SOUTHERN CALIFORNIA
EDISON®

An *EDISON INTERNATIONAL*® Company

(U 338-E)

Application of SCE Requesting Approval of its Grid Safety and Resiliency Program and Associated Ratemaking Mechanisms
A.18-09-002

Amended

Workpapers

SCE-01A2 Grid Safety and Resiliency

-

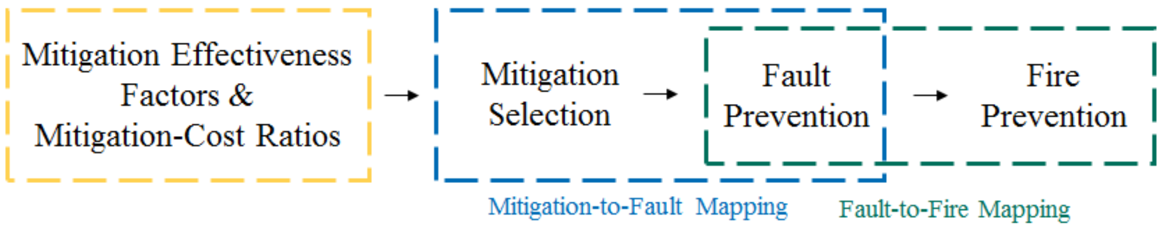
September 2018

Mitigation Effectiveness Comparison--Amended
Supporting Section IV(B)(1)(c)

<u>Objective Summary:</u>

The detailed risk mitigation analysis as described at Section IV(B)(1)(c) in support of the Wildfire Covered Conductor Program (WCCP) followed three sequential steps: fault-to-fire mapping; mitigation-to-fault mapping; and the calculation of mitigation effectiveness factors and mitigation-cost ratios to determine the mitigation measure that provides the most overall value to customers in terms of addressing increasing wildfire risk.

Figure 1 – Risk Mitigation Analysis[1]



This document provides a summary of the methodology and results of this analysis.

<u>Dataset Description – Fault Data</u>

The fault history was provided by SCE's Outage Database & Reliability Metrics (ODRM). The ODRM fault history was filtered for events observed in 2015-2017 on distribution circuits for portions of distribution circuits traversing SCE's high fire risk areas (HFRA), as defined in SCE's supporting testimony. This resulted in a total of ~~15,615~~ 16,973 fault events on these circuits in 2015-2017 with all fault causes included. Next, the fault list was further filtered to fault code causes as identified in the CPUC reportable Fire Data.[2] This included specific overhead cause codes such as contact from object and equipment/facility failure causes, but excluded other cause codes such as underground-related cause codes and cause codes like "unknown."

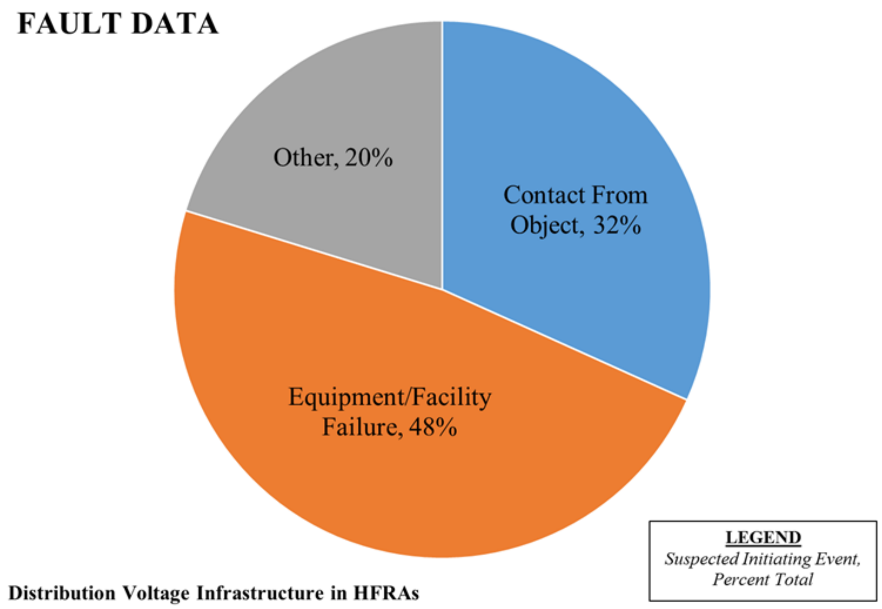
The resulting filtered ODRM data produced records of ~~8,458~~ 9,169 such distribution fault events in years 2015-2017. Based on these results, an expected average of ~~2,819~~ 3,056 faults per year was utilized within SCE's WCCP detailed risk mitigation analysis. Table 1 below provides the ODRM fault data details, and Figure 2 below provides a high-level pie chart summary of the percentage distribution of total faults into the three major categories, i.e., Contact From Object, Equipment/Facility Failure, and Other.

