jordan  
Jacob Ermio  
Jack Barton  
Eli Flower

## Ajeesh Azeez



- Implemented the parallel programming KLU solver for all WS1 tools.
- Stayed with us for a three month internship.
- PhD student from IISc, Bangalore, and the Centre for Development of Advanced Computing (CDAC), India.

# Improvements made by Ajeesh

- KLU solver (Clark Kent LU factorisation algorithm for sparse linear equations) with CPU parallel programming and Multi-Area Thévenin Equivalents (MATE) system splitting.
- Applied algorithm to North Island (506 Busses) and South Island (295 Busses) power systems, showing improvements against a dense LU factorisation algorithm:
  - Power flow application, simulation time improved from 10 minutes to 0.85 s.
  - Electromagnetic transient application, simulation time improved from 40 minutes to 5 minutes. (50  $\mu$ s time step, 50 s window)
- Further improvements can be made.

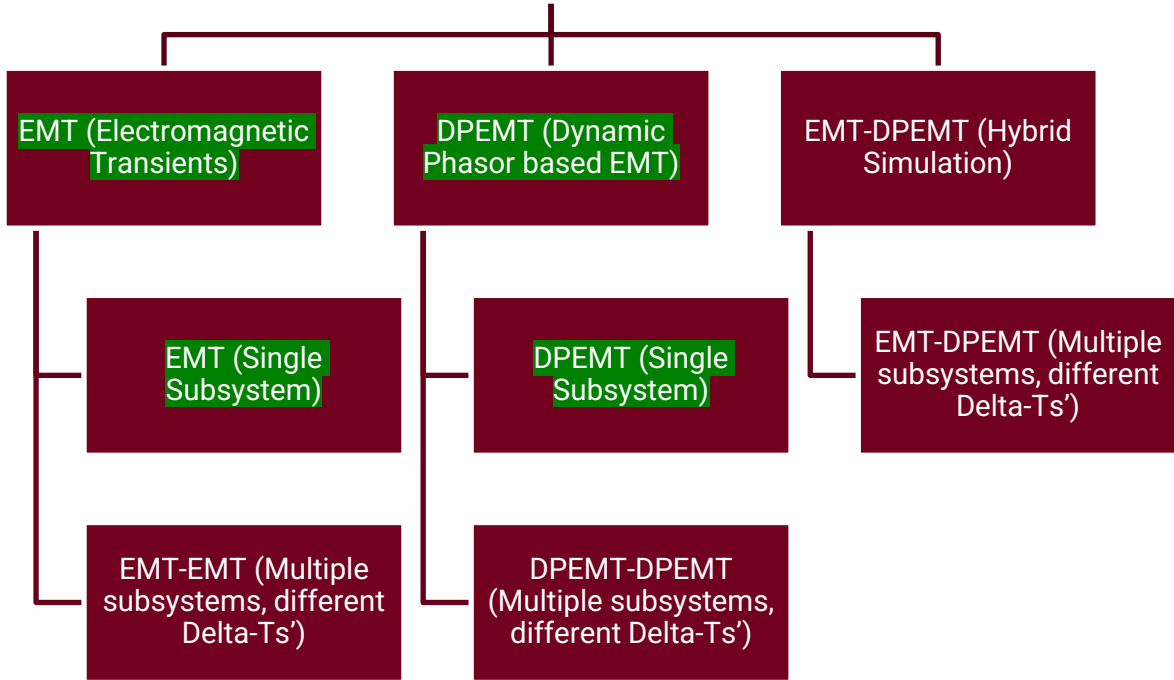
## Dr. Veerabrahmam Bathini



- Supporting the transient analysis tool and the short-circuit analysis tool.
- Transitioned to a new position at Transpower in June 2025 with one day a week with FAN. Full time at Transpower since January 2026.

# Transient Simulation Tool

(Unified Electromechanical and Electromagnetic Transients)



Green = Completed



## Dr. Aprajay Verma



- Started in January 2026 after arriving from Siemens, India.
- Recently completed PhD thesis at IIT Madras.
- His thesis topic was on applying optimisation methods to the dynamic line rating problem and distribution planning.
- Supporting the development of the transient analysis tool.

