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BEFORE THE PUBLIC UTILITIES COMMISSION OF THE

STATE OF CALIFORNIA

In the Matter of the Application of SOUTHERN CALIFORNIA EDISON COMPANY (U 338-E) for a Certificate of Public Convenience and Necessity Concerning the Tehachapi Renewable Transmission Project (Segments 4 through 11)	)))))	Application No. 07-06-031 (Filed June 29, 2007)

SOUTHERN CALIFORNIA EDISON COMPANY'S (U 338-E) PETITION FOR MODIFICATION OF DECISION 13-07-018

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I. INTRODUCTION

Pursuant to Rule 16.4 of the California Public Utilities Commission's (Commission) Rules of Practice and Procedure, and in response to the Commission's order in Decision (D.) 13-07-018, Southern California Edison Company (SCE) respectfully submits this petition for modification (PFM) of D.13-07-018.

Placing approximately 3.5 mile stretch of the Tehachapi Renewable Transmission Project (TRTP) underground through the City of Chino Hills (Chino Hills) results in a transmission system with greater line charging relative to a strictly overhead transmission system. To ensure safe and reliable transmission service, SCE's underground transmission system design included voltage control equipment (also referred to as reactive compensation) to mitigate the risk of flash-over where one end of the transmission line is open. Finding that SCE had not justified the cost or need of voltage control, however, D.13-07-018 ordered SCE to study a potential Basic Insulation Level (BIL) standard rather than voltage control. The Commission further ordered SCE to file a petition for modification within 60 days of the decision if SCE wished to update the Commission's finding of maximum cost to include either an increase in BIL rating, or voltage control (reactive compensation) if an increase in the BIL rating is shown to be impractical.[1]

SCE has determined that conducting the Commission's requested BIL study would be time-consuming and would significantly delay the in-service date of TRTP, perhaps as late as 2019. Consequently, as explained in more detail below, SCE requests that D.13-07-018 be modified to (1) remove the BIL study requirement; (2) reinstate the installation of voltage control equipment, as originally proposed in UG5; and (3) clarify that because the Commission's finding of maximum reasonable cost does not include the cost for voltage control and other necessary

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1 *See* D.13-07-018 at 40-41, 63-64, Finding of Fact 22.

activities, the Commission will not at this time make a specific finding of maximum cost for the underground portion of the overall project, and instead will address the issue when SCE seeks to amend the Commission's maximum prudent cost finding for the overall project. These proposed modifications will facilitate SCE's ability to construct the underground transmission line safely, reliably, and promptly.

II. PROCEDURAL BACKGROUND

On July 11, 2013, the Commission issued D.13-07-018, which adopted President Peevey's Alternate Proposed Decision to grant Chino Hills' PFM of D.09-12-044 and require undergrounding of Segment 8A of TRTP. The Commission ordered SCE to underground a single-circuit, two cable per phase 500 kV transmission system with ducts and structures for a future third cable through Chino Hills that the parties referred to as "UG5." SCE had previously estimated that UG5 would cost approximately $372 million to construct, based in part on a market-based procurement process that resulted in firm bids, good for a period of 180 days.[2]

After making several adjustments to SCE's design and cost estimates, the Commission estimated the costs of undergrounding UG5 in Chino Hills to be approximately $224 million; this cost, however, excluded the costs for voltage control that SCE had designed to mitigate excessive voltage conditions arising from underground construction.[3] SCE planned to implement shunt reactors for voltage control and to prevent electricity flash-over in case one end of the Mira Loma-Vincent 500 kV line should be opened, while the other remained closed.[4] However, in D.13-07-018, the Commission determined that SCE had not shown that the voltage

2 Attachment A, Declaration of Charles Adamson (Adamson Decl.) ¶ 28.

3 D.13-07-018 at 47.

4 *Id*. at 40.

control equipment was necessary, and suggested that an appropriate increase in BIL rating could be used instead of voltage control equipment to mitigate the same risk.[5] Regarding the cost of voltage control equipment for UG5, the Commission found:

> Without greater substantiation, we will not approve a cost cap component that approaches $23 million. Because the burden of producing additional evidence is on SCE, if SCE wishes us to amend the cost cap to include a reasonable sum for BIL in the design of UG5 (or for reactive compensation, if BIL is shown to be impracticable), SCE must file and serve a petition for modification of today's decision within 60 days of the date of today's decision. Such petition must include a report on the cost and timeline for developing an appropriate BIL standard for Segment 8A and for implementing it.[6]

In response to the Commission's directive, SCE submits this PFM explaining why: (1) an increase in the BIL rating would result in substantial project delays and unknown additional costs; (2) voltage control equipment is necessary; and (3) developing and implementing an increase in the BIL rating would not address the steady-state voltage control issue. This PFM also seeks clarification that associated costs for the undergrounding portion of Segment 8A will be addressed in a future update to the Commission's finding of maximum reasonable cost for the overall project.

III. LEGAL STANDARD

A party may file a PFM to request changes to an issued Commission decision. Under Rule 16.4, a PFM shall "concisely state the justification for the requested relief . . . ."[7] Facts

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5 *Id.* at 40, 63; Finding of Fact No. 21.

6 *Id.* at 40-41.

7 Rule 16.4(b).

must be supported by a declaration or affidavit.[8] The petitioning party bears the burden of justifying its requested modification.[9]

Rule 16.4(d) requires an explanation of timing for any PFM filing that is more than one year since the effective date of the Commission's decision. SCE is filing this PFM less than one year after D.13-07-018 and therefore has satisfied the Rule 16 timing requirements. Moreover, the Commission expressly ordered SCE to file a PFM in D.13-07-018 to resolve whether UG5 would require BIL or voltage control.

IV. REQUEST FOR MODIFICATION OF D.13-07-018

For the reasons explained below, SCE respectfully asks the Commission to modify D.13-07-018 to (1) remove the BIL study requirement; (2) authorize the installation of voltage control; and (3) clarify that associated costs for the undergrounding portion of Segment 8A will be addressed in a future update to the Commission's finding of maximum reasonable cost for the overall project in D.09-12-044—including the installation of voltage control, the costs associated with final engineering, and the cost of implementing Federal Aviation Administration (FAA) recommendations.

A. Investigating Whether UG5 Can Be Installed Without Voltage Control Will Cause Unreasonable Delays

For safety and reliability reasons, it is important for a transmission system to be operated within its rated voltage.[10] By undergrounding the approximately 3.5 miles of TRTP through

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[8] *Id*.

[9] *See* D.08-09-024 at 3.

[10] Adamson Decl. ¶ 4.

Chino Hills, there will be an increase in the transmission line charging current.[11] Under some circumstances, this could cause the voltage on the transmission system to exceed its 550 kV rating.[12]

The components of SCE's transmission system are rated to a maximum of 550 kV,[13] which is the transmission component voltage rating used for nominal 500 kV transmission systems by most utilities in North America.[14] Equipment subject to this maximum voltage rating include the cable, circuit breakers, disconnect switches, wavetraps, insulators, potheads, and surge arresters.[15] There are very few Alternating Current transmission systems in North America with components with a voltage rating higher than 550 kV; the next available voltage class is 765 kV, and the only installations at 765 kV are overhead construction.[16] For underground transmission systems, there is currently no XLPE cable available that is rated above 550 kV.[17]

Operating the existing 500 kV (rated at 550 kV) system at a voltage higher than its 550 kV rating could result in electricity flash-over and equipment failure, thus undermining system reliability and will not be considered by SCE.[18] With that in mind, SCE designed UG5 with voltage control equipment to control voltage conditions on the transmission system.[19] Failing to install voltage control equipment would result in higher voltage levels on the transmission

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11 *Id*. ¶ 19.

12 *Id*.

13 550 kV is 10% over the nominal transmission line voltage of 500 kV. *See* Attachment B, Declaration of Rachel Mosier (Mosier Decl.) ¶ 4.

14 Adamson Decl. ¶ 4.

15 *Id*.

16 *Id*.

17 *Id*.

18 *Id*.

