Electricity and Communication Resilience

Infrastructure Research Day

22 November 2022

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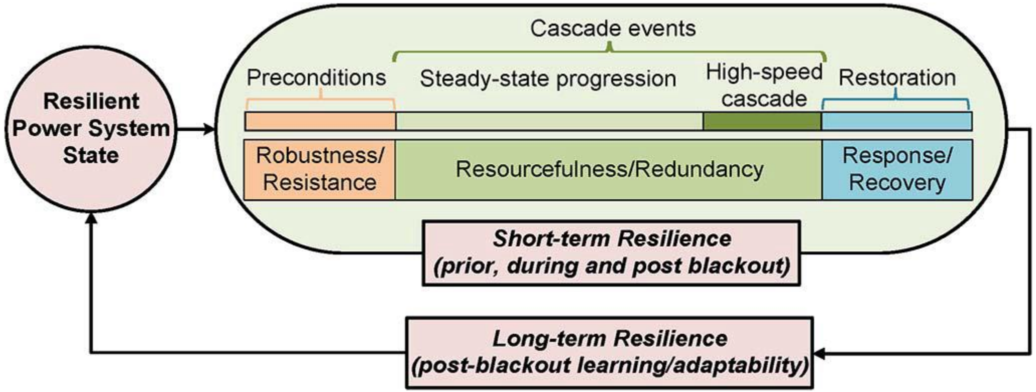
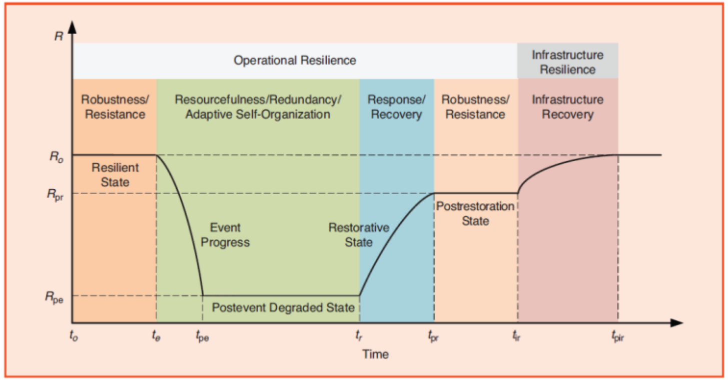
THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND
ENGINEERING
DEPARTMENT OF ELECTRICAL, COMPUTER, AND SOFTWARE ENGINEERING

National SCIENCE Challenges
RESILIENCE TO NATURE'S CHALLENGES
Kia manawaroa – Ngā Ākina o Te Ao Tūroa

Power System (Electricity) Resilience-Definition/Concept





Reliability	Resilience
Based on High probability, low impact events	Based on low Probability, high impact events
Static nature of event	Event is adaptive, ongoing, short and long-term.
Evaluation is based on power system states	Evaluation is based on power system states and transition times between states.
Issue of concern is customer interruption time	Issue of concern is customer interruption time and the infrastructure recovery time.
Based on the specific network	Considers interdependent network

- 4 R's according to CDEM:

Reduction	• Identification and mitigation of asset vulnerabilities to disasters
Readiness	• Assessment of adaptive capacity and specific contingency planning
Response	• Immediate loss of quality of service-immediate actions and stakeholder
Recovery	• Long term restoration of service levels

Electricity Distribution Resilience Framework through West Coast Alpine Fault Scenario

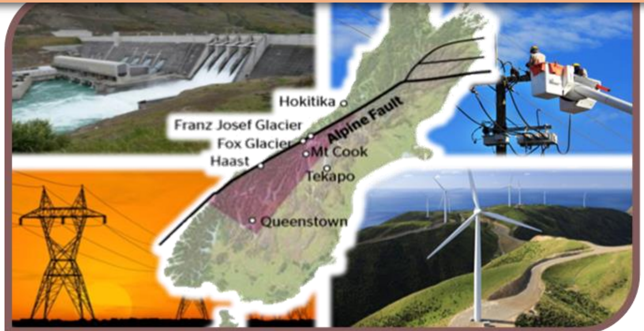
Nirmal Nair (PI), Farrukh Latif (ME, Chorus), Duncan Maina (PhD), Samad Shirzadi (PhD), Safa-Al Sachit (PhD), Rodger Griffiths (Westpower), Cosmin Cosma (Westpower)

- *Nov 2017 to May 2018* — *Seismic Hazard mapping to Infrastructure Impact*
- *Apr 2018 to Mar 2019* — *Communication Infrastructure Provisions*
- *Jun 2017 to June 2019* — *Simulation, Design and Testing for Micro-grid operation of West Coast*
- *May 2018 to July 2020* — *Resilient energy-communication Utility Service Framework*

Allied Work:

2010-2011 Canterbury Earthquake Sequence Impact on 11KV Underground Cables Scenario: Ebad Rehman (PhD), Peter Elliot (Orion), Nirmal Nair (UoA), Liam Wotherspoon (UoA)

Distribution system seismic resilience characterization toolbox: Yang Liu (Post-doc), Nirmal Nair (UoA), Liam Wotherspoon (UoA)



RESILIENCE TO NATURE'S CHALLENGES | Kia manawaroa – Ngā Ākina o Te Ao Tūroa

National SCIENCE Challenges — infrastructure — rural

THE UNIVERSITY OF AUCKLAND Te Whare Wānanga o Tāmaki Makaurau NEW ZEALAND — ENGINEERING DEPARTMENT OF ELECTRICAL, COMPUTER, AND SOFTWARE ENGINEERING — QuakeCoRE NZ Centre for Earthquake Resilience

Westpower — Orion — CHORUS

RNC Phase 1: Power System Group at University of Auckland

Infrastructure and Built-Environment Solutions

1. Networks and Components
2. Network Interdependencies
3. Performance Measures and Impacts
4. Electricity Distribution Resilience Framework

Electricity Distribution Resilience Framework

This project, funded from the Challenge's contestable funding process in 2017, is developing a novel electricity resilience framework, along with a realistic micro-grid restoration solution enabled through communication lifelines, following a significant Alpine Fault earthquake.

