National Science Challenges

RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

RNC Meeting

9th May 2022

Location-Based Strategies to Support the Electrical Power System Resilience During HIW

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Content

Introduction

This project is associated with exploring resilience impact assessment methods for regional electricity networks, using high-resolution high-impact weather scenarios, to help develop post impact recovery management and through some known case studies explore if any additional extra pre-preparatory information could have been extracted for future use.

Built Environment Theme

1. Horizontal Infrastructure
2. Vertical Infrastructure
3. Integrated Scenario

Weather and Wildfire

1. Hazard modelling
2. Extreme scenarios
3. Hazard mitigation

Assessment of Electricity System Impacts and Management Strategies Pre- and Post- HIW Events: Northland-Auckland-Waikato Weather Scenario

Horizontal Infrastructure

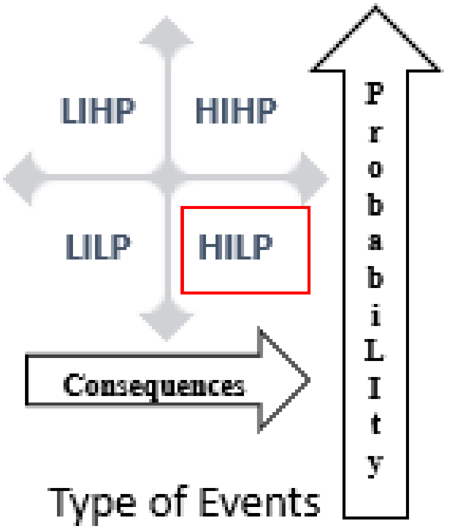
- *Models for infrastructure component performance across a range of natural hazards.*
- *Expanded geographic coverage and capabilities of infrastructure network models.*
- *High resolution regional and urban interdependency models.*
- *Decision making and rating tools for infrastructure.*

Different types of Weather Events

Hazardous Events described by NIWA

- Coastal hazards
- Planning for coastal adaptation
- Sea levels and sea-level rise
- Storm-tide red-alert days in 2021
- Coastal storm inundation
- Droughts
- Extreme weather - heavy rainfall
- Extreme weather - winds and tornadoes
- Floods
- Marine geological hazards
- Risk and vulnerability
- Snow and avalanches
- Tsunami
- Waves

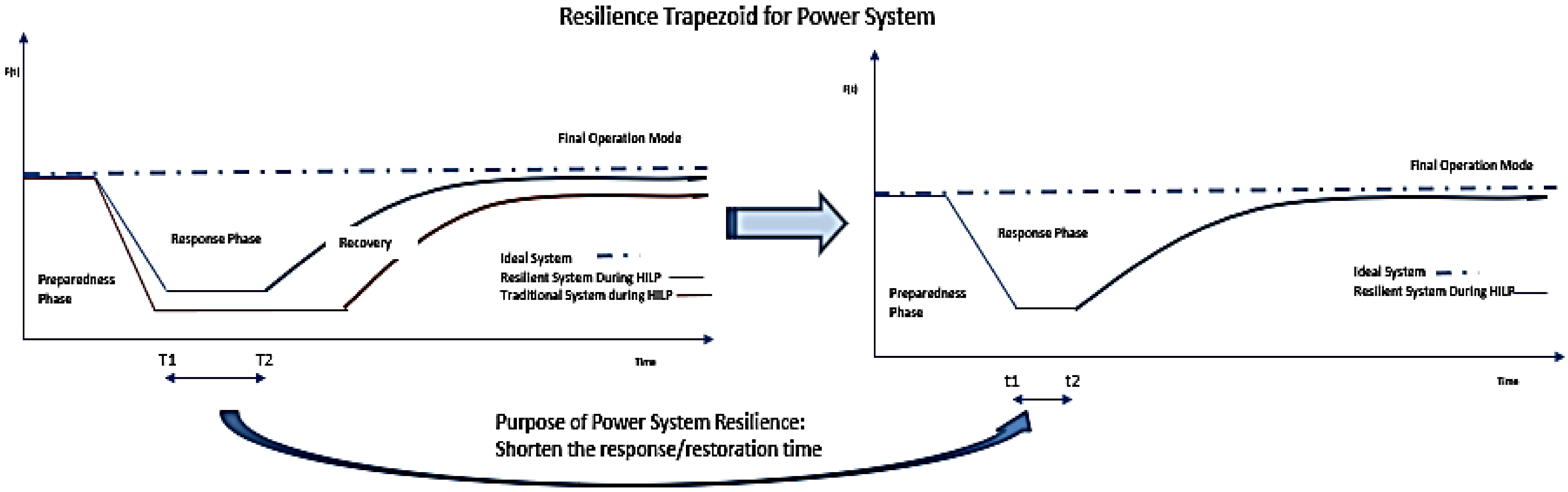
Events Based on Probability and Impact



High Impact Weather Events

- Tornado: clouds, strong wind, rain, hail.
- Hurricane or cyclone: strong wind, heavy rain.
- Blizzard: heavy snow, ice, cold temperatures.
- Dust storm: strong winds, arid conditions.
- Flood: heavy rainfall.
- Hail storm: cold or warm temperatures, rain, ice.
- Ice storm: freezing rain.