# Dr. Josh Schipper



- Publication of

Renewable and Sustainable Energy Reviews 215 (2025) 115564

Contents lists available at ScienceDirect

**Renewable and Sustainable Energy Reviews**

journal homepage: [www.elsevier.com/locate/rser](http://www.elsevier.com/locate/rser)



Review article

### Steady-state power system analysis revisited for hybrid AC–DC grids

Josh Schipper<sup>a,\*</sup>, Veerabrahmam Bathini<sup>a</sup>, Radnya Mukhedkar<sup>a</sup>, Neville Watson<sup>b</sup>, Mehrdad Pirnia<sup>c</sup>, Nirmal-Kumar Nair<sup>d</sup>, Jeremy Watson<sup>b</sup>

Electric Power Systems Research 249 (2025) 111987

Contents lists available at ScienceDirect

**Electric Power Systems Research**

journal homepage: [www.elsevier.com/locate/epsr](http://www.elsevier.com/locate/epsr)



### Generalised harmonic domain analysis for transformer core hysteresis modelling

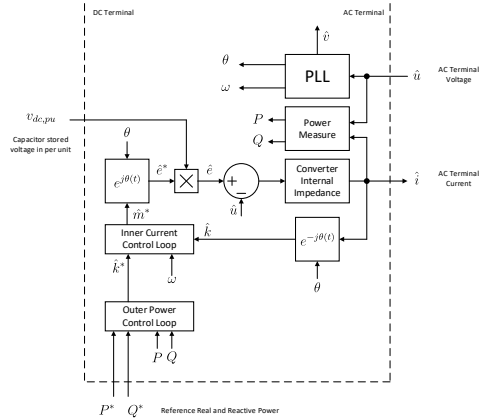
Josh Schipper<sup>a,\*</sup>, Radnya Mukhedkar<sup>a</sup>, Neville Watson<sup>b</sup>, Veerabrahmam Bathini<sup>a</sup>, Jan Meyer<sup>c</sup>



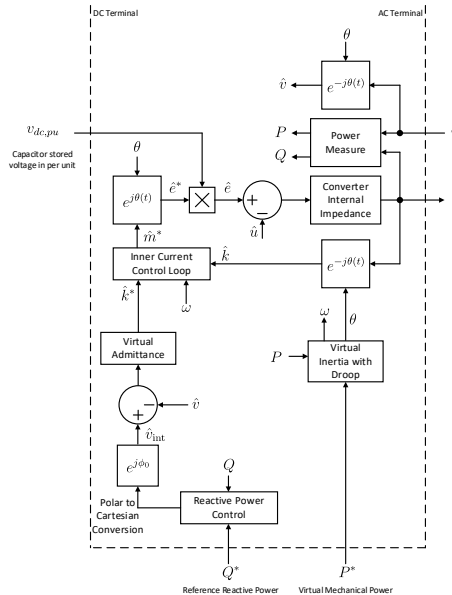
- Secondment to Siemens Energy, Erlangen