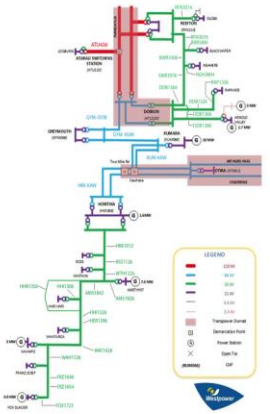
Network: West Coast
Hazard: Earthquake

- Power System Resilience
  - Asset Resilience
    - 2010-2011 Canterbury Earthquake Sequence Impact on 11kV Underground Cables
      - UG Cable Network
        - Ebad Ur-Rehman
  - System Resilience
    - NZ Electricity Distribution Network Resilience Assessment and Restoration Models following Major Natural Disturbance
      - Electricity
        - Duncan Maina
        - Samad Shirzadi
        - Safa Al-Sachit
      - Communication
        - Farrukh Latif

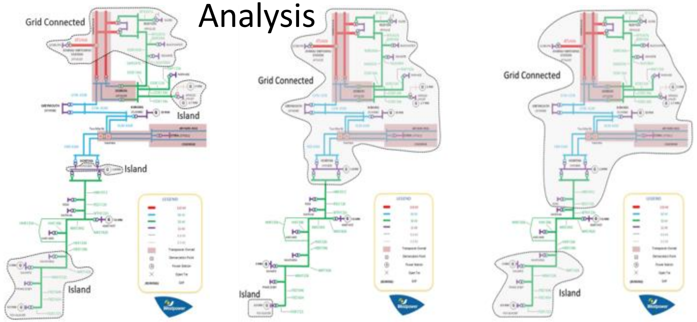
Westcoast Electricity Distribution Network Seismic Resilience

Earthquake scenarios:
- Central Hypocenter
- Northern Hypocenter
- Southern Hypocenter
- Empirical Southern Hypocenter

Hazard Mapping



Electrical Analysis



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Detailed Modelling

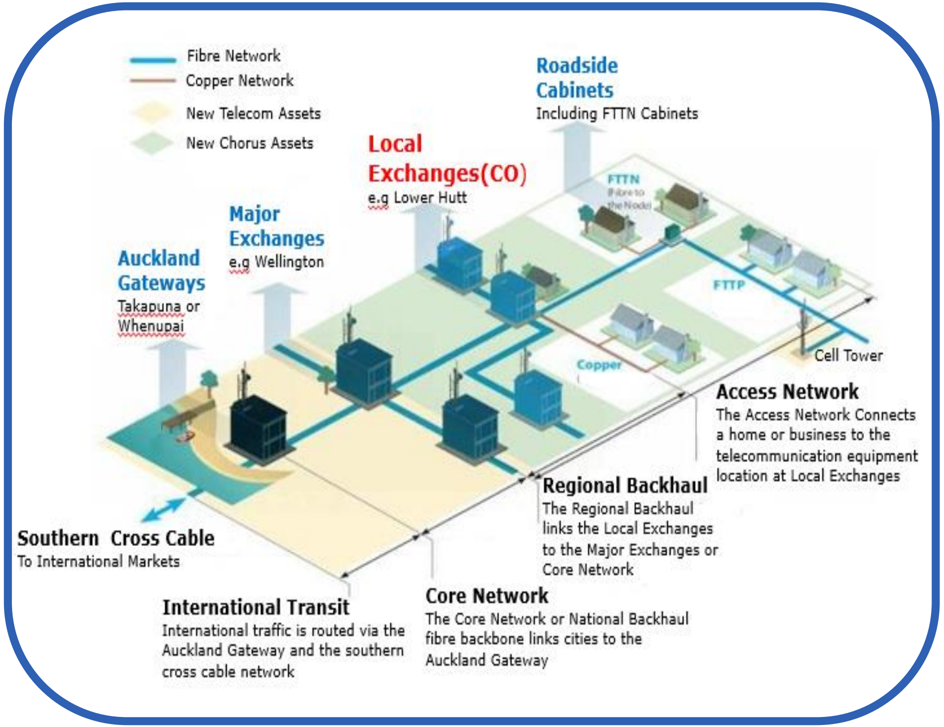
Blackstart Study

Transition to Islanded mode

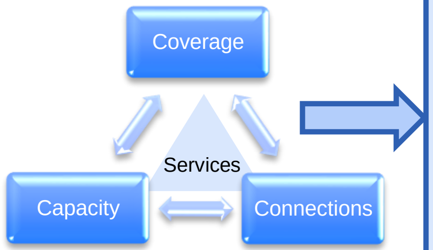
Protection Assessment

Resilience Framework

Milestone 2- Communication Infrastructure Provisions



Broadband and Voice Network (Courtesy of Chorus)



- Voice
- Internet
- Cloud/Datacentres
- Enterprise Services
- Emergency Response Services
- Mission Critical Services
- Defence Services
- IOT
- VR
- AI
- TV/On Demand Content

