Distributed Infrastructure Network RNC Project

12th June 2017

Disaster Related Recovery of Electrical Power Networks - A Primer

Duncan Kaniaru and Nirmal Nair

Discussion Research Slides
RNC Framework for Electricity Recovery and Restoration

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Agenda

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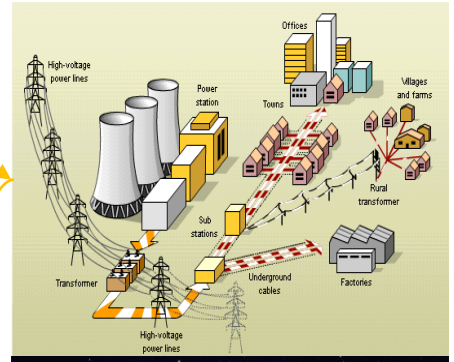
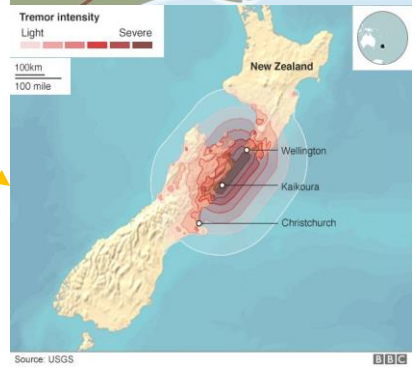
Introduction to Power System Structure and Power System Restoration



Hazard Model planning

mainpower
THE POWER TO MAKE IT HAPPEN

Case Study: Kaikoura Earthquake



Introduction to power system structure

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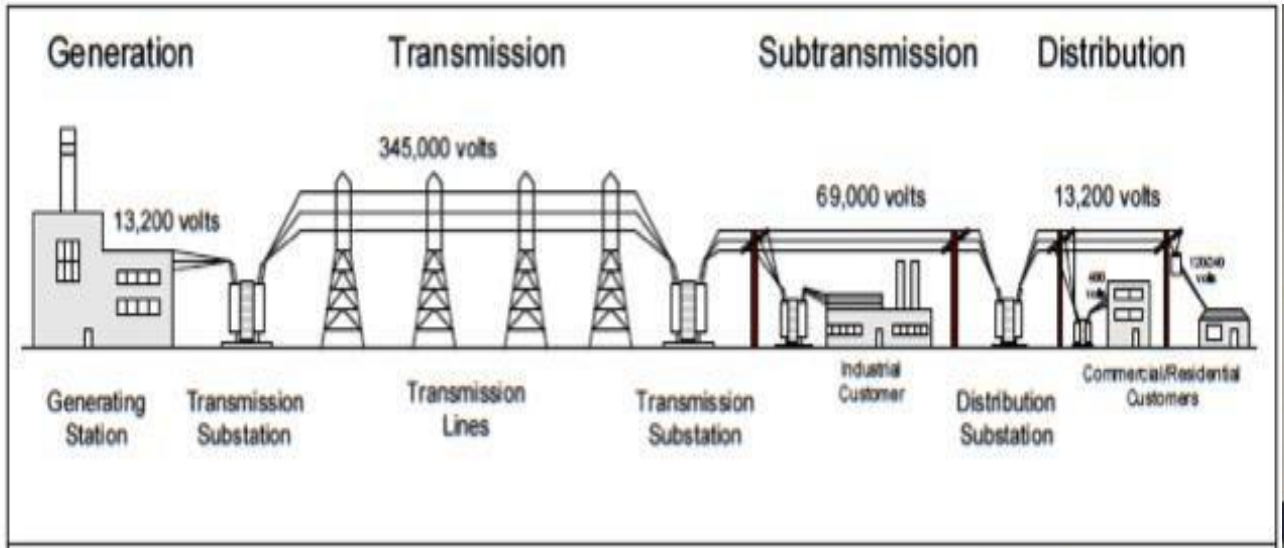