# HVDC - Grid Forming Converter (GFM) vs Grid Following Converter (GFL) in reducing subsynchronous resonance

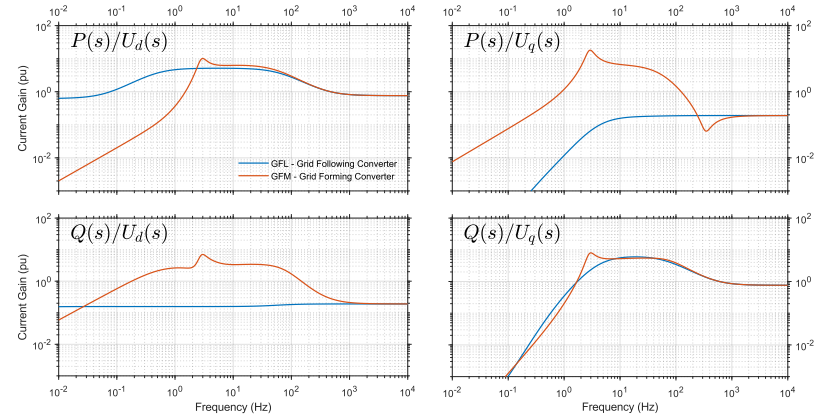
## GFL



## GFM



## Power Response

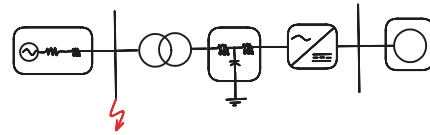


PhD Student  
Christian Yap

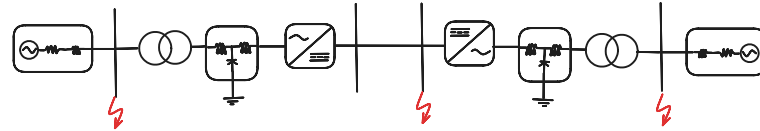


- Researching accurate and efficient short-circuit analysis for hybrid AC/DC grids.
- Applying dynamic phasors for time domain simulation.

Test Configuration 1



Test Configuration 2



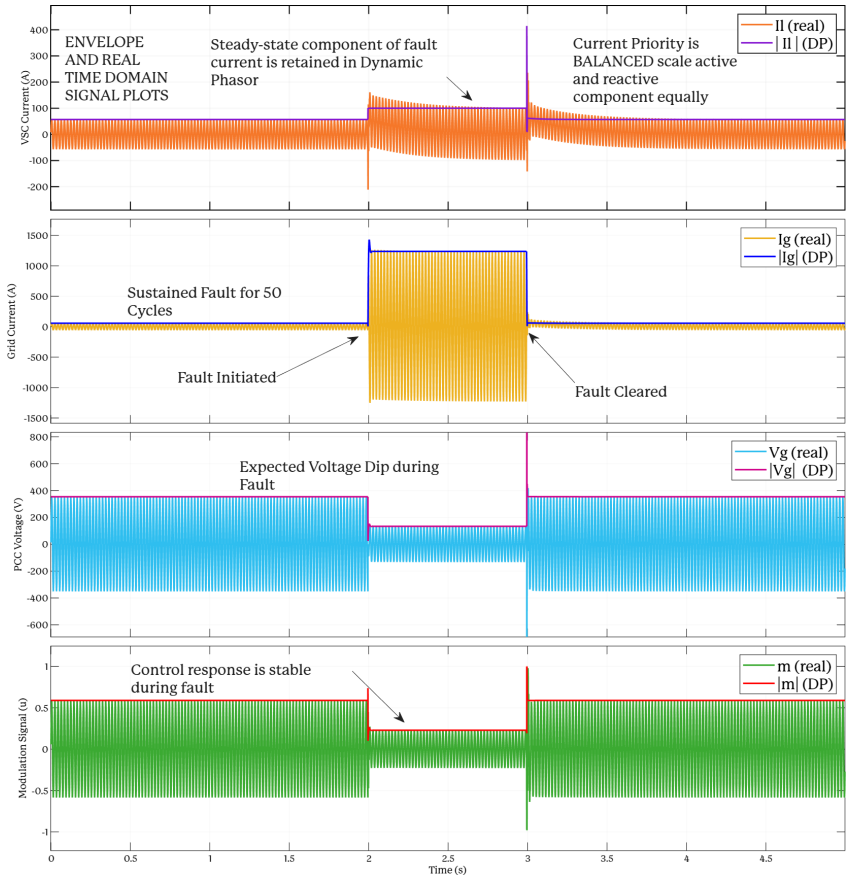
# Christian's example dynamic phasor simulation