NZ Communication Infrastructure and Services

Approach and Method for Seismic Risk Quantification

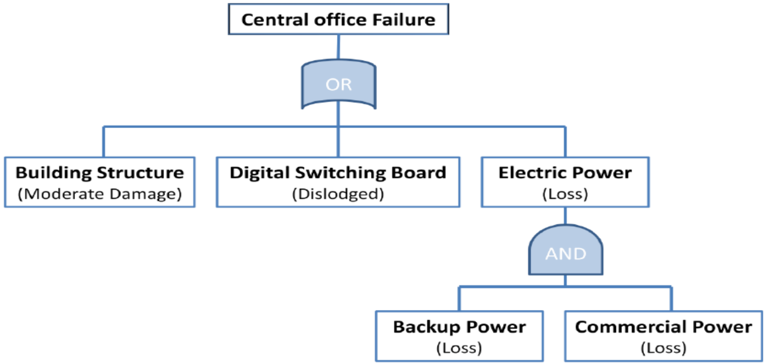
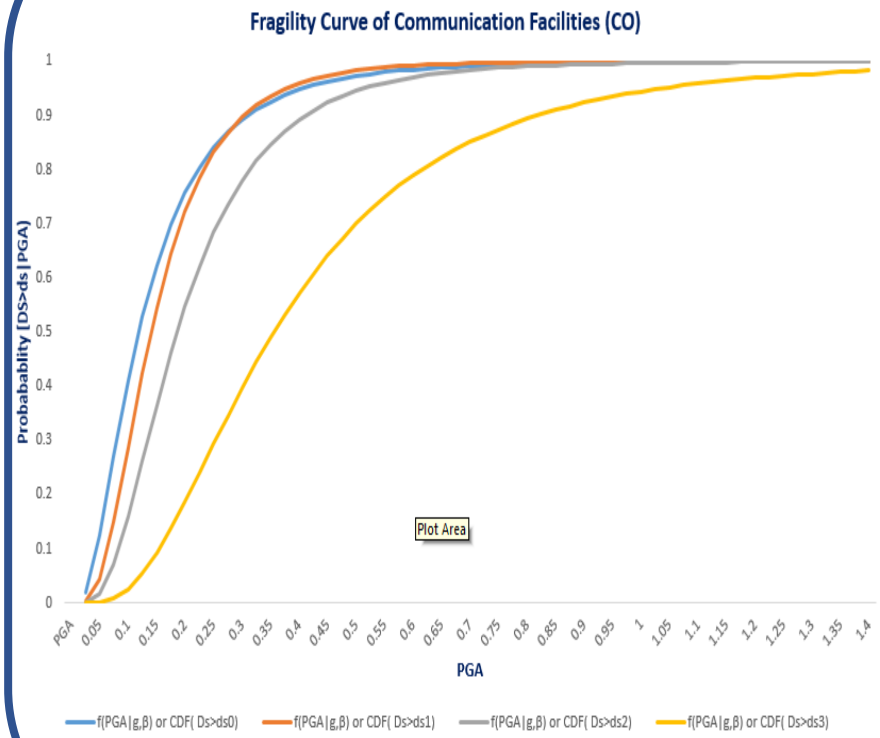


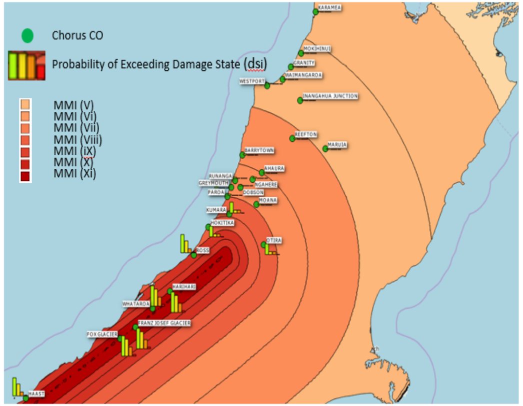
Figure 3-2: Fault Tree Diagram of Telephone Central Office Failure

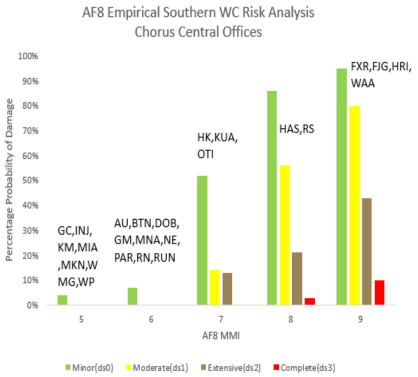
$$P(E_{CO}) = P\left(E_{Structure} \cup E_{Switching\_Board} \cup \left(E_{Backup} \cap E_{Commercial}\right)\right)$$

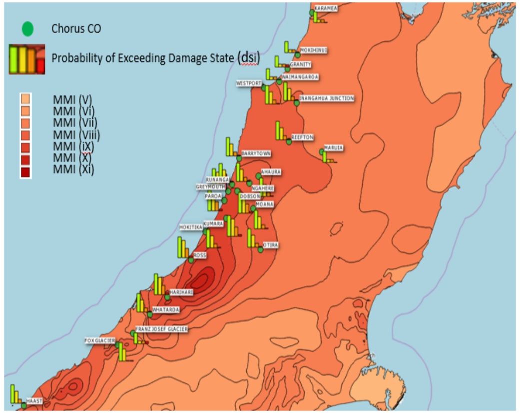
Damage State	Description	
ds0	minor	None
ds1	moderate	Power outage for few hours or days
ds2	extensive	Few electronic boards are dislodged and need replacement
ds3	Complete	Complete Blackout

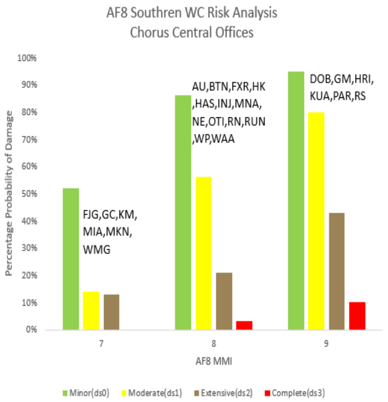


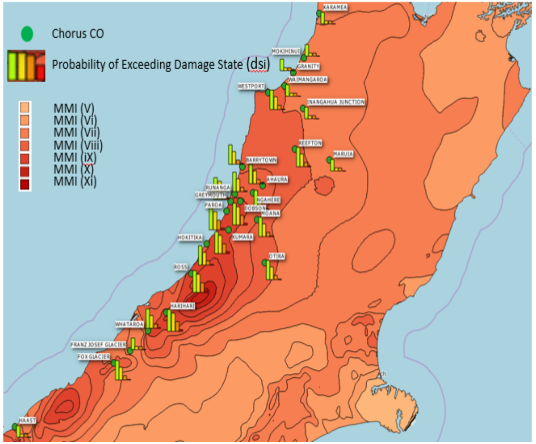
Milestone 2 – Communication Infrastructure

