Forward Thinking
ENERGY INFRASTRUCTURE CONSULTING

PROBABILISTIC RISK ASSESSMENT · TRANSMISSION ASSETS

Asset-to-System Probabilistic Risk Assessment for Transmission Assets

Risk-ranking transmission structures, conductors, and substation equipment to shape a long-range inspection and maintenance program

CLIENT
Transmission-owning utility, multi-state footprint

SCOPE
Transmission lines (structures, conductors, insulators, hardware) and substations (power transformers, breakers, disconnects)

SERVICE LINES
Probabilistic Risk Assessment, Decision Support Tools

DURATION
14 months

~20,000	2	15-yr	Top 5%
structures and substation assets scored	risk layers: line-level and network-level	inspection and maintenance investment roadmap	of assets prioritized for accelerated inspection

THE CHALLENGE

Transmission failures are rare but severe: a structure failure or transformer loss can cascade into wide-area outages, long lead-time replacements, and significant regulatory exposure. The utility's inspection program was calendar-based and its maintenance budget was allocated by voltage class rather than by the consequence of losing a specific line or substation.

The client needed to understand not just which individual assets were most likely to fail, but which failures would matter most to the network, and then to translate that into a multi-year inspection and maintenance program that could be justified to its board and regulators.

WHAT WE DID

1. **Asset-level failure probability.** We developed failure probability models for structures (steel, wood, concrete), conductor and hardware, insulators, power transformers, and breakers, using inspection findings, dissolved-gas and diagnostic test results, age, loading history, and environmental exposure (corrosion, icing, wind, seismic). Transformer models incorporated condition indices from diagnostic data.
2. **Line-level and network-level consequence.** Failure consequence was modeled in two layers. The line layer captured the direct effect of losing a line or substation element. The network layer used contingency analysis to identify where a single loss would violate operating limits, shed load, or leave the system exposed to a second contingency.
3. **Aggregation.** Asset risks were aggregated to line, corridor, substation, and region. Comparing the layers highlighted assets that were individually unremarkable but sat on lines the network could not afford to lose.
4. **Intervention and lifecycle modeling.** For each asset class we modeled the effect of inspection frequency, targeted refurbishment, and replacement on failure probability over a 15-year horizon, including the long procurement lead times for large transformers.
5. **Investment roadmap.** A constrained optimization produced a 15-year inspection and maintenance roadmap, with a shorter-term action list for assets in the top risk band.

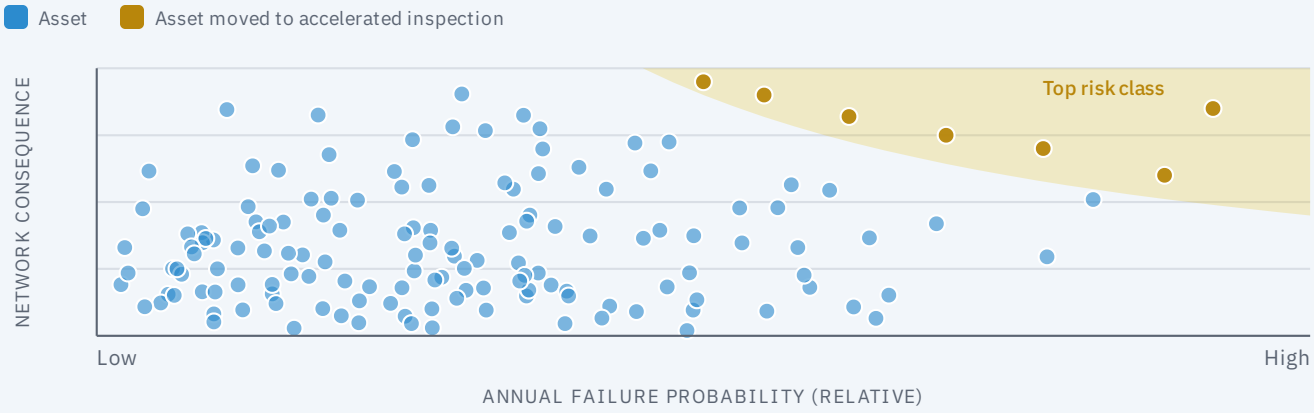
RESULTS

About 5% of assets were placed in the top risk band and moved to an accelerated inspection and diagnostic schedule. Several were high-consequence transformers with deteriorating diagnostic trends that had not been flagged by the calendar-based program.

The network-level layer changed the priority of several lines relative to their line-level ranking, showing that consequence, not just condition, needed to drive the program.

The 15-year roadmap smoothed transformer replacement spend to avoid a bow-wave of simultaneous end-of-life replacements, and set inspection intervals by risk class rather than by voltage level.

Asset-level failure probability vs. network consequence (each point one asset)



Illustrative. Assets in the upper-right band were moved to accelerated inspection; the shaded band marks the top risk class.

IMPACT FOR THE CLIENT

The utility can now explain its transmission inspection and maintenance budget in terms of network risk removed, and re-rank assets as diagnostic data change.

Long-lead-time replacements are planned years ahead on risk, reducing the chance of an unplanned loss of a critical transformer with no spare.

WHAT WE DELIVERED

- Failure probability models for line and substation asset classes
- Line-level and network-level consequence models with contingency analysis
- Asset-to-region risk aggregation and ranking
- 15-year inspection, maintenance, and replacement roadmap
- Priority action list and technical basis report

METHODS AND STANDARDS

Probabilistic risk assessment
Condition-index and diagnostic-trend modeling
N-1 / N-1-1 contingency analysis
Lifecycle cost and risk modeling
Constrained investment optimization