Expansion of Electricity Distribution Networks Under Uncertainty

Anton Aish and Alex de Beer

Supervised by Andy Philpott and Tony Downward

Background

Electricity providers are facing unprecedented levels of uncertainty in future demand for electricity[1].

A key contributor to this uncertainty is the response to climate change, including increased uptake of new technologies including electric vehicles.

[1] Vector (2021). *Vector Electricity Asset Management Plan 2021–2031.*

Background

In addition to conventional line upgrades, electricity providers are also increasingly considering the use of non-wires alternatives, including batteries and techniques for load reduction.

ENERGY NEWS

www.energynews.co.nz

Published on *Energy News* (https://www.energynews.co.nz)

Home > Vector eyes 'non-wires' tech for Warkworth

Vector eyes 'non-wires' tech for Warkworth

Eamon Rood - Wed, 26 Jan 2022

Vector is looking into 'non-wires' alternatives – such as batteries, solar and digital platforms – to help manage rapid customer growth in Warkworth.

The Auckland lines company forecasts customer numbers will grow by 56 per cent in Warkworth over the next 30 years – from 16,000 today to 25,000. It expects to see constraints on its existing infrastructure within the next decade.

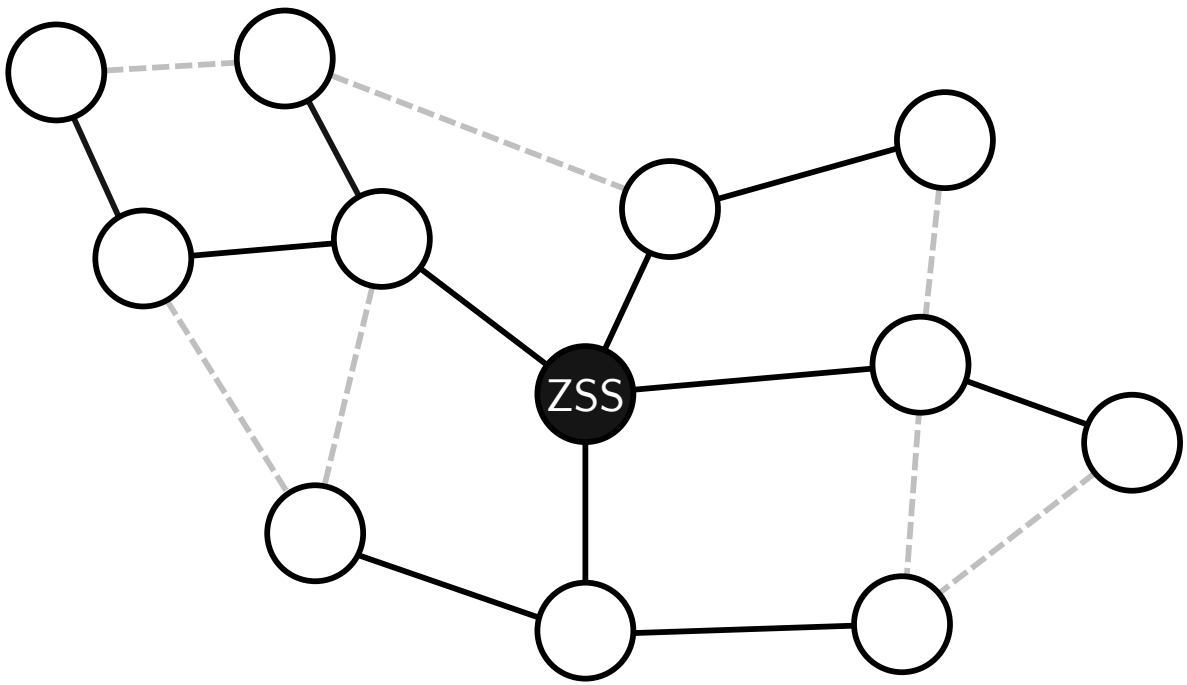
Research Objective

The objective of this research is to use stochastic programming to develop capacity expansion plans for distribution networks that

- minimise the total expected cost of expansion over a given time horizon, while maintaining a specified level of reliability; and
- account for uncertainty in future demand for electricity.

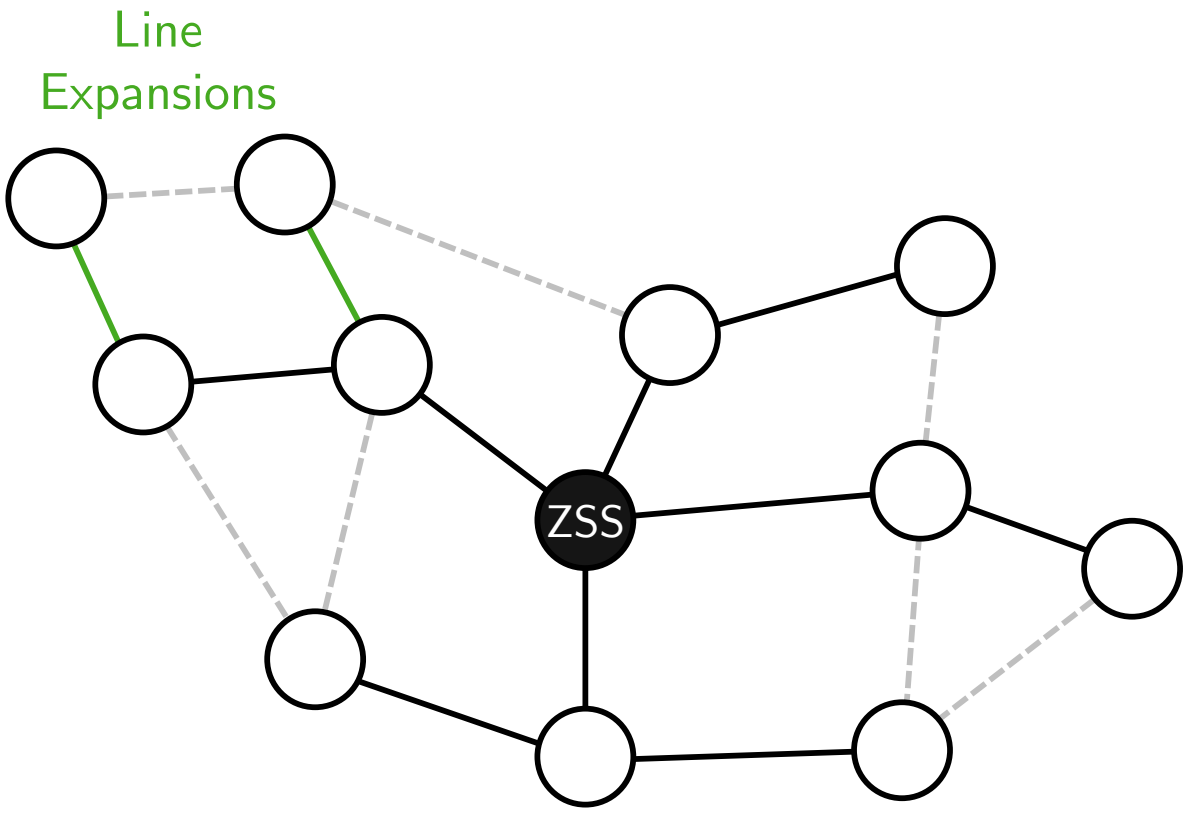
Model Components

We model several types of upgrades that can be made over the planning horizon.