19 *Id*. ¶ 5.

system, exceeding 550 kV, and would result in higher stress levels on all energized transmission system components.[20]

If SCE allowed its transmission system to operate at levels above 550 kV, it would have to either design an entirely new voltage class equipped to handle higher voltages, thoroughly test the existing design to see whether it could handle the higher voltage, or move to 765 kV class components where available.[21] Currently, however, the highest available underground cable is rated to only 550 kV, meaning that a new cable will have to be designed, manufactured and tested.[22] Under International Electrotechnical Commission (IEC) standard 62067, operating the current cable design to a higher voltage would require SCE (or its suppliers) to perform another round of prequalification (PQ) testing on the cable and related equipment to verify that the system could handle the higher voltages.[23] This would take approximately 18 months, including the actual electrical portion of the test, design work, manufacturing work, and preparing test reports.[24] SCE would also be required to re-test many other system components at a higher voltage, leading to further delays.[25] The additional testing and redesign process could delay the project up to three years, pushing an in-service date to early 2019.[26]

Notwithstanding the certain delays, in accordance with D.13-07-018, SCE contacted Mitsubishi Electrical Power Products, Inc. (MEPPI) in July 2013 to discuss whether UG5 could be operated safely and reliably without voltage control equipment. On August 1, 2013, MEPPI

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20 *Id*.

21 *Id*. ¶ 4.

22 *Id*.

23 *Id*. ¶ 5.

24 *Id*.

25 *Id*.

26 *Id*. ¶¶ 8, 9.

submitted to SCE a proposal for evaluating the voltage rise caused by placing the transmission line underground in Chino Hills.[27] MEPPI's study is scheduled to be complete in November 2013.[28] After completing the study, additional assessments would be required to determine system impacts and modifications needed based on the study results.[29] The voltage control analysis would likely extend through January 2014.[30]

Investigating whether the system can even accommodate the removal of voltage control equipment will further disrupt the project schedule.[31] There are no guarantees that a redesigned or 765 kV transmission system—even if found to be technically feasible—would be more cost-effective than the voltage control on the 550 kV-rated system.[32] At this time, it is unknown whether the voltage rating of underground and overhead system components could be increased to accommodate higher voltages.[33] SCE's original estimated in-service date for UG5 was based on several optimistic assumptions, one of which being no redesign of the underground system. The MEPPI study and potential redesign associated with removing voltage control could take several years, if not longer, to complete. This delay would be highly disruptive to generators who are relying on TRTP to be completed.

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27 *Id*. ¶ 6.

28 *Id*.

29 *Id*.

30 *Id*.

31 *Id*. ¶ 8.

32 *Id*.

33 *Id*.

B. Voltage Control is Necessary on an Underground Transmission System to Control Voltage and Prevent Damage

An underground cable, due to its construction, has much more capacitance than an overhead transmission line.[34] The high capacitance of underground cable circuits can have a significant effect on steady-state voltages throughout a power system due to the capacitive current that flows from the cable.[35] A capacitive current flowing through an inductance (i.e., through the transmission lines and transformer to the generator) causes a voltage rise across the inductor, known as the Ferranti Effect.[36] This effect is at its worst during light-load conditions, when the system voltage rise may be more than 110% of the nominal rating for which most power system components are designed.[37]

When this condition exists, reducing system voltages can be achieved by placing shunt reactors (i.e., compensation) at one or both ends of the cable circuit.[38] Shunt reactors draw the capacitive current away from the system, which then limits the voltage rise across the system.[39] Studies performed by SCE show that the voltage at the open circuit end of the cables may rise

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[34] Mosier Decl. ¶ 4.

[35] *Id.* Steady-state voltage refers to voltage that is not transient—as opposed to the surge voltages associated with a lightning strike. Steady-state voltages occur under numerous operating conditions including when a circuit breaker is opened at one end of the line and/or when the system is lightly loaded, and the voltage along the transmission line increases. Chacon Decl. ¶ 4.

[36] Mosier Decl. ¶ 4.

[37] *Id.*

[38] *Id.* ¶ 5.

[39] *Id.*

above acceptable limits, above 550 kV for UG5, if shunt compensation reactors are not electrically connected to the cables.[40]

1. Utilities Routinely Install Voltage Control to Protect Against Unintended Steady-State Voltage Rise

SCE must keep the 500 kV transmission system voltage under 550 kV to facilitate reliability, safety, and to prevent damaging the entire transmission system because its components are rated to a maximum 550 kV steady state voltage.[41] SCE must adhere to NERC and WECC reliability planning and operating standards taking into account all possible operating conditions when analyzing instances where voltage could exceed 550 kV.[42]

In most cases, the majority of the cable voltage control requirement for long transmission cable systems is supplied by shunt compensation reactors.[43] For example, the following utilities currently have shunt compensation reactors on their systems: SCE, Consolidated Edison of New York, Northeast Utilities System Company, Commonwealth Edison, Xcel Energy, American Electric Power, Pacific Gas & Electric, Hydro-Quebec, National Grid, Northern States Power, and BC Hydro.[44] Without shunt compensation reactors, the system voltage on the cable would increase from around nominal voltage during normal or heavy load conditions to voltages that

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[40] *Id*. ¶ 6.

[41] Attachment C, Declaration of Jorge Chacon (Chacon Decl.) ¶ 3.

[42] *Id*.

[43] Mosier Decl. ¶ 7.

[44] *Id*.

are over 4% above the 110% maximum continuous voltage during light load conditions.[45] This increase in voltage would damage the surge arresters, and may damage the cable system.[46]

Like many other utilities, to mitigate the risk of voltage rising over 550 kV under certain transmission conditions, SCE installs voltage control (shunt reactors) to ensure that the voltage stays below 550 kV.[47] Voltage control is typically installed in proximity to substations and/or underground cable transition stations.[48]

SCE has installed voltage control equipment to control voltage on many of its lines. SCE has installed line reactors on four 500 kV transmission lines at both ends, for a total of eight installations, and three 115 kV lines at one end.[49] These line reactors provide voltage control for transmission lines, similar to what is required for the Mira Loma-Vincent 500 kV line.[50] It would be inconsistent with best practice and industry standards not to use voltage control with this amount of charging current.[51] Tabulated below in Table 1 are line shunt reactors on the SCE system.[52]

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[45] *Id*. ¶ 8.

[46] *Id*.

[47] Adamson Decl. ¶ 18.

[48] *Id*.

[49] Chacon Decl. ¶ 8.

[50] *Id.*

[51] *Id.*

[52] *Id*.

Table 1
Line Shunt Reactors on SCE's Transmission System

Line No.	Line Name	kV	Reactor Location	Reactor Value (MVAR)	Distance (miles)	Line Charging (MVAR)
1	Eldorado-Moenkopi	500	Eldorado	125 @ 525 kV Base	215.0	416 @ 525 kV Base
	Eldorado-Moenkopi	500	Moenkopi(APS)*	125 @ 525 kV Base		
2	Eldorado-Lugo	500	Eldorado	100 @ 525 kV Base	177.2	343 @525 kV Base
	Eldorado-Lugo	500	Lugo	100 @ 525 kV Base		
3	Lugo-Mohave	500	Lugo	100 @ 525 kV Base	175.9	340 @525 kV Base
	Lugo-Mohave	500	Mohave	100 @ 525 kV Base		
4	Devers-Palo Verde	500	Devers	150 @ 525 kV Base	237.9	461 @525 kV Base
	Devers-Palo Verde	500	Palo Verde (SRP)*	150 @ 525 kV Base		
5	Control-Casa Diablo	115	Control	15 @ 115 kV Base	58.6	4.33
6	Control-Sherwin-Casa Diablo	115	Control	15 @ 115 kV Base	34.4	2.40
7	Casa Diablo-Rush	115	Rush	15 @ 115 kV Base	19.4	1.36

*Non SCE-Owned

For TRTP, the Mira Loma-Vincent 500 kV line will consist of approximately 73 miles of overhead conductor and approximately 3.5 miles of underground cable.[53] Based on SCE's most recent calculations, the overhead portion of the Mira Loma-Vincent 500 kV line will have line charging of approximately 250 MVAR at a 525 kV base voltage.[54] The underground portion through Chino Hills (only 3.5 miles) will add an additional approximately 285 MVAR of line

[53] *Id*. ¶ 9.