VSC Controller Current Saturation Order and Priority

Rise in Grid Current Contribution

Voltage Dip Response

Stable Modulation during Fault



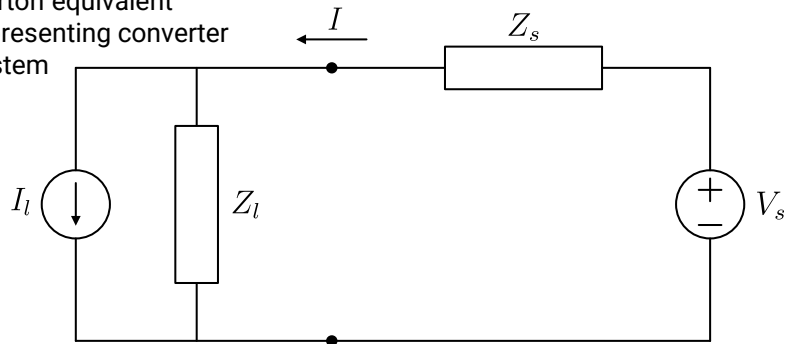
**PhD Student**  
**Dilshani Maheepala**



- Successfully completed confirmation report (1-year milestone).
- Supporting the transient analysis tool with frequency domain applications.
- Extending impedance-based stability analysis with nonlinear effects.

# Impedance Based Stability Analysis

Norton equivalent  
representing converter  
system



Thevenin equivalent  
representing grid connection

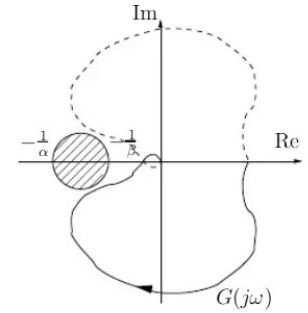
Current injection response

$$I = \left( I_l + \frac{V_s}{Z_l} \right) \underbrace{\left( 1 + \frac{Z_s}{Z_l} \right)^{-1}}$$

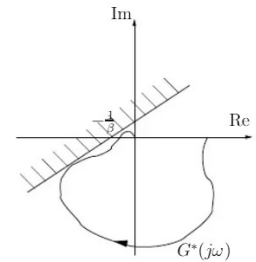
Nyquist stability criterion  
identifies any unstable poles.