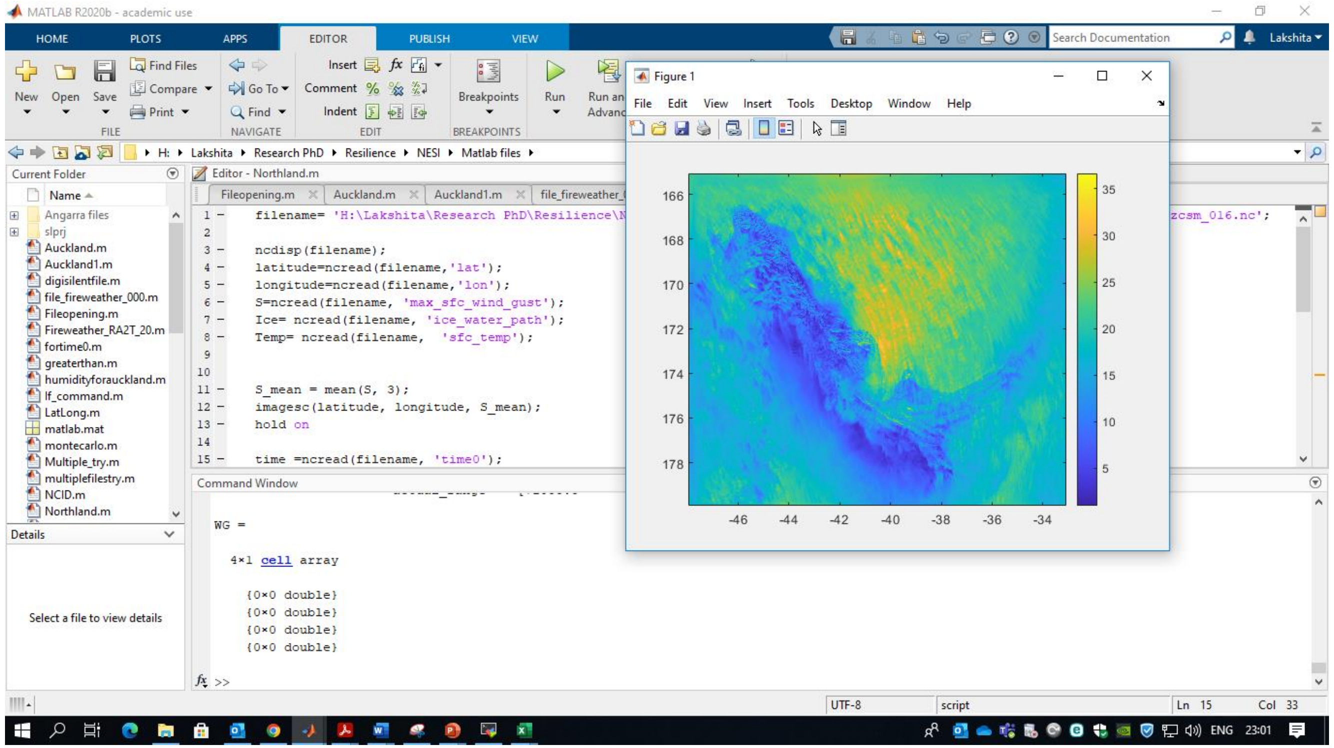
Power System Resilience : Trapezoid



Data Analysis Process

Opening in MATLAB

Data Sets	Folders: YearMonthDate	No. of files
Fire weather	20170213T00	130
	20180104T00	130
	20190205T00	130
	20200922T00	130
	20201003T12	130
Winter-Storm	20110723T12	98
	20110814T00	98
	20120605T06	98
	20130619T12	98
	20160805T12	98
	20190803T12	98



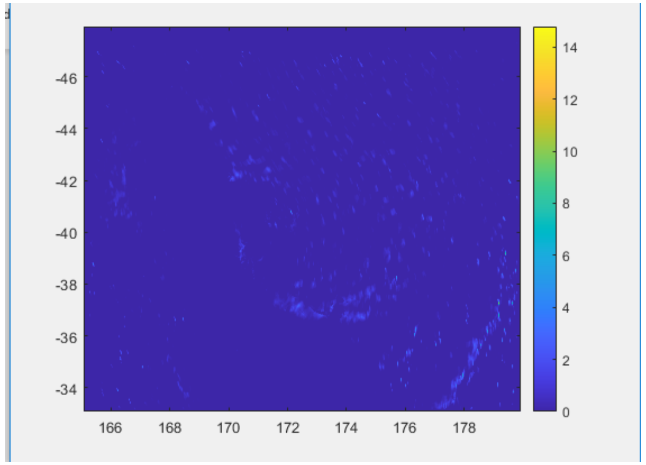
Files have been extracted from NESI via NIWA, Total Size on Disk = 1TB
There are 2 folders for every year folder as mentioned above
RA2M: Regional atmosphere 2 mid altitude
RA2T - Regional atmosphere 2 tropical

Weather Data Analysis: NetCDF file data

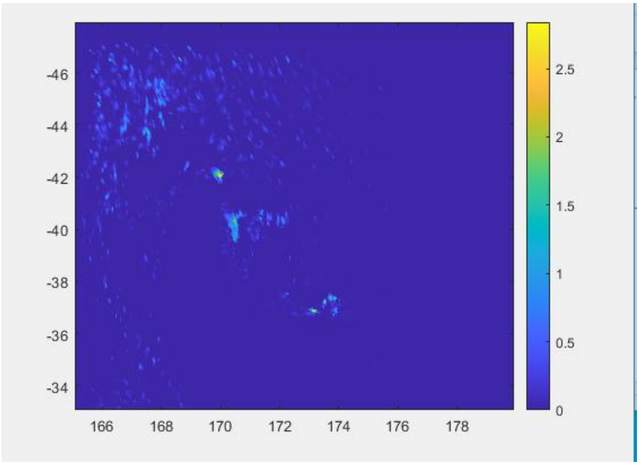
Consequences	RA2M-nwpsfc_2020092200-utc_nzcsm_020.nc	Data range	Unit
Rain can also cause short circuit	sum_rain_amount	[0 7.2148]	kg m-2
damage transmission lines	sum_snowfall_amount	[0 0.16016]	kg m-2
	column maximum hail diameter'	[0 0.0096133]	m
	graupel_water_path	[0 1.0586]	kg m-2
	ice_water_path	[0 10.9297]	kg m-2
	num_flashes	[0 1]	
	flash_rate_ice	[0 0.039063]	s-1
	sfc_zonal_wind	[-13.8125 30.4375]	m s-1
	sfc_merid_wind	[-26.75 11.125]	m s-1
heat flux for load demand management and causes fire	sfc_sens_heat_flux	[-671.125 615.5]	W m-2
	sfc_dnw_wf	[-0.00037611 0.00040513]	kg m-2 s-1
affect the transmission line, lead to fire and outages	sfc_latent_heat_flux_up	[-941 1013]	W m-2
	sfc_temp	[269.125 293]	k
affect the outdoor insulators/50% to 85% of humidity double the magnitude of the leakage current	sfc_rh:humidity	[0.37375 1.015]	1
power lines mixing with fog turned into what she called “conductive mud” and caused electrical arcing	sfc_fog	[0 1]	