[54] *Id*.

charging current at a 525 kV base voltage.[55] Taken together, the entire 73 mile-long Mira Loma-Vincent line charging will be approximately 535 MVAR at 525 kV base.[56]

The need for voltage control on the Mira Loma-Vincent 500 kV line is clear when comparing the transmission lines' capacitance to the four 500 kV transmission lines in the table above, and in particular to the Devers-Palo Verde 500 kV line (row 4 in the table above).[57] Due to its length of approximately 238 miles, the overhead Devers-Palo Verde 500 kV line has a line charging current of approximately 461 MVAR at a 525 kV base voltage.[58] To mitigate steady state voltage rise under certain transmission conditions, SCE has installed 150 MVAR of voltage control at each end of the Devers-Palo Verde transmission line.[59] Because the line charging of the Mira Loma-Vincent 500 kV transmission line (535 MVAR) is even greater than the Devers-Palo Verde 500 kV transmission line (461 MVAR), it is reasonable to expect that SCE will require voltage control equipment with greater MVAR total as previously identified in the studies performed.[60]

2. UG5 Needs Voltage Control for Safety and to Prevent Damage if One End of the Line is Open at Mira Loma

Undergrounding a 500 kV transmission line poses many significant technical and design challenges.[61] One consequence of undergrounding the approximately 3.5 miles of TRTP through Chino Hills is that there will be an increase in the line charging current caused by the

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55 *Id*.

56 *Id*.

57 *Id*. ¶ 10.

58 *Id*.

59 *Id*.

60 *Id*.

61 Adamson Decl. ¶ 19.

underground portion of the line compared to an equivalent overhead segment.[62] Under some circumstances, this could cause the voltage on the transmission line to exceed 550 kV.[63]

When a transmission line is connected to the network on one end, but not the other end and under certain conditions when loading is very light, the Ferranti effect causes voltage to rise significantly on the open or lightly loaded end.[64] If this is allowed to happen, and the voltage exceeds the equipment rating, an electricity flash-over could occur, posing a risk to human health and safety, as well as the reliable operation of the transmission system.[65] Because undergrounding greatly increases the line charging current on the transmission line segment, the risk and magnitude of flash-over is heightened if not mitigated by voltage control equipment.[66]

As shown in Table 2, SCE's internal calculations have shown that voltage control is needed to keep system voltages under 550 kV where TRTP is closed at the Vincent substation, but open at the Mira Loma substation.[67] Under a two cables per phase system, the voltage at the open end at Mira Loma substation will exceed 550 kV once the Vincent voltage reaches 525 kV.[68] To protect against the risk of damaging the system, shunt reactors must be installed to bring the voltage under 550 kV at the open end at Mira Loma substation.[69]

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62 *Id.*

63 *Id.*

64 *Id.* ¶ 20.

65 *Id.*

66 *Id.*

67 *Id.* ¶ 21.

68 *Id.*

69 *Id.*

Table 2
Open Circuit Voltage with Line Open at Mira Loma Without Voltage Control

End of Line Voltage (Open at Mira Loma)		
Vincent Voltage (kV)	**Original Overhead Design (kV)**	**UG5 (kV)**
525	533	551
530	539	556
535	544	561
540	549	567

There are several reasons why the transmission system could at times be operated with one line open on one side, including line switching, maintenance, protection, misoperation, and operator or technician error.[70] This is not a condition that can be eliminated fully by advanced planning.[71]

Line-switching is necessary during both commissioning and operation.[72] Before the line is brought into service, system protection needs to be proven by closing the line on one end and validating phase connections on the open end.[73] The process is then alternated.[74] The period of time that the line is held open is not necessarily seconds or minutes, but instead depends on how long it takes for the technicians to in-service and prove the protection.[75] Failure to do this testing

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[70] *Id.* ¶ 22.

[71] *Id.*

[72] *Id.* ¶ 23.

[73] *Id.*

[74] *Id.*

[75] *Id.*

could result in putting a line in-service that is not capable of operating as needed.[76] Manual switching is also used when maintenance activities require de-energizing part of a line.[77] Both sides of the line need to be opened and closed, but this cannot occur simultaneously and there is inevitably some period where only one end of the line is open.[78]

System protection can also result in operating with one line open on one side.[79] During certain maintenance periods, one end of the line will be brought down from two circuit breakers to one.[80] The Mira Loma and Vincent 500 kV substations each have two circuit breakers used to protect and disconnect the line.[81] If there is a condition during maintenance on one of the two circuit breakers, such as a stuck breaker, the bus where the stuck breaker is connected would open without opening the two breakers at the remote end.[82] Planning criteria requires that SCE be prepared for this situation.[83]

Misoperations and operator or technician error can also cause a need for voltage control.[84] There have been several well-publicized outages resulting from operator error and such events must be planned for when designing a transmission line.[85]

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[76] *Id.*

[77] *Id.*

[78] *Id.*

[79] *Id.* ¶ 24.

[80] *Id.*

[81] *Id.*

[82] *Id.*

[83] *Id.*

[84] *Id.* ¶ 25.

[85] *Id.*

Under the current system design, an open line at the Mira Loma substation would result in voltage above acceptable limits. [86] Based on its experience and a thorough investigation of system requirements (including analysis subsequent to D.13-07-018's directive to study Basic Insulation Level), SCE has determined that voltage control is necessary to ensure that system integrity and safety is maintained in the event that the transmission line is opened on one side—i.e., a voltage rise exceeds allowable limits.[87]

C. BIL and Voltage Control are Distinct Concepts and Mitigate Different Risks

Unfortunately, in the underlying proceeding, the purpose and nature of BIL was not clearly discussed. Chino Hills had testified that the risk of flash-over resulting from increased line charging current due to undergrounding could possibly be managed during steady-state operation by designing the transition station BIL to accommodate higher voltages.[88] Chino Hills' use of the term "BIL," however, confuses the issue by blurring the distinction between "steady state" and "impulse" voltage conditions.

Based on additional research, it has become evident that BIL and voltage control equipment are different and mitigate different risks.[89] While a shunt reactor is a separate *component* of a transmission system that regulates or controls the voltage, BIL is a *rating* given to all or nearly all components of a transmission system.[90] BIL is more accurately defined as "Basic Impulse Level" or "Basic Impulse Insulation Level," which represents the "strength" of

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86 *Id.* ¶ 26.

87 *Id*.

88 *See* Shirmohammadi, Ex. CH-90 at 26:13-19.

89 Adamson Decl. ¶ 11; Mosier Decl. ¶ 9; Chacon Decl. ¶ 6.

90 Adamson Decl. ¶ 11; Mosier Decl. ¶ 9.

equipment's insulation for a high-voltage impulse.[91] BIL is the lightning impulse withstand voltage of a system or piece of equipment, not the normal, steady-state power frequency operating voltage.[92] The difference between a lightning impulse voltage and normal steady-state operating voltage is that the lightning impulse voltage is transient—it peaks in 1.5 microseconds and falls to one-half that value in 40 microseconds.[93] While the BIL level on the 500 kV cable system is 1,550 kV, this level is simply a rating of the system's ability to withstand that higher transient voltage for the very short duration of the impulse.[94]

Shunt reactors, on the other hand, are a system component designed to mitigate the risk of a voltage rise above equipment rating on the open end of a transmission line during steady-state conditions, where the line is opened at one end and not the other; or under lightly loaded conditions (i.e., to address the Ferranti effect, discussed below).[95] While this voltage rise would be less intense than a lightning strike, it would be longer lasting (e.g., for minutes or days).[96] The BIL rating of system components would not be relevant to address or mitigate voltage issues under steady-state conditions or caused by the Ferranti effect.[97] Redesigning the Mira Loma-Vincent 500 kV line with components with a higher BIL, as Chino Hills and D.13-07-018 seem to suggest, would not address these same risks.[98]

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[91] Mosier Decl. ¶ 9.

[92] *Id.*

[93] *Id.*

[94] *Id.*

[95] Adamson Decl. ¶ 13.

[96] Mosier Decl. ¶ 9; Chacon Decl. ¶¶ 6-7.

[97] *Id.*

[98] *Id.*

This issue is illustrated by an analogy to a rubber garden hose rated to 40 pounds per square inch (psi). If the end of the hose has a closed nozzle on the end and the water pressure spikes to 100 psi for one second, but then fall back to 40 psi, the garden hose would stretch but probably be able to accommodate the short burst of increased pressure.[99] This accommodation would be a function of the hose's "BIL" rating. On the other hand, pushing 60 psi through a 40 psi garden hose for an entire afternoon would likely result in a failure of the hose.[100] Thus, to address the problem, one would install a pressure regulator ("voltage control") to keep the psi in the hose under 40 psi or replace the hose with a hose capable of steady state use of 60 psi.[101] If one were to extend this analogy to an entire house water system, increasing the pressure rating (voltage rating) would mean redesigning all of the pipes and water appliances in the house, whereas the voltage control approach would be analogous to installing a whole house pressure regulator where the city water line comes into the house.[102]

During the evidentiary proceedings, SCE and Chino Hills disputed the necessity of voltage control equipment under steady state conditions, despite Chino Hills' introduction of the term "BIL," which most accurately measures a system's ability to handle impulse or surge conditions.[103] While SCE's Rebuttal Testimony uses the term BIL for the sake of convenience, the fundamental disagreement between the parties was whether SCE's existing system could handle voltages in excess of 550 kV under normal, steady-state operation.[104] In that regard, SCE

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[99] Adamson Decl. ¶ 14.

