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Risk-controlled Expansion Planning With Distributed Resources (REPAIR)

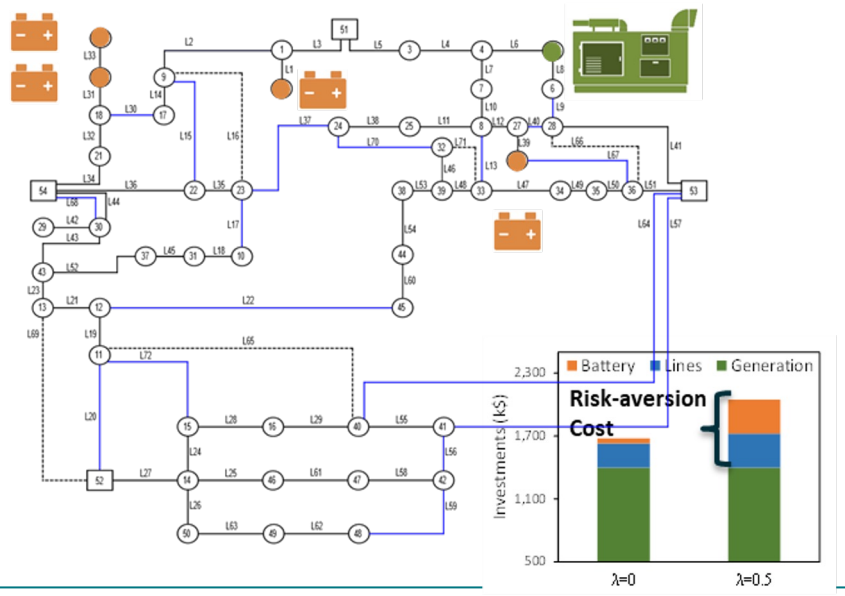
Miguel Heleno, Alan Valenzuela, Alex Moreira, Joe Eto

LBNL, Energy Technology Area, July 2022

REPAIR: project summary

Objectives and Outcomes:

A Distribution Grid Planning Tool to support ”cost vs risk” decisions, from utilities, around reliability and resilience investments.



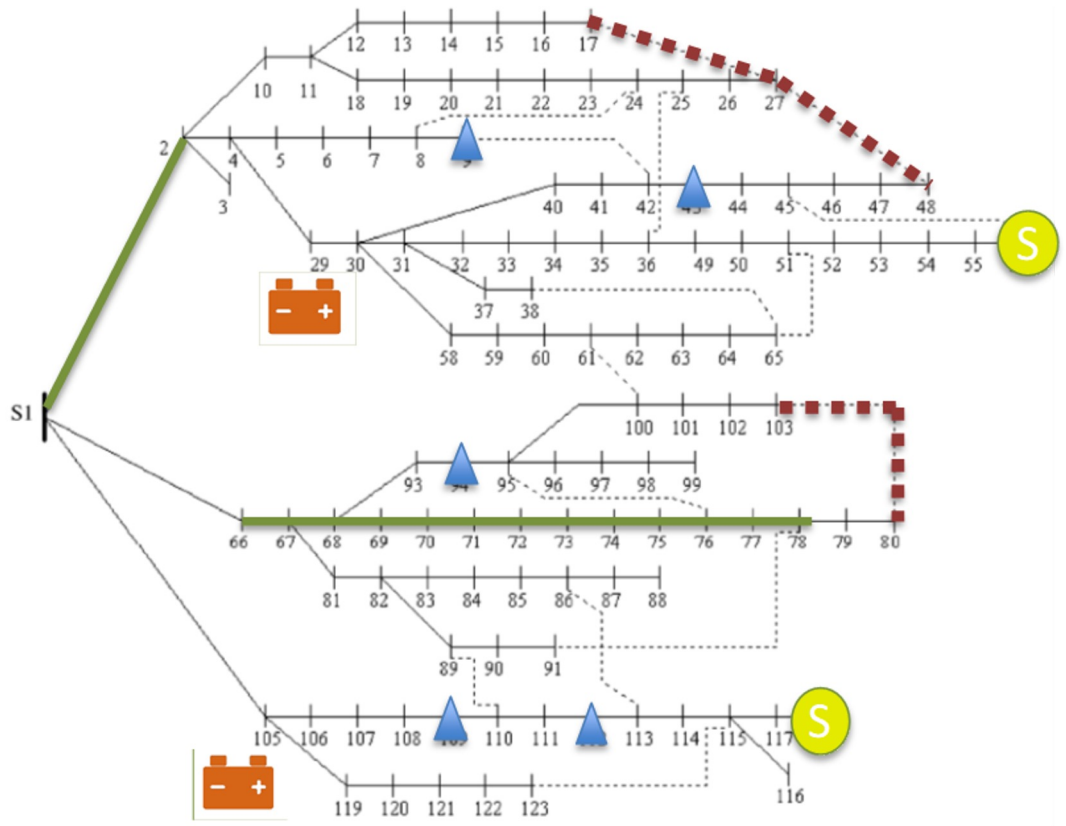
Technical Scope:

Stochastic optimal investment model considering uncertainty in routine grid failures and high impact low probability events.
State-space representation and decomposition to allow large scale application of the model.

Funding Summary:

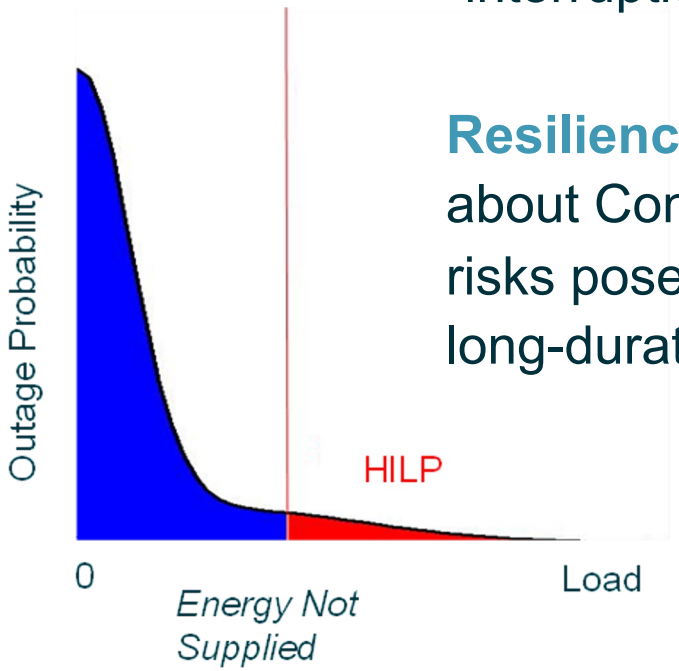
FY20 & prior, authorized	FY22, authorized	FY23, requested
$550k	$300k	$0k

REPAIR: a risk-based approach to resilience



Reliability planning is about mitigating outages caused by routine events.

- Expected value of interruptions.



Resilience planning is about Controlling the risks posed by rare, long-duration events.

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Project Progress

Project Scope by years

Year 1 - Base Model

- Stochastic model development
- Focused on line investments and reinforcement
- Engagement and demonstration using a small feeder from ComEd.

Year 2: Scale Model

- Operational aspects (network reconfiguration).
- Scale the model to be able to run networks with thousands of nodes.
- Large-scale demonstration with ComEd.

Year 3: Renewables + Tool

- Add renewable generation to the model
- Conduct a demonstration with a different use case
- Publish the materials, make the model open source and technology transition plan.

Project Scope by years

Year 1 - Base Model

- Stochastic model development
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Year 2: Scale Model

- Operational aspects (network reconfiguration).
- Scale the model to be able to run networks with thousands of nodes.
- Large-scale demonstration with ComEd.

Completed

Year 3: Renewables + Tool

- Add renewable generation to the model *in progress*
- Conduct a demonstration with a different use case
- Publish the materials, make the model open source and develop a tech transition plan.

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Recent Model Development

REPAIR - Methodology

Cost vs Risk Model – Stochastic Optimization Model

cost
- Investment cost
- Operation cost
- Loss of load cost

St
- nodal balance constraints
- power flow constraints
- substations constraints

time coupling constraints for battery operation

DG model and technical limits

For each hour "t" of a typical day "d"

Reliability
Expected value of the outages
(Routine events)

