Future Architecture of the Network (FAN) Project in New Zealand

J-HVDC seminar

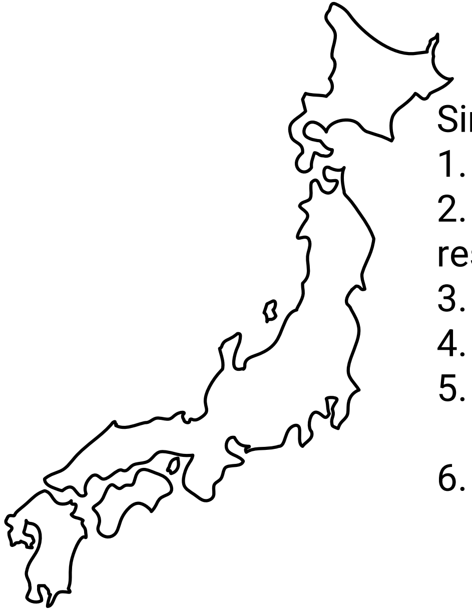
Presenter: Neville Watson
30 October 2024
neville.watson@canterbury.ac.nz

Future Architecture of the Network
TE WHATUNGA HIKO

Outline

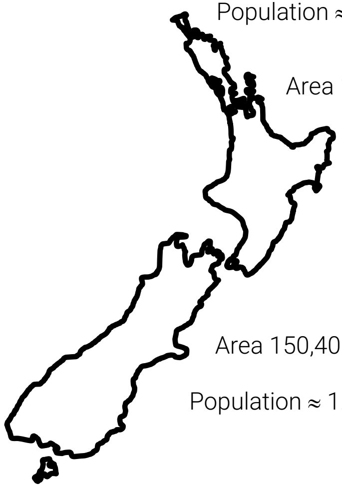
- Background
- Motivation for DC
- Vision for the Future Network
  - Future Architecture of the Network (FAN) programme
- International
  - Papers and conferences on DC
  - DC related projects and research being undertaken
  - Standards being developed
  - Advertisements for researchers in this area
- Progress to date on FAN programme
  - Workstream overviews
  - Training the next generation
  - Linkages with other of Advanced Energy Technology Platform programmes
- Conclusions

Japan and New Zealand



Similarities:

1. Both Island nations
2. Diverse natural landscapes (beautiful scenery) resulting in being a tourist destination.
3. Committed to Sustainability
4. Both known for safety, hospitality and quality of life.
5. Some similarities in cultural values, economic structures and social system.
6. On the Pacific rim so experience earthquakes.



Population ≈ 4.1 million

Area 113,700 km^2

Area 150,400 km^2

Population ≈ 1.3 million

Total Area 268,000 km^2

Total Population ≈ 5.4 million

Total Area 377,975 km^2

Total Population ≈ 123.9 million

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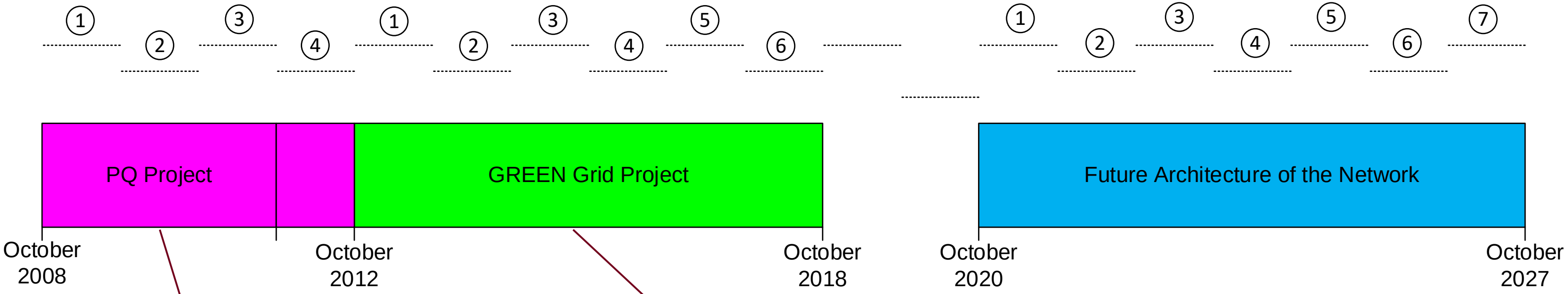
Previous Government Projects



Gathering **R**enewable **E**nergy into **E**lectrical **N**etworks (GREEN) – [Renewable Energy and the Smart Grid – Future Proofing New Zealand's Electricity]

PQ Project [**P**ower **Q**uality in Future Electricity Networks]

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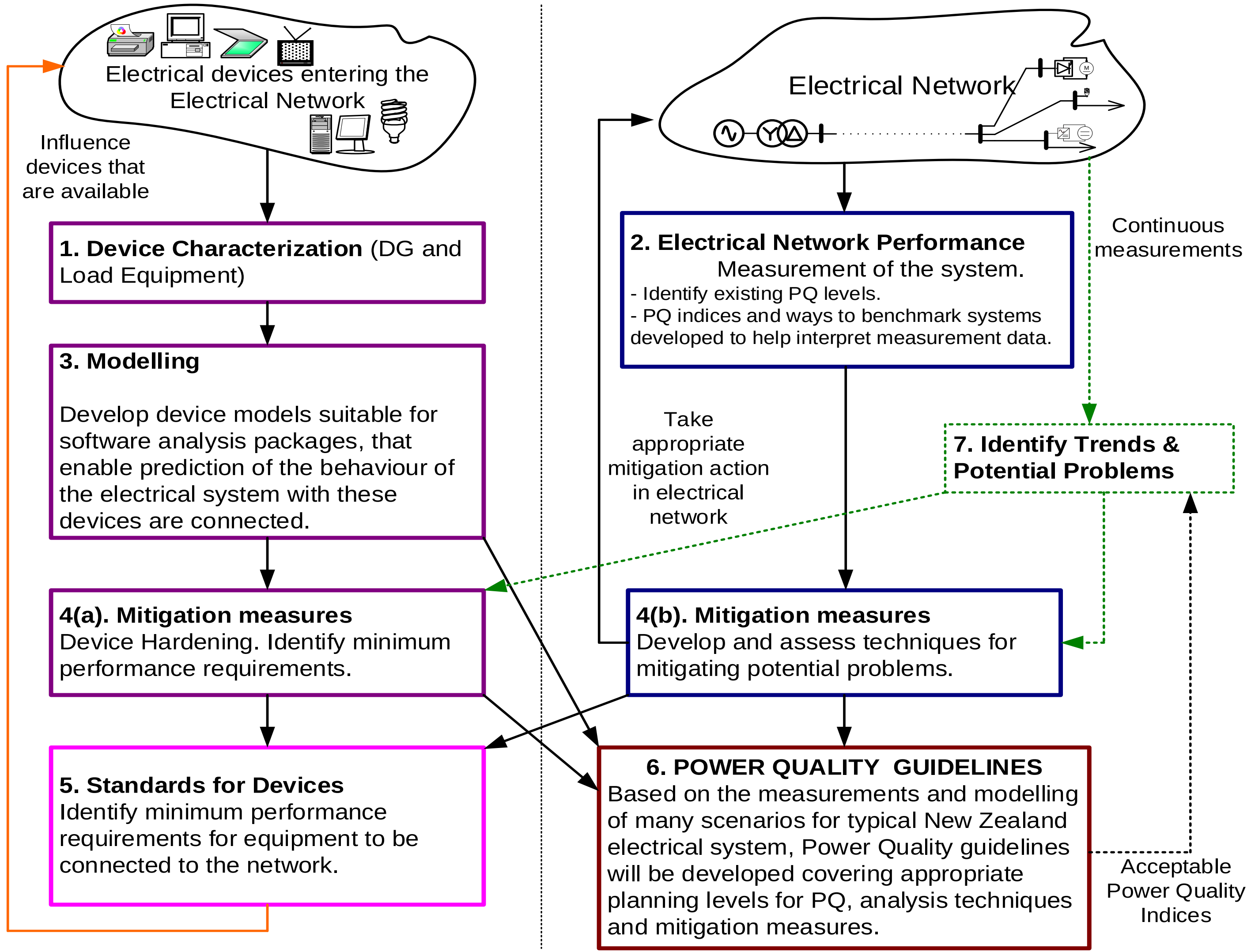
Master Plan (Concept Diagram)



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PQ Guidelines released

Revised PQ Guidelines released

Undertake all the technical investigations

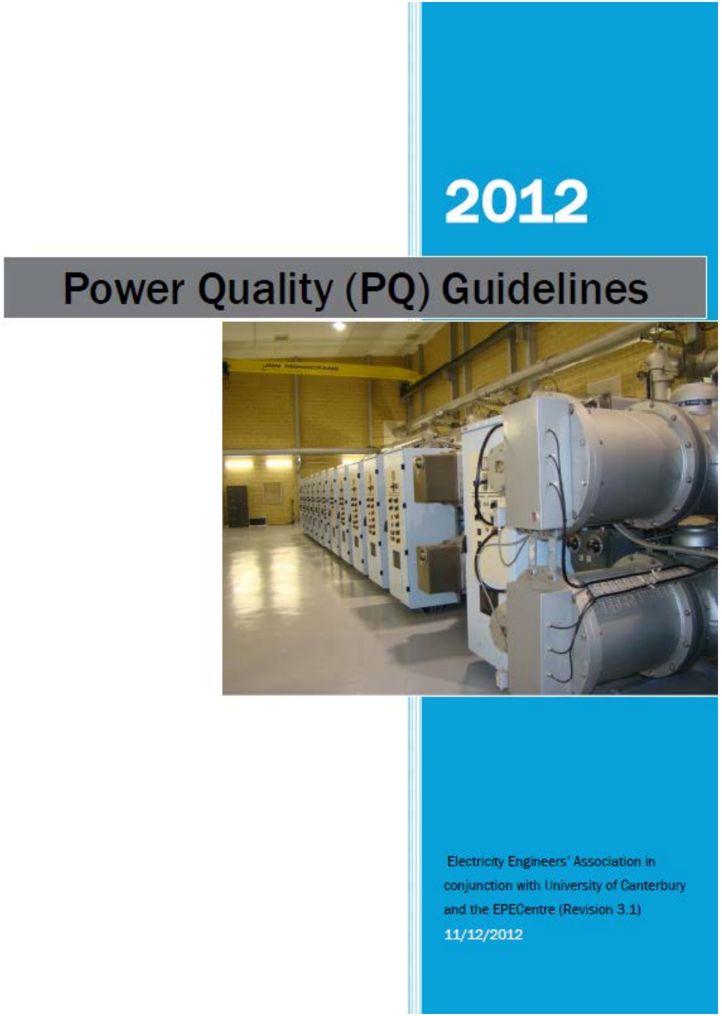
People use PQ Guidelines and provide feedback

