9 May 2022 – RNC2 Infrastructure Meeting

‘Vulnerability’ of Power Systems Exposed to Volcanic Hazards

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Outline

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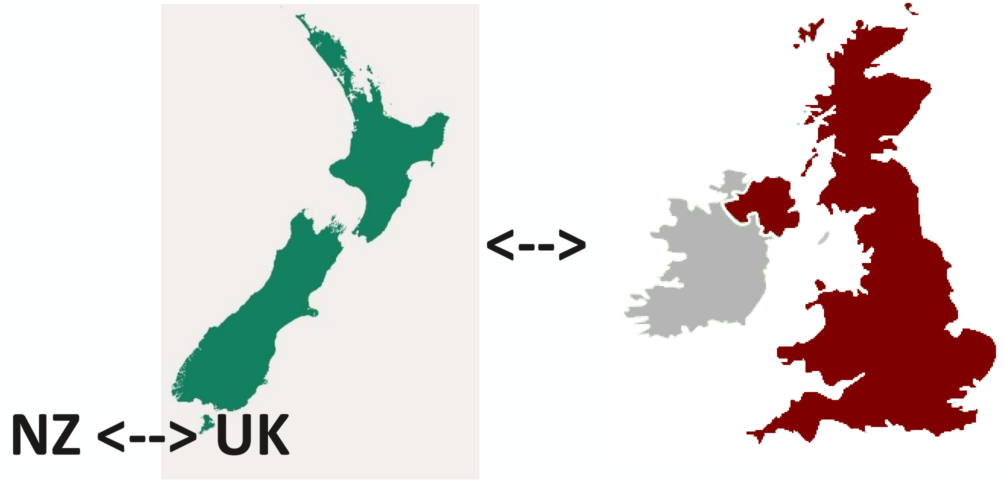
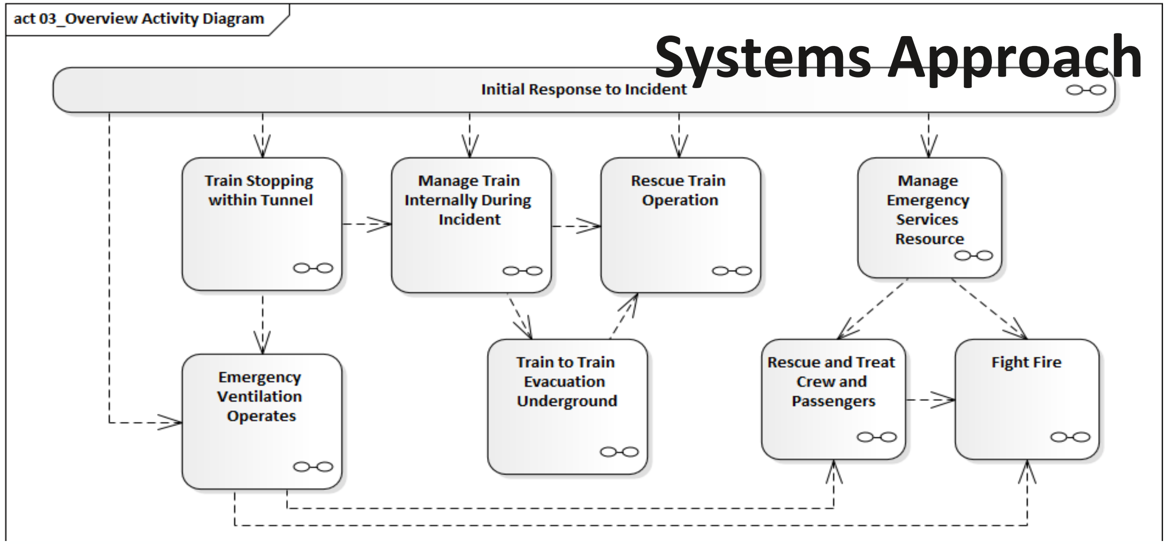
1. A bit about me for context
2. Overview of issues (via case study)
3. Existing research
4. Project direction and Objectives
5. Component Vulnerability
6. Power System Resilience
7. Risk Management - mitigations