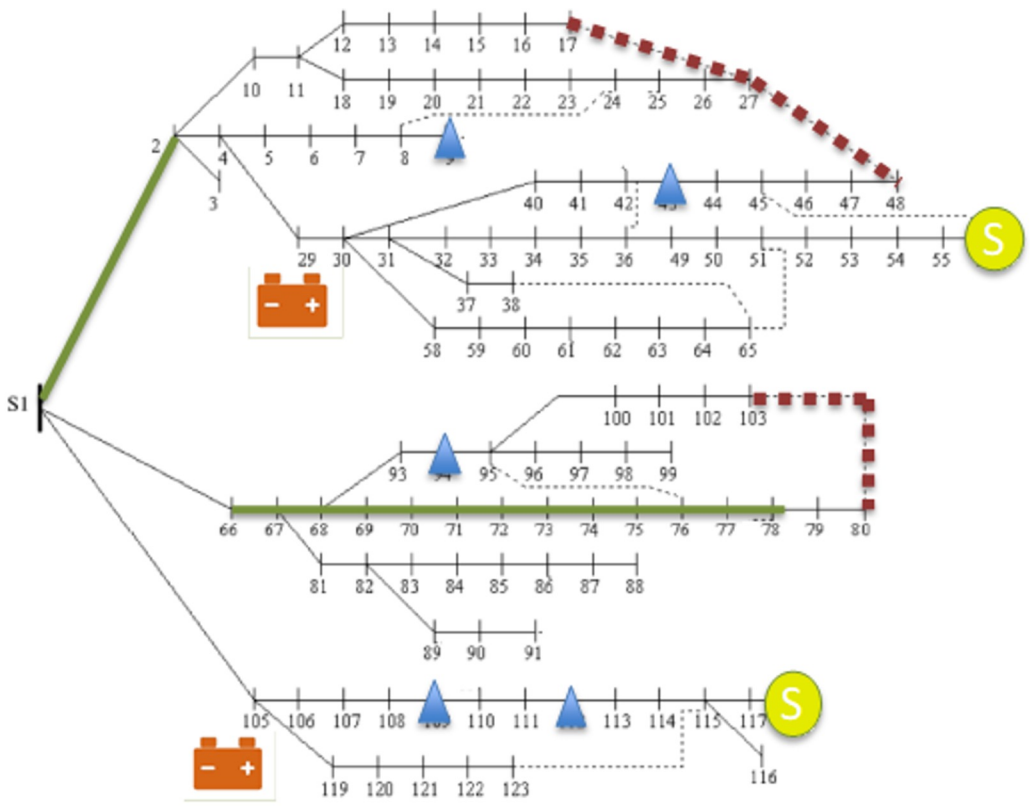
Resilience
Conditional value at Risk of outages
(HILP events)

$$\text{Minimize}(1-\lambda)\mathrm{E}[\text{cost}] + \lambda\mathrm{CVaR}[\text{cost}]$$

Level of Risk Aversion considered in the **reliability vs resilience** planning exercise

Optimization Model

A large problem



$$\text{Minimize}(1-\lambda)E[\text{cost}] + \lambda \text{CVaR}[\text{cost}]$$

Annualized investment | Operational costs | Loss of load costs

Investment solution

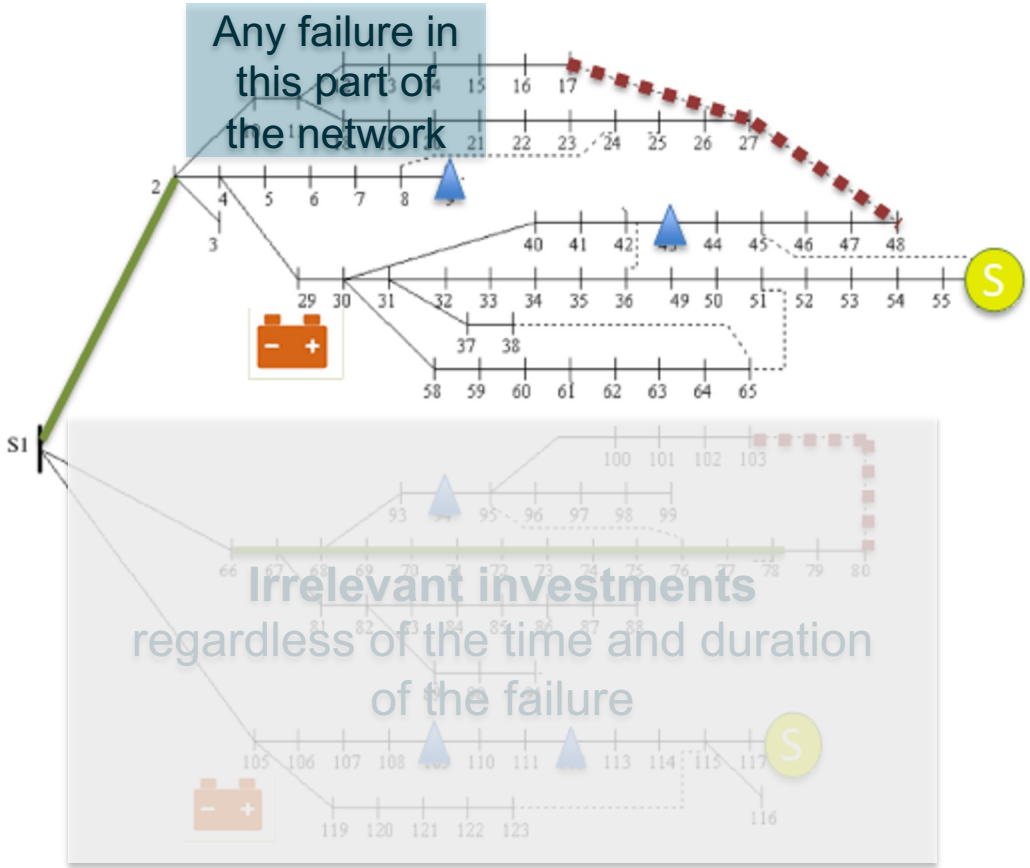
cut: annual load curtailment for scenario (s)

Operation Scenario

- hour
  - …
  - State of the system
    - …
    - duration
      - …
      - DER Operation decision variable

Optimization Model

Reducing complexity



$$\text{Minimize}(1-\lambda)\text{E}[\text{cost}] + \lambda\text{CVaR}[\text{cost}]$$

Annualized investment | Operational costs | Loss of load costs

Investment solution

States analysis

…

States in which investment solution is relevant

Loss of load of as a function of the **investment (i), netload (t) and duration (d) of the event**

Write set of constraints for each scenario s: (state, d, t)

This is effective in realistic conditions:

- The number investments is small in comparison with the number of outage scenarios.
- Time coupling operation decisions are not influenced by the probability of outages.

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ComEd Demonstration Target Feeder

Customer Target Feeder

FX1 Feeder - Performance (2021)

89 Official Customer Target Customers

681 customers

89 total miles of circuit (12kV)

These customers have had a large number of outages over the past three years.

FX1 Feeder - project

- Create ties with adjacent feeder (FX2)
- Create ties within the feeder
- Potential storage projects

Demonstration Objectives

Use REPAIR to understand:

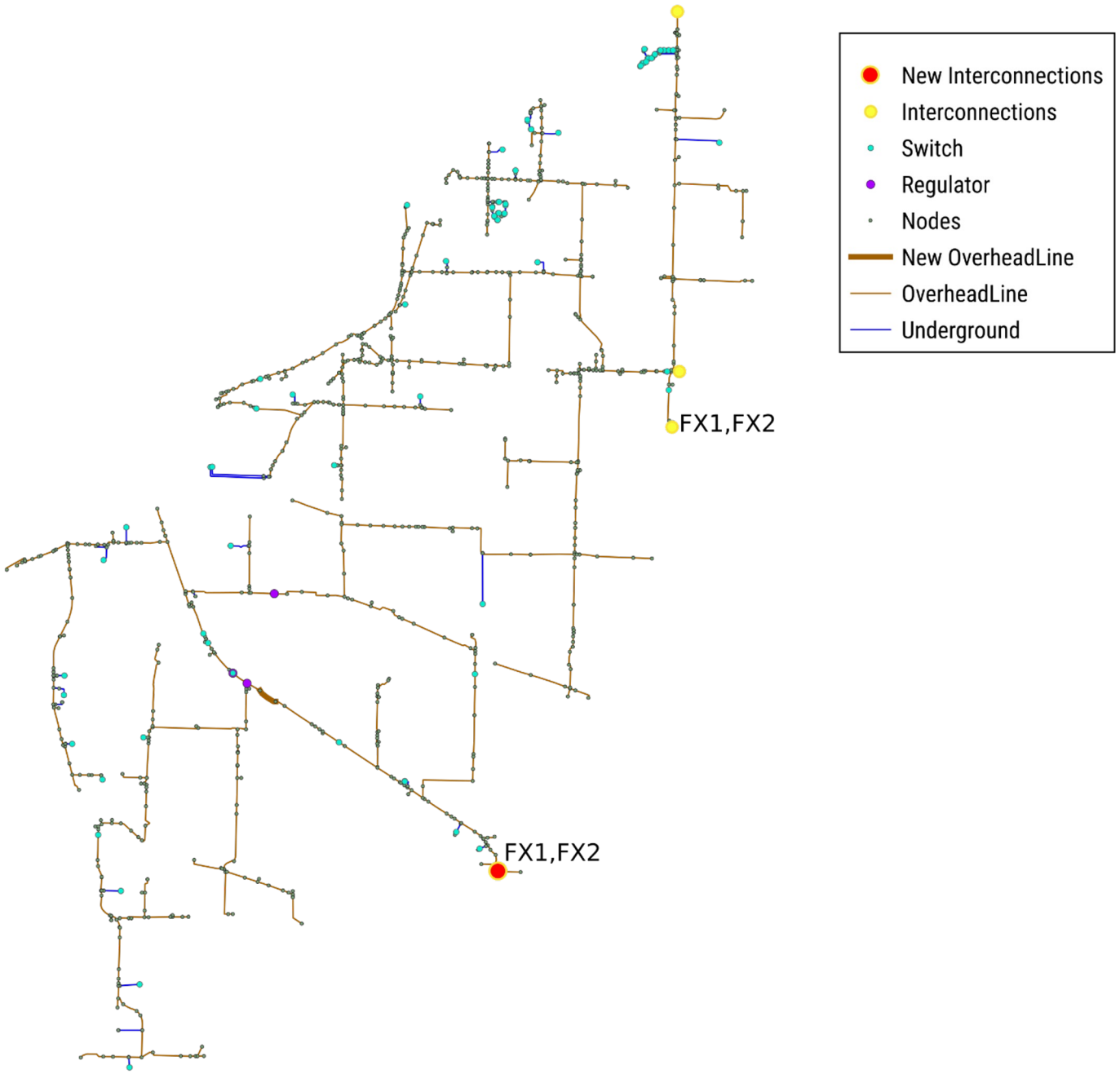
- The best portfolio of grid investments for different levels of risk-aversion.
- Different “Cost vs Risk” solution for feeder investments to support the conversation with regulators.

