SUBSTATION ASSET COMPOSITE RISK MODEL

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ABSTRACT

The document presents a comprehensive overview of the Substation Risk Model used by PG&E to manage the risks associated with its 914 electric substations. It details the challenges faced, asset management strategies, risk assessment methodologies, and continuous improvement practices aimed at enhancing safety and reliability.

INTRODUCTION

PG&E operates 914 electric substations. Within these substations, major and minor components function seamlessly to deliver safe and reliable electricity to PG&E communities and hometowns. Some of these components include power transformers, circuit breakers (CBs), batteries, civil structures, switches, and protective equipment.

PG&E's substations confront the following significant challenges:

- **Aging infrastructure:** Substation aging infrastructure demands substantial investments to sustain existing reliability levels. This warrants the need for increased adaptation measures to mitigate near-term impacts of asset failure (i.e., condition assessments, life extension, and asset health monitoring).
- **Long Lead Time Material:** We are experiencing extended lead times for equipment procurement. Paired with increasing equipment failure rates, there is a higher potential that the emergency material will not be available when needed. Significant increases in lead times are occurring for both the equipment and the equipment components. These lead times increase the need for long term planning for asset health in a PG&E environment that is challenged with funding long term plans for asset health.
- **Wildfire Risks:** Significant need to address wildfire (WF) risk, capacity growth, and generation interconnections has shifted investments from asset health replacement and system reliability improvements.
- **Compliance Requirements:** The growing regulatory compliance landscape requires more resources to support specific compliance and regulatory commitments and data requests. Some examples are WF safety mitigations, climate change, physical security, and regulatory reporting.
- **Environmental Risks:**
    - **PG&E's Million-Ton Challenge:** This initiative is aimed at substantially reducing PG&E greenhouse gas emissions by installing sulfur hexafluoride (SF6)-free equipment at substations and phasing-out existing high-voltage SF6 CBs ahead of California's stringent requirements by 2035. PG&E continues to actively detect and repair leaks from SF6-filled equipment at Company substations as resources permit.
    - **Climate Change:** Substations are challenged with expanding their understanding of flood, heat, and wind scenarios and developing new adaptation measures to address them.

Beyond risk drivers, a threat-based approach has been developed for substation equipment failures to identify specific failure mechanisms; this approach will further inform maintenance and replacement strategies to improve overall safety and reliability. This threat-based approach also allows for a better understanding of the most effective controls and mitigations to address specific failure mechanisms.

To effectively manage asset health risk, PG&E leverages a combination of asset management strategies. This whitepaper provides an overview of how Substation Asset Management (SAM) identifies risk and subsequently implements strategies to manage risk within PG&E's electric transmission and distribution substation systems.

ASSET STRATEGY OVERVIEW

The substation AM group (SAM) strives to achieve short- and long-term objectives and strategies. Short-term refers to years 0 through 5 from the current year. SAM plans to mitigate in-service failures as much as possible and maintain reliability by identifying and targeting equipment with the highest risk of failure. This includes the use of increased diagnostic testing and outage prevention measures by pulling equipment out of service before it fails, referred to as Just-In-Time (JIT) replacement.

Long-term generally refers to years 6 through 10 after the current year. A substation's long-term plan is to achieve a sustainable replacement rate by asset type so that the fleet age for each asset type is below or aligned with the industry-recognized service life. The derived calculation is referred to as the "guardrail" approach because the Institute of Asset Management's (IAM) guidance describes it as the minimum replacement level acting as a guardrail. The IAM's recommended method was used to determine the number of annual replacements needed to reach a steady-state/sustainable annual replacement rate. This IAM guidance was provided via an instructor providing an IAM certificate course and was referred to as an industry-wide understood common-sense approach although you won't find it listed in any IAM documentation.

Substation Asset Strategy (SAS) engineers are tasked with developing a sound strategy of addressing these risks by utilization of the following key components:

1. Asset Inventory and Data Management
2. Condition Monitoring and Maintenance
3. Risk Management
4. Capital/Expense Investment Planning
5. Performance Management

By focusing on these critical components, Asset Strategists can further develop and employ a variety of strategies to address the risks facing our service territory. Long-term mitigations, such as full station rebuilds, can be cost prohibitive. Therefore, a strategist will deploy short-term mitigations as needed to reduce and mitigate risk. Those short-term mitigations include:

1. Condition Based Assessment and Monitoring
2. Targeted Inspection and Maintenance
3. Asset Life Extension
4. Asset Replacement Programs
5. Emergency Response