[100] *Id.*

[101] *Id.*

[102] *Id.*

[103] Chacon Decl. ¶ 7; Mosier Decl. ¶ 9.

[104] Chacon Decl. ¶ 6.

also misused the term "BIL" as a proxy for the idea that the entire system would have to be tested or redesigned to accommodate steady-state voltages in excess of 550 kV.[105]

In sum, increasing the BIL rating cannot mitigate the same risks prevented by voltage control equipment. Shunt reactors and the BIL rating are not "either/or" solutions for the increased voltage levels caused by undergrounding. As such, increasing the BIL rating is technically infeasible.

D. The Decision Should be Modified to Remove the BIL Study Requirement and Order SCE to Install Voltage Control as Designed in UG5

D.13-07-018 suggests that SCE concedes that an increase in BIL rating could be used instead of voltage control.[106] To be clear, SCE does not concede this.[107] Based on its experience and a thorough investigation of system requirements (including analysis subsequent to D.13-07-018's directive to study BIL), SCE has determined that voltage control equipment is necessary to maintain system integrity and safety in the event a steady-state voltage rise exceeds allowable limits [108] Although SCE has retained MEPPI to determine whether UG5 can be installed without voltage control, the MEPPI study and subsequent analysis will not be completed for several months, and follow-up testing or redesign of system components would be necessary, injecting substantial delay into the project schedule. Eliminating D.13-07-018's requirement to further study BIL (correctly stated as an increase in rated voltage) and restoring SCE's ability to construct UG5 with the voltage control equipment originally contemplated in

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[105] *Id.*; *see also* Section IV.A.

[106] D.13-07-018 at 63.

[107] Adamson Decl. ¶ 16.

[108] *Id.*

SCE's design is the only way to possibly meet an in-service date of early 2016 (although such an in-service date remains very optimistic).[109]

The record in these proceedings and the additional facts presented along with this PFM confirm that voltage control equipment is necessary for a safe and reliable underground transmission system. At this time, SCE cannot prudently build the underground transmission system without it.[110] Because it is not reasonable to pursue an increased BIL rating as an alternative, SCE requests that D.13-07-018 be modified to authorize SCE to proceed to build the underground transmission line with the shunt reactors originally designed as critical components of UG5, with the appropriate location to be determined and approved, as appropriate, at a later date. Final engineering should also determine the design of voltage control needed. SCE will separately continue its studies to confirm the appropriate location for voltage control.

E. SCE Requests Permission to Seek Adjustment to the Commission's Maximum Prudent Cost Finding

In its decision, the Commission stated, "We adopt $224 million (in 2013 dollars) as a reasonable maximum cost for UG5, excluding allowance for funds used during construction, and Decision 09-12-044 is modified to increase the reasonable maximum cost of the Tehachapi Renewable Transmission Project (Segments 4-11) by that amount."[111] The Commission also acknowledged that D.09-12-044 directed SCE to file an advice letter to adjust the Commission's finding of maximum cost, and that SCE has not yet done so.[112] The Commission's decision also

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[109] *Id.*

[110] Adamson Decl. ¶ 26; *see also* SCE Comments on President Peevey's Alternate Proposed Decision at 5.

[111] D.13-07-018 at 68.

[112] *Id.* at pp. 4 n.2, 48.

notes that SCE has filed a separate PFM of D.09-12-044 in response to Project design changes the FAA has recommended as air safety mitigations.[113]

Specifically, SCE requests that D.13-07-018 be modified to acknowledge that the project's overall finding of maximum cost will need to be adjusted at a future date to include the cost of undergrounding, including voltage control, at the same time the cost finding will be adjusted to address more refined costs as engineering is finalized and additional costs associated with the FAA activities, regulatory delay, and other activities such as increased environmental monitoring and compliance.

While the Commission's initial $224 million estimate for this sub-portion of Segment 8A was based on "firm bids" that SCE solicited during the procurement process, those firm bids have since expired due to regulatory delays, and costs could therefore increase.[114] Importantly, the Commission's cost estimate discussed in D.13-07-018 includes *neither* voltage control *nor* an allowance for the additional costs of an increase to the BIL rating. Thus, the maximum prudent costs are too low, regardless of whether SCE had proceeded with voltage control or an increase in voltage rating (BIL) and its associated additional testing or system redesign.[115] Given that the costs of undergrounding are uncertain, SCE requests that D.13-07-018 be modified to eliminate any specific finding of maximum prudent cost for the underground portion of the project and that

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[113] *Id.* at 5.

[114] Adamson Decl. ¶¶ 28, 29. Although the firm bids expired on June 17, 2013, SCE has been able to negotiate pricing extensions through October 2013 with certain bidders. *Id.* ¶ 28.

[115] *Id.* ¶ 29.

instead, the costs of undergrounding be addressed in SCE's forthcoming advice letter to adjust the overall TRTP cost finding at an appropriate time during construction.[116]

V. CONCLUSION

For the foregoing reasons, SCE respectfully requests that the Commission modify D.13-07-018 to remove the BIL study requirement, include voltage control equipment, and eliminate any specific finding of maximum cost for the underground portion of the project and that instead, all undergrounding costs be addressed in SCE's forthcoming advice letter to adjust the overall TRTP cost finding at an appropriate time during construction.[117] These important modifications will allow SCE to continue its ongoing efforts to complete Segment 8A without additional undue delay. They will also allow the project to be built safely and reliably, and will result in a more accurate cost estimate that reflects the true costs of undergrounding through Chino Hills and TRTP as a whole.

Dated: September 9, 2013

Respectfully submitted,

LAURA GODFREY
BUCK ENDEMANN

/s/ Laura A. Godfrey________
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[116] A similar approach was used by the Commission in D.09-11-007 at 25 ("SCE requests that, in lieu of modifying the maximum cost at this time, we retain the advice letter process set forth in the Decision. We grant SCE's request.").

[117] As required by Commission Rule 16.4(b), Attachment D proposes specific wording to carry out all requested modifications to the decision.

ATTACHMENT A

ATTACHMENT A

DECLARATION OF CHARLES ADAMSON

I, Charles Adamson, declare as follows:

1. My name is Charles Adamson, and my business address is 6 Pointe Drive, Brea, California 92821. I am employed by the Southern California Edison Company (SCE) as Principal Manager of Large Transmission Projects in Transmission and Distribution. I am currently the acting Project Manager of licensing for the Tehachapi Renewable Transmission Project (TRTP) Segments 4-11. As Project Manager, I am responsible for all licensing aspects of the TRTP including siting, preliminary engineering, cost, schedule, environmental analysis, and licensing.

2. I supervised SCE's preparation of testimony ordered by the California Public Utilities Commission's (Commission) Scoping Memo and Ruling of Assigned Commissioner, dated July 2, 2012 (as amended by the Scoping Memo dated November 15, 2012) that required SCE to submit several rounds of testimony on the cost and scheduling associated with undergrounding an approximately 3.5 mile-long stretch of TRTP through the City of Chino Hills (Chino Hills). I also testified in the April 2013 evidentiary hearings before the Commission. I am familiar with the challenges presented by undergrounding a 500 kV transmission line through the existing right-of-way (ROW) in Chino Hills.

3. In D.13-07-018, the Commission ordered SCE to install a single-circuit, two cables per phase design (with ducts and structures for a third cable) (option UG5) in SCE's existing right-of-way in Chino Hills.

4. For safety and reliability reasons, it is important for a transmission system to be operated within its rated voltage. The components of SCE's transmission system are rated to 550 kV, which is the transmission component voltage rating used by most utilities in North

America. Equipment subject to this maximum voltage rating includes the cable, circuit breakers, disconnect switches, wavetraps, insulators, potheads, and surge arresters. There are very few alternating current transmission systems in North America with components with a voltage rating higher than 550 kV. The next available voltage class is 765 kV, and the only installations are overhead construction. For underground transmission systems, there is no XLPE cable currently available that is rated above 550 kV. If SCE allowed its transmission system to operate at levels above 550 kV, it would have to either design an entirely new voltage class equipped to handle higher voltages, thoroughly test the existing design to see whether it could handle the higher voltage, or move to 765 kV class components where available. For the underground cable and system, new cable and accessary components would have to be designed, manufactured and tested. Operating the existing 500 kV (550 kV rated) system at a voltage higher than rated could be catastrophic and will not be considered by SCE.