FX1 Feeder

Conversion from CYME to REPAIR

The FX1 Feeder was obtained from the analysis of these files, obtaining

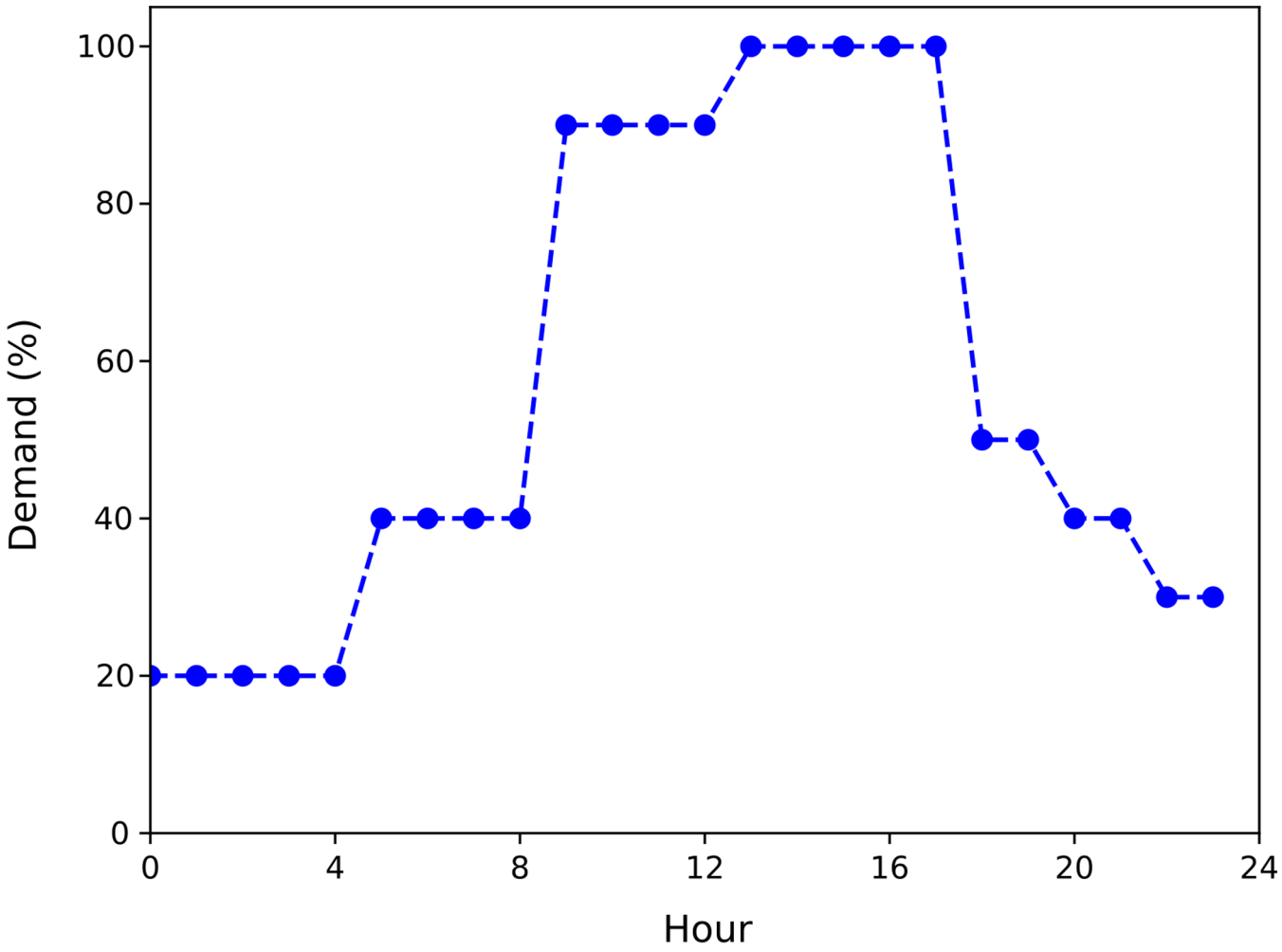
- 1100 connected nodes
- 1103 overhead and underground lines
- 84 switches
- 1.59 MW of peak demand
- 668 clients
- 3 voltage regulators
- 4 interconnections with other parts of the network



Demand Profile

The CYME files contained total peak and energy demand data for each node of the network.

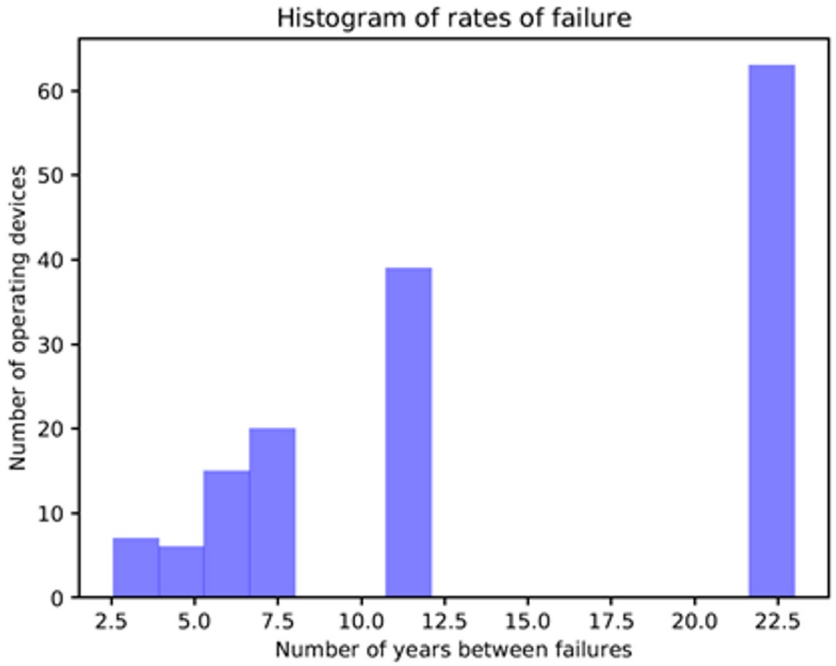
In order to have a better resolution of the model, we assumed the hourly demand profile in the figure.