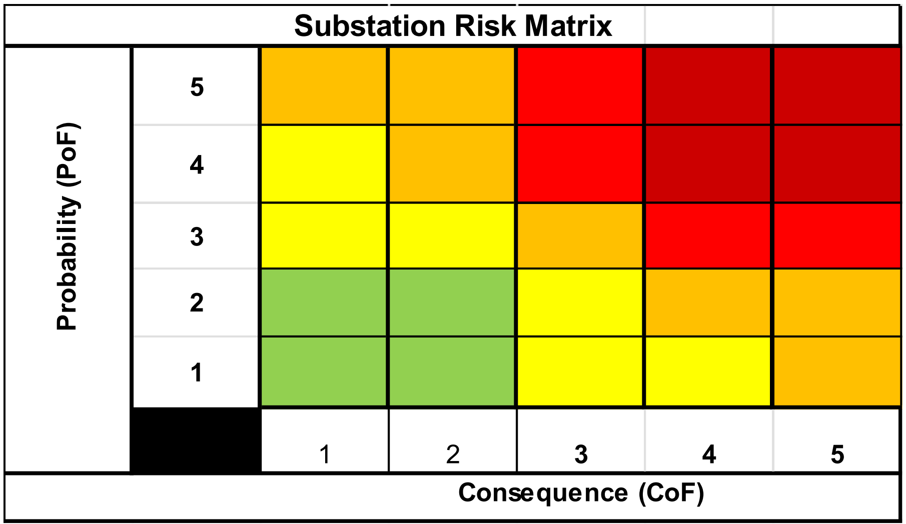
The greatest challenge each Asset Strategist must confront is which assets within their asset class should be given priority. PG&E's current business model as a regulated investor-owned utility (IOU) requires the company to apply for funding approvals from our regulators including the California Public Utilities Commission (CPUC) and Federal Energy Regulatory Commission (FERC). The company is only allotted a specific funding level to spend annually, regardless of whether additional funds are made available by investors or shareholders. Applying this constraint to the question of priority generates a need for a methodology to help identify the highest risk assets.

SAS engineers utilize a 5x5 risk matrix and other risk tools for this very purpose. The matrix is designed to illustrate a heat map and categorizes assets by risk scores. This matrix serves as a starting point for asset risk analysis. While the risk matrix is not meant to identify work by itself, it serves as a compass for each strategist to direct where effort should be applied and to validate whether there is a legitimate need for either short or long-term mitigations.

THE RISK MATRIX

The challenge is to make the complex simple for the purpose of risk prioritization, mitigation, decision making and stakeholder/leadership consumption. To do this we have chosen a 5x5 matrix to represent the combined risk for each major asset class as shown in Table 1.

Table 1
Substation Risk Matrix



Substation Risk Matrix

Probability (PoF)					
5	🟧	🟧	🟥	🟫	🟫
4	🟨	🟧	🟥	🟫	🟫
3	🟨	🟨	🟧	🟥	🟥
2	🟩	🟩	🟨	🟧	🟧
1	🟩	🟩	🟨	🟨	🟧
	1	2	3	4	5

Consequence (CoF)

PoF Confidence:

CoF Confidence:

RISK THRESHOLDS

Before we begin applying criteria, determining probability of failure (PoF) and consequence of failure (CoF), and producing values from 1-5 for our risk matrices, we need to define our consequences and probabilities/frequencies as they apply to the assets that we are ranking. Below is a table that defines both PoF and CoF, and shows its relation to risk matrix values.

Probability Thresholds

Table 2
Probability/Frequency Thresholds

Level	Description	POF%	Frequency Description	Frequency per year
5	Imminent Failure	>66%	Within 1.5 Years	F = 1 - 0.66
4	Within 5 years	20%-66%	Once every 1.5-5 years	F = 0.66 - 0.2
3	Within 10 years	10%-20%	Once every 5-10 years	F = 0.2 -0.1
2	Within 30 years	3.3%-10%	Once every 10-30 years	F = 0.1 -0.033
1	Within 100 years	<3.3%	Once every 30-100 years	F = 0.033 -0.01

The probability thresholds depicted in Table 2 are informed by experiences with asset failures, previous risk frameworks, and a previous Substation Failure Mode and Effects Analysis FMEA.

Consequence Thresholds

Table 3
Consequence Thresholds

IMPACT LEVEL	Sub Asset Management RAC Consequence Definitions
CRITICAL (5)	o Greater than xx CMIN o Greater than xx MWhrs load/Gen. dropped o See Calculation Table for Capacity Unavailable o Greater than $xx o Tier 1 Security
SIGNIFICANT (4)	o Greater than or Equal to xx CMIN but Less than xx o Greater than or equal to xx MWhrs load/Gen. dropped but Less than xx MWhrs o See Calculation Table for Capacity Unavailable o Multiple Fatalities o Less than $xx o Tier 2 Security
MODERATE (3)	o Greater than or Equal to xx CMIN but Less than xx CMIN o Greater than or equal to xx MWhrs load/Gen. dropped but Less than xx MWhrs o See Calculation Table for Capacity Unavailable o Single Fatality o Less than $xx o Tier 3 Security
MINOR (2)	o Greater than or Equal to xx CMIN but less than xx CMIN o Greater than or equal to xx MWhrs load/Gen. dropped but Less than xx MWhrs o See Calculation Table for Capacity Unavailable o Serious injury no fatalities o Less than $xx o Tier 4 Security
NEGLIGEABLE (1)	o Less than xx CMIN o Less than xx MWhrs total load/Gen. dropped o See Calculation Table for Capacity Unavailable o Zero injuries o Less than $xx o Tier 5 Security

The consequence threshold was based on experience with an old scoring system used in the past called Risk Informed Budget Allocation (RIBA) and a Substation FMEA conducted by Substation Asset Management in 2020/2021. These consequence thresholds were created to give the various asset SME's a consistent set of thresholds to use for proper scoring and placement within the risk matrices. The various consequence descriptions within each risk matrix consequence level are descriptions pertaining to varying asset types and risk categories. Since the most common risk categories are safety and reliability across all substation asset types, the descriptions within the 5 different impact levels give visibility into where each reliability or safety consequence might fall. Since there are SMEs on both the Distribution and Transmission side of the house, both a MWhrs description and an equivalent Customer Minutes description were provided for the Reliability risk category. The individual utilities can determine their own values for the thresholds based on their experience and what makes sense for them.