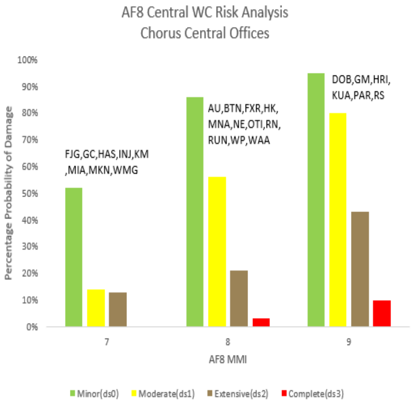


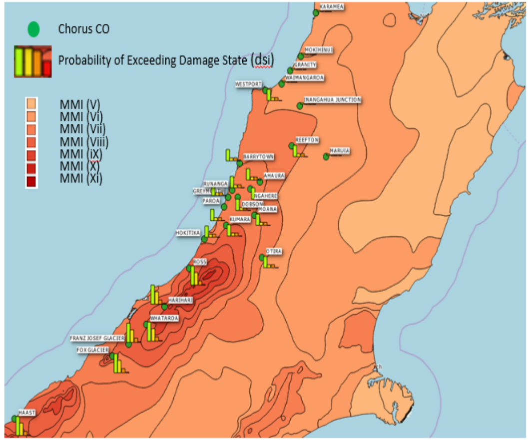


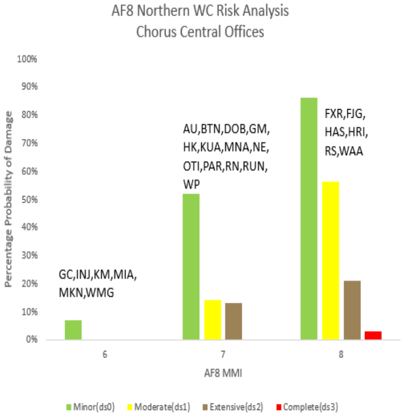








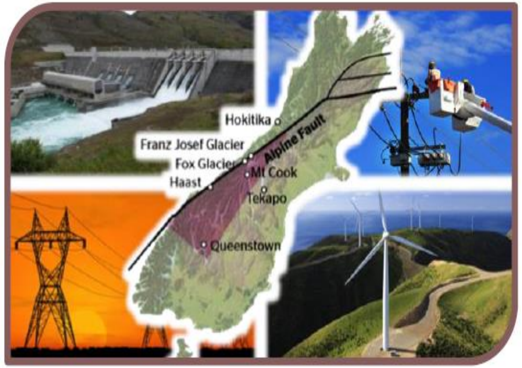




Key Recommendations

- Proper modelling of the different network components
- Possible switching sequences to be determined depending on the location of the blackstart generators
- Need to investigate different island detection techniques dependent on the specific network topology.
- Need to assess communication infrastructure and mutual dependency activities.

NZ Electricity Distribution Network Resilience Assessment and Restoration Models following Major Natural Disturbance



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DOCUMENTATION SUMMARY

This report presents collaborative work of members from the Power Systems Group of the University of Auckland for the project titled "NZ Electricity Distribution Network Resilience Assessment and Restoration Models following Major Natural Disturbance". The contributors to this report are Duncan Kaniaru Maina, Samad Shirzadi Deh Kohneh, Safa Al-Sachit, Leo Yang Liu and Nirmal Nair.

Document:

NZ Electricity Distribution Network Resilience Assessment and Restoration Models following Major Natural Disturbance

Prepared for:

Ministry of Business, Innovation and Employment, New Zealand

Consolidated by:

Duncan Kaniaru Maina
Samad Shirzadi Deh Kohneh
Safa Al-Sachit
Leo Yang Liu
Power Systems Group, University of Auckland

Revision	Date	Submission	Reviewer	Reviewer 's Feedback
1	September 2018	Milestone 1 Report	Daniel Blake (University of Canterbury)	Corrections on methodology explanation
2	July 2019	Milestone 3 Report	Rodger Griffiths (Westpower)	Corrections on network components descriptions

DOCUMENTATION SUMMARY

This report presents collaborative work of members from the Power and Communication Systems Group of the University of Auckland for the project titled "Functionality Assessment of West Coast NZ Fixed Communication Infrastructure following Major Earthquake". The contributors to this report are Farrukh Latif, Andrew Austin and Nirmal Nair.

Document:

Functionality Assessment of West Coast NZ Fixed Communication Infrastructure following Major Earthquake

Prepared for:

Ministry of Business, Innovation and Employment, New Zealand

Consolidated by:

Farrukh Latif
RNC1 Group, University of Auckland

Revision	Date	Submission	Reviewer 's Feedback
1	June 2019	Communication Infrastructure Assessment Report	Initial Draft
2	July 2019	Communication Infrastructure Assessment Report	Andrew Austin
3	Aug 2019	Communication Infrastructure Assessment Report	Liam Wotherspoon

NETWORK COMPONENT MODELLING FOR BLACKSTART PLANNED ISLANDING

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Fault Detection in Transmission Lines — A Novel Voltage-Based Scheme for Differential Protection

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Abstract—**Current-based protection schemes such as distance, overcurrent, and differential relays are usually used to protect transmission lines (TL) in power systems where the high fault current plays a key role in detecting faults. The continuous development in the power network and emerging new technologies have made the power grid more complicated and soon will start to affect the reliability of the existing protection schemes. Issues like current transformer saturation, the effect of the mutual coupling impedance of the TL and emerging new power electronic-based technologies have become major challenges in power systems from a protection perspective. To avoid all the current-based problems this paper proposes a new voltage-based relay principle for TL protection to indicate fault occurrences in transmission networks. The proposed scheme is tested under all fault events to show that it is highly accurate when it comes to rapid trip activation during any of the tested cases.**

Keywords: Differential relay, negative sequence voltage, relay modeling, symmetrical components, transmission line protection, unbalanced fault.