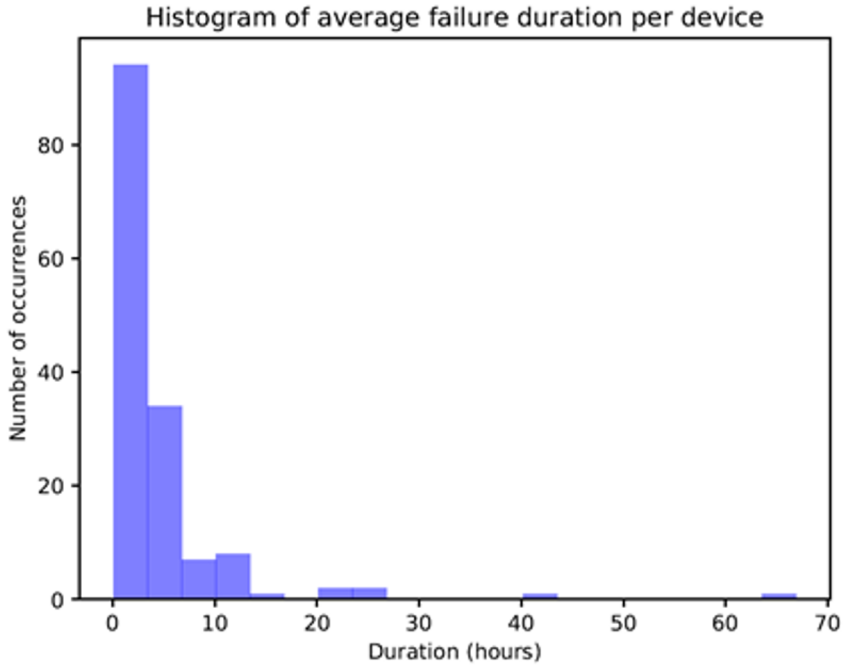


FX1 - Routine Failures

Historical data from Feb 1998 to Nov 2020

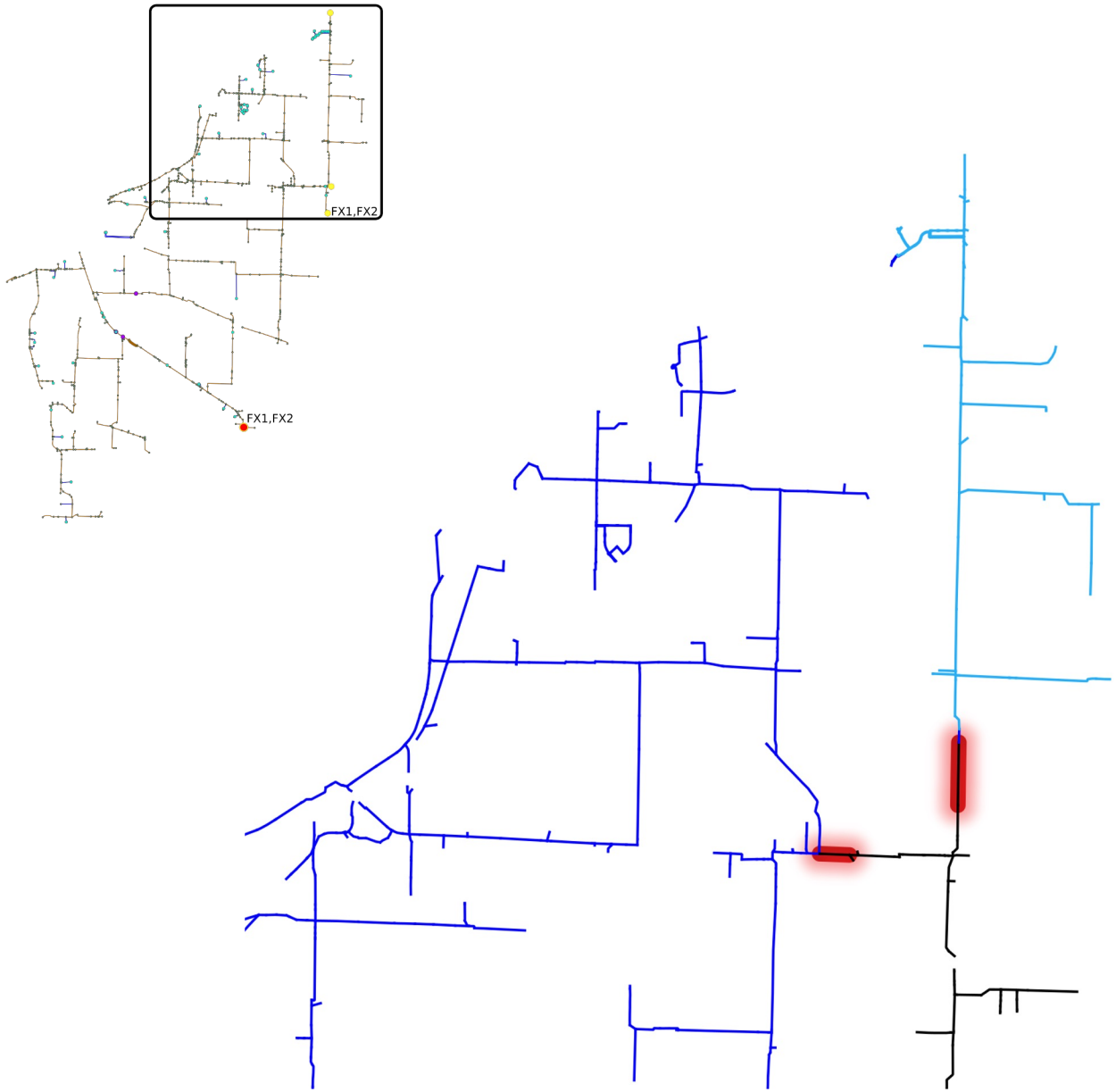
- 150 operating devices have failed
- Based on historical data, we obtained
  - Failure rate for each device
  - Average failure duration for each device
- Average failure duration: 4.67 hours





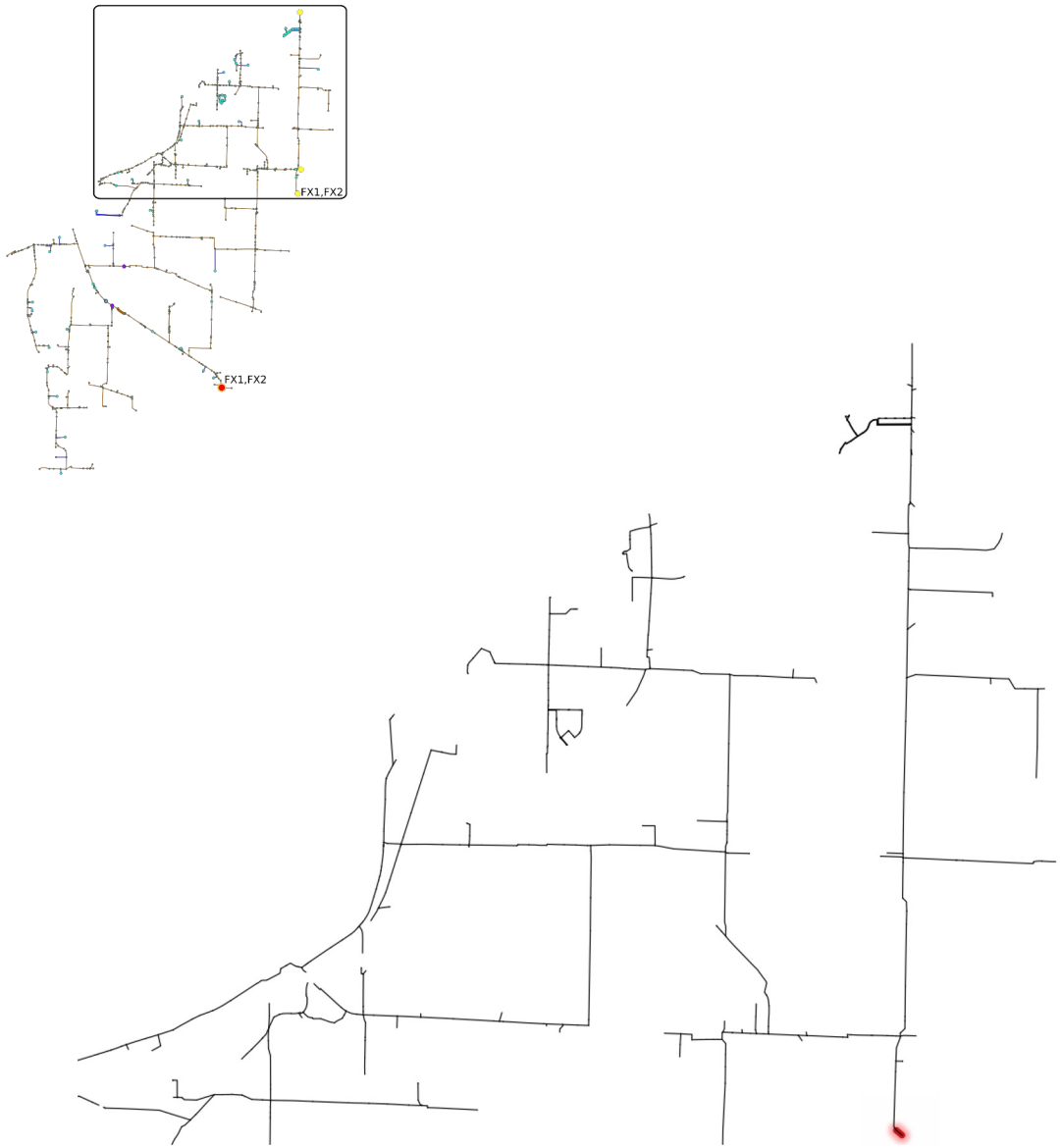
FX1 - Critical Failures

- 3 critical failures included
  - **Failure 1: 3-hour-duration**



FX1 - Critical Failures

- 3 critical failures included
  - Failure 1: 3-hour-duration
  - **Failure 2: 1-hour-duration**