A bit about me for context



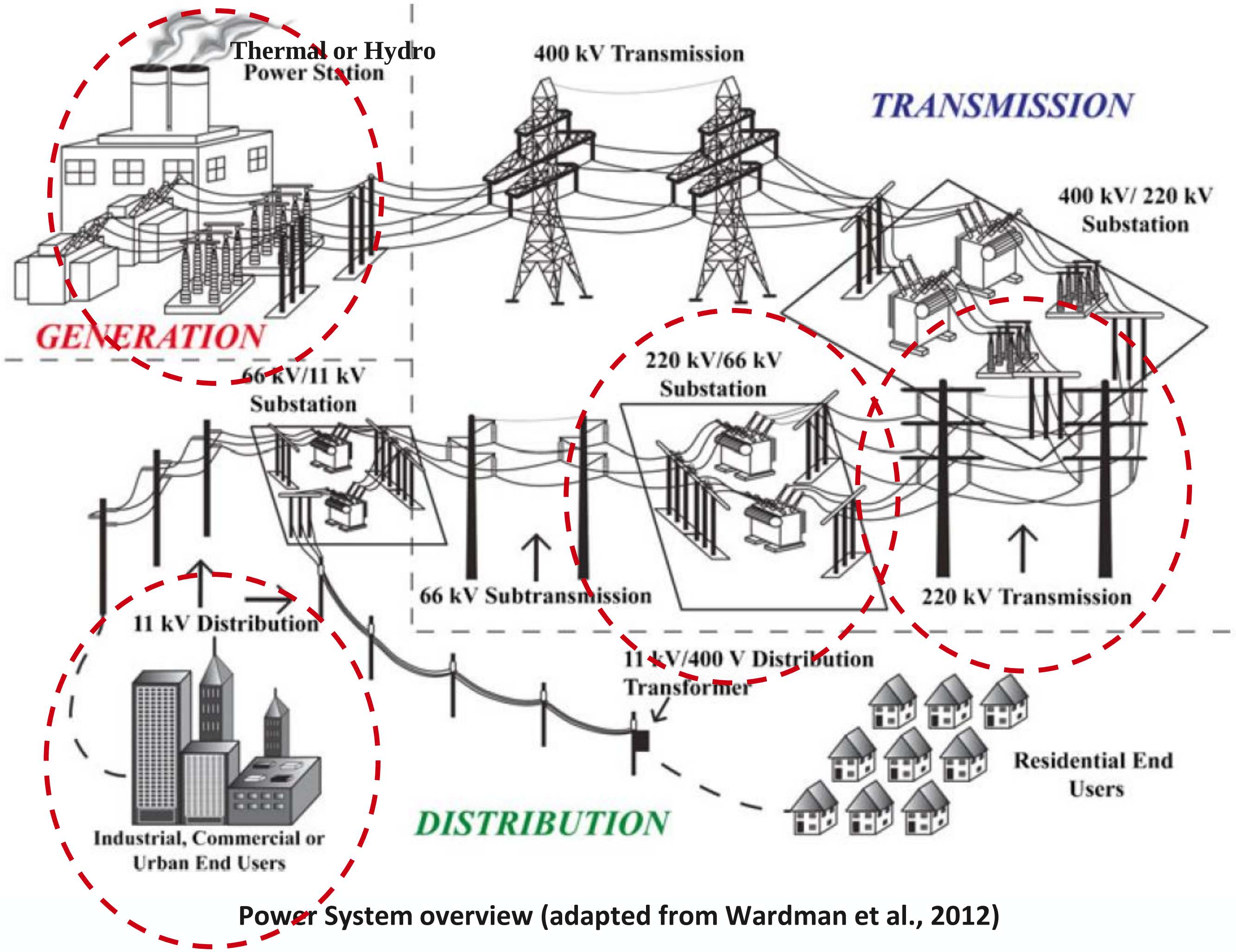


Power Issues during Ruapehu 1995

- Generating plant (15 years in 7 months)
- Flashover on transmission insulators
- Human intervention required
- Downstream power quality issues

-> don't forget non-tephra hazards

June 1996 eruption from Ruapehu, NZ (GNS Science via https://volcanoes.usgs.gov/volcanic_ash/ruapehu_1995.html)



Power System overview (adapted from Wardman et al., 2012)

Previous UC work (Wardman et al.)

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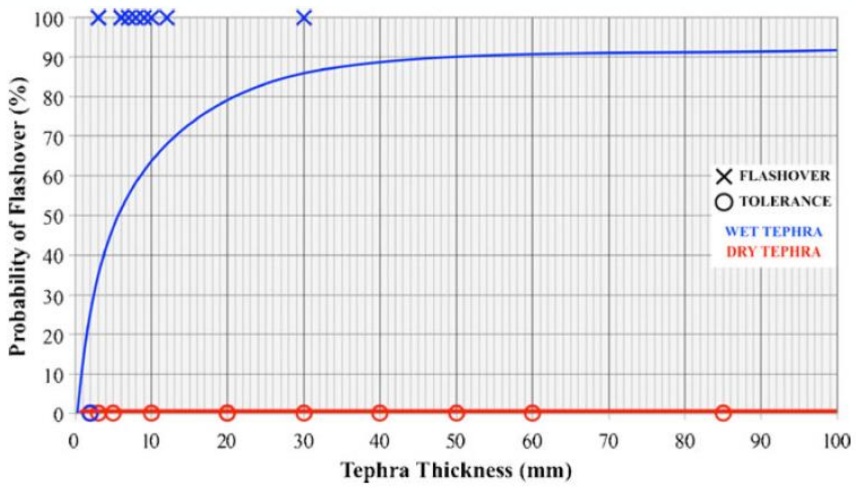
- Volcanic impacts on power systems
- Electrical properties of ash
- Physical modelling of insulation flashover



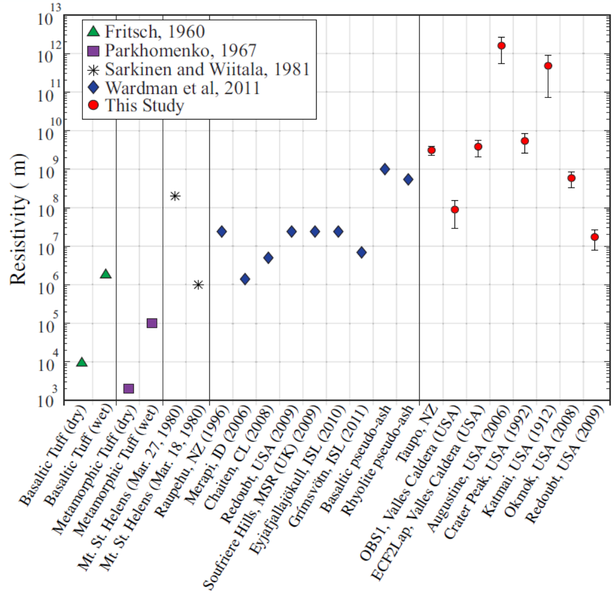
Probability of tephra induced flashover as a function of wet or dry tephra thicknesses (from Wardman et al., 2013)

Flashover across composite insulator in lab (from Wardman et al., 2013)

- 3 mm wet/damp ash causes impact
- Approach for modelling electrical infrastructure exposed to tephra (G. Wilson, 2015) (Weir, 2021)

Recent work examples

- Woods et al. (2020) – Ash resistivity / conductivity based on size and shape
- Saltos-Rodríguez et al. (2021) – lahar impact on power systems with resilience measures
- Schweikert and Deinert (2021) – “System property of persistence in function despite perturbance”
- Zorn et al. (2021) – system level interdependencies during disruption



Average electrical resistivity values from various ash samples (from Woods et al., 2020)

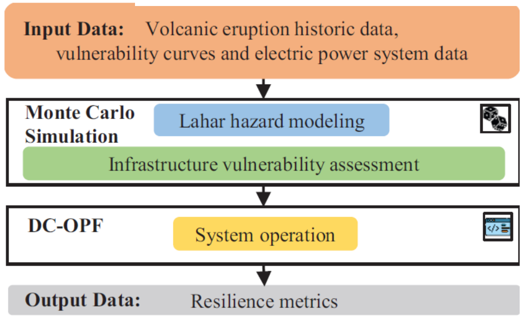


Fig. 1. Proposed methodology to assess the impact of volcanic lahars on electric power systems.