Consequences	RA2M-nwpsfc_2020092200-utc_nzcsm_020.nc	Data range	Unit
	sfc_visibility	[12 29080]	m
	sfc_vis_lt_1km	[0 1]	
	sfc_tile_fract	[0 1]	
	sfc_pot_evap	[-0.003011 0.0054877]	kg m-2 s-1
	sfc_wind_gust	[0.125 51.75]	m s-1
22m/s can damage trees, can lead to power lines damages	max_sfc_wind_gust	[0.375 51.75]	m s-1
	bl_type	[1 7]	
	scale_aware_sfc_wind_gust	[0.125 51.75]	m s-1
	max_scale_aware_sfc_wind_gust	[0.375 51.75]	m s-1
	soil_moisture	[2.886719 936.2266]	kg m-2
	soil_temp	[269 287.375]	k
	very_low_cloud	[0 1]	
	low_cloud	[0 1]	
	mid_cloud	[0 1]	
	low_cloud_base	[0 9401.8232]	m
	freeze_lev	[550.00574 3178.3315]	m
	theta_lev_temp	[265.5 295]	k
	mslp:air pressure at mean sea level	[99495 101695]	pa
	updraft_helicity	[-27.8759 76.6145]	m2 s-2
	model_spec_hum	[5.9605e-08 0.01029]	1
	sfc_snow_amount	[0 761.625]	kg m-2
impact of air temp on transmission lines, conductor's max tolerable temp	skin_temp	[266.375 297.125]	K
	blayer_depth	[10.375 2915.75]	m
	model_press	[64005.25 98550.75]	pa
	sfc_air_press	[74217 101659.75]	pa

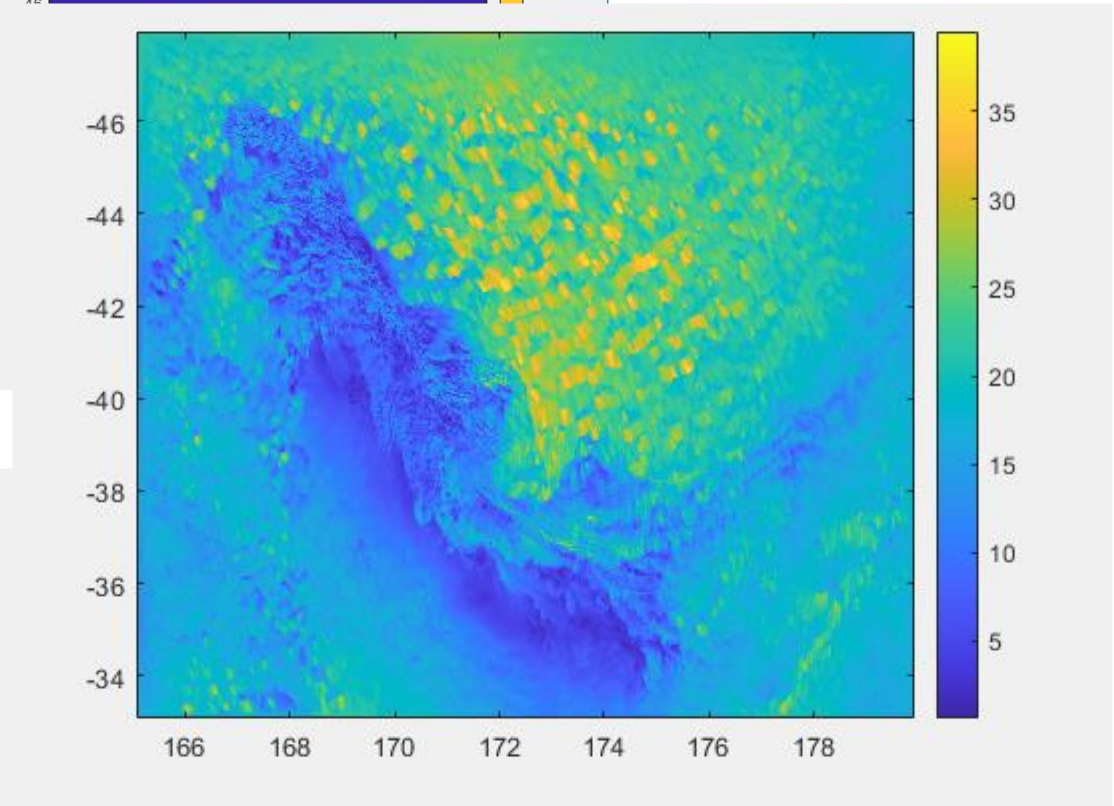
Why was Wind Gust Weather Event Selected?