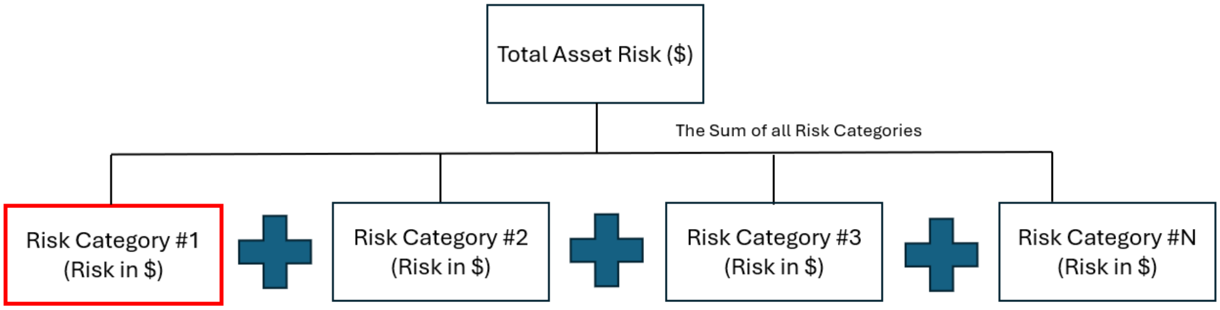
CONFIDENCE SCORING

Confidence scoring is a way to communicate to the model user the accuracy and completeness of the data used to produce risk probability and consequence results. In addition to this transparency, confidence scoring also provides the following benefits.

- **Creative Freedom –** Previously SMEs would limit their risk ranking for a given asset type to the data that they had. The substation composite model asks the SME to create an ideal model based on both data they have and the data they don't have and/or is hard to obtain or integrate. The incompletes or assumptions within the data set will then be represented as a decrease in confidence that can be increased as needed on an asset-by-asset basis.
- **Better Data for Investment Decision Making** — Before making investment decisions, the SME and model user would like to have some level of confidence in the risk data they are using to make those decisions. Trying to obtain 100% confidence might be too expensive and unnecessary but a goal of 70% or higher could make more sense. Having a score for confidence of data outputs allows the user to establish a goal threshold to meet before allocating precious capital or expense funding.
- **Blueprint for Data Mining** — The confidence scoring system can be used by the organization to identify the areas where they can obtain data accuracy increases. It can be a useful tool for the SME in quickly creating a detailed list of data required, which can then be used to initiate necessary requests to various departments to obtain it.

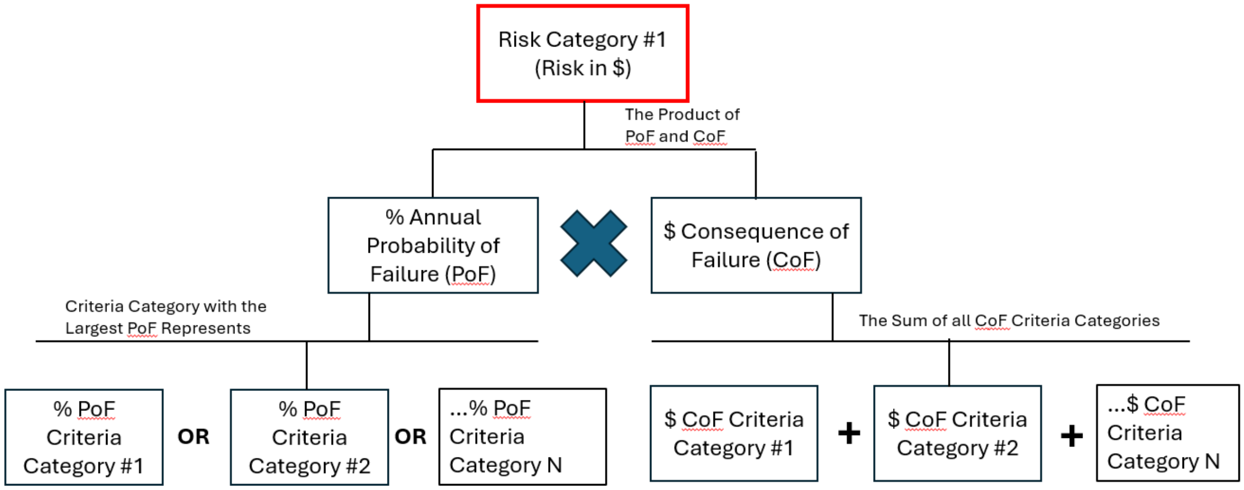
SUBSTATION ASSET RISK MODEL

The substation asset risk model is hierarchical in its design. There can be multiple Risk Categories that are summed together to produce the total annual risk for a given asset expressed in dollars. A graphical representation of this model can be found in Figure 1a below. Typical examples of risk categories would be reliability, safety, environmental, etc.



Risk Categories
Figure 1a

Below in Figure 1b, we take Risk Category #1 shown above in Figure 1a and we show how it is calculated. Each risk category value/score is the product of an annual probability multiplied by a consequence of occurrence in dollars. The probability used in the calculation is the largest probability of any number of independent criteria categories necessary to represent the probability for a given risk category. The consequence is the summation of however many consequence criteria categories are required to represent the consequence of an event for that risk category.