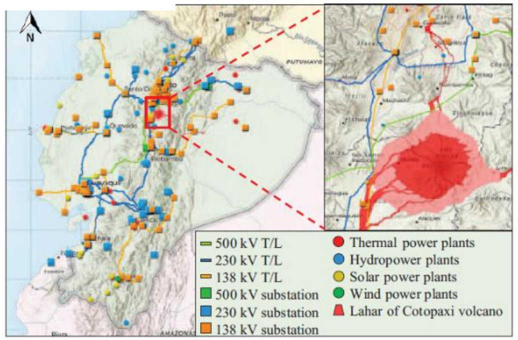


Fig. 5. Ecuadorian National Interconnected System one-line diagram considering lahar impacts.

(Saltos-Rodríguez et al., 2021)

Taranaki Region (Weir, 2021)

- Multi-phase, multi-hazard, multi-infrastructure
- Quantifies dynamic volcanic risk
- Electricity is important

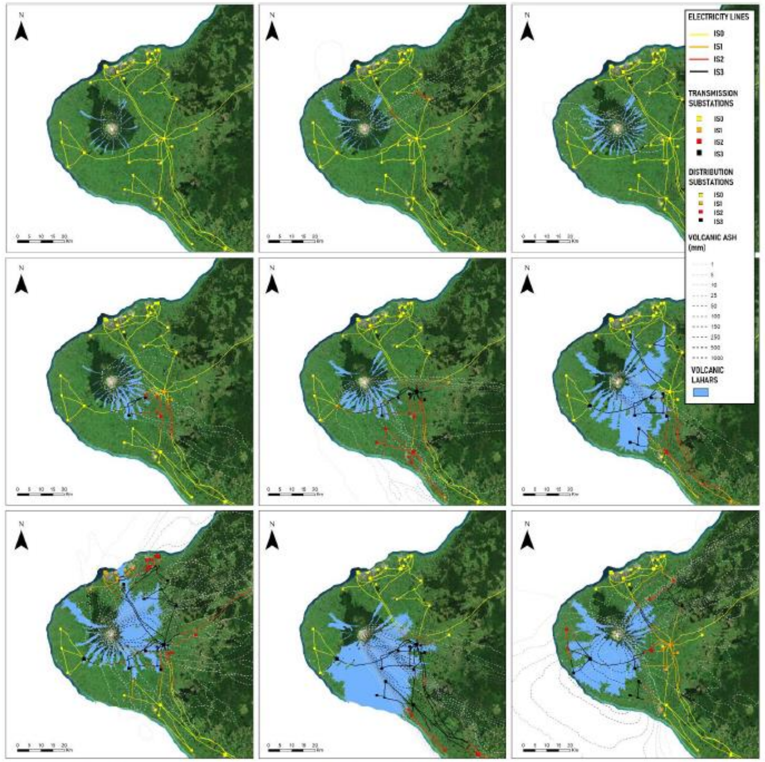
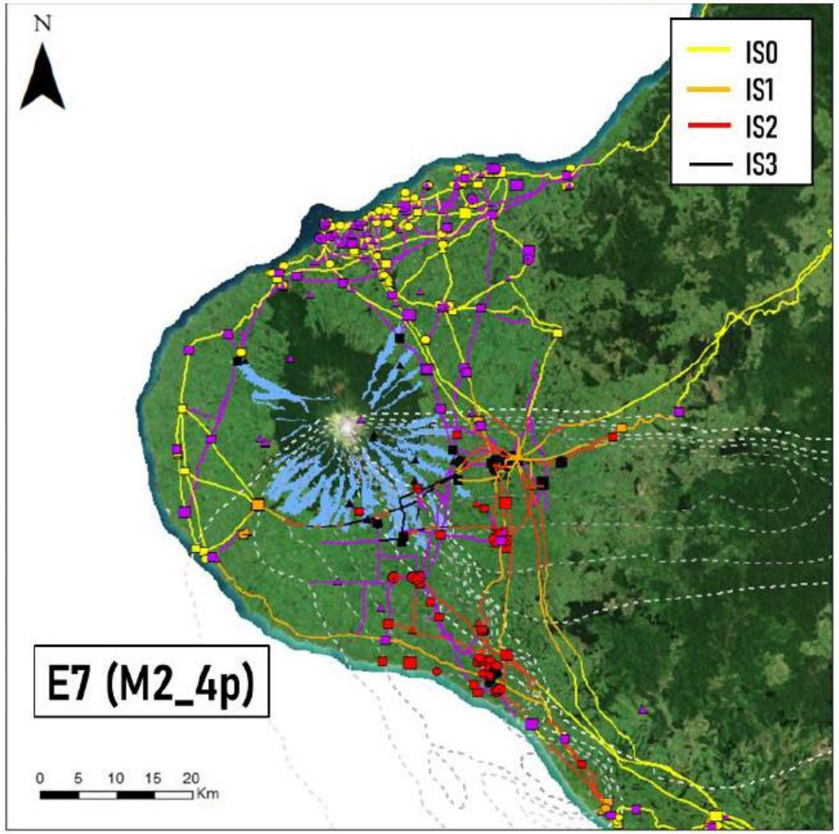