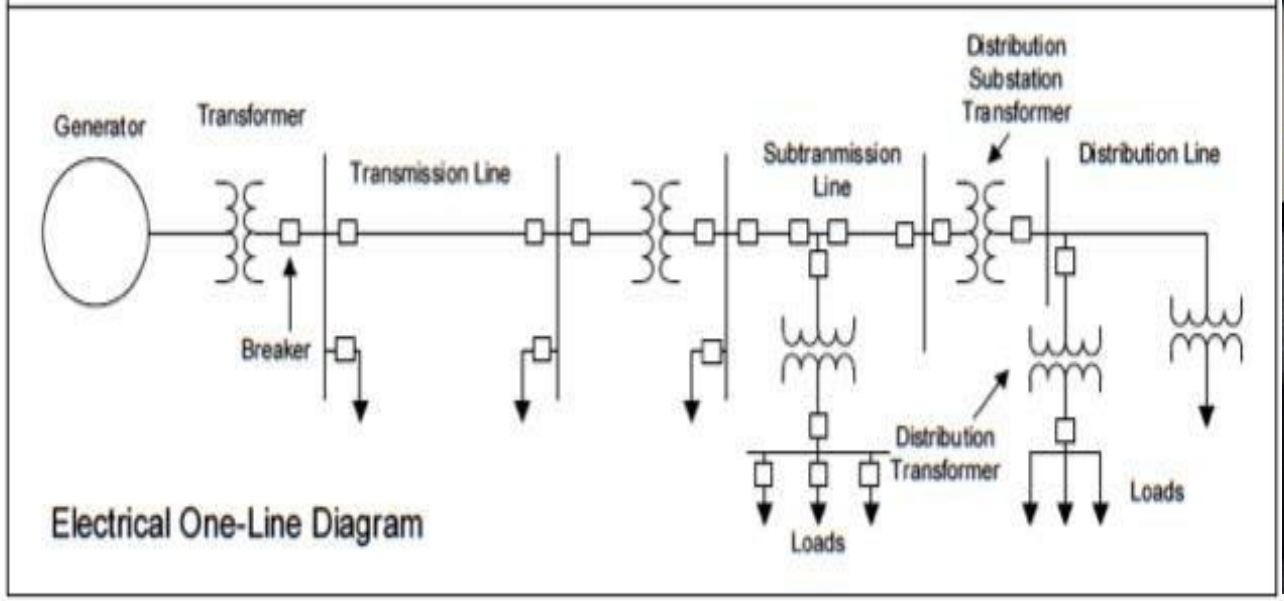

Power System Restoration

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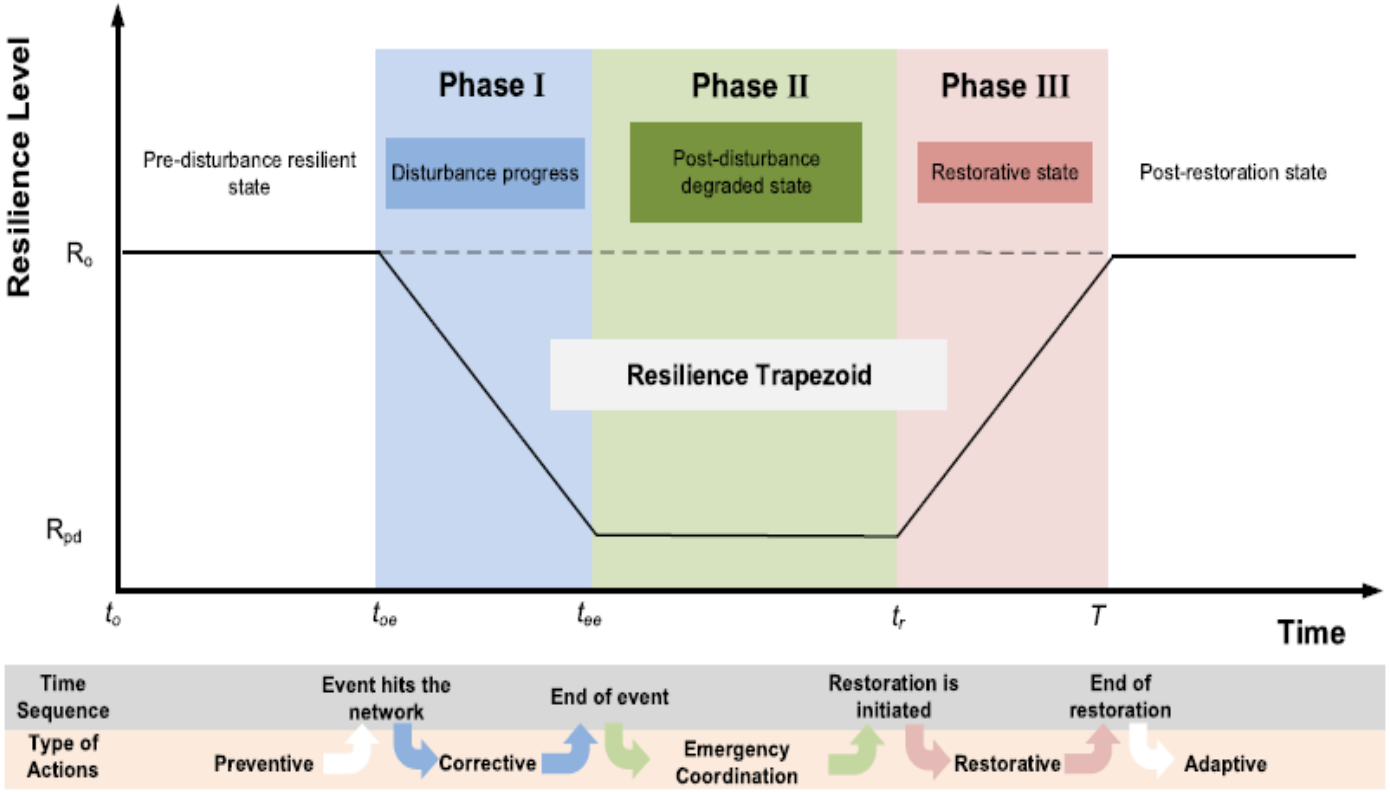