Risk Criteria Categories
Figure 1b

CALCULATING PROBABILITY OF FAILURE (POF)

Failure Mode Identification

The first steps in calculating probability of failure (PoF) are to list all the main <u>independent</u> failure modes and associated components for a given asset and then identify what data could be gathered to understand the health of that component. Relevant data examples would include inspections and tests results. These results, with measurements and historical statistics, are grouped into categories specific to the component and referred to as asset criteria categories. Using a substation power transformer as an example, there could be criteria categories such as – paper insulation/age, insulating oil quality, oil-dissolved gas, bushings, LTC, and design.

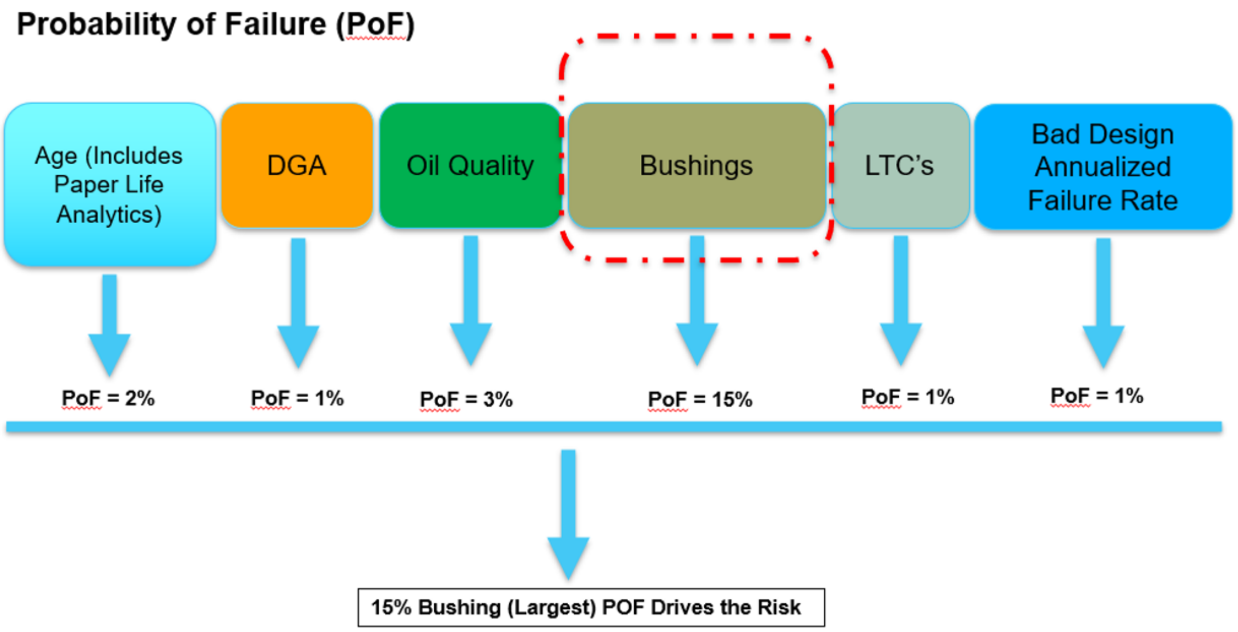
PoF to Criteria Category Association

The next step is to create a Probability of Failure (PoF) based model for each individual criteria category. The most common example, and easiest to produce, is PoF based on asset age. This exercise involves creating failure distribution curves based on asset failure data that records the age at failure. The failure distribution curves then assign individual PoFs to each age via Montecarlo simulations. SMEs usually have age at the time of failure as a part of their asset failure data set. However, in most cases the SME does not collect important data points associated with an asset's condition just prior to failure. These data points are essential to conduct the same PoF to criteria association that was conducted based on age. Criteria categories that have been created indicate what failure data will need to be collected moving forward. For example, in a transformer's bushing criteria category, power factor test results are important for understanding the health and PoF of a bushing. Collecting power factor test result data and understanding what the power factor results show just prior to bushing failure will inform future understanding of the failure mode for that make, model and voltage bushing. The SME often won't have this data right away and will have to collect it for a period before the SME can make the association statistically significant. To complete the PoF association exercise without a robust failure dataset, it is recommended to form a small team of experts to use their experience, any available relevant data, and industry data to make the initial association. Any assumptions or shortcomings can be communicated in confidence scoring for that criteria category.

It is also worth stating that in the instances where needed data isn't available, it is advisable to create a space for it in the model, and then when it is obtained it can be used. In the meanwhile, and until it is obtained, SMEs should allow the model to still produce a risk value based on some lesser data set or assumption as a fall back. When the backup/less reliable data is used it can be reflected in the confidence scoring system that is discussed in the "Calculating Confidence" section of this paper. For example, for bushing PoF, it would be ideal to use power factor test results, but what if there aren't any or none of them are recent? Instead of not being able to calculate a bushing PoF because there aren't any power factor test results, the SME should ensure that there is a backup calculation that can be done instead. In the case of bushings, we can use the age of the bushing and correlate that to the annual PoF. This is a less reliable way of coming up with the PoF of the bushing, but we can convey this via our confidence scoring. What if we don't know the bushing's age? Then we can assume it is the same age as the transformer and reduce the confidence yet again. Each criteria category for both PoF and CoF should always produce value. The confidence scoring system allows us to always produce a risk value based on what we do know, no matter how limited it may be, by informing the user how good the data is that was used to produce that risk value.