Figure 4.5 The direct impact to electricity transmission and distribution infrastructure in the Taranaki region of Aotearoa-New Zealand. The impact is shown at volcanic activity phase 6p (i.e. at the end of the eruption sequence) for each of the nine scenarios.

a) Impact on electricity infrastructure in Taranaki region for various volcanic scenarios (from Weir, 2021)

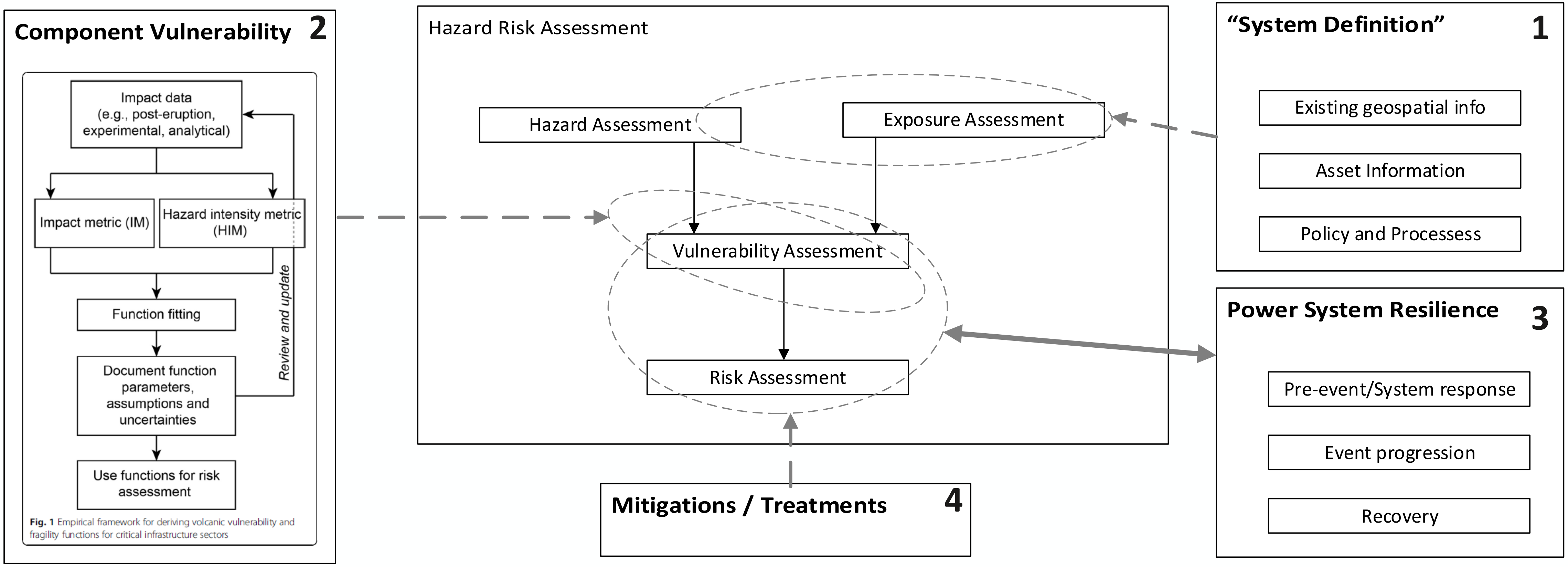


b) Impact on multiple critical infrastructure in Taranaki region for indicative volcanic scenario (from Weir, 2021)

Project Direction and Objectives

A) Assess component vulnerability of power systems exposed to volcanic hazards by considering impact on plant & equipment, people and processes during a multi-phase volcanic event

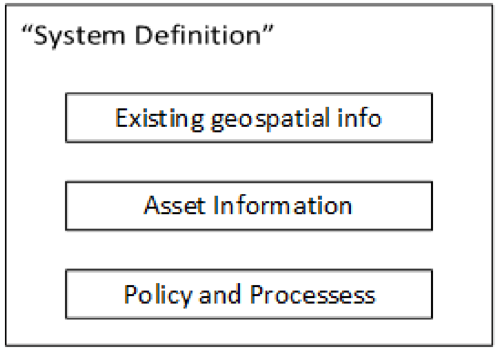
B) Develop power system representation to facilitate identification of critical aspects and understanding of resilience for a power system exposed to volcanic hazards



(G. Wilson et al., 2017)

Component and System Definition

- Case study Taranaki region
- System Definition
- Performance / loss of service
- System Operation and Configuration
- People, equipment (to do work) and work processes



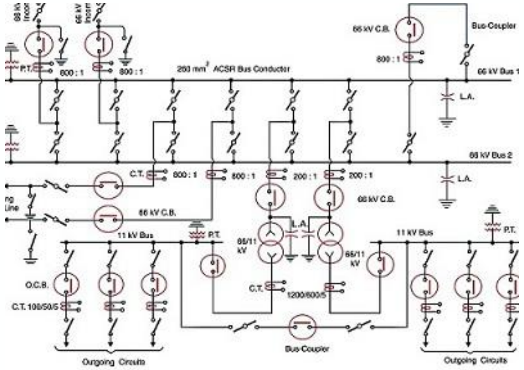


Image from https://www.powerco.co.nz/what-we-do/our-projects/improving-how-we-manage-our-assets

Developing (Component Vulnerability) Models

- Framework by G. Wilson et al. (2017)
- Qualitative / Quantitative
- Physical modelling (testing)
- Risk assessment methods
- Function fitting
- Mitigations -> ‘low hanging fruit’