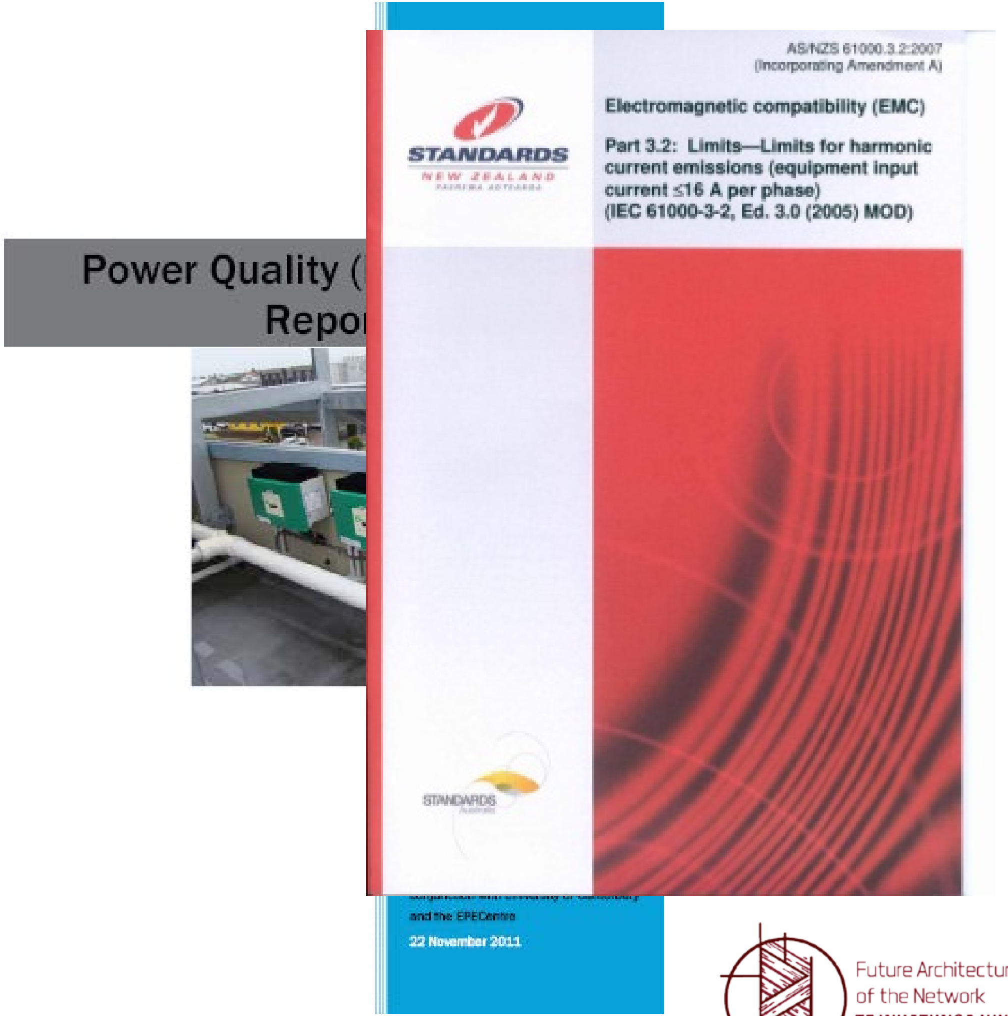
Look at special cases

October 2008

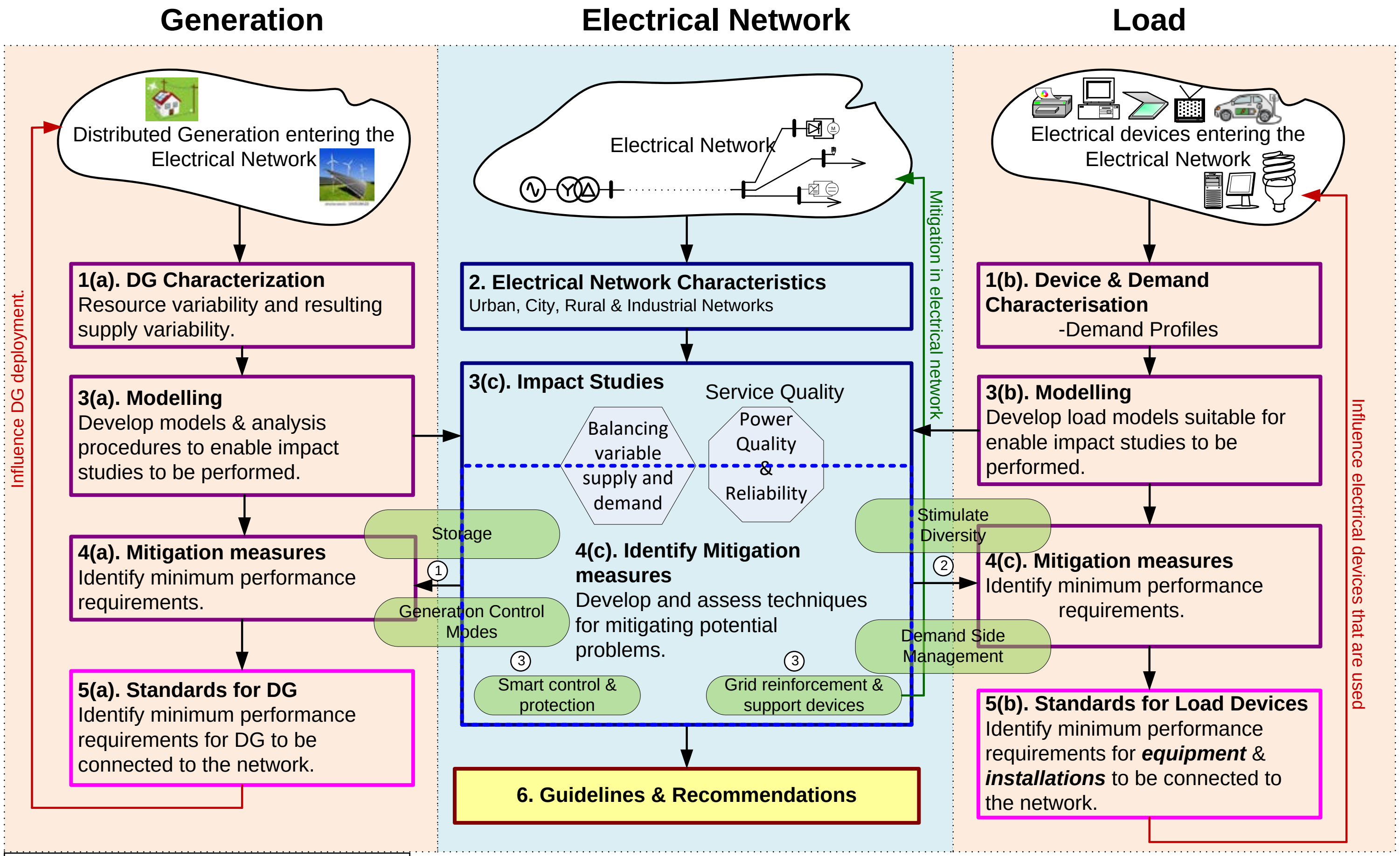
3 year mark
October 2011

4 year mark
October 2012


2012
Power Quality (PQ) Guidelines
Electricity Engineers' Association in conjunction with University of Canterbury and the EPECentre (Revision 3.1)
11/12/2012


Power Quality (
Repo
AS/NZS 61000.3.2:2007
(Incorporating Amendment A)
STANDARDS
NEW ZEALAND
Electromagnetic compatibility (EMC)
Part 3.2: Limits—Limits for harmonic current emissions (equipment input current ≤16 A per phase)
(IEC 61000-3-2, Ed. 3.0 (2005) MOD)
STANDARDS
and the EPECentre
22 November 2011

Master Plan (Concept Diagram)



Master-plan: Future Electrical Networks
Version: 13
Date Created: August 2008
Date Modified: 14 May 2015
Author: NRW

① Identify mitigation that can be taken at the generation level

② Identify mitigation that can be taken at the load level

③ Identify mitigation that can be taken at the network level

Indicates a mitigation measure

Other aspects to consider:
- Regulatory, Economic & Political Framework
- Structure of the Industry
- Environmental aspects & Sustainability
- Life-cycle costs

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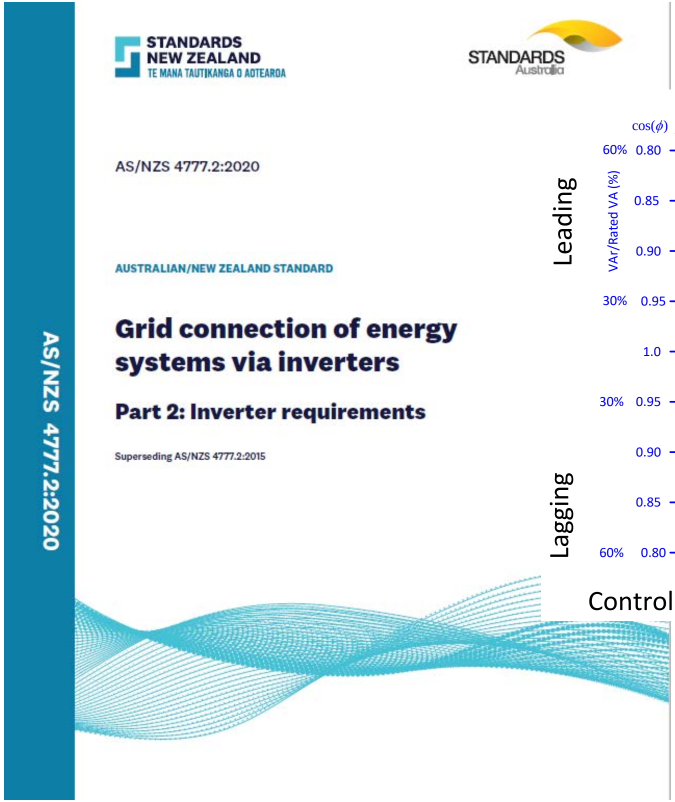
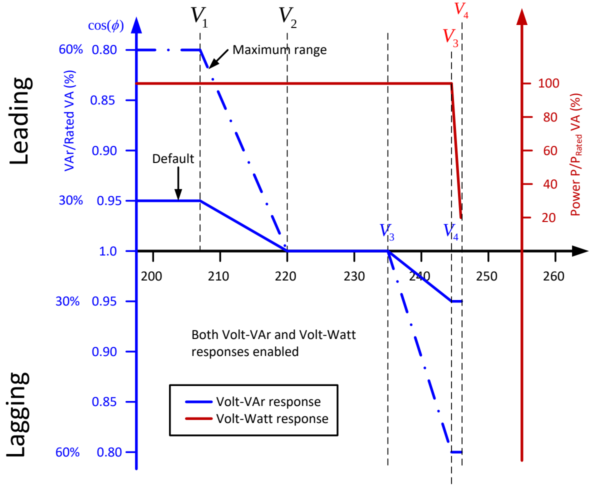
Outputs

Guide for the Connection of Small-Scale Inverter-Based Distributed Generation

First issued: Interim Guide July 2018

HEALTH + SAFETY
ASSET MANAGEMENT
PROF DEVELOPMENT





Control Response for New Zealand

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Motivation for DC: Drivers

Net Zero Energy Transition by 2050

Renewable energy integration

Integration of Distributed Energy Resources (DER)

Inverter dominated networks

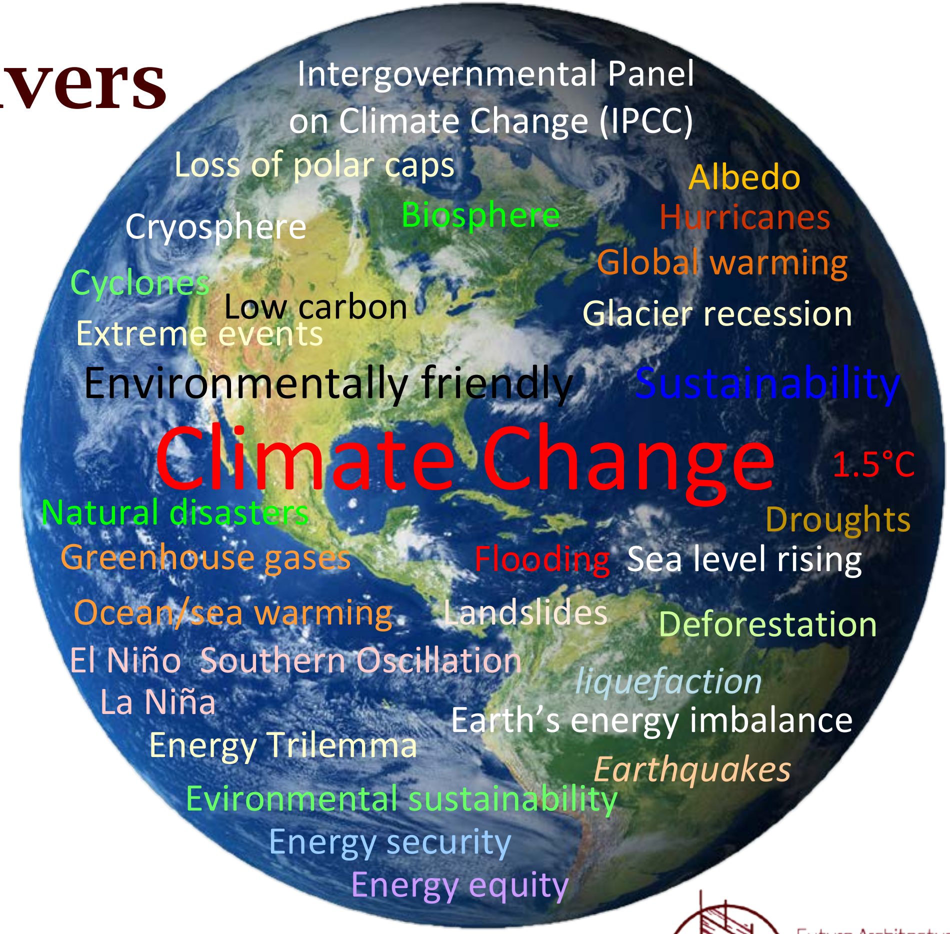
Decarbonisation

Sustainability

Renewable Energy Sources (RES)

Inverter-based resources (IBR)

Power system resilience and security



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International Energy Agency (IEA) 2022

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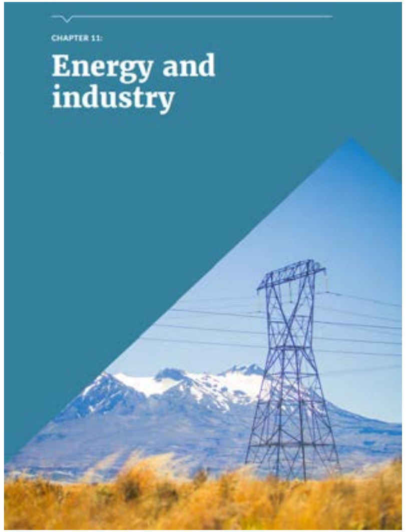
New Zealand's Emissions Reduction Plan (2022)



https://environment.govt.nz/what-government-is-doing/areas-of-work/climate-change/emissions-reduction-plan/

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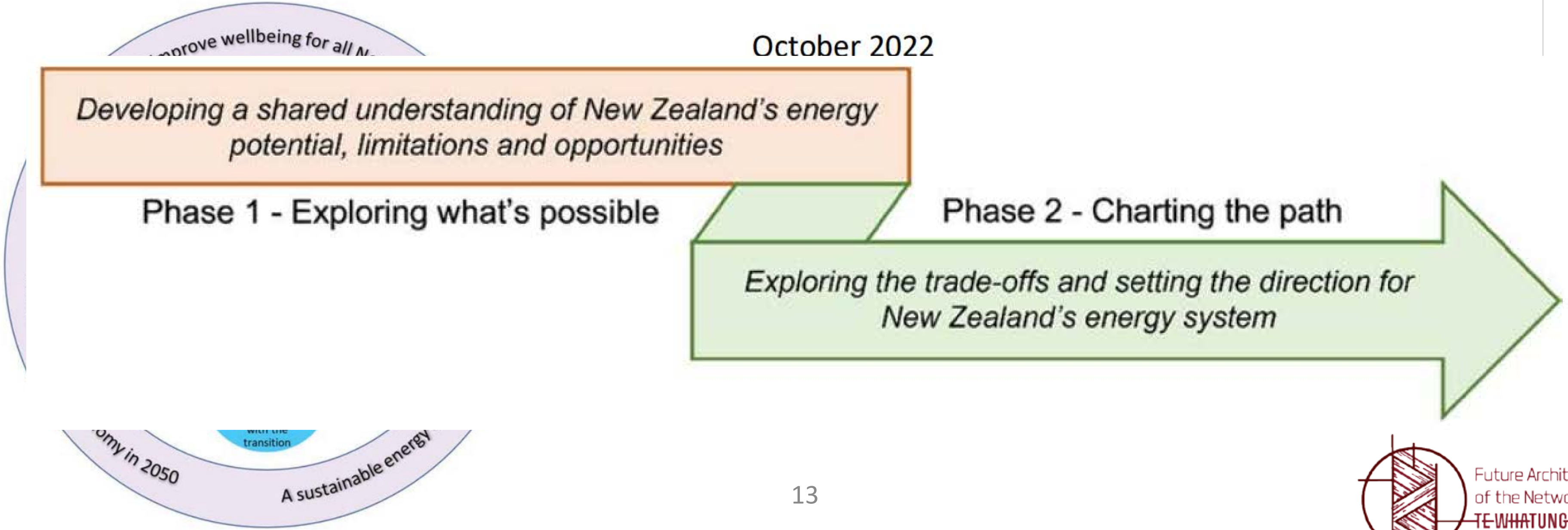
MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