[1] Shown as Figure IV-6 in SCE's prepared testimony.
[2] Data was provided to Commission in accordance with Decision (D.) 14-12-015.

Table 1 – ODRM Fault Data, Fire-Related Causes, 2015-2017

Suspected Initiating Event	Faults Observed Over 3 Years		Average Annual Faults	
Contact From Object	**~~2684~~**	**2,919**	**~~895~~**	**973**
Animal	~~750~~	817	~~250~~	272
Balloon	~~457~~	500	~~152~~	167
Other	~~144~~	152	~~48~~	51
Vegetation	~~713~~	769	~~238~~	256
Vehicle Hit	~~620~~	681	~~207~~	227
Equipment/Facility Failure	**~~4061~~**	**4,377**	**~~1354~~**	**1,459**
Capacitor Bank	~~25~~	28	~~8~~	9
Conductor/Wire	~~436~~	488	~~145~~	163
Crossarm	~~118~~	130	~~39~~	43
Fuse/BLF/Cutout	~~294~~	311	~~98~~	104
Insulator	~~71~~	79	~~24~~	26
Other - Equipment	~~332~~	350	~~111~~	117
Splice/Connector/Tap	~~413~~	461	~~138~~	154
Transformer	~~2372~~	2,530	~~791~~	843
Other	**~~1713~~**	**1,873**	**~~571~~**	**624**
Total	**~~8458~~**	**9,169**	**~~2819~~**	**3,056**

Figure 2 – ODRM Fault Data, Fire-Related Causes, 2015-2017



Dataset Description – Fire Data

The underlying fire data used for this analysis was previously provided to the CPUC in accordance with Decision (D.) 14-12-015. Similar to the fault data above, the fire data were filtered to include only fires that occurred in HFRA. In addition, only fires associated with distribution voltages (≤ 33kV) were used in the analysis.

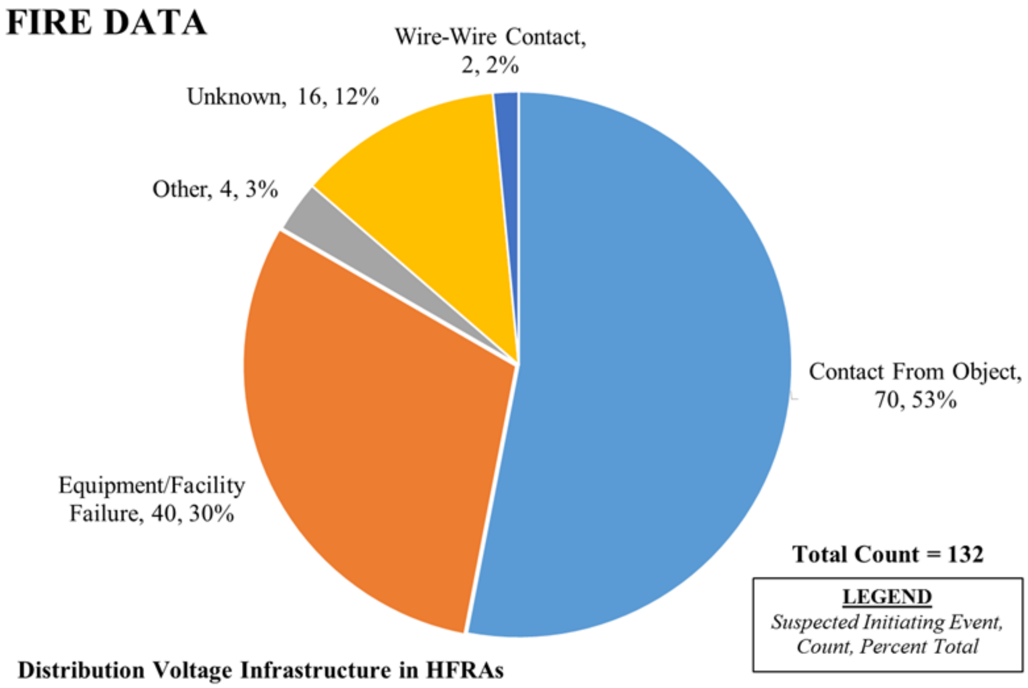
The fire data included records of 132 such fire ignition events in years 2015-2017. Based on these results, an expected annual average of 44 fire ignition events per year was used for this analysis. Table 2 below provides the fire data details, and Figure 3 below provides a high-level pie chart summary of the percentage distribution of total fires into the three major categories, i.e. Contact From Object, Equipment/Facility Failure, and Other (grouped together as 'Other, Unknown, Wire-Wire Contact').[3]