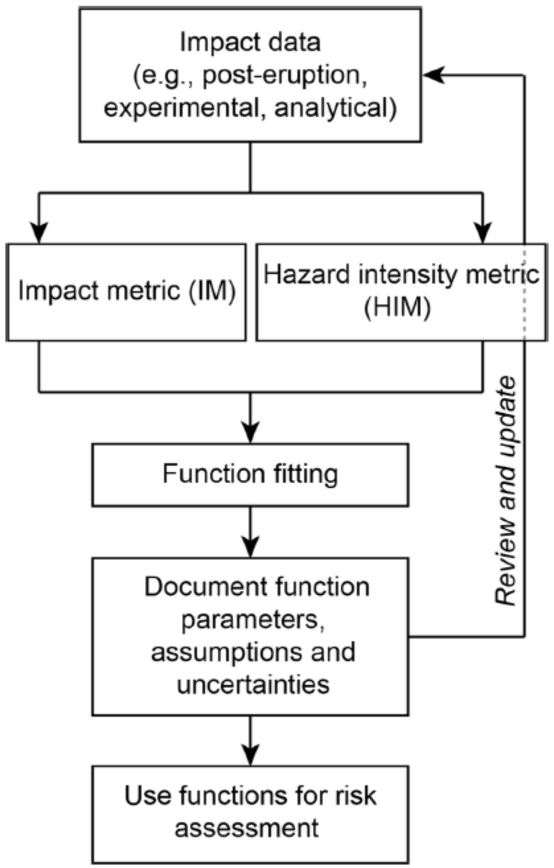


Fig. 1 Empirical framework for deriving volcanic vulnerability and fragility functions for critical infrastructure sectors

(G. Wilson et al., 2017)