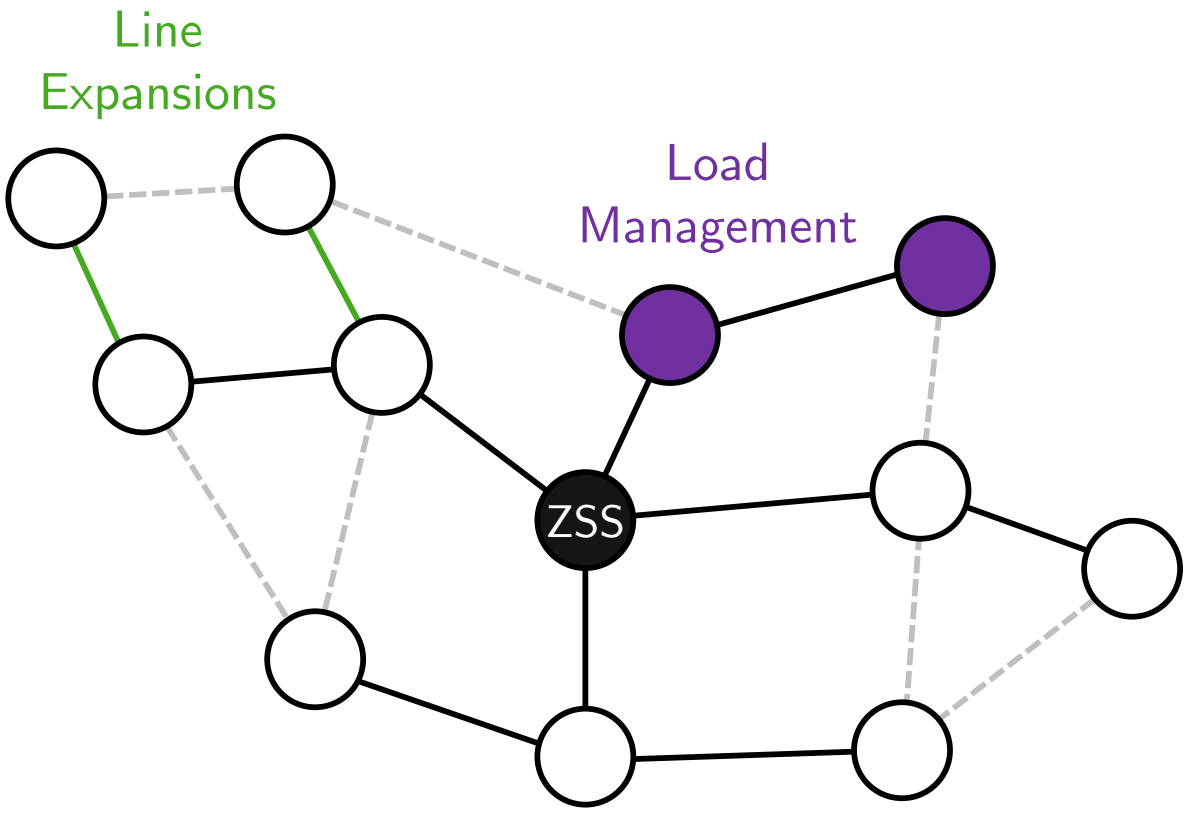
Model Components

We model several types of upgrades that can be made over the planning horizon.