Determining Asset PoF

PoF is calculated and produced for each independent criteria category. The PoF for the asset will then be equal to the criteria category with the highest PoF. An example can be seen visually in Figure 2.



PoF Logic Example
Figure 2

For the purposes of producing a risk matrix score for PoF, the largest PoF will be used to produce a 1 through 5 risk matrix score by using the risk matrix thresholds shown in Table 2 in section 3.1.1. This way of calculating risk is preferred over a weighted system because it gives visibility to the risk presented by any of the criteria categories/components of that asset, regardless of how important we believe the criteria category/component is with respect to that asset's reliability. When we have visibility on what exactly is causing the elevated risk, we can better prescribe the mitigation required to treat it. It is important to also identify the second largest PoF driver to ensure that it is sufficiently lower than the highest risk, so that any investment will produce a significant reduction in overall risk.

Focusing on asset specific criteria categories as depicted in Figure 2 is a good first step when creating an asset risk model, however there are other factors that could also be considered. There can be factors that are external to the asset that can also lead to or cause failure. For example, PG&E Distribution Power transformers see about 30% of in-service failures being attributed to external factors. Factors like animal contact and lightning strikes are among such external factors. These external factors could be represented as their own criteria categories with PoFs based on historical trends or statistics that are refreshed on an annual basis.

Determining the Probability of Any Event

As was mentioned in the Substation Asset Risk Model section and depicted in Figure 1a, there can be one or many different risk categories for a given asset. Reliability risk is a very common one with a probability that is based largely on the health of the asset, and so in subsection “Failure Mode Identification” to subsection “Determining Asset PoF” we spent a lot of time on how to calculate that probability (Probability of Failure) associated with that risk (Reliability) category. However, there can be other risk categories, as is depicted in Figure 1a. These other risk categories have different annual probabilities and consequences. Below we show an example of a safety risk category calculation that uses Bushing PoF from Figure 2. In summary, probabilities should be tailored to the unique events or scenarios being used to represent that particular risk category. When determining the calculation for PoF, one must understand whether the criteria categories are independent to the realization of the Event/Consequence being evaluated or if the criteria categories are dependent on one another, and therefore a conditional probability. The safety PoF is a conditional probability. Since the criteria categories are dependent on the presence or realization of one another, they must instead be multiplied together.

Example Safety Event/Scenario: This safety event for a distribution substation transformer involves an employee injury/death due to the distribution transformer catastrophically failing with an employee within its blast radius.

Example Safety Annual Probability Calculation:

Safety Probability = Annual Probability of Failure (0.15) x Annual Probability that Failure is Catastrophic (0.15) x Annual Employee exposure (0.020833) = 0.000469 annually or 0.0469% chance annually

As expected, this safety event is a very low probability, high consequence event. This is because it is a conditional probability. This event needs three different things to line up for it to happen:

1. The transformer has to fail.

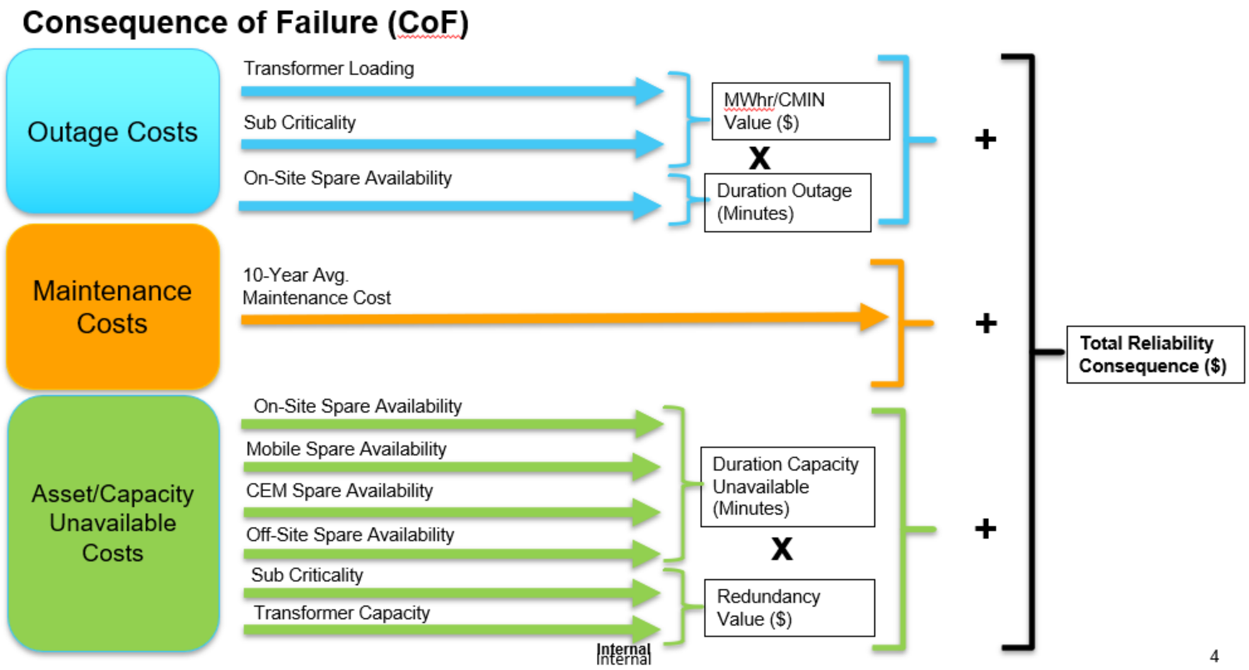
2. The transformer has to fail catastrophically (can use the average of all in-service failures that fail catastrophically or a more informed value if there is reason to believe catastrophic failure is more or less likely).