I. INTRODUCTION

Transmission lines are subject to many events that might cause small or bulk damage to them and to the other parts of the system. Events which might affect TL include current transformer (CT) saturation issue, zero current mutual coupling, fault current limitations of power electronic based devices (PED), and grid code obligations. As a result, a sensitive, reliable and fast protection scheme is required to reduce expected damage. Many protection strategies have been suggested for TL in high, medium and low voltage parts

scheme depends on measuring the impedance of the protected TL to identify the faulted zone. However, [2] recognized that distance relays have some obstacles regarding the phase shift between voltage and current, fault resistance and third zone maloperation [3]. The CT saturation effect appears prominently in the transmission network using distance protection schemes; hence it results in excessive tripping delay time [4-6]. The high fault current in some cases prevents CTs from sending the actual current value to the relay, and the relay will receive only a relatively low current at the secondary side during severe faults. However, distance protection is recommended for distribution networks due to it having a directional element that increases its ability to deal with meshed networks. The high cost of this scheme might be an obstacle since it requires both voltage and current transformers. However, it is only suitable for a small range of considerations and the correct settings may be more difficult to determine compared to the OCR [1].

Differential relays have also gained a wide recognition because it is a protection scheme rated as highly sensitive, selective, fast and insensitive to the bi-directional flow of current when compared to the distance and overcurrent schemes [1], [7]. The differential relay operational concept is based on calculating currents from the connected CTs across the protected section according to Kirchhoff's law. Differential relays face some issues due to the fault location discrimination besides the effect of CT saturation and CT mismatch on the relay operation [8]. Communication failures because of limited bandwidth channels over long distances also play a major role in reducing the effectiveness of this scheme. However, compared to distance relays it can be

2018 IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC)

Power system resilience through microgrids: A comprehensive review

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Abstract—**This paper reviews the role of microgrids in power system resilience improvement. Different definitions of system resilience that are addressed in different works are analyzed and summarized. Framework and metrics in power system resilience improvement and assessment are discussed and reviewed. Finally different microgrid based solutions for system resilience improvements are categorized and discussed.**

Keywords—microgrid, power system resilience, reconfiguration, operation, control, protection, hybrid microgrids

resilience. Third section explains the pow framework, resilience metrics and haza characterization. Fourth section covers the role of in power system resilience improvement and si provides a conclusion.

Blackstart of DFIG-based Windfarm

Duncan Kaniaru Maina, Mohammad Javad Sanjari, Department of Electrical and Computer Engineering, University of Auckland, Auckland, New Zealand
Nirmal-Kumar C. Nair, Department of Electrical and Computer Engineering, University of Auckland, Auckland, New Zealand

Abstract— **Increased penetration of DFIG-based windfarms demand their use not only in normal operating conditions but also in restorative conditions, if wind is forecasted to be available. This paper explores the possibility of starting DFIG-based windfarms in preparation of network restoration. Analysis of DFIG starting with the help of a diesel generator set is provided. The windfarm substation is assumed to be composed of a diesel gen-set, synchronous condenser and a dump load. Pitch control, different from the one used during high wind speeds, is modeled and incorporated in this scheme to control speed of rotor during switching on of RSC and stator resynchronisation to the grid. Results, from simulation in MATLAB/SIMULINK, show successful starting of DFIG windfarm by use of a standby diesel generator set. Also, the speed of rotor is controlled to achieve the required speed at any stage of the starting process.**

Index Terms— **Autonomous Operation, Blackstart, DFIG, Pitch Control**

I. INTRODUCTION

Many countries are gearing up towards 100% renewables by 2030. The generation portfolio is foreseen to be majorly composed of hydro, wind and solar. Whilst this is ongoing, there has been an increase in power blackouts, either due to natural disasters, increased grid interconnectivity or the changing trend in supply and demand that is leading to increased strain on the already ageing network. Restoration with high penetration of non-hydro renewables is thus an important aspect to be considered when preparing policies with regards to integration of renewables.

There are three stages of restoration: unit blackstart, network re-energization and load restoration. Conventionally, considering only renewable energy sources, large hydro power plants, due to their blackstart capability, have been used to re-energize the network [1]. In a 100% renewable generation portfolio, it is necessary to review and explore the restoration function of non-hydro renewable generation. This study will focus on windfarms as their penetration is higher, and in large scale, as compared to the other non-hydro renewable generation. Their usage during restoration has been restricted to the third stage of restoration (load restoration) after the core grid is stable. This is due to

type of wind energy conversion system (WECS) and its associated dynamics during starting. Research on the use of VSC-HVDC connected windfarms in the earlier stages of restoration, taking advantage of self-restoring capabilities of VSC-HVDC and also enhanced voltage and frequency control, has been discussed in [7, 8]. Blackstart of windfarms have been reviewed in [9] with focus on the available patented techniques of wind turbine blackstart and subsequent windfarm energization. Analysis has not been provided with respect to the blackstart process.

This work seeks to examine the starting process [10] of DFIG-based windfarm and its effect when started using a standby diesel gen-set. Energization using different sources of power has been explored by the same author in [11]. In this study, the DFIGs have been energized simultaneously to speed up the restoration process. Pitch control during start has been designed and implemented to ensure the correct rotor speed during the starting process. The remainder of this paper is organized as follows: Section II defines the models used in the study. Section III describes the step by step process of DFIG starting with different pitch control modes being applied at different stages to ensure smooth starting process under variable wind conditions. Results are discussed in section IV while the conclusion and future works is briefly provided in section V.

II. TEST SYSTEM MODEL DESCRIPTION

The system under study is shown in Fig. 1.

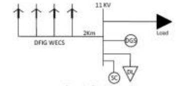

Figure 1. Test System

HOW DO YOU ASSESS AND QUANTIFY RESILIENCE FOR DISTRIBUTION NETWORKS?