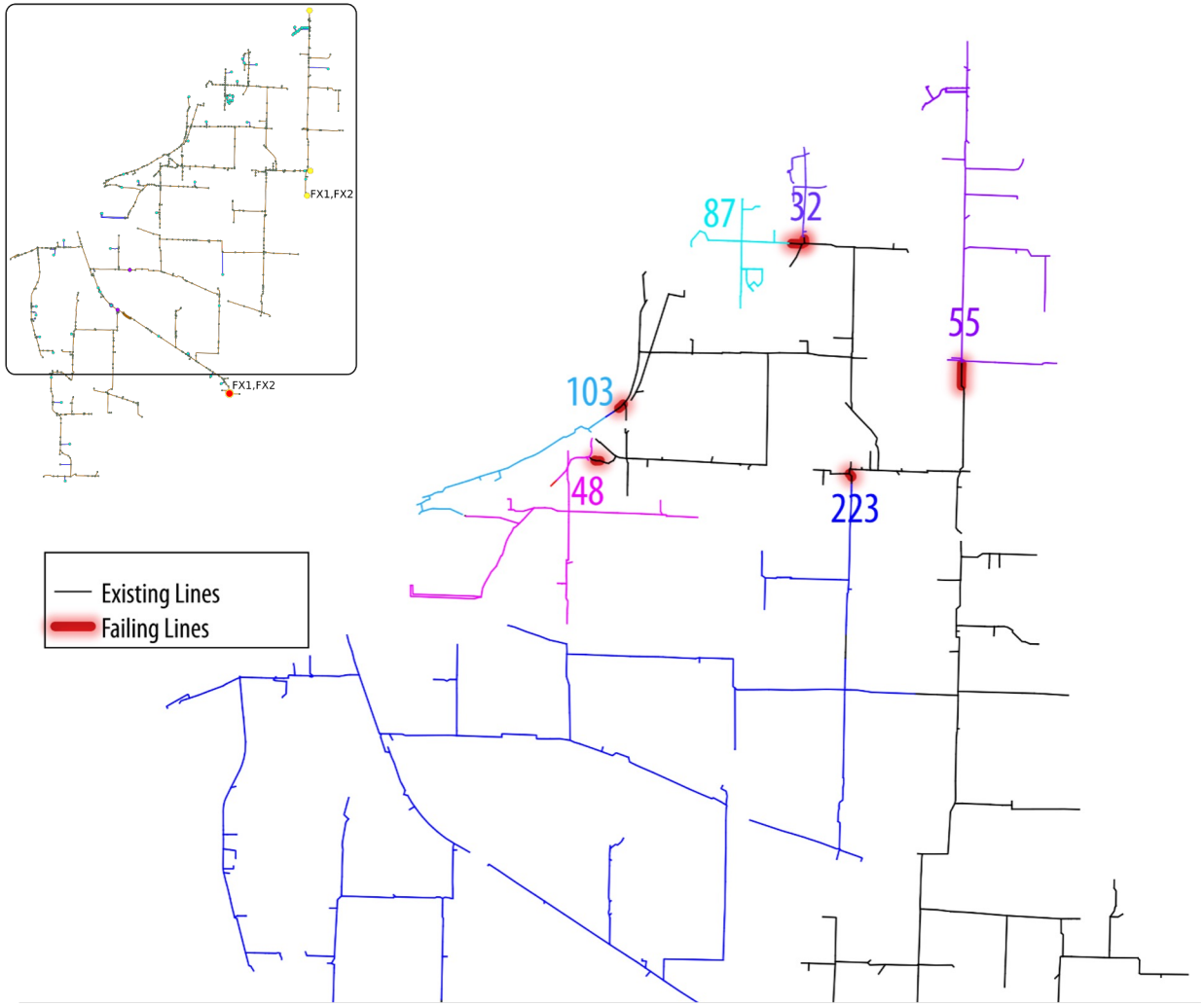


FX1 - Critical Failures

- 3 critical failures included
  - Failure 1: 3-hour-duration
  - Failure 2: 1-hour-duration
  - **Failure 3: 58-hour-duration**

- Failure 3 based on event in August 2020

- Rate of failure: once every 70 years.



Critical Event inspired by August 2020 outages, considering multiple failures and disconnected clients

FX1 - Critical Failures

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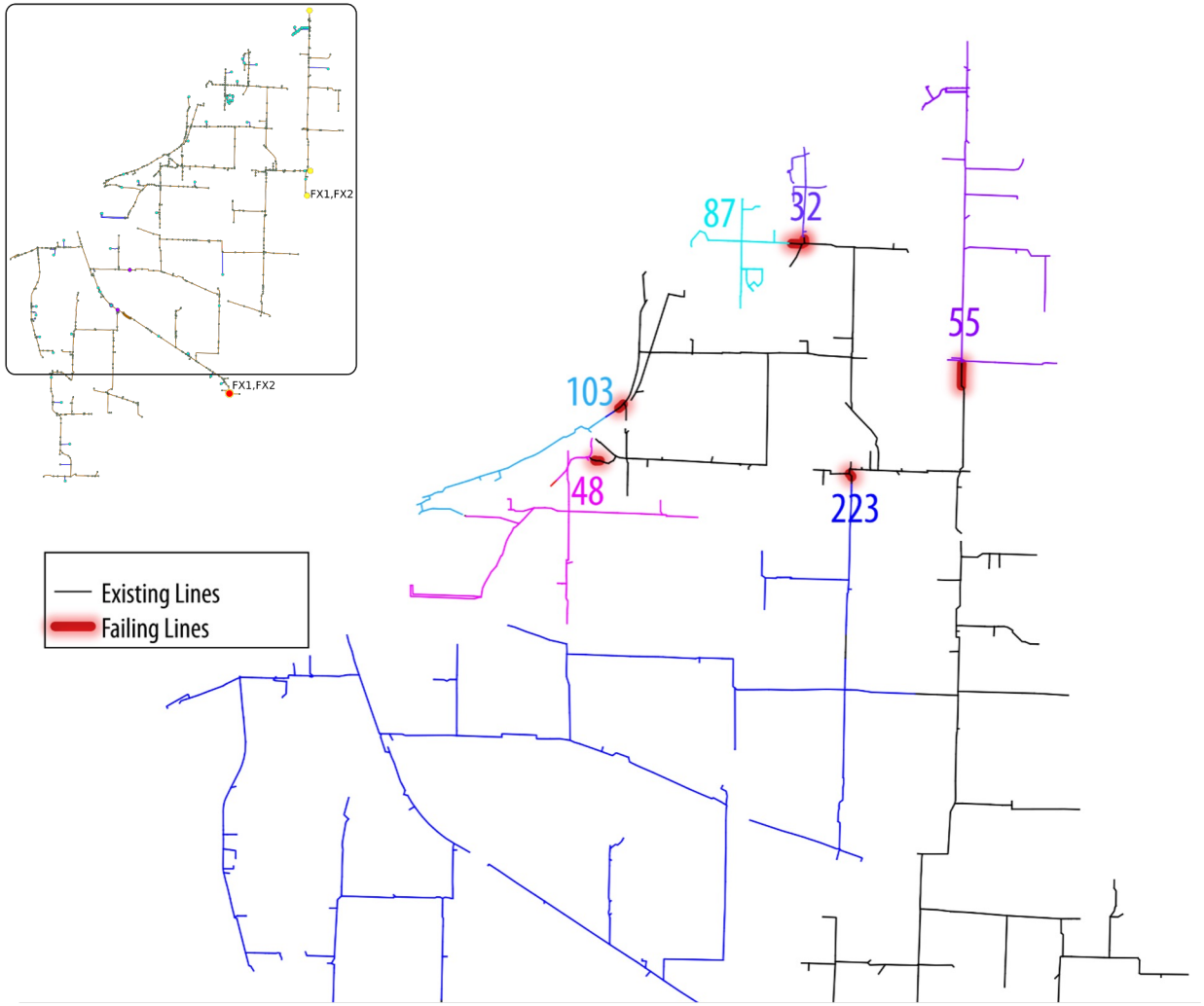

Critical Event inspired by August 2020 outages, considering multiple failures and disconnected clients

FX1 - C

- 3 critical fai
  - Failure 1:
  - Failure 2:
  - **Failure 3**

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SEVERE WEATHER

ComEd power outage leaves 260K across Chicago area in dark

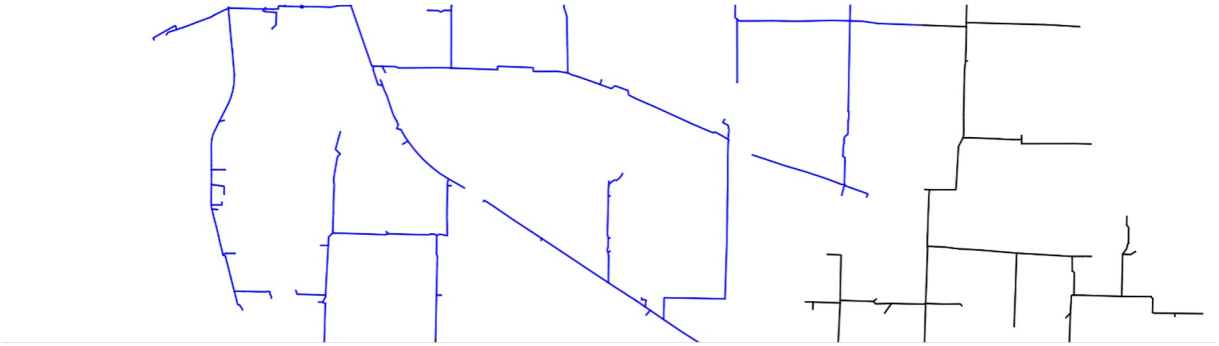
ComEd says it could take several days to restore power to all customers

By Jessica D'Onofrio, John Garcia, Cate Cauguiran and ABC7 Chicago Team Coverage

Tuesday, August 11, 2020

- Failure 3 based on event in August 2020

- Rate of failure: once every 70 years.