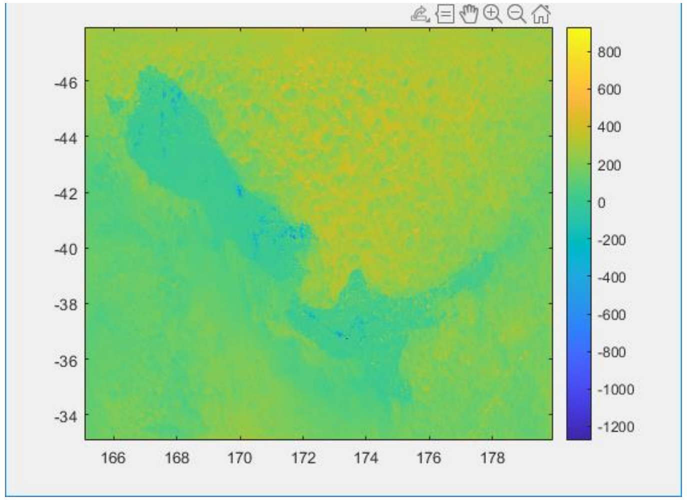
sum_rain_amount



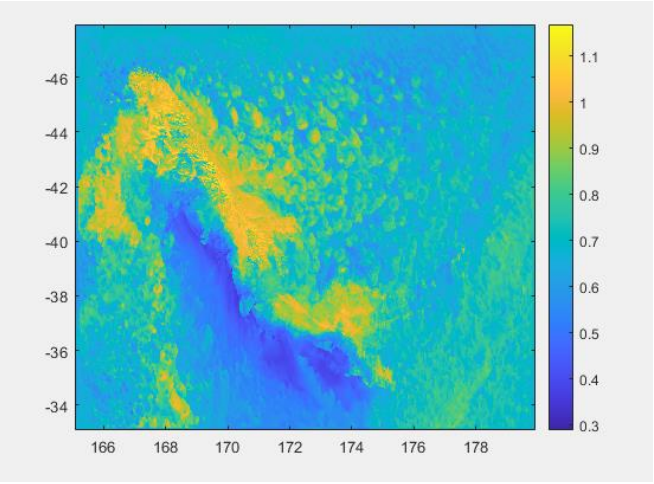
sum_snowfall_amount



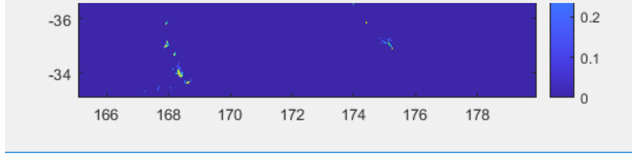
max_sfc_wind_gust



sfc_latent_heat_flux_up



sfc_rh



sfc_fog

Why was Wind Gust Weather Event Selected?

NetCDF files: Wind gust data has been selected for this research for Spring Season

Why?

NEW ZEALAND / WEATHER

Wild weather: Power cuts as strong wind batters Auckland

12:40 pm on 3 August 2021

Share this

SEVERE WEATHER

NZ weather: Power outages possible as 'strong winter blast' brings 90km/h winds, 'extreme' wind chill as low as -15C in mountains

06/08/2021 | Matt Burrows

Wild weather causes slips, power cuts, transport disruption

Sun, Feb 13 • Source: 1News

Hundreds of houses without power due to strong winds in Central Otago

Hanna McCallum · 18:09, Jul 06 2021

Wednesday, **23 January 2019**

'Extreme' wind cuts power to more than 4000

By Daisy Hudson and Josh Walton and Tracey Roxburgh 3038 36

Regions > Queenstown

7.05pm A tree has fallen and damaged power lines along State Highway 29, near Cambridge.

Police said the road is expected to be closed for some time and motorists are asked to avoid the area.

6.10pm Footage of a falling tree narrowly missing a moving car in Palmerston North has emerged online:

What’s next ? What can resilience researcher do to minimize the power outage duration (or to prevent from complete power outage)?

Existing Strategies for the Power System Resilience

Several strategies are there to support the electrical power system resilience, in terms of minimizing the power outage due to HIW such as:

- Hardening investment & system analysis
- Forecasting the storm network configuration
- Utilizing back-up or providing DERs

Such strategies includes the analysis of the system and providing the solutions for reducing the power outage duration, but existing analysis methods are somehow missing the concept of including **location-based strategies**

Location-Based Resilience Strategies

What do we **mean** by **location-based strategies** to support the power system resilience?

Different locations/zones have different weather scenario to deal with, which influences researchers/operators to adapt different strategies as per the location's conditions, such conditions could be:

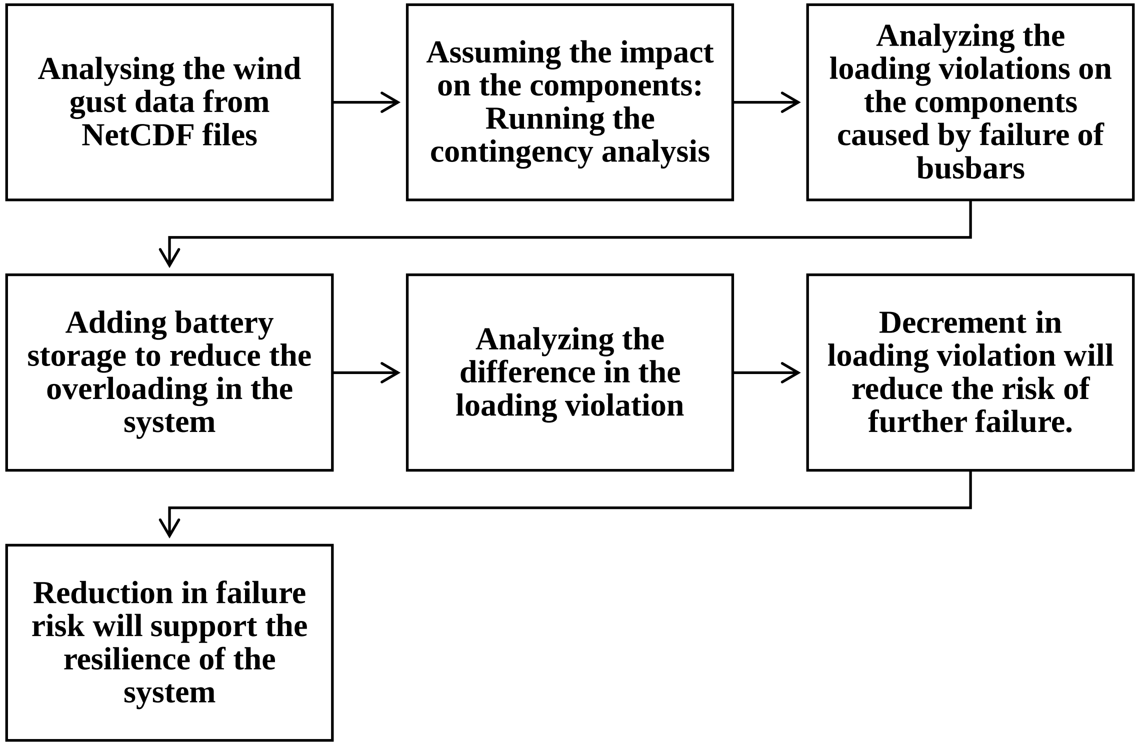
- Different **severity** of the weather events: some locations might have higher value of wind gust impacting the power lines and power poles.
- **Access** to the affected location: Transport access for maintenance
- No. of Consumers: **Impacted consumers** demand requirement; EENS. How much expected energy not served?