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2. Duncan Kaniaru Maina, B.Sc. (First class) at University of Nairobi, Kenya and, Master of Electrical Power System Engineering with Distinction at University of Manchester, UK. He is currently pursuing his PhD in Power system engineering group at the University of Auckland.
3. Leo Yang Li, B.E. degree (with first class Hons.) and PhD in Electrical Engineering from the University of Auckland in 2012 and 2016 respectively. He is currently a resear fellow at the Department of Civil and Environmental Engineering, University of Aucklanc

INVESTIGATING TRAVELLING WAVE FAULT LOCATION TECHNIQUES FOR DISTRIBUTION ASSETS

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Recovery Plan for Electric Distribution Networks under Major Impacts

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Abstract—**Power distribution system recovery after typical failures which hardly result in long lasting outages is a common practice. However, network recovery after a major impact such as extreme weather or other natural hazards can be much more complicated and time-consuming. Such events can easily cause costumers to experience an extended power outage which is associate explores and expla evolved a of inform**

Outage management and network task if the blackout is associated w This situation which is mainly ca results in an extended outage. A stati [2] shows an increase in the numbe

VOLTAGE AND FREQUENCY RESPONSE OF SMALL HYDRO POWER PLANT IN GRID CONNECTED AND ISLANDED MODE

Duncan Kaniaru Maina, Mohammad Javad Sanjari, Department of Electrical and Computer Engineering, University of Auckland, Auckland, New Zealand
Nirmal-Kumar C. Nair, Department of Electrical and Computer Engineering, University of Auckland, Auckland, New Zealand

Abstract— **Hydro-based power is gaining more interests as the penetration level of small-scale hydro power plants are being**

operation is reviewed in [6]. General distributed generation islanding techniques are first discussed after which a review of

EFFICIENT DISTRIBUTION NETWORK RECOVERY FOLLOW DISASTERS: NEW ZEALAND CASE STUDIES

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Negative Sequence-Based Schemes for Power System Protection - Review and Challenges

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Nirmal-Kumar C Nair, *Electrical and Computer Engineering, University of Auckland*, Auckland, New Zealand, n.nair@auckland.ac.nz

Abstract—**This paper presents a review of the negative sequence-based protection relays development and their applications on electrical power networks and discusses the related challenges. Recent power system requires selective, reliable, rapid fault detection and clearance mechanisms especially for the transmission line networks, which are highly exposed to environmental incidents. Most of the negative sequence protection techniques and recent challenges are**

especially line-line faults which are considered common events in power systems, in addition t advantages will be reviewed later in this paper.

II. NEGATIVE SEQUENCE PROTECTION OVERV

Negative sequence Protection (NSP) is a pro scheme used to protect the power system element by of negative sequence component. It was first introd

DFIG-based Windfarm Starting Connected to a Weak Power Grid

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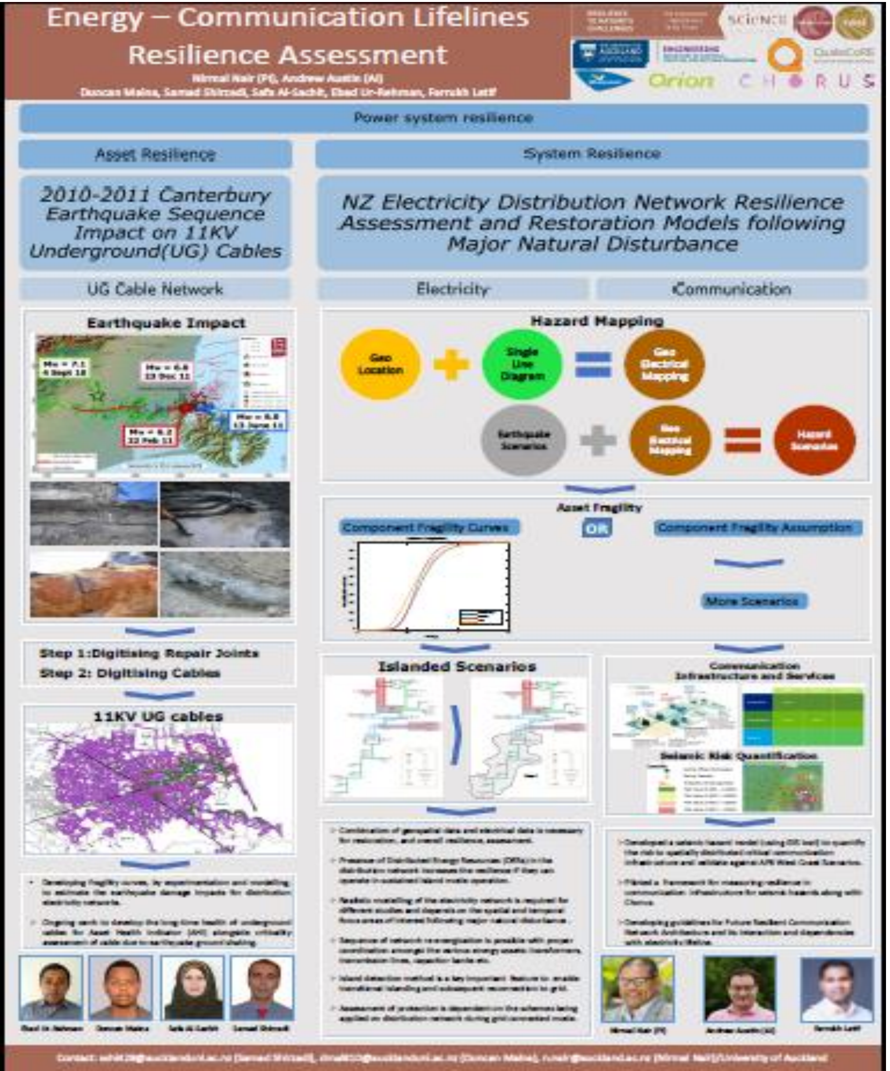
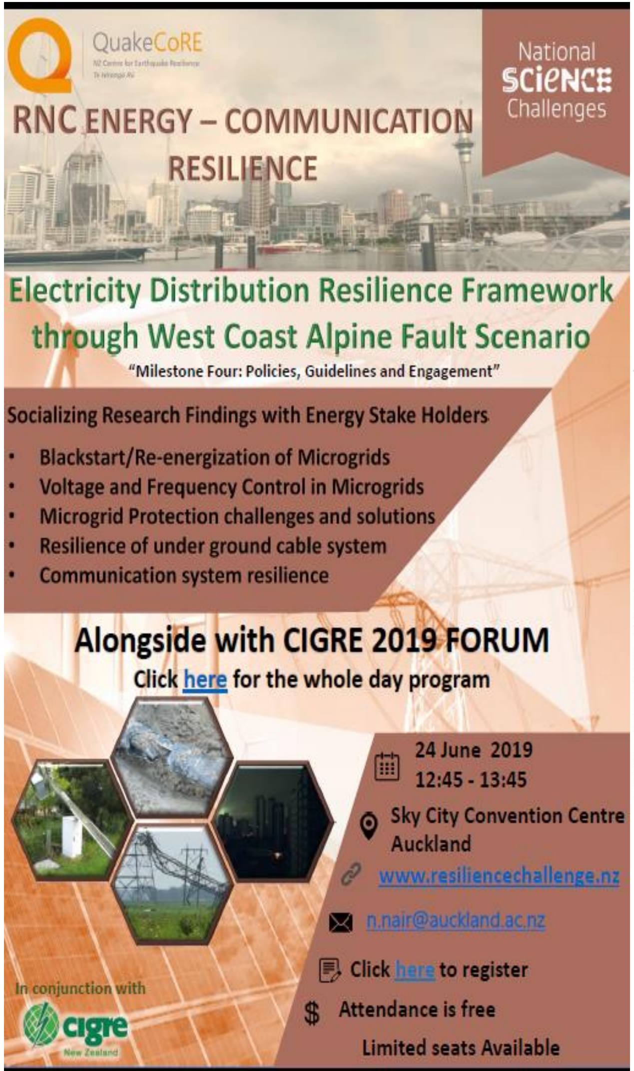
Abstract - **Starting and energization of windfarms has always been done under strong grid conditions. With the increase in blackouts and desire to run parts of the system in island mode, it is necessary to examine the starting of windfarms under different system conditions. This work provides an analysis into the starting of DFIG based windfarms under weak grid conditions including using a diesel gen-set and a hydropower plant. The starting procedure of the DFIG based wind turbine has been explored afterwhich multiple wind turbines have been started simultaneously. It is assumed that the windfarm substation will have a dump load to absorb excess power produced by**