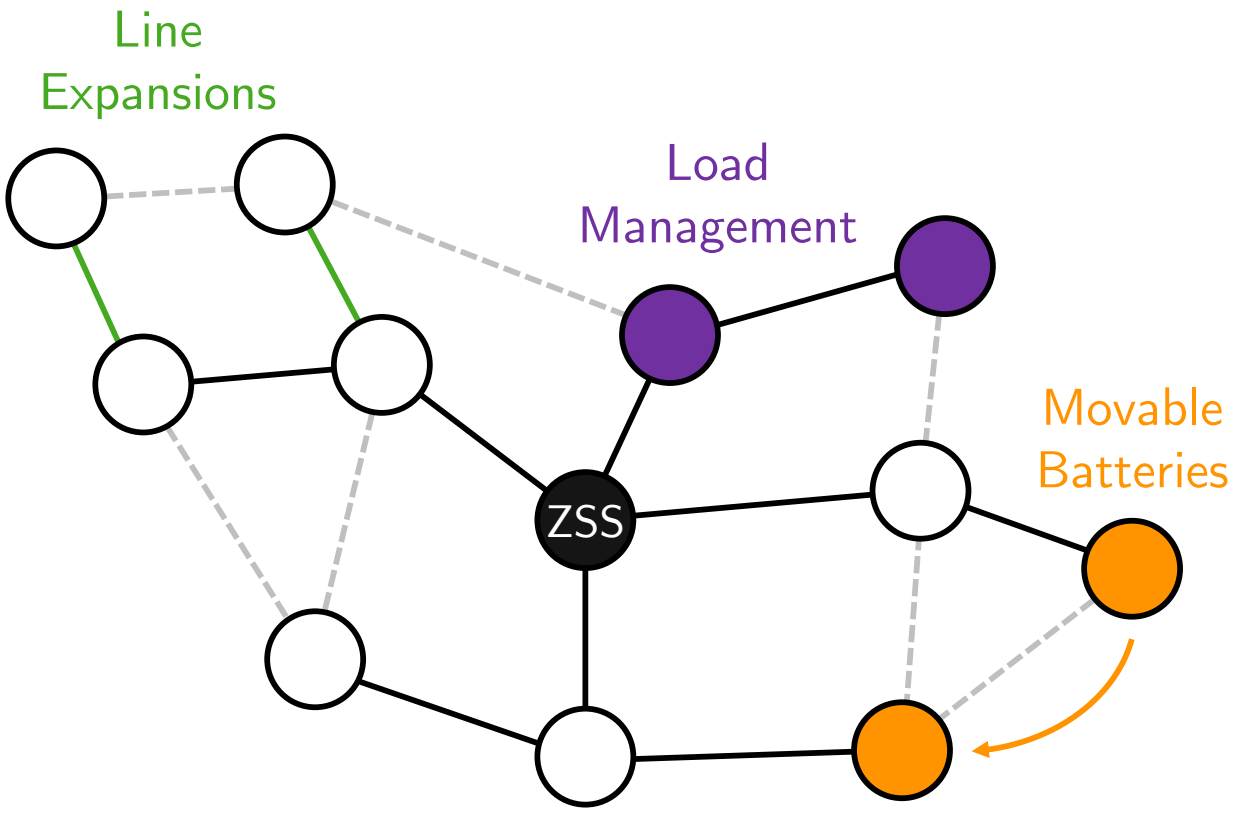
Model Components

We model several types of upgrades that can be made over the planning horizon.



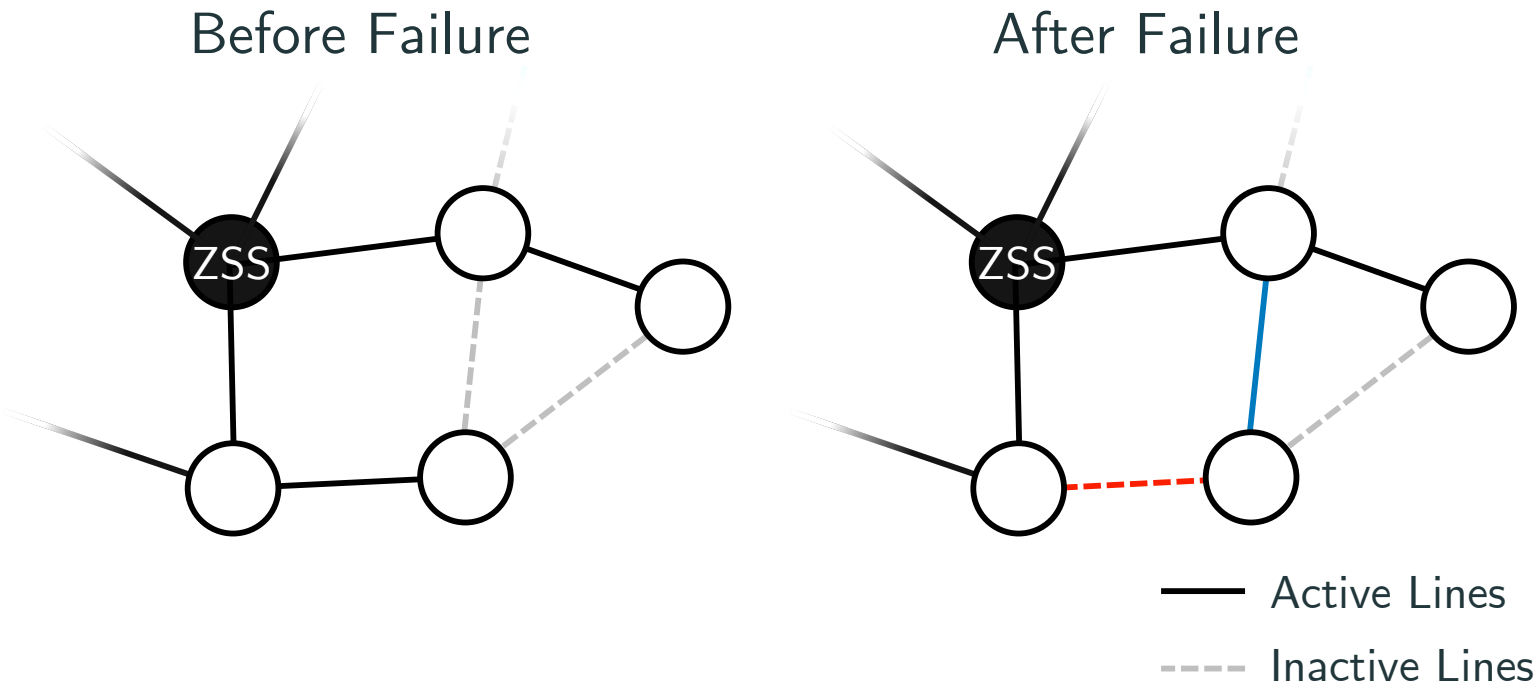
Model Components

We model several types of upgrades that can be made over the planning horizon.



Model Components

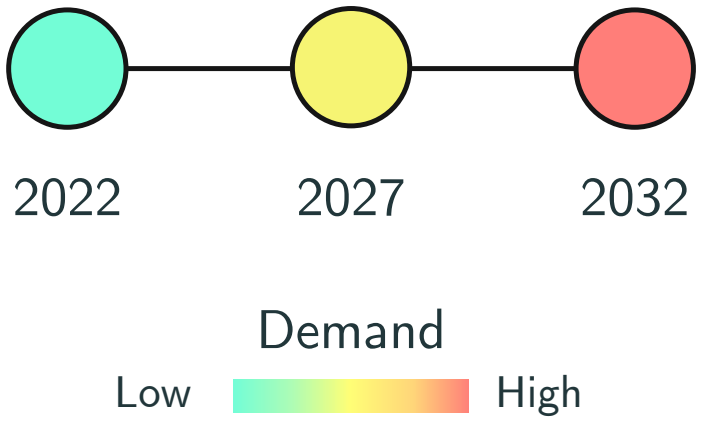
We also consider how the network adapts when a line fails.



The main metric we use to quantify network reliability is SAIDI (system average interruption duration index).