Critical Event inspired by August 2020 outages, considering multiple failures and disconnected clients

FX1

- 3 critic
  - Failu

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SEVERE WEATHER

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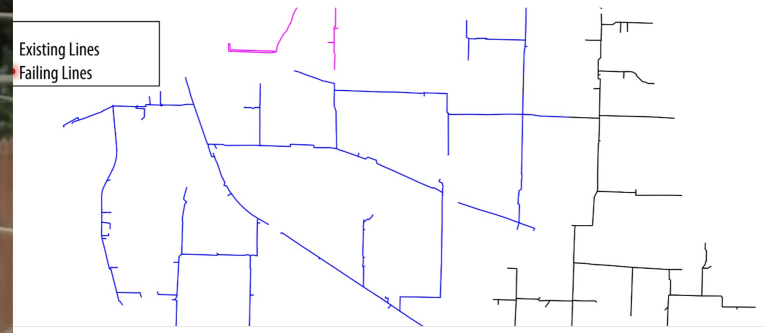
power to all customers

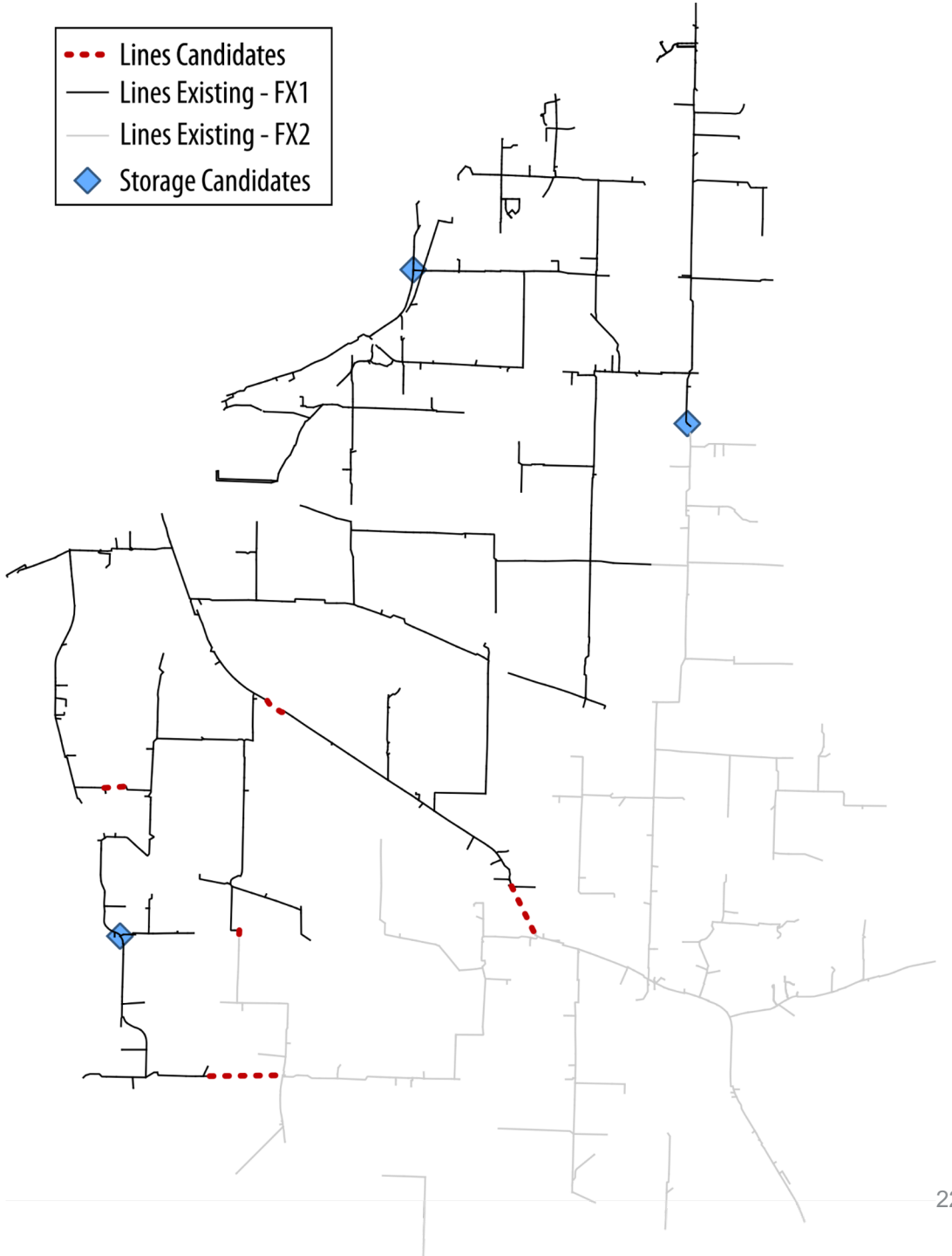
7 Chicago Team Coverage



Critical Event inspired by August 2020 outages, considering multiple failures and disconnected clients

FX1 Candidate Lines and Storage Investment

- 5 Candidate lines are proposed for the FX1 Network
  - Two lines were obtained by analyzing differences of the received CYME files
  - Three other candidates were obtained by analyzing the new funded projects for 2021
  - Estimated line cost: $160,000 per mile
- 3 Storage candidates are proposed in different zones of the network
  - Estimated storage cost: $660/KWh



Lines Cost Investment Estimation

Along with previously discussed files, we received information about project costs.

By analyzing this information, we estimated a value of lines of $158,259.7 per mile for each line connection.

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DE0014 - Design Details Report

Page 70 of 71

Labor multiplier: 1 Labor Cost multiplier: $ 100 Material multiplier: 1.19

Design - Version: 0000264697 001 Project: REL20-POCKETIP2 IP2 S433 SHT 12 INTERNAL TIE, WO# 16151376

Point: 0128 Cross Reference: P#653183034

				Passport Data							Adjusted Passport Data		
Action	Qty	CU or Cat ID	Title	Mhrs	Labor Cost	Rsrc Hrs	Rsrc Costs	Material	Permit Costs	Misc Costs	Adj Mhrs	Adj Labor	Adj Material
I	1	C7756.EC-O	ARMOR RODS & LINE GUARDS	0.2	39.08			1.82			0.2	22.00	2.17
I	2	C7761.4Q-O	RIGID CLEVIS AUTOMATIC DEAD-END	0.4	78.16			16.32			0.4	44.00	19.42
I	1	C8600.AAH-O	TRANSFORMER AND PRIMARY LINE FUSE	0.7	127.89			74.77			0.7	72.00	88.98
I	1	C8705.AA-O	1-PHASE FUSE/DISC INSTALLATION	0.3	58.62			76.05			0.3	33.00	90.50
I	1	DIG-TRFCCNTL-O	SETUP TRAFFIC CONTROL	0.8	133.22						0.8	75.00	
I	1	P40-2-CCA-O	P40-2-CCA, CATID: 0001607245	2.0	355.26			338.46			2.0	200.00	402.77
T	1	T-ANCHG-O											
T	1	T-FRPA-O	TRANSFER ARM, FIBERGLASS	6.0	1,065.78						6.0	600.00	
T	2	T-OPDEV-O	TRANSFER OPERATING DEVICES IN A SWITCHING ROUTINE	4.0	710.52						4.0	400.00	
				25.7	4,565.1			775.63			25.7	2,570.00	923.00

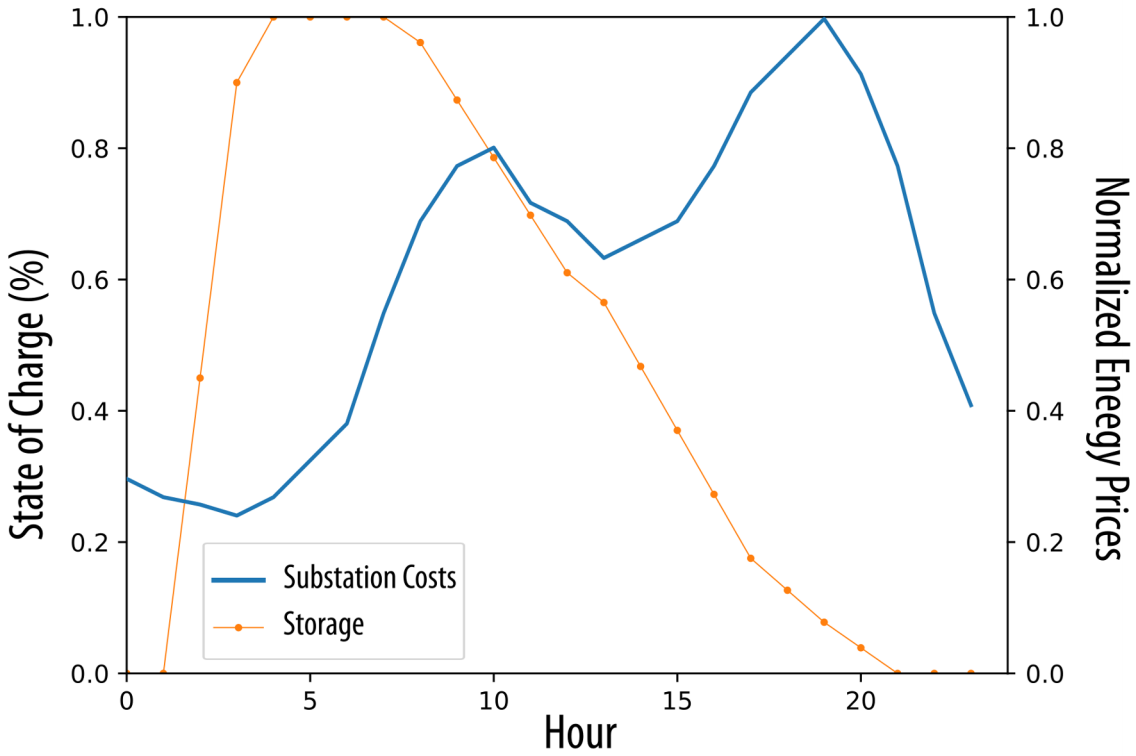
Point: 0129 Cross Reference: P#653291007