synchronization has been proposed and discussed in [11, 12]. [13] proposes the use of pre-charging resistors and separate rectifier circuit in charging the dc link capacitor. All of the above analysis into DFIG starting and energisation has only been provided under normal grid conditions. Limited work so far has provided analysis on DFIG windfarm starting under different system conditions, other than the normal grid condition. This analysis is important especially in understanding the restoration function of DFIG windfarms after a wide scale blackout.

The proposed work, through analysis of individual


Energy – Communication Lifelines
Resilience Assessment
Power system resilience
Asset Resilience
System Resilience
2010-2011 Canterbury Earthquake Sequence Impact on 11KV Underground(UG) Cables
NZ Electricity Distribution Network Resilience Assessment and Restoration Models following Major Natural Disturbance
UG Cable Network
Electricity
Communication
Earthquake Impact
Hazard Mapping
Asset Fragility
Component Fragility Curves
OR
Component Fragility Assumption
More Scenarios
Step 1:Digitising Repair Joints
Step 2: Digitising Cables
11KV UG cables
Islanded Scenarios
Seismic Risk Quantification


QuakeCoRE
National Science Challenges
RNC ENERGY – COMMUNICATION RESILIENCE
Electricity Distribution Resilience Framework through West Coast Alpine Fault Scenario
"Milestone Four: Policies, Guidelines and Engagement"
Socializing Research Findings with Energy Stake Holders
• Blackstart/Re-energization of Microgrids
• Voltage and Frequency Control in Microgrids
• Microgrid Protection challenges and solutions
• Resilience of under ground cable system
• Communication system resilience
Alongside with CIGRE 2019 FORUM
Click here for the whole day program
24 June 2019
12:45 - 13:45
Sky City Convention Centre Auckland
www.resiliencechallenge.nz
n.nair@auckland.ac.nz
Click here to register
Attendance is free
Limited seats Available
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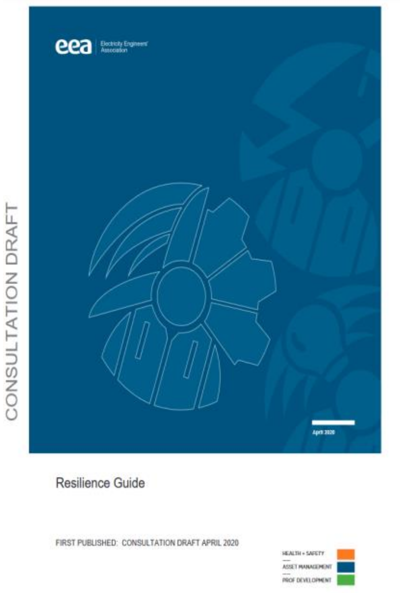
cigre
New Zealand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CONSULTATION DRAFT
Resilience Guide
FIRST PUBLISHED: CONSULTATION DRAFT APRIL 2020

RNC Phase 2: Power System Group at University of Auckland

Built Environment Theme

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

Weather and Wildfire

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

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.*

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

National SCIENCE Challenges

RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

Objectives To Enhance the Resilience of Power System

Strengthen the System

Failure Analysis for System & Resilience Cost for hardening

Components and Load At Risk

Interdependencies of components in power system

Optimal Scheduling for DERs

Investment cost for Resilience of power system

Challenges

Research Objectives for Enhancing the Resilience of Power System

1. **Pre** Extreme Weather Events: **Infrastructure Hardening Plan**

Step:
1.1 Planning: Failure Mode and Effect Analysis & Failure Probability

2. **During** Extreme Weather Events: **System Analysis**

Steps:
2.1 Planning & Operation: Risk Achievement Worth (RAW) & Risk Reduction Worth (RRW) and CLaR & LaR
2.2 Operation: Contingency Analysis

3. **Post** Extreme Weather Events: **Back-up for critical load**

Step:
3.1 Operation: Scheduling Model for Back-ups as a Resilience Resource

Outputs so far

1. Optimal Scheduling for Distributed Energy Resources (DER) Factoring power outage uncertainties caused by high wind gust.