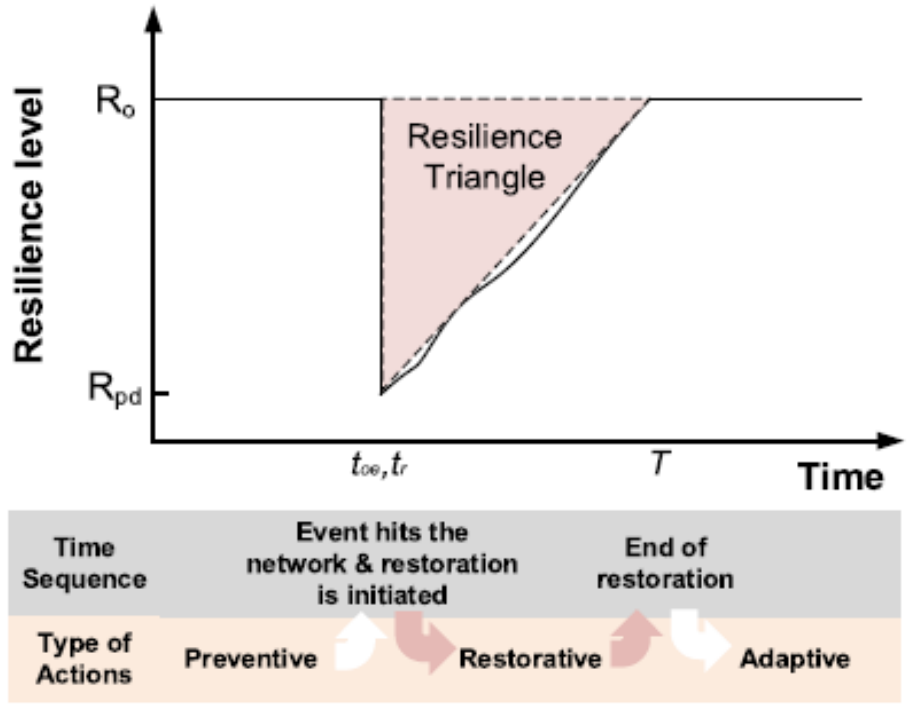
Definition – Network recovery after a blackout whether partial or complete blackout.

Two types: Typical outage and disaster related.