Schedule Delays

5. SCE designed UG5 with voltage control equipment included in the design to control voltage conditions on the transmission system. Failing to install voltage control would result in higher voltage levels on the transmission system, exceeding 550 kV, and would result in higher stress levels on all energized transmission system components. Under International Electrotechnical Commission (IEC) standard 62067, operating the current cable design to a higher voltage would require SCE (or its suppliers) to perform another round of prequalification (PQ) testing on the cable to verify that the cable can handle the higher voltages. Another round of PQ testing would take approximately 18 months, including the actual electrical portion of the test, design work, manufacturing work, and preparing test reports. SCE could also be required to re-test other system components at a higher voltage, leading to further delays.

6. Following the release of D.13-07-018, in July 2013, SCE contacted Mitsubishi Electrical Power Products, Inc. (MEPPI) to discuss whether UG5 could be operated safely and reliably without voltage control equipment. On August 1, 2013, MEPPI submitted to SCE a proposal for evaluating the voltage rise caused by placing the transmission line underground in Chino Hills. The overall study is scheduled to be completed in November 2013. After completion of the study, additional assessments would be required to determine system impacts and modifications needed based on the study results. This likely would extend through January 2014.

7. There is also the possibility that the MEPPI study could conclude that voltage could exceed 550 kV even with both breakers closed (i.e., the line is closed at both ends). This would make an even stronger case for voltage control.

8. Investigating the removal of voltage control will disrupt the project schedule. There are no guarantees that a redesigned or 765 kV transmission system will be more cost-effective than voltage control on the 550 kV-rated system. At this time, it is unknown whether the voltage rating of underground and overhead system components could be increased to accommodate higher voltages. SCE's original estimated in-service date for UG5 was based on several optimistic assumptions, one of which being no redesign of the underground system. The additional study and potential redesign associated with removing voltage control could take several years, if not longer, to complete.

9. SCE estimates that studying the removal of voltage control and implementing what system modifications will be needed could delay the project up to three years, pushing an in-service date to early 2019. At a minimum, SCE would need to re-do the PQ testing on all system components that could energized at over 550 kV, which takes approximately 18 months. This delay would be highly disruptive to generators who are relying on TRTP to be completed.

Basic Insulation Level (BIL) Study

10. In this proceeding, Chino Hills has claimed that the risk of flash-over resulting from increased line charging current due to undergrounding could possibly be managed by increasing the Basic Insulation Level (BIL) at the transition stations that facilitate the transition of the transmission line from overhead to underground. D.13-07-018 characterizes the choice between BIL and voltage control as a "major area of disagreement" between SCE and Chino Hills, and approved a maximum reasonable cost for the undergrounding project that did not account for any voltage control or increased BIL costs. D.13-07-018 requires SCE to file and serve a petition for modification to increase the maximum reasonable cost to include a reasonable sum for BIL, or for voltage control if BIL is shown to be impracticable.

11. BIL and voltage control are different and mitigate different types of risks for a transmission system. While voltage control is a separate *component* of a transmission system, BIL is a *rating* given to all or nearly all components of a transmission system. *See* Attachment B, Declaration of R. Mosier ¶ 9. BIL cannot mitigate the same risks prevented by voltage control. Voltage control and BIL are not "either/or" solutions for the increased voltage levels caused by undergrounding. Chino Hills confuses or misunderstands the issue where it states that "allowing voltages that are slightly above the accepted range at transition stations should not be a serious issue and so far as the transition station [BIL] is designed to accommodate the slightly higher voltages, if at all needed." *See* Ex. CH-90, Shirmohammadi, at 26:13-19.

12. BIL is more accurately defined as "Basic Impulse Level," which represents the "strength" of equipment's insulation for a high-voltage impulse. All electrical equipment has a BIL rating to address how the equipment can handle intense, very short bursts of electrical energy; for instance, a strike of lightning. According to the IEEE Standard General

Requirements for Liquid-Immersed Distribution, Power and Regulating Transformers C57.12.00, "[e]ach voltage class of equipment has a ANSI standard BIL rating."

13. Voltage control, on the other hand, is a system component designed to mitigate the risk of a voltage rise above equipment rating on the open end of a transmission line under steady-state conditions, where the line is opened at one end and not the other; or under lightly loaded conditions (i.e., to address the Ferranti effect). *See* Attachment B, Declaration of R. Mosier ¶ 9. While this voltage rise would be less intense, it would last longer than the very brief voltage rise addressed by the BIL rating. The BIL rating of system components would not be relevant to addressing or mitigating voltage rise issues under steady-state conditions caused by the Ferranti effect. *See* Attachment C, Declaration of J. Chacon ¶¶ 6-7.

14. By analogy, consider a rubber garden hose rated to 40 pounds per square inch (psi). If the end of the hose has a closed nozzle on the end and the water pressure spike to 100 psi for one second, but then fall back to 40 psi, the garden hose would stretch but probably be able to accommodate the short burst of increased pressure. This would be a function of the hose's short-term "BIL" rating. On the other hand, pushing 60 psi through a 40 psi garden hose for an entire afternoon would likely result in a failure of the hose. Thus, to address the problem, one would install a pressure regulator ("voltage control") to keep the psi in the hose under 40 psi or replace the hose with a hose capable of steady state use of 60 psi. If one were to extend this analogy to an entire house water system, increasing the pressure rating (voltage rating) would mean redesigning all of the pipes and water appliances in the house, whereas the voltage control approach would be analogous to installing a whole house pressure regulator where the city water line comes into the house.

15. During the course of designing UG5, SCE's internal studies suggested that voltage control would be required to mitigate increased voltage levels. Redesigning the Mira

Loma-Vincent 500 kV transmission line with components with a higher BIL would not address the same risks caused by the Ferranti effect.

16. As designed by SCE, voltage control is necessary for a safe and reliable underground transmission system. SCE does not concede that BIL can adequately protect against the same risks that voltage control was designed to address. Removing D.13-07-018's requirement to study BIL and restoring SCE's ability to construct UG5 with the voltage control originally contemplated in SCE's design is the only way to potentially meet an in-service date of early 2016, although such an in-service date remains very optimistic.

17. While SCE originally contemplated that voltage control would be located at the Mira Loma substation in Ontario, California, SCE is currently exploring other locations in addition to Mira Loma. Final engineering should also determine the exact amount of voltage control necessary. Should SCE determine that the proposed location is unworkable and a different location is needed, SCE will approach the Commission at that time.

Voltage Control

18. Like many other utilities, to mitigate the risk of voltage rising over 550 kV under certain transmission conditions, SCE installs voltage control (shunt reactors) to ensure that the voltage stays below 550 kV. Voltage control is a physical component of the transmission system used to control voltage on the transmission system, and typically is installed in proximity to substations and/or underground cable transition stations.

19. Undergrounding a 500 kV transmission line poses many significant technical and design challenges. One consequence of undergrounding the approximately 3.5 miles of TRTP through Chino Hills is that there is an increase in the line charging current as compared to an equivalent overhead transmission line. Under some circumstances, this would cause the system voltage to exceed the 550 kV rating.

20. When a transmission line is connected to the network on one end, but not the other end and under certain conditions when loading is very light, the Ferranti effect causes voltage to rise significantly on the open or lightly loaded end. If this is allowed to happen, and the voltage exceeds the equipment rating, an electricity flash-over could occur, posing a risk to human health and safety, as well as the reliable operation of the transmission system. Because undergrounding greatly increases the line charging current on the transmission line segment, the risk and magnitude of flash-over is heightened if not mitigated by voltage control equipment.

21. As shown in Table 2, SCE's internal calculations have shown that voltage control is needed to keep system voltages under 550 kV where TRTP is closed at the Vincent substation, but open at the Mira Loma substation. Under a two cables per phase system, the voltage at the open end at Mira Loma substation will exceed 550 kV once the Vincent voltage reaches 525 kV. To protect against the risk of damaging the system, shunt reactors must be installed to bring the voltage under 550 kV at the open end at Mira Loma substation.