				Passport Data							Adjusted Passport Data		
Action	Qty	CU or Cat ID	Title	Mhrs	Labor Cost	Rsrc Hrs	Rsrc Costs	Material	Permit Costs	Misc Costs	Adj Mhrs	Adj Labor	Adj Material
R	1	R-WA-O	REMOVE SINGLE WOOD ARM, INSULATORS AND BRACES	1.9	339.27						1.9	191.00	
I	1	C7430.B-O	WOOD CROSSARM BRACE	0.3	58.62			14.30			0.3	33.00	17.02
I	1	C7435.D0-O	2 & 3-PHASE LINE POLE	1.0	177.63			50.37			1.0	100.00	59.94
I	2	C7483.A-O	PIN TYPE INSULATORS	0.5	88.82			7.15			0.5	50.00	8.51
I	1	C7715.7B-O	12kV LIVE LINE CLAMP	0.9	156.31			48.84			0.9	88.00	58.12
I	1	C7724.1GJ-O	WEDGE CONNECTORS	0.2	39.08			2.51			0.2	22.00	2.99
I	2	C7754.TBB-O	CONDUCTOR TIES	0.9	156.31			25.22			0.9	88.00	30.01
I	1	C8505.F1-O	SURGE ARRESTERS	1.0	177.63			21.46			1.0	100.00	25.54
I	1	C8510.A-O	POLE MOUNTED ARRESTERS	1.2	206.05			71.49			1.2	116.00	85.07
I	1	C8550.AAB-O	GROUNDING INSTALLATION	1.5	259.34			93.22			1.5	146.00	110.93
I	4	DIG-TRFCCNTL-O	SETUP TRAFFIC CONTROL	3.0	532.89						3.0	300.00	
T	1	T-FRPA-O	TRANSFER ARM, FIBERGLASS	6.0	1,065.78						6.0	600.00	
				18.3	3,257.73			334.56			18.3	1,834.00	398.13

Point: 0130 Cross Reference: P#653302015 Passport Data Adjusted Passport Data

Market Operation of Storage

Although storage investments are used for resilience purposes, we assumed that, in normal circumstances, storage would be operating to respond to a market signal.



FX1 Results

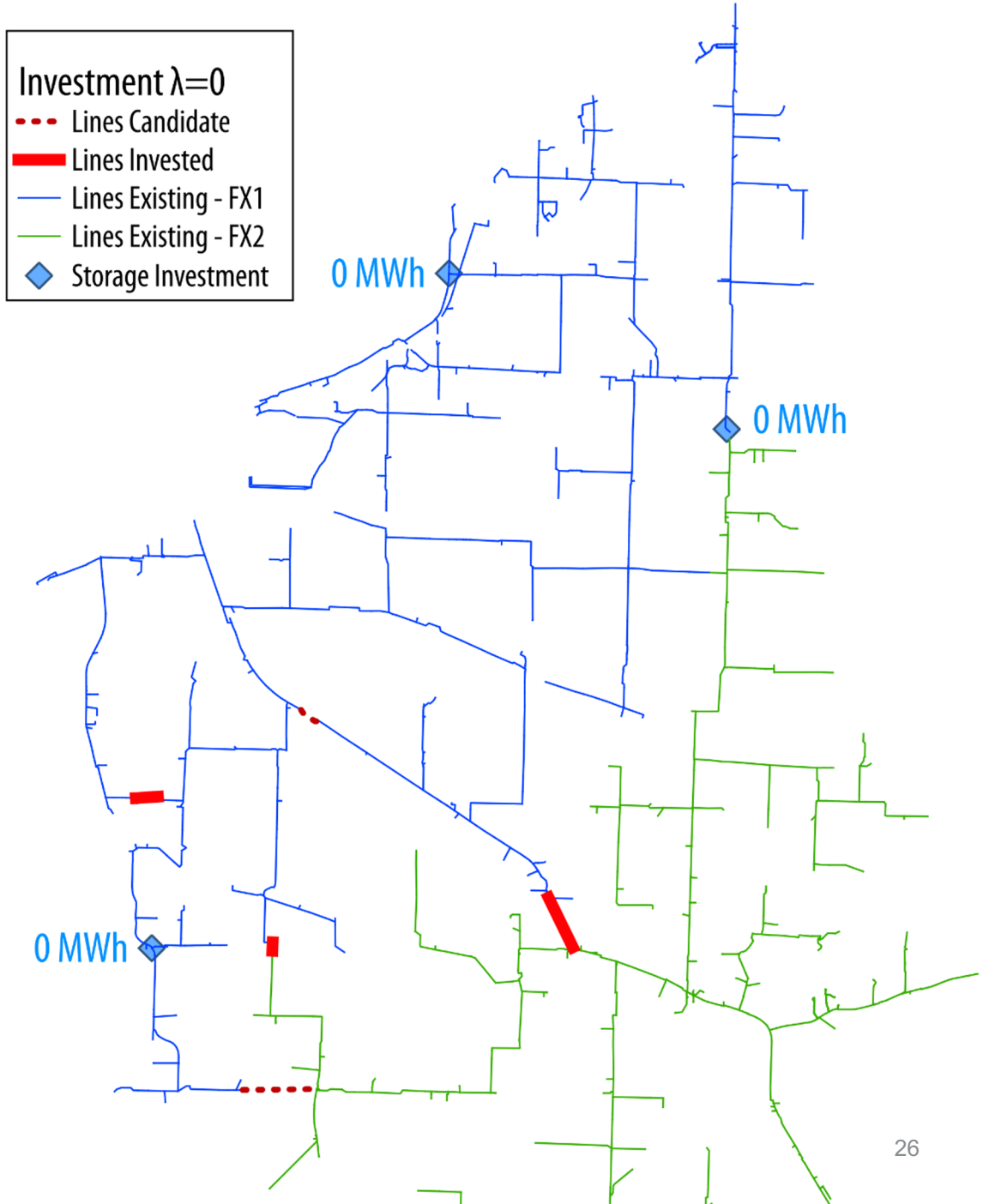
- REPAIR tool was run for 3 risk aversion levels

Risk Aversion (Lambda)	Annual Line Costs ($k)	Number of Invested Lines	Annual Storage Costs ($k)	Storage Investment (MWh)	Annual Expected Value Costs ($k)	Annual CvaR Costs ($k)
0	2.3	3	0.0	0	52.0	2,611,575.0
0.5	8.5	5	0.0	0	47.8	955.2
1	8.6	5	15.6	1.1	46.4	927.0

FX1 Investment Plans

Based on expected value

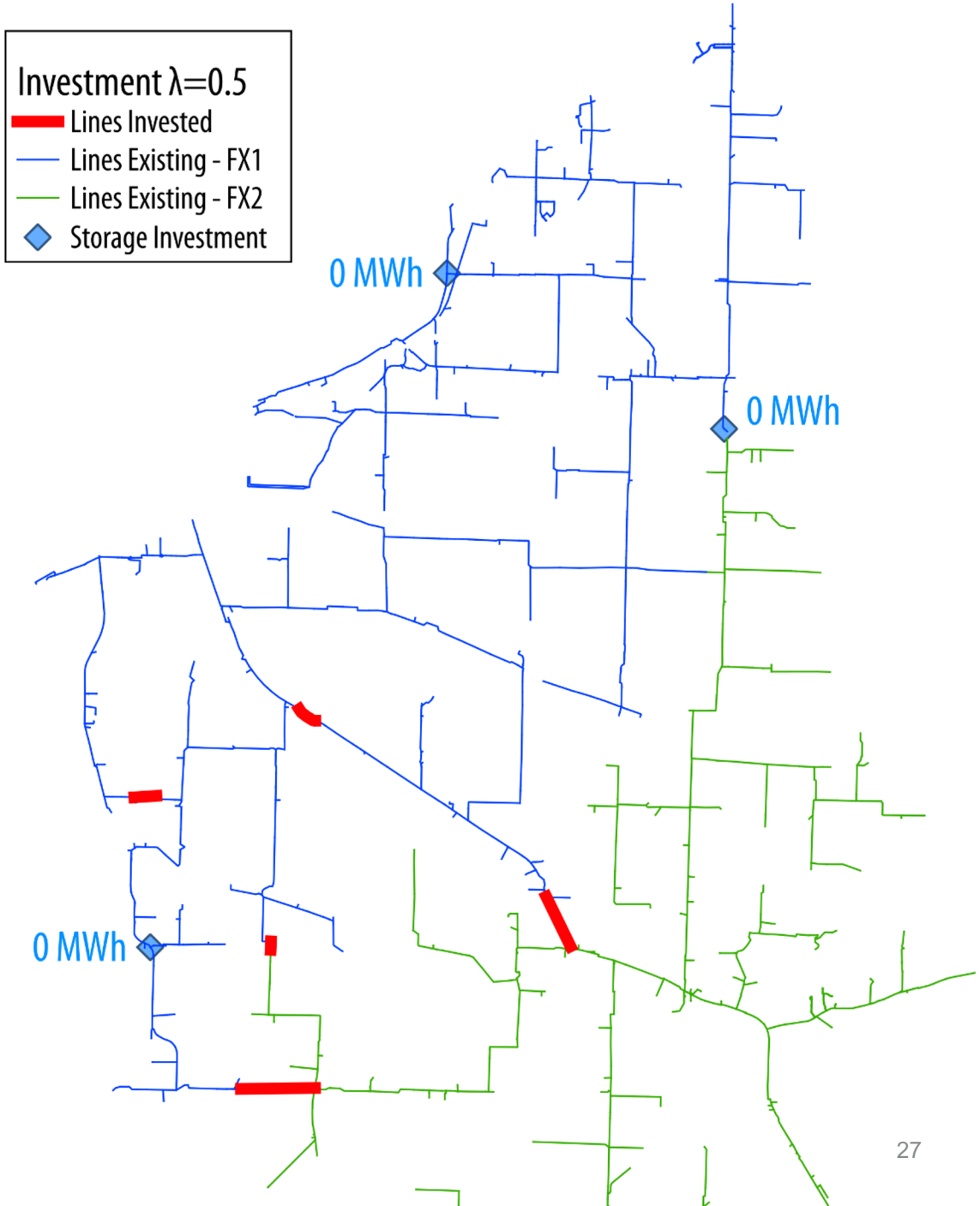
- Risk neutral
  - Moderate investment in the network
- Three lines should be built
  - Two interconnections FX1-FX2
  - One enhancing connectivity within FX1 network
- No storage investment