# Nonlinear extensions

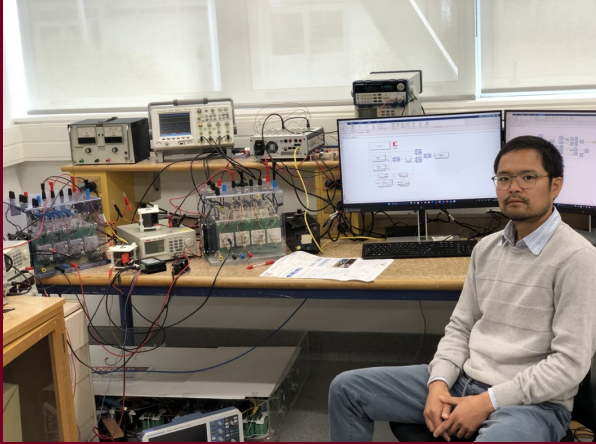
Circle Criteria



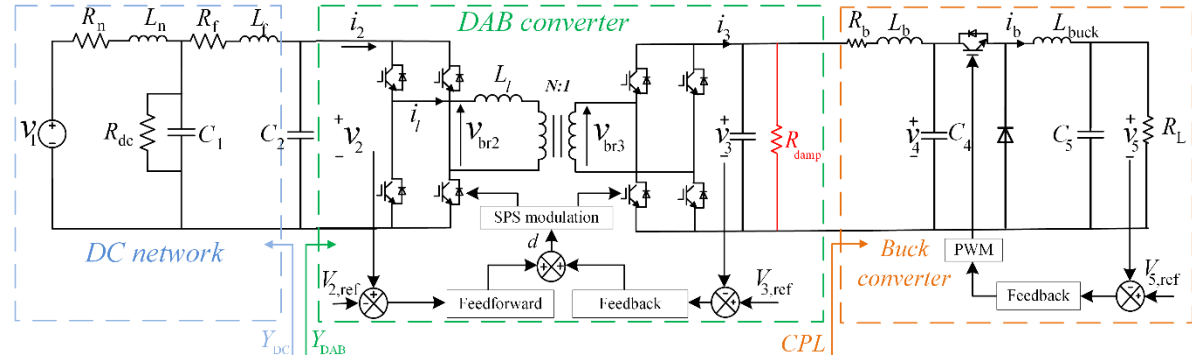
Popov Criteria



# PhD Student Choidorj Adiyabazar

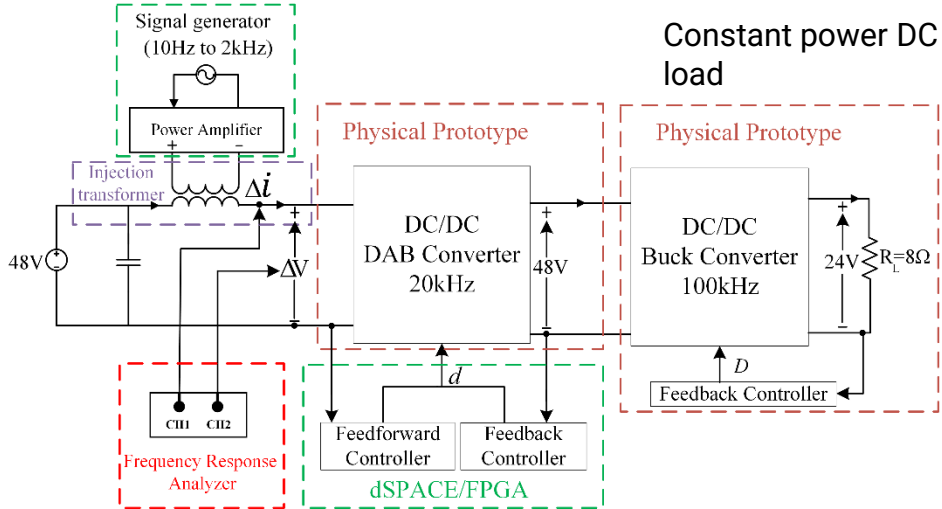


- Applying impedance based stability analysis in the control design of dual active bridge (DAB) DC/DC converter.
- Presented at IEEE International Conference on Energy Technologies for Future Grids in Australia.
- About to begin writing thesis.



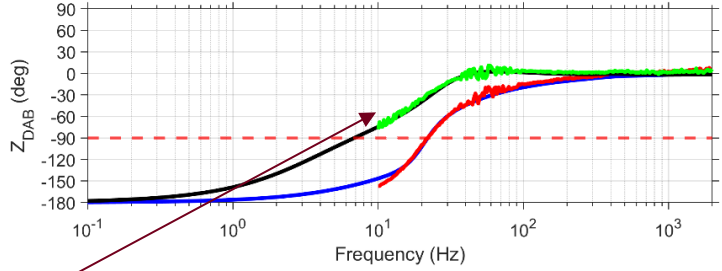
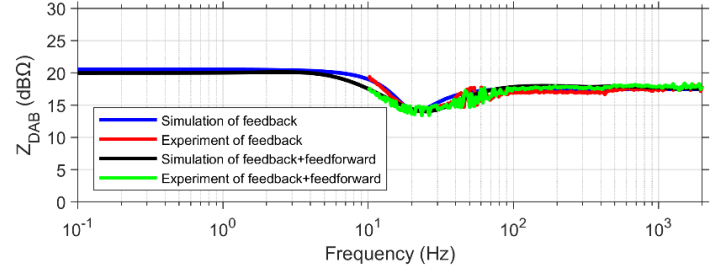
# Choidorj's test setup