Table 2
Open Circuit Voltage with Line Open at Mira Loma Without Voltage Control

End of Line Voltage (Open at Mira Loma)		
Vincent Voltage (kV)	**Original Overhead Design (kV)**	**2 cables/phase; 5000 kcmil (UG5) (kV)**
525	533	551
530	539	556
535	544	561
540	549	567

22. There are several reasons why the transmission system could be operated with one line open on one side, including line switching, maintenance, protection, misoperation, and

operator or technician error. This is not a condition that can be eliminated fully by advanced planning.

23. Line-switching is necessary during both commissioning and operation of the transmission line. Before the transmission line is brought into service, system protection needs to be proven by closing the line on one end and validating phase connections on the open end. The process is then alternated. The period of time that the line is held open is not necessarily seconds or minutes, but instead depends on how long it takes for the technicians to in-service and prove the protection. Failure to do this testing could result in putting a transmission line in service that is not capable of operating as needed. Manual switching is also used when maintenance activities require de-energizing part of a line. Both sides of the transmission line need to be opened and closed, but this cannot occur simultaneously and there is inevitably some period where only one end of the line is open.

24. System protection can also result in operating with one line open on one side. During certain maintenance periods, one end of the line will be brought down from two circuit breakers to one. The Mira Loma and Vincent 500 kV substations each have two circuit breakers used to protect and disconnect the transmission line. If there is a condition during maintenance on one of the two circuit breakers, such as a stuck breaker, the bus where the stuck breaker is connected would open without opening the two breakers at the remote end. Planning criteria require SCE to be prepared for this situation.

25. Misoperations and operator or technician error can also cause an open end condition requiring for voltage control. There have been several well-publicized outages caused by operator error and such events must be planned for when designing a transmission line.

26. Under the current system design, an open line at the Mira Loma substation would result in voltage above acceptable limits. Based on its experience and a thorough investigation

of system requirements (including analysis subsequent to D.13-07-018's directive to study BIL), SCE has determined that voltage control is necessary to maintain system integrity and safety in the event that the transmission line is opened on one side—i.e., a steady-state voltage rise exceeds allowable limits.

Reasonable Maximum Cost

27. D.09-12-044 established a reasonable maximum cost for TRTP as approximately $1.52 billion in 2009 dollars, excluding an allowance for funds used during construction (AFUDC). Including an allowance for funds used during construction, the reasonable maximum cost is approximately $1.78 billion in 2009 dollars. These figures assumed an overhead route through the Chino Hills area.

28. When preparing testimony on the cost and schedule of an underground configuration through Chino Hills, SCE developed a scalable full configuration to underground a 500 kV transmission line in the existing right-of-way in Chino Hills, relying on its own expertise, the help of two leading underground transmission consultants, and a market-based bid procurement process to arrive at cost estimates for various configurations. SCE and its consultants developed cable and civil construction engineering specifications. SCE used these technical specifications and preliminary engineering drawings in a procurement bidding process to test the market to obtain information on pricing certain system components. This procurement process yielded certain construction and cable cost estimates from bidders that were "firm" for 180 days from the bid due date of December 19, 2012. The bidder's estimates expired on June 17, 2013. SCE negotiated extending the bid validity period with the cable bidders an additional four months, to October 15, 2013. SCE has also negotiated extending the bid validity period for the civil award to October 1, 2013. SCE used this market-based pricing in connection with its own cost estimates, which (when totaled) estimated the cost of undergrounding through

Chino Hills from approximately $372 million for UG5 to $726 million for a double-circuit, three cables per phase configuration. D.13-07-018 used SCE's figures as a starting point in calculating the additional reasonable maximum costs for undergrounding UG5, which SCE had estimated to cost approximately $372 million.

29. D.13-07-018 adopts $224 million (in 2013 dollars) as a reasonable maximum cost for undergrounding UG5 through Chino Hills, excluding allowance for funds used during construction. D.13-07-018 modifies the original reasonable maximum cost included in D.09-12-044 to include these extra undergrounding costs for UG5. The $224 million for UG5 excludes any costs for voltage control or additional testing or a system redesign. $224 million will be insufficient to construct UG5 through Chino Hills, because, in addition to SCE's reasons detailed in its comments on Assigned Commissioner Peevey's Alternate Proposed Decision, the bidders' "firm" cost estimates that underlie a portion of that $224 million estimate have expired.

30. Certain other aspects of TRTP have changed since the Commission first approved TRTP in D.09-12-044, including (but not limited to) the requirement to underground through Chino Hills and the marking and lighting of certain overhead transmission structures and spans per Federal Aviation Administration (FAA) recommendations. SCE plans to file an advice letter that reflects the actual cost of constructing TRTP, as incurred and modified subsequent to D.09-12-044.

I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

Executed on September 9, 2013, at Rosemead, California.

/s/ Charles Adamson
By: Charles Adamson

ATTACHMENT B

ATTACHMENT B

DECLARATION OF RACHEL MOSIER

I, Rachel Mosier, declare as follows:

1. My name is Rachel Mosier, and my business address is 162 Bushy Hill Road, Deep River, Connecticut, 06417. I am employed by Power Delivery Consultants, Inc. (PDC), where I am a Senior Engineer and Vice President. At PDC, I am responsible for designing and advising on underground cable systems, including design, specifications, installation, operation, and maintenance.

2. I obtained a Bachelor of Science in Engineering from the University of Connecticut in 1992, and a Master of Science in Power Systems Management from Worcester Polytechnic Institute in 2010. I joined PDC in 2006. Before joining PDC, I worked as an engineer in the defense industry and then as an engineer for Northeast Utilities Service Company. While at Northeast Utilities, I worked in the underground distribution standards department, then moved to underground transmission. I was responsible for leading the cable system design of Northeast Utilities' transmission cable projects in Southwest Connecticut, including the first 345 kV extruded cable project with splices in the Western Hemisphere. I am the Immediate Past Chair of the Insulated Conductors Committee of the IEEE, acting as chair from 2008 to 2011. I have also served as vice chair and treasurer of the ICC and vice chair of the ICC Subcommittee C – Cable Systems. I served on the EPRI's Underground Transmission Task Force Green Book Working Group that guided and supported the 2006 Edition of the EPRI Green Book, and I also conducted the "whole book" review of the Green Book. I am a registered professional engineer in Connecticut, Texas, and Florida.

3. I have been retained by SCE as a consultant to address issues raised by the undergrounding of a portion of Segment 8A of the Tehachapi Renewable Transmission Project

(TRTP) that crosses through the City of Chino Hills. I also testified in the April 2013 evidentiary hearings before the Commission.

Background

4. An underground cable, due to its construction, has much more capacitance than an overhead transmission line. The high capacitance of underground cable circuits can have a significant effect on steady-state voltages throughout a power system due to the capacitive current that flows from the cable. A capacitive current flowing through an inductance (i.e., through the transmission lines and transformer to the generator) causes a voltage rise across the inductor, known as the Ferranti Effect. This effect is at its worst during light-load conditions, when the system voltage rise may be more than 110% of the nominal rating for which most power system components are designed.

5. When this condition exists, reducing steady-state system voltages can be achieved by placing shunt reactors (i.e., compensation) at one or both ends of the cable circuit. Shunt reactors draw the capacitive current away from the system, which then limits the voltage rise across the system.

6. Studies performed by SCE show that the voltage at the open circuit end of the cables may rise well above acceptable limits, above the 550 kV rating for the components that comprise UG5, if shunt compensation reactors are not electrically connected to the cables.

Necessity for Shunt Reactive Compensation

7. In most cases, the majority of the cable reactive charging requirement is supplied by shunt compensation reactors. For example, the following utilities currently have shunt compensation reactors on their systems: SCE, Consolidated Edison of New York, Northeast Utilities System Company, Commonwealth Edison, Xcel Energy, American Electric Power, Pacific Gas & Electric, Hydro-Quebec, National Grid, Northern States Power, and BC Hydro.

8. Without shunt compensation reactors, the system voltage on the cable would increase from around nominal voltage during normal or heavy load conditions to voltages that are over 4% above the 110% maximum continuous voltage during light load conditions. This increase in steady-state voltage would damage the surge arresters, and may damage the cable system. Therefore, if shunt compensation reactors are not employed to control the voltage, then a prequalification (PQ) test at the higher voltage and electrical stress level would be required to ensure the system can handle it.