[3] The majority of these "Other" ignition events were identified as "Unknown" in the data set.

Table 2 – CPUC Fire Data, Distribution Voltages, 2015-2017

Suspected Initiating Event	Fires Observed Over 3 Years	Average Annual Fires
Contact From Object	**70**	**23.3**
Animal	15	5.0
Balloon	14	4.7
Other	10	3.3
Vegetation	22	7.3
Vehicle Hit	9	3.0
Equipment/Facility Failure	**40**	**13.3**
Capacitor Bank	2	0.7
Conductor/Wire	12	4.0
Crossarm	1	0.3
Fuse/BLF/Cutout	1	0.3
Insulator	5	1.7
Other - Equipment	8	2.7
Splice/Connector/Tap	8	2.7
Transformer	3	1.0
Other, Unknown, Wire-Wire Contact	**22**	**7.3**
Total	**132**	**44.0**

Figure 3 – CPUC Fire Data, Distribution Voltages, 2015-2017



Fault-to-Fire Mapping Analysis

Utilizing the fault data and fire data shown above, a fault-to-fire mapping analysis was performed. This analysis aligned the ~~2,819~~ 3,056 faults per year with the 44 fires per year, which provided a method to calculate the *relative potential likelihood that a specific type of fault would be associated with a fire ignition event.*

For example, ~~250~~ 272 annual animal-related Contact From Object (CFO) faults were mapped to 5 animal-related CFO fires per year. This suggests that animal-related CFO faults have a ~~2%~~ 1.8% likelihood in being associated with a fire ignition event (since 5 fires per year / ~~250~~ 272 faults per year = ~~0.02~~ 0.018). Similar calculations were repeated for all fault and fire categories included in the data tables above.

The full results of this fault-to-fire mapping analysis are provided below in Table 3.

Table 3 – Fault-to-Fire Mapping Analysis

	~~Column A~~	~~Column B~~	~~Column C~~	~~Column D~~
~~Suspected Initiating Event~~	~~Annual Fires (Count)~~	~~Annual Fires (Percent)~~	~~Annual Frequency of Fault~~	~~Likelihood of being associated with a Fire~~
~~Contact From Object~~	**~~23.3~~**	**~~53%~~**	**~~895~~**	**~~2.6%~~**
~~Animal~~	~~5.0~~	~~11%~~	~~250~~	~~2.0%~~
~~Balloon~~	~~4.7~~	~~11%~~	~~152~~	~~3.1%~~
~~Other~~	~~3.3~~	~~8%~~	~~48~~	~~6.9%~~
~~Vegetation~~	~~7.3~~	~~17%~~	~~238~~	~~3.1%~~
~~Vehicle Hit~~	~~3.0~~	~~7%~~	~~207~~	~~1.5%~~
~~Equipment/Facility Failure~~	**~~13.3~~**	**~~30%~~**	**~~1,354~~**	**~~1.0%~~**
~~Capacitor Bank~~	~~0.7~~	~~2%~~	~~8~~	~~8.0%~~
~~Conductor/Wire~~	~~4.0~~	~~9%~~	~~145~~	~~2.8%~~
~~Crossarm~~	~~0.3~~	~~1%~~	~~39~~	~~0.8%~~
~~Fuse/BLF/Cutout~~	~~0.3~~	~~1%~~	~~98~~	~~0.3%~~
~~Insulator~~	~~1.7~~	~~4%~~	~~24~~	~~7.0%~~
~~Other~~	~~2.7~~	~~6%~~	~~111~~	~~2.4%~~
~~Splice/Connector/Tap~~	~~2.7~~	~~6%~~	~~138~~	~~1.9%~~
~~Transformer~~	~~1.0~~	~~2%~~	~~791~~	~~0.1%~~
~~Other~~	**~~7.3~~**	**~~17%~~**	**~~571~~**	**~~1.3%~~**
~~Total~~	**~~44.0~~**	**~~100%~~**	**~~2,819~~**	