Locations Selected for this Research

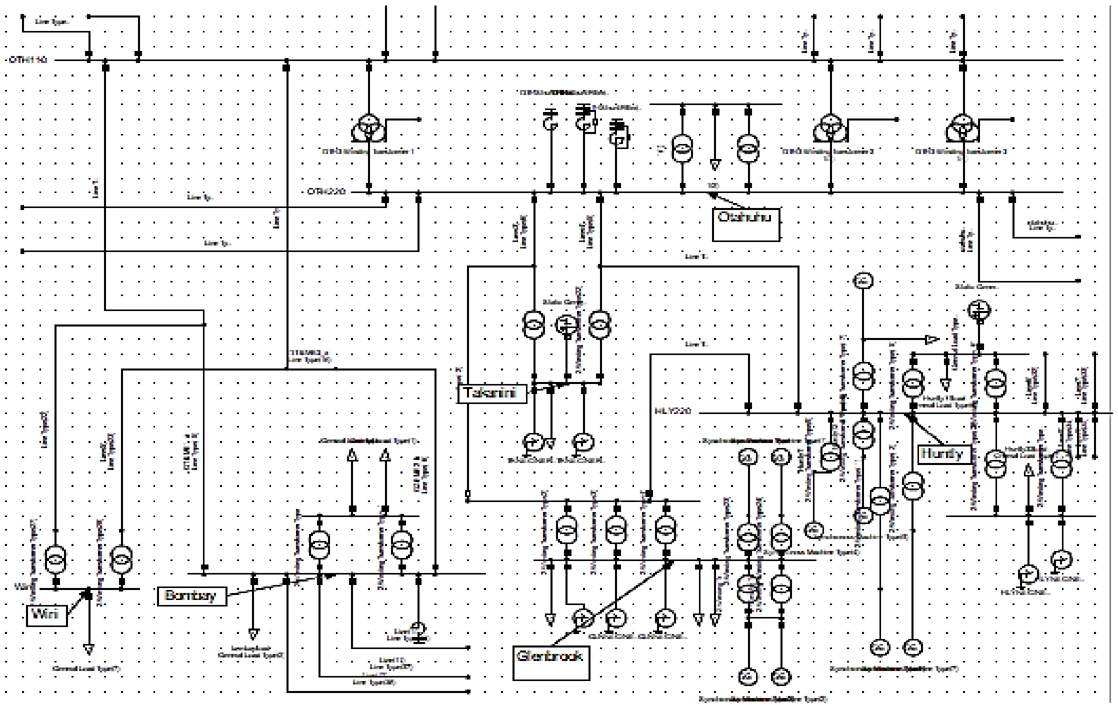
Northland, Auckland and Waikato

Let’s have a look at Auckland & Waikato wind gust data, where Auckland and Waikato’s electricity network were also analyzed

Location Based Strategies for Auckland

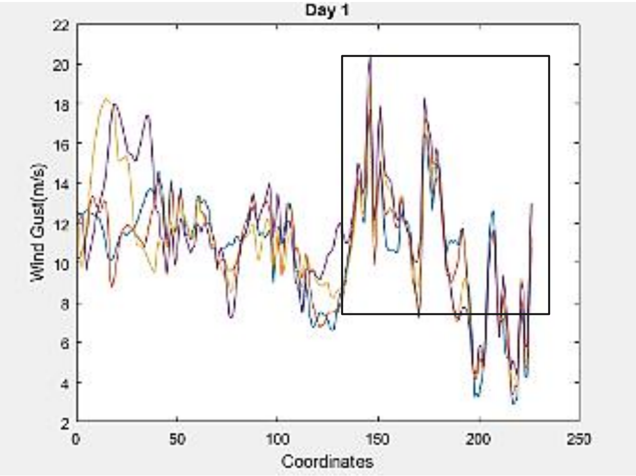


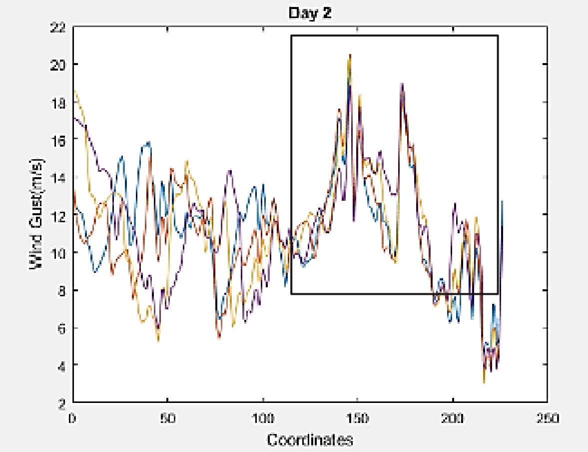
Methodology

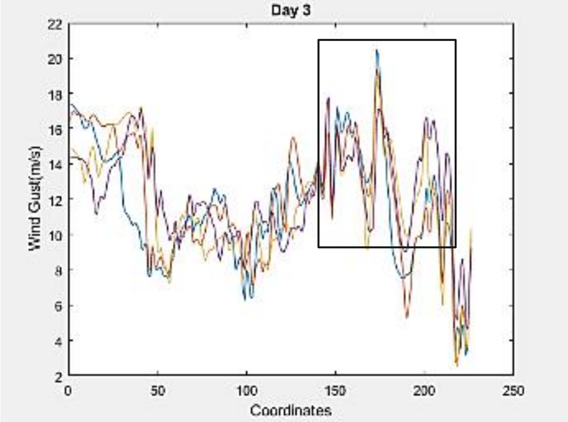


Simplified Auckland network in Powerfactory

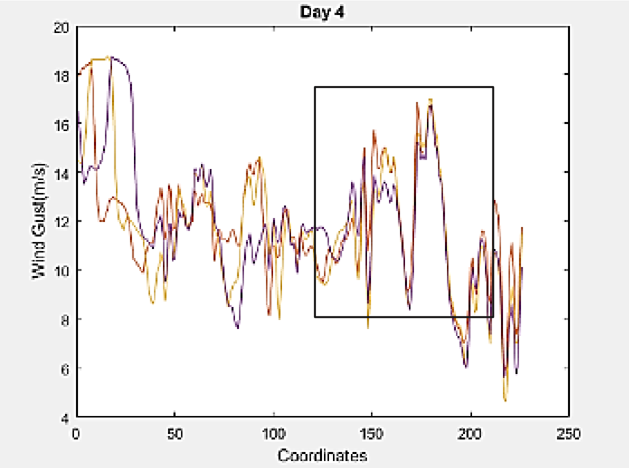
Weather Data Files Analysis: Auckland Region