2. Contingency analysis for Auckland network due to High Impact Low Probability Weatherization

3. Power System Location-based Resilience Assessment for Waikato region

4. Peer-to-Peer Energy Transaction Model during High-Impact Low Probability Weather Events: Electricity Market Model

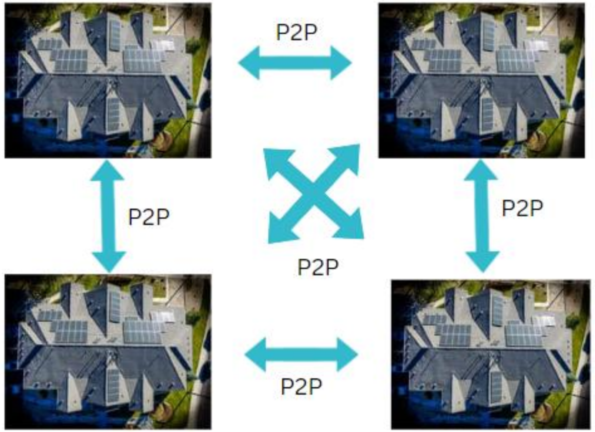
4. Peer to Peer(P2P) Energy Trading Models during HILP

Energy transaction model among DERs during the time of network contingency caused by high wind gust. The idea is to prevent the system from introducing the scarcity pricing during an outage caused by extreme weather events.

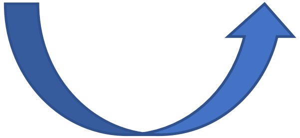
solarZero shares revenue from trading in the market with its community members through a monthly eco-bonus credit. Every member can expect to be credited $18,000 across the next 20 years by lending their battery and roof to take part in solarZero's virtual power station (VPP), which reduces their power bills. On an annual basis the solarZero community currently saves more than $2.3m on their energy costs.

Over the past year teams from NZX, Transpower, Panasonic and Auckland University have collaborated to develop the software, validate the capability of the VPP to participate in the market, and to integrate the solarZero platform.

Impact of High Wind Gust: Damaging power lines



If leading to an outage



Peer to Peer Transaction among Four Residential

SolarZero Enables World-first Trade In NZ Electricity Reserves Market

Monday, 7 November 2022, 10:19 am
Press Release: solarZero

Peer-Reviewed Publications

- 'Enabling Trusted Peer-to-Peer Microgrid Energy Transactions during High-Impact Low Probability Weather Events', **ISGT Asia, Singapore, Nov 2022**
- 'Peer-to-Peer Consumer Energy Transaction Support Models during High-Impact Low Probability Weather Events', **EEA New Zealand, Hamilton, Sept 2022** **(Best Paper Award)**
- 'Extreme Weather Risk Framework for Power System Location-Based Resilience Assessment', **IEEE POWERCON, Malaysia, Sept 2022** **(Best Paper Award)**
- 'High Impact Low Probability Weatherization Impact Analysis for Electricity Infrastructure', **IEEE TENCON, Dec 2021**
- 'Resilience Framework and Optimal Scheduling for DERs Factoring Uncertainties', **IEEE ISGT Asia, Dec 2021**
- 'Energy-Communication Infrastructure Resilience through the Lens of Seismicity', **EEA New Zealand, Aug 2021**

Defining Resilience for the Telecommunications Networks and Infrastructure

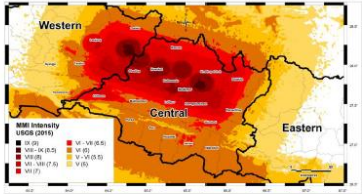
Eric Sauvage

Infrastructure Research Day, 21-22 November 2022

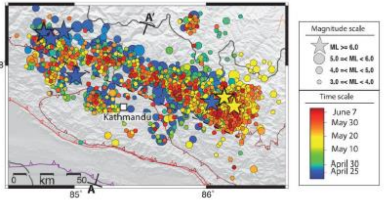
National Science Challenges

University of Auckland, Waipapa Taumata Rau, New Zealand

Insights from the Gorkha-Nepal Earthquake and its aftershock sequence (2015)



Shakemap with estimated Modified Mercalli Intensity (MMI) according to (USGS, 2015)



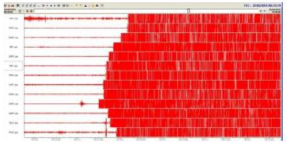
Earthquakes from April 25th to June 7th 2015 (Adhikari et al., 2015)

Telecom for Earthquake monitoring

STATIONS → *acquisition* → DATACENTER (*processing*) → $M_L > 4$ *dissemination* → RESPONDERS

Consequences of the Earthquake

- Effects on seismic network capability



- International relief
- Increase in demand / congestion of telecom networks

- Timeline

Start of the PhD (May 2022) → Telecom Resilience Literature review / Workshops (May-November 2022) → Major challenges / Research gaps (November 2022 -)

- Telecommunications and natural disasters since 2019
  - Fixed network
  - Mobile communications
  - Satellite

Thank
You
Raibh Maith Agat
ASANTE
GRAZIE
Chokrane
Juspaxar
Dankon
Maake
Ua Tsaug Rau Koj
Obrigado
DANK JE
Kiitos
Mamana
Mochchakkeram
Terma Kasih
Grazie
Asante
MATONDO
Welalin
Merci
SPASIBO
Kia Ora
Vinaka
Multumesc
Matondo
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