Power System Restoration





M. Panteli; D. N. Trakas; P. Mancarella; N. D. Hatziargyriou, "Power Systems Resilience Assessment: Hardening and Smart Operational Enhancement Strategies," in *Proceedings of the IEEE* , vol.PP, no.99, pp.1-12

Hazard Related Recovery Planning

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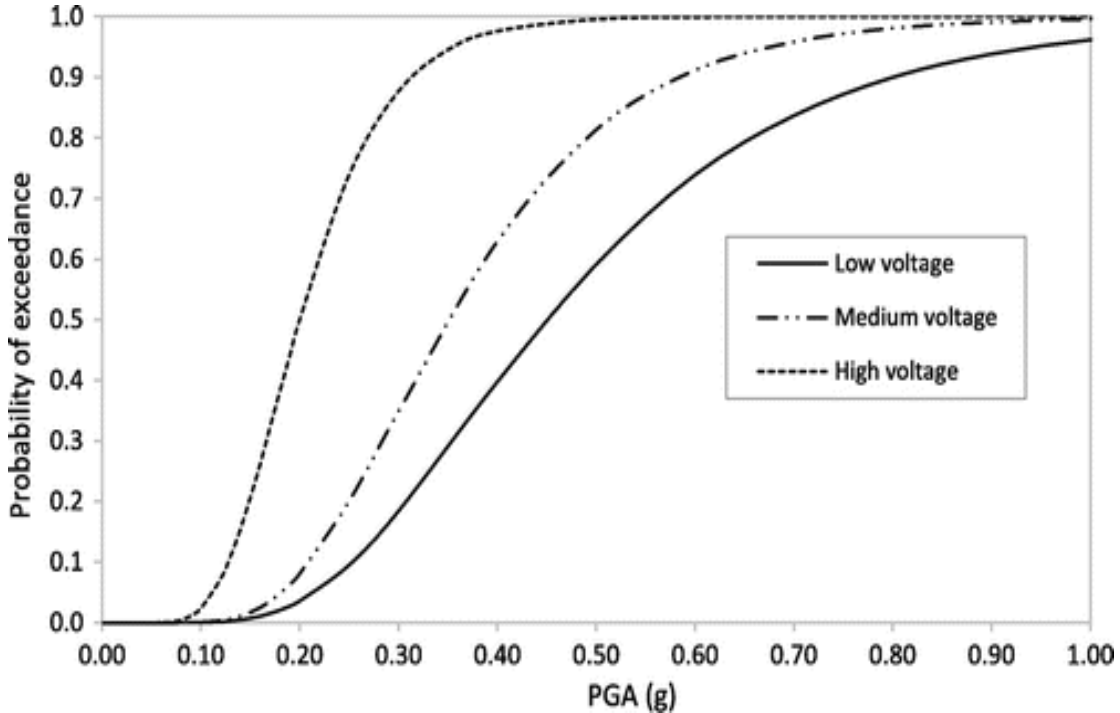
- Pre-hazard restoration model and Post hazard restoration model

Pre-hazard restoration model

- Emergency planning in case of a natural catastrophic hazard.
- Damage prediction by use of fragility curve.



