Risk-controlled Expansion Planning With Distributed Resources (REPAIR)

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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: $550k
- FY22, authorized: $300k
- FY23, requested: $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.
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.
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*Completed*
Recent Model Development
REPAIR - Methodology

Cost vs Risk Model – Stochastic Optimization Model

- Investment cost
- Operation cost
- Loss of load cost

- Expected value of the Conditional value at Risk of outages (HILP events)
- Risk of outages (Routine events)

Minimize \((1 - \lambda)E[cost] + \lambda CVaR[cost]\)

- Reliability
- Resilience

St
- Nodal balance constraints
- Power flow constraints
- Substations constraints

For each hour “t” of a typical day “d”

- Time coupling constraints for battery operation
- DG model and technical limits

Level of Risk Aversion considered in the reliability vs resilience planning exercise.
Optimization Model

A large problem

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

- Annualized investment
- Operational costs
- Loss of load costs

Cut: annual load curtailment for scenario (s)

Operation Scenario

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

Risk-controlled Expansion Planning with Distributed Resources (REPAIR)
Optimization Model

Reducing complexity

Any failure in this part of the network

Irrelevant investments regardless of the time and duration of the failure

Annualized investment
Operational costs
Loss of load costs

Investment solution

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

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

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

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.
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

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  – Failure 2: 1-hour-duration
FX1 - Critical Failures

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  - 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.
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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
Along with previously discussed files, we received information about project costs. By analyzing this information, we estimated a value of $158,259.7 per mile for each line connection.
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

<table>
<thead>
<tr>
<th>Risk Aversion (Lambda)</th>
<th>Annual Line Costs ($k)</th>
<th>Number of Invested Lines</th>
<th>Annual Storage Costs ($k)</th>
<th>Storage Investment (MWh)</th>
<th>Annual Expected Value Costs ($k)</th>
<th>Annual CvaR Costs ($k)</th>
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<td>1.1</td>
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<td>927.0</td>
</tr>
</tbody>
</table>
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
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.
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

Industry Groups
- "Evolving System Planning Considerations Including DER", ESIG 2021 Fall Technical Workshop, Online, October 2021.
Project Team

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