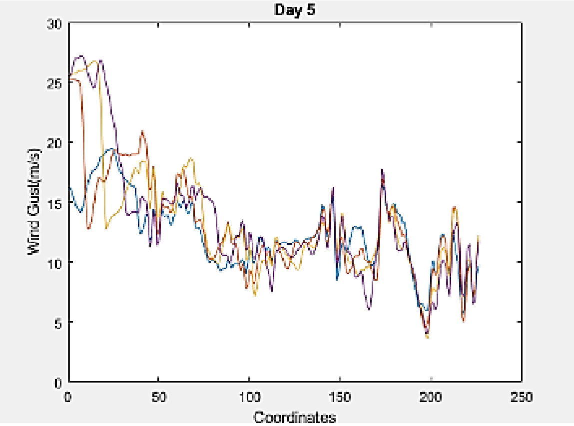


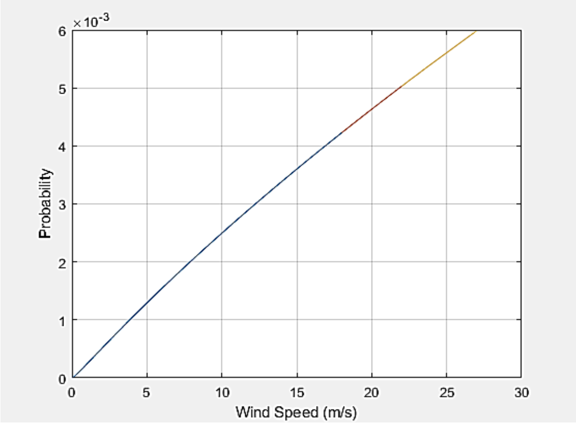




Wind Gust Data for 5 days for spring season of 2019

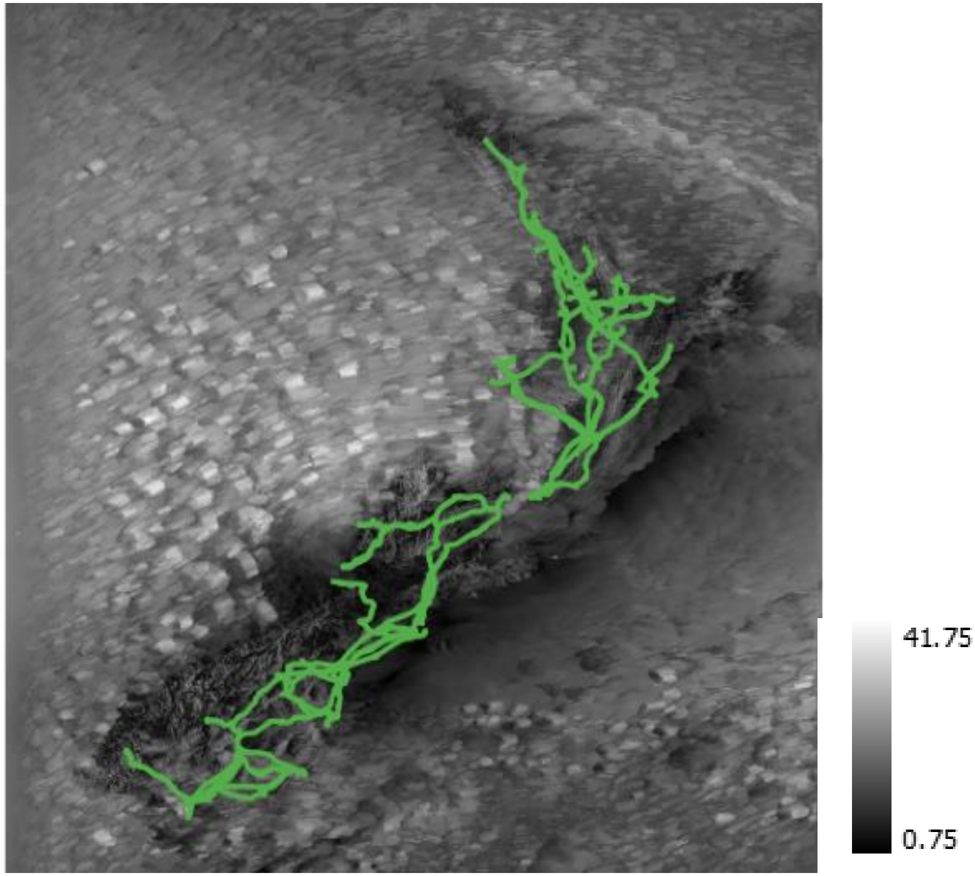






Lognormal probability distribution for wind gusts

Power System Analysis: Auckland Region

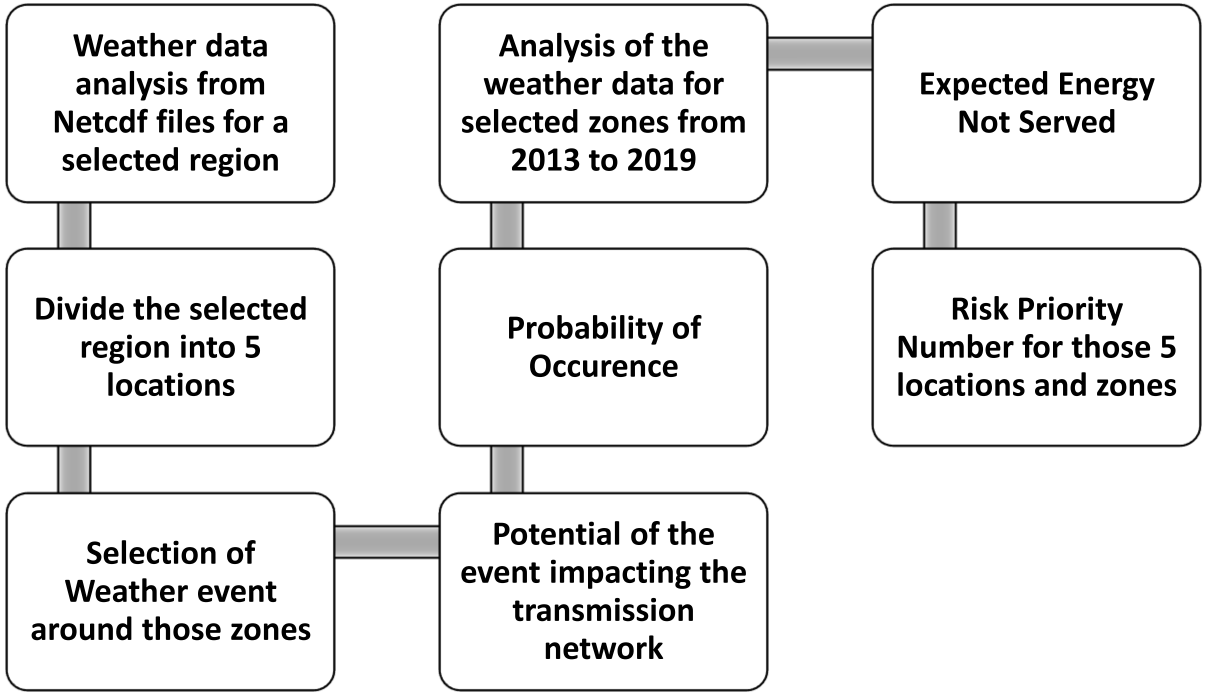


QGIS file, Wind gust data with transmission line data for NZ