Scenarios

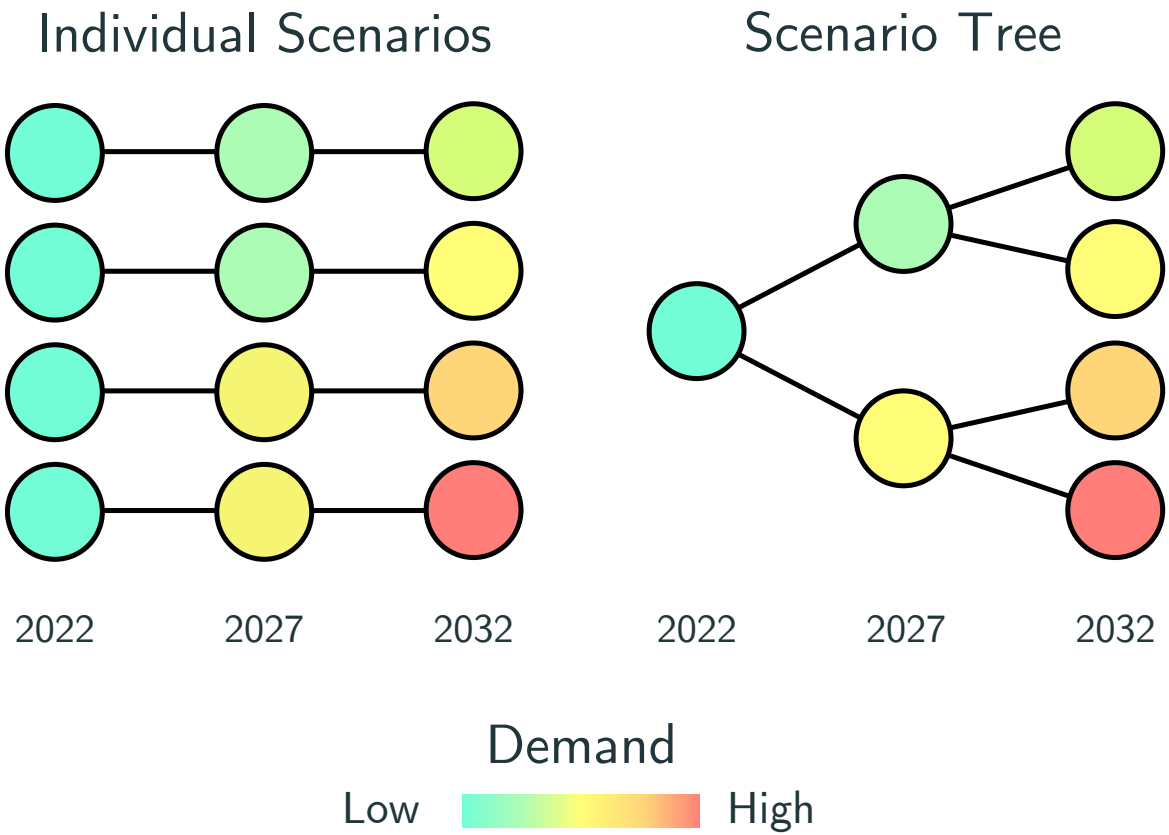
We discretise the planning horizon into a sequence of stages, with varying levels of demand, at which decisions can be made.



We aim to find an optimal expansion plan over the whole planning horizon, such that at each stage there are a set of operating configurations that maintain a desired level of reliability.

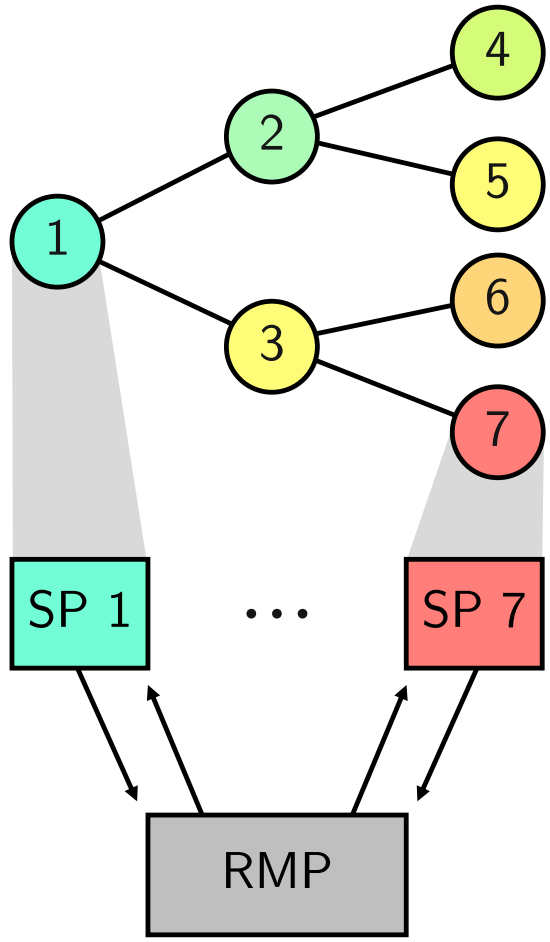
Scenario Trees

In practice, it is common to consider a range of scenarios with varying levels of demand. We can combine these into a scenario tree.



Solution Method: Decomposition Framework

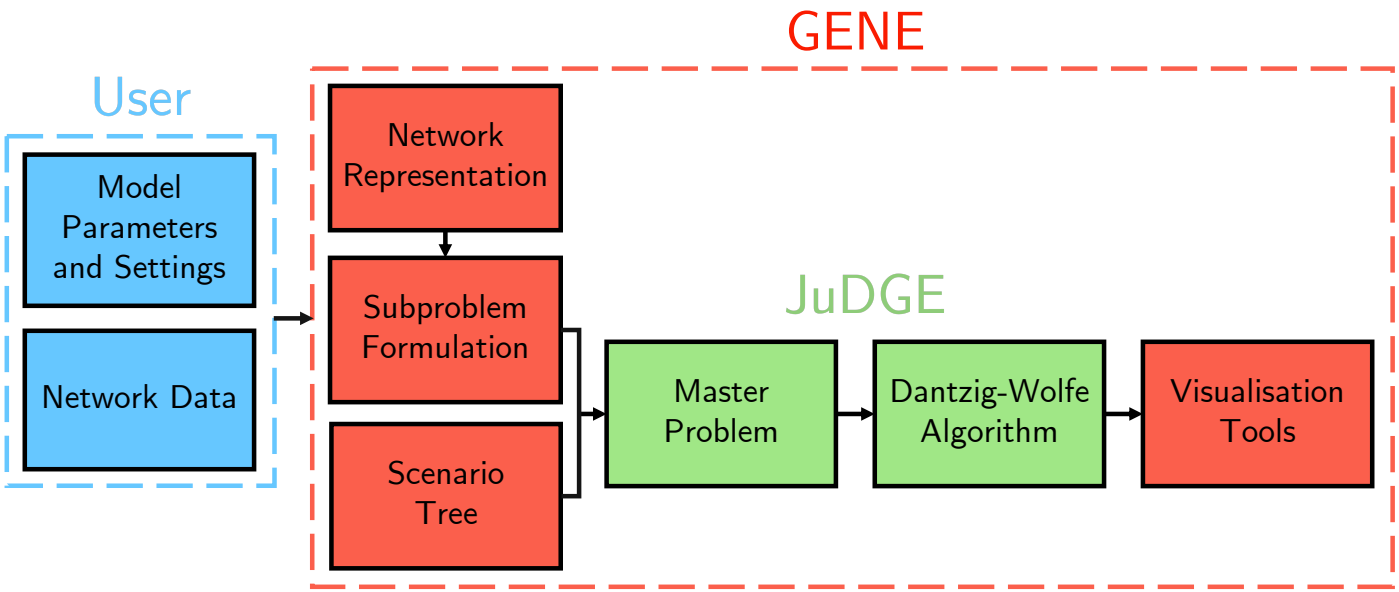
As the size of the problem grows, the resulting model becomes large and a form of decomposition is often needed to solve it. We use Dantzig-Wolfe decomposition[2].