Impedance frequency scanning circuits



Hardware under test

Incremental impedance seen from the input of the dual active bridge converter



Improved passivity of including feedforward controller

**PhD Student  
Reza Sepehrzad**

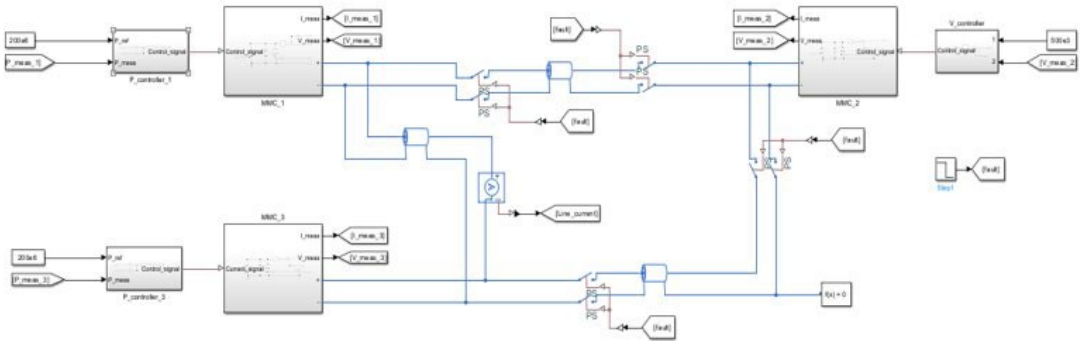


- Started in November 2025
- Intelligent computing methods for optimal AC-DC grid architecture

**Summer Student  
Edward Birchler-Stockdill**



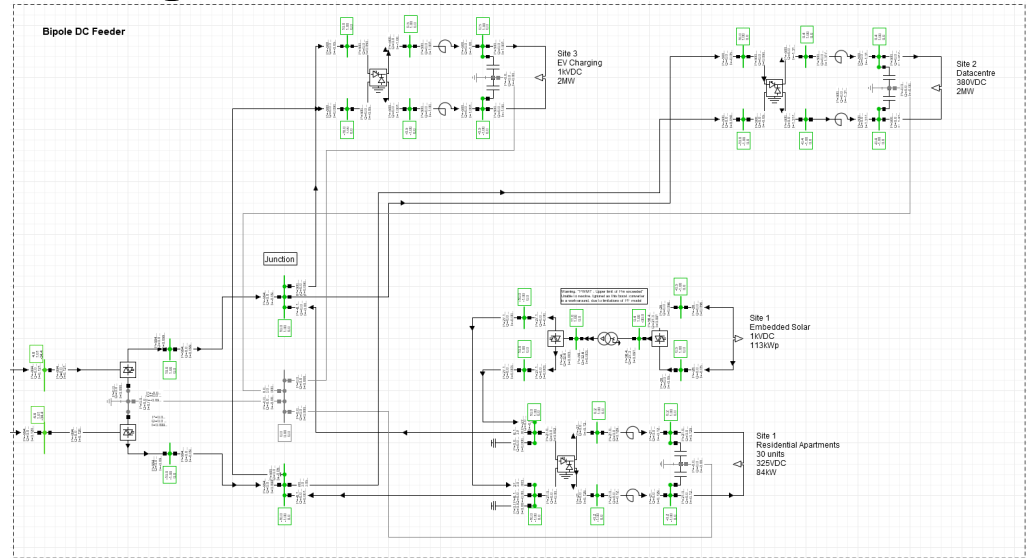
- Assessing AC/DC architecture from a reserve requirements perspective.
- How might converter control objectives change in HVDC grids?
- Where and how much reserve is needed to maintain N-1 security?



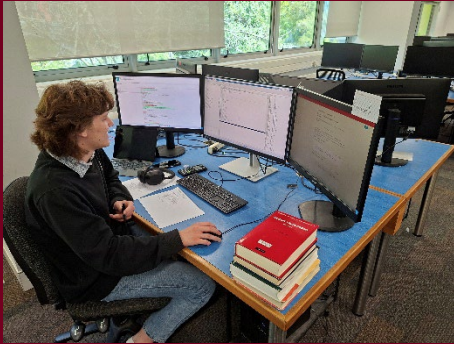
## Summer Student Corey Hamill



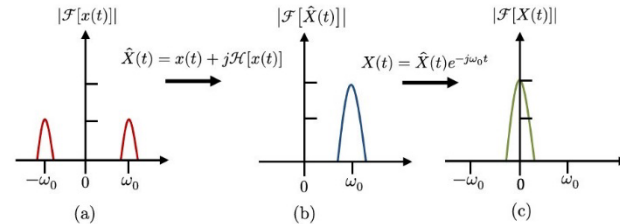
- DC feeder alternative to 11 kV AC feeders within the Orion network context.
- Comparison between AC and DC.