Pre-hazard restoration model - Cont

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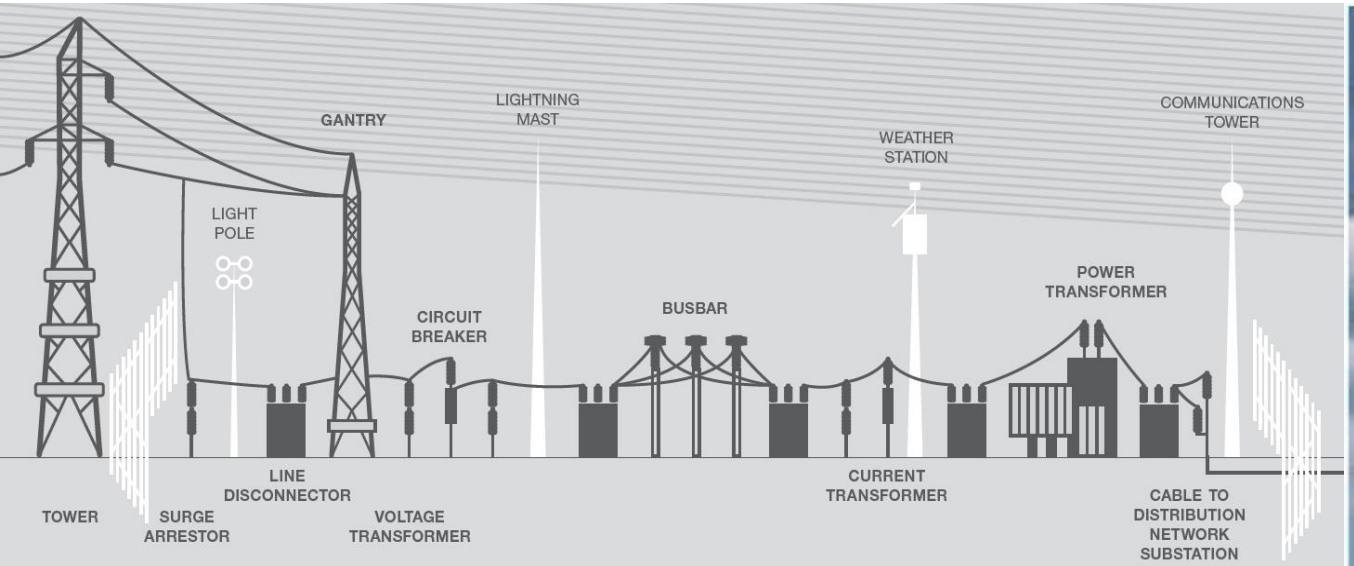
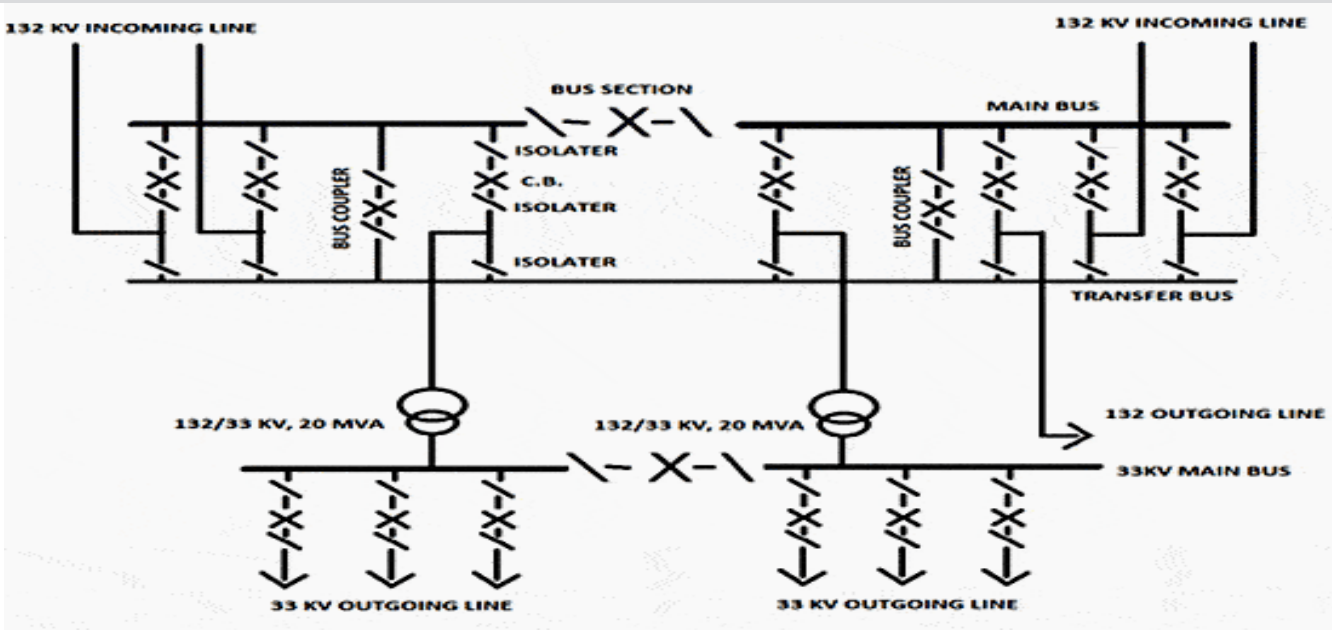
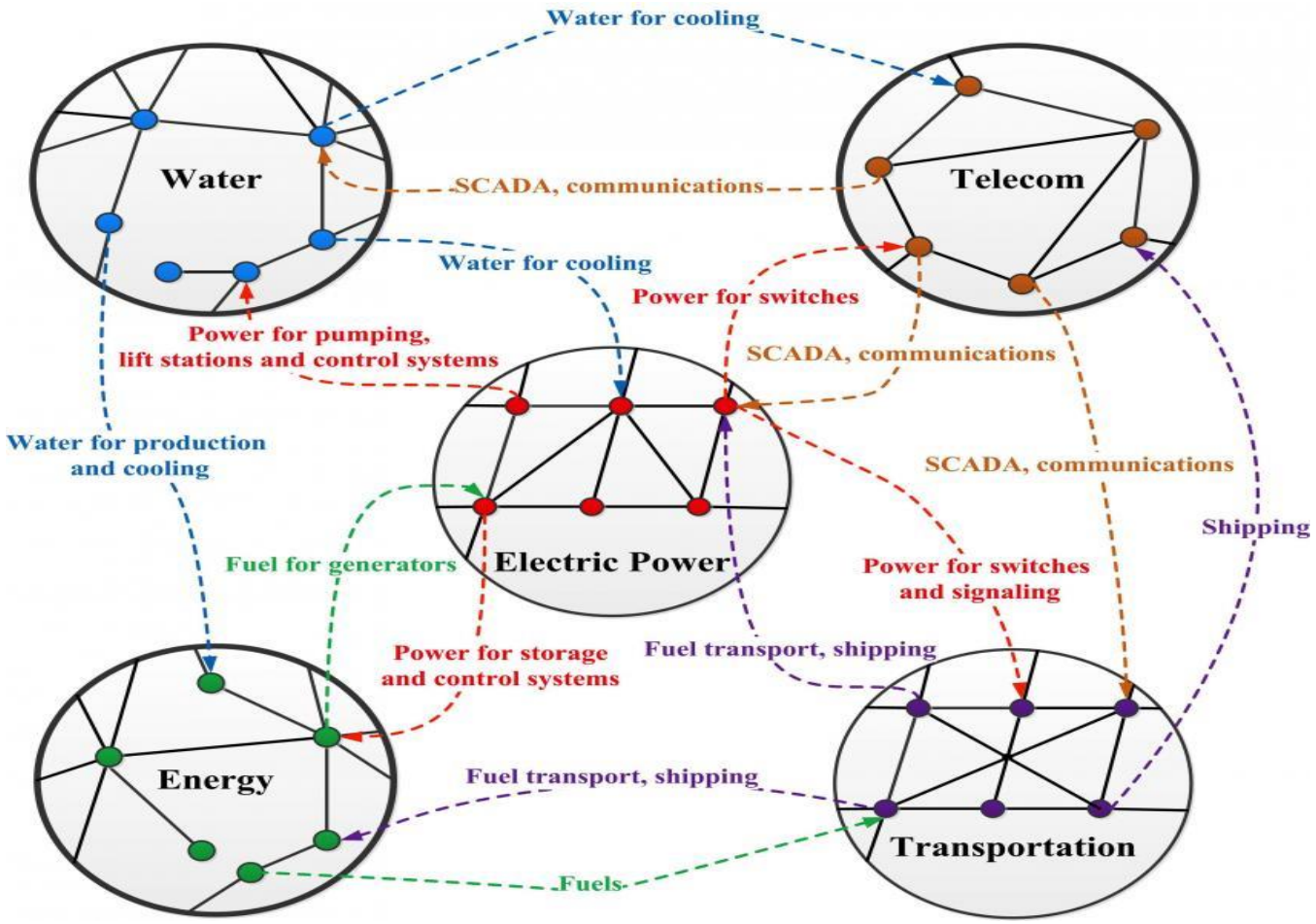