Power system resilience

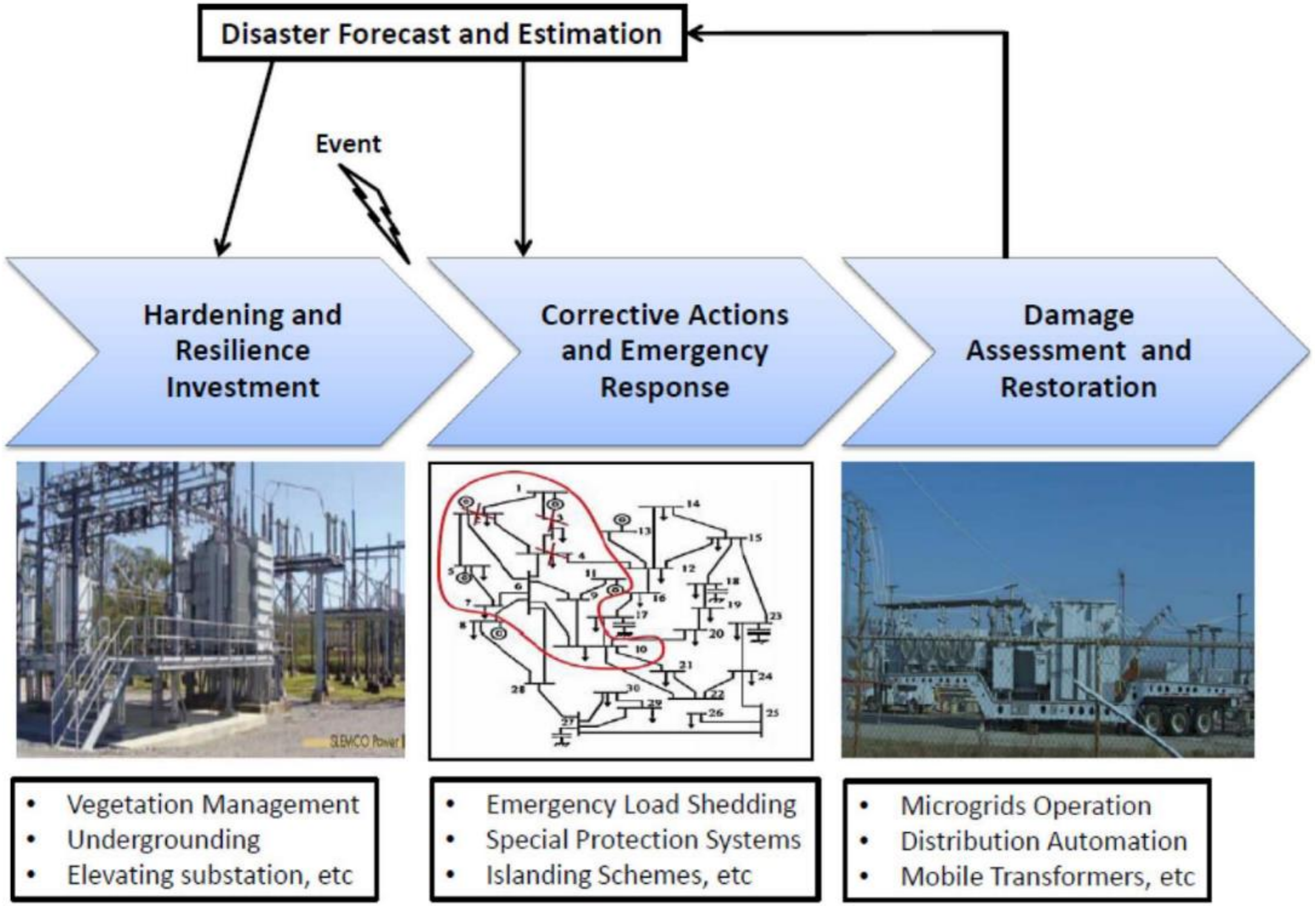
Component Vulnerability →

Power System Resilience

- Pre-event
- Event progression
- Response / Recovery

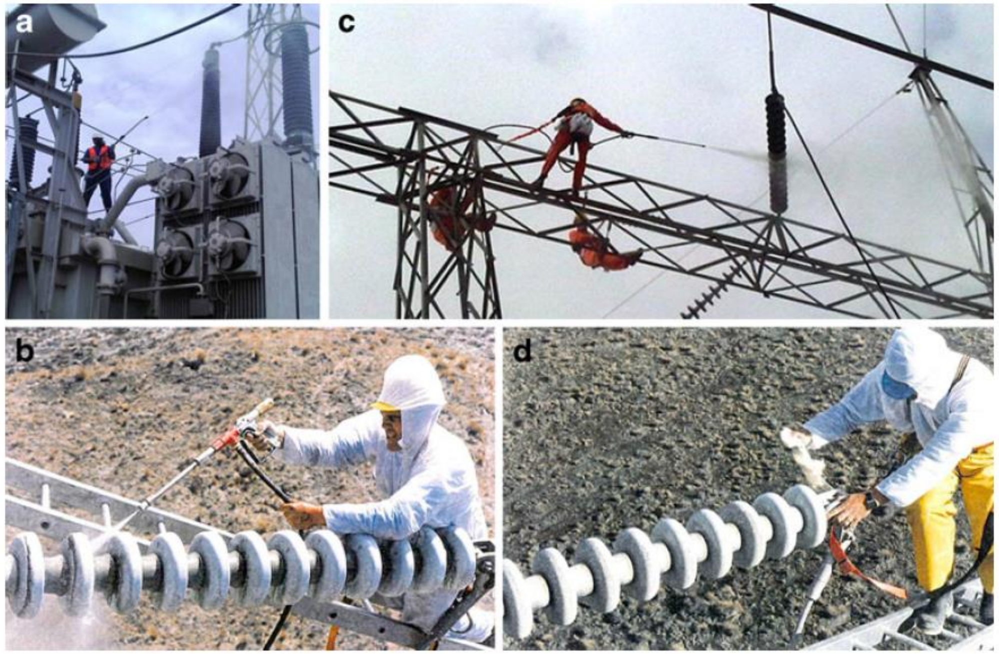
Eruption scenario, weather, resourcing etc.

System parts and internal / external interdependencies

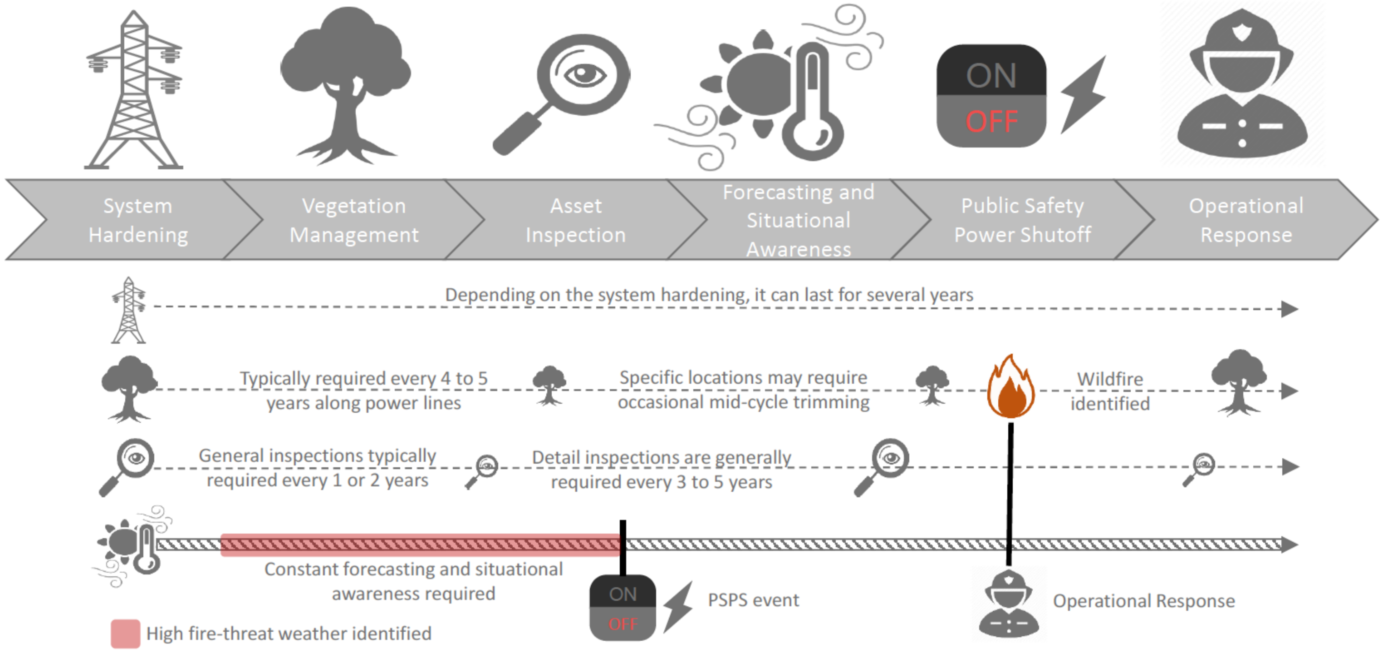


High level timeline for power system response to natural hazards (image from Wang et al., 2016)

Risk Management -> Mitigations



Cleaning electrical insulators (image from Wardman et al., 2012)



Mitigation timeline to safeguard power systems against wildfires (image from Zuniga Vazquez et al., 2022)