TERMS OF REFERENCE

NEW ZEALAND ENERGY STRATEGY

October 2022



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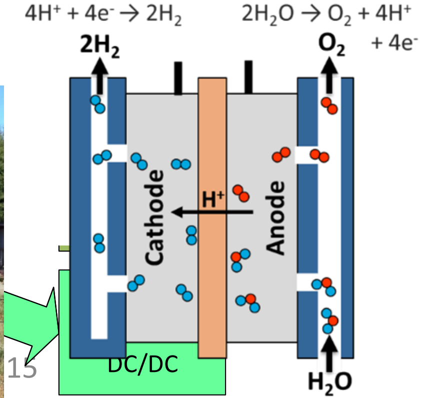
Electricity Engineers' Association (EEA) Conference

Motivation for DC: New Technologies

- Electric transportation
- PhotoVoltaic (PV) generation
- Type 4 Wind turbines
- Battery systems (stationary and mobile)
- Electrolysers



Household appliances

- Chargers and power supplies for equipment
- Lighting equipment
- Entertainment equipment (TV, Stereos, etc)
- Computer equipment
- Heat-pump/air-conditioners
- Domestic Photovoltaic (PV) systems
- Electric Vehicles
- New generation of:
  - Fridges and freezers
  - Washing machines and clothes dryers
  - Hot-water heaters

Inverter-based fridge and freezer

Inverter-based whiteware

Industrial loads and large-scale generation


- PhotoVoltaic (PV) generation
- Wind generation
- Transportation (cars, trucks, buses, light rail and trains)

- Pumps and fans for industrial processes
- Irrigation pumps
- Process heat
- Electroplating
- Electrolysis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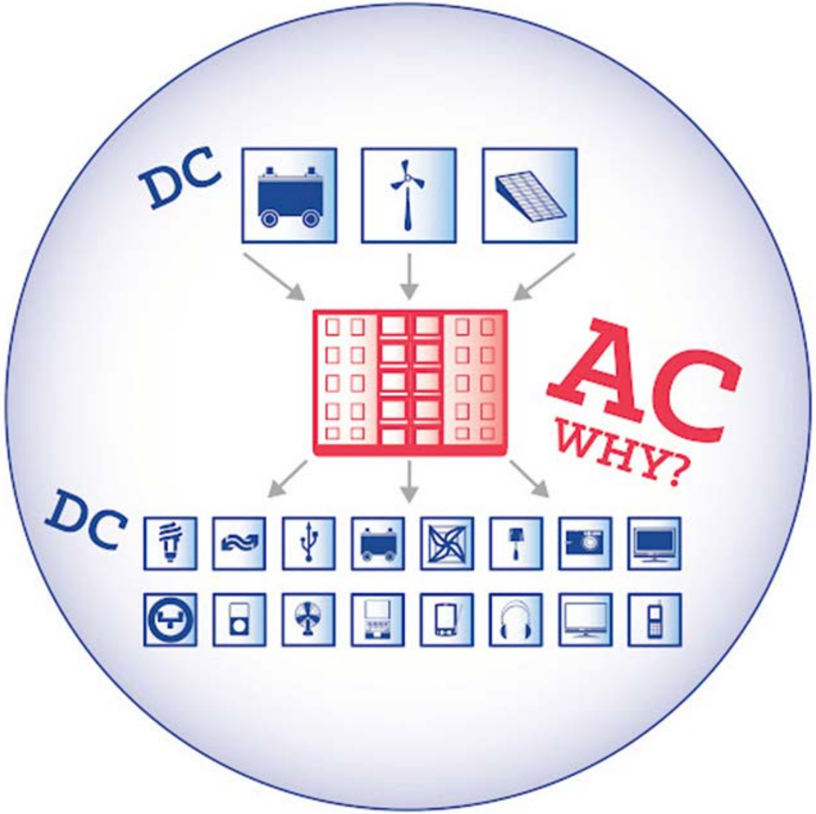
Motivation

The question is not whether DC conveyance and DC systems will have a role in the system moving forward, but where should it be used, how is it to be implemented and how fast should it be deployed.



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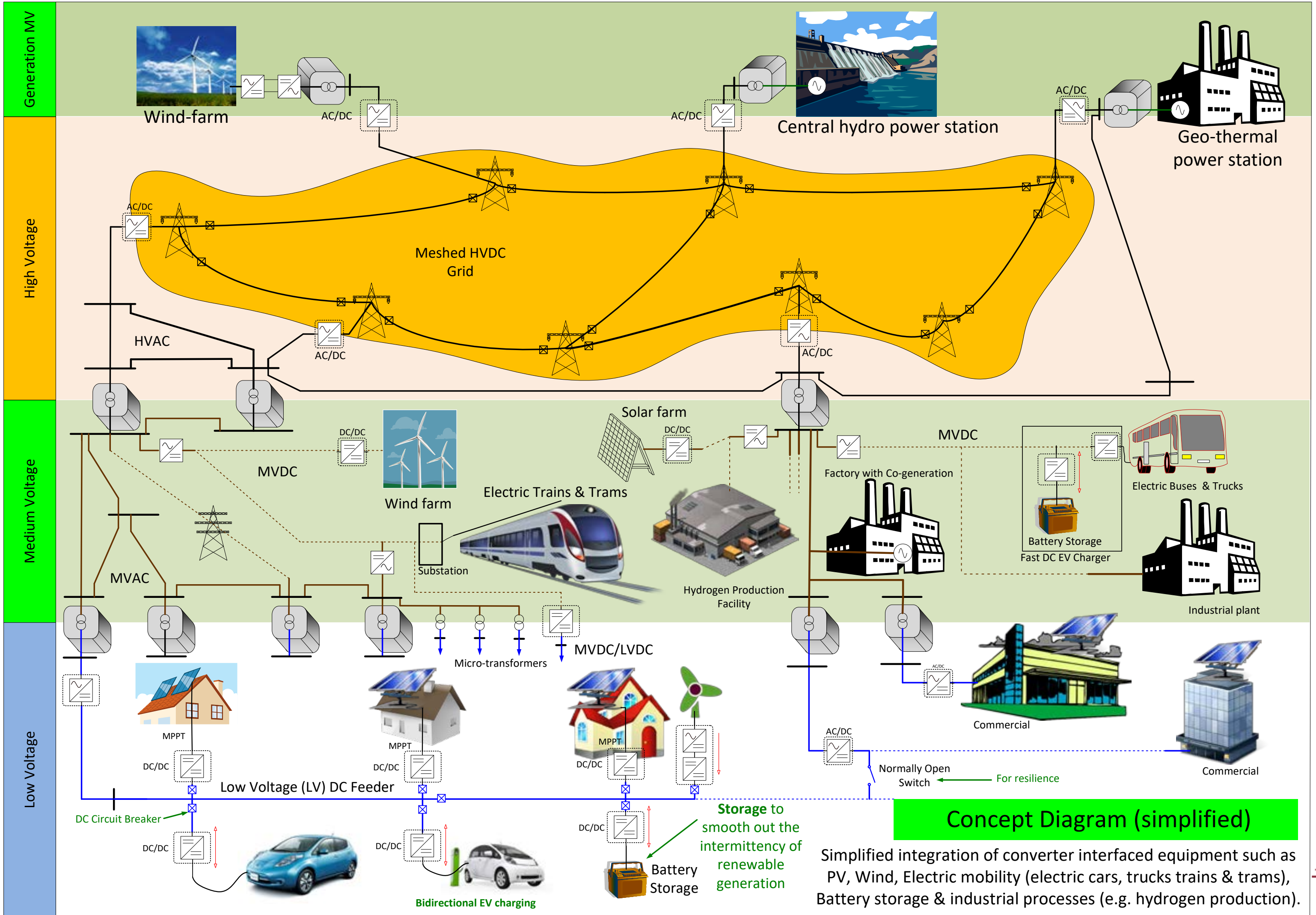
Concept Diagram



Concept Diagram (simplified)

Simplified integration of converter interfaced equipment such as PV, Wind, Electric mobility (electric cars, trucks trains & trams), Battery storage & industrial processes (e.g. hydrogen production).

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Why a Hybrid AC-DC Power system?

- There is an optimum voltage for a given distance and power to be conveyed.
  - The AC transformer is a mature technology with a high reliability and efficiency (Up to 99.7% for large power transformers)
  - DC/DC converters are available for lower voltage levels, but unlike to be available at 400 kV in the MW range in the foreseeable future.
  - A lot of money already invested in AC transformers
- Gives the best of both worlds. Easy integration of new technologies and easy translation of system voltage.
- Already DC already used for reticulation in some industries.
- Lower losses (Conversion and transmission).
- Direct integration of DC-based generation and loads.

About FAN

www.fan.ac.nz

Full Research programme name:

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

Short-form name of the programme:

Future Architecture of the Network (FAN)

or *Te Whatunga Hiko*

7-year project (started in the latter part of 2020)

Science Leader: Professor Neville Watson (University of Canterbury)

Contact: **futurearchitecturenetwork@canterbury.ac.nz**

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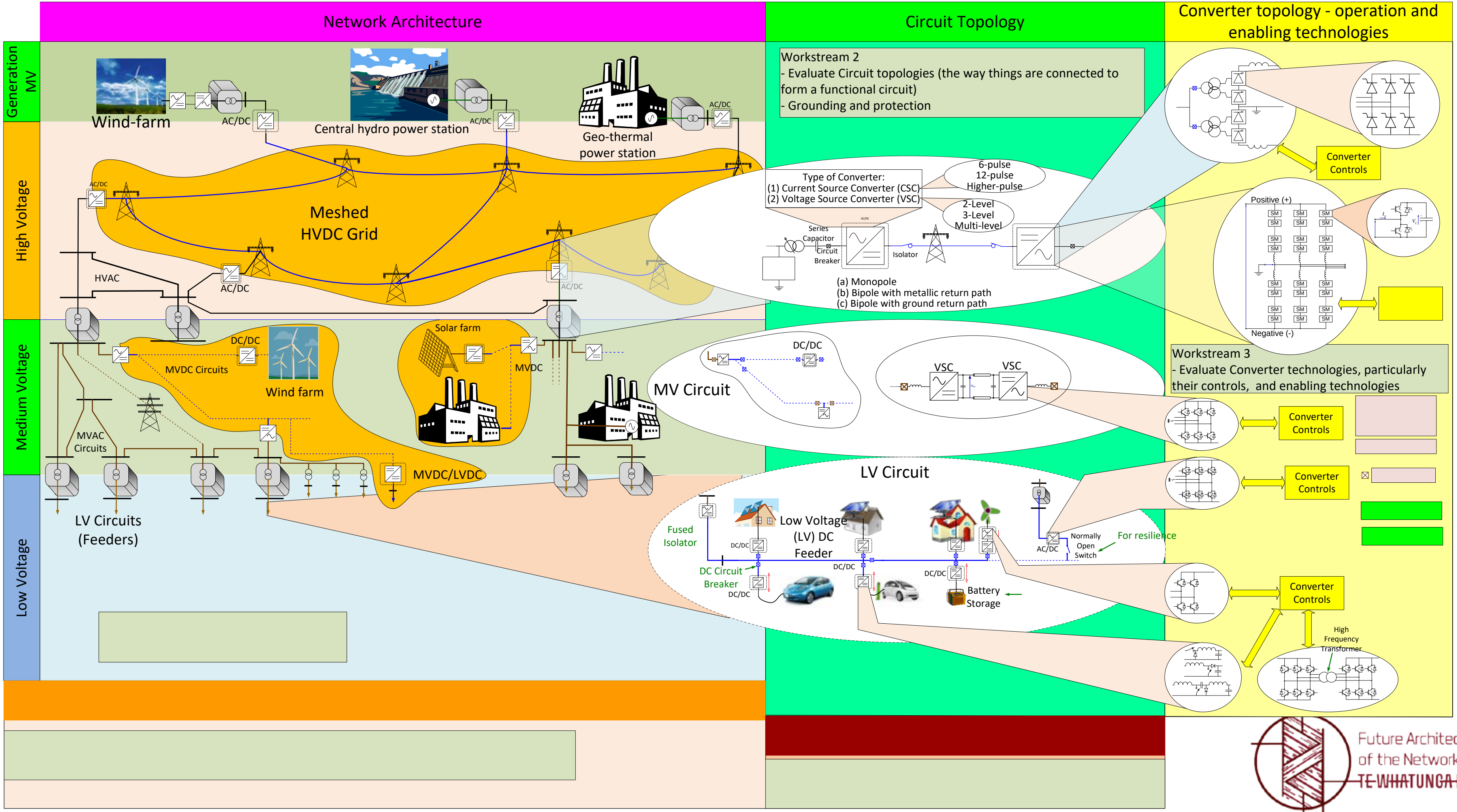