FX1 Investment Plans

Based on moderate risk-aversion

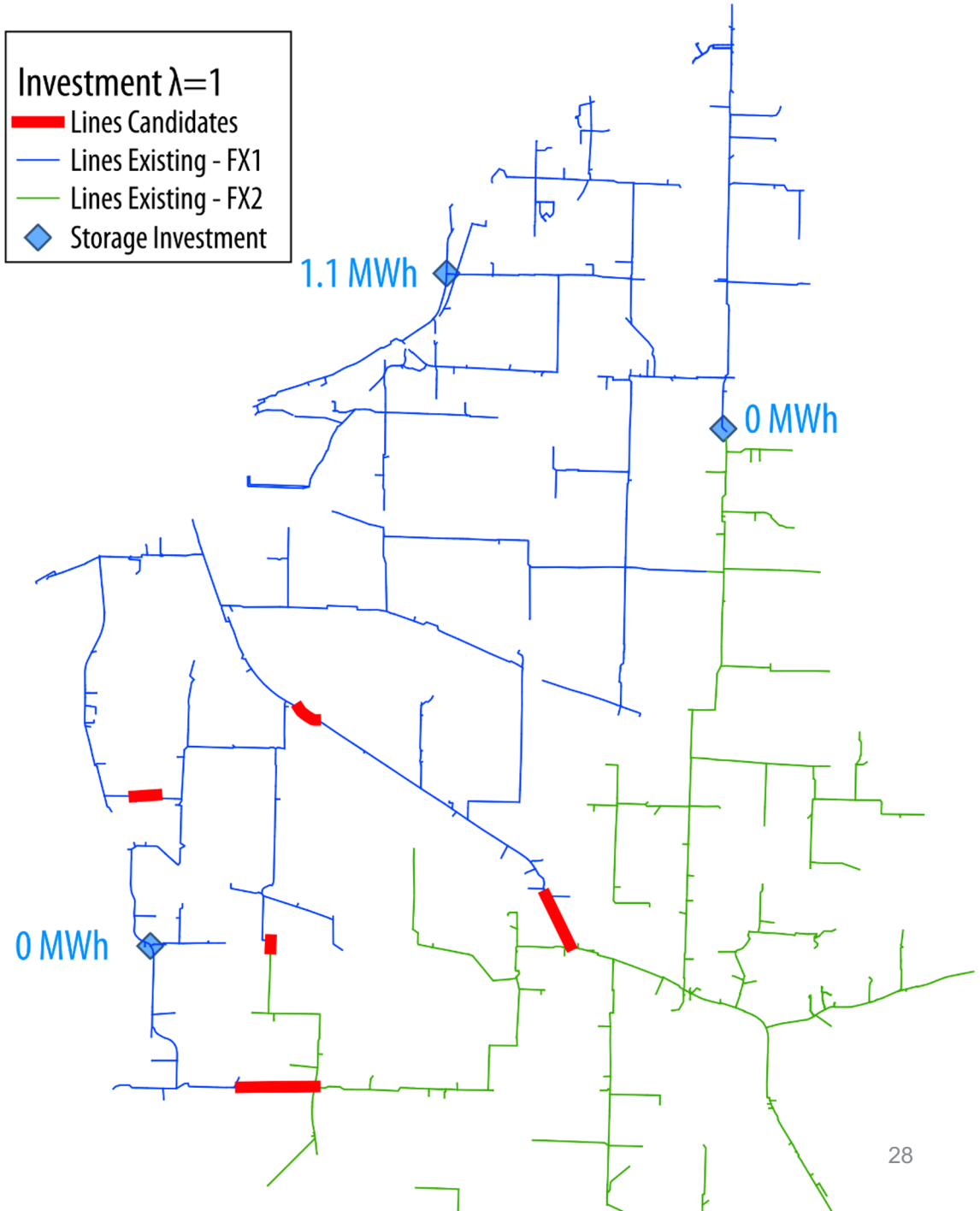
- Medium-level of risk-aversion
  - Resilience plays some role in the investment plan
- All candidate lines are built
  - Three interconnections FX1-FX2
  - Two lines within FX1
- No storage investment



FX1 Investment Plans

Based on high risk-aversion

- Highest level of risk aversion
  - Most resilient investment plan
- All candidate lines are built,
  - Three interconnections FX1-FX2
  - Two lines within FX1
- Storage investment in the northern area
  - Enhances the overall resilience of the system
  - Alleviates most vulnerable area



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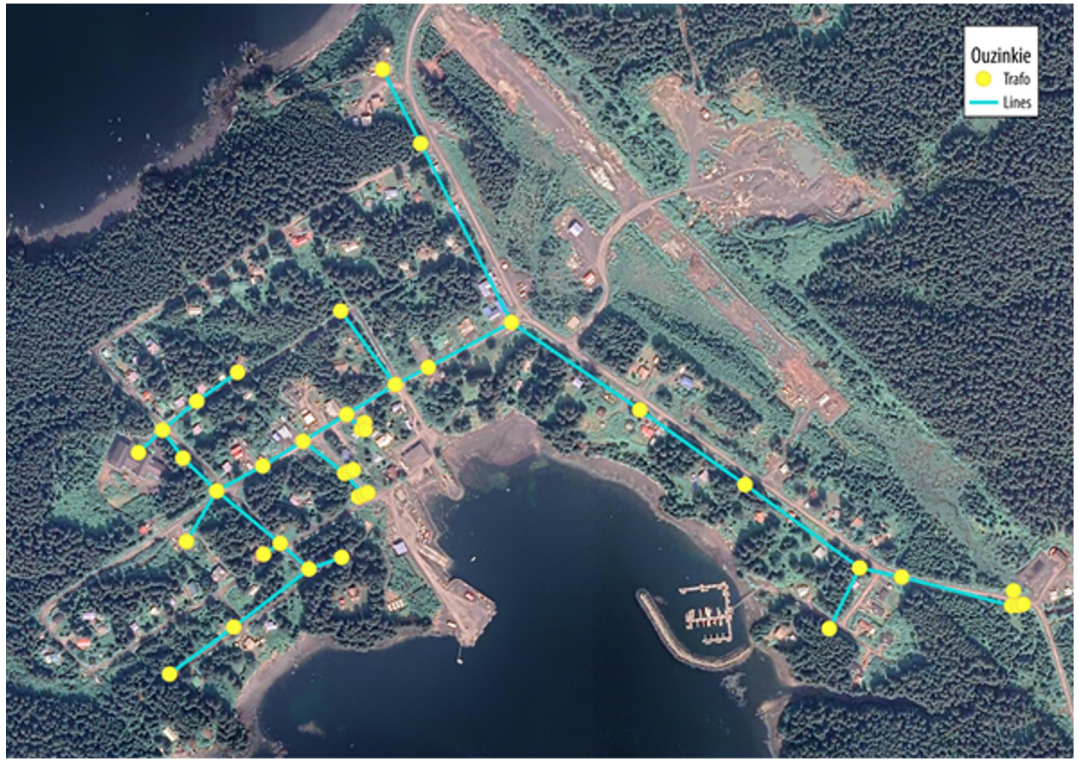
Ouzinkie Demonstration in partnership with ETIPP

Ouzinkie - ETIPP Partnership



- Partnership with ETIPP to use REPAIR as a Resource Planning Tool with Reliability/Resilience considerations.
- Development of risk-based model:
  - Integrates the uncertainty of renewable generation
  - Combines renewables with other uncertainties associated with device failures weather-related outages.

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Technology Transition

REPAIR Tech Transition

Potential Use Cases

- Capacity Expansion Planning
- Reliability Planning (Performance Enhancement)
- Resource Planning

Tech Transition Tasks

Study the existing regulatory framework around Utility Planning to understand how REPAIR can be used by utilities and Regulators

Partnership with ETIPP in Ouzinkie to understand how REPAIR can be used as TA tool

REPAIR Tech Transition (Industry feedback sessions)

Utilities

- *PG&E - Risk and Data Analytic*
- *SMUD - Distributed Energy Resources*
- *Portland General Electric [to be scheduled soon]*

Regulators

- *"Value of Resilience - Risk-controlled Expansion Planning with Distributed Resources", California Public Utilities Commission, Resiliency and Microgrids Working Group, July 2021*

Industry Groups

- *"Evolving System Planning Considerations Including DER", ESIG 2021 Fall Technical Workshop, Online, October 2021.*
- *"Risk-controlled Expansion Planning with Distributed Resources", IEEE PES Distribution Reliability Working Group Meeting, Online, July 2021.*

Project Team

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