Pre-hazard restoration model - Cont:



Interdependencies:

- Physical
- Cyber

https://phys.org/news/2014-12-scientists-worldwide-network-networks.html

Pre-hazard model - Cont

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- Creation of ‘what-if’ scenarios.
- Use of HAZUS software or Spatial-temporal Monte-Carlo simulations for damage prediction.
- Resource allocation planning
    - Crew availability: exploration crew and repair crew
    - Vehicle routing
    - Spare parts allocation and location of depots.
    - Mutual agreement for help between distribution companies
- Creation of system performance measures both energy and system resilience measures depending on the resilience trapezoid.

Pre-hazard model-MainPower perspective

- 2 Event Categories:
  - HILP (High Impact Low Probability) e.g. earthquakes
  - LIHP (Low Impact High Probability) mostly weather related e.g. floods, windstorms, electrical storms, snow storms, tsunami.
- Most crucial assets: 66 KV and 33 KV substations.
- Creation of 3 earthquake intensity scenarios to obtain the average damage ratios (assuming requirement of full replacement):
  - 1:500 6.2% - sub-transmission, 17% - Distribution network
  - 1:200 3.2% - sub-transmission, 9.8% - Distribution network
  - 1:100 1.2% - sub-transmission, 4.1% - Distribution network
- Seismic restraints installed at all zone substations apart form marble quarry zone substation.

MainPower New Zealand, "Asset Management Plan 2016 – 2026",.

Pre-hazard model-MainPower perspective

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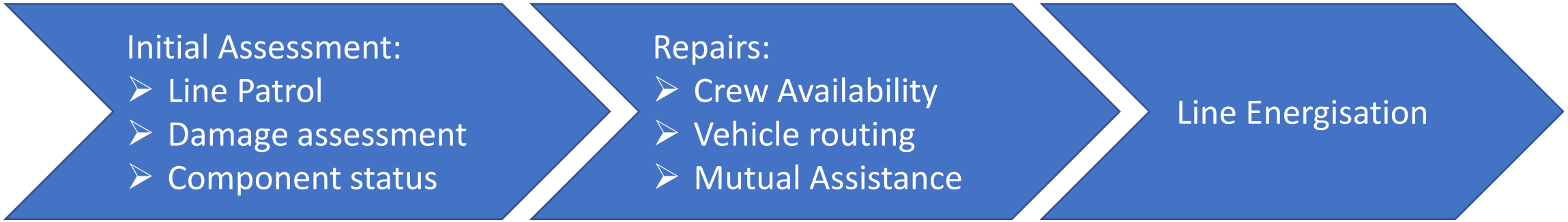
- Existence of mutual agreement between MainPower and other line companies for additional staff, cable fault location equipment and mobile generation
- Communication dependent power infrastructure: SCADA and Load Control.
- Location of Mainpower's radio sites: Mt Grey, Mt Cass, Mt Thomas, Mt Beltana, Wallace Peak, Williams Spur.
- In case of damage:
  - Failure of SCADA and Load control (Ripple injection system).
  - Local substation staff trained to assume responsibility and conduct manual operations.
  - Estimated restoration duration is one day due to access issues.
- Worst case scenario-Loss of both public telecommunication and utility communication.
  - Remedy: Company vehicles equipped with mobile simplex voice frequency for communication.

Post-hazard restoration model

- Formed after occurrence of the actual event.
- Three main phases:



Post-hazard restoration model - Cont

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- Use of Discrete Event Simulation to estimate restoration duration and relaying continuous information to consumers affected.
- Advantage: Incorporation of constraints
- Disadvantage: Large amount of data required.
- Key elements of a discrete event simulator:

Entities:
- Generating stations
- Substations
- Power lines

Resources:
- Exploration teams
- Repair teams
- Interdependency levels
- Spare availability

Attributes:
- Distance from EQ epicentre.
- Component status

Event: Actions undertaken are updated on the database.

- Creation of the restoration curve and evaluation of performance metrics.

Post-Kaikoura earthquake restoration

- Time of earthquake: 12:02 a.m. Epicentre: 15 kilometres north-east of Culverden
- Less load connected as time of occurrence of earthquake.
- Total number of customers affected: 7100
  - Hanmer-Conductor slashing–1500 customers–1.3 MVA
  - Cheviot-Conductor slashing-1000 customers-0.8 MVA
  - Mouse Pt Sub (Culverden)-Transformer Buchholz trip and feeder faults-1900 customers-1.2 MVA.
  - Ludstone Rd Substation (Kaikoura)- bus drop from Transpower GXP (Culverden) and extensive HV and LV lines -2700 customers-3MVA.