[2]Singh, Philpott, and Wood (2009). *Dantzig-Wolfe Decomposition for Solving Multistage Stochastic Capacity Planning Problems.*

GENE: Overview

We have developed a Julia package, GENE (Generalised Electricity Network Expansion). GENE wraps around an additional package, JuDGE[3], which performs the Dantzig-Wolfe algorithm.



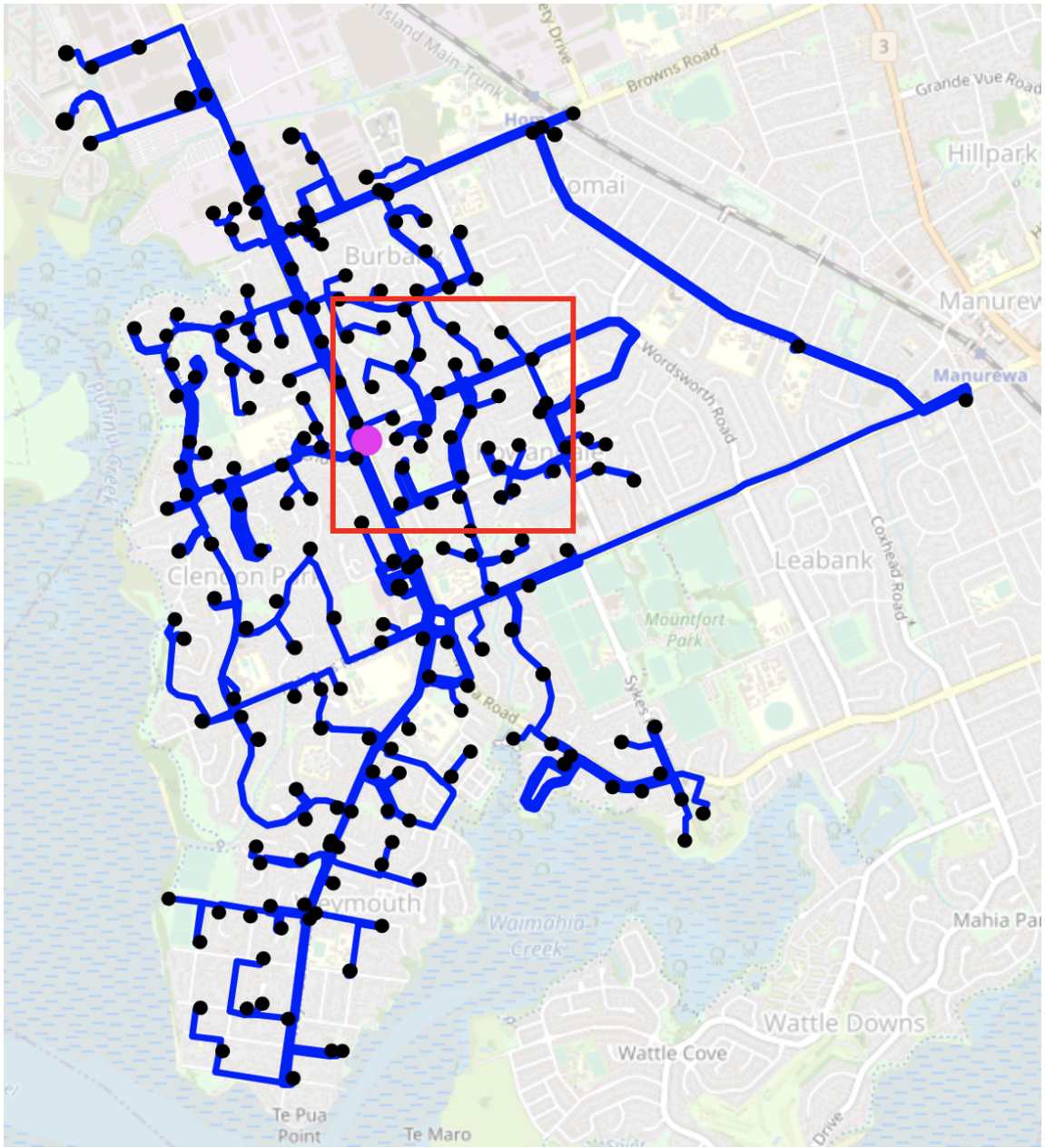
[3]Downward, Baucke, and Philpott (2020). *JuDGE.jl: a Julia package for optimizing capacity expansion.*

Case Study: Clendon Distribution Network

We have used GENE to investigate the Clendon distribution network over a 15-year planning horizon with four possible future demand scenarios. Today we will present

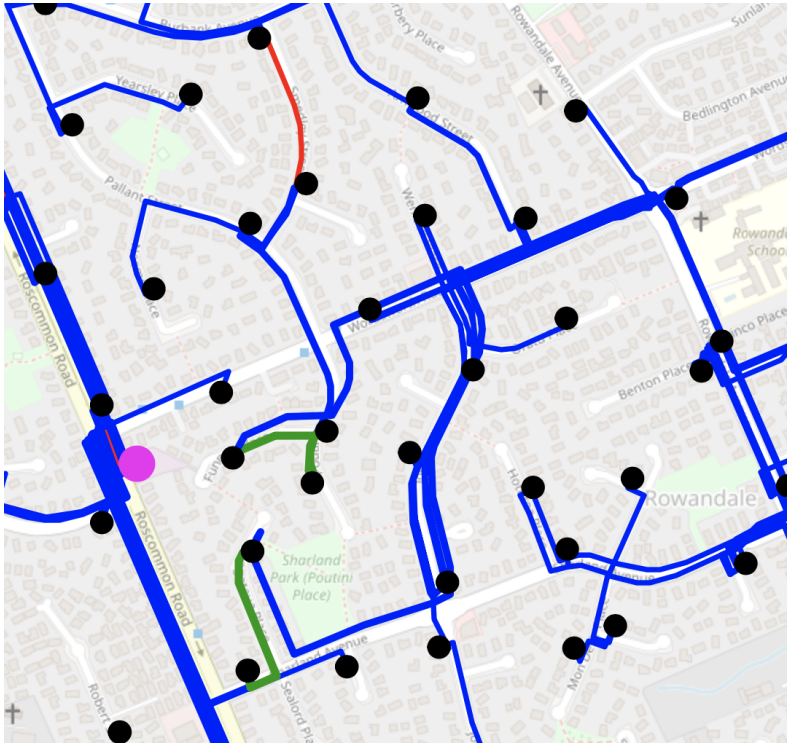
- how batteries can be used to delay line expansions; and
- how different SAIDI tolerances impact the expected cost of expansion.

