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

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

Workstream 2

Project 4

Fault Behaviour and Protection Challenges in Future DC Networks

Workstream: WS2

Background and Motivation

A core WS2 objective is to develop new methods of fault detection, location, and isolation for future DC and hybrid AC/DC networks, ensuring safety and minimizing outages. DC faults propagate much faster than AC faults because DC systems have no natural current zero crossings, and converter-dominated networks further complicate traditional protection assumptions.

FAN WS2 research has directly addressed this challenge. Saad Ahmed Khan's PhD work has produced a radial MTDC simulation and hardware prototype, with results on fault detection, classification, and localization published at APPEEC 2025 [1]. Leyla Zafari's research has delivered a comprehensive review of signal processing techniques for HVDC fault detection, published in the journal Energies [2], and a voltage-modulated time-domain decomposition method for fault classification [3]. Sruthi Babu's work has identified key protection challenges in hybrid AC–DC distribution systems through EMT simulation [4].

This project builds on these WS2 outputs by extending the fault analysis to a specific scenario, such as an NZ LV or MV DC network configuration, or by developing a comparative review of protection strategies suitable for the topologies identified by the WS2 team.

Key FAN References

[1] S.A. Khan, A. Ukil, N.-K.C. Nair, "Design and Simulation of Radial Multi-Terminal DC System with Zonal DC Protection," APPEEC 2025.

[2] L. Zafari, Y. Liu, A. Ukil, N.-K.C. Nair, "Advances in HVDC Systems: Signal Processing Techniques for Fault Detection," Energies, vol. 18, no. 12, 2025.

[3] L. Zafari, A. Ukil, K. Wang, N.-K.C. Nair, "Voltage-Modulated Time-Domain Decomposition for DC Transmission Line Fault Classification," APPEEC 2025.

[4] S. Babu, N.-K.C. Nair (2025), "Protection Challenges and Schemes in Hybrid AC–DC Distribution Systems", FAN WS2 Research.

Research Aim

To investigate fault characteristics and protection options for future DC and hybrid AC/DC electricity networks, building directly on existing FAN WS2 simulation and hardware results.

Research Objectives

The student will:

- Review WS2 fault detection and protection findings and identify a specific gap or extension scenario.
- Compare AC and DC fault characteristics and analyze protection challenges for a selected network topology.
- Evaluate one or more candidate protection approaches (signal processing, travelling waves, zonal protection) through simulation or literature synthesis.
- Develop recommendations aligned with WS2's 2027 KPI on optimum DC circuit topology.

Methodology

Targeted literature review building on WS2 publications; selection of a specific fault scenario or protection method; simulation using MATLAB/Simulink, PSCAD, or OPAL-RT (with guidance from WS2 researchers); synthesis of results into recommendations.

Expected Outcomes

- Extension of FAN WS2 fault behavior analysis for a specific DC topology or scenario.
- Comparative review of protection approaches relevant to NZ LV/MV DC networks.
- Recommendations for WS2 research pathway towards 2027 KPI.
- Technical report and presentation.

Potential Supervisor(s):

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