## Summer Student Russell Flint



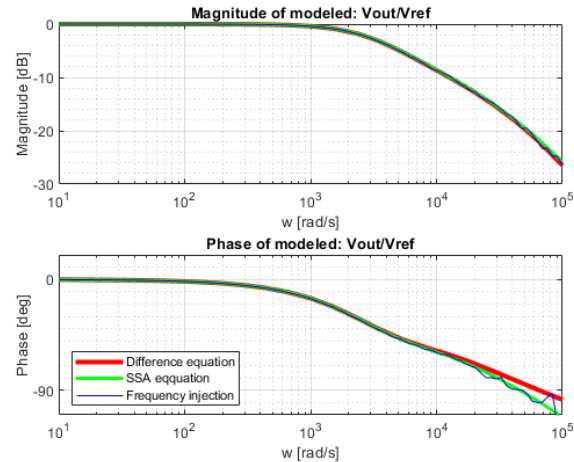
- Supporting Christian Yap's work in developing dynamic phasor simulations for short-circuit analysis.
- Split AC fault signals into a DC and 50 Hz dynamic phasors.
- The goal is to increase the simulation time-step and reduce the simulation effort.



## Summer Student Sarah Ruelens

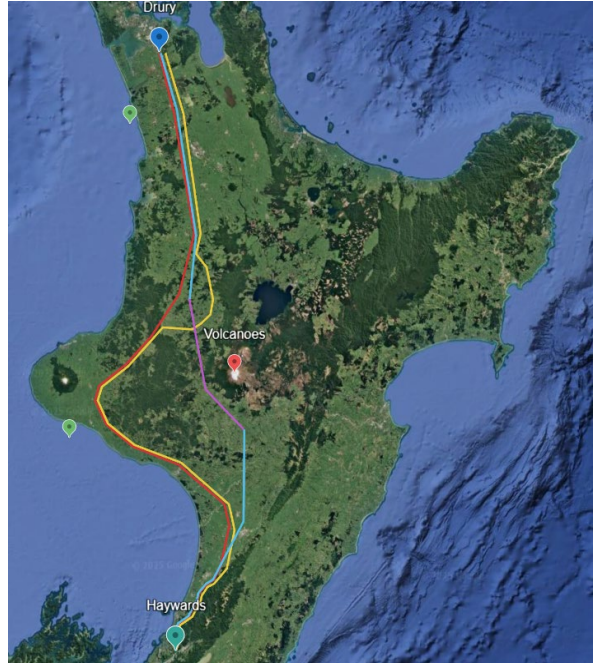


- Supporting Dilshani in developing frequency injection methods for impedance characterisation. (At least this was the goal)
- Instead assessed the modelling accuracy of a converter between two different averaging techniques:
  - State-space averaging
  - Detailed average switching period models



Final Year Project Students  
Alec Jordan  
Jacob Ermio  
Jack Barton  
Eli Flower

- Developed scenarios for HVDC grid expansion to assess a possible architecture in NZ.



- Key / Legend:
- 500 kV overhead lines
  - AC to DC tower conversion
  - Hybrid-500 kV underground cables
  - Hybrid-500 kV overhead lines
  - Proposed offshore windfarms
- Option 1  
Option 2  
Option 3

# Summary

- Our team is back to full strength.
- Focus moves towards transient analysis tool and proposing hybrid AC/DC architecture.

This work was supported by the Ministry of Business Innovation and Employment, New Zealand under the Strategic Science Investment Fund – Advanced Energy Technology Platform programme “Architecture of the Future Low Carbon, Resilient, Electrical Power System” contract number UOCX2007

# Thank you

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Future Architecture  
of the Network  
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# Questions?

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