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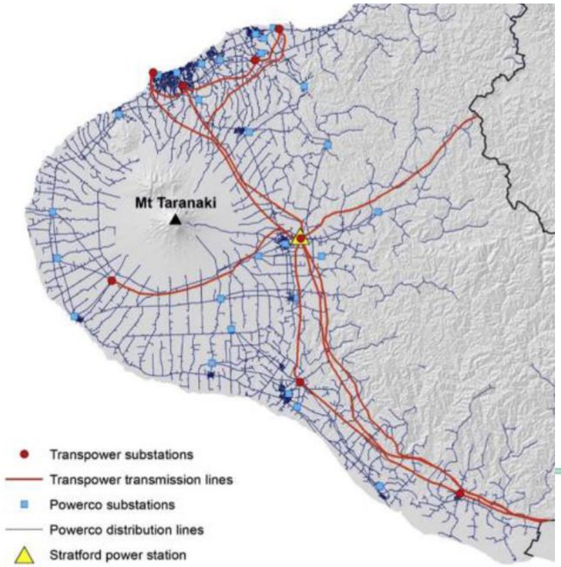
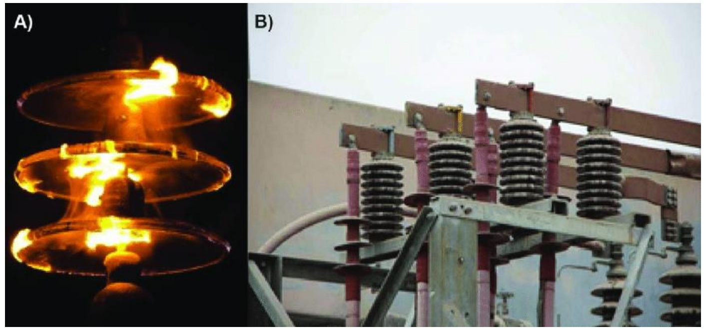
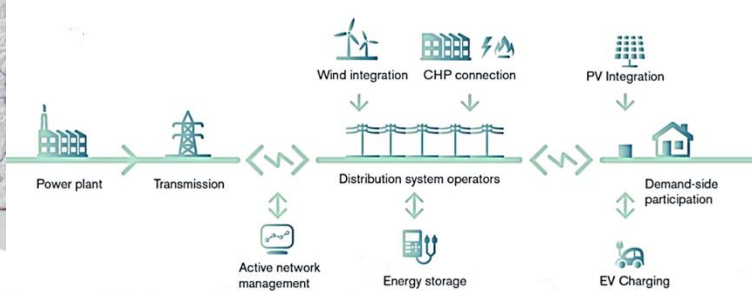
Summary

- Component vulnerability alongside system resilience in the context of power systems and volcanic hazards
- Building on work in Taranaki region for detailed examination of power system response to volcanic scenarios
- Systems approach to ensure coverage of topic while examining local & system level response & mitigations







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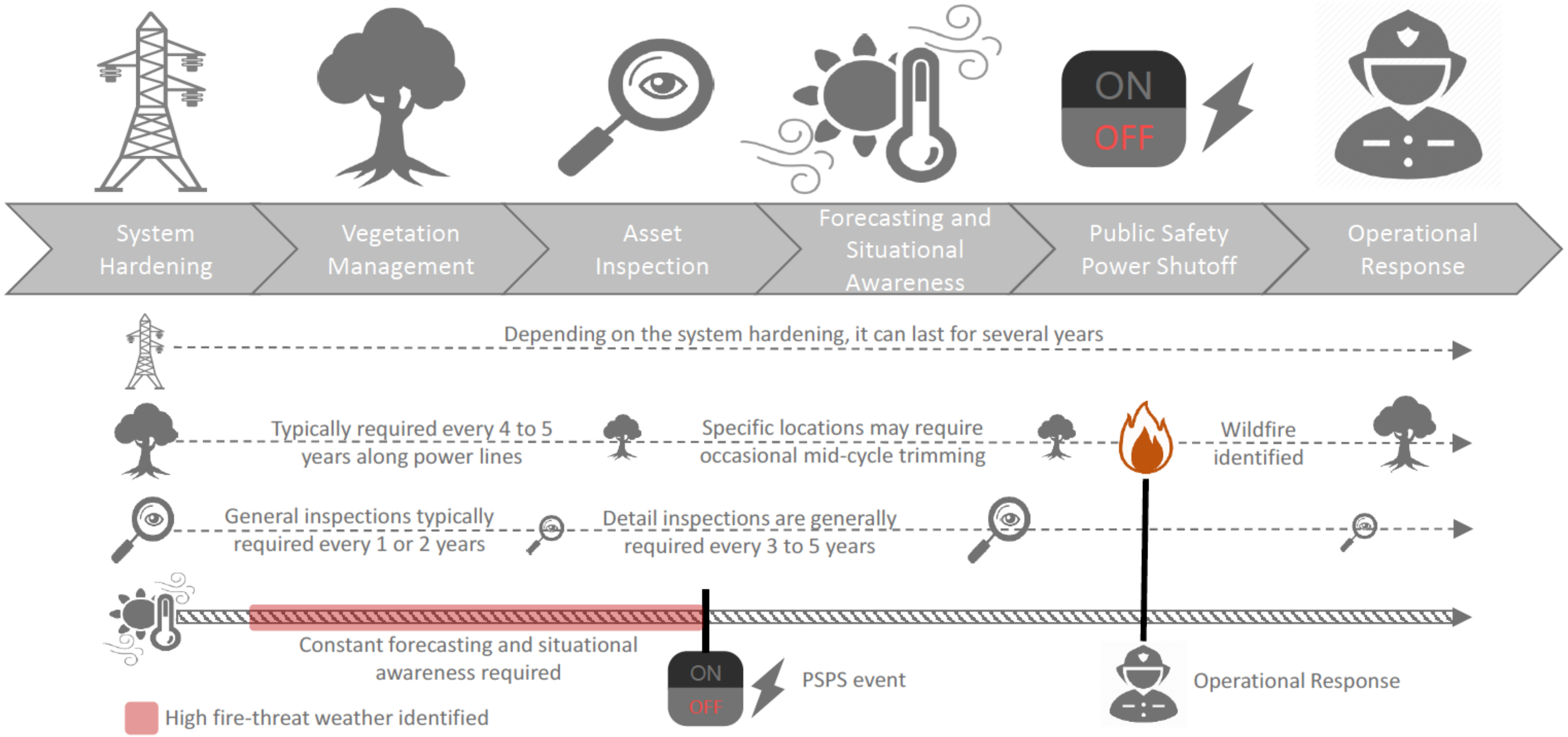
Risk Management -> Mitigations

- System Design
- Plant Design
- Equipment Design and Use
- System Operation
- Process Adaptation
- Temporary Works
- Situation Monitoring