	Column A	**Column B**	**Column C**	**Column D**
Suspected Initiating Event	Annual Fires (Count)	Annual Fires (Percent)	Annual Frequency of Fault	Likelihood of being associated with a Fire
Contact From Object	**23.3**	**53%**	**973**	**2.4%**
Animal	5.0	11%	272	1.8%
Balloon	4.7	11%	167	2.8%
Other	3.3	8%	51	6.6%
Vegetation	7.3	17%	256	2.9%
Vehicle Hit	3.0	7%	227	1.3%
Equipment/Facility Failure	**13.3**	**30%**	**1,459**	**0.9%**
Capacitor Bank	0.7	2%	9	7.1%
Conductor/Wire	4.0	9%	163	2.5%
Crossarm	0.3	1%	43	0.8%
Fuse/BLF/Cutout	0.3	1%	104	0.3%
Insulator	1.7	4%	26	6.3%
Other	2.7	6%	117	2.3%
Splice/Connector/Tap	2.7	6%	154	1.7%
Transformer	1.0	2%	843	0.1%
Other	**7.3**	**17%**	**624**	**1.2%**
Total	**44.0**	**100%**	**3,056**	

In Table 3 above, 'Column A' shows the annualized total of each type of fire as reported to the CPUC, with 'Column B' representing the percentage of each type as a percentage of the annual total. 'Column C' is the annualized total of ODRM fire-related faults. The value in 'Column D' is a derived value determined by dividing the associated value in 'Column A' by 'Column C' to estimate the historical likelihood that a certain fault type was associated with a fire ignition event.

Mitigation-to-Fault Mapping

Next, SCE conducted a comprehensive review of mitigation alternatives and their effectiveness at reducing or eliminating faults. This analysis relied on engineering subject matter expertise to identify how much of each general fault type—contact from object, equipment/facility failure, and other—could be mitigated by a specific mitigation measure.

During this review, the question analyzed was whether a mitigation alternative would be effective at avoiding each identified type of fault. As a simplifying assumption, mitigations were assumed to be either completely effective or ineffective against a specific ODRM cause code.[4]

The results of this mitigation-to-fault mapping are presented in Table 4 below.

Table 4 – Mitigation to Fault Mapping Analysis

	ODRM Cause Code	Covered Conductor Effective?	Bare Conductor Effective?	Undergrounding Effective?
Contact From Object	Animal	**Yes**	No	**Yes**
	Balloon	**Yes**	No	**Yes**
	Other	**Partial (Yes for 'Foreign Material')**	No	**Yes**
	Vegetation Blown; Vegetation Overgrown	**Yes**	No	**Yes**
	Vehicle Hit	No	No	**Yes**
Equipment / Facility Failure	Transformer	No	No	**Yes**
	Conductor / Wire	**Yes**	**Yes**	**Yes**
	Splice / Connector / Tap	**Yes**	**Yes**	**Yes**
	Fuse / BLF / Cutout	No	No	**Yes**
	Lightning Arrestor	No	No	**Yes**
	Crossarm	No	No	**Yes**
	Pothead	No	No	**Yes**
	Insulator	No	No	**Yes**
	Switch / Disconnect AR	No	No	**Yes**

Mitigation Effectiveness Factors

[4] 'Foreign Material' and 'Ice/Snow' cause codes are included within the 'Other' category shown in Table 4. For purposes of the analysis, covered conductor was assumed to be completely effective against 'Foreign Material' cause codes, and assumed to be completely ineffective against 'Ice/Snow'.