9. In this proceeding, the term “BIL” has been used. BIL is defined as the Basic Impulse Insulation Level, but has been referred to as Basic Insulation Level in this proceeding (BIL). BIL is the lightning impulse withstand voltage of a system or piece of equipment. It is *not* the normal, steady-state power frequency operating voltage. The difference between a lightning impulse voltage and normal operating voltage is that the impulse voltage is transient—it peaks in 1.5 microseconds and falls to one-half that value in 40 microseconds. The BIL level on the 500 kV cable system is 1,550 kV. But again, it can withstand that higher transient voltage for *only* the very short duration of the impulse. The BIL rating is *not* related to the increased voltage due to the Ferranti effect, because the Ferranti effect causes a steady-state voltage rise that can last for minutes or days, depending upon how long the situation is present.

I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

Executed on September 9, 2013, at Deep River, Connecticut.

/s/ Rachel Mosier
By: Rachel Mosier

ATTACHMENT C

ATTACHMENT C

DECLARATION OF JORGE CHACON

I, Jorge Chacon, declare as follows:

1. My name is Jorge Chacon, and my business address is 3 Innovation Way, Pomona, California 91768. I am employed by the Southern California Edison Company (SCE) as Manager of Generation Interconnection Planning in the Transmission and Distribution Business Unit. As Manager of Generation Interconnection Planning, I am responsible for identifying all planning aspects of the TRTP including voltage mitigation requirements.

2. I supervised SCE's planning studies that evaluated system performance associated with undergrounding an approximately 3.5-mile-long stretch of TRTP through the City of Chino Hills (Chino Hills). This included evaluating voltage performance under all possible operating conditions to ensure undergrounding project design included adequate high-voltage mitigation. In addition, I prepared testimony on issues involving transmission planning, including reactive compensation requirements. I also testified in the evidentiary hearings before the Commission on undergrounding in Chino Hills held in April 2013.

3. Because SCE's 500 kV transmission system design is rated to a maximum of 550 kV steady-state voltage, SCE must keep the 500 kV system voltage under 550 kV to ensure reliability and safety, and to prevent damaging SCE's transmission system. SCE must also adhere to NERC and WECC reliability planning and operating standards taking into account all possible operating conditions when analyzing instances where voltage could exceed 550 kV.

4. As described in SCE's April 4, 2013 Rebuttal Testimony (Rebuttal Testimony), reactive compensation, also referred to as voltage control, is absolutely necessary to maintain system integrity and safety under operating conditions due to the existing 500 kV system design steady-state voltage limitations. Steady-state voltage refers to voltage that is not transient—as

opposed to the surge voltages associated with a lightning strike. Steady-state voltages occur under numerous operating conditions, including when a circuit breaker is opened at one end of the line and/or when the system is lightly loaded, and the voltage along the transmission line increases.

5. In the Rebuttal Testimony, SCE discussed that it would need to undertake a time-consuming process to define a new standard if required by the Commission to implement a design that can withstand voltages in excess of 550 kV rather than the voltage control equipment SCE proposes. A higher voltage rating standard would be needed because SCE's standard 500 kV design is rated at only 550 kV and thus would not be sufficient to provide the higher voltage rating needed to accommodate the expected voltage rise on the Mira Loma-Vincent transmission line that will occur once the transmission line is placed underground in Chino Hills due to the high capacitance of an underground transmission cable.

6. The proper definition of BIL was unfortunately misunderstood in the underlying proceedings, as explained by Rachel Mosier in Attachment B. To clarify, SCE's discussion of BIL in its Rebuttal Testimony addressed design requirements needed to withstand steady-state operating voltages that are higher than the 550 kV steady-state voltages currently provided by the existing 500 kV system design along the Mira Loma-Vincent transmission line. Because voltage at the end of the transmission line under an open circuit breaker condition will increase due to the Ferranti effect, the risk of voltage rise in excess of design capability results in an unsafe and unreliable system operating condition. A new design of the transmission infrastructure of the line, both on the underground and overhead segments, could be required to withstand the higher steady-state voltages associated with day-to-day operations of the Mira Loma-Vincent transmission line under open circuit breaker conditions. For example, SCE could implement a 765 kV design operated at 500 kV to support voltages greater than 550 kV because the design

itself would allow for greater than 550 kV voltages. However, using this 765 kV design or any other voltage design that allows for greater than 550 kV would require removal of overhead portions of the transmission system located both within and outside of Chino Hills and replacement with the higher voltage design. In addition, because no 765 kV rated underground cable system exists at this time the underground facilities through Chino Hills would need to be redesigned to allow for operation at voltages in excess of 550 kV.

7. Based on additional research, an increase in BIL level is typically used to address surge voltages of very short duration, due to (among other things) a lightning strike along a transmission line. An increase in BIL level will not address the steady-state voltage rise that the Mira Loma-Vincent transmission line would experience with one end of the line open; however, the voltage control proposed by SCE would address the steady-state voltage rise.

8. Voltage control is a common feature on many transmission lines. SCE has installed line reactors on four 500 kV transmission lines at both ends, for a total of eight installations, and three 115 kV lines at one end. These line reactors provide voltage control for transmission lines, similar to what is required for the Mira Loma-Vincent line. It would be inconsistent with best practice and industry standards not to use voltage control with this amount of charging current. Tabulated below are line shunt reactors on the SCE system:

Line No.	Line Name	kV	Reactor Location	Reactor Value (MVAR)	Distance (miles)	Line Charging (MVAR)
1	Eldorado-Moenkopi	500	Eldorado	125 @ 525 kV Base	215.0	416 @ 525 kV Base
	Eldorado-Moenkopi	500	Moenkopi(APS)*	125 @ 525 kV Base		
2	Eldorado-Lugo	500	Eldorado	100 @ 525 kV Base	177.2	343 @525 kV Base
	Eldorado-Lugo	500	Lugo	100 @ 525 kV Base		
3	Lugo-Mohave	500	Lugo	100 @ 525 kV Base	175.9	340 @525 kV Base
	Lugo-Mohave	500	Mohave	100 @ 525 kV Base		
4	Devers-Palo Verde	500	Devers	150 @ 525 kV Base	237.9	461 @525 kV Base
	Devers-Palo Verde	500	Palo Verde (SRP)*	150 @ 525 kV Base		
5	Control-Casa Diablo	115	Control	15 @ 115 kV Base	58.6	4.33
6	Control-Sherwin-Casa Diablo	115	Control	15 @ 115 kV Base	34.4	2.40
7	Casa Diablo-Rush	115	Rush	15 @ 115 kV Base	19.4	1.36

*Non SCE-Owned

9. In comparison, the Mira Loma-Vincent 500 kV line will consist of approximately 73 miles of overhead conductor and approximately 3.5 miles of underground cable. Based on SCE's most recent calculations, the overhead portion of the Mira Loma-Vincent 500 kV line will have line charging of approximately 250 MVAR at a 525 kV base voltage. The underground portion through Chino Hills (only 3.5 miles) will add an additional approximately 285 MVAR of line charging current at a 525 kV base voltage. Taken together, the entire 73 mile-long Mira Loma-Vincent line charging will be approximately 535 MVAR at 525 kV base.

10. The need for voltage control on the Mira Loma-Vincent line is clear when comparing the lines' capacitance to the four 500 kV transmission lines in the table above, and in particular to the Devers-Palo Verde 500 kV line (row 4 in the table above). Due to its length of approximately 238 miles, the overhead Devers-Palo Verde line has a line charging current of

approximately 461 MVAR at a 525 kV base voltage. To mitigate steady state voltage rise under certain transmission conditions, SCE has installed 150 MVAR of voltage control at each end of the Devers-Palo Verde transmission line. Because the line charging of the Mira Loma-Vincent line (535 MVAR) is even greater than the Devers-Palo Verde line (461 MVAR), it is reasonable to expect that SCE will require voltage control equipment with greater MVAR total as previously identified in the studies performed.

I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

Executed on September 9, 2013, at Rosemead, California.

/s/ Jorge Chacon
By: Jorge Chacon

ATTACHMENT D

ATTACHMENT D

REQUESTED CHANGES TO THE FINDINGS OF FACT, CONCLUSIONS OF LAW, AND ORDERING PARAGRAPHS IN DECISION 13-07-018

SCE requests the following changes to the findings of fact, conclusions of law, and ordering paragraphs in Decision (D.) 13-07-018, consistent with Commission Rule of Practice and Procedure 16.4(b). Requested deletions to existing text are in strikethrough and requested additions are in underline:

- **Revise Finding of Fact 20 (D.13-07-018 at 63)**

SCE's bid process included a Request for Information and Request for Proposal process that resulted in firm, fixed price bids in response to detailed cable and civil specifications; the bids, received sometime in December 2012, contain fixed prices, good for 180 days from their receipt. **<u>The pricing for those bids has since expired</u>**. Chino Hills' costing process, admittedly much less formal, was not designed to produce bid documents nor obtain bids but to provide an independent test of SCE's numbers.