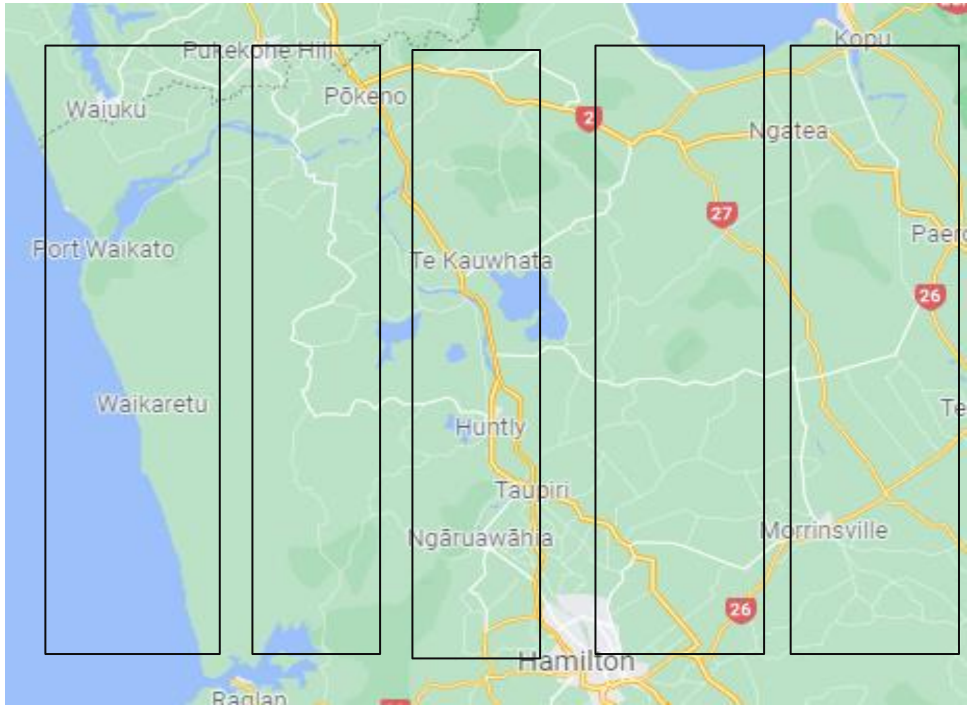
Loading Violation				
Components	**BMB contingency: Without battery**	**GLN contingency: Without battery**	**BMB contingency: With battery**	**GLN contingency: With battery**
H3:Huntly Transformer_330 MVA	98.1	98.1	89.3	89.3
H7:Huntly Transformer_485 MVA	96.4	99.2	95.6	98.1
OTH3 transformer:HV_117MVA	96.8	82.2	93.5	No loading violation