Next, SCE combined the results of the fault-to-fire mapping and the mitigation-to-fault mapping in order to calculate mitigation effectiveness factors for each mitigation alternative.

For example, an annual total of ~~250~~ 272 animal-related CFO faults were identified as being associated with 11% of the total wildfire risk (see Table 3). Furthermore, animal-related CFO faults were identified as being effectively mitigated by covered conductor in the mitigation-to-fault mapping. Therefore, animal-related CFO fires were identified as able to be mitigated through full deployment of covered conductor.

As another example, an annual total of ~~207~~ 227 vehicle-related CFO faults were identified as being associated with 7% of the total wildfire risk (see Table 3). However, vehicle-related CFO faults were identified as not being effectively mitigated by covered conductor in the mitigation-to-fault mapping. Therefore, vehicle-related CFO fires were characterized as unmitigated by covered conductor deployment.

The resulting mitigation effectiveness factors for the covered conductor mitigation alternative are provided in Table 5 below.

Table 5 – Covered Conductor Effectiveness Analysis

	Covered Conductor			
Suspected Initiating Event	**Mitigated Events**		**Equivalent Fires**	
Contact From Object	**~~677~~**	**734**	**~~19.5~~**	**19.6**
Animal	~~250~~	272	~~5.0~~	5.0
Balloon	~~152~~	167	~~4.7~~	4.7
Other	~~37~~	39	~~2.5~~	2.6
Vegetation	~~238~~	256	~~7.3~~	7.3
Vehicle Hit	~~0~~	0	~~0.0~~	0.0
Equipment/Facility Failure	**~~283~~**	**316**	**~~6.7~~**	**6.7**
Capacitor Bank	~~0~~	0	~~0.0~~	0.0
Conductor/Wire	~~145~~	163	~~4.0~~	4.0
Crossarm	~~0~~	0	~~0.0~~	0.0
Fuse/BLF/Cutout	~~0~~	0	~~0.0~~	0.0
Insulator	~~0~~	0	~~0.0~~	0.0
Other	~~0~~	0	~~0.0~~	0.0
Splice/Connector/Tap	~~138~~	154	~~2.7~~	2.7
Transformer	~~0~~	0	~~0.0~~	0.0
Other	**~~0~~**	**0**	**~~0.0~~**	**0.0**
Mitigated Total	**~~960~~**	**1,051**	**~~26.2~~**	**26.2**
Total Fires			**~~44.0~~**	**44.0**
Mitigation Effectiveness			**~~60%~~**	**60%**

In Table 5 above, "mitigated events" column shows the number of annual faults for those categories identified as "yes" in Table 4 or zero for those categories identified as "no" in Table 4. Likewise, the "equivalent fires" column shows the number of annual ignition events for categories identified as "yes" in Table 4 or zero for categories identified as "no" in Table 4.

Dividing the "mitigated total" of "equivalent fires" by "total fires" yields the mitigation effectiveness factor. In this case, 26.2 equivalent fires that could be mitigated with covered conductor represents approximately 60% of the 44 annual fires (26.2 equivalent fires / 44 annual fires = 0.60).

As shown below, this methodology was repeated for the bare conductor and underground conversion mitigation alternatives. Based on the results, an overall 15% mitigation effectiveness factor was calculated for bare conductor. See the Table 6 below.