- Y. Liu, N. Nair, A. Renton and S. Wilson, "Impact of the Kaikoura Earthquake on the Electrical Power System Infrastructure", *Bulletin of the New Zealand Society for Earthquake Engineering*, vol. 50, no. 2, 2017.
- http://www.mainpower.co.nz/contact-us/latest-news/mainpower-emergency-response

Post-Kaikoura earthquake restoration

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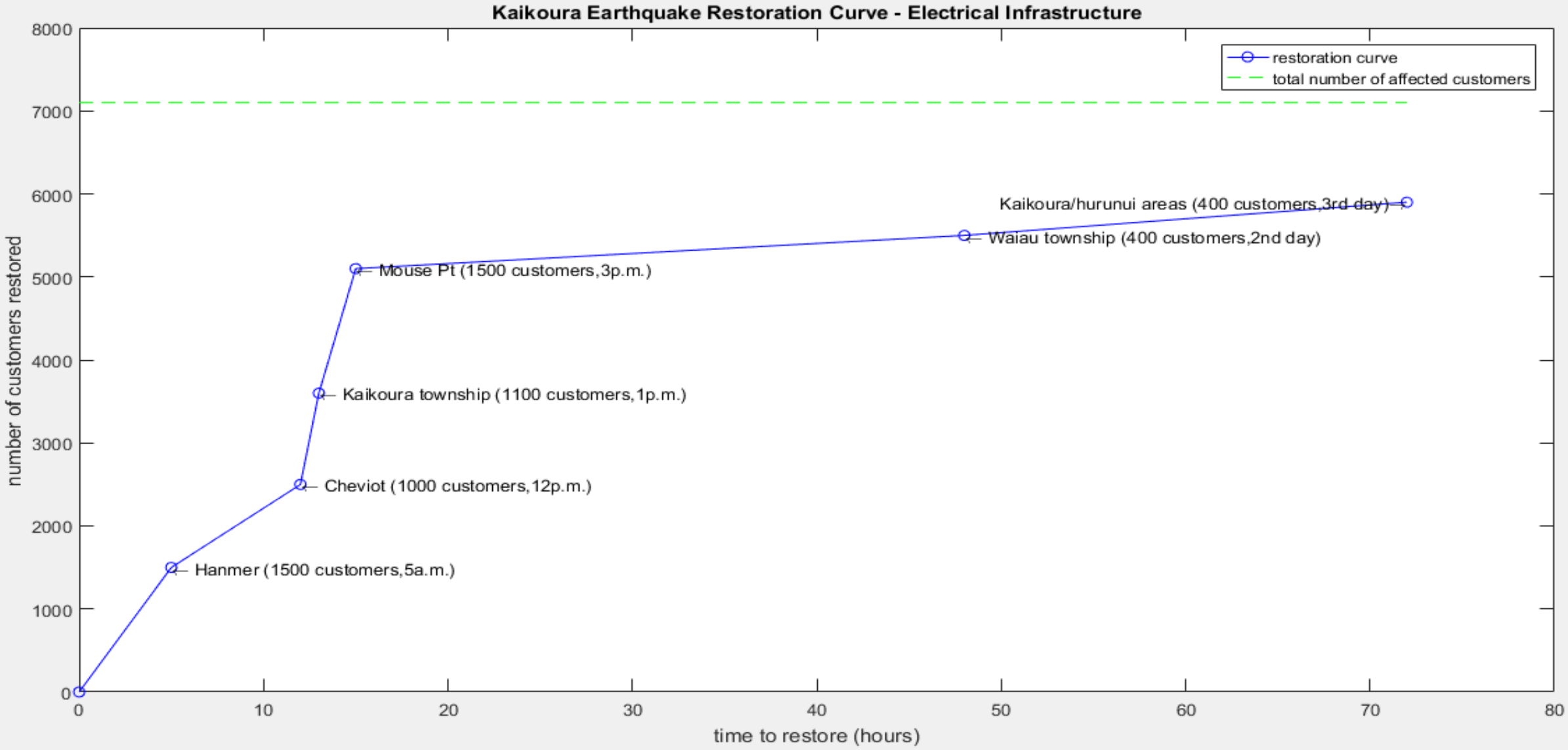

Ongoing Activities

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- Discrete Event Simulation to evaluate performance metrics of the electrical power restoration
- Generalized formulation for Restoration of electricity factoring other network interdependencies: Upper East of South Island (North Canterbury) Case study
- Develop an interdependency inclusive blackout-restoration model of the MainPower network and its application to urban and rural networks.
- Researching solution for future autonomous operation of North Canterbury region with loss of Transpower GXPs (islanded mode). An assumption is the availability of the proposed Mt Cass Windfarm of around 78 MW.

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