Clendon Distribution Network

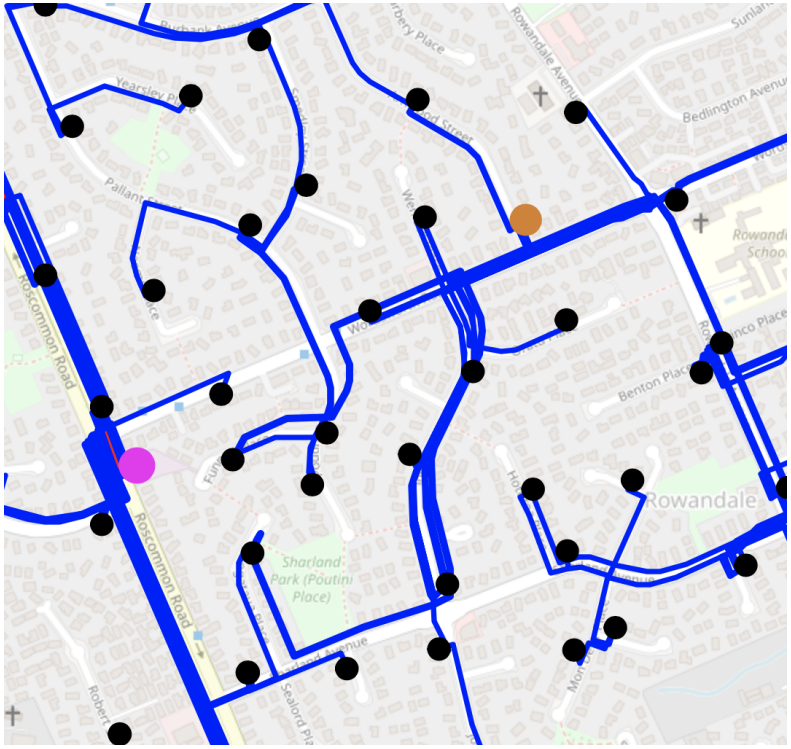


Utility of Batteries

No Batteries Available

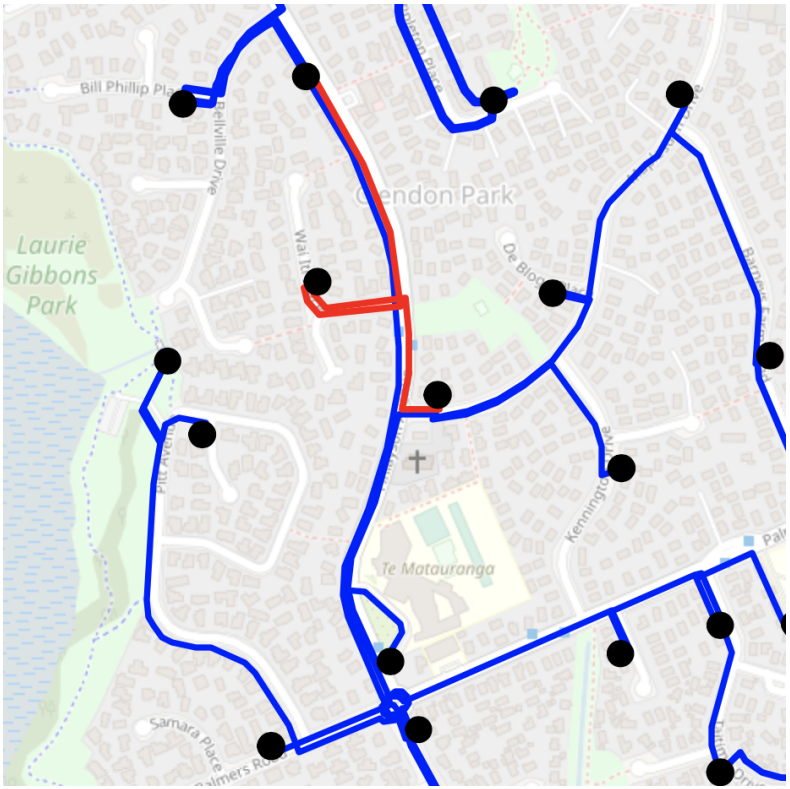


Two Batteries Available