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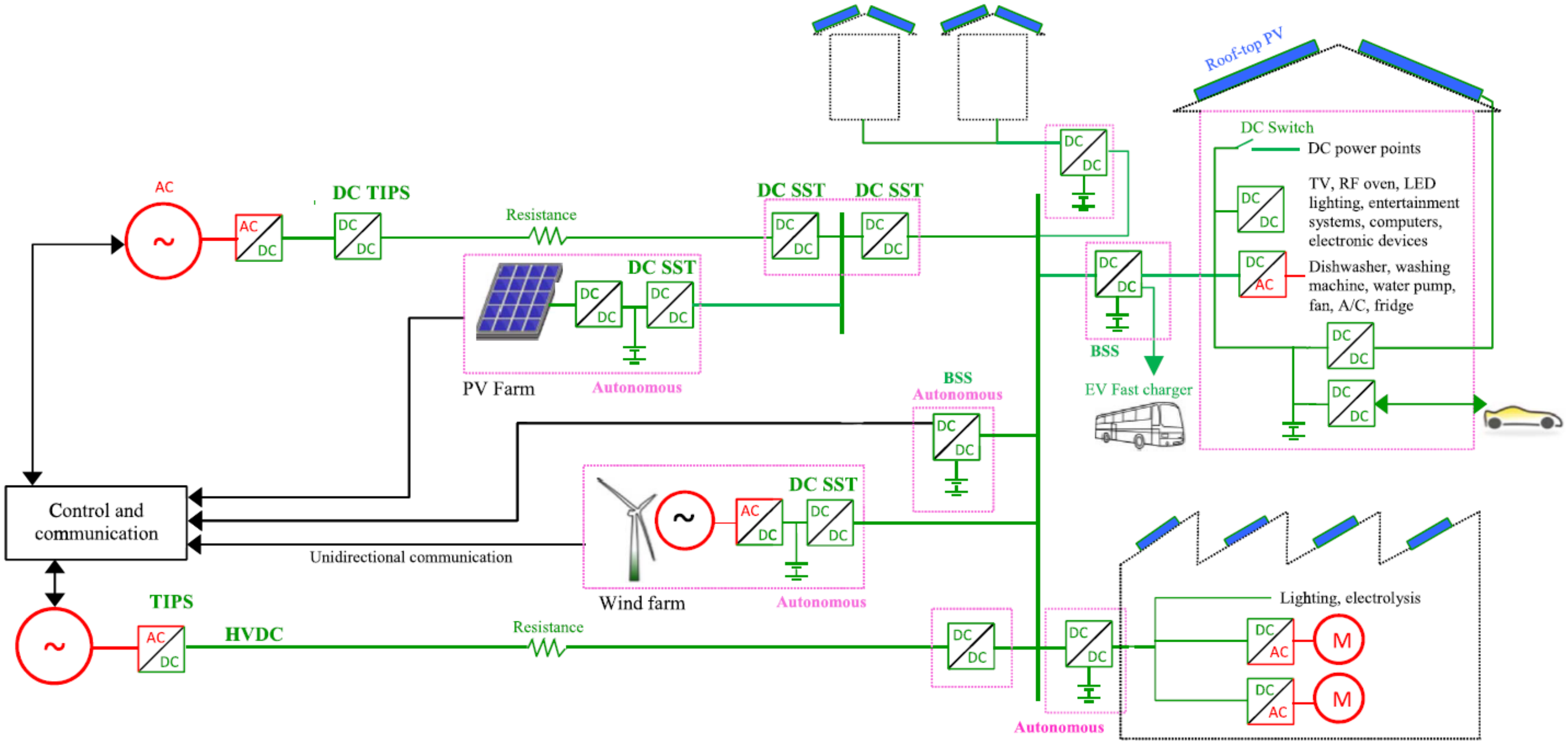
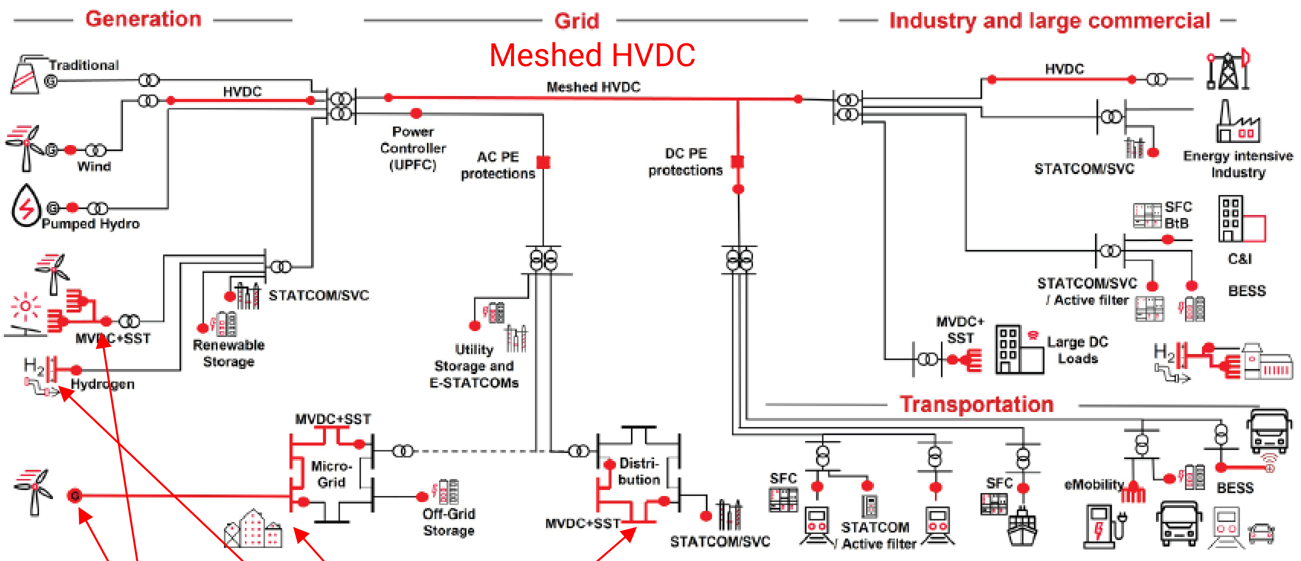
Proceedings of IEEE, Vol. 108, No. 5 May 2020



Hitachi ABB (August 2021)



MVDC for integrating generation

MVDC for Hydrogen production

MVDC

HITACHI ABB

HITACHI ABB POWER GRIDS

Power Electronics: Revolutionizing the world's future energy systems

August 2021

Powering Good for Sustainable Energy

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Papers on DC Home

9th International Conference on Power Electronics-ECCE Asia
June 1 - 5. 2015 / 63 Convention Center. Seoul. Korea

Design (
for Ho

DC Distribution Systems for Homes

Shreya Iyer, W G Dunford, Martin Ordonez
Dept. of Electrical & Computer Engineering
University of British Columbia
Vancouver, Canada
{siyer,wgd,mordonez }@ece.ubc.ca

C Research Center
ısung Electronics
Suwon, Korea
n@samsung.com

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for S

2014 IEEE I

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Appl

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Is DC's Place in the Home?

By Doug Houseman

Given changes in how people are using electricity, is an AC-only electrical system still the right option for a residence of the future? Conversion losses already are growing with wide use of consumer electronics, and they will get bigger still as photovoltaic and car-charging systems evolve. This is why experts are starting to seriously consider the prospect of hybrid AC/DC residential electrical systems.

According to the Energy Information Agency (EIA), the fastest growing portion of residential electricity use is consumer electronics and small appliances. In 1993, the EIA did not even bother (http://www.eia.gov/consumption/residential/data/1993) to measure the consumption in either category; eight years later it counted (http://www.eia.gov/emeu/recs/recs2001/enduse2001/enduse2001.html) over a dozen types of devices that fit in this category. By 2013, when a group of IEEE members audited their houses to get a snapshot of what they had, the list of categories expanded to over 50 small appliances and consumer electronics devices.

These devices primarily run on DC power. Even with improvements in power supplies, many of these devices have a conversion efficiency of no better than 80 percent (http://www.electronicproducts.com/Power_Products/Power_Semiconductors/Dc_dc_converter_efficiency_revisited.aspx) and some low-end devices have efficiencies as low as 65 percent in converting power. Such devices now account for between 15 and 30 percent of a
3)., depending on demographics, country and weather zone.

r Solar
ystem

IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 62, NO. 7, JULY 2015 4525

Effective Test Bed of 380-V DC Distribution System Using Isolated Power Converters

Myung-Hyo Ryu, *Member, IEEE*, Ho-Sung Kim, *Member, IEEE*, Ju-Won Baek, *Member, IEEE*, Heung-Geun Kim, *Senior Member, IEEE*, and Jee-Hoon Jung, *Senior Member, IEEE*

Faisalabad, Pakistan

Efficient Home Applianc

Miguel A. Rodríguez-Ot
Center for Power E
ical and Computer Engineering Depart
miguel.rodriguez.oterc

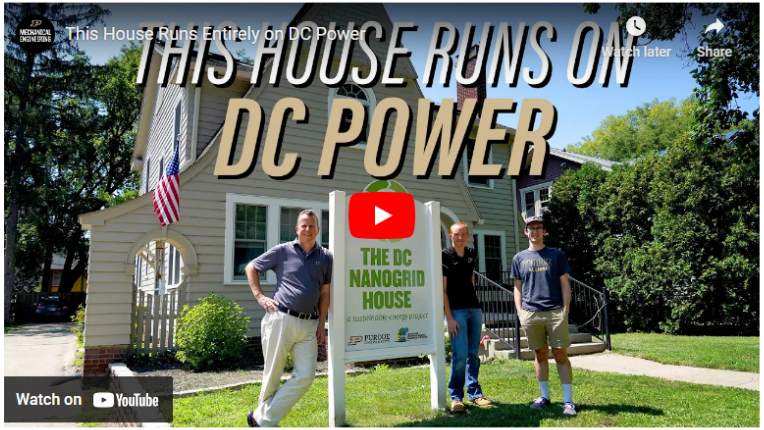
Power Distribution Systems for Future Homes

Po-Wa LEE and Yim-Shu LEE
Department of Electronic and Information Engineering
The Hong Kong Polytechnic University
Hung Hom, Kowloon
Hong Kong

Bo-Tao LIN
Department of Electronic Engineering
South China University of Technology
GuangZhou, 510641, China

Purdue house runs entirely on DC power: efficient nano-grid can be powered by solar panels, batteries or local utilities

Did you know there's a silent war going on inside your home? Alternating current (AC) electricity comes in from the grid, but many of your appliances and lighting run on direct current (DC). Every time you plug in a TV, computer or cell phone charger, power must be individually converted from AC to DC – a costly and inefficient process. Purdue University researchers have proposed a solution to the problem by retrofitting an entire house to run on its own efficient DC-powered nano-grid.



The project to transform a 1920s-era West Lafayette home into the DC Nanogrid House began in 2017 under the direction of Eckhard Groll, the William E. and Florence E. Perry Head of Mechanical Engineering, and

Why DC power?

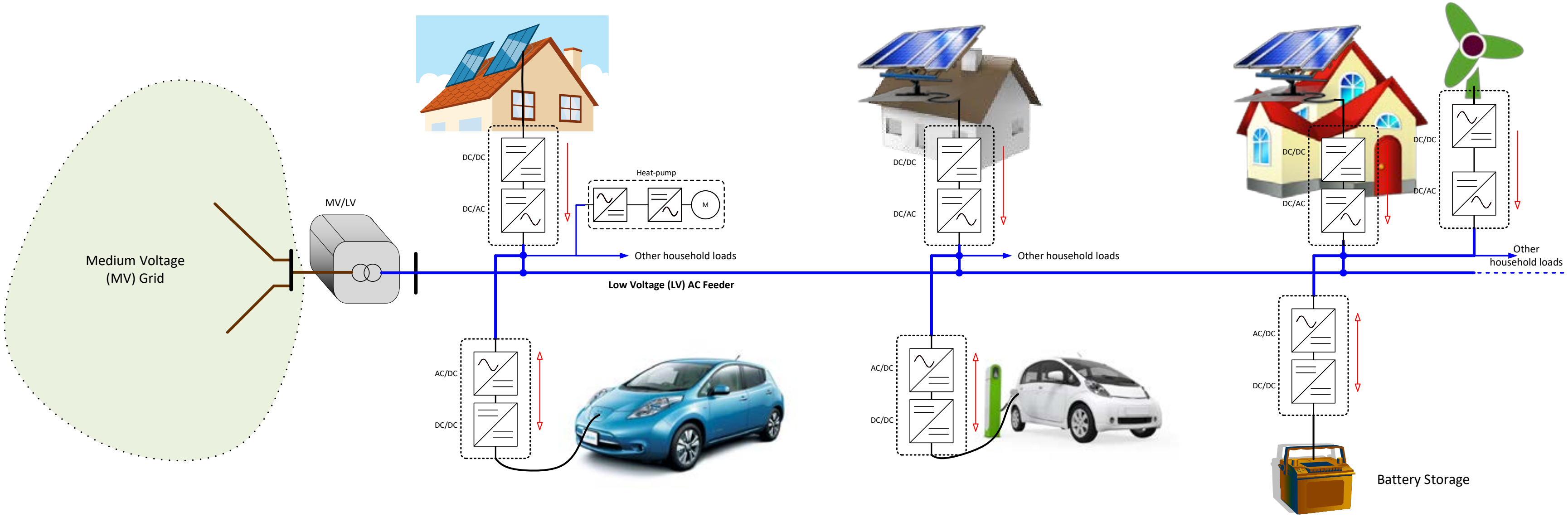
AC has been the dominant infrastructure in the world's electrical grids since the late 1800s, when the "war of the currents" saw Thomas Edison's dream of a DC-based electrical infrastructure lose out to George Westinghouse's AC system. But while the "war" may seem to be over, two recent developments have prompted researchers to re-investigate DC's benefits. The first is the increasing availability of renewable energy sources – solar panels and wind turbines – as well as energy storage in large home-based battery packs. These devices are all naturally DC, so to have a DC-based home infrastructure enables this energy to be delivered with almost no waste or inefficiency.

The second development is a series of extreme weather events, which have exposed the fragility of the U.S. electrical grid. Winter snowstorms in Texas, as well as extreme heat in the southwest, have caused brownouts and blackouts to become increasingly common.

"The United States grid is like one of those marble-balancing games where you tilt the table to keep the marbles from falling off. However, tilting in one direction to save one marble can cause the rest to come crashing down," Ore said. "When too many homes suddenly start requesting extra power for heating or air-conditioning, the grid can become severely unbalanced while trying to respond.

"A DC-house can potentially sustain itself for short periods of time by generating its own renewable energy and detaching from the grid through the help of on-site stored energy. This ultimately minimizes the strain on the outside grid in emergency situations. Events like the Texas storm are perfect illustrations of how a DC-house can benefit individuals and the community."