Table 6 – Bare Conductor Effectiveness Analysis

	Bare Conductor			
Suspected Initiating Event	**Mitigated Events**		**Equivalent Fires**	
Contact From Object	~~**0**~~	**0**	~~**0.0**~~	**0.0**
Animal	~~0~~	0	~~0.0~~	0.0
Balloon	~~0~~	0	~~0.0~~	0.0
Other	~~0~~	0	~~0.0~~	0.0
Vegetation	~~0~~	0	~~0.0~~	0.0
Vehicle Hit	~~0~~	0	~~0.0~~	0.0
Equipment/Facility Failure	~~**283**~~	**316**	~~**6.7**~~	**6.7**
Capacitor Bank	~~0~~	0	~~0.0~~	0.0
Conductor/Wire	~~145~~	163	~~4.0~~	4.0
Crossarm	~~0~~	0	~~0.0~~	0.0
Fuse/BLF/Cutout	~~0~~	0	~~0.0~~	0.0
Insulator	~~0~~	0	~~0.0~~	0.0
Other	~~0~~	0	~~0.0~~	0.0
Splice/Connector/Tap	~~138~~	154	~~2.7~~	2.7
Transformer	~~0~~	0	~~0.0~~	0.0
Other	~~**0**~~	**0**	~~**0.0**~~	**0.0**
Mitigated Total	~~**283**~~	**316**	~~**6.7**~~	**6.7**
Total Fires			~~**44.0**~~	**44.0**
Mitigation Effectiveness			~~**15%**~~	**15%**

Since underground conversion was used as the reference baseline for mitigation effectiveness (because it removes all exposures related to overhead power lines), SCE used a 100% mitigation effectiveness factor. See Table 7 below.

Table 7 – Undergrounding Effectiveness Analysis

	Undergrounding			
Suspected Initiating Event	**Mitigated Events**		**Equivalent Fires**	
Contact From Object	~~**895**~~	**973**	~~**23.3**~~	**23.3**
Animal	~~250~~	272	~~5.0~~	5.0
Balloon	~~152~~	167	~~4.7~~	4.7
Other	~~48~~	51	~~3.3~~	3.3
Vegetation	~~238~~	256	~~7.3~~	7.3
Vehicle Hit	~~207~~	227	~~3.0~~	3.0
Equipment/Facility Failure	~~**1,354**~~	**1,459**	~~**13.3**~~	**13.3**
Capacitor Bank	~~8~~	9	~~0.7~~	0.7
Conductor/Wire	~~145~~	163	~~4.0~~	4.0
Crossarm	~~39~~	43	~~0.3~~	0.3
Fuse/BLF/Cutout	~~98~~	104	~~0.3~~	0.3
Insulator	~~24~~	26	~~1.7~~	1.7
Other	~~111~~	117	~~2.7~~	2.7
Splice/Connector/Tap	~~138~~	154	~~2.7~~	2.7
Transformer	~~791~~	843	~~1.0~~	1.0
Other	~~**571**~~	**624**	~~**7.3**~~	**7.3**
Mitigated Total	~~**2,819**~~	**3,056**	~~**44.0**~~	**44.0**
Total Fires			~~**44.0**~~	**44.0**
Mitigation Effectiveness			~~**100%**~~	**100%**

Mitigation-Cost Ratios and Customer Value

Finally, these mitigation effectiveness factors were used in combination with unit costs to estimate mitigation-cost ratios. A mitigation-cost ratio is calculated by dividing the mitigation effectiveness factor (as calculated above and expressed as a decimal) by the mitigation unit cost (expressed in millions of dollars and on a per-mile basis).

The results of this analysis are summarized below.

Table 8 – Mitigation-Cost Ratio Analysis

Mitigation Option	Relative Mitigation Effectiveness Factor	Cost per Mile ($ million)	Mitigation-Cost Ratio
Re-conductor – Bare	0.15	0.30	0.50
Re-conductor – Covered	0.60	0.43	1.40
Underground Conversion	1.00	3.00	0.33

A mitigation-cost ratio is not the same as a typical cost-benefit ratio, since mitigation-cost ratios are not dimensionless (i.e., the numerators and denominators have different units). However, comparing the mitigation-cost ratios provides a meaningful indicator of the relative value of each mitigation (as compared to the alternatives considered). For example, a comparatively higher mitigation-cost ratio indicates greater overall mitigation value, i.e. greater overall customer benefit per dollar spent, and a comparatively lower mitigation-cost ratio indicates lower overall mitigation value for customers, i.e. less benefit per dollar spent. Comparing the mitigation-cost ratio of covered conductor results in covered conductor providing 2.8 times the value as bare re-conductoring (1.40 / 0.50 = 2.8) and 4.2 times the value as underground conversion (1.40 / 0.33 = 4.2).