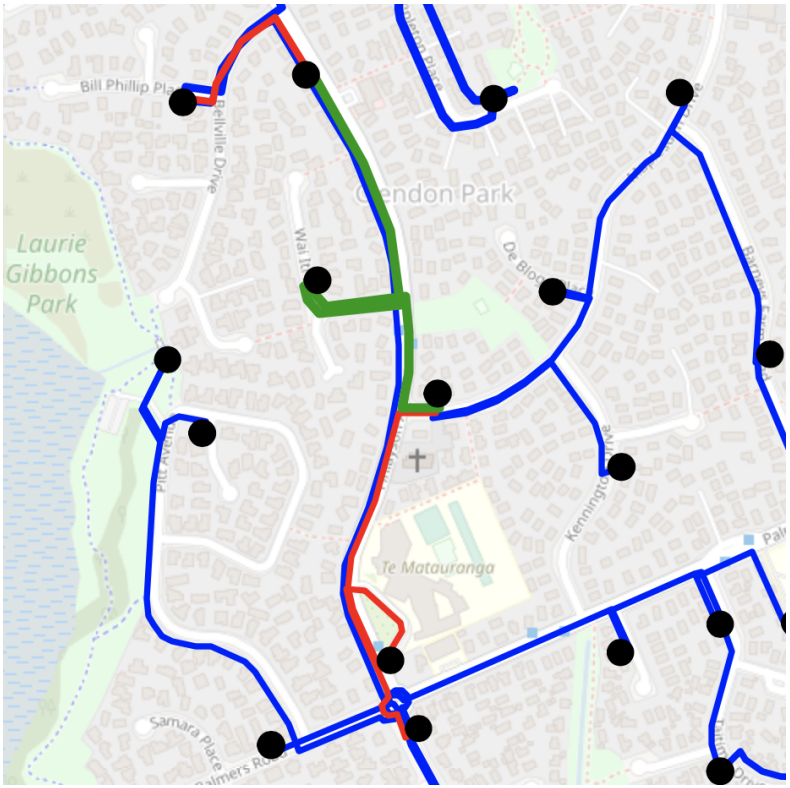


Different SAIDI Tolerances

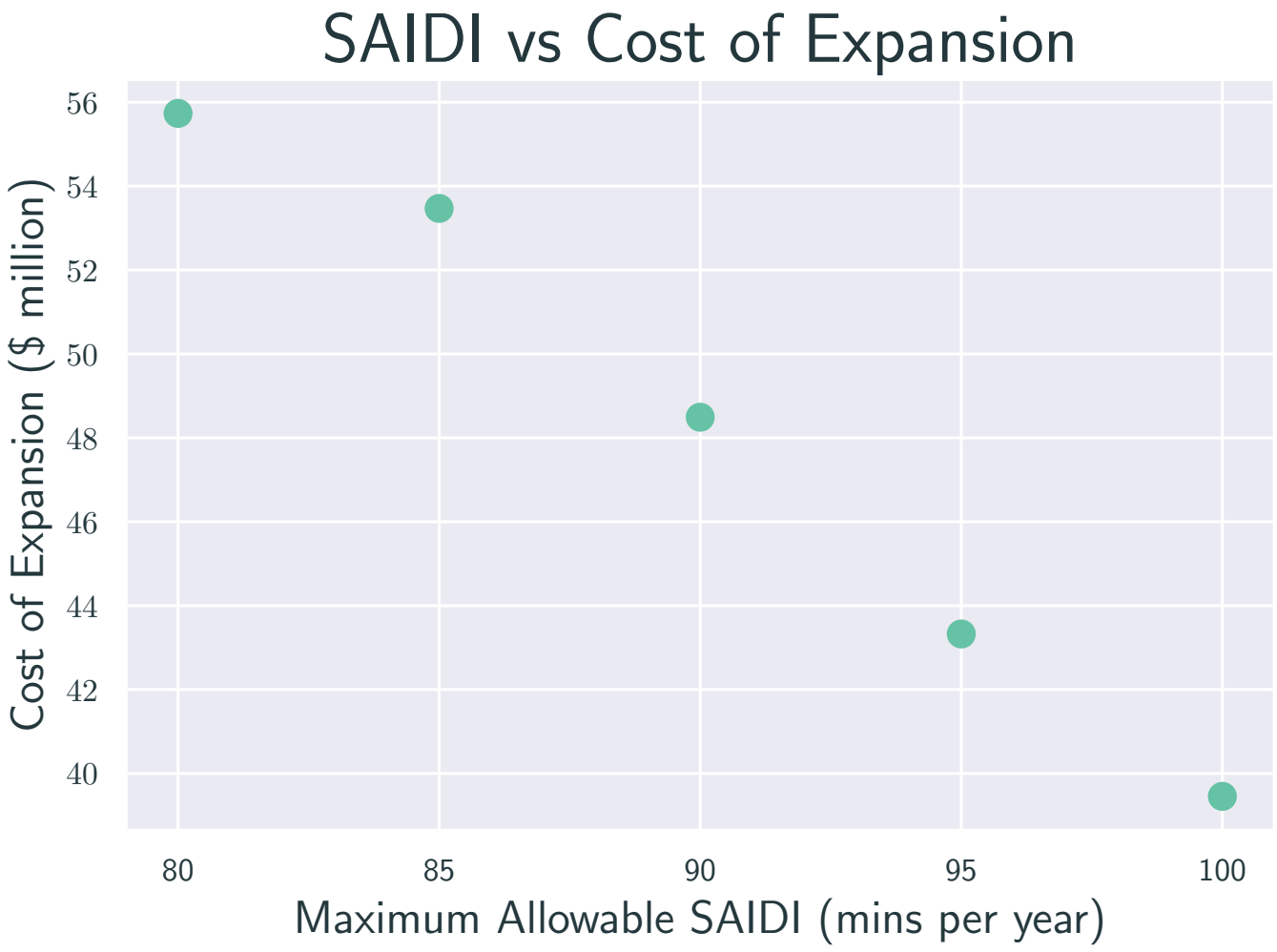
High SAIDI (Less Reliable)



Low SAIDI (More Reliable)