Low Voltage AC (LVAC) Distribution system



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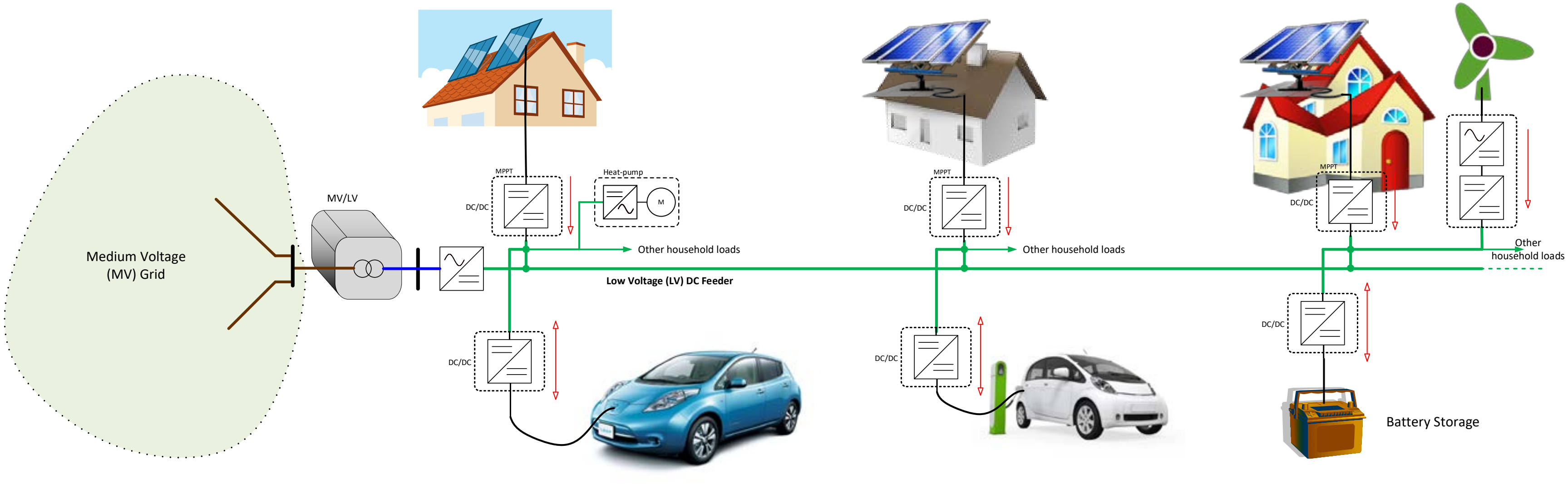
Low Voltage DC (LVDC) Distribution system



Medium Voltage DC Distribution Systems

Reference: 875

cigre
For power system expertise

July 2022

Technical Brochure

Received: 31 March 2022 | Revised: 12 May 2022 | Accepted: 22 May 2022 | High Voltage
DOI: 10.1049/hve2.12222

REVIEW

High voltage direct current transmission cables to help decarbonisation in Europe: Recent achievements and issues

Giovanni Mazzanti

Received: 3 April 2022 | Accepted: 26 May 2022 | High Voltage
DOI: 10.1049/hve2.12232

REVIEW

Insulating materials for realising carbon neutrality: Opportunities, remaining issues and challenges

Chuanyang Li[1,2] | Yang Yang[3] | Guoqiang Xu[2] | Yao Zhou[4] | Mengshuo Jia[5] | Shaolong Zhong[1] | Yu Gao[6] | Chanyeop Park[7] | Qiang Liu[8] | Yalin Wang[9,10] | Shakeel Akram[11] | Xiaoliang Zeng[12] | Yi Li[13] | Fangwei Liang[1] | Bin Cui[1] | Junpeng Fang[14] | Lingling Tang[15] | Yulin Zeng[15] | Xingtao Hu[16] | Jiachen Gao[17] | Giovanni Mazzanti[17] | Jinliang He[1] | Jianxiao Wang[18] | Davide Fabiani[17] | Gilbert Teyssedre[19] | Yang Cao[20] | Feipeng Wang[21] | Yunlong Zi[2,22,23]

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High Voltage Direct Current (HVDC)

HVDC-VSC Newsletter

September 2024

COBRAcable converter station in Denmark. Credit: Energinet

News p2-8

CIGRE WG B4.81 Releases a Key Technical Brochure

CIGRE TB 934 summary

Recent papers p9-10

A monthly list of research papers published

Overview of HVDC-VSC Systems p11-25

Operational systems

Future projects (details subject to change)

Gratitude

Many thanks to Kamran Sharifabadi, Convenor of the CIGRE WG B4.81, for his support on the TB#934 summary.

Many thanks to Niket Jain from Siemens Energy for his support on Indian projects.

For any comments and feedback, we kindly invite you to reach out to us via: HVDC@rte-international.com

→ Subscribe to RTEI's HVDC newsletter here ←

Power Electronics & Studies department

Editor: Markus Vor dem Berge
Author: Robin Lemaire, Magdalene Gleadow, Domagoj Hart
Reviewer: Mathieu Begrand
Support: Sébastien Dennetière

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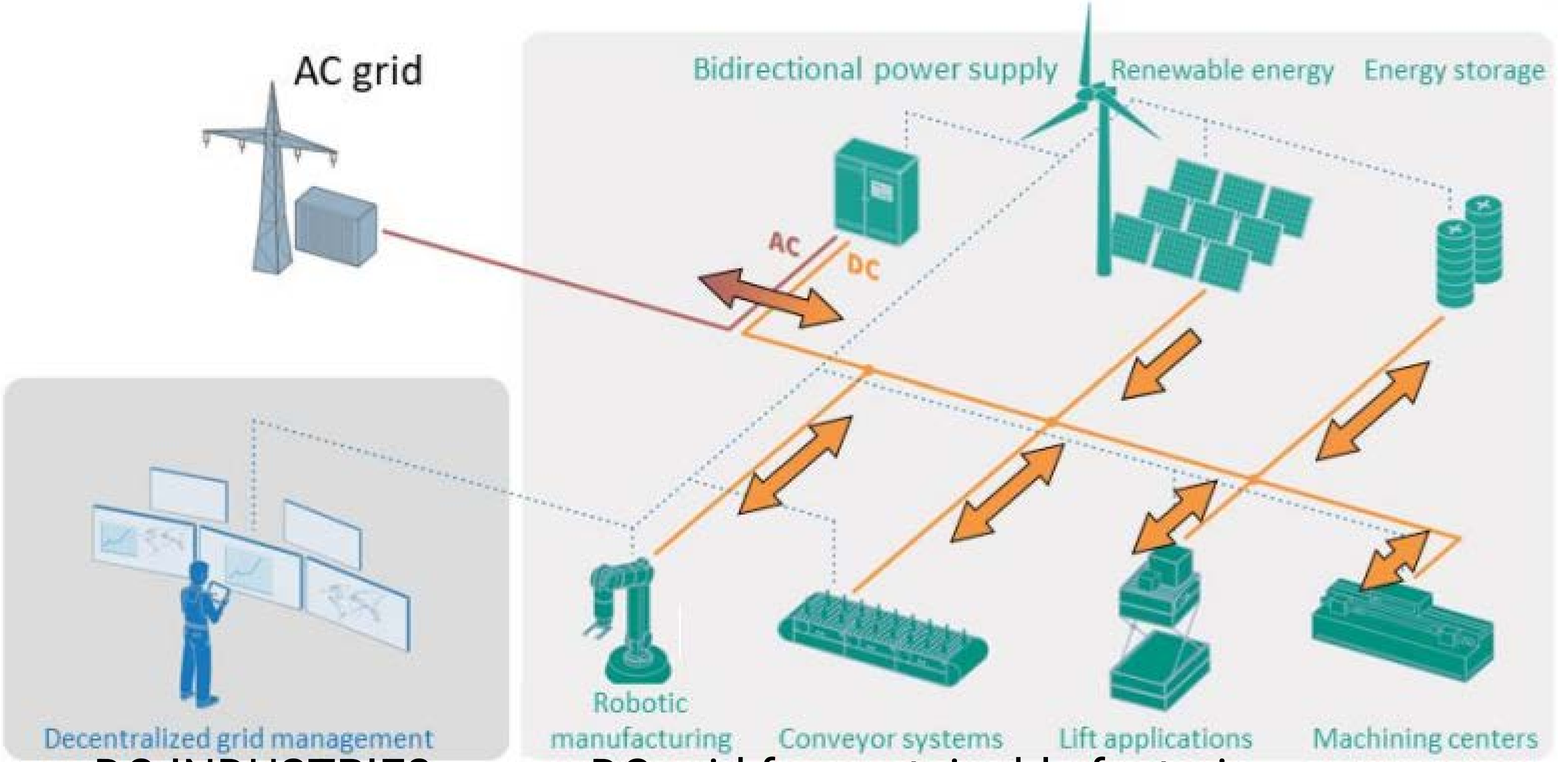
IEEE Transactions on Power Electronics Letters

- Special Section on *Highly Robust Power Electronics in the Era of DC Grid in* IEEE Transactions on Power Electronics Letters (TPEL).
- Open to Submission: 1 October 2024

DC related projects and research

1. Open DC Alliance (ODCA)
2. Technische Universität Dresden (AC2DC project)
3. Flexible Elektrische Netze (Flexible Electrical Networks) (FEN) hosted by RWTH Aachen University
4. Fraunhofer Institute for Integrated Systems and Device Technology IISB
5. New Energy and Industrial Technology Development Organisation (NEDO)
6. IEEE Power and Energy Society Committee on End-to-End Direct Current Power Networks
7. 20NRM03 DC Grids project, EMPIR (https://dc-grids.nl/)
8. IEC SyC LVDC (Low Voltage Direct Current and Low Voltage Direct Current for Electricity Access)
9. EU Horizon projects
10. European Metrology Networks (EURAMET), DC Grids and Applications (https://www.euramet.org/smart-electricity-grids/themes/dc-grids-and-applications)

Open DC Alliance (ODCA)



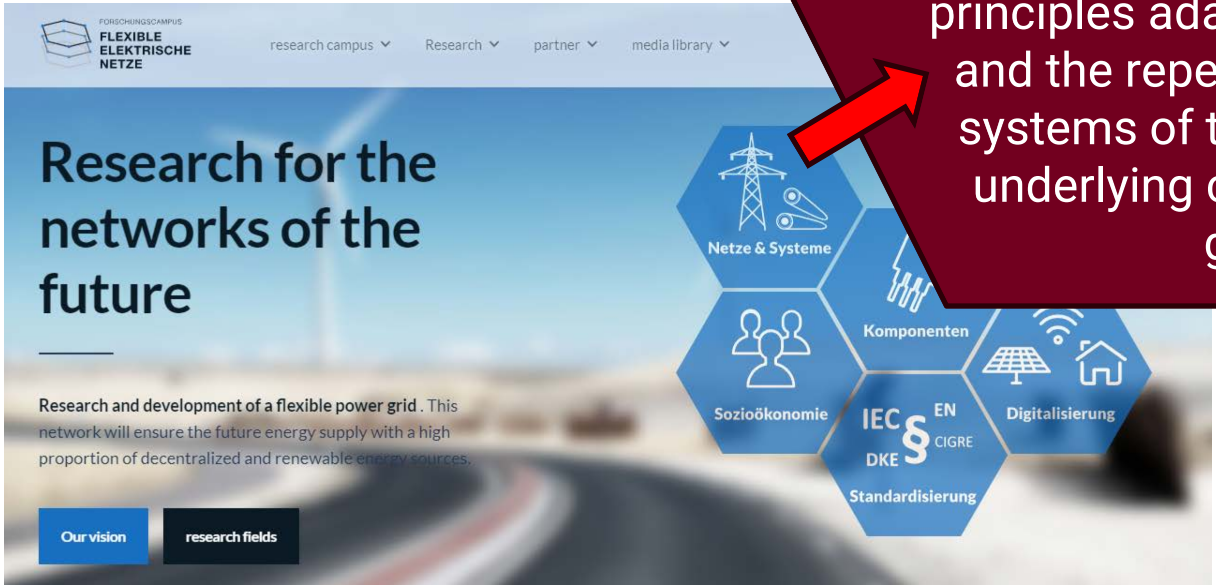
DC-INDUSTRIE2 - open DC grid for sustainable factories

Other Research Program

FEN project – Flexible Elekt

https://www.fenaachen.n

RWTH Aachen University



The scientists at FEN research campus are;
i) researching procedures and methods for the planning and operation of pure DC or hybrid grids (DC and AC grids).
ii) determining the planning principles adapted for DC grids, and the repercussions on the systems of the overlying and underlying conventional AC grids.

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Technische Universität Dresden

- AC2DC project

[concepts and their feasibility for operating DC distribution networks for LV and MV]

[1] S. Krahmer *et al.*, "Conversion of Existing AC into DC Cable Links in Distribution Grids: Benefits and Challenges," ETG Congress 2021, Online, 2021, pp. 1-6.

DC Grids at Fraunhofer IISB

- https://www.iisb.fraunhofer.de/en/research_areas/intelligent_energy_systems/DC-grids.html
- Fraunhofer Institute for Integrated Systems and Device Technology IISB

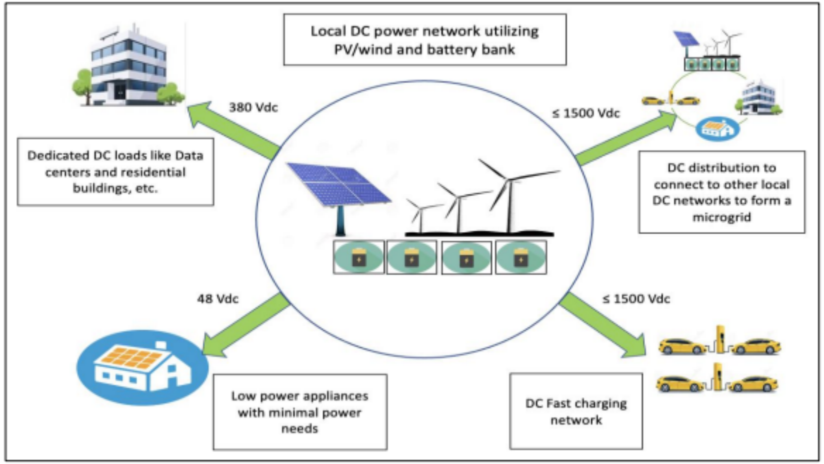
Concept Diagram

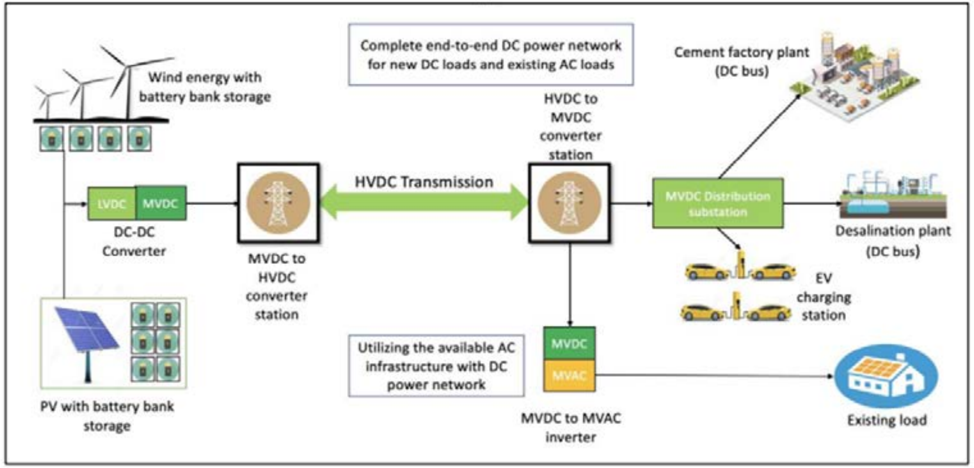
New Energy and Industrial Technology Development Organization

第 4. 2. 2 図　直流利活用の 2050 年のイメージ例

DC power technology and utilisation in the future.