- **Add three new Findings of Fact after Finding of Fact 20 (D.13-07-018 at 63)**

[20a] **<u>SCE must adhere to NERC and WECC reliability planning and operating standards taking into account all possible operating conditions when designing its transmission system.</u>**

[20b] **<u>By undergrounding the approximately 3.5 miles of TRTP through Chino Hills, there will be an increase in the transmission line charging current relative to the overhead portion of the line. Under some circumstances, this could cause the steady-state voltage on the transmission system to exceed its rating of 550 kV, increasing the risk of electricity flash-over and compromising system reliability.</u>**

[20c] **It is common practice for utilities to install voltage control at or near substations or transition stations to mitigate the risk of electricity flash over that could occur when one end of a transmission line is open while the other end remains closed (i.e., to mitigate issues caused by the Ferranti effect) and under certain conditions when loading is very light. There are several reasons why the transmission system could at times be operated with one line open on one side, including line switching, maintenance, protection, misoperation, and operator or technician error. Without the installation of voltage control, the transmission system would have to be retested to see whether it could handle higher voltage or redesigned with components rated to a higher voltage.**

- **Revise Finding of Fact 21 (D.13-07-018 at 63)**

"SCE **does not** concede~~s~~ than an appropriate BIL, based on a BIL standard for Segment 8A, could be used instead of **voltage control** ~~reactive compensation~~ (which it costs at close to a $23 million) at the transition station**.** ~~;however, SCE does not provide a timeline for developing the standard or implementing it as alternative. Without greater substantiation, we should not approve a cost cap component (for reactive compensation) that approaches $23 million.~~ **BIL and voltage control are different and mitigate different risks, and a BIL rating of system components would not be relevant to address or mitigate voltage issues under steady-state conditions or caused by the Ferranti effect.**

- **Remove Finding of Fact 22, replacing it with new Finding of Fact 22 (D.13-07-018 at 63-64)**

~~Any petition for modification that seeks an amendment to the cost cap for BIL or reactive compensation (if BIL is shown to be impracticable), must include a report on the cost and timeline for developing an appropriate BIL standard for Segment 8A and for implementing it,~~

~~based on the level of detail that the Commission's Energy Division may reasonably specify and must be supported by one or more declarations executed by knowledgeable persons under penalty of perjury, as provided by California law.~~

On September 9, 2013, SCE filed a Petition for Modification as directed by D.13-07-018. SCE included voltage control (i.e., reactive compensation) in the design of UG5 to ensure that the Mira Loma-Vincent 500 kV transmission line operates within its rated steady-state voltage rating of 550 kV. Determining whether UG5 could be operated without voltage control could unreasonably delay the in-service date of TRTP to early 2019, as SCE would have to retest system components and potentially redesign the transmission system to accommodate higher voltage levels. There is no indication that retesting or redesigning the system would cost less than voltage control.

- **Remove Finding of Fact 27, replacing with new Finding of Fact 27 (D.13-07-018 at 64)**

~~Applying all of the adjustments for reactive compensation, contractor overhead and risk, environmental, and contingency costs to SCE's UG5 estimate reduces that estimate from $350 million to approximately $241 million. These sums do not include an allowance for corporate overhead (which would be approximately $15.7.7 million, using SCE's factor of 6.5%).~~

We conclude that based on the cost record developed in the proceeding that it is reasonable and in the public interest to underground Segment 8A.

- **Revise Finding of Fact 30 (D.13-07-018 at 65)**

Although the cost estimates and determinations made in D.13-07-018 were sufficient to guide the Commission's determination of whether undergrounding was reasonable and in the public interest, we find that the actual cost estimates of the maximum and prudent

cost of the undergrounded portion is not sufficiently certain at this time due to uncertainty of actual procurement costs as a result of bid expiration, delay due to the initial exclusion of voltage control, the need to reinstate voltage control, and related activities. As such, we do not set a separate ~~The~~ reasonable maximum cost for construction of **the** UG5 **portion of the overall Project.** ~~in the Chino Hills Row is $224 million, which includes an offset for Chino Hills' contribution of real property to SCE in fee.~~

The overall project cost of TRTP will need to be adjusted at a future date to include the cost of undergrounding, including voltage control; to reflect more refined costs as engineering is finalized; and to adjust any additional costs associated with the FAA activities, regulatory delay, and other activities such as environmental monitoring and compliance.

- **Revise Finding of Fact 31 (D.13-07-018 at 65)**

~~On per mile basis, the total cost of $224 million is approximately $64 million per mile.~~ To the extent that undergrounding costs elsewhere in California provide a benchmark of sorts, the cost to underground UG5 is not much higher.

- **Revise Conclusion of Law 7 (D.13-07-018 at 66)**

~~Having conceded that BIL could be used on Segment a8A instead of reactive compensation, t~~**T**he burden of producing additional evidence on ~~BIL and a Segment 8A BIL standard~~ **whether it is reasonable and in the public interest for SCE to design UG5 with voltage control** is on SCE.

- **Insert new Conclusion of Law after Conclusion of Law 7 (D.13-07-018 at 66-67)**

<u>It is reasonable and in the public interest for TRTP to be completed without additional delay caused by investigating whether an increase in the BIL level can replace voltage control.</u>

- **Remove Conclusion of Law 8, replacing it with new Conclusion of Law 8 (D.13-07-018 at 67)**

~~Within 60 days of the date of today's decision, SCE should file and serve a petition for modification of today's decision if it wishes the cost cap adopted by today's decision to be amended to include a reasonable sum for development and implementation of a BIL standard in the design of UG5 (or for reactive compensation, if BIL is shown to be impracticable). Such petition must include a report on the cost and timeline for developing an appropriate BIL standard and for implementing it, based on the level of detail that the Commission's Energy Division may reasonably specify and, must be supported by one or more declarations executed by knowledgeable persons under penalty of perjury, as provided by California law.~~

<u>On September 9, 2013, SCE filed a petition for modification in accordance with the Commission's direction in D.13-07-018. Substantial evidence indicates that SCE included voltage control in the design of UG5 to ensure that TRTP operated within its rated voltage limit. Substantial evidence also indicates that studying whether UG5 could operate safely and reliably without voltage control poses an unreasonable risk of delay to TRTP's in-service date, with no guarantee that a redesigned system would be more cost-effective than the voltage control equipment originally designed by SCE.</u>

- **Replace Ordering Paragraph 3 with new Ordering Paragraph 3 (D.13-07-018 at 68)**

~~We adopt $224 million (in 2013 dollars) as a reasonable maximum cost for UG5, excluding allowance for funds used during construction, and Decision 09-12-044 is modified to increase the reasonable maximum cost of the Tehachapi Renewable Transmission Project (Segments 4-11) by that amount.~~

As contemplated in D.09-12-044, SCE shall file an advice letter addressing total project costs, including but not limited to the cost of undergrounding, including voltage control. In the same advice letter, SCE will also address cost adjustments as engineering is finalized, including additional costs associated with the FAA activities, regulatory delay, and other activities such as increased environmental monitoring and compliance.

- **Revise Ordering Paragraph 4 (D.13-07-018 at 68)**

All Findings of Fact, Conclusions of Law and Ordering Paragraphs adopted by Decision 09-12-044 **and Decision 13-07-018 (as issued on July 16, 2013)** that are inconsistent with these Ordering Paragraphs are hereby deemed to be modified to comport with these Ordering Paragraphs and shall be so construed.

- **Remove Ordering Paragraph 5 and replace with new Ordering Paragraph 5 (D.13-07-018 at 68)**

~~If Southern California Edison Company (SCE) wishes the Commission to amend the cost cap adopted in Ordering Paragraph 4, above, to include a reasonable sum for development and implementation of a Basic Insulation Level (BIL) standard in the design of UG5 (or for reactive compensation, if BIL is shown to be impracticable), SCE shall file and serve a petition for modification of this decision within 60 days of the date of this decision. Such petition must~~

~~include a report on the cost and timeline for developing an appropriate BIL standard and for implementing it, based on the level of detail that the Commission's Energy Division may reasonably specify and, shall be supported by one or more declarations executed by knowledgeable persons under penalty of perjury, as provided by California law.~~

SCE is directed to install voltage control equipment as originally designed and proposed in UG5, with the appropriate design and location to be determined and approved, as appropriate, at a later date.