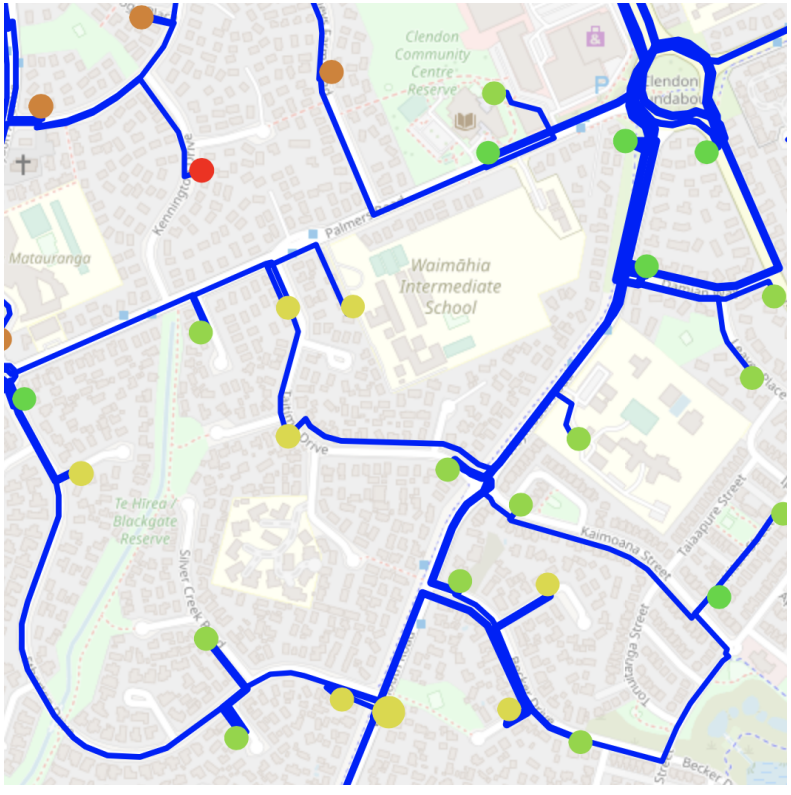


Different SAIDI Tolerances

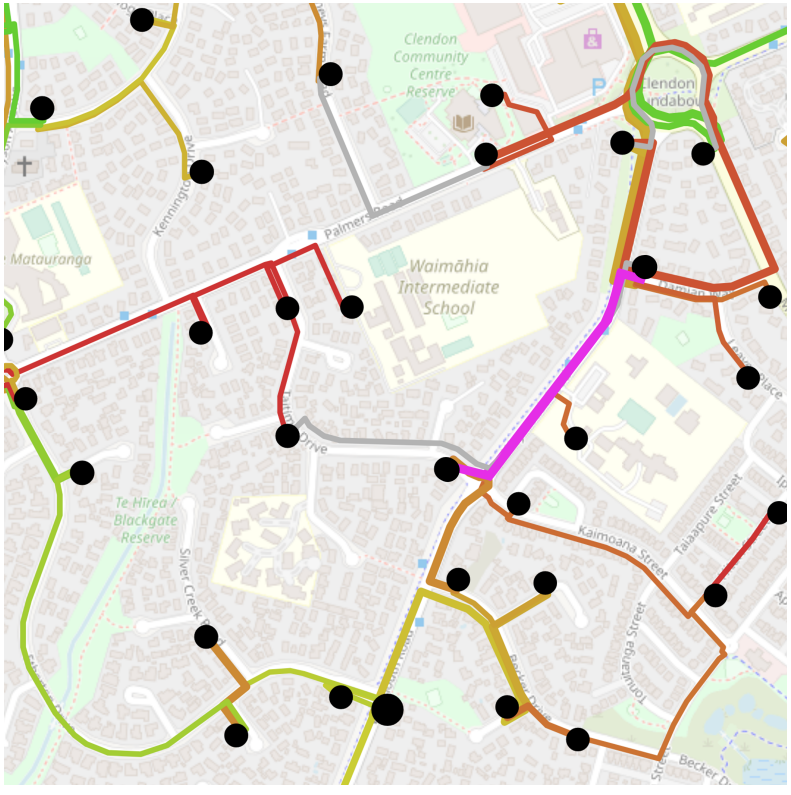


Visualisation: Additional Functionality

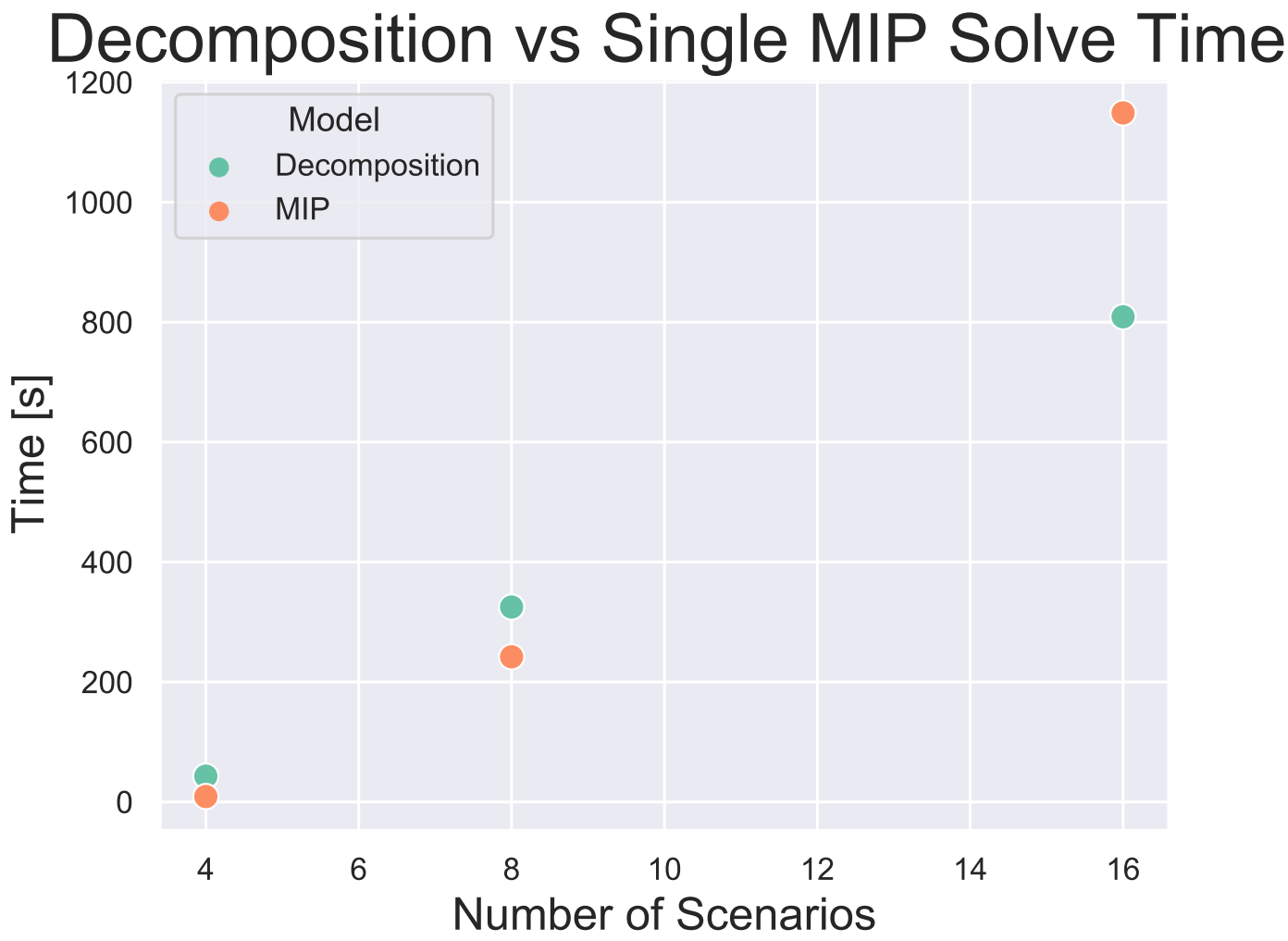
Network SAIDI



Line Failures



Solve Time Comparison



Summary

Today we have

- discussed the components used to model capacity expansion problems for an electricity distribution network under uncertainty in demand; and
- demonstrated how GENE can be used to investigate expansion plans for a distribution network.

Thank you!

Questions?