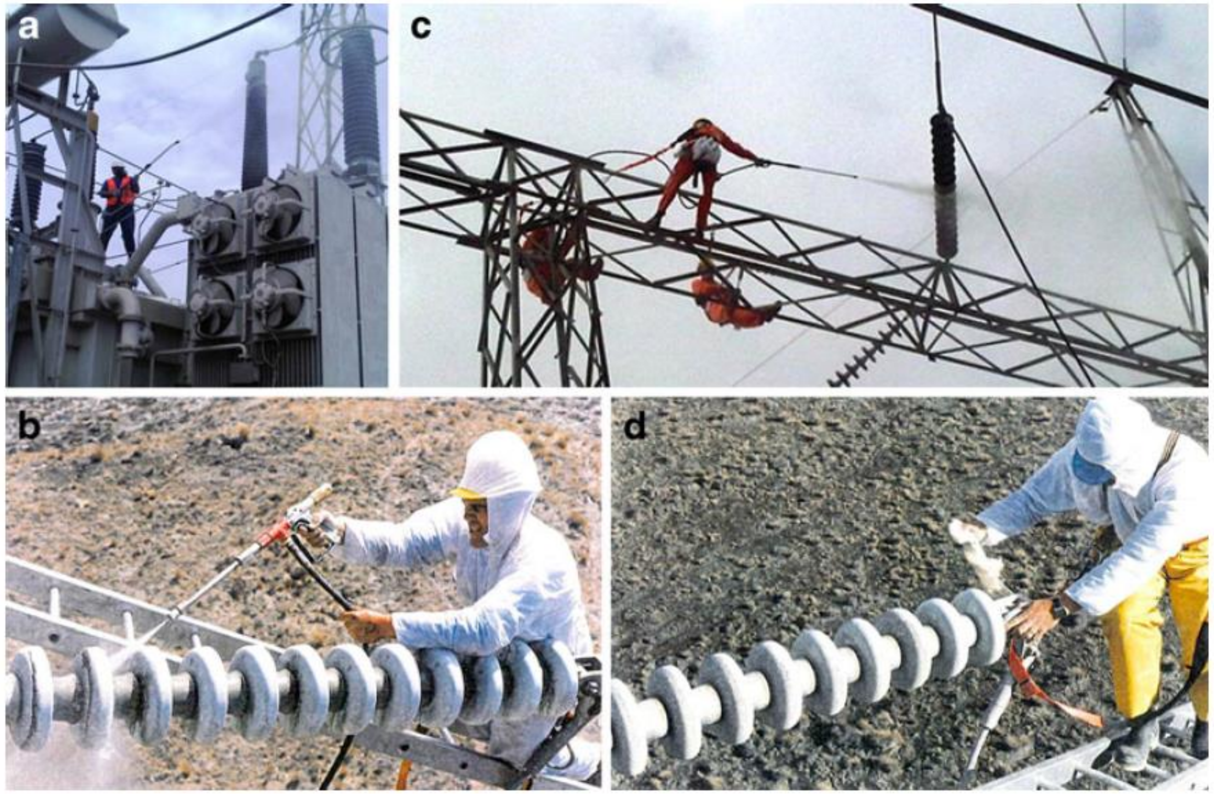


Mitigation timeline to safeguard power systems against wildfires (image from Zuniga Vazquez et al., 2022)

Mitigations for tephra

Considering tephra In the context of ISO 31000:2018

- Avoiding the risk - de-energise circuits
- Removing the risk source - cleaning, tephra attachment prevention
- Change the likelihood - modify insulation design (low hanging fruit?)
- Change the consequences – redundancy
- Retain the risk by informed decision - monitoring and analysis

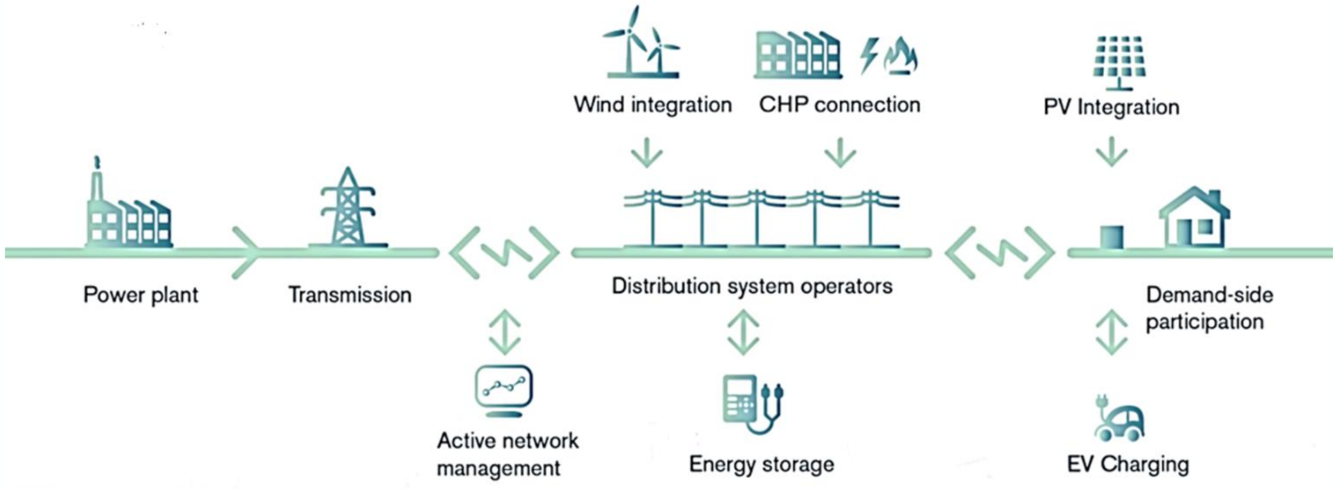


Cleaning electrical insulators (image from Wardman et al., 2012)

Final thoughts (for now)

And what about The 'Future' - technology, maintenance, operation etc.

- Will development resolve issues 'naturally’?
- Will development allow better system management?
- Will development protect against multiple hazards and risks?



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