Results from contingency analysis for Bombay and Glenbrook busbars

Location Based Strategies for Waikato



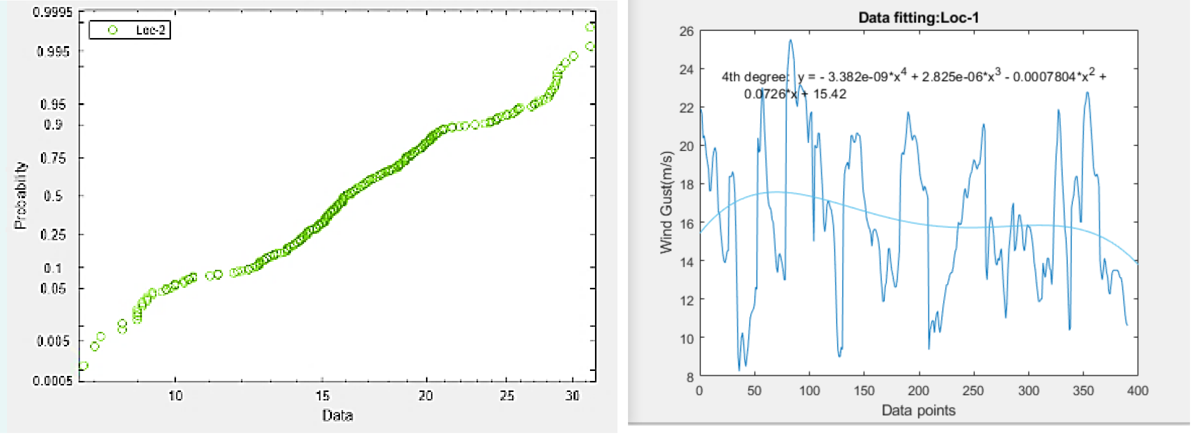
Methodology



Waikato region divided into 5 zones for better wind gust analysis

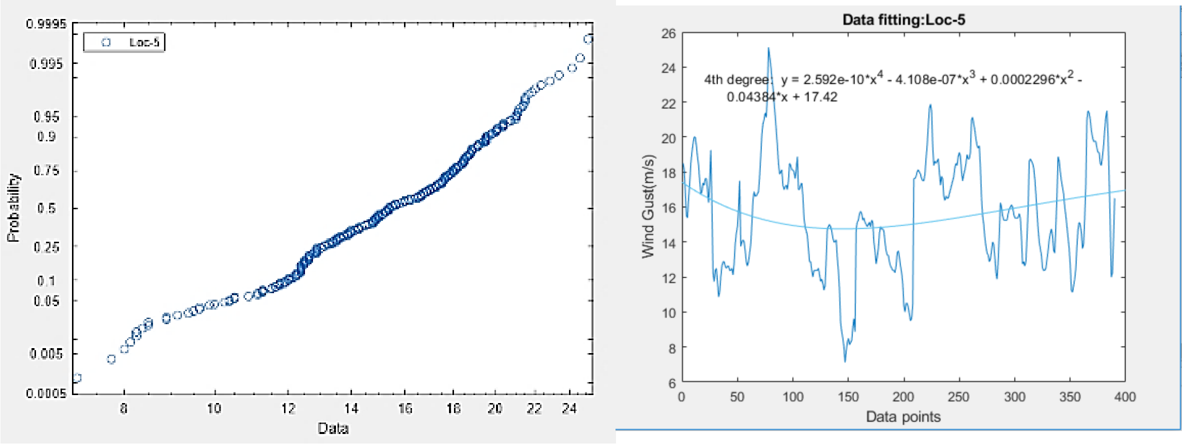
Weather and Power System Analysis: Waikato

Trend and probability distribution for wind gust data for 5 different locations



Loc-1

…………



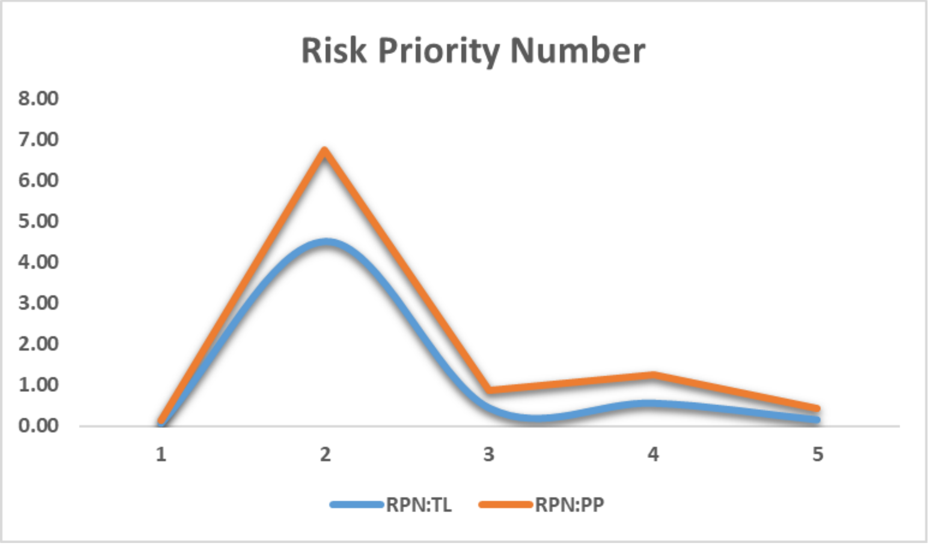
Loc-5

$$Risk\ Priority\ Number\ = [P\ x\ S\ x\ PF\ x\ I]mxn$$

$$S\ = \{W\,n/N\,n\}$$

$$I = \sum(Pi/Di) * T$$

P is the Probability of Occurrence of high wind gust for n number of locations, S being the severity for locations, PF is the probability of failure detection for different m number of failure modes and n number of locations. I is the loss of load (Impact Analysis) for n number of locations by the m number of failure modes. For the impact analysis, Pi is the demand for GXPs for the selected location; Di is the total maximum demand for the whole region, T is the outage duration for the GXPs.



Disciplinary peer-reviewed research Publications

- L. Lakshita and N. -K. C. Nair, "**High Impact Low Probability Weatherization Impact Analysis for Electricity Infrastructure**," TENCON 2021 - 2021 IEEE Region 10 Conference (TENCON), 2021, pp. 958-963, doi: 10.1109/TENCON54134.2021.9707369.
- L. Lakshita and N. -K. C. Nair, "**Resilience Framework and Optimal Scheduling for DERs Factoring Uncertainties,**" 2021 IEEE PES Innovative Smart Grid Technologies - Asia (ISGT Asia), 2021, pp. 1-5, doi: 10.1109/ISGTAsia49270.2021.9715670.
- As indicated before, socialization and discussion will be carried out with power system researchers around the possibility of electricity recovery framework particularly for high-impact localized wind gust- scenarios for North Island. Publication Accepted for EEA NZ 2022: **‘Peer-to-Peer Transactive Energy Platform For Neighbourhoods to be Utilized for Power System Resilience’**

Some Next Steps

- Finalizing common power system resilience strategies which can be utilized/applied across differing international power system networks.

- Expert solicitation phase with NZ electricity network operators, contractors and other planning and recovery stakeholders.

- Submitting a Journal publication with regards to this project for an inter-disciplinary high impact outlet.

Acknowledgments

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

ENGINEERING
DEPARTMENT OF ELECTRICAL, COMPUTER, AND SOFTWARE ENGINEERING

RESILIENCE TO NATURE'S CHALLENGES
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National SCIENCE Challenges

NIWA
Taihoro Nukurangi
Climate, Freshwater & Ocean Science

NeSI
New Zealand eScience Infrastructure

QuakeCoRE
NZ Centre for Earthquake Resilience
Te Hiranga Rū

Questions?

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