3. There has to be personnel in the station and/or near the transformer (a value determined by the number of hours on average or actual that employees are in the station).

CALCULATING CONSEQUENCE OF FAILURE (COF)

Consequence Identification/Valuation/Summation

For CoF, individual criteria categories can be developed similarly to PoF. CoF criteria categories will typically be Outage Costs, Maintenance Costs, and Asset/Capacity Unavailable Costs, but could differ for the different asset types. As you identify each consequence criteria to be used, create or obtain the means to translate the units of measure for a given criteria category to a dollar value. Within a given risk category, the outputs from each criteria category would then be summed to produce a total consequence for that risk category. A reliability risk category for transmission transformers has been provided in Figure 3.



CoF Logic Example
Figure 3

Reliability Consequence (Customer Outage)

The most common risk consequence evaluated when it comes to asset failure is reliability risk. Reliability risk is calculated by identifying the number of customers potentially impacted when that asset fails and the duration that those customers will be without power. There are multiple factors used to determine these criteria. Examples of elements within this criteria category could be on-site spare availability/viability, surplus spare availability, switching required, available capacity within a Distribution Planning Area (DPA), probability of a customer outage following a failure, customers served by the asset, and customer criticality. PG&E Substation Asset Management uses Customer Minutes (CMIN), which is calculated as Customers Experiencing Sustained Outage (CESO) x Duration of Sustained Outage in Minutes. If we take a distribution transformer failure again as our example with a sustained outage duration of 120 minutes and 4,000 customers served by the transformer, we will get 480,000 CMIN. The final step would then be to use the utilities value for a customer minute to articulate the customer reliability consequence in dollars. (480,000CMIN x $3.33 = $1,598,400).

Reliability Consequence (Capacity Lost)

Another part of reliability consequence that is often omitted is the value of the asset's capacity being available to the grid. Its unavailability following a failure then becomes a risk that should also be calculated and accounted for. The longer it is unavailable the greater the risk. This criterion is important when trying to provide the true reliability consequence of an asset failure, especially when that asset's failure may not lead to a sustained customer outage. Previous models would only show a value for risk consequence if there was a customer outage. However, we know that even if customers aren't without power, there can still be risk if there is an N-1. The PG&E Metcalf substation attack is a perfect example of an instance when there were multiple assets being shot and made unavailable to the grid, and yet still there were zero customer outages. We were at serious risk, but you wouldn't know it if you only used customer outages to articulate the consequence. Placing a value on redundancy or capacity unavailable to the grid is especially critical in properly conveying the risk for networked transmission substation assets, which unlike distribution assets, may not have a direct customer impact upon failure.

The challenge then becomes trying to place a value on this risk. PG&E Substation Asset Management has decided to use PG&E Electric Schedule SB Standby Service rates to place a value on redundancy. This is what we charge our customers who want standby/reserve capacity on the grid. This value is scaled up or down based on the criticality of the load being served in that area. Please see below for valuation details.

Value per kW x **kW Unavailable** x **85% of actual load** x **Time (Months) Capacity is Unavailable** x **Sub Criticality Factor** = **Capacity Lost Risk**

Defined Variables:

Value per kW = $17.90 for Distribution and $2.47 for Transmission

kW Unavailable = Asset Nameplate Capacity

85% of Actual Load = This is simply a discount factor used by the rate structure

Time (Months) Capacity is Unavailable = How long in months will the capacity that asset provided be missing from the grid?

Sub Criticality Factor = Substation Criticality Tiering used to increase or discount the value of capacity. (Tier 1 = 1.5, Tier 2 = 1.1, Tier 3 = 0.9, Tier 4 = 0.8, Tier 5 = 0.7)

If the loss of one asset would cause both a direct customer outage and a redundancy loss, then the cost of both would be summed together. Once the total dollar amount is known, a risk matrix score from 1 to 5 can be obtained using the risk matrix consequence thresholds described in the “Consequence Thresholds” subsection.

If we continue with our distribution transformer failure example, we can calculate the consequence associated with losing a 115/12kV 45MVA 3-phase transformer in a Tier 4 substation for 12 months as follows:

Capacity Lost Risk = $17.90 x 45,000kW x 0.85 x 12 x 0.8 = $6,572,880

Other Consequence Criteria Categories

Other consequences to consider when trying to put together a comprehensive consequence scoring can be anything associated with the specific asset that the SME identifies as meaningful. Projected annual maintenance expenditures could be another consequence of keeping an old asset in service past its expected life. Each additional asset consequence identified would then simply be summed together with all other consequence criteria categories.

CALCULATING TOTAL RISK

The risk matrices produced for each risk category for a given asset are just a deconstructed view of the overall risk that the asset presents to the utility on an annual basis. To get the total annual risk for a given asset, the product of PoF/Frequency and Consequence for each risk category must be found, and then all risk category products must be summed together as depicted in Figures 1a and 1b.