IEEE Working Group on Direct Current Power Networks





Advertisement for researchers 5 Sept. 2024

We are searching for a PhD candidate with background on power system modelling and optimization in the course of the Horizon Europe research project "DAEDALOS - Development, integration, and demonstration of Advanced software tools in SCADA systems for combining Teslas and Edisons world to realize high, medium and low voltage hybrid AC/DC grids". In particular, the successful candidate is expected to further advance existing open-source AC/DC grid optimization models to be used for the grid planning and operation in the industrial context

electrical energy. Topics covered are smart grids, reliable power systems with high penetration of renewable energy sources, HVDC and LVDC, energy markets, integration of renewable energy sources on transmission and distribution. Seven professors lead the group. They manage the

end, algorithmic approaches will be used to complement mathematical optimization methods. The position is situated in the recently established Energy Transmission Competence Hub – ETCH within EnergyVille, facilitating research HVDC and underground cable competence centre.

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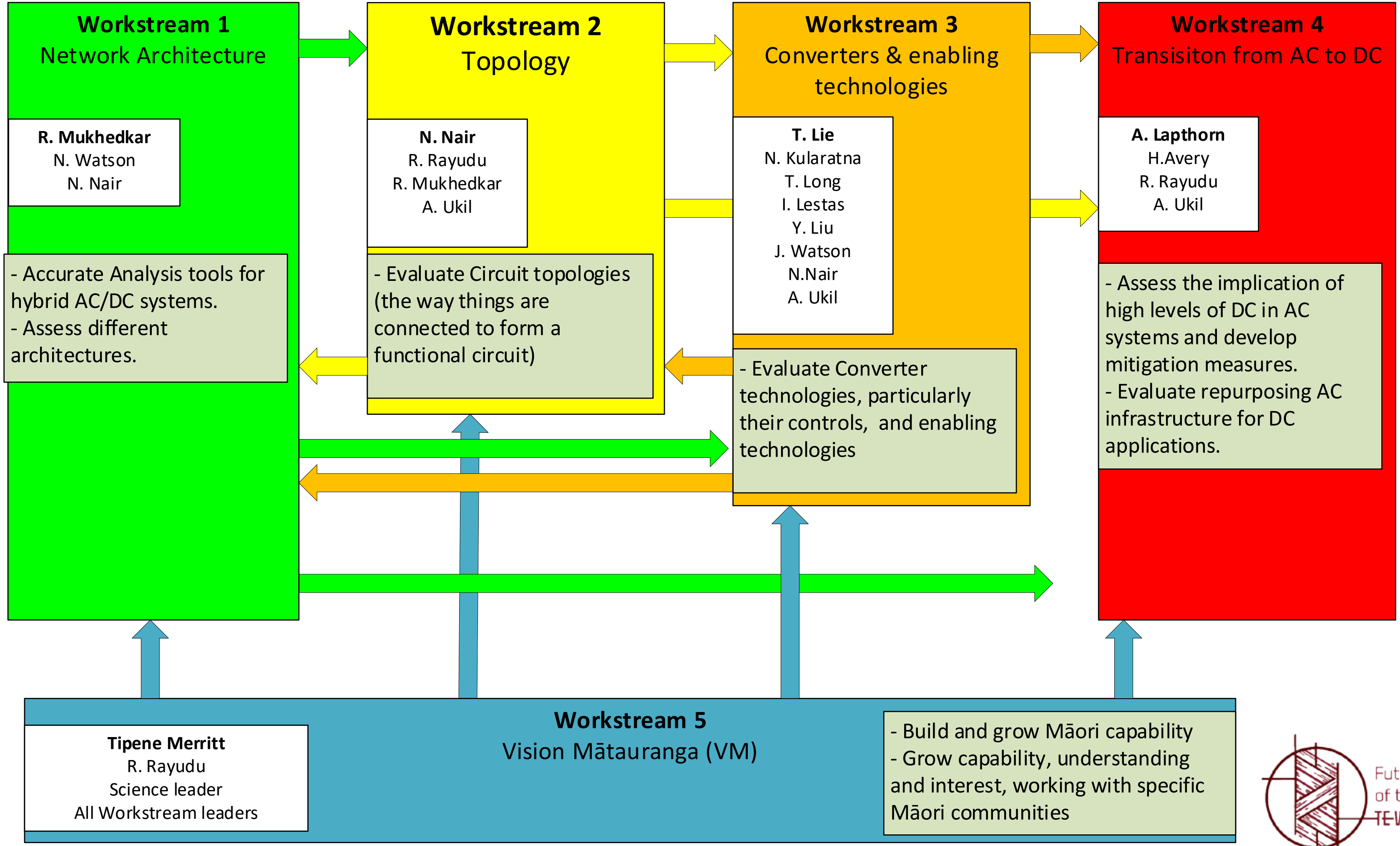

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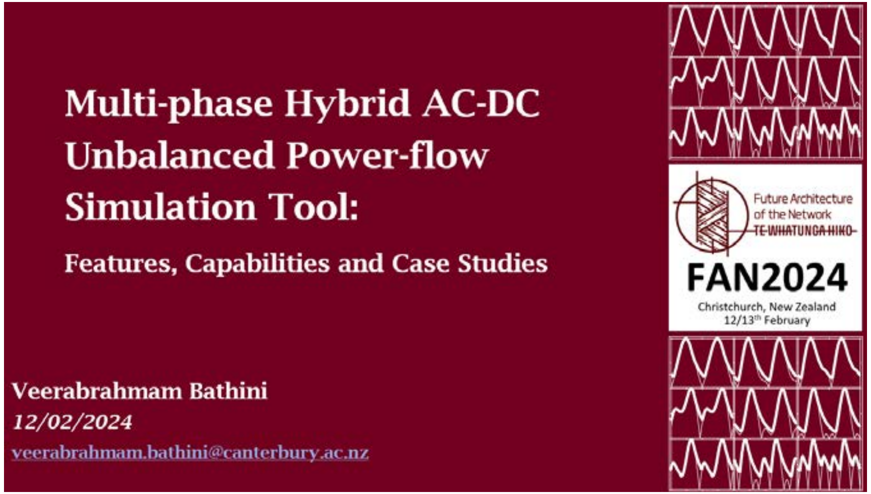
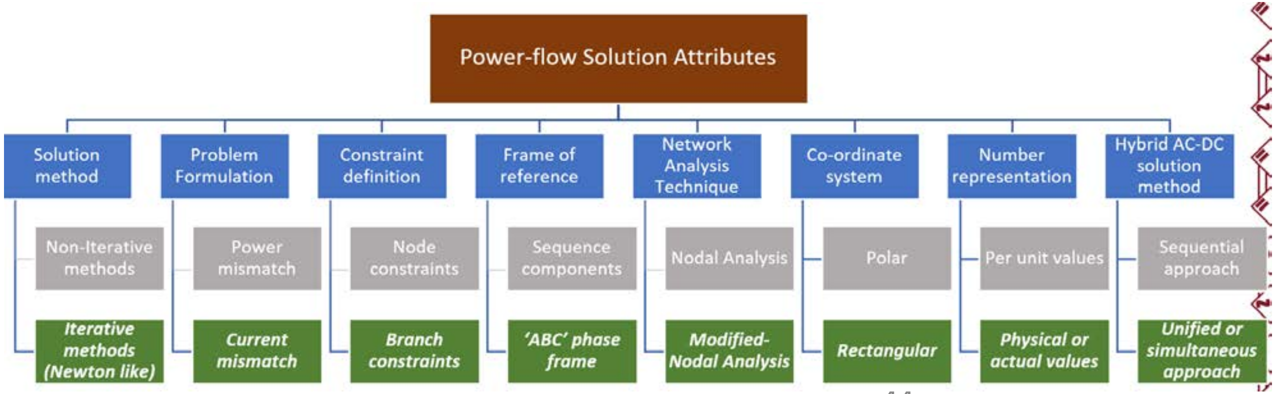
Workstream 1





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Workstream 2

8306 IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS, VOL. 20, NO. 6, JUNE 2024

Complex Domain Analysis-Based Fault Detection in VSC Interfaced Multi-terminal LVDC System

Dongyu Li, *Member, IEEE*, Abhisek Ukil, *Senior Member, IEEE*, and Gen Li, *Senior Member, IEEE*

Tripping Sequence Approach to Redı to be Interrupted in LVDC Microgrids

Sze Nin Yim, Tran The Hoang, Nirmal-Kumar C Nair, and Abhisek Ukil
Department of Electrical, Computer, and Software Engineering
University of Auckland, Auckland, New Zealand
wavenyim@gmail.com (SN. Yim), tran.the.hoang@auckland.ac.nz (Tran T. Hoang),
n.nair@auckland.ac.nz (N. Nair), a.ukil@auckland.ac.nz (A. Ukil)

ːsearch
ı91

ve assessment for hybrid /DC networks

Comparison of Low-Voltage AC and DC Distribution Networks for EV Charging

Wayne Huynh, Tran The Hoang, Abhisek Ukil, and Nirmal-K
Department of Electrical, Computer, and Software Engineeri
University of Auckland, Auckland, New Zealand
whuy461@aucklanduni.ac.nz (W. Huynh), tran.the.hoang@auckland.ac.nz
a.ukil@auckland.ac.nz (A. Ukil), n.nair@auckland.ac.nz (N-K. C

Multilayer Networks Framework Concept applied to Hybrid MV AC/DC Network Topologies

André N Cuppen 0000-0001-8206-7097
Tran The Hoang 0000-0002-5016-0059
Nirmal-Kumar C Nair 0000-0002-8456-3999
Abhisek Ukil 0000-0003-3100-7865
Department of Electrical, Computer, and Software Engineering, University of Auckland, Auckland, New Zealand

fault current capability of generation

Published in 2023

Workstream 3

Preliminary expe
process in a DC ci

Chamara Dassanayake[1], Nihal Kularatn
University
Email: cd173@students.waikato.ac.nz
[2]School of Engineering

Optimal Coordinated Control Strategy of Clustered DC Microgrids under Load-Generation Uncertainties Based on GWO

by Zaid Hamid Abdulabbas Al-Tameemi [1], Tek Tjing Lie [1,*], Gilbert Foo [1] and Frede Blaabjerg [2]

and Industrial Converters and Enabling Technologies

Review

Control Strategies of DC Microgrids Cluster: A Comprehensive Review

Zaid Hamid Abdulabbas Al-Tameemi [1], Tek Tjing Lie [1,*], Gilbert Foo [1] and Fre

Review

Current Context and Research Trends in Linear DC–DC Converters

Control Strategies and Stabilization Techniques for DC/DC Converters Application in DC MGs: Challenges, Opportunities, and Prospects—A Review

by Aphrodis Nduwamungu [1], Tek Tjing Lie [1,*], Ioannis Lestas [2], Nirmal-Kumar C. Nair [3] and Kosala Gunawardane [4]

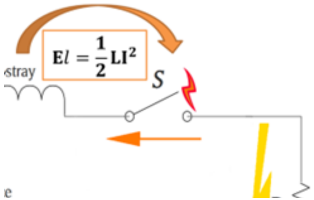
1 School of Engineering, Mathematics, and Computer Sciences, Auckland University of Technology, Auckland 1120, New Zealand
2 Department of Engineering, Information Engineering, University of Cambridge, Cambridge CB2 1TN, UK
3 Faculty of Engineering, Department of Electrical, Computer and Software Engineering, University of Auckland, Auckland 1010, New Zealand
4 School of Electrical and Data Engineering, University of Technology Sydney, Sydney 123, Australia
* Author to whom correspondence should be addressed.

Enhanced Grid-tie Converter Control Under Unbalanced Conditions with no PLL

Optimal Power Sharing in DC Microgrid Under Load and Generation Uncertainties Based on GWO Algorithm

Zaid Hamid Abdulabbas Al-Tameemi, Tek Tjing Lie, Gilbert Foo
Department of Electrical and Electronic Engineering
Auckland University of Technology, New Zealand
email:jxy3030@autuni.ac.nz, {tek.lie, gilbert.foo}@aut.ac.nz

Frede Blaabjerg
Department of Energy Technology
Aalborg University, Denmark
email: fbl@et.aau.dk



Auckland University of Technology
Mehdi.Moradian@autuni.ac.nz
Auckland University of Technology
Tek.Lie@aut.ac.nz
University of Technology Sydney
Kosala.Gunawardane@uts.edu.au

Abstract— This article presents a novel design for mechanical DC circuit breakers (M-DCCB) that aims to address the switching effect associated with the open circuit phenomenon in DCCBs. Previous techniques have focused on the protection of DCCBs, but certain weaknesses in design and performance have been identified. This article aims to contribute by emphasizing the significance of shock absorption through the supercapacitor (SC) bypassing in DCCBs and assessing a novel approach called SC-based Bypass Technique (SCBT). The proposed technique is thoroughly discussed, offering improvements to overcome the limitations of existing model. The objective is to verify the secure and stable operation of the proposed model in effectively mitigating the bypassed switching effects. By incorporating the SC as a shock absorber, the new design aims to enhance the overall performance and reliability of the M-DCCB.

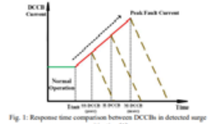


Fig. 1: Response time comparison between DCCBs in detected surge mitigation [1]

A significant drawback of M-DCCBs is the generation of large

Electronic Converters

Angaline Krishna
Department of Electrical & Electronic Engineering
Auckland University of Technology(AUT)
Auckland, New Zealand
vyq8464@autuni.ac.nz

Kosala Gu
Department of Electrical & Ele
Auckland University
Auckland,
kosala.gun

A Lyapunov-based nonlinear direct power control for grid-side converters interfacing renewable energy in weak grids ☆

Hailong Wang, Jeremy D. Watson, Neville R. Watson

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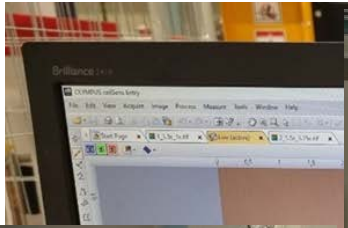
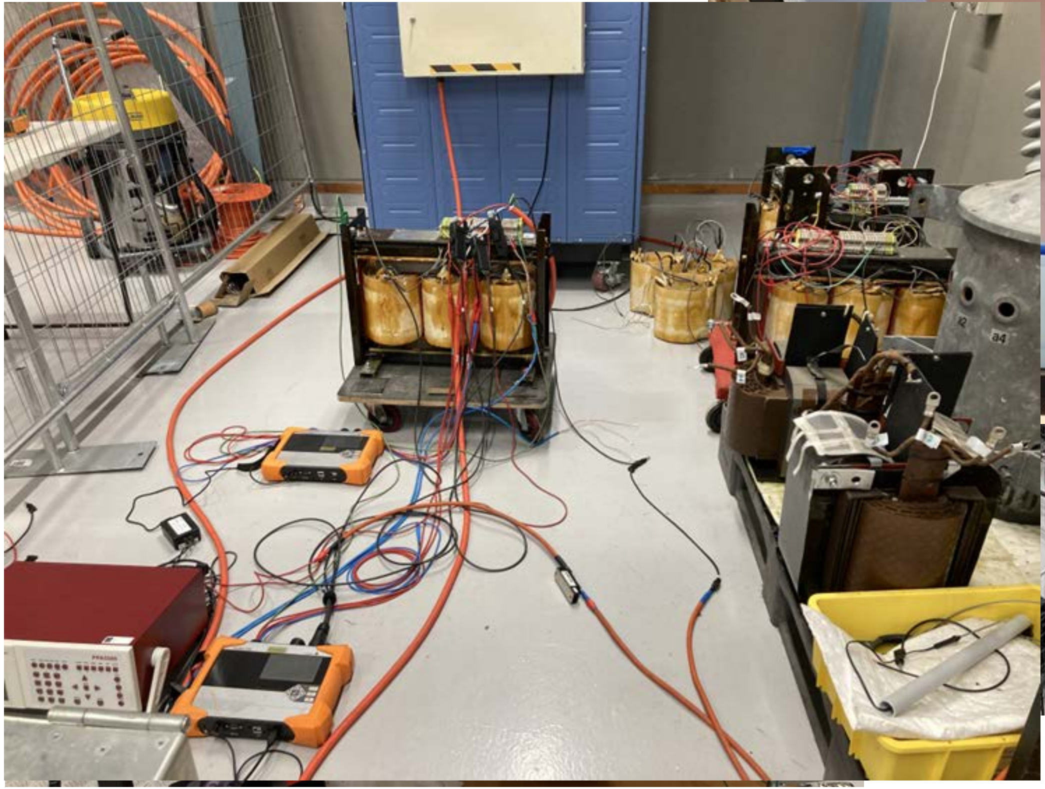
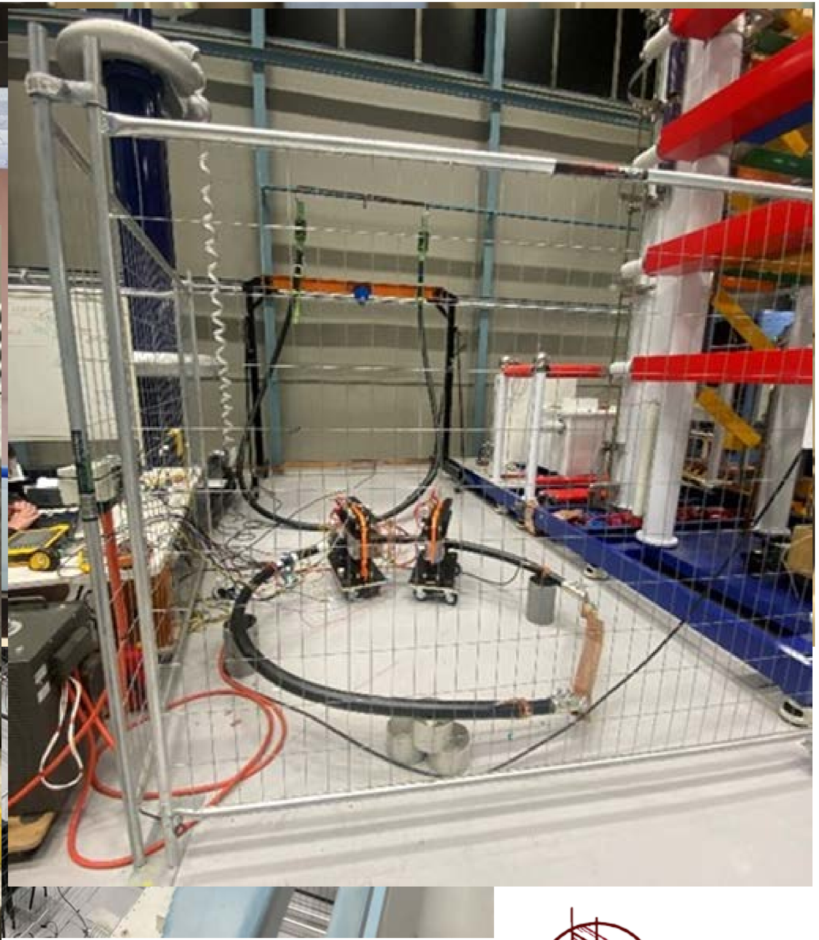
Workstream 4







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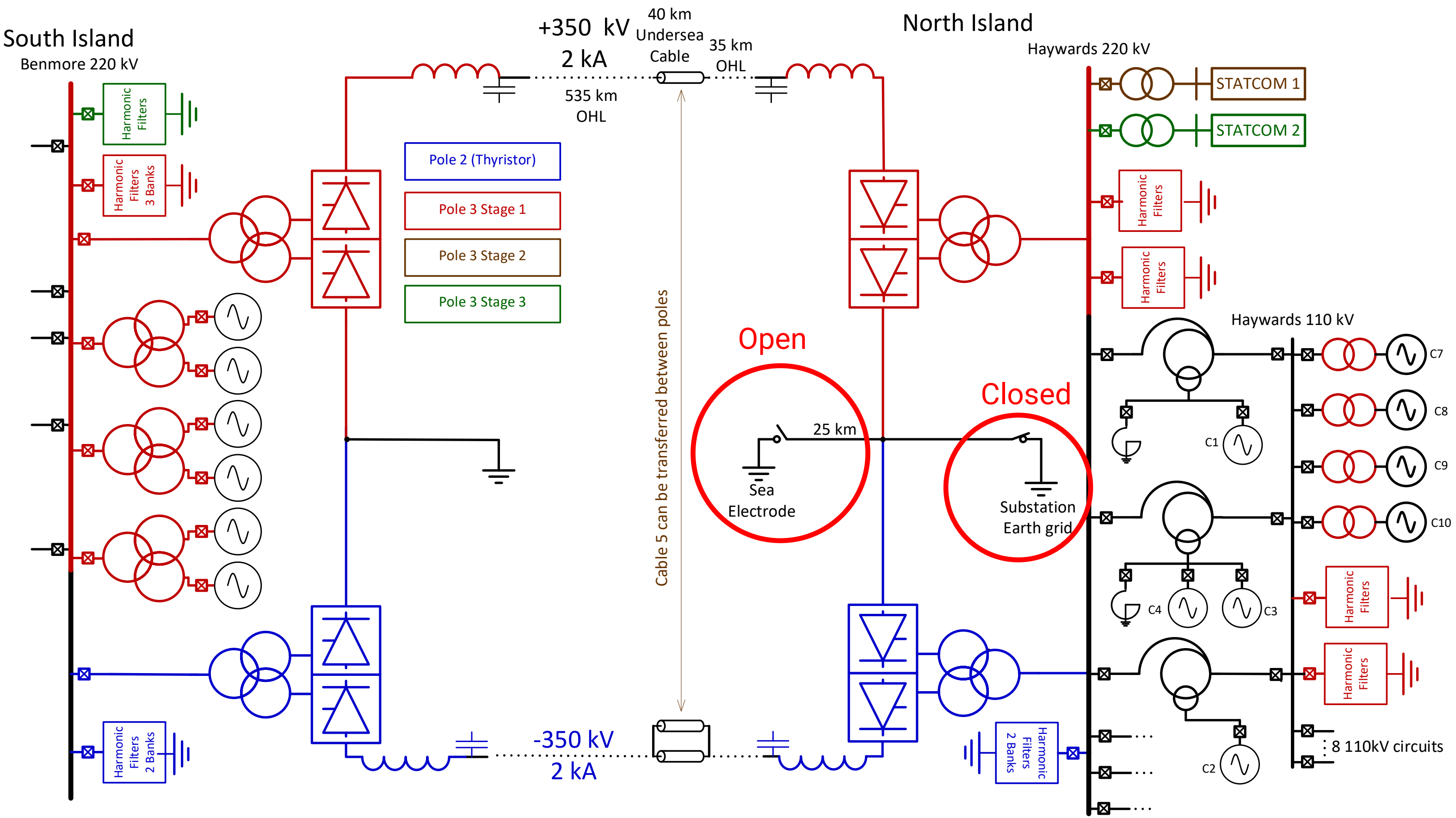
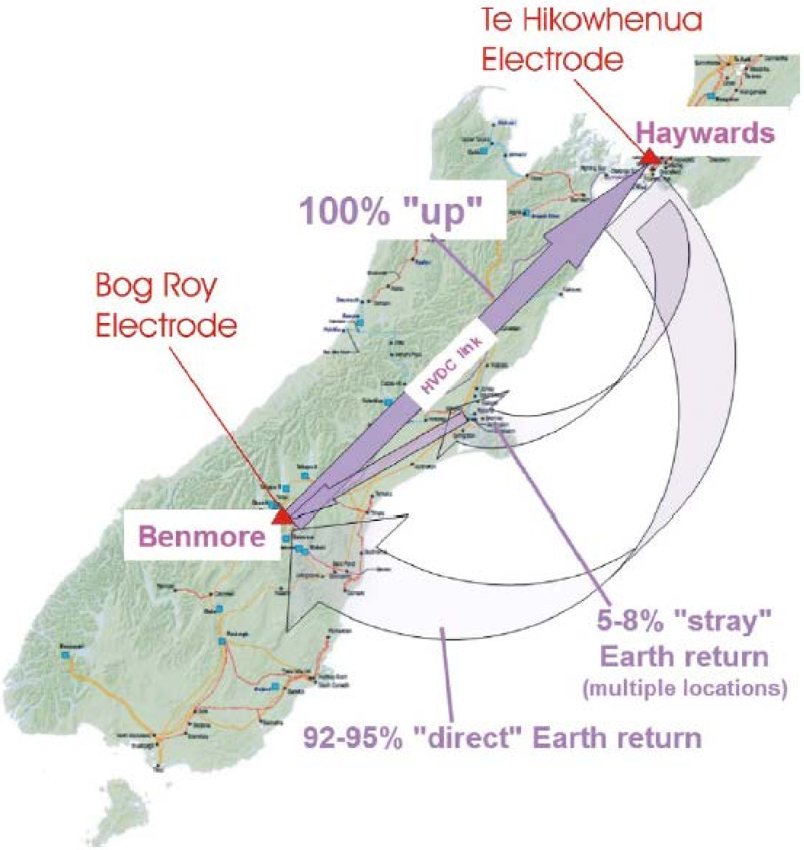
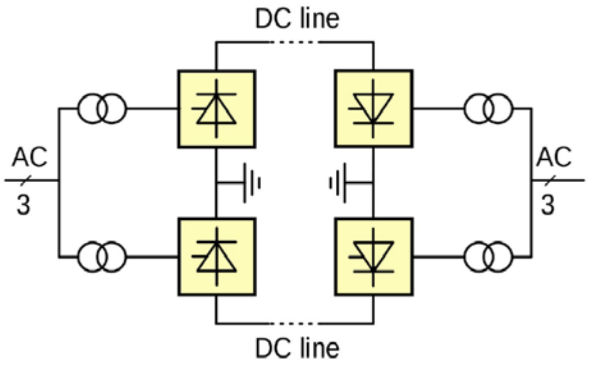
Haywards DC Injection Tests



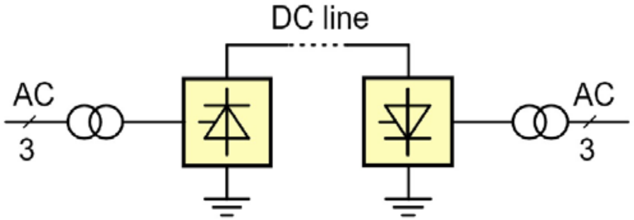
WS4 - DC Injection Test of Transformer



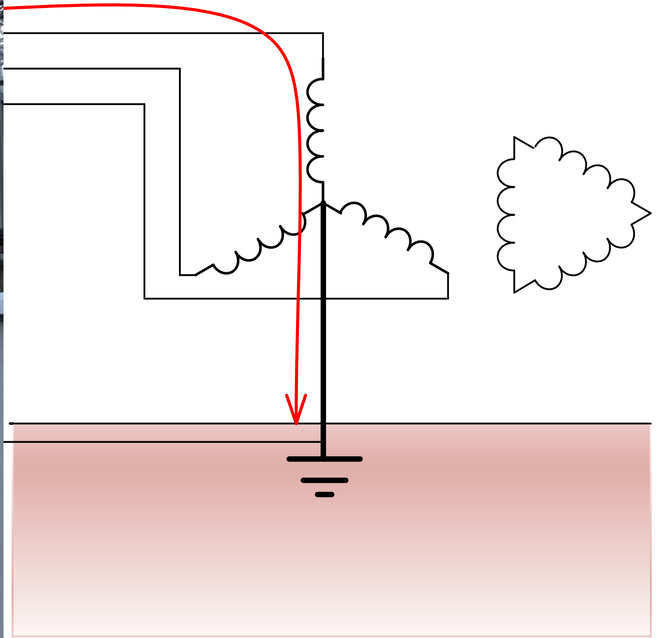
Normal Configuration



Atypical operation



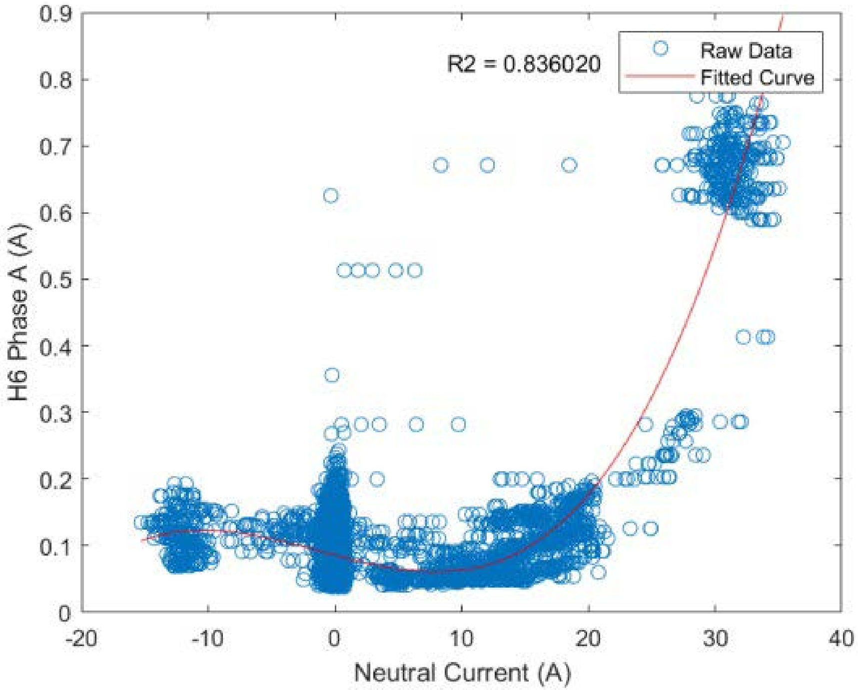
Haywards DC Injection Tests



DC injection tests (Ja)