For example, using our distribution transformer example from previous sections, an SME is using two risk categories, which are Reliability and Safety, to articulate the total risk for the asset. For the Reliability risk category, they have an annual PoF of 15% and a consequence of $8,171,280. For the Safety risk category, there is an annual probability/likelihood of employee fatality/serious injury of 0.0469% and a consequence of $16M. To get the total annual risk for the asset, we would perform the following calculation:

Total Asset Annual Risk = Reliability Risk + Safety Risk

Total Asset Annual Risk = (0.15 x [$1,598,400 + $6,572,880]) + (0.000469 x $16M)

Total Asset Annual Risk = $1,225,692 + $7,504

Total Asset Annual Risk = $1,233,196

It is important to highlight that while it is good to know and understand the total annual risk an asset contributes, this single value should not necessarily be used to prioritize and fund asset risk mitigations. The total risk is great for rolling up the total risk an asset type/family/fleet presents to a utility/grid, but to understand what is driving the risk, the subject matter expert conducting the risk analysis must go deeper. This requires reviewing on an asset-by-asset basis and prescribing the most cost-effective risk mitigation by breaking the risk down again into PoF and CoF and then looking further within PoF and CoF to understand the primary, secondary and tertiary risk drivers. This deeper analysis, along with ensuring an increased confidence in the data that led to the results, will ultimately lead to Asset Management's goal of a well-informed risk spend efficiency that balances risk, cost, and performance.

CALCULATING CONFIDENCE

If we used the model's initial risk output and ran with it, we could be making a big mistake. This is because the model is just a tool for the SME to use to show where risk might be with some degree of uncertainty. The model isn't a replacement for SMEs. It is up to the SME to go deeper with respect to asset analysis to verify if the risk is legitimate or not. This degree of uncertainty in the model should be measured and displayed to all who would use the model as a disclaimer and warning that the model has flaws in the form of data gaps, baked in assumptions, etc. The way this is done is via the creation of a confidence scoring system that is independent of the risk scoring.

A few of the many benefits of such a scoring system are displayed below.

- Provides transparency to users and leadership on the accuracy of the risk scoring
- Provides visibility to areas where more data and analysis is needed
- Gives the SME the freedom to create an ideal model unrestrained by data limitations

The independent confidence scoring system can be created after the criteria categories have been created for both probability and consequence. One of the simple yet critical parts of the scoring system creation is to assign weighted percentages based on the perceived importance of each of the criteria category's contributions to the overall understanding of PoF and CoF. Each criteria category is assigned a percentage so that the percentages add up to 100%. When assigning these criteria category percentages, consideration should be given to both the importance of the component on which the criteria category is focused, and the importance of the associated diagnostic tests used to obtain the data, which is used within that criteria category. This is often initially based on the subject matter expert's recommendation, but can be molded over time based on internal asset failure data, outage statistics, asset characteristics, FMEA's conducted, industry data, etc. For example, for our transformer example we have 6 PoF criteria categories: Age (Paper Insulation Life), Bushings, LTC, Oil Quality, DGA, and Design. In this example the percentages assigned are as follows:

Transformer Reliability PoF Criteria Category Confidence Scoring

Age (Paper Insulation Life) = 30%

Bushings = 15%

LTC = 10%

Oil Quality = 10%

DGA = 30%

Design = 5%

An example of adjusting for the inclusion of external factors is shown below.

Age = 26.25%

Bushings = 13.125%

LTC = 8.75%

Oil Quality = 8.75%

DGA = 26.25%

Design = 4.375%

Animal Contact – 5%

Lightning – 7.5%

Once this evaluation is completed, the next step is to assign the data elements that make up a criteria category with percentages based on their contribution. Once you establish the max percentage contribution of each data element, the next step would be to think of instances where those percentages could be impacted based on various factors, such as time since last test result, assumptions being made, and/or missing data. For example, for our transformer example, we will look at the criteria category, "Bushings." The data elements making up this criteria category are shown below along with their associated percentages based on their perceived importance in the overall understanding of bushing condition and associated bushing PoF.

Bushing Verified Age = 20% (If verified bushing age isn't available, then assume bushing age is the same as the transformer age, but reduce confidence by 5%)

Worst Bushing Power Factor Test Result = 80% (If Power Factor test results are older than 5 years, then the 80% is reduced to 0%, 5 years old then 16%, 4 years old then 32%, 3 years old then 48%, 2 years old then 64%, = < 1 year old then 80%)

Notice how assumptions and/or old test results can affect confidence. In some instances, there may not be any transformer bushing power factor test results, or a verified age of the bushing. In those instances, the bushing criteria category is returning a 15% bushing PoF confidence score out of the total confidence possible for bushings. This result then translates to:

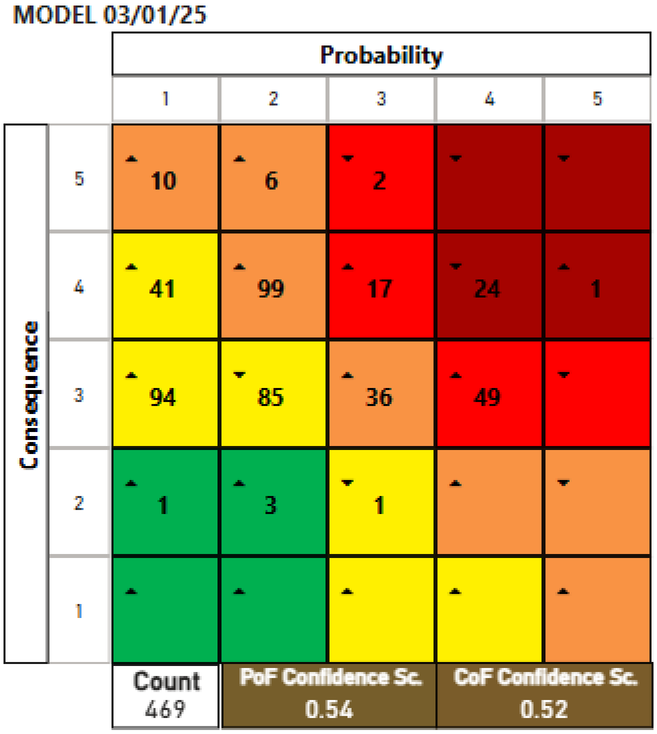
Bushing's confidence contribution to transformer PoF = [0 out of 0.8 (Power Factor Confidence Score) + 0.15 out of 0.2 (Bushing Age confidence score)] x 0.15 (Bushing total possible confidence contribution to transformer PoF) x 100 = 2.25%

So, if we had all the data we needed, then the bushing PoF confidence score would have contributed the full 15% of its overall possible contribution to transformer PoF. However, since we did not have all the data, it only contributed 2.25%.

At PG&E for T&D transformers, when we do this for each criteria category and add up all the confidence contributions, we often arrive at a PoF confidence score of approximately 50%. Over time we hope to raise this baseline confidence via online monitoring, better asset registry data quality, etc. But what this confidence scoring should signal to the user and/or SME is that the asset risk model and associated matrixes are useful, but overall, more data and analysis are often required before one can make significant risk-driven investments. Trying to achieve 100% confidence is not realistic due to the diminishing returns associated with trying to achieve it. The recommendation is to hit a happy medium of 70-75% confidence before initiating or requesting finances for the investment required to execute the risk mitigation. This percentage allows the SME to act on mitigating a risk without being stuck in a paralysis of analysis, while also achieving enough due diligence to ensure that investments are being directed toward the greatest risk reduction for the cost.

The same process for coming up with PoF confidence scoring in percentage should also be used to come up with consequence confidence. With confidence scoring for each asset, the risk matrix can then display a single average confidence for all assets within an asset type for both PoF and CoF as part of the risk matrix, as shown below for Transmission Transformers in Table 4.

Table 4
Risk Matrix w/ Confidence Scoring



MODEL 03/01/25

		Probability				
		1	2	3	4	5
Consequence	5	▲ 10	▲ 6	▼ 2	▼	▼
	4	▲ 41	▲ 99	▲ 17	▼ 24	▲ 1
	3	▲ 94	▼ 85	▲ 36	▲ 49	▼
	2	▲ 1	▲ 3	▼ 1	▲	▼
	1	▲	▲	▲	▲	▲
		Count 469	PoF Confidence Sc. 0.54		CoF Confidence Sc. 0.52	

CONTINUOUS MODEL IMPROVEMENT

Creating an asset risk model is merely the beginning. The model will require improvement over time as the subject matter expert works with it and the data within. Some recommendations on how to facilitate this improvement are listed below.

- Take an annual snapshot of the in-service asset fleet for which you are creating a risk model and archive it for future reference. The data will be helpful for future analysis, which could include grading the accuracy of the risk model, failure analysis, etc.
- On an annual basis, conduct an analysis of the model's accuracy in predicting failure and consequence by reviewing the past year's failures and seeing what predictions the model had for the asset prior to failure. Document these findings in an annual report along with any learnings and actions to be implemented toward future model improvement.
- Circulate the model among other internal and industry SMEs to get feedback for improvement. This can be done by sharing the entire model or sharing specific single criteria categories one at a time to a targeted group of SMEs with expertise on that specific criteria category.
- Within the model, create visibility on the #1 PoF driver, #2 PoF driver, etc., and the difference between the two. This will help you prescribe the proper mitigation/investment and determine viability. The same can be done for CoF.
- Within the model, create a calculation for visibility on risk reduction. This will be a calculation that will show how much the annual risk will decrease following the execution of the recommended mitigation/investment. The risk reduction can then be used to determine Risk Spend Efficiency. To calculate RSE you would use the formula: risk reduction / mitigation cost = RSE. Projects with higher RSE ratios are considered more cost-effective for reducing risk and are prioritized for implementation within limited budgets.

CONCLUSION

Models are only as good as the data used to inform them. If we waited for perfect data, however, we would never be able to use models. Therefore, it is important to provide a way to communicate to the model user(s) the quality and completeness of the data so that the model can be utilized while simultaneously understanding its limitations in identifying and quantifying asset risk. The substation risk model should always be thought of as a tool for the asset subject matter expert and not a replacement for the subject matter expert (SME). The subject matters expert's time is precious and so the model should be used to scan large numbers of assets and identify the subset of assets where elevated risk might exist. This will create time for the SME to conduct detailed analyses for those assets. This in turn will bring value to the company/utility as it invests in risk reduction with a higher level of overall confidence.

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BIOGRAPHY

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