WS4 - DC Injection Test of Transformer

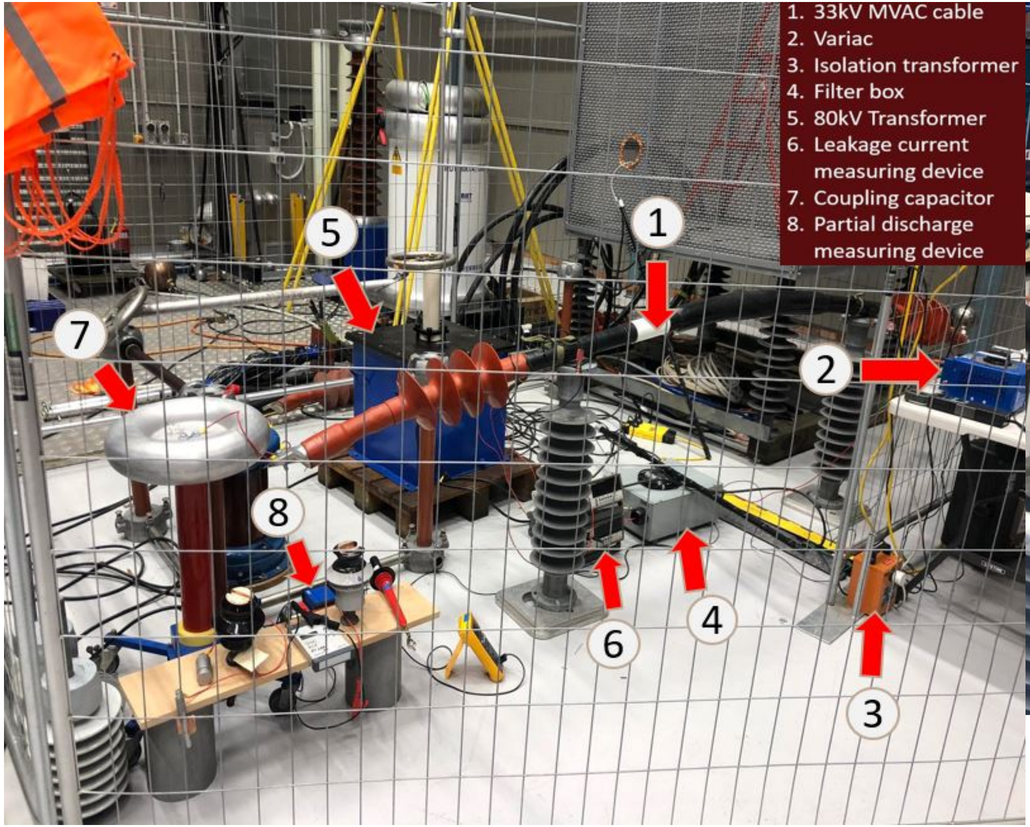
Testing in early 2023.



January 2023
DC injection tests

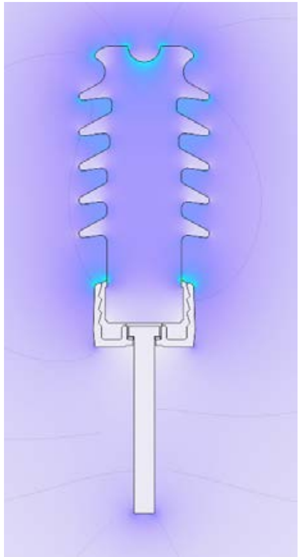
Repurposing AC Equipment: 33 kV Cable testing

19/33kV 800mm^2 MV AC XLPE cable

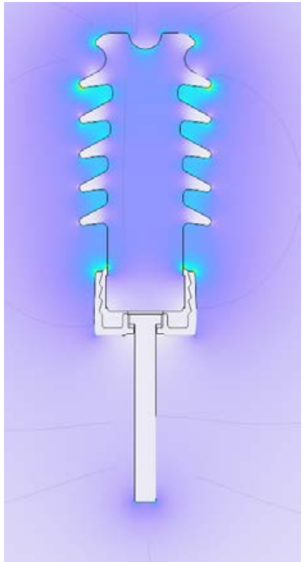


Insulator testing

Finite Element Modelling (COMSOL)



- Electric Field around insulator



11kV insulator with AC excitation*

11kV insulator with DC excitation *

* Dry AC flashover voltage as specified by the manufacturer

Future Architecture of the Network TE WHATUNGA HIKO

Workstream 5

THE PROGRAMME OVERVIEW

AIM: The Future Architecture of the Network (FAN) | Te Whatunga Hiko aims to develop a programme intended to be hosted by the Canterbury Museum.

ry aged tamariki from Māori
interests in STEMM (Science,
& Mātauranga).

spark'

NGĀ MIHI NUI FOR GUIDING THE WAKA ON THIS JOURNEY

MŌ TĀTOU, Ā, MŌ KĀ URI Ā MURI AKE NEI

Canterbury Museum

Future Architecture of the Network
TE WHATUNGA HIKO

Summer student project to develop an outreach programme for young children.

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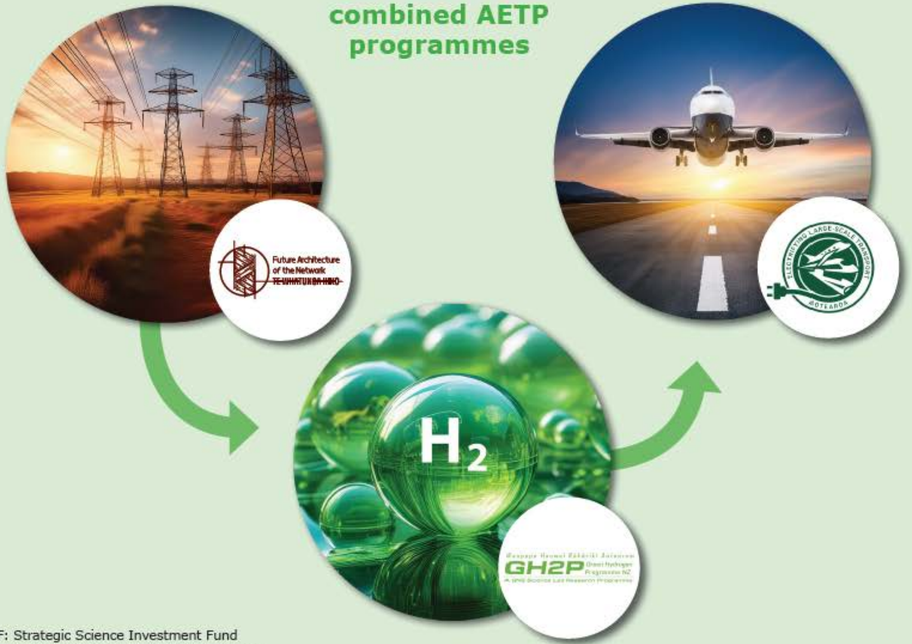
Training the Next Generation

Research and developing capability:

- Five Masters students (of which 2 have completed)
- Five Postdoctoral fellows
- Eighteen Ph.D. students plus two Ph.D. students related to but not funded by FAN. One Ph.D. has completed and seventeen are still pursuing their Ph.D. studies.
- Forty summer students (plus thirteen student projects currently being advertised for summer 2024-2025)
- Sixty-two undergraduate student projects
- Two interns from overseas
- One postgrad cert. student (completed)
- UC Tech. Boot camp (outreach to Māori and Pasifika students) Feb. 2024.

Aotearoa's leading teams working together **toward 2050** enabling **green energy** to provide **green transport**

Aotearoa's SSIF's combined AETP programmes



SSIF: Strategic Science Investment Fund
AETP: Advanced Energy Technology Platform

Keystone Partners

- GNS Science Te Pū Ao
- UC University of Canterbury Te Whare Wānanga o Waitaha Christchurch New Zealand
- Victoria University of Wellington Te Herenga Waka

Team Members (NZ)

- Callaghan Innovation Te Pokapū Auaha
- Ara
- Manukau Institute of Technology
- EPECentre
- The University of Waikato
- Te Whare Wānanga o Awanuiārangi
- MacDiarmid Institute
- Venture Taranaki
- Ara Ake
- AUT University
- University of Auckland Waipapa Taumata Rau New Zealand
- University of Otago

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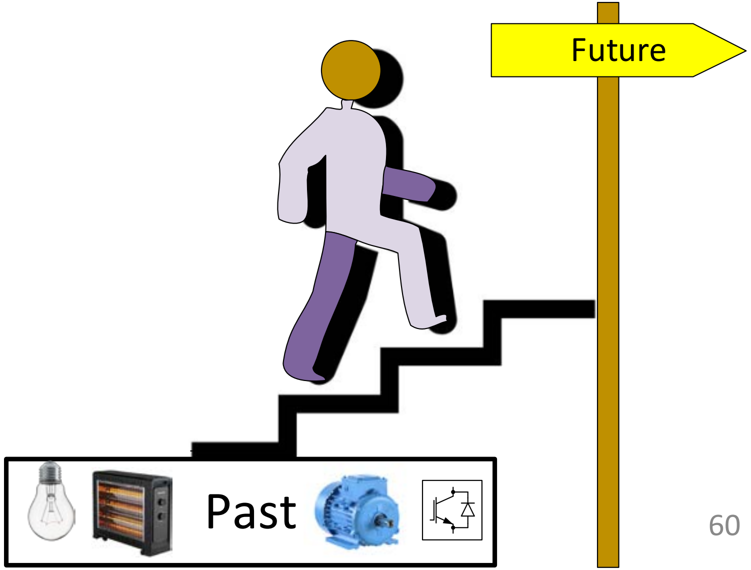
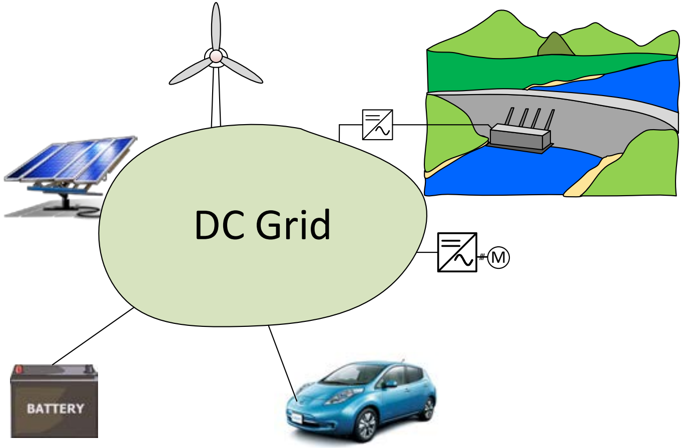
Conclusions

1. We are moving to a DC world
2. Many advantages and also many challenges to overcome.





Conclusions (continued)

3. DC will have a very important role in the future power system due to the energy transition underway and the technology available.
4. The vision for the Future Architecture of the Network programme (FAN) has been reinforced by the subsequent abundance of international activity on DC systems.
5. Although initial progress on the FAN programme was slow due to COVID, significant research momentum has now been achieved.

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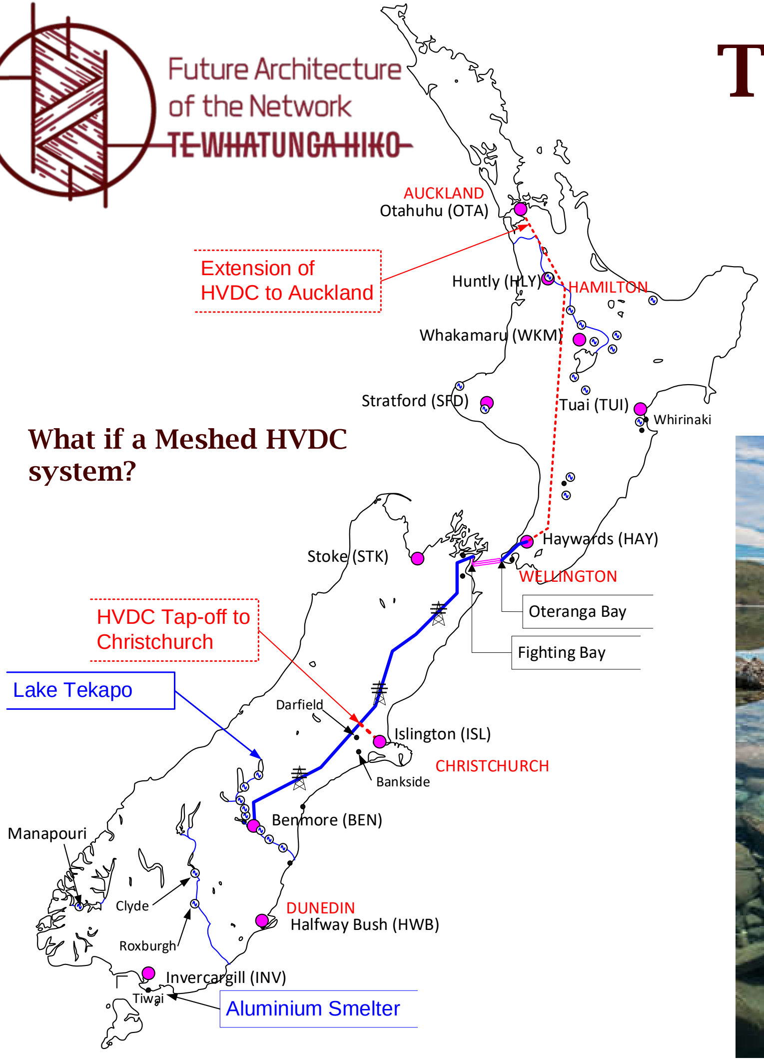
Thank you for your attention!

Questions?

What if a Meshed HVDC system?



Website: www.fan.ac.nz

By Krzysztof Golik - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=64777520